

Urban Green Infrastructure in Mystic River Communities Subwatershed Plan for Broadway, Chelsea MA

Produced by

Charles River Watershed Association
Mystic River Watershed Association
Chelsea Collaborative

for

The City of Chelsea, Massachusetts

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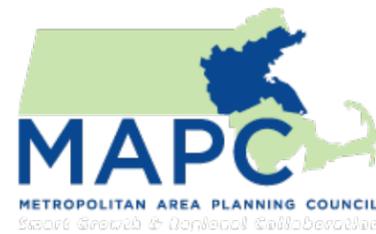


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INTRODUCTION

The City of Chelsea, Mystic River Watershed Association (MyRWA), Charles River Watershed Association (CRWA), and Chelsea Collaborative (CC) partnered to develop recommendations, conceptual designs, and community support for environmental improvements in a neighborhood in Chelsea, Massachusetts, a densely developed and highly impervious Metro-Boston community. As a result of the Urban Green Infrastructure (GI) in Mystic River Communities Project, the team has identified opportunities to incorporate low impact development (LID) stormwater treatment systems into an upcoming sewer separation project, and has identified additional opportunities for stormwater improvements that can inform future planning and capital improvement projects undertaken by the City.

The partners focused the efforts of the GI project on the City of Chelsea, as the presence of both critical environmental conditions and environmental justice populations warrant prompt efforts to reduce pollution. This GI project ran parallel to the early planning of a major sewer separation project on Broadway in Chelsea. This allowed for the project tasks, public participation, collaboration with the City and subwatershed planning in this GI project to be directed at a tangible, funded project (sewer separation) with near-term implementation.

This GI project identified opportunities to incorporate LID stormwater treatment systems into the upcoming Broadway sewer separation project, engaged residents in a dialogue on desired outcomes for Broadway and developed a Subwatershed Plan. Aforementioned strategies include recommendations on road design for Broadway, a set of conceptual designs for public spaces within Chelsea (e.g. City Hall Plaza, Toomey Square and City Stairs) and a set of conceptual designs for private properties within the City of Chelsea, where benefits would accrue from public-private partnerships. Each of the recommendations and designs will address stormwater pollution and improve the livability of the street. Many of



Figure 1.1 Broadway, Chelsea, MA

the recommendations outlined in this plan are applicable throughout the City and can inform future planning and capital improvement projects undertaken by the City.

The project team used the CRWA Blue Cities® Analysis Process and Design Approach as a project guide, beginning with an analysis of existing conditions and ending with development of this Subwatershed Plan. This plan incorporates information gathered through walking assessments conducted by the Environmental Chelsea Organizers (ECO Youth Team), an Existing Conditions Assessment, a Design Charette, input from Chelsea residents and members of Chelsea Green Space, and knowledge shared by Andrew DeSantis, Assistant Director of Chelsea Public Works and Patty Passariello, P.E. of Weston & Sampson. Throughout the project, participation of residents has been integral for identification of needs and opportunities, as well as development of community support for green infrastructure strategies.

Stormwater pollution is a problem in all urban communities and the conditions outlined in the Existing Conditions Analysis will resonate with many other communities. The tasks accomplished within this project and this Subwatershed Plan provide a model for how other municipalities in Massachusetts can reduce the impact of stormwater to local water bodies, engage residents in a participatory process, and consider how structural green infrastructure elements can be incorporated into an urban landscape.

Community Setting

Chelsea is an environmental justice community with a solid history of civic engagement in local environmental issues. Approximately 26,000 people live in the 2.2 square mile city, making it one of the most densely populated incorporated places in the country (US Census 2010). Chelsea is identified as an environmental justice community as a result of both minority populations (48% self-identified, 62% Hispanic) and poverty

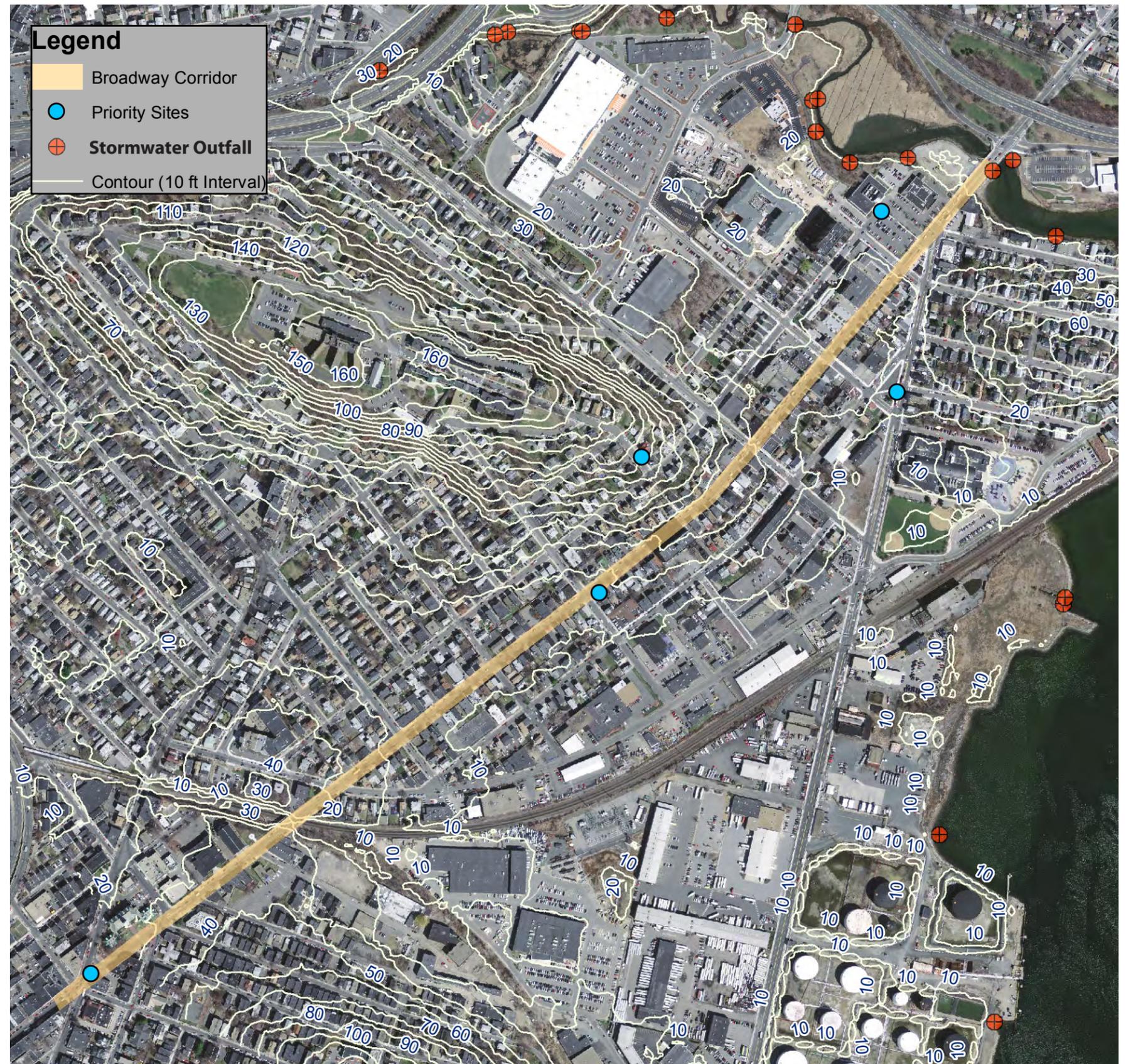


Figure 1.2 Broadway Improvement Corridor and Priority Sites

levels four-fold above the Massachusetts median. Furthermore, the City has been identified as the third most environmentally overburdened in the state of Massachusetts and has an overall impervious cover of 75% (Krieg and Faber, 2002). Chelsea is bordered on three sides by Chelsea Creek which is impaired for a number of pollutants as discussed in Section IV of the Existing Conditions report. Increased green space and pollution reduction practices will benefit the ecological environment and public health of Chelsea residents.

Project Area

The GI project performed analysis and planning on the subwatershed that drains to stormwater outfall CHE008 within Chelsea. A focus was placed on a length of the major two-lane collector road, Broadway, which is contained within the subwatershed area. This section of Broadway is currently being surveyed as a part of a sewer separation project that the City of Chelsea is undertaking. The length of Broadway analyzed in this study starts at Mill Creek at the north and runs to the intersection of Washington and Broadway at the south (1.1 mile length). The total geography in the study area is 120 acres (0.2 mi²). The study area within Chelsea is highly developed and characterized by a high percentage of impervious cover (75%) with a very small amount of green space (See Figure 1.3).

Analysis of a map from the 19th century indicates that Broadway was built predominately on existing bedrock/soil, but other parts of the built environment in the study area including eastern sections and portions along Mill Creek were built upon filled tidelands. Data compiled by the USDA National Resources Conservation Service indicate that most of the area has significant depth (>7 ft) to clay layers and water table. However, there is a lack of geo-hydrological data for Chelsea that informs on the soil types that may or may not allow infiltration. Also, while there are multiple AUL Hazardous Materials Sites and Underground Storage Tank sites identified as present in the study area, there is very limited data on the frequency and severity of soil contamination.



Figure 1.3 Extent of impervious cover in study area

The built environment is composed primarily of multi-family residential units and also contains areas of commercial, industrial and urban public/institutional land uses. Zoning within the study area is mainly residential, with higher density residential east of Broadway and lower density residential west of Broadway.

Broadway is a two lane collector road that runs southwest to northeast through the center of Chelsea. The conditions along this stretch of Broadway are similar to the whole of the study area as it is mainly residential, but some retail business and commercial use does occur northward of the intersection of Webster and Broadway. On-street parking is available along most of Broadway. An MBTA commuter rail line bisects Broadway on the southern end of the project area and commuter buses run along the length of Broadway with stops at 10 sites.

The project being undertaken by the City of Chelsea at Broadway will take the sanitary sewage and stormwater runoff, which is currently carried in a single pipe ('combined system') and direct the flow to two pipes - one for sanitary sewage and one for stormwater ('separate system'). Much of the study area outside of Broadway is also serviced with a combined system. The combined system does not send stormwater to the river but instead contributes flow to Deer Island treatment facility in low to moderate wet weather events, and results in combined sewer overflows (CSOs) to Chelsea Creek during heavy rainstorms. During such events, untreated sewage mixed with stormwater discharges directly into the Chelsea River. The proposed sewer separation along Broadway is intended to reduce the frequency and volume of overflows into Chelsea Creek (see Section IV Water Quality Analysis of Existing Conditions Report), but will increase the volume of stormwater reaching Mill and Chelsea Creek. The City also plans to perform an assessment of existing sewer and stormwater infrastructure on the cross streets in the area, stretching approximately one block to the north and one block to the south. Construction activities will likely be limited to the Broadway right of way.

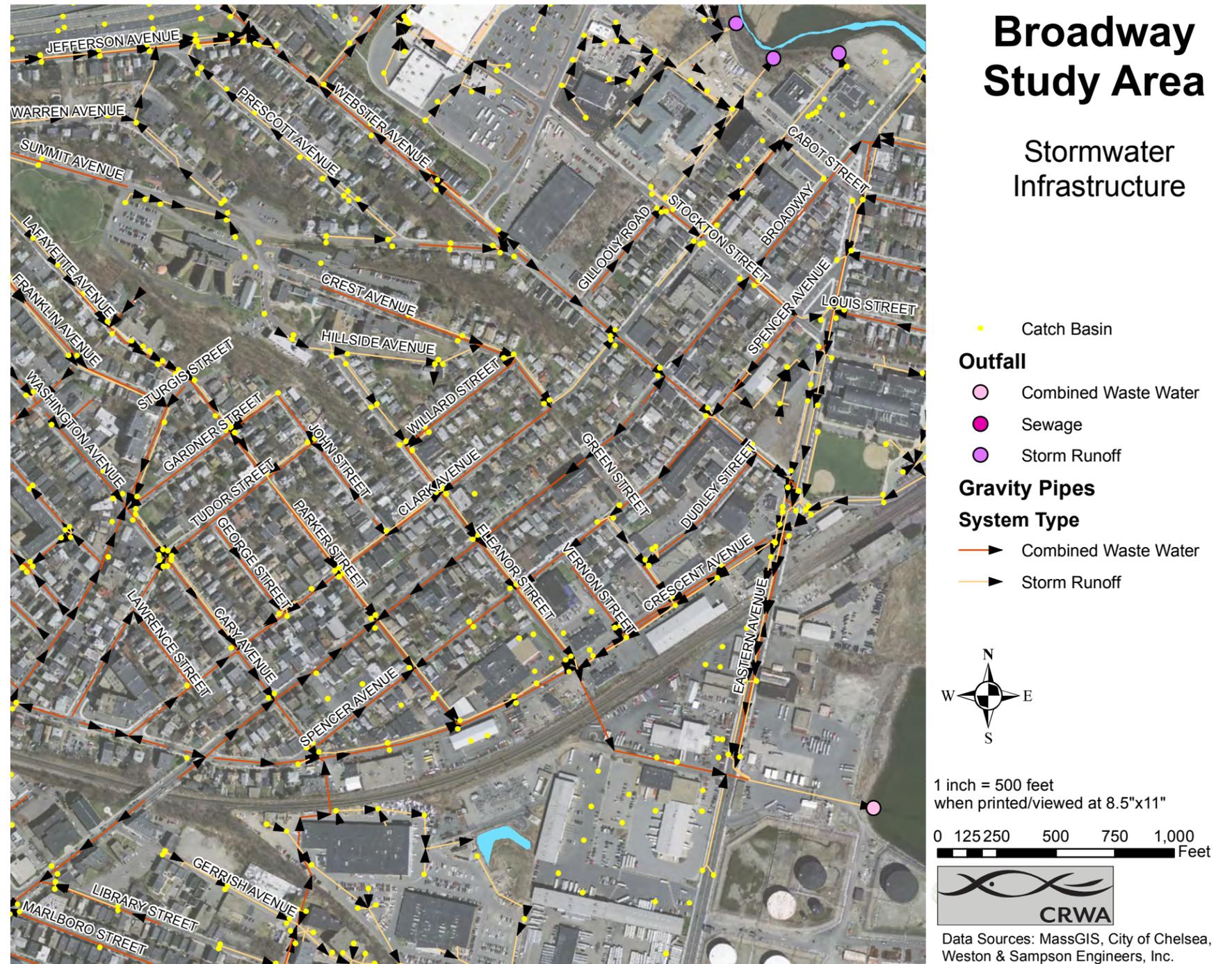


Figure 1.4 Stormwater infrastructure layout in study area

EXISTING CONDITIONS ANALYSIS

Methodology

In an effort to produce a more comprehensive analysis of the Broadway area, CRWA, MyRWA, and CC partnered to create an Existing Conditions Report, submitted April 2013.

Mapping Analysis

CRWA performed mapping analyses for the area in a Geographic Information System (GIS) using ESRI ArcGIS software. Geographic data was supplied by the City of Chelsea, Massachusetts Office of Geographic Systems (MassGIS), and the Natural Resources Conservation Service (NRCS). CRWA's analysis focused on identifying and understanding the opportunities and challenges in the following interrelated systems:

- Land Use and Zoning
- Open Space
- Publicly Owned Land and Public Right-of-Ways
- MBTA Bus Transportation
- Topography
- Surface Water Resources
- Stormwater Drainage Infrastructure
- Impervious Area
- Soils
- Hazardous Sites

Please refer to the Appendix for materials.

Water Quality Analysis

Chelsea River receives stormwater inputs from land surfaces in Chelsea, East Boston, Revere and Everett and is impaired for multiple urban contaminants. Water quality here has been well characterized by sampling performed by MyRWA and the Massachusetts Water Resources Authority (MWRA). The MA Department of Environmental Protection 2004-2008 Integrated List of Waters reported Chelsea River as impaired

under Category 5, 'Waters Requiring a TMDL.' Listed impairments included priority organics, (un)ionized ammonia, organic enrichment/low dissolved oxygen (DO), pathogens, oil and grease, turbidity, objectionable deposits, and taste, odor, and color (Division of Watershed Management Watershed Planning Program, Worcester, Massachusetts, 2010).

CRWA analyzed the available data on bacteria, nutrient, and other watershed contaminant levels in conjunction with additional data from Overflow Record at CHE008 and local precipitation records.

Historical Analysis

CRWA is particularly interested in the natural hydrology of the area, prior to alteration by stormwater infrastructure installation or land alterations such as filling in wetland areas or constructing dams. Understanding the natural, pre-development hydrology is essential to the Blue Cities® process which aims to restore or recreate an area's natural hydrology through the use of green infrastructure techniques (wetland and open space conservation and restoration, low impact development stormwater treatment practices, etc.).

Neighborhood Assessment

CC's Environmental Chelsea Organizers (ECO) is a group of Chelsea youth that raise awareness of environmental justice issues and advocate for green solutions. ECO conducted a site survey of the project focus area, including most of Broadway. (Figure 1.5) ECO gathered information on the character of the neighborhood, stormwater drainage issues, potential pollution sources, available open space, parking lot usage, and evaluated the potential of certain segments as green streets.

Summary of Findings

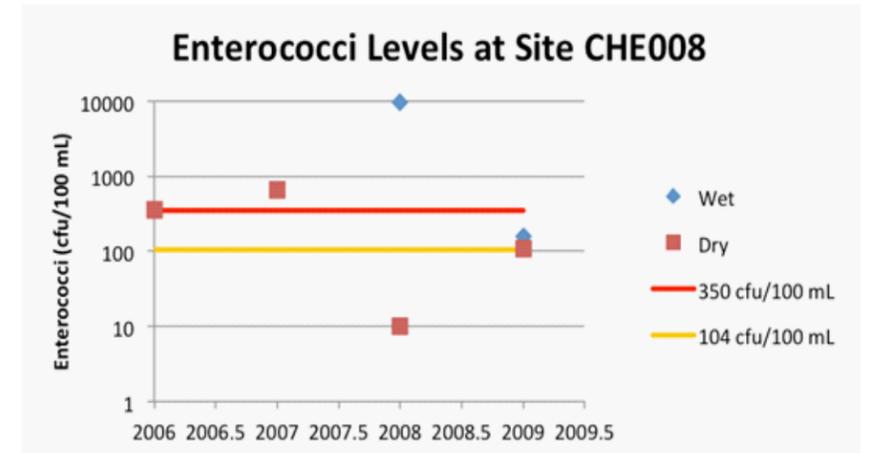


Figure 1.5 Enterococcus Levels at Chelsea River Site CHE008 for Wet and Dry Days. Source: MyRWA.

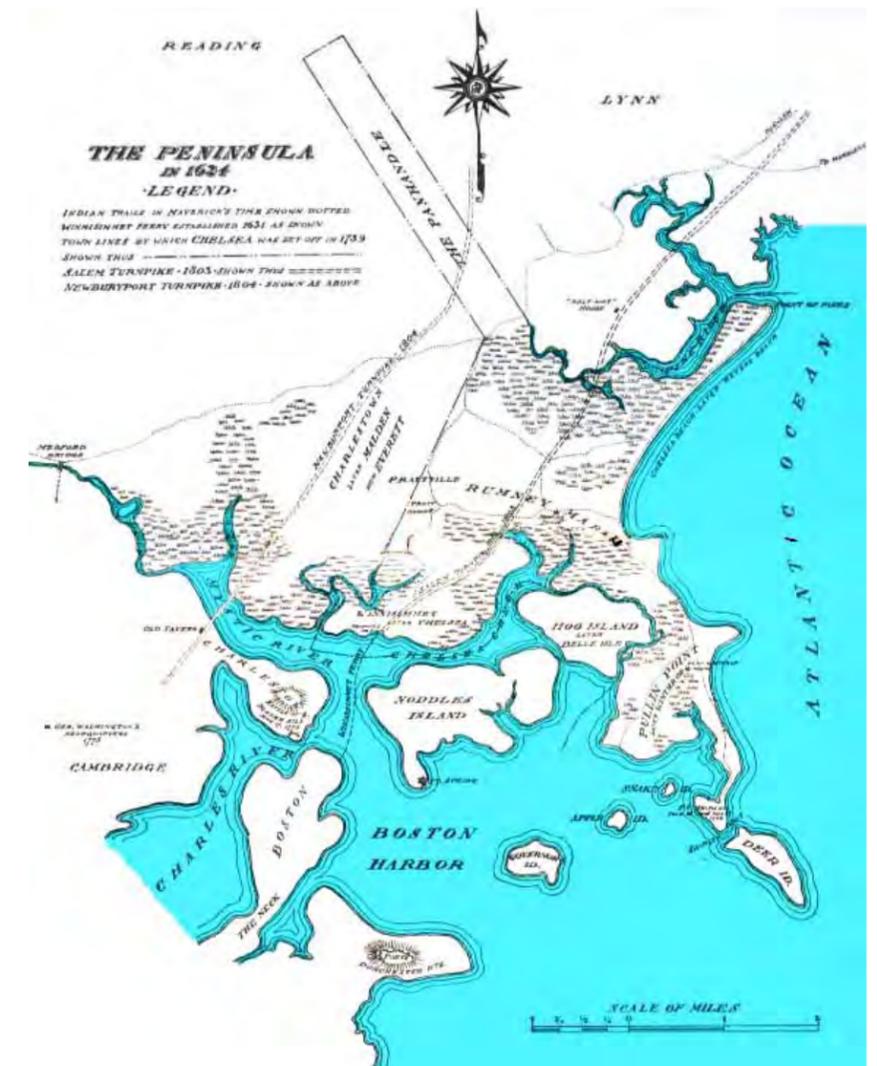


Figure 1.6 Map of the City of Chelsea, 1624.

Neighborhood Character

The ECO's focus area is primarily residential with a few clusters of businesses. Residences ranged from large apartment complexes to single family homes. The majority of land cover is impervious. Lawn and landscaped areas form only a small part of the overall area. Litter and trash, such as cigarette butts, plastic bottles and paper/wrapper material, were commonly found along the streets. Organic material (leaves, branches, and grasses) and sediment (sand, dirt, and mud) were also found, though less common. Roadways are generally in disrepair with cracked pavement and potholes. Green space is mostly found in the form of yards at single family homes. Street trees located in pits are common, particularly along Broadway, and are in fair condition.

Stormwater Infrastructure and Observations

The ECO team completed a visual inspection of storm drains throughout the study area and raised concerns about the amount of accumulated material in sumps and whether the drains might be clogged. Accumulated materials observed in the catch basin included dirt, sand, bottles, cigarettes, leaves and general trash. Sediment piles were observed inside catch basins and trash was observed accumulating on top of the openings of storm drains. ECO youth observed a greater frequency of storm drains with accumulated material on Broadway and posited that the heavy amount of foot and vehicle traffic led to the deposition of greater material. Streets with a more residential character tended to have a lesser accumulation of material in sumps and grates of storm drains. Mr. DeSantis of Chelsea DPW provided reassurance that the visible accumulation of materials in the sump was not an indication of clogging but the intended accumulation of materials to keep it out of the storm drain flow. The observed material would be collected under the regular mechanical maintenance plan. ECO youth identified car washing, dog waste and small construction sites as potential pollution sources and opportunities for deployment of additional public trash receptacles at the corners of commercial streets where trash had accumulated.

Green Street Potential

Based on the results of the survey, ECO concluded that among the streets surveyed, Broadway was the street that would benefit the most from implementation of green infrastructure. Reasons for this conclusion included the state of disrepair of the roadway, the accumulation of material in storm drain sumps, the lack of green space present and the trash accumulation problem. ECO also identified Eastern Avenue as a location with high potential as a Green Street since it is wide with adjacent open space including a school, park, and baseball field. However, the narrow sidewalk width (approx. 5 feet wide) could limit green infrastructure implementation. Finally, commercial areas with sufficient space should be considered for green infrastructure given that these streets had the least amount of green space.

Priority Site Selection

The priority sites were selected based on three criteria: (1) site visibility, (2) ownership, and (3) typology, and involved intense community participation. Typically, incorporating GI technology into an urban landscape requires committed community investment that begins in the conceptual design stage and continues through project implementation and post-construction maintenance, so community involvement in site selection was vital. Site visibility and ownership connect with this investment by fulfilling educational and aesthetic objectives. They give visible testimony to ecological stewardship and proof that green infrastructure incorporated into a densely populated urban context can be a viable alternative to conventional stormwater conveyance. This latter consideration connects with the third criteria, site typology. One of the primary goals of this project was to situate green infrastructure in a variety of land use contexts within Chelsea. Among the typologies considered were public/institutional sites, private commercial sites, parking lots, vacant/open space parcels and street intersections. Existing condition analysis and site survey provided additional parameters that informed the final site selection. Refer to Appendix for additional information.

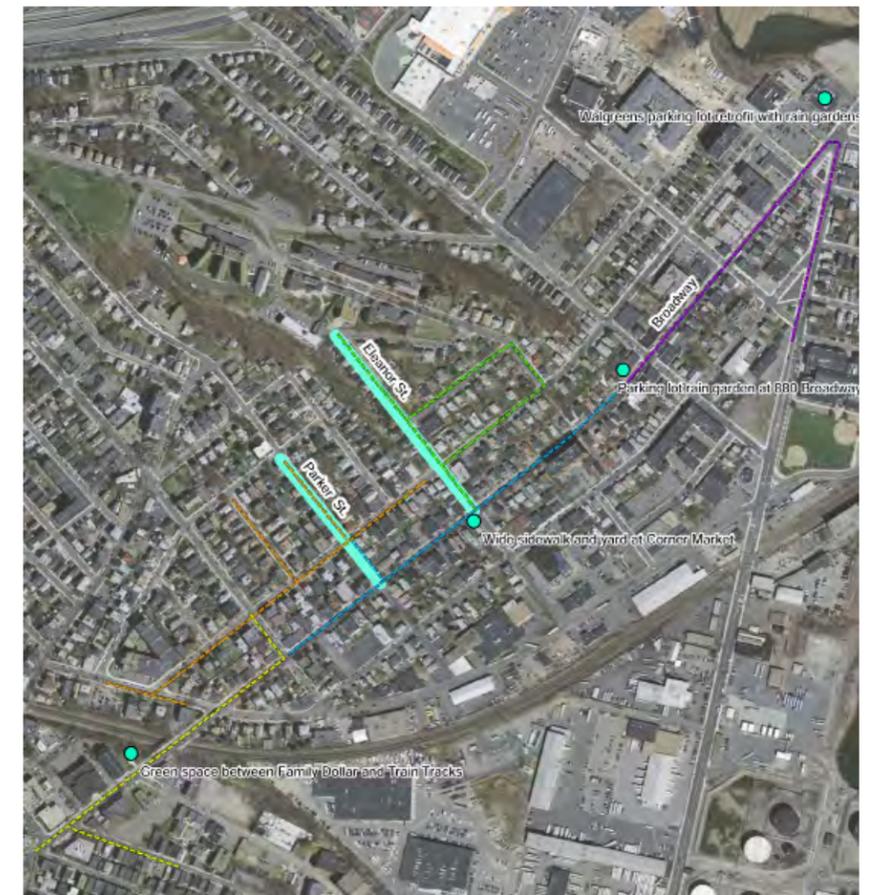
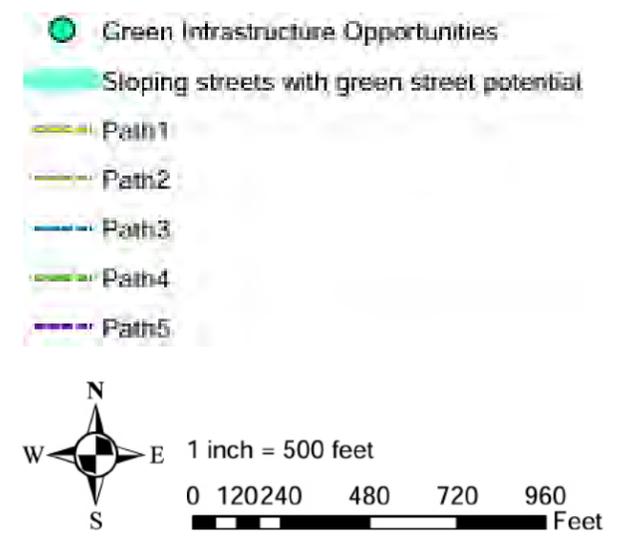


Figure 1.7 Green Infrastructure Opportunities Identified by Neighborhood Assessment Broadway Study Area



Data Sources: MassGIS, City of Chelsea, Weston & Sampson Engineers, Inc.

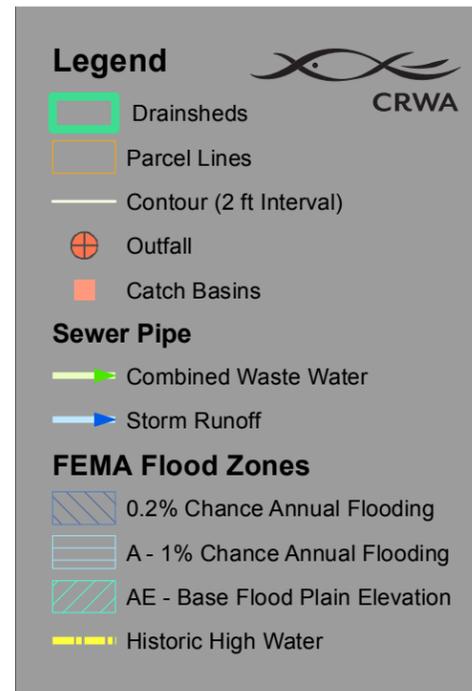
Priority Sites Analysis

Beth Israel Deaconess HealthCare Site at Mill Creek

Site 49 | Institutional

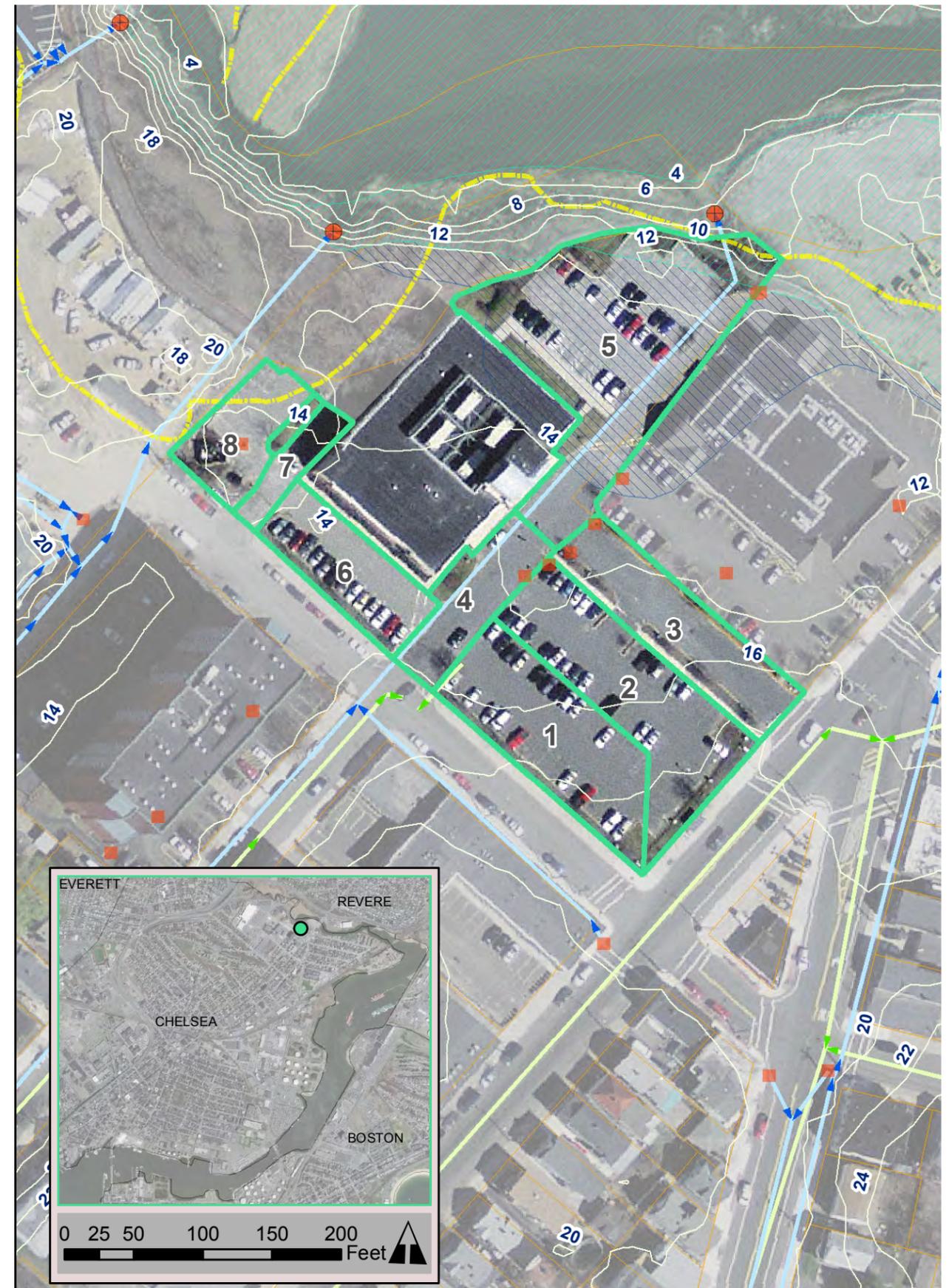
This mostly impervious, 80,133-square-foot parcel is composed of eight stormwater drainage areas. The site is adjacent to Mill Creek and its marshes, as well as Creekside Commons, a recently opened playground designed by ICON Parks in 2009. Two stormwater outfalls drain directly into Mill Creek. A public recreational access path runs along the naturalized, woody north-to-west edge of the property between Beth Israel and the creek, connecting Broadway with Parkway Plaza Shopping Center and Parkside Commons residential area. Strip islands planted with trees and grasses edge the perimeter of the property, and Beth Israel's building footprint interrupts the pavement pattern. A range of deciduous and wetland trees and shrubs are found on site but the developed area is almost exclusively planted with Callery Pear (*Pyrus calleryana* 'Bradford') and Thornless Honeylocust (*Gleditsia triacanthos* var. *inermis*).

Seven catch basins are located on the site: one in Drainage Area 8 on the western corner; two in Drainage Area 2 in the parking lot adjacent to the Beth Israel's entry; and two in Drainage Area 3 in the driveway across from the building's entrance. Two other catch basins are found on the border of Drainage Area 5 adjacent to the public walkway at the northeast edge in the parking area between Walgreen's and Beth Israel. The grade from Broadway to the building façade is approximately 3-4% flattening to standard parking lot grade at the south and west sides of the building. Parking at the building's north side is also at standard grade then drops off moderately to Mill Creek. No down spouts are visible on the building's exterior. The area is comprised of a mixed use of spaces along the southeast edge that is Broadway, a busy primary connector road and unifying spine running through Chelsea.



Site Facts Table

Drainage Area (Acres)	1.85
Impervious Area (Acres)	1.50
Pervious Area (Acres)	0.35
Land Use	Urban Public/ Institutional
Hydrologic Soil Group (at proposed BMP site)	Null



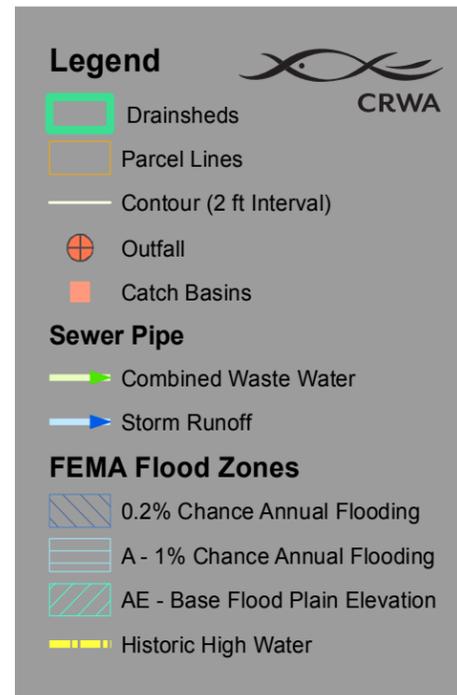
Toomey Square

Site 42 | Key Intersection

A triangular traffic island is located on Eastern Avenue at the juncture of Spencer Avenue and Louis and Stockton Streets at Toomey Square. It is owned by the French Naturalization Club located across from it on Spencer Avenue, and both the club and nearby Restaurant El Xielo use the area for parking. Its surface is almost entirely impervious and is ringed on two sides by an approximately 6.5 foot wide sidewalk. A 4 foot strip of brick pavers is set between the edge of the asphalt parking and the sidewalk on Eastern Avenue, and four trees are found within this strip. Two additional trees are located along the Stockton Street edge but no within a brick paver strip. The parking area is separated from these two sidewalk edges by a low wooden utility fence.

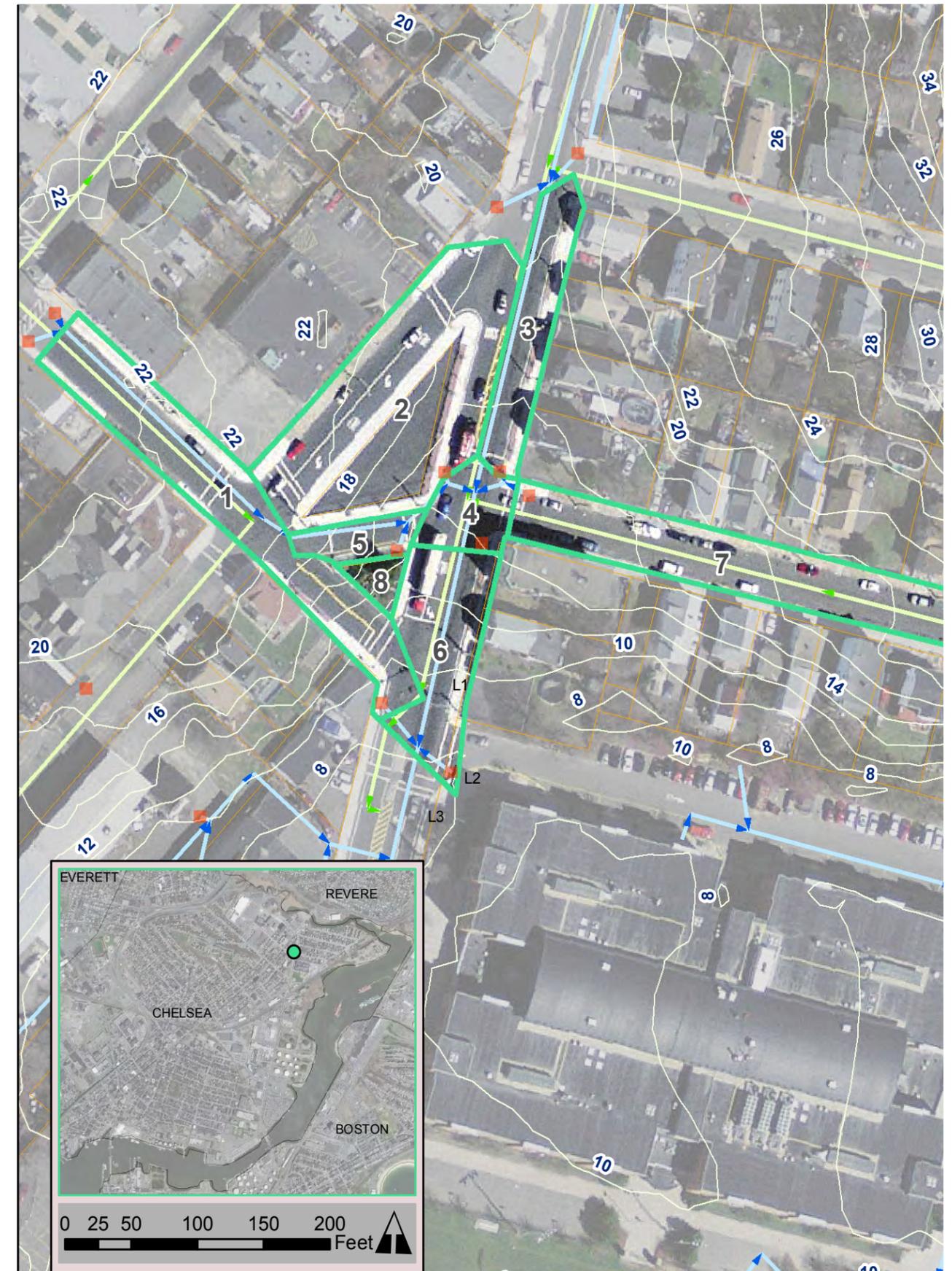
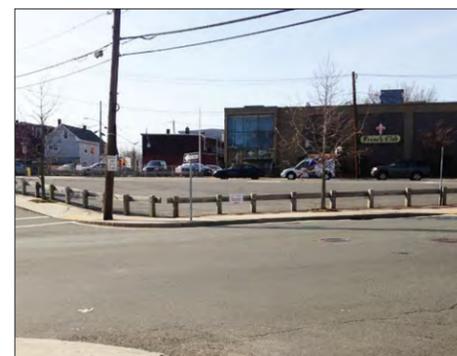
Toomey Square is an 81,109 square foot area with eight drainage areas that filter in to seven catch basins: One in Drainage Area 3 on Eastern at the corner of Louis; one in Drainage Area 7 on the north corner of Louis and Eastern; three in Drainage Area 6, the first on Eastern just south of Louis, and the other two on opposite corners of Stockton at the entrance to Burke Elementary School. A sixth catch basin falls within Drainage Area 5 at the north corner of an adjacent, smaller, planted island on Eastern Avenue. The last catch basin is located in the site's curbed edge on Eastern directly across from Louis.

The area is marked by small business, a school, social institutions and homes. The site is located on a pronounced grade, draining to the southwest corner. Eastern Avenue is a heavily-traveled secondary collector road. Reconstruction of this section of road occurred within the past five years.



Site Facts Table

Drainage Area (Acres)	1.87
Impervious Area (Arces)	1.84
Pervious Area (Acres)	0.03
Land Use	Commercial, High Density Residential & Urban Public/ Institutional
Hydrologic Soil Group (at proposed BMP site)	C

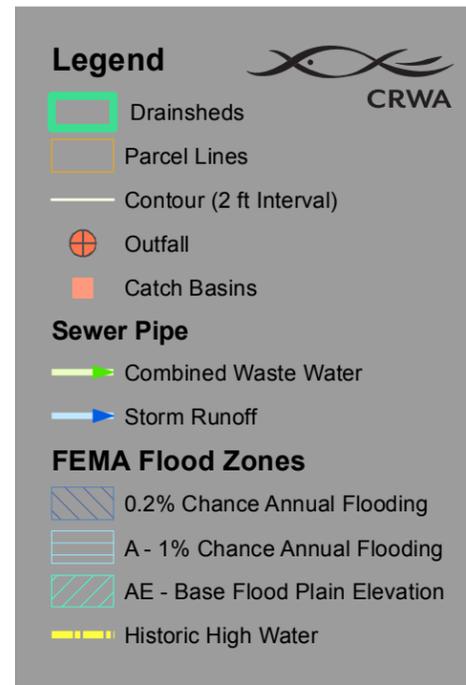


Powderhorn Hill City Stair

Site 38 | Public Vacant Lot

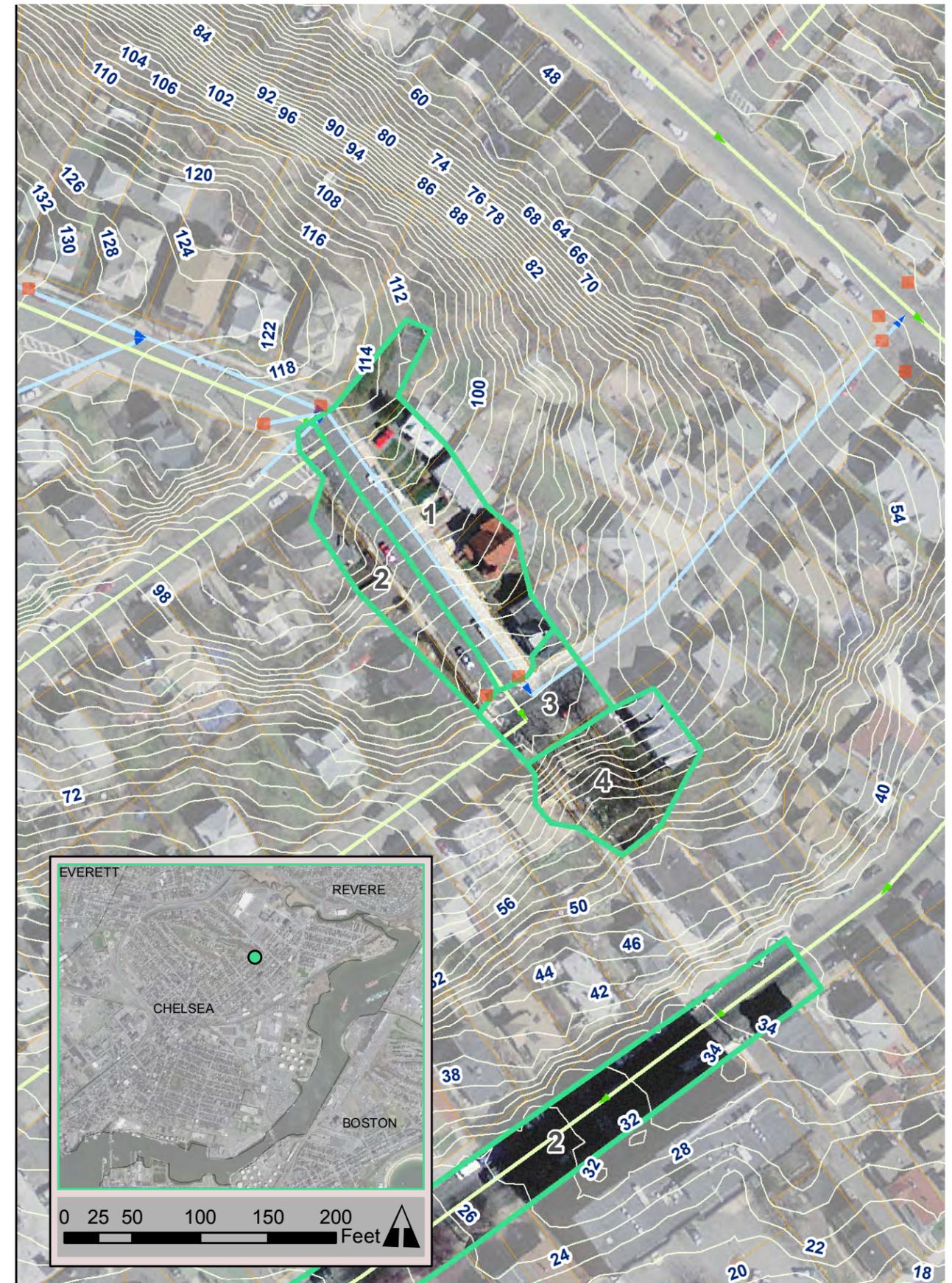
This neglected vacant parcel is located at the intersection of Crest and Clark Avenues on the southeastern side of a drumlin that rises 230 feet above sea level. The parcel is nestled at the edge of a historic residential neighborhood containing a number of Queen Anne Victorians - many of which have been converted to multifamily residences. The nearest public park is Malone Park located at the top of this hill adjacent to the historic Soldiers' Home.

This 29,882 square foot site (0.69 acres) slopes from Clark Avenue at a very steep grade starting with a convex form, becoming less steep but still pronounced as it descends. A concrete staircase with heavy iron railings lines the south side of the parcel and conforms to a significant grade that connects Clark Avenue with Broadway. Two- and three-story homes surround the parcel on three sides and create a strong verticality along its edges, as well as a sense of enclosure. The slope is grassy and pervious, dotted with several older trees such as native Black Cherry (*Prunus serotina*), a few Sycamore Maples (*Acer pseudoplatanus*), and an Elm (*Ulmus americana*). The sidewalk on Clark Avenue is approximately 10 feet wide. The site currently collects stormwater in three drainage areas - at catch basins on both sides of Crest (Drainage Areas 1 and 2); and at the southwest corner of the parcel near the stairs (Drainage Area 3).



Site Facts Table

Drainage Area (Acres)	0.88
Impervious Area (Arces)	0.63
Pervious Area (Acres)	0.25
Land Use	Multi-Family Residential
Hydrologic Soil Group (at proposed BMP site)	C



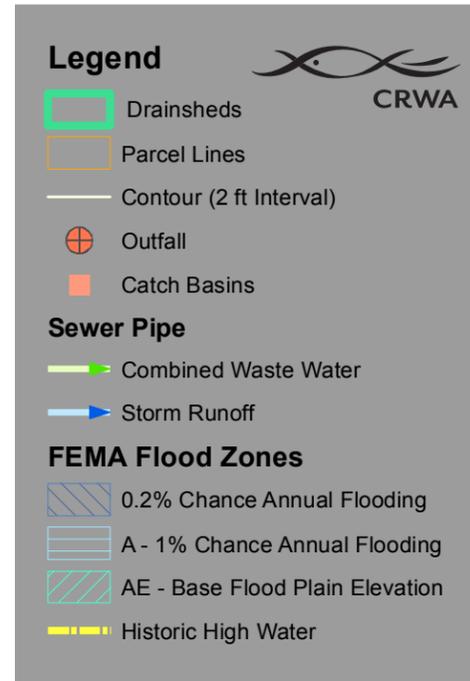
Bellingham Square

Site 1 | Public Plaza

Located in the heart of Chelsea's downtown historic district, Bellingham Square is a small plaza located on the west side of City Hall. The plaza is a popular gathering space and is actively-used for community events. Its design mirrors City Hall, using mortared brick pavers as its main material. A few low, concrete walls help define different areas within the plaza, and granite edge details add character and texture to the overall design.

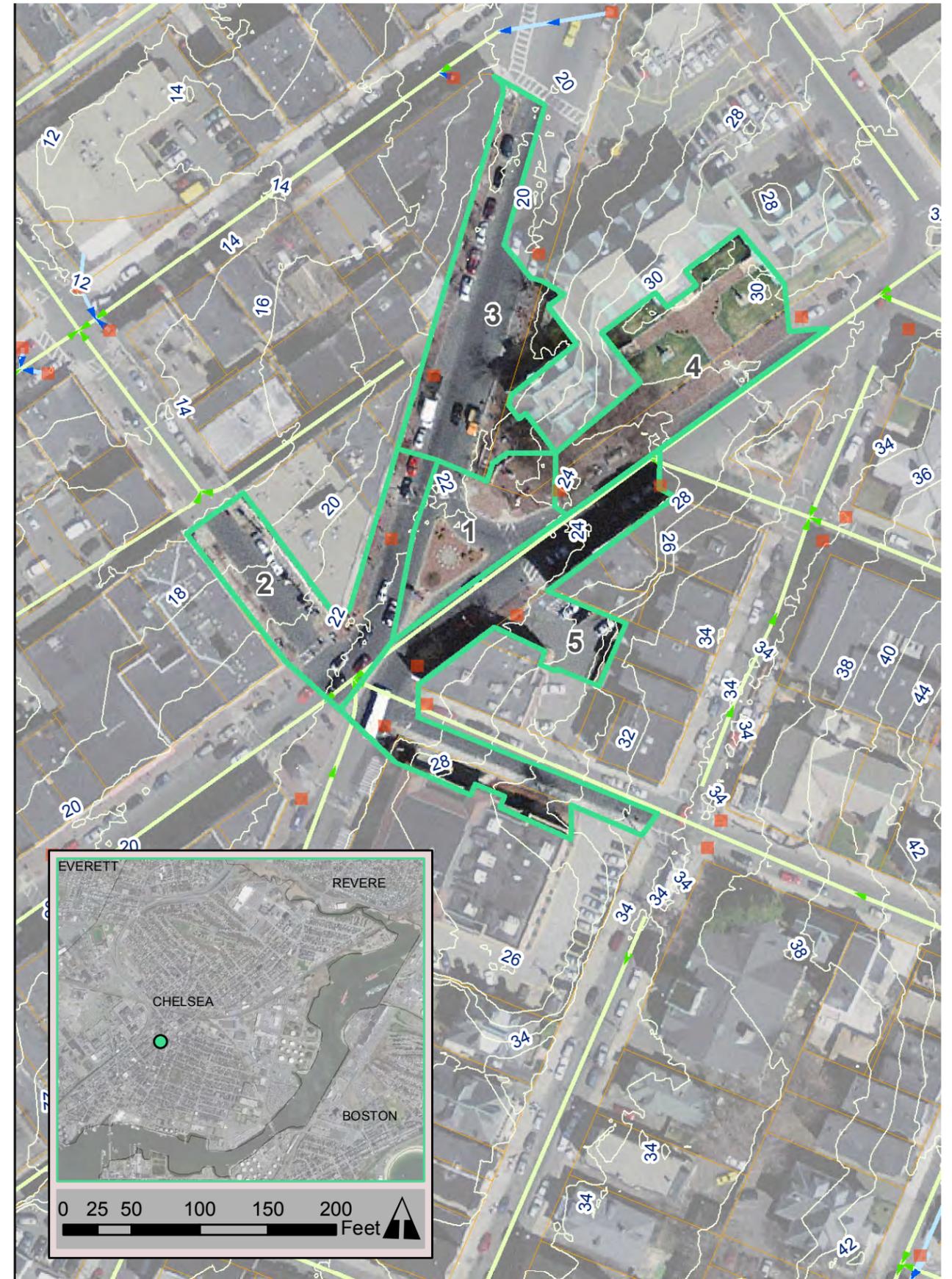
The plaza spans adjacent, varying grades within the site. There is a three-step staircase from street level to building level at City Hall's northwest corner. The plaza also gently slopes from building level to a broadly tapered southwestern edge. From here, pedestrian crosswalks span both Washington Avenue and Broadway, busy connector roads that converge here. A one-way vehicular turnoff from Washington Avenue to Broadway defines the front edge of the plaza, and creates a triangular island consistent in overall site design yet floating separate from the plaza within a dominant, heavily-trafficked intersection. Various, free-standing planters are located here as well as a large, brick-encircled bed at the island's triangular corner that juts furthest into the intersection.

This 37,418 square foot site contains four drainage areas. There are two catch basins within the designated drainage areas. The first catch basin is found in Drainage Area 2 toward the southwestern edge of the plaza. The second catch basin is in Drainage Area 4 along Broadway on the opposite side of the street from the island. Two drain pipes descend from the northwest and southeast corners of City Hall and flow to pipes attached at their ends.



Site Facts Table

Drainage Area (Acres)	1.72
Impervious Area (Arces)	1.72
Pervious Area (Acres)	0
Land Use	Commercial & Urban Public/ Institutional
Hydrologic Soil Group (at proposed BMP site)	Null



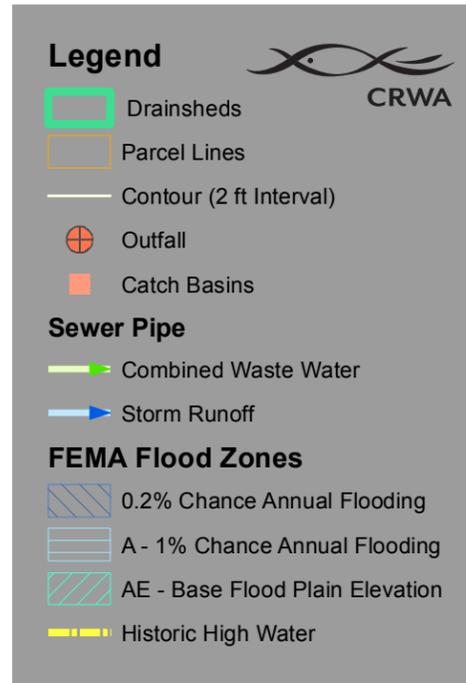
Broadway at Eleanor Street Corner Lots

Sites 34 and 35 | Private Commercial at Key Intersection

Eleanor Street is a local road with light to moderate traffic flow. It runs downhill approximately one third of a mile between Hillside and Crescent Avenues sloping in a northwest to southeast direction. The proposed project sites are located on the corner of Eleanor Street where it intersects with Broadway.

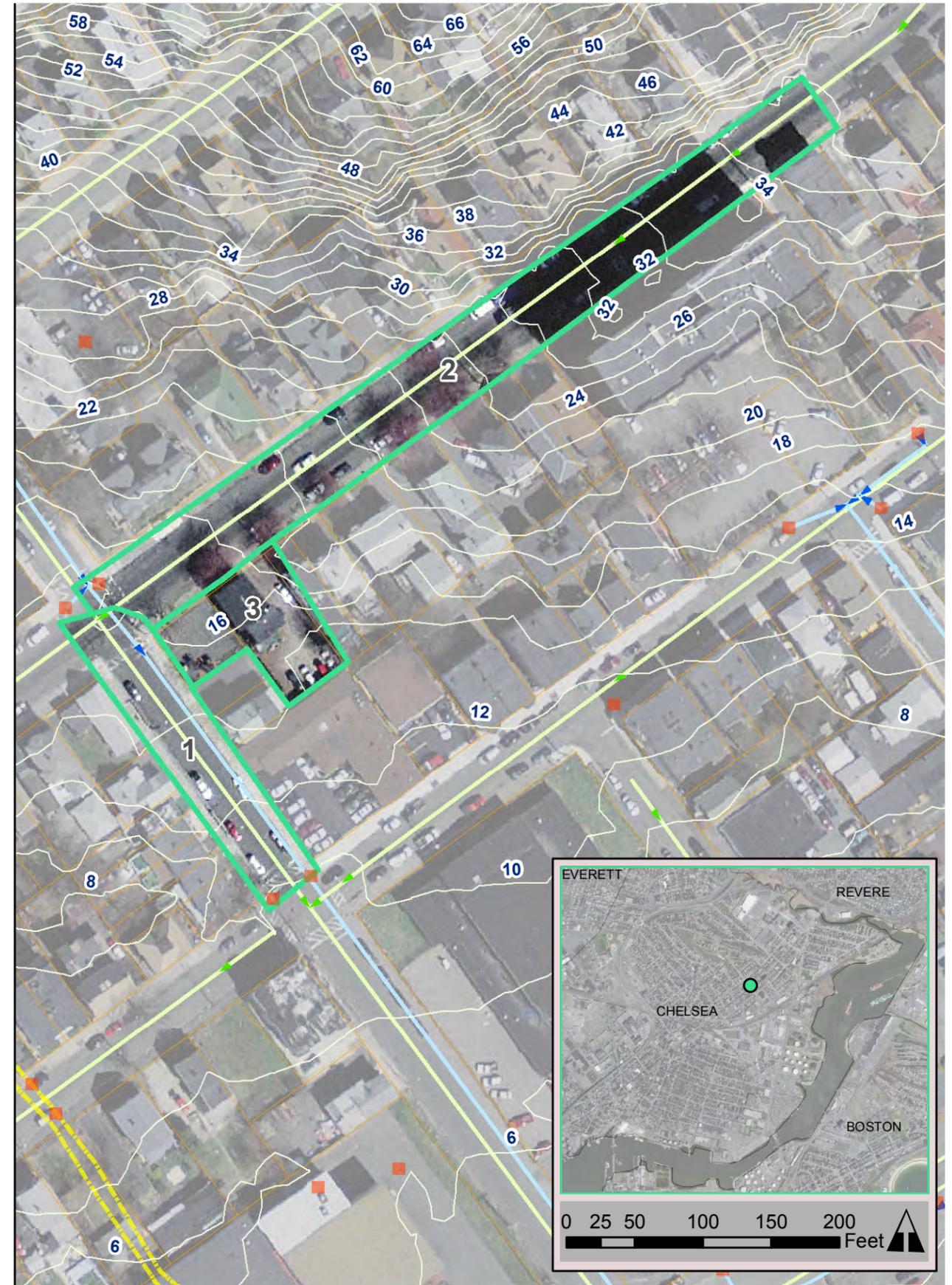
Impervious surfaces dominate the site and occur in the interstitial spaces between the building footprints. An exception to this is Drainage Area 3 which has a gravel surface. The Chappy Corporation parking lot at the corner of Eleanor Street and Spencer Avenue also was considered for green infrastructure due to its adjacency to Drainage Area 1. Downspout pipes are mounted from each corner of the Chappy Corporation building directly discharging stormwater to the ground. Empty tree pits are found on Broadway at Eleanor Street.

This commercial block covering a total of 54,145 square feet consists of three drainage areas. Four catch basins are present: two flanking northern corners of Eleanor Street where it intersects with Broadway, and two on the northern corners of Eleanor Street where it intersects with Spencer Avenue.



Site Facts Table

Drainage Area (Acres)	1.23
Impervious Area (Arces)	1.23
Pervious Area (Acres)	0
Land Use	Multi-Family Residential & Commercial
Hydrologic Soil Group (at proposed BMP site)	B



Recommended Stormwater Controls/Best Management Practices

Bioretention

Bioretention systems collect and filter stormwater through layers of mulch, soil and plant root systems where pollutants such as bacteria, nitrogen, phosphorus, heavy metals, oil and grease are retained, degraded and absorbed. Treated stormwater is then infiltrated into the ground or, if infiltration is not appropriate, discharged into a traditional stormwater drain system through under-drains.

Vegetated bioretention systems have a high aesthetic value, and are an attractive option in developed landscapes.

Sections Not to Scale

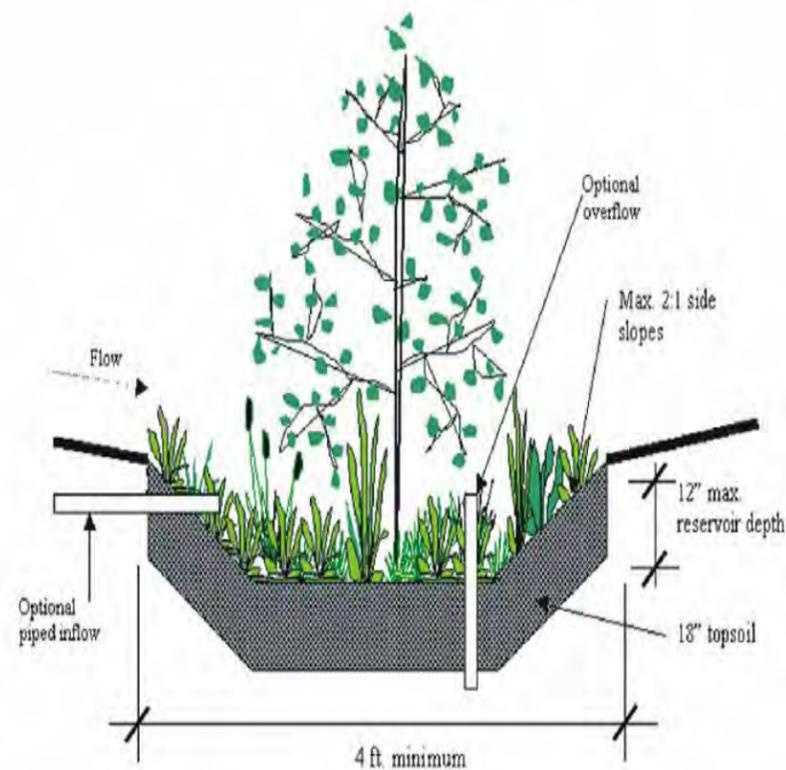


Figure 1.8 Typical Bioretention BMP Section

Rain Gardens

Rain gardens look similar to traditional gardens, but they differ in design and function. Rain gardens can be planted with a variety of perennials, grasses, shrubs and small trees, with native plants typically preferred. Important to note, selected plant and tree species should be able to tolerate occasional water inundation. Overall, rain gardens add aesthetic value to any site and can be installed at large or small sites.

Rain gardens use shallow detention and infiltration areas to reduce the volume, flow rate and temperature of stormwater runoff, increase groundwater infiltration and recharge and improve water quality in local surface waterways. Rain gardens are ideally located in already low-lying areas away from building foundations, and in areas that receive full to partial sun in order to maximize evaporation. Rain gardens work particularly well in areas that already have good soil drainage, though soil can be manipulated to improve its drainage characteristics.

Rain gardens provide a cost effective way of treating stormwater as the ratio of cost to volume of runoff treated is lower than many other stormwater controls.



Figure 1.9 Typical Rain Garden BMP Section

Stormwater Tree Pits

Stormwater tree pits consist of an underground structure and above ground plantings which collect and treat runoff using bioretention. Treated stormwater is infiltrated into the ground or, if infiltration is not appropriate, discharged into a traditional drainage system.

Stormwater tree pits resemble traditional street trees and are perfect for urban streets where space is limited. Ideally, stormwater tree pits are employed in conjunction with other stormwater best management practices.

Numerous prefabricated tree pit structures are commercially available and typically include a ready-made concrete box with an appropriate soil mixture. They may also include plantings, usually one tree or a few small shrubs.

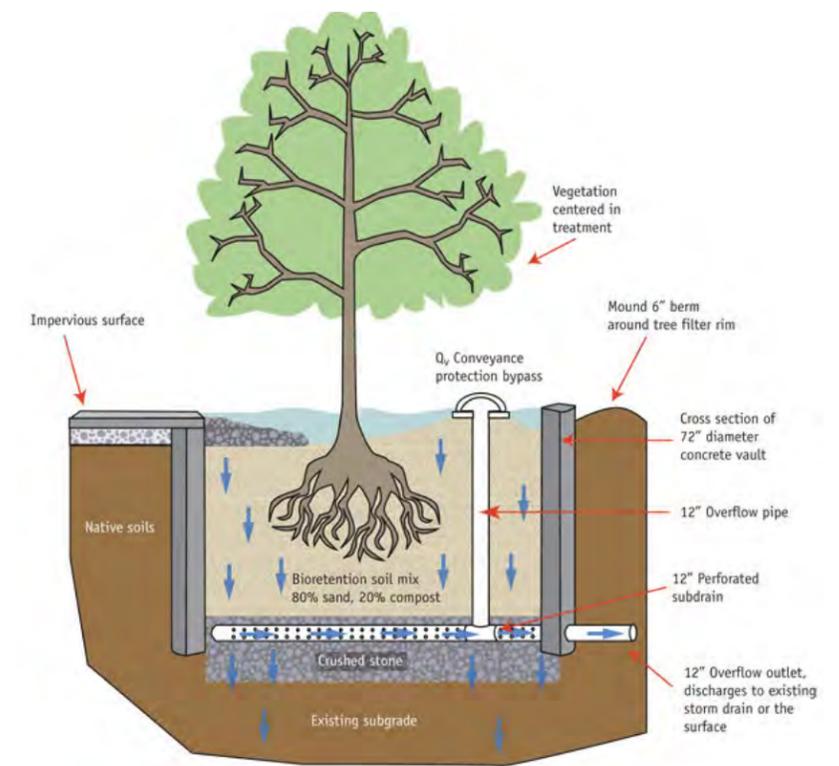


Figure 1.10 Typical Stormwater Tree Pit Section

PRIORITY SITE CONCEPT DESIGNS

Beth Israel Deaconess HealthCare Site at Mill Creek

Site 49 | Institution

Two types of best management practices are considered for treating stormwater runoff from five of the eight drainage areas defined for the Beth Israel Deaconess Medical Center site. Drainage Area two, subdivided into 2A and 2B, joined with Drainage Area 3 would drain into a series of bioretention basins along the entrance driveway and adjacent to the primary parking area. The system would overflow into existing catch basins at the foot of the entry drive in front of the medical center building.

An ecologically sensitive coastal marsh system exists on site. Drainage Area 5, dominated by a large parking area, directly impacts this system. The bioretention basin designed for this area would capture and treat stormwater runoff along the northwest edge of the drainage area. In addition to providing ecosystem services to this area, the bioretention will have the benefit of enhancing an interpreted public path system that follows this buffer between the medical center and the marsh. As an alternative treatment for Drainage Area 5, a gravel wetland could be installed at the margin of the property to treat flows from this drainage area and as well as additional flow from the larger sub-watershed.

Bioretention basins along the public pathway, to the north between the medical center building and Creekside Common play area would treat stormwater runoff from Drainage Areas 7 and 8. Similar to drainage area 5, the suggested location of this bioretention offers high visibility along the pathway providing educational and aesthetic benefits. A woodland buffer between the drainage area and the marsh occurs at this juncture along the path as it passes both Drainage Area 5, 7 and 8. A conversion of this woodland area into a park in the future would provide linkage for these drainage areas and represent a significant amenity to the residents.

Figure 2.1 Proposed Site Plan showing location of bioretention basins





Figure 2.2 Existing edge of Beth Israel parking lot



Figure 2.3 Proposed bioretention system at the edge

BMP Selection and Sizing

DA5

Type	Bioretention
Drainage Area (Acres)	0.57
Impervious Area (acres)	0.42
Water Quality Depth (Inches)	1.00
Water Quality Volume (Cubic Feet)	2373.21
BMP Surface Area (Square Feet)	1876.00

DA2 & 3 Combined

Type	Bioretention
Drainage Area (Acres)	0.54
Impervious Area (acres)	0.45
Water Quality Depth (Inches)	1.00
Water Quality Volume (Cubic Feet)	2060.93
BMP Surface Area (Square Feet)	1492.00

DA7 & 8 Combined

Type	Bioretention
Drainage Area (Acres)	0.17
Impervious Area (acres)	0.14
Water Quality Depth (Inches)	1.00
Water Quality Volume (Cubic Feet)	478.03
BMP Surface Area (Square Feet)	370.00



Figure 2.4 Existing conditions at the edge of Beth Israel rear parking lot

Figure 2.5 Proposed bioretention system at the edge of the parking lot

Toomey Square

Site 42 | Private Commercial at key intersection

Three bioretention areas are proposed for two of the seven drainage areas at Toomey Square. These bioretention areas collect and treat stormwater for Drainage Area 3 in two segments fit within the existing sidewalk. The first of these segments is connected to an existing catch basin that can accommodate overflow from the system during larger storm events.

The second bioretention area treats stormwater runoff for Drainage Area 4. The sidewalk does not currently have the width to accommodate the area, and therefore is extended into the street right of way. An existing catch basin is immediately adjacent to the bioretention area and is able to collect excess stormwater during larger rain event.

Tree filters serve as rainwater treatment and storage systems in Drainage Areas 2, 6 and 7. The tree filter for Drainage Area 6 would require installation of an additional catch basin.

A rain trench is proposed along two of the sloped edges of the parking lot island at the center of Toomey Square to provide both low volume infiltration of stormwater and conveyance to a tree filter situated at the lowest point of the drainage area. An existing catch basin can handle any overflows from the tree filter system.



Figure 2.6 Proposed Site plan showing location of BMPs



Figure 2.7 Existing view of parking lot edge along Stockton Street

BMP Selection and Sizing

DA2

Type	Tree Filter 2 of .25 DA
Drainage Area (Acres)	0.54
Impervious Area (acres)	0.54
BMP Surface Area (Square Feet)	1876.00



Figure 2.8 Proposed stormwater trench along parking lot edge

DA2

Type	Rain Trench
Drainage Area (Acres)	0.54
Impervious Area (acres)	0.54
BMP Surface Area (Square Feet)	585.00



DA3

Type	Bioretention
Drainage Area (Acres)	0.16
Impervious Area (acres)	0.16
Water Quality Depth (Inches)	1.00
Water Quality Volume (Cubic Feet)	543.90
BMP Surface Area (Square Feet)	280.00



Figure 2.9 Existing view of parking lot edge along Eastern Avenue



Figure 2.10 Proposed bioretention area along parking lot edge

DA4

Type	Bioretention
Drainage Area (Acres)	0.09
Impervious Area (acres)	0.09
Water Quality Depth (Inches)	1.00
Water Quality Volume (Cubic Feet)	296.05
BMP Surface Area (Square Feet)	154.00

DA6

Type	Tree Filter 1 of .25 DA
Drainage Area (Acres)	0.21
Impervious Area (acres)	0.21
BMP Surface Area (Square Feet)	36.00

DA7

Type	Tree Filter 1 of .50 DA
Drainage Area (Acres)	0.44
Impervious Area (acres)	0.44
BMP Surface Area (Square Feet)	36

Powderhorn Hill Public Stair (Crest and Clark Avenues)

Site 38 | Public Vacant Lot

Due to steep grades and limited space availability, a combination of tree pits and bioretention systems are suggested for the three drainage areas occurring at the junction of Crest and Clark Avenues.

Catch basins are available to handle overflows in case of large storms.

As an option to the tree filter system, a bioretention area may be proposed at the end of Crest Avenue by extending the existing sidewalk by a few feet.

The bioretention areas serving Drainage Areas 1 and 3 have the possibility for shaping the design of a neighborhood pocket park in what is now a topographically steep, unique parcel of vacant city-owned land, thereby creating a stormwater park in a historic neighborhood.

BMP Selection and Sizing

DA2

Type	Tree Filter 1 of .25 DA
Drainage Area (Acres)	0.19
Impervious Area (acres)	0.14
BMP Surface Area (Square Feet)	72.00



Figure 2.11 Proposed Site plan showing location of stormwater BMPs



Figure 2.12 Existing view of vacant parcel along City Stairs



Figure 2.13 Visualization of proposed rain garden along City Stairs



Figure 2.14 Drainage Areas 3 & 4; Section of proposed rain garden and bioretention system



DA1, 3 & 4 Combined

Type	Bioretention
Drainage Area (Acres)	0.70
Impervious Area (acres)	0.50
Estimated Infiltration Rate (K) (Inches/Hour)	0.21
Water Quality Depth (Inches)	1.00
Water Quality Volume (Cubic Feet)	1727.01
BMP Surface Area (Square Feet)	958.63

DA1, 3 & 4 Combined

Type	Rain Garden
Drainage Area (Acres)	0.70
Impervious Area (acres)	0.50
Estimated Infiltration Rate (K) (Inches/Hour)	0.21
Water Quality Depth (Inches)	1.00
Water Quality Volume (Cubic Feet)	1715.00
BMP Surface Area (Square Feet)	2001.10

Figure 2.15 Proposed Site plan of rain garden and bioretention area



Figure 2.16 Existing site condition from sidewalk along Clark Avenue



Figure 2.17 Visualization of proposed bioentention area along sidewalk

Bellingham Square

Site 1 | Public Plaza

Bellingham Plaza at City Hall is an opportune location to site a green infrastructure project education. This site is a landmark of the community with high foot and vehicular traffic.

To manage stormwater runoff from Drainage Area 1 a single bioretention area is proposed at the triangular tip of the central island at the convergence of Broadway, Washington Avenue, and Park Street. The island is currently enhanced by the placement of several raised planters. An existing catch basin can be connected with the bioretention system to handle overflows in the event of larger storms.

BMP Selection and Sizing

DA1

Type	Bioretention
Drainage Area (Acres)	0.20
Impervious Area (acres)	0.20
Water Quality Depth (Inches)	1.00
Water Quality Volume (Cubic Feet)	693.00
BMP Surface Area (Square Feet)	533.08

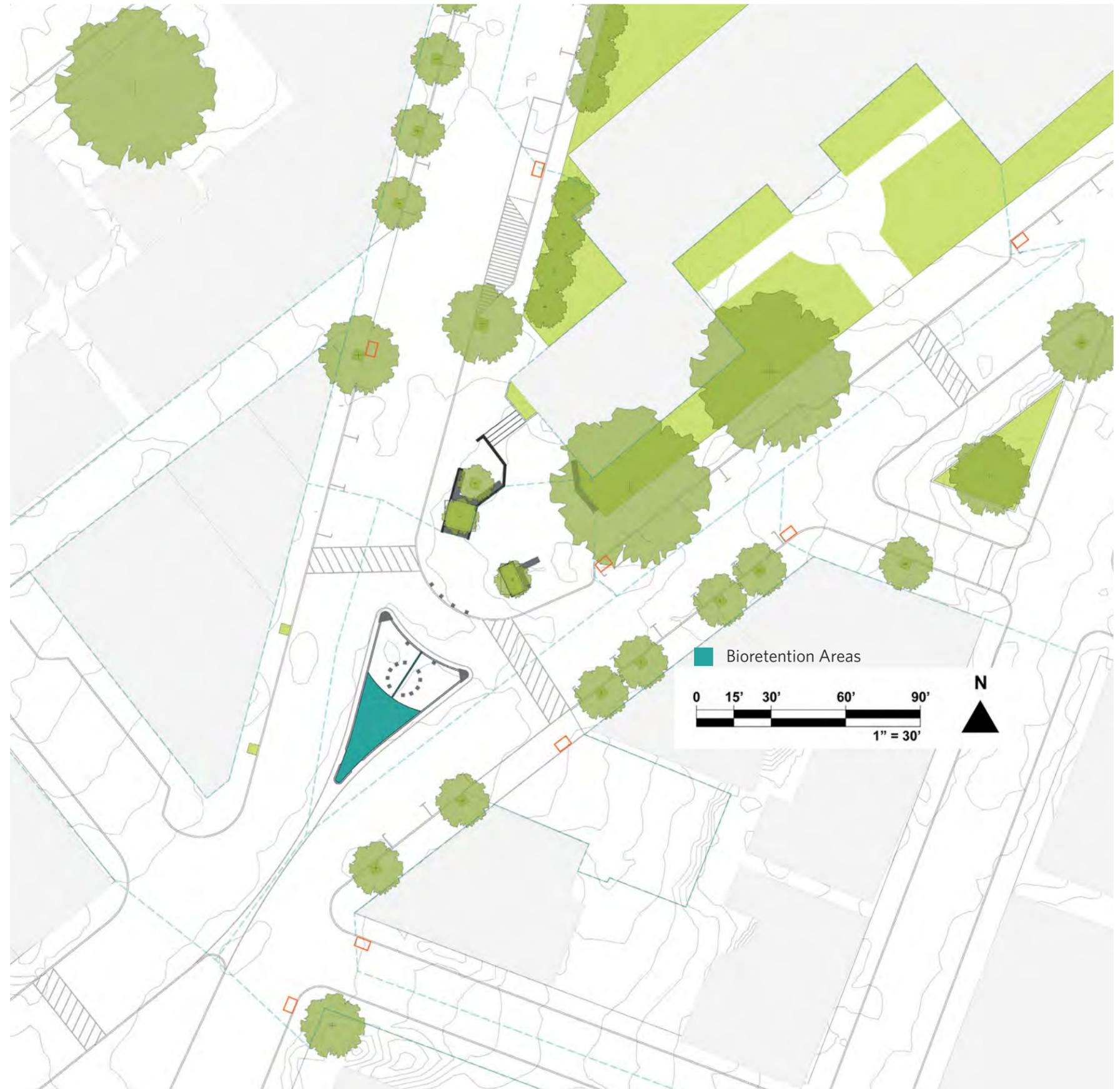


Figure 2.18 Site plan showing the location of BMPs

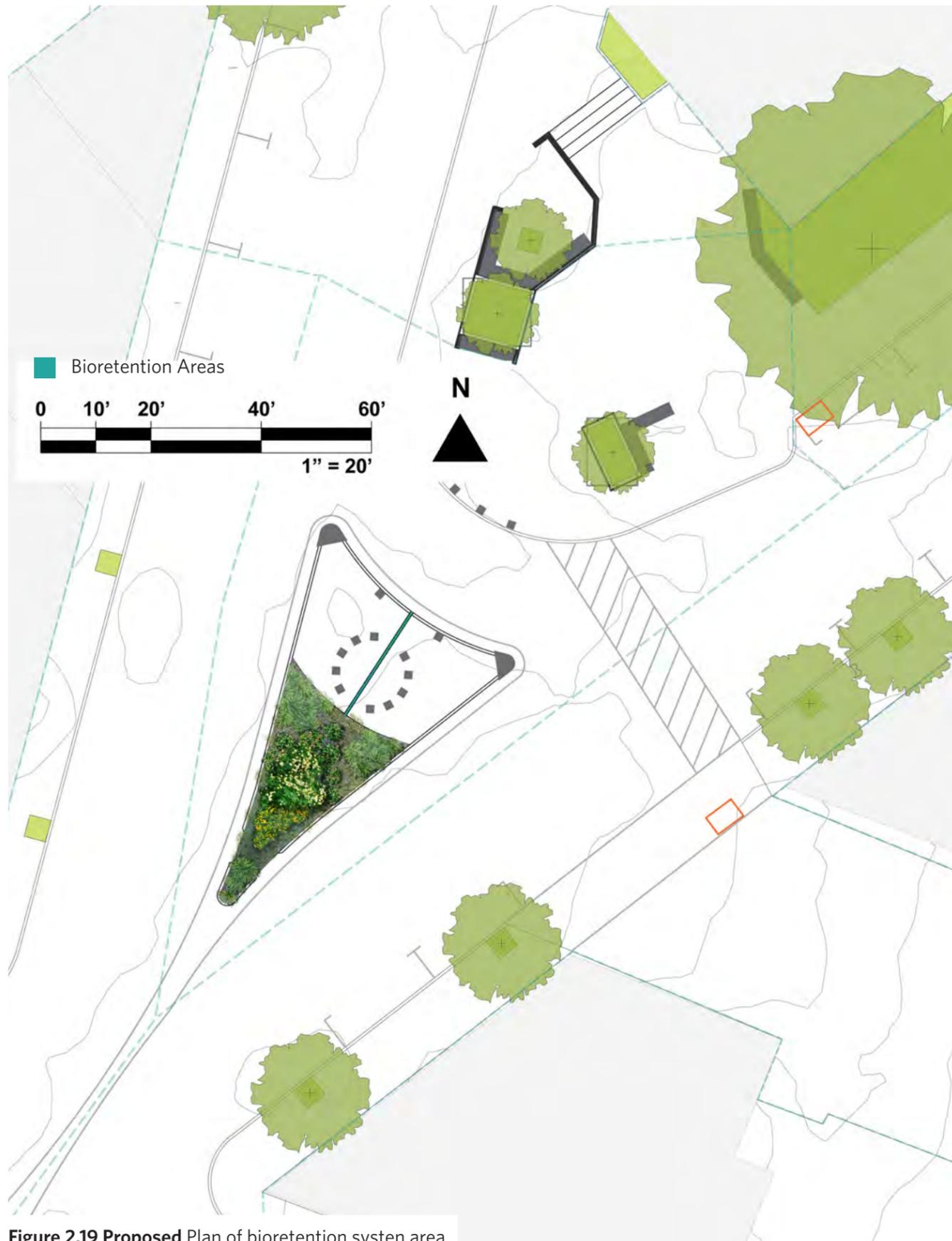


Figure 2.19 Proposed Plan of bioretention system area



Figure 2.20 Drainage Area 1 existing conditions



Figure 2.21 Drainage Area 1 Visualization of proposed bioretention system

Broadway at Eleanor Street Corner Lots

Sites 34 and 35 | Private Commercial at Key Intersection

Bioretention areas serving Drainage Area 2 are proposed for the intersection of Chelsea’s arterial Broadway and Eleanor Streets. The street right- of-way allows locating the bioretention site in the parking lane at the crosswalk area creating an opportunity for intersection bump outs, increasing the safety of crossing Broadway, and adding to the aesthetics of an area directly adjacent to a bus stop. An existing catch basin at the lower end of Drainage Area 2 can serve as overflow for the system on the north side of the road. An additional catch basin might be necessary to accommodate the bioretention areas along the south side of the street.

Due to the size of the drainage area, several bioretention areas of similar size and shape would need to be installed at locations fifty feet apart on both sides of Broadway. This is a favorable site to install vegetated bioretention systems as it increases the visibility of the innovative stormwater system and improves the aesthetics of the street.

Also proposed are tree filters systems connected with infiltration trenches along the edge of the parking lot that could accommodate stormwater from Drainage Area 1. Two existing catch basins at the corner of Eleanor and Spencer Streets can accommodate overflow during a large storm.

DA1

Type	Tree Filter 1 of .50 DA
Drainage Area (Acres)	0.28
Impervious Area (acres)	0.28
BMP Surface Area (Square Feet)	72.00



Figure 2.22 Site plan showing location of BMPs



Figure 2.23 View of intersection of Broadway and Eleanor Street



Figure 2.24 Visualization of proposed curb bump-out with bioretention areas

DA2

Type	Bioretention
Drainage Area (Acres)	0.76
Impervious Area (acres)	0.76
Water Quality Depth (Inches)	1.00
Water Quality Volume (Cubic Feet)	2625.77
BMP Surface Area (Square Feet)	1346.55

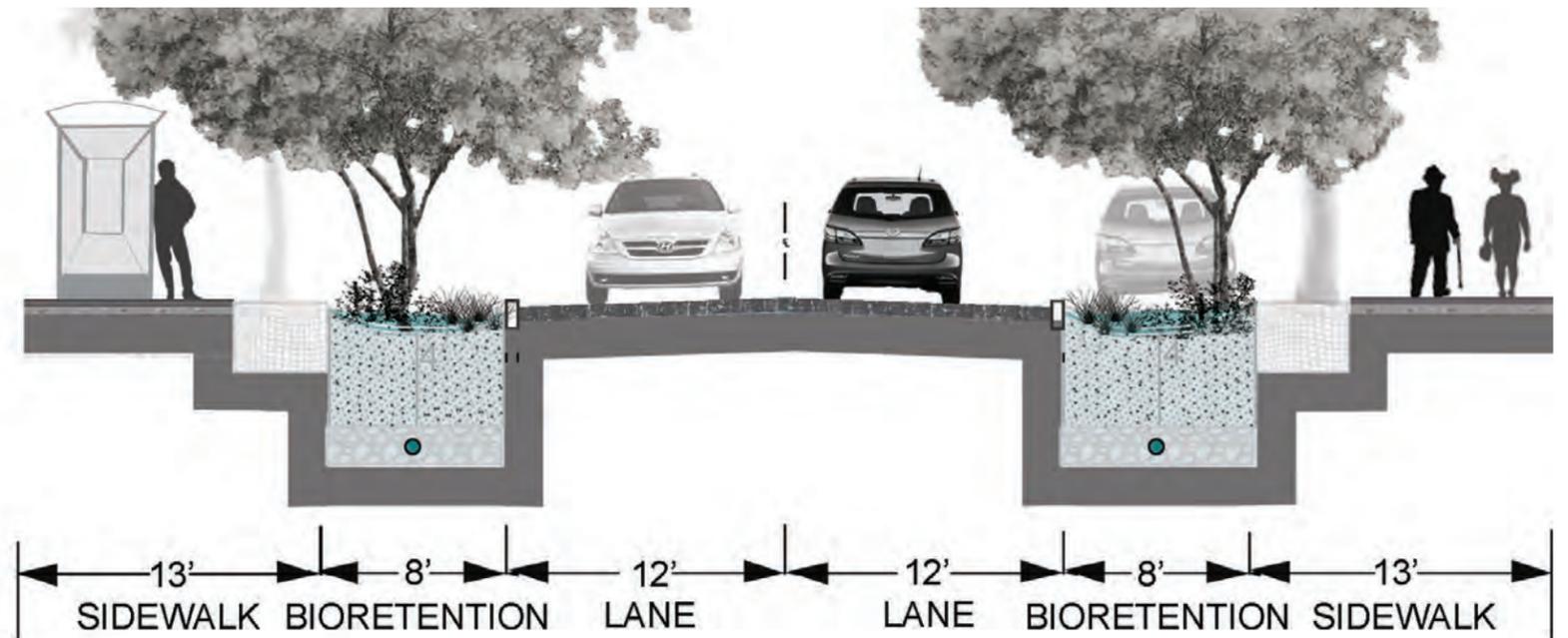


Figure 2.25 Proposed Curb bump-out section

BROADWAY GREEN STREETScape RETROFIT

Definition of a “Green Street”

A “green street” is a signifier of a healthy neighborhood. On a “green street,” part of the public right-of-way is designed so that stormwater runoff is captured and cleaned by vegetation and soils. Whether the vegetation consists of street trees, grass, or “raingardens,” a green street offers a way to decrease water pollution and beautify neighborhoods with vegetation. Further, a green street is a place for pedestrians to walk comfortably and safely; it is a place where the needs of community and environment are balanced with the need to accommodate the automobile.

From a watershed perspective, green streets differ from conventional city streets because they are designed to retain rainwater where it falls and where possible, replenish groundwater instead of conveying water off the land via underground pipe networks. Traditional pipe systems often cause flooding and water quality problems where the pipes end at outfalls – in streams, rivers, lakes and oceans. Water that flows off of paved surfaces (stormwater runoff) is contaminated with the byproducts from vehicles, lawn fertilizer, and other intensive land uses. These pollutants include heavy metals, oils and greases, excess nutrients, bacteria, and sediments. Water flowing through traditional gray infrastructure can exit the land surface at a higher rate than water that percolates slowly through vegetation and soils in an undeveloped environment. The more pavement and rooftops in a watershed, the more water is forced into the pipe network. These volumes of rainfall, along with their toxic mix of contaminants, are delivered rapidly to receiving waters causing flooding and erosion of streambanks and shorelines at the end of the pipes. Thus, the environmental goals of green street design, a component of the Low Impact Development (LID) approach, are to reduce the use of pipe networks and allow natural drainage systems to carry and clean rainfall in cities.

Elements of Green Streets (A) Public Realm

Roadways

Since walkability is one of the goals of creating green streets, the first step in designing green streets is to analyze just how much space one needs in order to accommodate cars, trucks, and emergency vehicles within the roadway. In many cities, autos are allocated wider stretches of pavement than necessary for mobility. This both encourages driving at faster (unsafe) speeds and translates to excessive impervious surfaces which lead to poor hydrology and water quality. Green street projects in Portland, Oregon and Seattle, Washington have shown that two-way, two-lane residential traffic can safely move within a twenty foot paved roadway. On mixed use, commercial, and industrial streets with heavy traffic, it may be necessary to utilize wider paved roadways. But on residential or low volume streets, planners and engineers should consider the value of setting widths near a minimum practical width. Narrower paved roadway widths mean less impervious surface to generate stormwater runoff and more space for pedestrian traffic, vegetation and water quality improvements

Vegetation

Within the streetscape trees, shrubs, ornamental plants and grasses create an attractive ambiance, but also provide functions that make for better human habitat and improve environmental quality.

Street trees shade their surroundings, improve air quality, increase evaporation, provide habitat, and reduce the urban heat island effect. The root zone of the tree pits in which street trees are placed can also serve as a storage area for stormwater runoff. A combination of engineered soils with extra pore space for water storage (voids created between soil components) and a selection of tree species that can tolerate “wet feet”

as well as drought, make expanded street tree networks a good option for reducing runoff and improving quality of life on urban streets.

Median Strips and Raingardens: In many cities cultivation of grass or other vegetation in planting strips and street medians have provided an aesthetic amenity and a buffer between auto traffic and pedestrians. These green strips, with or without trees, can be designed as raingardens and used to store and filter stormwater. In Portland, Oregon, they are planted with fine-stemmed, water-tolerant vegetation and placed within the curbs of the sidewalk; stormwater enters the strips through grates cut into the curb.

In a Seattle, Washington neighborhood development, the planting medians are designed with two different aesthetic styles. The first example is similar to Portland’s project within which water is held on the surface by plants. The fine-stemmed vegetation acts as a filter, catching the particles and sediments in stormwater and trapping many of the nutrients and heavy metals that are bound to them. In the second Seattle example, water is held briefly on the grass surface but much of the stormwater is actually stored underground in large cells of specially engineered soils. Collectively, these strategies can serve as examples of ways to avoid directing runoff to overburdened stormwater pipe infrastructure while retaining the mobility and safety functions of the street right-of-way. Depending on the desired street configuration these plantings can be located flanking the roadway adjacent to sidewalks or within median strips that separate driving lanes.

Sidewalks

Wider sidewalks improve the pedestrian realm of the public right-of-way and leave space for other street design elements such as street trees, benches, and lighting. While sidewalks traditionally contribute to the sum

of impervious area within a street corridor, it is possible to reduce their effective imperviousness by paving sidewalks with porous and permeable materials that allow water to flow through and recharge groundwater, rather than runoff into the storm sewer pipe network.

Bike Lanes

Biking is a healthier and more sustainable form of local transportation than driving. Bicycle safety is an important feature of any street design and, where possible, should be incorporated into any green street retrofit. If a right-of-way is narrow and auto traffic lane width needs confound the ability to designate a separate bike lane, the best option for bikes may be slowing car traffic. Ways to do so include shared travel lanes with appropriate signage, providing vegetation, pavement changes at intersections, visual amenities, and other traffic calming elements within the streetscape.

Parking Lanes

While sometimes indistinguishable from the adjacent roadway in terms of paved surfaces, parking lanes do not need to meet the traffic weight and speed requirements that driving lanes do. Accordingly, they provide an opportunity to incorporate alternative materials, such as porous asphalt or concrete and permeable pavers. If there is adequate off-street parking, choosing to replace parking lanes with bike lanes or vegetation will effectively reduce the amount of right-of-way allocated for cars and increase other street amenities.

Underground Infrastructure/Utilities

While we can't convert cities to their predevelopment landscapes, we can be more selective about using natural systems of plants and soils rather than artificial pipe systems to shape the watersheds in which we live. Sometimes the surface width of the street right-of-way is not large enough to incorporate significant areas of soil and vegetation. In that case, we must look beneath the street itself as a place to store and treat stormwater. Infiltration trenches and underground detention and

retention chambers can complement the other green streets elements mentioned above and work together to mimic natural hydrologic patterns in urban neighborhood settings. While underground utilities can present challenges for placement of green street elements, in many cases existing older pipes can be left in place during retrofits for overflow events during larger storms.

Plazas and Large Intersections

Large public spaces such as public plazas, traffic circles, and wide intersections may be ideal locations to locate green street features such as raingardens and deep tree pits. They may also serve as gathering places for the local community and as sites for public art. Stormwater elements can be incorporated in these high-visibility settings as demonstration projects, providing watershed education opportunities for neighborhood residents.

Elements of Green Streets (B) Private Realm

Adjacent Patios, Driveways and Parking Areas

The water that flows along typical city streets into catch basins and through underground pipes does not originate on streets alone. Driveways and parking lots are often graded to flow from private property into the public street right-of-way. Owners of adjacent property can lessen the burgeoning volumes of rainfall that enters the public street system by reducing the runoff from their property. Effective methods to reduce runoff from residential properties include downspout disconnection, redirecting flow from hardscapes to permeable areas (e.g. raingarden, lawn), substituting porous materials in driveways and amending soils or vegetation in existing green areas to promote infiltration or evapotranspiration. Maximizing vegetation on one's property not only increases absorption of water by plant roots, but increases evaporation, helping to cool the local climate. (Note that heavily compacted turf and lawn vegetation with thick root mats are surprisingly impervious to rainfall and can generate significant volumes of stormwater runoff.)

Rooftops and Water Collection

Roof area is also a large contributor to the total rainfall volume that makes its way into public streets and storm sewer pipes. Property owners can help reduce this runoff at the first place where it falls on their parcel by converting flat and low slope roofs to green roofs (also known as "eco-roofs"). Downspouts can also be disconnected from piped drainage systems (if they aren't already) and rainwater can be conveyed either into cisterns (rain barrels) for irrigation water storage or conveyed directly into raingardens on the property. By thinking about the ultimate destination of every drop of rainfall that lands on our private properties, we can make enormous improvements in urban watershed hydrology and health.

Right of Way Planning and General Design Considerations

In addition to the public and private realm retrofit approaches mentioned above, the following considerations should be used as a checklist in development reviews and as a part of any street retrofit design process.

Reduce Impervious Pavement

- Use porous pavement for areas such as under bicycle lanes, overflow parking areas, emergency access roads and other low-traffic areas. Porous pavement can be permeable asphalt, concrete, or pavers. However, pavers should not be used where a smooth, even surface is required such as on bicycle lanes.
- Encourage the use of shared parking to reduce the size and number of parking lots. Encourage underground or above ground parking structures for appropriately sized development projects.
- Encourage shared driveways between adjacent development projects or residences.
- Consider reducing parking requirements stipulated in the zoning code for commercial, industrial and multifamily use so as to reduce net impervious area. On-street parking or public parking lots in close proximity can provide some of the required off-street parking supply

Manage Run-Off Onsite

- Grade sidewalks so that stormwater runs off into adjacent unpaved areas such as planting strips or landscaped private property.
- Use raingardens such as vegetated street swales and stormwater planters whenever possible.
- Design stormwater facilities for specific runoff goals (e.g. one hundred year storm) and provide for overflow.
- All suggested BMPs should drain through infiltration or release to a designated discharge point such as another BMP or existing storm water pipe. When using perforated pipes clean-outs need to be provided.
- For surface stormwater facilities keep slopes and depths as low as possible. This will increase safety, prevent erosion, and improve aesthetics.
- Place infiltration stormwater planters 10' away from building foundations to protect foundations.
- For enclosed stormwater drainage systems, consider inline treatment strategies including special structures to trap sediment (catch basins, sump pits, oil/grit separators).

Improve Environment for Pedestrians and Bicyclists

- Whenever possible, provide adequately sized sidewalks that are handicap accessible.
- Add bike lanes or other ways for safer riding such as shared roads. Use signs and shared lane pavement markings (such as sharrows) to indicate that bikes and cars share the travel lane.
- Include placement of bicycle racks on sidewalks and plazas.
- Use street calming techniques whenever possible; reduced lane width, extended curbs, raised crosswalks, side-alternating parking lanes.
- Incorporate street furniture, trash receptacles, pedestrian scaled lighting and public art where appropriate.

Add Trees and Plants

- Plant street trees wherever possible. Follow Boston's planting requirements :
 - 15' from light pole
 - 10' from a driveway
 - 20-40' from intersection (depending on direction of traffic)
 - 10' from a fire hydrant
- Incorporate stormwater treatment into vegetated areas.
- Select plants that can withstand wet conditions and are appropriate for urban environments in areas where runoff is stored and/or conveyed.

Maintenance - General Guidelines

Whatever green streets elements are designed and constructed, maintenance will play an important role in their success. Maintenance activities within the street right-of-way can eliminate flooding and improve water quality. They will affect structures and materials as well as vegetation and soil health. Activities may range from general repairs of sidewalks to vactoring (cleaning) out catch basins to street sweeping to pruning trees and weeding other vegetated areas. Some of these activities are more common on typical street designs; others are particular to green streets. Some maintenance duties—such as emptying sedimentation structures or tree pruning—can be performed by city departments; others—such as weeding rain gardens and inspecting catch basins for clogging—may be accomplished by local residents and business owners who are interested in helping a green street function properly. Maintenance programs should be developed for all green streets; planners may want to borrow from maintenance manuals used by cities with successful green streets and green alleys programs, such as Seattle, Portland, Vancouver B.C. and Chicago. Ultimately, no green street should be planned without consideration of maintenance objectives and needs and agreements as to who will be responsible for maintenance activities during the project's life.

- Regularly remove trapped sediment and pollutants to avoid resuspending them in subsequent storms.
- Select grass species that produce a uniform cover of fine hardy vegetation that can withstand prevailing moisture conditions. Provide routine mowing to keep grass in active growth phase and to maintain dense cover.
- Follow guidelines for erosion control techniques during construction of regional streets and adjacent development projects.

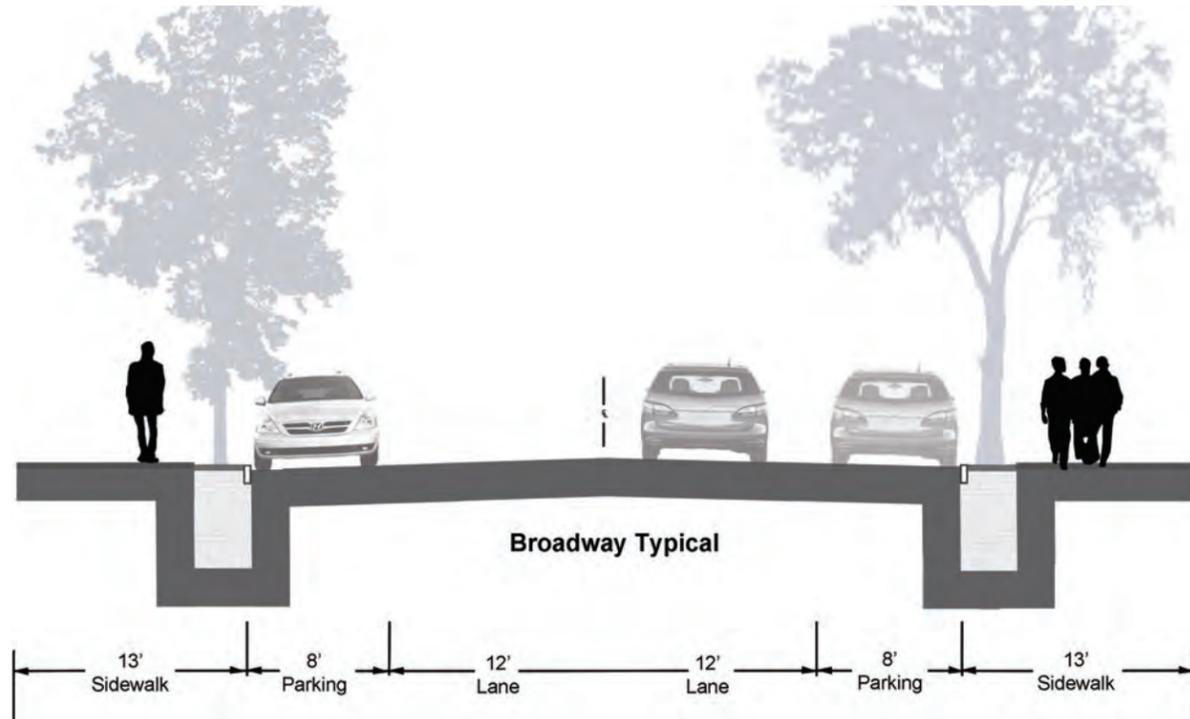


Figure 3.1 Typical Broadway street section

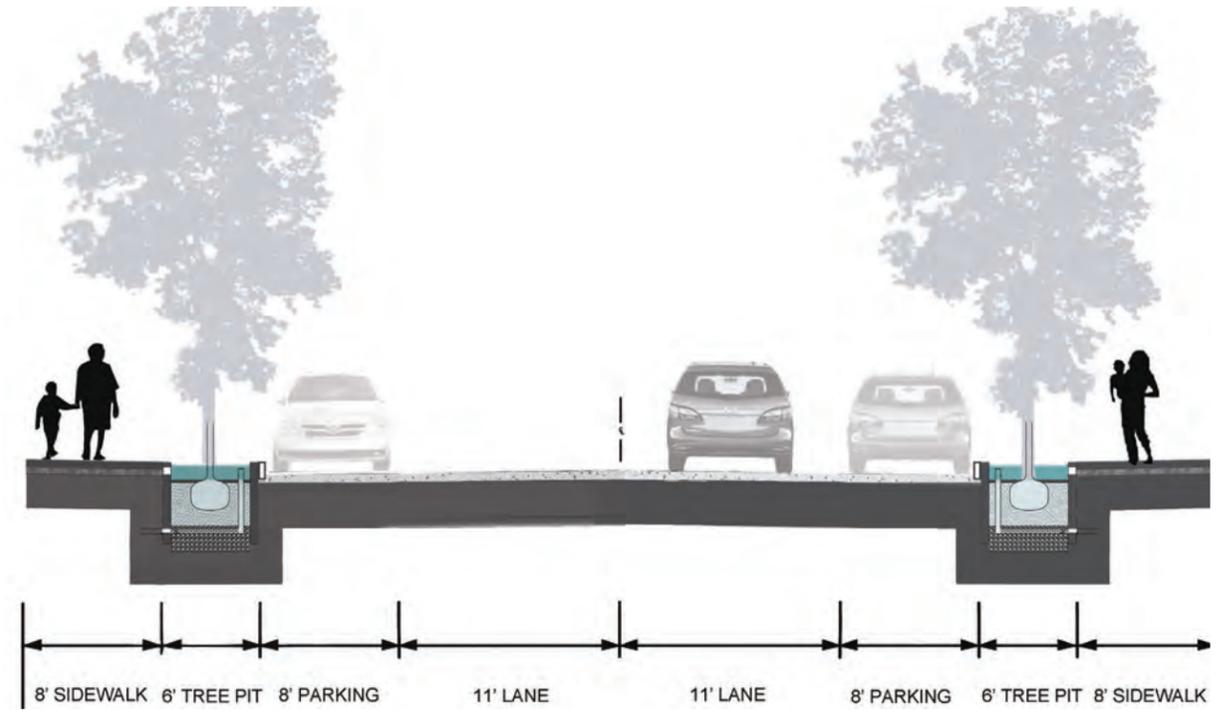


Figure 3.2 Proposed retrofit Option 2 - Tree pits

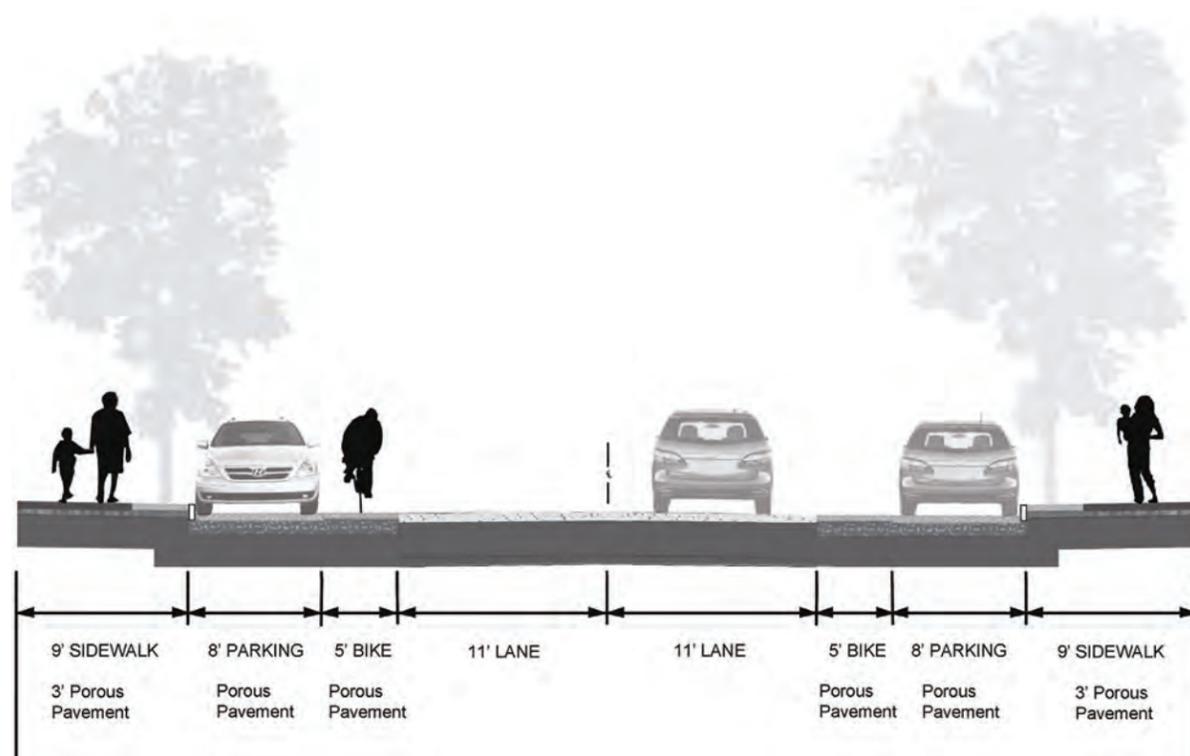


Figure 3.3 Proposed retrofit Option 1 - Permeable pavement and bike lanes

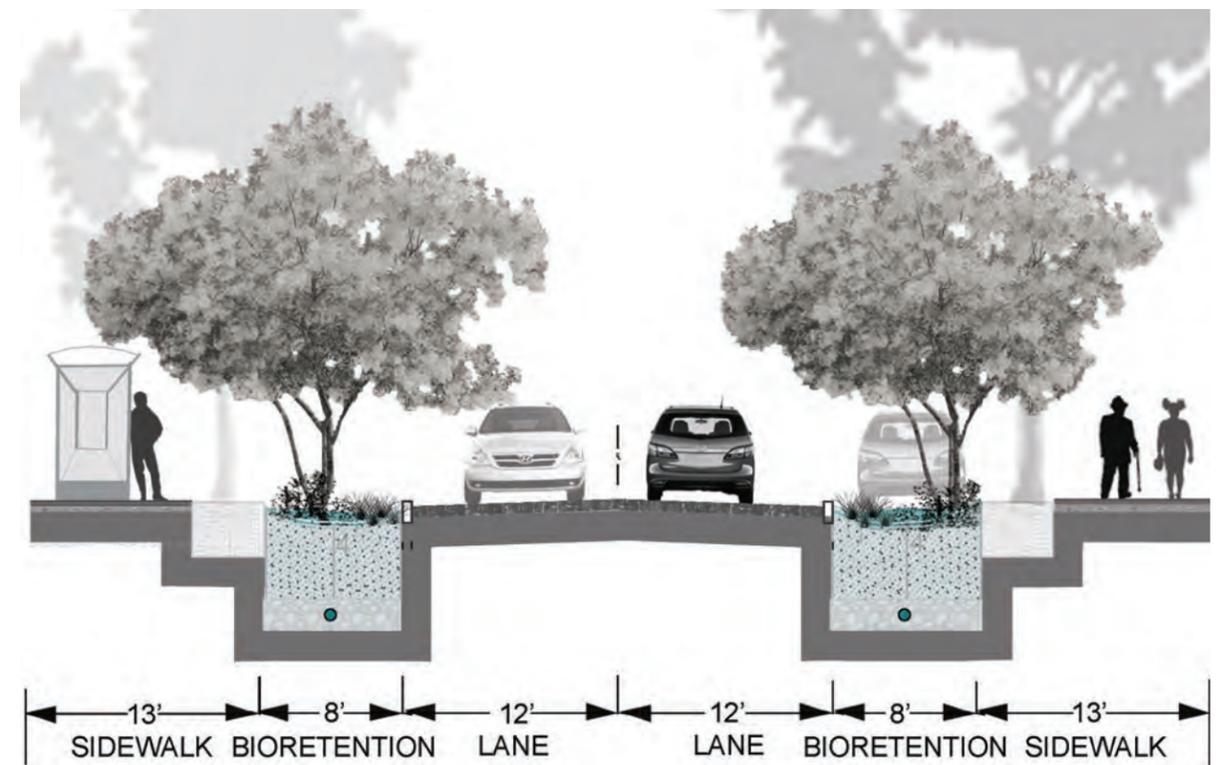


Figure 3.4 Proposed retrofit Option 3 - Curb bump-outs with bioretention system

CONCLUSION AND NEXT STEPS

The City of Chelsea, MyRWA, CRWA, and Chelsea Collaborative partnered to develop recommendations, conceptual designs and community support for environmental improvements in a neighborhood in Chelsea, Massachusetts. The partners focused the efforts of the Urban Green Infrastructure in Mystic River Communities project on the City of Chelsea as the environmental challenges in this urban community are representative of the challenges shared by many other Metro Boston communities. The tasks accomplished within this project and final Subwatershed Plan provide a model for how other municipalities in Massachusetts can reduce the impact of stormwater to local water bodies, engage residents in a participatory process and consider how structural green infrastructure elements can be fit into an urban landscape.

The project identified opportunities to incorporate low impact development (LID) stormwater treatment systems into the upcoming Broadway sewer separation project, and developed a Subwatershed Plan, which identifies green infrastructure strategies. Many of the recommendations outlined in this plan are applicable throughout the City and can inform future planning and capital improvement projects undertaken by the City.

Partners on the project found many opportunities to incorporate green infrastructure in the public space that would lead to reductions in flow to combined sewer systems and reduce loading of stormwater pollutants (nutrients, bacteria and metals). The proponents of the project see benefit in incorporating green infrastructure along the length of Broadway but are cognizant that feasibility, financial considerations and public process do not always allow full integration. Sites that seem obvious may be infeasible due to geologic conditions. Further, areas not considered will open up for consideration once new data or new interests emerge. Green Infrastructure planning along Broadway is made more feasible by the wide sidewalks that offer space for retrofits such as tree pits and stormwater planters.

Three areas emerge out of this study as outstanding opportunities to implement green infrastructure: A) Terminus of Broadway at Mill Creek - this site offers a splendid opportunity to add on to the existing path, further restoration work in Mill Creek, expand the rain garden at Mill Court and set the design standards and expectations for future development of vacant parcels B) City Hall - inclusion of green infrastructure will have high exposure, may be integrated into passive recreation at the plaza and offers the best opportunity to expose residents to a pilot site and C) Toomey Square - a site with a tremendous amount of paved area but one that has incited a shared interest by public and private parties to improve aesthetics; identified by residents at a public meeting as site of highest interest for green infrastructure and aligns with recently completed separation of sewer at Eastern Ave. Finally, some of the optimal sites for inclusion of green infrastructure are on private property. Efforts to leverage public-private partnerships can accrue greatest improvements in street aesthetics and pollutant reduction.

Summarizing objectives

CRWA's Stormwater Management Plan for the City of Chelsea offers a comprehensive, realistic strategy that illustrates how low impact development stormwater management treatment systems may successfully integrate into what is a densely populated, largely impervious, ecologically sensitive urban landscape. Three primary objectives direct the Chelsea green infrastructure model. The first is environmental concern. Chelsea faces numerous environmental challenges arising from untreated and conventionally conveyed stormwater runoff. Over time, due to this conventional stormwater conveyance, pollutants have seriously impaired Chelsea's waterways and marshlands. New stormwater treatment options (i.e. raingardens, bioretention, and tree filters) are proven technologies that when integrated as part of the urban fabric both qualitatively and measurably improves water quality.

The second objective of the Chelsea model addresses the educational benefit to the community. This project is built on the extraordinary longstanding tradition in Chelsea of civic public engagement. The Chelsea Collaborative, and in particular its youth initiative, the Environmental Chelsea Organizers, has driven much of this project's planning. The process of site analysis and site selection is largely due to community initiators who worked to highlight opportunities, identify challenges, select best sites based on visibility and develop collaboration with private property owners. Additionally, community education extends beyond the planning process. Visibility afforded by green stormwater infrastructure increases general public awareness about the connection between stormwater and the environment, adds aesthetically to publicly owned space and provides opportunity to include interpretive signage.

The third objective, selection of site based on typology, addresses the broader social and scientific benefits associated with siting green stormwater infrastructure within the context of Chelsea. Using typology as an important site selection criterion creates important evaluative precedent. Going forward these infrastructures applied to sites of different types can inform future interventions at other sites that bear similar typology.

Within the context of these three objectives CRWA intends this plan to serve as a guide for the City of Chelsea. A long-term plan such as this supports the municipality when identifying implementation opportunities as they arise in the future, and can inform innovative response to these opportunities- an investment that will comprehensively contribute to greater environmental health and improved quality of life for all of Chelsea's citizens.

Plan Recommendations Summary

Chelsea is uniquely positioned as a community to model the implementation of best management practices for stormwater. The recommendations presented in this report go further than independent interventions to represent the broader, far reaching possibilities for green infrastructure in Chelsea. Broadway, as a main arterial and historically Chelsea's 'central spine', was selected for its visibility and its shared association with community life. The suggested intervention for bioretention bumpouts at Eleanor and Broadway merely commences the examination of opportunity to incorporate green infrastructure along the length of Broadway. Not only can new bioretention be included, but other BMP types such as lined planters, tree filters and tree pits should also be considered.

Urban ecology is a special related branch of landscape ecology in the sense that its goals commonly look to knit together a fragmented landscape regenerated into a restored, interactive system. This can be achieved by considering the length of Broadway and its relationship to various extensions such as the edges around Beth Israel and how these parts connect with the larger hydrological system from Broadway down to Mill Creek; or as a second example by taking into account the linear green connectivity that could extend between Malone Park, Crest Avenue, the Clark and Crest vacant lot and the stair that leads to Broadway. If green infrastructure cannot be incorporated throughout the project, this stormwater management plan demonstrates the possibilities for initial concentrated investments in four primary areas: (1) Mill Creek, (2) City Hall, (3) Areas of CSO separation (along Broadway), and (4) Toomey Square (which already has garnered residents' interest). Such investment, though not addressing environmental fragmentation, would significantly improve stormwater conditions. Furthermore it could provide Mystic River Watershed Association (MyRWA) the occasion to select Chelsea as a pilot project that would examine how the implementation of green infrastructure reduces combined sewer overflows.

As noted for Toomey Square, residents have indicated their interest and desire for an improved streetscape. The value of green infrastructure design is not limited to environmental benefits, or fiscal advantage. A real social value and positive impact on quality of life stands as an important part of the equation that cannot be understated. The quantitative improvement of stormwater conditions and the quality of the streetscape are equally important outcomes and design considerations; they go hand in hand. With this said, it is important when implementing the plan for stormwater management to continue to foster and grow public and private partnerships. The vision and concerns of neighborhood residents, business owners, private institutions like Beth Israel as they pertain to their streets, corners, vacant lots and adjacencies will contribute greatly to the energy and success of the plan going forward.

Not addressed in the plan concretely, but directly related to stormwater planning and the development of healthful urban ecology is the urban forest. While the scattered placement of tree filters, designed to handle greater volumes of stormwater increases vegetation and by extension the ecological services that plants provide, the benefits of the broader restoration of tree cover is important to consider in this process of redevelopment. The street inventory conducted by the Environmental Chelsea organizers shows a number of empty existing tree pits that could be revamped to provide greater soil volumes that would support tree health and longevity. Various metrics are available that show savings over the long term that would mitigate upfront costs. Analysis using public access software like I-Tree <http://www.itreetools.org/> is one such metric that many cities have used to this end, and one that because of its accessibility could mobilize further community engagement.

In summary, the plan features five sites and subsequently five typologies. Site selection was informed through intensive community process, and the resulting suggestions provide a valuable foundation to build upon as other suitable sites for green infrastructure are identified within Chelsea, and additional funding becomes available. Part of the work to be done to

identify suitable sites involves more investigation of infiltration potential. Current understanding is that infiltration is very limited. While urban soils and utilities do constrain opportunities, a systematic completion of borings along the length of Broadway would uncover pockets of opportunity that would allow infiltration BMP's. Work still needs to be done to reevaluate existing ordinances that would prevent the installation of Green Infrastructures. Green Implementation can occur in phases dependent on municipal and community priorities, and appropriation process. To date the City has engaged with consulting engineers who are working on the Broadway Infrastructure Project with the understanding that this plan is actualized into the end design. Already plans to implement bioretention at a prominent site have begun, thus marking a first step toward the larger plan to incorporate innovative green stormwater design in Chelsea.

Next Steps

The City of Chelsea, residents of Chelsea, local property owners and advocates for clean water can use this report to guide expectations of the final outcome of the Broadway sewer separation project, identify LID elements for inclusion in the design and be better informed for the public participation process. Ultimately, the feasibility and opportunities for siting of green infrastructure will be informed by the early surveying and studies performed by the engineering firm for sewer separation. But with a flexible approach, the recommendations in this Subwatershed Plan can be used as a template for locations beyond Broadway in other parts of the City of Chelsea where infrastructure is being renewed and urban pollutants are a problem .

Delayed initiation of the sewer separation project in Chelsea until near completion of this Urban Green Infrastructure project meant that the project team was not able to incorporate informative surveying and traffic data into recommendations and conceptual design work for Broadway. But with this Subwatershed Plan in hand, the City of Chelsea may consider

inclusion of tasks in the scoping of the project that address the feasibility of LID components identified in this report. As one example, the completion of borings and test pits at a half dozen sites along Broadway would inform on the locations where hydrogeologic conditions allow installation of infiltration BMPs (e.g. porous pavement, planters, tree pits), or instead favor sealed bioretention elements. A second example of tasks to include might be to focus review in favorable geographic areas identified in the Subwatershed Plan (e.g. Terminus of Broadway at Mill Creek).

The goals of this work are to create streets that are more livable, reduce the pollutants that flow to the streams and create sustainable communities. The incorporation of LID into the City of Chelsea's toolkit when approaching projects will allow the City to meet these expectations. For the city, there is opportunity to extend consideration of green infrastructure to other areas, dedicate regular capital investment and systematically target external grant funding to pilot projects within the city.

Adoption of these strategies in planning and infrastructure work is iterative. Early projects build community knowledge, pilot new technologies, expose staff to maintenance challenges and reveal financial concerns. Review of the city code as initiated by the City of Chelsea in partnership with US-EPA and Horsley Witten is an important step toward addressing ordinances that may discourage LID installation. Eventually, the incorporation of LID into the toolkit that the City applies to projects can lead to more efficient application and leveraging of funds over the long term.

The formalized inclusion of LID into City wide plans and as a considered component for all street projects will result in measurable improvement in water quality and streetscapes. For residents, it is an opportunity to identify desired street aesthetics and water quality outcomes that are requested as a component of every project within the city. For the City and residents it is an opportunity to begin to set goals such as CSO reductions

or improvements of water quality at Mill Creek. Setting goals will guide the judicious application of resources to achieve measureable results.

Lessons Learned

Projects never proceed exactly as planned- in this case the expected synergies of overlapping this Urban Infrastructure project with the early public meetings, surveying and traffic studies of the Broadway sewer separation project did not happen. In response, this project was modified to add greater efforts outside of the Broadway corridor to survey for opportunities and develop conceptual designs for LID on public and private property. The efforts led to development of a deeper relationship with Trust for Public Land and efforts to attract future grant funding. While the project team adapted to the conditions, development of planning contingencies ahead of time may have furthered project goals.

Greater knowledge on geohydrologic conditions in Chelsea will allow targeted application of LID within Chelsea and potentially improve the expectations of what is possible in Chelsea. The City of Chelsea, CRWA and MyRWA have compiled a strong documentation of key parameters - topography, drainage, impervious cover, GIS data on infrastructure, public/private spaces, zoning, precipitation and water quality. But as discussed in the Existing Conditions Analysis, much of Chelsea is built on land reclaimed from harbor or wetlands. For that reason, there is an incomplete understanding of soil conditions. Development of this knowledge will inform feasibility and allow a targeted investment in infiltration BMPs in areas that permit it and consideration of sealed systems or alternatives in other areas of the City. Greater knowledge on the geohydrologic conditions will also relieve default views of infeasibility that may diminish efforts or enthusiasm to incorporate LID techniques.

The integration of LID into projects or long-term planning in the City of Chelsea is an iterative process that happens through individual people within the community. This project benefited from being able to work with

talented individuals in City Hall and at Chelsea Collaborative. If integration of LID happens it is because the members of the Chelsea Collaborative have become advocates after many hours of exposure and work on stormwater with MyRWA and CRWA. Adoption of new approaches happen because individuals within the community, whether they are staff, advocates or residents learn about and promote the adoption of the practices. It is not possible to convince everyone overnight that a change is needed, but over time, it is the accumulation of individual advocates or champions of an idea which outweigh the inertia of a traditional approach.

A model for integration of green infrastructure or a hybrid gray-green approach in small highly urbanized cities is needed. Philadelphia, Portland - these are models of cities that have integrated LID into the municipal infrastructure - but these are also cities of large geographic extent and incentives associated with CSO reductions or TMDL compliance. Chelsea is 2.5 square miles, over 75% of the land area is impervious and there are no incentives either regulatory or financial to reduce stormwater pollutant loading. Chelsea would benefit from learning from other small highly urbanized communities who have made the transition. Alternatively, as Chelsea continues to consider LID and incorporate pilot projects, the City itself will be an important model for municipalities at the state and federal level.

Beginning LID in other municipalities

The challenges that Chelsea faces in treating stormwater in a dense city environment are shared by urban municipalities across Massachusetts. In that sense, the tasks and subwatershed recommendations can be mimicked in other communities with some success. As we are learning in Chelsea, undertaking this type of work is inherently iterative and requires significant groundwork to build relationships, identify obstacles, educate the public and scale up projects. In that sense, Chelsea may be a bit ahead of other communities in Massachusetts and it is worth outlining a progression of activities for other municipalities or at a regional scale that can lead to the regular inclusion of green infrastructure and development of a sustainable environment.

A green infrastructure program starts small, iteratively changing and building as people, technology and funding emerge. Things rarely happen in the order you expect them to and sometimes opportunity knocks, disrupting any sense of order already established. Here is a general order of activities:

Examination of existing conditions is required to understand the scale of problems and opportunities. Work often includes development and examination of GIS data, locating environmental justice (EJ) populations, knowledge of urban infrastructure, highest polluting areas and status of natural resources. Early steps within a community rarely start with a complete assessment of the community but rather a focused examination of a smaller geographic area. **Development of goals** emerges out of the existing conditions analysis and the limited resources available. Green infrastructure for the sake of green infrastructure will lead to inefficient allocation of resources and lack of demonstrable outcomes. Examples of goals can include reduction of phosphorus loading, flow volumes or improved street aesthetics. **Team development and advocacy** is always required for the adoption of relatively new green infrastructure

in a municipality. Whether the project is self-started by municipal staff or by outside agency or residents, significant efforts need to be invested to build understanding and support. The team who moves these projects forward requires a local presence, connection with the political process and some technical knowledge. This team will change over time. Effective **public involvement** allows projects to develop in response to the needs of the community, reduces opposition and builds support. Urban communities can be diverse communities. Special efforts are required to make connections with neighborhood groups and residents that may not normally feel invited into the public process.

Following the aforementioned initial steps, a sense of linearity becomes less predictable. Regardless, the **development of pilot systems** will allow key stakeholders to gain familiarity and a comfort level with a new technology, and is a key building block of any GI program. Pilot projects happen when opportunities allow, so it is almost impossible to say if it will come at a certain time. Sometimes this is a deliberate progression of activities that culminates with an installation - other times these are incorporated in unforeseen opportunities. Teams should make sure to study performance, communicate results and celebrate success in initiation of a pilot project. Replication of projects and allocation of future funding will require demonstration that pilot projects are functioning as expected.

At some point, a municipality can move beyond the initiation of a green infrastructure program toward development of a sustainable program. Steps within this effort include the following:

1. Implementation of an extended existing conditions analysis that encompasses all of the geographic area to identify opportunities and get a sense of costs and benefits
2. Identification of drivers that favor LID (e.g. regulation, enforcement, public sentiment).
3. Review of codes and ordinances for obstacles to green infra-

structure and insure coordination across departments.

4. Development of multiple objectives (e.g. environmental, social and economic) in planning to extend work beyond meeting the standards of the Clean Water Act.
5. Development of a Master Plan that outlines guidelines for incorporation of green infrastructure and development of a gray/green hybrid approach.
6. Development of a sustainable funding plan for green infrastructure whether it be an enterprise fund, transportation funding or one-off opportunities.

On a regional scale

How can the challenges of stormwater pollution be addressed in the most cost effective manner? Consider two communities, A and B, in the same watershed who share flooding or water quality issues. Community A is lightly developed and built on sandy soils while community B is urban and built on clay. If both community A and community B share a financial responsibility to solve a water quality problem, does it make sense to build solutions in community B when it will be more cost effective to implement solutions in community A?

Water quality and flooding problems rarely stop at city boundaries and are often the outcome of watershed-wide development. The costs of implementing solutions to stormwater pollution also vary dramatically as a result of underlying hydro-geologic conditions and density of development. Identifying the most cost effective solutions across a geographic range is complicated by the question of how to distribute financial resources toward the most effective solutions, regardless of what community the opportunity is located within.

Within the time frame of this grant, MyRWA initiated a limited study to identify best opportunities for addressing stormwater pollutants on a watershed scale. Resource limitations did not allow for financial consid-

erations, but it is worth noting the thoughtful work of CRWA who have considered the challenges municipalities face in reducing phosphorus loading to the Charles River. CRWA developed a phosphorus trading platform which permits private investments to flow to the most cost effective solutions across parcel and municipal boundaries. While that platform is still in development, it holds promise for significantly reducing the cost of reducing phosphorus loading.

The MyRWA study used GIS data available through public sources to establish a metric of the feasibility to infiltrate stormwater at locations throughout a watershed (Mystic River Watershed). The focus was on infiltration as many of the most cost effective LID stormwater solutions use infiltration and provide a solution to both stormwater volume (flooding) and water quality. This study builds on previous work undertaken at the municipal scale done in collaboration with Jeff Walker and the Water: Systems, Science and Society Program at Tufts University funded by a 604B grant.

Method

Four parameters were used to estimate the feasibility for implementing stormwater infiltration BMPs: surficial geology, hydrologic soil group, depth to water table, and topographic slope. A feasibility index was assigned to each parameter based on ability to infiltrate water. Zero indicates low feasibility and 3 indicates higher feasibility for each parameter.

Surficial geology GIS data layer was downloaded from MassGIS as a polygon shapefile. The Mystic River watershed was found to have surficial geology of sand and gravel deposits (code 1), till or bedrock (code 2), fine-grained deposits (code 6), and floodplain alluvium (code 7). Areas of codes 1, 6, and 7 were assigned a feasibility index of 3 for high stormwater infiltration feasibility and areas of code 2 were assigned 0 for low feasibility.

Hydrologic Soil Group data was extracted from the Soil Survey Graphical (SSURGO) database of the USDA's Natural Resource Conservation Service through Soil Data Mart (<http://soildatamart.nrcs.usda.gov>). Hydrologic soil groups in the Mystic were each associated with one of four hydrologic soil groups (A, B, C, or D), unless data was not available. Soil groups were classified by their ability to infiltrate water, and were assigned a feasibility index accordingly (A = 3, B = 2, C = 1, D = 0), in order of high to low infiltration potential. Note, polygons with no data were assigned a default index value of 0.

Depth to Water Table was extracted from the same SSURGO dataset downloaded from NRCS for hydrologic soil group data above. Values less than 2 feet were assigned a feasibility index (FI) of 0, and values 2 feet or greater were assigned a feasibility index of 3, for higher stormwater infiltration feasibility.

Topographic Slope was derived from the USGS DEM downloaded from the USGS map viewer, < <http://viewer.nationalmap.gov/viewer/>>. The ArcGIS Slope tool was used to calculate the percent slope. A slope of 15% or greater was defined as not feasible with a FI of 0. Slopes less than 15% were assigned an FI of 3, to represent higher stormwater infiltration feasibility.

Calculating Overall Feasibility Index

With the exception of topographic slope, which was already in raster format, all of the data layers were converted to a raster file from a polygon shapefile (see Figure 4.1). The values assigned to each raster cell were equal to the feasibility index assigned. Due to a concern for overstating the feasibility of infiltration, a two-step grading index was assigned. For any cell that received a "0" on surficial geology, topographic slope or depth to water table, the final feasibility index would also be a "0". For any cell that did not receive a "0" all four rasters (surficial geology, hydrologic soil group, depth to ground water, and topographic slope) were

summed using the raster calculator in ArcGIS. The result is a discontinuous distribution of scores that include 0, 9, 10, 11, and 12, with 12 being a high feasibility location.

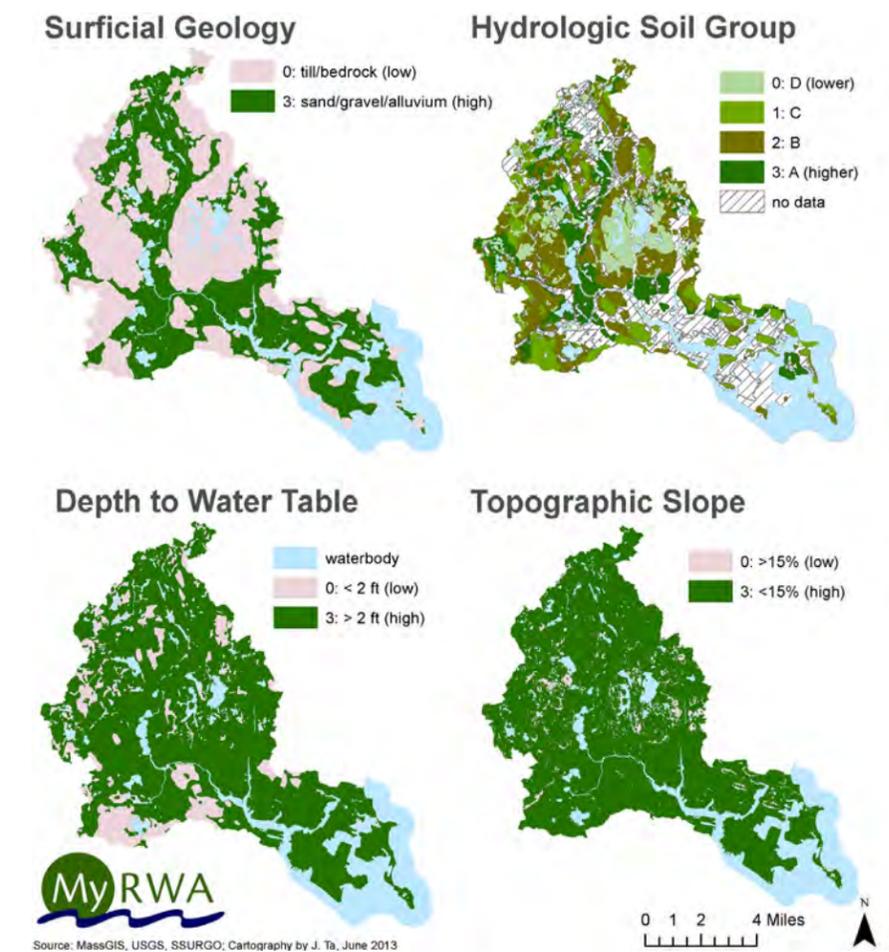


Figure 4.1 GIS layers used for infiltration feasibility index for Mystic River Watershed

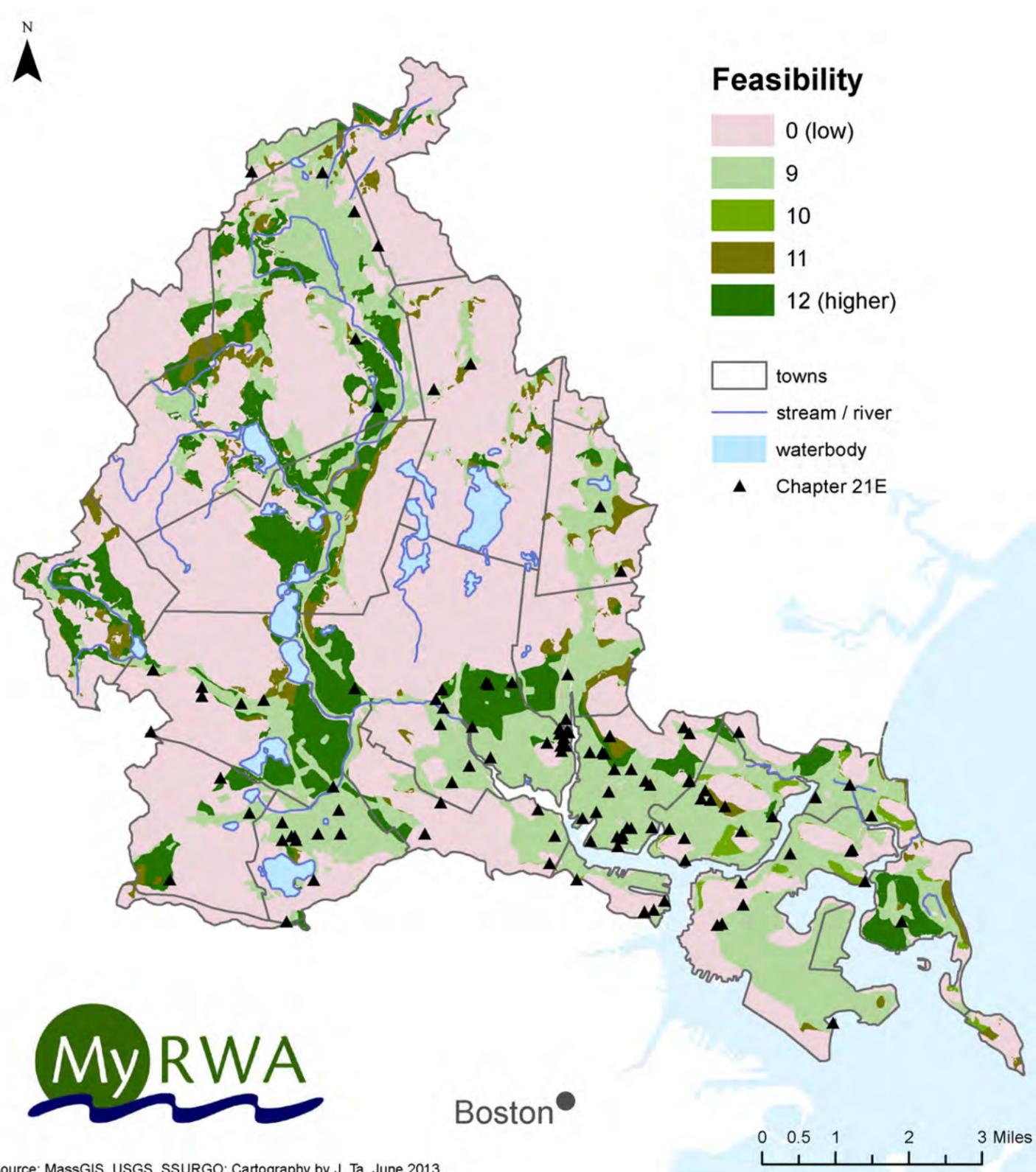
Results of analysis

The outcome of the analysis reveals that the geographic area amenable to infiltration of stormwater is not equally distributed throughout the communities of the watershed (see Figure 4.2). Optimal opportunities for infiltration are concentrated around the course of the Mystic River. Some communities will have limited area available for infiltration (e.g.

Belmont), while others will have significant area (e.g. Medford). The headwaters of the Mystic River Watershed (north section of map) are surprisingly sparse of areas feasible for infiltration. Contrastingly, many of the areas along Alewife Brook show high feasibility and may provide some of the best opportunities to remove stormwater. While these areas are highly developed and impervious currently, they are also contributing to CSO systems.

It is clear that there are constraints that go beyond the four raster layers. Without enough data on distribution of contaminants in soil, it was not possible to construct a GIS layer that would communicate infeasible areas due to contaminants. But as shown in Figure 4.2, many of the areas on the map that demonstrate high feasibility are sites where the state is following contaminants in the Massachusetts Waste Site Cleanup Program (21E). Some of these sites have been fully remediated and will not pose challenges, but many will not allow infiltration.

In order to learn more about the constraints of this mapping and index approach, a map of Chelsea was produced using these layers (Figure 4.3). The analysis shows that approximately 60% of Chelsea has the potential for infiltration-based BMPs to function. To get a sense of how these results would be interpreted at a localized area, results were shared with Patty Passariello, P.E. of Weston & Sampson Engineering and Andrew DeSantis, Assistant Director of the Chelsea Department of Public Works. Feedback highlighted that such a map is likely to overestimate the feasibility of infiltration because it does not provide enough site-specific data on geohydrological conditions. Distribution of debris and contamination in the soils throughout Chelsea were the largest concerns.



Source: MassGIS, USGS, SSURGO; Cartography by J. Ta, June 2013

Figure 4.2 Infiltration Feasibility Index Map for the Mystic River Watershed based on surficial geology, hydrologic soil group, depth to water table and topographic slope

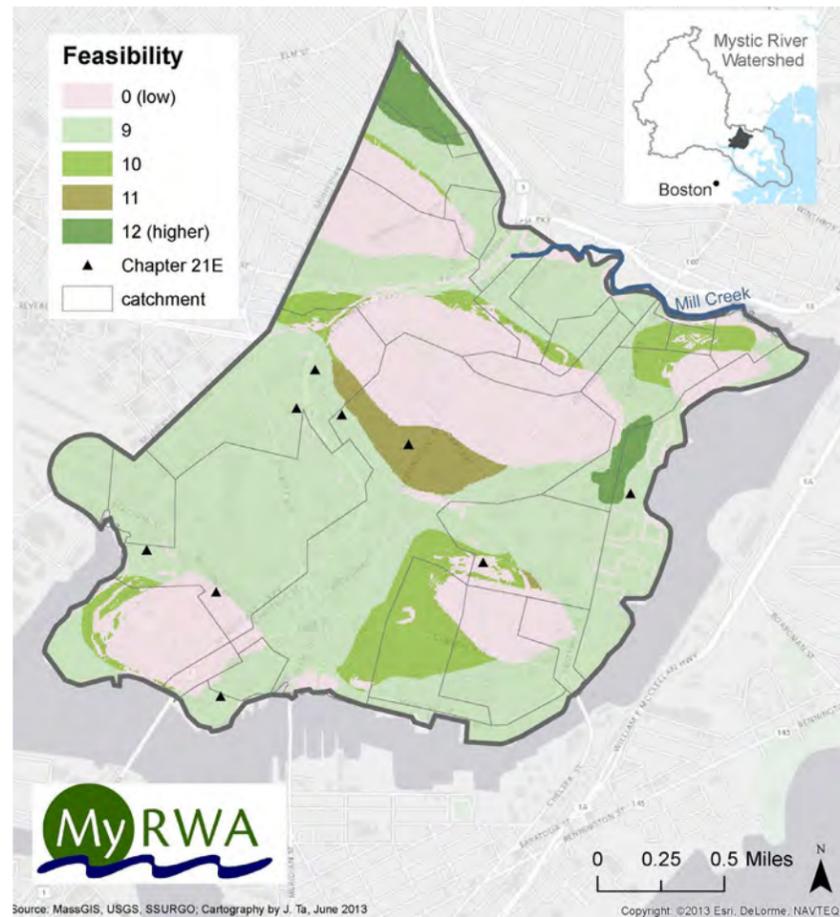


Figure 4.3 Infiltration Feasibility Index Map for the City of Chelsea

Value and limitations of feasibility indexing approach

Feasibility mapping at the watershed and municipal scale is a valuable approach, though not without its limitations. This study was a first attempt at an indexing of feasibility, the initial efforts of which are limited by availability of data at scale. Hydrologic soil group and levels of soil contamination are two areas where the quality of the data impacts the accuracy of the index. Much of the hydro-geologic data from SSURGO is modeled from limited sampling and would need to be field verified for site specific analysis. The final maps show Chapter 21E sites, but there may be other sources for areas that have potentially contaminated soils. A possible direction is to contact community representatives on local data or research URAM filings.

Much improvement can be made through incorporation of community specific data and ground-truthing (borings, trenching) in order to map out actual soil and water table conditions in communities of interest. Other information that may be relevant for determining feasibility of implementing stormwater infiltration BMPs are: private versus public land, water supply protection areas, wetlands, waterway buffers, and stormwater infrastructure. Finally, a great deal of the map had areas where hydrologic soil group was unknown, and was therefore assigned a “0”. Efforts to gather additional data in these areas would be especially helpful.

This effort to map hydro-geologic conditions and feasibility for infiltration in the Mystic River Watershed provides a template for how to undertake this work in other watersheds or add additional data. The work is early and we recognize that the coarse level of data available limits the scale of how this approach may be applied. It is clear that at the site level, this analysis does not provide enough detail for design. But, when fully developed, we could foresee an indexing effort being integrated into workflow in a number of areas. Proposed projects can be cross-validated against a feasibility map to determine where it is possible to assume infiltration can occur. Planners can then incorporate infiltration based LID in conceptual designs and prepare for surveying that will explore site-level detail on feasibility. As private development is presented to the building department, planning departments, and conservation commissions, determination of development occurring within feasible areas may trigger a requirement for developers to include infiltration-based LID in designs. Additionally, the map will have usefulness in modeling efforts to address questions on flooding, reducing CSO flows and runoff coefficients. Finally, the examination and prioritization of opportunities at a regional scale allows planners to bring credible projects to potential funders. Mapping work can establish where a project falls in a continuum of cost-effective solutions addressing pollution problems.

Stormwater pollution is frequently a shared problem that extends be-

yond city limits. Waterways are impacted by internal municipal sources and upstream sources outside of a municipal jurisdiction. The best opportunities to improve water quality are not homogeneously distributed in the landscape. Finding the most cost-effective solutions will require an examination of feasibility at a broad scale and efforts to distribute resources to the most efficacious approach.

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Appendix

Priority Site Selection Criteria (Additional Information)

The Environmental Chelsea Organizers (ECO) youth group played an important role in the process of site selection. One of their key tasks was to conduct an extensive survey to identify potential pollution sources, barriers to river access, areas with poor drainage/flooding problems, and other aspects of existing conditions. In addition to the above, the youth also identified opportunities for employing green infrastructure retrofits within the study area both in terms of streetscape improvements as well as identification of specific sites to be retrofitted. A design charette followed the on the ground site survey to invite community input and to finally select priority sites for retrofit opportunities in both the public realm and on private property. Of the 15 sites considered five ultimately were selected as representative typologies. The table on the right identifies the sites, their typology, the number of drainage areas, notes regarding their relevance and the green infrastructure that was considered.

Reference Name	ID	Typology	Drainage Areas	Relevance	Green Infrastructure Considered
Beth Israel	49	Large Private Commercial	8	Large private commercial lot abutting ecologically sensitive areas and public open green space.	Bioretention Gravel Wetland
Toomey Square	42	Small Private Commercial/ Key Intersection	6	Highly visible intersection near school with potential for traffic calming measures for improving pedestrian access	Tree Filters Rain Trench Bioretention
Clark and Crest	38	Publicly Owned Vacant Lot	3	Underutilized/ misused vacant public land that provides an opportunity for a stormwater park	Tree Filters Rain Garden/Bioretention
Eleanor and Broadway	34/35	Privately Owned Vacant Lot/ Key Intersection	3	Highly visible paved lot at a key intersection and adjacent to a private commercial business site	Tree Filters Bioretention
Bellingham Plaza at City Hall	1	Public Civic Space/Key Intersection	5	High visibility public space with converging circulation activity and adjacency to Town Hall	Bioretention

Additional Public-Private Site Recommendations

- New construction or redevelopment projects contribute to green streets funding or include green features to reduce stormwater runoff from project site itself
- Eliminate or mitigate for large areas of parking (especially that drain into public right-of-way)
- Neighborhood-scale fundraising to support commercial districts by greening streets and improving walkability
- Green roofs for residential, commercial, and institutional sites
- Downspout disconnect into rain barrels, cisterns or stormwater planters and raingardens

Summary of Recommended Green Street Design Elements

Permeable Pavement

Options for permeable pavement are porous concrete or asphalt (image on left) and permeable pavers (image on right).



Benefits:

- Reduce runoff
- Recharge groundwater (if soils allow infiltration)
- Filter pollutants
- Superior performance in cold conditions (less prone to crack, needs less salt)

Applications - Public Realm:

- Sidewalks/Intersections
- Bike lanes
- Parking lanes

Applications - Private Realm:

- New/Retrofitted Developments - Paths, plazas
- Parking lots
- Driveways

Street Trees



Benefits:

- Improve pedestrian environment
- Reduce runoff by intercepting rain
- Can be combined with stormwater planters/swales/raingardens to increase infiltration
- Reduce heat island effect and cooling cost of adjacent buildings
- Reduce and filter pollutants
- Promote wildlife habitat

Applications - Public Realm:

- Sidewalks
- Curb extensions

Applications - Private Realm:

- Private gardens

- New/Retrofitted Developments
- Parking lots

Rain Gardens

Raingardens are landscaped depressions that collect and treat stormwater runoff. As stormwater infiltrates through mulch, soils, and plant root systems pollutants such as bacteria, nitrogen, phosphorus, heavy metals, oil and grease are retained, degraded, and absorbed. Recommended rain garden types include stormwater planters, swales, and infiltration basins. Stormwater planters are structures that either infiltrate (infiltration planter) or slow and filter runoff (flow-through planters). Swales are planted depressions with gentle slopes that slow and filter runoff. Infiltration basins are vegetated depressions that store and infiltrate runoff.



Benefits:

- Enhance pedestrian environment
- Reduce and slow runoff
- Improve water quality
- Recharge groundwater (if infiltration is possible).
- Reduce heat island effect
- Promote wildlife habitat

Applications - Public Realm:

- Sidewalks
- Roads and Intersections (curb extensions)

Applications - Private Realm:

- Private gardens
- New/Retrofitted Developments
- Parking lots

Curb Extensions/Raised Intersections

Curb extension with swale shown in image on left. Raised crosswalk at roadway intersection shown in image on right.



Benefits:

- Improve pedestrian environment
- Slow traffic
- Provide opportunities for runoff treatment and added vegetation

Applications - Public Realm:

- Roads
- Intersections

Bike Lanes/Shared Roads

Urban street bike lane shown in image below.



Benefits:

- Safer environment for bicyclists
- Slow traffic
- Opportunity for runoff treatment when permeable pavement used

Applications - Public Realm:

- Roads
- Sidewalks

Applications - Private Realm:

- New/Retrofit Development

Public Art/Street Furniture/Educational Intervention

Street furniture in the form of wooden benches shown in image below.



Educational intervention in the form of signage shown in image below.



Benefits:

- Create pedestrian-friendly environment.
- Engage the community, especially if participation in the design and implementation of art projects is encouraged
- Provide opportunities to connect neighborhood to the Charles River
- Help the neighborhood recognize urban environments and can bring the importance of water and plants back into people's minds

Applications - Public Realm:

- Sidewalks
- Bridge Crossings
- Intersections

Applications - Private Realm:

- New/Retrofitted Developments

