Final Draft

Green Infrastructure Suitability Pilot Study

Prepared for

Greater New Haven Water Pollution Control Authority

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CH2MHILL®

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Contents

Acronyms and Abbreviations

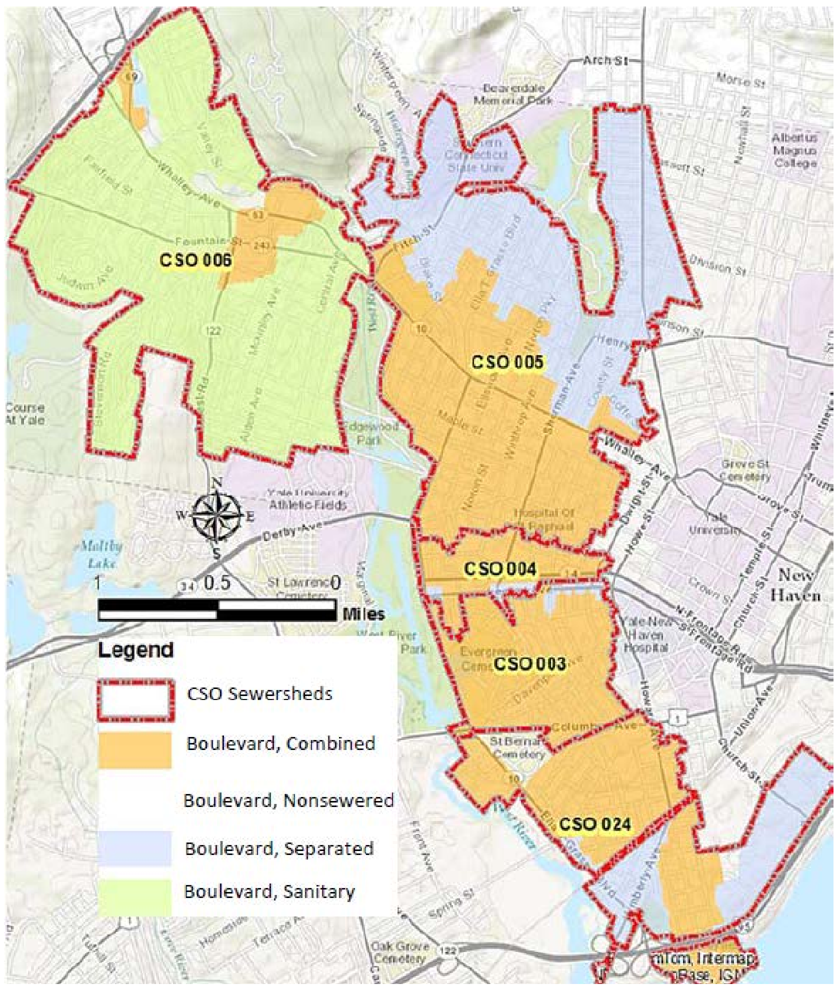
AACE	Association for the Advancement of Cost Engineering International
BTS	Boulevard Trunk Sewer
The City	New Haven, CT
CSO	combined sewer overflow
CWF	Clean Water Fund
DEEP	Connecticut Department of Energy & Environmental Protection
GI	green infrastructure
GIS	geographic information system
GNHWPCA	Greater New Haven Water Pollution Control Authority
LTCP	long-term control plan
MassDEP	Massachusetts Department of Environmental Protection
MG	million gallon(s)
mgd	million gallon(s) per day
NRCC	Northeast Regional Climate Center
O&M	operations and maintenance
PS	pump station
SSURGO	Soil Survey Geographic

SECTION 1
Introduction

1.1 Background

The Greater New Haven Water Pollution Control Authority (GNHWPCA or "the Authority") was assisted by CH2M HILL under the West River Combined Sewer Overflow (CSO) Abatement Study contract to analyze hydraulic conditions and evaluate potential control options for reducing CSOs along the West River. One of the tasks of this project was to describe planning level implementation opportunities for green infrastructure (GI). Since the state's environmental infrastructure assistance program (the Connecticut Clean Water Fund [CWF]) set aside funding to support the Authority's green demonstration for CSO abatement, the GI task was expanded to develop a pilot GI suitability study in CSO 003 and CSO 004 sewersheds. As an early planning effort, the main purpose of this task was to evaluate sites or parcels that were suitable to implement certain types of GI for CSO abatement by reducing the amount of stormwater runoff discharging into the combined sewer system.

FIGURE 1-1
Boulevard Trunk Sewer Sewershed



Three types of sewers comprise New Haven's system: sanitary sewers, separated sewers and combined sewers. In neighborhoods served by sanitary or separated sewers, there is a piping system to collect sanitary sewage and another to collect stormwater runoff. In neighborhoods served by combined sewers, a single pipe collects both sanitary sewage and stormwater runoff. During wet weather, large quantities of stormwater enter the combined sewer system. As a result, portions of the system may become overloaded, in which case CSO regulators divert high flows from the interceptor sewer to a CSO outfall where combined sewage overflows to nearby receiving waters in accordance with the Authority's National Pollutant Discharge Elimination (NPDES) Permit.

There are four permitted CSO outfalls along the West River: CSOs 006, 005, 004, and 003. Regulators along the Boulevard Trunk Sewer (BTS) control these CSO outfalls. During rainfall events, excess flow is diverted into the Truman Storage Tank where it is held until flow subsides. Excess flows may also discharge into New Haven Harbor if they exceed the capacity of the Boulevard Pump Station. If the flows continue to rise, the regulators along the West River will discharge CSOs through 003, 004, 005 and/or 006. Since their flow monitoring program began in June 2012, the Authority has installed several meters in the BTS and along the CSO outfalls to monitor flows. Based on the flow data, the Authority identified some potential improvements that can be made to the sewer system and CSO regulators that will reduce the number of CSOs to the West River during rain events.

1.2 Green Infrastructure for CSO Abatement

Green infrastructure (GI) is a viable option for CSO abatement by preventing stormwater runoff entering the combined sewer system. Many other combined sewer communities, including Onondaga County, NY, Milwaukee Metropolitan Sewerage District, WI, and the Philadelphia Water Department, PA, have demonstrated that GI can be an effective tool for CSO abatement in combination with gray infrastructure projects. GI refers to a decentralized network of site-specific stormwater management techniques. GI techniques are implemented to reduce the volume of stormwater runoff entering the sewer system while also restoring the natural hydrologic cycle. In addition to gray infrastructure, which is the traditional network of costly, large-scale conveyance and treatment systems necessary to control CSOs during significant rain events, green infrastructure manages stormwater through a variety of small, cost-effective landscape features located onsite for less intense rain events.

GI is particularly important in urban areas with combined sewers where, during wet weather events, CSOs result in untreated combined sewage being discharged directly into waterbodies. As cities are increasingly required by legislation to reduce the frequency and volume of CSO events, greater emphasis is being placed on implementing alternative ways of managing urban stormwater runoff using GI techniques.

The main drivers for using GI as an approach to wet weather management are its overall cost-effectiveness compared to conventional gray infrastructure and its ability to provide sustainable and environmentally friendly means of controlling wet weather discharges, making GI a viable option. In contrast to gray infrastructure, a green infrastructure approach often has a higher return on investment and offers the following benefits:

- Environmental: recharges and improves the quality of surface and ground waters, provides natural storm water management, improves energy efficiency, reduces urban heat island effect, and improves aquatic and wildlife habitat.
- Social: improves aesthetics and livability of urban communities, increases recreational opportunities, improves health through cleaner air and water, and fosters environmental education opportunities.
- Economic: reduces existing and potential future costs of gray infrastructure, increases property values and reduces energy consumption costs.

1.2.1 Green Infrastructure Technologies

GI technologies employ the following three processes in order to design a hydrologically functional site that mimics predevelopment conditions:

- Infiltration (allowing water to slowly sink into the soil)
- Evaporation/transpiration using native vegetation
- Rainwater capture and reuse (storing runoff to water plants, etc.).

Table 1-1 lists each of the GI technologies considered for implementation in this study.

TABLE 1-1
Green Infrastructure Technologies

GI Technique	Capital Cost	Maintenance
Downspout Disconnection	Low	Low
Rainwater Harvesting	Low/Medium	Medium
Bioretention Areas (Rain Gardens)	Medium	Medium

TABLE 1-1
Green Infrastructure Technologies

GI Technique	Capital Cost	Maintenance
Vegetated "Green" Roofs	High	Medium
Stormwater Planter Boxes	Low/Medium	Medium
Infiltration Practices (Basins, Trenches, Dry Wells)	Medium	Medium
Permeable Pavement with Infiltration	Medium	Medium
Bioswales	Low/Medium	Low/Medium
Tree Trenches/Urban Tree Canopy	Medium	Medium
Vegetated Curb Extensions	Low	Low/Medium
Land Conservation	Low	Low
Green Streets/Green Alleys	Medium	Medium/High
Green Parking	Medium	Medium

Various individual or combinations of GI technologies, as listed in Table 1-1, can be implemented on potential sites. GI implementation experiences from many municipalities suggest that it is most cost-effective to construct GI together with other public work (e.g., roadway repavement, streetscape, public open space landscaping, etc.) or private development projects.

Implementation can also be enhanced by emphasizing the GI in the regulatory review process for new or redevelopment projects, changing by-laws to allow implementation, and incentivizing local residents' GI efforts or other development/redevelopment projects to incorporate GI design that reduces wet weather flow contribution to the combined sewer system.

1.2.2 GI Design Requirements

Implementation of GI technologies is highly dependent on the site conditions including land use, soils, and depth to the groundwater table. In general, the study area has favorable site conditions for both infiltration and bioretention types of GI. The following are GI design requirements of site conditions:

- Infiltration Class GI will require the depth to the groundwater table to be greater than 6 feet as the *Massachusetts Stormwater Handbook* (MassDEP, 2008) recommends a minimum of 2 feet of separation between the bottom of GI and the groundwater table. The typical depth of infiltration GIs is greater than 4 feet. Also, sites with well-drained soil (Hydrologic Soil Group A or B) will result in a higher pollutant removal efficiency as well as a smaller GI footprint to treat the same size area.
- Porous pavement requires a site with a minimum infiltration rate of 0.17 inches per hour and a soil void space higher than 40 percent. The site cannot be a high speed traffic area. A typical design of porous pavement with a 4 foot porous layer (pavement and subsurface porous media) requires a depth to groundwater to be greater than 6 feet.
- Bioretention GI design requirements vary based on their specific types. Some require depth to groundwater to be greater than 6 feet (e.g., bioretention with 4 feet of soil media) while planter boxes can be placed above grade. Although well drained soil improves removal efficiency, it is generally not a restriction factor to this class of GIs.
- Rain barrels and cisterns provide irrigation benefits. They can store rooftop runoff and delay discharge to pervious areas for infiltration. They are a popular choice for buildings, particularly in residential areas, and many municipalities have provided rain barrels to homeowners for free or at discounted prices.

Combining site conditions discussed above produces 10 GI categories as listed in Table 1-2.

TABLE 1-2
Summary of GI Categories

GI Category #	Land use	Groundwater Depth	HSG Soil Type	Priority GI
1	Others	> 6 ft	A/B	Infiltration Class GIs
2			C/D/Unknown	Bioretention GIs
3		< 6 ft	A/B/C/D/Unknown	Bioretention GIs
4	Commercial, Industrial & Institutional	> 6 ft	A/B	Infiltration Class GIs
5			C/D/Unknown	Bioretention GIs
6		< 6 ft	A/B/C/D/Unknown	Bioretention GIs
7	Parking Lots	> 6 ft	A/B/Unknown	Porous Pavement
8	Residential	> 6 ft	A/B	Dry Well
9			C/D/Unknown	Bioretention GIs
10		< 6 ft	A/B/C/D/Unknown	Rain Barrel/Cistern

1.2.3 Selected Pilot Study Area

CSO sewersheds 003 and 004 were selected to investigate the potential GI opportunities to reduce runoff discharge into the combined sewer system because CSO outfalls 003 and 004 account for 85% of the annual CSO volume to the West River. Using the existing ArcGIS build-in tool, a procedure was developed to rank the sites or parcels for potential GI opportunities and prioritize these rankings for potential GI implementation by combining the likelihood of implementation and suitability results.

SECTION 2

Implementation Suitability Analysis

2.1 Overview

A geographic information system (GIS)-based screening analysis was performed within CSO sewersheds 003 and 004, a subset of the Boulevard Trunk Sewer sewershed in New Haven, to determine site suitability for GI. The analysis used a scoring and ranking process that quantitatively evaluated sites where GI is most applicable based on multiple criteria.

The site suitability screening process included the development of criteria and ranking of the criteria to identify areas within the City that may be suitable for implementation of GI for CSO reduction. Each criterion was broken down into ranked categories depending on the relative suitability of conditions within each criterion. In addition, the criteria were weighted against one another to determine their relative importance within the scoring process. The criteria were overlain on a 3-foot by 3-foot grid spanning the study area. Each grid cell was then evaluated individually, resulting in millions of composite cells throughout the City. Weighted average calculations were then performed based on parcel and street boundaries to obtain effective GI suitability ratings. Figure 2-1 illustrates the processes utilized to develop said GI suitability scores.

FIGURE 2-1
Development of GI Suitability Scores

2.2 Data for GI Suitability Analysis

The data used for the analysis included the following:

- The Connecticut Department of Energy & Environmental Protection (DEEP) data can be downloaded from the following link: http://www.ct.gov/deep/cwp/view.asp?a=2698&q=322898&deepNav_GID=1707

  Data layers used for the GI suitability analysis include:

  – Connecticut Parcels (for Protected Open Space Mapping) data set, containing property (land lot) boundaries, and database information from individual municipalities.

- GNHWPCA GIS database for the following:

  – Pavement type
  – Sewershed type

- USDA NRCS Web Soil Survey. http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx.

  Datasets used for the suitability analysis include:

  – Hydrologic soil groups using: http://soildatamart.nrcs.usda.gov
  – Groundwater depth from the Soil Survey Geographic (SSURGO) database

2.3 Ranking

The geospatial datasets described above were processed to raster datasets with 3-foot by 3-foot grid cell resolution. Each grid cell's value field was then given a rank for each criterion, ranging from one to five:

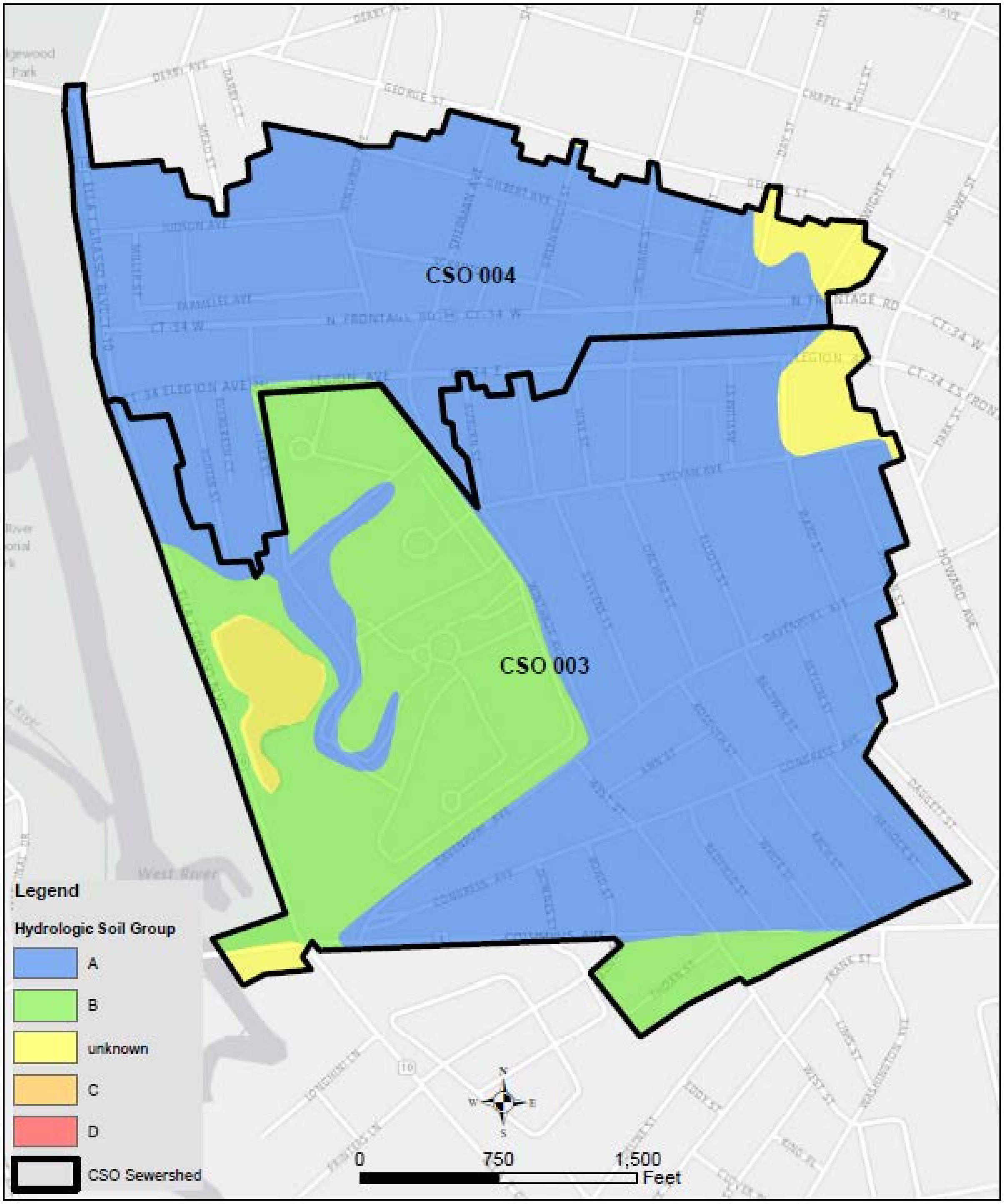
- 1 is the lowest score and represents the lowest suitability or runoff capture potential for GIs; this rank typically indicates a least favorable or not feasible physical condition.
- A score of 2 represents a site condition that should be examined on a case-by-case basis due to unfavorable conditions.
- A score of 3 represents a site condition that is not ideal but still has utilization potential; the likelihood of implementation is low.
- A score of 4 is given to a site condition that meets some GI design requirements; the likelihood of implementation is medium.
- 5 is the highest score and represents the highest site suitability for GIs. The site conditions meet most or all GI design requirements.

Table 2-1 summarizes the criteria and assigned ranks described above. The resulting ranked criteria are shown in Figures 2-2 to 2-6.

TABLE 2-1
Ranking Criteria for Site Conditions

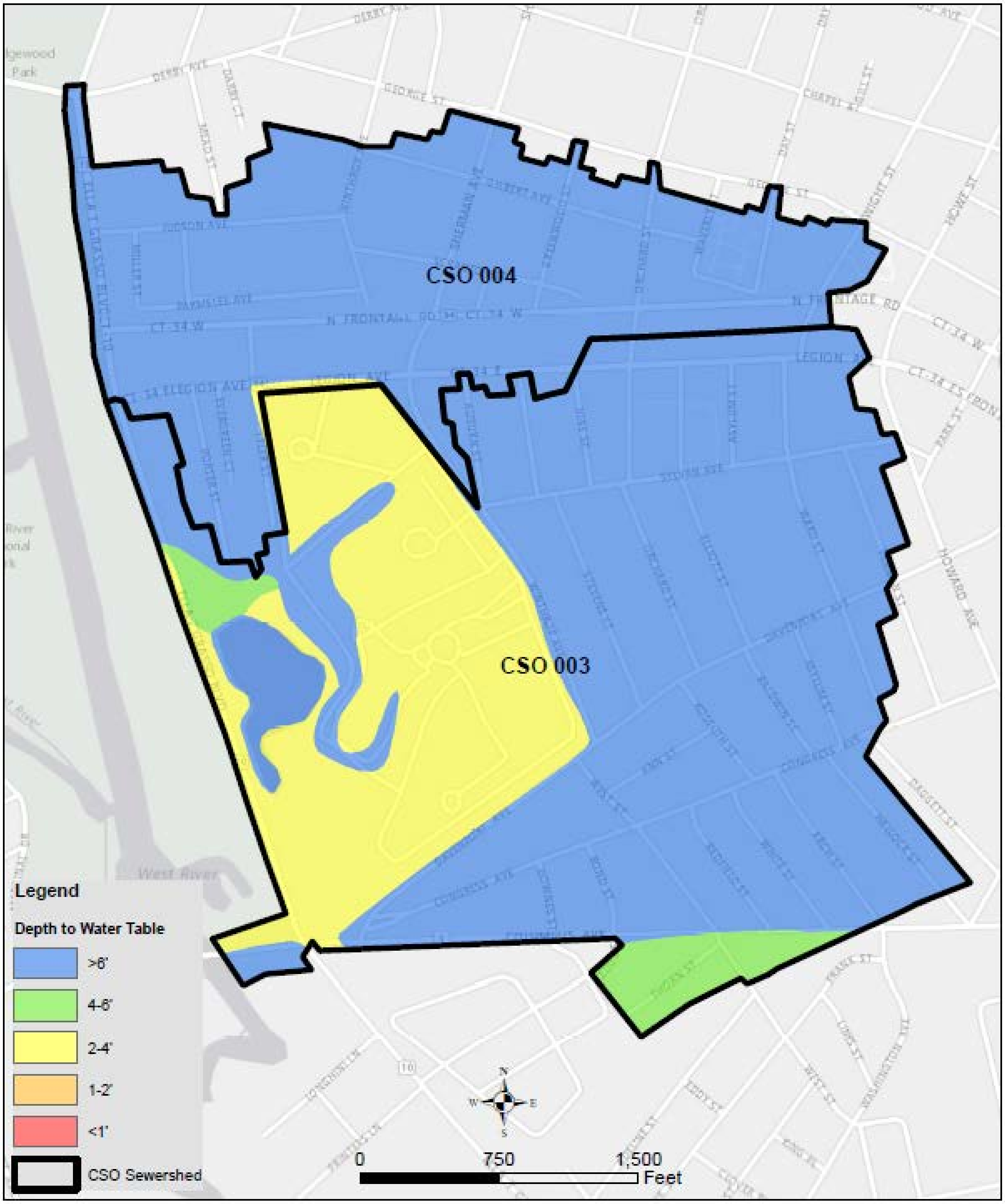
GI Implementation Suitability Criteria					
Ranking Score	1	2	3	4	5
Hydrologic Soil Group	D	C	not rated	B	A
Depth to Groundwater (feet)	< 1	1 - 2	2 - 4	4 - 6	> 6
Pavement Type	Driveway	Private Parking Lot	Non-paved/ other	Road	Public Parking Lot
Parcel	Residenial	-	Commercial/ Industrial	Exempt/ other	Public/Planned Development
Sewershed Type	Separated/non-sewered	-	Partially Separated	-	Combined

FIGURE 2-2
Hydrologic Soil Group Ranking



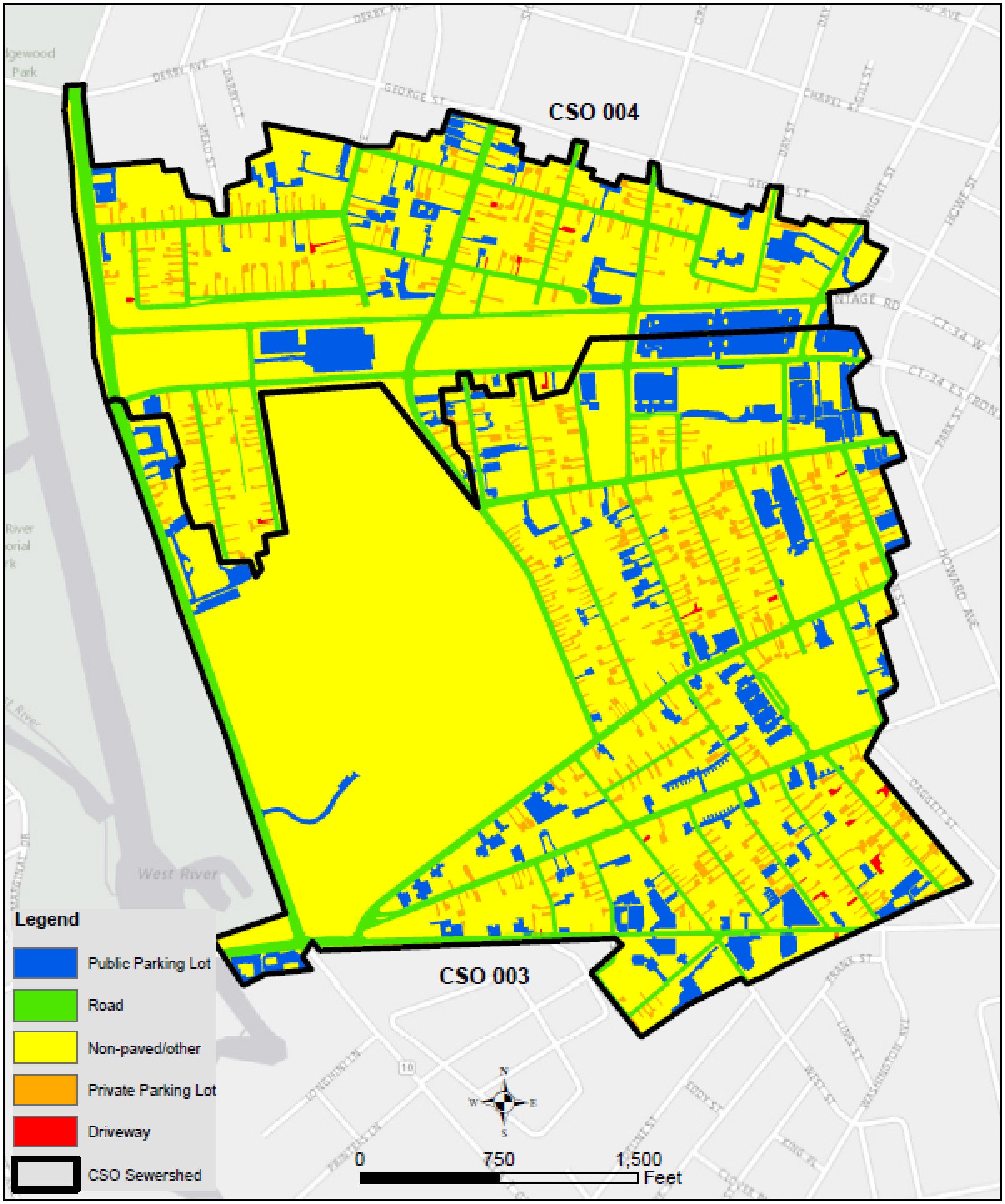
Hydrologic Soil Group. This criterion refers to soil percolation rates. Group A soils are ranked the highest for their ability to readily infiltrate runoff (saturated hydraulic conductivity > 1.42 in/hr). Group B soils have moderate infiltration potential when thoroughly wet (1.42 in/hr < saturated hydraulic conductivity > 0.57 in/hr). Groups C and D soils have poor infiltration potential and often result in more standing water; therefore, they are ranked lower.

FIGURE 2-3
Depth to Groundwater Ranking



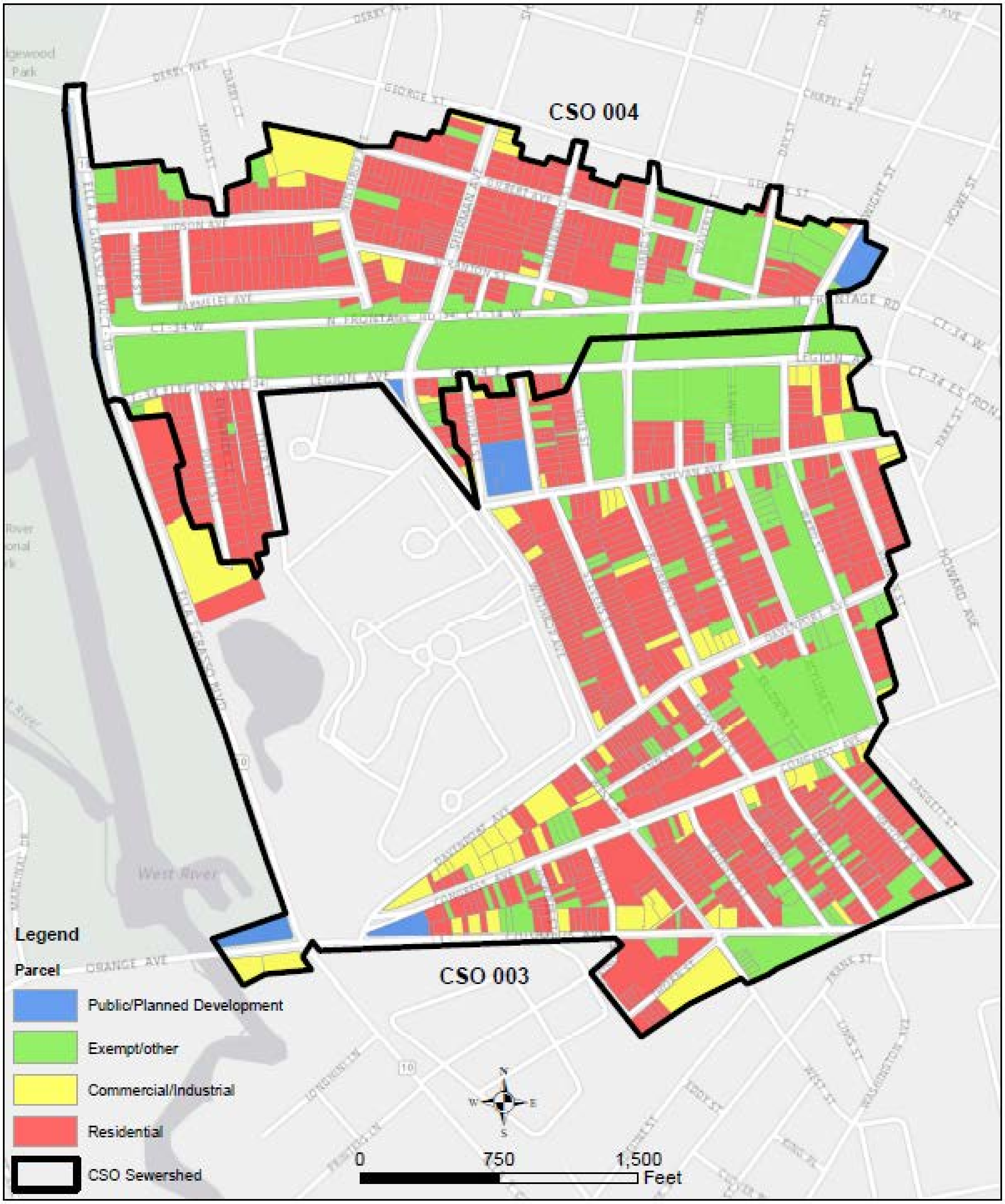
Depth to Groundwater. This criterion refers to the minimum depth from the ground surface to the highest elevation of the water table. Values greater than 6 feet have high feasibility, values between 4 and 6 feet have medium feasibility, and values from 2 to 4 feet have low feasibility. No other groundwater depths are present within this study area according to the Soil Survey Geographic (SSURGO) database.

FIGURE 2-4
Pavement Type Ranking



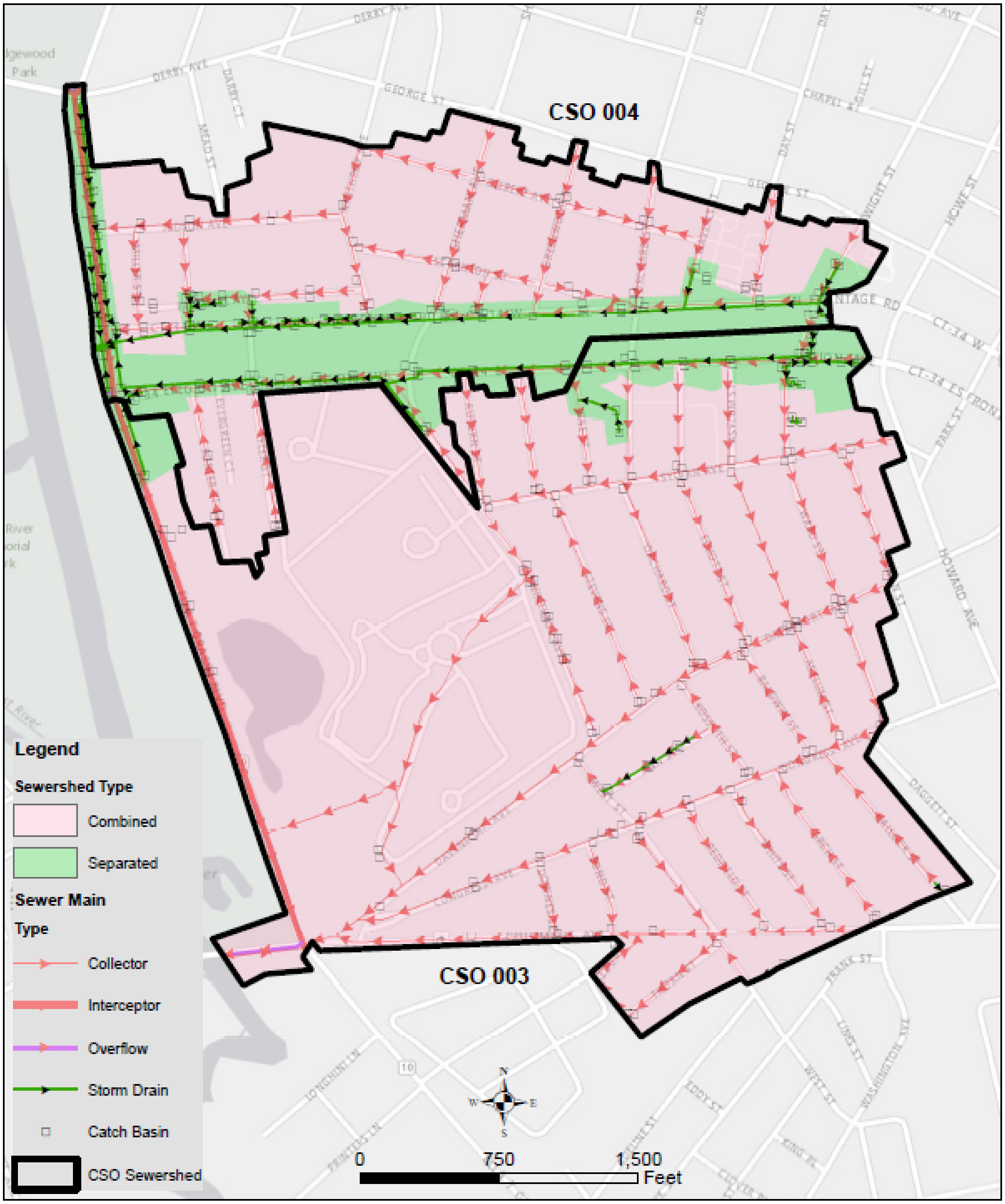
Pavement Type. This criterion refers to the functional usage type of pavement according to the Authority's database. Public parking lots depicted in blue are ranked the highest for their conversion potential to porous pavement. Removing impervious parking lots while providing additional storage and infiltration capacity would be a significant improvement. Roads depicted in green are also ranked high for their public domain and ability to construct infiltration trenches and green streets. Private parking lots and driveways have low priority, as they are small, numerous, and mainly residential.

FIGURE 2-5
Parcel Ranking



Parcels. This criterion refers to zoning and property usage. Public and planned development areas (depicted in blue) where future construction is already on the horizon are ideal candidate sites for incorporating GIs during the construction process; therefore, they are ranked the highest. Conversely, residential parcels are ranked the lowest to account for marginal runoff capture (due to small lot sizes) while likely encountering difficulties collaborating with a wide variety of property owners. Commercial or Industrial as well as exempt areas (e.g., open lots adjacent to buildings) are ranked in the middle of the spectrum.

FIGURE 2-6
Sewershed Type Ranking

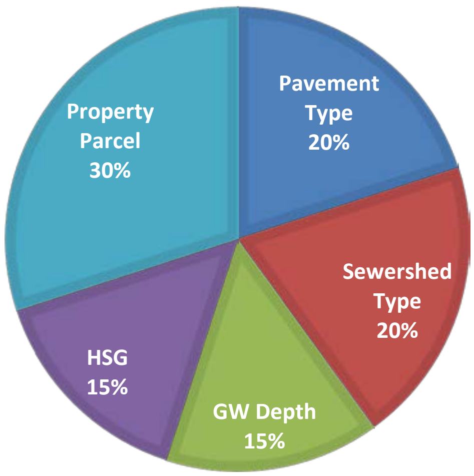


Sewershed Type. This criterion accounts for sewered areas that have already been separated. Since separate storm drains capture runoff to bypass the combined sewer system, adding GI in a separated area would not be beneficial. Therefore, combined areas are ranked high and separated areas are ranked low.

2.4 Weighting

The GI ranking raster datasets for the criteria were weighted against one another to determine the overall suitability for implementing GI technologies. Each criterion was considered for relative importance within the group to determine criteria weighting factors. Figure 2-7 shows the criteria weighting distribution.

FIGURE 2-7
Criteria Weighting Distribution
HSG = Hydrologic Soil Group; GW = Groundwater



Parcels were assigned the highest weight to account for implementation practicality and feasibility. Public parks and planned development areas where future construction is to occur anyway are ideal candidate sites for incorporating GIs during the construction process. Sewershed type is weighted highly to promote combined sewer areas. Pavement type is also highly weighted in order to highlight public parking lots where porous pavement could be constructed and roads where infiltration trenches and green streets would thrive. Hydrologic soil type and groundwater depth together comprise only 30 percent of the total weighting, as these two criteria have identical boundary divisions and similar spatial rankings. Soil and groundwater conditions are also less strictly evaluated to ensure maximum applicable implementation when these land use areas undergo development or redevelopment in the future.

2.5 Suitability Analysis Result

Due to the intricate spatial relationships among the various datasets and the high resolution raster calculations involved, highly ranked composite 3-foot by 3-foot grid cells are often interspersed among lower-scoring adjacent grid cells (and vice-versa). To visualize broader data trends and summarize overarching GI suitability results, it is useful to vectorize the composite raster grid data into weighted average parcels and street corridors.

The geospatial distribution of the resulting suitability for parcels and streets are presented in Figures 2-8 and 2-9, respectively. Blue parcels or street segments represent high suitability for implementing GI technologies while red parcels or streets are poor candidates for GI implementation. Cemeteries were assumed to be ineligible.

FIGURE 2-8

GI Suitability Categories for Parcels

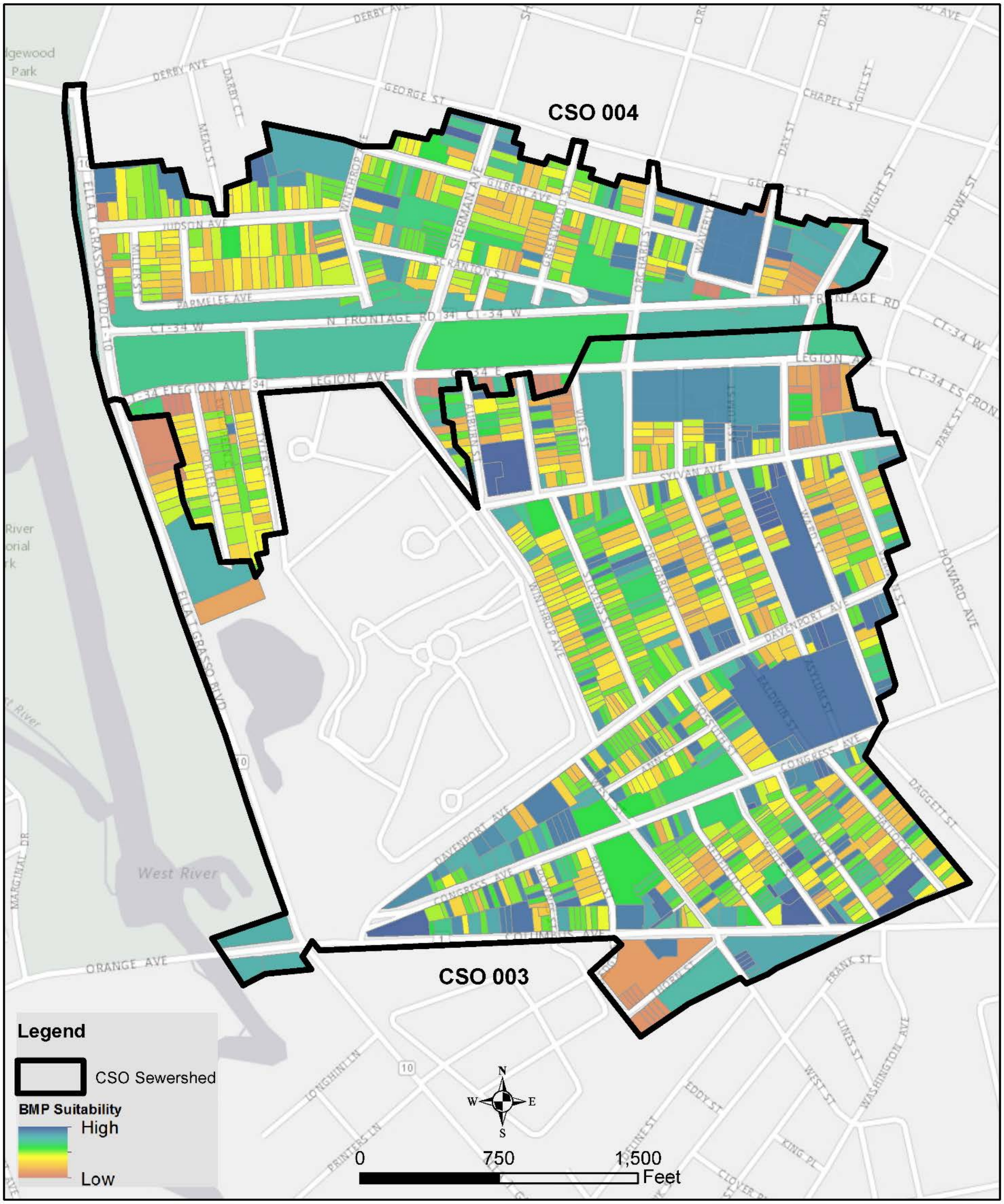
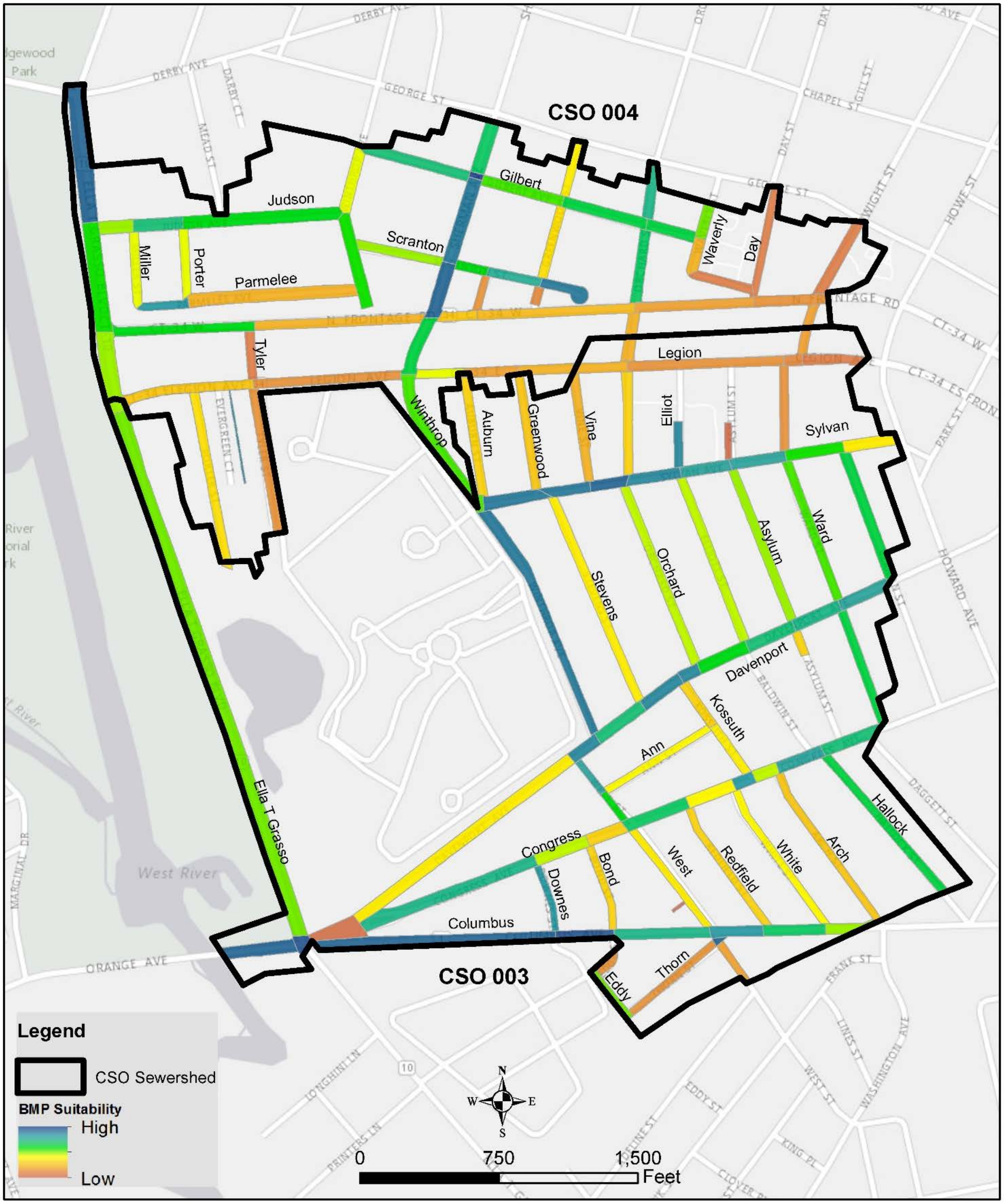


FIGURE 2-9
GI Suitability Categories for Streets



SECTION 3

Recommendations and Cost-Benefit Estimates

3.1 Recommendations for GI Demonstration Projects

The intent of this initial site suitability analysis is to serve as a guide for green infrastructure (GI) implementation at potential sites. Although it is important to maximize potential runoff reduction through GI implementation, it is critical to factor in the likelihood of implementation for a particular parcel or street segment. Experiences from many other municipalities (Milwaukee, Philadelphia, Kirkland, WA, Lancaster, PA, and Onondaga County, NY) demonstrate that implementation of GI programs is most cost-effective in cooperation with other ongoing municipalities' capital improvement projects or private development projects. Based on the pilot analysis described above, the below actions are recommended.

Incorporate GI as a component of streetscape or road reconstruction project. Incorporating GI elements to the design of the street would modify runoff patterns and improve water quality. In addition, the streets are publically-owned and therefore, accessible for systematic implementation as well as for future operations and maintenance (O&M) needs. Based on GI implementation suitability analysis results, it is recommended to investigate the potential of incorporating GI in the suitable streets (colored green in Figure 3-1) within the pilot study area. An example of implementation of GI integrated with municipalities' streetscape program is also shown in Figure 3-1.

Investigate and potentially implement GI in parcels with high suitability. The top 20 parcels are shown in Figure 3-2 as well as tabulated in Table 3-1 by rank according to their weighted composite scores along the suitability spectrum. Development or modification of these parcels would require the developer to retain the runoff from a 2-year, 6-hour storm onsite to meet current GNHWPCA requirements. It is recommended to implement GI technologies based on the category listed in Table 1-2, in order to achieve maximum reduction of runoff to sewer system. Examples of GIs that potentially can be implemented to some of the sites are shown in Figures 3-3 and 3-4 with the photos of GIs that were constructed for Onondaga County, NY's "Save the Rain" program.

Currently, a planned development at 915 Ella T. Grasso Boulevard is in an active development planning stage, as shown in Figure 3-2. It located in the CSO 004 sewershed and the proposed development includes installation of two stormwater infiltration systems totaling almost 75,000 gallons.

FIGURE 3-1

Recommended Streetscape GIs in Suitable Streets (Colored Green)

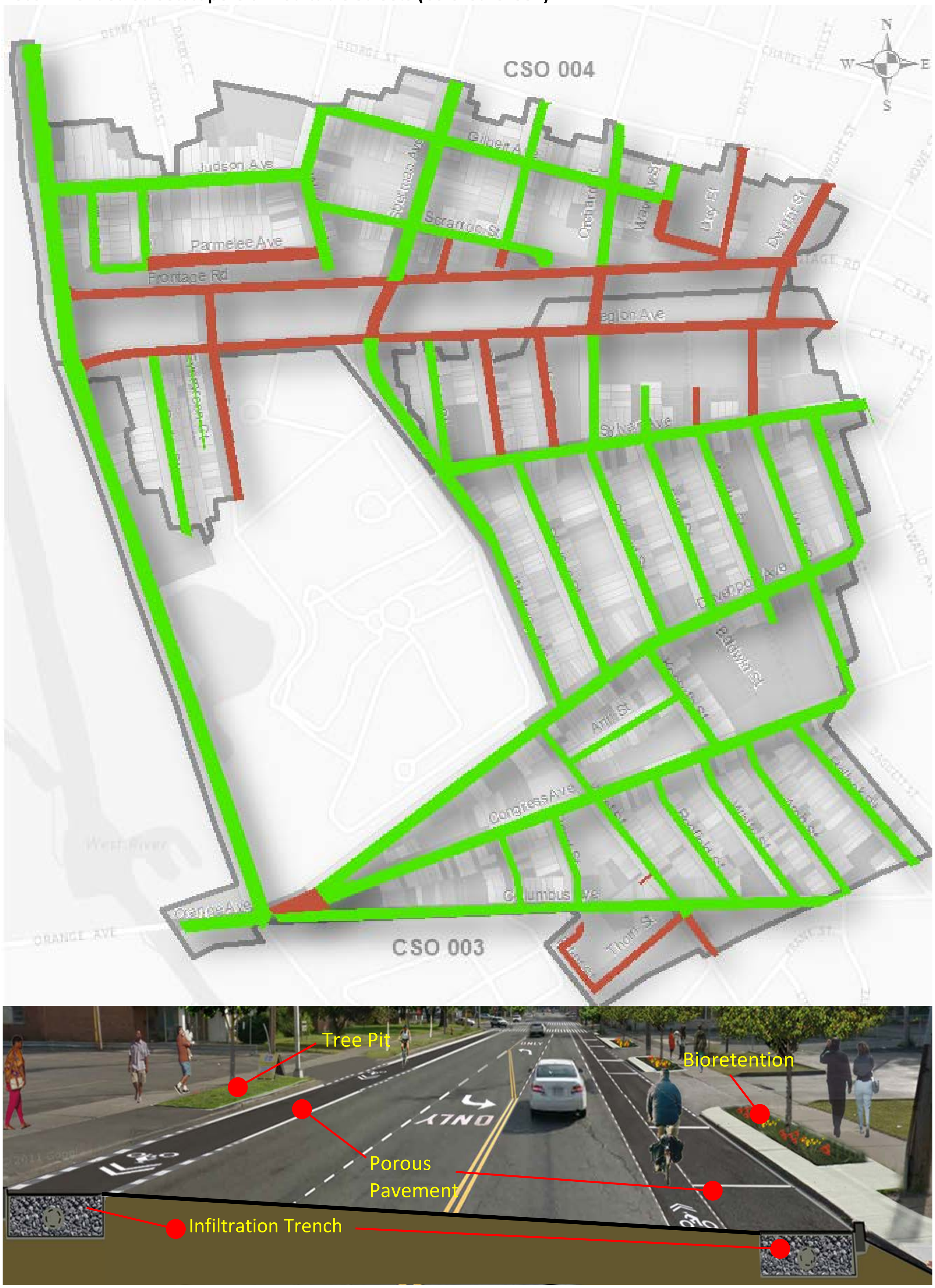


FIGURE 3-2

Top 20 Parcels Ranked with Highest Suitability and Current Active Development Site

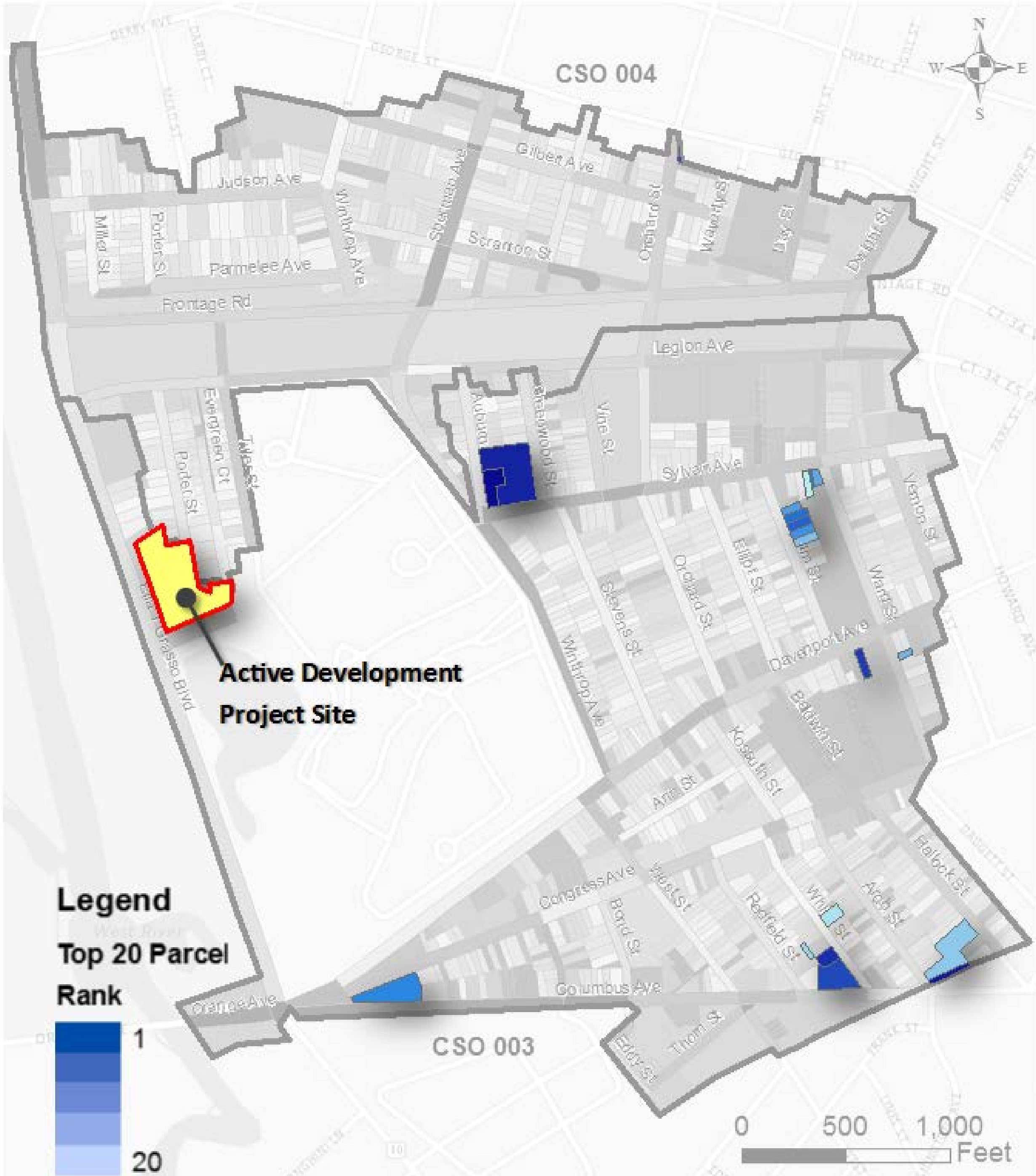


TABLE 3-1
Top 20 Ranked Parcels

Rank	MEAN	Area_ac	MBP_ED	UseDescrip	Property_1	Zoning
1	4.815	0.31	314-0155-00100	RELIGIOUS MDL-94	Exempt	PDD 44-RM2
2	4.690	0.27	301-0097-03201	-	Exempt	RM2
3	4.677	1.24	314-0155-03200	APT Over12 MDL-94	Apartment 5+ Units	PDD 44-RM2
4	4.677	0.15	301-0095-01400	NON-PROFIT MDL-00	Exempt	RM2
5	4.674	0.13	278-0132-02900	RELIGIOUS MDL-00	Exempt	RM2
6	4.666	0.48	301-0095-01600	NON-PROFIT MDL-00	Exempt	BA
7	4.644	0.09	315-1291-00500	PVT HOSP MDL-94	Exempt	RO
8	4.633	0.11	278-0147-03200	EXEMPT COM MDL-00	Exempt	RM2
9	4.631	0.11	278-0147-03300	EXEMPT COM MDL-00	Exempt	RM2
10	4.602	0.02	278-0147-00600	EXEMPT COM MDL-00	Exempt	RM2
11	4.599	0.67	310-0091-00100	REC FACIL MDL-00	Exempt	PARK-RM2
12	4.589	0.11	278-0147-03100	EXEMPT COM MDL-00	Exempt	RM2
13	4.588	0.08	278-0147-03400	EXEMPT COM MDL-00	Exempt	RM2
14	4.582	0.07	278-0147-00601	EXEMPT COM MDL-00	Exempt	RM2
15	4.578	0.05	278-0133-02500	MUNICIPAL MDL-00	Exempt	RM2
16	4.553	0.11	278-0147-03000	EXEMPT COM MDL-00	Exempt	RM2
17	4.535	0.71	301-0097-03300	RELIGIOUS MDL-94	Exempt	RM2
18	4.532	0.04	301-0095-02001	MUNICIPAL MDL-00	Exempt	RM2
19	4.529	0.14	301-0096-03900	RELIGIOUS MDL-94	Exempt	RM2
20	4.525	0.10	278-0147-00500	EXEMPT COM MDL-00	Exempt	RM2

FIGURE 3-3
Examples of Potential Green Infrastructures in Defender's Park

NOTE: Bioretentions or ponds can be constructed in the Park and they could manage stormwater runoffs generated both in and outside of the Park (e.g., redirecting catch basin flows to GIs in the Park).

FIGURE 3-4
Examples of Potential Green Infrastructures in Suitable Sites

NOTE: These sites are Cornell Scott Hill Health Center Parking Lot, Arch Street Church and 31 White Street.

3.2 Cost-Benefit Estimates

The cost estimate was prepared in accordance with the guidelines of the Association for the Advancement of Cost Engineering (AACE) International. According to the definitions of AACE International, the Class 5 Estimate is defined as the following:

> ***Class 5 Estimate.*** *This estimate is prepared based on limited information, where little more than proposed plant type, its location, and the capacity are known. Strategic planning purposes include but are not limited to, market studies, assessment of viability, evaluation of alternate schemes, project screening, location and evaluation of resource needs and budgeting, and long-range capital planning. Examples of estimating methods used would include cost/capacity curves and factors, scale-up factors, and parametric and modeling techniques. Typically, little time is expended in the development of this estimate. The expected accuracy ranges for this class estimate are –20 to –50 percent on the low side and +30 to +100 percent on the high side.*

As a source reduction technique, green infrastructures implemented in combined sewersheds are most effective in reducing CSO discharges to the West River. For early planning purposes, it is reasonable to estimate CSO reduction due to implementation of GIs with an estimated ratio of CSO volume reduction to runoff volume reduction. This ratio varies by system conditions. For example, combined sewer systems with storage tanks differ from systems without offline storage tanks.

Onondaga County, NY, is a combined sewer community with a system very similar to the Authority's system in that combined areas are mostly located downstream with offline storage tanks while upstream sewersheds are mostly separated sanitary sewer. Onondaga County has constructed more than 150 GIs across the City of Syracuse, NY. A state of the art modeling study combined with a comprehensive monitoring program concluded that the CSO to runoff reduction ratio is approximately 0.4. That is, every 1 gallon of runoff capture by GIs eliminated 0.4 gallons of CSO during an average year.

Assuming an average excess rainfall runoff coefficient of 0.85 and an average annual rainfall volume of 47.1 inches, annual stormwater runoff volumes for each of the 20 top ranked parcels are calculated and shown in Table 3-2. With a project runoff elimination to CSO reduction ratio of 0.4 from communities with similar systems as discussed above, the benefit of implementing GIs can be estimated as annual CSO reduction volume (shown in Table 3-2).

In summary, the projected annual stormwater runoff generated from the top 20 most suitable sites is approximately 5.4 million gallons (MG) and it would potentially reduce CSO volume approximately 2.2 MG on an average annual basis. The total cost for these projects is approximately $1.48 million including design and services during construction.

TABLE 3-2
Summary of Cost and Benefit for Green Infrastructure Implementation

GI Suitability Rank	Parcel ID	Assumed GI Technology	Parcel Size (Acres) A	[1]Projected Annual Runoff (gallons) B	[2]Estimated Annual CSO Reduction (gallons) C = 0.4 x B	[3]Typical Construction Costs ($/acre area managed by GI) D	[4]Construction Cost E = A x D	30% Contingency F = 30% x E	[5]Design and SDC Cost G = 25% (E + F)	Total Project Cost H = E + F + G
1	314-0155-00100	Bioretention and Porous Pavement	0.31	336,000	134,400	$192,000	$59,000	$17,700	$19,175	$95,875
2	301-0097-03201	Bioretention	0.27	293,000	117,200	$184,000	$49,000	$14,700	$15,925	$79,625
3	314-0155-03200	Porous Pavement	1.24	1,347,000	538,800	$199,000	$246,000	$73,800	$79,950	$399,750
4	301-0095-01400	Infiltration Trench	0.15	163,000	65,200	$144,000	$21,000	$6,300	$6,825	$34,125
5	278-0132-02900	Bioretention and Porous Pavement	0.13	141,000	56,400	$192,000	$24,000	$7,200	$7,800	$39,000
6	301-0095-01600	Infiltration Trench	0.48	521,000	208,400	$144,000	$69,000	$20,700	$22,425	$112,125
7	315-1291-00500	Porous Pavement	0.09	97,000	38,800	$199,000	$17,000	$5,100	$5,525	$27,625
8	278-0147-03200	Bioretention	0.11	119,000	47,600	$184,000	$20,000	$6,000	$6,500	$32,500
9	278-0147-03300	Bioretention	0.11	119,000	47,600	$184,000	$20,000	$6,000	$6,500	$32,500
10	278-0147-00600	Bioretention	0.02	21,000	8,400	$184,000	$3,000	$900	$975	$4,875
11	310-0091-00100	Bioretention	0.67	728,000	291,200	$184,000	$123,000	$36,900	$39,975	$199,875
12	278-0147-03100	Bioretention	0.11	119,000	47,600	$184,000	$20,000	$6,000	$6,500	$32,500
13	278-0147-03400	Bioretention	0.08	86,000	34,400	$184,000	$14,000	$4,200	$4,550	$22,750
14	278-0147-00601	Bioretention	0.07	76,000	30,400	$184,000	$12,000	$3,600	$3,900	$19,500

TABLE 3-2

Summary of Cost and Benefit for Green Infrastructure Implementation

GI Suitability Rank	Parcel ID	Assumed GI Technology	Parcel Size (Acres) A	[1]Projected Annual Runoff (gallons) B	[2]Estimated Annual CSO Reduction (gallons) C = 0.4 x B	[3]Typical Construction Costs ($/acre area managed by GI) D	[4]Construction Cost E = A x D	30% Contingency F = 30% x E	[5]Design and SDC Cost G = 25% (E + F)	Total Project Cost H = E + F + G
15	278-0133-02500	Porous Pavement	0.05	54,000	21,600	$199,000	$9,000	$2,700	$2,925	$14,625
16	278-0147-03000	Bioretention	0.11	119,000	47,600	$184,000	$20,000	$6,000	$6,500	$32,500
17	301-0097-03300	Bioretention and Porous Pavement	0.71	771,000	308,400	$192,000	$136,000	$40,800	$44,200	$221,000
18	301-0095-02001	Porous Pavement	0.04	43,000	17,200	$199,000	$7,000	$2,100	$2,275	$11,375
19	301-0096-03900	Bioretention and Porous Pavement	0.14	152,000	60,800	$192,000	$26,000	$7,800	$8,450	$42,250
20	278-0147-00500	Bioretention	0.1	108,000	43,200	$184,000	$18,000	$5,400	$5,850	$29,250
	Total		**4.99**	**5,413,000**	**2,165,200**		**$913,000**	**$273,900**	**$296,725**	**$1,483,625**

[1]: based on average annual rainfall of 47.1 inches and excess rainfall rate of 0.85

[2]: based on green program implemented from other community with similar system

[3]: unit costs per acre of area managed by GI are based on constructed green infrastructure projects in other communities

[4]: costs are calculated by multiplying unit cost per acre with parcel sizes

[5]: design and service during construction (SDC) costs are assumed to be 25% of construction cost