

Attachment B

Maps of Potential Green Infrastructure Retrofit Sites

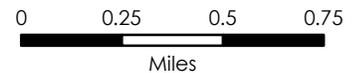
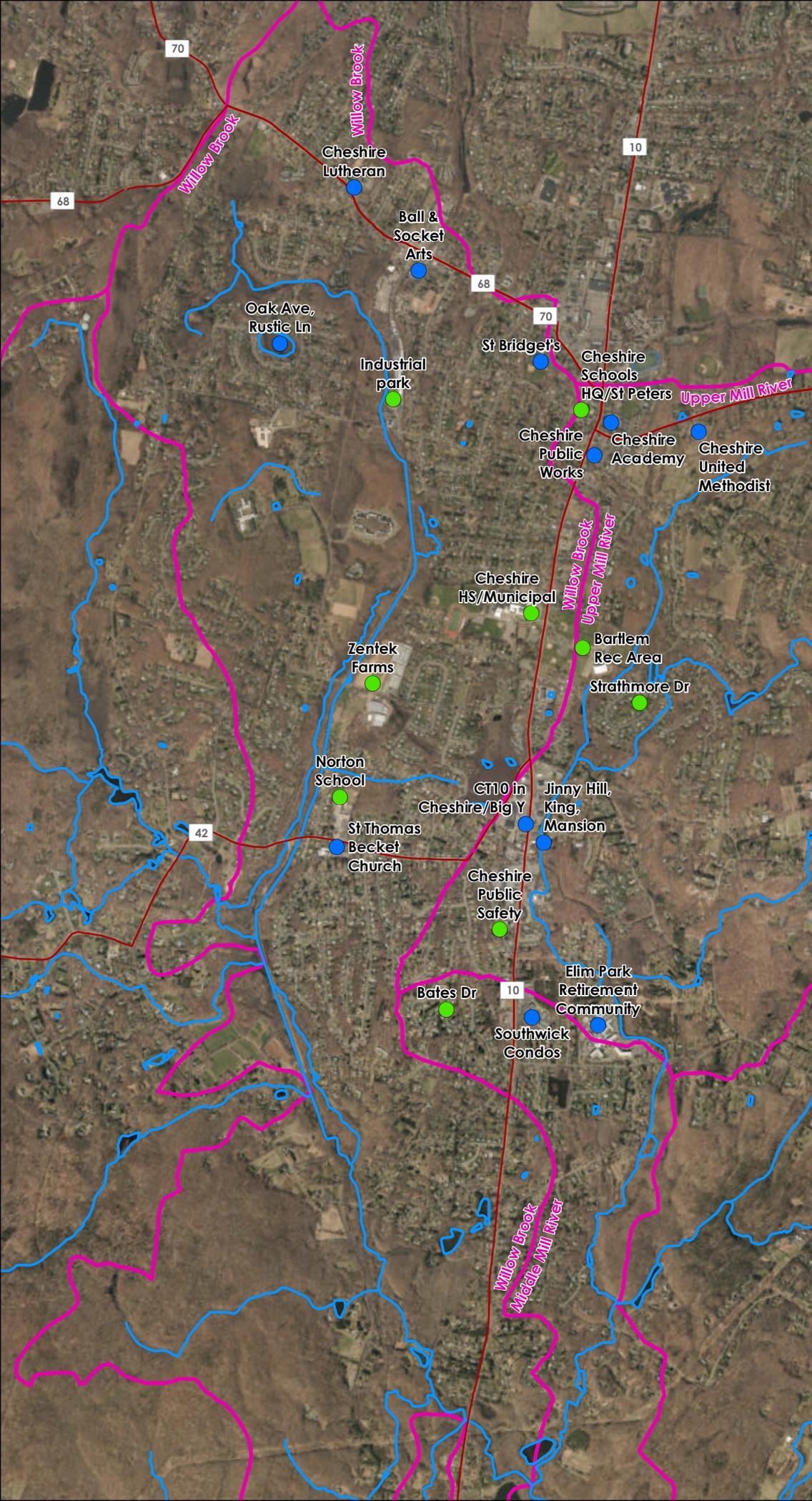
Mill River Watershed Based Plan

LID/Green Infrastructure Assessment

Upper Watershed

Potential Sites

- Higher Priority
- Lower Priority
- Water Body
- Subwatersheds Boundary



Mill River Watershed Based Plan

LID/Green Infrastructure Assessment

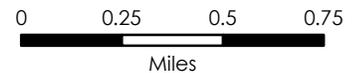
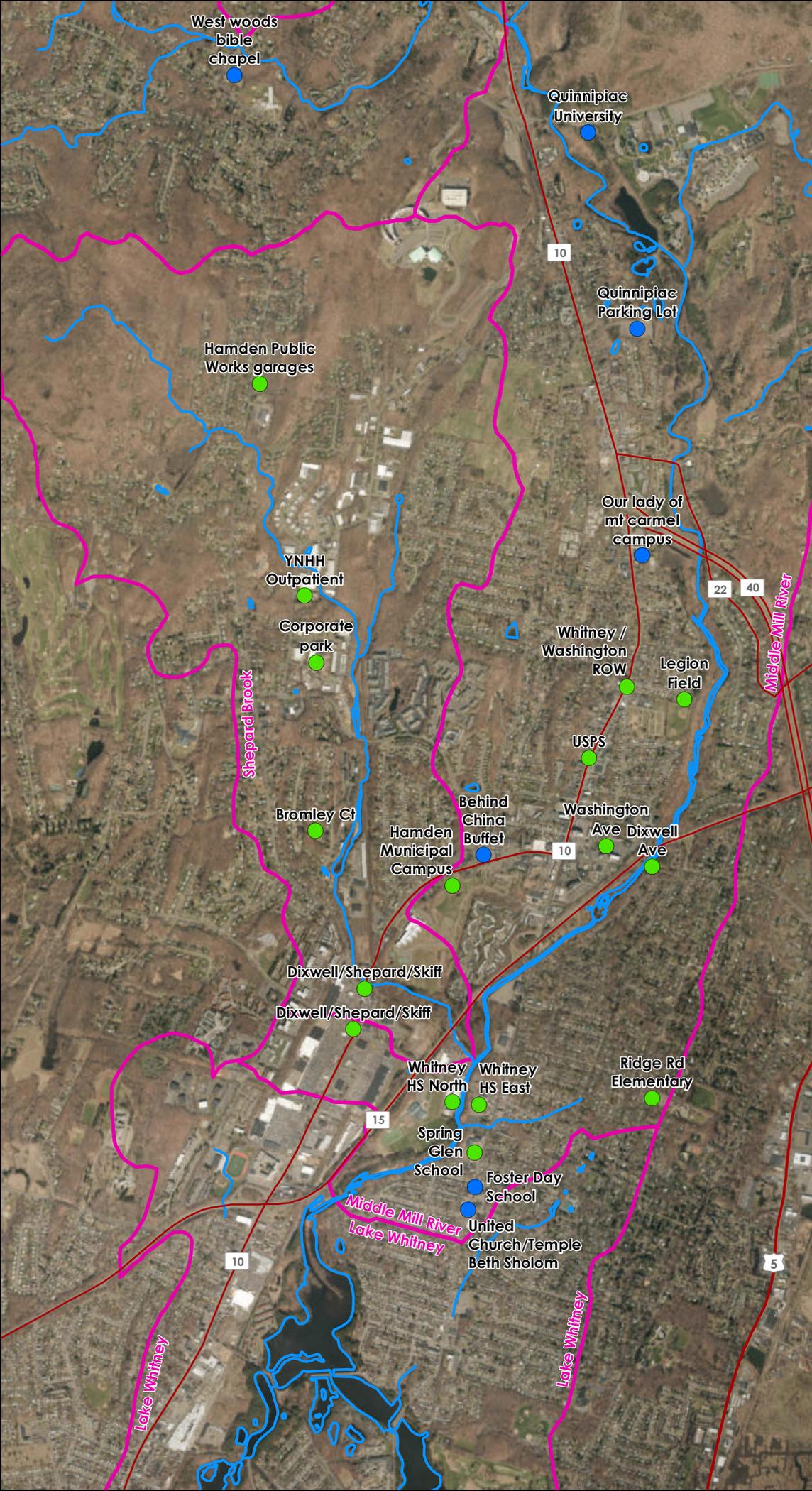
Middle Watershed

Potential Sites

- Higher Priority
- Lower Priority

— Water Body

Subwatersheds Boundary



Mill River Watershed Based Plan

LID/Green Infrastructure Assessment

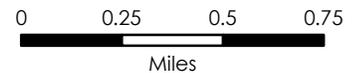
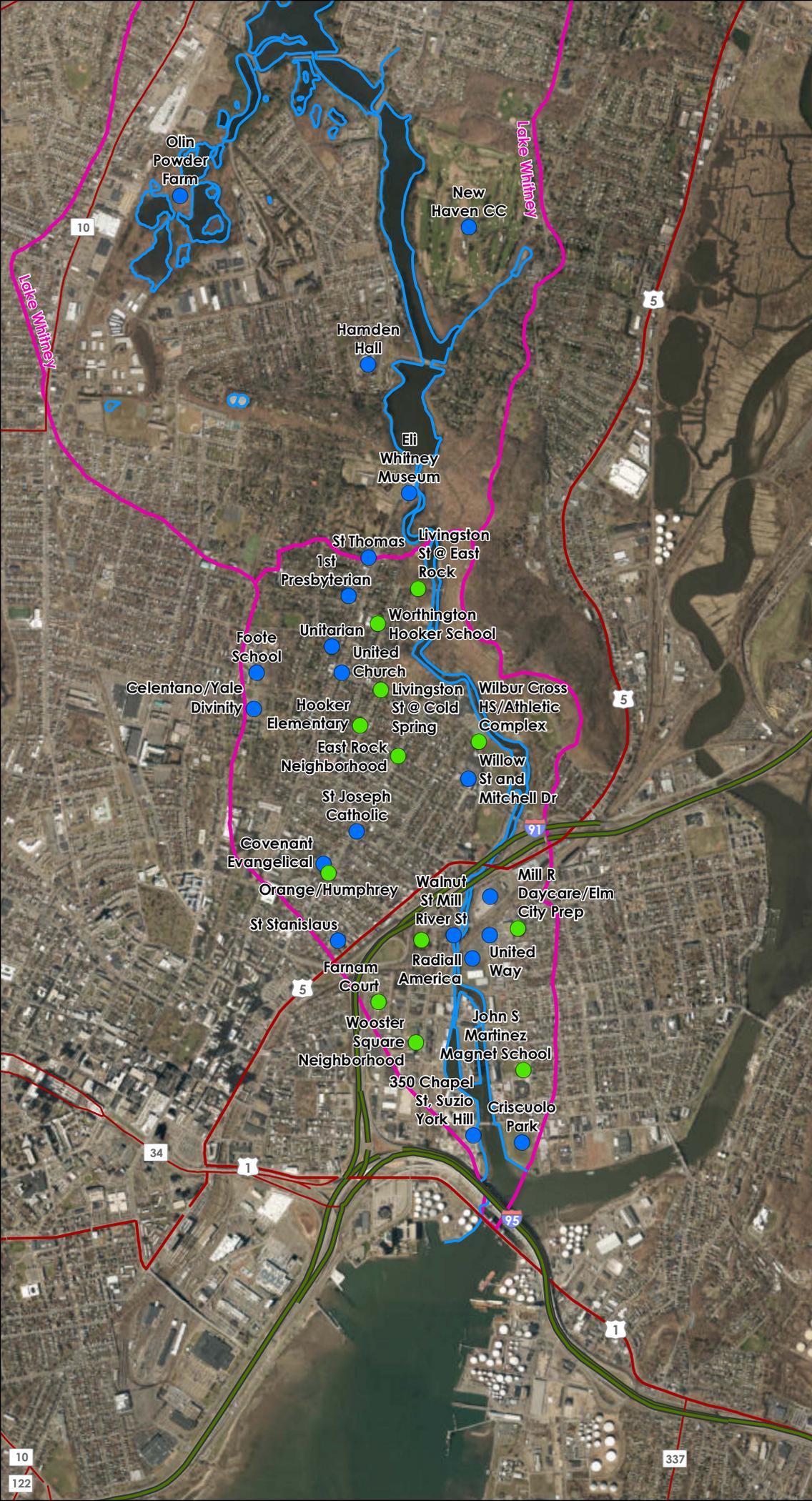
Lower Watershed

Potential Sites

- Higher Priority
- Lower Priority

— Water Body

Subwatersheds Boundary



Attachment C

Green Infrastructure Cost Estimates

Order of Magnitude Cost Range															
Location and Element	Construction				Planning and Design		Cost Range			Life Cycle					
	Unit Cost	Unit	Quantity	Cost (2018\$)	Allowance	Cost	Total Cost	-30%	50%	Lifespan (yrs)	Annual Cost over Lifespan	O&M (% Cost)	O&M (\$/yr)	Total Capitalized Cost/yr over lifespan	
Elm City College Preparatory Elementary															
1	Tree Box Filter	\$6,576.00	ea	1	\$6,576	30%	\$1,970	\$9,000	\$6,000	\$14,000	15	\$810	4%	\$30	\$840
2	Curbside Bioswales	\$15,000.00	ea	2	\$30,000	30%	\$9,000	\$39,000	\$27,000	\$59,000	15	\$3,510	4%	\$140	\$3,650
3	Subsurface Infiltration Chambers- adjacent to turf field	\$20.00	cf of runoff treated	4,150	\$83,000	30%	\$24,900	\$108,000	\$76,000	\$162,000	20	\$7,950	4%	\$320	\$8,270
Alt-3	Pervious Pavement - adjacent to turf field	\$3.07	sf	1,100	\$3,376	30%	\$1,010	\$5,000	\$4,000	\$8,000	20	\$370	4%	\$10	\$380
4	Pervious Pavement - parking stalls parallel to James Street	\$3.07	sf	2,500.00	\$7,672	30%	\$2,300	\$10,000	\$7,000	\$15,000	20	\$740	4%	\$30	\$770
5	Management of Dumpster Area	\$600.00	ea	1	\$600	30%	\$180	\$1,000	\$1,000	\$2,000	15	\$90	4%	\$0	\$90
Total							\$167,000	\$117,000	\$252,000						
James Street															
1	Tree Box Filters	\$6,576.00	ea	1	\$6,576	30%	\$1,970	\$9,000	\$6,000	\$14,000	15	\$810	4%	\$30	\$840
2	Bump-outs	\$15,000.00	ea	6	\$90,000	30%	\$27,000	\$117,000	\$82,000	\$176,000	15	\$10,520	4%	\$420	\$10,940
2	Curbside Bioswales	\$15,000.00	ea	7	\$105,000	30%	\$31,500	\$137,000	\$96,000	\$206,000	15	\$12,320	4%	\$490	\$12,810
Total							\$263,000	\$184,000	\$396,000						
Mill River Trail, Haven and Exchange Street Green Infrastructure															
1	Bioretention Areas and Trail Improvements	\$230,500.00	ea	1	\$230,500	30%	\$69,150	\$300,000	\$210,000	\$450,000	15	\$26,980	4%	\$1,080	\$28,060
Total							\$300,000	\$210,000	\$450,000						
Wilbur Cross High School															
1	Bioretention Areas	\$35.62	sf	1,700	\$60,554	30%	\$18,170	\$79,000	\$55,000	\$119,000	15	\$7,110	4%	\$280	\$7,390
2	Subsurface Infiltration Chambers	\$20.00	cf of runoff treated	3,400	\$68,000	30%	\$20,400	\$89,000	\$62,000	\$134,000	20	\$6,550	4%	\$260	\$6,810
Total							\$168,000	\$117,000	\$253,000						
Livingston Street at East Rock Road															
1	Vegetated Water Quality Swale	\$10.96	sf	4,250	\$46,580	30%	\$13,970	\$61,000	\$43,000	\$92,000	16	\$5,240	4%	\$210	\$5,450
2	Bioretention Areas	\$35.62	sf	550	\$19,591	30%	\$5,880	\$26,000	\$18,000	\$39,000	15	\$2,340	4%	\$90	\$2,430
3	Trail Enhancement and boardwalk/bridge	\$3,500.00	ea	1	\$3,500	30%	\$1,050	\$5,000	\$4,000	\$8,000	15	\$450	4%	\$20	\$470
Total							\$92,000	\$65,000	\$139,000						
YNHH Outpatient Services															
1	Pervious Pavement	\$3.07	sf	5,000	\$15,344	30%	\$4,600	\$20,000	\$14,000	\$30,000	20	\$1,470	4%	\$60	\$1,530
2	Front Lawn Bioretention Area	\$35.62	sf	200	\$7,124	30%	\$2,140	\$10,000	\$7,000	\$15,000	15	\$900	4%	\$40	\$940
3	Main Lawn Bioretention Areas	\$35.62	sf	600	\$21,372	30%	\$6,410	\$28,000	\$20,000	\$42,000	15	\$2,520	4%	\$100	\$2,620

Order of Magnitude Cost Range															
Location and Element	Construction				Planning and Design		Cost Range			Life Cycle					
	Unit Cost	Unit	Quantity	Cost (2018\$)	Allowance	Cost	Total Cost	-30%	50%	Lifespan (yrs)	Annual Cost over Lifespan	O&M (% Cost)	O&M (\$/yr)	Total Capitalized Cost/yr over lifespan	
Total							\$58,000	\$41,000	\$87,000						
Whitney High School North/West															
1	Pervious Pavement	\$3.07	sf	14,500	\$44,498	30%	\$13,350	\$58,000	\$41,000	\$87,000	20	\$4,270	4%	\$170	\$4,440
2	Subsurface infiltration--behind Staff Development Building	\$20.00	cf of runoff treated	1,800	\$36,000	30%	\$10,800	\$47,000	\$33,000	\$71,000	20	\$3,460	4%	\$140	
3	Bioretention Area	\$35.62	sf	800	\$28,496	30%	\$8,550	\$38,000	\$27,000	\$57,000	15	\$3,420	4%	\$140	\$3,560
Total							\$143,000	\$101,000	\$215,000						
Counter Weight Brewery, Spring Glen Nursery, and Raccio Park Road															
1	Rain Garden Trio- within parking area	\$35.62	sf	325	\$11,577	30%	\$3,470	\$16,000	\$11,000	\$24,000	15	\$1,440	4%	\$60	\$1,500
2	Bioretention Area/ Rain Garden-Raccio Park Road	\$35.62	sf	200	\$7,124	30%	\$2,140	\$10,000	\$7,000	\$15,000	15	\$900	4%	\$40	
3	Pervious Pavement	\$3.07	sf	2,000	\$6,138	30%	\$1,840	\$8,000	\$6,000	\$12,000	20	\$590	4%	\$20	\$610
Add-on	Additional Pervious Pavement- front lot	\$3.07	sf	7,500	\$23,016	30%	\$6,900	\$30,000	\$21,000	\$45,000	20	\$2,210	4%	\$90	\$2,300
Total							\$34,000	\$24,000	\$51,000						
Bartlem Recreation Area															
1	Linear Bioretention	\$35.62	sf	300	\$10,686	30%	\$3,210	\$14,000	\$10,000	\$21,000	15	\$1,260	4%	\$50	\$1,310
2	Vegetated Water Quality Swale	\$10.96	sf	2,500	\$27,400	30%	\$8,220	\$36,000	\$25,000	\$54,000	15	\$3,240	4%	\$130	\$3,370
3	Pervious Pavement	\$3.07	sf	15,000	\$46,032	30%	\$13,810	\$60,000	\$42,000	\$90,000	20	\$4,410	4%	\$180	
4	Bioretention Area/Raingarden	\$35.62	sf	300	\$10,686	30%	\$3,210	\$14,000	\$10,000	\$21,000	15	\$1,260	4%	\$50	\$1,310
Total							\$124,000	\$87,000	\$186,000						
Strathmore Drive															
1	Bioretention Area	\$35.62	sf	500.00	\$17,810	30%	\$5,340	\$24,000	\$17,000	\$36,000	15	\$2,160	4%	\$90	\$2,250
Total							\$24,000	\$17,000	\$36,000						
Total							\$1,373,000	\$963,000	\$2,065,000						

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 screening-level evaluations of site characteristics. Construction costs could vary significantly.

Unit Costs Table

Element	2018 Adjusted Cost	Unit	Cost	YEAR	Source
Green Infrastructure Elements					
New Haven Curbside Bioswale	\$ 15,000.00	ea			Actual construction cost provided by CFE for the Edgewood School bioswale construction (2014) - \$15,000 for contractor plus \$5,000 of in-kind services provided by City of New Haven. Recent bids for West River Bioswales were approximately \$15,000 per bioswale for up to 92 bioswales.
Large Bioretention Retrofit	\$ 13.10	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)	\$ 35.62	sf	\$ 32.50	2012	District of Columbia Water and Sewer Authority, George S. Hawkins, General Manager, Green Infrastructure Summit 2012, February 29, 2012.
Rain Garden	\$ 7.98	sf	\$ 7.28	2012	Woodard & Curran - Route 1 Falmouth Commercial District Stormwater Management, 2012
Water Quality Swale	\$ 10.96	sf	\$ 10.00	2012	District of Columbia Water and Sewer Authority, George S. Hawkins, General Manager, Green Infrastructure Summit 2012, February 29, 2012.
Porous Asphalt	\$ 3.07	sf	\$ 2.80	2012	UNH Stormwater Center 2012 Biennial Report, Page 12
Permeable Pavers	\$ 10.96	sf	\$ 10.00	2012	Center for Watershed Protection Urban Subwatershed Retrofit Manual 3 (2007), cost adjusted, Page E-5
Reinforced Gravel Parking	\$ 5.48	sf	\$ 5.07	2013	http://www.boddingtonsonline.com/products/grass-ground-reinforcement/grass-reinforcement-protection/bodpave-85-permeable-gravel-pavers.php ; Added \$2/sf for installation
Subsurface Infiltration	\$ 20.00	cf of runoff treated	\$ 20.00	2018	Fuss & O'Neill, City of Pawtucket Grant Application, 2018.
Green Roof	\$ 25.21	sf	\$ 23.00	2012	District of Columbia Water and Sewer Authority, George S. Hawkins, General Manager, Green Infrastructure Summit 2012, February 29, 2012.
Blue Roof	\$ 5.48	sf	\$ 5.00	2012	NYC Department of Environmental Protection (2012), Rooftop Detention: A Low-Cost Alternative for Complying with New York City's Stormwater Detention Requirements and Reducing Urban Runoff.
Subsurface Gravel Wetland	\$ 23.93	cf of runoff treated	\$ 21.83	2012	Woodard & Curran - Route 1 Falmouth Commercial District Stormwater Management, 2012
Pond Retrofit	\$ 13,852.80	impervious acre of runoff treated	\$11,100.00	2006	Center for Watershed Protection Urban Subwatershed Retrofit Manual 3 (2007), cost adjusted, page E-2
French Drain/Infiltration Trench	\$ 19.97	lf	\$ 16.00	2006	Center for Watershed Protection Urban Subwatershed Retrofit Manual 3 (2007), cost adjusted, page E-11
Tree Box	\$ 6,576.00	ea	\$ 6,000.00	2012	UNH Stormwater Center 2012 Biennial Report, adjusted based on professional judgement, inflation, and materials cost.
Constructed Wetland	\$ 5.08	sf	\$ 4.07	2006	Center for Watershed Protection Urban Subwatershed Retrofit Manual 3 (2007), cost adjusted, page E-11
Restoration Elements					
Riparian Buffer Restoration	\$ 12,166.62	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.
Stream Channel Restoration	\$ 14,232.28	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.
Remove Invasive Species	\$ 3,692.80	acre	\$ 3,200	2010	Professional Engineering Experience
Tree Planting	\$ 500.00	ea			Street tree cost
Construction Elements					
6" to 12" Rip Rap	\$ 49.32	CY	\$ 45.00	2012	Professional Engineering Experience
Outlet Structure	\$ 4,500	ea	\$ 4,500	2013	Professional Engineering Experience
Manhole	\$ 2,500	ea	\$ 2,500	2013	Professional Engineering Experience
Dam Removal	\$ 19,848.80	ea	\$ 17,200	2010	Selle, Andy (2010). Dam Removal – A Primer, Presentation; \$17,200 is median for dams 1-3 feet high.
Educational Signage	\$ 1,200	ea	\$ 1,200	2013	Professional Engineering Experience

Inflation Rates Table

Inflation from	Inflation to	Percent
2006	2018	24.80%
2010	2018	15.40%
2011	2018	11.80%
2012	2018	9.6%
2013	2018	8.0%

<http://www.usinflationcalculator.com/>

Attachment D

Other Green Infrastructure Retrofit Opportunities in the Mill River Watershed

Mill River Watershed – Other Green Infrastructure Opportunities

Site Location	Municipality	Existing Conditions	Recommendation	Photo
Cheshire HS	Cheshire	Large amount of impervious cover, multiple parking areas. Internal roof drainage from buildings.	Disconnect roof downspouts. Potential for infiltration or bioretention using existing landscaped areas in front lawn, just west of entrance, and/or under fire lane by gym. Replace impervious parking lots with pervious pavers. Low-lying area behind operations/maintenance building could also receive water.	
Cheshire Public Works/Town Hall	Cheshire	Large parking lot, drains via catch basins. Catch basin in NE corner of parking lot was observed to have moderate flow, despite no rain in past 24h. Dumpsters without secondary containment adjacent were located adjacent to another catch basin.	Potential for subsurface infiltration under NE corner at catch basin.	
Route 10 Corridor	Cheshire	Large amount of impervious cover, multiple parking areas many of which back up to the Mill River with little or no Riparian Buffer	Decrease impervious cover throughout Route 10 Corridor.	

Mill River Watershed – Other Green Infrastructure Opportunities

Site Location	Municipality	Existing Conditions	Recommendation	Photo
Quinnipiac University - Albert Schweitzer Institute	Hamden	Paved parking lots with no storm drains next to Mill River	Install educational rain garden to capture runoff from the front parking area.	
Quinnipiac University – Bobcat way parking areas	Hamden	Extensive parking areas with curbed planted islands	Potential for bioretention in existing landscaped area with catch basin adjacent to each island	
Alice Peck School	Hamden	Roof leaders and parking lot drain to paved open channel. Renovations to the school are expected during 2019.	Potential for bioretention and swale between parking lot and baseball field.	

Mill River Watershed – Other Green Infrastructure Opportunities

Site Location	Municipality	Existing Conditions	Recommendation	Photo
Hamden Public Works	Hamden	Large parking lot drains to low point on south side of lot. Discharges to eroded channel into wet, wooded area south of site. No curbing or catch basins.	Bioretention or created wetland at south side of parking lot. Replace parking lot with pervious pavers.	
Whitney Washington ROW	Hamden	Bituminous island at intersection.	Potential to install bioretention cell or infiltration practice and/or remove impervious cover.	
USPS Whitney Ave	Hamden	Existing catch basins full of sediment. Roof leaders buried, discharge to catch basin on property.	Disconnect roof downspout. Potential for subsurface infiltration in parking lanes, under pervious pavement. Bioswale or linear bioretention between parking lot and road.	
Washington Ave between Lincoln and Harding	Hamden	Wide ROW, no curb, sediment collecting at grass edge. Onstreet parking.	Linear bioretention or bioswales along west side of street. Bioswales where practicable elsewhere on Washington Ave. Replace parking lanes on either side of street with pervious pavement.	

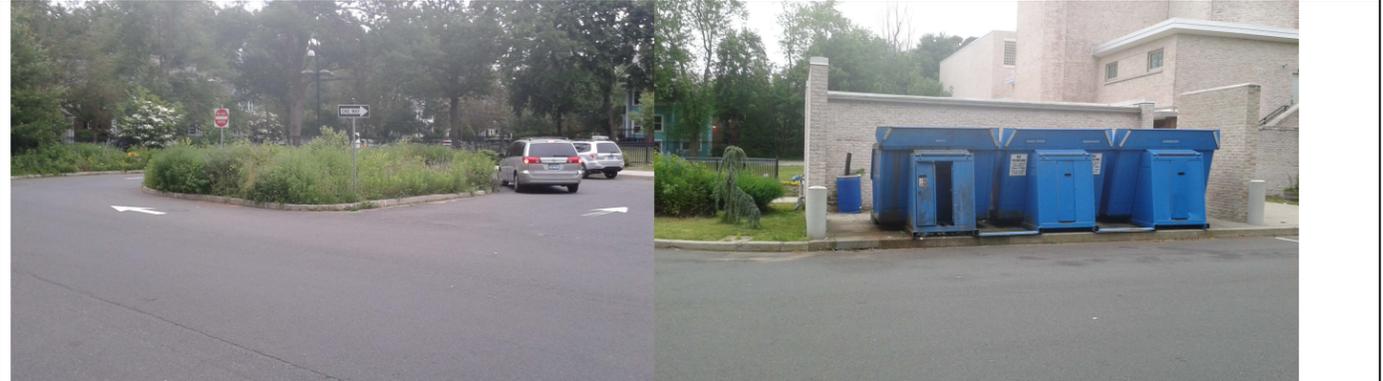
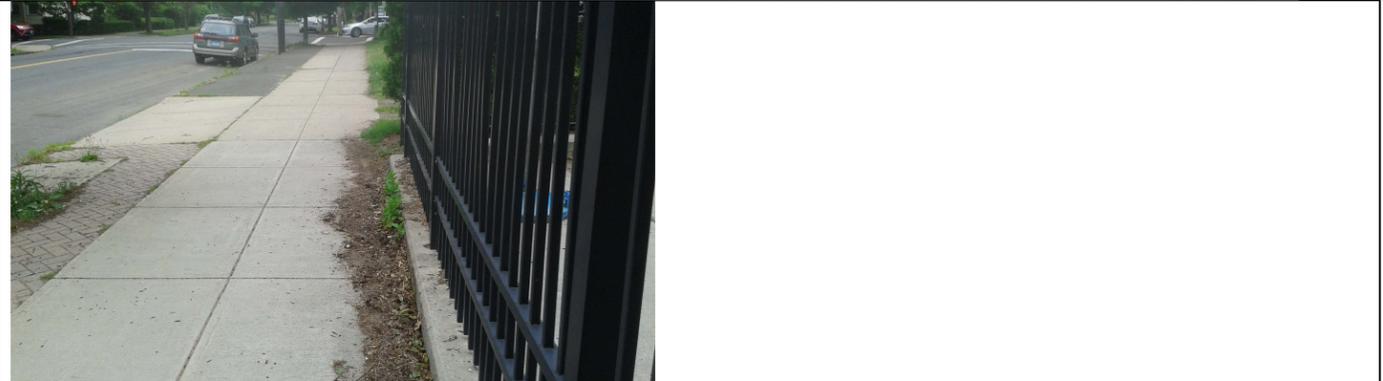
Mill River Watershed – Other Green Infrastructure Opportunities

Site Location	Municipality	Existing Conditions	Recommendation	Photo
Hamden Municipal Campus	Hamden	Large parking lots at Hamden Senior Center, Library, Middle School, and Town Hall.	Develop a Municipal Campus Stormwater Masterplan.	
Dixwell Ave./ Shepard Ave./ Skiff Street	Hamden	Busy intersection near many large parking lots and commercial center.	Potential for bioretention or infiltration in ROW island and linear practices in ROW. Paved ROW could, at minimum, be replaced with pervious cover.	
Ridge Road Elementary	Hamden	Cracked pavement in parking lot, may be due for repaving.	Regrade parking lot, remove western curb and install bioretention or infiltration practice. Potential to replace parking lot with pervious pavers.	
Spring Glen School	Hamden	Medium sized parking lot, recent pavement, trees in median.	Potential for bioretention in existing landscaped area with catchbasin adjacent to lower play area. Rain garden at SW corner of site.	

Mill River Watershed – Other Green Infrastructure Opportunities

Site Location	Municipality	Existing Conditions	Recommendation	Photo
Town Center Park	Hamden	Town Park that receives runoff from 88 acres or surrounding urban land use (commercial and residential). Impervious cover is estimated to be 21%.	<p>Installation of best management practices (BMPs) that slow, treat, capture, and filter the stormwater before it reaches the Pardee Brook diversion channel and Shepard Brook. The designs consist of reinforcing the existing plunge pool with a boulder overflow weir; installing a sediment filter riverbed, a stormwater treatment pond, constructed wetland and rain garden; and restoring the meadow area to create an emergent marsh. This series of engineered but natural stormwater management practices will reduce pollutant loading and erosion entering Pardee Brook</p> <p>**High Priority Project</p>	
RWA Water Center	Hamden	Hard packed access road with downspout discharging to access road	Install Rain barrel to capture roof runoff. Potential for demonstration bioretention.	
Eli Whitney Museum	Hamden	Hard pack and paved parking area with catch basins discharging directly to river; curbed island and planters in the center of parking lot	Potential to retrofit curbing and islands in the center of the parking lot to be used for bioretention. Potential to install bioswales in grass areas along the paved driveway. Potential to install rain barrels to capture water from existing building and reuse onsite.	

Mill River Watershed – Other Green Infrastructure Opportunities

Site Location	Municipality	Existing Conditions	Recommendation	Photo
Hooker Middle School	New Haven	Church converted to school in 2009. Island in turnaround. Catch basins in parking lot, including beneath dumpsters. Former PTA constructed native habitat, but now is not maintained (invasives present). School has signage about native habitat and outdoor classroom.	Potential for green roof above main entrance, bioretention in island and at lower elevation on property in existing, unmaintained habitat garden. Recommend native plantings in bioretention. Rain garden by eastern gate. Secondary containment around dumpsters.	
Hooker Elementary School	New Haven	Moderately old street/sidewalk, possibly separated sewer/past CSO. Buried roof leaders to catchbasins.	Linear bioretention to subsurface infiltration along Canner, east of Livingston. Replace paved ROW area on Livingston, south of the school, with bioretention; connect to low points of playground via trench drain or replace with pervious pavers.	
Jocelyn Square Park	New Haven	Broken 6' wide sidewalk on north side of park. Drainage existing along Humphrey. Leaching catch basin in private parking lot across Humphrey, at 175 Humphrey St.	Bioswale in ROW between utility poles. Potential for subsurface storage/infiltration under paved park entrance.	
Humphrey Street and Mill River Street	New Haven	Large parking area comprised of sand, gravel and pavement, which slopes towards the Mill River. The stream bank is eroded with no riparian area.	Potential for living shoreline	

Mill River Watershed – Other Green Infrastructure Opportunities

Site Location	Municipality	Existing Conditions	Recommendation	Photo
Radiall America	New Haven	Large parking lot, buried roof leaders	Disconnect roof leaders, bioretention in existing landscaped areas.	
United Way	New Haven	Large parking area, landscaped islands.	Bioretention in islands.	
Haven Street	New Haven	Existing drainage along Haven Street captures private driveway.	Potential for bioretention to capture road runoff and stormwater from residential properties and to serve as connection to the Mill River Trail.	

Mill River Watershed – Other Green Infrastructure Opportunities

Site Location	Municipality	Existing Conditions	Recommendation	Photo
Fair P.A.C Housing	New Haven	Large parking lot and connected roof leaders	Potential for retention in the vegetated areas in the front and rear of the building	
St James Unity	New Haven	Buried roof leaders, underutilized parking area.	Disconnect roof leaders, potential for pervious pavement.	
Yale Divinity	New Haven	Buried roof leaders, potential evidence of gray water from building in catch basins along driveway between Divinity School buildings and adjacent conference center. Drainage system appears to drain east towards large landscaped area and potentially out to Whitney Ave. Possible existing infiltration basins at conference center.	Potential for curb cuts to bioretention, potential for subsurface infiltration, disconnect roof leaders.	
First Unitarian Church	New Haven	Buried roof leaders, compacted gravel. Paved play area sheet flow to parking lot.	Potential for subsurface infiltration.	
Orange/Edward Canner/Foster	New Haven	Cracking pavement. Possibly separated sewer/past CSO area. No Standing Anytime signs on all corners.	ROW bump-out bioretention or bioswale at intersection without removing on-street parking or infringing on bike lane. Potential for pervious pavers in parking/cycling lane.	

Mill River Watershed – Other Green Infrastructure Opportunities

Site Location	Municipality	Existing Conditions	Recommendation	Photo
James and River Street	New Haven	Curbed bump out with gutter	Potential to retrofit bump out for use as bioswale. Location next to Criscuolo park also offers potential for education and outreach.	
Criscuolo park	New Haven	Heavily used urban park and playing fields	Potential for riparian plantings and demonstration rain garden.	