Technical Memorandum #2: Low Impact Development & Green Infrastructure Assessment

Rooster River Watershed Based Plan

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Prepared For:

City of Bridgeport

In Cooperation With:

Connecticut Department of Energy & Environmental Protection
Southwest Conservation District

FUSS & O'NEILL

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1 Introduction

1.1 What is LID and Green Infrastructure?

Low Impact Development (LID) and green infrastructure are the preferred approaches for stormwater management by CTDEEP and EPA, but are also relatively new and sometimes not well-understood by designers, municipalities, and the public.

Coventry Town Hall Annex, Coventry CT; Source: CTDEEP

LID is an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. LID principles include preserving and restoring natural landscape features, minimizing effective impervious cover (i.e., the impervious cover that is directly connected to the storm drainage system and/or receiving waters), and creating functional and appealing site drainage that treats stormwater as a resource. The goal of LID is to mimic a site's pre-development hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source. LID addresses stormwater through small, cost-effective landscape features located throughout a site. LID is a versatile approach that can be applied equally well to new development, urban retrofits, and redevelopment projects.

Evergreen Walk Mall Parking Lot, South Windsor, CT Source: CT NEMO

Green infrastructure is similar to LID and refers to systems and practices that use or mimic natural processes to infiltrate, evapotranspire, or reuse stormwater. Green infrastructure and LID include stormwater management practices such as rain gardens, permeable pavement, green and blue roofs, green streets, infiltration planters, trees and tree boxes, and rainwater harvesting, for example. These practices capture, manage, and/or reuse rainfall close to where it falls, thereby reducing stormwater runoff and keeping it out of receiving waters.

In addition to reducing polluted runoff and improving water quality, green infrastructure has been shown to provide other social and economic benefits relative to reduced energy consumption, improved air quality, carbon reduction and sequestration, improved property values, recreational opportunities, overall economic vitality, and adaptation to climate change. For these reasons, many communities are exploring the use of and are adopting green infrastructure within their municipal infrastructure programs.

1.2 Objectives

As documented in Technical Memorandum #1, State of the Rooster River Watershed (March 2013), stormwater runoff is a significant cause of water quality impairments and contributes to urban flooding in the Rooster River and Ash Creek watershed. Much of the watershed was developed prior to the adoption of stormwater quality regulatory requirements. Therefore, most of the existing drainage infrastructure consists of traditional storm drains/catch basin and drainage pipes that discharge directly to surface waters without treatment, other than detention to maintain peak rates of discharge. Uncontrolled stormwater runoff from impervious surfaces is a significant source of impacts to surface waters and water quality within the watershed. An important objective of this watershed plan is to reduce runoff volumes and pollutant loads through the use of LID and green infrastructure.

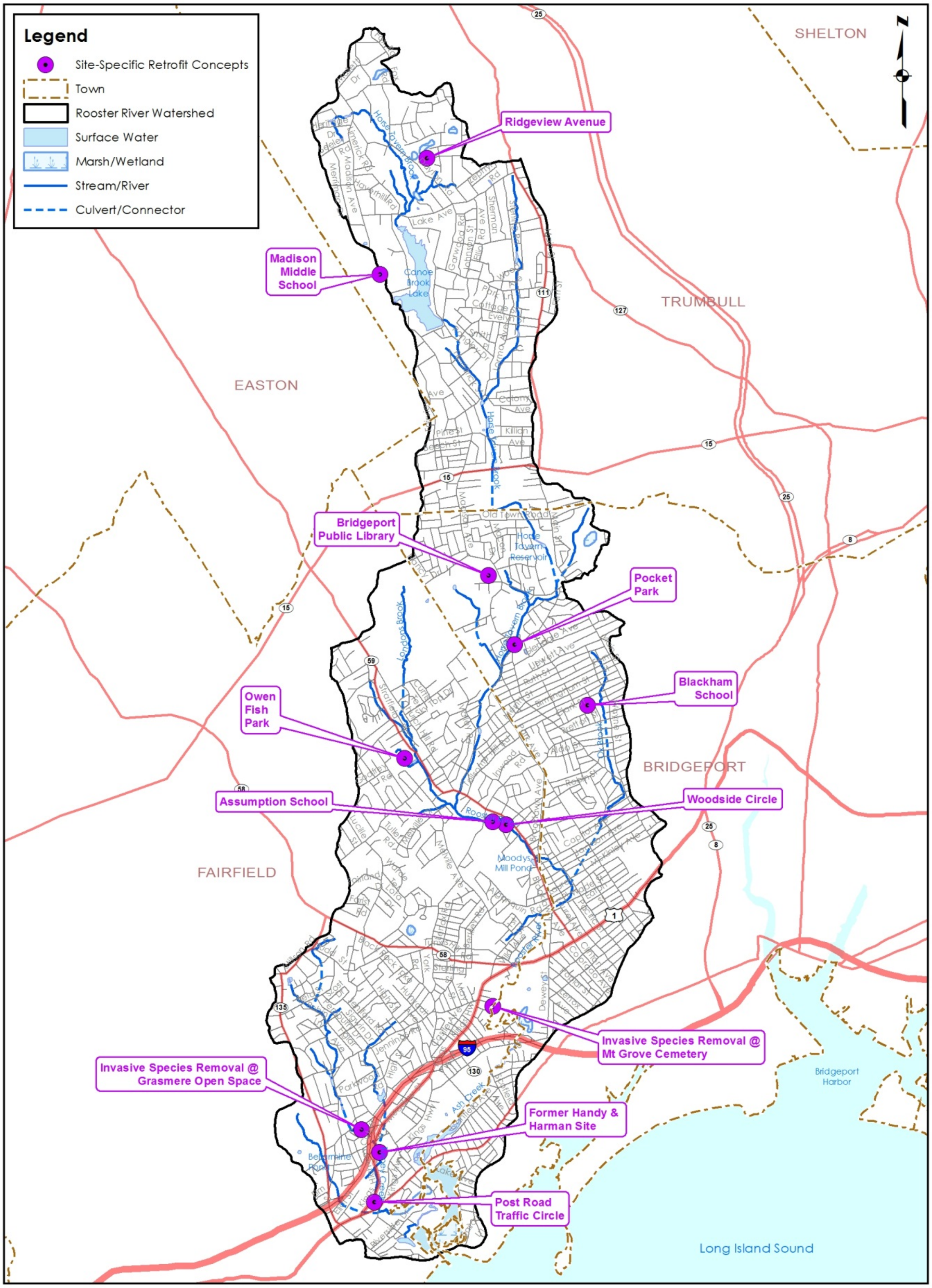
A watershed assessment was performed to identify opportunities and develop concepts for site-specific LID and green infrastructure retrofits that could also be applied to other similar land uses and locations in the watershed. This technical memorandum documents the methods and findings of this assessment.

2 Site-Specific Project Concepts

Site-specific restoration or retrofit concepts were developed for selected sites using a two-step approach. First, a desktop screening-level review was performed to initially identify potential areas of the watershed with the greatest feasibility for stormwater retrofits. This screening-level review considered watershed characteristics such as soils, land use, land ownership, and proximity to surface waters and identified impairments. Field inventories were then conducted in May 2013 within areas identified by the screening-level review, and retrofit concepts were developed for the most feasible sites.

The site-specific project concepts presented in this section are intended to serve as potential on-the-ground projects for future implementation. The locations of the potential projects described in this section are shown in the figure on the next page. They provide examples of the types of projects that could be implemented at similar sites throughout the watershed. It is important to note that the concepts presented in this section are examples of potential opportunities, yet do not reflect site-specific project designs. Property owners and other affected parties are responsible for evaluating the ultimate feasibility of these and similar site-specific concepts.

Preliminary, planning-level costs were estimated for the site-specific restoration concepts presented in this section. These estimates are based upon unit costs derived from published sources and the proposed concept designs. Capital (construction, design, permitting, and contingency) and operation and maintenance costs were included in the estimates, and total annualized costs are presented in 2013 dollars based on the anticipated design life of each restoration concept. A range of likely costs is presented for each concept, reflecting the inherent uncertainty in these planning-level cost estimates. A more detailed breakdown of the cost estimates is included in *Appendix A*.



Site-Specific Project Locations

2.1 Assumption School Parking Lot Retrofit

Our Lady of the Assumption School ("Assumption School") is located in Fairfield along Stratfield Avenue. The school is an ideal candidate for green infrastructure retrofits since it is located in close proximity to the Rooster River, which flows adjacent to the school in the rear of the property. There is a large parking area in front of the school that is shared with the church. This is a representative institutional property LID retrofit that could be applied at similar schools, civic buildings, hospitals or other properties with large parking areas throughout the watershed.

Stormwater runoff from approximately half of the paved parking lot drains toward a leak-off that discharges directly to the Rooster River on the western side of the school. The other half of the parking lot drains to the eastern side of the school and also discharges directly to the river. Site drainage is conveyed via sheet flow since there are no catch basins or piped drainage on the site.

Assumption School Parking Lot Retrofit

Location:
Stratfield Avenue, Fairfield

Objectives:
Reduce parking lot runoff via infiltration and bioretention; repair erosion in outflow channel to stream; restore the stream channel behind the school; provide educational elements for students and the public.

Essential Elements:
Bioretention, french drain, pervious pavers, filter strip, armored outflow channel

Estimated Cost: $76,000 –$164,000

The proposed concept for this site, shown in *Figure 1,* incorporates LID retrofits without removing any parking spaces by using the existing vegetated areas around the site and by converting a paved area next to the school that is not used for parking into a bioretention basin. The concept also includes stream restoration in back of the school building. The proposed concept includes the following elements:

Pervious Pavement in Parking Stalls with a Vegetated Swale. The existing conventional asphalt pavement within the parking stalls on the western side of the parking lot could be retrofitted with pervious pavement, pervious concrete, or open-jointed block pavers to reduce effective impervious cover and provide stormwater treatment. A vegetate swale would collect runoff that does not infiltrate in the pervious parking area and treat stormwater prior to discharging to the river. A typical pervious parking stall is shown in *Figure 2*. Different types of pervious pavement are discussed in *Section 2.2*.

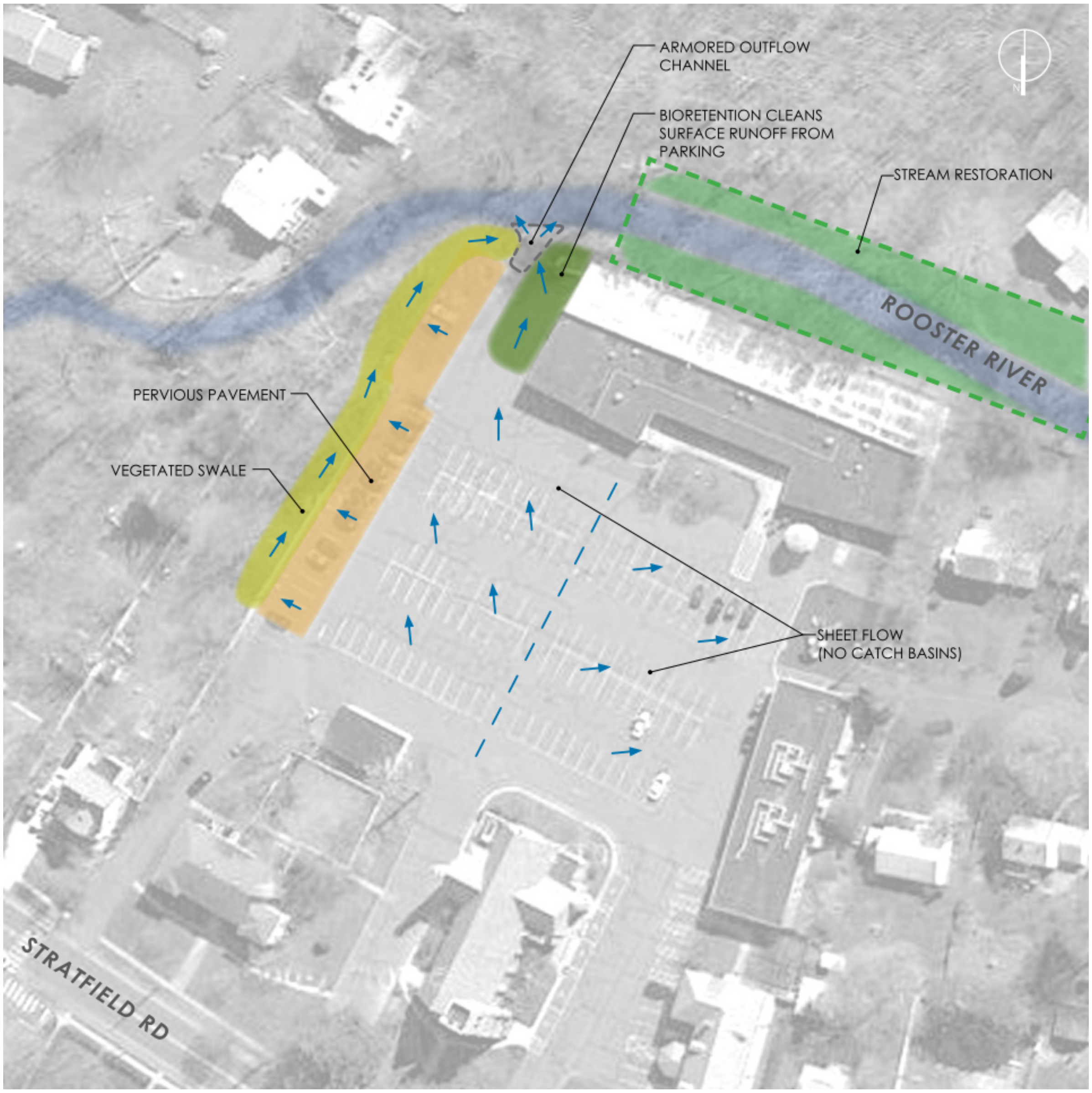


Figure 1. Retrofit Concept Plan for Assumption School

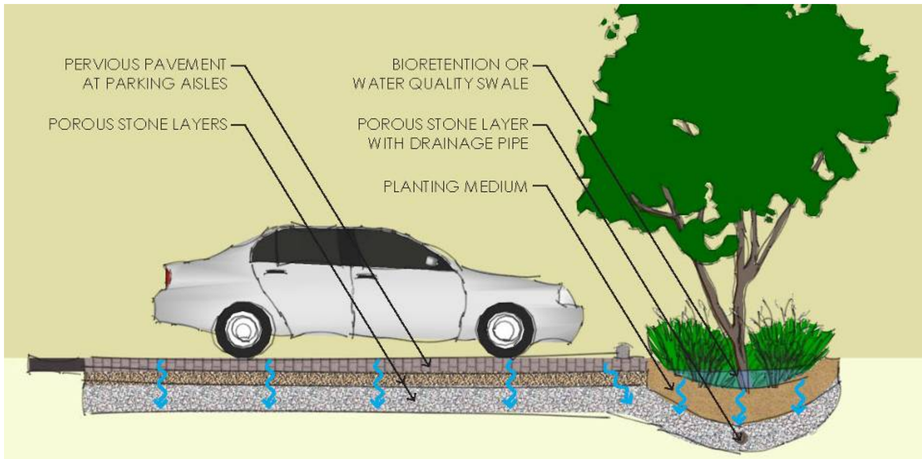


Figure 2. Typical Pervious Parking Stalls with Vegetated Swale

Bioretention Area and Armored Outflow Channel. A bioretention area could be installed to treat stormwater from approximately half of the paved lot. This area would capture, treat, and infiltrate runoff prior to discharging it through an armored channel to the river. A schematic of a typical bioretention area is shown in *Figure 3*.

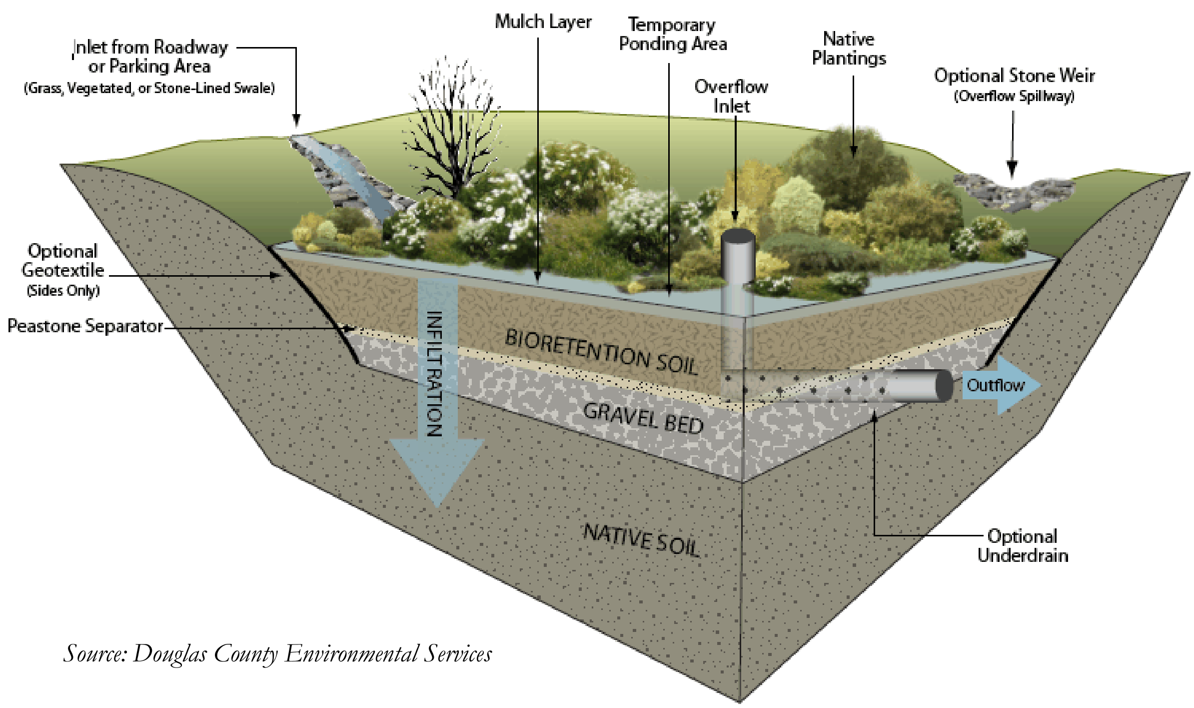


Figure 3. Typical Bioretention Design

Stream Restoration. The segment of the Rooster River that runs along the rear of the school could be restored to its original channel. Historical fill had been placed in this location and the restoration of this site could include removal of this fill behind the school building and restoration of the original stream channel location.

2.2 Blackham School LID Retrofit

Blackham School is situated in a densely developed urban neighborhood in Bridgeport at the corner of Thorme Street and Amsterdam Avenue. The school grounds contain two baseball fields, a playground, the school building, and associated parking and landscaping. *Figure 4* shows the school building and the significant impervious area of the roofs and parking areas around the site. The northern side of the site has plenty of available underutilized lawn area that could accommodate bioretention retrofits; however, the parking lots drain predominantly from north to south, limiting the ability of the northern side of the property to capture and treat on-site runoff. The site drainage is predominantly toward the intersection of Amsterdam and Bretton Street, as evidenced by ponded water and accumulated sediment in the parking lot. The corner of the parking lot was observed to be covered with sediment. However, it may not be possible to eliminate parking spaces for LID retrofits if parking at the school is at capacity.

Blackham School LID Retrofit

Location:

Thorme Street and Amsterdam Avenue, Bridgeport

Objectives:

Reduce parking lot runoff and improve water quality using bioretention areas, permeable pavers, and subsurface infiltration; reduce roof runoff using a green roof; provide educational benefits to school children and the public.

Essential Elements:

Green Roof, Permeable Paver, Bioretention, and Subsurface Infiltration

Estimated Costs:

Green Roof	$213,000 – $456,000
Permeable Pavers	$70,000 - $150,000
Bioretention Areas	$39,000 - $83,000
Subsurface Infiltration Chambers	$76,000 – $162,000
Total Cost:	$398,000 – $851,000

Figure 4. Blackham School LID Retrofit Concept

The proposed LID retrofit design for Blackham School involves bioretention basins in existing grass medians or lawn areas that have some impervious areas draining toward them, permeable pavers in the rear lot, and a green or blue roof. Specific elements of the design include:

Green or Blue Roof. Public buildings with large flat roofs are potential candidates for green or blue roof retrofits. Green roofs are engineered planting systems that can be installed on buildings to absorb and retain rainwater, reducing peak stormwater flows and runoff volumes. Green roofs are more costly than conventional roofs but they are capable of absorbing and retaining large amounts of stormwater. In addition, green roofs provide sustainability benefits such as absorbing air and noise pollution, rooftop cooling by reducing ultraviolet radiation absorption, creating living environments for birds, and increasing the quality-of-life for residents.

Blue roofs are non-vegetated rooftop source controls that detain stormwater. Weirs at the roof drain inlets and along the roof can create temporary ponding and gradual release of stormwater. Blue roofs are less costly than green roofs. Coupled with light colored roofing material they can provide sustainability benefits through rooftop cooling. New York City has begun to use blue roofs as part of its green infrastructure strategy for addressing CSOs and stormwater management.

A portion of the school building's roof could be converted to a green roof or blue roof, as shown in *Figure 5*.

Figure 5. Modular Green Roof System Installation

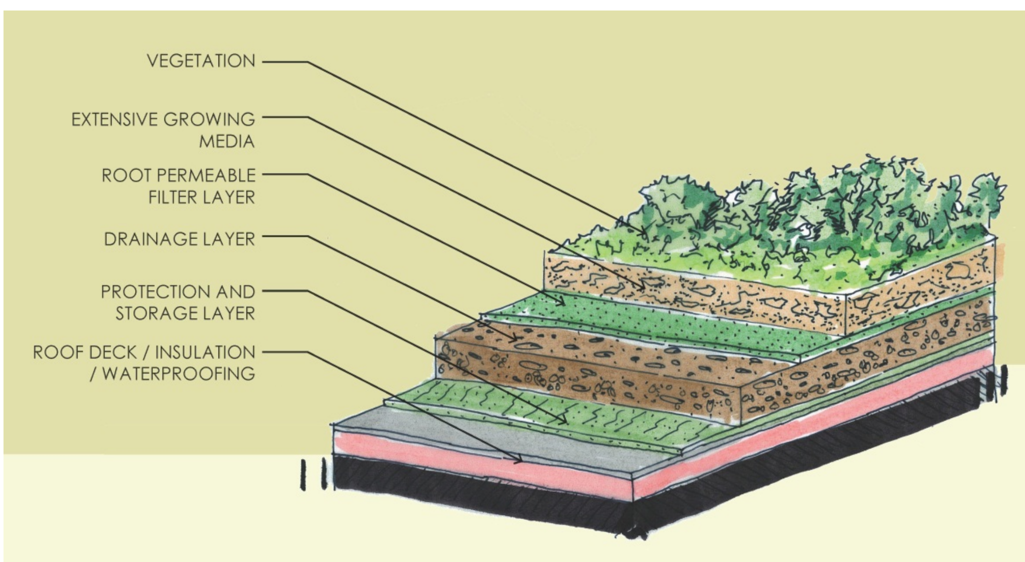


Figure 6. Typical Green Roof Design

Bioretention Island. The building's rear entrance along Amsterdam Avenue has a small grass island between the roadway and parking lot that could be converted to a bioretention area to capture, treat, and infiltration runoff from the adjacent parking area during small storms. Additional rain gardens could be created adjacent to the building to treat roof runoff.

Figure 7. Before and After Concept Design for a Bioretention Area for the Parking Lot

Source: StormTech Product Manual

Subsurface Infiltrators. A subsurface infiltration system is proposed to receive stormwater runoff from the parking area and infiltrate it through a subsurface galley such as the one shown in the picture to the left. The stormwater infiltrates through the stone bottom. The outlet would tie into the existing piped drainage system along Amsterdam Avenue to avoid water backup into the parking area.

Pervious Pavement. A variety of materials are available to replace conventional paved surfaces (roadway, driveway, and parking) with pervious pavement *(Figure 8)*. Pervious pavement material should be selected based on the characteristics of the application. The block pavers are easy to install and relatively inexpensive, but are suitable for applications where vehicle traffic is relatively light.

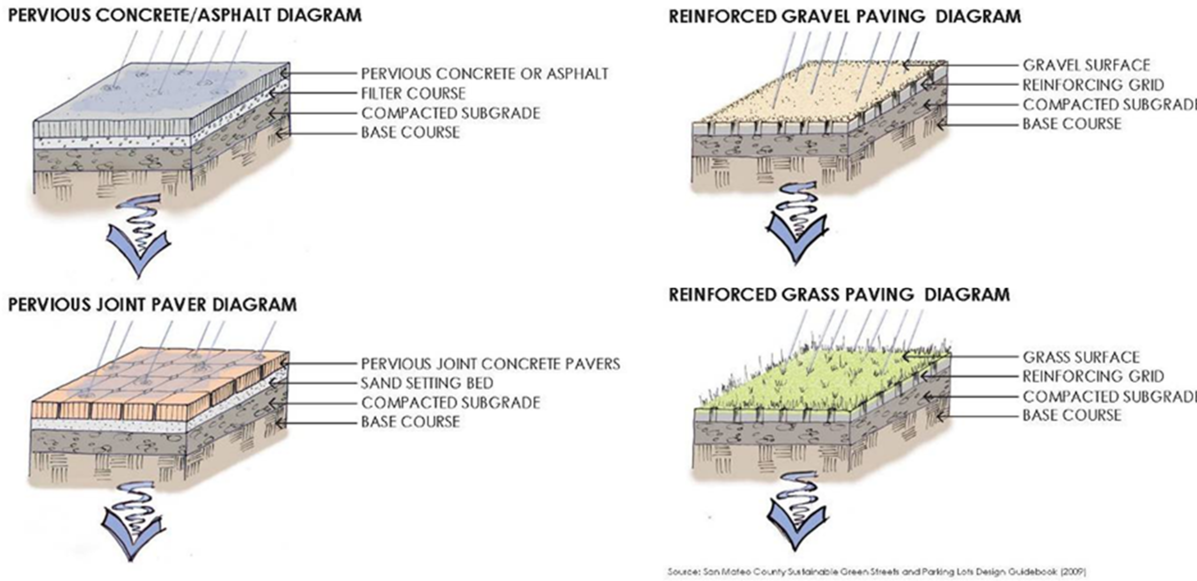


Figure 8. Diagrams of Selected Permeable Pavement Systems

Parking spaces in urban areas can be paved with open-jointed block pavers, which are more attractive than pervious asphalt or concrete, but provide a smoother surface and are somewhat more suited to constant vehicle use, although at slow speeds. For areas where heavier traffic loads are anticipated, pervious asphalt or pervious concrete may be more appropriate. These pavements are similar to common asphalt and concrete but are much more permeable and can be used for roadway surfaces.

2.3 Former Handy & Harman Site Flood Storage and Tidal Wetland Restoration

The former Handy & Harman site is located at the corner of Grasmere Avenue and Kings Highway in Fairfield, which was a precious metals refining factory that manufactured sheets, bars, wire and anodes for electroplating and recycled precious metals from scrap. At one time, the facility employed about 430 workers, although it closed in 2002. The site was designated as an EPA Superfund site due to elevated levels of cadmium, arsenic and lead in soil, and dissolved arsenic and mercury in surface water. The portion of the site to the east of Grasmere Avenue was remediated and redeveloped into the "Kings Crossing" retail complex.

The portion of the site that was the former employee lot on the western side of Grasmere Avenue is still vacant and is in need of remediation for hazardous materials. The pavement from the former employee lot is badly deteriorating and is sinking into the

Flood Storage and Tidal Wetland Restoration

Location:
Grasmere Avenue and Kings Highway, Fairfield

Objectives:
Tidal wetland restoration, flood storage, riparian restoration, and pollutant reduction

Essential Elements:
Detention basin for flood storage, and tidal wetland restoration.

Estimated Cost: $56,000 –$120,000

encroaching wetland area. The area near Grasmere Avenue, and the western side of the parcel where the Rooster River daylights after flowing through a culvert beneath I-95 and the Route 1 interchange ramps, is reverting back to tidal wetlands. Restoration of the site could occur after the site is fully remediated for any hazardous materials. A potential restoration concept involves the following elements *(Figure 7)*:

Tidal Wetland Restoration. Enhance the tidal wetland area around the existing stream reach between Route 1 and the railroad.

Creation of Detention Area. A proposed outlet structure with a low-flow orifice would allow flood waters to be stored for a short period within a proposed detention area to improve flooding downstream. The proposed forebay at the inlet would provide some water quality benefits at both low and high flows. Lows flows would be conveyed in essentially the same channel as existing conditions.

Figure 9. Flood Storage and Tidal Wetland Restoration at the Former Handy & Harman Site

2.4 Invasive Species Removal

Invasive Species Removal

Location: Mt. Grove Cemetery, Grasmere Open Space Area, and others

Objectives:

Habitat improvement and public outreach

Essential Elements:

Removal of Japanese knotweed

Estimated Cost: $12,000 –$26,000

Japanese knotweed (*Fallopia japonica*) was identified in many areas of the Rooster River watershed and has displaced native species and threatens local biodiversity and ecosystem function in the watershed. The plant has hollow stems with distinct raised nodes that give it the appearance of bamboo, as shown in *Figure 10*, taken along the Rooster River and Turney Creek in the Mt. Grove Cemetery and the Grasmere Open Space Area, respectively. An invasive species management plan could be developed for eradication and control methods within the watershed including planting plans for native vegetation. The Grasmere Open Space Area and the Mt. Grove Cemetery were preliminarily identified and other areas may be identified following a vegetation survey of the watershed.

Japanese knotweed in Mt Grove Cemetery

Japanese knotweed in Grasmere Open Space Area

Figure 10. Photos of Japanese knotweed in the Rooster River Watershed

2.5 Green Infrastructure Retrofit at Madison Middle School

Green Infrastructure Retrofit at Madison Middle School

Location: Madison Avenue, Trumbull

Objectives:

Reduce parking lot runoff and remove pollutants with bioretention islands and a subsurface gravel wetland; reduce runoff using permeable pavement on isolated parking lots; install a green roof to reduce roof runoff; and install a rain garden in the front of the school for educational purposes.

Essential Elements: Bioretention, subsurface gravel wetland, and porous asphalt.

Estimated Cost: $204,000 - $348,000

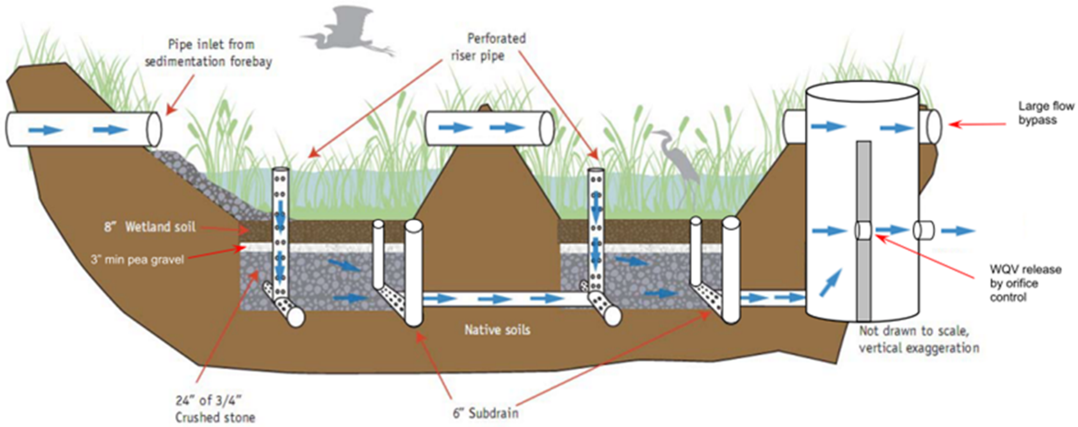
Madison Middle School is located along Madison Avenue in Trumbull. The school property is located partially within the adjacent Mill River watershed; however, the site is an excellent candidate for a demonstration LID retrofit due to the public exposure, site drainage, and available open space on the site. The school has a three-tiered parking lot that drains stormwater from the school and upper lots into a tributary of the Mill River along Madison Avenue.

A proposed concept for improving stormwater management at the school is shown in *Figure 11* and includes the following elements:

Bioretention. Construct bioretention areas in traffic islands between parking areas and the student drop-off loop in the back of the school to capture, treat, and infiltrate stormwater. Construct water quality swales or filter strips along the perimeter of the parking area on the south side of the school to capture runoff and sediment from the parking lot. Trees could also be planted along the strip to increase shading of the parking lot.

Subsurface Gravel Wetland. A subsurface gravel wetland is proposed for treating the runoff from the parking areas that does not infiltrate in the bioretention island. The subsurface gravel wetland uses a series of horizontal flow-through treatment cells, preceded by a sedimentation forebay and provides sedimentation, filtration, physical and chemical sorption, and treatment of bacteria (UNHSC, 2009).

Figure 11. School Greening Concept



Source: University of New Hampshire Stormwater Center (UNHSC), 2009, Subsurface Gravel Wetland Design Specifications.

Figure 12. Typical Subsurface Gravel Wetland Design

Pervious Pavement. The two smaller rear parking lots are good candidates for pervious pavement such as porous asphalt or pavers since they do not receive any stormwater run-on and do not have heavy traffic.

2.6 Green Infrastructure Retrofit at Bridgeport Public Library

The North Branch Bridgeport Public Library is located on Madison Avenue in Bridgeport adjacent to Veteran's Memorial Park. The site has a moderate amount of impervious areas associated with the tennis courts, the parking lots and the library roof.

Green Infrastructure Retrofit at Bridgeport Public Library

Location: Madison Avenue, Bridgeport

Objectives:

Runoff reduction, infiltration, pollutant reduction, and public outreach

Essential Elements:

Infiltration Trenches
Bioretention Islands and Tree Boxes
Sidewalk tree box filters
Rain Garden
Bioretention Area Retrofit.

Estimated Cost: $133,000 –$286,000

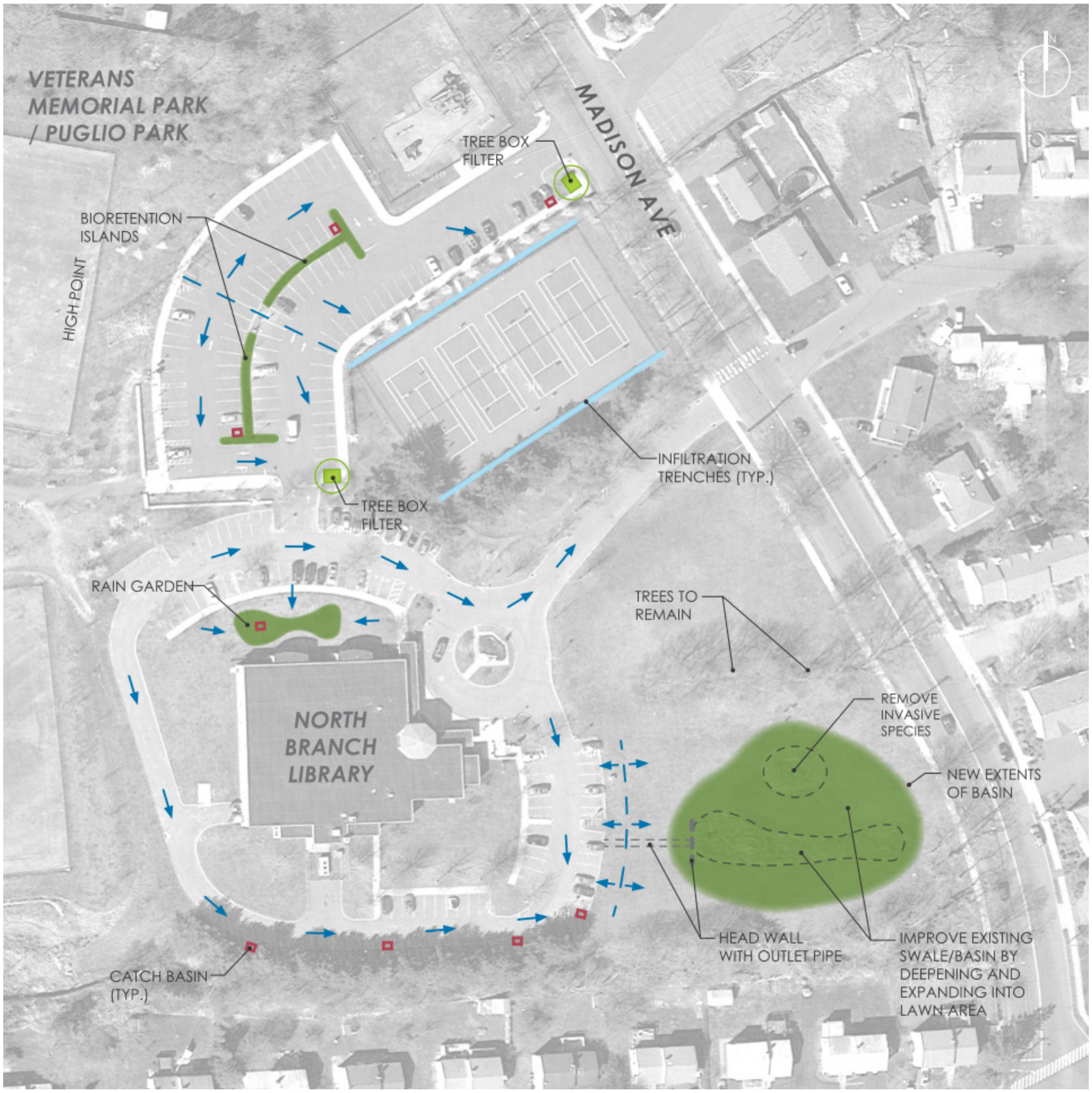


Figure 13. North Branch Public Library LID Concept

A proposed retrofit concept includes the following features:

Infiltration – Tennis Courts. The site appears to have some existing LID features. Linear strips of pea stone or gravel are located around the tennis courts, although they could be enhanced or expanded into infiltration trenches to increase infiltration of runoff from the tennis courts.

Bioretention Islands and Tree Boxes. The stormwater runoff from the parking area adjacent to the tennis courts and playground drains into catch basins at the edges of the parking stalls. The proposed concept includes bioretention islands in the middle of the parking area for the upper parking tier.

Sidewalk tree box filters. Tree box filters could be installed to capture and treat the runoff from the lower parking area during small storms. Tree box filters are a form of bioretention, consisting of precast concrete planters with tops that install flush with the curb. The majority of the device is below ground and includes a soil media to support tree growth and for pollutant removal via filtration. The curb inlet allows stormwater to enter the tree box filter. Trash and debris is deposited on top of the soil media and can be removed, while stormwater is treated as it passes through the soil media. The system can be configured to infiltrate the treated stormwater depending on soil and groundwater conditions. A typical schematic of a tree box filter is shown in *Figure 14*.

Existing pea stone/gravel along the tennis courts

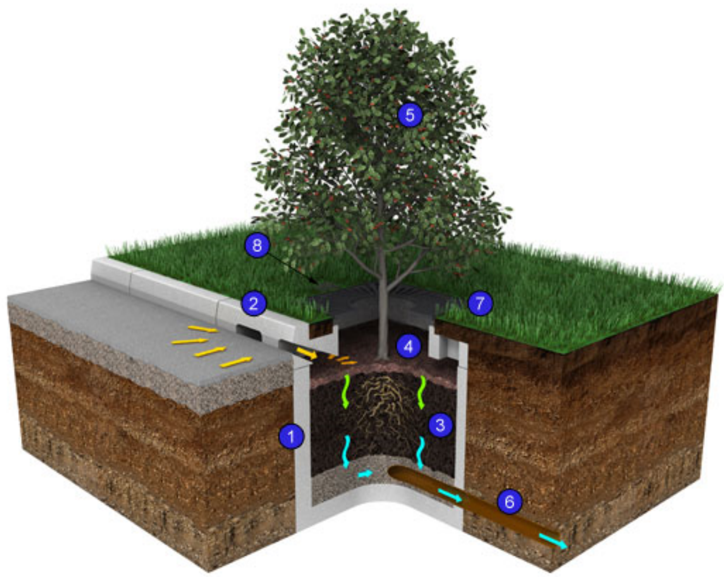


Figure 14. Typical Tree Box Filter (Source: Hydro International, Inc.)

Rain Garden. A rain garden is proposed in front of the library, where there is a depressed area in the grass with an existing catch basin, making the area ideal for conversion to a LID feature, which is believed to capture mostly roof runoff.

Bioretention Area Retrofit. The other impervious parking areas around the library generally drain to the east to a common outfall which discharges into an existing bioretention area in the lawn before being conveyed offsite. The existing bioretention area is relatively shallow and could be retrofitted to widen and deepen the basin to enhance the water quality and runoff reduction benefits. Additional benefits of the bioretention area at the library may include benches and picnic areas for outdoor reading or library programming.

Figure 15. Existing and Proposed Bioretention Basin at the Bridgeport Public Library

2.7 Green Infrastructure at Owen Fish Park

Owen Fish Park, also called Lilalyn Park, is a recreational field and pond area located along Stratfield Road in Fairfield. The parking area is located in the rear of the parcel adjacent to a tributary to Londons Brook. In this area, London Brook flows north to south along Stratfield Avenue and flows in an underground culvert or a channelized daylighted culvert. The tributary that flows behind Owen Fish Park discharges to the on-site pond and then flows over a dam into Londons Brook prior to reaching the confluence with Horse Tavern Brook and forming the Rooster River.

Green Infrastructure at Owen Fish Park

Location: Stratfield Road in Fairfield

Objectives:

Retrofit the parking lot to provide water quality treatment prior to discharge to the tributary stream and riparian buffer restoration along a highly visible area within the park.

Essential Elements:

Parking Lot Retrofit and Riparian Buffer Restoration

Estimated Cost: $14,000 –$30,000

A proposed retrofit concept for Owen Fish Park consists of the following elements:

Parking Lot Retrofit and Riparian Buffer Restoration. The parking lot at the site is dilapidated. Runoff from the eastern half of the lot flows toward a catch basin, which pipes water into the pond on the southeast side of the site. The western half of the parking lot flows via sheet flow into the tributary. There is space at the edge of the parking lot to construct a vegetative swale to treat the parking lot runoff and to create a riparian buffer. Decreasing direct runoff to the stream would help lower a potential source of bacteria and other pollutants to the pond and Londons Brook.

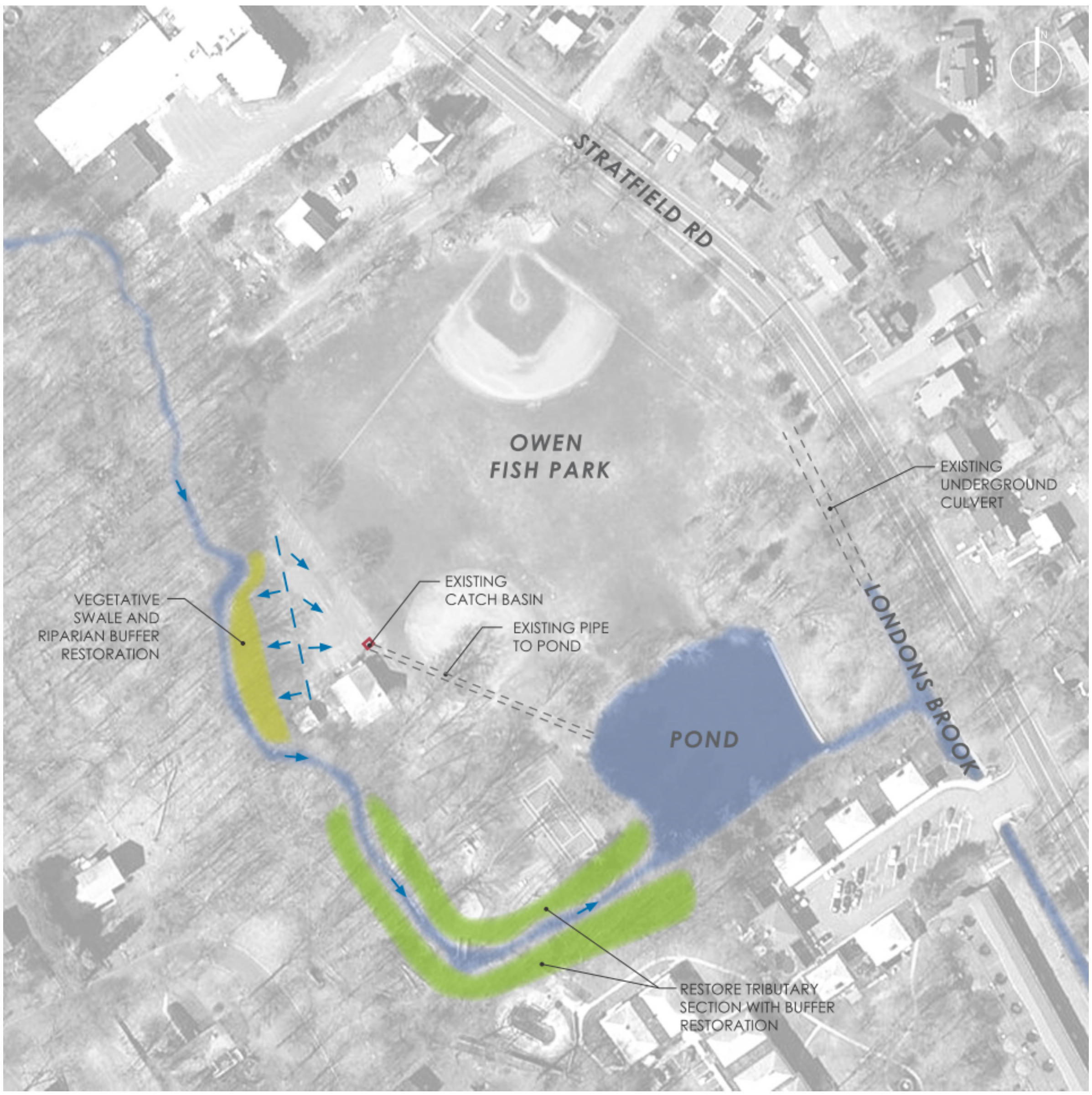


Figure 16. Green Infrastructure and Buffer Restoration Concept at Owen Fish Park

Figure 17. Existing Stream and Proposed Stream Restoration Concept (Typical)

2.8 Pocket Park at Madison Avenue and Vincellette Street

The Mayor of Bridgeport has identified the parcel located at the corner of Madison Avenue and Vincellette Street as a priority for acquisition for the creation of a "pocket park" along Horse Tavern Brook. The proposed park would be situated between condominium complexes, single family residences and a Stop & Shop grocery store in an under-served community.

The park is small, only approximately 0.5-acres; however it is highly visible from Madison Avenue, and Horse Tavern Brook runs through the middle of the parcel, providing residents who live in walking distance easy access to the river. The proposed pocket park concept is to create a short trail along the stream that would allow people to have easy access to view the stream and to provide a few picnic tables. Riparian buffer restoration is proposed throughout the entire park to remove invasive species and replant the stream banks. Armoring may be required to stabilize the banks. Educational signage and interpretive stations could be provided at the park describing the history, natural environment, water quality, and ecological resources of the Rooster River and its watershed. The cost of the pocket park includes the estimated cost to acquire the parcel, which is estimated at approximately $256,000.

Pocket Park at Madison Avenue and Vincellette Street

Location:

Madison Avenue and Vincellette Street, Bridgeport

Objectives:

Stream restoration, public education, riparian restoration, and public open space

Essential Elements:

Restore riparian buffer and create a pocket park with a gravel trail and picnic tables.

Estimated Cost: $195,000 –$417,000

Note: The estimated appraisal value of the parcel is $256,000, which is included in the total cost estimate.

Figure 18. Pocket Park at Madison Avenue and Vincellette Street Concept

2.9 Green Streets Design for Ridgeview Avenue

Green Streets Design for Ridgeview Avenue

Location: Ridgeview Avenue in Trumbull

Objectives:

Reduce runoff volumes, pollutant loads, and peak flow rates, as well as infiltrating and treating stormwater through the use of green infrastructure practices .

Essential Elements:

Pervious pavement in on-street parking stalls and bioretention bulb-outs at intersections

Estimated Cost: $83,000 –$180,000

A "green street" retrofit of Ridgeview Avenue in Trumbull would address stormwater management and streetscape improvement objectives. Ridgeview Avenue is typical of residential streets within single-family neighborhoods in Trumbull; it is wider than necessary, terminating in a large cul-de-sac, and provides for parking on both sides of the street, which is unnecessary since most homes have two-car driveways and garages. Many urban and suburban streets, sized to meet code requirements for emergency service vehicles and provide a free flow of traffic, are oversized for their typical everyday functions. The Uniform Fire Code requires that streets have a minimum 20 feet of unobstructed width. The width on Ridgeview is approximately 30 feet.

One potential concept (*Figure 19)* consists of reducing the amount of effective impervious cover along Ridgeview Avenue to reduce runoff volumes, pollutant loads, and peak flow rates, as well as infiltrating and treating stormwater through the use of other green infrastructure practices. This concept maintains on-street parking and integrates stormwater management and streetscape improvements using green infrastructure approaches within the right-of-way, while providing an aesthetic benefit and traffic calming. This concept could be applied to many residential streets within the watershed. The City of Bridgeport is undertaking several green streets projects within the city.

Figure 19. Ridgeview Avenue Green Street Retrofit Concept Visualization

The proposed concept for Ridgeview Avenue includes the following elements, which can be implemented on other low-traffic volume residential streets:

Pervious pavement in on-street parking stalls. Ridgeview Avenue is approximately 30 feet wide with one travel lane in each direction and the remainder used for on-street parking. On-street parking could be limited to one side, which would allow more area to construct pervious pavement, such as pervious concrete, pervious asphalt, or open-jointed block pavers. These areas would be available for parking but, unlike conventional asphalt pavement, would reduce infiltrate stormwater and reduce roadway runoff volumes and pollutant loads. *Figure 20* shows a typical detail of a green street parking bay.

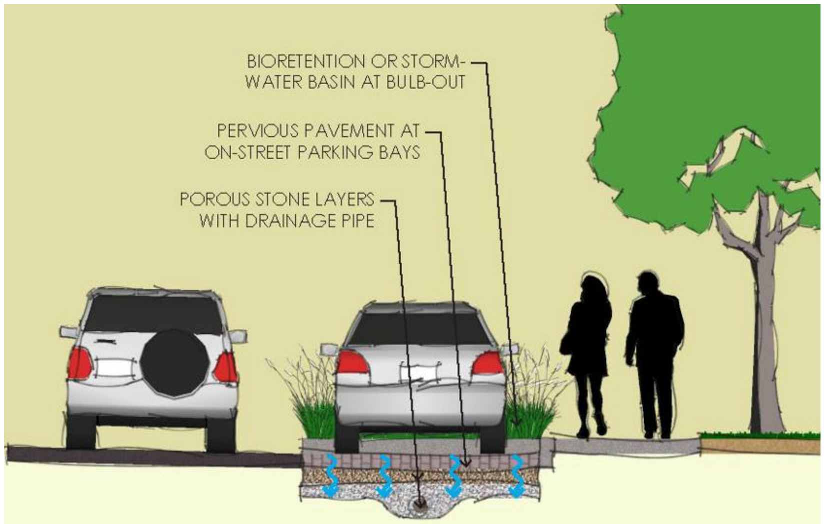


Figure 20. Typical Green Street Parking Bay

Bioretention bulb-outs at intersections. Near intersections, where on-street parking is discouraged to maintain site distance for turning vehicles, bioretention bulb-outs could be used to capture, treat, and infiltrate or filter stormwater. Bulb-outs at intersections can also serve to provide traffic calming. A typical bioretention bulb-out detail is presented in *Figure 21*. These bioretention areas would have a soil media layer to temporarily store and treat runoff prior to infiltration into underlying soils or discharge to the storm drainage system in areas with high groundwater or poor soils. The bulb-outs could be planted with attractive, low-growing and low-maintenance native landscape plants with a mulch layer.

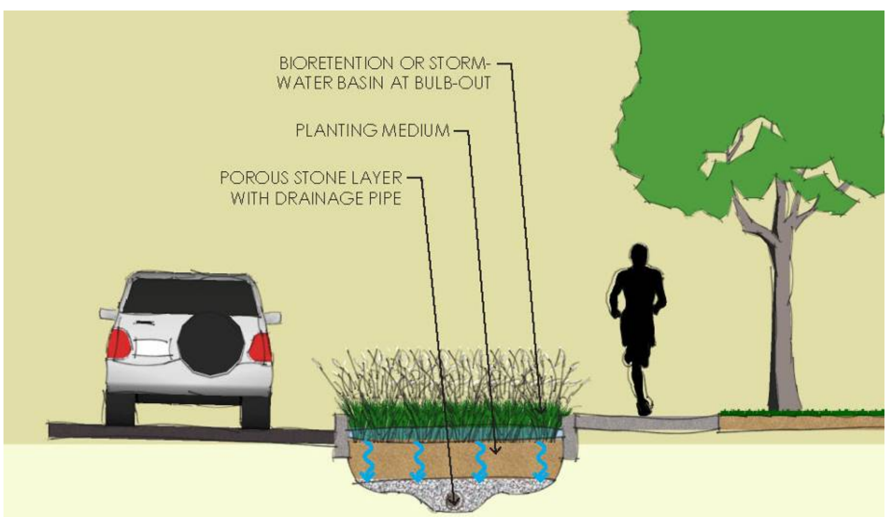


Figure 21. Typical Bioretention Bulb-out

2.10 Green Infrastructure Retrofit at Post Road Traffic Circle

Turney Creek flows parallel to Route 1 from north to south in a trapezoidal concrete channel, then goes underground in an approximately 865-foot culvert beneath the Post Road traffic circle, and daylights south of Post Road (Route 130) in Fairfield. There is an approximately 1-acre semi-circular grass area adjacent to the McDonald's parking lot. The grass area contains several catch basins to collect stormwater and convey it into the culvert, as well as manholes for access to the underground culvert. The existing topography of the grass area slopes toward the center of the area, and runoff from the McDonald's parking lot flows toward the grass to the northeast. The retrofit concept for the Post Road traffic circle consists of the following elements:

Green Infrastructure Retrofit at Post Road Traffic Circle

Location: Post Road (Route 130), Fairfield

Objectives:

Daylight Turney Creek for approx. 200 feet and create a constructed wetland and green infrastructure for the parking lot runoff.

Essential Elements:

Stream daylighting, constructed wetland area, and parking lot improvements including filter strips and infiltration trenches.

Estimated Cost: $197,000 –$421,000

Stream Daylighting and Constructed Wetland Area. The approximately 200-foot section of culvert below the grass area could be removed to its end and replaced with a restored stream channel to carry Turney Creek. The channel could be created from a combination of boulders, cobbles, and gravel, with deep pools at intervals for habitat. Due to concerns with traffic sight distances, a restored riparian area with high plantings should not be used.

Parking Lot Improvements. The existing McDonald's parking lot could be retrofitted with a filter strip and infiltration trench to capture, treat, and infiltrate stormwater prior to discharging into the wetland area. These improvements could effectively eliminate the stormwater contribution of this parking lot to Turney Creek during most storms.

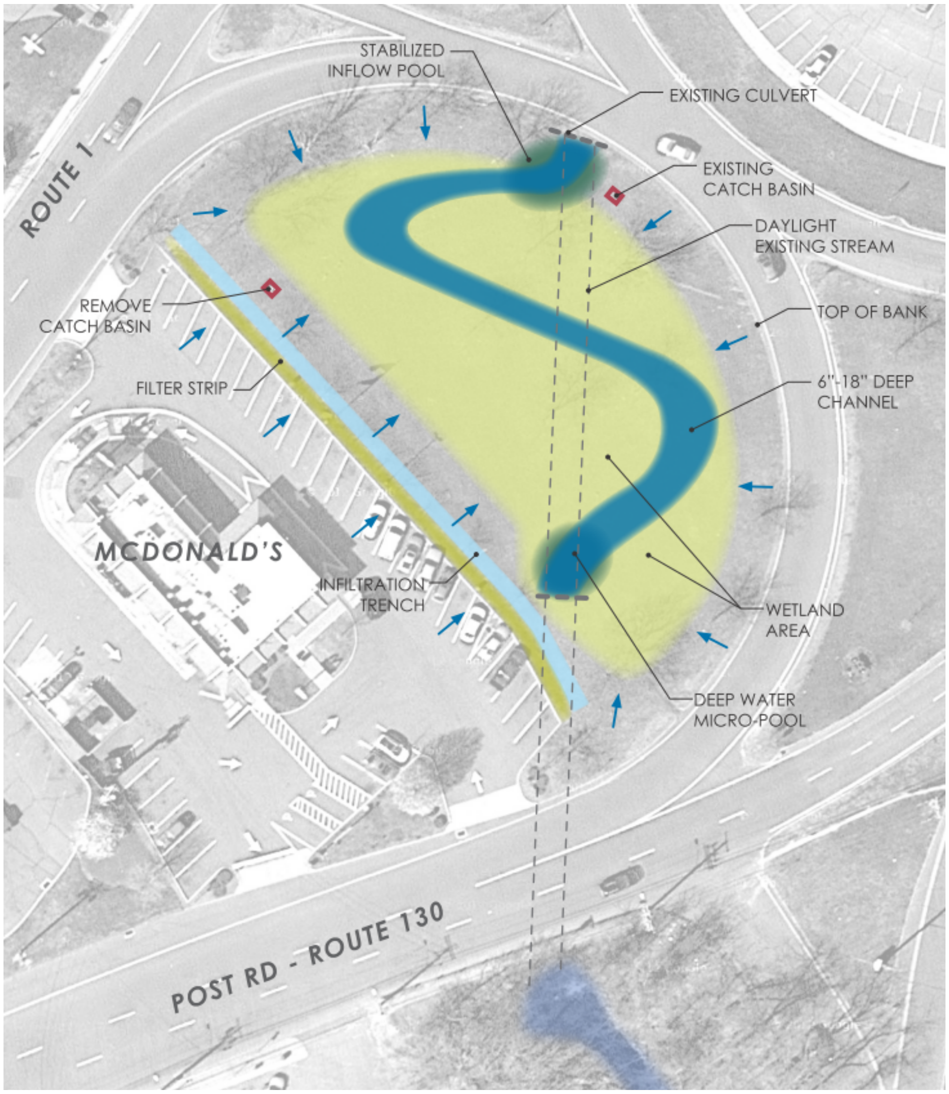


Figure 22. Turney Creek Restoration Concept at the Post Road Traffic Circle

2.11 Woodside Circle Open Space Stream Restoration

The Woodside Circle Open Space is located approximately 2,500 feet downstream of the confluence of Londons Brook and Horse Tavern Brook, where the Rooster River begins. The Rooster River has severely impacted buffers along this entire reach of river due to riparian buffer encroachment at the Brooklawn Country Club and dense residential development. The Woodside Circle Open Space area provides an opportunity to restore a portion of the riparian buffer since it is publicly-owned. The banks of the river within Woodside Circle are

Woodside Circle Open Space Stream Restoration

Location: Woodside Circle, Fairfield

Objectives:

Stream bank and riparian restoration

Essential Elements:

Stream restoration and drainage swale armoring

Estimated Cost: $111,000 –$239,000

severely eroded due to turf being planted right to the bank of the river, which is not stabilizing the bank. In addition, impervious areas upstream of the park are increasing runoff volume, peak flows and velocities to the river, exacerbating the problems.

A study was recently conducted by Tighe & Bond for the Town of Fairfield Engineering Department called "Woodside Circle Velocity Distribution Study for Rooster River in the vicinity of Assumption School and Woodside Circle" to examine potential restoration of the bank to alleviate erosion. The study recommended hard armoring of the banks due to the high flows in the stream reach.

Surface stabilization could consist of a layered series of bioengineered stabilization and planting techniques, based on potential for river inundation and erosive forces. Where flow velocities are expected to exert highest shear forces, riprap could be installed with root wads providing additional interlocking and habitat. Varying vegetated surfaces could transition from the top of the riprap layer to the top of slope as the potential for inundation and erosion decreases. Upslope from the bank, a riparian buffer of native trees and shrubs could replace the existing grass to better slow direct stormwater runoff and provide improved stormwater treatment and infiltration *(Figure 23)*.

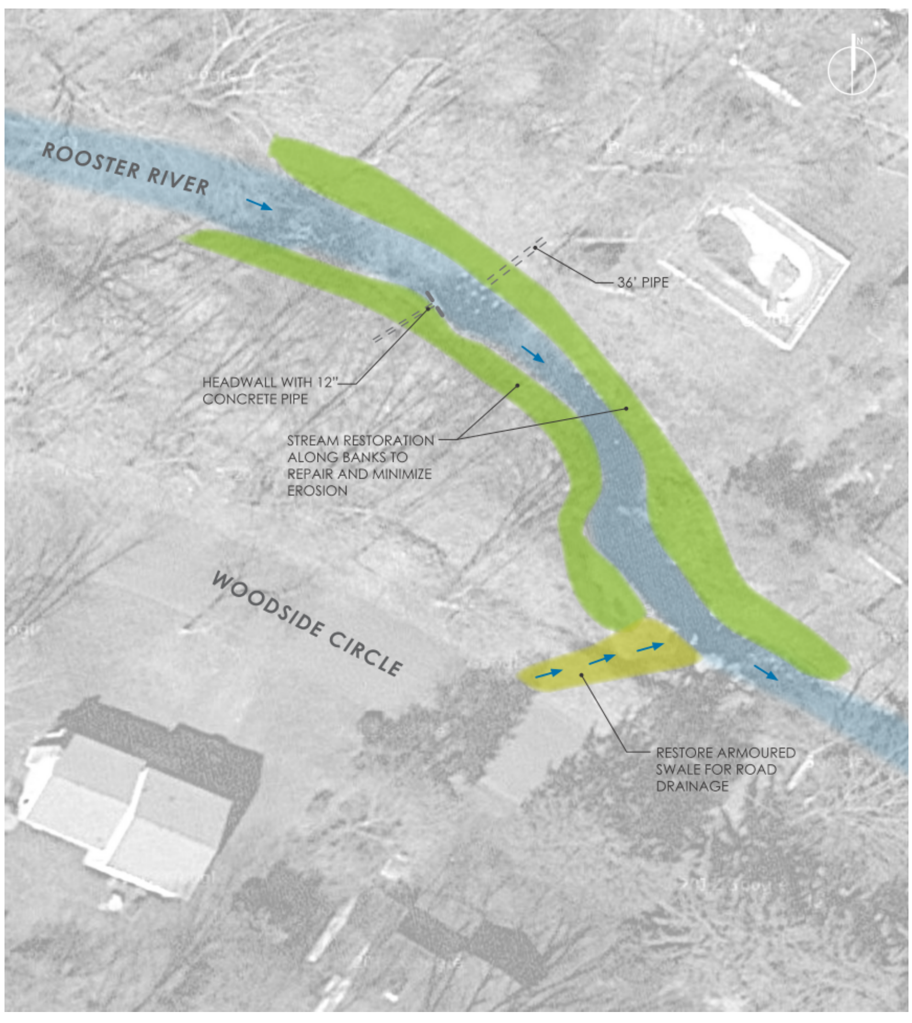


Figure 23. Woodside Circle Open Space Stream Restoration Concept

3 Other Potential Green Infrastructure Retrofits

Opportunities for stormwater retrofits exist throughout the Rooster River watershed, in addition to the site-specific retrofits that are presented in the previous section. The most promising retrofit opportunities are generally located on publicly-owned land and include:

- Parking lot upgrades (bioretention, pervious pavement, vegetated buffers, water quality swales)
- Municipal and institutional properties (bioretention, pervious pavement green roofs, blue roofs, tree planting, stormwater harvesting)
- Athletic fields at parks and educational institutions (water quality swales, vegetated buffers, infiltration, bioretention, stormwater reuse for irrigation)
- Road repair/upgrades (green or "complete" streets – bioretention, water quality swales, tree planters, below-ground infiltration chambers)
- Roadway stormwater outfalls, particularly at or near roadway stream crossings
- Vacant or underutilized parcels owned by the watershed municipalities

Potential target areas for retrofits on public land (e.g., golf courses, schools and other institutional uses, and cemeteries) are shown in *Figure 25*.

Residential lots offer opportunities for small-scale LID retrofits such as roof leader and downspout disconnection, rain barrels, and rain gardens, but typically require homeowner incentives and outreach/education for widespread implementation. Commercial and industrial facility retrofits can also be effective as these sites are typically characterized by high impervious cover and pollutant sources. However, commercial and industrial retrofits also require incentives and cooperation of private land owners if they are not regulated through a local, state, or federal permit program. Target areas in the watershed for residential, commercial and industrial retrofits are shown in *Figure 26*.

Two community workshops were held at the Discovery Museum and Planetarium in Bridgeport on May 8, 2013. The workshops focused on soliciting input from residents, municipal staff, and land use commissions in the major watershed communities of Bridgeport, Fairfield, and Trumbull. *Table 1* summarizes potential green infrastructure retrofit sites that were identified during the desktop screening-level review, field inventories, and during the community workshops, in addition to the site-specific retrofits that are presented in this document.

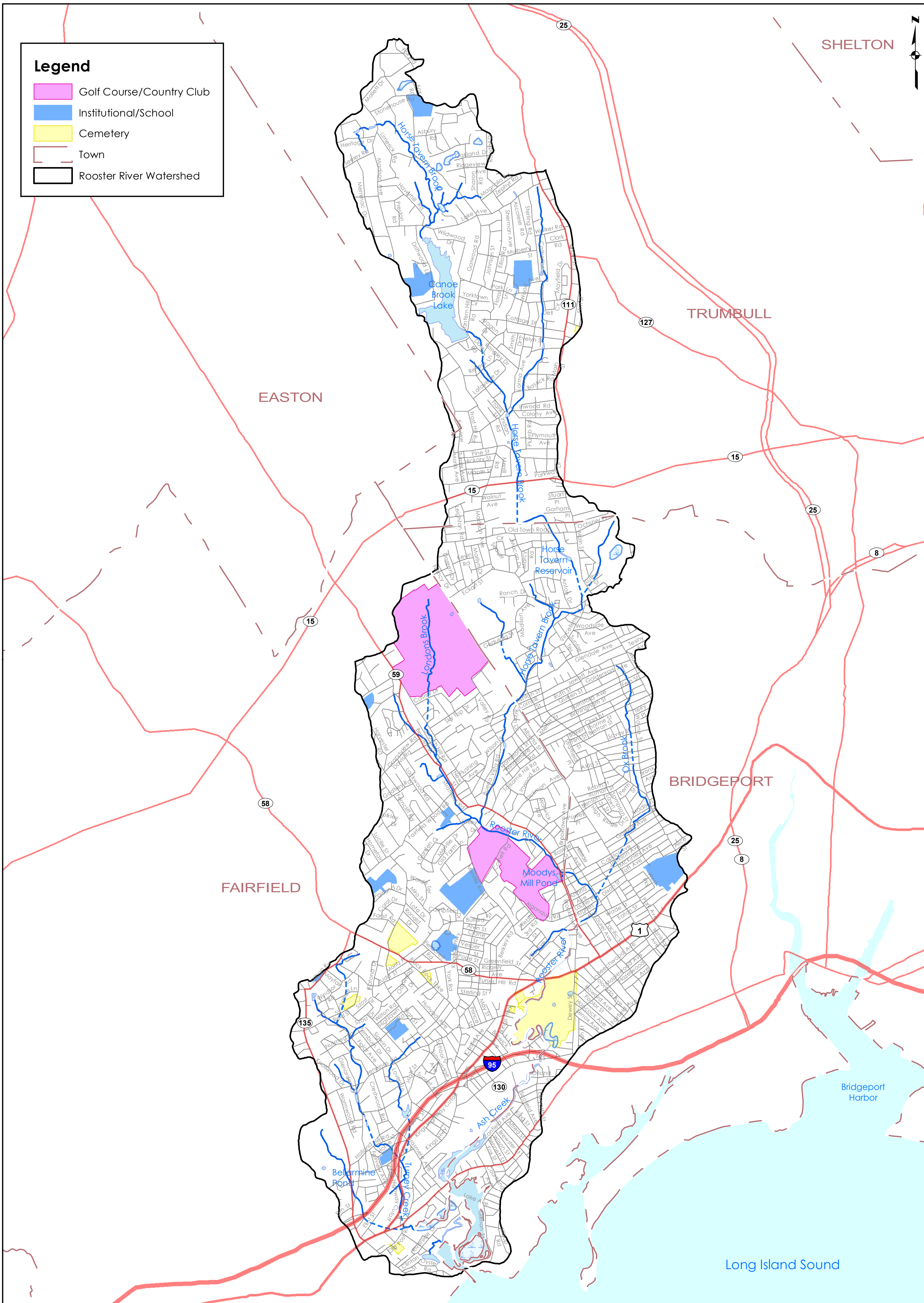
Table 1. Other Potential Green Infrastructure Retrofits

Site	Land Use	Town	Description/Potential Retrofits
Tashua School	Institutional	Trumbull	Potential retrofits include bioretention, pervious pavement, green roofs, blue roofs, tree planting, and stormwater harvesting.
Westfield Shopping Center	Commercial	Trumbull	Horse Tavern Brook is culverted under the shopping center. Stormwater retrofit opportunities exist on the southern side of the shopping center to reduce peak flows and infiltrate runoff from the mostly impervious site.

Site	Land Use	Town	Description/Potential Retrofits
Jane Ryan School	Institutional	Trumbull	Potential site for a demonstration project using stormwater retrofits to treat parking lot or athletic field runoff.
Fairchild/Wheeler Golf Course	Recreation	Fairfield	The golf course is owned by the City of Bridgeport. Potential projects may include: • Improving water quality • Improve plant and animal habitats • Restore wetlands around the golf course • Restore the natural floodplain • Construct a detention basin at the golf course discharge pipe (along the southern side of the course) to improve stormwater detention and attenuate downstream flooding
Tunxis Hill Park	Recreation	Fairfield	Opportunity to construct a bioretention or detention area to reduce runoff and flooding potential in a forested area northwest of Nordstrom Avenue along the western edge of Tunxis Hill Park where the discharge from the park in coveyed.
Stratfield Elementary	Institutional	Fairfield	Potential retrofits include bioretention, pervious pavement, green roofs, blue roofs, tree planting, and stormwater harvesting.
Brooklawn Country Club	Recreation	Fairfield	Improve water quality and provide flood relief by restoring the floodplain and natural channel along the river at Brooklawn Avenue and north of Cornell Road. This course is privately-owned.
Fairfield Metro Center	Transportation	Fairfield	Follow-up inspections for the embankment rehabilitation project at the new Metro Station.
Grasmere Brook Open Space	Open Space	Fairfield	Provide public access by restoring the inland wetland by removing accumulated fill and debris while providing an access trail and sound attenuator berm to reduce traffic noise form I-95. Restore the floodplain from historical fill.
Turney Creek Trapezoidal Channel near Post Road Traffic Circle	Transportation	Fairfield	Relieve flooding by redesigning and removing all or a portion of the State's open concrete trapezoidal channel of Turney Creek between the Circle and the Railroad right-of-way.
Stratfield Elementary	Institutional	Fairfield	Potential retrofits include bioretention, pervious pavement, green roofs, blue roofs, tree planting, and stormwater harvesting.

Site	Land Use	Town	Description/Potential Retrofits
Scofield Avenue Extension Bridge	Transportation	Fairfield & Bridgeport	The Rooster River Hydrologic Study performed by Vollmer Associates (now Stantec) recommended the demolition of the two bridges over the Rooster River at Scofield Avenue and replace them with a single bridge to improve the stream hydraulics. As a part of this project, the stream could be restored and riparian buffers improved.
Rooster River between North Avenue Bridge and Brewster Street Bridge	Various	Bridgeport	Stream restoration along this approximately 1.75 mile stream segment to restore wetlands and channel widths
Laurel Avenue between Hughes and Capital Avenues	Residential	Bridgeport	Alleviate flooding issues by encouraging small-scale residential retrofits in this neighborhood or incorporation of LID within the public right-of way (i.e., green streets). Providing fish passage past the Lower and Upper Brooklawn Avenue flood relief culverts.
Rooster River upstream of I-95 Road Crossing	Transportation	Bridgeport	Sediment is filling in the area causing a significant loss of floodplain storage volume, increased flood elevations, and has caused debris dams of floating trash, expansion of the flooded area into new areas, and increased mosquito breeding. In-filling has also resulted in the elimination of natural salt marsh plant and animal habitats. Restore the floodplain and tidal wetland habitat by excavating the accumulated sediment and restoring the wetlands.
Brookside Shopping Center	Commercial	Bridgeport	Horse Tavern Brook is culverted under the shopping center. Daylight stream and provide water quality treatment for stormwater runoff from the site.
Ox Brook Buffer Restoration	Residential	Bridgeport	Restore stream buffer and daylight stream, especially in the vicinity of Wayne Street, Amsterdam Avenue from Madison Ave to Thorme Street
John Winthrop Middle School	Institutional	Bridgeport	Potential retrofits include bioretention, pervious pavement, green roofs, blue roofs, tree planting, and stormwater harvesting.
St. Mary's Sand Spit	Open Space	Bridgeport	Restore dunes from damage caused by Tropical Storm Sandy

Site	Land Use	Town	Description/Potential Retrofits
Various tidally-influenced stream locations	Various	Fairfield & Bridgeport	Improve tidal gate flow along Turney Creek and Riverside Creek
Park Avenue near Plankton Street	Transportation	Bridgeport	Eroding Bridge Abutments



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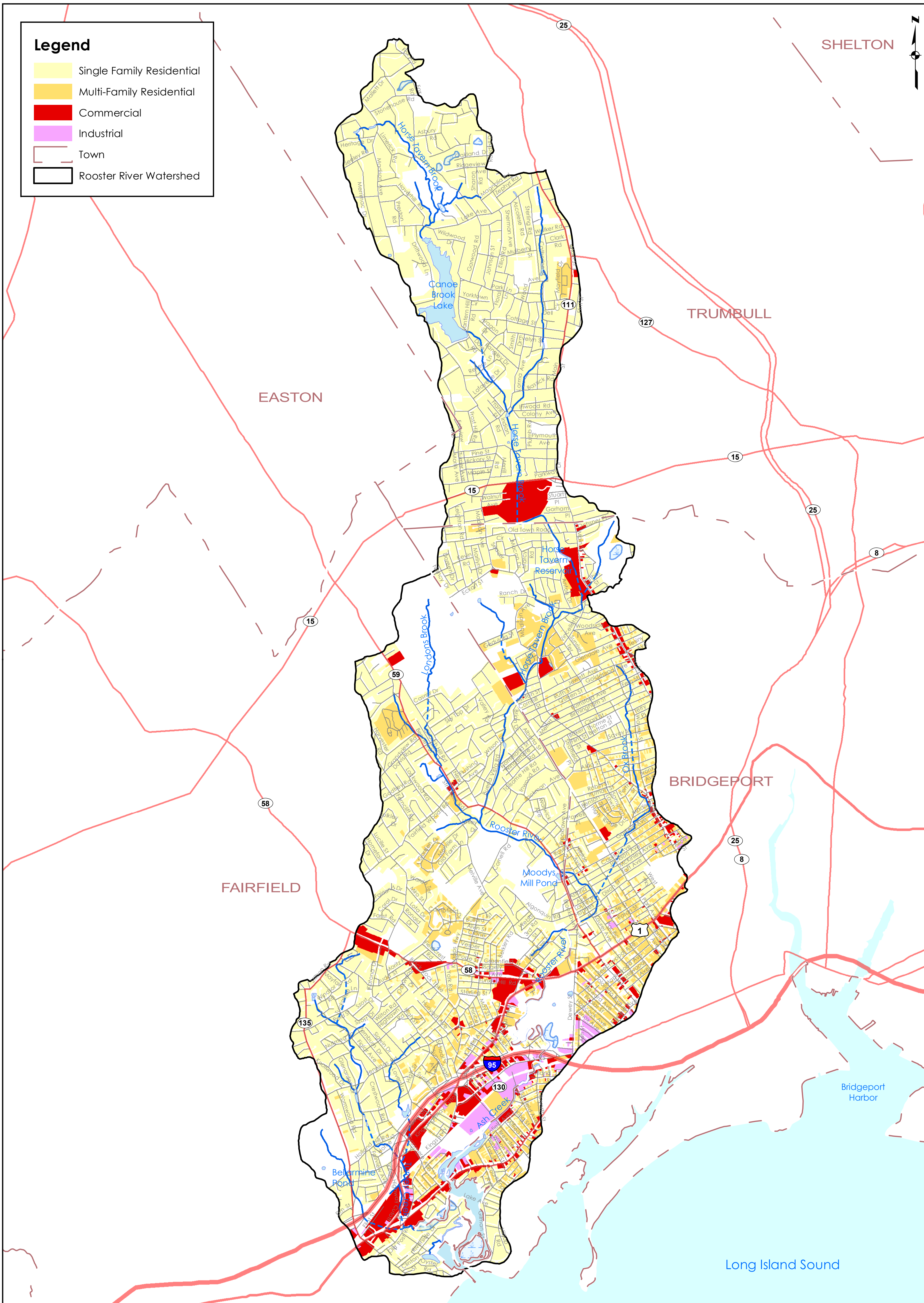
Map References:
Land use based on GIS data from City of Bridgeport (2008), Town of Fairfield (2012), and Greater Bridgeport Regional Planning Agency (GBRPA) (2000) for Trumbull; Water based on National Hygrography Dataset (NHD); Recreation/Open Space and Roadways adjusted using Connecticut Department of Energy & Environmental Protection (CTDEEP) data. Land use data verified using Ortho_2010_4Band_Color_NAIP.

ROOSTER RIVER WATERSHED BASED PLAN

FIGURE 24
HIGHER-PRIORITY TARGET RETROFIT AREAS



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Map References:
Land use based on GIS data from City of Bridgeport (2008), Town of Fairfield (2012), and Greater Bridgeport Regional Planning Agency (GBRPA) (2000) for Trumbull; Water based on National Hygrography Dataset (NHD); Recreation/Open Space and Roadways adjusted using Connecticut Department of Energy & Environmental Protection (CTDEEP) data. Land use data verified using Ortho_2010_4Band_Color_NAIP.

ROOSTER RIVER WATERSHED BASED PLAN

FIGURE 25
LOWER-PRIORITY TARGET RETROFIT AREAS

4 References

District of Columbia Water and Sewer Authority, *Green Infrastructure Summit 2012*. February 29, 2012. Presentation by George S. Hawkins, General Manager.

Oregon Department of Environmental Quality, 2010, *Cost Estimate to Restore Riparian Forest Buffers and Improve Stream Habitat in the Willamette Basin, Oregon*. March 2010 Water Quality Division, Watershed Management Section.

Schueler, T., Hirschman, D., Novotney, M., Zielinski,J. 2007. Manual 3: Urban Stormwater Retrofit Practices Manual.:Urban Subwatershed Restoration Manual Series. Center for Watershed Protection, Ellicott City, MD.

University of New Hampshire Stormwater Center (UNHSC), 2009, *Subsurface Gravel Wetland Design Specifications.*

University of New Hampshire Stormwater Center (UNHSC), 2012 Biennial Report.

Appendix A

Site-Specific Project Cost Estimates

Order of Magniude Cost Range															
		Construction				Design and Planning		Cost Range			Life Cycle				
	Location and Element	Unit Cost	Unit	Quantity	Cost (2013$)	Allowance	Cost	Total Cost	-30%	50%	Lifespan (yrs)	Annual Cost over Lifespan	O&M (% Cost)	O&M ($/yr)	Total Capitalized Cost/yr over lifespan
Assumption School Parking Lot Retrofit															
1	Pervious Pavement	$ 2.84	sf	5,200	$ 14,793	30%	$4,000	$19,000	$13,000	$29,000	20	$1,400	4%	$60	$1,460
2	Vegetated Swale	$ 10.16	sf	900	$ 9,144	30%	$3,000	$13,000	$9,000	$20,000	15	$1,170	4%	$50	$1,220
3	Rip Rap at Leakoff	$ 45.72	CY	19	$ 847	30%	$0	$1,000	$1,000	$2,000	20	$70	4%	$0	$70
4	Bioretention Area	$ 33.02	sf	1,280	$ 42,266	30%	$13,000	$56,000	$39,000	$84,000	15	$5,040	4%	$200	$5,240
5	Stream Restoration	$ 13,106.28	ac	1.00	$ 13,106	30%	$4,000	$18,000	$13,000	$27,000	15	$1,620	4%	$60	$1,680
6	Remove fill	$ 7.62	CY	50	$ 381	30%	$0	$1,000	$1,000	$2,000	15	$90	4%	$0	$90
							Total	**$108,000**	**$76,000**	**$164,000**					
Blackham School LID Retrofit															
1	Green Roof	$ 23.37	sf	10,000	$ 233,680	30%	$70,000	$304,000	$213,000	$456,000	15	$27,340	4%	$1,090	$28,430
2	Permeable Pavers	$ 10.16	sf	7,500	$ 76,200	30%	$23,000	$100,000	$70,000	$150,000	20	$7,360	4%	$290	$7,650
3	Bioretention Areas	$ 33.02	sf	1,270	$ 41,935	30%	$13,000	$55,000	$39,000	$83,000	15	$4,950	4%	$200	$5,150
4	Subsurface Infiltration Chambers	$ 36.73	cf of runoff treated	2,240	$ 82,272	30%	$25,000	$108,000	$76,000	$162,000	20	$7,950	4%	$320	$8,270
							Total	**$567,000**	**$398,000**	**$851,000**					
Former Handy & Harman Site Flood Storage and Tidal Wetland Restoration															
1	Rip Rap Low Flow Channel	$ 46	CY	509	$23,283	30%	$7,000	$31,000	$22,000	$47,000	20	$2,280	4%	$90	$2,370
2	Forebay	$ 46	CY	241	$11,007	30%	$3,000	$15,000	$11,000	$23,000	20	$1,100	4%	$40	$1,140
3	Precast Concrete Outlet Structure (8 x 12 x 16' high)	$ 25,000	ea	1	$25,000	30%	$8,000	$33,000	$23,000	$50,000	20	$2,430	4%	$100	$2,530
4	Tidal Wetland Restoration	$ 2.03	SY	2256	$4,583	30%	$1,000	$6,000	$4,000	$9,000	20	$440	4%	$20	$460
							Total	**$79,000**	**$56,000**	**$120,000**					
Invasive Species Restoration															
1	Remove Invasive Species @ Grasmere Brook	$ 3,401	acre	1.7	$ 5,781	30%	$2,000	$8,000	$6,000	$12,000	2	$4,240	4%	$170	$4,410
1	Remove Invasive Species @ Mt Grove Cemetery	$ 3,401	acre	2.0	$ 6,801	30%	$2,000	$9,000	$6,000	$14,000	2	$4,770	4%	$190	$4,960
							Total	**$17,000**	**$12,000**	**$26,000**					
Green Infrastructure Retrofit at Madison Middle School															
1	Pervious Pavement	$ 2.84	sf	12,300	$ 34,991	30%	$10,000	$45,000	$32,000	$68,000	20	$3,310	4%	$130	$3,440
2	Subsurface Gravel Wetland	$ 22	cf of runoff treated	1,980	$ 43,915	30%	$13,000	$57,000	$40,000	$86,000	15	$5,130	4%	$210	$5,340
3	Rain Gardens	$ 7.40	sf	1,000	$ 7,396	30%	$2,000	$10,000	$7,000	$15,000	15	$900	4%	$40	$940
4	Bioretention Areas	$ 33.02	sf	4,150	$ 137,033	30%	$41,000	$179,000	$125,000	$269,000	15	$16,100	4%	$640	$16,740
							Total	**$291,000**	**$204,000**	**$438,000**					

	Order of Magniude Cost Range														
		Construction				Design and Planning		Cost Range			Life Cycle				
	Location and Element	Unit Cost	Unit	Quantity	Cost (2013$)	Allowance	Cost	Total Cost	-30%	50%	Lifespan (yrs)	Annual Cost over Lifespan	O&M (% Cost)	O&M ($/yr)	Total Capitalized Cost/yr over lifespan
Green Infrastructure Retrofit at Bridgeport Public Library															
1	Large Bioretention Area (Rain Garden)	$ 7.40	sf	12,000	$ 88,758	30%	$27,000	$116,000	$81,000	$174,000	15	$10,430	4%	$420	$10,850
2	Rain Garden	$ 7.40	sf	1,300	$ 9,615	30%	$3,000	$13,000	$9,000	$20,000	15	$1,170	4%	$50	$1,220
3	Parking Island Bioretention	$ 33.02	sf	680	$ 22,454	30%	$7,000	$30,000	$21,000	$45,000	15	$2,700	4%	$110	$2,810
4	Tree Box Filters	$ 6,096	ea	2	$ 12,192	30%	$4,000	$17,000	$12,000	$26,000	15	$1,530	4%	$60	$1,590
5	Infiltration Trenches	$ 18.58	lf	580	$ 10,777	30%	$3,000	$14,000	$10,000	$21,000	20	$1,030	4%	$40	$1,070
							Total	**$190,000**	**$133,000**	**$286,000**					
Green Infrastructure at Owen Fish Park															
1	Vegetated Swale	$ 10.16	sf	1,000	$ 10,160	30%	$3,000	$14,000	$10,000	$21,000	15	$1,260	4%	$50	$1,310
2	Riparian Buffer Restoration	$ 11,204	ac	0.39	$ 4,398	30%	$1,000	$6,000	$4,000	$9,000	15	$540	4%	$20	$560
							Total	**$20,000**	**$14,000**	**$30,000**					
Pocket Park at Madison Avenue and Vincellette Street															
	Riparian Buffer Restoration	$ 11,204	ac	0.32	$ 3,601	30%	$1,000	$5,000	$4,000	$8,000	15	$450	4%	$20	$470
	Gravel Trail	$ 30.48	CY	18.5	$ 564	30%	$170	$1,000	$1,000	$2,000	20	$70	4%	$0	$70
	Picnic Tables	$ 200.00	ea	3	$ 600	30%	$180	$1,000	$1,000	$2,000	10	$120	4%	$0	$120
	Parcel Acquisition	$ 256,209	ea	1	$ 256,209	5%	$13,000	$270,000	$189,000	$405,000	100	$11,020	4%	$440	$11,460
							Total	**$277,000**	**$195,000**	**$417,000**					
Green Streets Design for Ridgeview Avenue															
1	Pervious Pavement (20 spaces)	$ 2.84	sf	2,240	$ 6,372	30%	$2,000	$9,000	$6,000	$14,000	20	$660	4%	$30	$690
2	Bioretention Areas	$ 33.02	sf	700	$ 23,114	30%	$7,000	$31,000	$22,000	$47,000	15	$2,790	4%	$110	$2,900
3	Tree Box	$ 6,096	ea	10	$ 60,960	30%	$18,000	$79,000	$55,000	$119,000	15	$7,110	4%	$280	$7,390
							Total	**$119,000**	**$83,000**	**$180,000**					
Green Infrastructure Retrofit at Post Road Traffic Circle															
1	Constructed Wetland Area	$4.38	sf	38,000	$ 166,368	30%	$50,000	$217,000	$152,000	$326,000	15	$19,520	4%	$780	$20,300
2	Stream Daylighting	$25,000	ea	1	$ 25,000	50%	$13,000	$38,000	$27,000	$57,000	100	$1,550	4%	$60	$1,610
3	Filter Strip	$10.16	sf	875	$ 8,890	30%	$3,000	$12,000	$8,000	$18,000	15	$1,080	4%	$40	$1,120
4	Infiltration Trench	$18.58	lf	292	$ 5,419	30%	$2,000	$8,000	$6,000	$12,000	20	$590	4%	$20	$610
5	Excavation/Earthwork	$7.62	CY	500	$ 3,810	30%	$1,000	$5,000	$4,000	$8,000	20	$370	4%	$10	$380
							Total	**$280,000**	**$197,000**	**$421,000**					
Woodside Circle Open Space Stream Restoration															
1	Stream Restoration	$ 13,106	ac	0.50	$ 6,553	30%	$2,000	$9,000	$6,000	$14,000	15	$810	4%	$30	$840
2	Streambank Stabilization	$ 100,000	ea	1	$ 100,000	50%	$50,000	$150,000	$105,000	$225,000	15	$13,490	4%	$540	$14,030
							Total	**$159,000**	**$111,000**	**$239,000**					

Notes:
Rate of Inflation used = 2%
Interest (discount) rate used = 6%
*Projects are proposed for these locations already. Costs estimated in this table are for adding ecological and water quality elements to the assumed original purpose of the proposed projects.
Costs should be used for planning purposes only based on cursory evaluations of site characteristics. Construction costs could vary significantly.

Unit Costs Table

Element	2013 Adjusted Cost	Unit	Cost	$YEAR	Source
Large Bioretention Retrofit	$ 12.19	cf of runoff treated	$ 10.50	2006	Center for Watershed Protection Urban Subwatershed Retrofit Manual 3 (2007), cost adjusted, Page E-3
Small Bioretention Retrofit (<0.5 acre)	$ 33.02	sf	$ 32.50	2012	District of Columbia Water and Sewer Authority, George S. Hawkins, General Manager, Green Infrastructure Summit 2012, February 29, 2012.
Water Quality Swale	$ 10.16	sf	$ 10.00	2012	District of Columbia Water and Sewer Authority, George S. Hawkins, General Manager, Green Infrastructure Summit 2012, February 29, 2012.
Rain Garden	$ 7.40	sf	$ 7.28	2012	Woodard & Curran - Route 1 Falmouth Commercial District Stormwater Management, 2012
French Drain	$ 18.58	lf	$ 16.00	2006	Center for Watershed Protection Urban Subwatershed Retrofit Manual 3 (2007), cost adjusted, page E-11
Subsurface Infiltration Chambers	$ 36.73	cf of runoff treated	$ 36.15	2012	Woodard & Curran - Route 1 Falmouth Commercial District Stormwater Management, 2012
Green Roof	$ 23.37	sf	$ 23.00	2012	District of Columbia Water and Sewer Authority, George S. Hawkins, General Manager, Green Infrastructure Summit 2012, February 29, 2012.
Subsurface Gravel Wetland	$ 22.18	cf of runoff treated	$ 21.83	2012	Woodard & Curran - Route 1 Falmouth Commercial District Stormwater Management, 2012
Constructed Wetland	$ 4.38	sf	$ 3.77	2006	Center for Watershed Protection Urban Subwatershed Retrofit Manual 3 (2007), cost adjusted, page E-11
Tree Box	$ 6,096	ea	$ 6,000	2012	UNH Stormwater Center 2012 Biennial Report
Porous Asphalt	$ 2.84	sf	$ 2.80	2012	UNH Stormwater Center 2012 Biennial Report. Page 12
Permeable Pavers	$ 10.16	sf	$ 10.00	2012	Center for Watershed Protection Urban Subwatershed Retrofit Manual 3 (2007), cost adjusted, Page E-5
Remove Invasive Species	$ 3,400.64	acre	$ 3,200	2010	Professional Engineering Experience
Riparian Buffer Restoration	$ 11,204.05	ac	$ 10,543	2010	Oregon Department of Environmental Quality, 2010, Cost Estimate to Restore Riparian Forest Buffers and Improve Stream Habitat in the Willamette Basin, Oregon. Page 20
Stream Channel Restoration	$ 13,106.28	ac	$ 12,333	2010	Oregon Department of Environmental Quality, 2010, Cost Estimate to Restore Riparian Forest Buffers and Improve Stream Habitat in the Willamette Basin, Oregon. Page 20
6" to 12" Rip Rap	$ 45.72	CY	$ 45.00	2012	Professional Engineering Experience
Gravel Borrow	$ 30.48	CY	$ 30.00	2012	Professional Engineering Experience
Seeding	$ 2.03	SY	$ 2.00	2012	Professional Engineering Experience
Earth Excavation	$ 7.62	CY	$ 7.50	2012	Professional Engineering Experience

Inflation Rates Table

Inflation from	Inflation to	Percent
2006	2013	16.13%
2010	2013	6.27%
2011	2013	4.57%
2012	2013	1.6%