GREEN INFRASTRUCTURE PLAN

the city of Lancaster
a city authentic

April 2011

the city of Lancaster
a city authentic

Each year, the City of Lancaster is responsible for about 1 billion gallons of polluted water flowing into the Conestoga River and eventually into the Chesapeake Bay. This is common in historic cities like Lancaster that rely on a combined sewer system. A combined sewer system collects and transports both domestic sewage and rainwater flowing from downspouts, streets, sidewalks, parking lots and over impervious surfaces into the City's storm drains. Eighty-five percent of the time, the City's Advanced Wastewater Treatment Facility is able to manage and clean the volume of water flowing through this combined system. However, during rainstorms and other wet weather events, the system becomes overwhelmed and untreated stormwater overflows into rivers.

The problem of stormwater runoff and combined sewer overflow is not going away; nor will our responsibility to help clean and restore "the Bay." This Green Infrastructure Plan provides a strategy that addresses the problem of stormwater runoff with techniques that are both cost-effective and responsible.

We began the planning process with two important questions:

1. Can the City realistically eliminate 1 billion gallons of storm water runoff in twenty-five years employing green infrastructure?

2. Can this approach provide more benefits per dollar than traditional gray infrastructure alternatives?

With commitment and concerted effort on the part of City government, residents, and businesses, the answer to both questions is "yes." Full implementation of the Plan will also rely on the continued availability of grant funding; on-going community education and outreach; and development of a long-term financing strategy to sustain green infrastructure investments well into the future.

The first of its kind in Pennsylvania, Lancaster City's Green Infrastructure Plan serves as a model for other Third Class Cities. Our Plan will continue to be updated based on lessons learned, new technologies and continued analysis and data collection. Community feedback regarding the Plan's components is essential now and will be in the future. Already, the City has begun working with LIVE Green to engage the community in specific green infrastructure projects in our neighborhoods. There are some 50 potential projects identified in this Plan, and many, many more will be required to accomplish our vision. As such, this Plan provides both a starting point and a roadmap.

Our Green Infrastructure Plan "roadmap" lays out a pathway to stormwater management and environmental preservation. At the same, it marks a journey towards a more livable, sustainable and economically viable City. We invite you to join us on that journey.

Sincerely,

J. Richard Gray
Mayor, City of Lancaster

Charlotte Katzenmoyer
Director of Public Works

GREEN INFRASTRUCTURE PLAN

ACKNOWLEDGEMENTS

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In addition, the following individuals and organizations played a pivotal role in bringing this plan to fruition. They include:

- Jay Braund, Pennsylvania Department of Environmental Protection
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And, finally, to the leadership of J. Richard Gray, Mayor of the City of Lancaster for his vision for creating a greener and more economically and aesthetically attractive City.

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Prepared February 2011

by CH2M Hill, Inc.

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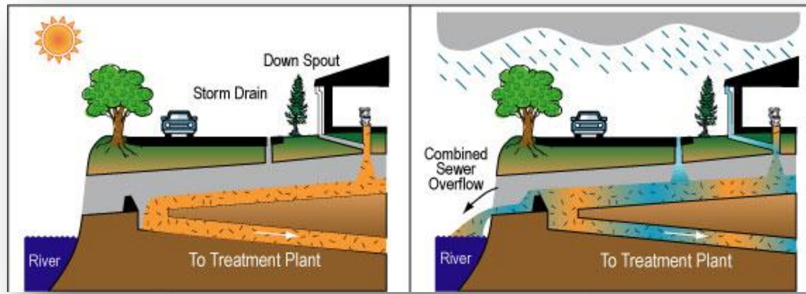


The City of Lancaster is one of about 770 cities nationwide with a combined sewer system (EPA). Combined sewer systems collect and transport both domestic sewage (wastewater from plumbing in buildings) and rainwater that flows from downspouts, streets, sidewalks, parking lots and other impervious surfaces common in urban areas. Eighty-five percent of the time, the City's Advanced Wastewater Treatment Facility is able to manage and clean the volume of wastewater flowing through this combined system. However, during intense rainstorms and other wet weather events, the system becomes overwhelmed. Each year, this causes about 1 billion gallons of untreated wastewater (mixed sewage and stormwater) to overflow into the Conestoga River. These events are referred to as combined sewer overflows (CSOs) or simply "overflows".

At the time that combined sewer systems were being built across the country 100-200 years ago, they were considered a highly efficient method of treating all forms of waste from urbanized areas since they collected stormwater, sanitary sewage and industrial wastewater all in the same pipe and conveyed them to a treatment plant to be processed before discharging treated water to the nearby streams. What better way to keep streams pristine, fishable and swimmable than to treat **all the waste including runoff**? But as urbanized areas grew and eventually overwhelmed these systems, the methods used did not change or keep up with development. Our forefathers kept adding onto the same system.

Efforts to clean up our local waterways and the Chesapeake Bay have brought renewed federal, state and regional attention on initiatives designed to protect and restore the network of polluted streams and rivers in the Chesapeake Bay watershed, many of which fail to meet water quality standards. The Conestoga River is one such river. The Environmental Protection Agency, for example, has begun enforcing limits on nitrogen, phosphorous and sediment pollution, referred to as a Total Maximum Daily Load (TMDL). The TMDL, or "pollution diet," sets accountability measures for communities located within the 64,000 square mile watershed to ensure that cleanup commitments are kept. The TMDLs are being promulgated not only for combined sewer systems, but also for municipal separate stormwater systems (MS4s) across the Bay watershed. So the costs to comply with these new regulations are going to be felt by every community.

With this backdrop, Lancaster City has been working proactively to reduce combined sewer system overflows and at the same time, to identify economically viable, long-term strategies for mitigating the negative impact of wet weather overflows on our water quality. To date, most of the strategies under consideration have been limited to "gray infrastructure" options, such as increasing the capacity of the City's wastewater conveyance and treatment infrastructure; adding storage or holding tanks to detain wastewater flows until treatment capacity returns; or providing some form of wastewater treatment to the overflow discharges.

Over the past 12 years, the City has aggressively pursued upgrades to its existing gray infrastructure. More than $18 million has been invested in the City's wastewater system including construction of the first wastewater treatment system in the Commonwealth to meet nutrient removal requirements. These nutrient removal projects are being implemented at other treatments plants in the Chesapeake Bay watershed now that the TMDLs are going into effect. Additional capital investment has increased the efficiency of pumping stations to optimize the flow of wastewater to the treatment facility and these investments have resulted in further capture of wet weather flows for treatment.

Despite this progress, there remains a significant amount of untreated combined sewage overflowing into the Conestoga River. Based on prior evaluations and experience in many other communities, gray infrastructure options are expensive to construct and maintain. One storage tank alone in the City's Northeast section of the City has an estimated price tag of $70 million and this would only manage 1/10 of the City's annual CSO volume. The estimated price tag to store and treat the billion gallons of annual overflows would be well over $250 million. This cost does not include the annual operational costs in energy and personnel to run the new gray systems.

Given the expense of gray infrastructure modifications, the City has instead opted for a two-prong strategy for reducing the volume of stormwater entering the combined sewer system:

1. Increase the efficiency and capacity of the City's existing gray infrastructure; and
2. Employ "green infrastructure" methods of stormwater management.

Green infrastructure encompasses a variety of technologies that replicate and restore the natural hydrologic cycle and reduce the volume of stormwater entering the sewer system. This, in turn, reduces overflows. Green infrastructure generally includes stormwater management methods that:

- infiltrate (porous pavements, sidewalks, and gutters; linear infiltration systems)
- evaporate, transpire and reduce energy consumption (vegetated roofs, trees, planter boxes)
- infiltrate and transpire (rain gardens and bioretention)
- capture and reuse rainfall (rain barrels, cisterns, irrigation supply systems, and gray water systems)

In contrast to gray infrastructure, a green infrastructure approach often has a higher return on investment and offers multiple benefits:

- *Environmental* – recharges ground water, provides natural storm water management, reduced energy usage, improved water quality.
- *Social* – beautifies and increases recreational opportunities, improves health through cleaner air and water, improves psychological well-being.

- *Economic* – reduces future costs of stormwater management and increases property values.

In May 2010, the City of Lancaster began to develop Pennsylvania's first- Class 3 Green Infrastructure Plan (GI Plan). Building upon the Lancaster County Comprehensive Plan as reported in the Planning Commission's *Greenscapes: The Green Infrastructure Element*, Lancaster City's plan was developed in conjunction with LIVE Green, the Lancaster County Planning Commission, PA Department of Environmental Protection (DEP), PA Department of Conservation and Natural Resources (DCNR) as well as local stakeholders. The City's GI Plan clearly articulates a vision for Lancaster:

MISSION: To provide more livable, sustainable neighborhoods for City residents and reduce combined sewer overflows and nutrient loads

The goals of the GI Plan are equally clear:

1. Strengthen the City's economy and improve the health and quality of life for its residents by linking clean water solutions to community improvements (e.g. green streets).
2. Create green infrastructure programs that respond comprehensively to the multiple water quality drivers (e.g. TMDL, CSO and stormwater regulations) to maximize the value of City investments.
3. Use GI to reduce pollution and erosive flows from urban stormwater and combined sewer overflows to support the attainment of the Watershed Implementation Plan for the Chesapeake Bay and to improve water quality in the Conestoga River.
4. Achieve lower cost and higher benefit from the City's infrastructure investments.
5. Establish Lancaster City as a national and statewide model in green infrastructure implementation.

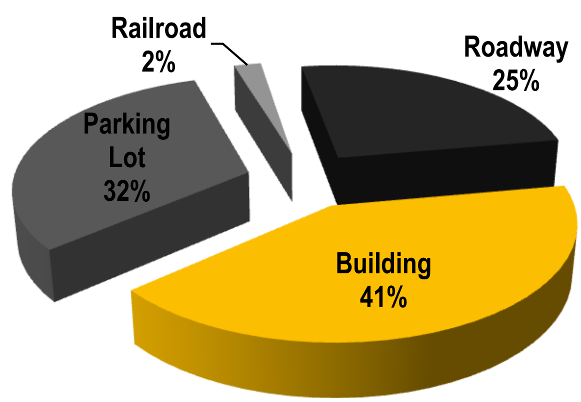
ASSESSMENT

The study involved a three-step process:

(1) evaluate impervious cover by type and land ownership;

(2) identify potential GI project sites and grant funding for early implementation to understand cost/benefit for each; and

(3) determine potential citywide benefits and provide actions and policy direction to institutionalize GI in the City.



The impervious cover analysis revealed that 41 percent of the city's impervious surface is attributable to buildings, 32 percent to parking lots, 25 percent to roadways and 2 percent to railroads. In addition, most of the impervious area besides roads is on privately held lands which shows why private investment is necessary to make this a successful program. The City cannot solve this problem cost effectively on its own.

Further analysis of land ownership identified more than 50 existing and potential GI projects in various locations:

- Streets, Alleys & Sidewalks
- Parking Lots
- Rooftops
- Parks
- School and City-owned properties

From these locations, the GI Plan provides conceptual designs and cost estimates for 20 initial projects that the City can use to demonstrate each green infrastructure technology. These demonstration projects will remove an estimated 21 million gallons of urban runoff from the combined sewer system per year, and, at the same time the demonstration projects will provide much-needed data on the long-term effectiveness of employing green infrastructure strategies on a broader scale to reduce urban stormwater runoff and combined sewer system overflows. GI project types were determined to be capable of scaling to significant implementation levels when applied to specific land uses common in urban setting such as Lancaster City:

STREETS, ALLEYS AND SIDEWALKS

Green streets, alleys and sidewalks use existing roadways and the public right of way to manage stormwater runoff with tree trenches, porous sidewalks, curb-extensions, and sidewalk planters. Initial demonstration projects are being located at street corners undergoing ADA ramp upgrades and in areas slated for streetscape improvements. The City has identified approximately 20 blocks of streets that are either scheduled for repair or ADA ramp upgrades in 2011. These blocks will serve as green street prototypes that can be incorporated into the City's on-going street repair program. The plan calls for approximately 468 blocks of green streets to be developed over the long term - many of which can be implemented as the City repaves and reconstructs its roads year after year. Another key strategy in developing green streets is enhanced street tree planting. Lancaster City has an estimated 28% tree canopy based on the urban tree canopy analysis completed in February 2011 (see Appendix F). Various studies indicate that a 40% tree canopy in urban areas is feasible and can provide a substantial reduction in stormwater runoff.

This potential is being verified by the City in a separate DCNR funded study to evaluate existing tree canopy using a top down (high resolution aerial imagery) and bottom up approach (walking inventory). This will provide a baseline measure of the city's existing tree canopy, assess the age and health of existing trees, and identify possible locations for additional plantings. As an initial goal to be refined when the inventory is complete, the GI Plan proposes to increase the City's tree canopy in the right-of-way with 6,250 ad hoc trees or about 250 plantings per year over 25 years. In addition, tree plantings will be incorporated in most green infrastructure projects, thereby increasing canopy further.

PARKING LOTS

Green parking lots are usually created by excavating a portion of an existing lot and installing a stone subsurface infiltration bed in conjunction with porous pavement or water quality inlets that redirect stormwater into the stone bed. Runoff from adjacent areas such as streets and buildings can also be redirected into the infiltration bed. Tree trenches can also be integrated with the design to increase the tree canopy and promote evapotranspiration. These projects are most cost effective when the pavement is in need of replacement or the lot requires reconfiguration for other reasons. The GI Plan includes conceptual designs for four public parking lots in need of restoration. The GI Plan calls for retrofitting and, managing runoff from 130 acres of primarily privately-owned parking lots over 25 years.

ROOFTOPS

Multiple strategies can be employed to manage the rainwater that falls on rooftops. Lancaster City currently has 51,000 square feet (well over 1 acre) of green roofs. This translates into almost 1 square foot per resident – perhaps more than any municipality in Pennsylvania. Building on the success and lessons learned from the Lancaster County Roof Greening Project administered by the Lancaster County Planning Commission and implemented by LIVE Green, the GI Plan calls for an additional 2 acres of green roofs in the next 5 years and over 30 acres in the long term.

Water from rooftops can also be managed through disconnection of downspouts. Most downspouts in the City go directly into the combined sewer system. Water from downspouts can be redirected to open green space, rain barrels, cisterns, rain gardens or stormwater planters. Through its Urban Watershed Initiative LIVE Green has been providing rain barrels to residents seeking low-cost solutions. The work of LIVE Green demonstrates how the installation of 250 rain barrels and rain gardens can reduce the amount of stormwater that enters the municipal sewer system and local streams by over 3 million gallons per year. The GI Plan calls for an additional 2,000 buildings to disconnect their downspouts.

The 6th Ward Park porous basketball court provides runoff reduction at 1/2 the cost of separate grey controls, while also providing community improvements

PARKS

The GI Plan leverages the City's previous investment in the Urban Park, Recreation and Open Space Plan completed in 2009 as it moves forward with recommended park restoration and reconstruction projects. The GI Plan proposes green infrastructure retrofits of 26 of the City's 30 Parks to manage water runoff from 17 acres of impervious surface area. The GI Plan lays out specific concepts for the renovation and restoration of 3 parks and uses these park areas to manage storm water runoff from adjacent roadways and other impervious areas. An example is the recently completed Sixth Ward Memorial Park project that employs a porous basketball court and infiltration bed to reduce runoff from adjacent roadways and other impervious areas by an estimated 700,000 gallons per year. The new court was designed and built at half the cost of separate grey infrastructure designed to achieve the same level of benefit.

SCHOOLS AND CITY-OWNED PROPERTIES

The GI Plan establishes a long term goal of greening 38 acres of impervious surface area associated with 15 public schools. Implementing a variety of green infrastructure techniques to manage stormwater generated on-site can also manage additional impervious areas from adjacent properties. Libraries and other publicly owned facilities offer the same green infrastructure and storm water management opportunities as schools. The GI Plan includes conceptual designs for the Lancaster Public Library and two public schools.

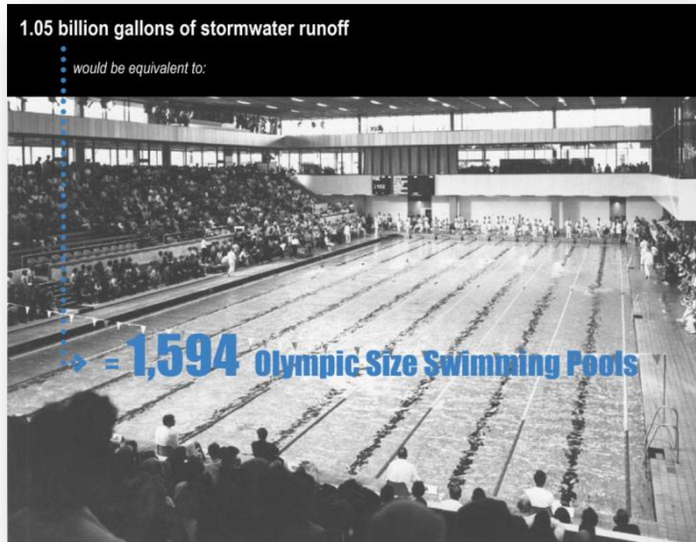
INCENTIVES FOR RESIDENTIAL AND COMMERCIAL PROPERTIES

To fully institutionalize green infrastructure into the City of Lancaster's urban landscape, the GI Plan proposes a combination of policy actions, incentives for residential and commercial property owners, and innovative funding approaches to support ongoing implementation costs.

POLICY ACTIONS: ORDINANCES & STANDARDS- As part of its stormwater ordinance, the City currently has a "first flush" control requirement that requires property owners who are adding new impervious surface areas (e.g., a building addition, driveway, garage or impervious patio) to manage the first 1-inch of rainfall on their property and not allow it to discharge to the combined sewer. The GI Plan recommends that the City's Stormwater regulations be extended to control the first flush from the impervious area within the entire disturbed area of the redevelopment project. For example, if an addition to a building was being built on top of an existing parking lot, runoff from the addition as well as the existing building would fall under the ordinance and would need to be managed for the first flush. Over time, this change will gradually reduce stormwater runoff to the combined sewer. In addition to this revision of the storm water ordinance, the GI Plan recommends that the City evaluate other ordinances that may impact green infrastructure implementation, and review its current Streetscape Design Standards to incorporate green infrastructure options.

INCENTIVES - For private properties that may not redevelop in the foreseeable future, the City continues to evaluate programs that can incentivize owners to construct green infrastructure retrofits. The existing efforts have focused on securing grant dollars that can be used to implement demonstration projects on privately-owned property. The GI Plan proposes the establishment of a Green Infrastructure Grant Fund to support the marginal cost (e.g., the cost difference to install a green roof instead of a conventional one) of constructing GI on private property.

FUNDING - The City is evaluating a utility structure that would allocate the costs of stormwater management and water pollution control based on the amount of impervious surface area on each parcel. Known as a "stormwater utility," this would apportion the costs of controlling combined sewer overflows and storm water based on each parcel's proportionate use (as determined by impervious area) of the wastewater collection and treatment facilities. Because controls are now required for wet weather flows, this method of cost allocation would be based on actual use of the sewer system and treatment services and allow reductions in a bill if a property owner installed green infrastructure to manage his or her impervious area and reduce flows to the sewer.



Over 1.05 billion gallons of stormwater runoff is projected to be removed through long-term implementation of this GI Plan. This volume of water would fill over 1,500 Olympic-sized swimming pools.

BENEFIT AND COST

The GI Plan evaluated the runoff reduction benefits of the initial demonstration projects, a conceptual 5-year implementation scenario and a long-term scenario that might be expected to be achievable over a period of about 25 years or so based on typical rates of redevelopment and renewal rates for other City infrastructure like roads and sidewalks. Based on the characteristics of the demonstration projects, the potential benefits and costs associated with GI were estimated for each implementation scenario. The projected benefits of the program over the long term scenario are summarized below.

Table E-1 - Assumed implementation levels for the long-term scenario

Area / Impervious Source	Impervious/ Contributing Area (acres)	Approx. Percent Imperv.	Green Infrastructure Project / Program Type	Assumed Percent of Impervious Area Managed	Impervious Area Managed (acres)	Implementation Level - Alternative Description
Roads / Alleys	529	100%	Green Streets	30%	159	468 blocks
Parks	241	8%	Park Improvements / Greening	85%	17.0	26 parks
Sidewalks	124	100%	Disconnection, Porous Pavement	35%	43.3	89 miles of sidewalks
Parking Lots	648	100%	Porous Pavement, Bioretention	20%	130	287 parking lots
Flat Roofs	218	100%	Vegetated Roofs / Disconnection	15%	32.7	246 roofs
Sloping Roofs	654	100%	Disconnection/Rain Gardens	25%	164	2195 buildings
Street Trees	N/A	N/A	Enhanced Tree Planting	N/A	45.1	6250 tree plantings
Public Schools	175	29%	Green Schools	75%	38.4	15 schools
Various (Ordinance)	1274	100%	First-Flush Ordinance	50%	637	2536 non-resid. parcels
Total					**1,265**	

Table E-2 - Summary of GI Plan benefits for 5 year and long-term implementation scenarios

Parameter	5-year Implementation	Long-Term (25-yr) Implementation
Impervious Area Managed by Green Infrastructure (ac)	221	1,265
Average Annual Runoff Reduction (MG/yr)	182	1,053
Average Annual Total Suspended Solids (TSS) Reduction (lb/yr)	252,000	1,457,000
Average Annual Total Phosphorus (TP) Reduction (lb/yr)	4,800	27,800
Average Annual Total Nitrogen (TN) Reduction (lb/yr)	10,700	61,600
Total Marginal Cost	$7,800,000	$77,000,000
Total Capital/Implementation Cost	$14,000,000	$141,000,000
Marginal Cost Per Gallon CSO Reduction ($/gal)	$0.06	$0.10
Total Cost Per Gallon CSO Reduction ($/gal)	$0.10	$0.18

RECOMMENDATIONS

To achieve these benefits and put the GI Plan to action, the following recommendations are made in four key areas described as follows.

1. **Implement a comprehensive demonstration program** to allow the details of each project type and technology to be worked through and adapted for the specific requirements of the City's unique land use types and
   a) **Establish a prioritized capital program for GI implementation** within Department of Public Works;
   b) **Apply a screening process to review existing City capital programs for possible green infrastructure project opportunities** (e.g. roofing, pavement restoration and other projects that restore or reconstruct impervious surfaces); and
   c) **Create a Green Infrastructure Grant Fund to incentivize action** by funding the marginal cost of the green portion of improvements on private property.
2. **Implement the recommended policy actions including:**
   a) **Institute a GI advisory committee** comprised of City leaders to discuss and remove implementation barriers and endorse selected implementation programs. Create working subcommittees at the local neighborhood level to suggest projects to the advisory committee;
   b) **Convene a review process to evaluate City Codes to include Green Infrastructure Options;**
   c) **Revise City Standard Design Guidelines and Details;**
   d) **Evaluate and revise the First Flush Ordinance to manage all impervious area in the full area of disturbance for redevelopment;**
   e) **Implement an impervious cover-based storm water rate to equitably apportion the cost of wet weather controls; and**
   f) **Develop a program to utilize vacant land (publicly and privately owned) for management of stormwater runoff.**

3. **Implement partnering and outreach including:**
   a) **Develop and manage a list of key partners and volunteers** to help deliver outreach messages, host workshops, and provide support for grant funding pursuits;
   b) **Develop partnerships and volunteer efforts to implement the results of the Urban Tree Canopy Project** being conducted by PA DCNR and evaluate additional models for expanding street tree programs;
   c) Coordinate with County efforts to **implement the state and federal pollution reduction requirements;**
   d) Coordinate with County efforts to **implement the Greenscapes Plan**;
   e) **Develop a GI Portal on the City website** to disseminate information to the public about GI technologies, program updates, and what home owners can do to help;
   f) **Develop a homeowner's guide to GI**;
   g) **Provide GI Fact Sheets and education materials** on the Portal and brochures for selected audiences;
   h) **Develop a public outreach plan, presentation materials and schedule** for outreach to key neighborhood groups, business leaders, the Mayor, City Council, and other stakeholders through public meetings; and
   i) **Leverage learning through local and state key stakeholders** to inform the adoption and implementation of green infrastructure in other urban centers.

4. **Implement other studies & technical tools including:**
   a) **Conduct a Green Streets workshop** to support the selection and development of projects and approaches to demonstrate green streets in various types of road and alley reconstruction practices;
   b) **Update the City Hydrologic and Hydraulic Models to simulate green infrastructure** improvements in relation to other grey infrastructure alternatives;
   c) **Update the CSO LTCP** to include GI Plan recommendations;
   d) **Expand the GI Plan to evaluate the required implementation levels of the Chesapeake Bay TMDL and the nutrient reductions required for Lancaster** in the PA Watershed Implementation Plan (WIP) and **develop an integrated strategy for meeting CSO reduction and nutrient reduction objectives at the least cost and highest benefit to the City;**
   e) **Partner with PA DEP in the development of the revised WIP** for meeting the Chesapeake Bay TMDL requirements;
   f) **Develop a project tracking system** to document GI Implementation projects including the first flush projects and the area that they control; and
   g) **Identify direct stream inflow sources for potential removal from the combined sewer system;**
   h) **Prepare a comprehensive Tree Management Plan** by analyzing and developing a more specific tree planting goal based on the results of the Urban Tree Canopy Project and street tree inventory; and
   i) **Address GIS data needs and update** parcel-based landuse data, impervious area data, and parcel ownership information.

By implementing these recommendations, the needed investment in expensive, separate new grey infrastructure for water quality improvement can be significantly reduced and the City can realize many additional environmental, social and economic benefits.

The top map shows the existing City green space that does not contribute significantly to runoff problems. The lower graphic illustrates the 1,265 acres of impervious area proposed to be managed over the long term through the GI Plan.

Chapter 1 – Introduction

INTRODUCTION

Lancaster City was incorporated in 1818. It served as the National Capital of the American Colonies during a brief time of the American Revolutionary War. As the county seat, surrounded by some of the most productive non-irrigated farmland soil in the country, the City became a market place for the sale and purchase of various crops and livestock. This market place tradition continues today with Central Market – the oldest, continuously operating farmer's market in the country.

The City is divided north and south by King Street and east and west by Queen Street. The City population increased to 59,322 in the 2010 census, which increased 5.6% from 56,000 in 2000. The City has been designated by the Pennsylvania Department of Environmental Protection (PADEP) as an environmental justice community based on both race and income. Of the sixty municipalities within Lancaster County, the City has the second lowest taxing capacity of any municipality in the County. In terms of age of housing, the City has the fourth oldest housing stock (median year built as of 2007 was 1908), and the highest percentage of people living below the poverty level (17.91%). According to the 2000 census (2010 data not yet available), there were fifteen census tracks within the City of Lancaster where 40% or more of the population were living at or below the poverty level.

Lancaster City, like many urban communities in the Northeast is served by combined sewers where both stormwater runoff and sanitary sewage are combined in one pipe (Figure 1-1) for conveyance to the City's Advanced Wastewater Treatment Facility (AWWTF). During heavy rainfall, the runoff exceeds the capacity of the AWWTF, and a portion of the combined runoff and sanitary sewage overflows to the Conestoga River. Historically, combined sewers were built as a solution to water pollution and associated diseases like Typhoid and Cholera. This allowed polluted sanitary sewage and storm flows to be conveyed downstream of the drinking water source on the Conestoga River. In many cases, polluted stream flows were buried and / or diverted into sewers to allow development to occur on the overlying land as shown in Figure 1-2 and 1-3.

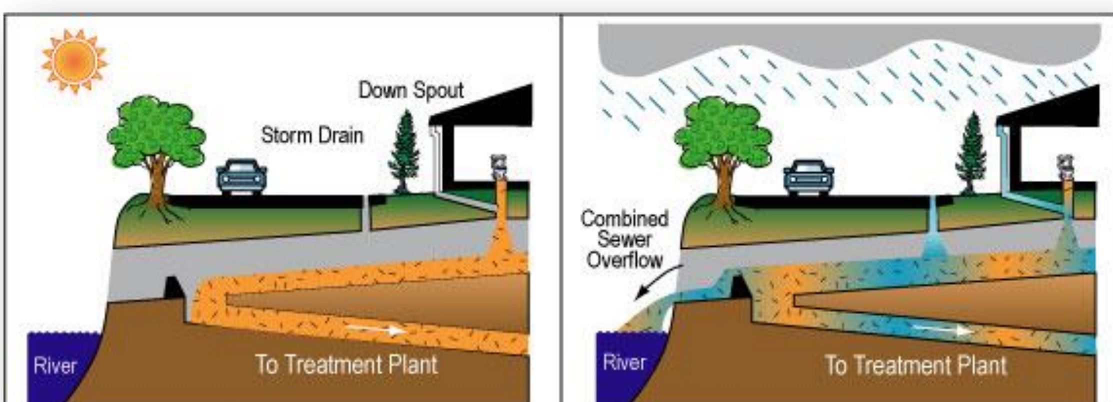


Figure 1-1 - Schematic of Separate and Combined Sewer System

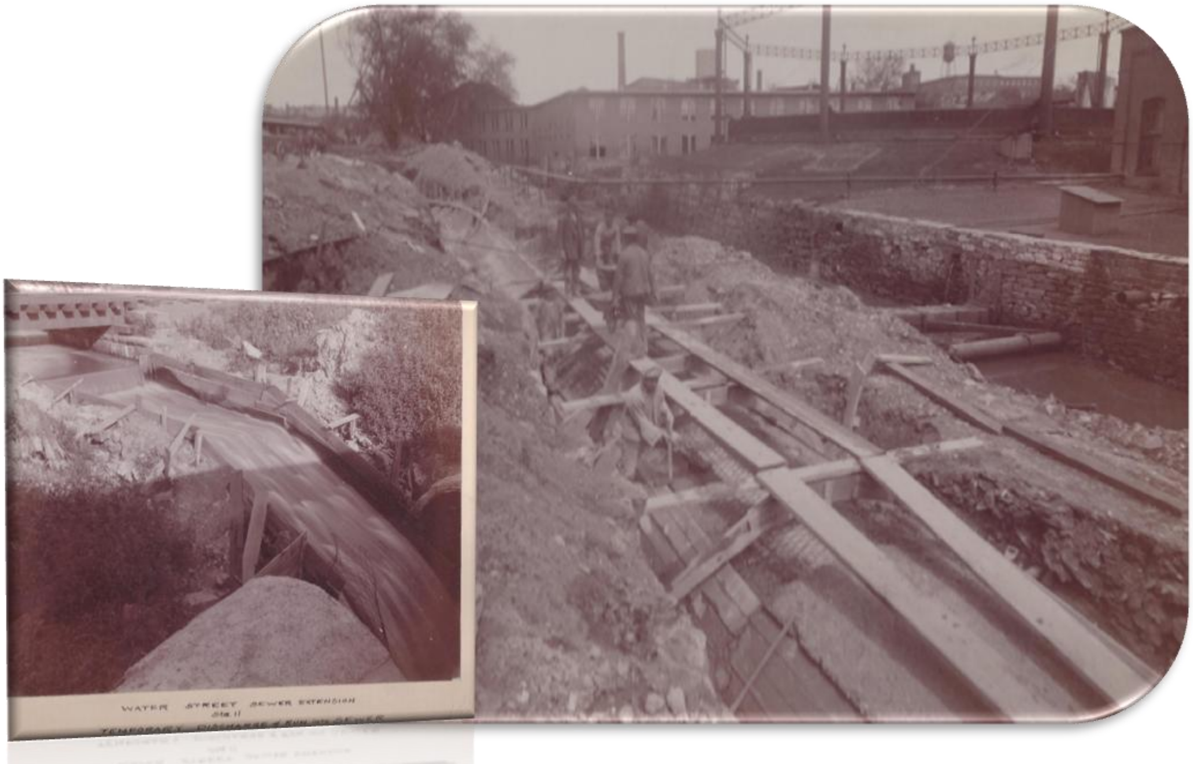


Figure 1-2 – Former stream diverted into the Water Street Sewer during its construction in the early 1900's

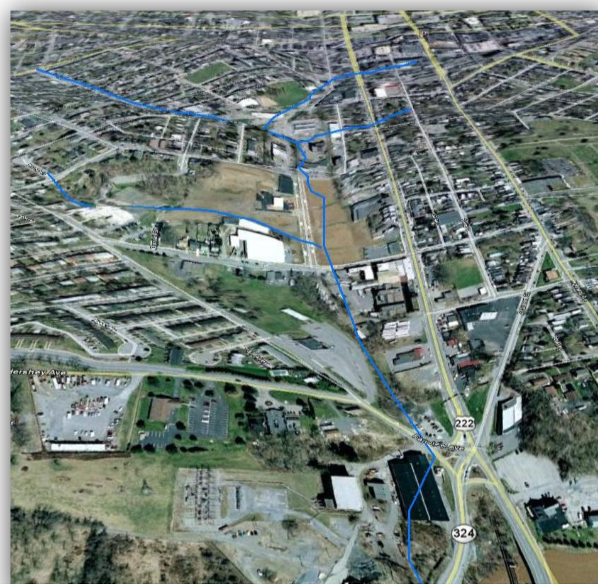


Figure 1-3 - Modern day aerial photograph depicting the location of the historic buried stream

Since the construction of the original combined sewers, the City has continued to work proactively to reduce these overflows and to find economically viable long term solution to mitigate the water quality impacts of wet weather overflows. Most of the controls to date have focused on "gray infrastructure" options, such as increasing the capacity of the conveyance and treatment systems, adding storage to detain storm flows until treatment capacity returns, or providing some form of water quality treatment to the overflow discharges.

Alternate approaches, including green infrastructure techniques, reduce the volume of stormwater runoff entering the combined sewer system and restore the natural hydrologic cycle. Various stormwater management technologies developed over the past three decades have been given closer consideration for application in the urban environment. Measures that infiltrate (porous pavements, linear infiltration systems, porous sidewalks, and gutters); measures that transpire and reduce energy (vegetated roofs, urban tree canopies, and planter boxes); measures that infiltrate and transpire (rain gardens and residential beds); and measures that capture and reuse rainfall (rain barrels, potable supply systems, and grey water systems) have all evolved in different regions around the globe, depending on the local ecology and water resource requirements or limitations. Runoff control practices that rely on these measures are commonly referred to as Green Infrastructure (GI).

WHY WAS THIS PLAN CREATED?

The City of Lancaster comprises 7.34 square miles (sm), and includes 241 acres of publicly-owned park land and playgrounds, 135 miles of streets of which 27 miles are classified as alleys, and over 860 acres of buildings, according to the GIS analysis performed for this Green Infrastructure Plan (GI Plan). As is with many urban town centers, the City is heavily paved with structures, roadways, parking lots, sidewalks and other hardscaping features. These impervious surfaces increase urban runoff, interfere with the natural hydrologic cycle and obstruct the natural processes of infiltration, evapo-transpiration and stream baseflow. Figure 1-4 shows the impact of urbanization on the natural hydrologic cycle as runoff increases and pollutants are conveyed downstream of the urbanized area.

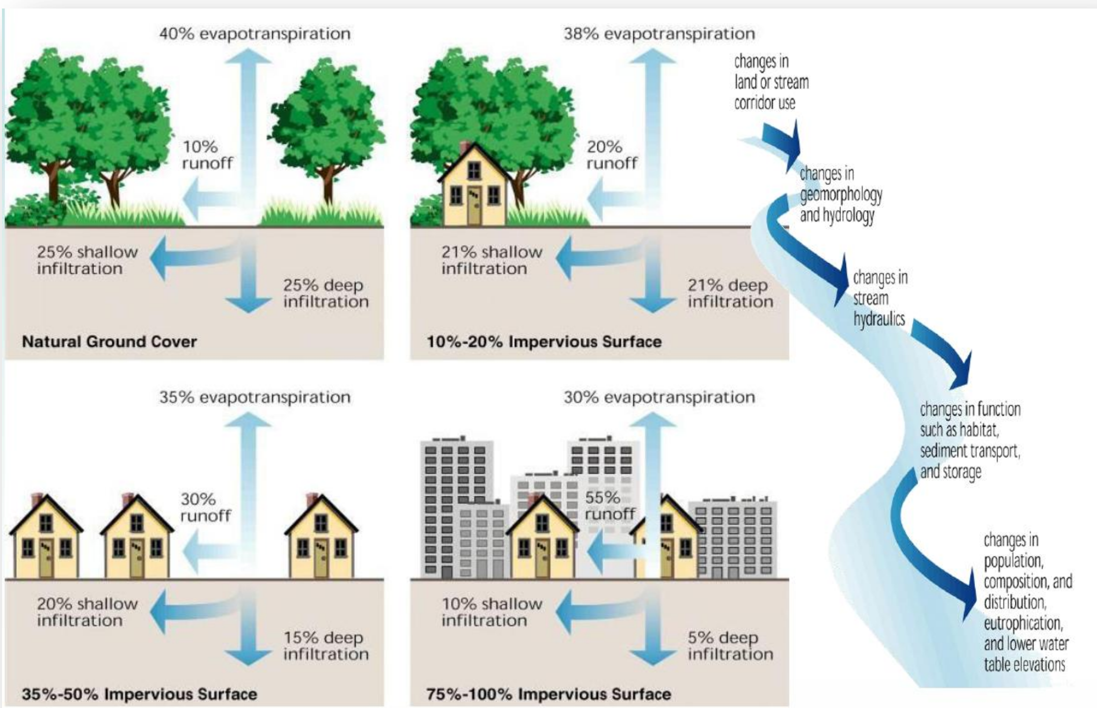


Figure 1-4 - Impact of urbanization on the Hydrologic Cycle (Source - US EPA)

The City is served by a combined sewer system (CSS) and a municipal separate storm sewer system (MS4), both of which have outfalls located along the river's edge (Figure 1-5 below). Both systems convey polluted urban runoff and excessive storm volumes, which can lead to flooding, stream erosion and water quality problems downstream. The CSS, which covers 45% of the City, is the primary source of wet-weather pollution to the Conestoga River. The CSS transports not only rainwater, but also a small portion of domestic sewage and industrial waste to the City's Advanced Wastewater Treatment Facility (AWWTF). During heavy rain events, combined flows are conveyed to the AWWTF to the point when the treatment plan cannot handle the large volume of stormflow, and a smaller portion of the combined flow is overflowed to the River. These overflow events happen during less than 15% of the storm events.

Figure 1-5 – CSO Outfall locations along the Conestoga River

During wet weather events, combined sewage flows exceed the capacity of the AWWTF, and untreated combined sewage is discharged directly to the Conestoga River. The Conestoga River is a tributary of the Susquehanna River which discharges to the Chesapeake Bay. The combined sewer overflows (CSOs) significantly degrade the downstream water quality by contributing nutrients and other pollutants and eroding sediment in the Conestoga River. Based upon the City's annual CSO status reports, about one billion gallons of untreated combined sewage is discharged into the Conestoga River on average, each year. The City must implement alternate means of managing urban stormwater runoff to reduce the frequency and volume of CSO events. The urban environment of the City along with the concentrated impervious surfaces will benefit from rainwater infiltration if the City's stormwater management techniques are tied to green infrastructure.

A Green Infrastructure approach offers multiple benefits that can achieve the three-pronged approach to sustainability, including:

- Environmental Benefits: Recharges and protects quality of surface and ground waters; provides natural stormwater management; reduces energy use, improves water quality which benefits fish species, fish-eating mammals and raptors, aquatic bugs in the Conestoga – and eventually – Bay species like oysters, blue crabs and stripers;

- Social Benefits: Beautifies and increases recreational opportunities; improves health through cleaner air and water; improves psychological well-being;
- Economic Benefits: Reduces future costs associated with stormwater management, increases property values.

This plan provides the City of Lancaster – the agencies, builders, developers, and public alike – with guidance on green infrastructure techniques that seek to solve the problems created by combined sewer system and is applicable to the older areas of the city and surrounding suburban area as well. This plan is intended to facilitate broad application of GI techniques throughout the City of Lancaster, building off the momentum of many preexisting redevelopment processes and existing planning efforts undertaken by the City and County alike. The GI Plan will show how the concept of *Integrated Infrastructure* – an approach that achieves multiple benefits by incorporating stormwater management features into infrastructure renewal projects along with improved aesthetics, increased urban tree canopy, reduction of urban heat island impacts, and other community improvements – is the key to transforming the City into a sustainable healthy community.

Integrated Infrastructure – an approach that achieves multiple benefits by incorporating stormwater management features into infrastructure renewal projects along with improved aesthetics, increased urban tree canopy, reduction of urban heat island impacts, and other community improvements

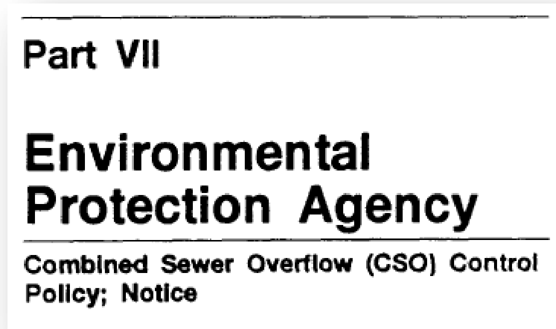
The Pennsylvania Department of Environmental Protection (PA DEP) and the Department of Conservation of Natural Resources (DCNR) have also supported the development of this plan and indicated an interest in it serving as an implementation framework that can be utilized for other Pennsylvania Class 3 cities.

The U.S. Environmental Protection Agency (EPA) under the Chesapeake Bay Program is leading a major initiative to restore polluted streams in the Chesapeake Bay watershed that currently do not meet water quality standards. Working with state partners, EPA is setting binding limits on nutrient (nitrogen and phosphorus) and sediment pollution through a total maximum daily load (TMDL) analysis or pollution "diet". The TMDL is a tool of the federal Clean Water Act and sets accountability measures in the form of pollutant load reduction requirements that ensure cleanup commitments are met by communities that are tributary to the Chesapeake Bay. The present program seeks to ensure that all practices to fully restore the health of the Bay are in place by 2025, with 60% of the actions taken by 2017. More information on the Chesapeake Bay Program and the TMDLs are discussed on later in this Chapter.

BACKGROUND AND LANCASTER CITY'S EFFORTS TO DATE:

The GI Plan provides an opportunity to integrate several programs being undertaken by the City to comply with various overlapping environmental regulations, including the City's Long Term Control (CSO) Plan Update, stormwater permit, and the total maximum daily load requirements (TMDL) for the Chesapeake Bay watershed. The GI Plan provides opportunities to satisfy these requirements in a way that integrates with broader City and County goals. A major goal of the GI Plan is to ensure that projects developed to meet these various regulations are complementary to one another and also support and reinforce other City initiatives and plans.

LANCASTER CITY LONG TERM CONTROL PLAN UPDATE


Part VII

Environmental Protection Agency

Combined Sewer Overflow (CSO) Control Policy; Notice

In early 2008, the EPA initiated correspondence with the City of Lancaster requesting information on the City's Long-Term Control Plan (LTCP) for combined sewer overflows. In response to EPA's correspondence, the City prepared an update to its LTCP in mid-2009 and continues to make system upgrades and communicate progress on these improvements and the ongoing long term planning. The City is continuing to discuss the adaptation of the CSO control program to include green infrastructure through this planning effort and has already initiated implementation of green infrastructure throughout the City to reduce combined sewer flows as well as to respond to the evolving requirements of the Chesapeake Bay TMDL and associated Watershed Implementation Plan (WIP) being prepared by PA DEP. The following is a concise summary of the City's actions to continue to reduce the impacts of CSO's on the Conestoga River[1]:

The Nine Minimum Controls (NMC) Report for the City of Lancaster was completed in December 1996, and was approved by PADEP in November 1997. It provides for ongoing maximization of the use of existing facilities for capture of CSO and proper maintenance of the CSS. The Final CSO Long Term Control Plan (LTCP) Report for the City of Lancaster is dated September 1998, and was approved by PADEP in December 1998. Since this time, the City has implemented over $18 million in capital improvements to provide increased conveyance and treatment capacity and treatment process improvements to treat nutrients and wet weather flows.

Since 2000, over $13 million has been spent on the following treatment process improvements:

- Permission was granted for a CSO-related bypass at the AWWTF in an NPDES permit issued on October 26, 2005. This work was completed in February 2009 under City Contract 2008-13, South Train Flow Diversion Project and this project now treats up to an additional 15 million gallons of wet-weather flow for each storm event.
- In 2005 and after a Biological Nutrient Removal (NR) pilot project started in 2001, the City led all other plants in the state with regard to nutrient discharges to the Chesapeake Bay and opted in early for National Pollutant Discharge and Elimination NPDES permit nutrient limits of 8 mg/L for Total Nitrogen and 1.0 mg/L for Total Phosphorus at the projected 2010 annual

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[1] City of Lancaster, Amended CSO Long Term Control Plan Status Report, October 2010

average flows. Therefore, the City's NPDES permit limits did not change after January 1, 2007 and the City is continually in a nutrient credit status due to the performance of the AWWTF exceeding the load reduction requirements within the state credit trading framework.

- Treatment process improvements constructed as part of the Act537 Upgrade project were constructed to allow for handling and disposal of the additional solids transported to the AWWTF by the increased wet-weather flow capture. In addition, a lime stabilization system was implemented, activated sludge tanks and belt filter presses rehabilitated. The AWWTF control building was renovated in 2009.
- Phase 1 of a wastewater facilities plan was prepared in 2010 and rehabilitation of aerator gear boxes completed at the AWWTF.

Over $2.4 million in studies and upgrades were performed for the combined sewer system including:

- Rehabilitation of the Water Street Sewer and Engleside sewer culverts in 2002 and extensive sewer replacement in 2008
- A comprehensive flow monitoring study was conducted in the North, Stevens Avenue and Engleside drainage basins in 2009 and the City plans to install enhanced permanent monitoring for these basins in 2011.
- The City continues to upgrade and expand its Geographic Information System (GIS) and develop a computerized maintenance management system to guide the repair and replacement of the old combined sewers most in need. Development and initial calibration of a comprehensive, system wide hydraulic model was completed by ARRO Consulting, Inc., in July 2010. The main objective of the model is to establish a fully functional, calibrated model for the City's sewer collection and conveyance system which can be used to identify hydraulic bottlenecks, surcharged pipes, and overflowing manholes simulated within the sewer system under specific flow conditions and to evaluate proposed design modifications at the City's pumping stations for CSO reduction.
- Condition assessments were performed for the North and Stevens Avenue Force Mains in 2010

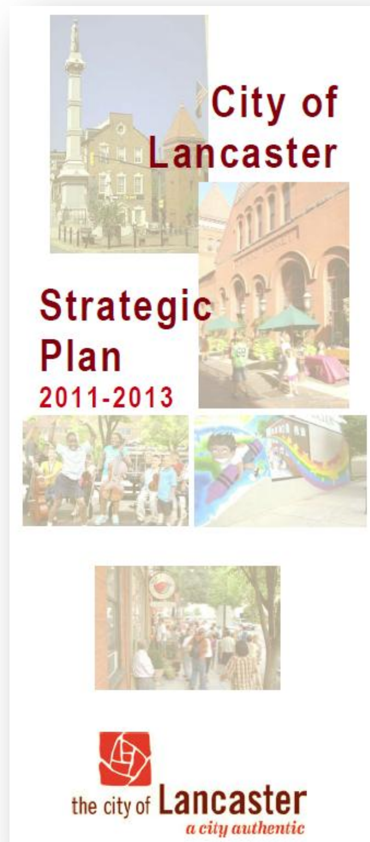
$1.9 million in upgrades to pump stations were completed, including:

- Upgrades to the Susquehanna Pumping Station and installation of grinder pumps at the North Pumping station in 2000.
- The Stevens Avenue pump station received valve and communicator replacements and a backup generator to improve reliability in 2010.
- The City is beginning the process of designing the expansion of its North sewage pumping station (NPS) and optimizing the conveyance of flows through the force main shared by the Steven Avenue Pump Station to be able to handle future growth as well as capture additional combined sewage overflows. Upgrades for the Main Pumping station are also in progress.

LANCASTER CITY STORMWATER ORDINANCE

The City has already adopted a “first flush” control requirement as part of its stormwater ordinance (Chapter 260) that is applied within the combined sewer area to require capture of the first 1-inch of rainfall for retention. For exempted regulated activities (§ 260-15) where the proposed site is only served by a combined sewer, the first flush and stormwater flow is required to be directed to landscaped areas that can detain the first flush or into private stormwater detention facilities and not into the public sewer or private inlet. Stormwater detention facilities for this must conform to the technical standards for first flush detention facilities in the *Construction Specifications and Guidelines Manual of the City of Lancaster*. For MS4 regulated earth disturbance activity, stormwater management will prohibit non-stormwater discharges into the storm sewer system and require post-construction stormwater runoff controls.

All development and land disturbance activities require submission of a drainage plan or a first flush control plan to the City for review. The standard application form for review of development plans to be implemented is provided in Appendix D and the form includes basic information about the size of the development project and impervious areas being created and how they will be managed. Innovative methods, such as basins, rooftop storage, grass pavers, subsurface facilities, and vegetated strips are encouraged and subject to the approval of the City Engineer (described in § 260-9). Presently this ordinance applies to newly-created impervious cover.



LANCASTER CITY STRATEGIC PLAN

The City of Lancaster Strategic Plan identifies seven strategic focus areas that the City’s is advancing including a goal to be Green and Sustainable. Within each focus area, specific directions are indicated that reflect the priorities of the City and a list of indicators or measures of success established to track progress with respect to each of these priorities. The strategic plan has been updated to include metrics recommended in the GI Plan, which embraces the green and sustainable
movement because it:

- Will help to minimize the daily wear and tear on the City’s very old infrastructure.
- Will lessen the City’s negative impact on surrounding environments including the Chesapeake Bay.
- Will allow the City to serve as a role model encouraging its residents and businesses to support green and sustainable initiatives.
- Signifies a modern city that cares about the environment.

LANCASTER CITY URBAN TREE CANOPY ASSESSMENT

During the fall of 2010, the PA Department of Conservation and Natural Resources (DCNR) Bureau of Forestry undertook an Urban Tree Canopy (UTC) analysis for the City of Lancaster. The purpose of the project was to baseline the existing tree canopy in the County and City and to project what a possible tree canopy could be if addition restoration of the urban forest was undertaken.

The UTC project was undertaken as part of the Chesapeake Bay Program's Directives. The Directives are directly tied to the President's Executive Order 13508 which requires Total Maximum Daily Loads (TMDLs) of pollutants to be set for the Chesapeake Bay and the eight river basins that flow into it. Urban tree planting is one technique, or best management practice (BMP), that a municipality can receive credit for when sediment and nutrient allocations and limits are required in nearby waterways. Appendix F provides a copy of the study and the potential benefits of increasing tree canopy to reducing stormwater runoff are discussed in Chapter 5.

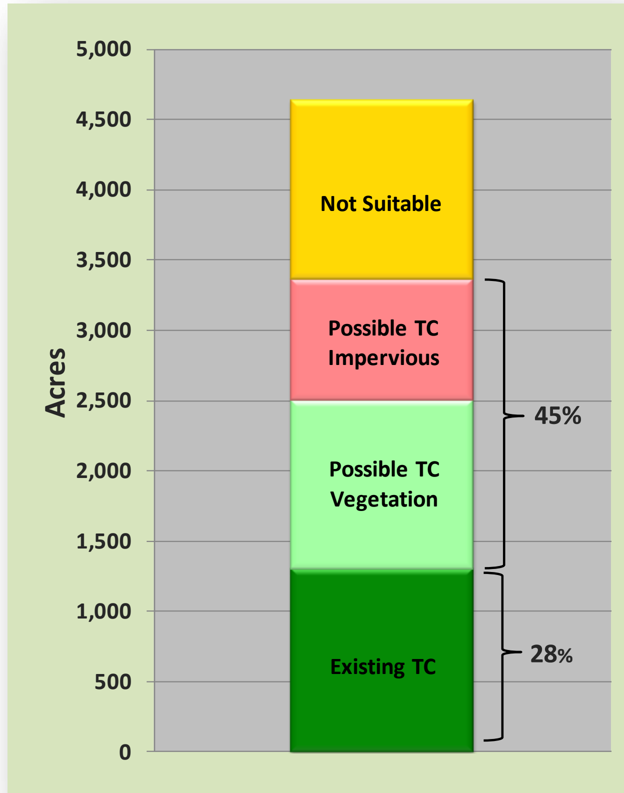


Figure 1-6 The Urban Tree Canopy study completed by PA DCNR identified existing tree canopy at 28% of the City area with potential for an additional 45% (DCNR, 2011)

The study used a detailed land cover map derived from high resolution aerial imagery, elevation data, community planimetric data (e.g. roads, hydrology, and buildings) zoning, and high resolution imagery are used in ArcGIS and object-based image analysis software to extract features and determine the existing tree canopy. The analysis covered the entire city and was developed with accuracy sufficient to be scalable to the parcel level at 95% or greater accuracy. The results of this analysis will be used to prioritize and target tree plantings and preservation practices, and form the basis for refining the City's objectives and long term goals for green infrastructure implementation and urban forestry. As a next step, the Chesapeake Bay forester for the Bureau of Forestry will assist the City and its partners in developing strategies and goals for preserving and increasing tree canopy by utilizing the analysis. The UTC project will help combine efforts and direct refinements in green infrastructure development that pertains to trees and other land cover classes. Initial estimates of tree planting goals and their relationship to reducing stormwater runoff were developed in Chapter 5 and strategies will be adjusted or developed to establish an urban tree canopy goal for the City and the ongoing tree inventory is completed.

INTEGRATION WITH OTHER FEDERAL, STATE AND REGIONAL EFFORTS

The GI Plan was developed to be consistent with and reinforce federal, state and regional comprehensive, regional resource management or economic development plans and to connect these plans and their respective output to seek more efficient ways of achieving water quality improvements to the Conestoga River and Chesapeake Bay.

CHESAPEAKE BAY PROGRAM

President Obama issued an executive order in May 2009 which declared the Chesapeake Bay a national treasure and ushered in a new era of shared federal leadership, action and accountability. In May 2010, the "Strategy for Protecting and Restoring the Chesapeake Bay Watershed" was developed under the executive order and focuses on protecting and restoring the environment in communities throughout the 64,000-square-mile watershed and in its thousands of streams, creeks and rivers. The strategy includes using rigorous regulations to restore clean water, implementing new conservation practices on 4 million acres of farms, conserving 2 million acres of undeveloped land and rebuilding oyster beds in 20 tributaries of the bay.

The City of Lancaster recently received an *Innovative Nutrient and Sediment Reduction Program* grant from the Chesapeake Bay Program and National Fish and Wildlife Foundation through the U.S. Environmental Protection Agency. The federal funds, combined with matching City monies, will be used to fund green infrastructure demonstration/pilot projects intended to divert stormwater runoff that now goes into the city's sewer system and provide a model to reduce impacts to the Chesapeake Bay. Lancaster City has been identified as one of the largest urban sector contributions of nitrogen and phosphorous. A long term strategy to implement green infrastructure techniques in Lancaster will not only reduce nutrient and sediment discharges but also serve as a model for other Class 3 cities in Pennsylvania.

EPA CHESAPEAKE BAY TOTAL MAXIMUM DAILY LOAD (TMDL)

The U.S. Environmental Protection Agency (EPA) under the Chesapeake Bay Program is leading a major initiative to restore polluted streams in the Chesapeake Bay watershed that currently do not meet water quality standards. Working with state partners, EPA is setting binding limits on nutrient (nitrogen and phosphorus) and sediment pollution through a total maximum daily load (TMDL) analysis or pollution "diet". The TMDL is a tool of the federal Clean Water Act and sets accountability measures in the form of pollutant load reduction requirements that ensure cleanup commitments are met by communities that are tributary to the Chesapeake Bay. The present program seeks to ensure that all practices to fully restore the health of the Bay are in place by 2025, with 60% of the actions taken by 2017.

CONESTOGA WATERSHED TOTAL MAXIMUM DAILY LOAD (TMDL)

The TMDL and required pollutant reductions have been divided among each of the 6 jurisdictions (Maryland, Virginia, Pennsylvania, Delaware, New York, West Virginia and the District of Columbia) and published in form of a Watershed Implementation Plan (WIP) for each state and its watersheds. The WIPs are released and refined in Phases and document the required pollutant reductions for each watershed, community, and pollutant source type (i.e. agriculture, point source discharges such as wastewater treatment plants, and urban runoff). Lancaster City resides within the 475 square mile Conestoga River watershed which is tributary to the Susquehanna River watershed and Chesapeake Bay. The Conestoga River watershed TMDL is being prepared by the Susquehanna River Basin Commission (SRBC) as part of the TMDL program. As part of this effort, the SRBC is undertaking a watershed characterization which inventories contaminant sources. The data obtained in the study will assist SRBC in determining the pollutant load for the watershed, which will then be allocated to various contaminant sources (agricultural, urban, wastewater treatment plants, etc.) within the Conestoga Watershed. The pollution "diets" will then be incorporated into NPDES Permits for treatment plants or MS4 and agricultural permits.

Urban runoff and CSOs are a major focus of the required reductions and urban redevelopment as well as suburban development in Municipal Separate Storm Sewer Systems (MS4s) areas must incorporate better runoff controls. The EPA Nutrient Innovations Task Force recently estimated that 50% of the existing urban landscape will be redeveloped by 2030 and controls on redevelopment practices are expected to play a bigger role in the future to reduce pollution to the Bay. The projects defined in this GI Plan complement Lancaster County's smart growth focus on redevelopment and infill development by demonstrating opportunities to reduce pollutants through green redevelopment practices. The demonstration projects discussed in Chapter 4 and the citywide implementation vision in Chapter 5 illustrate the potential to demonstrate efficient, simultaneous progress on nutrient reduction, urban stormwater management and smart growth. These approaches are expected to play a large role in addressing the City's share of the required pollution reductions spelled out in the WIP.

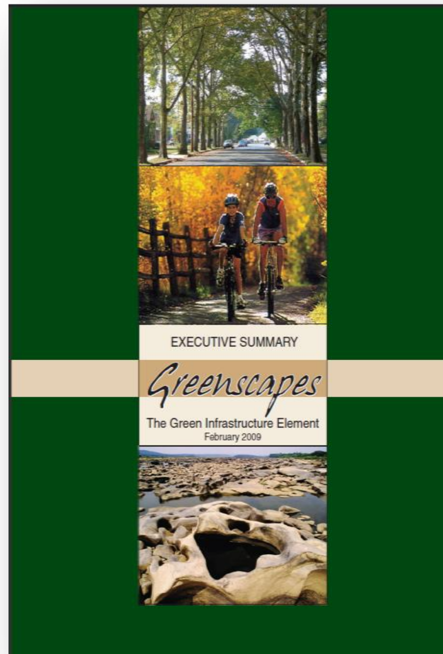
PENNSYLVANIA PHASE 1 WATERSHED IMPLEMENTATION PLAN (WIP)

In September 2010, Pennsylvania Department of Environmental released a Draft Phase 1 Watershed Implementation Plan (WIP) and on November 29, 2010 released the Final Phase 1 WIP as mandated by EPA. The Phase 1 WIP identifies pollution reduction targets by major watershed and source sector (agriculture, stormwater, wastewater treatment plants, etc.) and includes a description and schedule of actions to be taken to achieve the reductions. Now that EPA has approved the WIP, the plan will be supported by a series of two-year milestones for achieving specific near-term pollution reductions needed to keep pace with long-term restoration commitments. Pennsylvania and EPA will monitor the effectiveness of those actions in order to assess progress and water quality improvement. EPA would take federal steps if there are insufficient commitments in a jurisdiction's implementation plan or a failure to meet the established two-year milestones.

INTEGRATION WITH COUNTY AND LOCAL PLANNING EFFORTS

LANCASTER COUNTY GREENSCAPES PLAN

The GI Plan aligns very closely with the goals and objectives of *Greenscapes: The Green Infrastructure Element of the Lancaster County Comprehensive Plan*. A primary goal of *Greenscapes* is to "restore ecological connections and natural resource systems throughout Lancaster County's urban, suburban, and rural areas." One objective specific to that Goal is to incorporate green elements throughout the built environment. The GI Plan will accomplish this objective by providing conceptual plans that incorporate rain gardens, tree trenches, vegetated curb extensions, and other green infrastructure techniques throughout the City's urban environment. A second Objective to the County's Goal is to "enhance the quality of surface and groundwater resources." The City of Lancaster's GI Plan will achieve this objective by providing detailed guidance on demonstration projects that capture stormwater and infiltrate it into the local groundwater table as well as allow for increased evapo-transpiration, rather than sending it through the combined sewer system.



The Lancaster County Planning Commission is in the process of updating the water resources element for the County Comprehensive Plan. A priority of this plan is the development of demonstration sites to improve water quality management practices. To date, there is an over reliance on conventional stormwater management practices such as detention basins. Detention basins take up a lot of valuable land, have a low efficiency rating with respect to water quality improvement and do not offer as many benefits as other newer stormwater management practices. Given the County's goal to achieve higher density in urban areas, we need to expand knowledge and understanding of stormwater management techniques that can preserve valuable land and provide a greater return on investment.

LIVE GREEN

LIVE Green

LIVE Green's mission is to build strong and healthy communities through environmental projects. The mission is accomplished by convening key players from all three sectors (nonprofit, for-profit and government) around pivotal opportunities; facilitating and leveraging government and private resources to invest in effective strategies; facilitating direct financial support to the extent possible; and serving as a catalyst for new environmental initiatives.

Key focus areas for LIVE Green include energy conservation, greening facilities, and an Urban Stormwater Initiative. As part of the Urban Stormwater Initiative, LIVE Green has initiated residential outreach in key areas including helping homeowners install and manage rain barrels, tree plantings, native habitat restoration, and rain garden workshops. In addition, LIVE Green is a lead partner in the development and implementation of the Lancaster Roof Greening program.

CITY OF LANCASTER COMPREHENSIVE PLAN

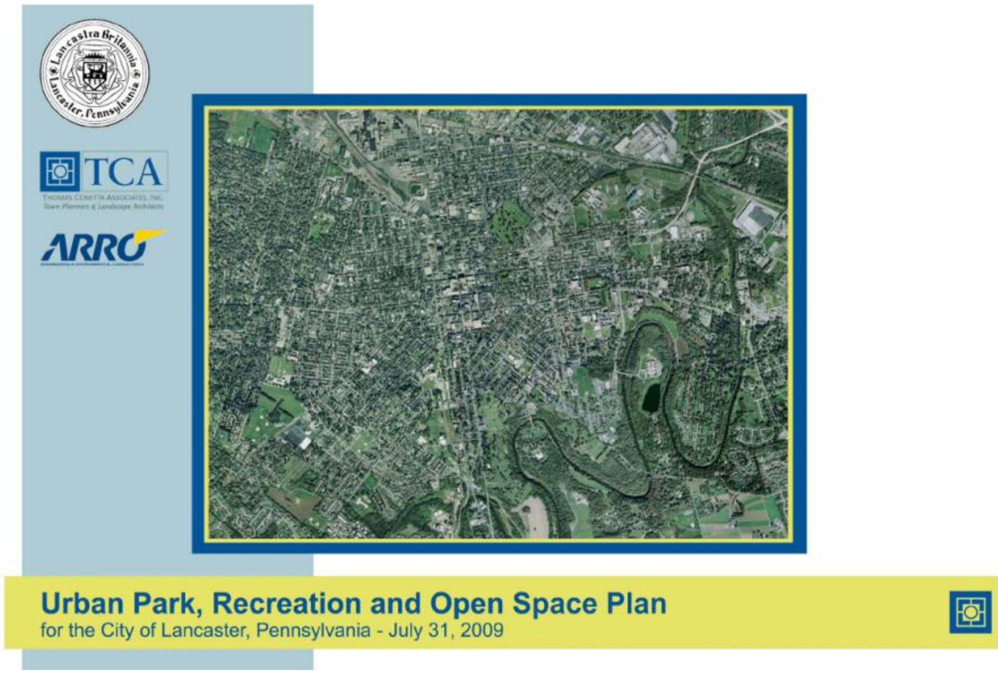
The City of Lancaster's Comprehensive Plan, originally adopted in 1993 and reaffirmed by City Council in 2007, contains the following objective in its Facilities and Services chapter: "The City should assure that adequate water, sanitary sewer and stormwater facilities are provided." The Plan states the following: "Storm and sanitary sewers exist as a combined system in many areas of the city. Heavy storms can and do overload the system; therefore, it is recommended that a capital improvements program be undertaken to improve upon and upgrade the sewer collection system and, where possible, separate the storm from the sanitary system." Given the realization of the pollutants generated in separate stormwater, it is considered to be cost prohibitive to separate combined sewers. The GI Plan and the proposed demonstration project will ultimately divert stormwater runoff away from the combined sewers and redirect it into green infrastructure improvements, such as infiltration beds and rain gardens, where the pollutants will be removed and the water will infiltrate into the groundwater table.

MULTI-MUNICIPAL COMPREHENSIVE PLAN

Growing Together, the multi-municipal comprehensive plan adopted by the City of Lancaster and ten neighboring municipalities in 2007, contains the following objective: "Carefully maintain existing sewer and water utilities within Designated Growth Areas." Wet weather flows cause excessive wear on the City's wastewater collection and treatment systems. The GI Plan will achieve this objective by proposing demonstration projects that will reduce the amount of stormwater runoff entering the combined sewer system thus increasing capacity to handle domestic sewage needs within designated growth areas served by the City's wastewater treatment plant.

URBAN PARK RECREATION & OPEN SPACE PLAN

Initiated by the City of Lancaster, the Urban Parks, Recreation and Open Space Plan (UPROS), was adopted in 2009. The plan includes specific goals and objectives, as well as conceptual redevelopment plans, for the 30 unique park sites located within the City of Lancaster. The GI Plan builds off the conceptual redevelopment plans and maximizes green infrastructure techniques that could be implemented in the redevelopment of select parks. Green Parks are a key green infrastructure program recommended in the GI Plan.


TCA
ARRO
Urban Park, Recreation and Open Space Plan
for the City of Lancaster, Pennsylvania - July 31, 2009

Chapter 2 – Program Goals

MISSION: To provide more livable, sustainable neighborhoods for City residents and reduce combined sewer overflows and

GOALS

1. Strengthen the City's economy and improve health and quality of life for its residents by linking clean water solutions to community improvements.
2. Create a green infrastructure program to respond comprehensively to the multiple water quality drivers to maximize the value of the City's investments meeting the numerous overlapping environmental regulations and programs.
3. Use green infrastructure to reduce nutrients and erosive flows from urban storm water runoff and combined sewer overflows to support the attainment of Pennsylvania's Watershed Implementation Plan for the Chesapeake Bay.
4. Achieve lower cost and higher benefit from the City's infrastructure investments.
5. Establish Lancaster City as a national and statewide model in green infrastructure implementation.

OBJECTIVES

1. Implement a results-oriented City-wide philosophy and processes to incorporate green initiatives to deliver sustainable clean water and energy.
2. Facilitate the efforts of residents and businesses to incorporate green strategies and technologies into their homes and facilities.
3. Build capacity within Lancaster City government to effectively plan and employ green infrastructure strategies.
4. Advance objectives in the Lancaster County *Greenscapes* Plan to reduce nutrient/sediment loads to the Bay and local waters.
5. Establish a technical partnership in which federal, state and local governments work together to maximize environmental improvements for each dollar spent on urban infrastructure.
6. Implement a comprehensive suite of green infrastructure demonstration projects on City-owned lands to provide examples and to incentivize private land owners to manage storm water on-site.
7. Incorporate green infrastructure as a significant and accepted component of the City's Long Term CSO control plan and stormwater management programs.
8. Enable City residents and businesses to guide and implement the green infrastructure program
9. Seek and obtain grant funding to implement green infrastructure projects.
10. Support Lancaster County's Smart Growth achievements by providing smart urban renewal in Lancaster City.
11. Provide an outreach and education program to promote the benefits of green infrastructure to City businesses and resident.

Chapter 3 – Existing Conditions / Project Area

EXISTING CONDITIONS

Lancaster City covers a land area of 7.34 square miles and includes 241 acres of publicly-owned park land and playgrounds, 135 miles of streets of which 27 miles are classified as alleys within the Conestoga River watershed with a small portion within the Little Conestoga Creek watershed and a minor portion draining to the Mill Creek watershed. The City is the urban center of one of the nation's most productive agricultural farming areas.

A Geographic Information System (GIS) was used to document and analyze the existing conditions for the planning area. Data was organized into a geospatial database to support the mapping of existing resources and other land and environmental features which are critical inputs for green infrastructure planning. The existing resource inventory includes maps of land use, impervious surfaces and open space opportunities which support specific locational strategies to implement green infrastructure technologies.

HYDROLOGIC RESOURCES

The City of Lancaster resides in the Conestoga watershed, a tributary of the Susquehanna River watershed as shown in Figure 3-1. The Susquehanna River watershed is the largest major tributary draining into the 64,000 mi^2 Chesapeake Bay watershed, shown in Figure 3-2. The majority of study area drains to the Conestoga River, with portions of the north/northwest township draining to the Little Conestoga River. The topographic relief and watersheds of the study area are shown in Figure 3-3.

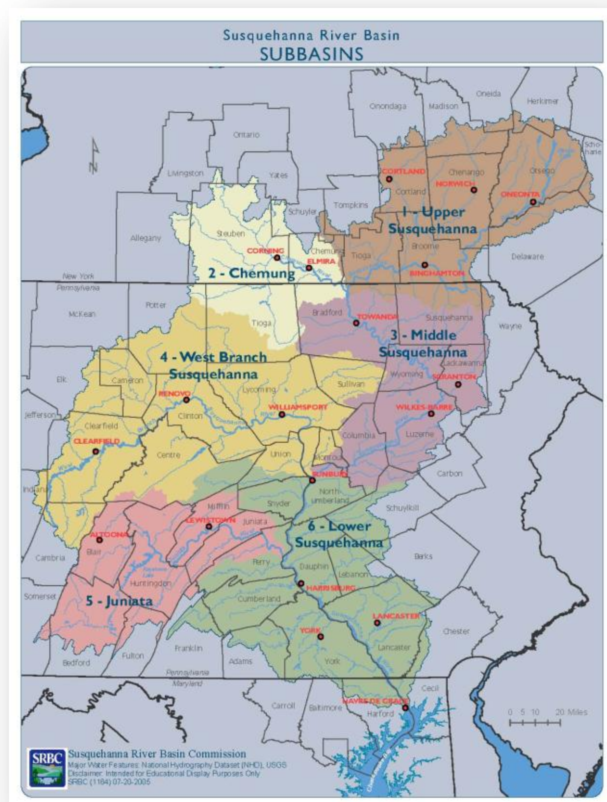


Figure 3-1 – City of Lancaster (upper) and City of Lancaster Location within the Susquehanna River Basin (lower image)

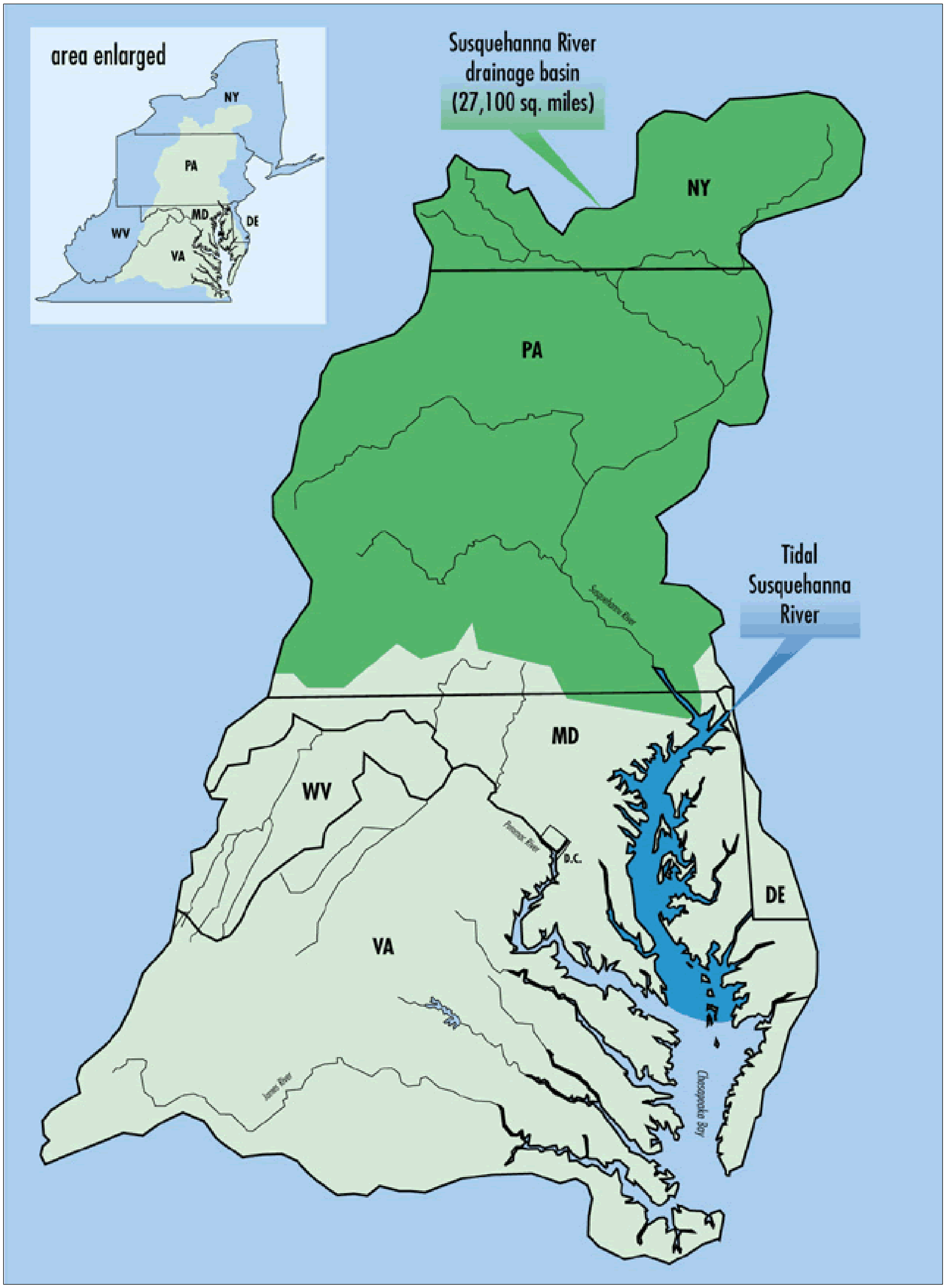


Figure 3-2 – Susquehanna Watershed draining into the Chesapeake Bay Watershed (Source: Chesapeake Bay Foundation)

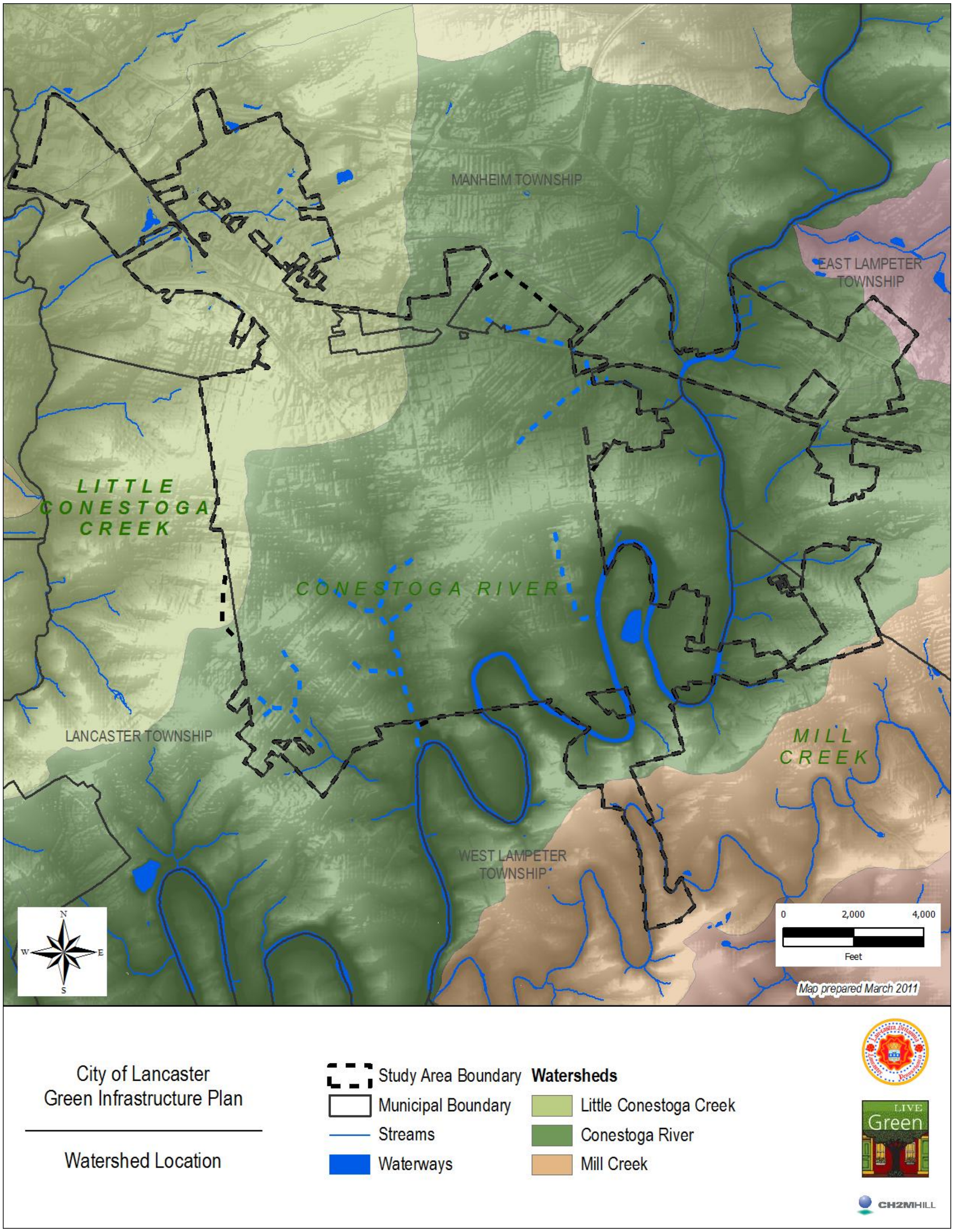


Figure 3-3 - Lancaster City topography and watershed features

303D/305B LISTING STATUS

The Pennsylvania State water quality standards regulations (PA Code, Title 25, Chapter 93) protect four stream water uses: aquatic life, fish consumption, potable water supply, and recreation. These regulations provide for protection of the aquatic life in the Conestoga River as a warm water fishery and for migratory fishes. These uses require that the river water quality supports the maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat. Migratory fish passage provides for the maintenance and propagation of anadromous and catadromous fishes and other fishes which move to or from flowing waters to complete their life cycle in other waters.

The state provides periodic reviews of waterbodies to assess the attainment of these standards as part of sections 303(d) and 305(b) of the Clean Water Act. Figure 3-4 provides a summary of the §303(d) and §305(b) listing (also called the Integrated List) status for stream segments that have been evaluated for attainment of their designated uses. Segments determined as not attaining are considered impaired waters and may require that a TMDL to be developed for that waterbody. In the case of the Conestoga River, a specific TMDL is not required, but the river and its watershed needs to be included in the Chesapeake Bay TMDL and watershed implementation plan since the Conestoga is upstream of the Bay and contributes pollution to it.

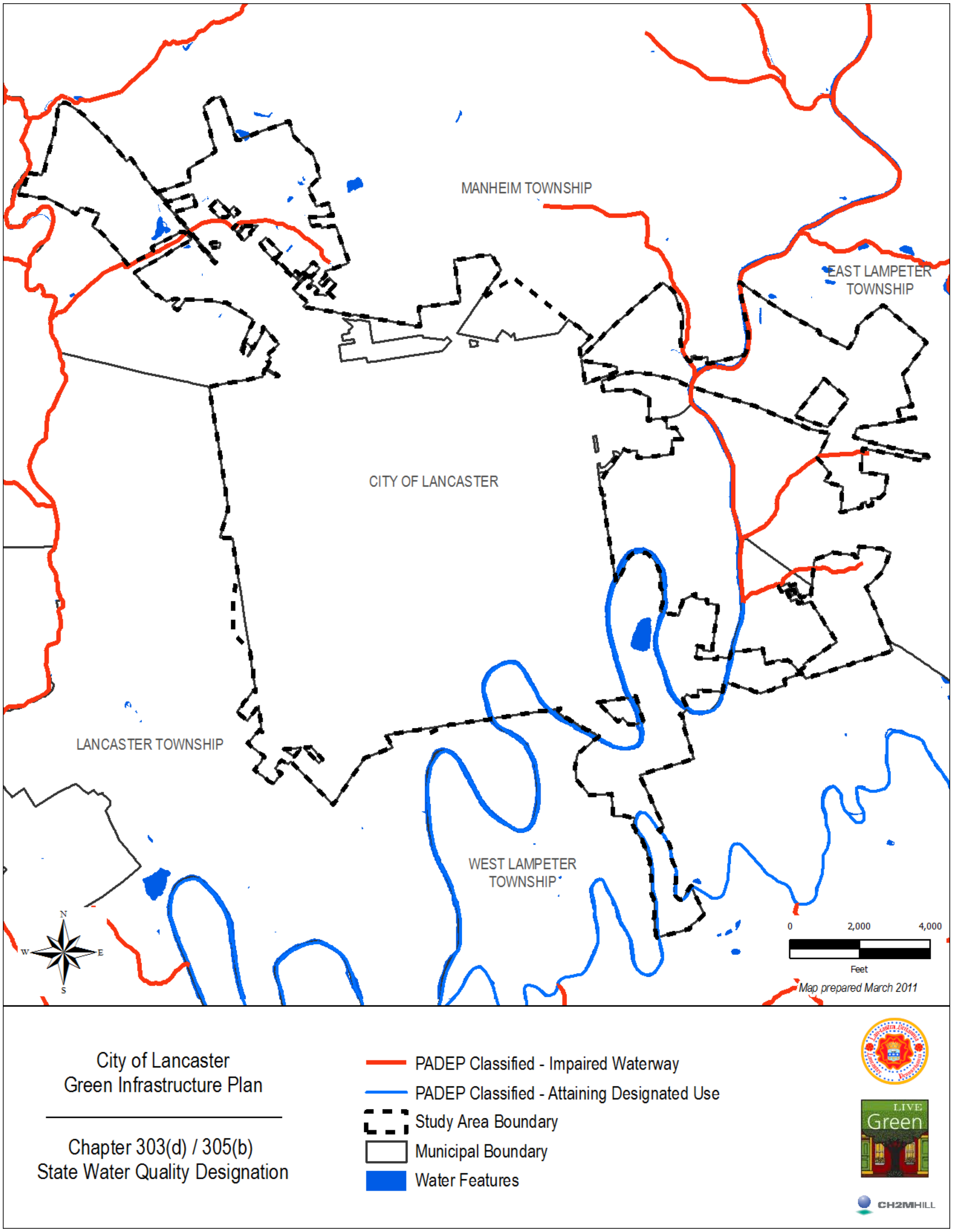


Figure 3-4 - PA DEP 2010 State Water Quality Standards 303d / 305 B Listing Status

HISTORIC HYDROLOGY

Historically, the City of Lancaster had numerous surface water features, as shown in Figure 3-5. Like older cities across the nation, some surface water features were buried and replaced with combined sewers, which drained the overlying developed areas.

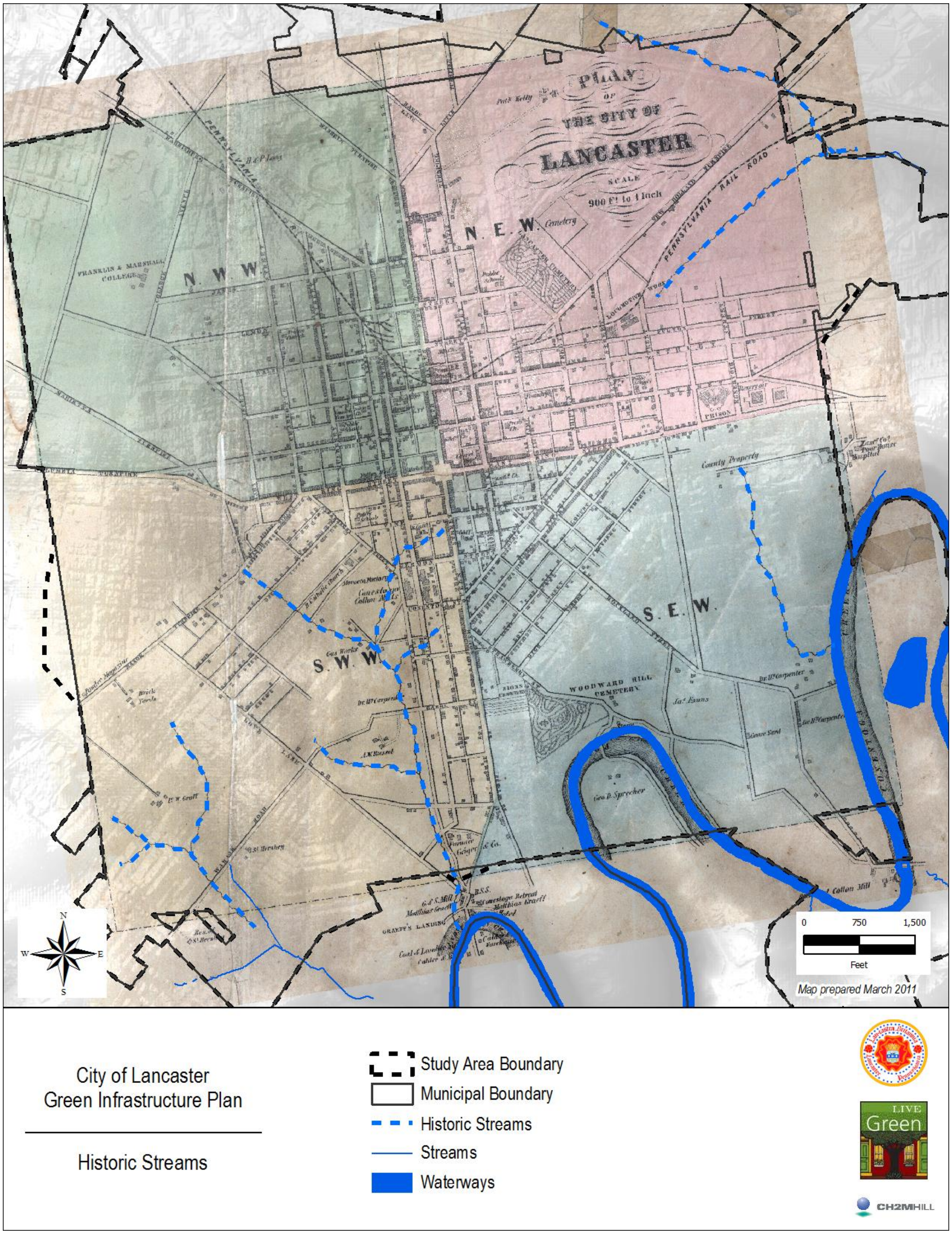


Figure 3-5 – Map of Lancaster City showing historic surface water features

SURFICIAL GEOLOGY

The majority of the City of Lancaster is situated in the Conestoga formation, found in the Piedmont lowlands. Limestone bedrock (carbonate geology) is prolific throughout the study area (Figure 3-6). Limestone is a fairly young rock that is easily eroded and is often characterized by karst topography (limestone land with sinkholes, caves, subsurface depressions, and mines). All stormwater systems in karst areas should be designed and constructed to minimize the risk of subsidence with appropriate site investigations conducted to evaluate the specific geologic and soil conditions for each site. Special care should be taken not to overly concentrate stormwater in systems that can infiltrate and vegetation should be incorporated in stormwater systems where possible to maximize evapotranspiration and restore the natural hydrologic function to a site.

The green infrastructure technologies recommended in this plan (e.g., tree trenches, green roofs, bioretention, and porous pavements) generally adhere to these guidelines. For more details on stormwater management in karst areas, see Chapter 7 of the Pennsylvania Stormwater Best Management Practices Manual (PADEP, 2006). The Lancaster City stormwater ordinance also has requirements related to stormwater facilities in carbonate areas (see Appendix C). Much of the study area is also likely to have urban soil conditions that may impact the type or configuration of green infrastructure measures. Site investigations and soil testing can help identify historic cut and/or fill, soil compaction, building debris, contamination, pH, lack of plant nutrients and other issues.

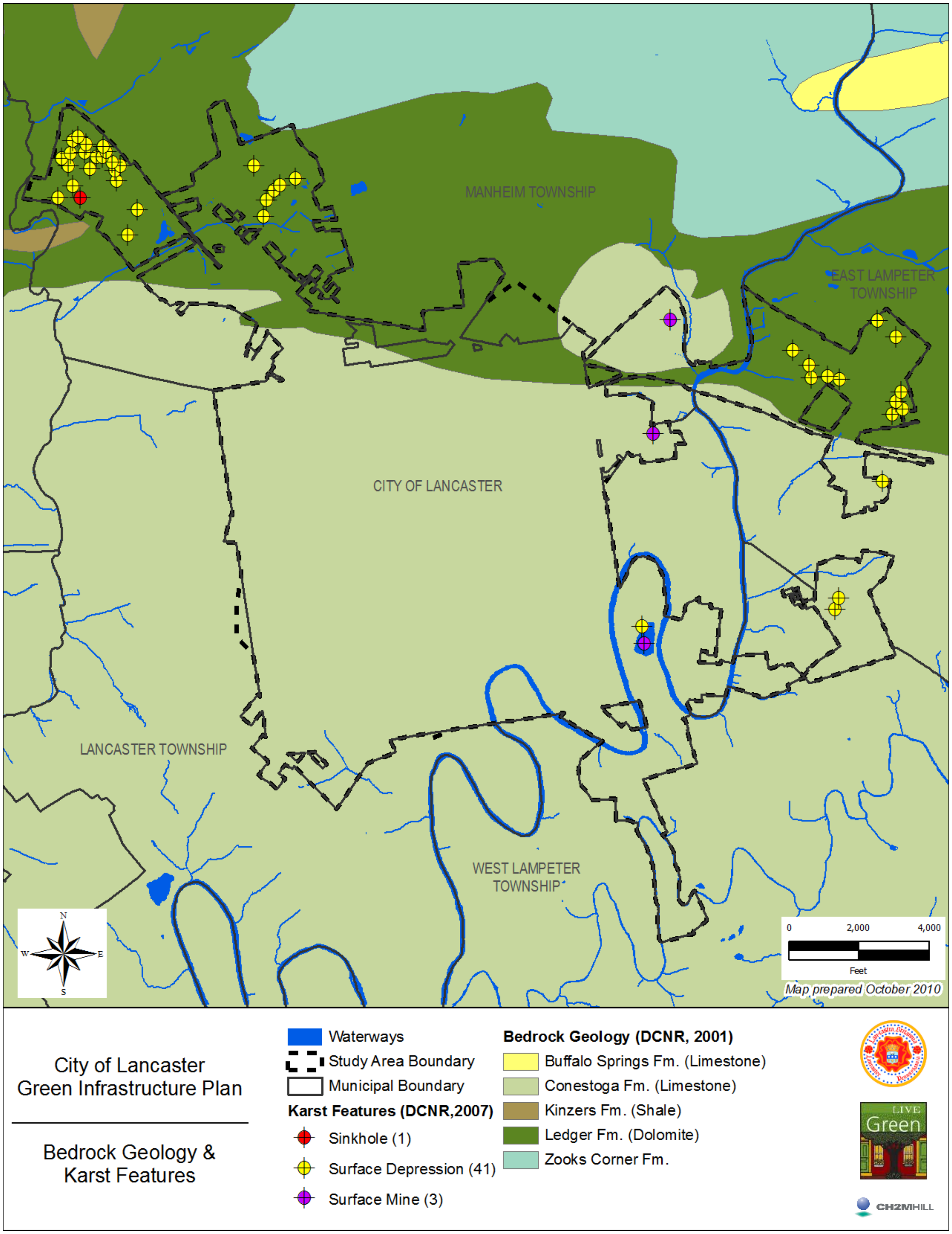


Figure 3-6 – Bedrock Geology and Karst features within the Study area (Source: PA DCNR)

BROWNFIELDS

As shown in Figure 3-7, there are seven properties that fall under the 2009 Brownfields program, five of which are owned by the City. According to the U.S. EPA, the term "brownfield site" refers to "real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant". Some additional properties fall under the 2009 list of Land Recycling Cleanup Program (also shown in Figure 3-7), eight of which have achieved compliance and are considered inactive.

The EPA Nutrient Innovations Task Force recently estimated that 50% of the existing urban landscape will be redeveloped by 2030. Pennsylvania's *Land Recycling and Environmental Remediation Standards Act* (Act 2), which outlines clear cleanup standards based on risk and provides an end to liability when that cleanup standard has been achieved, has been applied to numerous sites throughout the City. In some cases "cleanup" involves the use of institutional and/or engineering controls, which could preclude the infiltration of stormwater or restrict other activities on the site. For this reason, it will be important to investigate any limitations to the use of the site when considering the incorporation of green infrastructure on a brownfield site. See Figure 3-7 for the general location of sites identified by the PA DEP as Brownfields or Land Recycling Cleanup Locations (Pa Department of Environmental Protection, eMapPA, 11-22-10).

EPA's Brownfields Program Website (www.epa.gov/brownfields) provides information on and resources for assessing, cleaning up and redeveloping brownfields, including grant funding opportunities. A PDF fact sheet – Design Principles for Stormwater Management on Compacted, Contaminated Soils in Dense Urban Areas – describes design considerations and general principles for using green infrastructure on brownfield sites, and has a page of additional resources for further consideration. Brownfield sites in the City of Lancaster were not initially targeted for demonstration projects due to the possibility of redevelopment in the future and to minimize site uncertainties. It is generally more cost-effective to implement green infrastructure as part of the redevelopment process. A brownfield sites are considered for redevelopment or other uses, the possible inclusion of green infrastructure can be evaluated on a case by case basis.

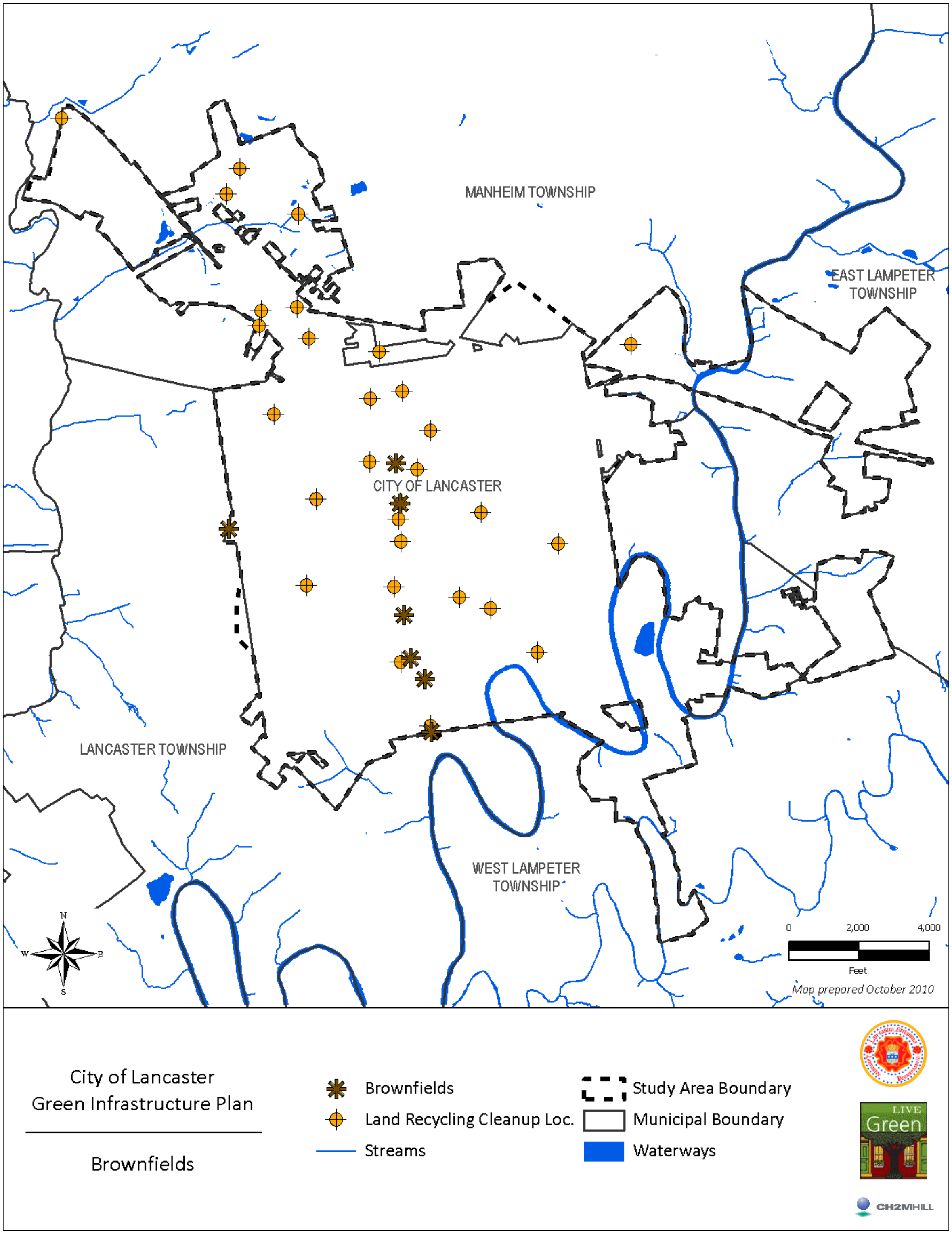


Figure 3-7 – Locations of Brownfields and Land Recycling Clean-up sites in the Study area (Data Source: PADEP)

LAND USE CLASSIFICATION

Parcel based land use data was provided by Lancaster County IT Department, GIS Division. Land use classes were assigned to parcels using the standardized classification scheme provided by the Lancaster County Assessment Office and is shown in Figure 3-8 and 3-9.

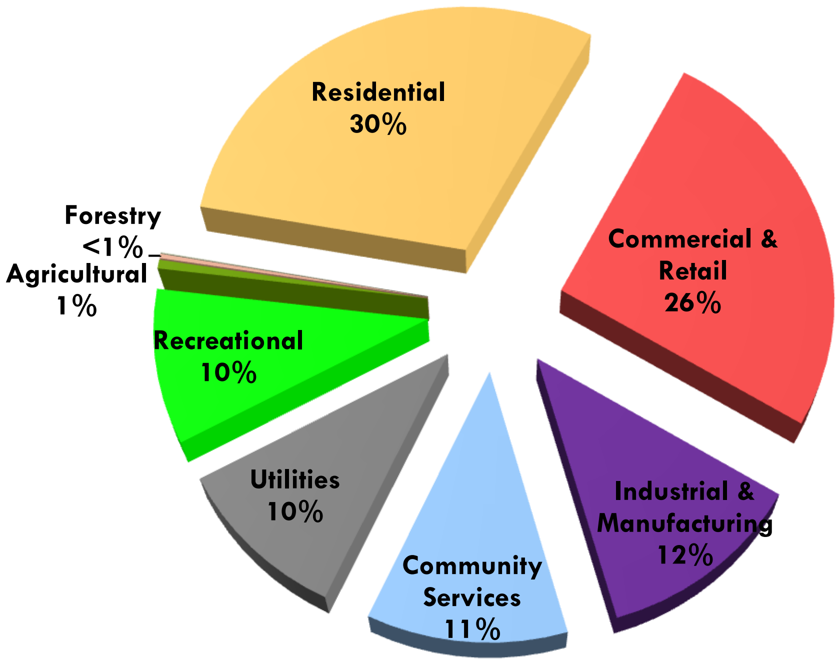


Figure 3-8 – Land Use Composition in the Study area (Source: Lancaster County, 2010)

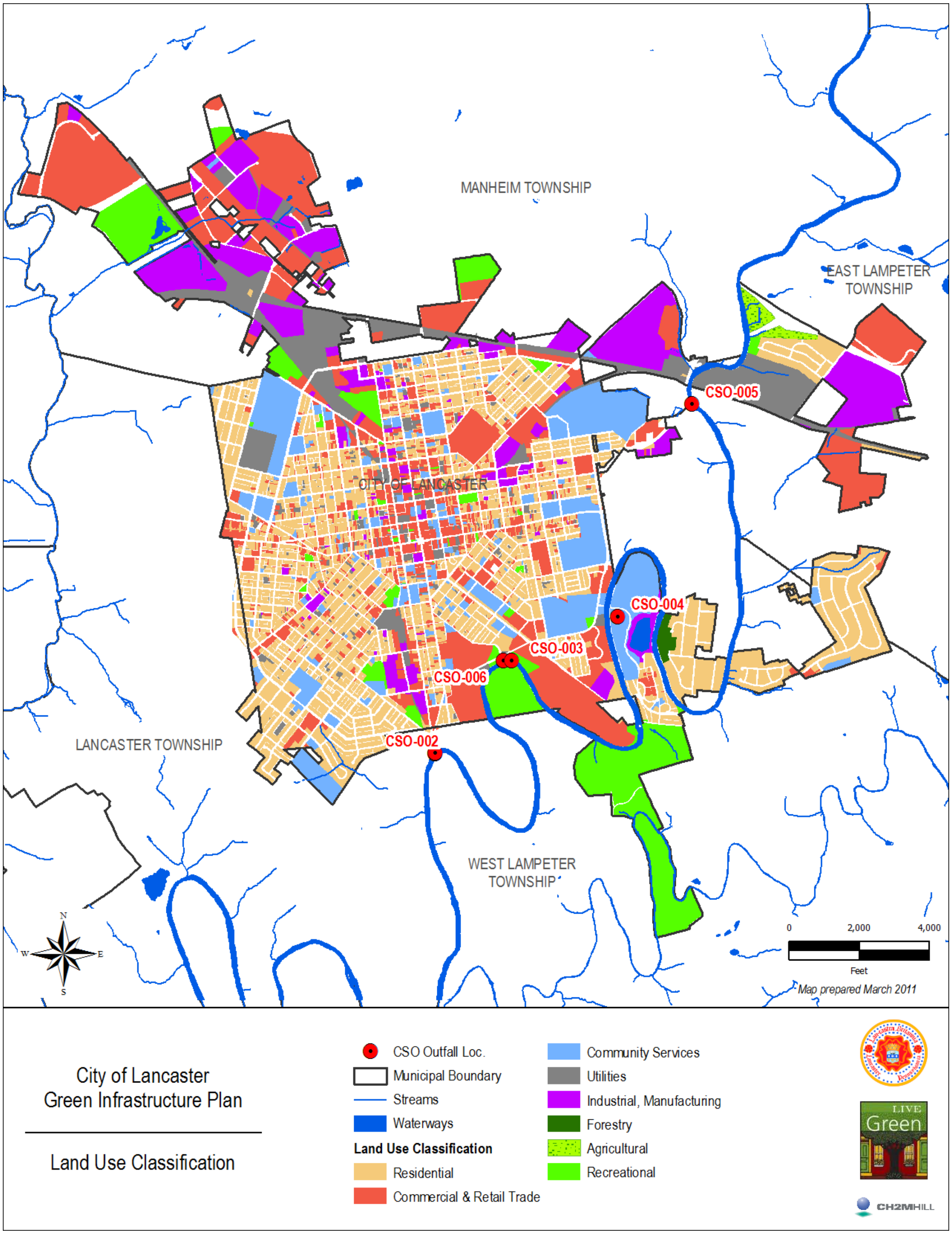


Figure 3-9 – Land Use Characteristics across the Study area (Source: Lancaster County, 2010)

IMPERVIOUS AREA ANALYSIS

Stormwater impacts are directly linked to the amount and type of impervious land cover. This section describes the process and methodology used to analyze the impervious areas of the City. The impervious area data was used to develop specific green infrastructure concept plans shown in Chapter 4, as well as to scale the potential widespread impact over increasing levels of implementation over the long term as discussed in Chapter 5.

DATA SOURCES & LIMITATIONS

A comprehensive GIS database was developed to identify specific impervious area types and suitable locations for GI implementation. Land cover data layers were provided by the County of Lancaster IT Department, GIS Division. High resolution aerial orthophotography, downloaded from the online geospatial data clearinghouse, Pennsylvania Spatial Data Access (PASDA), was provided by Pennsylvania Department of Conservation and Natural Resources' (PA DCNR) Bureau of Topographic and Geologic Survey and U.S. Geological Survey (USGS). All land cover data was provided in shapefile format and then converted into ArcInfo coverage for the analysis. The final output layers were converted into a geospatial database feature class. Table 3-1 below summarizes the data source and year for the data used in the analysis.

Table 3-1 - GIS data layers used for the impervious cover analysis

Dataset	Source year	Provider
Aerials	2008	PAMAP Program
Buildings	2005	Lancaster County GIS Div.
Parking Lot	2001	Lancaster County GIS Div.
Roadway	2005	Lancaster County GIS Div.
Driveway*	2005	Lancaster County GIS Div.
Parcels	2006	Lancaster County GIS Div.
Sewershed Areas	2010	City of Lancaster DPW
Inlets, Sewers, Outfalls	2010	City of Lancaster DPW

**Driveway features were reclassified as Roadways in the final impervious cover data layer*

Features used to create the impervious cover layer include building footprints, roadways, driveways, and parking lots. It should be noted that the purpose and scope of this plan did not provide for updating the GIS to reflect changes that may have occurred to actual land cover since the time that the source map data was collected. For example, the parking lot layer was developed in 2001 by directly digitizing map sources and as a result, the layer is missing some recently developed parking areas that have been added since the map was originally developed. For the purpose of planning for demonstration projects in Chapter 4, this does not have any affect. In the case of the City-wide implementation analysis is Chapter 5, the City believes the true parking lot coverage in the study area may be underrepresented due to development that has occurred since the GIS data was collected.

However, since 2004, the City has had a first flush requirement for new impervious coverage to manage the first one-inch of storm flow on site. So much of the new impervious area has had some stormwater management provided to these areas when they redeveloped.

In addition, sidewalks were not digitized in prior data conversion efforts and therefore were not included in the impervious cover analysis for the study area. Other impervious surfaces that exist but were omitted from the impervious area analysis due to the unavailability of GIS data to describe them include: recreational courts, playfields, pathways, patios and other right-of-way features.

Until the impervious cover dataset is made more current, the difference is considered to be more conservative (i.e. there is more opportunity to implement GI technology). The inability of the GIS to describe the omitted impervious features was not considered to significantly limit the planning analysis of citywide benefits discussed in Chapter 5 or the development of viable demonstration projects in Chapter 4. A parallel analysis that is being performed by DCNR to create accurate land cover data for the purpose of defining existing and potential tree canopy for the City is nearing completion. This new data may improve the impervious area classification and is discussed in more detail in Chapter 4.

IMPERVIOUS AREA CLASSIFICATION METHODOLOGY

The impervious area analysis was undertaken in a three-step process described below.

STEP 1 - STUDY AREA ANALYSIS

The first step in the analysis involved creating a study area boundary in GIS that could be used as the accurate boundary file to clip all the contributing datasets. An accurate study area boundary layer was critical to the overall analysis since there was a disparity between the City boundary and the combined sewershed area boundary. As shown in Figure 3-10, small portions of Engleside and North basins actually drain portions of the adjacent municipalities of Manheim Township and Lancaster Township. The hatched line depicts the study area boundary and the solid line depicts the municipal boundary. Results are discussed in the Results Section below.

STEP 2 - IMPERVIOUS AREA ANALYSIS

In the second step of the analysis, individual land cover datasets were combined and overlaid in GIS, and an impervious cover GIS layer was created for the entire study area. This step involved overlaying individual land cover data layers, as well as editing the land cover data attributes to retain land cover classification. Once the impervious cover data layer was created, the resulting file was overlaid with the study area data layer in order to summarize information based on location within the CSO sewersheds and City boundary. The parcel data layer, which is helpful in sorting out ownership questions, was not used for this portion of the analysis. Figure 3-11 shows the impervious cover classification for the project study area. Results are presented and discussed in detail later in this Chapter.

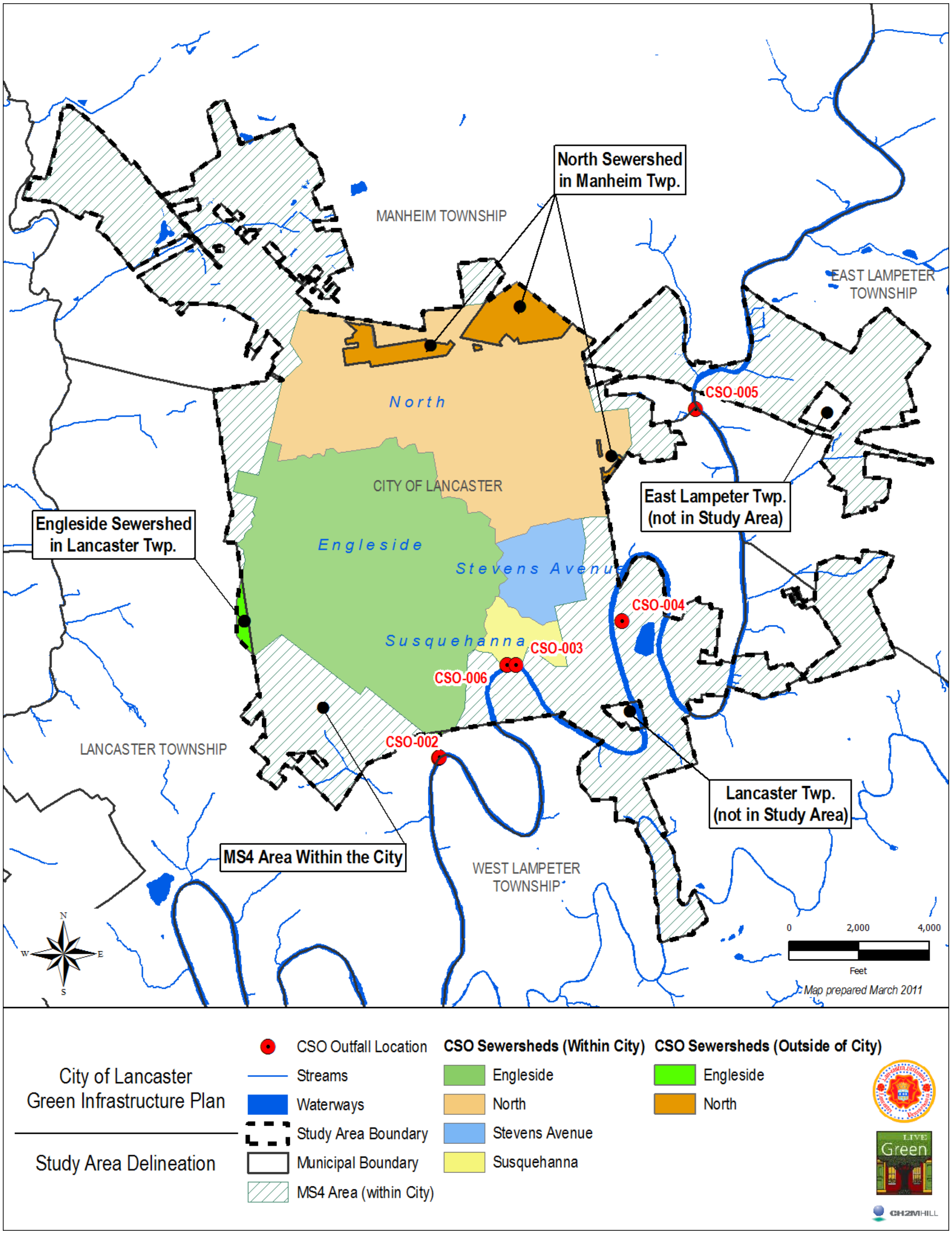


Figure 3-10 - Green Infrastructure Plan Study Area is the combination of the City of Lancaster boundary along with total drainage area served by combined sewers

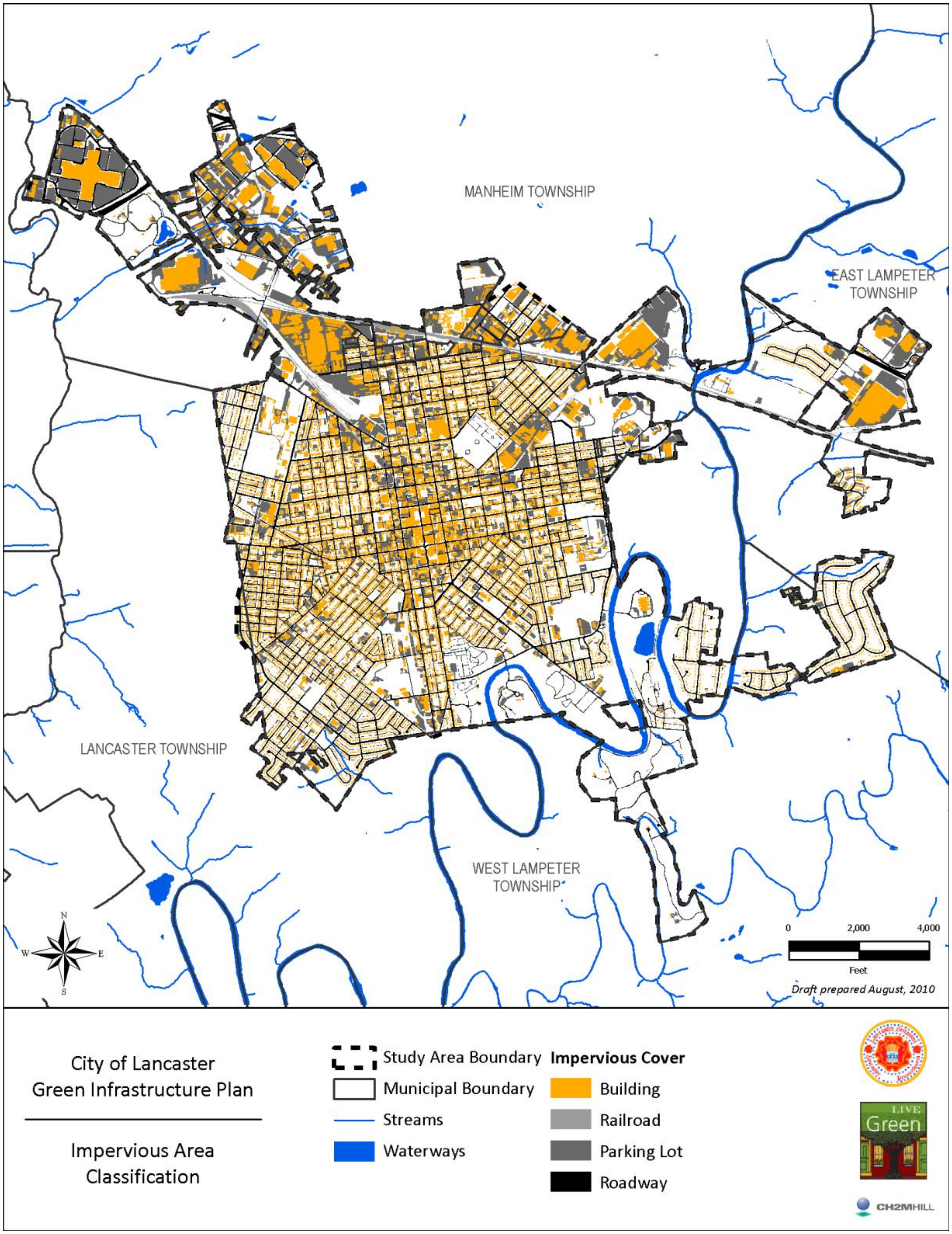


Figure 3-11 - Impervious Area classification across the Study area

STEP 3 – PARCEL BASED LAND USE AND OWNERSHIP ANALYSIS

In the final step of the analysis, the impervious data layer was combined with the parcel data layer in order to determine land cover types based on land ownership categories. This data was used as the basis for developing GI concept plans and base mapping as shown in Chapter 4, as well as the calculation of runoff reductions achievable through green infrastructure discussed in Chapter 5.

Parcel data was provided by the Lancaster County IT Department, GIS Division and was prepared by the Lancaster County Assessment Office. The parcel layer contained attributes that were critical for the overall analysis, including OWNERNAME (name according to files in the Assessment Office database) and LANDUSECD (an Assessment Office Code that indicates land use for the parcel). However, data included in both OWNERNAME and LANDUSECD attributes needed to be edited in order to get the parcel layer into a format that would expedite the analysis. The OWNERNAME field contained entries with multiple inconsistent formatting; for example, “City of Lancaster” and “Lancaster, City of”. This field was edited to standardize the owner names for all publicly owned parcels.

Because the County parcel data was developed in 2006, it may not reflect actual land use cover in cases where a parcel has redeveloped or ownership has changed. For example, in 2009, a large vacant/park parcel (Sunnyside Peninsula) was transferred from County ownership to City ownership and other examples were noted in reviews of the draft plan. These discrepancies are not believed to have significantly changed the impervious areas or the balance of City public/private ownership over the City as whole and were deemed suitable for planning purposes to assess the citywide benefit of GI in Chapter 5. A recommendation is included in Chapter 6 to update the ownership information as necessary, in conjunction with County Assessment office.

The LANDUSECD field was populated with a 3-digit numeric code that corresponds to a given land use classification. Lancaster County provided a look up table which defined each of the codes in the parcel file. The coding numbers fall between 100 and 990, with each code having a Major Property Classification or higher level classification that allows for more generalized land use characterization, and a specific land use designation. For example, any parcel coded “113” was determined to be a Residential Property Class with a “One Family Dwelling” land use designation. The look up table data was joined to the attributes of the parcel data and the results were used in the land use portion of the analysis. Table 3-2 shows the generalized land use designations for the parcels in the study area used for the map shown in Figure 3-9 above.

Table 3-2 - Property Classification Look-Up Table (Source: Lancaster County)

Code	Property Classification (Major)
100	Residential
200	Industrial – Manufacturing & Processing
300	n/a
400	Trans-utility – Transportation, Communication & Utilities
500	Commercial and Retail
600	Community Service
700	Cultural Activities, Entertainment & Recreational
800	Agriculture
900	Forestry and Related Activities

STUDY AREA / DRAINAGE AREA RESULTS

The size of the study area (defined as the City of Lancaster and the CSO sewershed area which includes a small portion in Manheim Township and Lancaster Township residing outside the City) is 4,835 acres (or 7.6 square miles). Areas outside of the study area – areas not in the City and not in the CSO sewersheds – were not included in the analysis. The total area of the City of Lancaster is 4,703 acres (ac), or 7.34 square miles (sm). About 45% of the City, or 2,112 ac (3.3 sm), drains to a combined sewershed, according to GIS analysis and a small portion of the combined sewershed (133 ac) drains portions beyond the City boundary. The total land area served by the Combined Sewer System is 2,245 ac. Over half of the City of Lancaster (2,591 acres, or 54% of the total area) drains into separated stormwater sewers system. Table 3-3, Figure 3-12, and Figure 3-13 describes this information.

Table 3-3 - Drainage Area by Sewershed and City Limit (See Figure 3- 11 for mapped version)

Drainage Area	Within City Boundary (ac)	Outside City Boundary (ac)	Study Area Total (ac)
Engleside CSO	1,000	13	1,013
North CSO	913	120	1,033
Stevens Ave CSO	130		130
Susquehanna CSO	69		69
Separate/MS4	2,591		2,591
TOTAL	**4,703**	**133**	**4,835**

CSO Area: 2,245 Ac.

Study Area: 4,835 Ac.

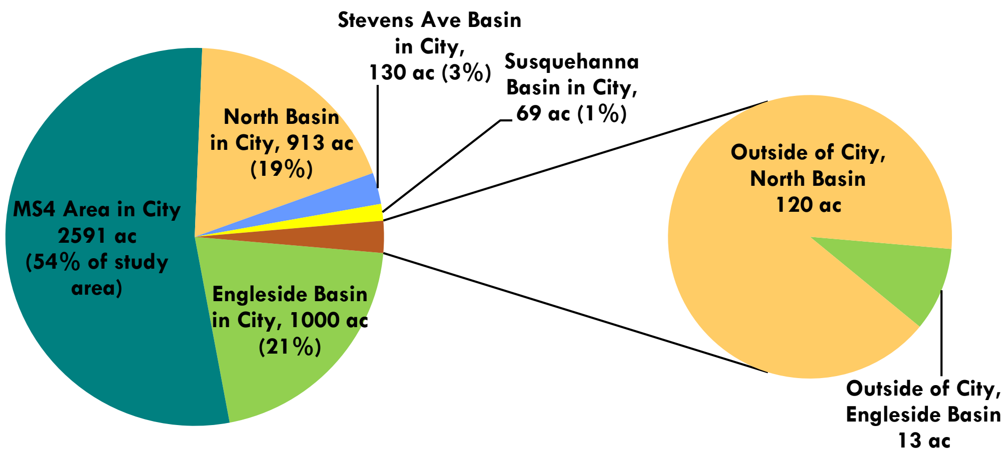


Figure 3-12 - Drainage Area broken down by Sewershed within and outside of City Limits

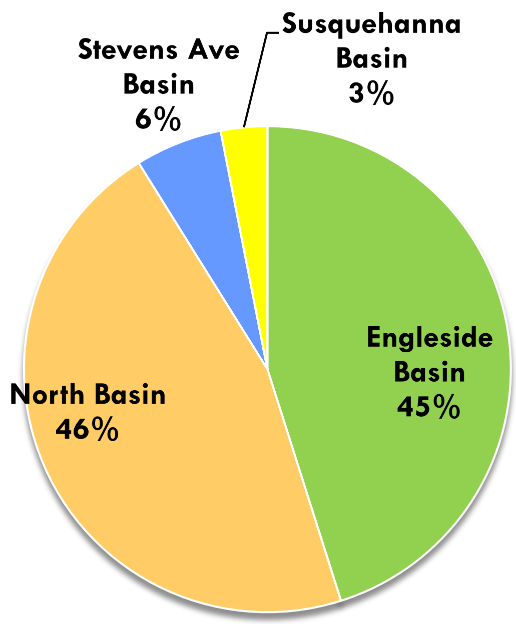


Figure 3-13 – Combined Sewersheds in the Study area as a Percentage of Total CSO Area

SUMMARY RESULTS OF IMPERVIOUS COVER ANALYSIS

According to the GIS analysis performed as part of the GI Plan, the City of Lancaster has 865 acres of buildings and 649 acres of parking lots. As described above, the impervious data creation process utilized data layers that are somewhat dated and therefore may likely be under-representing the true imperviousness of the study area that may have occurred from development and redevelopment. The results based on this analysis are still representative of the impervious areas on a citywide basis and suitable for estimating the overall impervious characterization of the City for overall GI planning purposes

The impervious area data layer that resulted from the process described above summarized information for the City of Lancaster, the CSO sewersheds and the Study area (overlap of the City and sewershed area). The total impervious cover within the City of Lancaster, shown in Table 3-4, is 2,079 acres. The total impervious area for the CSO sewersheds is shown in Table 3-5 and Figure 3-14. The North Basin is 60% impervious and the Engleside Basin is 55% impervious, based on the GIS analysis performed for the GI Plan. The total impervious area broken out for the entire study area, shown in Table 3-7, is 2,166 acres. Since sidewalks were not explicitly included in the GIS data, an assumption of 124 acres of sidewalks was included in the calculations based on 255 miles of sidewalk (Rob Ruth verbal communication) and an assumed average width of 4 feet. This brings the total impervious cover in the study area to 2290 acres for the Green Calculator Analysis (Chapter 5).

Table 3-4 Summary of impervious cover area (acres) in the City of Lancaster

Impervious Cover	Area, ac
Building	865
Parking Lot	649
Railroad	46
Roadway/ Driveway	518
Total Impervious Area	2,079

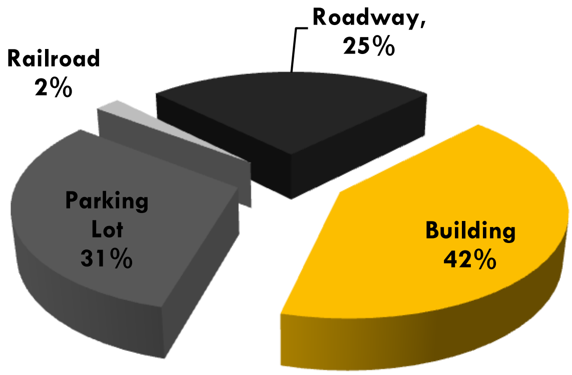


Table 3-5 Summary of impervious cover area (acres) broken out by CSO Sewersheds

CSO Sewershed	Total Area, Ac	IMPERVIOUS COVER AREA (AC)					Percent Impervious
		Building	Parking Lot	Railroad	Roadway	TOTAL	
Engleside Basin	1,012	285	107	0	162	554	55%
North Basin	1,033	273	195	18	131	617	60%
Stevens Ave Basin	130	33	10	0	20	62	48%
Susquehanna Basin	69	9	7	0	12	28	40%
TOTALS	2,244	600	319	18	324	1,261	56%

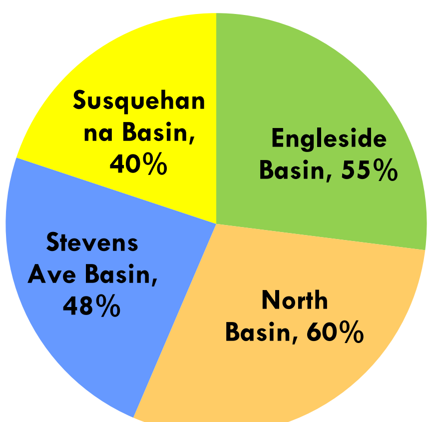


Figure 3-14 – Percent Impervious of CSO sewersheds

Table 3-6 Summary of impervious cover area (acres) for study area (which includes area outside of the City)

Impervious Cover	Area, ac
Building	898
Parking Lot	684
Railroad	46
Roadway	537
Total Impervious Area	2,166

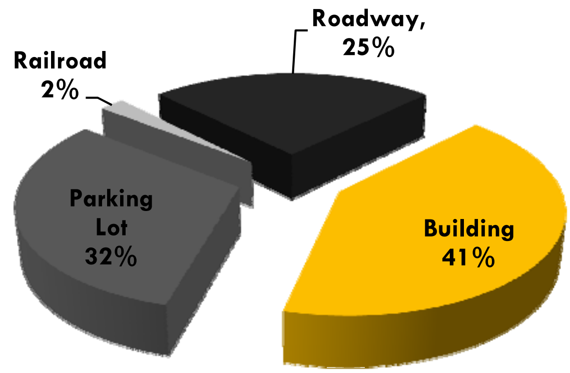
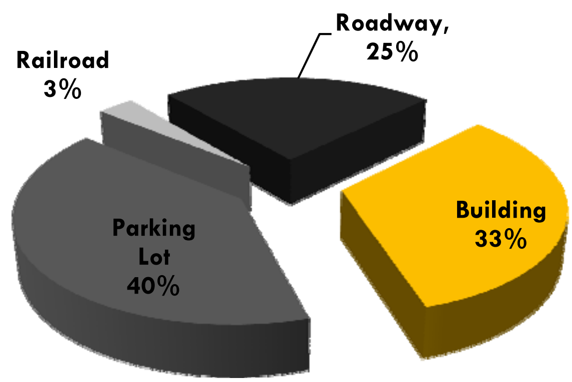


Table 3-7 Summary of impervious cover features for the MS4 (separated stormwater drainage area) portion of the study area

Impervious Cover	Area, ac
Building	297
Parking Lot	366
Railroad	28
Roadway	213
Total Impervious Area	904



PUBLICLY OWNED PARCELS

Overall, there are 363 parcels that are owned by a public entity totaling 632 acres (13 %) of the study area. Publicly-owned parcels are the basis for the analysis and overall implementation of GI techniques, as these parcels offer a defined process for incorporating GI into redevelopment or new land development process. Table 3-8, Figure 3-15 and Figure 3-16 summarize the major categories of public ownership across the entire study area.

Table 3-8 – Total number and area (acres) of public owned parcels for the study area

Public Ownership - Major Category	Total # of Parcels	Total Parcel Area, ac
City	195	185
School	20	175
Parks	17	241
Public, Other*	131	31
Total	363	632

** Includes parcels owned by the County, City of Philadelphia, State, and Federal entities*

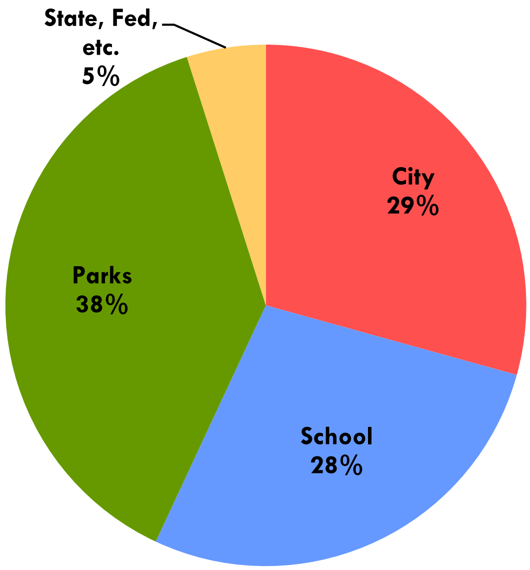


Figure 3-15 – Distribution of publicly-owned parcels in the study area

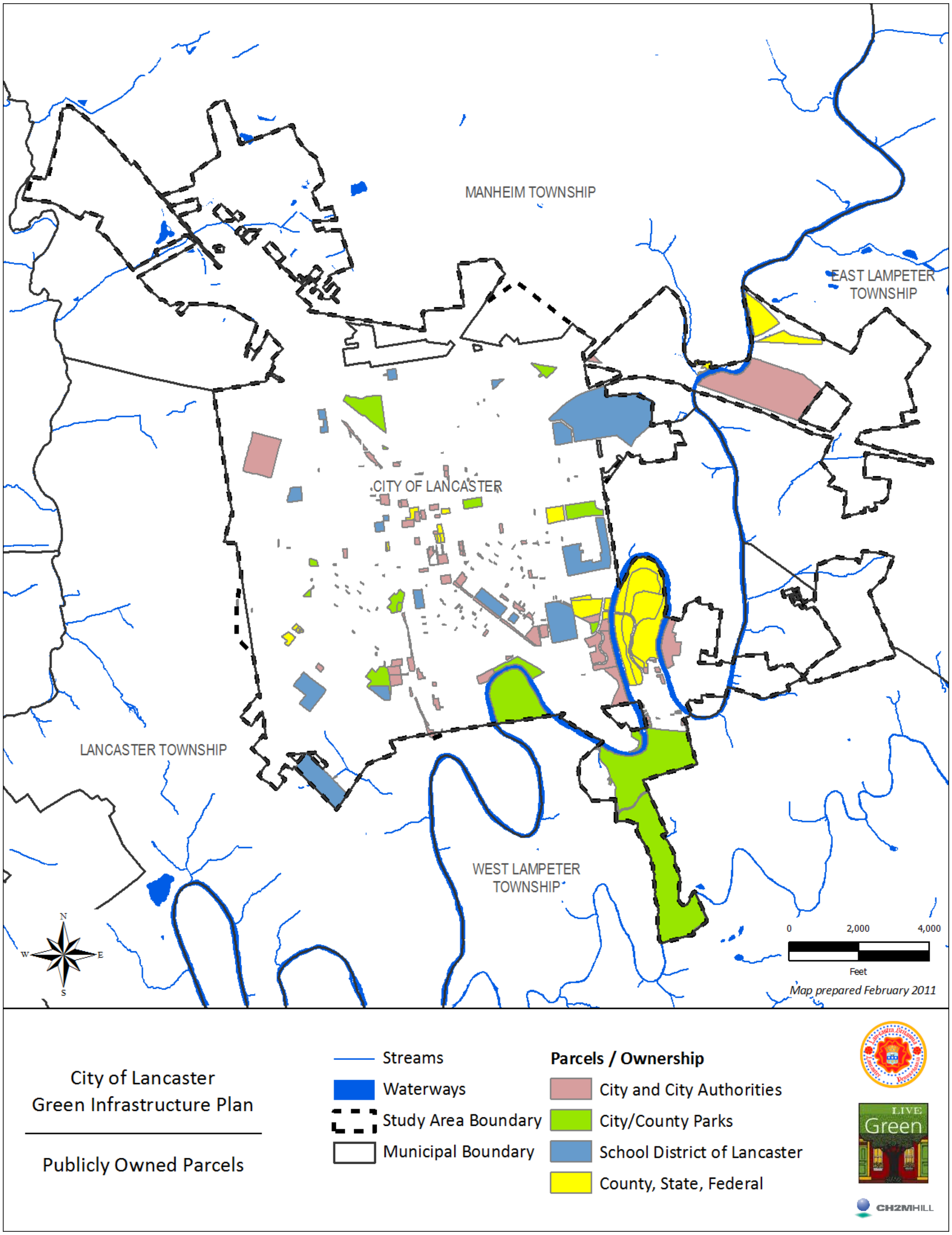


Figure 3-16 – Map showing location of publicly-owned parcels in the Study area

PUBLICLY-OWNED PARK PARCELS

Park parcels typically have a low amount of impervious cover within the parcel itself, but have the ability to manage adjacent stormwater runoff (from adjacent roadways and sidewalks, for example) within the park parcel itself. Because park parcel have a unique GI implementation strategy, this ownership category was treated uniquely in the GI plan analysis.

The parcel layer was queried and any publicly-owned parcel with land use code 764 (Federal/State Park), 765 (County Park), or 766 (Municipal Park) were reclassified as "Parks" in the attribute table. Park parcels make up the largest category of publicly-owned parcels in the study area, totaling 241 acres over 17 parcels. Both the County and City own various parcels, with the City owning a higher number of parcels, but the County controlling a higher land area, summarized in Table 3-9. Table 3-10 provides a summary of impervious cover for all of the publicly-owned parcels in the study area.

Table 3-9
Publicly-Owned parcels by owner category

Ownership	Number of Parcels	Area, ac
City	12	30
County	5	211
Total	17	241

Table 3-10
Impervious cover for publicly-owned parks parcels

Impervious Cover	Area, ac
Building	16
Parking Lot	13
Roadway *	1
Total	30

* *Note – Impervious areas (land cover features) were clipped to the parcel boundary (ownership category). Parcels typically exclude roadways, sidewalks, and other right-of-way features which is why this impervious cover category has a seemingly low value.*

CITY-OWNED PARCELS

City ownership is one of the most important categories for implementation of GI techniques as the City controls the redevelopment of the parcel and land development process. Table 3-11 shows the total number and area (acres) of city-owned parcels in the study area. A number of City authorities, including the Housing Authority, the Parking Authority, and the Redevelopment Authority own significant portions of real estate in the study area and were included in this analysis. The City and various authorities own 195 parcels totaling 185 acres. The City itself owns 76 parcels totaling 151 acres within the study area. Once the total parcel area was assessed, the impervious cover was determined so that GI implementation could be calculated. Table 3-12 and Figure 3-17 shows the summary of impervious cover for city owned parcels.

Table 3-11 - Number and Area of City and Authority-Owned Parcels in Study Area

Ownership	Number of Parcels	Area, ac
City	76	151
Parking Authority	12	8
Redevelopment Authority	8	2
Housing Authority	99	25
Total	195	185

Figure 3-17 – Distribution of types of City owned parcels in the Study Area

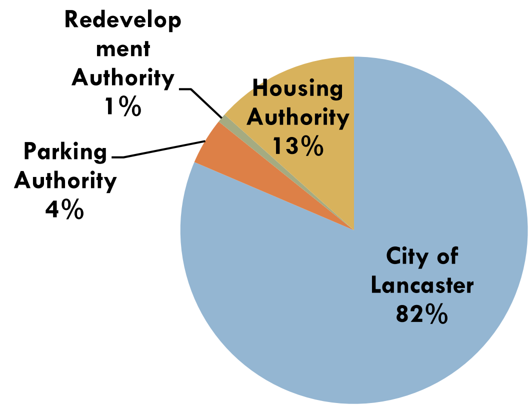


Table 3-12 - Summary of Impervious Cover for City Owned Parcels in Study Area

Impervious Cover	Area, ac
Building	16
Parking Lot	13
Roadway*	1
Total	30

** Note – Impervious areas (land cover features) were clipped to the parcel boundary (ownership category). Parcels typically exclude roadways, sidewalks, and other right-of-way features which is why this impervious cover category has a seemingly low value.*

SCHOOL DISTRICT OF LANCASTER OWNED PARCELS

Parcels owned by the school district comprise a significant portion of public land in the study area with 20 parcels spanning120 acres as shown in Table 3-9. The school district is undertaking significant capital investment in facility upgrades and restoration, which represents an opportunity for additional GI implementation. Table 3-13 provides a summary of the impervious area for the parcels owned by the School District of Lancaster.

Table 3-13 - Impervious Cover for Parcels owned by the School District of Lancaster

Impervious Cover	Area, ac
Building	23
Parking Lot	28
Roadway *	0.13
Total	51

** Note – Impervious areas (land cover features) were clipped to the parcel boundary (ownership category). Parcels typically exclude roadways, sidewalks, and other right-of-way features which is why this impervious cover category has a seemingly low value.*

OTHER PUBLICLY-OWNED PARCELS

The final category of public ownership is "other" which comprises all the remaining parcels that are owned by a public entity in the study area. A total of 31 parcels are owned by various entities totaling 131 acres. Table 3-14 provides a summary of the owners of the other public parcels and Table 3-15 provides a detailed summary of the impervious cover for these parcels.

Table 3-14 - Summary of other publicly owned parcels according to owner

Ownership	# of Parcels	Area, ac
County of Lancaster	18	104
City of Philadelphia	9	4
State (PennDOT)	3	23
Federal	1	0.08
Total	31	131

Table 3-15 - Impervious Cover for publicly owned parcels in the study area

Impervious Cover	Area, ac
Building	9
Parking Lot	5
Railroad	-
Roadway	2
Total	16

Chapter 4 – Green Infrastructure Demonstration Project Concept Plans

The City's green infrastructure (GI) demonstration program includes technologies and specific projects applicable for implementation in Lancaster City and similar communities. Conceptual plans were developed for 20 initial projects that can be undertaken by the City to demonstrate the feasibility of GI over a range of different application types and within each major combined and separate sewer service area. Conceptual-level estimates of constructed cost are provided for each project. The projects are recommended for implementation to demonstrate that the program is scalable to achieve much more significant reductions in urban runoff and combined sewer overflows when similar techniques are applied on a widespread basis over the long term. The potential benefits of long term implementation are evaluated in Chapter 5.

Detailed fact sheets for each GI technology proposed in this GI Plan are provided in Appendix A. The fact sheets were formatted as stand-alone sheets which can be used to communicate to various stakeholders in the City. Funding for the development of the fact sheets were provided by Lancaster County Urban Enhancement Fund.

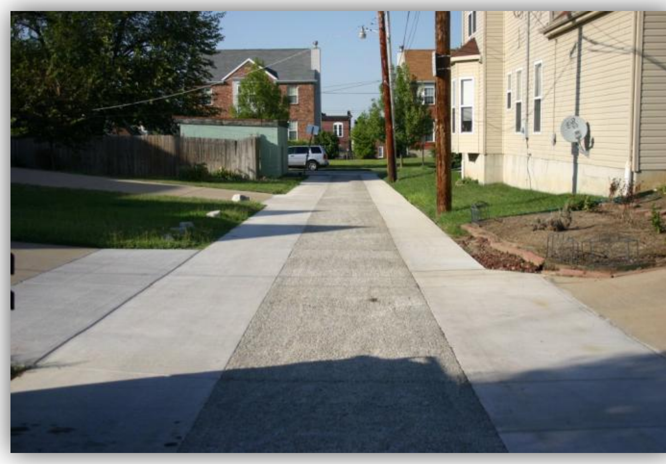
GREEN INFRASTRUCTURE PROGRAM TYPES

Each GI project can be classified into a broader GI Program. For example, all publicly-owned school sites can fall within a common classification of green schools and city owned sites. GI programs as a classification scheme serve to organize the drivers for implementation and can help shape the priorities for short and long-term City efforts. The following eight GI program "types" were considered in relation to the specific land uses common to Lancaster City with an initial focus on public ownership:

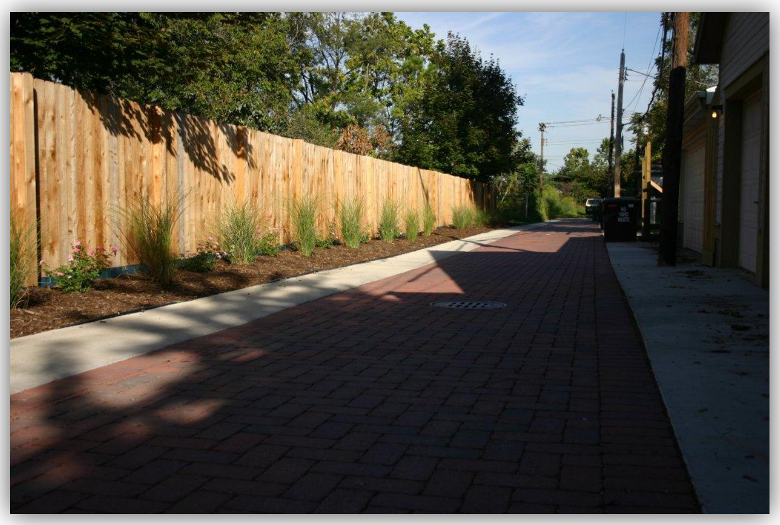
1. green streets/green alleyways
2. green sidewalks
3. green parking lots
4. green roofs
5. private disconnection / rain gardens & rain barrels
6. enhanced street tree plantings
7. green parks, and
8. green schools and city-owned sites.

GREEN STREETS / GREEN ALLEYWAYS

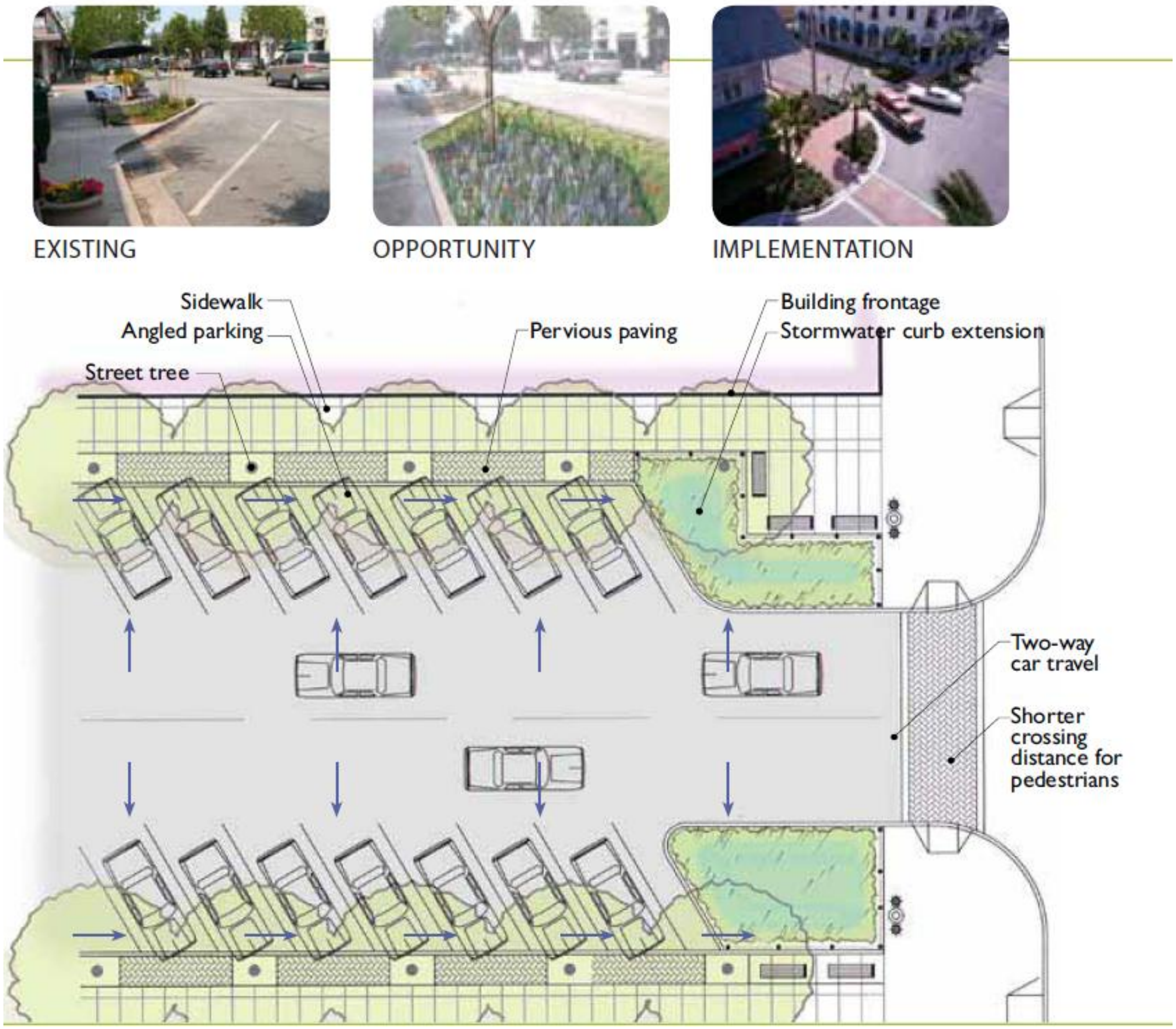
Green streets and alleys use the existing form and construction of roadways to allow the public right of way area to manage the runoff that it creates. Green infrastructure opportunities are implemented at lower overall costs when they are incorporated during street repaving or other street reconstruction activities. Impervious surfaces can then be replaced with porous pavements – asphalt, concrete, or pavers – or can be standard pavements with inlets routed into a storage and/or infiltration bed beneath. Landscaping and vegetation (street trees, curb extensions, and sidewalk planters) can be incorporated in available spaces. An optimized green street or green alley will capture stormwater runoff from not only the right of way, but also the adjacent properties to maximize the stormwater capture.



Green Alley with Porous Concrete in St Louis, MO



Green Alley with Pervious Pavers in St. Louis, MO

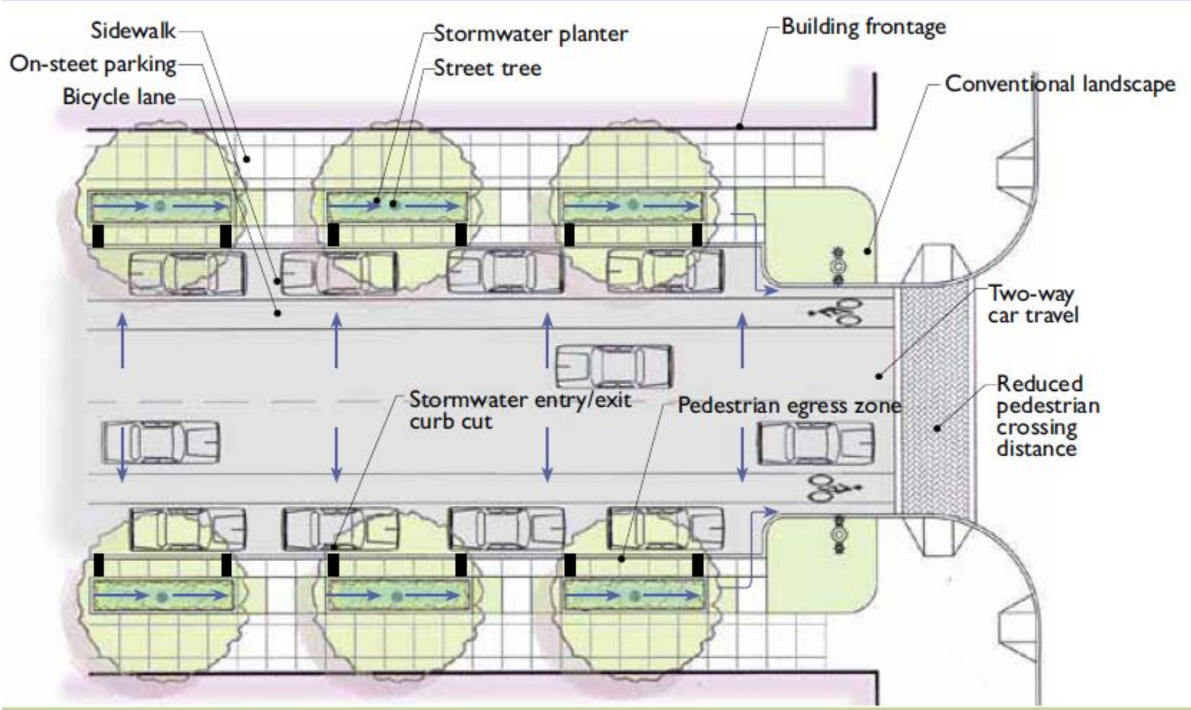


Green street application integrated with angled parking (Image Source - EPA 2010)

TYPICAL STREET

OPPORTUNITY

IMPLEMENTATION

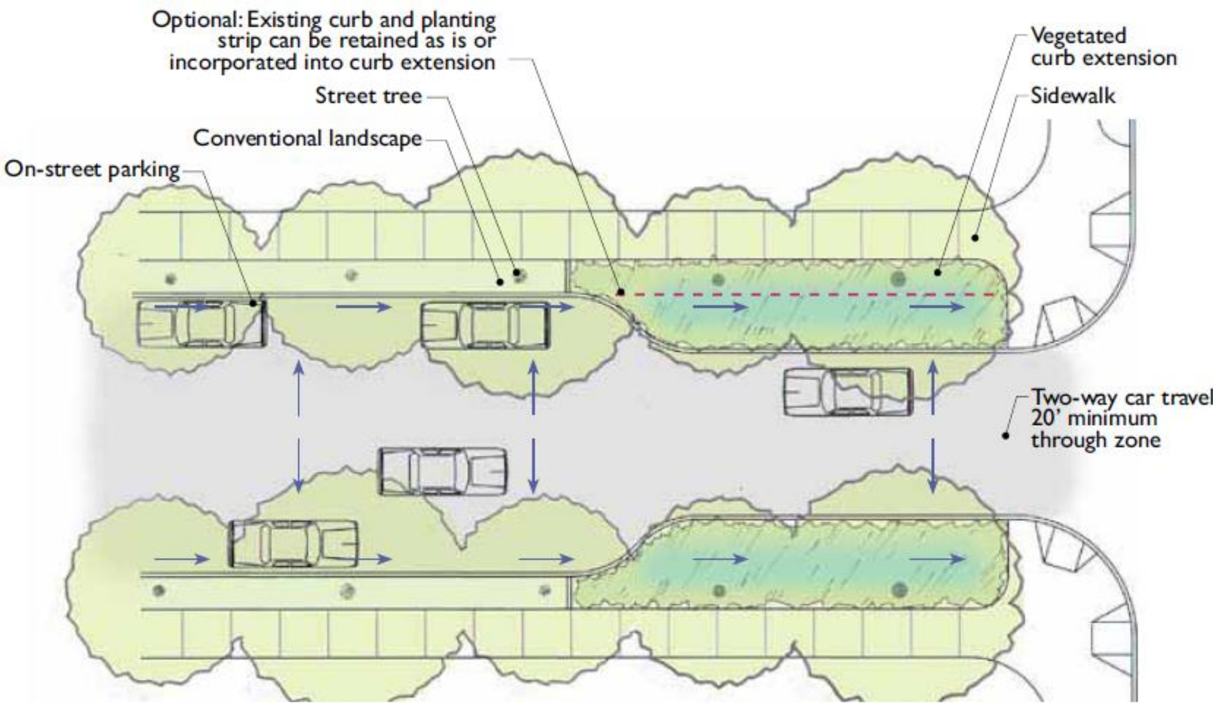


Commercial green street example with planter beds suitable for downtown commercial streets (Image Source, EPA 2010)

TYPICAL STREET

OPPORTUNITY

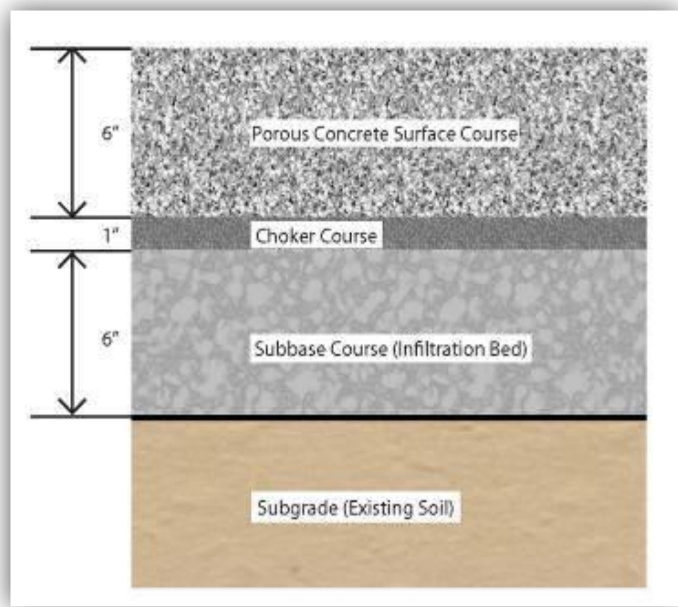
IMPLEMENTATION



Green street example with curb extension planters suitable for urban residential areas (Image Source - EPA, 2010)

GREEN SIDEWALKS

Opportunities to implement green sidewalks are created when sidewalks are constructed to improve streets, as part of the reconstruction of utility infrastructure or to incorporate ADA requirements. Green infrastructure technologies applicable for sidewalks include curb extensions, sidewalk planters, tree trenches and porous pavements. Silva cells and root barriers can be incorporated into the design which will serve to minimize root upheaval and sidewalk displacement.



GREEN PARKING LOTS

Green parking lots are typically built by excavating the existing lot and installing a stone subsurface infiltration bed in conjunction with porous pavements or stormwater inlets and catch basins redirected into the stone bed. Runoff from adjacent areas like streets and buildings can be redirected into the infiltration bed and tree trenches or bioretention can be integrated with the design to increase tree canopy, promoting evapotranspiration. These projects are built most cost effectively when the pavements need replacement or the lot requires reconfiguration for other reasons.

Example Parking lot with Cross Section for Porous Parking Lot with Tree Trench.
Photos – F&M College Parking lot with bioretention installed to meet City "first flush" ordinance.

GREEN ROOFS

Lancaster City is already at the forefront of green roof implementation as a result of the Lancaster County Roof Greening Project, a grant program which provides funding to offset the higher capital cost of green roof construction. Table 4-1 summarizes the existing green roof installations across the City. Table 4-2 compares City-wide installation with other cities across the US and Canada. The estimated stormwater runoff managed by these green roofs and eliminated from the combined sewer system is one million gallons (1MG) annually.

Table 4-1 - Summary of Green Roof Projects for Lancaster, PA

Project	Area (SF)	Status
Wharton Elementary	8,500	Complete
Lafayette Elementary	11,500	Complete
Ross Elementary	2,500	Complete
National Novelty Brush Co.	16,900	Complete
F&M Brooks Bump out	1,250	Complete
F&M Wohlsen Center for Sust. Environment	1,825	Complete
Groff Family Funeral Home	8,910	Complete
Total Area (SF)	**51,385**	**7 Completed Projects**

Table 4-2 - Comparison of Green Roofs for Lancaster City with other Cities in US and Canada (Source - www.greenroofs.org Green Roofs for Healthy Cities 2009 List)

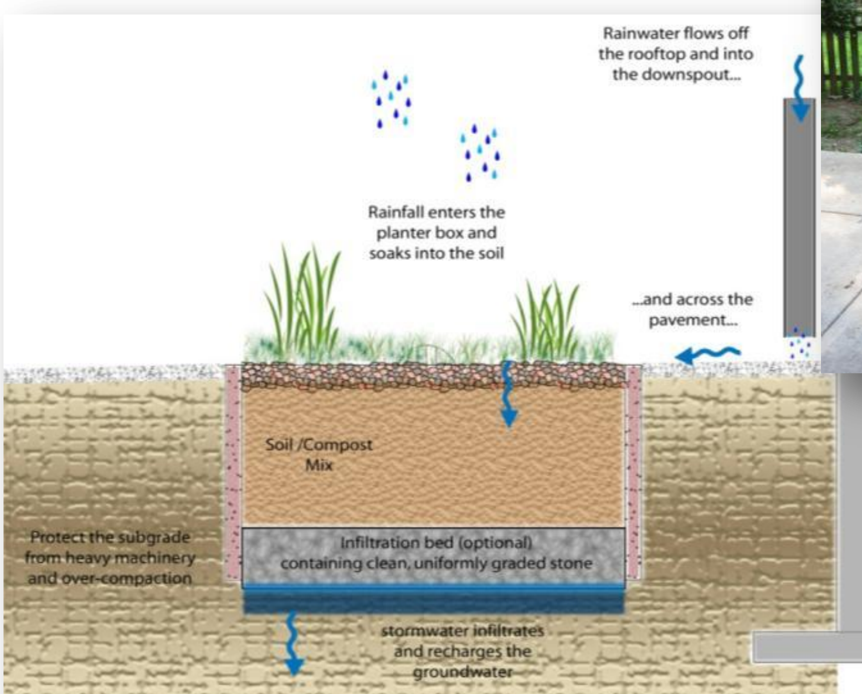
Metropolitan Area	State/Province	Installed (SF)	# of Projects
Chicago	IL	534,507	84
Washington	DC	501,042	67
New York	NY	358,986	35
Philadelphia	PA	353,337	38
Vancouver	BC	320,000	1
Baltimore	MD	150,032	21
Montreal	Quebec	75,700	17
Grand Rapids	MI	74,784	16
Princeton	NJ	56,250	4
Lancaster *	PA	51,385	7
Newtown Square	PA	48,130	1

PRIVATE DOWNSPOUT DISCONNECTION

RAIN GARDENS, RAIN BARRELS AND OTHERS

Private properties offer a smaller range of GI technologies and opportunities, primarily due to lack of available land area to manage runoff generated from impervious surfaces. Downspout disconnection is one GI solution that can be applied using a variety of technologies including rain barrels, cisterns, rain gardens or stormwater planters. The fact sheet in Appendix A describes these features in greater detail.

To date, LIVE Green has distributed 125 rain barrels to City residents through its Rain Barrel grant program.



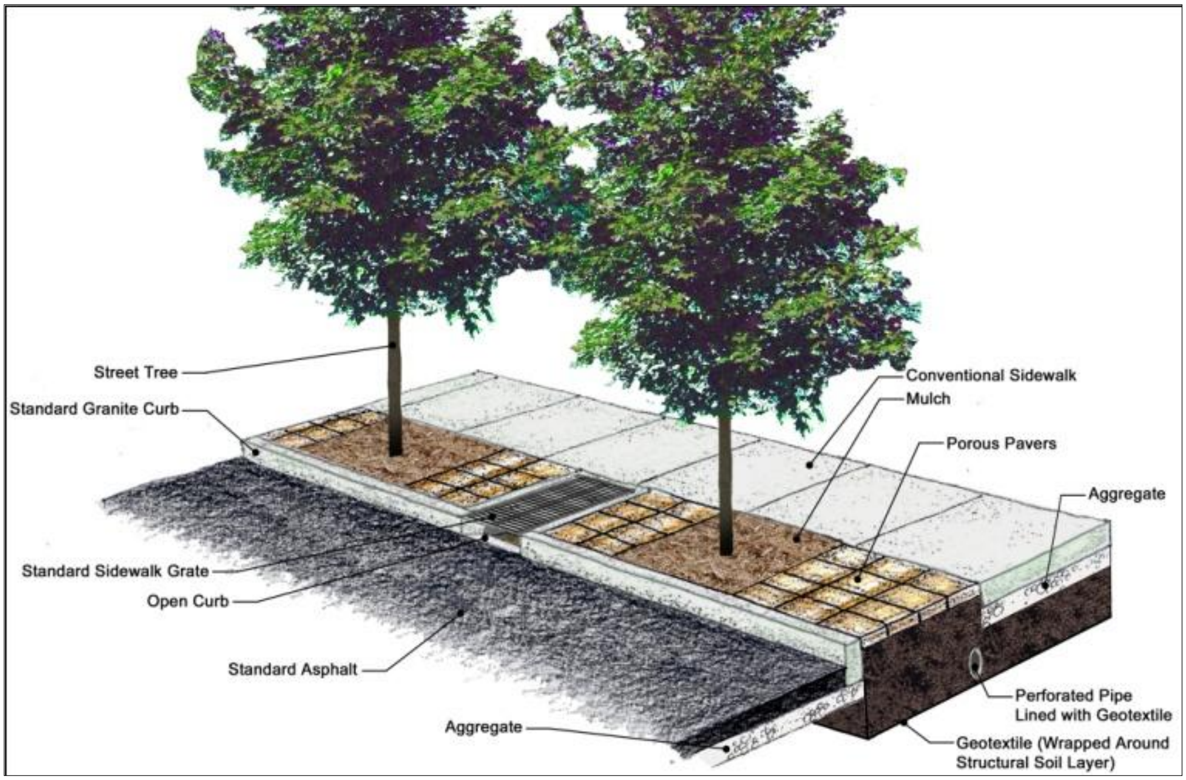
ENHANCED STREET TREE PLANTINGS

According to the urban tree canopy assessment released in February 2011 (see Appendix F), Lancaster City has an estimated 28% tree canopy with an additional 45% theoretically possible. This estimate highlights the opportunity to restore the critical ecosystem services that are provided by urban trees. The benefits of increased urban tree canopy are substantial. By increasing tree canopy, the City will benefit from enhanced aesthetics, reduced stormwater volumes, reduced air pollution, improved public health, increased property values, reduced energy costs associated with cooling and heating buildings, reduced heat island affect, and more.

American Forests, a non-profit group devoted to conservation and the environment, advocates for a higher tree canopy goal noting that an average of 40% over the entire study area might be possible based on land uses. Tree canopy goals for Lancaster City will be refined as the tree inventory is completed and the tree inventory and management plan is developed. The GI technique of enhanced street tree plantings (example cross section shown in the figure below) can help manage stormwater volumes while simultaneously working towards achieving urban tree canopy goals. While the stormwater benefit of trees will be variable (by species, planting location, and as a tree grows over time), it is assumed that the average enhanced tree planting will – at the end of the implementation period – intercept, infiltrate, or otherwise manage 0.3 inches of runoff from an area covered by a 10-foot radius canopy (314 square feet). Based on the precipitation analysis described in Chapter 5, this is estimated to reduce stormwater runoff by approximately 3,440 gallons per year per tree. This reduction could also be achieved by managing 1 inch of runoff from a 179 square-foot impervious area (for example roadway runoff as shown in the figure below).

There are a number of resources available for estimating the benefits of trees – including energy, air quality, carbon, and property value benefits. For example, the National Tree Benefit Calculator estimates that a 21-inch river birch tree in this region will intercept 3,248 gallons of stormwater and provide $265 in overall benefits each year (www.treebenefits.com).

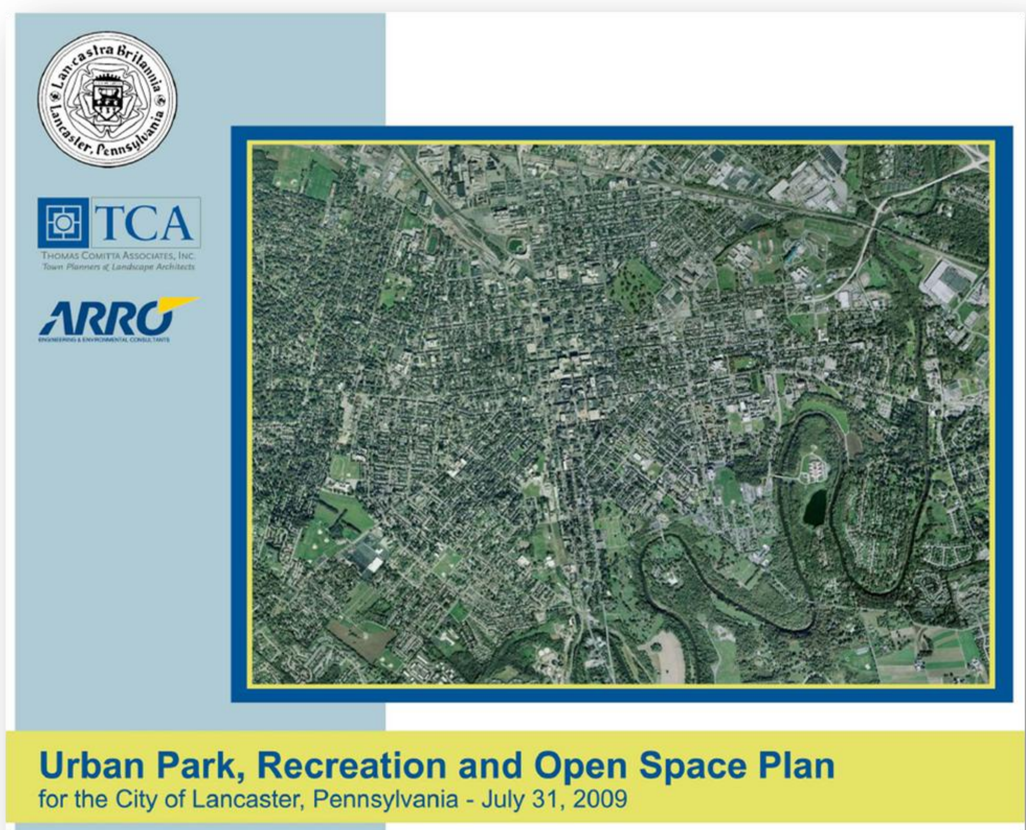
While this GI Plan recommends new plantings to increase the overall number of trees in the City, protecting existing trees is at least if not more important. The results of the urban tree canopy assessment, being funded and conducted by Pennsylvania Department of Conservation and Natural Resources in conjunction with this planning effort, can be used to develop a comprehensive tree management plan for both new and existing trees. This is a recommendation for future studies in Chapter 6.



Enhanced street tree plantings can be integrated with sidewalk and roadway improvements to manage stormwater and achieve urban tree canopy goals. By providing adequate soil rooting volume and selecting appropriate species, the risk of damage to sidewalks and other improvements can be minimized. When roadway runoff is conveyed to vegetated systems, care must be taken during design and species selection [e.g., soil volume, salt tolerant species].

GREEN PARKS

In 2009, Lancaster City completed an Urban Park, Recreation and Open Space Plan through grant funding from DCNR. The Plan lays out specific concepts for the renovation and restoration of parks throughout the City. Green infrastructure techniques are recommended for implementation on City owned and managed parks which can be undertaken at a reasonable cost. Implementation of GI techniques on park properties can also manage stormwater from adjacent impervious surfaces such as surrounding neighborhood streets and through downspout disconnections to manage stormwater from surrounding roofs. The benefits of this include a natural source of irrigation for these valued green spaces. A case study for a recently constructed Green Park project – Sixth Ward – is provided later in this chapter and details the cost/benefits to implementation of GI on city-owned park land.



GREEN SCHOOLS AND CITY-OWNED SITES

Public schools are typically situated on larger-sized parcels with a high percentage of their land area occupied by impervious play surfaces, parking, rooftops and other areas. Since ownership of school parcels are within the public realm, schools can provide a variety of green infrastructure techniques that manage stormwater generated on-site, but can also manage additional impervious area from adjacent properties similar to green parks. Libraries and other publicly-owned facilities offer the same green infrastructure and educational opportunities as schools.

POTENTIAL GREEN INFRASTRUCTURE PROJECTS

An initial list of potential green infrastructure projects was developed in consultation with City Staff and LIVE Green. The full list of potential GI projects that were initially screened is shown in Table 4-3 and in Figure 4-1. This list of possible GI projects represents only a snapshot in time, and is envisioned to be continually updated with additional projects as they are identified within the community. From this "master" GI project List and through additional follow-up site visits, 20 initial GI demonstration projects were selected for the detailed development of conceptual plans. Following the project kickoff meeting on 11 May, 2010, site visits were conducted on several days to screen for potential candidate sites that would be well–suited for green infrastructure retrofit projects.

It should be noted city-owned properties make up the overwhelming majority of potential demonstration projects selected for short-term implementation. This selection was intentional as it was deemed necessary to show targeted GI opportunities that can be implemented relatively quickly and to evaluate the cost-benefit of these approaches. As presented in Chapter 3, publicly-owned lands make up only 13 percent of the total land area. This underscores the fact that the private community must be part of the solution and draw from the experience gained from the solution implemented on public lands. One privately-owned project was provided to serve as a conceptual example of how this same process can be applied for developing projects to retrofit GI into projects completed by private landowners. The GI techniques described in this chapter are applicable across all land ownership categories.

A porous basketball court at 6th Ward Park plan progressed from idea, to concept, to construction during the development of the GI Plan.

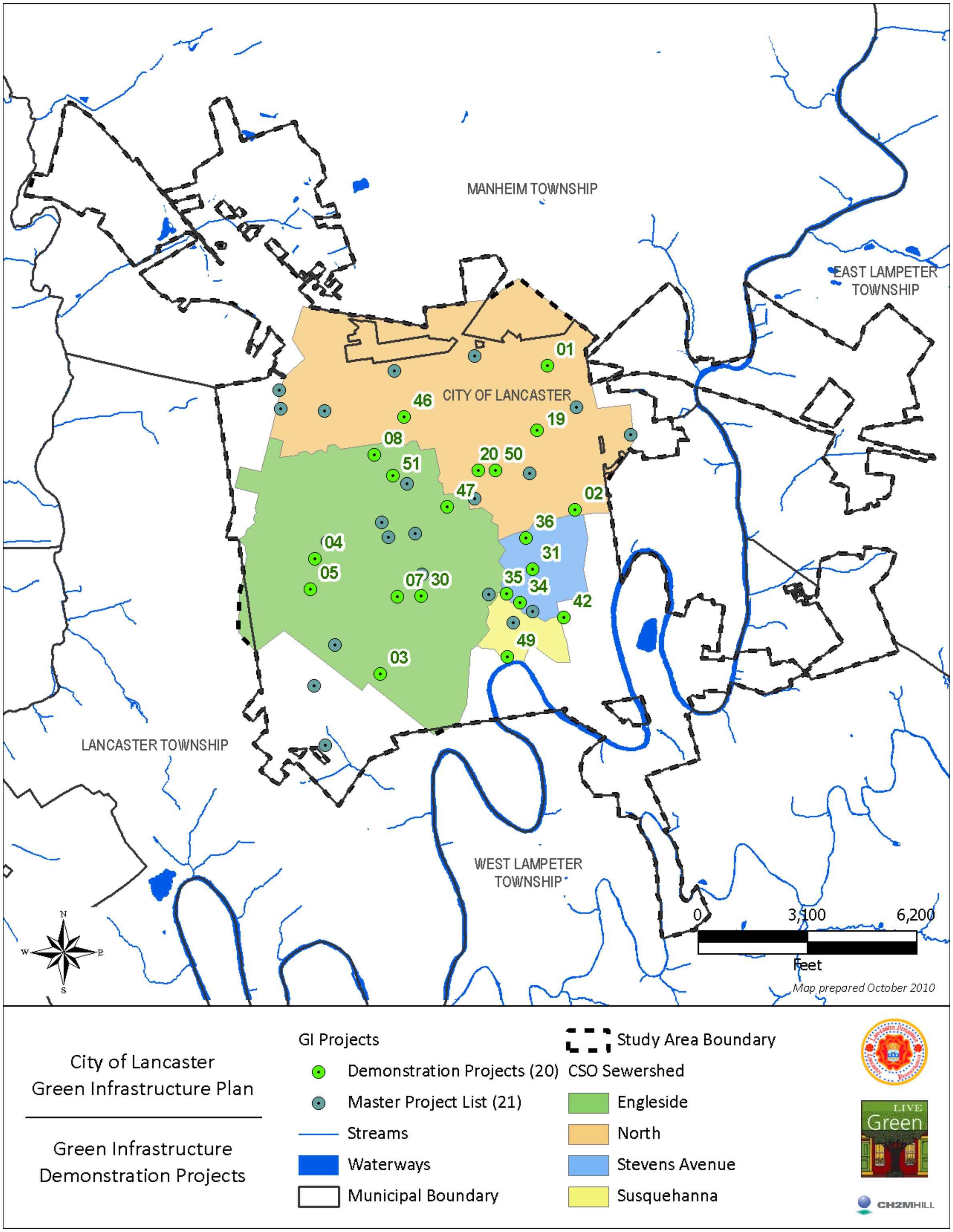


Figure 4-1- Green Infrastructure Demonstration Project Location Map

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Table 4-3 - Green Infrastructure Potential Projects List (November, 2010)

Project Reference ID	Project Name	Address	Possible GI Technology	GI Prototype Project Type	Status	Landuse	CSO Basin	Owner
P-01	6th Ward Park	E Ross St & Hamilton St	Porous Basketball; Vegetated Curb Ext; Rain Garden behind sign; RG at Fredrick St	Green Park	Under Construction	Recreational	North	City
P-02	Reservoir Park	E King St & N Franklin St	Porous Play Courts, Sidewalks, Pavements, Cisterns	Green Park	Concept Mapped	Recreational	North	City
P-03	Brandon Park	Wabank St & Hazel St	Porous Paving; Bioinfiltration	Green Park	Concept Mapped	Recreational	Engleside	City
P-04	Crystal Park	1st St & Reiker Ave	Porous Pavement Basketball Court captures upland pkg lot/roof runoff; convert alley on E to park extension/greenpath	Green Park	Concept Mapped	Recreational	Engleside	City
P-05	Rodney Park	W 4th St & N Rodney St	Bioretention, Porous play surfaces and walkways	Green Park	Concept Mapped	Recreational	Engleside	City
P-06	Musser Park	N Shippen St & E Marion St	Bioretention, Porous play surfaces and walkways	Green Park	Idea	Recreational	North	City
P-07	Conlin Field/Farnum Park	South Water St and E Filbert St	Porous Pavement Parking Lot; Por Concrete Sidewalks; existing RG proposed, bump out/tree replacement at hydrant near bball court; capture road runoff at gateway inlet and direct into parking lot bed.	Green Park	Concept Mapped	Recreational	Engleside	City
P-08	Northwest Corridor Linear Park	W. Lemon St & Harrisburg Ave	Rain gardens, Green trail, Green parking lot with pedestrian enhancements, Landscape restoration, Infiltration trench	Green Park	Concept Mapped	Recreational	North	
P-09	Streetscape Phase III	Market District	Tree Trench, Curb Extension Planter	Green Street	Concept Designed	Commercial	Engleside	City
P-10	Streetscape Phase IV	Queen and Prince; Chestnut to Lemon	Tree Trench, Curb Extension Planter	Green Street		Commercial	Engleside	City
P-11	Barber Property	500 block West Walnut Street	Green Planting Strips	Green Street	Complete	Residential	TBD	Private
P-13	Beaver Street Redevelopment	100 block Beaver Street	TBD	TBD	TBD	Commercial	Engleside	City
P-14	West Grant Street Improvement District	200 block W Grant Street	Tree Trench, Curb Extension Planter	Green Street	Concept Mapped	Commercial	Engleside	City
P-18	Church Street Towers	333 Church Street	Green Roof	Green Roof	Inactive	Residential	Engleside	Private
P-19	Northeast Greenway Corridor	McCaskey HS to E Walnut St	green trailway	Green Park	Concept Mapped	Recreational	North	Private
P-20	Triangle Park	New Holland Ave at E Walnut St	Infiltration bed beneath parking lot; tree trench to intercept adjacent residential rooftop runoff		Concept Mapped	Recreational	North	City
P-21	Two Dudes Painting Company	750 Poplar St	Infiltration / Tree Planters	Private	Concept Designed	Commercial	Engleside	Private
P-22	Wharton Elementary	705 N Mary St	Green Roof	Green Roof	Constructed	Institutional	North	SDL
P-23	Lafayette Elementary	1000 St Joseph St	Green Roof	Green Roof	Constructed	Institutional	Separate	SDL
P-24	Ross Elementary	840 N Queen St	Green Roof	Green Roof	Constructed	Institutional	North	SDL
P-25	National Novelty Brush Co.	505 E Fulton St	Green Roof	Green Roof	Constructed	Commercial	North	Private
P-26	F&M Brooks Bump out	TBD	Green Roof	Green Roof	Constructed	Institutional	North	Private
P-27	F&M Wohlson Center for Sustainable Envr.	TBD	Green Roof	Green Roof	Constructed	Institutional	North	Private
P-29	Groff Family Funeral Home	528 W Orange St	Green Roof	Green Roof	Constructed	Commercial	Engleside	Private
P-30	Carter & MacRae Elementary School	201 S Prince St	3 Cisterns on south roof; Porous Play Court and Tree Plantings;	Green Schools	Concept Mapped	Institutional	Engleside	SDL
P-31	Public Parking Lot: S Plum St	600 block South Plum Street	Porous Pavement & Green Alley	Parking Lot - Public	Concept Mapped	Transportation	Stevens	City
P-32	Public Parking Lot: Rockland St	700 block Rockland Street	Infiltration Tree Planters / Porous	Parking Lot - Public	Basemap	Transportation	Susquehanna	City
P-33	Public Parking Lot: S Lime St	600 block South Lime Street	Green Street - Lot drains to street	Parking Lot - Public	Basemap	Transportation	Stevens	City
P-34	Public Parking Lot: Dauphin St	200 block Dauphin Street	Bioretention	Parking Lot - Public	Concept Mapped	Transportation	Stevens	City
P-35	Public Parking Lot: Penn Ave.	500 block Penn Ave.	Porous Pavement	Parking Lot - Public	Basemap	Transportation	Stevens	City
P-36	Public Parking Lot: E Mifflin St	400 block E. Mifflin Street	Bioretention	Parking Lot - Public	Concept Mapped	Transportation	Stevens	City

Table 4-3 - Green Infrastructure Potential Projects List (Cont.)

Project Reference ID	Project Name	Address	Possible GI Technology	GI Prototype Project Type	Status	Landuse	CSO Basin	Owner
P-40	F&M Parking Lot	Race Ave	Porous Pavement	Parking Lot - Private	Complete	Institutional	North / Separate	Private
P-41	Residential Green Street @ Ice Ave	300 Block Ice Ave	TBD	Green Street	Idea	Residential	North	Public
P-42	Hand Middle School	431 South Ann Street	Tree trench along roadway; Green roof; tree trench adjacent to parking lot	Green School	Concept Mapped	Institutional	Susquehanna	SDL
P-43	Fulton Elementary	225 West Orange Street	Phase 2	Green School	Idea	Institutional	Engleside	SDL
P-44	MLK Elementary	466 Rockland Street	TBD pending future capital project	Green School	Idea	Institutional	Engleside	SDL
P-45	Scheffey Administrative Building	1020 Lehigh Avenue	Phase 2	Green School	Basemap	Institutional	North	SDL
P-46	Green Street along Prince St	James Street Improvement District	tree trench	Green Street	Concept Mapped	Commercial	North	TBD
P-47	Lancaster County Library	125 N Duke St	Green Roof, Bioretention	Library	Concept Mapped	Institutional	Engleside	County
P-48	Duke Street Mall Streetscape	500-800 blocks S Duke St	tree trenches; curb extension	Green Street	Concept Mapped	Transportation	Susquehanna	City
P-49	Strawberry St. Separation	E. Strawberry & Chesapeake Sts	Model Area Refinement	Green Street	Concept Mapped	Utility	Susquehanna	City
P-50	Commercial Green Street @ Walnut & Plum	Intersection of Walnut and Plum St	Tree trench along roadway	Green Street	Concept Mapped	Transportation	North	City
P-51	Private Parking Lot #1 at The Crossings	354 N. Prince St	Infiltration Tree Planters / Bioretention	Parking Lot - Private	Concept Mapped	Commercial	Engleside	Private
P-52	Residential Green Street @ Euclid Ave	500 block Euclid Ave	Green street	Green Street	Idea	Transportation	Separate	Public
P-53	Groundwater Inflow Removal #1	511 N Franklin Street (McCaskey High school)	Cistern; Capture and Re-use of 50,000 GPD from elevator	Green School	Idea	Institutional	North	SDL
P-54	Washington Elementary School	545 South Ann St	TBD pending future capital project	Green School	Idea	Institutional	Stevens	SDL
P-55	East Fulton	Reservoir to Franklin	Green street	Green Street	Idea	Transportation	North	City
P-56	East Marion	N. Plum to N. Shippen	Green street	Green Street	Idea	Transportation	North	City
P-57	North Jefferson	East New to East Clay	Green street	Green Street	Idea	Transportation	North	City
P-58	Lehigh Avenue	N. Franklin to N. Marshall	Green street	Green Street	Idea	Transportation	North	City
P-59	Burrowes Avenue	N. Franklin to N. Reservoir	Green street	Green Street	Idea	Transportation	North	City
P-60	Marshall Avenue	Lititz Pike to Stadium	Green street	Green Street	Idea	Transportation	North	City
P-61	East Fulton Street	Ann to Plum	Green street	Green Street	Idea	Transportation	North	City
P-62	East Grant	N. Ann to N. Plum	Green street	Green Street	Idea	Transportation	North	City
P-63	Lehigh Avenue	N. Broad to N. Reservoir	Green street	Green Street	Idea	Transportation	North	City
P-64	East Grant Street	N. Marshall to N. Ann	Green street	Green Street	Idea	Transportation	North	City
P-65	First Street	Coral to Old Dorwart	Green street	Green Street	Idea	Transportation	Engleside	City
P-66	A+ Gas Station	Intersection of Prince and Orange	TBD	TBD	Idea	Commercial		Private
P-67	Proposed Garage at Market Street	N Prince St & Lemon St	TBD	TBD	Idea	Transportation		Private
P-68	Fulton Bank	E King St & N Christian	TBD	TBD	Idea	Commercial		Private
P-69	City Hall Annex Expansion	N Duke Street	TBD	TBD	Idea	Institutional		City
P-70	Parking Authority project	N Cherry	repaving	TBD	Idea	Institutional		Private
P-71	Snavely's Lumber	400 block N. Charlotte	Excessive parking lot retrofit green street down to Lemon ST; adjacent to Linear Park	TBD	Idea	Commercial		Private
P-72	George Street	Pearl to Coral	Green street	Green Street	Idea	Transportation	Engleside	City
P-73	Ocean Avenue	Ruby to Coral	Green street	Green Street	Idea	Transportation	Engleside	City
P-74	South West End Avenue	Columbia to First	Green street	Green Street	Idea	Transportation	Engleside	City

GREEN INFRASTRUCTURE DEMONSTRATION PROJECTS

GI CONCEPT PLAN DEVELOPMENT PROCESS

GI concept plans were developed using the process shown in Figure 4-2. This process used the impervious area data analysis from Chapter 3 to provide impervious areas for each site considered. Each of these areas was evaluated for an appropriate GI technology in conjunction with site visits and discussions with City staff to integrate the concept with other improvements the City was considering. Each technology was sized to capture runoff from the contributing impervious areas, a conceptual cost estimate prepared, and the concept documented in a map using the GIS. The selected demonstration projects are summarized in Table 4-5 and locations of the projects selected for development of conceptual plans at a project selection meeting held in November 2010 are shown in Figure 4-3.

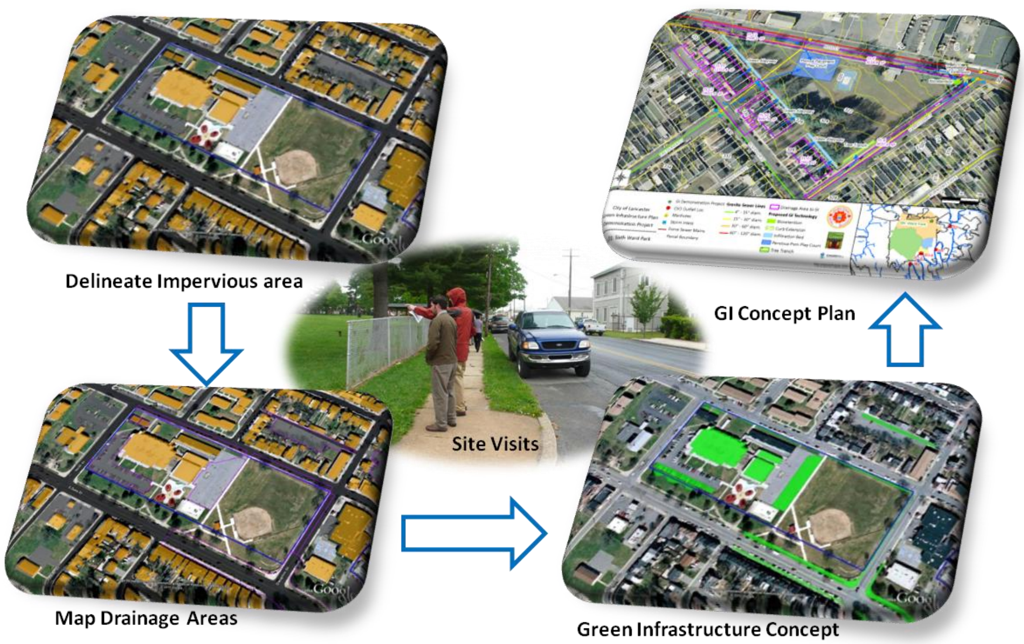


Figure 4-2 - Green Infrastructure Concept Development Process

The GI demonstration projects are classified according to one of the eight recommended GI program “types” and a brief orientation to the site (both narrative and photographic) and GI opportunities are also provided. A GIS-based concept plan depicts the specific GI technologies recommended and provides a summary of the Cost/Benefit analysis. These concepts were used to target grant funding for implementation.

Concept plans depicted throughout this chapter were created based on input from the City of Lancaster Department of Public Works and other stakeholders. The concept plans are considered to be preliminary and provide a concept for what is possible at a given site in terms of green infrastructure features that could be implemented and the approximate benefit that these measures can provide. As such, the concepts will likely change based on owner input, design issues, site surveys, infiltration test results and other site specific issues and investigations.

CONCEPTUAL PLANNING-LEVEL DESIGN ASSUMPTIONS

The conceptual development and sizing of the demonstration projects were built upon industry-based common design assumptions, including information contained in the 2006 Pennsylvania Stormwater Best Management Practices (BMP) Manual and other literature sources. In addition, conceptual planning assumptions are based on CH2M HILL's experience with and knowledge of GI design and implementation. Design assumptions used in the analyses performed for the City of Lancaster GI Plan include:

- Annual average rainfall in Lancaster of 42.04 inches based on 71 years of rainfall records from 1926 through 2000, provided by the Pennsylvania State Climatology website);
- A composite runoff coefficient of 85% was used to calculate the total annual runoff generated from the impervious drainage area which can subsequently be reduced by GI technologies;
- While specific infiltration rates were not included in the conceptual sizing of the BMPs, it was assumed that infiltration technologies would fully dewater within an acceptable timeframe. If during the design phase, infiltration rates are deemed too low at a particular site (e.g., less than 0.5 inches per hour), then a strategy of slow release to the combined sewer can be implemented;
- Capture goal for all BMPs except porous pavement: 1 inch of stormwater runoff;
- Capture goal for porous pavement: 2 inches of stormwater runoff;
- For subsurface BMPs, the "bed" area beneath the surface was assumed to have 40% voids (i.e., storage) in aggregate beds/trenches wrapped in geotextile;
- For green roof technologies, the vegetated roof media was assumed to have 30% void space for storage of stormwater;
- Bioretention BMPs are assumed to have 6 inches of surface storage of stormwater;
- The loading ratio for each technology (ratio of contributing impervious drainage area to GI area) was generally kept lower than 5:1, consistent with the PA Stormwater BMP Manual;
- The determination of contributing drainage area was based on available GIS data, 2009 aerial ortho-photographs, and site visits/photographs; for 17 of the 20 projects, the drainage area was considered to be entirely impervious based on preliminary investigations, for the remaining three projects, the contributing impervious/pervious areas were separated by the delineation of contributing drainage area in GIS;
- For certain demonstration projects, it was assumed that certain modifications to existing drainage infrastructure (i.e. downspout, inlets) would be feasible; and

- Conceptual level costs were developed using the unit costs summarized in Table 4-4. A 20% contingency was added to the conceptual estimates of constructed cost for each project in Table 4-5.

Table 4-4 provides the unit costs used to develop conceptual costs for each projects. The unit costs are based on the costs of similar public projects implemented in Lancaster and other comparable cities. They are planning-level estimates only and may vary considerably over time and based on project-specific conditions.

Table 4-4 Summary of approximate unit implementation costs for estimating cost of conceptual GI Plans (2010 dollars)

Green Infrastructure Technology	Unit	Unit Capital Cost
Bioretention	ft^2	$15.90
Cistern/Rain Barrel	gallon	$3.00
Enhanced Street Trees*	each	$2,000
Extended Detention/Slow Release	ft^2	$20.00
Green Roof	ft^2	$17.85
Median/Traffic Island	ft^2	$15.00
Green Street	ft^2	$20.00
Infiltration Bed	ft^2	$7.31
Infiltration Trench	ft^2	$19.76
Pavement Removal	ft^2	$3.54
Pervious Pavement Parking Lot	ft^2	$13.31
Pervious Pavement Sidewalk	ft^2	$8.94
Sidewalk Planter	ft^2	$15.00
Storage Bed	ft^2	$15.78
Stream Inflow Removal	ft^2	$0.00
Tree Trench	ft^2	$13.38
Urban Forestry (tree planting in denser groves)	ft^2	$4.61
Urban Garden	ft^2	$15.12
Vegetated Infiltration Basin	ft^2	$6.25
Vegetated Swale	ft^2	$9.64
Flexipave	ft^2	$8.94
Parking Expansion	ft^2	$13.31
Curb Extension	ft^2	$8.94
Porous Pavement Road	ft^2	$16.00
Porous Pavement Playcourt	ft^2	$15.00

**The enhanced street tree cost is an estimated average assuming that plantings will range from inexpensive ones in relatively open green spaces (typically costing a few hundred dollars) to much more expensive installations in urban areas requiring structural soils and other ancillary items (often costing several thousand dollars).*

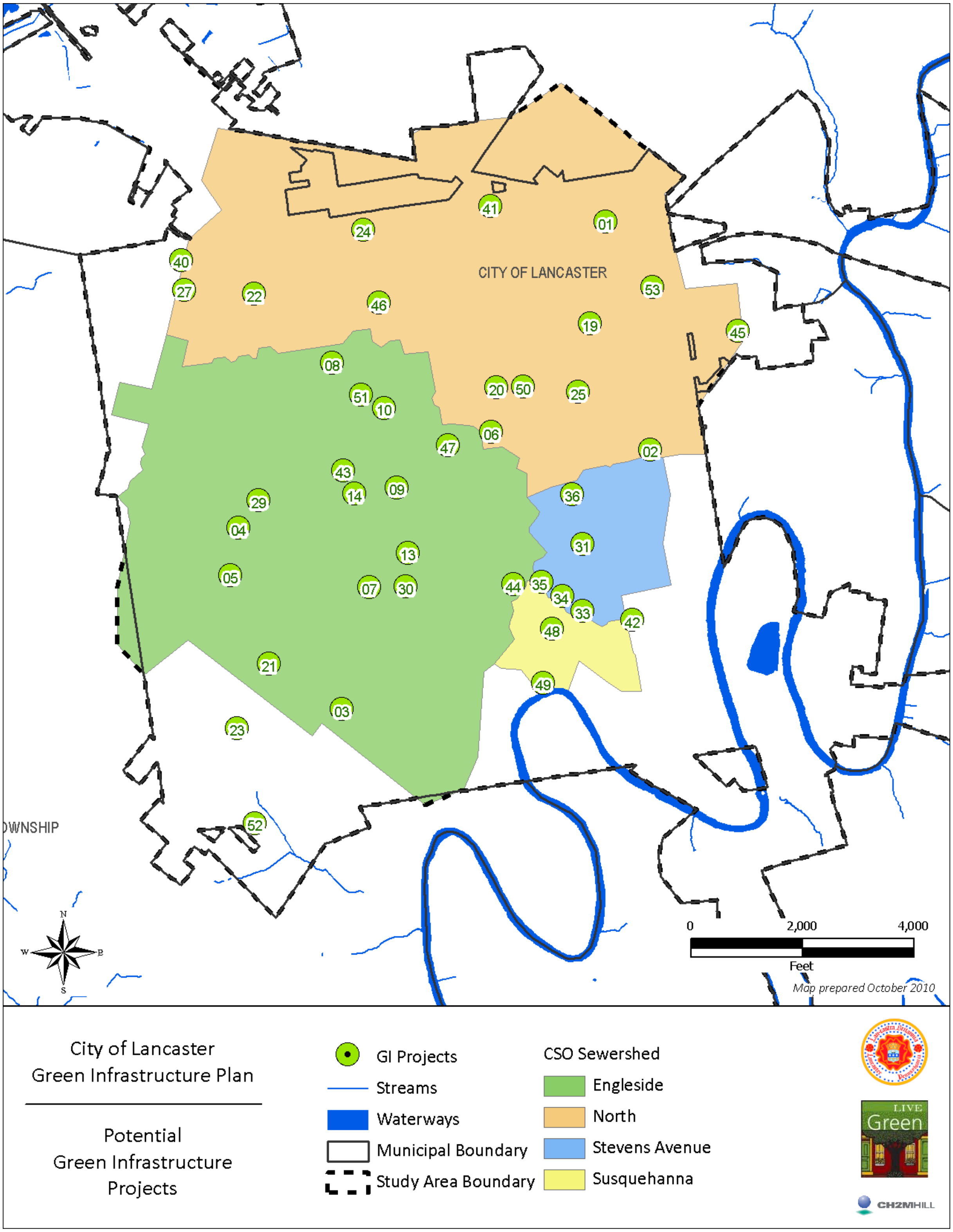


Figure 4-3 - Location Map of Potential Green Infrastructure Project Opportunities

Table 4-5 – Initial List of Recommended Green Infrastructure Demonstration Projects, Summary of Runoff Reduction Benefits, and Estimated Constructed Cost

Project ID	Project Name	Project Owner	Sewershed	Impervious Area Contributing (sq. ft.)	GI Area (sq. ft.)	Estimated Annual Capture Volume (gal)	Estimated Capital Costs with Contingency ($)
P-01	Green Park 1: 6th Ward Park	City	North	77,712	15,965	1,653,000	$200,886
P-02	Reservoir Park	City	North	57,660	41,273	1,228,000	$725,478
P-03	Brandon Park	City	Engleside	250,735	37,139	5,069,000	$776,006
P-04	Crystal Park	City	Engleside	37,292	7,458	753,000	$110,536
P-05	Rodney Park	City	North	29,707	10,821	626,000	$143,702
P-07	Conlin Field/Farnum Park	City	Engleside	58,477	17,920	1,250,000	$330,553
P-08	Northwest Greenway Linear Park	City	North	47,171	32,183	944,000	$401,158
P-19	Northeast Greenway Corridor	Private	North	45,150	45,150	987,000	$484,220
P-20	Triangle Park	City	North	6,630	1,963	133,000	$20,338
P-30	Carter & MacRae Elementary School	School District	Engleside	29,084	5,080	624,000	$98,640
P-31	Public Parking Lot: S Plum St	City	Stevens	23,402	4,680	511,000	$89,862
P-34	Public Parking Lot: Dauphin St	City	Stevens	20,582	4,516	411,000	$61,822
P-35	Public Parking Lot: Penn Ave.	City	Stevens	22,758	4,219	455,000	$60,749
P-36	Public Parking Lot: E. Mifflin St	City	Stevens	13,242	1,324	265,000	$27,013
P-42	Hand Middle School	School District	Stevens	70,487	40,113	1,410,000	$825,394
P-46	Green Street @ Prince Street	City	North	63,687	11,322	1,274,000	$181,761
P-47	Lancaster County Library	City	Engleside	35,367	12,288	706,000	$285,382
P-49	Strawberry St. Separation	City	Susquehanna	55,549	18,469	1,111,000	$376,768
P-50	Commercial Green Street@Walnut/Plum	City	North	34,021	9,154	680,000	$114,991
P-51	Private Parking Lot - Water Street	Private	Engleside	61,715	11,708	1,234,000	$182,544
Total				**1,040,430**	**332,745**	**21,324,000**	**$5,497,801**

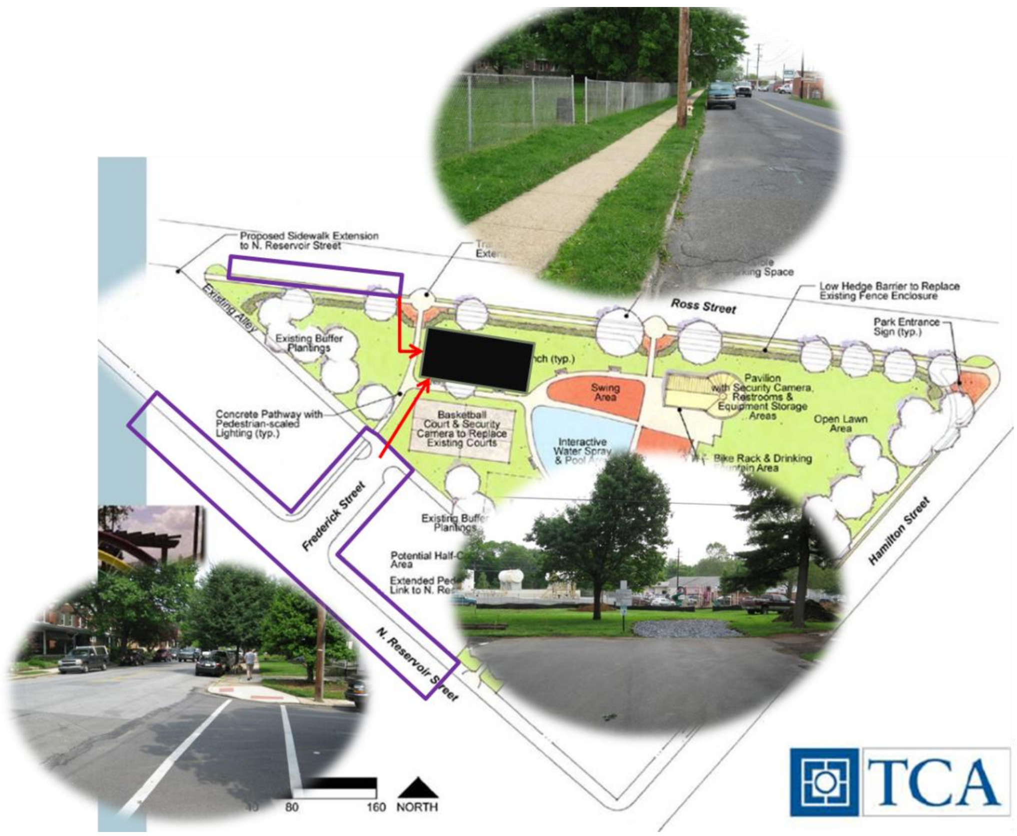
PROJECT P-01: 6TH WARD PARK

PROJECT TYPE:

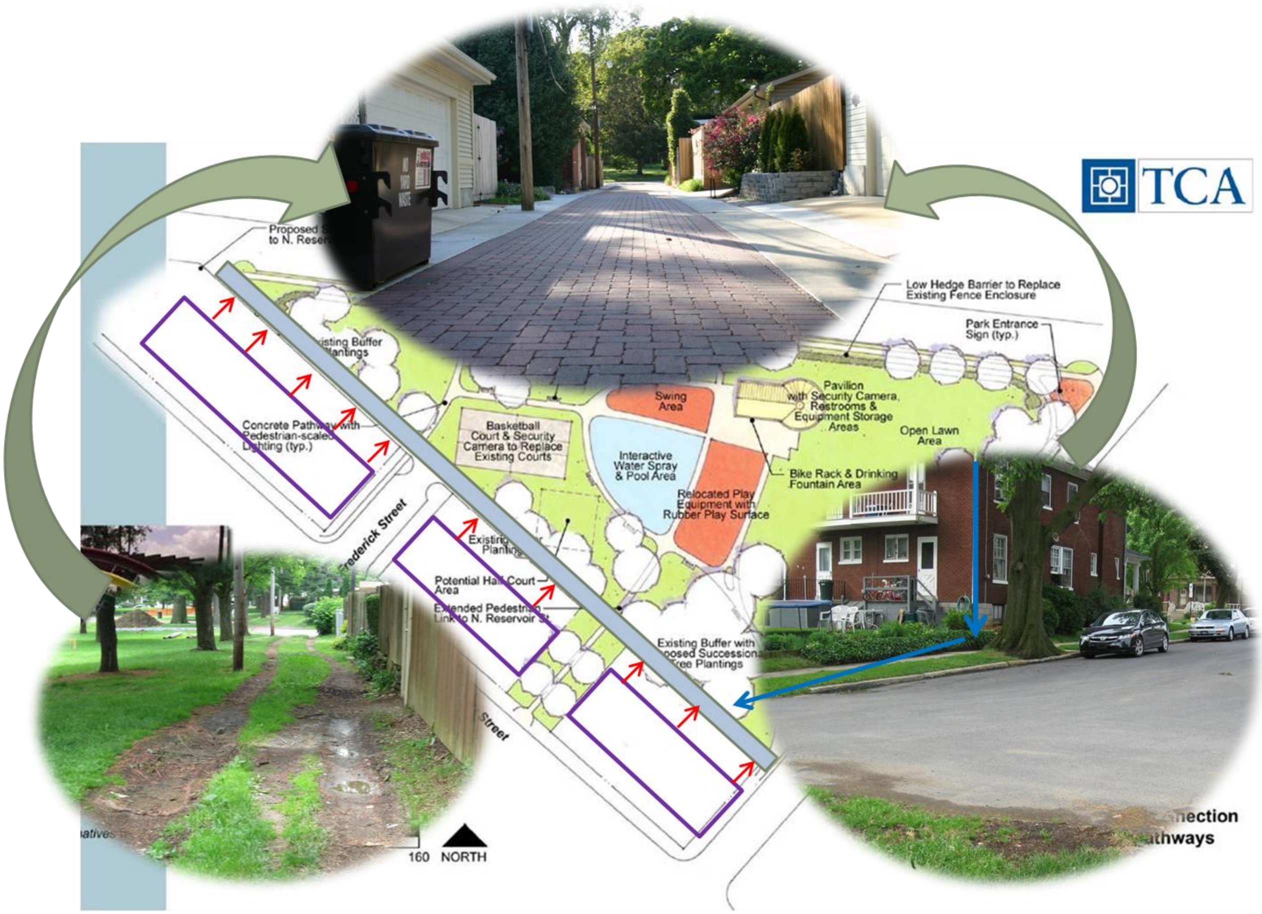
Green Park

DESCRIPTION:

A green park will be created in the North sewershed to manage runoff from adjacent roadway areas using multiple green infrastructure technologies. A porous basketball court was constructed in November 2010, as part of the Phase 1 park improvement project. The stone bed underlying the court manages runoff from the roadways adjacent to the park including E. Ross, N. Reservoir, and Frederick streets. Two vegetated curb extensions are proposed at the entrance to 6th Ward Park to manage runoff from E Ross Street and Hamilton St. A tree trench is planned for the southern portion of Hamilton St. and green alley to capture disconnected roof laterals from the homes along N. Reservoir St. Refer to Figure "Site 01Sixth Ward Park Demonstration Project" overall site plan.



E. Ross, N. Reservoir, and Frederick Streets are connected to the porous basketball play court



Green Alley Concept for disconnecting rooftop area from N. Reservoir St.

SUMMARY OF BENEFIT AND COST

During the planning process, early implementation projects were built into existing redevelopment efforts in the City, including the construction of a porous pavement basketball court at the 6th Ward Park. Based on the bid costs and comparison with a plan for a storage tank alternative to control CSOs in the North sewershed discussed in Appendix B, the project achieves runoff reductions at over a 50% savings when compared to storage tank costs to achieve a similar unit reduction in CSO volume. The following table provides a comparison of the unit cost per gallon treated by the basketball court with that of a centralized storage tank.

Comparison of unit cost reductions per gallon of 6th Ward basketball court with centralized storage costs

Proposed GI Technology	Drainage Area (sf)	Unit
Runoff Reduction	694,600	gallons / yr
Bid1	$116,300	
Cost of Court Only2	$49,650	
Marginal Cost of GI	$66,650	
Total Cost	$0.17	/gallon
Marginal Cost	$0.10	/gallon
Preliminary Grey Storage Cost	$0.23	/gallon

Proposed GI Technology	Drainage Area (sf)	GI Area (sf)	Capture Vol (gal)	Capital Costs with Contingency ($)
Porous Pavement Playcourt	32,300	9,775	695,000	$116,300
Curb Extension	7,572	347	151,000	$12,492
Bioretention	7,571	420	151,000	$8,568
Pervious Pavement Sidewalk	27,256	4,416	596,000	$47,360
Tree Trench	3,013	1,007	60,000	$16,166
Total	**77,712**	**15,965**	**1,653,000**	**$200,886**


City of Lancaster
Green Infrastructure Plan
Demonstration Project
Site 01: Sixth Ward Park
GI Demonstration Project
CSO Outfall Loc.
Manholes
Storm Inlets
Parcel Boundary
Gravity Sewer Lines
4" - 15" diam.
15" - 30" diam.
30" - 60" diam.
60" - 120" diam.
Drainage Area to GI
Proposed GI Technology
Bioretention
Curb Extension
Infiltration Bed
Pervious Pvm Play Court
Tree Trench
Map prepared August, 2010
CH2MHILL
Porous Pavement Play Court
Green Alleyway
Green Alleyway
Green Alleyway
Tree Trench
Vegetated Curb Extension
Bioretention
ROSS ST
HAMILTON ST
BURROWES AVE
RESERVOIR ST
REYNOLDS AVE
FREDERICK ST
HAND AVE
6th Ward Park
005
004
003
006
002
0
50
100
Feet

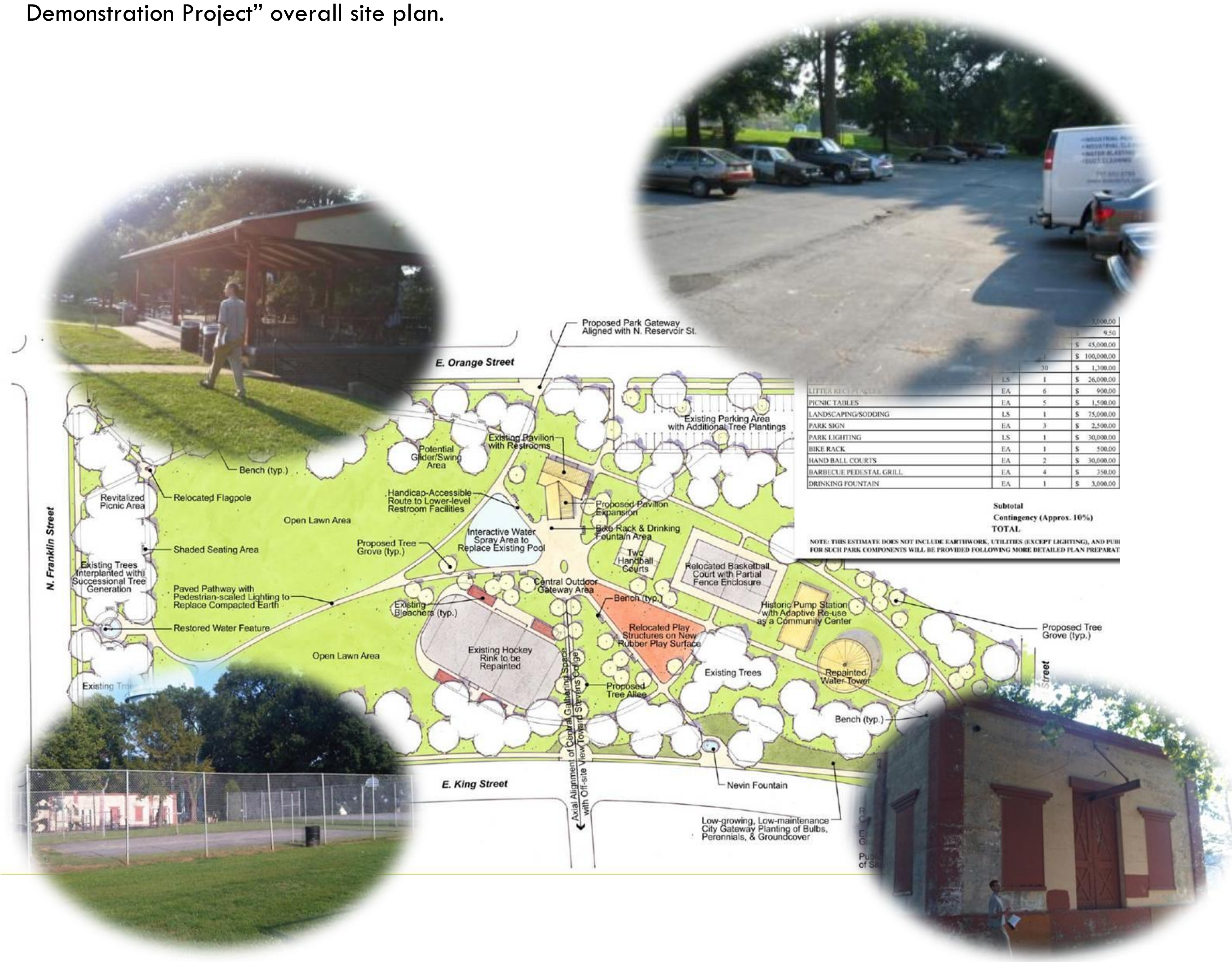
PROJECT P-02: RESERVOIR PARK

PROJECT TYPE:

Green Park

DESCRIPTION:

The concept for Reservoir Park builds upon the conceptual plan contained in the City's Urban Parks, Recreation and Open Space Plan. The existing parking lot will be retrofit with porous pavement and subsurface infiltration bed with adjacent rooftop and roadway runoff being diverted into the bed. The new planned pavilion building would have its roof leaders directed to cisterns or rain barrels. The basketball courts will be constructed with porous asphalt with infiltration bed, and the new rubber play surface/path area will also have an infiltration bed. The old pump house is being considered for a future environmental education center and would have a green roof. Refer to Figure "Site 02 Reservoir Park Demonstration Project" overall site plan.



SUMMARY OF BENEFIT AND COST

Proposed GI Technology	Drainage Area (sf)	GI Area (sf)	Capture Vol (gal)	Capital Costs with Contingency ($)
Porous Pvm Playcourt	9,879	9,879	216,000	$177,827
Cistern/Rain Barrel	1,500	-	30,000	$24,000
Pervious Pavement Parking Lot	30,603	15,628	669,000	$281,313
Infiltration Bed	13,315	13,315	266,000	$191,740
Green Roof	2,362	2,362	47,000	$50,599
Total	**57,660**	**41,185**	**1,228,000**	**$725,478**


City of Lancaster
Green Infrastructure Plan
Demonstration Project
Site 02: Reservoir Park
GI Demonstration Project
Manhole
Inlets
Parcel Boundary
Drainage Area to GI
Gravity Sewer Lines
4" - 15" diam.
15" - 30" diam.
30" - 60" diam.
60" - 120" diam.
Proposed GI Technology
Cistern/Rain Barrel
Green Roof
Infiltration Bed
Pervious Pvmt Parking Lot
Pervious Pvmt Play Court
Map prepared October 2010
CH2MHILL
Porous Pavement Parking Lot
Porous Pavement Playcourts
Green Roof
Porous Pavement
Permeable Rubber Play Surfaces
Infiltration Bed Beneath walkways
Stormwater Cistern-Planter
ORANGE ST
RESERVOIR ST
KING ST
FRANKLIN ST
Reservoir Park
0
50
100
Feet

PROJECT P-03: BRANDON PARK

PROJECT TYPE:

Green Park

DESCRIPTION:

Brandon Park is situated in the valley of a former creek where a combined sewer was constructed during the early 1900's in the former stream bed that flows into Water St. The valley is a very good location to capture runoff from the impervious features in the park as well as the adjacent upland areas from Wabank St.

The reconstruction of parking areas planned for the park creates an opportunity for porous paving and the infiltration beds that can be placed throughout the park are proposed to be developed so they can manage the runoff from the upland areas generally bounded by Wabank Ave to the southeast, Laurel St. to the northeast, Freemont St. to the northwest, and Fairview Ave. to the southwest. Refer to Figure "Site 03 Brandon Park Demonstration Project" overall site plan.

SUMMARY OF BENEFIT AND COST

Proposed GI Technology	Drainage Area (sf)	GI Area (sf)	Capture Vol (gal)	Capital Costs with Contingency ($)
Bioretention	219,913	22,968	4,398,000	$438,244
Porous Pavement Parking Lot	26,126	9,475	571,000	$181,920
Porous Pavement Playcourt	3,096	3,096	68,000	$55,728
Vegetated Swale	1,600	1,600	32,000	$18,514
Pipe and inlets (outside of park)	-	-	-	$81,600
Total	**250,735**	**37,139**	**5,069,000**	**$776,006**

ADDITIONAL CONCEPTS

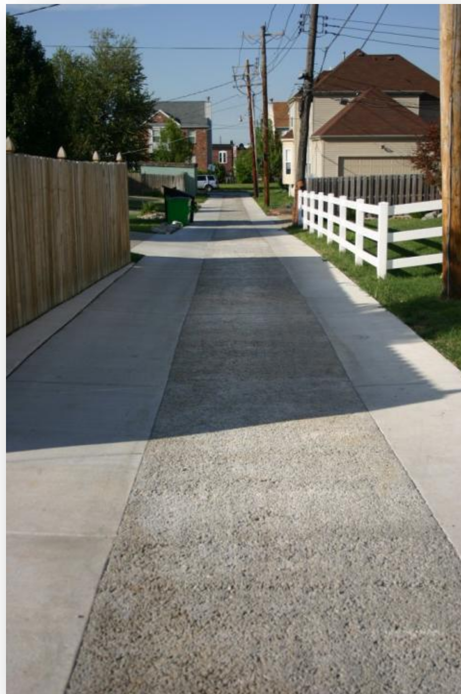
Additional options are being considered for Brandon Park including sewer separation of the upstream residential area to be routed into the park stormwater features. In addition, the play area off of Fairview Ave is being considered for a green skate park similar to the photo below from a similar park in Portland, OR.

Brandon Park Play Area off of Fairview Ave.

E. Benedict Skatepark, Portland, OR

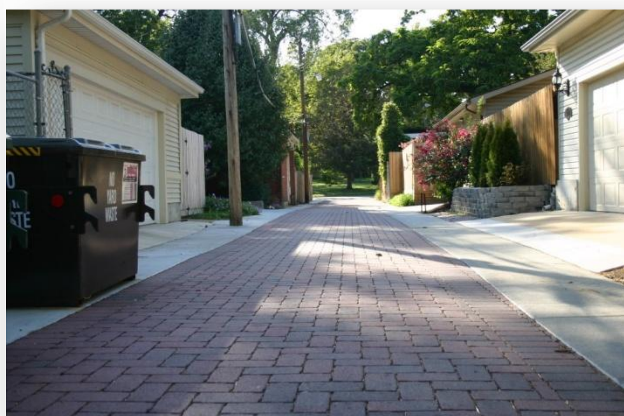
This upstream area has several alleys that would make ideal candidates for green alley projects

SW114th Alley between Laurel & Fairview Ave

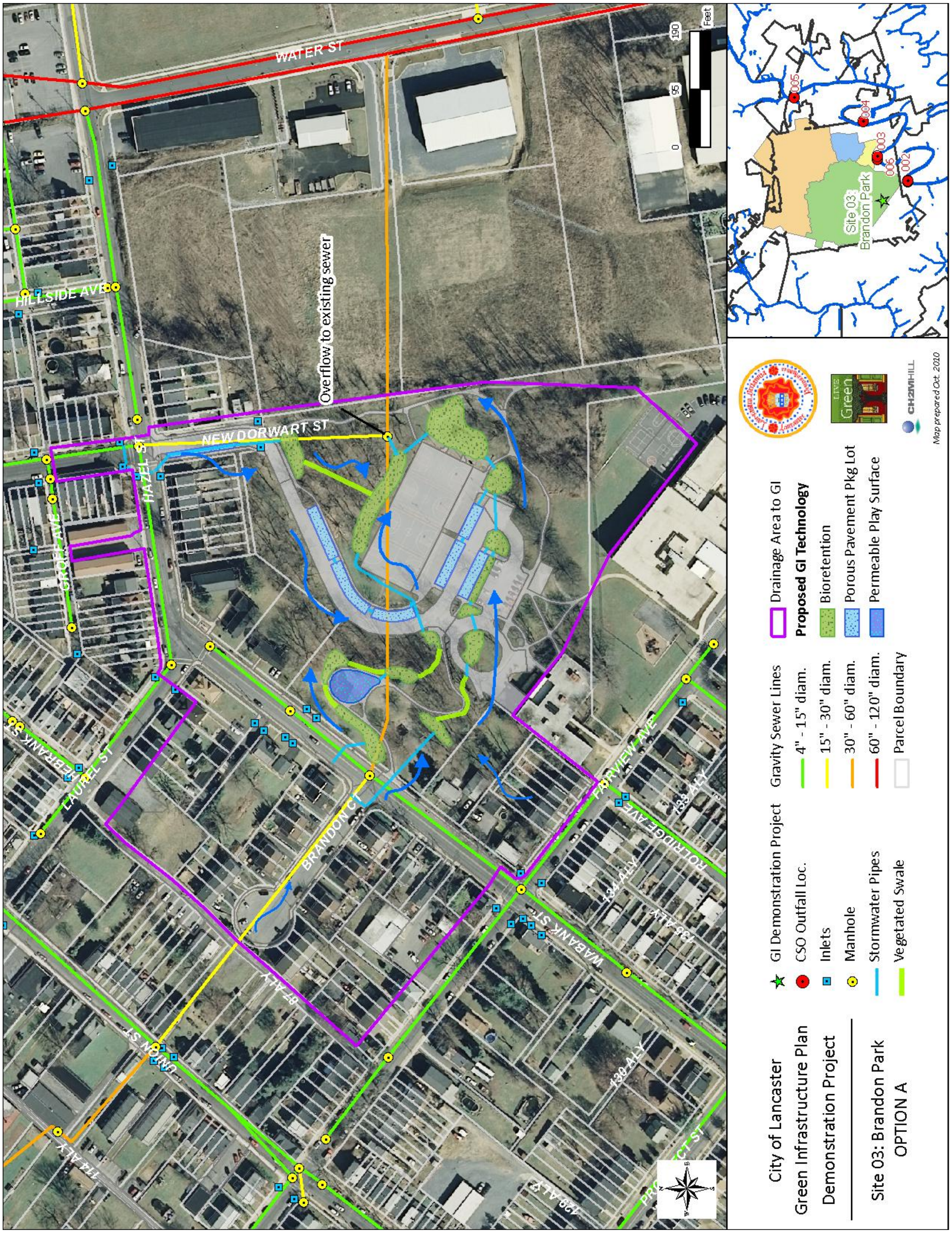


Eads St. Porous Concrete Alley, St. Louis, MO

SW87th Alley between Laurel & Fairview Ave



Geyer Porous Paver Alley, St. Louis, MO



City of Lancaster
Green Infrastructure Plan
Demonstration Project
Site 03: Brandon Park
OPTION A
GI Demonstration Project
CSO Outfall Loc.
Inlets
Manhole
Stormwater Pipes
Vegetated Swale
Gravity Sewer Lines
4" - 15" diam.
15" - 30" diam.
30" - 60" diam.
60" - 120" diam.
Parcel Boundary
Drainage Area to GI
Proposed GI Technology
Bioretention
Porous Pavement Pkg Lot
Permeable Play Surface
Map prepared Oct. 2010
CH2MHILL
Green
Site 03: Brandon Park
005
004
003
006
002
0
95
190
Feet
WATER ST
HILLSIDE AVE
NEW DORWART ST
HAZEL ST
GROFF AVE
LAUREL ST
BRANDON CT
FAIRVIEW AVE
ROHRIDGE AVE
WABANK ST
UNION ST
PROSPECT ST
87 ALY
114 ALY
124 ALY
128 ALY
130 ALY
Overflow to existing sewer

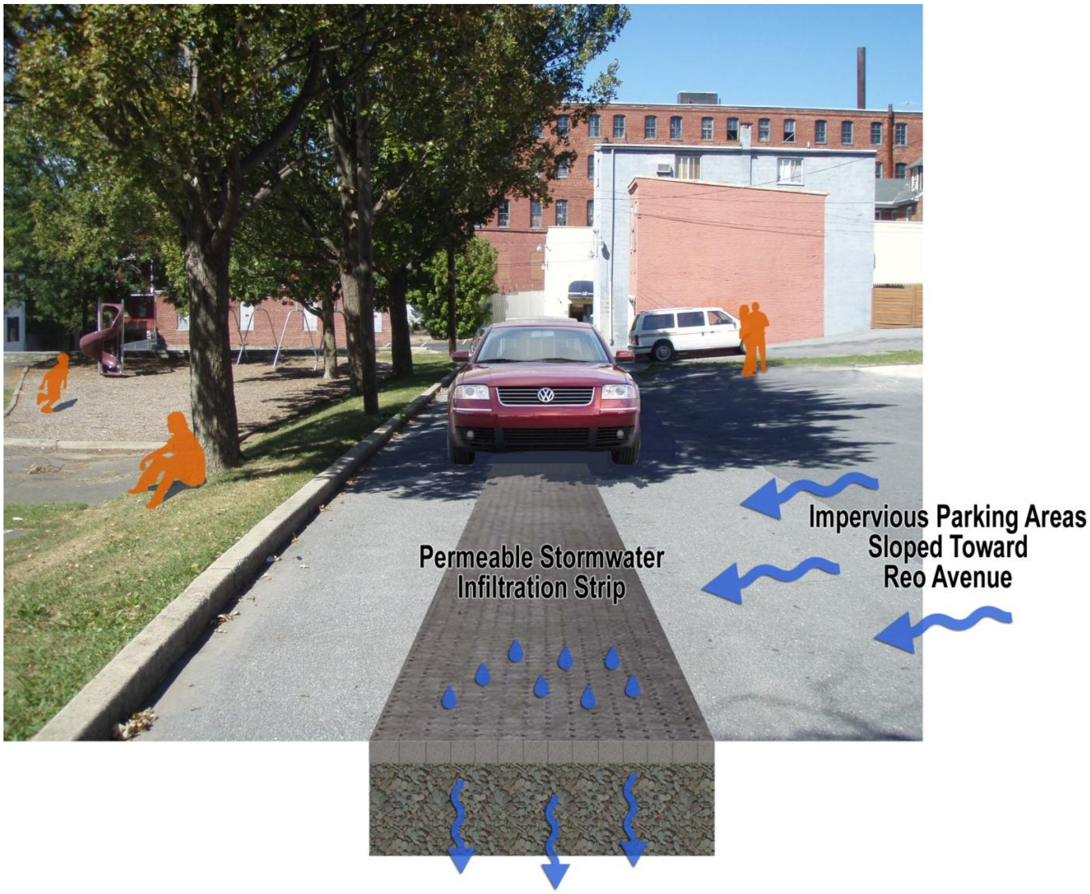
PROJECT P-04: CRYSTAL PARK

PROJECT TYPE:

Green Park

DESCRIPTION:

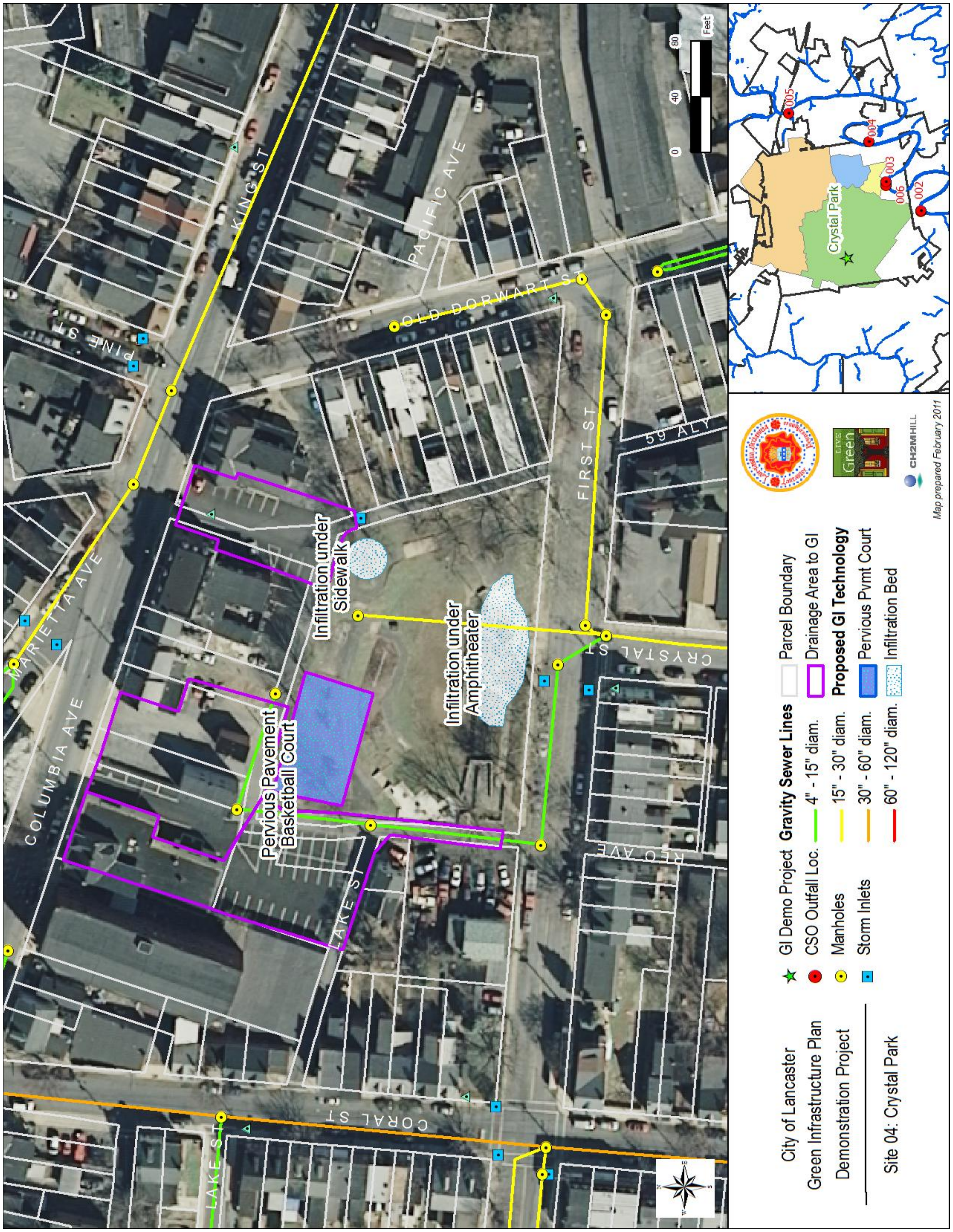
An existing alley will be converted to a green pathway. A porous pavement basketball court will be constructed and additional upland runoff from a large parking area will be directed into the infiltration bed beneath the court. A storage and infiltration area will be constructed under the terminus circle and manage runoff from the upland parking areas and the lower roof and parking areas will be routed to an infiltration bed under the play area and performance stage area. Refer to Figure "Site 04 Crystal Park Demonstration Project" overall site plan.



Green Alley example cross section with subsurface infiltration bed (Rendering - TCA, Inc., 2010)

SUMMARY OF BENEFIT AND COST

Proposed GI Technology	Drainage Area (sf)	GI Area (sf)	Capture Vol (gal)	Capital Costs with Contingency ($)
Porous Pvmt. Playcourt	4,354	871	95,000	$15,676
Infiltration Bed	32,938	6,588	658,000	$94,860
Total	**37,292**	**7,458**	**753,000**	**110,536**


City of Lancaster
Green Infrastructure Plan
Demonstration Project
Site 04: Crystal Park
GI Demo Project
CSO Outfall Loc.
Manholes
Storm Inlets
Gravity Sewer Lines
4" - 15" diam.
15" - 30" diam.
30" - 60" diam.
60" - 120" diam.
Parcel Boundary
Drainage Area to GI
Proposed GI Technology
Pervious Pvmt Court
Infiltration Bed
CH2MHILL
Map prepared February 2011
Crystal Park
005
004
003
006
002
0
40
80
Feet
Pervious Pavement Basketball Court
Infiltration under Sidewalk
Infiltration under Amphitheater
KING ST
PACIFIC AVE
OLD DORWART ST
PINE ST
MARIETTA AVE
COLUMBIA AVE
FIRST ST
59 ALY
CRYSTAL ST
REO AVE
LAKE ST
CORAL ST

PROJECT P-05: RODNEY PARK

PROJECT TYPE:

Green Park

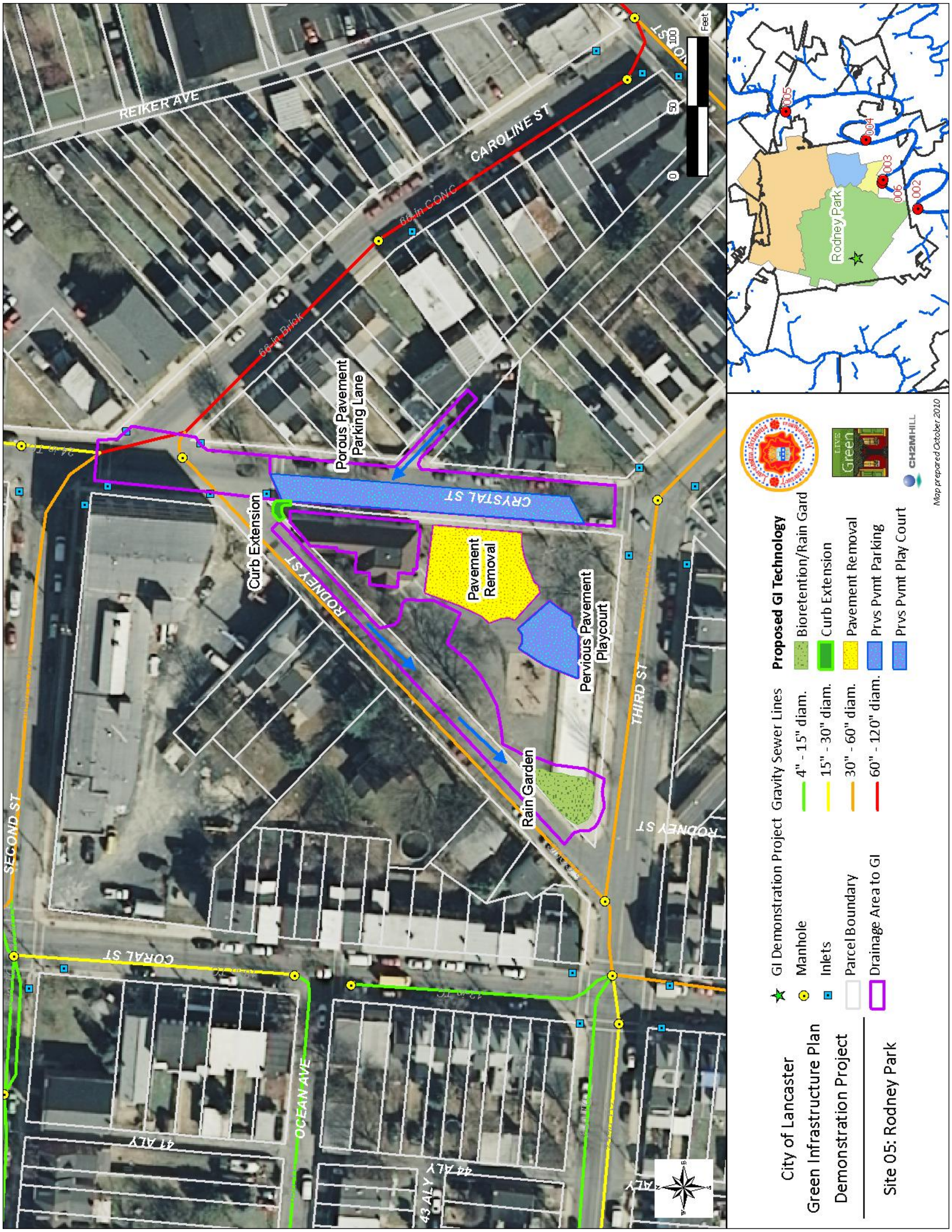
DESCRIPTION:

Using the concept plan provided in the Urban Parks, Recreation and Open Space Plan, many GI techniques are incorporated into Rodney Park. A bioretention area at the intersection of Third and Rodney collect street runoff off Rodney Street. The proposed parking on Crystal can be reconstructed as back-in parking over porous pavement, and can manage runoff from most of Crystal and a portion of the adjacent alleyway. The proposed play court can be constructed with a pervious surface to manage additional runoff. Refer to Figure "Site 05 Rodney Park Demonstration Project" overall site plan.

Many mature trees have been cut down making this location idea for tree plantings to fill in lost tree canopy

SUMMARY OF BENEFIT AND COST

Proposed GI Technology	Drainage Area (sf)	GI Area (sf)	Capture Vol (gal)	Capital Costs with Contingency ($)
Bioretention	8,578	1,085	172,000	$20,704
Porous Pavement Road	15,411	4,018	337,000	$77,146
Porous Pavement Playcourt	1,520	1,520	33,000	$27,367
Pavement Removal	4,097	4,097	82,000	$17,398
Curb Extension	101	101	2,000	$1,088
Total	**29,707**	**10,821**	**626,000**	**$143,702**


REIKER AVE
CAROLINE ST
60 in CONC
60 in Brick
Porous Pavement Parking Lane
CRYSTAL ST
Curb Extension
RODNEY ST
Pavement Removal
Pervious Pavement Playcourt
Rain Garden
THIRD ST
SECOND ST
CORAL ST
OCEAN AVE
41 ALY
44 ALY
43 ALY
0
50
100
Feet
Rodney Park
005
004
003
006
002
City of Lancaster
Green Infrastructure Plan
Demonstration Project
Site 05: Rodney Park
GI Demonstration Project
Manhole
Inlets
Parcel Boundary
Drainage Area to GI
Gravity Sewer Lines
4" - 15" diam.
15" - 30" diam.
30" - 60" diam.
60" - 120" diam.
Proposed GI Technology
Bioretention/Rain Gard
Curb Extension
Pavement Removal
Prvs Pvmt Parking
Prvs Pvmt Play Court
Map prepared October 2010

PROJECT P-07: CONLIN FIELD/FARNUM PARK

PROJECT TYPE:

Green Park

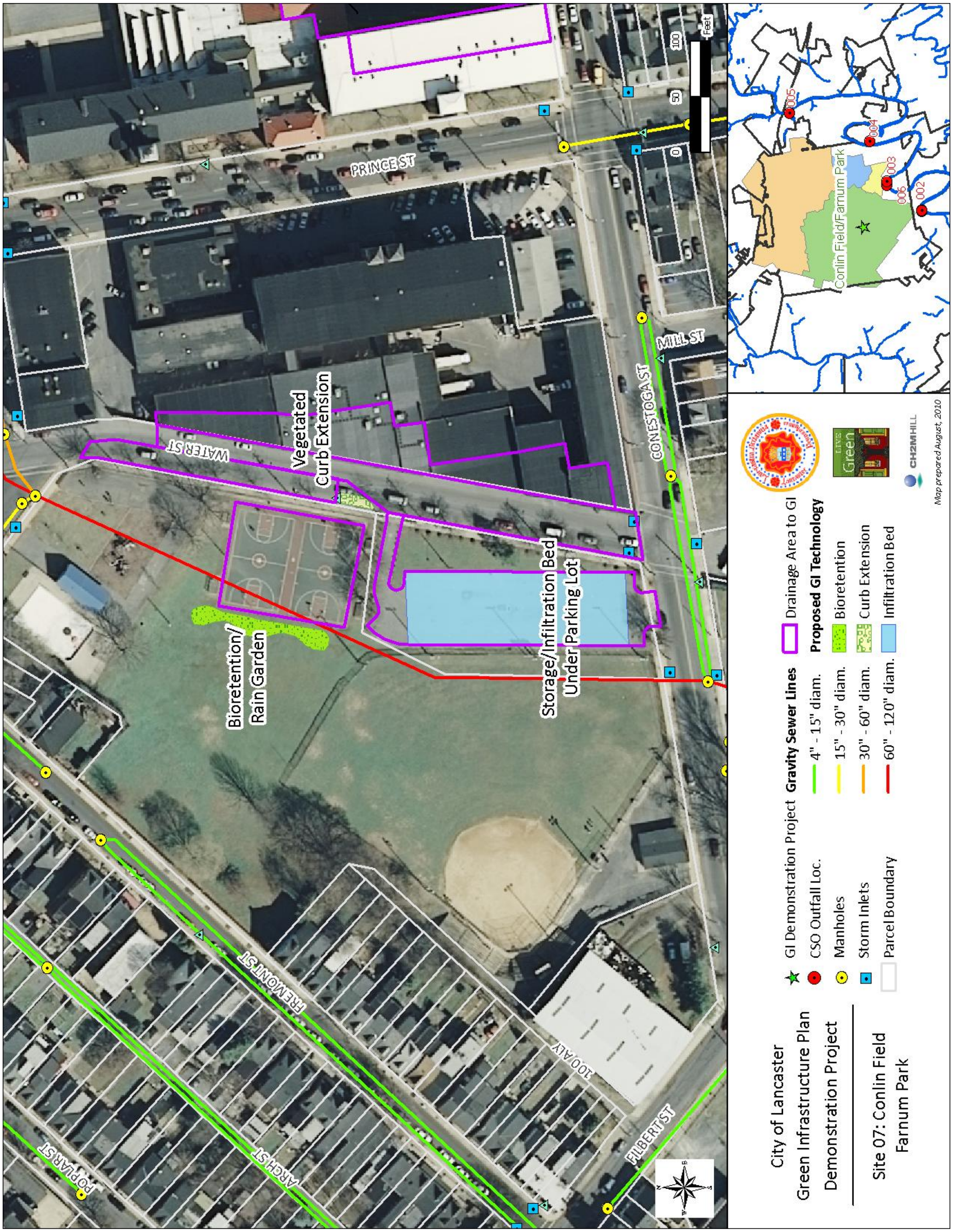
DESCRIPTION:

A rain garden will be constructed to capture runoff from an existing basketball court. A large porous pavement parking lot will replace the existing parking lot and runoff from the adjacent street and large roof areas will be redirected into the infiltration bed under the parking lot. A vegetated curb extension will be constructed to manage street runoff and tree plantings will be used throughout. Refer to Figure "Site 07 Conlin Field/Farnum Park Demonstration Project" overall site plan.

SUMMARY OF BENEFIT AND COST

Proposed GI Technology	Drainage Area (sf)	GI Area (sf)	Capture Vol (gal)	Capital Costs with Contingency ($)
Bioretention	78,021	1,088	218,000	$22,199
Curb Extension	4,487	299	90,000	$10,769
Pervious Pavement Parking Lot	43,108	16,532	942,000	$297,584
Total	**125,616**	**17,920**	**1,250,000**	**$330,553**

Additional concepts consider the rooftop for the large building on Water Street (Water Street Rescue Mission) with exposed roof leaders. These roof leaders can be directed to cisterns and / or the infiltration beds in the Park across the street.


City of Lancaster
Green Infrastructure Plan
Demonstration Project
Site 07: Conlin Field
Farnum Park
GI Demonstration Project
CSO Outfall Loc.
Manholes
Storm Inlets
Parcel Boundary
Gravity Sewer Lines
4" - 15" diam.
15" - 30" diam.
30" - 60" diam.
60" - 120" diam.
Drainage Area to GI
Proposed GI Technology
Bioretention
Curb Extension
Infiltration Bed
CH2MHILL
Map prepared August, 2010
Vegetated
Curb Extension
Bioretention/
Rain Garden
Storage/Infiltration Bed
Under Parking Lot
PRINCE ST
WATER ST
MILL ST
CONESTOGA ST
FREMONT ST
ARCH ST
POPLAR ST
FILBERT ST
IOOF ALY
Conlin Field/Farnum Park
002
003
004
005
006
0
50
100
Feet

Bioretention manages runoff from basketball court (Rendering - TCA, Inc., 2010)

PROJECT P-08: NORTHWEST CORRIDOR LINEAR PARK

PROJECT TYPE:

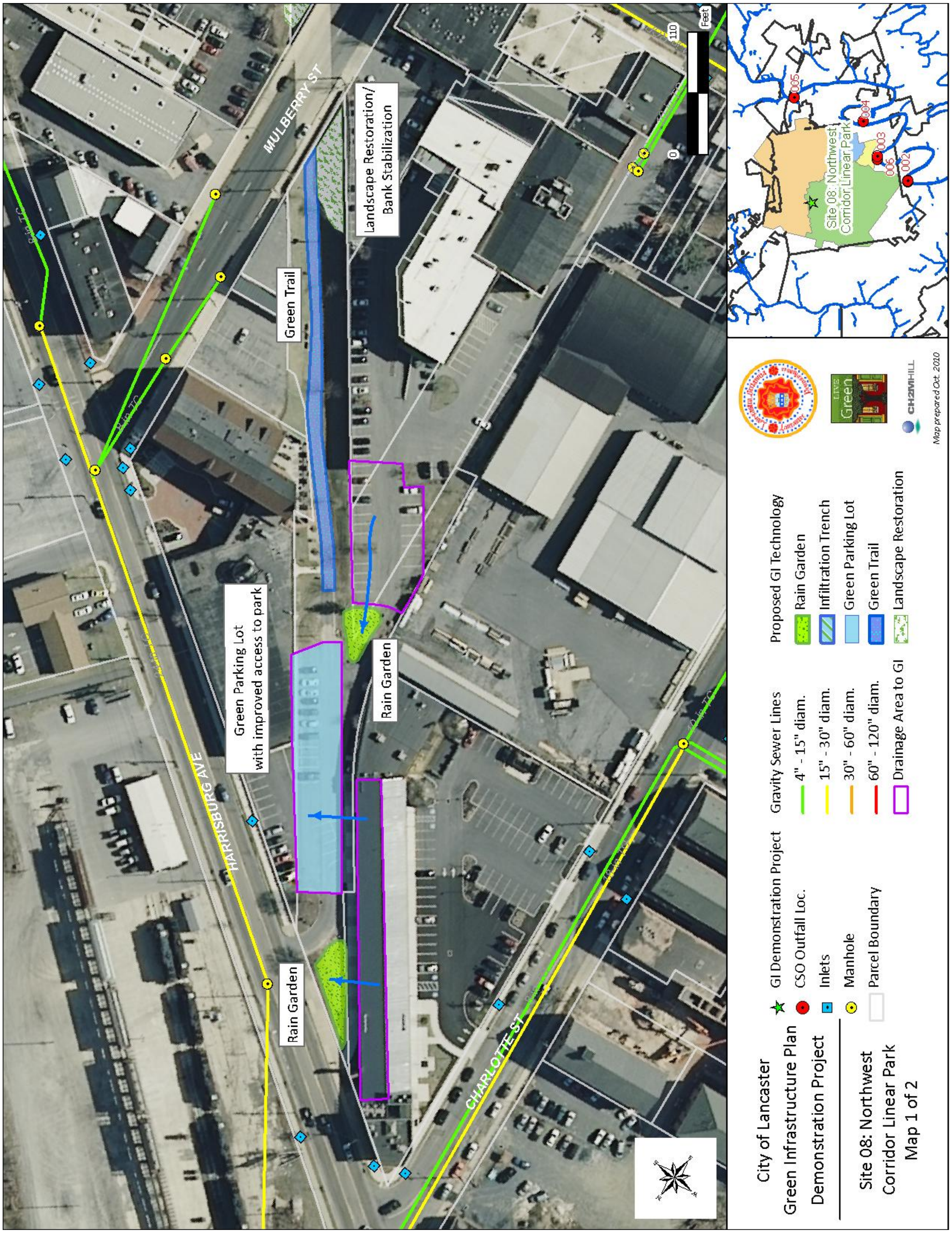
Green Park

DESCRIPTION:

A rain garden constructed at the entrance off Harrisburg Ave can manage a portion of the adjacent rooftop runoff. A portion of the parking lot can be constructed with an infiltration bed to manage stormwater from the parking area and some of the adjacent rooftop runoff. A second rain garden can manage runoff from another parking area. The trail can be reconstructed as a green trail in which all runoff from the trail is managed at the site. A third rain garden could be constructed to manage runoff of the adjacent basketball court. An infiltration trench can mitigate runoff from an adjacent rooftop. Refer to Figure "Site 08 Northwest Corridor Linear Park Demonstration Project" overall site plan.

SUMMARY OF BENEFIT AND COST

Proposed GI Technology	Drainage Area (sf)	GI Area (sf)	Capture Vol (gal)	Capital Costs with Contingency ($)
Bioretention	13,835	3,605	277,000	$68,782
Landscape Restoration	7,048	7,048	141,000	$38,977
Infiltration Trench	2,335	968	47,000	$22,961
Green Trail	11,042	11,042	221,000	$118,425
Green Parking Lot	12,911	9,520	258,000	$152,015
Total	**47,171**	**32,183**	**944,000**	**$401,158**


City of Lancaster
Green Infrastructure Plan
Demonstration Project
Site 08: Northwest
Corridor Linear Park
Map 1 of 2
GI Demonstration Project
CSO Outfall Loc.
Inlets
Manhole
Parcel Boundary
Gravity Sewer Lines
4" - 15" diam.
15" - 30" diam.
30" - 60" diam.
60" - 120" diam.
Drainage Area to GI
Proposed GI Technology
Rain Garden
Infiltration Trench
Green Parking Lot
Green Trail
Landscape Restoration
Map prepared Oct. 2010
CH2MHILL
Green
Rain Garden
Green Parking Lot
with improved access to park
Rain Garden
Green Trail
Landscape Restoration/
Bank Stabilization
MULBERRY ST
HARRISBURG AVE
CHARLOTTE ST
0
110
Feet
Site 08: Northwest
Corridor Linear Park
005
004
003
006
002


City of Lancaster
Green Infrastructure Plan
Demonstration Project
Site 08: Northwest
Corridor Linear Park
Map 2 of 2
GI Demonstration Project
CSO Outfall Loc.
Inlets
Manhole
Parcel Boundary
Gravity Sewer Lines
4" - 15" diam.
15" - 30" diam.
30" - 60" diam.
60" - 120" diam.
Drainage Area to GI
Proposed GI Technology
Rain Garden
Infiltration Trench
Green Parking Lot
Green Trail
Landscape Restoration
Map prepared Oct. 2010
Infiltration Trench
Rain Garden
Green Trail
Landscape Restoration/
Bank Stabilization
WATER ST
ARCH ST
LEMON ST
JAMES ST
MULBERRY ST
0
110
Feet
Site 08: Northwest
Corridor Linear Park
005
004
003
006
002

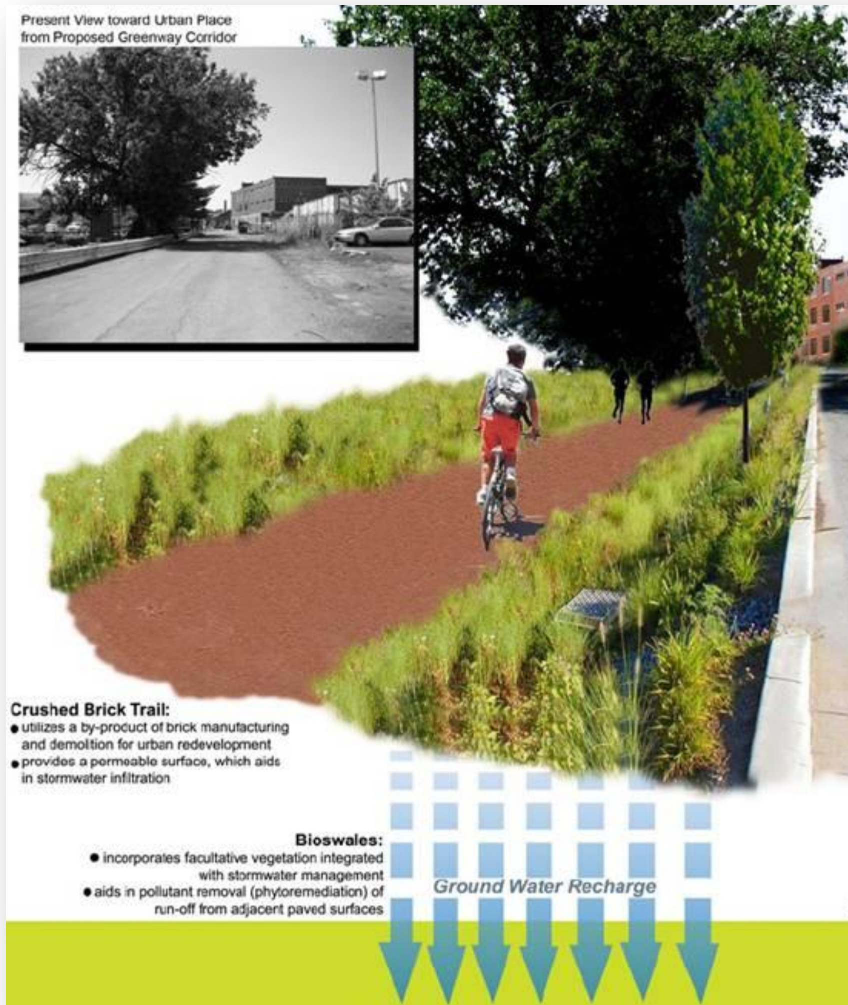
PROJECT P-19: NORTHEAST GREENWAY CORRIDOR

PROJECT TYPE:

Green Park

DESCRIPTION:

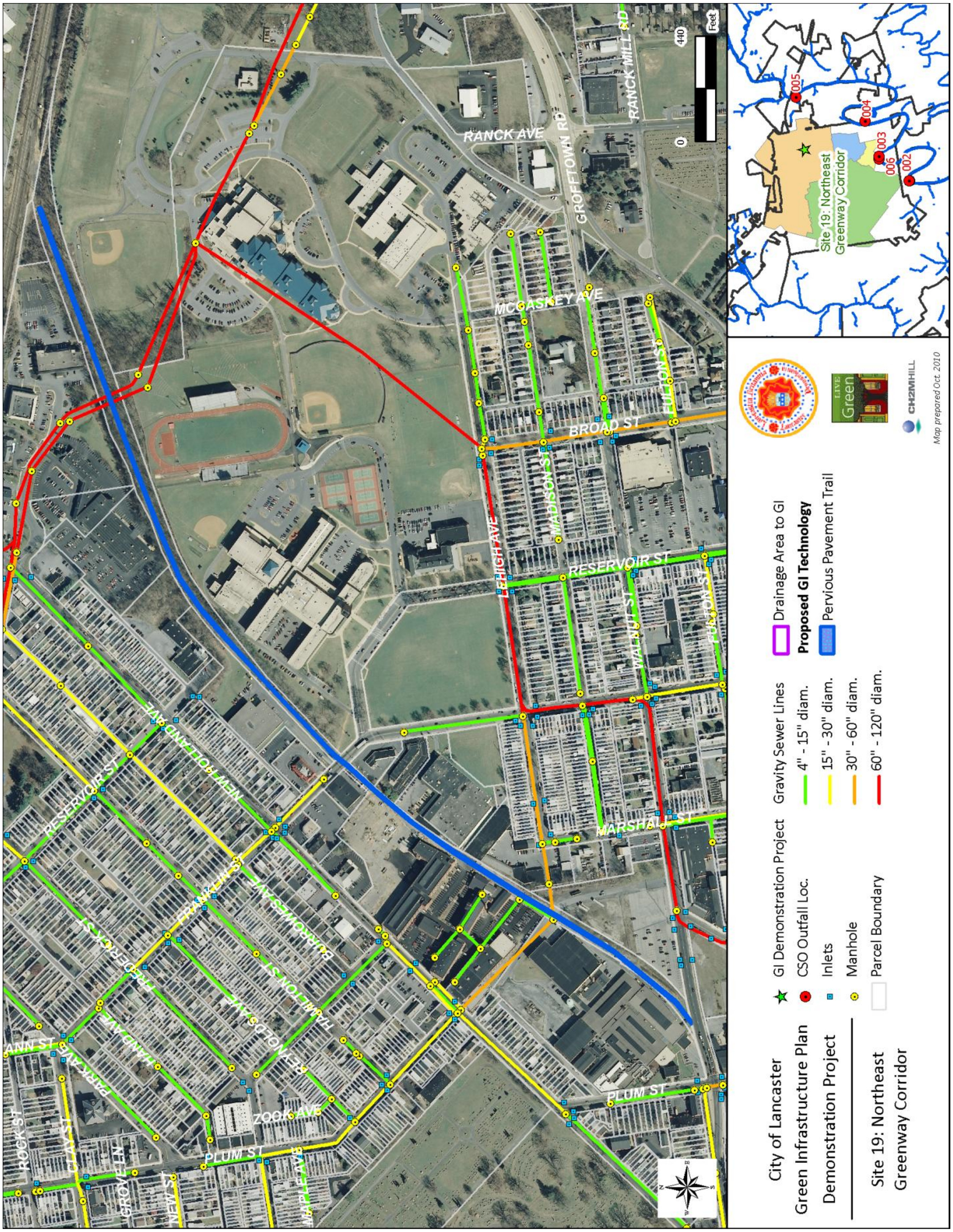
As recommended in the City of Lancaster Northeast Revitalization Initiative Plan (2007), the Northeast Greenway is envisioned as a linear green space and trail along a former rail corridor. This concept plan would maximize stormwater capture associated with the proposed greenway. The trail for this potential project could be constructed with an infiltration bed that will mitigate all runoff associated with the trail development. Refer to Figure "Site 19 Northeast Greenway Corridor Demonstration Project" overall site plan.



Conceptual rendering of green trail (Rendering - TCA, Inc)

SUMMARY OF BENEFIT AND COST

Proposed GI Technology	Drainage Area (sf)	GI Area (sf)	Capture Vol (gal)	Capital Costs with Contingency ($)
Green Trail	45,150	45,150	987,000	$484,220


City of Lancaster
Green Infrastructure Plan
Demonstration Project
Site 19: Northeast Greenway Corridor
GI Demonstration Project
CSO Outfall Loc.
Inlets
Manhole
Parcel Boundary
Gravity Sewer Lines
4" - 15" diam.
15" - 30" diam.
30" - 60" diam.
60" - 120" diam.
Drainage Area to GI
Proposed GI Technology
Pervious Pavement Trail
Map prepared Oct. 2010
Site 19: Northeast Greenway Corridor
005
004
003
006
002
0
440
Feet
RANCK AVE
GROFFTOWN RD
RANCK MILL RD
MCCASKEY AVE
BROAD ST
FULTON ST
MADISON ST
LEHIGH AVE
RESERVOIR ST
WALNUT ST
MARSHALL ST
PLUM ST
NEW HOLLAND AVE
FRANKLIN ST
BURROWES AVE
HAMILTON ST
REYNOLDS AVE
FREDERICK ST
ZOOK AVE
PARK AVE
ANN ST
ROCK ST
CLAY ST
NEW ST
MAPLE AVE

PROJECT P-20: TRIANGLE PARK

PROJECT TYPE:

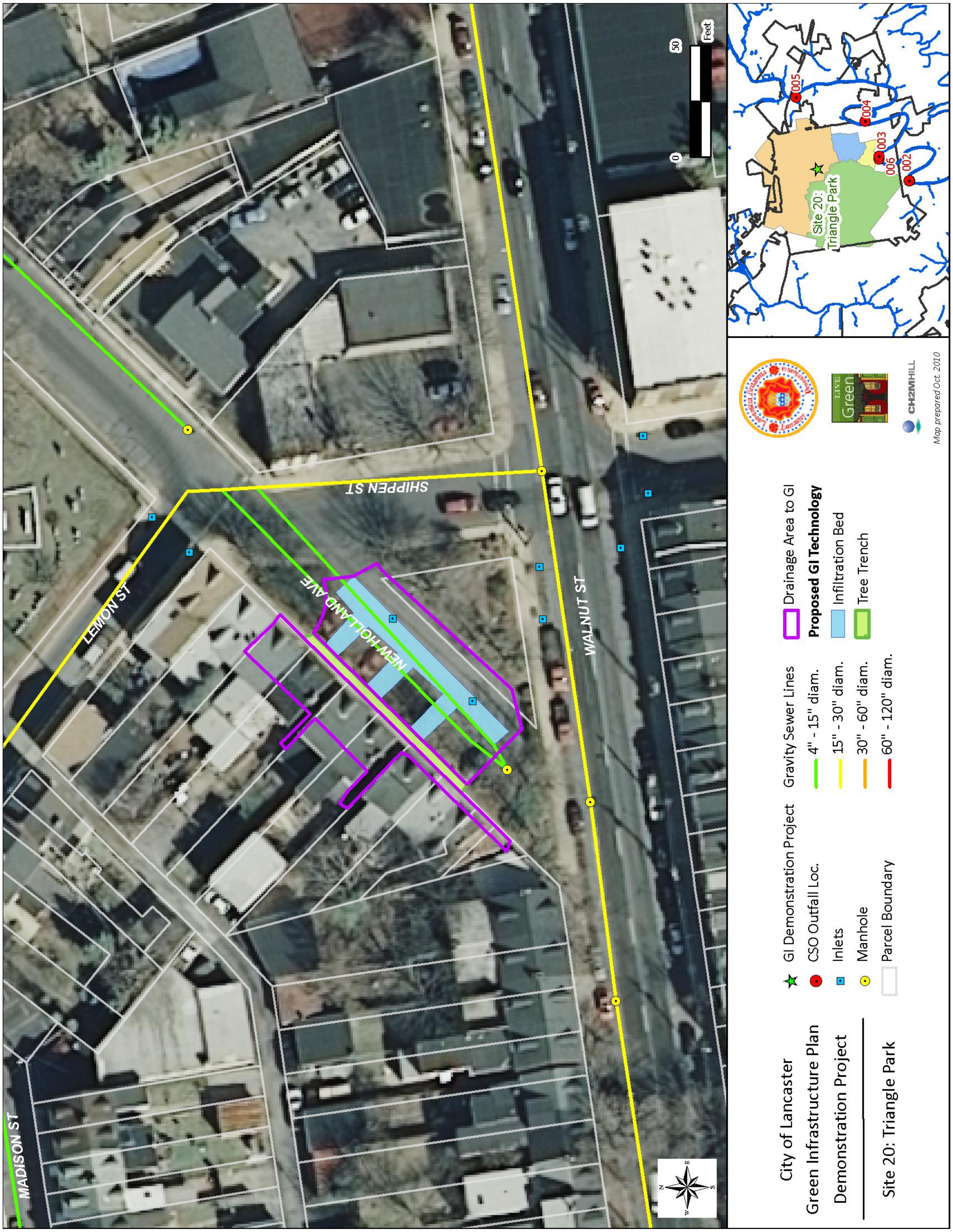
Green Park

DESCRIPTION:

Triangle Park is a small park that provides an opportunity for an infiltration bed to be constructed beneath the parking area to manage runoff from the immediate parking lot. A tree trench could be planted along the perimeter of the park and roof leaders from the homes on the park can be readily disconnected to the tree trench. The tree trench would be linked to the infiltration bed. Refer to Figure "Site 20 Triangle Park Demonstration Project" overall site plan.

SUMMARY OF BENEFIT AND COST

Proposed GI Technology	Drainage Area (sf)	GI Area (sf)	Capture Vol (gal)	Capital Costs with Contingency ($)
Infiltration Bed	4,339	1,534	87,000	$13,453
Tree Trench	2,291	429	46,000	$6,885
Total	**6,630**	**1,963**	**133,000**	**$20,338**


City of Lancaster
Green Infrastructure Plan
Demonstration Project
Site 20: Triangle Park
GI Demonstration Project
CSO Outfall Loc.
Inlets
Manhole
Parcel Boundary
Gravity Sewer Lines
4" - 15" diam.
15" - 30" diam.
30" - 60" diam.
60" - 120" diam.
Drainage Area to GI
Proposed GI Technology
Infiltration Bed
Tree Trench
Map prepared Oct. 2010
CH2MHILL
Site 20:
Triangle Park
005
004
003
006
002
0
50
Feet
SHIPPEN ST
LEMON ST
NEW HOLLAND AVE
WALNUT ST
MADISON ST

PROJECT P-30: CARTER MACRAE ELEMENTARY SCHOOL

PROJECT TYPE:

Green School

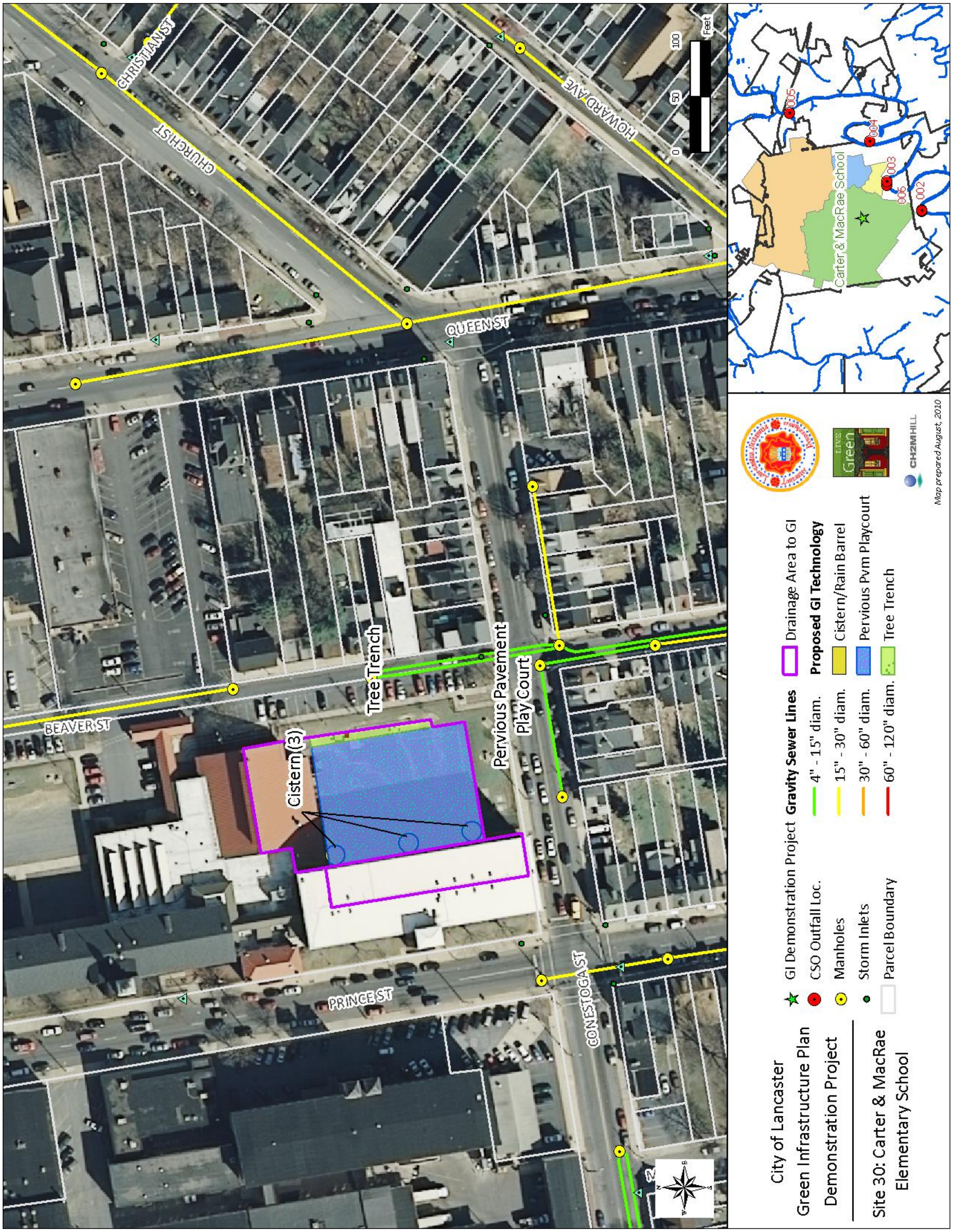
Description:

Approximately 20,000 square feet of existing storage space at the Carter MacRae School is planned to be converted to District offices. The extensive rooftop area and exposed roof leaders provide for economical capture of rooftop runoff by disconnection from the combined sewer and redirection large cisterns located adjacent to the building on the existing asphalt play court. The large impervious play area could also be retrofitted to a porous pavement system. Since the building is large and will have many people passing through in its present and future function, it offers an ideal opportunity for educational programming or signage. Refer to Figure "Site 30 Carter MacRae Elementary School Demonstration Project" overall site plan.

Cistern with Green wall at Chicago Center for Green Technology

SUMMARY OF BENEFIT AND COST

Proposed GI Technology	Drainage Area (sf)	GI Area (sf)	Capture Vol (gal)	Capital Costs with Contingency ($)
Porous Pavement Playcourt	30,572	4,480	490,000	$80,640
Cistern/Rain Barrel	6,686	-	134,000	$18,000
Total	**37,258**	**4,480**	**624,000**	**$98,640**


City of Lancaster
Green Infrastructure Plan
Demonstration Project
Site 30: Carter & MacRae
Elementary School
GI Demonstration Project
CSO Outfall Loc.
Manholes
Storm Inlets
Parcel Boundary
Gravity Sewer Lines
4" - 15" diam.
15" - 30" diam.
30" - 60" diam.
60" - 120" diam.
Drainage Area to GI
Proposed GI Technology
Cistern/Rain Barrel
Pervious Pvm Playcourt
Tree Trench
LIVE Green
CH2MHILL
Map prepared August, 2010
Carter & MacRae School
005
004
003
006
002
0
50
100
Feet
CHRISTIAN ST
CHURCH ST
HOWARD AVE
QUEEN ST
BEAVER ST
PRINCE ST
CONESTOGA ST
Tree Trench
Pervious Pavement
Play Court
Cistern (3)

PROJECT P-31: PLUM STREET LOT

PROJECT TYPE:

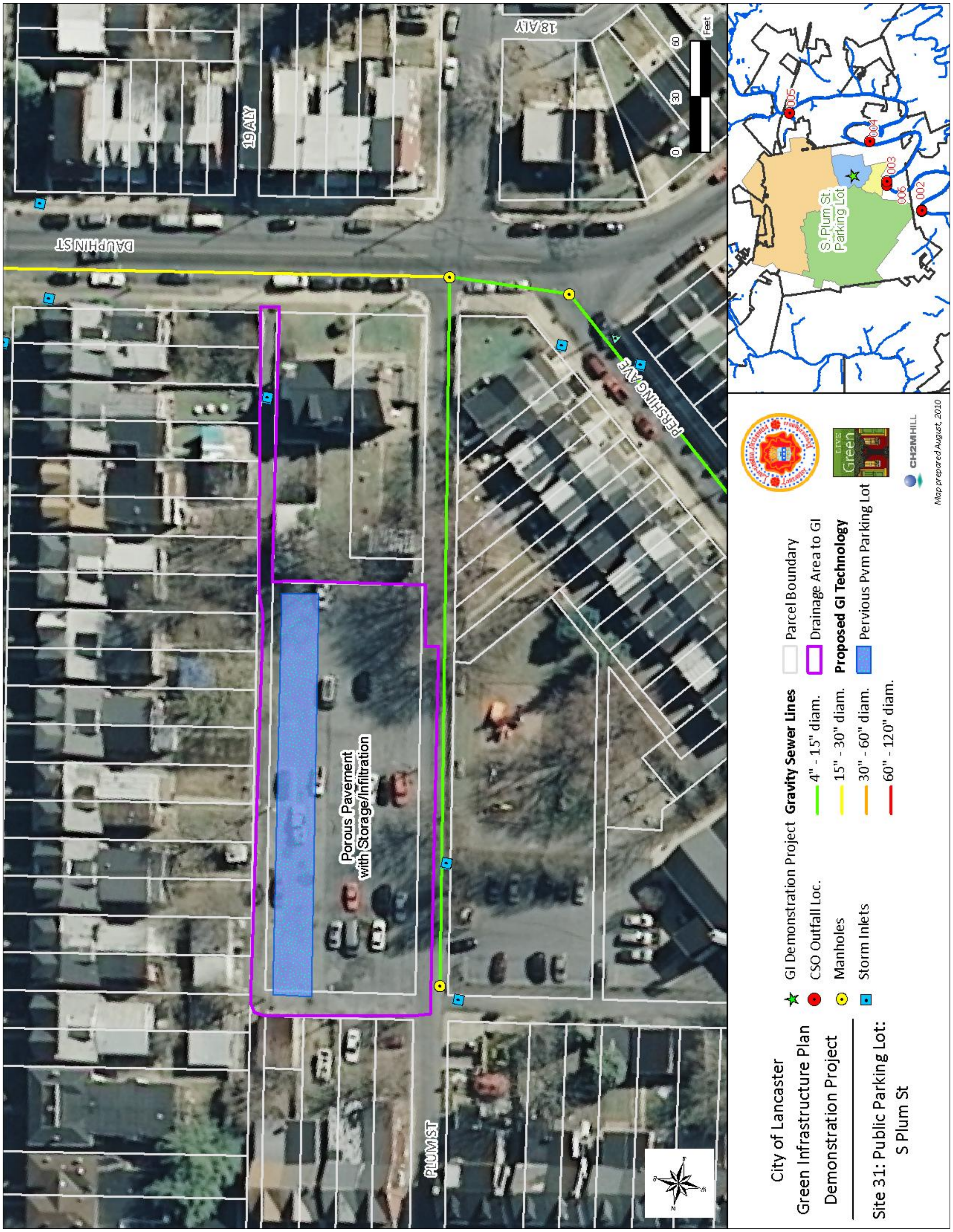
Green Parking Lot

DESCRIPTION:

The existing parking lot will be retrofitted with porous pavement with subsurface infiltration bed. Refer to Figure "Site 31 Plum Street Lot Demonstration Project" overall site plan.

SUMMARY OF BENEFIT AND COST

Proposed GI Technology	Drainage Area (sf)	GI Area (sf)	Capture Vol (gal)	Capital Costs with Contingency ($)
Porous Pavement Road	23,402	4,680	511,000	$89,862


City of Lancaster
Green Infrastructure Plan
Demonstration Project
Site 31: Public Parking Lot:
S Plum St
GI Demonstration Project
CSO Outfall Loc.
Manholes
Storm Inlets
Gravity Sewer Lines
4" - 15" diam.
15" - 30" diam.
30" - 60" diam.
60" - 120" diam.
Parcel Boundary
Drainage Area to GI
Proposed GI Technology
Pervious Pvm Parking Lot
Map prepared August, 2010
Porous Pavement
with Storage/Infiltration
DAUPHIN ST
19 ALY
18 ALY
PERSHING AVE
PLUM ST
0 30 60
Feet
S Plum St.
Parking Lot
005
004
003
006
002

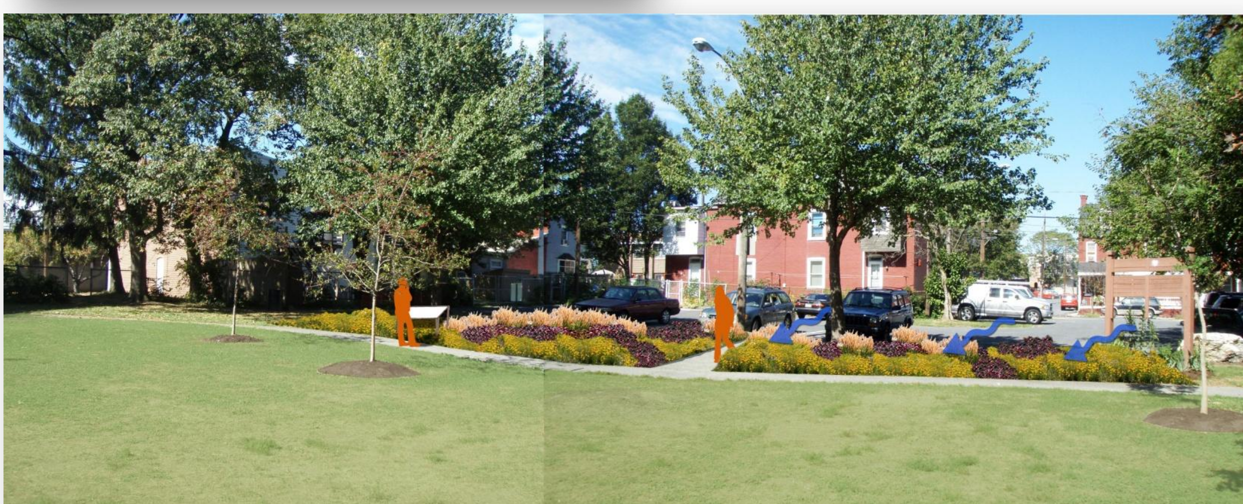
PROJECT P-34: DAUPHIN ST. PARKING LOT

PROJECT TYPE:

Green Parking Lot

DESCRIPTION:

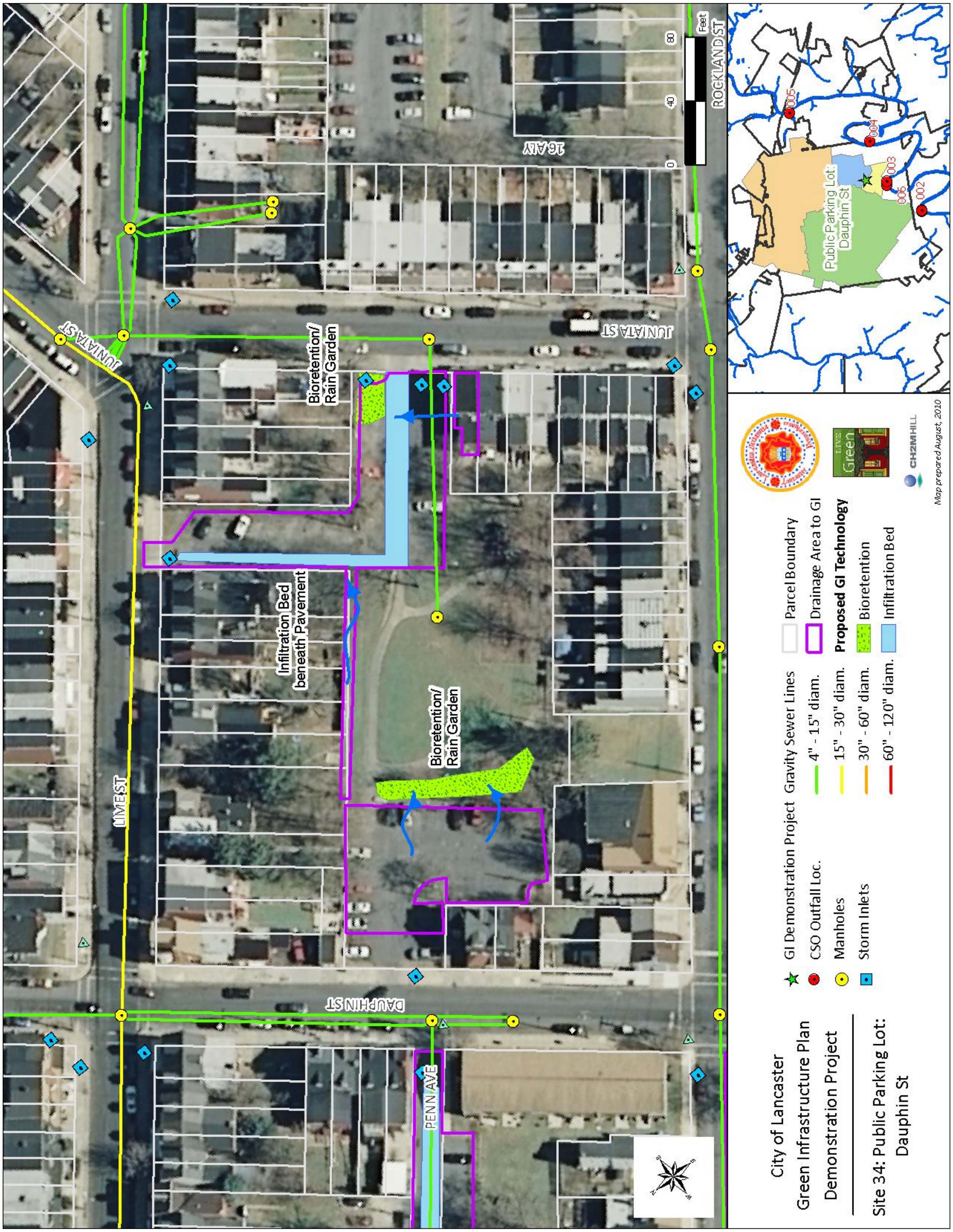
A bioretention garden will capture runoff from the Dauphin Street parking lot. A combination bioretention garden and infiltration bed will capture runoff from the Dauphin Street and Lime Street entrances. Refer to Figure "Site 34 Dauphin Street Parking Lot Demonstration Project" overall site plan.



Bioretention enhances natural space and manages runoff from the parking lot (Rendering TCA, Inc.)

SUMMARY OF BENEFIT AND COST:

Proposed GI Technology	Drainage Area (sf)	GI Area (sf)	Capture Vol (gal)	Capital Costs with Contingency ($)
Bioretention	8,777	1,910	175,000	$38,957
Infiltration Bed	11,805	2,607	236,000	$22,865
Total	**20,582**	**4,516**	**411,000**	**$61,822**


City of Lancaster
Green Infrastructure Plan
Demonstration Project
Site 34: Public Parking Lot: Dauphin St
GI Demonstration Project
CSO Outfall Loc.
Manholes
Storm Inlets
Gravity Sewer Lines
4" - 15" diam.
15" - 30" diam.
30" - 60" diam.
60" - 120" diam.
Parcel Boundary
Drainage Area to GI
Proposed GI Technology
Bioretention
Infiltration Bed
Map prepared August, 2010
CH2MHILL
Bioretention/ Rain Garden
Infiltration Bed beneath Pavement
Bioretention/ Rain Garden
JUNIATA ST
JUNIATA ST
LIME ST
DAUPHIN ST
PENN AVE
ROCKLAND ST
16 ALY
0
40
80
Feet
Public Parking Lot: Dauphin St
005
004
003
006
002

PROJECT P-35: PENN AVE. PARKING LOT

PROJECT TYPE:

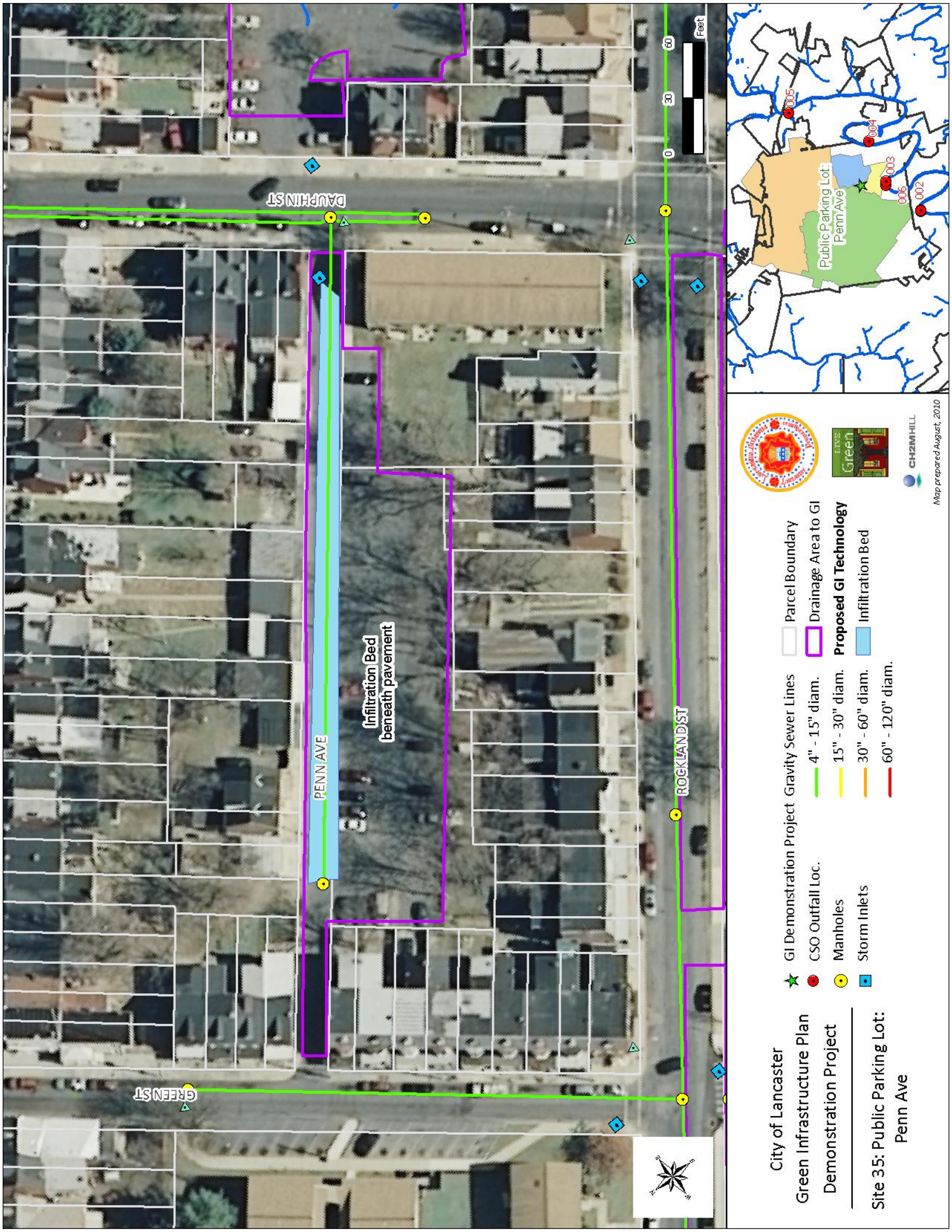
Green Parking Lot

DESCRIPTION:

The existing parking lot will be retrofit with a subsurface infiltration/storage bed. The lot pavements are currently in poor condition. Refer to Figure "Site 35 Penn Ave Parking Lot Demonstration Project" overall site plan.

SUMMARY OF BENEFIT AND COST:

Proposed GI Technology	Drainage Area (sf)	GI Area (sf)	Capture Vol (gal)	Capital Costs with Contingency ($)
Infiltration Bed	22,758	4,219	455,000	$60,749


City of Lancaster
Green Infrastructure Plan
Demonstration Project
Site 35: Public Parking Lot: Penn Ave
GI Demonstration Project
CSO Outfall Loc.
Manholes
Storm Inlets
Gravity Sewer Lines
4" - 15" diam.
15" - 30" diam.
30" - 60" diam.
60" - 120" diam.
Parcel Boundary
Drainage Area to GI
Proposed GI Technology
Infiltration Bed
CH2MHILL
Map prepared August, 2010
Public Parking Lot: Penn Ave
002
003
004
005
006
DAUPHIN ST
GREEN ST
PENN AVE
ROCKLAND ST
Infiltration Bed beneath pavement
0
30
60
Feet

PROJECT P-36: MIFFLIN STREET PARKING LOT

PROJECT TYPE:

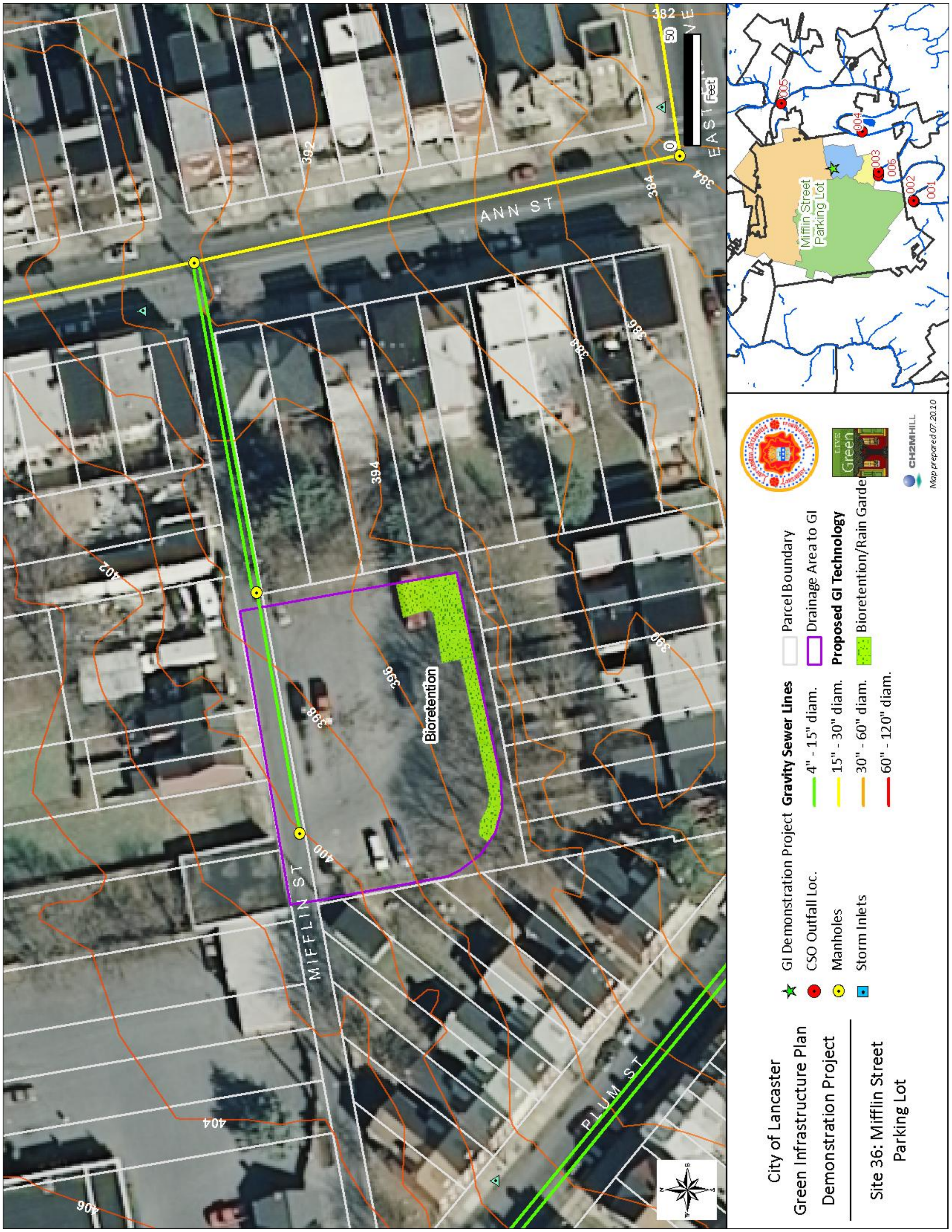
Green Parking Lot

DESCRIPTION:

The existing parking lot will be retrofitted with a bioretention area to capture runoff from the lot. Refer to Figure "Site 36 Mifflin Street Parking Lot Demonstration Project" overall site plan.

SUMMARY OF BENEFIT AND COST

Proposed GI Technology	Drainage Area (sf)	GI Area (sf)	Capture Vol (gal)	Capital Costs with Contingency ($)
Bioretention	13,242	1,324	265,000	$27,013


City of Lancaster
Green Infrastructure Plan
Demonstration Project
Site 36: Mifflin Street Parking Lot
GI Demonstration Project
CSO Outfall Loc.
Manholes
Storm Inlets
Gravity Sewer Lines
4" - 15" diam.
15" - 30" diam.
30" - 60" diam.
60" - 120" diam.
Parcel Boundary
Drainage Area to GI
Proposed GI Technology
Bioretention/Rain Garde
Map prepared 07.2010
CH2MHILL
Bioretention
ANN ST
MIFFLIN ST
PLUM ST
EAST
Feet
0
50
382
384
386
388
390
392
394
396
398
400
402
404
406
Mifflin Street Parking Lot
005
004
003
006
002
001

PROJECT P-42: HAND MIDDLE SCHOOL

PROJECT TYPE:

Green School

DESCRIPTION:

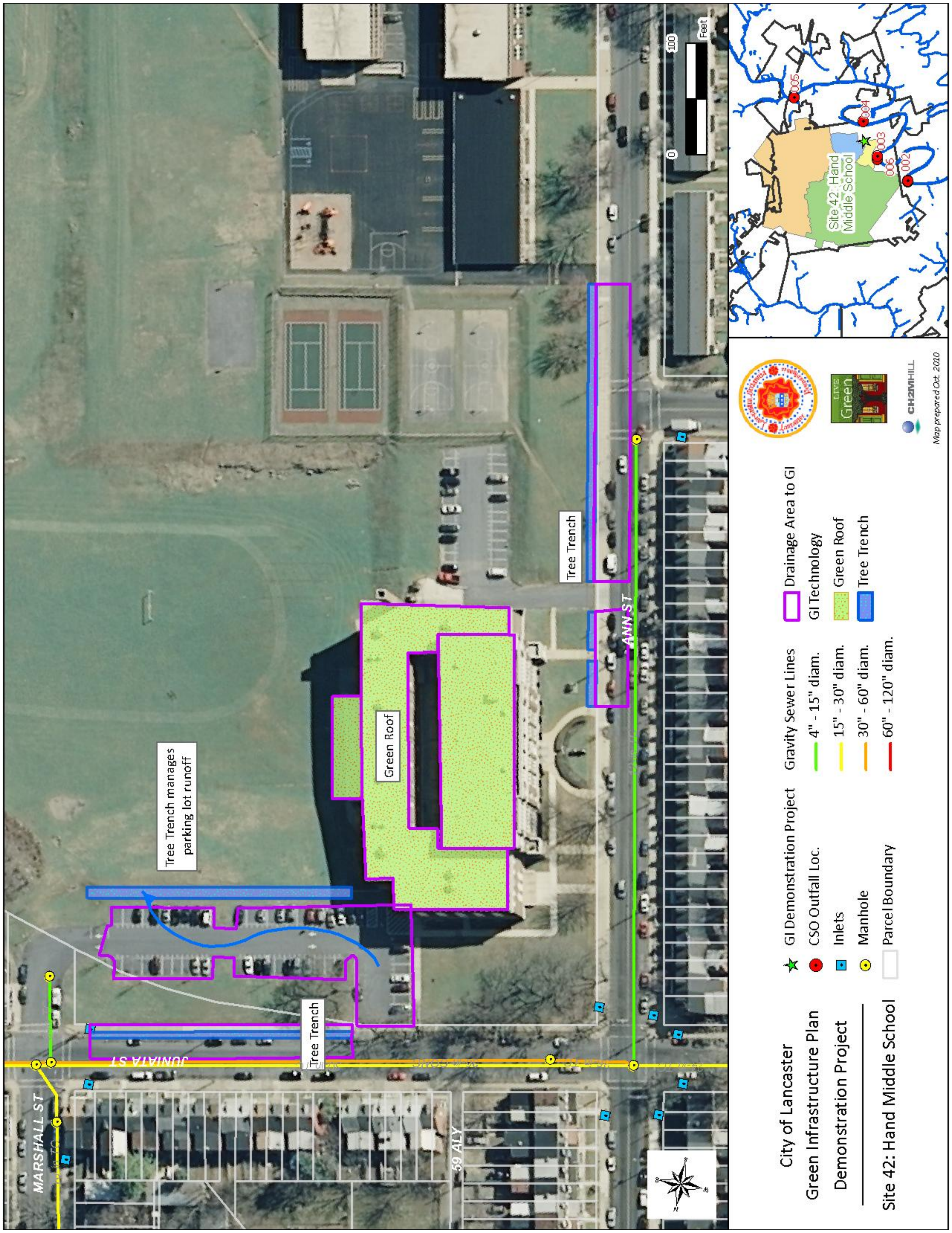
The primary opportunity for green infrastructure at the Hand School is a system of enhanced tree trenches around the perimeter of the school to manage runoff from the streets. The street trees in many cases are missing. Approximately 18 acres shared between the Hand School property and the adjacent Washington Elementary School property is shown contributing to the combined sewer system based on existing drainage area maps and the model basins. This area is also recommended for follow-up study to define the drainage areas to the combined system. Based on a field visit the areas except for the front of the school and rooftops appear largely disconnected. If new construction occurs, there would be an additional opportunity to implement green infrastructure techniques such as a green roof. Refer to Figure "Site 42 Hand Middle School Demonstration Project" overall site plan.

Approximately 18 acres shared between the Hand School and adjacent Washington Elementary School property is shown in green on the right photo as contributing to the CSS based on existing drainage area maps and the system model.

Existing Parking lot connected to grassed swale and outflow to open field.

SUMMARY OF BENEFIT AND COST

Proposed GI Technology	Drainage Area (sf)	GI Area (sf)	Capture Vol (gal)	Capital Costs with Contingency ($)
Green Roof	33,793	33,793	676,000	$723,942
Tree Trench	36,694	6,320	734,000	$101,452
Total	**70,487**	**40,113**	**1,410,000**	**$825,394**


City of Lancaster
Green Infrastructure Plan
Demonstration Project
Site 42: Hand Middle School
GI Demonstration Project
CSO Outfall Loc.
Inlets
Manhole
Parcel Boundary
Gravity Sewer Lines
4" - 15" diam.
15" - 30" diam.
30" - 60" diam.
60" - 120" diam.
Drainage Area to GI
GI Technology
Green Roof
Tree Trench
Map prepared Oct. 2010
Tree Trench manages parking lot runoff
Green Roof
Tree Trench
Tree Trench
ANN ST
JUNIATA ST
MARSHALL ST
59 ALY
0
100
Feet
Site 42: Hand Middle School
005
004
003
006
002

PROJECT P-46: COMMERCIAL GREEN STREET @ PRINCE STREET

PROJECT TYPE:

Green Street

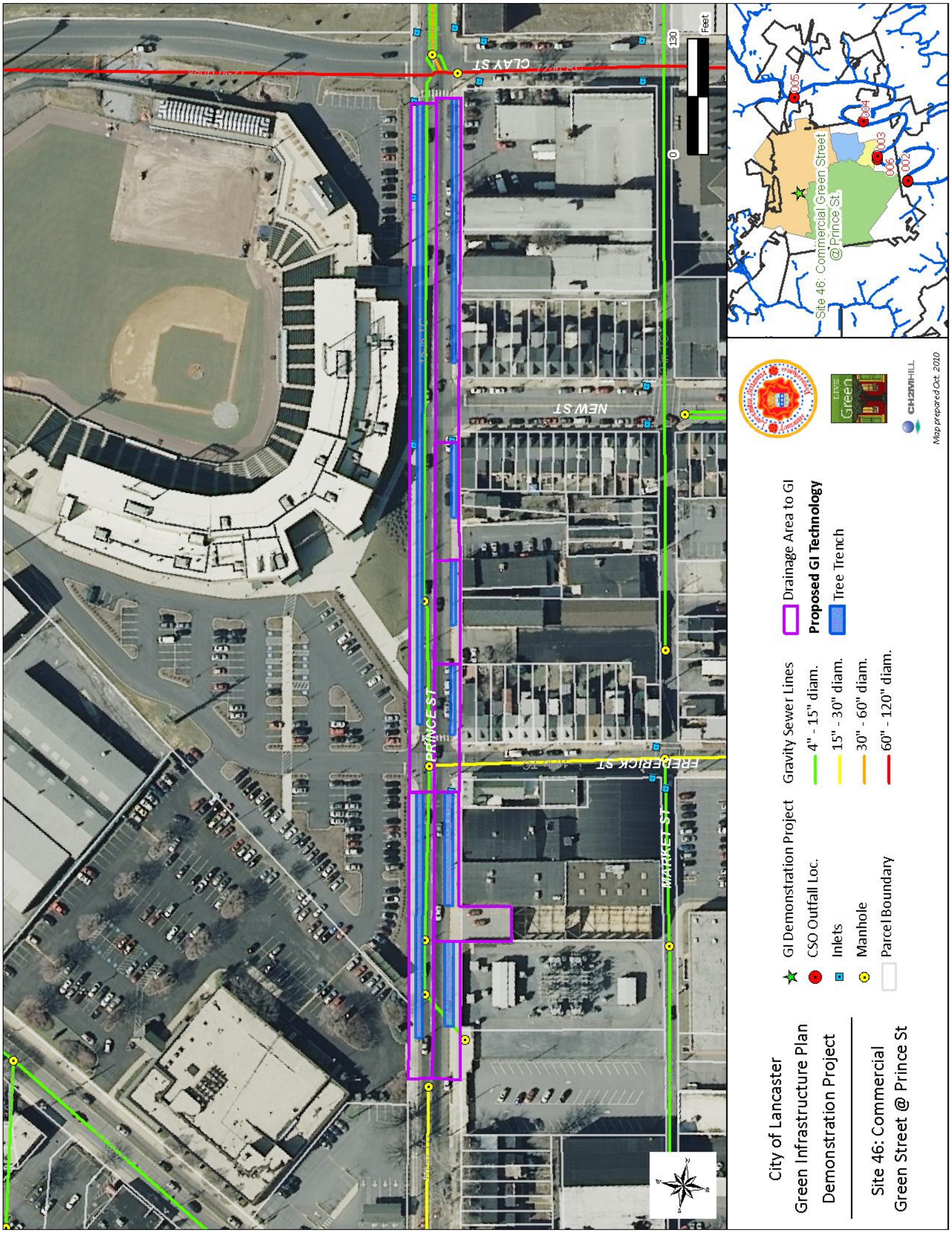
DESCRIPTION:

This project is part of the James Street Improvement district and was initially evaluated as a potential green street. The streetscape has already moved forward to construction so this concept is included to conceptually illustrate the changes that could occur in similar streets from the use of tree trenches and enhanced tree planting designed for storm water capture along N. Prince Street. Refer to Figure "Site 46 Commercial Green Street at Prince Street Demonstration Project" overall site plan.

Before and after rendering of tree trenches on N. Prince Street near Clipper Magazine Stadium

SUMMARY OF BENEFIT AND COST

Proposed GI Technology	Drainage Area (sf)	GI Area (sf)	Capture Vol (gal)	Capital Costs with Contingency ($)
Tree Trench	63,687	11,322	1,274,000	$181,761


City of Lancaster
Green Infrastructure Plan
Demonstration Project
Site 46: Commercial
Green Street @ Prince St
GI Demonstration Project
CSO Outfall Loc.
Inlets
Manhole
Parcel Boundary
Gravity Sewer Lines
4" - 15" diam.
15" - 30" diam.
30" - 60" diam.
60" - 120" diam.
Drainage Area to GI
Proposed GI Technology
Tree Trench
Map prepared Oct. 2010
CLAY ST
NEW ST
FREDERICK ST
PRINCE ST
MARKET ST
0
130
Feet
Site 46: Commercial Green Street @Prince St.
005
004
003
006
002

PROJECT P-47: LANCASTER COUNTY PUBLIC LIBRARY

PROJECT TYPE:

Green City Facilities

DESCRIPTION:

The Library concept includes a green roof on three separate roofs, multiple rain barrels and cisterns, bioretention area, and a green alleyway feature adjacent to the parking lot. Refer to Figure "Site 47 Lancaster County Public Library Demonstration Project" overall site plan.

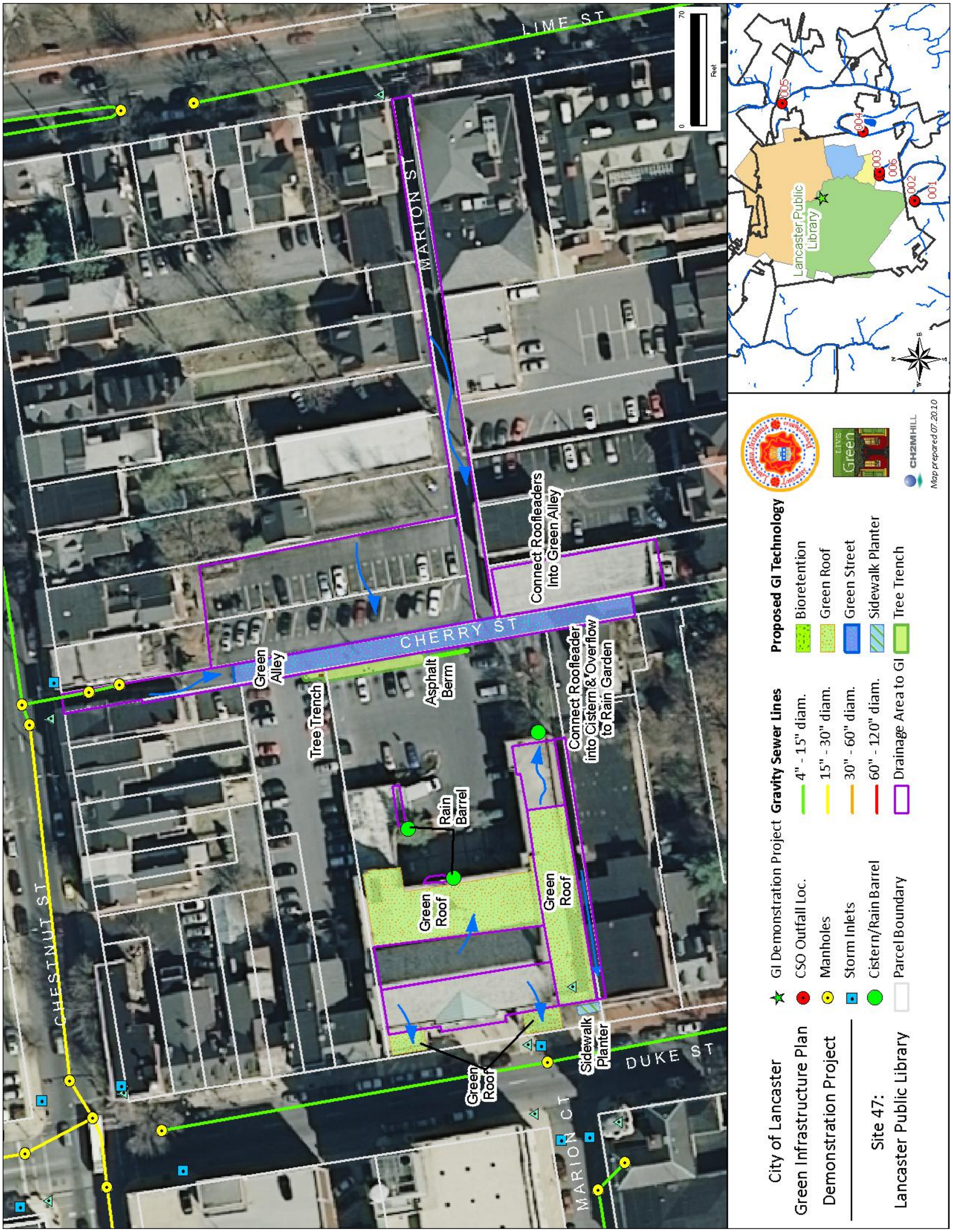
Accessible roof leaders and high public access create great opportunity for rain barrels and cisterns

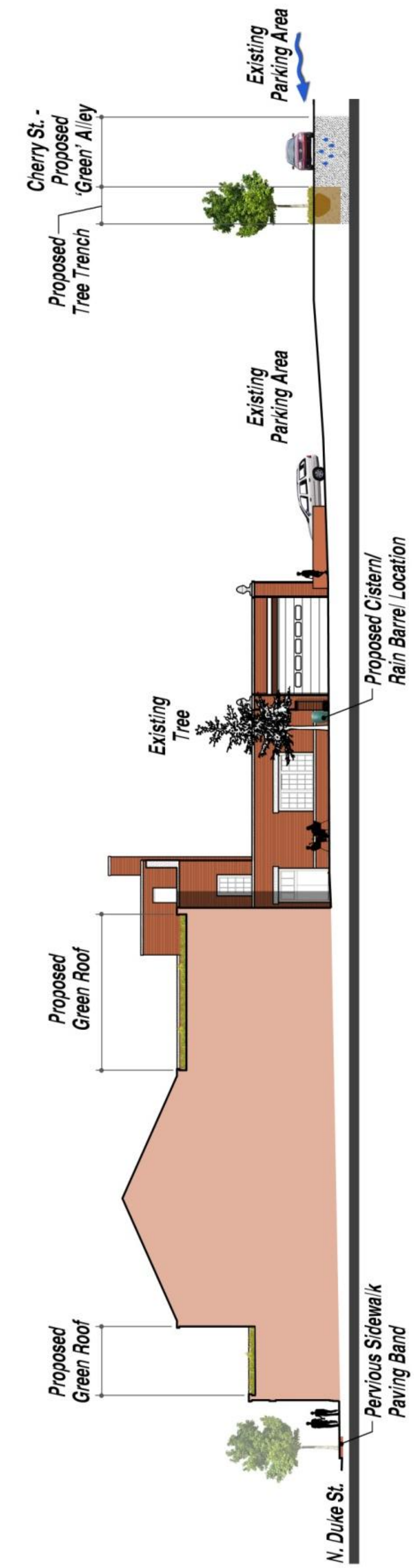
Runoff from the alley and adjacent parking lots and rooftops flows towards the library parking lot

Cherry and Marion Streets represent good opportunities for green streets

SUMMARY OF BENEFIT AND COST

Proposed GI Technology	Drainage Area (sf)	GI Area (sf)	Capture Vol (gal)	Capital Costs with Contingency ($)
Green Roof	11,371	7,633	227,000	$163,525
Green Street	20,123	3,496	402,000	$83,900
Tree Trench	556	556	11,000	$8,928
Bioretention	1,047	503	21,000	$9,589
Cistern/Rain Barrel	1,223	-	24,000	$18,000
Sidewalk Planter	1,047	80	21,000	$1,440
Total	**35,367**	**12,268**	**706,000**	**$285,382**


City of Lancaster
Green Infrastructure Plan
Demonstration Project
Site 47:
Lancaster Public Library
GI Demonstration Project
CSO Outfall Loc.
Manholes
Storm Inlets
Cistern/Rain Barrel
Parcel Boundary
Gravity Sewer Lines
4" - 15" diam.
15" - 30" diam.
30" - 60" diam.
60" - 120" diam.
Drainage Area to GI
Proposed GI Technology
Bioretention
Green Roof
Green Street
Sidewalk Planter
Tree Trench
Map prepared 07.2010
CH2MHILL
LIME ST
MARION ST
CHERRY ST
CHESTNUT ST
DUKE ST
MARION CT
Connect Roofleaders Into Green Alley
Green Alley
Tree Trench
Asphalt Berm
Connect Roofleader into Cistern & Overflow to Rain Garden
Rain Barrel
Green Roof
Green Roof
Green Roof
Sidewalk Planter
Lancaster Public Library
001
002
003
004
005
006
Feet
0
70


N. Duke St.
Pervious Sidewalk Paving Band
Proposed Green Roof
Proposed Green Roof
Existing Tree
Proposed Cistern/ Rain Barrel Location
Existing Parking Area
Proposed Tree Trench
Cherry St. - Proposed 'Green' Alley
Existing Parking Area

PROJECT P-49: STRAWBERRY ST. DISCONNECTION

PROJECT TYPE:

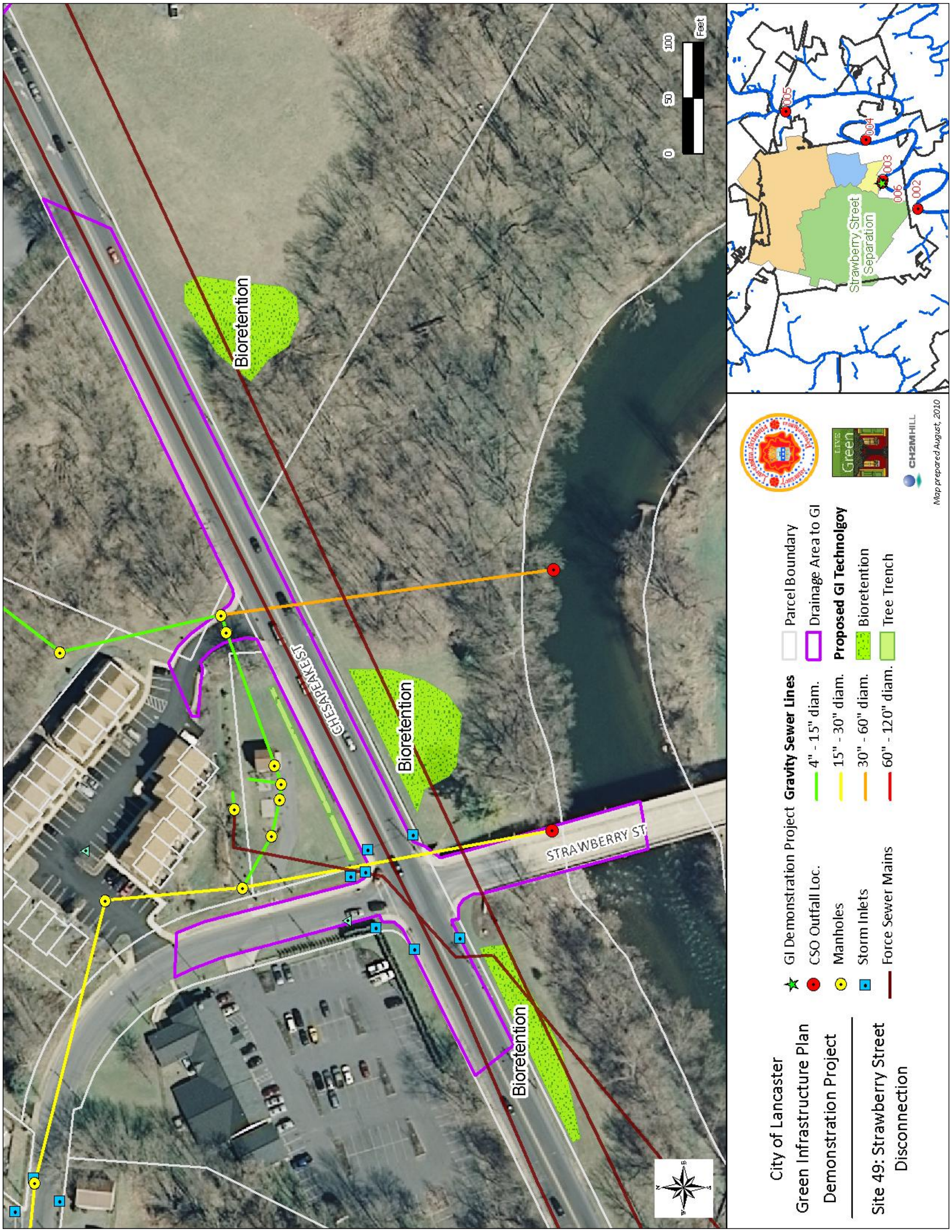
GIS & Model Upgrades - Improvements to Drainage Area Maps

DESCRIPTION:

Strawberry St. Pump Station serves the Susquehanna drainage area tributary to permitted overflow 003. Parcels owned by SACA Development Corporation and the County of Lancaster originally showed up as being included in the drainage area tributary to the pump station and CSO 003A/B. The 7 acre area shown in green was removed from the new collection system GIS and model and illustrates the value of the City efforts to improve system mapping. The concept developed for this impervious area shown in purple illustrates a green infrastructure retrofit approach for routing the 1.3 acres of roadway runoff to bioretention areas developed in the park land to the south. Refer to Figure “Site 49 Strawberry Street Disconnection Demonstration Project” overall site plan.

SUMMARY OF BENEFIT AND COST

Proposed GI Technology	Drainage Area (sf)	GI Area (sf)	Capture Vol (gal)	Capital Costs with Contingency ($)
Bioretention	55,549	18,469	1,111,000	$376,768


City of Lancaster
Green Infrastructure Plan
Demonstration Project
Site 49: Strawberry Street
Disconnection
GI Demonstration Project
CSO Outfall Loc.
Manholes
Storm Inlets
Force Sewer Mains
Gravity Sewer Lines
4" - 15" diam.
15" - 30" diam.
30" - 60" diam.
60" - 120" diam.
Parcel Boundary
Drainage Area to GI
Proposed GI Technolgoy
Bioretention
Tree Trench
Map prepared August, 2010
Bioretention
Bioretention
Bioretention
CHESAPEAKE ST
STRAWBERRY ST
0
50
100
Feet
Strawberry Street
Separation
005
004
003
006
002

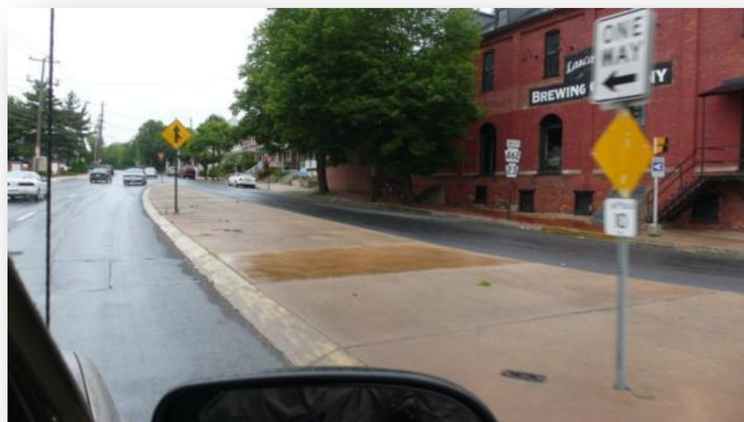
PROJECT P-50: COMMERCIAL GREEN STREET @ PLUM AND WALNUT STREET

PROJECT TYPE:

Green Street

DESCRIPTION

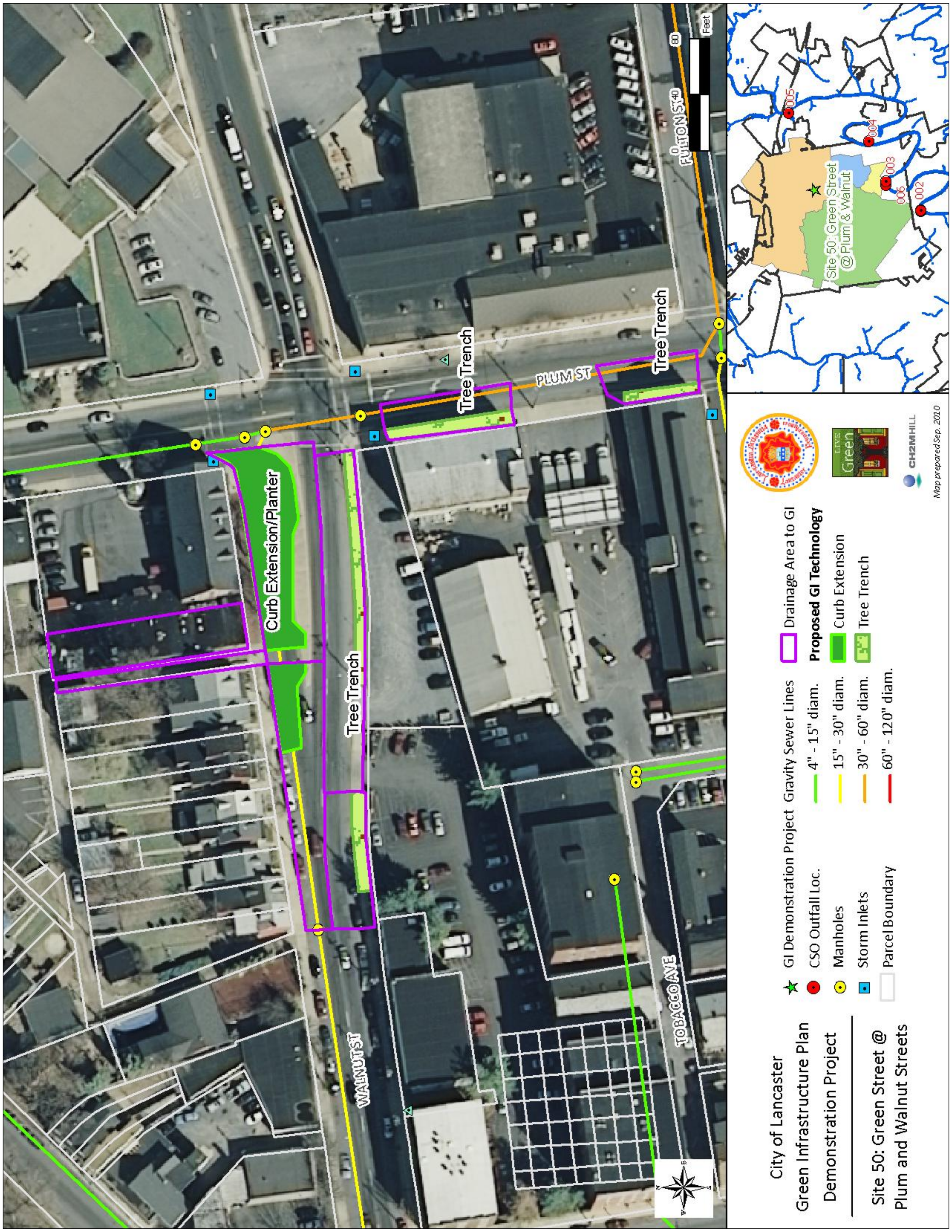
The intersection at Plum and Walnut streets was recommended for reconstruction as part of a long term solution to mitigate high number of angle and merge related collisions (McCormick and Taylor, 2009). The report also observed that the roadway and concrete elements were in poor condition making the project an ideal candidate for green infrastructure retrofit. The reconfiguration of the intersection allows for the incorporation of green infrastructure into the new side walk and traffic island in the form of curb extension planters. Significant adjacent impervious areas drain to the streets and tree trenches are also recommended for each side of the street to capture flow from these areas. Since PennDOT approval would be necessary, this project can also serve as a pilot for using green infrastructure in state roadways. Refer to Figure "Site 50 Commercial Green Street at Plum and Walnut Streets Demonstration Project" overall site plan.



SUMMARY OF BENEFIT AND COST

Proposed GI Technology	Drainage Area (sf)	GI Area (sf)	Capture Vol (gal)	Capital Costs with Contingency ($)
Curb Extension	19,459	5,997	389,000	$64,319
Tree Trench	14,563	3,156	291,000	$50,671
Total	**34,021**	**9,154**	**680,000**	**$114,991**

The total conceptual-level estimate of constructed cost for the green infrastructure components is $95,825 and $114,991 including a 20% contingency.


Tree Trench
Tree Trench
PLUM ST
FULTON ST
0
40
80
Feet
Curb Extension/Planter
Tree Trench
WALNUT ST
TOBACCO AVE
005
004
003
006
002
Site 50: Green Street @ Plum & Walnut
City of Lancaster
Green Infrastructure Plan
Demonstration Project
Site 50: Green Street @
Plum and Walnut Streets
GI Demonstration Project
CSO Outfall Loc.
Manholes
Storm Inlets
Parcel Boundary
Gravity Sewer Lines
4" - 15" diam.
15" - 30" diam.
30" - 60" diam.
60" - 120" diam.
Drainage Area to GI
Proposed GI Technology
Curb Extension
Tree Trench
Map prepared Sep. 2010

PROJECT P-51: PRIVATE PARKING LOT @ THE CROSSINGS

PROJECT TYPE:

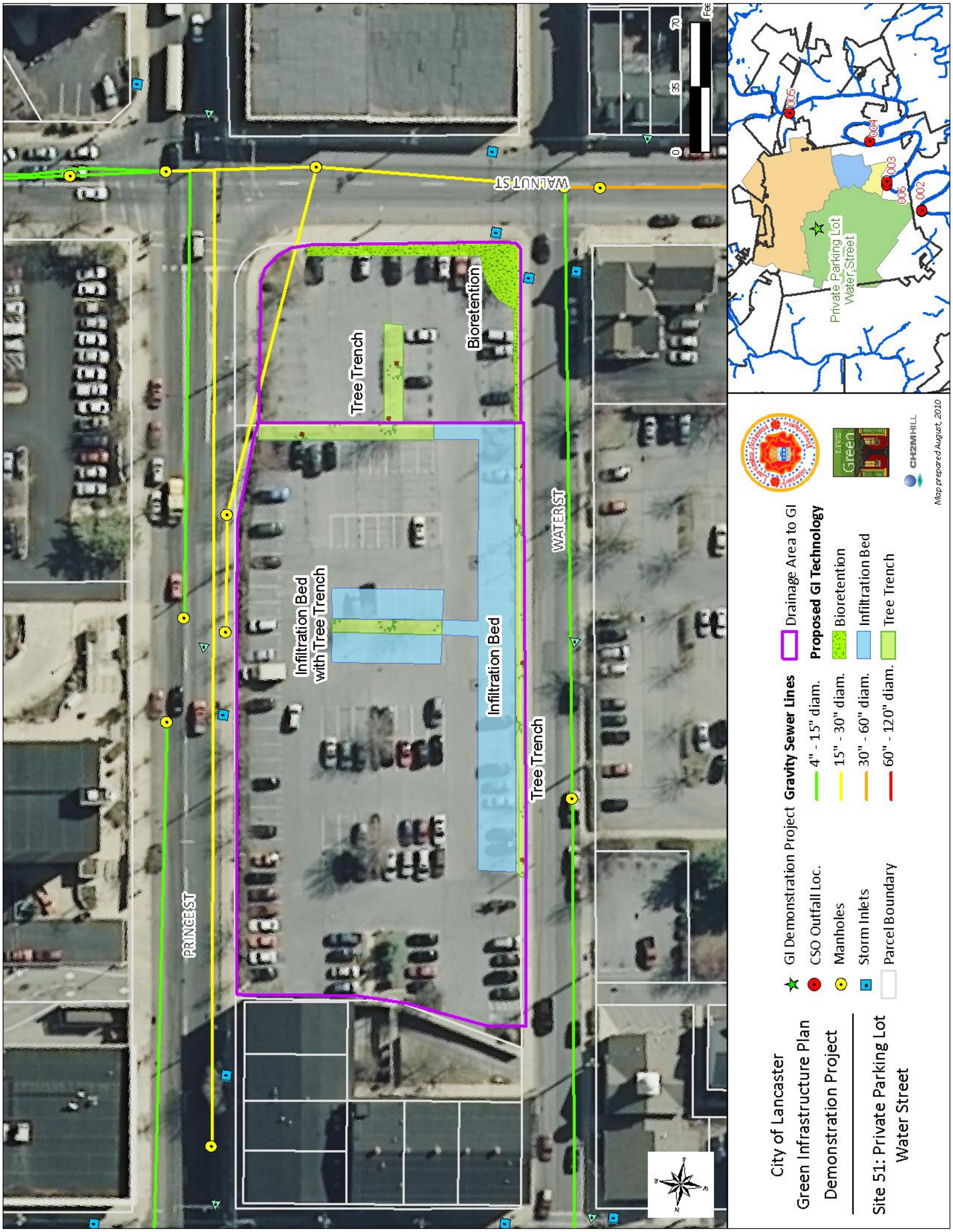
Private Parking Lot Retrofit

DESCRIPTION

Retrofit privately owned parking lot to include tree trench along sidewalk, planter/tree trench with subsurface infiltration bed, and bioretention garden. Refer to Figure "Site 51 Private Parking Lot at the Crossings Demonstration Project" overall site plan.

SUMMARY OF BENEFIT AND COST

Proposed GI Technology	Drainage Area (sf)	GI Area (sf)	Capture Vol (gal)	Capital Costs with Contingency ($)
Infiltration Bed	33,361	7,095	667,000	$102,169
Tree Trench	18,354	3,157	367,000	$50,687
Bioretention	10,000	1,455	200,000	$29,689
Total	**61,715**	**11,708**	**1,234,000**	**$182,544**


City of Lancaster
Green Infrastructure Plan
Demonstration Project
Site 51: Private Parking Lot
Water Street
GI Demonstration Project
CSO Outfall Loc.
Manholes
Storm Inlets
Parcel Boundary
Gravity Sewer Lines
4" - 15" diam.
15" - 30" diam.
30" - 60" diam.
60" - 120" diam.
Drainage Area to GI
Proposed GI Technology
Bioretention
Infiltration Bed
Tree Trench
Live Green
CH2MHILL
Map prepared August, 2010
WALNUT ST
WATER ST
PRINCE ST
Bioretention
Tree Trench
Infiltration Bed with Tree Trench
Infiltration Bed
Tree Trench
Private Parking Lot Water Street
005
004
003
006
002
0
35
70

Chapter 5 – Analysis of Runoff Reduction Benefits and Cost Effectiveness: *The Green Infrastructure Benefit Calculator*

INTRODUCTION AND PURPOSE

This chapter describes the "green infrastructure benefit calculator" (hereafter referred to as the "green calculator" or simply "calculator") that CH2M HILL developed for the study area which includes the entire City of Lancaster (4,703 ac) and an additional 132 acres from outside the City which is included in the combined sewer system (CSS). Based on the characteristics of the demonstration projects (see Chapter 5 on the demonstration projects for details), the green calculator was used to evaluate the potential stormwater benefits and costs associated with the implementation of green infrastructure (GI) in the study area at two implementation levels representing approximately a 5-year period and an aggressive long-term period (approximately 25 years).

This chapter provides a detailed description of the inputs, assumptions, outputs, and calculation methodologies used in the green calculator. These are described through text, equations, figures, and a number of example tables showing portions of the calculator. A higher level summary and summary table can be found in the last section starting on page 5-15. In addition, the final table (5-12) includes the majority of the calculator for the long-term scenario for those that would like a more holistic view to compliment the various more focused tables found throughout the chapter.

INPUTS

The major inputs to the green calculator to estimate the stormwater benefits and pollutant load reductions of GI include the following (Tables 5-1 through 5-3):

- Impervious area (IA) by type based on the GIS analysis described in Chapter 3 (including an estimated 124 acres of sidewalks since they were not explicitly included in the GIS data);
- Capture volume/efficiency by GI type (based on CH2M HILL's experience and the demonstration projects where applicable);
- Implementation levels (e.g., the amount of the impervious area captured by GI, the number of street trees planted per year, the rate of redevelopment which must comply with the first-flush ordinance);
- The average annual runoff coefficient for impervious areas (assumed to be 85% based on other comparable cities);
- Average Annual rainfall (42.04 inches) for the 71-year record (approximately 1926 through 2000) provided by the Pennsylvania State Climatology website;
- The implementation/analysis period (years);
- The portion of the total predicted stormwater reduction that is estimated to occur within the CSS, assumed to be equal to the percentage of the total impervious cover that is in the CSS (58% based on the GIS analysis: 1261/2166 acres) increased by 15% to account for the fact that implementation efforts and redevelopment would likely be higher in the CSS than outside of it;

- The relationship between stormwater reduction and CSO reduction within the CSS (i.e., for every 1 gallon of stormwater that is captured by GI, the amount of CSO reduction that occurs on average). To estimate the pollutant load reduction that will be achieved by reducing CSO discharges, this value has been initially set at 75% based on other similar CSO communities and will be adjusted as appropriate as the City continues to refine its system model;
- The average rate that impervious area is redeveloped/reconstructed in the study area over the implementation period (to determine the area that could fall under a revised first-flush ordinance). This rate was assumed to be 2% of the applicable impervious cover types per year based on national predictions of urban redevelopment (U.S. EPA, *Watershed Academy Webcast*, 12/1/09); and
- Typical pollutant (TSS, TP, TN) concentrations for both urban stormwater runoff and CSO discharges.

IMPERVIOUS AREA AND MANAGEMENT LEVEL INPUTS

Table 5-1- Major inputs to the calculator include impervious area by type, implementation levels (% managed), and capture volume

Area / Impervious Source	Impervious/ Contributing Area (acres)	Approx. Percent Imperv.	Green Infrastructure Project / Program Type	Assumed Percent of Impervious Area Managed	Impervious Area Managed (acres)	Assumed WQv or BMP Capture Volume (in.)
Roads / Alleys	529	100%	Green Streets	2.5%	13.2	1.0
Parks	241	8%	Park Improvements / Greening	20%	4.0	1.0
Sidewalks	124	100%	Disconnection, Porous Pavement	2.5%	3.1	1.0
Parking Lots	648	100%	Porous Pavement, Bioretention	1%	6.5	2.0
Flat Roofs	218	100%	Vegetated Roofs	1%	2.2	1.0
Sloping Roofs	654	100%	Disconnection/Rain Gardens	2.5%	16.4	1.0
Street Trees	N/A	N/A	Enhanced Tree Planting	N/A	9.0	0.3
Public Schools	175	29%	Green Schools	10%	5.1	1.0
Various (Ordinance)	1615	100%	First-Flush Ordinance	10%	161.5	1.0

GLOBAL INPUTS

Other major inputs to the calculator are shown in Table 5-2 and include the implementation/analysis period, annual rainfall, impervious runoff coefficient, the portion of the total predicted stormwater reduction that is estimated to occur within the CSS, the relationship between stormwater volume reduction and CSO discharge reduction, the average number of enhanced street trees planted per year (over and above replacement plantings), and the average rate of redevelopment.

Table 5-2 - Global calculator Inputs

Implementation Period (yr)	5
Annual Rainfall (in/yr)	42.04
Average Percent of Rainfall on Impervious Areas Becoming Runoff	85%
Percentage of Green Infrastructure in CSS*	67%
Ratio: Stormwater Reduction to CSO Reduction**	75%
Total Imperv. Area (ac.)	2,290
Street Trees Planted Per Year (#/yr)	250
Assumed Average Redevelopment Rate (%)	2%

** Used to estimate the portion of the total runoff reduction attributed to the combined sewer area.*

*** Estimated based on other CSO communities in similar settings.*

POLLUTANT LOAD REDUCTION ESTIMATION

In order to estimate pollutant reductions, the calculator uses typical pollutant concentrations for both urban stormwater and CSO discharges as summarized in Table 5-3.

Table 5-3 – Concentrations applied for Pollutant Load Reduction Estimation

Pollutant	Average Stormwater Concentration* (mg/L)	Average CSO Discharge Concentration* (mg/L)
Total Suspended Solids (TSS)	84	275
Total Phosphorus (TP)	1.2	5.5
Total Nitrogen (TN)	0.7	13.5

** Based on the midpoint pollutant concentrations in USEPA's CSO Report to Congress, 2001*

COST-BENEFIT ANALYSIS

The major inputs related to the cost/benefit analysis include the following, refer to Tables 5-4 and 5-5:

- Estimated unit construction/implementation capital costs and the marginal implementation costs by GI program type (based on the demonstration projects where applicable);
    - This concept of marginal costs that is included in the green calculator is an important one. M**arginal cost vs. total cost:** If a parking lot is being repaved and porous pavement is used instead of conventional pavement, there is typically a marginal/incremental cost involved (the difference between the cost of porous and conventional pavements). This is different than the total cost of the project. As a simple example, if the total cost of a porous asphalt system is $12/SF and conventional asphalt costs $5/SF, then the marginal cost of the porous asphalt is $7/SF (simply $12/SF minus $5/SF). **Since leveraging other projects (e.g., incorporating GI in a streetscape improvement) is more cost effective and will result in**

more widespread implementation than undertaking stand-alone GI projects, marginal cost is a critical concept. This concept can also be used to support incentive programs - for example, the City could fund some of the cost of GI (up to the marginal cost) for private entities that voluntarily implement green measures;

- Average loading ratio (the ratio of a GI measure's drainage area to the area of the GI itself) by GI program type (based on the demonstration projects where applicable) and assumed to be 5 or less because of the limestone geology within the study area (not concentrating too much runoff in a small area reduces the risk of subsidence as well as other potential issues such as groundwater mounding and clogging);
- Unit costs for grey CSO reduction ($0.23 per gallon based on the estimated cost and performance of a 15 million gallon storage facility evaluated for the North basin – see Appendix B);
- Wastewater treatment/pumping costs ($0.00125/gallon based on information provided by the City of Lancaster); and
- Amount of stormwater runoff initially captured by GI measures that may re-enter the combined sewer system and therefore require subsequent treatment (initially assumed to be 25 percent).

Table 5-4 - Inputs used for Cost-Benefit Calculation

Area / Impervious Source	Green Infrastructure Project / Program Type	Assumed Average Loading Ratio	Area / Number of Green Infra-structure (ac. or no.)	Unit	Assumed Unit Implementation Cost ($/Unit)	Assumed Marginal Unit Implementation Cost ($/Unit)
Roads / Alleys	Green Streets	5.0	2.64	SF	$20	$15
Parks	Park Improvements / Greening	3.0	1.33	SF	$15	$7.50
Sidewalks	Disconnection, Porous Pavement	2.0	1.55	SF	$15	$7.50
Parking Lots	Porous Pavement, Bioretention	3.0	2.16	SF	$13.00	$6.50
Flat Roofs	Vegetated Roofs	1.1	2.08	SF	$18	$5
Sloping Roofs	Disconnection/Rain Gardens	5.0	3.27	SF	$16	$12
Street Trees	Enhanced Tree Planting	N/A	1250	Each	$2,000	$500
Public Schools	Green Schools	3.0	1.70	SF	$12	$6
Various (Ordinance)	First-Flush Ordinance	3.0	53.83	SF	$0.55	$0.55

Other inputs affecting costs/benefits are shown in Table 5-5. These include the unit cost for grey storage, the unit cost for treatment and pumping, and the amount of captured stormwater that re-enters the system (and therefore is subsequently treated at the plant)

Table 5-5 - Inputs used for comparison with Grey Infrastructure and Energy Savings

Unit Cost for Grey ($/Gallon CSO Reduction)*	**$0.23**
Unit Cost for Pumping and Treatment at AWWTP ($/gal)	**$0.00125**
Amount of captured runoff that re-enters CSS	**25%**

** Based on the cost estimate for the 15 MG storage facility ($70M) in the North Basin*

IMPLEMENTATION LEVELS

The GI implementation levels were initially determined using professional judgment based on field surveys, GIS analyses, the demonstration projects, costs/benefits, and other communities looking to widely implement green infrastructure. They are provided as a guideline as to what might be possible to achieve within these approximate timeframes and could be increased or decreased depending on a variety of factors including available capital budget, regulatory need, restoration priorities for the various impervious surfaces, redevelopment rates, the urban tree canopy assessment, and other factors.

The implementation levels – in terms of the impervious area managed within each category of impervious cover – for the scenarios representing approximately 5-year and 25-year periods are shown in Tables 5-1/5-6 and Figures 5-1/5-2. For comparison, the total impervious area in the study area is estimated to be approximately 2,290 acres (including the estimated area of sidewalks).

PRIVATE PROPERTY

Over 97% of the area within the parking lot and roof impervious cover categories is privately owned (parking lots and buildings at public schools and parks are counted separately under their respective categories). These categories account for 1,520 impervious acres, nearly two-thirds of the total estimated impervious area in the study area. GI implementation on private property would need to be driven largely by incentive/regulatory programs that could include:

- Enhancement of the existing first-flush ordinance to expand applicability to the full reconstructed/redeveloped impervious area during redevelopment projects (see Chapter 6 for more information on the proposed ordinance changes);
- Impervious-area based stormwater utility rates and/or allocations;
- Direct incentive or grant programs such as the Lancaster County green roof incentive program (Lancaster County Roof Greening Project: www.lancasterroofgreening.org); and
- Voluntary efforts to encourage private property owners to incorporate GI for other reasons (marketing, LEED®, public recognition, "doing the right thing", etc.).

These drivers, along with implementation on the 2.7% of publicly-owned parking lots/roofs, are collectively represented by the implementation levels (percent of impervious area managed) for the parking lot and roof categories (see Tables 5-1/5-6 and Figures 5-1/5-2). The inputted redevelopment rate (initially assumed to be 2%/year based on EPA predictions for the U.S.) is applied to privately-owned impervious cover ***not managed*** under other GI categories to prevent areas from being "double-counted." **The green calculator assumes that the first-flush ordinance will be updated such that redeveloped/reconstructed/disturbed impervious area is included in the area from which stormwater runoff must be managed. This process has been successfully implemented in other cities. It does require significant change and should evaluate economic and policy issues as recommended in Chapter 6.**

PUBLIC-PROPERTY

The conceptual program envisioned in the green calculator calls for a significant level of investment in publicly-owned lands to serve as a demonstration of the various GI technologies and to address large publicly-owned contributing areas (e.g., roads, sidewalks, schools). To gain cost-efficiency and maximize long-term implementation, it is recommended that green infrastructure on public property be primarily implemented in concert with other public projects such as park improvements, school renovations, streetscape or paving projects, utility replacements, etc. Implementation levels for parks and public schools have been assumed to be relatively high because of the improvement/renovation programs already planned by the City and School Board. These types of projects offer a good opportunity to achieve cost savings through integrated infrastructure restoration and reconstruction.

Table 5-6 - Assumed implementation levels for the long-term scenario

Area / Impervious Source	Impervious/ Contributing Area (acres)	Approx. Percent Imperv.	Green Infrastructure Project / Program Type	Assumed Percent of Impervious Area Managed	Impervious Area Managed (acres)	Implementation Level - Alternative Description
Roads / Alleys	529	100%	Green Streets	30%	159	468 blocks
Parks	241	8%	Park Improvements / Greening	85%	17.0	26 parks
Sidewalks	124	100%	Disconnection, Porous Pavement	35%	43.3	89 miles of sidewalks
Parking Lots	648	100%	Porous Pavement, Bioretention	20%	130	287 parking lots
Flat Roofs	218	100%	Vegetated Roofs / Disconnection	15%	32.7	246 roofs
Sloping Roofs	654	100%	Disconnection/Rain Gardens	25%	164	2195 buildings
Street Trees	N/A	N/A	Enhanced Tree Planting	N/A	45.1	6250 tree plantings
Public Schools	175	29%	Green Schools	75%	38.4	15 schools
Various (Ordinance)	1274	100%	First-Flush Ordinance	50%	637	2536 non-resid. parcels
Total					**1,265**	

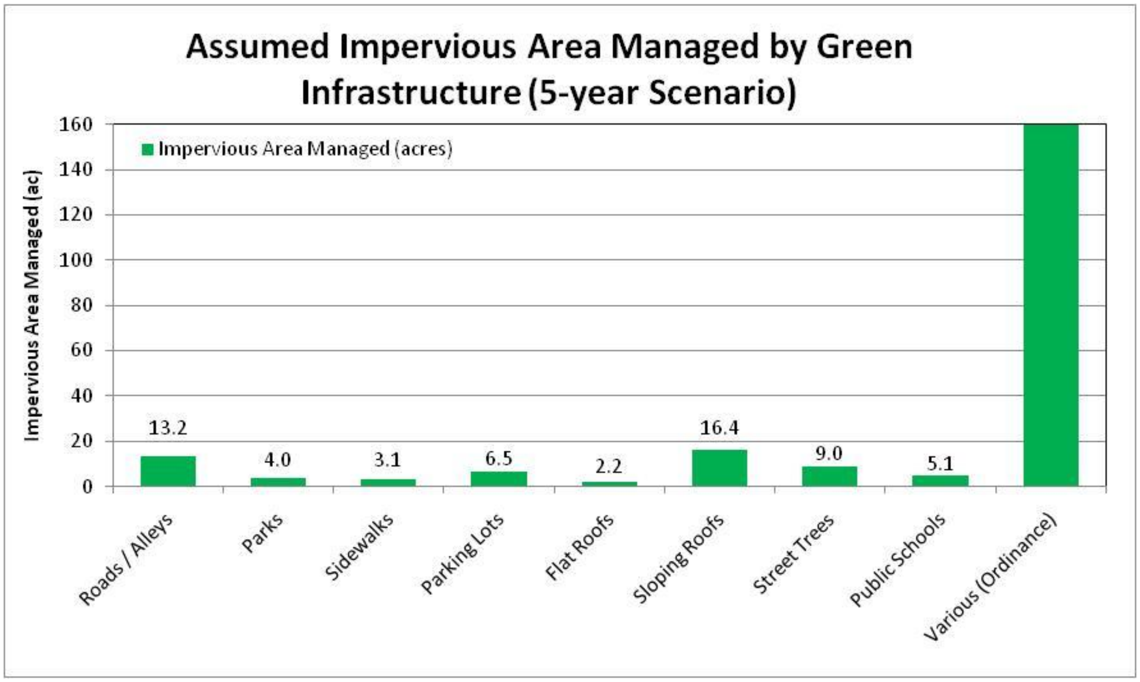


Figure 5-1 - Assumed implementation levels (impervious area managed) for the 5-year GI implementation scenario

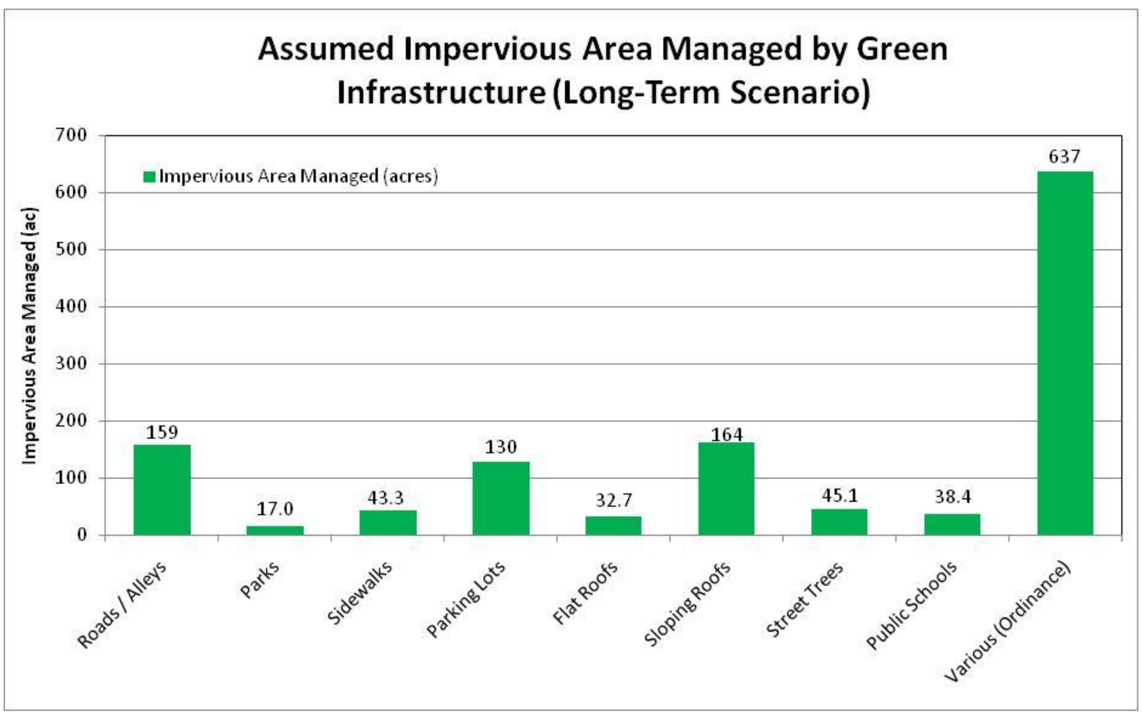


Figure 5-2 - Assumed implementation levels (impervious area managed) for the long-term GI implementation scenario

CALCULATOR OUTPUTS

The primary outputs of the green calculator are listed below and shown for the 5-year implementation scenario in Tables 5-7 through 5-10. Outputs related to "annual" represent the estimated average annual quantities based on the long-term precipitation record.

Outputs calculated include:

- Total impervious area (IA) managed by GI (acres and percent of the total IA),
- Total annual stormwater runoff by impervious area type,
- Percentage of annual runoff reduced as a function of the capture volume provided by each GI type (based on long-term rainfall analysis),
- Annual stormwater runoff reduction by GI type,
- Annual unit stormwater benefit by GI type (gallons reduced per unit of GI),
- Annual unit cost benefit by GI type (grey storage and treatment/pumping costs that would be avoided by using GI instead of grey infrastructure),
- Benefit/marginal cost ratio by GI type,
- Total estimated construction/implementation capital costs and marginal implementation costs,
- Marginal and total costs per gallon stormwater runoff reduction by GI type and cumulatively, and
- Estimated pollutant removals from stormwater/CSO reductions as well as total pollutant reductions.

As described above and shown for the 5-year scenario in Table 5-7, some of the primary green calculator outputs include the impervious area managed, total stormwater (SW) runoff, and the annual runoff reduction (% and MG).

Table 5-7- Runoff Reduction Estimates for the 5-Year Implementation Scenario

Area / Impervious Source	Green Infrastructure Project / Program Type	Assumed Percent of Impervious Area Managed	Impervious Area Managed (acres)	Total SW Runoff (MG/yr)	Average Annual Runoff Reduction	Runoff Reduction (MG/yr)
Roads / Alleys	Green Streets	2.5%	13.2	513	86%	11.0
Parks	Park Improvements / Greening	20%	4.0	19	86%	3.3
Sidewalks	Disconnection, Porous Pavement	2.5%	3.1	120	86%	2.6
Parking Lots	Porous Pavement, Bioretention	1%	6.5	628	97%	6.1
Flat Roofs	Vegetated Roofs / Disconnection	1%	2.2	212	86%	1.8
Sloping Roofs	Disconnection/Rain Gardens	2.5%	16.4	635	86%	13.6
Street Trees	Enhanced Tree Planting	N/A	9.0	9	49%	4.3
Public Schools	Green Schools	10%	5.1	50	86%	4.3
Various (Ordinance)	First-Flush Ordinance	10%	161.5	1567	86%	134.8
TOTAL	**TOTAL**		**221**	**3,752**		**181.8**
			9.6%			

Other green calculator outputs are related to the costs/benefits of implementing green infrastructure. Unit Benefit (gal/unit) is the average amount of runoff reduced per unit GI per year, Unit Benefit ($/unit) is the cost that would be avoided if an approximately equivalent volume of CSO control was provided using grey infrastructure, and the Benefit/Marginal Cost is the Unit Benefit ($/unit) divided by the Assumed Marginal Cost ($/unit) – values over 100% indicate that the green infrastructure is predicted to be more cost-effective than grey infrastructure (based on CSO control only – not including any other community benefits that might be provided by GI). **The CSO reduction benefit is estimated to outweigh the "marginal" cost for most of the GI types.** Porous sidewalks are assumed not to capture runoff from as much impervious area relative to many other GI types, therefore their benefit/marginal cost ratio is somewhat below 100 percent. Likewise, because vegetated roofs are relatively expensive and generally only capture incident rainfall, they have the lowest CSO benefit/marginal cost ratio (however, they have many other benefits in addition to stormwater management). Results are shown for the 5-Year period in Table 5-8.

Table 5-8 – Unit Benefit Calculations for Each GI Program Type for the 5-Year Implementation Scenario

Area / Impervious Source	Green Infrastructure Project / Program Type	Unit	Unit Benefit (SW gallon / unit)	Unit Benefit (Grey Costs Avoided - $/unit)	Benefit / Marginal Cost
Roads / Alleys	Green Streets	SF	95.8	$17.12	114%
Parks	Park Improvements / Greening	SF	57.5	$10.27	137%
Sidewalks	Disconnection, Porous Pavement	SF	38.3	$6.85	91%
Parking Lots	Porous Pavement, Bioretention	SF	64.5	$11.53	177%
Flat Roofs	Vegetated Roofs / Disconnection	SF	20.1	$3.59	72%
Sloping Roofs	Disconnection/Rain Gardens	SF	95.8	$17.12	143%
Street Trees	Enhanced Tree Planting	Each	3442	$615	123%
Public Schools	Green Schools	SF	57.5	$10.27	171%
Various (Ordinance)	First-Flush Ordinance	SF	57.5	$10.27	1867%

Unit Capital/Implementation and Unit Marginal Costs are applied to the various implementation levels to develop Total Marginal and Total Capital/Implementation Costs. These are also reported as costs per gallon CSO reduction to enable a simple comparison to the assumed cost of CSO reduction with grey infrastructure ($0.23/gallon based on a storage tank evaluated for the North basin). Again it should be noted that this is based on assumed ratio between CSO reduction and stormwater reduction. An initial assumption of 0.75 (75%) was used based on other similar CSS communities and will be refined as the system model is updated. Results are shown for the 5-year period in Table 5-9. Benefit / Marginal Cost ratios for sidewalks and green roofs are relatively low as they assume only the sidewalk impervious area and rooftop area is managed. They would be more cost effective if additional impervious area could be managed.

Table 5- 9 - Total Capital and Marginal Costs for the 5-year Implementation Scenario

Area / Impervious Source	Green Infrastructure Project / Program Type	Total Marginal Cost	Total Capital Cost	Marginal Cost/Gal CSO Reduced ($/gal)	Total Cost/Gal CSO Reduced ($/gal)
Roads / Alleys	Green Streets	$1,728,000	$2,304,000	$0.21	$0.28
Parks	Park Improvements / Greening	$435,000	$869,000	$0.17	$0.35
Sidewalks	Disconnection, Porous Pavement	$505,000	$1,010,000	$0.26	$0.52
Parking Lots	Porous Pavement, Bioretention	$611,000	$1,222,000	$0.13	$0.27
Flat Roofs	Vegetated Roofs / Disconnection	$452,000	$1,628,000	$0.33	$1.19
Sloping Roofs	Disconnection/Rain Gardens	$1,709,000	$2,279,000	$0.17	$0.22
Street Trees	Enhanced Tree Planting	$625,000	$2,500,000	$0.19	$0.78
Public Schools	Green Schools	$445,000	$891,000	$0.14	$0.28
Various (Ordinance)	First-Flush Ordinance	$1,290,000	$1,290,000	$0.01	$0.01
TOTAL		**$7,800,000**	**$13,990,000**	**$0.06**	**$0.10**
		$8,970,000 Total w/ 15% Contingency	**$16,090,000 Total w/ 15% Contingency**		

Unit stormwater and CSO pollutant concentrations are applied to the volume reductions to estimate the removal of nutrients and solids through GI implementation. Results are shown for the 5-year period in Table 5-10.

Table 5-10 - Pollutant Removal Estimates for Total Suspended Solids, Total Phosphorus, and Total Nitrogen for the 5-year Implementation Scenario

Pollutant	Average Stormwater Concentration* (mg/L)	Average CSO Discharge Concentration* (mg/L)	Pollutant Reduction from Stormwater (lb/yr)	Pollutant Reduction from CSOs (lb/yr)	Total Est. Pollutant Reduction (lb/yr)
Total Suspended Solids (TSS)	84	275	42,100	210,000	**252,000**
Total Phosphorus (TP)	1.2	5.5	600	4,200	**4,800**
Total Nitrogen (TN)	0.7	13.5	350	10,300	**10,700**

** Based on the midpoint pollutant concentrations in USEPA's CSO Report to Congress, 2001*

CALCULATION METHODOLOGY

RUNOFF REDUCTION CALCULATION

The basic runoff reduction calculation procedure begins with an estimate of the average annual stormwater runoff generated by the contributing impervious area of a given type (using the annual rainfall and the average runoff coefficient).

Stormwater Runoff = Impervious Area * Annual Precipitation * Runoff Coefficient (with unit conversions to million gallons [MG])

The implementation levels (as percentages) are then applied to this volume of stormwater runoff resulting in the stormwater runoff that could potentially be captured by GI.

Runoff Available for Capture = Stormwater Runoff * Percent of Impervious Area Managed

The annual stormwater runoff reduction is then calculated using the applicable GI capture volume (typically 1 inch) which is converted to annual runoff reduction (%) based on a rainfall analysis (Figure 5-3).

Annual Runoff Reduction (%) → Regression Equation based on Capture Volume

For example, a 1-inch capture volume is estimated to result in an 86% reduction in the annual runoff volume.

Annual Runoff Reduction (MG/yr) = Runoff Available for Capture * Annual Runoff Reduction (%)

The total annual stormwater runoff reduction from GI is simply the sum of the reductions for each GI category. To complete some of the cost/benefit and pollutant reduction calculations, the total runoff reduction is converted to the estimated CSO reduction using the assumed percentage of GI that will be implemented in the CSS (runoff captured outside the CSS does not contribute to CSO reductions) as well as the assumed ratio between CSO reduction and stormwater reduction (even within the CSS, not every gallon of runoff reduction equates to a gallon of CSO reduction because some runoff is conveyed to the plant for treatment under existing conditions):

Estimated CSO Reduction (MG/yr) = Stormwater Reduction * Percentage of GI in the CSS (67%) * CSO to Stormwater Ratio (0.75)

ANNUAL PRECIPITATION AND CAPTURE VOLUME

As discussed above, an analysis of long term daily precipitation data was performed to develop a relationship between the capture volume provided by various GI types and the percent of total precipitation captured. For example, capturing 1 inch from all storms in the 71-year record would result in the overall capture of approximately 86% of the total precipitation.

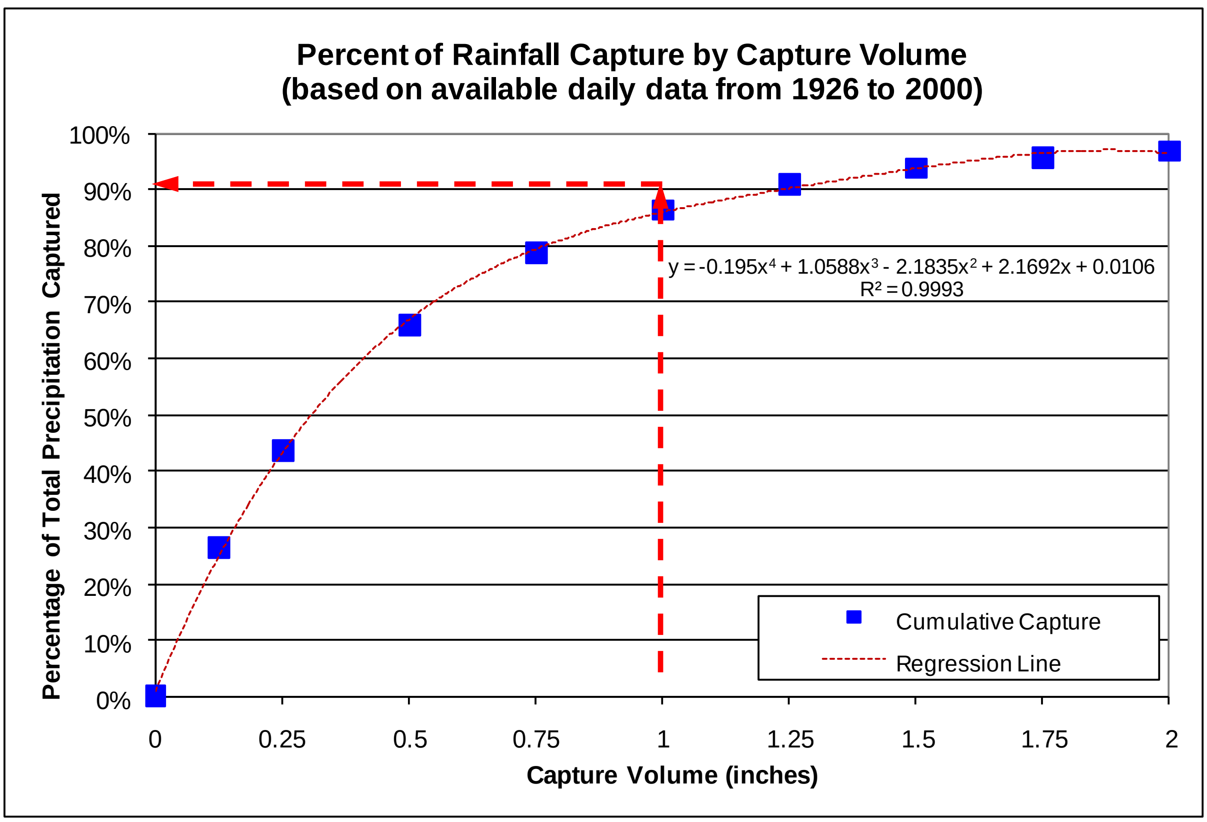


Figure 5-3 - Percent Total Rainfall Capture by Capture Volume

CAPITAL AND MARGINAL GREEN-GREY COST ESTIMATION

While the stormwater and CSO reductions are based on the amount of impervious area managed, costs are based on the actual assumed areas of green infrastructure. The area of each applicable type of green infrastructure is calculated based on the impervious area managed and the average loading ratio.

Area of Green Infrastructure (ac) = Impervious Area Managed (ac) ÷ Average Loading Ratio

The area of each GI type is also used to calculate the total and marginal implementation costs as well as the unit benefits (gal/unit/yr).

Total Capital/Implementation Cost ($) = Unit Cost ($/unit area) * Area of GI

Marginal Implementation Cost ($) = Marginal Unit Cost ($/unit area) * Area of GI

Unit Stormwater Benefit (gal/unit area/yr) = Annual Runoff Reduction ÷ Area of GI

The unit CSO benefit (i.e., the grey storage/treatment/pumping costs that are avoided by using GI instead of conventional grey techniques for CSO control) is calculated based on the unit stormwater benefit, the CSO to stormwater reduction ratio, the unit cost for grey CSO reduction, the unit cost for treatment/pumping, the amount of runoff captured by GI that re-enters the CSS (and therefore still would be treated at the plant), and the duration of the program. **It should be noted that this financial benefit does not include any other benefits related to the use of green infrastructure (recreation, property values, air quality, improved water quality, aesthetics, etc.).** This value is only directly applicable to the CSS area as stormwater reductions in separate sewer areas would have different benefits not related to CSS storage/treatment/pumping costs.

Unit Benefit ($/unit area) = [(Unit Stormwater Benefit * CSO to Stormwater Ratio) * Unit Cost for Grey CSO Reduction ($0.23/gal)] + [Unit Stormwater Benefit * Implementation Period * Unit Cost for Treatment/Pumping ($0.00125/gal) * (1 – Fraction of Captured Runoff that Re-Enters CSS)]

The benefit/marginal cost is simply the unit benefit ($/unit area) divided by the marginal unit cost ($/unit area). Values greater than a 100% indicate that the green infrastructure measures are estimated to be more cost-effective than comparable grey techniques, **based solely on CSO reduction and ignoring all other benefits of GI.** Again, this value is only directly applicable to the CSS area.

Benefit/Margin Cost (%) = Unit Benefit ($/unit area) ÷ Marginal Unit Cost ($/unit area)

Finally, pollutant reductions are calculated separately for stormwater (outside the CSS) and CSO discharges (inside the CSS) based on their applicable volume reductions and typical pollutant concentrations. The estimated CSO volume reduction is calculated as described previously and the stormwater reduction outside the CSS is calculated based on the amount of GI implementation assumed to occur outside the CSS (33%).

Pollutant Reduction (lb/yr) = Applicable Pollutant Concentration * Applicable Reduction in Volume (either CSO reduction volume, or stormwater reduction from the separate sewer areas) with unit conversions to lb/yr

SUMMARY OF BENEFITS

A summary of the results from the Green Infrastructure Benefit Calculator for both the 5-year and the long-term implementation periods is included in Table 5-11. Given the inputs and assumptions discussed previously, the green calculator estimates that **long-term implementation of green infrastructure can reduce the average annual stormwater runoff in the study area by over 1 billion gallons per year (see Figure 5-4), total suspended solids by 1,457,000 pounds per year, phosphorus by nearly 30,000 lb/yr, and nitrogen by over 60,000 lb/yr.** The total capital/implementation cost of this program in 2010 dollars is estimated to be $141 million, although the marginal/increased cost of incorporating green infrastructure as a part of other projects is estimated to be only $77 million.

Perhaps most importantly, the estimated cumulative total cost per gallon CSO reduction ($0.18/gal) is quite competitive with the preliminary cost of a large storage tank in the North basin ($0.23/gal). Furthermore, **the estimated cumulative marginal cost for green infrastructure, $0.10/gallon, is significantly less than that preliminary cost for gray infrastructure.** The green calculator representing the long-term period is shown in Table 5-12.

Table 5-11. Summary of the estimated green calculator results for the 5-year and long-term implementation periods

Parameter	5-year Implementation	Long-Term Implementation
Impervious Area Managed by Green Infrastructure (ac)	221	1,265
Average Annual Runoff Reduction (MG/yr)	182	1,053
Average Annual Total Suspended Solids (TSS) Reduction (lb/yr)	252,000	1,457,000
Average Annual Total Phosphorus (TP) Reduction (lb/yr)	4,800	27,800
Average Annual Total Nitrogen (TN) Reduction (lb/yr)	10,700	61,600
Total Marginal Cost	$7,800,000	$77,000,000
Total Capital/Implementation Cost	$14,000,000	$141,000,000
Marginal Cost Per Gallon CSO Reduction ($/gal)	$0.06	$0.10
Total Cost Per Gallon CSO Reduction ($/gal)	$0.10	$0.18

Figure 5-4 - Over 1.05 billion gallons of stormwater runoff is projected to be removed through long-term implementation of this GI Plan. This volume of water would fill over 1,500 Olympic-sized swimming pools.

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Table 5-12. Green Infrastructure Calculator for long-term (approximately 25-year) period

Area / Impervious Source	Impervious/ Contributing Area (acres)	Approx. Percent Imperv.	Green Infrastructure Project / Program Type	Assumed Percent of Impervious Area Managed	Impervious Area Managed (acres)	Total SW Runoff (MG/yr)	Assumed WQv or BMP Capture Volume	Average Annual Runoff Reduction	Runoff Reduction (MG/yr)
Roads / Alleys	529	100%	Green Streets	30%	159	513	1.0	86%	132.4
Parks	241	8%	Park Improvements / Greening	85%	17.0	19	1.0	86%	14.2
Sidewalks	124	100%	Disconnection, Porous Pavement	35%	43.3	120	1.0	86%	36.1
Parking Lots	648	100%	Porous Pavement, Bioretention	20%	130	628	2.0	97%	121.3
Flat Roofs	218	100%	Vegetated Roofs / Disconnection	15%	32.7	212	1.0	86%	27.3
Sloping Roofs	654	100%	Disconnection/Rain Gardens	25%	164	635	1.0	86%	136.5
Street Trees	N/A	N/A	Enhanced Tree Planting	N/A	45.1	44	0.3	49%	21.5
Public Schools	175	29%	Green Schools	75%	38.4	50	1.0	86%	32.0
Various (Ordinance)	1274	100%	First-Flush Ordinance	50%	637	1236	1.0	86%	531.6
Total					**1,265**	**3,752**			**1,053**
					55%				

Pollutant	Average Stormwater Concentration* (mg/L)	Average CSO Discharge Concentration * (mg/L)	Pollutant Reduction from Stormwater (lb/yr)	Pollutant Reduction from CSOs (lb/yr)	Total Est. Pollutant Reduction (lb/yr)
Total Suspended Solids (TSS)	84	275	243,938	1,213,345	**1,457,000**
Total Phosphorus (TP)	1.2	5.5	3,485	24,267	**27,800**
Total Nitrogen (TN)	0.7	13.5	2,033	59,564	**61,600**

** Based on the midpoint pollutant concentrations in USEPA's CSO Report to Congress, 2001*

OTHER INPUTS

Implementation Period (yr)	**25**
Annual Rainfall (in/yr)	**42.04**
Average Percent of Rainfall on Impervious Areas Becoming Runoff	**85%**
Percentage of Green Infrastructure in CSS*	**67%**
Ratio: Stormwater Reduction to CSO Reduction**	**75%**
Total Imperv. Area (ac.)	**2,290**
Street Trees Planted Per Year (#/yr)	**250**
Assumed Average Redevelopment Rate (%)	**2%**

** Used to estimate the portion of the total runoff reduction attributed to the combined sewer area.*
*** Estimated based on other CSO communities in similar settings.*

GREY COST ASSUMPTIONS

Unit Cost for Grey ($/Gallon CSO Reduction)*	**$0.23**
Unit Cost for Pumping and Treatment at AWWTP ($/gal)	**$0.00125**
Amount of captured runoff that re-enters CSS	**25%**

** Based on the cost estimate for the 15 MG storage facility ($70M) in the North Basin*

Table 5-12 – Green Infrastructure Calculator for long-term (approximately 25-year) period (continued)

Assumed Average Loading Ratio	Area / Number of Green Infra-structure (ac. or no.)	Unit	Unit Benefit (SW gallon / unit)	Unit Benefit (Grey Costs Avoided -	Assumed Unit Implementation Cost ($/Unit)	Assumed Marginal Unit Implementation Cost ($/Unit)	Benefit / Marginal Cost	Total Marginal Cost	Total Capital Cost	Marginal Cost/Gal CSO Reduced ($/gal)	Total Cost/Gal CSO Reduced ($/gal)
5.0	31.73	SF	95.8	$17.12	$20.00	$15.00	114%	$20,735,000	$27,647,000	$0.21	$0.28
3.0	5.65	SF	57.5	$10.27	$15.00	$7.50	137%	$1,847,000	$3,694,000	$0.17	$0.35
2.0	21.63	SF	38.3	$6.85	$15.00	$7.50	91%	$7,067,000	$14,133,000	$0.26	$0.52
3.0	43.17	SF	64.5	$11.53	$13.00	$6.50	177%	$12,222,000	$24,444,000	$0.13	$0.27
1.1	31.15	SF	20.1	$3.59	$18.00	$5.00	72%	$6,784,000	$24,421,000	$0.33	$1.19
5.0	32.70	SF	95.8	$17.12	$16.00	$12.00	143%	$17,095,000	$22,793,000	$0.17	$0.22
N/A	6250	Each	3442.0	$615.04	$2,000	$500.00	123%	$3,125,000	$12,500,000	$0.19	$0.78
3.0	12.78	SF	57.5	$10.27	$12.00	$6.00	171%	$3,341,000	$6,682,000	$0.14	$0.28
3.0	212.34	SF	57.5	$10.27	$0.55	$0.55	1867%	$5,090,000	$5,090,000	$0.01	$0.01
								$77,310,000	**$141,400,000**	**$0.10**	**$0.18**
								$88,910,000 Total w/ 15% Contingency	**$162,610,000** Total w/ 15% Contingency		

Chapter 6 – Implementation & Recommendations

IMPLEMENTATION OF THE GREEN INFRASTRUCTURE PLAN

This Chapter provides a series of recommended next steps for implementing the Green Infrastructure Plan. Recommendations are broken down into the following four categories:

1. Implement GI Demonstration Projects,
2. Policy Actions,
3. Partnering & Outreach, and
4. Studies & Technical Efforts.

1- IMPLEMENT DEMONSTRATION PROJECTS

Implement demonstration projects to "prove" key green infrastructure technologies and their application on various publicly-owned land uses. By implementing a comprehensive demonstration program, the City develops the details of each project type and technology to be worked through and adapted for the specific requirements of the City's unique land use types. Demonstration projects also help to develop an increased understanding of the benefits that green infrastructure provides among approving agencies and the general public. A summary of the recommended green infrastructure demonstration projects and costs is provided in Table 6-1 and the following additional actions are recommended for initiating this program:

a. **Establish a prioritized capital program for GI implementation** within Department of Public Works;

b. **Screen the City Capital programs for possible green infrastructure project opportunities** (e.g. roofing, pavement restoration and other projects that restore/reconstruct impervious surfaces) and institute guidelines for incorporating green infrastructure into capital projects that are amenable to green alternatives; and

c. **Establish a Green Infrastructure Grant Fund to incentivize action** on privately-owned lands by funding the marginal cost of the green portion of the improvements. Grant improvement funds can be an effective way to jump start implementation on privately owned lands by providing the marginal cost difference to allow a project to incorporate green infrastructure when it would not occur otherwise. This method has been used by other communities to allow for early action projects to be built as examples for others to follow. Long term maintenance agreements should be considered to ensure projects provide long term sustainable benefits for the funds provided through this program.

A multi-criteria prioritization was performed for the demonstration projects to establish a relative priority that maximizes total benefit to the City. This process is discussed in detail in Appendix E. The overall priority of the projects is summarized in Figure 6-2. The prioritization was performed using four evaluation criteria that were developed in conjunction with City and LIVE GREEN staff, including:

1. Grant Funded - Level to which project costs could be funded externally from City funds;
2. Integrated Infrastructure - Degree to which project supports other City infrastructure needs;
3. Public Acceptance & Education - Degree to which project would be expected to generate public support and educational opportunities; and
4. Cost Efficiency – Runoff capture cost efficiency (i.e., Cost / Gallon Captured) expressed as a percent of the most efficient project identified

Each criterion was weighted by the team and the results normalized to a 100 point scale. The distribution of the weightings is shown in Figure 6-1.

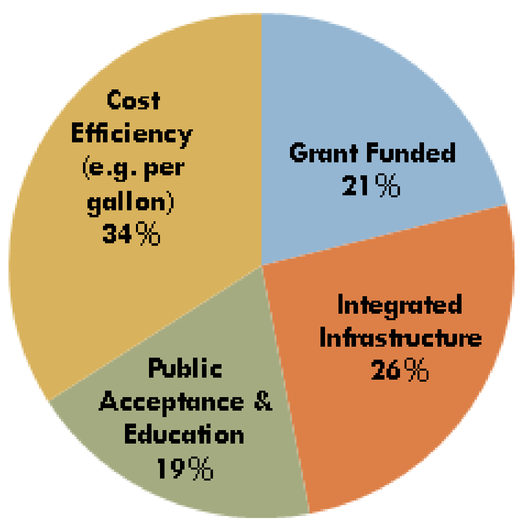


Figure 6-1 - Distribution of Evaluation Criteria and Weights

Table 6-1 - Summary of recommended green infrastructure projects

ID	Name	Address	Owner	CSO	Project Description	Impervious Area Contributing (ft^2)	GI Area (ft^2)	Estimated Capture Volume (gal)	Estimated Capital Cost w/ Contingency
P-01	Green Park 1: 6th Ward Park	E Ross St & Hamilton St	City	North	Porous Basketball; Vegetated Curb Ext; Rain Garden behind sign; RG at Fredrick St	77,712	15,965	1,653,000	$200,886
P-02	Reservoir Park	E King St & N Franklin St	City	North	Porous pavement parking lot; play court; cisterns; subsurface infiltration bed	57,660	41,273	1,228,000	$725,479
P-03	Brandon Park	Wabank St & Hazel St	City	Engleside	Bioretention, porous pavement parking stalls; porous play court, vegetated swales	250,735	37,139	5,069,000	$776,006
P-04	Crystal Park	1st St & Reiker Ave	City	Engleside	Porous Pavement Basketball Court captures upland pkg lot/roof runoff; convert alley on E to park extension/greenpath	37,292	7,458	753,000	$110,536
P-05	Rodney Park	W 4th St & N Rodney St	City	North	Bioretention, porous pavement parking Lane; porous play court	29,707	10,821	626,000	$143,702
P-07	Conlin Field/Farnum Park	South Water St and E Flbert St	City	Engleside	Porous pvm parking lot; Existing RG proposed, Veg curb extension with tree replacement at hydrant near bball court; capture road runoof at gateway inlet and direct into parking lot bed	58,477	17,920	1,250,000	$330,553
P-08	Northwest Greenway Linear Park	W. Lemon St & Harrisburg Ave	City	North	Rain gardens, Green trail, Green parking lot with pedestrian enhancements, Landscape restoration, Infiltration trench	47,171	32,183	944,000	$401,158
P-19	Northeast Greenway Corridor	McCaskey HS to E Walnut St	Private	North	Green trailway	45,150	45,150	987,000	$484,220
P-20	Triangle Park	New Holland Ave at E Walnut St	City	North	Infiltration bed beneath parking lot; tree trench to intercept adjacent residential rooftop runoff	6,630	1,963	133,000	$20,338
P-30	Carter & MacRae Elementary School	201 S Prince St	School District	Engleside	Cisterns (3) on south roof; Porous playcourt and tree plantings;	29,084	5,080	624,000	$98,640
P-31	Public Parking Lot: S Plum St	600 block South Plum Street	City	Stevens	Porous pavement/green alley	23,402	4,680	511,000	$89,862
P-34	Public Parking Lot: Dauphin St	200 block Dauphin Street	City	Stevens	Bioretention; Infiltration bed beneath alleyway	20,582	4,516	411,000	$61,822
P-35	Public Parking Lot: Penn Ave.	500 block Penn Ave.	City	Stevens	Porous pavement parking lot	22,758	4,219	455,000	$60,749
P-36	Public Parking Lot: E. Mifflin St	400 block E. Mifflin Street	City	Stevens	Bioretention	13,242	1,324	265,000	$27,013
P-42	Hand Middle School	431 South Ann Street	School District	Stevens	Green rooftop, infiltration trench adjacent to parking lot and roadway	70,487	40,113	1,410,000	$825,394
P-46	Green Street @ Prince Street	500-700 blocks N Prince St	City	North	Pavement reduction; replacement with Tree Trench for urban canopy enhancement	63,687	11,322	1,274,000	$181,761
P-47	Lancaster County Library	125 N Duke St	City	Engleside	Green Roof, Bioretention; Cistern; Tree Trench	35,367	12,288	706,000	$285,382
P-49	Strawberry St. Separation	E. Strawberry & Chesapeake Sts	City	Susquehanna	Bioretention	55,549	18,469	1,111,000	$376,768
P-50	Commercial Green Street @ Walnut & Plum	302 N. Plum St.	City	North	Curb extension/planter with tree trench at Brewery; Tree Trench along Walnut and Plum Streets	34,021	9,154	680,000	$114,991
P-51	Private Parking Lot - Water Street	Water Street, between	Private	Engleside	Infiltration bed; tree trench and bioretention	61,715	11,708	1,234,000	$182,544
					TOTAL	1,040,430	332,745	21,324,000	$ 5,497,801

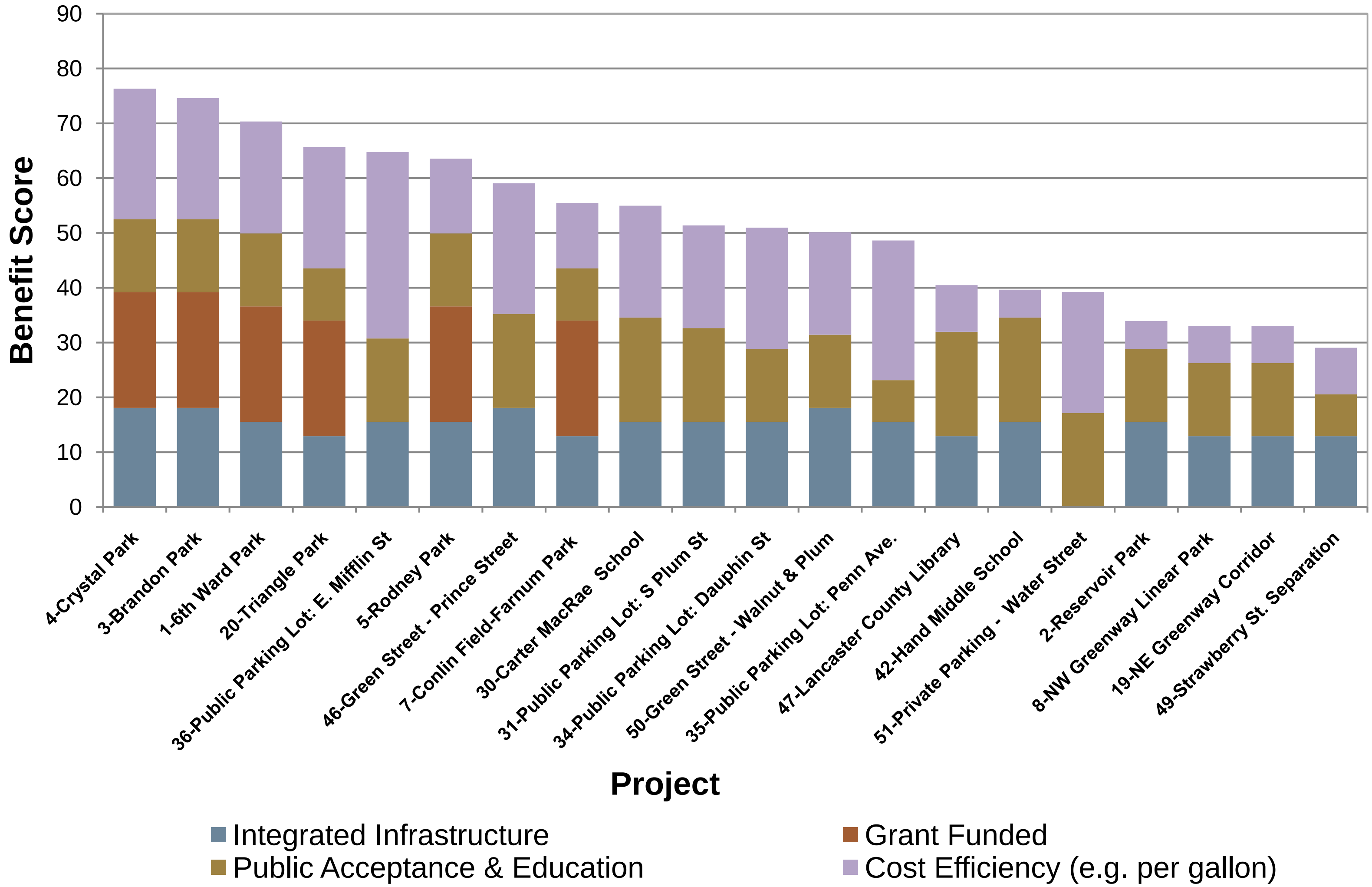


Figure 6-2 - Green demonstration project prioritization by total benefit score

2-IMPLEMENT POLICY ACTIONS

Policy Actions include legislative, financial, and other high level changes that remove barriers or create incentives to implementing green infrastructure.

A. **Institute a GI advisory committee** comprised of City leaders to discuss and remove implementation barriers and endorse selected implementation programs. Create working subcommittees at the local neighborhood level to suggest projects to the advisory committee;

B. **Revise City codes to remove barriers to implementing green infrastructure by** convening a process to review and evaluate codes governing tree planting, sidewalk restoration, parking lots, etc. For example, the City ordinance requiring that the strip of land between the sidewalk and the street curb be restored and maintained as grass (e.g pervious area). It is recommended that landscaping and other existing and potential model codes and development standards be evaluated for inclusion in a future ordinance that could help to propel the efforts to increase tree canopy and facilitate other aspects of GI implementation.

c. **Revise City standard design guidelines and details to incorporate green infrastructure –** The City is evaluating revisions to its roadway reconstruction process to include GI for roadway and alley reconstruction projects. As this program unfolds, the standard design details can be revised to document the new and accepted approaches for including GI in each project. This recommendation is supported by the public outreach recommendation to conduct workshops on green streets designs to develop consensus on appropriate design approaches.

d. **Evaluate and revise the First Flush Ordinance to manage all impervious area created in the full area of a site disturbance for redevelopment –** It is recommended that the City's stormwater regulations be evaluated and extended to control the first flush from the entire disturbed area of the redevelopment project. For example, if an addition to a building was being built on top of an existing parking lot, runoff from the addition would fall under the ordinance (not runoff from the original building itself). Although the first flush ordinance ensures that the stormwater runoff does not get any worse from the site, this situation results in very little improvement in terms of managing the runoff from the entire site.

   In many cases, a redevelopment project disturbs a site with a lot of impervious area. Typically in this case, the post-development condition will result in little or no increase to impervious area because of the high amount of existing impervious area. As a result, the disturbed area is large, but the stormwater management requirements are minor or even non-existent and opportunity is lost to make cost effective improvements using the approaches outlined in this plan. Although this change has been done in other cities, it would need to be evaluated for the specific policy and economic impacts on Lancaster City and how the development review process could be modified to save the developer time. The new ordinance could include a variety of measures that continue to incentivize redevelopment and address difficult site conditions.

e. **Implement an impervious cover-based rate allocation –** The City is presently undertaking an analysis that is examining the structure of a storm water utility and rate allocation program that will reapportion costs for the ongoing maintenance and capital upgrade of the City's drainage and water pollution control infrastructure. This program would apportion the costs of stormwater and combined sewer overflow programs based on the amount of impervious area on each individual parcel. This process provides a more equitable means for charging for the use of the City's drainage system by allocating costs by each parcels proportionate use of the sewer system instead of water meter size, the current method of calculating sewer drainage. If implemented, this utility would create the opportunity for private land owners to implement stormwater controls to achieve long term costs savings by reducing their flow (and pollutants) to the City sewer system. A credit system would need to be evaluated and developed to ensure that impervious area measurements and property specific improvements were properly valued in the process.

F. **Develop a program to utilize vacant land (publicly and privately owned) for management of stormwater runoff**. In the CSO areas of the City that are also underserved with park and recreation land (according to the new City park plan), consider acquiring land to serve the dual purpose of green infrastructure/stormwater infiltration and recreational/open space.

3-IMPLEMENT PARTNERING & OUTREACH ACTIONS

a. **Develop and manage a list of key partners and volunteers** to help deliver outreach messages, host workshops, and provide support for grant funding pursuits.

b. Develop partnerships and volunteer efforts to **implement the results of the Urban Tree Canopy Project** being conducted by PA DCNR and evaluate additional models for expanding street tree programs.

c. **Coordinate with County efforts to implement the state and federal pollution reduction requirements and the State Watershed Implementation plan (WIP)** for the Chesapeake Bay TMDL and MS4 requirements.

d. Coordinate with County efforts to **implement the Greenscapes Plan.**

e. **Develop a GI Portal on the City website** to disseminate information to the public about GI technologies, program updates, and what home owners can do to help.

f. **Develop a homeowner's guide to green infrastructure.**

g. **Provide GI Fact Sheets and education materials** on the Portal and brochures for selected audiences. Example fact sheets are provided in Appendix A and were funded by the Lancaster County Urban Enhancement Fund.

h. **Develop a public outreach plan, presentation materials and schedule** for outreach to key neighborhood groups, business leaders, the Mayor, City Council, and other stakeholders through **public meetings.** Use individual and group educational programming to gain public input in areas that have promising GI opportunities.

i. **Leverage learning through local and state key stakeholders** to inform the adoption and implementation of green infrastructure in other urban centers.

4-IMPLEMENT OTHER STUDIES & ADDITIONAL TECHNICAL ANALYSIS

a. **Conduct a Green Streets workshop** to support the selection and development of projects and approaches to demonstrate green streets in various types of road and alley reconstruction projects. Evaluate partnering with the Lancaster County Transportation Coordinating Committee as part of developing the Green streets strategy.

b. **Update the City Hydrologic and Hydraulic Models to simulate green infrastructure** improvements in relation to other grey infrastructure alternatives.

c. **Update the CSO LTCP** to include the green infrastructure plan recommendations.

d. **Expand the GI Plan to evaluate the required implementation levels of the Chesapeake Bay TMDL and the nutrient reductions required for Lancaster City** in the PA Watershed Implementation plan and **develop an integrated strategy for meeting CSO reduction and nutrient reduction objectives at the least cost and highest benefit to the City.**

e. **Partner with PA DEP in the development of the revised Watershed Implementation Plans (WIP)** for meeting the Chesapeake Bay TMDL requirements.

f. **Develop a project tracking system** to document GI implementation projects including the first flush projects and the area that they control.

g. **Identify direct stream inflow sources for potential removal from the combined sewer system** - evaluate drainage areas around the perimeter of the City to identify sources of separate stormwater and natural stream inflow for impact and potential removal projects.

h. **Prepare a comprehensive tree management plan** by analyzing and develop more specific tree planting goal based on the results of the Urban Tree Canopy Project and street tree inventory with forthcoming data from the Urban Tree Canopy study.

i. **Proactively implement GI on brownfields.** Evaluate opportunities for GI implementation on brownfields, in conjunction with redevelopment and economic revitalization projects that may be undertaken in the future.

j. **Address GIS data needs and updates:**

    1) Update parcel-based land use dataset as new data becomes available.

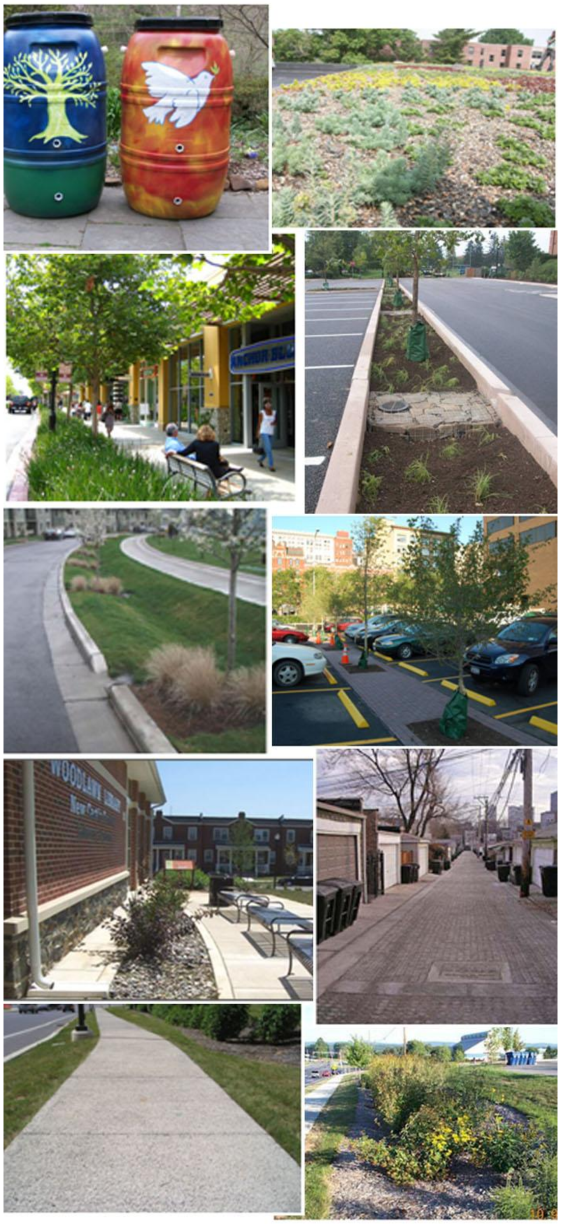
    2) Update impervious cover dataset: Original data provided by the County under-represents land cover/impervious area conditions. Undertake an update process in coordination with City and County planning staff by which impervious and pervious conditions are accurately represented.

    3) Update parcel-based ownership info in conjunction with the County Assessment office.

Appendices

APPENDIX A - GREEN INFRASTRUCTURE TECHNOLOGY FACT SHEETS

FACT SHEET: Overview of Green Infrastructure



Examples of Green Infrastructure (GI) techniques, including several from Lancaster City

DESCRIPTION

What is Green Infrastructure? Green infrastructure (GI) refers to a decentralized network of site-specific stormwater management techniques (see below for examples). GI techniques are implemented to reduce the volume of stormwater runoff entering the sewer system while also restoring the natural hydrologic cycle. As opposed to gray infrastructure - the traditional network of costly large scale conveyance and treatment systems - green infrastructure manages stormwater through a variety of small, cost-effective landscape features located on-site.

Green infrastructure is particularly important in urban areas with combined sewers, where during wet weather events, combined sewer overflows (CSOs) result in untreated combined sewage being discharged directly into water bodies. (See diagram on page 2). These CSO events can significantly impact downstream water quality. 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.

How does Green Infrastructure work? Green infrastructure employs the following processes 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 re-use (storing runoff to water plants, flush toilets, etc.)

Common Green Infrastructure Techniques

- Downspout Disconnection
- Cisterns/Rain Barrels
- Bioretention (Rain Gardens)
- Vegetated ("Green") Roofs
- Stormwater Planter Boxes
- Infiltration Practices (Basins, Trenches, Dry Wells)
- Pervious Pavement with Infiltration
- Green Streets/Green Alleys
- Vegetated Swales
- Tree Trenches
- Vegetated Curb Extensions

BENEFITS OF GREEN INFRASTRUCTURE

Environmental Benefits

- Recharges and improves quality of ground and surface waters
- Provides natural stormwater management
- Improves energy efficiency
- Reduces urban heat island effect
- Improves aquatic and wildlife habitat

Social Benefits

- Improves aesthetics and livability of urban communities
- Increases recreational opportunities
- Improves water and air quality
- Fosters environmental education opportunities

Economic Benefits

- Reduces existing and potential future costs of gray infrastructure
- Increases property values
- Reduces energy consumption costs

Image Source: artfulrainwaterdesign.net

GREEN INFRASTRUCTURE CAN REDUCE THE FREQUENCY AND VOLUME OF CSO EVENTS

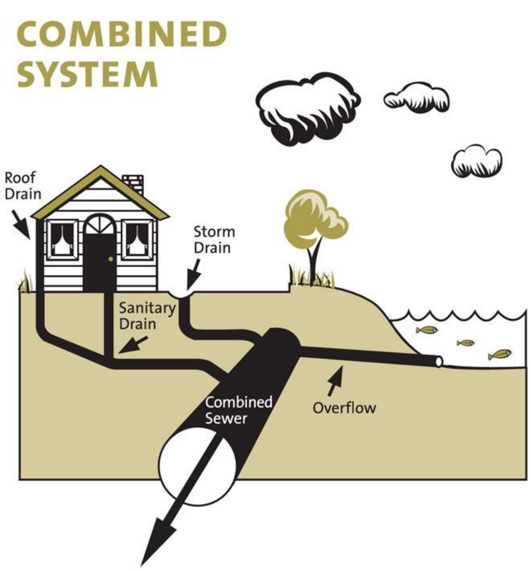


Diagram of combined sewer system
Source: EcoJustice.ca

ADDITIONAL CONSIDERATIONS

Maintenance of Green Infrastructure

Similar to conventional gray infrastructure, green infrastructure does require some level of maintenance to ensure optimal performance:

- Many GI techniques require regular maintenance, whether related to vegetation (weeding, pruning, mulching) or operational maintenance/repair (cleaning pervious pavement)
- The life cycle of the technology or vegetation used in the GI technique must be taken into account when preparing a maintenance plan

Cost of Green Infrastructure

- Costs for green infrastructure vary widely depending on specific site conditions and the type of GI techniques being used
- Often the cost of GI projects is competitive with or less than comparable gray infrastructure projects

FACT SHEET: Downspout Disconnection

DESCRIPTION

In urban areas, roof runoff flows through gutters and downspouts and out to the storm or combined sewer. Disconnecting downspouts is the process of separating roof downspouts from the sewer system and redirecting roof runoff onto pervious surfaces. This reduces the amount of directly connected impervious area in a drainage area.

For disconnection to be safe and effective, each downspout must discharge into a suitable receiving area. Roof runoff can be redirected to a garden, yard, planter, or a rain barrel or cistern for eventual reuse. Runoff must not flow toward building foundations or onto adjacent property.

A plan for downspout disconnection will work with the existing downspouts on a building assuming there is an adequate receiving area; however, for buildings with internal drainage, disconnecting internal downspouts may be difficult or impractical.

BENEFITS

- Provides supplemental water supply when used in conjunction with capture/reuse systems
- Wide applicability
- Reduces potable water use and water supply costs when used in conjunction with capture/reuse systems
- Related cost savings and environmental benefits
- Reduced runoff volume, CSOs Peak

MAINTENANCE

- Check materials for leaks and defects
- Remove accumulated debris, especially from gutters

COST

- Inexpensive; materials are readily available at hardware store

POTENTIAL LIMITATIONS

- Internal drainage more difficult to disconnect
- Do not disconnect onto adjacent property owner
- Need adequate receiving area

POTENTIAL APPLICATIONS	
Residential	Yes
Commercial	Yes
Ultra Urban	Limited
Industrial	Yes
Retrofit	Limited
Highway/Road	No
Recreational	Yes
Public/Private	N/A

Residential downspout disconnect in Portland Oregon (Source: Portland Stormwater Website)

Residential downspout disconnection in Lancaster, PA

VARIATIONS

- Scuppers
- Drip chains
- Decorative gargoyles

KEY DESIGN FEATURES

- Install splashblock at the end of the extension to prevent erosion
- Roof runoff must be discharged at least 5 feet away from property lines including basements and porches

SITE FACTORS

- Water table to bedrock depth – N/A
- Soils – N/A
- Slope – N/A
- Potential hotspots – Yes (with treatment)
- Maximum drainage area – N/A

STORMWATER QUANTITY FUNCTIONS		STORMWATER QUALITY FUNCTIONS		ADDITIONAL CONSIDERATIONS	
Volume	Medium	TSS	Medium	Capital Cost	Low
Groundwater Recharge	Medium/High	TP	N/A	Maintenance	Low
Peak Rate	Medium	TN	N/A	Winter Performance	High
Erosion Reduction	Medium	Temperature	Medium/High	Fast Track Potential	Low/Medium
Flood Protection	Low			Aesthetics	High

FACT SHEET: Cistern/Rain Barrel

DESCRIPTION

Cisterns and Rain Barrels are structures designed to intercept and store runoff from rooftops to allow for its reuse, reducing volume and overall water quality impairment. Stormwater is contained in the cistern or rain barrel structure and typically reused for irrigation or other water needs. This GI technology reduces potable water needs while also reducing stormwater discharges.

Rain Barrel – rooftop downspouts are directed to an above-ground (typically) structure that collects rainwater and stores it until needed for a specific use, such as landscape irrigation.

Cistern – Underground (typically) container or tank with a larger storage capacity than a rain barrel, and typically used to supplement greywater needs (i.e. toilet flushing) in a building, as well as irrigation.

Cisterns and rain barrels can be used in urbanized areas where the need for supplemental onsite irrigation or other high water uses is especially

BENEFITS

- Provides supplemental water supply
- Wide applicability
- Reduces potable water use
- Related cost savings and environmental benefits
- Reduced stormwater runoff impacts

MAINTENANCE

- Discharge before next storm event
- Clean annually and check for loose valves, etc.
- May require flow bypass valves during the winter

COST

- Rain Barrels range from $100 to $300
- Cisterns typically range from $500 to $5000

POTENTIAL APPLICATIONS	
Residential	Yes
Commercial	Yes
Ultra Urban	Yes
Industrial	Yes
Retrofit	Yes
Highway/Road	No
Recreational	Yes
Public/Private	Yes/Yes

POTENTIAL LIMITATIONS

- Manages only relatively small storm events which requires additional management and use for the stored water.
- Typically requires additional management of runoff
- Requires a use for the stored water (immigration, gray water, etc.

VARIATIONS

- Rain barrels
- Cistems, both underground and above ground
- Tanks
- Storage beneath a surface using manufactured products
- Various sizes, materials, shapes, etc.

KEY DESIGN FEATURES

- Small storm events are captured with most structures
- Provide overflow for large storms events
- Discharge water before next storm event
- Consider site topography, placing structure upgradient of planting (if applicable) in order to eliminate pumping needs

SITE FACTORS

- Water table to bedrock depth – N/A (although must be considered for subsurface systems)
- Soils – N/A
- Slope – N/A
- Potential hotspots – yes with treatment
- Maximum drainage area – N/A

Top-left and bottom-left photos: Rain barrels in use in the City of Lancaster (Source: LiveGREEN)

Bottom-right photo: Rain barrel prototype example

STORMWATER QUANTITY FUNCTIONS		STORMWATER QUALITY FUNCTIONS		ADDITIONAL CONSIDERATIONS	
Volume	Low/Medium	TSS	Medium	Capital Cost	Low/Medium
Groundwater Recharge	Low	TP	Medium	Maintenance	Medium
Peak Rate	Low	TN	Medium	Winter Performance	Medium
Erosion Reduction	Low	Temperature	Medium	Fast Track Potential	Medium/High
Flood Protection	Low/Medium			Aesthetics	Low/Medium

FACT SHEET: Bioretention (Rain Gardens)

Residential rain garden at the Village at Springbrook Farm in Lebanon, PA

Rain garden at Woodlawn Library in Wilmington, DE

DESCRIPTION

Bioretention Areas (often called Rain Gardens) are shallow surface depressions planted with specially selected native vegetation to treat and capture runoff and are sometimes underlain by sand or gravel storage/infiltration bed. Bioretention is a method of managing stormwater by pooling water within a planting area and then allowing the water to infiltrate the garden. In addition to managing runoff volume and mitigating peak discharge rates, this process filters suspended solids and related pollutants from stormwater runoff. Bioretention can be designed into a landscape as a garden feature that helps to improve water quality while reducing runoff quantity. Rain Gardens can be integrated into a site with a high degree of flexibility and can balance nicely with other structural management systems including porous pavement parking lots, infiltration trenches, and other non-structural stormwater BMPs. Bioretention areas typically require little maintenance once established and often replace areas that were intensively landscaped and require high maintenance.

BENEFITS

- Volume control & GW recharge, moderate peak rate control
- Versatile w/ broad applicability
- Enhance site aesthetics and habitat
- Potential air quality & climate benefits

MAINTENANCE

- Watering: 1 time / 2-3 days for first 1-2 months, then as needed
- Spot weeding, pruning, erosion repair, trash removal, and mulch raking: twice during growing season
- As needed, add reinforcement planting to maintain desired density (remove dead plants), remove invasive plants, and stabilize contributing drainage area
- Annual: spring inspection and cleanup, supplement mulch to maintain a 3 inch layer, and prune trees and shrubs
- At least once every 3 years: remove sediment in pre-treatment cells/inflow points and replace the mulch layer
- Maintenance cost is similar to traditional landscaping

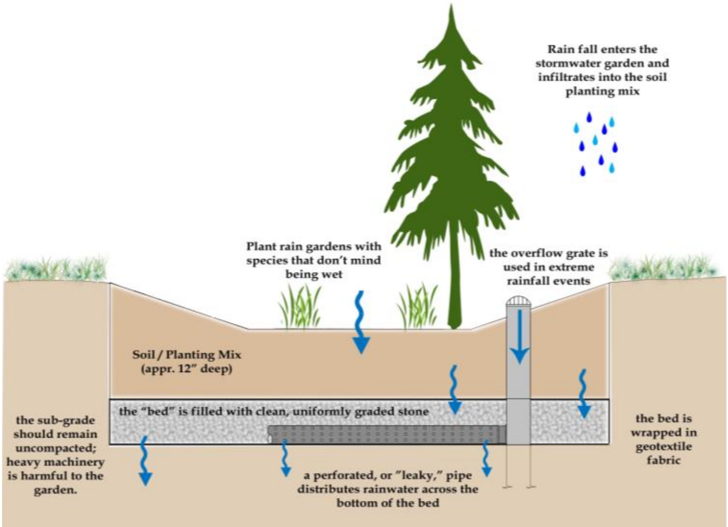
COST

- Cost will vary depending on the garden size and the types of vegetation used; typical costs are $10-17 per sq. foot

POTENTIAL APPLICATIONS	
Residential	Yes
Commercial	Yes
Ultra Urban	Limited
Industrial	Yes
Retrofit	Yes
Recreational	Yes
Public/Private	Yes
Residential	Yes

POTENTIAL LIMITATIONS

- Higher maintenance until vegetation is established
- Limited impervious drainage area to each BMP
- Requires careful selection & establishment of plants



Conceptual diagram showing process of bioretention

Linear bioretention area along roadway
Source: Low Impact Development Center, Inc.

VARIATIONS

- Subsurface storage/infiltration bed
- Use of underdrain
- Use of impervious liner

KEY DESIGN FEATURES

- Flexible in size and configuration
- Ponding depths 6 to 18 inches for drawdown within 48 hours
- Plant selection (native vegetation that is tolerant of hydrologic variability, salts, and environmental stress)
- Amend soil as needed
- Provide positive overflow for extreme storm events
- Stable inflow/outflow conditions

SITE FACTORS

- Water Table/ Bedrock Separation: 2-foot minimum, 4-foot recommended
- Soils: HSG A and B preferred; C & D may require an underdrain
- Feasibility on steeper slopes: medium
- Potential Hotspots: yes with pretreatment and/or impervious liner
- Maximum drainage area: 5:1; not more than 1 acre to one rain garden

STORMWATER QUANTITY FUNCTIONS		STORMWATER QUALITY FUNCTIONS		ADDITIONAL CONSIDERATIONS	
Volume	Medium/High	TSS	High (70-90%)	Capital Cost	Medium
Groundwater Recharge	Medium/High	TP	Medium (60%)	Maintenance	Medium
Peak Rate	Medium	TN	Medium (40-50%)	Winter Performance	Medium
Erosion Reduction	Medium	Temperature	High	Fast Track Potential	Medium
Flood Protection	Low/Medium			Aesthetics	High

FACT SHEET: Vegetated Roof

BENEFITS

- High volume reduction (annual basis)
- Moderate ecological value and habitat
- High aesthetic value
- Energy benefits (heating/cooling)
- Urban heat island reduction

POTENTIAL APPLICATIONS	
Residential	Limited
Commercial	Yes
Ultra Urban	Yes
Industrial	Yes
Retrofit	Yes
Highway/Road	No
Recreational	Yes
Public/Private	Yes/Yes

POTENTIAL LIMITATIONS

- Higher maintenance needs until vegetation is established
- Need for adequate roof structure; can be challenging on retrofit application

DESCRIPTION

A vegetated roof cover is a veneer of vegetation that is grown on and covers an otherwise conventional flat or pitched roof, endowing the roof (< 30 degree slope) with hydrologic characteristics that more closely match surface vegetation than the roof. The overall thickness of the veneer typically ranges from 2 to 6 inches and may contain multiple layers, consisting of waterproofing, synthetic insulation, nonsoil engineered growth media, fabrics, and synthetic components. Vegetated roofs, also called "green rooftops" can be optimized to achieve water quantity and water quality benefits. Through the appropriate selection of materials, even thin vegetated covers can provide significant rainfall retention and detention functions.

Depending on the plant material and planned usage for the roof area, modern vegetated roofs can be categorized as systems that are intensive, semi-intensive, or extensive. **Intensive** vegetated roofs utilize a wide variety of plant species that may include trees and shrubs, require deeper substrate layers (usually > 4 inches), are generally limited to flat roofs, require 'intense' maintenance, and are often park-like areas accessible to the general public. **Extensive** vegetated roofs are limited to herbs, grasses, mosses, and drought tolerant succulents such as sedum, can be sustained in a shallow substrate layer (<4 inches), require minimal maintenance once established, and are generally not designed for access by the public. These vegetated roofs are typically intended to achieve a specific environmental benefit, such as rainfall runoff mitigation. Extensive roofs are well suited to rooftops with little load bearing capacity and sites which are not meant to be used as roof gardens. **Semi-intensive** vegetated roofs fall between intensive and extensive vegetated roof systems. More maintenance, higher costs and

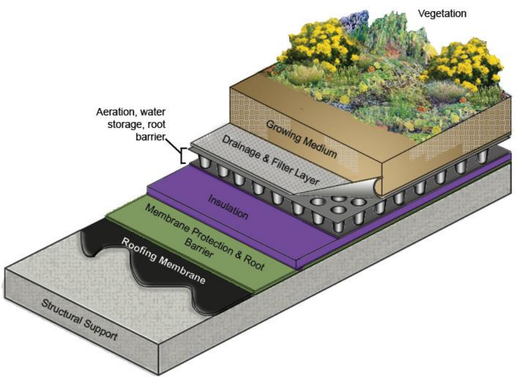
MAINTENANCE

- Once vegetation is established, little to no maintenance needed for the extensive system
- Maintenance cost is similar to traditional landscaping, $0.25-$1.25 per square foot

COST

- $5 - $50 per square foot, including all structural components, soil, and plants; more expensive than traditional roofs, but have longer lifespan; generally less expensive to install on new roof versus retrofit on existing roof

Residential vegetated roof in the City of Lancaster (Source: LiveGREEN)



Cross-section showing components of vegetated roof system

Vegetated Roof at F&M College in Lancaster, PA (Source: LiveGREEN)

VARIATIONS

- Single media system
- Dual media system
- Dual media system with synthetic layer
- Intensive, Extensive, or Semi-intensive

KEY DESIGN FEATURES

- Engineered media should have a high mineral content. Engineered media for extensive vegetated roof covers is typically 85% to 97% nonorganic.
- 2-6 inches of non-soil engineered media; assemblies that are 4 inches and deeper may include more than one type of engineered media.
- Vegetated roof covers intended to achieve water quality benefits should not be fertilized.
- Irrigation is generally not required (or even desirable) for optimal stormwater management using vegetated covers.
- Internal building drainage, including provision to cover and protect deck drains or scuppers, must anticipate the need to manage large rainfall events without inundating the cover.
- Assemblies planned for roofs with pitches steeper than 2:12 (9.5 degrees) must incorporate supplemental measures to insure stability against siding.
- The roof structure must be evaluated for compatibility with the maximum predicted dead and live loads. Typical dead loads for wet extensive vegetated covers range from 8 to 36 pounds per square foot.
- The waterproofing must be resistant to biological and root attack. In many instances a supplemental roof-fast layer is installed to protect the primary waterproofing.

STORMWATER QUANTITY FUNCTIONS		**STORMWATER QUALITY FUNCTIONS**		**ADDITIONAL CONSIDERATIONS**	
Volume	Medium/High	TSS	Medium	Capital Cost	High
Groundwater Recharge	Low	TP	Medium	Maintenance	Medium
Peak Rate	Medium	TN	Medium	Winter Performance	Medium
Erosion Reduction	Low/Medium	Temperature	Medium	Fast Track Potential	Low
Flood Protection	Low/Medium			Aesthetics	High

FACT SHEET: Stormwater Planter Box

Planter box in Lansing, Michigan

DESCRIPTION

A Planter Box is a container or enclosed feature located either above ground or below ground, planted with vegetation that captures stormwater within the structure itself. Planter Boxes can play an important role in urban areas by minimizing stormwater runoff, reducing water pollution, and creating a greener and healthier appearance by retaining stormwater rather than allowing it to directly drain into nearby sewers. Planter Boxes receive runoff usually from rooftop areas and must be located reasonably close to downspouts or structures generating runoff. Stormwater runoff is used to irrigate the plants, and the vegetation in the planter box reduces stormwater through evapotranspiration.

Boxes can take any number of different configurations and be made out of a variety of different materials, although many are constructed from wood or concrete. Underground Planter Boxes designed to infiltrate can be constructed alongside buildings provided that proper waterproofing measures are used to protect foundations.

BENEFITS

- Enhance site aesthetics and habitat
- Potential air quality and climate benefits
- Potential runoff and combined sewer overflow reductions
- Wide applicability including ultra-urban areas

POTENTIAL APPLICATIONS	
Residential	Yes
Commercial	Yes
Ultra Urban	Yes
Industrial	Limited
Retrofit	Yes
Highway/Road	Limited
Recreational	Limited
Private	Yes

MAINTENANCE

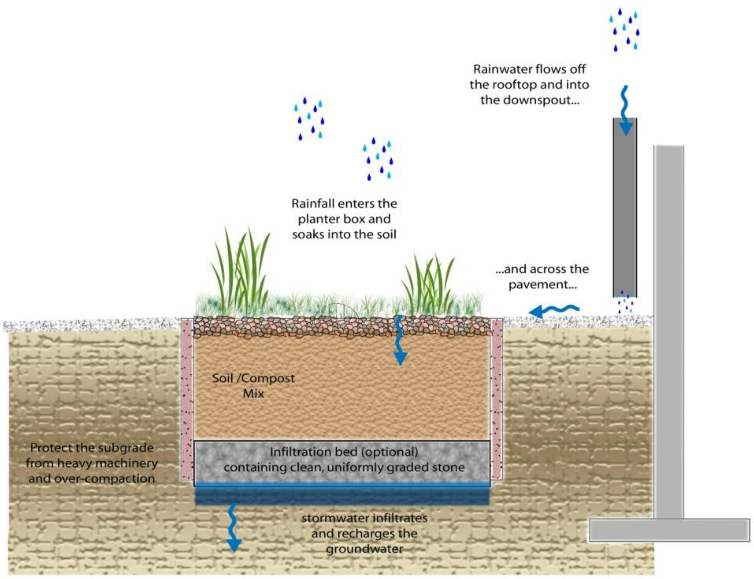
- See Rain Garden maintenance
- Bypass valve during winter
- Maintenance cost: $400-$500 per year for a 500 square foot planter; varies based on type, size, plant selection, etc.

COST

- Varies based on type, size, plant selection, etc., but is approx. $8-15 per square foot

POTENTIAL LIMITATIONS

- Limited stormwater quantity/quality benefits
- Relatively high cost due to structural components for some variations



Conceptual diagram showing infiltration

Infiltration planter box at Woodlawn Library, Wilmington, DE

VARIATIONS

- Contained (above ground)
- Infiltration (below ground)
- Flow-through

KEY DESIGN FEATURES

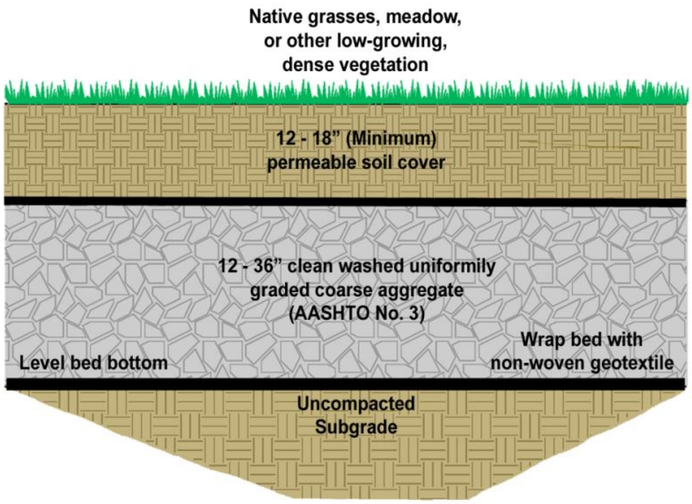
- Native vegetation
- May be designed as pretreatment
- May be designed to infiltrate
- Captured runoff to drain out in 3 to 4 hours after storm even unless used for irrigation
- Receive less than 15, 000 square feet of impervious area runoff (typ.)
- The structural elements of the planters should be stone, concrete, brick, or pressure-treated wood
- Flow bypass during winter

SITE FACTORS

- Water Table and Bedrock Depth – N/A for contained and flow-through, 2 feet minimum for Infiltration Planter Box
- Soils – N/A for contained and flow-through, HSG A&B preferred for Infiltration
- Potential Hotspots – yes for contained and flow-through; no for infiltration

STORMWATER QUANTITY FUNCTIONS		**STORMWATER QUALITY FUNCTIONS**		**ADDITIONAL CONSIDERATIONS**	
Volume	Low/Medium	TSS	Medium	Capital Cost	Low/Medium
Groundwater Recharge	Low	TP	Medium	Maintenance	Medium
Peak Rate	Low	TN	Medium	Winter Performance	Medium
Erosion Reduction	Low	Temperature	Medium	Fast Track Potential	Low
Flood Protection	Low			Aesthetics	High

FACT SHEET: Infiltration Practices



BENEFITS

- Reduces volume of stormwater runoff
- Reduces peak rate runoff
- Increases groundwater recharge
- Provides thermal benefits
- Increased aesthetics
- Multiple use/Dual use

MAINTENANCE

There are a few general maintenance practices that should be followed for infiltration BMPs. These include:

- All catch basins and inlets should be inspected and cleaned at least twice per year
- The overlying vegetation of subsurface infiltration feature should be maintained in good condition and any bare spots revegetated as soon as possible.
- Vehicular access on subsurface infiltration areas should be prohibited (unless designed to allow vehicles) and care should be taken to avoid excessive compaction by mowers.

POTENTIAL LIMITATIONS

- Pretreatment requirement to prevent clogging
- Not recommended for areas with steep slopes

DESCRIPTION

Infiltration practices are natural or constructed areas located in permeable soils that capture, store, and infiltrate the volume of stormwater runoff through a stone-filled bed (typically) and then into surrounding soil.

Dry wells, also referred to as seepage pits, French drains or Dutch drains, are a subsurface storage facility (structural chambers or excavated pits, backfilled with a coarse stone aggregate or alternative storage media) that temporarily store and infiltrate stormwater runoff from rooftop structures. Due to their size, dry wells are typically designed to handle stormwater runoff from smaller drainage areas, less than one acre in size.

Infiltration basins are shallow surface impoundments that temporarily store, capture, and infiltrate runoff over a period of several days on a level and uncompacted surface. Infiltration basins are typically used for drainage areas of 5 to 50 acres with land slopes that are less than 20 percent.

Infiltration berms use a site's topography to manage stormwater and prevent erosion. Berms may function independently in grassy areas or may be incorporated into the design of other stormwater control facilities such as Bioretention and Constructed Wetlands. Berms may also serve various stormwater drainage functions including: creating a barrier to flow, retaining flow for volume control, and directing flows.

Infiltration trenches are linear subsurface infiltration structures typically composed of a stone trench wrapped with geotextile which is designed for both stormwater infiltration and conveyance in drainage areas less than five acres in size.

Subsurface infiltration beds generally consist of a rock storage (or alternative) bed below surfaces such as parking lots, lawns, and playfields for temporary storage and infiltration of stormwater runoff with a maximum drainage area of 10 acres.

Bioretention can be an infiltration practice and is discussed in the Bioretention fact sheet.

COST

- Dry Well: Construction costs – \$4-9/ft^3, Maintenance Costs – 5-10% of capital costs
- Infiltration basin: Construction costs – varies depending on excavation, plantings, and pipe configuration
- Infiltration Trench: Construction costs – \$20-30/ft^3, Maintenance Costs – 5-10% of capital costs
- Subsurface Infiltration Bed: Construction costs – 13/ft^3

Subsurface Infiltration Bed using Rainstore ™ blocks for storage media, Washington National Cathedral, DC

VARIATIONS

- Rain barrels
- Cistems, both underground and above ground
- Tanks
- Storage beneath a surface using manufactured products
- Various sizes, materials, shapes, etc.

KEY DESIGN FEATURES

- Depth to water table or bedrock
- Pretreatment is often needed to prevent clogging
- Often required level infiltration surface
- Proximity to buildings, drinking water supplies, karst features, and other sensitive areas
- Soil types (permeability, limiting layer, etc.)
- Provide positive overflow in most uses

SITE FACTORS

- Maximum Site Slope: 20 percent
- Minimum depth to bedrock: 2 feet
- Minimum depth to seasonally high water table: 2 feet
- Potential Hotspots: yes with pretreatment and/or impervious liner
- HSG Soil type: A and B preferred, C & D may require an underdrain
- Maximum drainage area – N/A

Potential Applications

	Residential	Commercial	Ultra Urban	Industrial	Retrofit	Highway/ Road	Recreati-onal	Private
Dry Well	Yes	Yes	Yes	Limited	Yes	No	Yes	Yes
Infiltration Basin	Yes	Yes	Limited	Yes	Yes	Limited	Yes	Yes
Infiltration Berm	Yes	Yes	Limited	Yes	Yes	Yes	Yes	Yes
Infiltration Trench	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Subsurface Infiltration Bed	Yes	Yes	Yes	Yes	Yes	Limited	Yes	Yes

Stormwater Quantity Functions

	Volume	Groundwater Recharge	Peak Rate	Erosion Reduction	Flood Protection
Dry Well	Medium	High	Medium	Medium	Low
Infiltration Basin	High	High	High	Medium	High
Infiltration Berm	Low/Medium	Low/Medium	Medium	Medium/High	Medium
Infiltration Trench	Medium	High	Low/Medium	Medium/High	Low/Medium
Subsurface Infiltration Bed	High	High	High	Medium/High	Medium/High

Stormwater Quality Functions

	TSS	TP	TN	Temperature
Dry Well	Medium (85%)	High/Medium (85%)	Medium/Low (30%)	High
Infiltration Basin	High (85%)	Medium/High (85%)	Medium (30%)	High
Infiltration Berm	Medium/High (60%)	Medium (50%)	Medium (40%)	Medium
Infiltration Trench	Medium (85%)	High/Medium (85%)	Medium/Low (30%)	High
Subsurface Infiltration Bed	High (85%)	Medium/High (85%)	Low (30%)	High

The Vegetated Infiltration Basin beneath this playfield manages rooftop runoff from the adjacent school building, Philadelphia, PA

Infiltration trench Chester County, PA

Vegetated Infiltration Basin outside of Allentown, PA

Additional Considerations

Capital Cost	Medium
Life Cycle Costs	Medium
Maintenance	Medium
Winter Performance	High
Resistance to Heat	High
Fast Track Potential	Medium
Aesthetics	Medium

FACT SHEET: Pervious Pavement with Infiltration

Porous pavers on the right, standard asphalt on the left, in San Diego, CA

Porous concrete sidewalk at State College, PA

BENEFITS

- Volume control & GW recharge, moderate peak rate control
- Versatile with broad applicability
- Dual use for pavement structure and stormwater management

POTENTIAL APPLICATIONS	
Residential	Yes
Commercial	Yes
Ultra Urban	Yes
Industrial	Yes
Retrofit	Yes
Highway	Limited
Recreational	Yes
Public	Yes

DESCRIPTION

Pervious pavement is a Green Infrastructure (GI) technique that combines stormwater infiltration, storage, and structural pavement consisting of a permeable surface underlain by a storage/infiltration bed. Pervious pavement is well suited for parking lots, walking paths, sidewalks, playgrounds, plazas, tennis courts, and other similar uses.

A pervious pavement system consists of a pervious surface course underlain by a storage bed placed on uncompacted subgrade to facilitate stormwater infiltration. The storage reservoir may consist of a stone bed of uniformly graded, clean and washed course aggregate with a void space of approximately 40% or other pre-manufactured structural storage units. The pervious pavement may consist of asphalt, concrete, permeable paver blocks, reinforced turf/gravel, or other emerging types of pavement.

MAINTENANCE

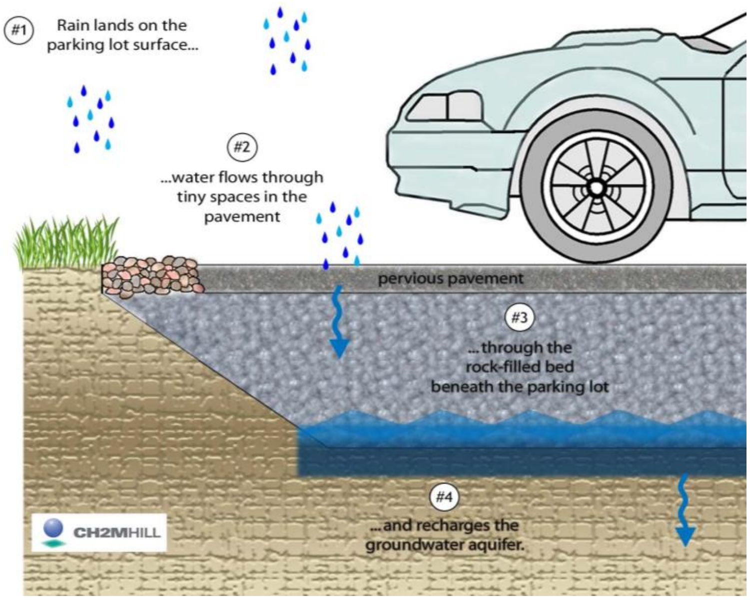
- Clean inlets
- Vacuum annually
- Maintain adjacent landscaping/planting beds
- Periodic replacement of paver blocks
- Maintenance cost: approximately $400-500 per year for vacuum sweeping of a half acre parking lot

COST

- Varies by porous pavement type
- Local quarry needed for stone filled infiltration bed
- $7-$15 per square foot, including underground infiltration bed
- Generally more than standard pavement, but saves on cost of other BMPs and traditional drainage infrastructure

POTENTIAL LIMITATIONS

- Careful design & construction required
- Pervious pavement not suitable for all uses
- Higher maintenance needs than standard pavement
- Steep slopes



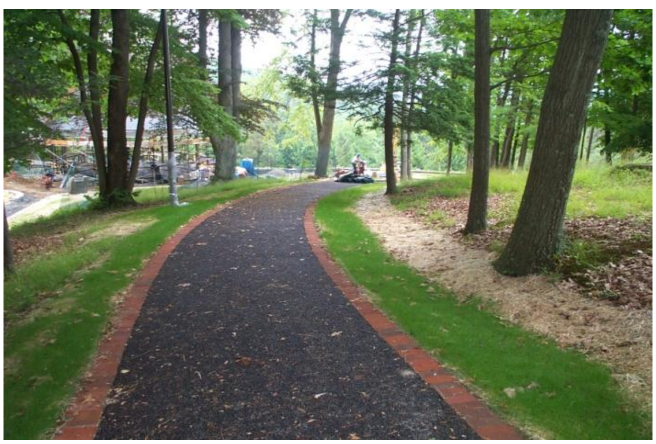
Conceptual diagram showing how porous pavement functions

KEY DESIGN FEATURES

- Infiltration testing required
- Do not infiltrate on compacted soil
- Level storage bed bottoms
- Provide positive storm water overflow from bed
- Surface permeability >20"/hr
- Secondary inflow mechanism recommended
- Pretreatment for sediment-laden runoff

SITE FACTORS

- Water Table/Bedrock Separation: 2-foot minimum
- Soils: HSG A&B preferred; HSG C&D may require underdrains
- Feasibility on steeper slopes: Low
- Potential Hotspots: Not without design of pretreatment system/impervious liner



Porous asphalt path at Gray Towers Natl. Historic Site, PA

Porous asphalt parking lot in Wilm., DE

STORMWATER QUANTITY FUNCTIONS		STORMWATER QUALITY FUNCTIONS		ADDITIONAL CONSIDERATIONS	
Volume	High	TSS	High	Capital Cost	Medium
Groundwater Recharge	High	TP	Medium	Maintenance	Medium
Peak Rate	Medium/High	TN	High	Winter Performance	Medium/High
Erosion Reduction	Medium/High	Temperature	High	Fast Track Potential	Low/Medium
Flood Protection	Medium/High			Aesthetics	Low/Medium

FACT SHEET: Green Street/Green Alley

Green Alleyway in Andersonville, Chicago IL, Source: Chicago Department of Transport

Example of enhanced street tree infiltration facility

DESCRIPTION

Green Streets incorporate a wide variety of Green Infrastructure (GI) elements including street trees, permeable pavements, bioretention, water quality devices, planter boxes and swales. Although the design and appearance of green streets will vary, the functional goals are the same: provide source control of stormwater, limit its transport and pollutant conveyance to the collection system, restore predevelopment hydrology to the extent possible, and provide environmentally enhanced roads. Also, other benefits include aesthetics, safety, walkability, and heat island reduction.

Green Street technologies can be applied to residential, commercial and arterial streets as well as to alleys. The range of GI technologies that can be incorporated into a Green Street allow its developer to manipulate the stormwater management strategy of a given project. For example, San Mateo County, CA identified five levels of green street design as shown in the graphic on Page 2.

For specific details on the individual GI technologies (e.g., pervious pavement, bioretention, planter boxes etc) that can be incorporated into a Green Street, please consult the specific GI fact sheet.

BENEFITS

- Provide efficient site design
- Balance parking spaces with landscape space
- Utilize surface conveyance of stormwater
- Add significant tree canopy
- Provide alternative transportation options/improve walkability
- Increased pedestrian safety
- Improved aesthetics
- Reduction of urban heat island
- Reduced runoff volume, increased groundwater recharge and evapotranspiration
- Significant public education potential

MAINTENANCE

- See maintenance requirements for individual GI practices

COST

- $120-$190 per linear foot of block managed (i.e. capture of 1" of runoff)

POTENTIAL LIMITATIONS

- Maintenance needs
- Utility conflicts
- Conflicts with structures and other infrastructure (building foundations, etc)

Level 1	Maximizes landscape areas along the street and minimizes overall impervious areas of the land. Some runoff from sidewalks may be managed in landscape areas.	
Level 2	Significant tree canopy is added to the urban streetscape.	
Level 3	Fully manages street, sidewalk, and driveway runoff by using a landscape system. Design solutions are cost effective, provide direct environmental benefits, and are aesthetically pleasing.	
Level 4	Green street provides direct focus on alternative modes of transportation including mass transit, biking, and walking.	
Level 5	Green street frontage manages both public and private stormwater runoff. Building, site, and street frontage become one integrated space designed for stormwater management.	

VARIATIONS

- Porous pavement (street and/or sidewalk)
- Vegetated curb extensions
- Infiltration planters
- Infiltration trenches
- Enhanced tree plantings
- Water quality inlets

KEY DESIGN FEATURES

- See individual GI fact sheets: Tree Trench, Vegetated Curb Extension, Porous Pavement, etc.

SITE FACTORS

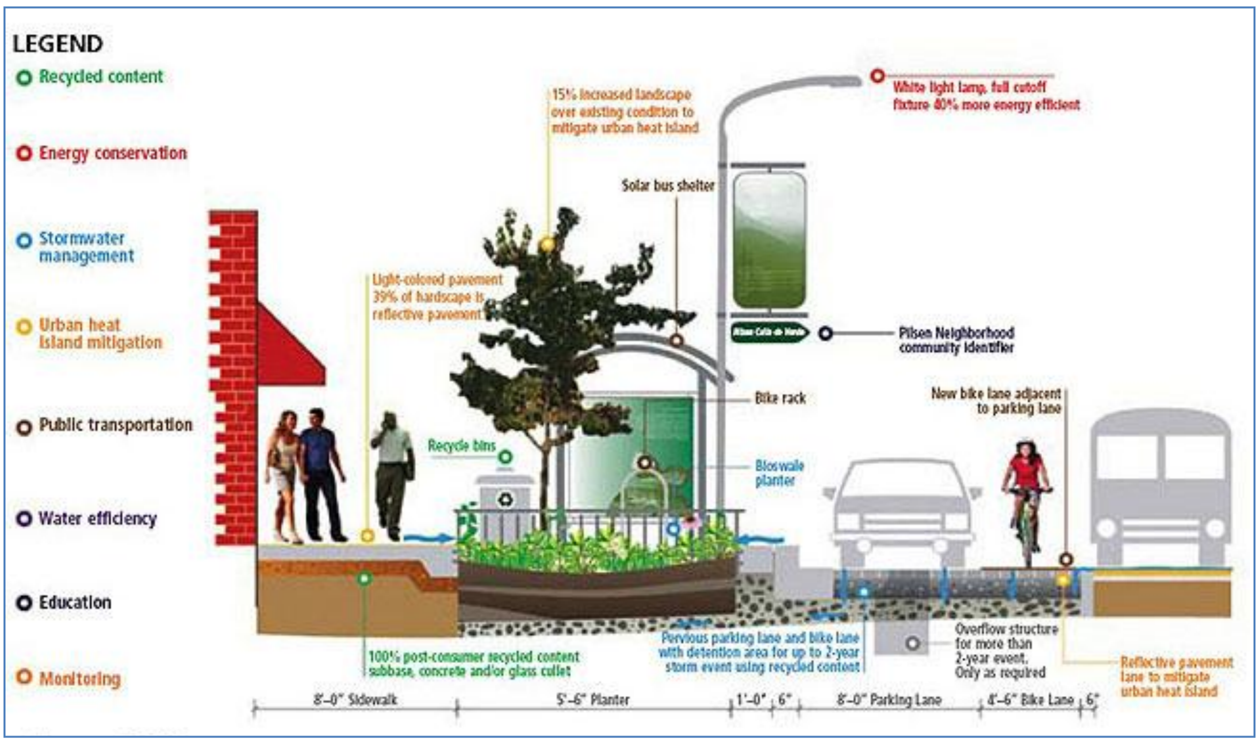
- Slope
- Soils
- Utilities
- Size of right-of-way
- See site factors for individual GI practices

POTENTIAL APPLICATIONS			
Residential	Yes	Retrofit	Yes
Commercial	Yes	Highway/Road	Yes
Ultra Urban	Yes	Recreational	Yes
Industrial	Yes	Public/Private	Yes

STORMWATER QUANTITY FUNCTIONS		STORMWATER QUALITY FUNCTIONS		ADDITIONAL CONSIDERATIONS	
Volume	Medium	TSS	High (70-90%)	Capital Cost	Medium
Groundwater Recharge	Medium	TP	Medium (60%)	Maintenance	Medium/High
Peak Rate	Medium	TN	Medium (40-50%)	Winter Performance	High
Erosion Reduction	Medium	Temperature	High	Fast Track Potential	Low/Medium
Flood Protection	Low/Medium			Aesthetics	High

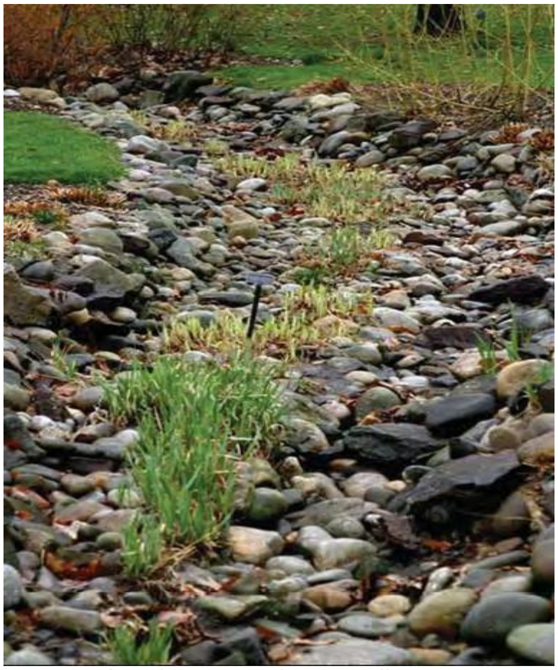
Bioretention along New York Street
Source: NYC Dept. of Parks and Rec

Route 9A, NYC
Source: NY Sustainable Stormwater Mgmt. Plan



Cross section through a green street showing the various components and benefits
(Source: Chicago Department of Transportation)

FACT SHEET: Vegetated Swale



Vegetated swales at Swarthmore College (Swarthmore, PA)

BENEFITS

- Can replace curb and gutter for site drainage and provide significant cost savings
- Water quality enhancement (i.e. filtration)
- Peak and volume control with infiltration
- Can fit into the layout, topography, and landscaping plans of a particular project with relative ease

POTENTIAL APPLICATIONS	
Residential	Yes
Commercial	Yes
Ultra Urban	Limited
Industrial	Yes
Retrofit	Limited
Highway/Road	Yes
Recreational	Yes
Public/Private	Yes

DESCRIPTION

A vegetated swale, also called a drainage swale or bioswale, is a shallow stormwater channel that is densely planted with a variety of grasses, shrubs, and/or trees designed to slow, filter, and infiltrate stormwater runoff. Vegetated swales are an excellent alternative to conventional curb and gutter conveyance systems, because they provide pretreatment and can distribute stormwater flows to subsequent BMPs.

Vegetated swales are sometimes used as pretreatment devices for other structural BMPs, especially from roadway runoff. While swales themselves are intended to effectively treat runoff from highly impervious surfaces, pretreatment measures are recommended to enhance swale performance. Check dams can be used to improve performance and maximize infiltration, especially in steeper areas. Check dams made of wood, stone, or concrete are often employed to enhance infiltration capacity, decrease runoff volume, rate, and velocity. They also promote additional filtering and settling of nutrients and other pollutants. Check-dams create a series of small, temporary pools along the length of the swale, which drain down within a maximum of 48 hours.

MAINTENANCE

- Remulch void areas, treat or replace diseased trees and shrubs, and keep overflow free and clear of leaves as needed
- Inspect soil and repair eroded areas, remove litter and debris, and clear leaves and debris from overflow
- Inspect trees and shrubs to evaluate health
- Add additional mulch, inspect for sediment buildup, erosion, vegetative conditions, etc. annually
- Maintenance cost: approximately $200 per year for a 900 square foot vegetated swale

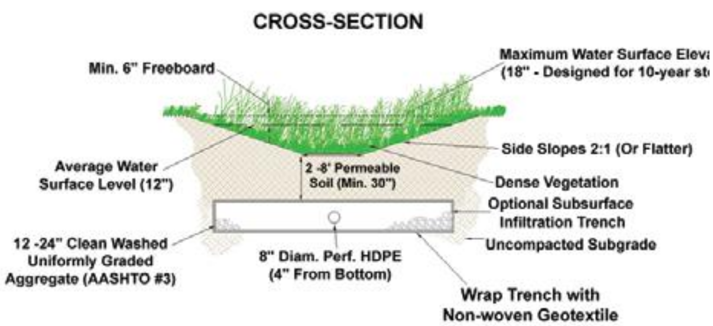
COST

- $5-20 per linear foot depending on extent of grading and infrastructure required, as well as the vegetation used

POTENTIAL LIMITATIONS

- Limited application in areas where space is a concern
- Unless designed for infiltration, there is limited peak and volume control

Curb opening to grass swale in residential development



VARIATIONS

- Vegetated swale with infiltration trench
- Linear wetland swale
- Grass swale
- Check-dams

KEY DESIGN FEATURES

- Handles the 10-year storm event with some freeboard
- Two-year storm flows do not cause erosion
- Maximum contributing drainage area is 5 acres
- Bottom width of 2-8 feet
- Side slopes from 3:1 (H:V) to 5:1
- Longitudinal slope from 1% to 6%
- Check dams can provide additional storage and infiltration

SITE FACTORS

- Water table to bedrock depth – 2 foot minimum
- Soils – A&B preferred, C&D may require an underdrain
- Potential hotspots – No

STORMWATER QUANTITY FUNCTIONS		STORMWATER QUALITY FUNCTIONS		ADDITIONAL CONSIDERATIONS	
Volume	Low/Medium	TSS	Medium/High (50%)	Capital Cost	Low/Medium
Groundwater Recharge	Low/Medium	TP	Low/High (50%)	Maintenance	Low/Medium
Peak Rate	Low/Medium	TN	Medium (20%)	Winter Performance	Medium
Erosion Reduction	Medium	Temperature	Medium/High	Fast Track Potential	High
Flood Protection	Low			Aesthetics	Medium

FACT SHEET: Tree Trench

Tree trench in urban setting (Viridian Landscape Studio)

DESCRIPTION

Tree trenches perform the same functions that other infiltration practices perform (infiltration, storage, evapotranspiration etc.) but in addition provide an increased tree canopy.

MAINTENANCE

- Water, mulch, treat diseased trees, and remove litter as needed
- Annual inspection for erosion, sediment buildup, vegetative conditions
- Biannual inspection of cleanouts, inlets, outlets, etc.
- Maintenance cost for prefabricated tree pit: $100-$500 per year

COST

- $850 per tree
- $ 10-$15 per square foot
- $8000-$10,000 to purchase one prefabricated tree pit system including filter material, plants, and some maintenance; $1500-$6000 for installation

BENEFITS

- Increased canopy cover
- Enhanced site aesthetics
- Air quality and climate benefits
- Runoff reductions
- Water quality benefits
- High fast track potential
- Enhanced tree health/longevity

POTENTIAL APPLICATIONS	
Residential	Yes
Commercial	Yes
Ultra Urban	Limited
Industrial	Yes
Retrofit	Yes
Highway/Road	Yes
Recreational	Yes
Public/Private	Yes

POTENTIAL LIMITATIONS

- Required careful selection of tree species
- Required appropriate root zone area
- Utility conflicts, including overhead electric wires, posts, signs, etc.
- Conflicts with other structures (basements, foundations, etc.)

VARIATIONS

- Structural soil or alternative (eg. Silva Cell)
- Porous pavers
- Open vegetated tree trench strip (planted with ground cover or grass)
- Tree grates
- Alternate storage media (modular storage units)
- Prefabricated tree pit

KEY DESIGN FEATURES

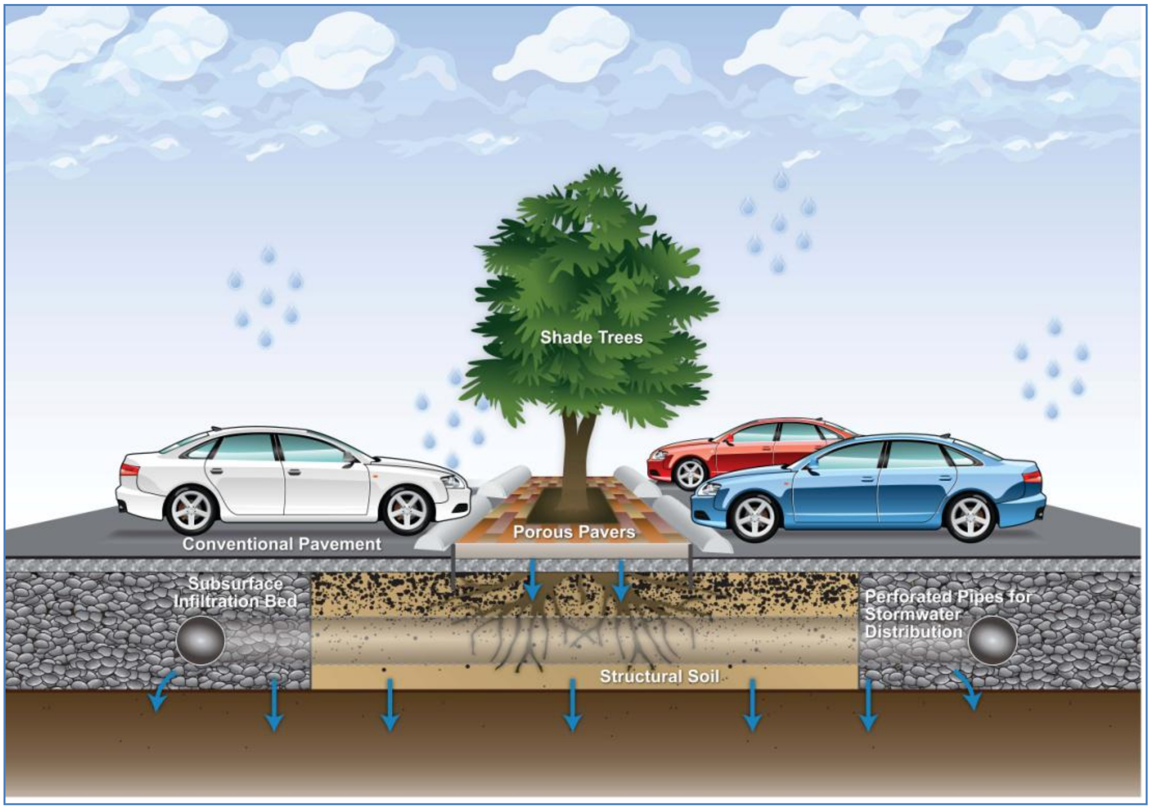
- Flexible in size and infiltration
- Native Plants
- Quick drawdown
- Linear infiltration/storage trench
- Adequate tree species selection and spacing
- New inlets, curb cuts, or other means to introduce runoff into the trench

SITE FACTORS

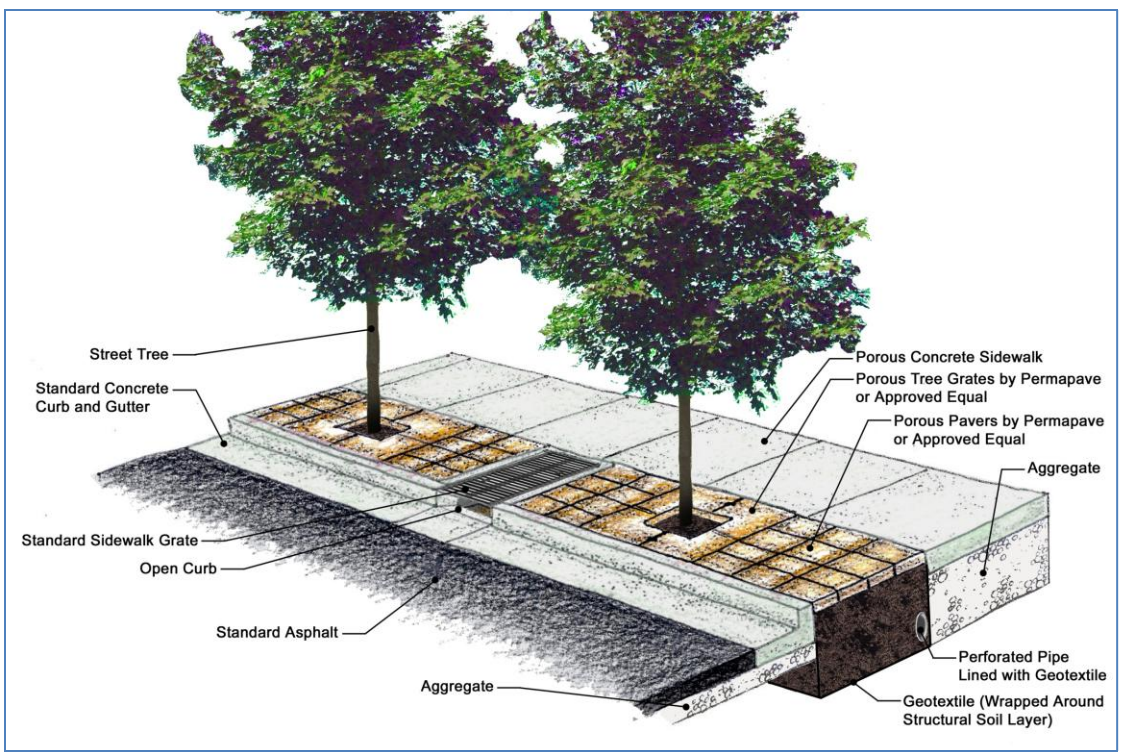
- Overhead clearance; minimize utility conflict
- Root zone
- Water table
- Soil permeability/Limiting zones

TOP LEFT: Tree trench with porous pavers and subsurface infiltration bed, located in City Lot No. 21, Syracuse, NY
LEFT: Tree trench located at Upper Darby Park outside of Philadelphia, PA

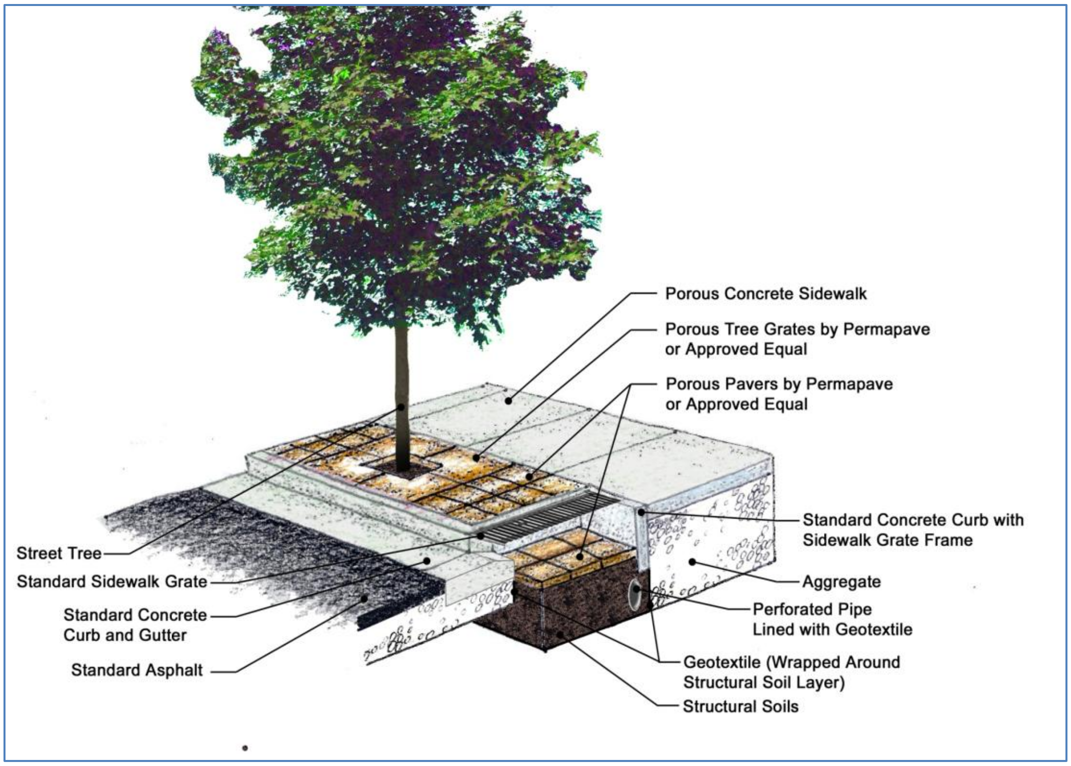
STORMWATER QUANTITY FUNCTIONS		STORMWATER QUALITY FUNCTIONS		ADDITIONAL CONSIDERATIONS	
Volume	Medium	TSS	High (70-90%)	Capital Cost	Medium
Groundwater Recharge	Medium	TP	Medium (60%)	Maintenance	Medium
Peak Rate	Medium	TN	Medium (40-50%)	Winter Performance	High
Erosion Reduction	Medium	Temperature	High	Fast Track Potential	High
Flood Protection	Low/Medium			Aesthetics	High



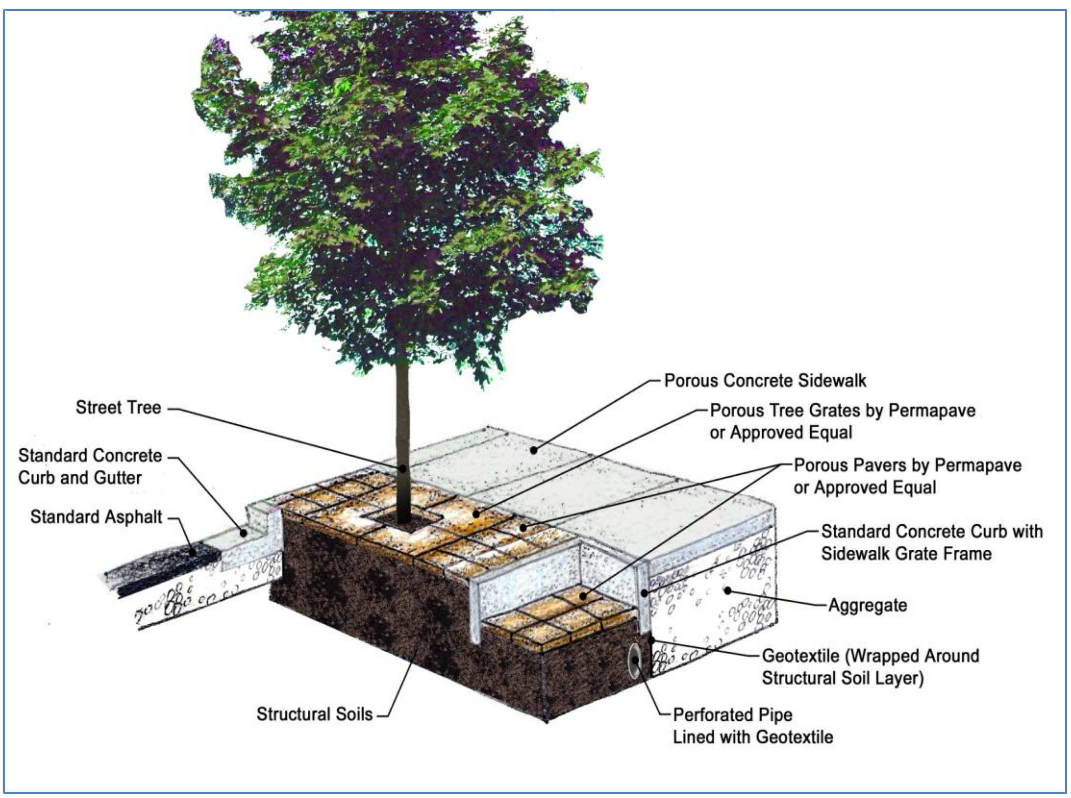
Example of Tree Trench adjacent to a Subsurface Infiltration Bed



Example of Street Tree Trench with Structural Soil and Adjacent Infiltration Trench – Cross-Section A



Example of Street Tree Trench with Structural Soil and Adjacent Infiltration Trench – Cross-Section B



Example of Street Tree Trench with Structural Soil and Adjacent Infiltration Trench – Cross-Section C

FACT SHEET: Vegetated Curb Extension

Urban application of a vegetated curb extension in Portland, Oregon (Source: www.artfulstormwater.net)

BENEFITS

- Traffic calming and pedestrian safety
- Enhanced site aesthetics, habitat
- Potential air quality and climate benefits
- Potential combined sewer overflow reductions
- Wide applicability, including in ultra-urban areas
- Reduced runoff, improved water quality

POTENTIAL APPLICATIONS	
Residential	Yes
Commercial	Yes
Ultra Urban	Yes
Industrial	Yes
Retrofit	Yes
Highway/Road	Limited
Recreational	Yes
Private	Yes

DESCRIPTION

Vegetated curb extensions, also called stormwater curb extensions, are landscaped areas within the parking zone of a street that capture stormwater runoff in a depressed planting bed. The landscaped area can be designed similar to a rain garden or vegetated swale, utilizing infiltration and evapotranspiration for stormwater management. They can be planted with groundcover, grasses, shrubs or trees, depending on the site conditions, costs, and design context.

Vegetated curb extensions can be used at a roadway intersection, midblock, or along the length or block of the roadway, and can be combined with pedestrian crosswalks to increase safety along a roadway. Additionally, vegetated curb extensions provide traffic calming opportunities along with stormwater management opportunities. Vegetated curb extensions can be added to existing roadways with minimal disturbance and are very cost effective as retrofit opportunities. They can be used in a variety of land uses, and are a good technique to incorporate along steeply sloping roadways. They are also effective pretreatment (i.e. filtration) practices for runoff entering other Green Street practices, such as infiltration trenches.

MAINTENANCE

- Remove accumulated debris
- Clean inlets

COST

- Relatively inexpensive to retrofit
- $ 30/square foot for new construction

POTENTIAL LIMITATIONS

- Could require removal of on-street parking
- Conflict with bike lane
- Utility and fire hydrant conflicts

Residential application of a vegetated curb extension in Portland, Oregon (Source: www.artfulstormwater.net)

Vegetated curb extensions in Berwyn, PA
Source: CH2M HILL

VARIATIONS

- Bulb-out; Bump-out
- Stormwater Curb Extension

KEY DESIGN FEATURES

- Design can incorporate existing inlets
- Size to handle runoff from the catchment area
- Infiltration testing required
- Do not infiltrate on compacted soil
- Level storage bed bottoms
- Native vegetation
- Work around existing utilities
- Mark curb cuts highly visible to motorists

SITE FACTORS

- Water Table/Bedrock Separation; 2-foot minimum.
- Soils: HSG A&B preferred; HSG C&D may require underdrains
- Feasibility on steeper slopes: high. Design to include backstop or check dam

STORMWATER QUANTITY FUNCTIONS		STORMWATER QUALITY FUNCTIONS		ADDITIONAL CONSIDERATIONS	
Volume	Medium	TSS	Medium/High	Capital Cost	Low
Groundwater Recharge	Medium	TP	Medium	Maintenance	Low/Medium
Peak Rate	Medium	TN	Medium	Winter Performance	Medium
Erosion Reduction	Medium	Temperature	Medium/High	Fast Track Potential	Low/Medium
Flood Protection	Low/Medium			Aesthetics	High

APPENDIX B - UNIT COSTS OF TREATMENT, PUMPING AND STORAGE FOR GREEN INFRASTRUCTURE COST COMPARISON

Baseline Unit Costs of Treatment, Pumping, and CSO Storage for use in Evaluation of Green Infrastructure

PREPARED FOR: City of Lancaster, PA

PREPARED BY: CH2M HILL

DATE: August 3, 2010

City staff and consultants were canvassed to establish the unit costs of the Advanced Wastewater Treatment Plant (AWWTP) the pumping stations for comparison with green infrastructure alternatives. In addition, the cost and overflow reduction estimates for a storage-based CSO control alternative were documented in this memorandum. From this analysis, the following costs were extracted for later comparison with typical costs of green infrastructure control alternatives:

Table 1 - Summary of Unit Treatment, Pumping, and CSO Storage Costs

System Component	Unit Cost	
Treatment at AWWTP	$ 1.0815	/ 1,000 gallons
Pumping	$ 0.17	/ 1,000 gallons Total Flow
Pumping	$ 0.22	/ 1,000 gallons wet weather flow
Storage	$ 4.67	/ gallon of constructed storage volume
Storage	$ 0.23	/ gallon CSO Treated in an Average Year

Cost of Treatment at the AWWTP

The current cost of treatment at the Lancaster AWWTP was estimated by Camp Dresser & McKee to be $1.0815 per 1,000 gallons not including the North, Stevens Avenue, or Main Pumping Stations.[1] Pumping Costs were compiled separately in the following section. Power for the Main Pump Station (Main PS) is supplied via the WWTP and is typically $150,000 annually. The AWWTP treated a total flow of 7,302 million gallons in 2009.

Cost of Pumping

The City owns 8 Pumping Stations, four (4) of which pump flow from the 4 combined sewer service areas. As reported by the City, all flow into the City's WWTP is delivered via these PSs except for approximately 1 MGD in gravity flow. Of the 20 MGD that was received by the City's WWTP last year, 52% for was City flow. The other 48% was outside municipal authority flow that went through the City's PSs and includes costs for non-City flow (all sanitary) received at the City PSs. City Flow Records were evaluated for 2009 to determine the cost of pumping for flows conveyed to the AWWTP. These results are summarized in Table 2. The City provided typical year operating costs for the pump stations and this data is summarized in Table 3 and Figure 1. To be conservative in the comparison, the Total Flow Unit Cost / 1,000 gallons of pumped flow of $0.17 will be used in the comparisons.

Table 2 - Summary of Total System and Wet-Weather Flows for all Lancaster City Pump Stations (2009)

Flow Statistic	2009 Annual Flow Volume (MG)	% of Total Annual Treated Flow
Total Flow Treated at the AWWTP	7,302	
AWWTP Wet Weather Flow (MG)	3,399	47%
AWWTP ADDWF (MG)	4,860	67%
Rain+1 AWWTP Wet Flow (MG) [1]	4,609	63%
Rain +2 AWWTP Wet Flow (MG) [2]	5,547	76%
AWWTP Dry Flow (MG)	2,754	38%

Notes

1 - Includes flows from the 1 day following each rain event

2 - Includes flows from the following 2 days after a rain event

Rain Event defined as greater than 0.01 inches as measured at the Water Plant Gage

Table 3 - Summary of Typical Annual Pump Station Budget

Component Costs	Budget	% of Total
Salaried Personnel [a]	$ 573,599	47%
Overtime [b]	$ 15,000	1.2%
Maint. Equipment	$ 90,000	7.4%
Power Electric	$ 520,000	43%
Other Operating Costs and Supplies [c]	$ 22,623	1.9%
Total	**$ 1,221,222**	

Notes

[a] 40% associated with City PSs other $ for WWTP maintenance and operation of Suburban Lancaster Sewer Authority PSs

[b] 40% attributed to City PSs

[c] including Fuel Oil Vehicle Leases, and Building Maintenance

Source - Email: Bryan Harner, City of Lancaster, Mon 7/19/2010 8:26 AM

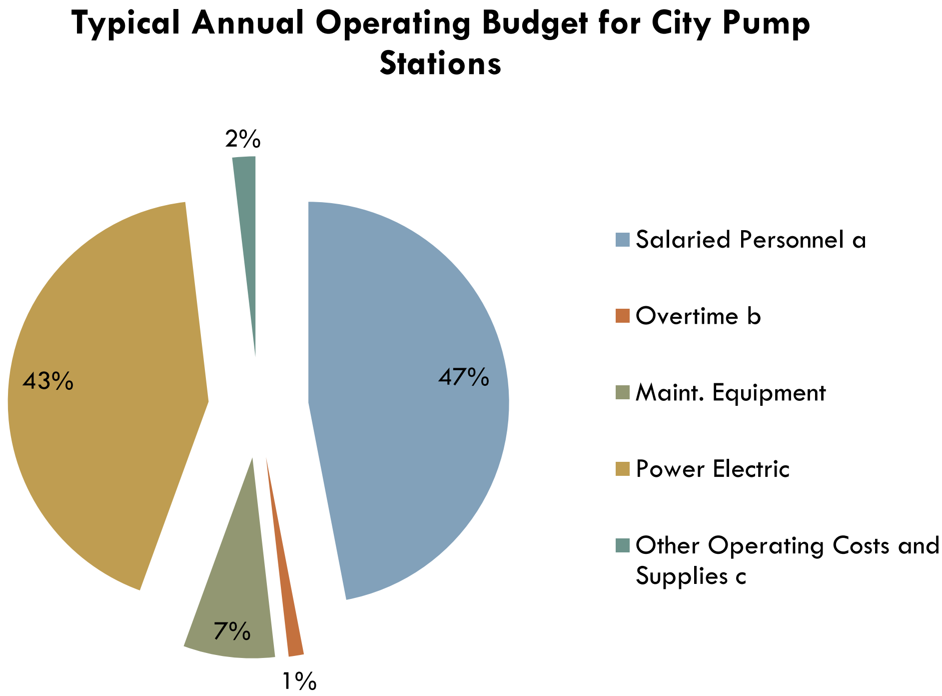


Figure 1 - Typical Annual Operating Budget for City Pump Stations

Cost of CSO Storage Alternative

Based on the preliminary planning work performed in the North drainage area for the City's Amended CSO Long Term Control Plan (City of Lancaster, July 2009), a 15 MG storage facility was considered and cost estimates developed. This facility was estimated to achieve a 78% reduction in CSO volume and reduce CSO discharge frequency to 10 overflows per year in the North basin. The estimated cost of the diversion structure, piping, storage facility, and pumping facilities for pump back to the North Pumping Station was $70M and included engineering design and construction services. The North drainage basin represents approximately 30 percent of the City's combined sewer service area.

The total estimated annual overflow volume for the North basin was estimated at 387 M gallons.[1] A unit cost of $0.23/gallon CSO captured for treatment at the AWWTP was determined based upon the estimated 78% reduction in the total annual overflow. The unit cost of constructed storage is $4.67 /MG based on the facility conceptualized for the North Basin.

[1] Email from Russell McNair, CDM, Thu 1/21/2010 3:17 PM

APPENDIX C – REVIEW OF LANCASTER CITY STORMWATER ORDINANCE AND FIRST FLUSH REQUIREMENTS

Lancaster Ordinance Review: Ch. 260 Stormwater Mgmt.

TO: CH Project Team **DATE:** June 3, 2010

FROM: Lynn Scofield/CH2M HILL Hill

The regulations apply to:

- All development and land disturbance within all watershed areas of the City of Lancaster
- Permanent storm water management facilities constructed as part of any of the regulated activities
- Stormwater management, erosion and sediment control during construction activities

Regulated activities include: Construction of new or additional impervious or semipervious surfaces, subdivisions, buildings, building additions, diversion or piping of a stream channel
PaDEP, Chapter 105 of Title 25 applies to the all interactions with water obstructions.

For water courses other than permanent streams, a drainage easement would be built on the same course.

For carbonate geology a registered professional geologist will certify the stormwater facilities are not in, over or immediately adjacent to sinkholes, closed depressions, lineaments in carbonate areas, fracture traces, caverns, intermittent lakes, ephemeral streams, or bedrock pinnacles (surface or subsurface). There are specified distances from each type of disturbance (260-9 H2).

For exempted (260-15) regulated activities where the proposed site is only served by a combined sewer the first flush and stormwater flow will be directed to landscaped areas that can detain the first flush or into private stormwater detention facilities and not into the public sewer or private inlet. Stormwater detention facilities for this must conform to the technical standards for first flush detention facilities in the Construction Specifications and Guidelines Manual of the City of Lancaster.

For MS4 regulated earth disturbance activity, stormwater management will prohibit non-stormwater discharges into the storm sewer system and require post-construction stormwater runoff controls.

<u>Stormwater Management Performance Standards</u>
All development and land disturbance activities shall submit a drainage plan to the City.
Runoffs from impervious areas are to be drained to pervious areas of property when practical.
Stormwater from a project site should flow in a manner similar to predevelopment. Stormwater can be collected in a combined sewer with the approval of the City Engineer if it is less than or equal to predevelopment. The code gives specific runoff limits for Little Conestoga Creek, Conestoga River and Mill Creek watersheds.

Additional impervious areas on a single lot of up to a max. 1,000 sqft in the Mill and Little Conestoga Creek Watersheds and 5,000 sqft in the Conestoga River Watershed shall be exempt from the provisions of this chapter requiring submission of a drainage plan, provided that flows from the site after development do not cause negative impacts on existing stormwater facilities or neighboring properties and that all first flush stormwater from any additional impervious surface on lots whose flows will enter a combination sewer will be detained.

Innovative methods, such as basins, rooftop storage, grass pavers, subsurface facilities, and vegetated strips are encouraged and subject to the approval of the City Engineer (260-9,2).

Principals to be followed in the design plan include retaining natural vegetation, limiting the disturbed area, drainage provisions throughout development and installing soil erosion facilities prior to on-site grading.

Berms and earthen embankments must have a one foot freeboard under 100yr postdevelopment conditions. A dam permit maybe necessary depending on the stormwater facility but the criteria in Chapter 260 is not the same as those in a dam permit. Many specifications for berms, basins, trenches, spillways, pipes, inlets and outlet structures are listed in 260-11.

APPENDIX D – LANCASTER CITY FIRST FLUSH PROJECT APPLICATION FORM

City File No. ______________

CITY OF LANCASTER
APPLICATION FOR DRAINAGE PLAN APPROVAL

✓ 1. Project Address ______________________________

2. Project Name ______________________________

3. Owner's Name and Address ______________________________

______________________________ Zip Code __________

Telephone ____________ Fax ____________ E-Mail ____________

4. Name and address of applicant if other than property owner:

____

______________________________ Zip Code __________

Telephone ____________ Fax ____________ E-Mail ____________

5. Name and address of engineer who prepared the drainage plan:

____

______________________________ Zip Code __________

Telephone ____________ Fax ____________ E-Mail ____________

✓ 6. Does this plan accompany a subdivision/land development plan? ____Yes ____No

✓ 7. Type of development proposed:

____ Residential	____new	____ addition	____ demolition
____ Commercial	____new	____ addition	____ demolition
____ Industrial	____new	____ addition	____ demolition
____ Other ______________________________			

✓ 8. Site data:

Total area (footprint) of existing buildings: ________ square feet
Total area of existing impervious areas (buildings and paving): ________ square feet
Total area of new buildings: ________ square feet
Total area of new impervious: ________ square feet
Total area of earth disturbance: ________ square feet

9. Watershed: ____ Conestoga River ____ Little Conestoga ____ Mill Creek

✓ 10. Sanitary Sewer: __________ Combined __________Separate

11. Have you identified the pre- post-peak rate of runoff for the various storm events, as stipulated in the Storm Water Management Ordinance? ____ Yes ____ No

12. Has the runoff rate been controlled according to the limitations imposed on the watershed? ____ Yes ____ No

13. If an exemption is requested under Section 402, have you attached supporting justification? ____ Yes ____ No

✓ 14. Is First Flush storm water management provided? ____ Yes ____ No

15. Are any waivers or modifications being requested? ____ Yes ____ No
If yes, attach appropriate documentation and request.

16. Have you submitted a soil erosion and sedimentation control plan for all proposed earth moving activities? ____ Yes ____ No

17. Are facilities being offered for public dedication? ____ Yes ____ No

18. Has an itemized cost breakdown been prepared for posting of a financial surety of any required storm water improvements? ____ Yes ____ No

19. Have you submitted four copies of the Drainage Plan? ____ Yes ____ No

20. Application Fee: For Storm Water Drainage Plan applications that are submitted with a subdivision and/or land development (SLD) plan, the SLD Plan application fees shall apply. For non-SLD activities, the following fees shall be submitted:

- Application Fee(Includes two plan sheets and a report)	$75.00
- Each additional sheet	35.00
- Modifications / Waivers (per section)	50.00
- Exemption from Drainage Plan Submission	30.00
- Billable fees – Actual professional consulting fees incurred by the City for the review of applications and/or the inspection of improvements shall be the responsibility of the applicant.	-------
Total Amount Submitted	$________

Signature of Applicant ______________________ Date __________

****

Approved by City: Comments:

Building ______________ Date ________ ______________

Engineering ______________ Date ________ ______________

Planning ______________ Date ________ ______________

Zoning ______________ Date ________ ______________

Wastewater ______________ Date ________ ______________

APPENDIX E – GREEN INFRASTRUCTURE DEMONSTRATION PROGRAM PROJECT PRIORITIZATION METHODOLOGY

Lancaster City Green Infrastructure (GI) Demonstration Program Project Prioritization Methodology

PREPARED FOR: Lancaster City

PREPARED BY: CH2M HILL

DATE: November 28, 2010

Purpose

CH2M HILL has developed conceptual designs for 20 green infrastructure projects in Lancaster City as part of the Green Infrastructure Planning work. The purpose of this technical memorandum is to briefly describe the proposed methodology for evaluating and prioritizing these projects. The following items are presented in this memo:

- Key Definitions and Types of Alternatives
- Evaluation Procedure and Data Needs
- Evaluation Criteria and Performance Scoring Method
- GI Project Prioritization

Key Definitions

Terminology used in this memorandum are defined as follows:

Prioritization - Systematic process (i.e., multi-attribute utility analysis [MUA]) of weighting, score, and ranking projects based on evaluation criteria and performance scales that address the goals and objectives of Lancaster City.

Evaluation Criteria - A measure of expected project performance that is used to identify the relative importance of projects against other criteria in order to reflect the goals and objectives of the City. For each criterion, a performance scale is defined in order to systematically score each project against the identified criterion.

Criteria Weights – a measure of the relative importance or value of each criterion to addressing stakeholder priorities. The criteria weights are use to define trade-offs between goals and to build a defensible foundation for ranking projects.

Performance Scale - A constructed scale that provides a scoring system in which each project can be evaluated according to its predicted performance. For example, one criterion might be Public Acceptance and Education in which each project is scored based on a performance scale that reflects the anticipated level of public support and visibility.

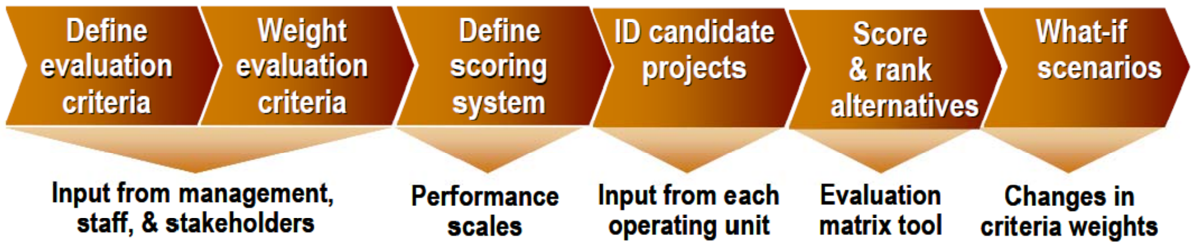
Benefit Score - A value calculated at the project level, based on how each project is scored against each criterion. The benefit score is the sum of the products of the criteria weight and the performance score. The higher the score, the more benefits (as they have been defined and weighted).

Cost Benefit Score - A value calculated by dividing the Benefit Score by the estimated project costs. The lower the score, the more benefit per dollar.

Procedure and Data Needs for Alternative Evaluation Process

The project prioritization process is proposed to follow a series of steps that systematically screen the green infrastructure projects. Screening will rely on the set of evaluation criteria adopted by Lancaster City Staff, LIVE GREEN, and the consultant team. Figure 1 illustrates the prioritization process.

FIGURE 1
Steps Involved in the Prioritization of Alternatives/Projects



Evaluation Criteria

Evaluation criteria were developed in conjunction with City and LIVE GREEN staff and included:

1. Grant Funded - Level to which project posts could be funded externally from City funds
2. Integrated Infrastructure - Degree to which project supports other City infrastructure needs
3. Public Acceptance & Education - Degree to which project would be expected to generate public support and education
4. Cost Efficiency – Runoff capture cost efficiency (i.e., Cost / Gallon Captured) expressed as a percent of most efficient project identified

Each criterion was weighted by the team and the results normalized to a 100 point scale. The distribution of the weightings is shown in Figure 2.

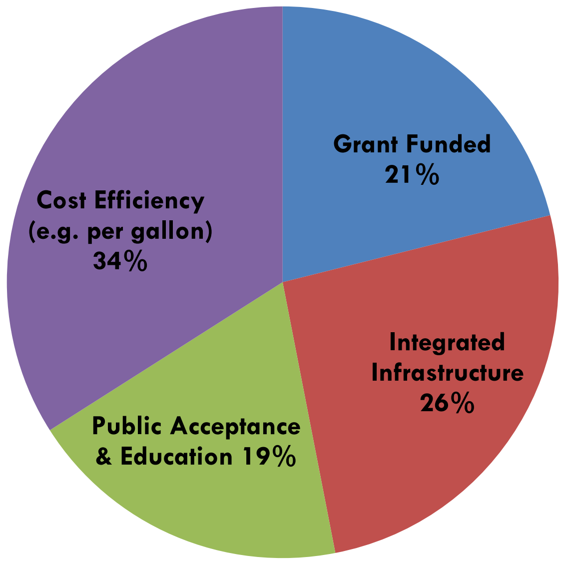


Figure 2 - Distribution of Criteria Weights

Performance Scales

Performance scales are created to provide a scoring system in which each project can be evaluated according to its expected performance. The following scales were developed for each criterion for prioritizing the Green Infrastructure Projects and Tables 1 to 4 provide examples of the relative scoring across a scale from 1 to 10, with 10 representing the highest benefit

TABLE 1 - GRANT FUNDED
Level to Which Project Costs are Funded Externally

Score	Description
10	50% or more of project is externally funded
5	Project is partially funded by external sources
0	Project does not have external funding or cost leverage

TABLE 2 - INTEGRATED INFRASTRUCTURE
Degree to which project supports other City infrastructure needs

Score	Description
10	Project is highly integrated with other City infrastructure needs
5	Project provides some benefit to other City infrastructure priorities
0	Project does satisfy any other City Infrastructure priorities

TABLE 3 - PUBLIC ACCEPTANCE AND EDUCATION
Importance of project to public and educational opportunities

Score	Description
10	Expected to be highly visible and to garner strong public support
5	Expected to be moderately visible and to garner moderate public support
0	Project is not visible to the Public

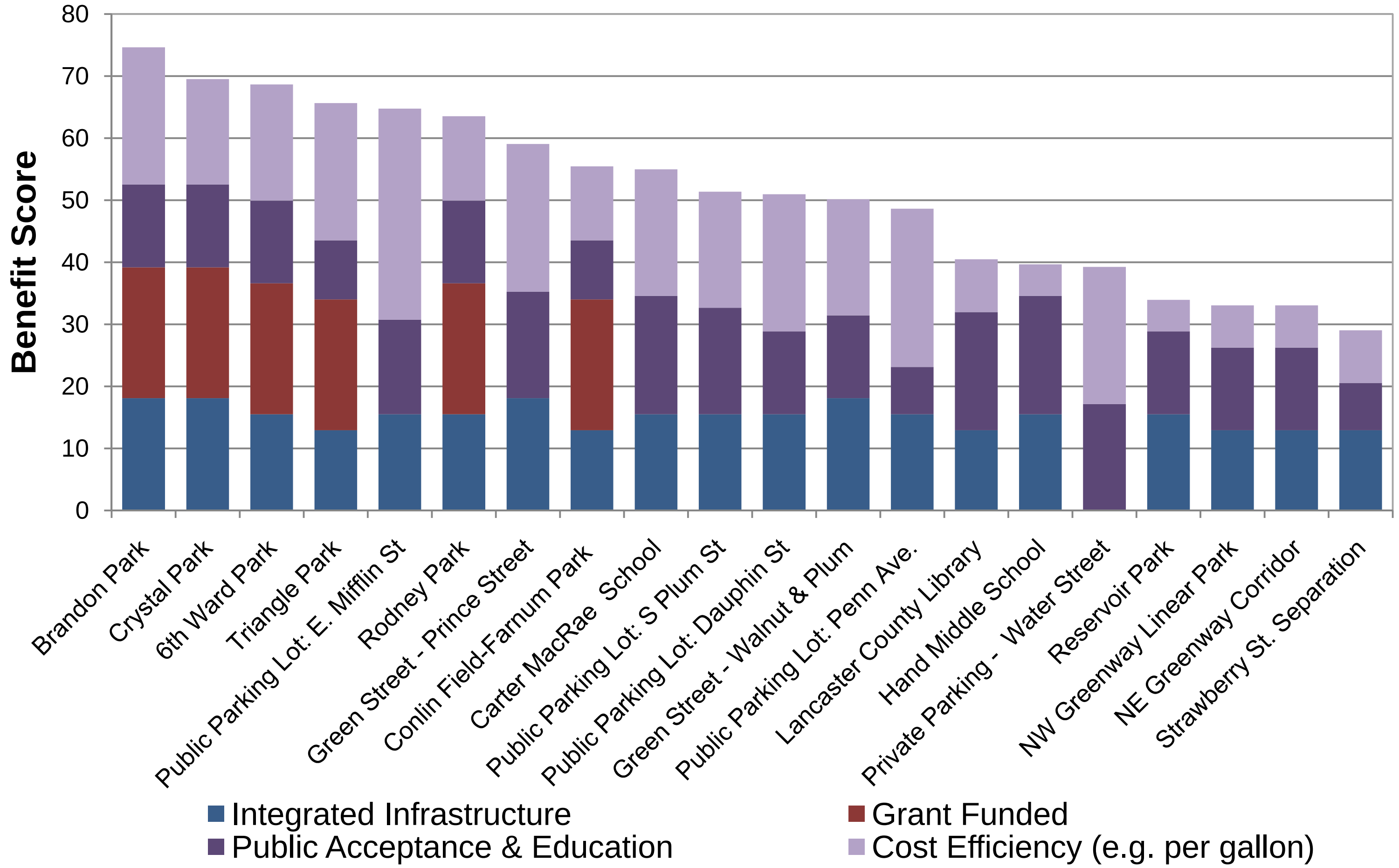
TABLE 4 - RUNOFF CAPTURE COST EFFICIENCY
Runoff capture cost efficiency expressed as a percent of most efficient project identified

Score	Description
10	Highest cost efficiency
5	Cost efficiency 50% that of most efficient project
1	Cost efficiency 10% that of most efficient project

Project Prioritization Tool Results

To help facilitate the scoring and prioritization of projects, CH2M HILL applied a tool that has been used effectively to prioritize Capital Improvement Program (CIP) projects for many of its clients. The tool is a spreadsheet-based Multi-attribute Utility Analysis (MUA) prioritization model, which is a proven analytical approach used to prioritize CIP projects and support the decision-making process. The results of the tool are illustrated in Figures 3.

Figure 3
Green Infrastructure Project Benefit Score by Criteria Composition



APPENDIX F – DCNR URBAN TREE CANOPY ASSESSMENT

A Report on the City of Lancaster's Existing and Possible Tree Canopy

Why is Tree Canopy Important?

Tree canopy (TC) is the layer of leaves, branches, and stems of trees that cover the ground when viewed from above. Tree canopy provides many benefits to communities, improving water quality, saving energy, lowering city temperatures, reducing air pollution, enhancing property values, providing wildlife habitat, facilitating social and educational opportunities, and providing aesthetic benefits. Establishing a tree canopy goal is crucial for communities seeking to improve their green infrastructure. A tree canopy assessment is the first step in this goal-setting process, providing estimates for the amount of tree canopy currently present in a city as well as the amount of tree canopy that could theoretically be established.

How Much Tree Canopy Does Lancaster Have?

An analysis of the City of Lancaster's tree canopy based on land cover data derived from high-resolution aerial imagery and LiDAR (Figure 1) found that 1,299 acres of the city were covered by tree canopy (termed Existing TC), representing 28% of all land in the city. An additional 45% (2,063 acres) of the city could theoretically be modified (termed Possible TC) to accommodate tree canopy (Figure 2). In the Possible TC category, 19% (863 acres) of the city was classified as Impervious Possible TC and another 26% was Vegetated Possible TC (1,200 acres). Vegetated Possible TC, or grass and shrubs, is more conducive to establishing new tree canopy, but establishing tree canopy on areas classified as Impervious Possible TC will have a greater impact on water quality and summer temperatures.

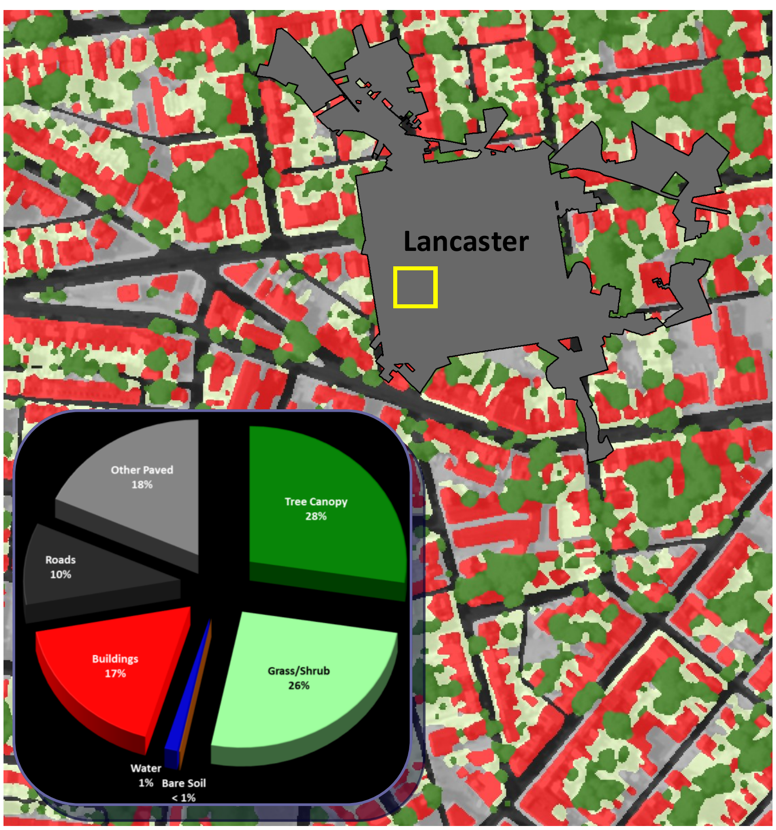


Figure 1: Land cover derived from high-resolution aerial imagery for the City of Lancaster.

Project Background

The goal of the project was to apply the USDA Forest Service's TC assessment protocols to the City of Lancaster. The analysis was conducted based on year 2010 data. This analysis of the City of Lancaster's tree canopy (TC) was conducted in collaboration with the PA Department of Conservation and Natural Resources Bureau of Forestry, City of Lancaster, Lancaster County, the University of Vermont, and the Northern Research Station. The Spatial Analysis Laboratory (SAL) at the University of Vermont's Rubenstein School of the Environment and Natural Resources conducted the assessment.

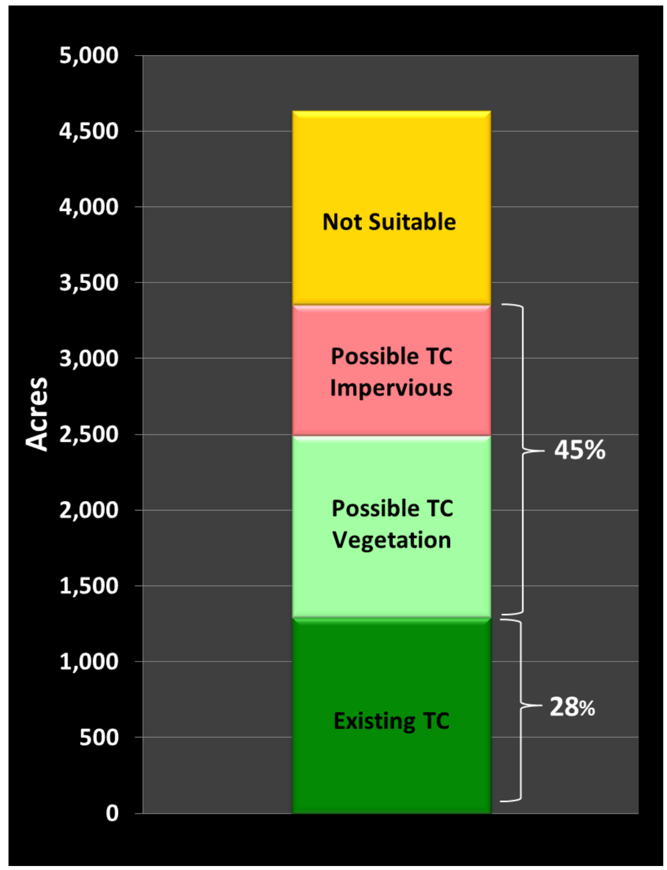


Figure 2: TC metrics for the City of Lancaster based on % of land area covered by each TC type.

Key Terms

TC: Tree canopy (TC) is the layer of leaves, branches, and stems of trees that cover the ground when viewed from above.

Land Cover: Physical features on the earth mapped from aerial or satellite imagery, such as trees, grass, water, and impervious surfaces.

Existing TC: The amount of urban tree canopy present when viewed from above using aerial or satellite imagery.

Impervious Possible TC: Asphalt or concrete surfaces, excluding roads and buildings, that are theoretically available for the establishment of tree canopy.

Vegetated Possible TC: Grass or shrub area that is theoretically available for the establishment of tree canopy.

Mapping the City of Lancaster's Trees

Prior to this study, the only comprehensive remotely sensed estimates of tree canopy for the City of Lancaster was from the 2001 National Land Cover Database (NLCD 2001). While NLCD 2001 is valuable for analyzing land cover at the regional level, it is derived from relatively coarse, 30-meter resolution satellite imagery (Figure 3a). Using high-resolution aerial imagery acquired in 2010 (Figure 3b), in combination with LiDAR and advanced automated processing techniques, land cover for the city was mapped with such detail that trees as short as 6ft tall were detected (Figure 3c). NLCD 2001 estimated a mean percent tree canopy of 10% for the City of Lancaster largely because it failed to capture many isolated trees.

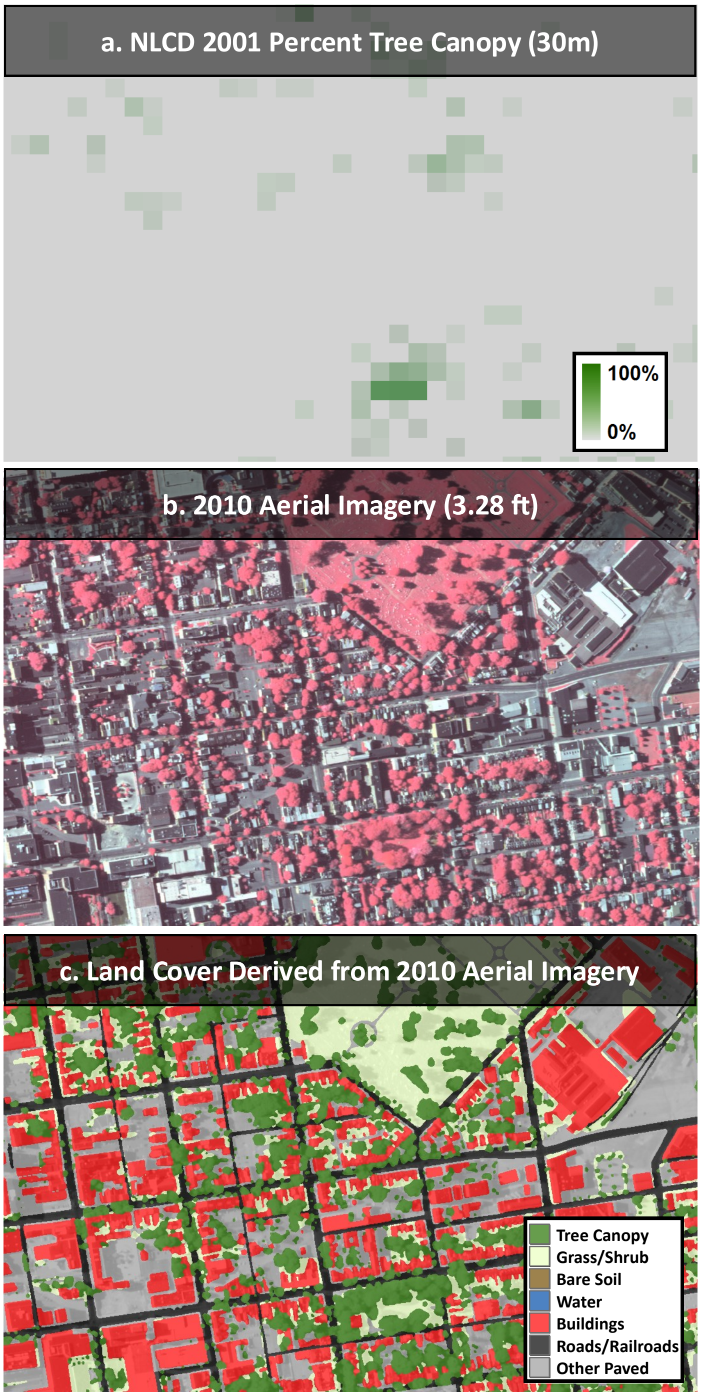


Figure 3a, 3b, 3c: Comparison of NLCD 2001 to high-resolution land cover.

Parcel Summary

After land cover was mapped city-wide, Tree Canopy (TC) metrics were summarized for each property in the city's parcel database (Figure 4). Existing TC and Possible TC metrics were calculated for each parcel, both in terms of total area and as a percentage of the land area within each parcel (TC area ÷ land area of the parcel).

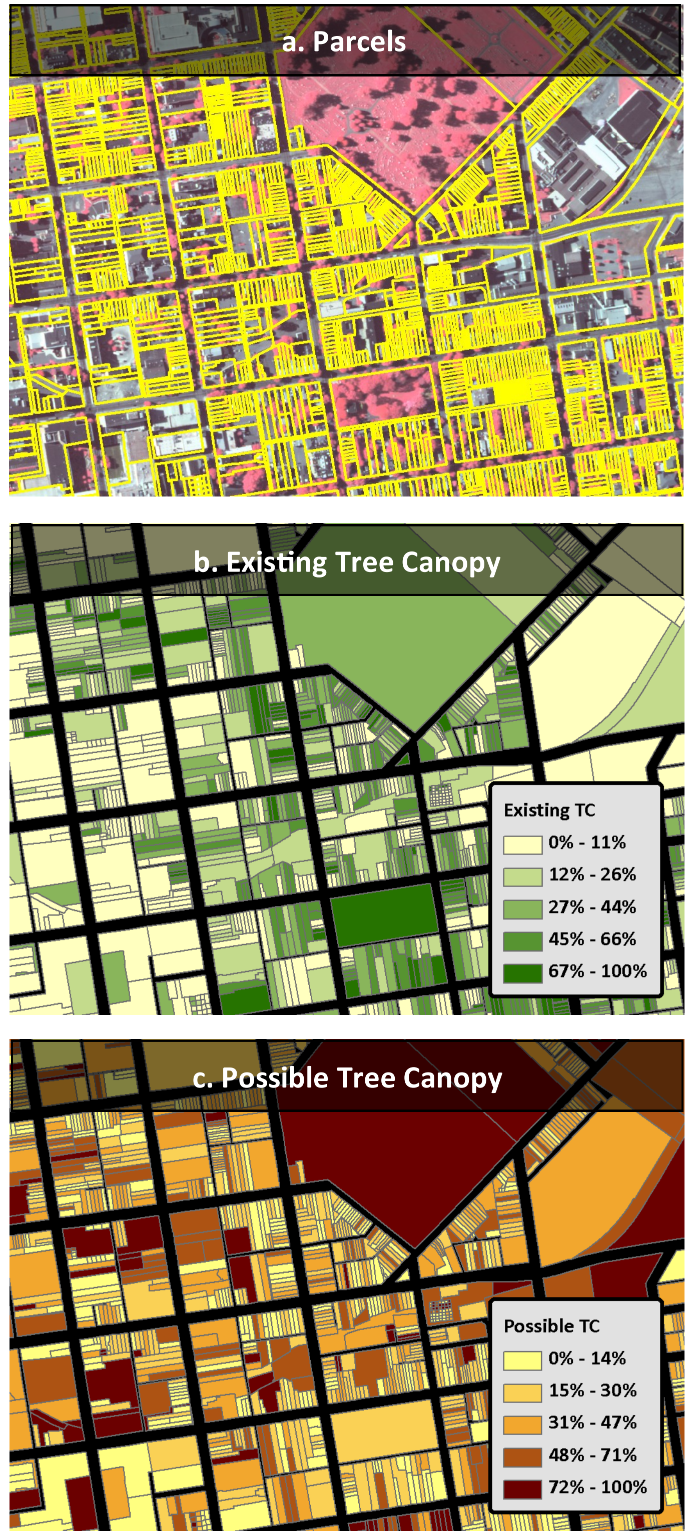


Figure 4a, 4b, 4c: Parcel-based TC metrics. TC metrics are generated at the parcel level, allowing each property to be evaluated according to its Existing TC and Possible TC.

Land Use

Lancaster County maintains a comprehensive land use layer for the County which includes Lancaster City. For the this study the land use data were aggregated into thirteen general categories. Existing and Possible tree canopy was summarized for the thirteen aggregated land use classes (Figure 5, Table 1). For each land use category, Tree Canopy (TC) metrics were calculated as a percentage of all land in the city (% Land), as a percentage of land area in the specified land use category (% Category), and as a percentage of the area for TC type (% TC Type). Residential land use had the largest amount of tree canopy of any land use category with 31% of all tree canopy. Residential land use also had the largest percentage of land area covered by tree canopy (9%). Residential land use had most of the Possible Vegetated TC available to support tree plantings (32%) while Commercial and Retail Trade had the most Impervious Possible TC (36%) available for planting trees of all land use categories. Vacant Lands also had a high percentage of Existing TC (39%), Possible Vegetated TC (33%), and Possible Impervious TC (18%).

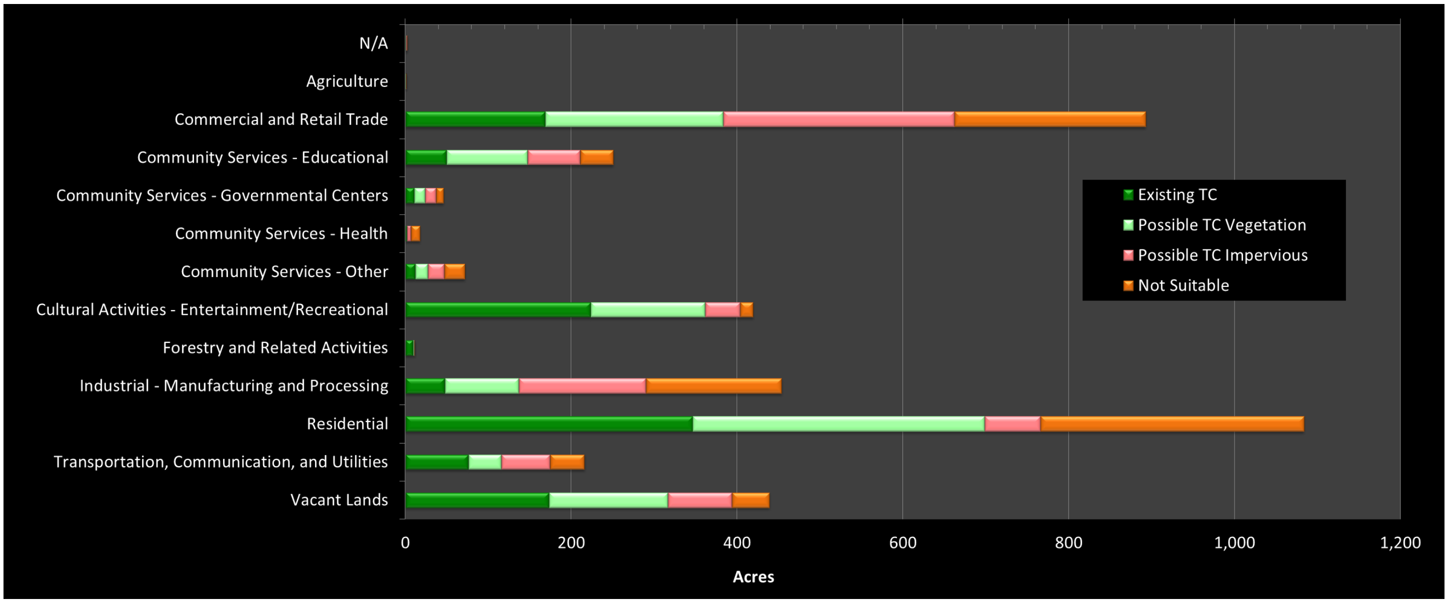


Figure 5: Tree Canopy (TC) metrics summarized by land use category.

Land Use	Existing TC			Possible TC Vegetation			Possible TC Impervious		
	% Land	% Category	% TC Type	% Land	% Category	% TC Type	% Land	% Category	% TC Type
N/A	0%	19%	0%	0%	9%	0%	0%	48%	0%
Agriculture	0%	65%	0%	0%	21%	0%	0%	14%	0%
Commercial and Retail Trade	4%	19%	15%	5%	24%	19%	7%	31%	36%
Community Services - Educational	1%	20%	4%	2%	39%	9%	2%	25%	8%
Community Services - Governmental Centers	0%	22%	1%	0%	30%	1%	0%	28%	2%
Community Services - Health	0%	6%	0%	0%	5%	0%	0%	26%	1%
Community Services - Other	0%	17%	1%	0%	21%	1%	1%	28%	3%
Industrial - Manufacturing and Processing	1%	11%	4%	2%	20%	8%	4%	34%	20%
Residential	9%	32%	31%	9%	32%	32%	2%	6%	9%
Transportation, Communication, and Utilities	2%	35%	7%	1%	18%	4%	2%	27%	8%
Vacant Lands	4%	39%	15%	4%	33%	13%	2%	18%	10%

% Land = **Area of TC type for land use category** / **Area of all land**

The % Land Area value of 9% indicates that 9% of Lancaster's land area is covered by tree canopy in the Residential land use class.

% Category = **Area of TC type for land use category** / **Area of all land for specified land use**

The % Land value of 32% indicates that 32% of land in the Residential land use category is covered by tree canopy.

% TC Type = **Area of TC type for land use category** / **Area of all TC type**

The % TC Type value of 31% indicates that 31% of all tree canopy is in the Residential land use category.

Table 1: Tree Canopy (TC)metrics were summarized by land use category. For each land use category, TC metrics were computed as a percentage of all land in the city (% Land), as a percentage of land in the specified land use category (% Category), and as a percentage of the area for TC type (% TC Type).

Zoning Analysis

Existing and Possible Tree Canopy (TC) was analyzed by Zoning category for Lancaster (Figure 6). Land zoned as Residential and Conservation/Park/Open Space account for 56% and 29% of the Existing TC by land area, respectively. Manufacturing/Central City and Residential Medium Density categories had the most acreage available for Possible TC with 437 acres and 301 acres representing 21% and 15% of the Possible TC by zoning category.

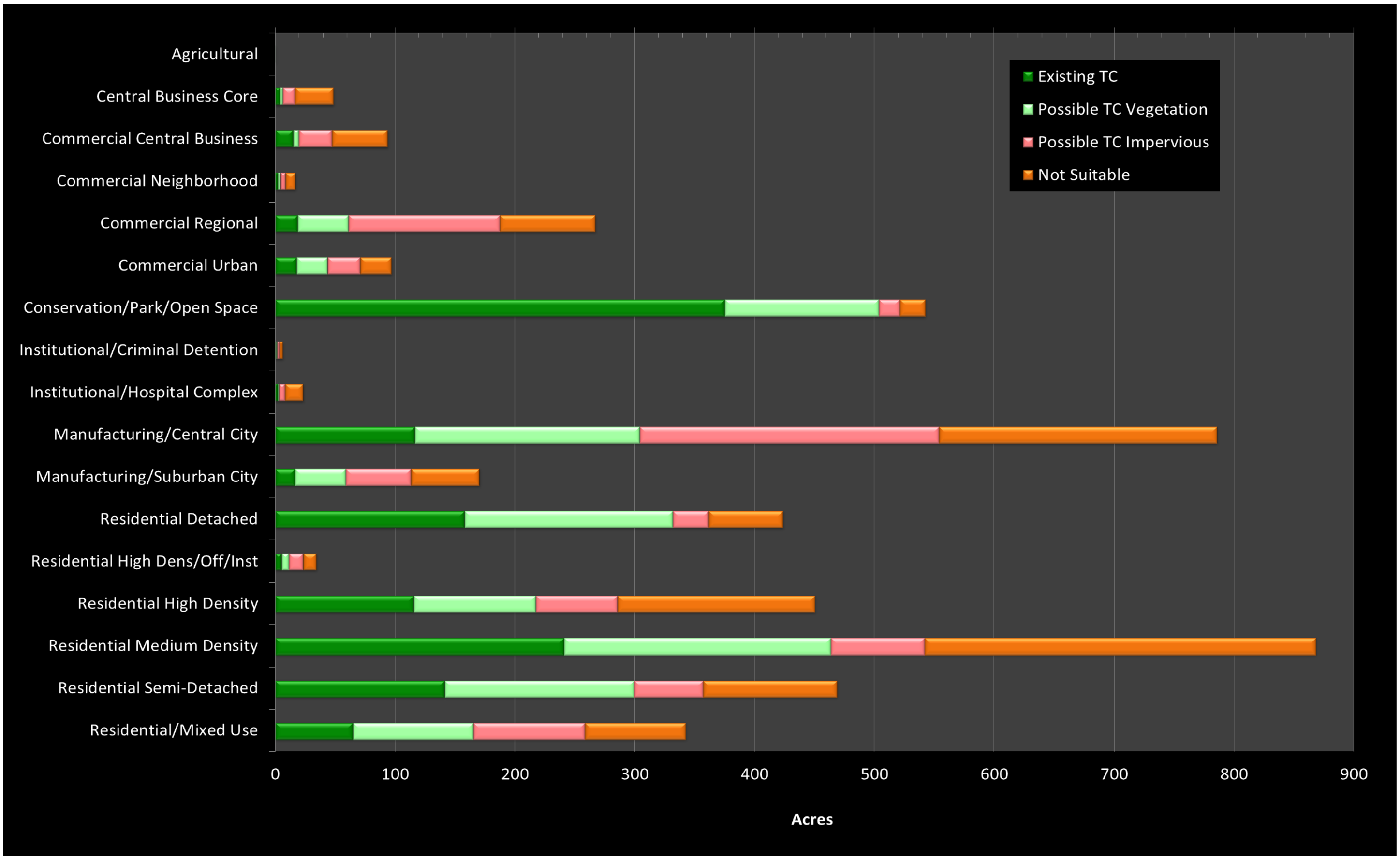
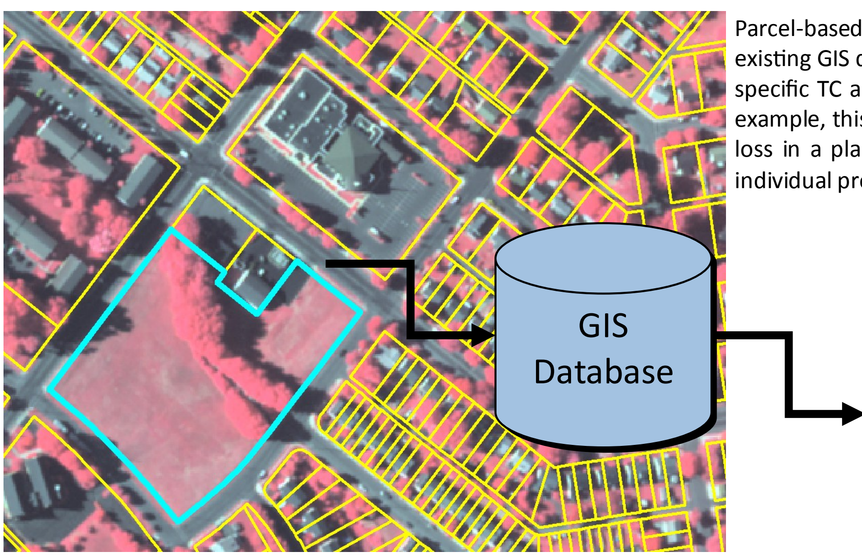


Figure 6: Tree Canopy (TC) metrics summarized by zoning category.

Decision Support

Parcel-based Tree Canopy (TC) metrics were integrated into the city's existing GIS database (Figure 7). Decision makers can use GIS to query specific TC and land cover metrics for a parcel or set of parcels. For example, this information can be used to estimate the amount of tree loss in a planned development or set TC improvement goals for an individual property.



Attribute	Value
Land Use	Vacant Land
Parcel ID	141605
Address	64 Springhouse Road
Existing TC	19%
Possible TC	82%
Possible TC—Vegetation	79%
Possible TC—Impervious	3%

Figure 7: GIS-based analysis of parcel-based TC metrics for decision support. In this example, GIS is used to select an individual parcel. The attributes for that parcel, including the parcel-based TC and land cover metrics, are displayed in tabular form providing instant access to relevant information.

Parks Analysis

Cabbage Hill Veterans Memorial, Hand W.O.O.D.S., Holly Pointe Conservation Area, and Triangle Park have the highest Existing Tree Canopy (> 95%). Nine parks had 8% or less tree canopy. Edward Hand Jr. High and Washington Elementary, Ewel/Ganz Playground, George Ross Elementary, and Wharton Elementary School each had relatively high amounts of Possible TC (> 93%).

Existing Tree Canopy

Possible Tree Canopy

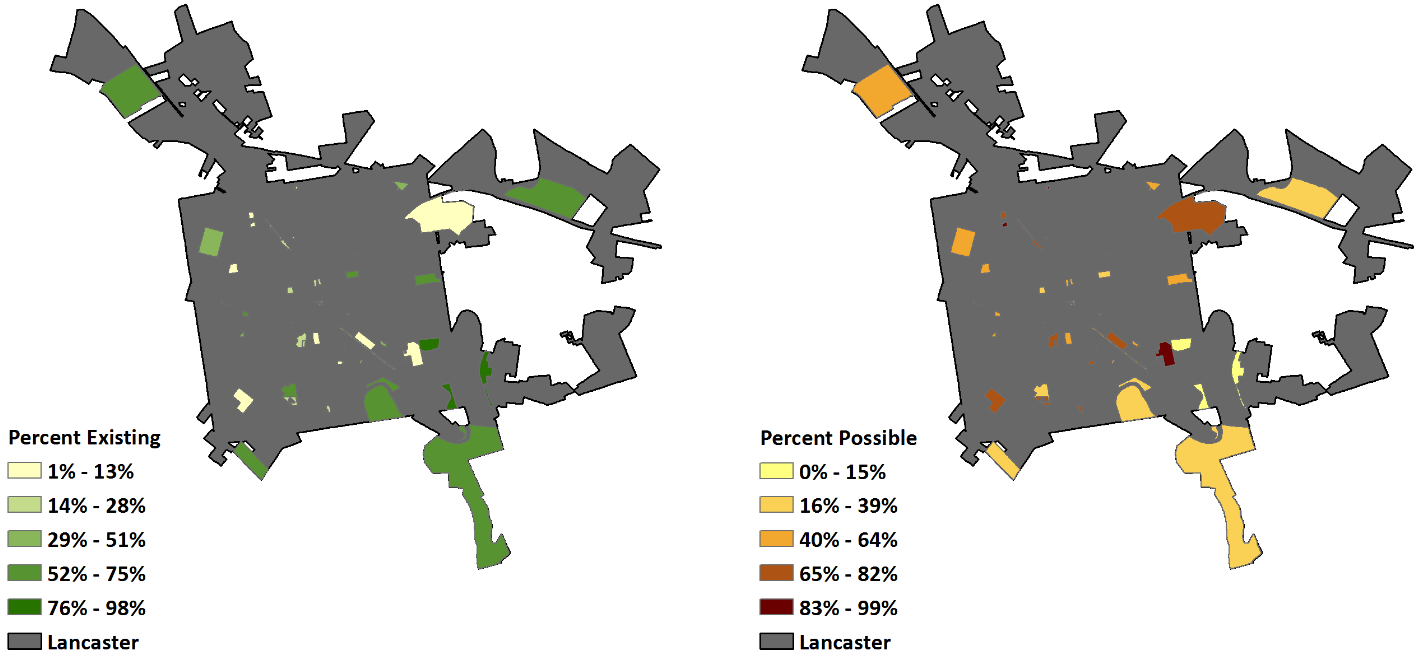


Figure 8: Existing TC (left) and Possible TC (right) as a percentage by Park.

Priority Habitat Restoration Area Analysis

The Priority Habitat Restoration Area layer was used to summarize Existing and Possible TC within Lancaster. Twenty-four of the restoration areas (27%) had Existing TC exceeding 93%. Over 35% of the restoration areas had greater than 50% Possible TC.

Existing Tree Canopy

Possible Tree Canopy

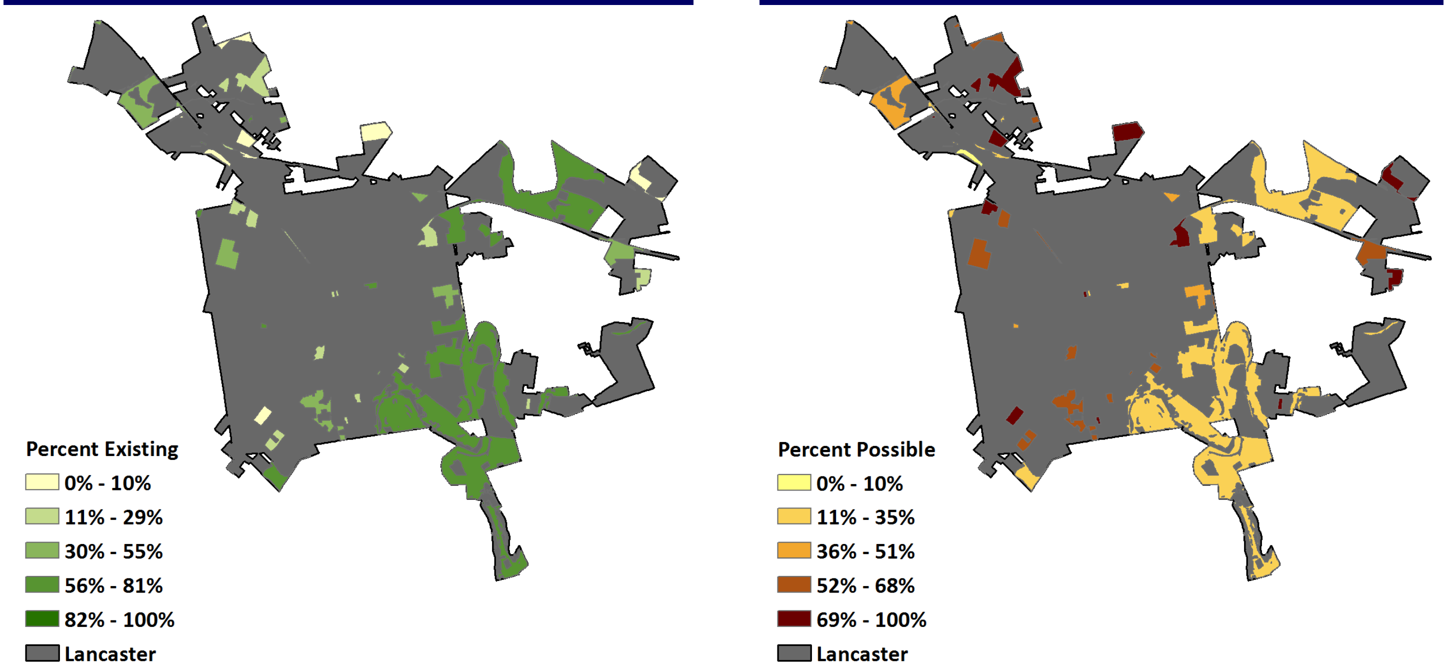
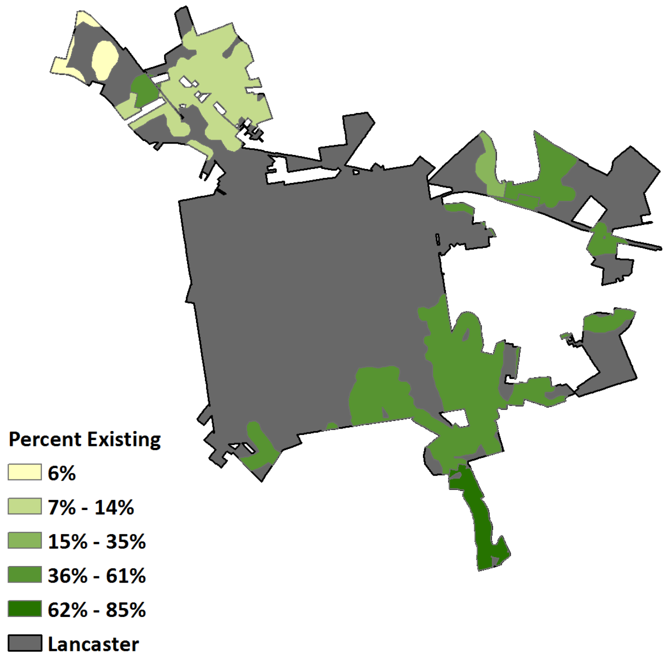


Figure 9: Existing TC (left) and Possible TC (right) as a percentage by Priority Restoration Habitat Area.

Riparian Buffer Analysis

Tree canopy metrics were calculated for riparian buffers within Lancaster. Higher amounts of Existing Tree Canopy are clustered in both the southern and eastern parts of the city along Conestoga and Mill Creek. Riparian buffers located in the northern portions of the city along Little Conestoga Creek had the highest amounts of Possible TC.

Existing Tree Canopy



Possible Tree Canopy

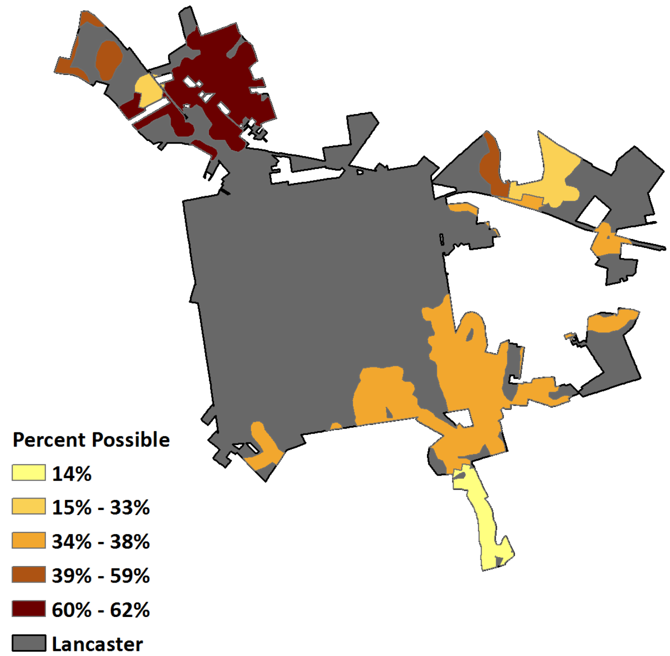


Figure 10. Existing TC (left) and Possible TC (right) as a percentage by riparian buffer.

Roads and Rights-of-Ways Analysis

Tree Canopy (TC) metrics were summarized by roads and rights-of-ways (ROW) as a surrogate analysis of street trees in Lancaster. Tree canopy overhanging roads accounts for 96 acres of tree canopy or 20% of all road areas while 24% of ROW are covered by tree canopy (24%). Within ROW, 24% of the land was mapped as Possible TC suggesting there are opportunities for adding street trees in the city.

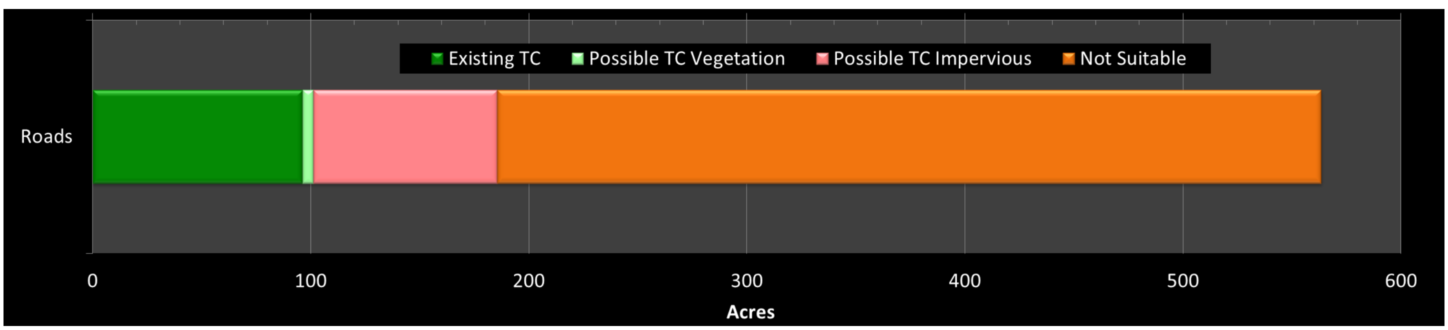


Figure 11: Tree Canopy metrics summarized for all roads.

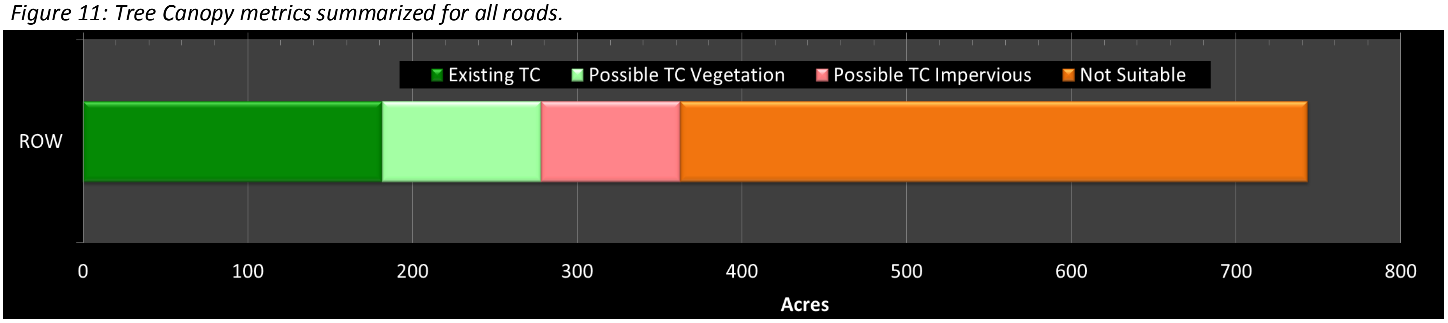


Figure 12: Tree Canopy metrics summarized for all rights-of-ways.

Conclusions

- City of Lancaster's urban tree canopy is a vital city asset that reduces stormwater runoff, improves air quality, reduces the city's carbon footprint, enhances quality of life, contributes to savings on energy bills, and serves as habitat for wildlife.
- Although this assessment indicates that 45% of the land in Lancaster could theoretically support tree canopy, planting new trees on much of this land may not be social desirable (e.g. recreation fields) or financially feasible (e.g. parking lots). Setting a realistic goal requires a detailed feasibility assessment using the geospatial datasets generated as part of this assessment.
- With Existing and Possible TC summarized at the parcel level and integrated into the city's GIS database, individual parcels and subdivisions can be examined and targeted for TC improvement. Of particular focus for TC improvement should be parcels in the city that have large, contiguous impervious surfaces. These parcels contribute high amounts of runoff, which degrades water quality. The establishment of tree canopy on these parcels will help reduce runoff during periods of peak overland flow.
- Lancaster's residents control the majority of the City's tree canopy and have most of the land to plant tees. Programs that educate residents on tree stewardship and provide incentives for tree planting are crucial if City of Lancaster is going to sustain its tree canopy in the long term.
- Commercial and Retail Trade land use has high amounts of Possible TC therefore incentive programs could be used to encourage business owners to maintain or plant additional tree canopy on their property.
- Park and Priority Habitat Restoration Area summaries can be used for targeting tree planting and preservation efforts in different parts of the city.
- With TC metrics summarized by riparian buffers, individual streams can be examined and targeted for TC improvement and establishing or maintaining tree canopy along streams for reducing surface runoff, controlling streambank erosion, and providing wildlife habitat.
- The city's rights-of-way (ROW) contain 24% Existing TC and 24% Possible TC, suggesting that opportunities exist for increasing the number of street trees.

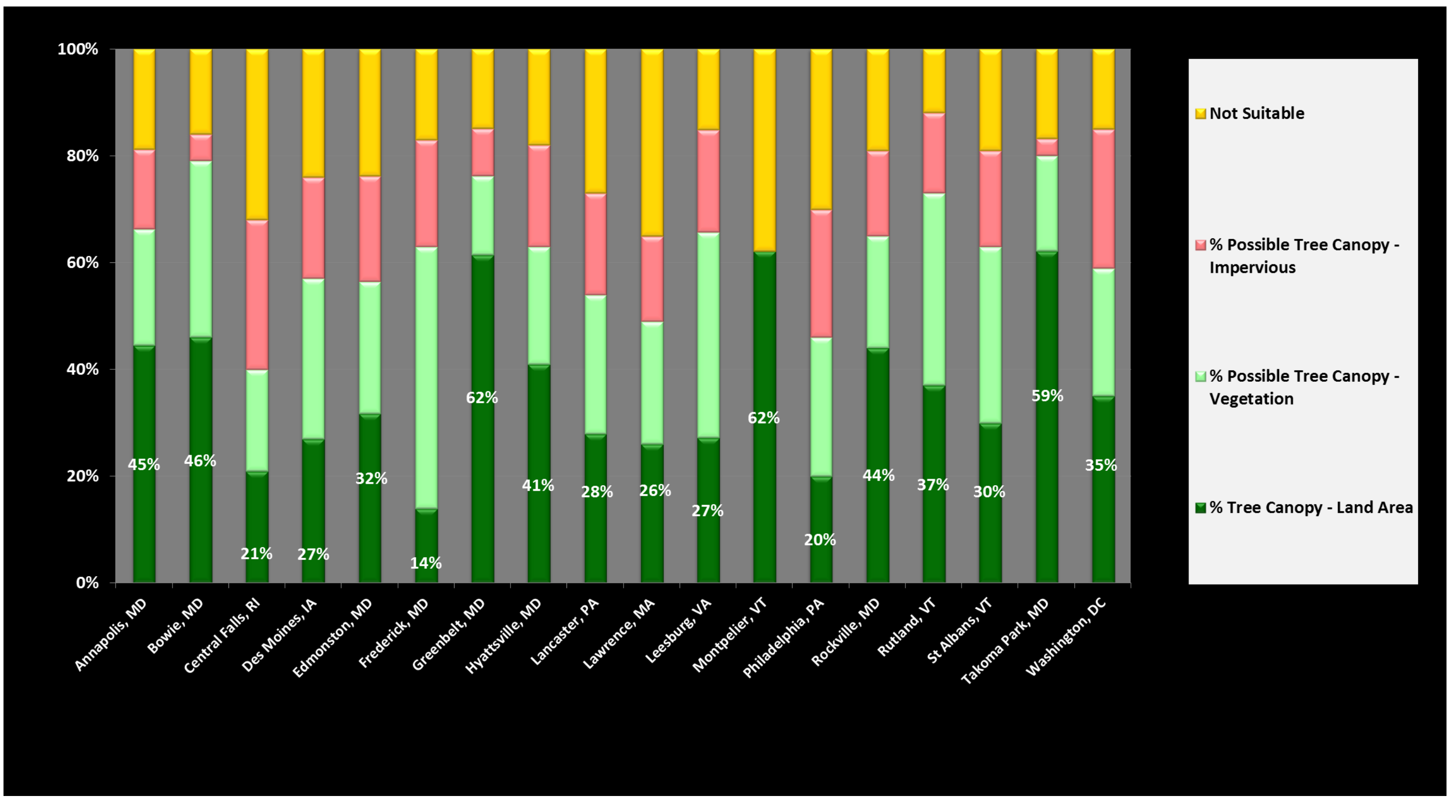


Figure 13: Comparison of Existing and Possible Tree Canopy with other selected cities that have completed Tree Canopy Assessments.

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Additional Information

Funding for the project was provided by PA Department of Conservation and Natural Resources Bureau of Forestry. More information on the TC assessment project can be found at the following web site: **http://nrs.fs.fed.us/urban/utc/**

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