RESOLUTION NO. 20100819-035

WHEREAS, on January 29, 2009, the City Council adopted the Urban Design Guidelines which serve as recommendations for all urban development and redevelopment projects by both the public and private sector; and

WHEREAS, the Urban Design Guidelines recognize the significant impact of the built environment on the historic, iconic, and unique characteristics of Austin and its neighborhoods; and

WHEREAS, as Austin continues to mature as a city, new infrastructure projects will be needed to meet the demands of its population, including water towers and electric substations, which are important elements of a city's built environment; and

WHEREAS, considerable community dialogue has already occurred regarding the placement and design of city infrastructure projects needed for the additional population created by the Mueller Airport redevelopment and the surrounding communities; and

WHEREAS, the Austin Design Commission serves as a tremendous resource to the City Council to offer expert advice on how infrastructure projects can enhance the built environment and how to successfully engage community input; **NOW, THEREFORE,**

BE IT RESOLVED BY THE CITY COUNCIL OF THE CITY OF AUSTIN:

The City Manager is directed to work with the Austin Design Commission on recommendations for design guidelines for infrastructure projects commissioned by the City of Austin, including Austin Energy, the Austin Water Utility, and other city-owned enterprises and departments. These recommendations shall include policies and procedures for the design and placement of infrastructure projects, incorporating opportunities for public notification and input.

ADOPTED: August 19, 2010 **ATTEST:** Shirley A. Gentry

Shirley A. Gentry
City Clerk

RESOLUTION NO. 20120816-060

WHEREAS, the Austin Design Commission serves as an advisory body to the Austin City Council; and

WHEREAS, the Austin Design Commission provides a unique bridge between City staff, Designers, and the Stakeholders/Public and additionally recognizes fiscal responsibility is important with public projects and that they contribute to our overall quality of life; and

WHEREAS, the City Council recognizes the need to create Infrastructure Design Guidelines to facilitate careful planning to ensure projects respect Austinites' quality of life; and

WHEREAS, on August 19, 2010 City Council approved Resolution No. 20100819-035 directing the City Manager to work with the Austin Design Commission on recommendations for design guidelines for infrastructure projects commissioned by the City of Austin; and

WHEREAS, on October 24, 2011 the Austin Design Commission conveyed recommendations for such guidelines per Exhibit A; **NOW, THEREFORE,**

BE IT RESOLVED BY THE CITY COUNCIL OF THE CITY OF AUSTIN:

The City Council directs the Austin Design Commission to develop Infrastructure Design Guidelines with associated review processes as outlined in their recommendations.

BE IT FURTHER RESOLVED:

The City Council directs the City Manager to support the Austin Design Commission in their development of Infrastructure Design Guidelines.

BE IT FURTHER RESOLVED:

The Austin Design Commission and City Manager are directed to provide a report to the City Council on the status of the effort within 90 days, including an estimated timeline for completion.

ADOPTED: August 16 , 2012 **ATTEST:** Shirley A. Gentry

Shirley A. Gentry
City Clerk

CITY OF AUSTIN

DESIGN COMMISSION

INTERIM

INFRASTRUCTURE DESIGN GUIDELINES


Mueller Water Tower


Seaholm Bridge (proposed)


Seaholm Wall (proposed)


Great Streets

Introduction

The Design Commission provides advisory recommendations to the City Council on matters pertaining to the quality of proposed urban development, and as requested by the Council, assists in developing public policy and in promoting excellence in the design and development of Austin's built environment. In our capacity as stewards of Austin's built identity, Council has asked the Design Commission to broaden its scope to include policies and standards for the design and review of the infrastructural components of our city. This Manual of Infrastructure Design Guidelines is meant to complement both the city's Urban Design Guidelines, and the Imagine Austin Comprehensive Plan. The Infrastructure Design Guidelines address the design character and construction of components and systems that structure and support the ongoing development and growth of the City of Austin and aim to enable the City to attain its vision of becoming the most livable city in the country. Design excellence in infrastructure contributes to sustainable growth and supports Austin's civic identity.

Because of Austin's extraordinary rapid growth and its focus on becoming a more "compact-and-connected" city, the need for new infrastructure to support new development has increased as well, almost becoming out of control. To ensure that these infrastructure projects do not have an adverse effect on the public realm, and that they are integrated into the concept of smart growth, the City Council passed Resolution 20100819-035, which assigned the Design Commission to develop guidelines for these infrastructure projects. This document will be quite similar to the Urban Design Guidelines produced in 2009, and will reflect many of the visions of the Imagine Austin Comprehensive Plan, which was adopted in 2012. The Manual of Infrastructure Design Guidelines (IDG) will provide the necessary framework for all future, applicable public infrastructure projects with the goal of enhancing Austin's quality of life. The IDG focuses on projects that have a significant impact on the public realm and will build on values expressed in the Urban Design Guidelines and Imagine Austin Comprehensive Plan.

What is Infrastructure?

Infrastructure can generally be defined as the set of interconnected structural components that provide the necessary supporting framework for urban development. Typically referring to the technical structures that support a society's needs, such as roads, bridges, water supply, sewers, electrical grids, telecommunications, and so forth, infrastructure is comprised of "the physical components of interrelated systems providing commodities and services essential to enable, sustain, or enhance societal living conditions."[Fulmer, 2009]. The Design Commission is primarily concerned with achieving excellence in the design of such structures and systems.

Infrastructure plays two primary roles in the design of urban environments: performative, and connective. Performative in this context refers to the capacity of the infrastructure to accomplish the technical function for which the system has been designed, be it the distribution and collection of water, electricity, transportation, etc., or the provision of systems of public space, streets, sidewalks, etc. Performative standards and criteria are the purview of City Staff and City Departments. Connective refers to the ability of infrastructure to integrate disparate urban development components and projects into an integrated system.

Connective also refers to the socially supportive role that infrastructure may play in enhancing the quality of life of the citizens of Austin. The Design Commission seeks to work with and advise City Staff, City Departments, and developers on was to attain excellence in the design and integration of the physical and social systems of our city.

The Infrastructure Guidelines outline the vision, principles and connective design criteria that are required for the design of our city's urban structure. The Infrastructure Design Guidelines provide the necessary framework for the design of a compact, connected and sustainable urban environment for Austin. The Design Commission's role in evaluating infrastructure proposals is to ensure that each development project is designed adequately and systematically reflects the values and principles espoused by the framework in order to realize the goals of the Imagine Austin Comprehensive Plan.

The Merits of Integrated Infrastructure

As the City of Austin strives to implement its compact, connected and sustainable agenda for the future, the necessity to integrate the various infrastructural systems that organize, construct and service the metropolitan landscape is of vital importance. The urban environment has become a complex organism requiring the expertise of many professionals, from multiple disciplines, to construct and manage. This complexity is reflected in the multiple departments that are responsible for the various components of infrastructural design within the city. The segregation of technical expertise, into distinct city departments, is a reflection of the segmentation of professional responsibility that has evolved with modern society. This disciplinary separation encourages the use of infrastructural solutions that are designed to solve singular dilemmas, without full consideration of the consequent effect on the totality of the urban environment. The urban landscapes, produced by this disciplinary separation, are comprised of systems of infrastructure that are engineered and implemented to function for individual purposes and are rarely integrated into the type of complex multi-functional systems needed to service the contemporary city.

Best design practices have shown that integration provides benefits that are social, environmental and economic. Planning for land-use development and mobility issues, for example, are often separately considered spatial planning disciplines. However, in practice there is a strong connection between land use issues and mobility factors, these issues strongly influencing each other in terms of livability and the subsequent financial-economic positions of neighborhoods. While optimizing a particular design may satisfy the technical engineering requirements necessary for infrastructure to perform a singular function, the resultant urban landscape is often dispersed, disconnected, and unsustainable.

The construction of a compact and integrated urban environment requires that the design and construction of infrastructural systems be able to operate on several levels. Systems must be both performative and connective. This is best accomplished by assimilating multiple purposes within an integrated system. Integrated infrastructure has the ability to respond to issues of mobility across a range of uses from the pedestrian, to bicycles, automobiles and public transportation, while additionally responding to the ecological needs of storm water mitigation, and the social roles of public space, all within the mechanisms of an integrated system.

10 Core Principles for an Integrated Infrastructure

1 CONTEXTUAL

Infrastructure should be thoughtfully designed and adapted to enhance surrounding neighborhoods and environments.

Context is the physical scale, space and ambience of a place and establishes the built and natural forms within which individual buildings and infrastructure are sited. As such, the design of infrastructure affects the balance between natural ecosystems and the built environment.

2 CONNECTED

Infrastructure should be strategically planned to so as to facilitate multi-modal linkages and pathways through the city.

Infrastructure should be designed bind the districts, neighborhoods and public spaces of the city together so as to create a vital social, economic and ecologically responsible urban environment.

3 INTEGRATED

Infrastructure should be designed to accommodate competing interests in the urban environment.

A well-designed and efficient urban infrastructure must allow for the intensification of functions in the urban environment by providing for the integration of social and technical systems. This requires an integrated approach to design that supports multiple simultaneous programs and functions.

4 COMPACT

Infrastructure should be designed to promote sustainable urban environments.

Infrastructure that supports compact urban development should be designed to sustain a relatively high-density urban environment comprised of mixed land uses. It must provide for an efficient public transport system and be structured to encourage walking and cycling, low energy consumption, and a reduced carbon footprint. A compact urban population, served by suitable public infrastructure will provide opportunities for social interaction, the building of community and increased public safety.

5 SUSTAINABLE

Infrastructure should aspire to improve the quality of life for its citizens, while living within the carrying capacity of the supporting eco-systems.

Sustainable infrastructure provides for environmental, economic, and social equity in the urban environment. The built environment is an extension of the ecological systems that allows for a dense human population to live in a compact area in relative comfort. Sustainable infrastructure practices encompass: low impact development practices to protect water resources, public transportation systems, distributed energy systems, and the provision of wildlife corridors to protect the health of the natural environment.

6 HYBRIDIZED

Infrastructure should be designed for the efficient integration of multiple programs and uses.

Constructing a compact city requires that infrastructure be designed efficiently in order to provide for a multiplicity of uses within a single area. This technique of hybridization can contributes to the activation of urban areas that would otherwise be vacated, and provides for the continuous use of urban space for diverse programs and events.

7 HUMANE

Infrastructure should contribute to the creation of a vibrant public realm with superior public spaces.

The design of infrastructure can either divide communities, or bring them together. Urban Infrastructure performs an important social role in the city, and proper consideration should be given to the role public space plays in the formation of an accessible and civilized urban landscape, one that serves the entire urban population.

8 ECOLOGICAL

Infrastructure should provide for healthy natural environments.

The unification of natural systems into the city helps to soften the impact of a dense cityscape and provides city dwellers with pockets of respite from the activities of urban life. A healthy environment is created through the use of green infrastructure to support communities of plants and animals, transforming parks and water bodies into spaces for community activities. The integration of nature is not only aesthetically pleasing, but also improves the air quality and mitigates heat island effects in the city.

9 TIMELESS

Infrastructure should recognize the historic significance of important buildings and places.

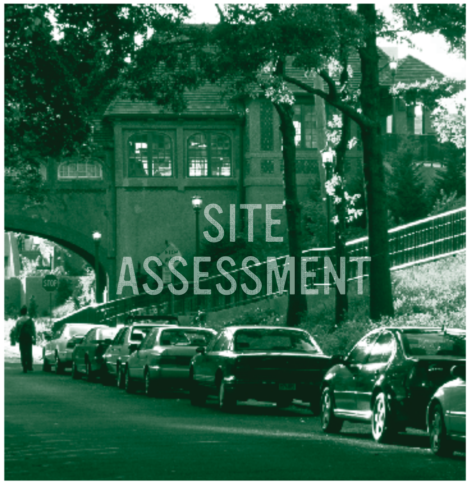
Culturally important places are constructed incrementally over long periods of time. This aspect can reinforce the authenticity of a place while providing the basis for contemporary urban lifestyles.

10 INCLUSIVE

Decisions about infrastructure should be made with the participation of the effected community.

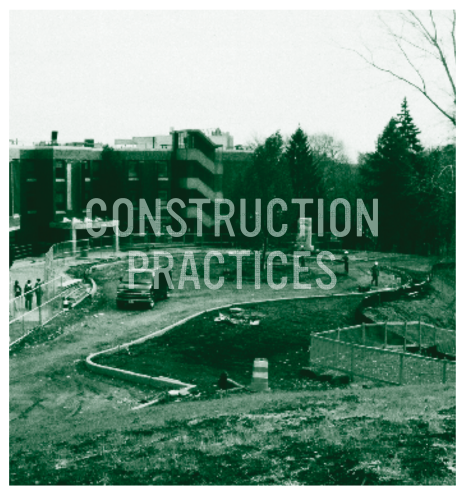
From the seemingly trivial activities of everyday life (e.g. using a plastic bag) to the overtly transformational (e.g. growing the city), citizens have a role to play and a responsibility. It is only through the sum total of individual choices, of individual actions, that change will come about.

Residents and stakeholders must be part of the planning and designing of their cities and their communities. They must also be part of delivering a new vision: by choosing to walk, by engaging each other, by generating awareness, and by demanding higher standards.



HIGH PERFORMANCE INFRASTRUCTURE GUIDELINES

OCTOBER 2005



NEW YORK CITY DEPARTMENT OF
DESIGN + CONSTRUCTION

DESIGN TRUST
FOR PUBLIC SPACE

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High Performance Infrastructure Guidelines: Best Practices for the Public Right-of-Way
is a project of the New York City Department of Design and Construction and the Design Trust for Public Space.

New York City Department of Design and Construction
http://www.nyc.gov/html/ddc/

Design Trust for Public Space
http://www.designtrust.org/

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DESIGN TRUST PREFACE

The Design Trust for Public Space is a private non-profit organization dedicated to improving New York City's public realm. Since our founding in 1995, we've tackled a broad range of projects, but our goal has never varied: to provide project-specific, state-of-the-art design expertise to New York City. It is our conviction that the city's cultural and democratic life depends on viable public space. To achieve our goals, we organize teams of experts – architects, urban planners, graphic designers, landscape architects, ecologists, economists, or whoever may be required for a particular project. The selected experts become "fellows" of the Design Trust, which supports their work with public agencies and community groups. These powerful and unexpected public/private collaborations generate solutions to complicated civic issues and overcome formidable political and logistical hurdles.

Fundamental to all public space design is environmental sustainability, which the United Nations World Commission on Environment and Development defines as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The Design Trust has taken the lead in helping New York City become more sustainable through an ongoing partnership with the New York City Department of Design and Construction (DDC). This collaboration began in 1999, with the publication of the *High Performance Building Guidelines*. Since that document's publication, DDC has built more than two dozen green buildings – a revolution in terms of city building practices – and incorporated sustainable features in numerous projects. In 2003, the Design Trust and DDC expanded these efforts by undertaking creation of the *High Performance Infrastructure Guidelines*. Nationally unique, this document will improve New York City's environmental quality through design, as the innovative materials and construction techniques it details are implemented over time.

To create the *High Performance Infrastructure Guidelines*, the Design Trust and DDC assembled a remarkable team, comprised of Design Trust fellows Hillary Brown, Stephen Campbell, and Steven Caputo; DDC Assistant Commissioner Dino Ng and his staff; and Signe Nielsen Landscape Architects. This document attests to their dedication and commitment to excellence. The team worked closely with the City agencies that have jurisdiction over New York City's infrastructure and solicited input from an array of other expert sources, including an advisory panel of regional officials and academic and private-sector peer reviewers. This collaborative process provided invaluable feedback and evinced a deep-rooted optimism for the future of high performance infrastructure.

By implementing sustainable practices in the public right-of-way, we will conserve energy, improve air and water quality, and protect our waters, making New York City more beautiful and livable. Just as the *High Performance Building Guidelines* received wide acclaim and inspired comparable guidelines in other U.S. cities, we are confident that the *High Performance Infrastructure Guidelines* will encourage a groundswell of innovation here and throughout the nation. Implementing sustainable practices in the public right-of-way enriches the urban experience for all New Yorkers, now and for generations to come.

Deborah Marton
Executive Director, Design Trust for Public Space
October 2005

DDC PREFACE

New York City has bit of a reputation. It is the most crowded, frenetic, and gritty city in the United States. However, like the proverbial tough guy with a heart of gold, New York City is also, quietly, one of the *greenest* cities by several measures – including energy use per capita and percentage of open space devoted to parkland. As Environmentalism in the 21st Century is reconsidered, its traditionally perceived nemesis – dense, concentrated urbanism – has emerged as its more energy-efficient redeemer. The two philosophies, once thought to be incompatible, are in fact complementary.

In 1999, DDC's Office of Sustainable Design, in partnership with the Design Trust, affirmed a commitment to green building practices by publishing the *High Performance Building Guidelines*. Today, six years later, DDC's building portfolio is advancing the goal of more environmentally responsible strategies. In order to also extend those strategies to our public right-of-way, the DDC and Design Trust have reunited here to publish the *High Performance Infrastructure Guidelines*.

The manner by which we design, build, maintain, and operate infrastructure within our urban right-of-way profoundly affects our ecology and every measure of our environment. Our natural resources, such as air quality, waterway health, and vegetation, exist in a state of interdependence with each other and with our built urban infrastructure. Whether directly or indirectly, both the built and natural environment affect our health, well-being, and quality of life. Although the environmental, social, and economic benefits of green buildings have been understood for some time, the concept of green infrastructure is relatively new.

This document outlines the range of possibilities suggested by the notion of green infrastructure. The landscape-intensive nature of this concept demands a certain kind of approach, and the reader may note that particularly urban variables, such as scale, age, and proximity, have been given special consideration. Consideration has also been given to the type of infrastructure work addressed in order to endorse practices that promise the most benefits.

In New York City, the majority of work performed in the right-of-way is remedial and space is at a premium, precluding certain conventional notions of "greening." However, the massive scale of our built environment ensures even the most minor and invisible improvements to our current practice will resonate in a way that is both real and powerful. The city is proceeding with a new era of infrastructure reconstruction and rehabilitation, both in lower Manhattan and citywide, and the publication of this document could not be more timely. The sound practices and intelligent ideals embodied within represent and reaffirm DDC's commitment to a more fiscally, socially, and environmentally responsible future for New York City.

David J. Burney, AIA
Commissioner, New York City Department of Design and Construction
October 2005

PART ONE
ACHIEVING HIGH PERFORMANCE

OVERVIEW

"Streets and their sidewalks – the main public places of a city – are its most vital organs…" Jane Jacobs

WHAT IS THE PUBLIC RIGHT-OF-WAY?

The public right-of-way organizes the massive flow of energy and matter that courses through the city on a daily basis. Right-of-way components include the roadway, sidewalks, sub-grade systems, and landscaped areas, and the design of each these components profoundly affects our experience of the city. By undertaking coordinated, sustainable approaches to streetscape design, construction, operations, and maintenance – and by joining considerations of function and performance with concern for the human experience of the urban environment – cities can promote safety, reliability, cost effectiveness, public health, and quality of life.

On its surface, the right-of-way rationalizes and choreographs the complex circulation of automobiles, buses, bicycles, and pedestrians, prioritizing them through its geometry, lane markings, crosswalks, and signaling – allowing each to yield to the other in a safe mix. The streetscape is also shared public real estate for the social and economic activity that enriches civic life. City streets double as play space and rallying grounds, while sidewalks serve as zones of casual interchange, shopping, dining, and display.

Below grade, the right-of-way houses a complex and vital network of utility infrastructure. Pipes and conduits convey potable water, gas, electricity, and telecommunications, while others carry off storm- and wastewater.

Finally, the right-of-way is host to nature and natural processes. Trees, vegetation, and soil interspersed throughout the streetscape offset the sharp edges and hard surfaces of the built environment. Landscaped areas perform invaluable services by producing oxygen, improving air quality, providing shade and local cooling, and absorbing and treating stormwater.

Sustainable practices can be applied each of these aspects of the right-of-way. The public right-of-way in New York City comprises over 20,000 paved lane miles – approximately 1.2 billion square feet – or an area nearly double the size of Manhattan. Given the size of this asset and the scope of the City's annual infrastructure investments – over $2 billion – there is potential to gain considerable benefit from even modest improvements in right-of-way components.

WHY HIGH PERFORMANCE GUIDELINES?

This publication, *High Performance Infrastructure Guidelines (Guidelines)*, provides a roadmap for incorporating 'best management practices' (BMPs) into New York City's right-of-way infrastructure capital program. The *Guidelines* are written for the Department of Design and Construction (DDC), but they are also intended for use by planners, designers, engineers, public officials, and anyone else involved in constructing, operating, or maintaining the right-of-way.

Through publishing these *Guidelines*, the City and the Design Trust for Public Space seek improved environmental, social, and economic outcomes for the City's infrastructure investments. Furthermore, the Guidelines consider improving natural-system and human health an essential part of an infrastructure capital project.

The *High Performance Infrastructure Guidelines* allow for a practical, incremental approach to implementing best management practices. The BMPs that are described in Part Three of the document are applicable to a wide range of maintenance and capital construction work, including minor structural roadbed work, street resurfacing projects, sewer or water main rehabilitation, sidewalk construction projects, and major right-of-way reconstruction or new construction – all undertakings of the Department of Design and Construction. DDC's implementation of best practices in a series of pilot projects over time, coupled with the agency's ongoing upgrading of standards through research and development, represents a measured but committed approach to enhancing the performance of right-of-way infrastructure.

Many of the best practices contained in the *Guidelines* already have a proven track record in New York City. Photographs and brief descriptions of exemplary New York projects are woven throughout the Guidelines, and six of these projects are described in detail in Part One. Other best practices are drawn from public and private sources in the United States and abroad and were chosen for their relevancy to the metropolitan area. Some of these best practices are readily achievable in New York City, while others are more far-sighted. By weaving together innovative goals and proven best management practices, the *Guidelines* will help diverse stakeholders make coordinated, incremental infrastructure improvements according to a long-term shared vision.

GUIDELINES ORGANIZATION

On any given capital project, players from both the public and private sectors participate in planning, scoping, funding, designing, constructing, and maintaining municipal infrastructure. *Part One* of the *Guidelines* provides each participant with an overview of the desirability of improved infrastructure and a general understanding of critical objectives. *Part One* also assists external stakeholders – politicians, community groups, developers, and citizens – in strategic thinking about place-based, environmentally sound infrastructure solutions.

Part Two provides an overview of how infrastructure is planned, funded, designed and built by the New York City Department of Design and Construction, in collaboration with its client agencies. Part Two contains recommendations for helping the involved City agencies and private utilities incorporate high performance practices into both typical and special infrastructure work. Part Two also proposes enhancements to decision-making techniques – including life cycle cost analysis and environmental valuation that is fundamental to achieving the most cost effective, best performing, and sustainable infrastructure projects. This section advocates for a more coordinated right-of-way planning effort and integrated design among public agencies as well as residential, commercial and industrial stakeholders, helping them effectively coordinate long-term implementation across space and time.

Part Three is the technical component of the *Guidelines*. It begins with a discussion of optimal site assessment and scoping techniques. It then sets out numerous best management practices organized according to the primary categories of infrastructure work – streetscape design, pavement, utilities, stormwater management, and landscape. A final section in Part Three contains best practices for construction and site management. The BMPs in Part Three are formatted to help frame both problems and solutions. They contain useful background information, key objectives for improved performance, and detailed technical strategies for achieving those objectives. The BMPs also explain benefits and limitations, and identify opportunities for integrating multiple practices.

A brief case study on the development of Gateway Estates in Brooklyn, New York, follows the BMPs. Based on a design simulation conducted during the development of the *Guidelines*, the case study envisions how the *High Performance Infrastructure Guidelines* could be implemented in future phases of Gateway Estates and other projects like it. A glossary, acknowledgements section, and index conclude the *Guidelines*.

GUIDELINES DEVELOPMENT PROCESS

The *High Performance Infrastructure Guidelines* are the product of collaboration between the Design Trust for Public Space and the New York City Department of Design and Construction (DDC). Founded in 1995, the Design Trust for Public Space is a private non-profit organization dedicated to improving the quality and understanding of New York City's public realm. Also founded in 1995, The Department of Design and Construction is the centralized agency that performs the majority of New York City's capital improvement projects that were formerly undertaken by a number of separate agencies. DDC's interagency mission is a tremendous asset to implementing high performance infrastructure practices citywide.

The *High Performance Infrastructure Guidelines* are conceived to complement a previous publication that DDC and the Design Trust collaboratively produced in 1999, the *High Performance Building Guidelines*.[1] The publication of the *Building Guidelines* provided a roadmap for DDC to incorporate sustainable practices into its capital building program. Since publication, DDC has designed and built 25 green buildings, and it is continually revising design standards to mainstream sustainable practices. The *High Performance Building Guidelines* were widely acknowledged throughout the building industry and public sector, and led to the development of similar guidelines in major U.S. cities.

To develop the *High Performance Infrastructure Guidelines*, the team – comprised of Design Trust fellows, DDC representatives, and landscape architecture consultants – worked closely with the City agencies that have jurisdiction over right-of-way infrastructure, including the Departments of Transportation (DOT), Environmental Protection (DEP), Parks and Recreation (DPR), and Housing Preservation and Development (HPD). DDC's 'client agencies' influenced the scope of research, advised on technical and procedural issues, and conducted a peer review of the *Guidelines*.

The team also solicited input from a regional advisory panel – consisting of infrastructure planning officials from northeastern cities and states – and a peer review panel – consisting of New York City consultants, academicians, and infrastructure experts. Finally, the authors of *InfraGuide* – the Canadian National Guide to Sustainable Municipal Infrastructure – and the sustainable design consultants, Steven Winter Associates, Inc., conducted separate technical reviews of the *Guidelines*.[2] All of these groups provided invaluable feedback, enthusiasm, and direction for the project. For a complete list of contributors, please see the acknowledgements section, beginning on page 208.

1 *The High Performance Building Guidelines* were also made possible through funding from the Robert Sterling Clark Foundation, the New York State Council on the Arts, and the New York State Energy Research and Development Authority.

2 InfraGuide is funded by Infrastructure Canada and implemented by the Federation of Canadian Municipalities in collaboration with the National Research Council.

GUIDING PRINCIPLES

Promote sustainable urban ecology

The emerging field of 'urban ecology' increases our understanding of how urban environments are the product of complex interactions between constructed and natural systems. While people are the dominant agents of change in cities, ecological processes are also dynamic, and they may be affected in ways that significantly impact human health and the built environment. Examples of these phenomena include the urban heat island effect, smog formation, flooding and hydrologic disruptions, and the proliferation of invasive species. The protection and regeneration of local and regional ecosystems is essential since urban dwellers vitally depend on 'ecosystem services' such as breathable air, safe drinking water and nutritious food. City planners, architects, engineers, and ecologists can develop infrastructure that promotes harmony and synergy with the natural environment, resulting in improved ecological productivity and better public health outcomes.

Enhance public health, safety, and quality of life

The design of the public right-of-way critically impacts urban living. Variations in streetscape geometry, grading, materials, colors, textures, and thermal and acoustic properties can either help or hinder our safe and comfortable navigation of the city. Well designed streetscapes balance the needs of pedestrians, bicyclists, mass transit users, and automobile drivers, and they offer a range of amenities and enhancements that will benefit public health, safety, and quality of life. Undertaking streetscape improvements will encourage civic pride and social engagement, reduce crime rates, bolster property values, foster economic development, and help to revitalize communities.

Optimize lifecycle and performance

The 'lifecycle' of an infrastructure asset includes all the stages of its existence from 'cradle to grave' – i.e. from the initial production of its material inputs through the end of its service life and disposal. The *Guidelines* seek to minimize costs and environmental impacts throughout the entire lifecycle of infrastructure assets, while maximizing performance and longevity. Critical objectives include effectively coordinating right-of-way construction, using best-available technologies, designing utilities for easy access, reducing conflicts between adjacent or overlapping components, using non-destructive maintenance techniques, and undertaking timely preventative maintenance. Consequently, the City will realize better returns on infrastructure investments and will benefit from greater reliability, less environmental impact, and less disruption to communities and businesses.

Manhattan's Greenwich Street (top) and Route 9A (bottom) have both been redesigned using high performance principles.

BEST MANAGEMENT PRACTICES

High Performance Infrastructure best management practices are based on the core principles of sustainable design:

- limiting waste and hazardous substances
- using materials and resources efficiently
- reducing detrimental impacts to the air, water, soil and vegetation
- promoting energy efficiency
- improving lifecycle and performance
- enhancing public health, safety and quality of life

The *Guidelines* contain best management practices (BMPs) applicable to the typical section of the public right-of-way, encompassing street and sidewalk, underground utilities, stormwater infrastructure, landscapes, and streetscape elements. In the City of New York, considerable opportunity exists for incorporating BMPs into projects of different scales and levels of complexity. Many BMPs will be implemented incrementally through the upgrade and replacement of individual infrastructure components over time. In new developments or major roadway reconstruction projects, the City can maximize benefits by employing best practices to coordinate capital investments and to develop integrated designs for the entire roadway system.

Component Optimization

At the single-component level, standard details or specifications may be improved to optimize performance, minimize environmental impact, use materials more efficiently, improve construction practices, or extend lifecycle.

Examples of component optimization:

- *Using reclaimed 'supplementary cementitious materials' to increase pavement strength.* **(PA.6)**
- *Using light-emitting diodes for streetlighting to increase efficiency and reduce energy consumption.* **(SS.8)**
- *Designing drought-tolerant, water-efficient landscapes to reduce irrigation needs and potable water consumption.* **(LA.13)**

Multifunctional Optimization

The density and close proximity of components in the right-of-way can lead to unanticipated damage or degradation. Recognizing the mutual impact of adjacent systems, the *Guidelines* seek to minimize conflicts among parts and, wherever possible, to promote synergies. Undertaking multifunctional optimization strategies could lead to long-term cost savings, improved performance and lifecycle, reduced environmental impact, and increased returns on municipal investments.

Examples of multifunctional optimization:

- *Using 'structural soils' in tree planters will provide load-bearing capacity for sidewalk pavements while offering a better medium for trees to develop deep roots. This practice will significantly enhance tree health and also minimize damage to pavements by preventing upward root growth.* **(LA.4)**
- *Using pervious pavement will reduce stormwater runoff and peak demand on stormwater management infrastructure, while providing an adequate driving surface for vehicles.* **(PA.4)**
- *Utilizing trenchless technologies to repair water-main infrastructure will minimize trench cutting and subsequent pavement degradation.* **(UI.3)**

Integrated Design

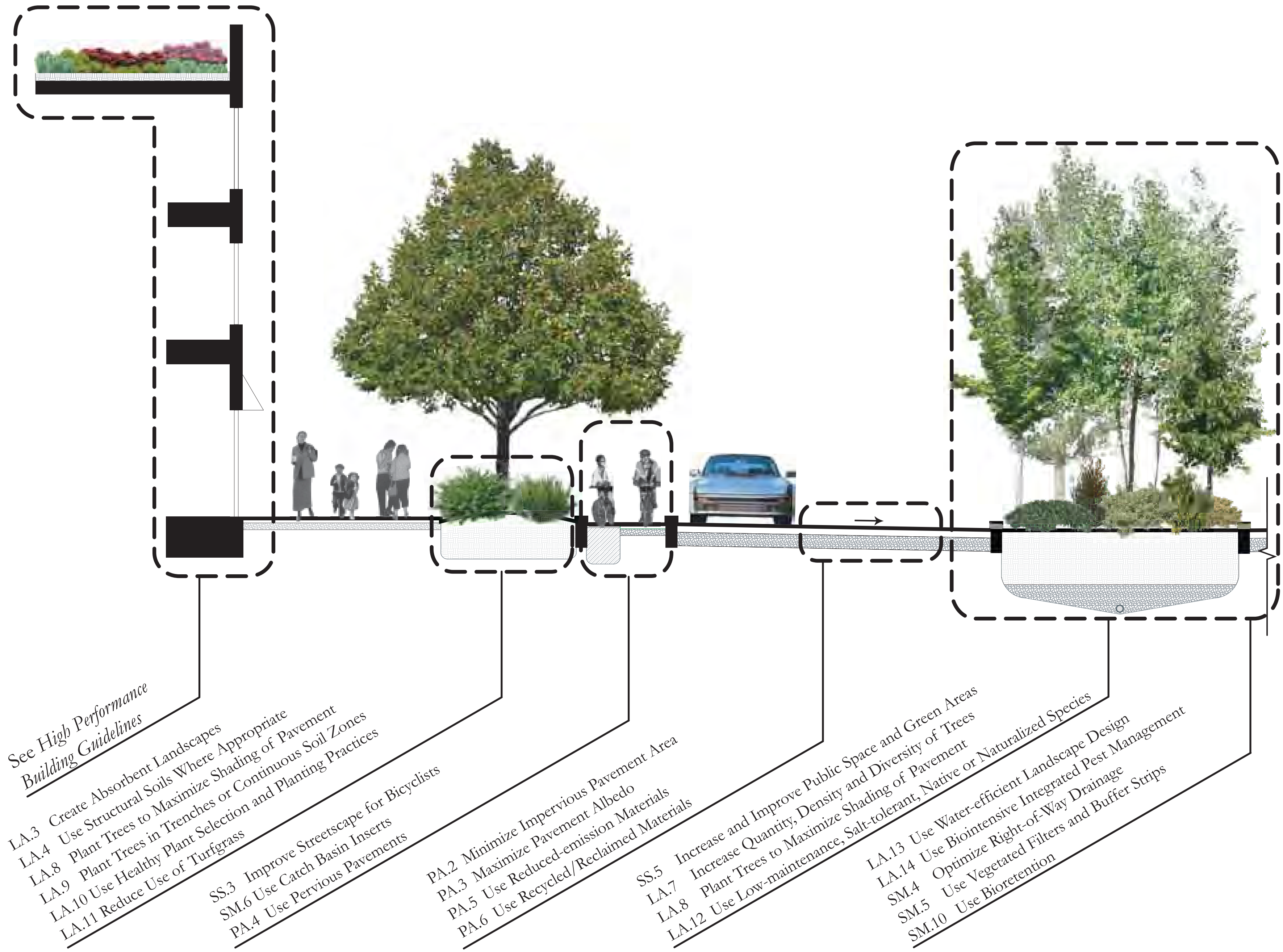
This systems-oriented approach focuses on improving the performance of the entire roadway system. Design integration requires cross-disciplinary teamwork at the planning, scoping, design, and construction stages. It promotes comprehensive performance improvements, compounds environmental benefits, and potentially offers substantial cost savings. Undertaking design integration is beneficial for infrastructure upgrade and it is critical in creating new infrastructure. The "integration" section in each BMP identifies opportunities for integrated design. In addition, a graphic on the following pages illustrates opportunities for integrating BMPs within a typical streetscape.

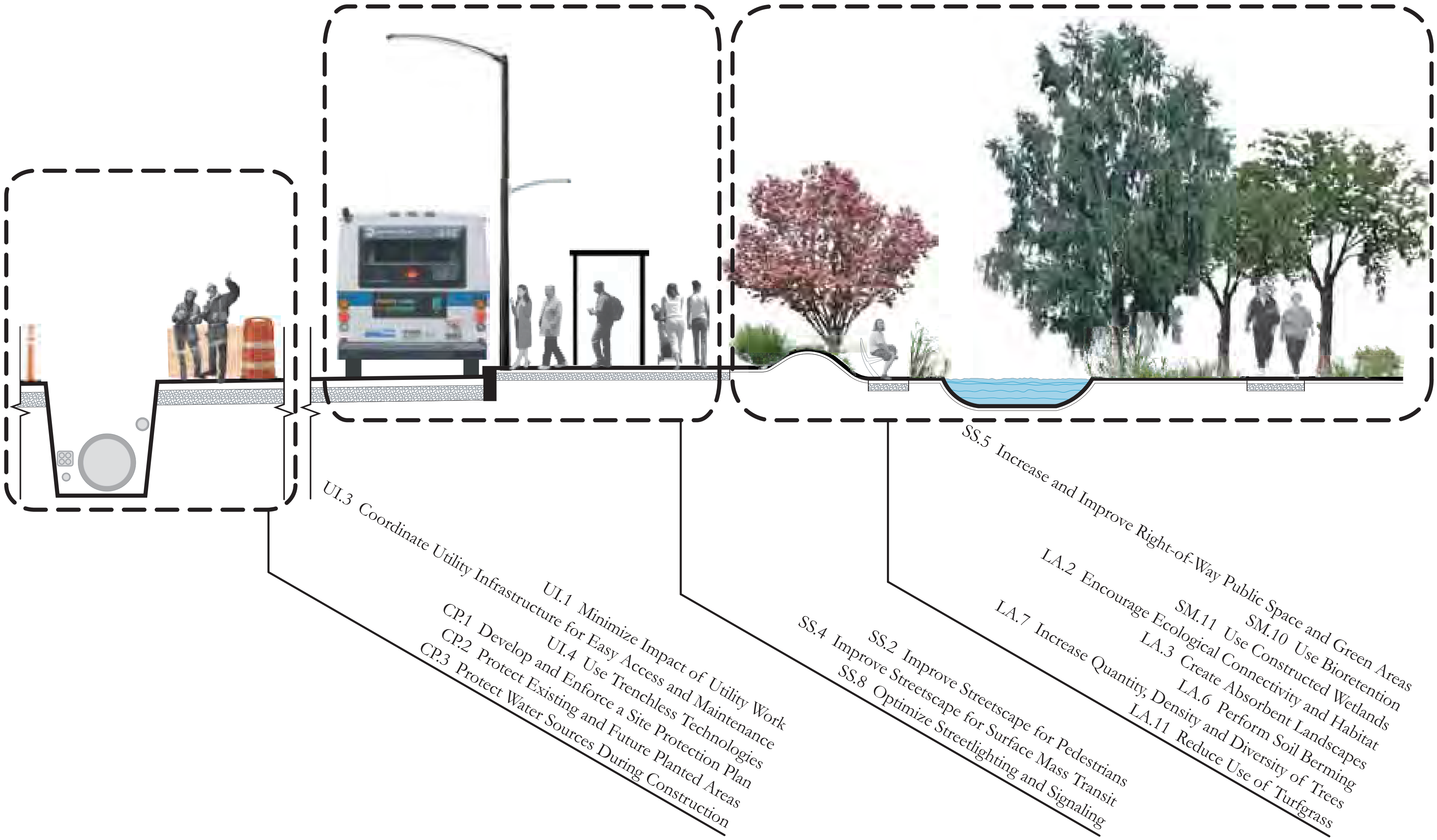
Examples of integrated design:

- *Designing a roadway with a diversely planted center median that functions as both a traffic calming device and a stormwater bioretention area will improve pedestrian safety, minimize stormwater runoff, dampen street noise, and improve air quality.*
- *Designing an accessible utility corridor for subsurface utilities within the roadway will allow for easy maintenance, minimization of right-of-way disruption, extended pavement lifecycle, and reduced environmental impact from repeated excavation and disposal of sub-base.*
- *Designing a right-of-way with reduced impervious pavement area, high-albedo pavements, and maximum shading by trees will substantially help to reduce local urban heat buildup, improve air quality, increase pavement durability, and calm traffic.*

The advantages of employing these principles are explored in more detail in the section titled 'High Performance Infrastructure Benefits' starting on page 12. A visual matrix relating best management practices to benefits is provided on pages 16 and 17 to increase understanding and to aid in navigation of the document.

INTEGRATION OF BEST MANAGEMENT PRACTICES




UI.3 Coordinate Utility Infrastructure for Easy Access and Maintenance
UI.1 Minimize Impact of Utility Work
UI.4 Use Trenchless Technologies
CP.1 Develop and Enforce a Site Protection Plan
CP.2 Protect Existing and Future Planted Areas
CP.3 Protect Water Sources During Construction
SS.2 Improve Streetscape for Pedestrians
SS.4 Improve Streetscape for Surface Mass Transit
SS.8 Optimize Streetlighting and Signaling
SS.5 Increase and Improve Right-of-Way Public Space and Green Areas
SM.10 Use Bioretention
SM.11 Use Constructed Wetlands
LA.2 Encourage Ecological Connectivity and Habitat
LA.3 Create Absorbent Landscapes
LA.6 Perform Soil Berming
LA.7 Increase Quantity, Density and Diversity of Trees
LA.11 Reduce Use of Turfgrass

BENEFITS

HIGH PERFORMANCE INFRASTRUCTURE BENEFITS

Through employing best practices that treat the right-of-way as a series of linked and interacting systems – and by making capital improvements accordingly – the City can capture a range of environmental, social, and economic benefits. A matrix on page 16 depicts the relationships among the numerous best practices and their associated benefits. These benefits are described on the following pages.

Urban Heat Island Effect Mitigation

The Urban Heat Island (UHI) effect is the increase in urban air temperatures resulting from the proliferation of dark colored, heat-absorptive pavements and surface materials of buildings, as well as from changes to landscape and hydrology that reduce evaporative cooling. An increase in air temperatures as much as six to eight degrees Fahrenheit can trigger a range of public health problems, especially affecting children, the elderly, and people with existing respiratory ailments.[3] The urban heat island effect exacerbates the concentration of ground level ozone, a harmful eye and respiratory irritant for which NYC is in 'severe non-attainment' of federal air quality standards.[4] The urban heat island effect also increases demand for air conditioning, resulting in higher energy consumption and power plant emissions. Projections indicate that the combined effects of urban heat and global warming, if left unchecked, could increase average temperatures by an additional five to ten degrees over the next 100 years, resulting in as many 90-degree days in NYC as currently in Miami.[5]

New York City has 20,000 lane miles of dark colored, impervious pavement in the right-of-way alone – in aggregate an area nearly double the size of Manhattan. Undertaking a comprehensive strategy to minimize urban heat island effect – reducing paved area, using pervious pavements, increasing pavement albedo (reflectivity), and designing landscapes to maximize shading of pavements – could reduce summertime temperatures by several degrees and could save the City millions of dollars. A recent study of the City of Los Angeles indicated that increasing pavement albedo citywide could be worth $90 million a year in energy savings, smog reduction, and related public health benefits.[6] Another study estimated that a reduction in urban temperatures of approximately 3 degrees Farenheit would produce air quality benefits equivalent to replacing a city's entire fleet of gas-powered cars with electric vehicles.[7] While no similar studies exist for New York City, the benefits of reducing urban heat island effect are clear.

Improved Air Quality

Vehicular emissions, especially diesel-powered trucks and buses, are a primary source of harmful air pollutants in urban areas – including greenhouse gases, carbon monoxide (CO), sulfur dioxide (SOx), nitrogen dioxide (NOx), and particulate matter – and they are a contributing factor in up to 250,000 asthma attacks per year in New York City.[8] Numerous studies have linked particulate matter to respiratory ailments, chronic lung diseases, pneumonia, heart disease, and increased mortality rates. In the past two decades, the amount of 'vehicle miles traveled' (VMT) on the City's highways has increased significantly, making it difficult to attain federal air quality standards for a number of air pollutants.[9]

Undertaking best practices in right-of-way design and construction can result in considerable air quality improvements. For example, streetscape improvements encouraging walking, bicycling, and mass transit use in Portland, Oregon, resulted in an 8% decrease in vehicle miles traveled, a 6% decrease in NOx emissions, and a 3% decrease in CO emissions.[10] Other studies have documented the effectiveness of urban trees and vegetation in producing oxygen, intercepting and settling pollutant particles, and absorbing gaseous pollutants. One such study found that localized air quality improvements in urban areas containing 100% tree cover are as high as 15% for ozone, 14% for SOx, 13% for particulate matter, and 8% for NOx.[11] Studies conducted by the USDA Forest Service in New York City estimate that in one year the City's trees were responsible for removing over 1800 metric-tons of air pollution at an estimated value of nearly $10 million.[12] Yet another study found that a single mature tree can absorb 48 pounds of carbon dioxide per year and release enough oxygen to support two human beings.[13] The economic benefits of urban trees are likely to increase as financial markets for trading carbon dioxide emissions develop in the near future.

3 Lawrence Berkeley Lab Heat Island Group. http://eetd.lbl.gov/HeatIsland/

4 City of New York Department of City Planning. *2002 Report on Social Indicators.* Chapter 8 – The Environment. http://www.nyc.gov/html/dcp/pdf/pub/socind02ch8.pdf

5 Janine Bloomfield. Environmental Defense Fund. *Hot Nights in the City: Global Warming, Sea-Level Rise and the New York Metropolitan Region.* New York: EDF, 1999. Page 5. http://www.environmentaldefense.org/documents/493_HotNY.pdf

6 Lawrence Berkeley Lab Heat Island Group http://eetd.lbl.gov/HeatIsland/Pavements/Cost.html

7 Brian Stone Jr and Michael O. Rodgers. *Urban Form and Thermal Efficiency, How the Design of Cities Influences Urban Heat Island Effect.* APA Journal Spring, 2001. Vol. 67, No. 2. http://www.wisc.edu/urpl/people/stone/UFTE.pdf

8 Diesel exhaust, in particular, contains dozens of constituent chemicals that are human toxicants, carcinogens, reproductive hazards, or endocrine disruptors. Diesel exhaust contains approximately 100 times more fine particulate matter than gasoline exhaust. Natural Resources Defense Council. *Exhausted By Diesel: How America's Dependence on Diesel Engines Threatens Our Health.* Page V. http://www.coalitionforcleanair.org/pdf/reports/cca-reports-exhausted-by-diesel.pdf

9 Vehicle Miles Traveled on NYC's highways and principle arteries increased by 40% between the years 1982 and 1996, while population grew by only 3%. US Environmental Protection Agency. *Our Built and Natural Environments: A Technical Review of the Interaction Between Land Use, Transportation, and Environmental Quality.* Page. 29. http://www.epa.gov/smartgrowth/pdf/built.pdf

10 US Environmental Protection Agency. *Improving Air Quality Through Land Use Decisions.* Page 28. http://www.epa.gov/otaq/transp/trancont/r01001.pdf

11 David J. Nowak. USDA Forest Service, Syracuse, NY "The Effects of Urban Trees on Air Quality." http://www.fs.fed.us/ne/syracuse/gif/trees.pdf. (Page 1)

12 Estimate based on data from the year, 1994. Ibid. (Page 2)

13 Mike McAliney. *Arguments for Land Conservation.* Trust for Public Land, Sacramento, CA. As referenced in "Benefits of Trees in Urban Areas." Colorado Tree Coalition. http://www.coloradotrees.org/benefits.htm#2

Improved Water Quality, Hydrology, and Aquatic Ecosystem Health

Despite major gains in water quality over the past few decades, New York City still faces a critical hurdle. Between 70% and 80% of the City's 6,000 mile sewage system consists of combined sanitary and stormwater sewers that become overwhelmed during large storm events. As many as 40 billion gallons of 'combined sewer overflows' (CSOs) – containing around 20% untreated sewage – are discharged into the City's receiving waters each year.[14] CSOs are the single largest source of pathogens in the NY harbor region, and also contribute high levels of nutrients, suspended solids, metals, oxygen-demanding substances, bacteria, and viruses.[15] Besides causing combined sewer overflows, urban stormwater runoff also disrupts natural hydrologic cycles and harms receiving waters by causing erosion, habitat damage, temperature increases, eutrophication, turbidity, and toxicity. In fact, studies show that untreated urban stormwater runoff generated during the first hour of intense storm events – referred to as the first-flush or 'water quality volume' – can have even greater pollutant concentrations than raw sewage.

The *Guidelines* recommend numerous strategies to reduce, control, and treat stormwater runoff as close to its source as possible. One highly successful and versatile strategy is to use landscaped, or "bioengineered," structures to capture runoff, enabling infiltration or evapotranspiration to return water to natural hydrologic pathways. Since soil and vegetation are excellent sinks for hydrocarbons, metals and other stormwater pollutants, bioengineered BMPs offer the most cost-effective and environmentally beneficial method of improving urban stormwater quality.

The City of Seattle recently completed a pilot project to reconstruct a residential street in a threatened watershed using bioengineered stormwater management infrastructure. Known as the 'Street Edge Alternative', the reconstructed street not only controls and treats runoff for storms as large as a once-in-two-years storm, but also it cost 20% less to build than a conventional street.[16] Furthermore, the Street Edge Alternative enhances roadway aesthetics, improves air quality, and offers other environmental, social, and economic benefits. The City of Philadelphia is undertaking similar initiatives in abandoned lots, roadway medians, and other hard-surface spaces to reduce CSOs and simultaneously promote urban revitalization.[17] In a similar fashion, improving New York City's streetscapes for stormwater management will cost-effectively reduce combined sewer overflows and improve water quality, while beautifying the urban environment, bolstering property values, and enhancing public health and quality of life.

14 "Exploring the Nature of New York." http://www.cs.gc.cuny.edu/~nature/nature/water.htm

15 NYC Department of Environmental Protection. *2003 Harbor Water Quality Report.* http://www.nynjcoast.org/NYCDEPHarbor_survey/docs/factors/cso.htm

16 Seattle Public Utilities. http://www.ci.seattle.wa.us/util/About_SPU/Drainage_&_Sewer_System/index.asp

17 Glen J. Abrams. "New Thinking in an Old City: Philadelphia's Movement Towards Low-Impact Development." NWQEP NOTES: The NCSU Water Quality Group Newsletter. February, 2004. ISSN 1062-9149. Number 112. North Carolina State University Water Quality Group. http://www.bae.ncsu.edu/programs/extension/wqg/issues/notes112.pdf

Enhanced Ecological Health and Productivity

In recent decades, the pace of urbanization in New York City has far exceeded the rate of population growth, resulting in degradation of natural habitat and loss of biodiversity.[18] One endangered, yet still vital, natural resource in New York City is Jamaica Bay, which is part of the Gateway National Recreation Area. Jamaica Bay provides habitat for over 350 types of waterfowl and shorebirds, making it one of the best bird watching locations in the western hemisphere.[19] However, salt water marshes in the bay have diminished at an alarming rate in recent years as the result of landfilling operations, channel dredging, water pollution, and hardening of the bay's shores with infrastructure. Future efforts to develop infrastructure and housing in the bay's watershed must seek to minimize environmental impact and enable regeneration.

As the home of nearly 500,000 street trees, New York City's public right-of-way comprises essential connective tissue for the regional ecosystem. The *Guidelines* demonstrate numerous opportunities that exist within the right-of-way to improve ecological health and productivity, from the micro-scale of the streetscape to the regional scale of Jamaica Bay. Increasing urban vegetation, promoting sustainable landscape practices, and using bioengineered structures to reduce and treat stormwater are among the many strategies.

Given its ability to reduce urban heat, sequester atmospheric carbon, reduce noise, provide habitat and control stormwater runoff, the value of urban vegetation cannot be overstated. According to the USDA Forest Service, a single urban tree generates $31,250 worth of oxygen, provides $62,000 worth of air pollution control, recycles $37,500 worth of water, and controls $31,250 worth of soil erosion, over a 50 year lifetime.[20] In many cities, urban vegetation is responsible for billions of dollars of stormwater control.[21] Investing in urban vegetation as part of a comprehensive plan to improve infrastructure is extremely cost-effective. A recent study of the Chicago metropolitan area analyzed the costs and benefits of planting and maintaining 95,000 trees over a 30-year period. The study found that the benefits of air quality improvement, energy-use reduction, and stormwater management outweighed the planting and maintenance costs by an average of nearly three-to-one, with payback periods of as little as eight years after planting.[22]

18 From 1970 to 1990, urbanization in NYC increased 65% while population increased 8%. New York City Audubon Society. http://www.nycas.org/issues/population/

19 "A Report on Jamaica Bay." US Park Service. http://www.planning.nps.gov/document/gatenews1.pdf, According to the US Fish and Wildlife Service, birdwatchers spent $14.4 billion dollars – including $6 billion on trip related expenses – in 1991 alone, and more than 24 million Americans took trips for the express reason of bird watching.

20 USDA Forest Service Pamphlet #R1-92-100. Quoted in http://www.coloradotrees.org/benefits.htm#2.

21 A recent study of the Washington DC region concluded that the existing 46% tree canopy reduces the need for stormwater retention structures by 949 million cubic feet, valued at $4.7 billion. American Forests. "Trees and Ecosystem Services." http://www.americanforests.org/resources/urbanforests/naturevalue.php

22 David J. Nowak, et al. *Chicago's Urban Forest Ecosystem: Results of the Chicago Urban Forest Climate Project.* USDA Forest Service, 1994. Referenced in "Trees as Community Infrastructure" from the Rhode Island Statewide Planning Program. http://www.planning.ri.gov/forestplan/pdf/Part3.PDF

Reduced Noise Pollution

Noise pollution is a serious public health hazard. In New York City, noise complaints are the single most common call to the 311 citizen hotline, at an average of 1,000 calls per day. Noise pollution not only causes hearing loss but can also pose higher risks of hypertension and certain types of heart disease. Unwanted noise also contributes to tiredness, impacts productivity, and induces anti-social and depressed behavior.[23] A primary objective for reducing noise is to minimize right-of-way construction and use proper noise-control techniques when construction is necessary. The *Guidelines* advocate using greater discretion in granting permits for night and weekend work, developing 'noise management plans' with community input on large projects, and using special equipment to minimize the impact of construction-related noise. To buffer noise from traffic and street-level activity, the *Guidelines* recommend increasing the quantity and density of tree planting, and using earth berms. The U.S. Department of Energy estimates that street trees can absorb 50% of urban noise if planted appropriately.[24] Earth berms can reduce noise levels 3 to 5 dBa, while also providing aesthetic benefits and serving as repositories for excavated soil that would otherwise be transported to a landfill.[25] Improving right-of-way design and construction to reduce noise pollution will lead to happy and healthier communities throughout the City.

Reduced Waste

Since the recent closing of Fresh Kills Landfill – the site that formerly received 13,000 tons of New York City's garbage per day – the City has faced rapidly increasing costs for municipal waste disposal. Up to 40% of NYC's annual landfill material is construction and demolition waste. Finding ways to minimize waste and recycle materials in right-of-way construction will help reduce pressure on the City's waste disposal system, decrease pollution, save money and energy, and in some cases improve performance. For example, the use of coal fly ash and other reclaimed products as 'supplementary cementitious materials' in concrete not only offsets the need for large quantities of energy-intensive Portland cement, but also increases strength compared to conventional mixes. Through seeking a high rate of recycling and waste reduction in infrastructure construction, New York City can promote significant economic development. The Netherlands, a small coastal country with limited space for landfills, achieves 100% recycling for many materials used in its transportation sector, offering New York City a successful waste management model to emulate.[26]

23 Center For Disease Control. National Center for Environmental Health. http://www.cdc.gov/nceh/hsb/noise/

24 US Department of Energy Report. Quoted in http://www.coloradotrees.org/benefits.htm.

25 Highway Engineering Branch, Ministry of Transportation and Highways, British Columbia. *Noise Control Berms: Guidelines for the Use of Earth Berms to Control Highway Noise.* January 1997. www.th.gov.bc.ca/publications/eng_publications/environment/references/Noise_Control_Earth_Berms-Guidelines.pdf

26 Taylor T. Eighmy and Katherine Holtz. "Scanning European Advances in the Use of Recycled Materials in Highway Construction." *Public Roads.* U.S. Department of Transportation, Federal Highway Administration, July, 2000. Vol.64. No.1. http://www.tfhrc.gov/pubrds/julaug00/recycscan.htm

Improved Energy Performance

New York City is already the most efficient urban energy consumer in America. For example, the average New York City household consumes 370 kilowatt hours per month compared to 865 kilowatt hours per month in the average American household.[27] Nevertheless, rising demand for electricity must be met with increased energy conservation and efficiency to maintain the viability of New York's energy system. As previously mentioned, undertaking strategies in the right-of-way to reduce urban heat will bring substantial energy savings. Additionally, New York City seeks to realize savings and improve emergency preparedness by maximizing the energy efficiency of streetlighting and signaling, and using renewable energy sources wherever possible.

Reduced Use of Potable Water

New York City relies on over 1.1 billion gallons of water per day supplied from upstate reservoirs. Although the City's water supply is one of the most plentiful and highest quality urban water supplies in the world, water conservation is a crucial objective to ensure long-term viability and ecosystem health. The City has an existing conservation program that has successfully reduced consumption by more than a million gallons per day over the past few years. Notwithstanding this positive trend, the potential need to develop new water filtration systems and to expand sewage infrastructure could result in significant capital expenditures in the future. The *Guidelines* seek to strengthen the City's existing water conservation programs by advocating water-efficient landscape design to minimize irrigation needs. Additionally, the *Guidelines* promote stormwater management techniques that will help to replenish underground aquifers, support the natural hydrologic cycle, and promote the reuse of stormwater.

Improved Public Health, Safety, and Quality of Life

Many of the environmental benefits previously discussed translate directly into improved public health, safety, and quality of life. For example, using urban vegetation and other strategies to decrease urban heat and air pollution will help reduce asthma rates, infant mortality, heat-related illness, cancer and other ailments. Furthermore, studies show that the presence of urban vegetation leads to a significant reduction in crime and domestic violence, and helps to improve community relations and property values. Other beneficial strategies recommended by the *Guidelines* include designing streetscapes to support walking, biking, and other forms of 'active' transportation; undertaking traffic calming to discourage dangerous driving and reduce accidents; and enhancing right-of-way aesthetics and amenities.

27 Mayor Rudolph W. Giuliani. "Addressing the Need for Long-term Reliable Energy in NYC." Speech given on March 27th, 2001. http://www.nyc.gov/html/rwg/html/2001a/energy.html

Reduced Impact of Construction

As discussed above, the *Guidelines* seek to minimize preventable construction activity whenever possible, and also to expedite construction and maintenance to minimize disruption to communities, street closures, traffic congestion and noise. Other best practices are aimed at reducing the impact of construction on natural resources through implementing site protection measures, protecting water sources, minimizing damage to existing vegetation and habitat, using reduced-emission materials, and using cleaner construction equipment.

Enhanced Right-of-Way Lifecycle and Performance

The *Guidelines* advocate the use of 'lifecycle analysis' to account for the full range of costs – including environmental and social impacts – over the entire life of an infrastructure asset. The goal of lifecycle analysis is to determine the most cost-effective technical strategies and investment decisions. Employing lifecycle analysis beginning in the early planning stages of an infrastructure project encourages designers to take proactive steps to ensure the reliability and durability of the infrastructure asset. It also emphasizes the importance of effective, long-term maintenance, and minimization of unnecessary right-of-way construction that would lead to lifecycle degradation.

A compelling example of lifecycle degradation is the fact that over 100,000 cuts are made annually in the City's streets to gain access to subsurface utilities. Utility cuts cause significant pavement degradation, which can eventually lead to water main breaks and other types of utility failure. The *Guidelines* contain recommendations for reducing the frequency of utility cuts, designing utilities for easy access and maintenance, using non-destructive trenchless technologies, and improving pavement restoration techniques. Other methods for improving infrastructure performance and extending lifecycle include creating healthy low-maintenance landscapes, promoting strategies to minimize damage to sidewalks caused by tree-roots, using certain recycled materials in pavements, and improving energy performance of lighting and signaling.

Decreased First Costs

The most compelling scenario for decreasing first costs as a result of applying high performance practices is a project like the Staten Island Bluebelt. The award-winning Bluebelt program uses bioengineered structures to provide ecologically-sound and cost-effective storm water management for approximately one third of Staten Island's land area. The Bluebelt is estimated to have saved as much as $50 million in infrastructure construction costs. First costs could also be reduced by decreasing roadway widths, using less expensive recycled or reclaimed materials in pavement, minimizing construction and demolition waste, and so on. Many other techniques in the *Guidelines* are cost-neutral, yet advantageous because they offer important residual environmental and social benefits.

Decreased Operations and Maintenance Costs

The *Guidelines* offer many strategies that could help reduce the cost of operating and maintaining the public right-of-way. For example, the use of trenchless technologies to repair a water main section would be far less expensive – not to mention less harmful to the environment and less disruptive to local residents and businesses – than fully excavating the pavement to gain access to the utility. Other strategies, particularly for landscape, achieve cost savings by simply reducing the need for maintenance. Techniques include using low-maintenance native species in landscapes, designing water-efficient landscapes, reducing the use of turf-grass, using biointensive integrated pest-management, and so on. Finally, through improving the energy performance of streetlighting and signaling, the City could realize substantial operational cost savings.

Deferred or Avoided Municipal Capital Costs

Undertaking citywide, integrated stormwater management planning and seeking to reduce, control, and treat stormwater runoff as close to its source as possible, are practices that could help defer or avoid enormous expenditures on centralized water treatment facilities in the future. Experts agree that these techniques offer the most cost-effective method of managing stormwater, minimizing combined sewer overflows, and improving water quality. Expanding or creating new centralized water treatment facilities costs billions of dollars per site, and many communities throughout the City are opposed to such facilities. A change in approach would not only save money, it would also expedite water quality improvement. The cities of Philadelphia and Seattle have recognized the value of localized stormwater initiatives, paired with other city planning initiatives, and have begun to realize significant financial, social, and environmental benefits.

Compliance with Environmental Regulations

Implementing the *Guidelines* will help New York City cost-effectively achieve compliance with local, state, and federal regulations for air and water quality.

Increased Property Values and Economic Development

Streetscape improvements have the potential to reinvigorate neighborhoods and increase property values – particularly in areas that currently suffer from urban blight or disuse – since they help to improve community aesthetics, improve environmental health, reduce crime rates, increase commercial and pedestrian activity, and increase business investment. A persuasive example of this phenomenon is the community surrounding the Bluebelt in Staten Island, which has experienced significant increases in property values since the Bluebelt's completion. Additionally, as the largest consumer of construction-related services in the northeast region, New York City can promote the development of sustainable technologies, products and businesses, thereby enhancing long- term competitiveness of its regional construction industry.

MATRIX OF BEST MANAGEMENT PRACTICES AND BENEFITS

	Urban Heat Island Effect Mitigation	Improved Air Quality	Improved Water Quality, Hydrology, and Aquatic Ecosystem Health	Enhanced Ecological Health and Productivity	Reduced Noise Pollution	Reduced Waste	Improved Energy Performance	Reduced Use of Potable Water	Improved Public Health, Safety, and Quality of Life	Reduced Impact of Construction	Enhanced Right-of-Way Lifecycle and Performance	Decreased First Costs	Decreased Operations and Maintenance Costs	Deferred or Avoided Municipal Capital Investment	Compliance with Environmental Regulations	Increased Property Values and Economic Development
SITE ASSESSMENT																
SA.1 Assess Site and High Performance Opportunities	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SA.2 Conduct Soil Analysis			✓	✓		✓				✓			✓			
SA.3 Conduct Hydrologic and Hydraulic Analysis			✓	✓												
SA.4 Survey Existing Vegetation	✓	✓	✓	✓	✓	✓			✓	✓		✓				
STREETSCAPE																
SS.1 Work with Community Groups to Enhance and Maintain Streetscape					✓				✓	✓	✓		✓			✓
SS.2 Improve Streetscape for Pedestrians	✓	✓	✓	✓	✓				✓						✓	✓
SS.3 Improve Streetscape for Bicyclists		✓							✓						✓	✓
SS.4 Improve Streetscape for Surface Mass Transit		✓					✓		✓						✓	✓
SS.5 Increase and Improve Right-of-Way Public Space and Green Areas	✓	✓	✓	✓	✓				✓						✓	✓
SS.6 Optimize Security Enhancements									✓							✓
SS.7 Optimize Streetlighting and Signaling				✓			✓		✓				✓			✓
PAVEMENT																
PA.1 Maximize Pavement Lifecycle Citywide						✓			✓	✓	✓		✓	✓		
PA.2 Minimize Impervious Pavement Area	✓	✓	✓	✓		✓	✓		✓	✓		✓	✓		✓	
PA.3 Maximize Pavement Albedo	✓	✓					✓		✓						✓	
PA.4 Use Pervious Pavements	✓	✓	✓				✓		✓						✓	
PA.5 Use Reduced-Emission Materials		✓	✓						✓							
PA.6 Use Recycled and Reclaimed Materials						✓				✓	✓	✓				✓
UTILITIES																
UI.1 Minimize Impact of Utility Work						✓			✓	✓	✓		✓	✓		
UI.2 Improve Restoration of Utility Cut Trenches									✓	✓	✓		✓	✓		
UI.3 Coordinate Utility Infrastructure for Easy Access and Maintenance		✓	✓		✓	✓			✓	✓	✓		✓	✓		✓
UI.4 Use Trenchless Technologies		✓	✓		✓	✓			✓	✓	✓	✓	✓	✓		✓

	Urban Heat Island Effect Mitigation	Improved Air Quality	Improved Water Quality, Hydrology, and Aquatic Ecosystem Health	Enhanced Ecological Health and Productivity	Reduced Noise Pollution	Reduced Waste	Improved Energy Performance	Reduced Use of Potable Water	Improved Public Health, Safety, and Quality of Life	Reduced Impact of Construction	Enhanced Right-of-Way Lifecycle and Performance	Decreased First Costs	Decreased Operations and Maintenance Costs	Deferred or Avoided Municipal Capital Investment	Compliance with Environmental Regulations	Increased Property Values and Economic Development
STORMWATER MANAGEMENT																
SM.1 Conduct Integrated Stormwater Management Planning	●	●	●	●				●	●			●		●	●	●
SM.2 Prevent Water Pollution and Practice Source Control		●	●	●				●	●						●	
SM.3 Minimize Runoff from New Building Construction and Major Renovations			●	●				●	●					●	●	
SM.4 Optimize Right-of-Way Drainage			●						●			●		●	●	●
SM.5 Use Vegetated Filters and Buffer Strips			●	●					●						●	●
SM.6 Use Catch Basin Inserts			●						●				●		●	
SM.7 Use Water Quality Inlets			●						●						●	
SM.8 Use Detention Structures			●						●					●	●	
SM.9 Use Infiltration Structures			●						●					●	●	
SM.10 Use Bioretention	●	●	●	●					●			●		●	●	●
SM.11 Use Constructed Wetlands	●	●	●	●					●			●		●	●	●
LANDSCAPE																
LA.1 Optimize Citywide Landscape Planning	●	●	●	●	●				●						●	●
LA.2 Encourage Ecological Connectivity and Habitat	●	●	●	●					●						●	●
LA.3 Create Absorbent Landscapes			●	●					●						●	●
LA.4 Use Structural Soils Where Appropriate	●	●	●	●					●		●		●			●
LA.5 Amend Existing Soils			●	●		●							●			
LA.6 Perform Soil Berming		●			●	●						●				
LA.7 Increase the Quantity, Density and Diversity of Trees	●	●	●	●	●		●		●						●	●
LA.8 Plant Trees to Maximize Shading of Pavement	●	●		●	●		●		●		●				●	●
LA.9 Plant Trees in Trenches or Continuous Soil Zones	●	●	●	●	●				●		●		●		●	●
LA.10 Use Healthy Plant Selection and Planting Practices	●	●	●	●	●				●		●		●		●	●
LA.11 Reduce Use of Turfgrass		●	●				●	●					●			
LA.12 Use Low-Maintenance, Salt-Tolerant, Native or Naturalized Species		●	●	●				●	●		●		●			
LA.13 Use Water-Efficient Landscape Design				●				●			●		●			
LA.14 Use Biointensive Integrated Pest Management		●	●	●					●				●			
LA.15 Use Biotope-Based Plant Arrangement Along the Shade-Light Continuum	●	●	●	●			●	●	●				●			
CONSTRUCTION PRACTICES																
CP.1 Develop and Enforce a Site Protection Plan		●	●	●	●	●			●	●						
CP.2 Protect Existing and Future Planted Areas	●	●	●	●	●	●			●	●						●
CP.3 Protect Water Sources During Construction		●	●						●	●					●	
CP.4 Implement a Waste Management and Recycling Plan		●	●			●				●						●
CP.5 Minimize Disruption and Impact of Right-of-Way Construction		●							●	●						
CP.6 Use Cleaner Construction Equipment		●	●						●	●					●	

TRENDS AND PRECEDENTS

TRENDS

Throughout the country, people are developing local initiatives and practical programs to promote sustainable development. A number of trends are converging to work in favor of constructing high performance infrastructure. These include emerging public awareness, political vision, and market forces.

Increasing 'civic environmentalism': As part of a changing national attitude and one already emergent here in New York City, citizens are increasingly calling for local, incremental actions to prevent or solve environmental problems rather than relying on regulatory measures or capital improvement projects to address them. Local Business Improvement Districts (BIDs), community greening programs, neighborhood block associations, and grass-roots nonprofit groups are adopting innovative practices through citizen engagement and partnership with local businesses that can improve community and regional environmental quality.

Sustainability as an emerging principle for capital planning: Cities and states across the country are increasingly implementing 'smart growth,' transit-oriented development, responsible energy policies, environmentally-preferable procurement, and green building measures to promote sustainable development. These entities are realizing that undertaking integrated planning processes, applying best available technologies, and coupling these efforts with positive economic development forces can revitalize communities, improve environmental quality, and realize cost-savings simultaneously.

Market-driven innovation: The national green building movement's success at market transformation is the model for similar change from within the infrastructure sector. The US Green Building Council has promoted widespread use of its green building rating tool LEED® (Leadership in Energy and Environmental Design), which is an assembly of consensus-based best management practices, similar to the *Guidelines*. National use of LEED® – in particular its adoption by many state and local governments and federal agencies – has significantly impacted conventional practices in the building sector. Promotion of high performance practices in the infrastructure sector can emerge from a coalition among industry professionals, government officials, economic experts, and product manufacturers. Greener products and technologies are already beginning to emerge in the pavement and wastewater infrastructure industries, and more are likely to follow.

The following section outlines a number of compelling initiatives occurring in cities and states across the country.

NATIONAL PRECEDENTS

The City of Philadelphia

The Philadelphia Office of Watersheds was created in 1999 to create and oversee a multidisciplinary program to mitigate combined sewer overflows (CSOs). Since that time, the Office of Watersheds has conducted integrated stormwater management planning to implement citywide and localized strategies for reducing stormwater runoff. Using GIS mapping and lifecycle analysis, the City has determined that the most cost effective approach to reducing CSOs and improving water quality is to manage stormwater as close to its source as possible, rather than expanding or creating costly new centralized stormwater treatment plants. One example of a successful local intervention is the conversion of vacant lots throughout the city into small 'stormwater parks.' Each stormwater park contains small-scale treatment and detention structures to manage the runoff from the lot and surrounding buildings. The Office of Watersheds worked with local community groups in the design of the park environment, including seating, play areas, murals and landscaping. The result is not only a cost-effective solution to managing stormwater runoff, but also the creation of valuable public space, which improves quality of life for residents, improves environmental quality, increases property values, and encourages urban revitalization.

Philadelphia vacant lot (top) transformed into stormwater park (bottom)

Philadelphia is also conducting demonstration projects to construct bioretention BMPs in urban right-of-ways. The success of these demonstration projects could transform public rights-of-way throughout the city in an effort to optimize on-site stormwater management. Other projects include creating new parks and community gardens with bioengineered stormwater management BMPs, renovating school yards to reduce impervious area and increase green space, constructing infiltration basins underneath playing fields, resurfacing basketball courts with pervious pavement, building stormwater treatment and control structures in parking lots, and constructing green roofs. Future objectives for the Office of Watersheds include overhauling the city's existing stormwater ordinance, updating land development codes, providing economic incentives for eliminating runoff, and educating the public about the importance of watershed health.

The City of Seattle
Seattle Public Utilities recently constructed a bioengineered stormwater management demonstration project called the 'Street Edge Alternative' to test new approaches to on-site stormwater management and streetscape improvement. The 660 foot long reconstructed street has 11% less impervious pavement surface than a traditional street, provides stormwater detention in small, diversely landscaped swales, and contains over 100 new evergreen trees and 1,100 shrubs. The Street Edge Alternative street not only controls and treats 98% of the stormwater from up to a two-year storm, it also cost 20% less to build than a conventional street and offers a range of social and environmental benefits.

Seattle Public Utilities is also partnering with Seattle Housing Authority to construct a natural drainage system for a 129 acre housing redevelopment – one of Seattle's largest redevelopments in recent history – located in the threatened Longfellow Creek Watershed. The natural drainage system integrates 22,000 linear feet of bioretention swales into the right-of-way, providing both storage and infiltration for stormwater from surrounding blocks. Once built, the natural drainage system will provide water quality treatment for the 6-month storm and attenuate the two-year, 24-hour storm to pre-developed pasture conditions, resulting in substantially improved water quality compared to conventional drainage infrastructure.

A proposed natural drainage system in Seattle


The green roof on Chicago's City Hall

The City of Chicago
The City of Chicago has undertaken a series of innovative projects to reduce urban heat, minimize stormwater reduce runoff, improve urban hydrology, enhance air quality, increase urban vegetation and habitat, and promote urban revitalization. Chicago's most renowned initiative is the construction of a 38,800-square-foot green roof on top of the City Hall, the most visible structure in the entire city. The roof is a living laboratory that was designed to test cooling effects, stormwater control, vegetative health, and habitat creation potential of three different green roof designs containing over 100 plant species. Initial monitoring for heat reduction has proven enormously successful: Surface temperatures of the roof have decreased over 70 degrees during the summer, resulting in a reduction of air temperatures on the roof by 15 degrees.

Chicago has also undertaken groundbreaking initiatives in landscaping and streetscape design. For nearly 15 years, the City has abided by – and periodically improved – a municipal landscape ordinance that requires plantings along roadways, adjacent to buildings, in parking lots, and in many other areas citywide. The Chicago Department of Transportation recently published streetscape guidelines to encourage high quality, pedestrian-oriented design of the public right-of-way. The cumulative effect of these initiatives has been transformative for the city. As Steve Berg of the Minneapolis Star-Tribune wrote, "few boulevards in the world can match the flower-bedecked splendor of Michigan Avenue, and public beauty is spreading like a contagion down every street in the Loop and into the neighborhoods. No corner gas station is safe from decorative lampposts and baskets of drooping geraniums. No surface parking lot can escape a border of wrought-iron fencing and leafy canopies of newly planted trees."[28]

[28] Steve Berg, Minneapolis Star-Tribune, September 10, 2000. http://www.newrules.org/environment/chiland.html

The City of Portland, Oregon

The City of Portland started its *Skinny Streets* Program in 1991 to reduce street widths, calm traffic, and improve pedestrian safety. The result of this initiative was the development of the Portland Pedestrian Design Guidelines, the nation's first major planning effort aimed at enhancing walkability in cities. The Pedestrian Design Guidelines became the model for pedestrian design initiatives in cities across the country.

In 1995, Portland implemented an innovative, long-range planning initiative called Metro 2040 to lay the groundwork for achieving a sustainable city in the future. The Metro 2040 plans defines an urban growth boundary, encourages dense urban infill development, promotes mass-transit ridership and walking, and seeks to minimize urban sprawl over the coming decades. Ten years after its adoption, the Metro 2040 plan remains a model of enlightened urban planning in terms of its promotion of efficient land use, proactive application of economic development forces, protection of farmland and natural areas, advocacy of balanced transportation systems, inclusion of diverse housing options, and overall sensitivity to urban ecology.

Portland's Metro 2040 growth concept

Newark Liberty International Airport infiltration trench

The Port Authority of New York and New Jersey

The Port Authority of New York and New Jersey has undertaken significant initiatives to develop sustainable landscape specifications, improve planting and maintenance practices, and optimize on-site stormwater maintenance at a number of regional facilities. An important example is the recent construction of a diversely landscaped infiltration trench at the Newark Liberty International Airport. Functioning as a landscape median/buffer adjacent to a busy two-way road, the bioretention area has a low curb profile to allow stormwater to flow across land and be captured. A pervious paver buffer strip and a grass filter strip remove coarse sediments, debris, and salt from runoff. Pretreated stormwater then flows into the infiltration trench, which is landscaped with low-maintenance, salt-tolerant, native or naturalized species. Nearby, the Port Authority built a long, narrow infiltration structure between a large impervious parking area and the right-of-way. The infiltration structure is able to control and treat stormwater runoff from both areas while taking up minimal space. These stormwater management systems represent a significant enhancement to the aesthetics and functionality of the airport's right-of-way, and are well suited for application at many other urban locations.

NEW YORK CITY PRECEDENTS

New York City has a history of producing innovative infrastructure. It initiated municipal streetlighting as early as 1762. In 1842, it began constructing what likely is today the largest and highest quality urban water system in America. It was in New York, in 1870, that America's first underground subway was built. New York revolutionized urban travel and recreation with the creation of the parkway system in the 1920's and 1930's. But perhaps New York City's most impressive infrastructure achievement is one that few people would consider as such: Central Park.

Unsuspecting visitors to Central Park could mistake it for a swath of primordial landscape. The Park's meandering hills, broad water courses, and jutting rock formations are such a stark contrast to its highly urbanized surroundings that it seems to be a piece of preserved wilderness. In fact, Central Park is an entirely constructed domain. Beginning in 1858, its construction involved 20,000 workers, the transportation of five million cubic yards of rock and soil, the planting of more than one million trees and shrubs, and the installation of over 100 miles of drainage pipe.[29] With this in mind, one can appreciate how ingenious the Park is as infrastructure. It offers the City's greatest recreational opportunities, with 250 acres of lawns, over 50 miles of walking trails and bike paths, and dozens of playing fields. An innovative series of bridges, tunnels, ring- and transverse-roadways enables cars to drive through the Park with little impact. The Park contains a large reservoir and system of lakes and subsurface infrastructure that control and treat huge volumes of stormwater runoff. Its diverse vegetation provides habitat for over 275 species of resident and migratory birds, making it one of the great bird watching locations in America. So instrumental is Central Park's landscape to cleaning New York City's air that since 1870, New Yorkers have referred to the park as the City's "lung" and "breathing place."

It is the deft interweaving of constructed and natural systems that makes Central Park – like other great City parks – such a compelling example of urban infrastructure. Its provisions for recreation, transportation, water storage, stormwater management, air quality improvement, and extensive natural habitat, have enriched urban living and provided environmental benefits for generations of New Yorkers. The presence of the Park has also spurred economic development, with nearby property values increasing exponentially in its first decades of existence and rising ever since. At present, the Park annually attracts 25 million visitors.[30] Central Park is an enduring and instructive model of the purposeful role of nature in the city, and a vision of the profound benefits of urban design innovation. Its legacy is revealed in the recent New York City projects described on the following pages.

Birds Eye View of Central Park in 2000 (top) and 1863 (bottom)

29 Robert A.M.Stern, et al. New York 1880: Architecture and Urbanism in the Guilded Age. New York: Mancellli Press, 1999. Page 89.

30 Undeveloped lots at the corner of Fifth Avenue and 86th Street that were valued at little more than $500 in 1847 were worth in excess of $20,000 by 1868. Matthew Gandy, *Concrete and Clay: Reworking Nature in New York City*, Cambridge: The MIT Press, 2002. Page 84.

EXAMPLE GREENING OF GREENWICH STREET

Location: Chambers to Hubert Streets, Manhattan
Client: NYC Economic Development Corporation
Completed: 2000
Designer: Signe Nielsen Landscape Architect PC
Project Cost: $3.5 Million

The Friends of Greenwich Street, a local community group, lobbied for nearly a decade to have changes made to an eight-block stretch of Tribeca. The 110-foot right-of-way was a holdover from the days when Greenwich Street was a major truck route and an overhead railroad to transport goods from the waterfront to inland warehouses. In 1996, NYC Economic Development Corporation funded a streetscape improvement project to narrow the roadway to 38 feet from 80 feet, and to add 42 feet to the west side sidewalk. Today, Greenwich Street has been reclaimed as a neighborhood street. Festivals and parades are frequent occurrences, parents teach children to ride bikes, and residents of all ages enjoy the sunny or shaded sitting areas. The Friends of Greenwich Street has become a 501(c)(3) not-for-profit maintenance corporation and oversees landscape maintenance, public education programs to curtail dog damage, de-icing salt spreading, and participation in seasonal plantings.

Project Goals

- Calm traffic and improve safety through narrowing the roadway, adding traffic signals, clarifying crosswalks and providing safe bus loading zones for children.
- Provide as much planting as possible within the widened sidewalk.
- Create a supportive space for a twice-weekly farmers market.
- Integrate and expand a popular neighborhood park.
- Provide pedestrian amenities including seating, bike racks, additional street lighting and bollards at parking garage exits.
- Upgrade subsurface utilities to limit future reconstruction.
- Support local retail by encouraging more pedestrian movement.

Project Challenges

- A plethora of utility lines under the widened sidewalk that could not be relocated, including a high-temperature steam line, water and gas mains and fiber optic cables.
- Very limited area for in-ground tree planting due to utility conflicts.
- Opposition by some neighborhood businesses to perceived traffic congestion, reduced double parking space, and potential for undesirable nighttime gatherings.
- Concern by local property managers over increased maintenance needs.
- Multiple agency approvals and jurisdictions.

Project Outcomes

- The 38 foot roadway includes two parking lanes and two moving lanes.
- Three laybys accommodate truck and school bus loading and double as head-in parking at night to accommodate the local restaurant traffic.
- All intersections were upgraded with ADA-compliant ramps and striped crosswalks.
- Two traffic signals and one stop sign were added.
- In-ground trees were planted in double and triple rows by creating insulated, continuous structural soil trenches that protect the roots from heat generated by the high-pressure steam line.
- Above-grade trees were added over water and gas lines by sealing the bottom of the tree planters with concrete to protect the utility lines.
- Low in ground planters provide additional vegetation and are maintained by locals.
- Passive irrigation was provided for all planted areas for use during drought periods.
- The farmers market takes place in an unobstructed sidewalk zone with a mountable curb and reinforced pavement to accommodate trucks. In-ground hydrants were provided for wash down.
- The neighborhood park was expanded by 20 feet and the new fence integrated into the sidewalk design.
- Pedestrian amenities were added throughout the streetscape, particularly at pleasant viewing spots, residential and park entrances and popular retail locations.
- All street lighting was upgraded with a more attractive fixture type and lower height poles were added to illuminate the widened sidewalk.

EXAMPLE RECONSTRUCTION OF ROUTE 9A

Location:	**Battery Place to 59th Street, Manhattan**
Client:	**New York State Department of Transportation**
Completed:	**2001**
Engineers:	**Vollmer Associates**
Landscape Architect:	**Signe Nielsen Landscape Architect PC**
Project Cost:	**$457 Million**

The reconstruction of Route 9A was originally conceived in the 1970s – in response to the collapse of the elevated West Side Highway – as an eight-lane underground superhighway. However, heavy community resistance and a protracted legal battle ultimately led to the project's demise. The project was revived and redesigned in the late 1990's, with significant public involvement, as an at-grade, tree-lined urban boulevard accommodating six to eight lanes of traffic, a continuous five-mile Class I bikeway, and a continuous walkway. To calm traffic and improve pedestrian safety, the design speed was lowered from 60 mph to 40 mph. Substantial public amenities, landscaping, and traffic calming features were provided while maintaining the roadway's capacity and efficient operation.

Because of successful public participation and interdisciplinary planning, the reconstruction of Route 9A is considered a premier example of 'Context Sensitive Design', the FHWA's methodology for creating safe, community-friendly, and environmentally-beneficial transportation projects.

Project Goals

- Improve air quality by eliminating bottlenecks and improving signal timing.
- Improve pedestrian access to the waterfront and along Hudson River Park.
- Provide an important link in the Manhattan bikeway system.
- Ensure public participation in the planning and design process.
- Make utility upgrades to protect the 50-year pavement.
- Create a landscaped boulevard character by providing significant areas for planting.

Project Challenges

- Potential negative impacts to historic structures, public open space and neighborhoods.
- Disruption of travel, congestion and noise during construction.
- Concerns over increased traffic on local streets serviced by Route 9A.
- Maintenance of access to waterfront during construction.

Project Outcomes

- Community groups participated in the planning process and contributed significantly to the selection of light fixtures, crosswalk locations and local street access, and construction impact mitigation.
- Construction was staged in six segments to minimize congestion and disruption, and to maintain waterfront access.
- A crusher plant was constructed to create recycled aggregate; a local concrete plant was reopened to avoid long distance transportation of concrete.
- The roadway is constructed of high-albedo concrete with a 50-year design life.
- The Class I bikeway is 16 feet wide to accommodate two directions of travel plus rollerbladers. A nine-foot raised, planted median separates it from the roadway.
- A 19-foot wide raised center median includes a double row of trees underplanted with native shrubs (in lieu of turfgrass), and is protected from de-icing salts.
- Multiple tree and shrub species were used to avoid a monoculture; all plants are drought-, salt-, and wind-tolerant.
- Sidewalk trees are planted in continuous structural soil trenches overlaid with recycled, un-grouted granite blocks.
- Shoulders were eliminated to reduce the roadway width and increase the size of the adjacent Hudson River Park. Parking is permitted on one side only.
- Many new pedestrian crossings were added, occurring approximately every three blocks. Bulb-outs were used on the east side to minimize crossing distance.
- A continuous 15-foot wide pedestrian walkway is located between the bikeway and the park, and is separated by a 5-foot planted median with pedestrian-scale fixtures.
- Lowered design speed (40 mph) improves safety and reflects urban character.
- Four new landscaped open spaces containing passive and active recreation facilities were created in conjunction with the realignment.

EXAMPLE STATEN ISLAND BLUEBELT

Location: Staten Island, New York
Client: Department of Environmental Protection (DEP)
Completion Date: Ongoing
Project Team: Hazen and Sawyer; Center for Watershed Protection; Environmental Concern; Blumberg & Butter

Large sections of Staten Island – NYC's least populous borough – remain undeveloped, particularly near the southern coast where the topography is glacial low-lying outwash plain lined with streams, ponds, and wetlands. The combination of pre-existing wetlands and extensive undeveloped land area – much of which was already owned by the City – presented an opportunity to develop a unique stormwater management system that would alleviate the excessive flooding that plagued local neighborhoods and accommodate urban development, while minimizing environmental impact and infrastructure construction costs.

The Staten Island Bluebelt provides ecologically sound and cost-effective stormwater management for one third of Staten Island's land area. The program connects structural stormwater control measures with existing natural drainage features to manage runoff for 19 watersheds over 14,000 acres. Bluebelt-managed runoff is diverted into a series of constructed features, such as settling ponds, sand filters, and constructed wetlands, that capitalize on the unique topography of the glacial plain and provide water quantity and quality. Runoff then passes into the area's natural wetlands for final treatment, storage, and drainage. The Bluebelt has received numerous awards and accolades worldwide, most recently a US EPA Region 2 Environmental Quality Award.

Project Goals

- Preserve and restore natural drainage corridors, including streams, ponds, and other wetland areas.
- Capitalize on the ability of natural and constructed wetlands to reduce the rate, velocity and volume of stormwater runoff, promote aquifer recharge, and improve overall area water quality.
- Connect natural drainage corridors with conventional storm sewers for an integrated stormwater management system.
- Achieve community and environmental benefits from the preservation of open space and wildlife habitat.
- Incorporate other publicly and privately owned wetland areas through DEP's acquisition program.
- Actively expand Bluebelt concept in mid-Island to develop 5,400 additional acres of watershed.

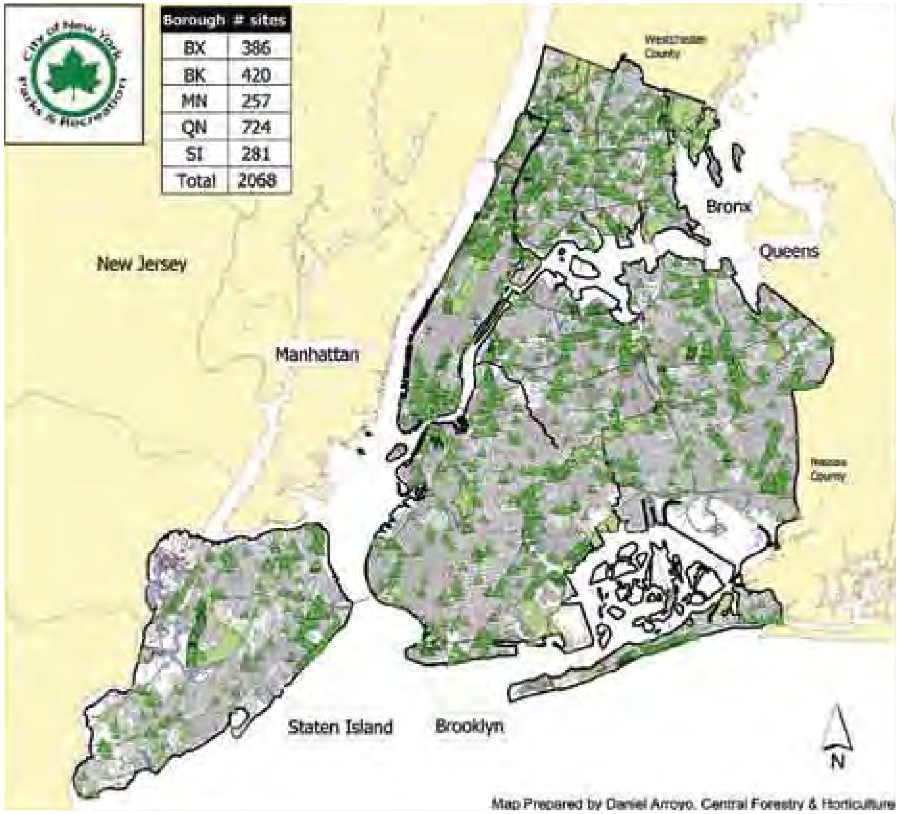
Project Challenges

- New mid-island acquisitions are tidally influenced, with phragmites marsh vegetation and flat topography.
- The arts and technologies of wetland restoration and artificial wetland construction are relatively new and have never been attempted on such a large scale.
- Special attention to the problem of invasive species and other landscape maintenance issues was needed.
- Required extensive interdisciplinary planning among ecologists, hydrologists, soil scientists, landscape architects, and engineers.

Project Outcomes

- The Bluebelt system currently drains 15 watersheds at the southern end of the island as well as Richmond Creek Watershed (approximately 10,000 acres).
- Preservation of existing wetland systems allows them to continue performing their functions of conveying, storing, and filtering water.
- Community benefits include increased property values, enhanced aesthetics, and provision of new open space resources.
- The Bluebelt provides diverse wildlife habitats.
- Community involvement is achieved through the Citizen's Advisory Committee.
- The Bluebelt has lead to the development of new technical know-how that can be applied in projects of different scales throughout the City. The Bluebelt offers a compelling new model for urban stormwater management.
- The Bluebelt has received numerous awards and accolades worldwide, most recently a US EPA Region 2 Environmental Quality Award.
- The Bluebelt program saves tens of millions of dollars in infrastructure costs (estimated at $50 million in 1999) when compared with the costs of providing miles of conventional storm sewers to the same land area. This program demonstrates how wetland preservation can be economically prudent and environmentally responsible.

EXAMPLE GREENSTREETS PROGRAM



Location: Citywide
Client: New York City Department of Parks & Recreation
Completed: Ongoing
Designers: Multiple DPR Landscape Architects

Greenstreets is the most extensive urban beautification project in New York City since the start of citywide neighborhood street planting in the early 20th century. In conjunction with the Department of Transportation (DOT), the Department of Parks & Recreation (DPR) has transformed over 2,000 street triangles, medians, and other impervious right-of-way areas into street gardens citywide. Greenstreets – "pint -sized parks," as the *New York Times* referred to them – have lastingly greened the streetscape, improved air quality, reduced stormwater runoff, and improved quality of life for communities throughout the City. The total area of greenstreets equals more than 125 acres, providing bits of nature where least expected.

Project Goals

- Transform barren concrete street islands, medians, and other impervious sections of the right-of-way into gardens or allées.
- Encourage local stewardship of greenstreets.
- Promote urban beautification and revitalization cost-effectively.

Project Challenges

- Choosing appropriate sites and making sure that no underground utilities hinder construction.
- Solving jurisdictional issues to gain access to the properties, especially sites that were privately owned. Furthermore, sites must be of the right size and location.
- Designing the garden space to fit within very small boundaries;
- Designing to take in the flavor and texture of the community and a particular street.
- Ensuring that DOT curb standards are followed and that traffic signs remain visible. All designs for DOT owned sites had to be approved by DOT.
- Determining the types of plants and landscapes that would survive in tough conditions.
- Conducting excavation of complicated sites, particularly sites that were 'painted lines' and needed curb and sidewalk construction.
- Maintaining the health and beauty of thousands of citywide street gardens.

Project Outcomes

- The 2,068 greenstreets citywide have added over 125 acres of green space to the City – tens of thousands of shrubs, groundcover, and flowers. The green space has markedly softened the streetscape environment.
- The addition of plant material helps clean the City of atmospheric pollutants and moderates urban temperatures. In addition, it increases the space for wildlife habitats and increases the beauty and property values of all New York City neighborhoods.
- The Central Forestry and Horticulture Division receives dozens of requests for greenstreets each year, coming from individuals, community groups, and politicians.
- About 40-50 sites are constructed or restored each year.
- A palette of hardy, pollution tolerant, and handsome plants has been developed and refined. The greenstreets 'formula' is reproduced for small streets or street-adjacent horticultural sites all over the City.
- DPR has developed a successful maintenance program, with a team in each borough. The agency keeps detailed data on the maintenance program, including data on soil moisture and frequency of watering, cleaning, pruning, mulching, and number of times a site has been visited.
- DPR has developed a stewardship program that has recruited individuals and groups throughout the City to help care for greenstreets.
- The greenstreets program has helped DPR refine its contract specifications, so that contractors must guarantee their plants for two years and must water the same plants for two years.
- DPR now grows replacement plants for all its greenstreets that are no longer under contract guarantee at the Arthur Ross Citywide Plant Nursery.

EXAMPLE NEIGHBORHOOD GREEN CORRIDOR

Location: South Bronx, New York
Client: Design Funded by the National Oceanic and Atmospheric Administration
Completion Date: To Be Determined
Project Team: Signe Nielsen Landscape Architect PC; Gaia Institute; Leonard Strandberg Associates; Sam Schwartz LLC

The Neighborhood Green Corridor has the goal of transforming de-designated truck routes into attractive pedestrian thoroughfares, while at the same time providing a range of safety, environmental and health benefits, both locally and regionally. The prototypical widened sidewalk will capture and infiltrate stormwater from up to a ten-year storm in broad vegetated zones and deep soil buffers within the streetscape. The Neighborhood Green Corridor is designed to meet all NYC DEP and DOT requirements and is particularly well suited for areas of the City where changes in land use from former industrial buildings to residential enable reduction in roadway width.

Design development requires an integrated dialogue between ecology, hydrogeology, civil and environmental engineering, and soil science. The aim of this approach is to provide an innovative and cost-effective model for urban stormwater capture while simultaneously creating a more attractive and healthful landscape for local residents.

Project Goals

- Eliminate stormwater runoff from storms as large as a ten-year design storm.
- Reduce impervious surface area.
- Calm traffic and improve safety through narrowing the roadway.
- Provide as much planting as possible within the widened sidewalk.
- Provide pedestrian amenities including seating, bike racks, additional street lighting and bollards at driveways.
- Design to meet all DEP and DOT design standards and regulations.
- Use low-maintenance, salt-tolerant native species that are adapted to both wet and dry conditions.
- Save money on stormwater infrastructure improvements.
- Improve air quality through increased biomass.
- Enhance quality of life for community residents.

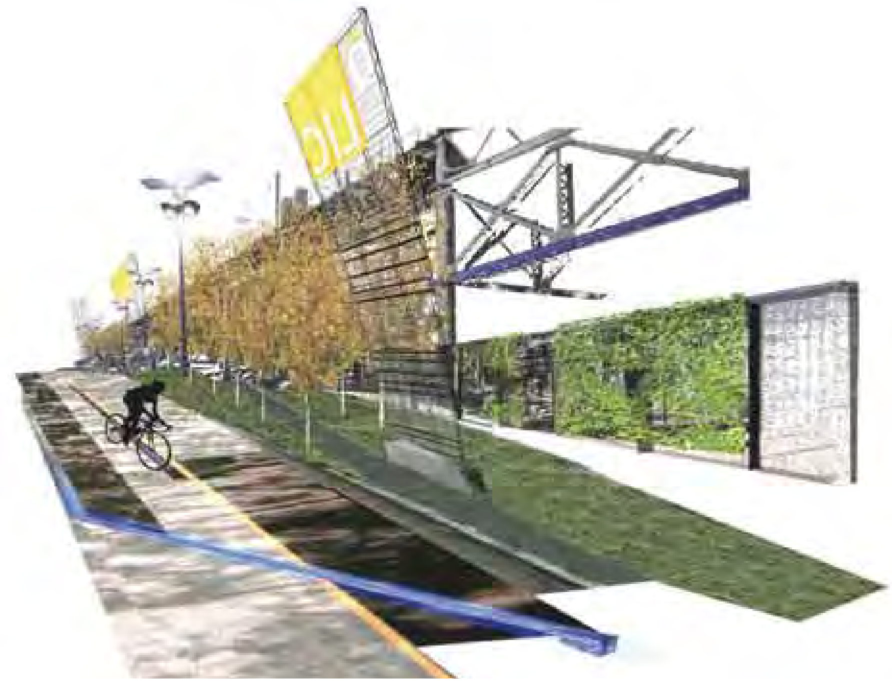
Project Challenges

- Accommodating driveways for truck access to remaining businesses along the corridor.
- Developing a solution for conditions where a significant longitudinal slope moves water too quickly for effective infiltration and plant root uptake.
- Selecting tree species that do not interfere with overhead utility lines.
- Mitigating the concern expressed by public agencies regarding maintenance and safety.

Project Outcomes

- An engineered soil was developed that allows for surface recharge of storm water using a gap graded stone and organic soil medium.
- For streets with a gradient in excess of 5%, below grade check dams slow the flow of stormwater to allow for greater infiltration and uptake of water by plant roots.
- A broad range of woody and herbaceous native plants have been selected for their tolerance of significant fluctuations in soil moisture. Wet tolerant species are located on the downhill side where water will collect behind the check dams while dry tolerant plants are located on the uphill side of the check dams.
- Plant material was also selected for tolerance to de-icing salts as well as a maximum height that, without pruning, will not become entangled in overhead utility lines.
- The hedgerow concept of planting within the widened sidewalk offers the opportunity to separate a bikeway from slower speed pedestrian movement along building faces. Periodic open joint pavers allow pedestrians to cross the planted zone.
- Pedestrian experience is enhanced by buffering noise and visibility of traffic while adding shade, improved air quality, and seasonal enjoyment of plantings.
- When situated near schools or community centers, the planted zones can be ‘adopted’ for ongoing maintenance and educational purposes.

EXAMPLE QUEENS PLAZA RECONSTRUCTION



Location: East River to the Tompson Van Dam Intersection, Long Island City, NY
Client: NYC Department of City Planning, NYC Economic Development Corporation
Completed: Design Completed in 2005; Implementation Pending Funding
Designer: Margie Ruddick Landscape Planning and Design
Project Cost: $18-$22 Million

A team of designers, engineers, scientists, and artists is introducing a new landscape at Queens Plaza, where the Queensboro Bridge sets down in Long Island City. The team has conceived the site as an urban green machine; two new urban parks as well as an overall greening of the massive urban infrastructure are included in the scope. New structures will be designed to latch on to, cut through, build under, grow over, and link vertically, in order to make use of interstitial spaces and underused sites. Slivers of green, patchwork gardens, and strips of water retention, all working within restructured patterns of movement, will reinvent the site, providing layers of vegetation to clean air and stormwater and mitigate noise pollution.

The design presents a clear, simple, and buildable vocabulary that will enhance and amplify what is most compelling about Queens Plaza – its industrial character and history, the interweaving of its infrastructure, and the existing green systems of the alley along Queensbridge Houses and the waterfront – while improving environmental conditions, increasing the legibility of the landscape and streetscape, and reuniting the Dutch Kills and Hunter's Point Neighborhoods.

Project Goals

- Improve the site's legibility, accessibility, and connectivity.
- Increasing public space for pedestrians and bikers.
- Treat and celebrate the area's infrastructure.
- Dramatically green the area to create a series of useful and beautiful places for relaxation, recreation, and circulation.
- Create a streetscape environment that emphasizes rhythm and continuity to ameliorate the chaotic existing conditions.
- Transform this gateway to Queens and Long Island City with an overall artistic and environmental design.

Project Challenges

- Massive site infrastructure consists of up to 14 lanes of traffic, multiple subway lines including the convergence of two elevated subway structures, and the landing of the Queensboro Bridge and associated ramp structures.
- Extensive network of utility lines and existing structural footings create conflicts for water management and greening strategies.
- Concern by City agencies over increased maintenance needs.
- Multiple agency approvals and jurisdictions.

Project Outcomes

- A system of local water retention planting strips will visibly collect surface stormwater from major public spaces as well as mitigate stormwater outfalls from elevated subway stations and the Queensboro Bridge that currently empty into the street and contribute to flooding and erosion.
- The main site-wide pavement strategy plans to use light colored high albedo asphalt aggregates, recycled asphalt from roadway reconstruction, and reused demolition material for the sub-base.
- Tree, shrub, and grass species have been selected to reference historical landscape types such as wetland and upland conditions that were common to the area before development; all plants are also selected for drought, salt, and pollution tolerance.
- Vegetated berms are used to separate pedestrians and bikers from traffic lanes to reduce exposure to noise and air pollution as well as to clarify points of crossing.
- A bike lane is planned from the landing of the Queensboro Bridge bike lane to connect both east and west to existing and future bike lanes and greenways.
- Existing elevated structures will be highlighted with light and mesh scrims to define the streetscape as a cohesive space, transforming an otherwise negative piece of urban infrastructure into an icon to be celebrated.
- Vertical axis wind turbines are being considered for the East River Waterfront as well as along the viaduct above Sunnyside Yards, where wind may help to generate a small amount of electricity to power streetscape lighting.
- Community groups are actively participating in the planning and design process.

IMPLEMENTATION

BARRIERS

A number of institutional constraints pose challenges to the process of mainstreaming high performance infrastructure practices:

Lack of 'integrated' asset management: Roadway improvements, tree planting, storm water management, and utility trenching are often conceived, budgeted, and executed in isolation from each other, with separate agency priorities and often contradictory mandates. Utility companies, private development, and public agencies that narrowly perceive their own mission make it difficult for cities to obtain the long-term synergies and economies of integrated right-of-way design. Worse still, this leads to frequent doing, undoing and redoing of right-of-way work.

Difficulty funding incremental first cost: Appropriate planning and budgeting mechanisms must be created to encourage and underwrite citywide implementation of high performance infrastructure practices. The high cost of capital makes any funding increases challenging to obtain. Creative financing for streetscape improvements should be considered, including shared public/private capital funding. Partnering mechanisms should be developed to encourage local voluntary groups to accept stewardship of low–risk improvements and limited responsibility/liability for maintenance. To affect this, cities should consider a tiered system of 'shared' maintenance agreements.

Difficulty funding additional maintenance costs: Some BMPs may require routine preventative maintenance to remain effective, particularly those that integrate with natural systems. For most governments, necessary expense budget funds are the scarcest. Nonetheless, lifecycle cost analysis factoring in the environmental and social benefits of long-term upkeep will reveal the economic efficacy of proper streetscape maintenance.

Perception of risk and lack of local precedent: The uniqueness or perceived complexity of a non-conventional system may be viewed as a liability. Because of relatively limited data on successful high performance infrastructure projects, many strategies may be easily dismissed as unproven or too costly. NYC is increasing the pace and scope of its infrastructure pilot projects to demonstrate the feasibility of many strategies.[31]

Learning curve for the construction industry: Knowledge of environmentally progressive design and construction strategies is not sufficiently widespread among design and construction firms to optimize the right-of-way design on a consistent basis.

OPPORTUNITIES

New York City's revitalized neighborhoods and business communities are indicators of its economic health. Several ambitious redevelopment projects in progress demonstrate an emerging trend towards mixed-use, pedestrian-oriented planning, including:

- Restoration and enhancement of lower Manhattan.
- Implementation of a vision for Hudson Yards on Manhattan's west side.
- Streetscape improvements and economic development initiatives along the entire 125th Street corridor in Harlem.
- Redevelopments of Governors Island and the Brooklyn waterfront in the East River.
- Strengthening of regional business districts in downtown Brooklyn, Jamaica, Flushing, and Long Island City.

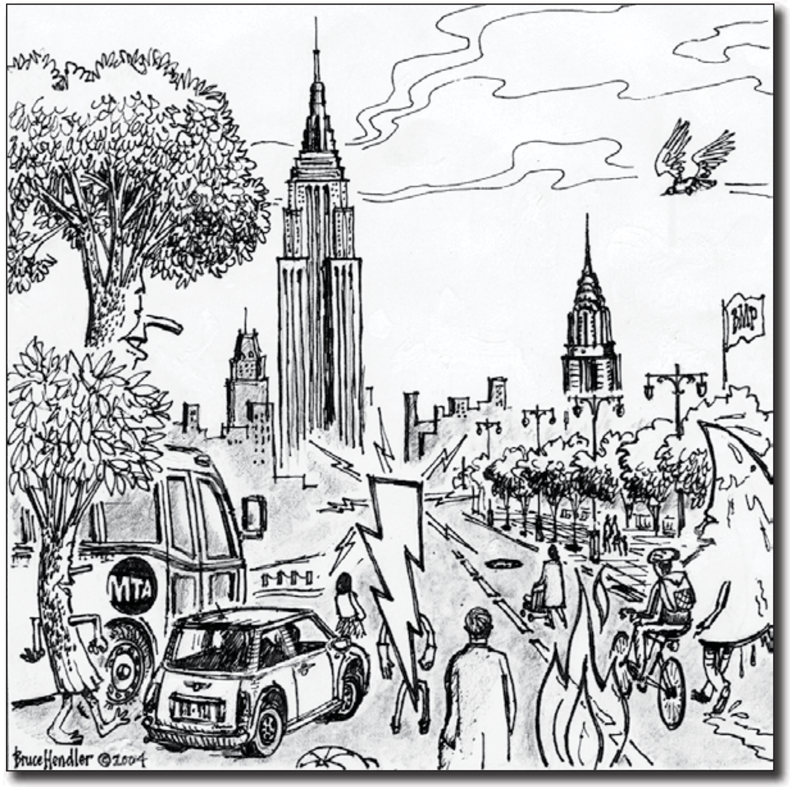
These large-scale investments represent an unprecedented opportunity to comprehensively upgrade the right-of-way using high performance best practices, thereby promoting environmental, social and economic benefits for significant areas of the City.

As the City adopts sustainability and high performance as a core management outlook for its construction, planning, and economic development agencies, it will increasingly need to draw upon the collective intelligence of agency leadership, the real estate development sector, and the local professional community to employ innovative solutions holistically across all public and private construction programs.

Public works account for a large percentage of the metropolitan region's construction economy. As a significant consumer of technical services, the Department of Design and Construction will help accelerate the introduction of high performance infrastructure practices, while growing the market for competitively-priced, environmentally sound products. Thus, from an economic development standpoint, proficiency with high performance concepts, technologies, materials and procedures will help ensure the New York City construction industry's continuing prominence in global markets.

Through use of this manual as a policy instrument, the City can encourage residential and commercial developers to undertake high performance objectives as an integral component of New York's real estate renaissance. Each of the major public/private initiatives mentioned above represents an unprecedented opportunity to undertake integrated planning, execute best practices, and develop exceptional designs. These projects will become models for high performance infrastructure and urban design excellence in the future.

31 As part of the development of the *Guidelines*, the Design Trust and DDC held a forum on March 11, 2004 to share information on progressive infrastructure initiatives in the region.



THE PUBLIC RIGHT-OF-WAY

PART TWO
CITY PROCESS

DESCRIPTION OF EXISTING PROCESS

The design and construction of New York City's infrastructure projects requires extensive coordination among multiple City agencies and other entities that own, lease, operate or maintain utilities in the right-of-way. Infrastructure spending comprises the largest percentage of the City's capital expenditures, in all totaling 57% of all allocations in the Mayor's current Ten Year Capital Improvement Plan. In Fiscal Year 2003, DDC managed a portfolio of over $2.18 billion worth of infrastructure capital projects.

Infrastructure spending is primarily allocated to the Department of Transportation (DOT) and the Department of Environmental Protection (DEP), with DOT managing much of the City's transportation infrastructure – streets, highways, sidewalks and bridges, street signs, traffic signals and street lighting – and DEP managing the City's water supply, watershed protection, wastewater management, noise, and hazardous materials. Other New York City agencies involved in infrastructure projects include the Department of City Planning (DCP) and the Department of Parks & Recreation. All of these agencies are considered 'client agencies' of the Department of Design and Construction, which is mandated by the City charter to provide design and construction services for all of the City's capital improvement projects.

This section is divided into three parts. The first outlines the current process of executing capital infrastructure projects, which occurs in three phases: 1) capital planning and project initiation, 2) preliminary design investigation, and 3) final design. The second part discusses 'Near-Term High Performance Objectives,' which can be realized immediately by augmenting the existing City processes. The third section discusses 'Longer-term High Performance Objectives,' which may require broad consensus among stakeholders and public officials to attain administrative and process changes to the infrastructure management process, as well as the introduction of alternative financing mechanisms. The near-term and longer-term objectives share a common requirement: for the City to maximize benefits, high performance practices must be scoped, planned, budgeted for, and coordinated in an interagency context as early as possible, and must be continually refined throughout the entire process.

Capital Planning and Project Initiation

DDC's client agencies develop ten-year Capital Improvement Plans that prioritize potential capital projects based on the agency's assessment of current inventories, maintenance requirements, census and demographic data, complaint history, community board requests, environmental conditions, and mandates. City agencies are then allocated an annual discretionary budget with which they are authorized to develop and fund priority capital projects; larger projects with individual budgets exceeding $5 million are subject to interim review by the Office of Management and Budget (OMB), which ultimately authorizes project funding.

Once client agencies have identified a need for service, they demarcate the limits of the project, prepare a project scope with identified funding lines, and submit it to the DDC as the Capital Project Initiation (CPI) report. Close coordination is often required between the DOT and the DEP in order to prepare the CPI document. DDC reviews the CPI, ensuring a valid scope of work, resolving any uncertainties regarding project limits, and suggesting necessary modifications.

Typical infrastructure capital project types

Projects with minimal impact or need for coordination:

- Resurfacing Projects
- Pedestrian Ramp Projects
- Sidewalk Reconstruction Projects
- Miscellaneous Structural Work *(Retaining walls, bulkheads, step streets)*

Projects with considerable impact and need for coordination:

- Sewer/Water Main Installation or Rehabilitation
- Emergency Repair Work
- Roadway Reconstruction Projects *(typically includes utilities, pavement, curb, sidewalks, street lighting, traffic signals, and fire alarms).*

Preliminary Design Investigation

The Preliminary Design Investigation (PDI) phase has two components:

1) data collection and analysis, and
2) schematic geometric design.

Small and uncomplicated projects – about 25 to 30% of DDC's projects – may bypass the PDI phase and move directly to Final Design.

Data Collection and Analysis

- Topographic and utility surveys: Production of base, topographic, and utility location drawings.
- Traffic counts and studies: Assessment of present level of service and accident analysis. Analysis of the need for, and impact of, comprehensive intersection controls, traffic calming measures, lane reconfigurations, and street geometry changes. Recommendations made to the DOT for accident mitigation measures and traffic.
- Investigation of Street Elements: Investigation of the condition of pavement, curbs, traffic markings, etc. Causal determination of any existing deterioration. Confirmation or modification of CPI work proposal.
- Concerns and Requirements: Consideration of needs of other agencies owning or operating facilities within the right-of-way, as well as the community board.
- Tree Inventories.
- Manhole and Catch Basin Inventories.
- Soils Investigation.

Schematic Geometric Design

- Pavement Design: Layout of roadway using AASHTO and other design methods, based on available soil support, traffic conditions, presence of utilities and other urban elements, and duration of serviceability.
- Impact Assessments: Preliminary Environmental Impact Assessment, Tree Assessment, and Utility Assessment

Several alternate geometric designs are developed and analyzed for social, economic, and environmental impacts. The designs must safely accommodate the projected traffic volumes for the specified time duration and level of service.

If it is determined that a project will result in environmental impact, a review process must be undertaken, beginning with the preparation of the New York State-mandated Environmental Assessment Statement (EAS). If the EAS determines the possibility of significant impact, a more in depth Environmental Impact Statement (EIS) must be prepared and reviewed by relevant parties. The EIS discusses a project's environmental and social impacts, considers alternative solutions, and determines appropriate mitigation measures. The EIS analyzes land use, natural resources, water quality, ecology, habitat, economic context, historic and archaeological significance, infrastructure and energy, hazardous materials, noise and traffic, and economics. Once the EIS is approved, the project typically proceeds.

At the conclusion of the PDI and environmental review process, a specific design, and any necessary mitigation measures, are recommended and presented to the local community board. Once the PDI is completed and approved, a reference document containing a project narrative, drawings, and analysis is prepared and the project proceeds to Final Design.

Final Design

In Final Design, conceptual decisions made during the PDI are fully detailed and coordinated with other right-of-way stakeholders. Construction drawings are developed for roadway alignment, grading, sewer and water main design, street drainage, and any additional work. Several mailings are sent out and meetings conducted with stakeholders to ensure appropriate coordination, design and construction. An alignment meeting is held with private utility companies to identify and resolve utility interferences, and cost-sharing arrangements are made between the City and utilities. Plans, cost estimates and specifications for bidding are developed. Final review by relevant agencies, utilities, the Art Commission and the Landmark Commission is undertaken.

Once all coordination issues are resolved, the final scoping, cost estimate, and specifications are prepared and reviewed by the Office of Management and Budget (OMB) and DDC's legal department. After approval, OMB issues a Certificate to Proceed (CP), which allows the City Comptroller to register the project and furnish capital funding. After contract documents are finalized, a contractor is selected in an open competitive bid. Permits are obtained and construction work may begin.

'NEAR-TERM' HIGH PERFORMANCE OBJECTIVES

Capital Planning and Project Initiation

Include executing agencies in CIP planning process: Improve mechanisms to coordinate asset management data, and utilize the perspective and expertise of DDC to assist the client agency decision-makers in incorporating high performance objectives into the Ten Year Capital Improvement Program (CIP) planning process.

Initiate pilot projects: Undertake pilot projects to evaluate whether emerging technologies or best management practices meet New York City's stringent performance requirements. Develop monitoring criteria to quantify performance of pilot projects. Pilot projects may be initiated at the client agency or DDC level.

Prepare a High Performance Matrix:[32] Utilize a relational database for each project as the primary consensus document for recording and tracking decisions. Use of the matrix during budgeting, scoping, planning and design will facilitate collaboration among City agencies and will ensure that consideration of high performance objectives is fully integrated into the infrastructure production process. Use of the matrix provides a legacy document that tracks emerging practices, monitors research efforts, and eventually leads to the full implementation of best practices.

Adequately budget to design and build high performance projects: The development of high performance projects may require the provision of additional technical and consultant expertise, testing, or specialized construction practices in order to maximize benefits, so it is crucial to budget accordingly. Where projects involve interagency collaboration, ensure adequate inter-fund agreement (IFA) time is budgeted at each agency.

Plan and budget for maintenance and monitoring: Coordinate with maintenance divisions within the client agency to ensure provision of appropriate levels of funding for post-construction monitoring, preventative maintenance, corrective maintenance, and periodic condition assessment. Consider using a 'progress payment schedule' to ensure contractors comply with special requirements.

Preliminary Design Investigation

Augment data collection and analysis with the following BMPs:

- Assess Site and High Performance Opportunities. **(SA.1)**
- Conduct Soil Analysis. **(SA.2)**
- Conduct Hydrologic and Hydraulic Analysis. **(SA.3)**
- Survey Existing Vegetation. **(SA.4)**
- Work with Community Groups to Enhance and Maintain Streetscape. **(SS.1)**

Identify and prioritize high performance objectives in the kickoff meeting: Establish and prioritize high performance objectives concurrently with determining project goals, budget, scope, and schedule.

Incorporate high performance measures into geometric design alternatives.

32 See "Assess Site and High Performance Opportunitites" (SA.1) for more details.

Prepare a preliminary high performance memorandum: Analyze the environmental, social, and economic benefits of each BMP alternative, and present as part of the PDI report.

Final Design

Finalize the high performance memorandum: Prepare a narrative describing how the project addresses key high performance criteria established during preliminary design. The memorandum ensures communication about, and fulfillment of, the project's goals for high performance. Distribute memorandum as part of the initial mass mailing.

Discuss and coordinate high performance practices with stakeholders: Discuss at the alignment meeting and other meetings and review forums.

Develop specifications, cost estimates, drawings and other relevant materials to implement high performance practices.

Ensure that the contract drawings and specifications comply with high performance objectives.

'LONGER-TERM' HIGH PERFORMANCE OBJECTIVES

Capital Planning and Project Initiation

Utilize high performance criteria to identify and prioritize CIP projects: During the CIP process, prioritize projects that will provide the greatest environmental, social and economic benefits to the agency and the City. Analyze quality of service, synergy with other local projects, ability to reduce infrastructure loads or increase lifecycle, reduction of long-term maintenance, and opportunity to measure efficacy of experimental BMPs.

Achieve integrated infrastructure planning and implementation: Use interdisciplinary integrated design management approaches, consider pooling agency fiscal resources and co-sponsoring projects, and encourage public dialogue and partnership to maximize benefits.

Conduct coordinated asset management: Improve existing asset management processes to provide for more systematic, cost-effective, and environmentally sound management of right-of-way infrastructure components. Enhanced and coordinated asset management will result in extended infrastructure lifecycles, improved performance, more consistent levels of service, and better investment returns.[33]

Develop a secure system for shared information management: Link existing databases and geographic information systems (GIS) to monitor, evaluate, and make decisions about adjacent road, sewer, and water systems. Coordinate with other available data, including complaint reports, customer service records, maintenance data, financial and budgetary data, and condition assessment ratings. Update the data management plan periodically to reflect new needs and opportunities.

Expand the current condition assessment system to rate the condition and deterioration of each infrastructure asset, forecast its future performance, and assess the risk and benefits of different maintenance and upgrade scenarios. Use data to determine infrastructure renewal priorities and set benchmarks for improved performance.

Create infrastructure improvement districts: Based on economic, ecological and social criteria, coordinate among agencies to develop plans for comprehensive local infrastructure improvements. Develop partnerships with local community boards, business improvement districts, block associations, and streetscape gardening groups.

Develop a citywide high performance infrastructure master plan: Encourage innovative practices for citywide infrastructure management by developing a master plan that integrates the following objectives:

- Open space and habitat preservation or rehabilitation.
- Citywide landscape planning.
- Urban heat island mitigation.
- Air and water quality improvement objectives.
- Combined sewer overflow elimination.
- Watershed-based, land-use and stormwater management planning.
- Pedestrian, bicycling, and surface mass-transit initiatives.
- Traffic calming or traffic management initiatives.
- Economic development and city planning objectives.

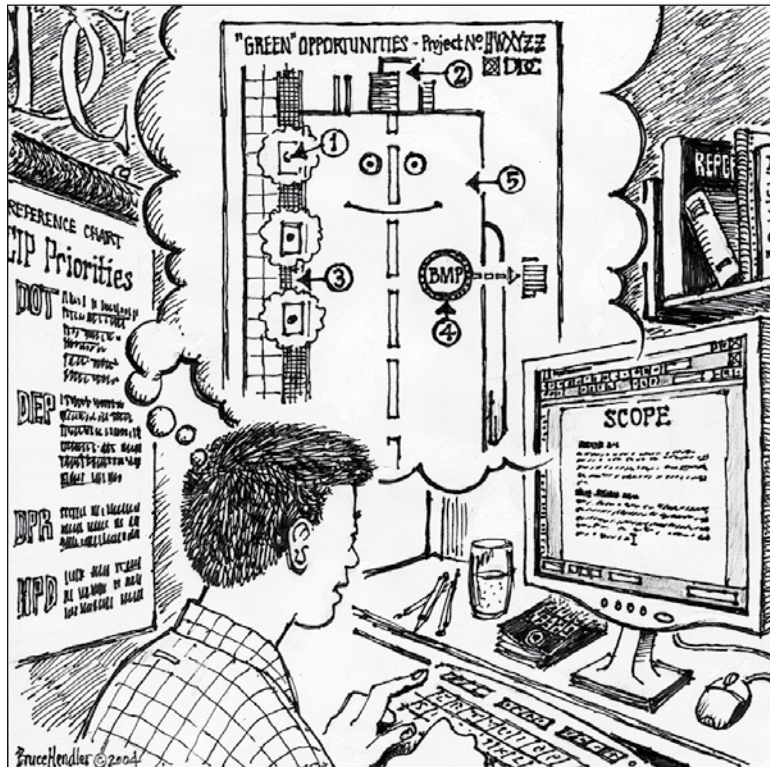
Preliminary Design Investigation

Perform lifecycle cost analysis (LCCA): Use lifecycle cost analysis in coordination with the high performance matrix to select the most cost-effective and environmentally beneficial methods of infrastructure rehabilitation. According to the Federal Transportation Equity Act for the 21st Century (TEA-21), LCCA is "a process for evaluating the total economic worth of a usable project segment by analyzing initial costs and discounted future costs, such as maintenance, user, reconstruction, rehabilitation, restoring and resurfacing costs, over the life of the project segment." Analyzing lifecycle costs is essential to achieving long-term goals for sustainability.

Final Design

Conduct a high performance workshop: At start of final design phase convene a meeting among DDC, client agencies, and consultants to implement high performance objectives. DDC may propose raising goals or pursuing alternative practices to meet the high performance objectives. The high performance matrix will be edited and distributed to all attendees as the final design 'High Performance Report'. Conduct a second workshop at the completion of the 75% contract documents to ensure compliance with, and coordination of, high performance strategies.

[33] The Canadian National Guide to Sustainable Municipal Infrastructure states that the goal of coordinated asset management is to 'spend the right amount of money, on the right things, at the right time, while minimizing economic, social and environmental costs.'



CITY PROCESS

PART THREE: BEST PRACTICES
SITE ASSESSMENT

SA.1
ASSESS SITE AND HIGH PERFORMANCE OPPORTUNITIES

OBJECTIVE

Assess the site and determine opportunities for implementing High Performance best management practices (BMPs) in the planning, design and construction of ROW projects.

BENEFITS

+ Improves environmental performance of infrastructure.
+ Improves public health, safety, and quality of life.
+ Optimizes municipal infrastructure investments.
+ Potentially reduces construction and operations costs.
+ Potentially reduces waste.

LIMITATIONS

– Increases need for up front coordination and potentially cost.
– Ineffective without coordination among various City agencies responsible for urban redevelopment and infrastructure construction.

INTEGRATION

- **SA.2** Conduct Soil Analysis
- **SA.3** Conduct Hydrologic and Hydraulic Analysis
- **SA.4** Survey Existing Vegetation
- **SS.1** Work with Community Groups to Enhance and Maintain Streetscape
- **SS.5** Increase and Improve Right-of-Way Public Space and Green Areas
- **SM.1** Conduct Integrated Stormwater Management Planning
- **LA.1** Optimize Citywide Landscape Planning

TECHNICAL STRATEGIES

Gather and analyze information about the site:
- Conduct workshops, interviews and surveys to gain perspective of community. **(SS.1)**
- Conduct on-site observations of user behavior and activities.
- Determine daily traffic counts and average travel speed.
- Document adjacent buildings, structures, and landforms and their effect on solar access and prevailing winds.
- Consider using time lapse filming or documentary photography.
- Incorporate data from site analysis into a citywide geographic information system (GIS) database that is coordinated with existing GIS information.
- Conduct soil analysis. **(SA.2)**
- Conduct hydrologic and hydraulic analysis. **(SA.3)**
- Survey existing vegetation. **(SA.4)**

Consider the proximity of the site to features that could reduce the need for, cost or impact of construction.
- Assess availability of existing materials that could be recycled or reused. **(PA. 6)**
- Assess alternative building scenarios for environmental, social and economic benefits.
- Assess possibilities for promoting local, sustainable urban ecology.

Develop and utilize a 'high performance matrix': Utilize a relational database for each major infrastructure project as an information management tool to coordinate the efforts of various participants in creating a high performance design.
- Utilize the matrix to analyze high performance design opportunities, site conditions, operations and maintenance considerations, and other feasibility issues.
- Utilize the matrix to facilitate communication and decision-making among diverse project participants. Record and track decisions.
- Use lifecycle analysis to determine the cost-effectiveness of competing options.
- Use the matrix as a legacy document to enhance knowledge gain, track emerging practices, monitor research efforts, and aid in future implementation of best practices.
- Use the matrix to help educate and motivate infrastructure planners regarding the possibilities of high performance design.

Plan and budget appropriately to accomplish and maintain high performance objectives. See individual BMPs for details.

Seek to minimize noise and disruption to the community. (CP.5)

Work with community groups to enhance and maintain streetscape. (SS.1)

EXAMPLE

The New York Metropolitan Transportation Authority, in collaboration with DMJM Harris and Arup, developed a sophisticated information management tool known as the "design for the environment" matrix to guide the preliminary design phase for the proposed Second Avenue Subway project. The matrix enabled hundreds of industry consultants and City stakeholders to work simultaneously at analyzing sustainable design opportunities, site conditions, operations and maintenance considerations, and other feasibility issues. The matrix facilitated and tracked communications and decision-making among a diverse group of participants. In the process, the matrix helped to educate and motivate infrastructure planners regarding the possibilities of high performance design. The result of the "design for the environment" endeavor was the creation of an innovative, cost-effective, and sustainable plan for the proposed subway expansion. The process is an impressive model for the planning of high performance infrastructure projects in the future.

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Metropolitan Transportation Authority
Second Avenue Subway Documents and Presentations Webpage
http://www.mta.nyc.ny.us/capconstr/sas/sas_documents.htm

SA.2 CONDUCT SOIL ANALYSIS

OBJECTIVE

During the preliminary design investigation, perform appropriate soil tests corresponding to BMP strategies. Different tests are necessary to ascertain planning and design responses as well as cost implications for
a) landscape,
b) stormwater management, and
c) susceptibility to erosion.

Assess soil test results for each category of BMPs and develop a comprehensive report that makes recommendations for proposed strategies.

BENEFITS

+ Aids in determining landscape and stormwater management design strategies and budgets early in the design process.
+ Reduces the long-term need for fertilizers and maintenance.
+ Predicts costs associated with on-site soil remediation, soil amendments, soil importation and excavation.
+ Minimizes environmental impact and costs associated with transporting and introducing imported topsoil or fill.
+ Aids in determining appropriate plant palette for revegetation.
+ Helps identify fragile soils and set limits on the use of heavy equipment, reducing soil disturbance.
+ Reduces risk of slope failure, erosion and siltation, and protects water bodies from sediment loading.

LIMITATIONS

– Soil tests add up-front cost to project.

INTEGRATION

- **SA.4** Conduct Hydrologic and Hydraulic Analysis
- **SA.4** Survey Existing Vegetation
- **PA.4** Use Pervious Pavements
- **SM.3** Minimize Runoff from New Building Construction and Major Renovations
- **SM.4** Optimize Right-of-Way Drainage
- **SM.5** Use Vegetated Filters and Buffer Strips
- **SM.9** Use Infiltration Structures
- **SM.10** Use Bioretention
- **SM.11** Use Constructed Wetlands
- **LA.2** Encourage Ecological Connectivity and Habitat
- **LA.3** Create Absorbent Landscapes
- **LA.4** Use Structural Soils Where Appropriate
- **LA.5** Amend Existing Soils
- **LA.6** Perform Soil Berming
- **LA.7** Increase the Quantity, Density and Diversity of Trees
- **LA.12** Use Low-maintenance, Salt-tolerant, Native or Naturalized Species
- **LA.13** Use Water-efficient Landscape Design
- **LA.14** Use Biointensive Integrated Pest Management
- **LA.15** Use Biotope-based Plant Arrangement Along Shade-Light Continuum
- **CP.2** Protect Existing and Future Planted Areas
- **CP.3** Protect Water Sources During Construction

TECHNICAL STRATEGIES

Planning

Develop a consistent testing and reporting protocol:
- Coordinate with testing laboratories prior to obtaining test reports.
- Request testing laboratory to compare test results with relevant ASTM standards and NYS DEC (or USEPA) standards.
- Prepare detailed logs for each test site showing locations, depth of test, soil descriptions, depth to water and bedrock, presence of stratification, testing standards and methods.
- Develop a comprehensive soils report that makes recommendations for each category of BMP.

Conduct tests for planting soils: Perform soil tests to determine nutrient levels, soil reaction, biologic composition and possible contaminants. These tests should be conducted by a qualified geotechnical engineer or soils scientist licensed in the State of New York. Tests should include the following:
- **Chemical tests:** Examine particle size analysis compared to USDA Soil Classification System per ASTM D422 (hydrometer test) or ASTM F1632 (pipette test). Silt and clay content to be determined on soil passing #270 sieve. Test for hydraulic conductivity per ASTM F1815. Determine amounts of nitrate, ammonium, nitrite,

phosphorous, potassium, calcium, magnesium, iron, manganese, zinc, copper, soluble salts, cation exchange capacity and pH.

- **Biological tests:** Obtain active bacterial biomass, total bacterial biomass, active fungal biomass, total fungal biomass, protozoa content, nematode count and hyphal diameter. Identify organic content by Ash Burn Test or Walkley/Black Test per ASTM F1647.
- **Contamination tests:** Test for molybdenum, aluminum, boron, lead, selenium, mercury, chromium, cadmium and PCB's, petroleum distillates and hydrocarbons in accordance with the testing methods of NYS DEC.
- **Drainage rate test:** Test for soil drainage rate using the hydrometer test or combined hydrometer and wetsieving method in accordance with ASTM D 422. Use this as a guide to measure pre- and post-construction drainage rates to allow attribution of responsibility for worsened conditions as a result of construction disturbance.

Tests For Landscape Health

Determine best strategy for planting soils: Suitable in-situ soils are those that fall within the following ranges without amendments:

- Soil: Sandy loam per USDA classification, ASTM D 422 or ASTM F 1632.
- Organic content: 3% minimum.
- Hydraulic conductivity: no less than 3 inches per hour.
- PH: 5.0 – 6.5 +/- 0.5.
- Soluble salt content: 0.08-0.50 mmhos/cm (dS/m).
- Carbon nitrogen ratio: 10:1 to 25:1.
- Contaminants: within NYSCEC or USEPA limits of acceptability for proposed site use.
- If in situ soils do not fall within these ranges, determine if they can be amended. **(LA.5)**
- Determine appropriate planting palette based on test results to minimize importation of amendments or new soil.

Tests For Stormwater Management

Perform tests for stormwater management design: Determine the site's suitability for stormwater management BMPs by taking soil borings to at least 5 to 10 feet below the underside of the proposed BMP. Take enough borings to obtain a comprehensive understanding of soil conditions surrounding the proposed BMP. Tests should include the following:

- **Standard penetration testing (SPT):** Test every 2' to a depth of 5' below the BMP bottom.
- **Soil classification:** Determine USDA or USC soil classification at the proposed facility bottom and 4' below the bottom.
- **Groundwater depth test:** Determine the depth to the groundwater table upon initial testing and then again after 24 hours.
- **Bedrock depth test**.
- **Soil gradation tests:** Perform enough tests to characterize soil strata across the entire facility. Conduct at least one soil gradation test per soil stratum. Describe all soil horizons.
- **Contamination tests:** Ensure that soil is not contaminated.
- Organic content and cation exchange capacity (CEC) tests: Ensure sufficiency of soil organic content and cation exchange capacity (CEC) to treat polluted runoff.
- **Infiltration tests and evaluation** (see next section).
- **See individual BMPs for more details.**

Determine if site is suitable for infiltration practices: Based on stormwater and hydrologic tests, ensure the site meets the following criteria for design of infiltration practices:

- Minimum infiltration rate of 0.5 inches per hour.
- Able to exfiltrate design storm water volume completely in time for the next storm, preferably within 24 hours.
- Sufficient organic content and cation exchange capacity (CEC).
- No contaminated soils.
- Sub-grade maintains structural stability with extended saturation or head loading.
- Sufficient clearance from the groundwater table, bedrock or impermeable soil layers.
- Sufficient clearance from building foundations, roads, subsurface infrastructure, drinking water wells, septic tanks or drain fields.
- Will not impact sensitive aquifers or violate groundwater quality standards.
- See "Use Infiltration Structures" **(SM.9)** and "Use Bioretention" **(SM.10)** for more details.

Coordinate results of stormwater management and infiltration testing with hydrologic and hydraulic analysis. (SA.3)

Tests For Erosion Prevention

Perform tests for susceptibility to erosion: Determine if any soils on site that are anticipated to be stripped, relocated or reused as fill are susceptible to erosion from natural forces. Tests should include the following:

- **Pinhole dispersion test:** Determine colloidal erosion tendencies of fine grained cohesive soils (clays) in accordance with ASTM D 4647 'Standard Method for Identification and Classification of Dispersive Clay Soils by the Pinhole Test'.
- **Crumb test:** Determine field performance of dispersive soils.
- **US Soil Conservation Service dispersion test:** Identify types and extent of dispersive clays.
- **Universal soil loss equation:** Use as a measure to predict erosion potential.

Determine strategies for erosion control during and post construction:

- **Pinhole dispersion test results:** Cloudy soil specimens indicate a likelihood of erosion.
- **Crumb test results:**
  Soils registering readings of 3 or 4 indicate a high likelihood of erosion.
- **US SCS test results:** Rates in excess of 50% indicate a significant likelihood of erosion.
- **Measure change** in surface water quality before, during and after construction to monitor efficacy of erosion control devices. Perform corrective action if evidence of turbidity in excess of pre-disturbance condition.
- Soils that exhibit a low susceptibility to erosion are suitable for creating on site berms and may also be suitable as planting soil depending on other test results. Timing of earthwork should be coordinated with optimum planting seasons to establish a vegetated cover to avoid erosion and sedimentation.
- Soils that exhibit a moderate susceptibility to erosion may also be suitable for on site reuse but should be immediately covered with a biodegradable erosion control blanket until such time as a vegetated cover becomes well established.

Forest Hills Station – Queens, NY
New landscaping for historic LIRR station required soil tests to determine type of soil conditioning required prior to selecting plants and writing specifications.

- Soils that exhibit a high susceptibility to erosion should, ideally, not be disturbed. They are likely to have a very poor bearing capacity as well as being very poor candidates for infiltration BMPs and cannot be amended for use as planting soils without significant cost of imported amendments.

Design

Use soil test data and assessment to aid in the following activities:

- Determination of suitability of soils for planting.
- Design of berms. **(LA.6, SM.10, SM.11)**
- Selection of plant material. **(LA.10 to LA.15)**
- Selection of soil amendments to produce viable growing medium. **(LA.5)** Seek to reduce long-term needs for fertilization and maintenance. **(LA.12, LA.14)**
- Identification of construction protection zones. **(CP.1)**
- Hydrologic and hydraulic analysis. **(SA.3)**
- Design of stormwater management BMPs. **(SM.5 to SM.11)**
- Selection of in-situ soil remediation strategy. **(LA.5)**

Incorporate data from soil analysis into a citywide geographic information system (GIS) database that is coordinated with existing geologic information.

EXAMPLE

Battery Park City, built completely on granular fill, must import planting soils for its new landscape projects. All landscape projects since 1992 require testing of imported, manufactured planting soils to meet specific soil characteristics using procedures cited in this BMP. The results, now proven in 90% of all its parkland (32 acres) are soils that are self-sustaining and require no chemical fertilizer applications.

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SA.3 CONDUCT HYDROLOGIC AND HYDRAULIC ANALYSIS

OBJECTIVE

Conduct hydrologic and hydraulic analysis of the site's existing and proposed conditions to determine stormwater management needs and high performance opportunities. Based on the analysis, design projects to minimize stormwater runoff and incorporate best management practices.

BENEFITS

+ Could enable downsizing stormwater infrastructure, resulting in capital cost savings.
+ Helps prevent unexpected flooding and downstream impact.
+ Helps optimize onsite stormwater management, resulting in reduced runoff and combined sewer overflows, and improved water quality and hydrology.

LIMITATIONS

– Adds up-front cost to projects.

BACKGROUND

Hydrology is the science that studies the "source, properties, distribution, and laws of water as it moves through its closed cycle on the earth (the hydrologic cycle)." Hydrologic analysis addresses and quantifies the "movement of rainfall over a defined piece of land in the form of stormwater runoff." Hydraulic analysis addresses and quantifies the movement of water through engineered structures.[34]

INTEGRATION

- **SA.2** Conduct Soil Analysis
- **PA.4** Use Pervious Pavements
- **SM.1** Conduct Integrated Stormwater Management Planning
- **SM.3** Minimize Runoff from New Building Construction and Major Renovations
- **SM.4** Optimize Right-of-Way Drainage
- **SM.5** Use Vegetated Filters and Buffer Strips
- **SM.6** Use Catch Basin Inserts
- **SM.7** Use Water Quality Inlets
- **SM.8** Use Detention Structures
- **SM.9** Use Infiltration Structures
- **SM.10** Use Bioretention
- **SM.11** Use Constructed Wetlands
- **LA.3** Create Absorbent Landscapes
- **CP.3** Protect Water Sources During Construction

TECHNICAL STRATEGIES

Perform a preliminary site evaluation:
- Conduct soil analysis. **(SA.2)**
- Analyze site history. Determine history of flooding, erosion, channelization, siltation, and sedimentation.
- Analyze site topography, vegetation, and urban context. **(SA.1, SA.4)**
- Consider the general feasibility and suitability of the site for best management practices.

Use a calibrated continuous simulation hydrologic model: For the design of stormwater management BMPs for major projects, use a calibrated continuous simulation hydrologic model based on EPA's Hydrologic Simulation Program-Fortran (HSPF), or best available technology.[35]

Analyze existing and proposed conditions: Analyze the following considerations, among others, across the entire site and drainage watershed:
- Runoff volumes, velocities, and rates.
- Patterns of water inflows and drainage outflows.
- Time of stormwater concentrations.
- Water surface elevations.
- Capacity and performance of existing stormwater infrastructure, including overflow and bypass infrastructure.
- Existing and potential downstream impacts from site runoff, including flooding, erosion, channelization, siltation, and sedimentation.

34 Definition from Washington State Department of Ecology.

35 According to the Washington State Department of Ecology, continuous simulation models are advantageous because they account for the storms that precede and follow the design storm, while single-event based models are only capable of considering the single design storm. Furthermore, continuous simulation models based on EPA's Hydrologic Simulation Program-Fortran incorporate local parameters and actual rainfall data, and are, therefore, a better estimation of actual runoff circumstances.

Use hydrologic and hydraulic data to design onsite stormwater management BMPs:
- Design site to maintain, restore or mimic natural drainage patterns. Seek to eliminate stormwater runoff. **(SM.3, SM.4)**
- Design stormwater management BMPs to control design storm at a minimum. If possible, provide additional detention capacity.
- If possible, design BMPs to provide onsite infiltration and/or retention.
- Design overflow or bypass system to manage runoff from large storms. **(SM.4)**

Use hydrologic and hydraulic data to minimize water pollution during construction. (CP.3)

Incorporate data from hydrologic and hydraulic analysis into a citywide geographic information system (GIS) database to aid in future planning.
- Coordinate with citywide drainage master planning activities. **(SM.1)**
- Consider allowing public use of this database.

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SA.4 SURVEY EXISTING VEGETATION

OBJECTIVE

Survey existing vegetation. Develop a plan for protecting existing plant material to preserve habitat, minimize site disturbance, and reduce capital costs for reinstallation of new plants. If necessary, determine opportunities for transplanting existing planting material. Eliminate invasive species to minimize long-term maintenance costs and protect preferred planting material.

BENEFITS

+ Mature tree specimens provide immediate shade, cover, and landscape character.
+ Mature tree specimens improve environmental quality by decreasing air and noise pollution, reducing and treating stormwater runoff, and reducing urban heat.
+ Reduces overall site disturbance.
+ Minimizes costs by reducing need for soil amendments and new plantings.
+ Reduces long-term maintenance needs and costs, protects desirable plants from becoming crowded or shaded out, and improves biodiversity and animal habitat.
+ Mass plantings of valuable or native species provide immediate windbreak, cover and protect against erosion and sedimentation.

LIMITATIONS

– Protection zones may limit contractor maneuverability on site and add cost to relocate protection fencing.
– Manual eradication of invasive species is time consuming and costly.
– Chemical eradication of invasive species can harm water quality or desirable species.

INTEGRATION

- **SA.2** Conduct Soil Analysis
- **SS.5** Increase and Improve Right-of-Way Public Space and Green Areas
- **SM.1** Conduct Integrated Stormwater Management Planning
- **SM.3** Minimize Runoff from New Building Construction and Major Renovations
- **SM.4** Optimize Right-of-Way Drainage
- **LA.1** Optimize Citywide Landscape Planning
- **LA.2** Encourage Ecological Connectivity and Habitat
- **LA.3** Create Absorbent Landscapes
- **LA.12** Use Low-maintenance, Salt-tolerant, Native or Naturalized Species
- **LA.13** Use Water-efficient Landscape Design
- **LA.15** Use Biotope-based Plant Arrangement Along the Shade-Light Continuum
- **CP.1** Develop and Enforce a Site Protection Plan
- **CP.2** Protect Existing and Future Planted Areas

TECHNICAL STRATEGIES

Planning

Perform a site visit to survey existing vegetation:

- Evaluate health and viability of valuable species.
- Identify and record individual specimen plantings and mass plantings to be protected during design and construction.
- Identify individual plants by species, caliper and crown extent.
- Note conditions that will impact protection (grading, utilities, access routes, etc).
- Identify physical extent and density of invasive species, and determine optimal eradication technique.
- Consider potential of transplanting beneficial on-site species.
- Discuss tree and vegetation protection plans at the alignment meeting and take necessary steps to coordinate utility work to reduce impact.

Develop a tree and vegetation protection plan:

- Prepare a tree protection plan providing protection within critical root zone (12 x diameter of diameter breast height (DBH)).
- Prepare a massed planting protection plan showing limit of shrub canopy or 12 x diameter of DBH of perimeter trees, whichever is greater.
- Illustrate protection plan(s) on all relevant site plans, including the site preparation/demolition/removals plan and on the grading and site utilities plans.
- Include designated stockpile location(s) and truck access route(s).
- Indicate on plans and in specifications that protection barriers may have to be relocated and reinstalled during construction to provide temporary access.
- Require contractor to maintain protection barrier in good condition throughout the life of the contract.
- Specify that under no circumstances shall material, equipment or debris be stockpiled within the protection zones.

- Require the use of grade beams and microtunneling to protect structural tree roots.
- Ensure that all disciplines respect the protection plan throughout the design process.

Develop a plan to eradicate invasive herbaceous species:
- Identify species to be eradicated.
- Understand invasive species' growth habit and identify optimal season(s) for eradication by hand or chemical means.
- Identify if permanent root barriers are required for long term protection of site.
- Specify contractor with experience and full-time supervisory personnel.
- Specify appropriate soil sterilant or non-residual systemic herbicide as applicable to the particular specie to be eradicated and the surrounding vegetation and hydrologic conditions. **(CP.2)**
- Request material safety data sheet on chemical treatment, if used.
- Specify that surrounding areas are to be protected from migration of chemical applications.
- Specify that all parts of invasive plants are to be removed from the site and disposed of legally.
- Exercise caution when using chemical treatment adjacent to aquifer, high quality water, etc.
- Protect water sources during construction. **(CP.3)**

Develop a plan for tree and vegetation removal and transplantation:
- Identify individual trees and shrubs for removal. Select species based on their relative invasiveness (as defined by NYSDEC or local experience), state of health/viability for survival, and conflict with proposed construction.
- Specify top-down tree cutting rather than felling to protect viable trees/vegetation.
- If possible, tree cutting during migration periods.
- Identify species for transplant and show new locations; identify root pruning and transplant procedures and timing in specifications.
- Require warrantee on transplants for two years.

Construction

- Perform root pruning of trees to be transplanted during dormant periods.
- Coordinate transplanting with seasonal limitations.
- Protect and maintain vegetation throughout construction duration. **(CP.2)**
- Enforce protection by specifying liquidated damages or imposing fines on contractor(s) for violations.

EXAMPLE

New York City Department of Parks and Recreation (NYCDPR) requires tree inventories and tree impact mitigation plans as part of any infrastructure project that may adversely impact existing vegetation. For new construction projects within sites exhibiting invasive vegetation, NYCDPR has developed standard specifications for invasive species eradication.

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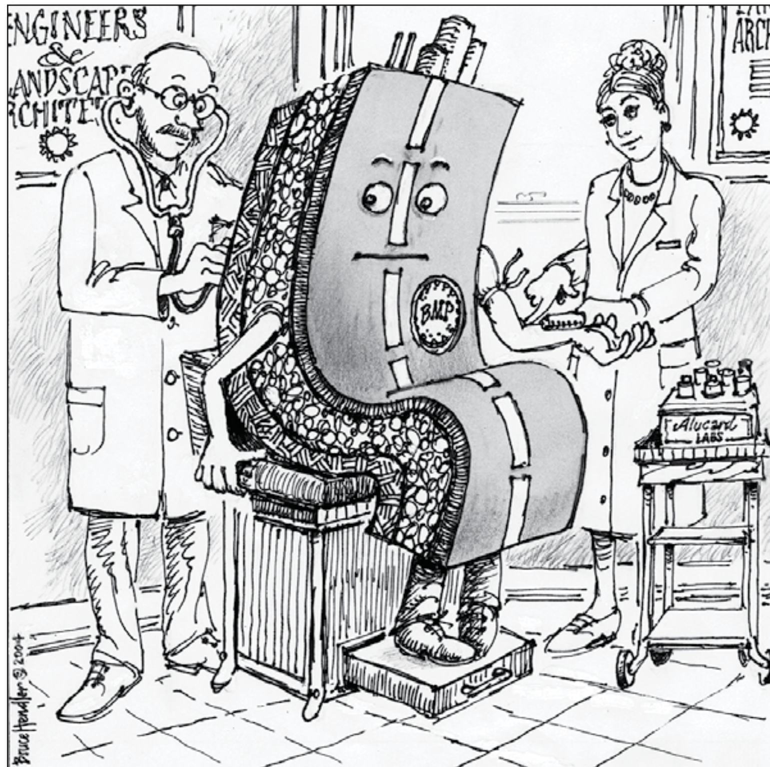

SITE ASSESSMENT

PART THREE: BEST PRACTICES
STREETSCAPE

SS.1
WORK WITH COMMUNITY GROUPS TO ENHANCE AND MAINTAIN STREETSCAPE

OBJECTIVE

As part of street reconstruction projects or area-wide planning initiatives, work with community groups, business improvement districts (BIDs), and key stakeholders to enhance and maintain streetscape.

BENEFITS

+ Encourages active community participation and ownership of improvements.
+ Partnership with BIDs is an effective way to enhance, beautify, and maintain the streetscape environment.
+ BIDs and community groups may have the ability to maintain non-standard pedestrian amenities and landscaped areas.
+ BIDs are effective at encouraging active street life through minimizing retail vacancy, providing security patrols and trash collection, and offering shopkeepers assistance loans to enhance signage and security.

LIMITATIONS

– Disagreement among various stakeholders may prolong the planning process.
– Too many BIDs within close physical proximity may cause visual confusion through inconsistency in streetscape furnishings.
– NYC Department of Small Business Services (NYCSBS) needs to enforce regulations and agreements with BIDs to ensure guidelines are followed.

BACKGROUND

Involving community members and key stakeholders in the process of improving and maintaining streetscapes is critical to long-term success. In recent years, New York City has had particular success working with business improvement districts (BIDs) and private community groups to plan, undertake, and maintain streetscape improvements. These models of public-private partnership should be replicated wherever possible.

INTEGRATION

- **SA.2** Conduct Soil Analysis
- **SA.1** Assess Ste and High Performance Opportunities
- **SS.2** Improve Streetscape for Pedestrians
- **SS.3** Improve Streetscape for Bicyclists
- **SS.4** Improve Streetscape for Surface Mass Transit
- **SS.5** Increase and Improve Right-of-Way Public Space and Green Areas
- **SS.6** Optimize Security Enhancements
- **SS.7** Optimize Streetlighting and Signaling
- **PA.2** Minimize Impervious Pavement Area
- **SM.1** Conduct Integrated Stormwater Management Planning
- **SM.4** Optimize Right-of-Way Drainage
- **LA.1** Optimize Citywide Landscape Planning
- **LA.7** Increase the Quantity, Density, and Diversity of Trees

TECHNICAL STRATEGIES

Planning

Assess site and high performance opportunities. (SA.1)

Undertake a community-based planning process:
- Identify a cross-section of community stakeholders and establish a task force.
- Gather historical data about neighborhood and identify critical issues for the future.
- Develop strategic goals and a shared vision.
- Evaluate various improvement options and involve community members in decision-making whenever possible.
- Maintain active participation throughout the planning and design process.
- Encourage ongoing community stewardship of improvements.
- Develop partnerships to manage and maintain improvements.

Consider developing a Business Improvement District (BID):
- Develop a project plan among stakeholders to determine if a BID is appropriate.
- Develop a steering committee. Conduct public meetings and hold them regularly to maintain an informed constituency.
- Determine boundary of district.
- Survey local businesses and develop a database.
- Determine needed services and improvements and their scope and cost; Identify potential funding sources.
- Determine assessment formula and submit it to NYC Department of Small Business Services.

Reconstructed Greenwich Street – Manhattan, NY

Consider developing partnerships with community groups to maintain and manage streetscapes:

- Encourage the formation of 501(c)(3) not-for profit community park maintenance groups.
- Use flexibility when developing maintenance agreements with community groups.
- Consider establishing prizes and other incentives to encourage exceptional streetscape maintenance.

Construction

- Work with community groups to develop plans to minimize construction impact. (SA.1, CP.1, CP.5)

Operations and Maintenance

- After project completion, ensure proper maintenance and upkeep of streetscape improvements.
- Overtime evaluate and respond to new or changing community needs.
- Develop more flexible maintenance contracts to encourage community participation in streetscape upkeep.

EXAMPLE

Greening of Greenwich Street: The Friends of Greenwich Street, a local community group, lobbied for nearly a decade to have changes made to an eight-block stretch of Tribeca. The 110-foot right-of-way was a holdover from the days when Greenwich Street was a major truck route and an overhead railroad to transport goods from the waterfront to inland warehouses. In 1996, NYC Economic Development Corporation funded a streetscape improvement project to narrow the roadway to 38 feet from 80 feet, and to add forty-two feet to the west side sidewalk.

Today, Greenwich Street has been reclaimed as a neighborhood street. Festivals and parades are frequent occurrences, parents teach children to ride bikes and residents of all ages enjoy the sunny or shaded sitting areas. The Friends of Greenwich Street have become a 501(c)(3) not-for-profit maintenance corporation and oversee landscape maintenance, public education programs to curtail dog damage, de-icing salt spreading and seasonal plantings.

Reconstructed Greenwich Street – Manhattan, NY

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SS.2 IMPROVE STREETSCAPE FOR PEDESTRIANS

OBJECTIVE

Design streetscapes that are conducive to walking and that optimally balance the needs of pedestrians, bicyclists, mass-transit users, and automobiles. Undertake physical improvements and management measures to improve quality of life, health and safety, accessibility, connectivity, comfort, amenity and aesthetics.

BENEFITS

+ Minimizes conflicts between pedestrians and vehicles, making the experience of walking safer and more enjoyable.
+ Reduces vehicle miles traveled (VMT), automobile congestion, and air pollution.[36]
+ Improves public health by encouraging exercise and active forms of transportation.
+ Attracts pedestrians to local businesses, reduces crime, and increases property values. Serves as a catalyst for community regeneration.
+ Well-proportioned sidewalks include space for plantings that reduce the urban heat island effect, improve air quality and local microclimate, and add scale and beauty.
+ Restores urban streetscapes that were degraded by excessive automobile activity.
+ When designed appropriately, streetscape improvements and traffic calming measures do not adversely impact motorized traffic or emergency vehicle service.[37]
+ Encourages the efficient use of precious right-of-way space.

LIMITATIONS

– May increase project design, construction and maintenance cost.
– Acquisition of additional sidewalk space may be cost prohibitive or unfeasible.
– May require the relocation of catch basins.[38]
– Maintenance of non-standard street materials is difficult due to frequent utility repairs.
– Isolated traffic calming treatments may only divert traffic problems.[39]

BACKGROUND

Over recent decades, accommodation of automobiles has usurped public space, corroded health and safety, and visually degraded the urban fabric. The *High Performance Infrastructure Guidelines* seek to correct this condition by advocating for streetscapes that balance the needs of pedestrians, bicyclists, surface mass transit users, and automobiles. The NYC Department of Transportation has envisioned three typologies for well-designed streetscapes:[40]

Travel Streets are large scale, multiple-lane thoroughfares that make up the skeleton of the roadway system. Travel streets provide critical transportation connections, major mass-transit links, and local truck-routes; they also accommodate substantial pedestrian activity and contain commercial, cultural, institutional, and occasionally residential building types. Despite their importance for private automobiles, travel streets must also facilitate safe and comfortable movement for pedestrians, bicycles, and surface mass-transit. Travel streets should enhance connectivity between different neighborhoods, destinations, and other major streets – not pose a barrier – and should therefore offer attractive and spacious streetscape environments. Travel streets should incorporate traffic calming and management measures to promote efficient travel, minimize congestion, and ensure safety.

Community Streets are medium to large scale streets that serve as 'town centers' for neighborhoods and business districts, and are usually fronted by mixed commercial, institutional and residential uses. Community streets often link travel streets with living streets. Pedestrian activity is substantial on community streets since they offer a range of destinations including shopping, entertainment, dining, services, cultural centers, mass-transit connections, parks and public spaces. Private vehicle travel is also substantial, but truck travel should be minimal. Design of community streets should reflect a careful balance between vehicular travel, bicycling, and pedestrian activity. As 'town centers', community streets should be attractively landscaped, well-lit, amenity-rich, active places that encourage civic engagement, commerce, cultural activity, and social exchange.

Living Streets are narrow streets that are primarily residential and are not intended as major transit routes. Quality of life and safety for pedestrians and residents is the major concern, and impact of motor vehicles should be kept to a minimum. Traffic calming measures should be substantial to minimize vehicle speeds, discourage through-traffic and truck travel, and minimize disruption. Streetscapes should provide attractive landscapes and gathering places, and offer pedestrian scale lighting to create a safe nighttime environment. Bicycling and other forms of active transportation and exercise should be highly encouraged.

36 New York City Department of Transportation. 2004. Downtown Brooklyn Traffic Calming Project – Final Report. http://www.nyc.gov/html/dot/html/motorist/dntnbklyntraf.html. (Accessed June 2004). Pages 45-68.

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40 Street typologies adapted from Downtown Brooklyn Traffic Calming Final Report (NYCDOT).

Union Square – New York, NY
Enlargement of traffic island decreases roadway pavement, increases landscaping and provides safe pedestrian crossing at a busy thoroughfare.

INTEGRATION

- **SA.1** Assess Ste and High Performance Opportunities
- **SS.1** Work with Community Groups to Enhance and Maintain Streetscape
- **SS.3** Improve Streetscape for Bicyclists
- **SS.4** Improve Streetscape for Surface Mass Transit
- **SS.5** Increase and Improve Right-of-Way Public Space and Green Areas
- **SS.6** Optimize Security Enhancements
- **SS.7** Optimize Streetlighting and Signaling
- **PA.2** Minimize Impervious Pavement Area
- **LA.1** Optimize Citywide Landscape Planning
- **LA.7** Increase the Quantity, Density, and Diversity of Trees

TECHNICAL STRATEGIES

Site Assessment

Assess site and high performance opportunities. **(SA.1, SS.1)**

Evaluate pedestrian and vehicular movement:
- Evaluate pedestrian volumes and movement.
- Evaluate vehicular activity, conduct traffic counts, and determine needs for traffic calming or traffic management.
- Evaluate bicycle and non-motorized vehicle traffic. Determine need for streetscape improvements to encourage active transportation.
- Anticipate future pedestrian volumes and determine appropriate level of service.
- Consider increasing pedestrian level of service, comfort and protection.
- Consider reducing automobile level of service or design speed.

Planning

Develop a master plan that incorporates some or all of the following practices:
- Area wide traffic management and traffic calming.
- Bicycling facilities. **(SS.3)**
- Surface mass transit improvements. **(SS.4)**
- Public space, street furniture and green areas. **(SS.5)**
- Security enhancements. **(SS.6)**
- Streetlighting and signaling. **(SS.7)**

Integrate other high performance objectives into the planning process.
- Improve on-site stormwater management and minimize runoff. **(SM.1 to SM.11)**
- Undertake additional utility work to minimize future impact. **(UI.1)**
- Improve utility coordination for easy access and maintenance. **(UI.3)**
- Design to reduce urban heat island effect: Maximize pavement albedo **(PA.3)** and increase shading of pavement. **(LA.8)**
- Use pervious pavements where appropriate. **(PA.4)**
- Maximize landscaping to improve microclimate, air quality, stormwater management, etc. **(SS.5, LA.1, LA.2, LA.3, SM.1)**

Conduct scoping and budgeting:
- Develop project scope based on community planning process, infrastructure reconstruction or upgrade needs, and high performance objectives.
- Identify first costs, maintenance costs, maintenance entities, and funding sources.
- Coordinate proposed improvements with other publicly funded initiatives to maximize effective use of funds.
- Ensure adequate funds for timely preventative and corrective maintenance.

Design

Sidewalks

Enhance sidewalk accessibility, continuity and connectivity:
- Plan sidewalk dimensions and layout on a district-wide scale.
- Develop a strong pedestrian orientation and character to the streetscape to encourage walking and active environments.
- Promote connectivity, continuity and accessibility.

Provide adequately sized sidewalks:
- Determine the width of the 'through pedestrian zone', or the area that accommodates unobstructed movement between a 'furnishing zone' (the area adjacent to the street containing street furniture, trees and landscaping, light poles, signage, etc) and a 'frontage zone' (the area adjacent to storefronts that

accommodates window shopping and entrance facilities).

- Eliminate obstructions in the pedestrian zone and ensure ADA compliance wherever possible, with a minimum clear width of five feet.
- Where appropriate, allow eight feet of pedestrian space to enable two pairs of pedestrians to pass each other comfortably.
- Ensure furnishing zone is wide enough to accommodate trees and landscaping, bus shelters, street furniture, and other amenities.
- Where the curbside lane is a travel lane, attempt to provide a buffer zone or planting strip of at least four feet.

Consider expanding sidewalks to enhance pedestrian safety and level of service:

- Consider reducing roadway space and widening sidewalks.
- Downsize travel lanes and parking lanes to minimum sizes.
- If the entire sidewalk cannot be modified, consider widening at congested locations, intersections, entrances to major destinations, etc.

Corners and Intersections

Keep corners clear of obstructions:

- Prohibit newspaper boxes and other street furniture from obstructing corners.
- Avoid locating light poles, above ground utilities, and traffic signals at corners.
- Locate street trees and other plantings away from corners to maximize visibility.

Improve intersections:

- Provide two, ADA compliant pedestrian ramps per corner, located to facilitate movement straight into the crosswalk.
- Design to avoid standing water and icy conditions.
- Utilize tactile pavements to alert the visually impaired to the intersection.
- Use curb extensions, bulb-outs and neck-downs at busy intersections to minimize pedestrian crossing distance, calm traffic and improve safety. Incorporate bollards, planters, or other devices to alert drivers to the presence of curb extensions.
- Ensure that bicycle lanes and emergency access are not impeded by curb extensions.
- Consider using raised intersections to enhance visibility and safety of crossing areas.
- Where appropriate, reconstruct intersection corners with a smaller turning radius to slow turning vehicles.

Enhance crosswalk visibility and effectiveness:

- Use crosswalk enhancements at complex intersections and high volume crossings.
- Consider the use of high visibility, piano style crosswalks – designed to allow tires of motor vehicles to pass between the lines – to enhance visibility while minimizing maintenance of markings.
- Consider color-reinforced stamped, imprinted or embedded light-colored pavement within the crosswalk.
- Consider ADA compliant textured or grooved surfaces to alert drivers of crosswalk.
- Consider light-colored interlocking paving stones within the crosswalk.

Consider raised crosswalks with gentle side slopes:

- Move vehicle stop line back from crosswalk (10 to 20 ft. from crosswalk).
- Consider using an advanced warning stenciling to alert drivers to crosswalk.
- Ensure that crosswalk enhancements will be properly maintained.

Provide pedestrian refuge islands where appropriate:

- Use raised islands in the center of wide streets to facilitate safe crossing.
- Consider using in conjunction with corner curb extensions.
- Maintain bicycle lanes and ensure ability of emergency vehicle access.
- Incorporate attractive, low-maintenance, absorbent landscaping. **(SS.5, LA.3)**

Area Wide Traffic Calming and Management Plans

With input from community groups, develop area wide traffic management and traffic calming plans:

- Reduce traffic congestion, idling and impact.
- Designate and enforce truck routes: minimize disruption on community streets and living streets.
- Maximize pedestrian accessibility, circulation, orientation, and connectivity.
- Support biking and other forms of active transportation. **(SS.3)**
- Alert drivers that they are entering a traffic-calmed environment.
- Utilize visible amenities such as shade trees, benches, and landscapes to enhance pedestrian orientation of streetscape.
- Incorporate physical measures including center islands, medians, roundabouts, traffic circles and so on.

Route 9A – Manhattan, NY
Provision of separated walking path improves safety and comfort for pedestrians and encourages active transportation and exercise along waterfront.

- Consider traffic management measures including street direction changes, street closings, modified signal times, etc.

Utilize Intelligent Transportation Systems (ITS): Implement a range of communication technologies to optimize management of the entire transportation system.
- Integrate ITS with surface mass transit improvements. **(SS.4)**

Signalization

Consider signalization changes to increase pedestrian safety and travel efficiency:
- Evaluate existing signal timing and pedestrian level of service.
- Determine if signalization changes would be beneficial and feasible.
- Consider extending pedestrian crossing intervals.
- Consider adjusting signal progression to calm traffic during high-pedestrian volume periods and to minimize congestion during vehicle rush hour.
- Consider utilizing leading pedestrian intervals (LPI) to give pedestrians a head start in crossing prior to allowing motorists to turn.
- Consider utilizing 'Barnes Dance' (all-walk phases) at high pedestrian intersections to stop all vehicles on all approaches while allowing pedestrians to cross in all directions.
- Consider utilizing pedestrian detection signals – infrared systems or 'pedestrian user friendly intelligent crossing' (PUFFIN) systems – to delay signal change until remaining pedestrians clear the intersection.
- Consider using audible signals to indicate crossing intervals at major intersections.
- Consider using countdown signals to indicate crossing time to pedestrians.

Improve visibility and legibility of signals:
- Consider increasing the size of the red signal heads (to 12 inch maximum) to improve visibility and to emphasize traffic control.
- Use symbolic pedestrian walking signals instead of message-type pedestrian walking signals.

Signage

Improve signage to enhance traffic safety:
- Survey existing signage, examine accident reports, and interview community members to determine needs and goals for improved signage.
- At critical crossing areas with high pedestrian volumes or histories of accidents, utilize fluorescent signs and post reflectors to caution motorists.
- Use oversized street name signs to help orient motorists and prevent erratic driving.
- Place speed-limit signs in areas with high pedestrian volumes.

Develop wayfinding or interpretive signage:
- Use a distinct system of signage to provide useful information in urban areas for pedestrians, bicyclists, and vehicles. Wayfinding signage helps encourage sense of place and efficient pedestrian and vehicular movement.
- Provide information about major destinations, including places of cultural, historic, and geographic importance, and preferred pedestrian streets.
- Distinguish between wayfinding systems for tourists and systems for locals.
- Maintain graphic or symbolic continuity throughout wayfinding area.
- Develop innovative ways to express historic or cultural heritage.
- Imaginatively use materials, landscaping, or architectural elements to evoke understanding of a place without adding to street clutter.

EXAMPLE

The Freedom Trail in Boston, Massachusetts, is a wayfinding trail that links sites of importance to the Revolutionary War. The trail, and the foundation that manages it, is dedicated to preserving and promoting the Revolution as the "cornerstone of Boston's distinct historic and cultural character." Originally designed in the 1960's with a red stripe painted down the center of the street, it was later enhanced for pedestrians by using a double-brick pattern in the designated sidewalks making up the trail. Pedestrians can use maps, signage, and a new audio self-guided tour to navigate the trail. Significant sites feature an attractive bronze plaque inset into the sidewalk. According to the Freedom Trail Foundation, approximately 3 million people walk the trail each year and the trail is a $400 million economic driver in the City's $9 billion tourism industry.
http://www.thefreedomtrail.org/

Sidewalk Enhancements – Brooklyn, NY
As part of the Downtown Brooklyn Traffic Calming Project, the NYC Department of Transportation installed neckdowns and pedestrian ramps at Fulton and South Oxford streets.

The NYC DOT's Downtown Brooklyn Traffic Calming Initiative is a highly successful, community informed initiative that piloted traffic calming techniques and developed an area-wide streetscape improvement plan that is currently under construction. Dozens of streets in Downtown Brooklyn were classified as 'travel streets', 'community streets', and 'living streets', and streetscape improvements were undertaken to enhance the quality, safety, and efficiency of each street according to its needs. For more details, see: http://www.nyc.gov/html/dot/html/motorist/dntnbklyntraf.html

Portland, Oregon found that improving the quality of the pedestrian environment to a level comparable to that of Portland's most pedestrian-oriented zones would result in a 10 percent reduction in vehicle miles traveled (VMT).

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SS.3 IMPROVE STREETSCAPE FOR BICYCLISTS

OBJECTIVE

Improve streetscape to support bicycling and other forms of non-motorized active transportation. Implement area-wide bicycling master plans to facilitate bicycling on a citywide basis. Dedicate bicycling-only zones and install bike racks and other features to support bicycling. Anticipate future demand in sizing bicycling facilities. Integrate design of these areas with other objectives.

BENEFITS

+ Improves safety for bicyclists and non-motorized vehicle users.
+ Reduces automobile speeds and increases safety.
+ Reduces vehicle miles traveled (VMT), automobile congestion, and the emission of greenhouse gases, particulate matter and volatile organic compounds.[41]
+ Improves public health and fitness by reducing air pollution and encouraging outdoor exercise and active transportation.
+ Encourages the efficient use of precious road space, with no adverse impact to the visual environment.

LIMITATIONS

– May increase project design and construction costs.
– May be difficult to implement where right-of-way space is limited.
– Communities may oppose bike lanes if parking is reduced.

INTEGRATION

- **SS.2** Improve Streetscape for Pedestrians
- **SS.4** Improve Streetscape for Surface Mass Transit
- **SS.5** Increase and Improve Right-of-Way Public Space and Green Areas

TECHNICAL STRATEGIES

Develop and implement area-wide bicycle master plans:

- Prioritize bicycling as an integral part of the overall transportation system.
- Seek to maximize accessibility, continuity and convenience of bike travel citywide.
- Promote traffic calming and management through physical and operational improvements to the right-of-way. **(SS.2)**
- Assess current bike ridership through sampling, surveys, etc. Anticipate future demand.
- Develop strategies to facilitate intermodal transportation. Provide properly sized bike facilities at mass-transit stops.
- Encourage businesses and public facilities to provide bike parking and storage, and lockers and showers for bicyclists.
- Conduct public awareness and education initiatives to inform riders about bicycling safety measures, bike path navigation, and the environmental and public health benefits of bicycling.

Dedicate highly-visible zones for bicycling in the right-of-way:

- Provide bike paths with adequate widths, smooth surfaces and proper drainage.
- Retrofit existing streets with dedicated bicycle lanes. If possible, narrow automobile lanes to reduce speeds and improve safety.[42]
- In new or reconstructed streets, integrate bike lanes into streetscape design to increase safety and improve aesthetics.
- When possible, separate bike lanes from vehicular traffic and pedestrians through the use of small medians or other features.
- Where space is limited for dedicated bike lanes, consider combined, dedicated bike and bus lanes. Consider implementing part-time bike lanes.
- Use traffic calming to improve safety of bicyclists. **(SS.2)**
- Use light-colored pavement where possible to differentiate bike lanes. **(PA.3)**
- Use highly visible pavement markings and signage to indicate bicycle zones and to alert cars to drive safely and share road space with bicyclists.
- Use bike-friendly catch basins.
- Consider bike-only boulevards or 'thru streets' to separate bike and vehicular traffic.[43]

41 New York City Department of Transportation. 2004. Downtown Brooklyn Traffic Calming Project – Final Report. http://www.nyc.gov/html/dot/html/motorist/dntnbklyntraf.html. (Accessed June 2004). Pages 45-68.

42 In NYC, this practice has resulted in a reduction in motor vehicle speeds of between 3-5 mph. NYCDOT. School Safety Engineering Project. General Mitigation Measures-Final Report. 2004.

43 The Thru Street's in Manhattan have successfully decreased cross-town travel times and congestion on designated streets. This concept could be applied to a series of dedicated, bicycle only streets. A pilot-project could be conducted on several east-west streets in Manhattan: the streets could be designed for limited vehicular access – using bollards or other physical measures – allowing bikes to be the dominant mode of transportation. Only local delivery trucks, emergency vehicles and other necessary vehicles would be able to travel on the designtated bike thru-streets.

Greenwich Street – Manhattan, NY
Provision of bicycle lanes and amenities encourages ridership.

EXAMPLE

In the reconstruction of Route 9A in Manhattan, portions of the NYC Greenway Plan and Bicycle Master Plan were implemented, signaling the start of a multi-year effort to create new public recreational opportunities and increase the mobility of cyclists and pedestrians. Currently the NYC Greenway Plan is at 90% completion around the island of Manhattan with an ultimate goal of creating 350 miles of landscaped bicycle and pedestrian paths crisscrossing New York City.

The City of Chicago recently constructed a 12,000-square-foot bicycle station in Millennium Park. The station has parking space for 300-bikes and also provides changing, showering and locker storage facilities for bike riders. Since its opening the bike station has been operating at or near capacity and there is now a lengthy waiting list for access to the facility. The bike station was funded by the Congestion Mitigation and Air Quality program, administered by the Federal Highway Administration and the Federal Transit Administration under the TEA-21 Act. Chicago is currently improving bicycle lanes and facilities throughout the city as part of an effort to increase bike ridership substantially.

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New York City Department of Transportation
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http://www.nyc.gov/html/dot/html/motorist/dntnbklyntraf.html

Shore Parkway Bike Path – Queens, NY

SS.4 IMPROVE STREETSCAPE FOR SURFACE MASS TRANSIT

OBJECTIVE

Make physical and operational improvements to the right-of-way to improve the efficiency, cost-effectiveness, convenience, and sustainability of surface mass transit.

BENEFITS

+ Establishes a clear priority for mass-transit vehicle operations and provides more convenient transit stops.
+ Improves safety and quality of life for mass transit users and pedestrians.
+ Improves the efficiency of mass-transit by reducing loading times, idling times, and conflicts with other vehicles.
+ Reduces emission of greenhouse gases, particulate matter, volatile organic compounds, and other pollutants.
+ Improves energy efficiency and reduces operating expenses.
+ Use of intelligent transportation systems (ITS) enables mass-transit users to make better transportation decisions by providing them with real-time information.
+ Improves overall efficiency of the transportation system.

LIMITATIONS

- May increase construction cost.
- May require the relocation of catch basins.
- Traffic management measures are ineffective without proper enforcement.
- ITS technology requires significant investment to purchase, install and maintain communication systems.
- Clean-fuel technology requires investments in research and development, new equipment, and non-standard maintenance procedures.

INTEGRATION

- **SS.2** Improve Streetscape for Pedestrians
- **SS.5** Increase and Improve Right-of-Way Public Space and Green Areas
- **SS.7** Optimize Streetlighting and Signaling
- **CP.6** Use Cleaner Construction Equipment

TECHNICAL STRATEGIES

Physical Improvements

Consider constructing bus nubs: Bus nubs are sidewalk extensions that extend through the parking lane to the travel lane, enabling the bus to travel and stop in the same lane, thus reducing loading time and conflicts with other vehicles, and increasing transit efficiency and timeliness.[44]

- Consider employing temporary, pre-manufactured bus nubs to evaluate their performance and appropriateness at new locations.
- Integrate seating, bus shelters, landscaping, and other amenities into the design of bus nubs. **(SS.5)**

Consider creating transit-priority or transit-only lanes:

- Adequately mark and enforce mass-transit lanes to increase efficiency and service.
- Consider whether mass-transit lanes could double as bike lanes, if space for fully dedicated bike lane is limited. **(SS. 3)**
- Consider implementing turning restrictions to increase transit efficiency.
- For mass-transit only lanes, consider using priority green signals that give buses a head start at intersections, allowing them to pick up passengers with minimal traffic interference.[45]

Improve transit facilities:

- Work with community stakeholders to improve transit facilities. **(SA.1, SS.1)**
- Develop designs that will improve both transit operation and community well-being.
- Adequately light transit facilities and surrounding area. **(SS.5)**
- Provide well-designed, accessible, comfortable, convenient, and safe bus-shelters where appropriate.
- Provide amenities for mass-transit users and pedestrians, including benches, trash receptacles, adequate signage, telephones, clocks, etc. **(SS.5)**
- Increase landscaping and provide features that will improve aesthetics. **(LA.3, SS.5)**
- Integrate transit facility improvements with larger area-wide streetscape improvements.
- Develop partnerships with community groups that will help ensure the maintenance and upkeep of the improved transit facility. **(SS.1)**

44 Research in San Francisco showed that delays for motorists caused by bus nubs are small or nonexistent.

45 European example.

Streetscape Enhancements for Mass Transit – Brooklyn, NY
As part of the Downtown Brooklyn Traffic Calming Project, the NYC Department of Transportation installed new bus lanes on Fulton Street.

Intelligent Transportation Systems (ITS)

Employ a range of communication technologies to improve mass-transit efficiency, reliability and safety, and to provide real-time information to travelers:

- Use automatic vehicle locator (AVL) systems.
- Integrate vehicle location data into real-time passenger information systems located at mass-transit facilities, on-line, and at other prominent locations. Provide users with alternate route planning information.
- Coordinate vehicle locator systems with traffic signal system to enable real-time transit signal priority for transit vehicles.
- Use ITS data to respond to demographic and demand changes, facilitate inter-modal transportation coordination, improve cost-efficiency, increase ridership, and plan future transit initiatives.
- Integrate ITS data into wayfinding systems. **(SS.2)**

Facilitate Intermodal Transportation.

Use Clean Fuel Technologies (CP.6): In September of 2000, MTA New York City Transit (NYCT) became the first and largest bus fleet operator using ULSD in the country, using it in all 4,500 buses in their fleet. Nationally, they are the largest single user of ULSD, having used approximately 47 million gallons of ULSD annually. They do not report any engine or fuel system problems related to ULSD use, and have not experienced a change in fuel economy from the fleet. After-treatment retrofits implemented by NYCT include diesel particulate filters and diesel oxidation catalysts Review the NYCT case study at http://www.epa.gov/otaq/retrofit/retronyc.htm. Refer to DDC Low Sulfur Fuel Manual (see references) for detailed emission reductions, a general description and evaluation of each fuel formulation, and current feasibility.

EXAMPLE

As part of the Downtown Brooklyn Traffic Calming initiative, the NYC Department of Transportation piloted various techniques to improve surface mass transit operation. Downtown Brooklyn is serviced by eighteen bus routes, but traffic congestion slows bus speeds, causes bus bunching, and leads to conflicts when buses merge back into traffic after stopping. Implementing bus nubs and undertaking other traffic management measures improved the flow of surface mass transit. For more details, see: http://www.nyc.gov/html/dot/html/motorist/dntnbklyntraf.html

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National Guide to Sustainable Municipal Infrastructure
2003

SS.5
INCREASE AND IMPROVE RIGHT-OF-WAY PUBLIC SPACE AND GREEN AREAS

OBJECTIVE

Increase the quality and quantity of right-of-way public spaces, green spaces, street furniture, and parks within or adjacent to the public right-of-way. Where adequate space exists, encourage economic, cultural, and recreational activities to enhance streetscape vitality. Integrate with other high performance objectives.

BENEFITS

+ Activating the street as a public space encourages social interaction and a stronger sense of community.
+ Increases neighborhood safety.
+ Increases property values.
+ Improves quality of life by offering 'pauses' for socializing and leisure activities.
+ Green areas reduce air pollution and stormwater runoff.
+ Economic activities such as green markets support local businesses and enable consumers to purchase fresh produce and healthy goods.[47]
+ Encourages public stewardship of streetscapes.

LIMITATIONS

– May encounter reluctance to change conventional standards, incur risk, increase potential maintenance costs or reduce on-street parking.
– Existing sidewalks may not allow for additional green space and open public space.

[47] Supporting local farmers maintains attractive and productive agrarian landscapes within close proximity to urban areas. It also consumes less energy and raw material in transport and packaging, and reduces solid waste disposal.

INTEGRATION

- **SA.1** Assess Site and High Performance Opportunities
- **SS.1** Work with Community Groups to Enhance and Maintain Streetscape
- **SS.2** Improve Streetscape for Pedestrians
- **SS.3** Improve Streetscape for Bicyclists
- **SS.4** Improve Streetscape for Surface Mass Transit
- **SS.6** Optimize Security Enhancements
- **PA.2** Minimize Impervious Pavement Area
- **PA.4** Use Pervious Pavements
- **SM.1** Conduct Integrated Stormwater Management Planning
- **SM.4** Optimize Right-of-Way Drainage
- **SM.10** Use Bioretention
- **SM.11** Use Constructed Wetlands
- **LA.1** Optimize Citywide Landscape Planning
- **LA.2** Encourage Ecological Connectivity and Habitat
- **LA.3** Create Absorbent Landscapes
- **LA.7** Increase the Quantity, Density, and Diversity of Trees
- **LA.8** Plant Trees to Maximize Shading of Pavement

TECHNICAL STRATEGIES

Planning

- Work with stakeholders to plan, design and maintain public spaces. **(SA.1, SS.1)**

Design

Incorporate green areas or public spaces where space exists:

- Replace impervious areas in medians, traffic circles or triangles, and roadway shoulders with low-maintenance, salt-tolerant vegetation. **(LA.1 to LA.3, LA.12, SM.4)**
- Create more opportunities for planting by using bulb-outs/neckdowns or similar traffic calming devices on residential streets. **(SS.2)**
- Integrate stormwater management practices. **(SM.3 to SM.11)**
- Consider converting parking areas into green spaces.
- Create inviting and open entrances to public spaces.
- Incorporate paths to encourage connectivity and movement through public spaces.

Meet or exceed the following minimum width requirements for planting soil zones:

- Lawn or herbaceous planting: 3 feet.
- Shrubs: 5 feet.
- Single row of trees: 8 feet.
- Double or staggered row of trees: 12 to 18 feet.

Incorporate seating and street furniture into public spaces and throughout streetscape:

- Locate benches in desirable locations to encourage sitting and socializing.
- Place benches in view of pedestrians, but avoid obstructing movement.

- Incorporate seating at transit stops, outside department stores and offices, and anywhere else where seating may be utilized.
- Construct seating of durable, weather resistant and vandal resistant materials.
- Use recycled materials where possible, while maintaining aesthetic standards.
- Make steps, ledges, and other features conducive for sitting.
- Increase trash, recycling, and composting receptacles. Use separate organic waste bins and integrate with localized composting programs.[48] Incorporate with the citywide waste management initiative. **(CP.5)**

Incorporate public art into streetscapes and public spaces:

- Encourage 'integrated' public art that is incorporated into design elements of the streetscape such as paving, railings, sets, bollards, fountains, bridges or plantings.
- Encourage 'stand alone' public art, such as sculptures, permanent or temporary installations, wall murals, or interpretive panels.
- Encourage performance art or temporal events that celebrate seasons, events, historic or cultural expressions.

Encourage green markets and other forms of economic activity:

- Provide infrastructure in the streetscape or adjacent public spaces to support outdoor activities including water and electric supply, tent tie-downs and pavements that can withstand truck loading.
- If necessary, redirect traffic during market times.

Provide lighting for pedestrians:

- Consider scale, geometry, and character of space when determining appropriate lighting criteria for green areas and public space amenities.
- Where appropriate, employ smaller-scale fixtures to emphasize pedestrian activity and reduce energy costs.
- Provide lighting at transit stops, entrances of public and residential buildings, and other destinations.
- Light the edges of public spaces and parks.
- Light sculpture, fountains, architectural details, and other notable streetscape elements.

Use Environmentally Preferable Materials in Streetscapes:[49]

- Use sustainably harvested / certified woods. Possible applications include benches, playground equipment and street furniture.
- Utilize recycled materials (recovered content plastic, aluminum, concrete, glass, steel, rubber, etc.) in street furniture, fencing, playground equipment, curbing, parking stops, and other elements. (See **PA.6** for additional applications in pavement design).
- Use low-emission, non-toxic and/or bio-based products. Examples include water-based coatings, arsenic-free pressure-treated wood, and naturally rot-resistant hardwoods (See **PA.5** for additional applications in pavement design).
- Use products with low embodied energy. (e.g., wood or other bio-based products, locally harvested stone).
- Use products that are locally manufactured or extracted.
- Use products that offer lifecycle benefits over conventional products (e.g. products with improved durability, or products that can be refurbished and reused).
- Utilize the Comprehensive Procurement Guideline (CPG) program, part of the EPA's continuing effort to promote the use of materials recovered from solid waste.
- See EPA RMANS recommended recycled-content levels for bike racks, light poles, street signs and street sign posts for right-of-way applications.
- Utilize recycled content in transportation products such as temporary traffic control devices, traffic cones, channelizers, etc.
- Ensure that street furniture using recycled materials meets aesthetic standards and maintains streetscape ambiance.

Reconstruction of Stone Street – New York, NY
Reuse of granite blocks stockpiled on-site for street furniture in historic district

[48] 2500 tons of organic waste is generated in the City per day, and could be diverted from the wastestream and reused for landscape fertilization.

[49] According to the EPA, an 'environmentally preferable' product will have 'a reduced effect on human health and the environment when compared with competing products or services that serve the same purpose.' Considerations include raw materials acquisition, production, manufacturing, packaging, distribution, reuse, operation, maintenance or disposal of the product or service.

Duane Street – Manhattan, NY
Conversion of a traffic triangle into an attractive urban landscape and public space that is maintained by a 501(c)(3) community maintenance group

EXAMPLES

The New York City Department of Parks and Recreation began the Greenstreets program in 1996 to convert barren concrete triangles, traffic islands and other impervious streetscape areas into productive and attractive landscapes containing trees, shrubs and flowers. Since its founding, the program has created more than 2,000 Greenstreets throughout the five boroughs. Over the same period, the Parks Department also planted more than 85,000 trees. Parks employees and community volunteers regularly water, weed and clean the Greenstreets spaces.

The City of Vancouver began a Green Streets program in 1994 to encourage local citizens to beautify traffic circles, sidewalks and corner bulb outs. The City installs the initial 'structural' plants – drought tolerant, evergreen and seasonally diverse shrubs and trees. Seasonal flowers may be provided by the City or contributed by local volunteers. Members of the volunteer Green Streets program receive regular newsletters, free classes on responsible gardening practices and hold an annual party to share images and ideas on successful spaces.

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http://www.ecpl.com/products.html

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U.S. Environmental Protection Agency, Office of Solid Waste
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for the Comprehensive Procurement Guideline (CPG)
2001
http://www.epa.gov/cpg/pdf/rmanal3.pdf

Example sources for sustainably harvested / certified woods:

- Natural Forest Products – http://www.forestworld.com
- Certified Forest Products Council – http://www.certifiedwood.org

Examples of recycled plastic manufacturers within 500 miles of NYC:

- American Ecoboard – http://www.americanecoboard.com (NY)
- Millennium Lumber – http://www.bjmindustries.com (PA)
- Perma-Deck – http://www.cascadesreplast.com (Montreal, Canada)
- Plastic Lumber – http://www.aeo1.com (PA)
- Plastic Lumber – http://www.4-inteqcorp.com (OH)
- Plastic Lumber – http://www.plasticlumber.com
- Polywood Plastic Lumber Inc. – http://www.polywood.com (NJ)
- SeaTimber – http://www.weaward.com (VA)
- The Forever Deck – http://www.plasticlumberyard.com (PA)
- Trex – http://www.trex.com (VA)

Examples of recycled content safety surface manufacturers within 500 miles of NYC:

- Child Safe Products, Inc. – http://www.childsafeproducts.com (NY)
- Cushion Play – http://www.playworlsystems.com (PA)
- Playface – http://www.turtleplastics.com (OH)
- Playground surfaces – http://www.surfam.com (NY)
- Safe Guard Surfacing – http://www.safeguardsurfacing.com (NY)
- Softile kroslock – http://www.sofsurfaces.com (Petrolia, Canada)
- Tirec – http://www.perma-turf.com (NJ)
- Tire Turf – http://www.continetalturf.com (OH)
- Vitriturf – http://www.vitriturf.com (NY)

The following are examples of low-VOC and low-toxic exterior paints for metal:

- SafeCoat MetalCoat Acrylic Metal Primer – http://www.afmsafecoat.com
- Benjamin Moore M29 Direct to Metal Acrylic – http://www.benjaminmoore.com
- Sherwin-Williams EnviroSpecDTM – http://www.sherwin-williams.com
- CCI – http://www.neutrarustinc.com
- DTM – http://www.fuhrinternationall.com
- Rust-Oleum, Sierra Performance Coatings S-37 MetalmaxTM DTM – http://www.rustoleum.com

SS.6 OPTIMIZE SECURITY ENHANCEMENTS

OBJECTIVE

Balance legitimate security objectives with good urban design practices. Preserve uncluttered and uncongested access to public space, sidewalks and streets. Integrate streetscape enhancements and beautification with security improvements. Expand the palette of elements that can provide perimeter security while also providing amenity and improved aesthetics. Incorporate other BMPs into the design of security measures.

BENEFITS

+ Attracts pedestrians to local businesses, reduces crime, and increases property values.
+ Replaces unsightly and makeshift barriers with well-designed, appropriately scaled security solutions.
+ Opens streets to emergency vehicles and maintains public access appropriate to an open and democratic society.
+ Coordinated security measures within a district reduce individual project costs and overall maintenance.
+ Well-designed and well-sited security measures minimize disruption and space consumption on public streets and sidewalks.
+ Well-designed, 'hardened' streetscape elements can offer both security and amenity.

LIMITATIONS

– Maintaining high urban design standards in security retrofits is challenging. Best results are achieved when streetscape measures are designed in conjunction with new building construction.
– Achieving consistency and aesthetic continuity is difficult since security strategies are usually highly site specific.
– Quality materials and custom design are more costly than off-the-shelf solutions.
– Underground utilities may require relocation to accommodate footings for 'hardened' elements.

BACKGROUND

Since the terrorist attacks of September 11th, 2001, heightened security in New York City has led to the proliferation of security features within the streetscape environment, particularly near public buildings, religious and financial institutions, transportation centers and other facilities of regional or symbolic importance. While enhancing security in urban spaces is an essential objective, equally important is the need to maintain the City's vitality and openness. Security measures do not necessarily have to restrict access and movement, nor do they have to detract from streetscape aesthetics. Security enhancements can integrate measures to beautify the public realm, provide increased amenity and landscaping, and improve the streetscape environment for pedestrian movement. In fact, actively used streetscapes or public spaces are safer and easier to police over the long run than empty ones.[50]

INTEGRATION

- **SA.1** Assess Site and High Performance Opportunities
- **SS.5** Increase and Improve Right-of-Way Public Space and Green Areas
- **LA.7** Increase the Quantity, Density and Diversity of Trees

TECHNICAL STRATEGIES

Site Assessment

- Convene designers, security experts, and local/state/federal agencies to conduct a risk assessment and threat analysis of site. **(SA.1)**
- Determine an appropriate 'protection level'.
- Avoid over-design of security measures.

Planning

Develop a security master plan for site:

- Produce a coherent strategy for deploying specific families of streetscape and security elements. Achieve aesthetic continuity along streets.
- Coordinate planning for specific buildings with larger area-wide planning initiatives to ensure compatibility and avoid duplication/redundancy of security measures.
- Provide perimeter security in a manner that does not impede commerce and vitality, and does not excessively restrict pedestrian and vehicular mobility.
- At locations where greater standoff zones impact roadways, coordinate solutions to improve surface mass transit operation, bicycle lanes, increased pedestrian and green space, and emergency access routes.
- Evaluate whether positive streetscape elements such as streetlights, planters and benches can be 'hardened' so they can function as both amenities and components of perimeter security before resorting to bollards and walls. Avoid practices that will compromise the health of street trees.
- Develop an efficient and cost-effective implementation strategy.

Design

- Consider the site context and architecture to design measures that are complementary.

50 Project for Public Spaces. 'Safety & Security in Public Space.' http://www.pps.org/info/placemakingtools/issuepapers/safety_security.

Coney Island Water Pollution Control Plant – Brooklyn, NY
Sweet-smelling and flowering plants are trained up the security fence surrounding a sewage treatment complex.

- Preserve historic features in significant or landmarked buildings.
- Conduct engineering and crash testing of all elements prior to installation as security measures.
- In new building designs, integrate walls, terraces, raised planting beds, and other security features so that they appear to be an extension of the building itself.
- Plant or maintain mature trees (8' caliper minimum) as effective security barriers.
- Use 'hardened' planters between trees to maintain required distance between vertical barriers.
- 'Harden' other streetscape elements such as kiosks, newsstands, trashcans, benches, bike racks, tree guards and drinking fountains.
- If required, use posts and bollards that are compatibly scaled and attractively designed; utilize retractable and removable bollards at vehicular access points.
- In locations of sufficient width consider incorporating ornamental fountains or pools.
- Integrate stormwater management objectives. **(SM.3, SM.4)**
- Where appropriate, consider 'jujitsu', or 'tank trap' techniques that allow surfaces to collapse under the weight of a truck causing the penetrating vehicle to nose dive into a below-grade bunker.
- Integrate other high performance practices with security measures, including traffic calming, increased landscaping, stormwater management, etc.

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SS.7 OPTIMIZE STREETLIGHTING AND SIGNALING

OBJECTIVE

Achieve the most energy efficient streetlighting and signaling while maintaining a safe, uniformly lighted, and aesthetically pleasing nighttime environment.

BENEFITS

+ Reduces energy use and saves money.
+ Improves streetscape for pedestrians by increasing visibility and safety.
+ Off-grid street lighting enhances emergency preparedness and improves security during blackouts and emergencies.
+ Minimizes glare and light-pollution caused by light trespass.
+ Highlights the identity and character of an area.

LIMITATIONS

– Additional research, prototyping and pilot installations are needed for emerging technologies.

BACKGROUND

New York City has provided lighting on its streets since 1762, and currently maintains approximately 300,000 street lights within its five boroughs. In the City, pedestrians' nighttime safety is of primary importance in determining illuminance design standards since NYC is predominately a walking and mass-transit city.[51] To improve lighting systems, it is essential to consider their environmental, physiological, social and biological impacts. These impacts can be discussed in terms of light, energy, and materials:

Light

The nighttime environment has the potential for high contrast lighting and glare due to multiple man-made light sources under the dark sky vault.
Accordingly, specific lighting quality issues must be taken into account:

- Nighttime visibility, peripheral detection, adaptation.
- Security, safety, shadows, facial recognition, uniformity.
- Color appearance and contrast.
- 'Light trespass' is unwanted light from an adjacent source, which causes spill and glare.[52] Light trespass causes annoyance and discomfort and may become a safety concern by impairing nighttime visibility.
- 'Light pollution' is a reduction in sky magnitude, or the relative visibility of the stars or darkness of the sky. It is caused by the direct loss of light up into the atmosphere and also reflected light off the earth or other surfaces.

Energy

Globally, 8% of lighting energy use is devoted to street and other exterior lighting.[53] In terms of energy expended, street lighting has considerably less impact than lighting in the residential, service, and industrial sector. However, it is estimated that 15 TWh are used annually for street lighting in the United States, which in itself is considerable.[54] Diminishing fossil fuel resources, air pollution from power plants, and the increasing cost of energy make increasing energy efficiency in streetlighting a high priority.

Materials

The embodied energy of streetlighting and signaling fixtures can be minimized by using recycled materials in poles and appurtenances, which are typically aluminum or steel. Additionally, hazardous wastes such as lead, mercury and other chemical compounds should be eliminated from lamps and ballasts.

INTEGRATION

- **SS.1** Work with Community Groups to Enhance and Maintain Streetscape
- **SS.2** Improve Streetscape for Pedestrians
- **SS.4** Improve Streetscape for Surface Mass Transit
- **SS.5** Increase and Improve Right-of-Way Public Space and Green Areas
- **PA.3** Maximize Pavement Albedo

51 The NYC DOT's Division of Street lighting is responsible for determining street lighting standards, and installation, operation and maintenance of all City lights and most signals.

52 Spill is increased direct or reflective illumination, and glare is the sensation caused by an excessively bright source directly within view.

53 http://eetd.lbl.gov/emills/PUBS/PDF/Global_Lighting_Energy.pdf

54 1TWh = 25 trillion lumen-hours

TECHNICAL STRATEGIES

Retrofit of Existing Fixtures

Re-lamp existing luminaries to reduce light trespass, provide more even illumination, and improve energy efficiency and sustainability:

- Attempt to reduce light trespass and pollution without increasing light fixture numbers or decreasing light levels on the ground.
- Use highest-cutoff fixtures possible while still meeting photometric requirements.
- Use flat lens lamps.
- Reduce luminance ratios to provide more even illumination.
- Install shielding devices.
- To reduce the amount of kilowatt-hours consumed, re-lamp with lamps that have high relative efficacies, and re-install luminaires with high relative efficiencies. Select lamps with long rated lamp life.[55]
- Clean luminaires regularly to maintain greater efficiency.
- Replace electromagnetic ballasts with electronic ballasting, where applicable, to achieve improved lifetime lamp performance.[56]
- Re-lamp with reduced or no-mercury lamps to minimize environmental impacts associated with disposal of hazardous material.

Installation of New Lighting Fixtures

Prevent light trespass and improve ground-level illumination:

- Consider the use of full-cutoff fixtures. If necessary – and if energy consumption is not increased – install new poles at a closer spacing to meet photometric requirements.
- Use flat-lens lamps to reduce glare.

Optimize energy performance:

- To reduce the amount of kilowatt-hours consumed, select lamps with high relative efficacies, and select luminaires with high relative efficiencies and long rated lamp life.[57]
- Select lamps with high average lamp life.
- Use electronic ballasts.
- Minimize luminaire dirt depreciation (LDD)[58] by properly sealing and gasketing fixtures to prevent the ingress of dirt, water, and other foreign objects. Select luminaires that can be easily cleaned.

NYC 2004 City Lights Streetlight Competition – Winning Design

In 2004, the NYC Department of Design and Construction, in partnership with the NYC Department of Transportation, conducted an international design competition to seek out a new streetlight design for the City in the 21st Century. The winning proposal, currently under development by the City, incorporates light-emitting diodes and photovoltaic panels to allow for a more energy-efficient and environmentally beneficial design.

- Consider the synergy between light colored, high albedo pavement and improved light reflectance from street lights, in order to optimize energy performance. See **PA.2** for more details.

Consider employing emerging lighting technologies:

- Consider induction lighting (60-75 lm/W, with up to 100,000 hours of life).[59]
- Consider light-emitting diodes (LEDs) for signaling and streetlighting (see examples).[60]

55 Lamp efficacy is the ratio of light output to the electric power consumed (Lumens per Watt). Lamp efficiency is the percentage of light exiting the fixture. New York City employs High Pressure Sodium lamping technology, which has an efficacy of as much as 110 lumens per watt, and rated lamp life that outperforms most other technologies.

56 For more information regarding ballasting refer to the Advanced Lighting Guidelines published by the New Buildings Institute, sponsored by the California Energy Commission.

57 High Pressure Sodium and Metal Halide lamps have higher efficacies than Mercury Vapor Lamps - 80-130 lm/W for HPS and 70-110 lm/W for MH, as compared with 40-60 lm/W for MV. High intensity fluorescent lamps have high luminous efficacies for mesopic/night-time light levels and may consume less energy overall than HPS. High-efficiency roadway luminaires generally have an efficiency of >75%.

58 The accumulation of dirt on luminaires results in loss of light output and therefore wastes energy and impairs performance of streetlight.

59 Induction lighting is an energy efficient, emerging lamp technology used widely in Europe with good color rendering (but high initial costs).

60 City traffic lights are illuminated with light-emitting diodes (LED), as opposed to the incandescent lights many other cities currently employ. Red, yellow and green-colored LEDs are now available with efficacies of 25-40 lm/W. Besides having efficacies that are comparable with or better than incandescents, they do not incur the losses – up to 70% – due to filters used with incandescent lamps. The efficacy of white LEDs now achieves as much 40 lm/W and is advancing rapidly.

- Consider fluorescent lighting, which provides better color rendition and visual acuity.
- Explore possibility of installing sensors that would send a signal to a central location when the light is out to reduce maintenance costs.
- Use photocells to ensure streetlights operate only when daylight or ambient light is insufficient.
- To reduce demand on the central grid and increase emergency preparedness, consider installing photovoltaic panels on a portion of street lighting and consider using distributed generation energy sources.[61]

Use environmentally preferable materials and resources:

- Use a high percentage of recycled-content materials in support structures.
- Reuse materials and components where possible.
- Use low-emitting (low VOC) paints and primers on poles and appurtenances.
- Use local materials to reduce embodied energy.
- Repair and reuse damaged poles. Re-galvanize if necessary.
- Recycle unusable, damaged poles and other materials.
- Enforce proper handling and safe disposal of lamps, ballasts, and other lighting elements containing hazardous materials.

EXAMPLES

Tucson, Arizona replaced 22,000 street lights with hooded light fixtures, preventing light trespass and reducing wattage by 50% compared to the old fixtures. The resulting energy savings enabled Tucson to recover the costs of installation in three years. Remarkably, the Milky Way became visible to the downtown population of 500,000 people for the first time in decades.

Calgary, Canada is the first city in North America to embark on an extensive program to retrofit residential streetlights with new, lower-wattage, flat lens fixtures.

Easthampton, Massachusetts utilized new prototype fluorescent streetlights in a project in cooperation with the U.S. EPA, the Lighting Research Center, and a local utility. These fixtures used 30% less energy than high pressure sodium.

San Diego, California retrofitted 179 five-globe HPS fixtures in a historic district with induction lamps, with expected annual energy and maintenance savings of nearly $13,000.

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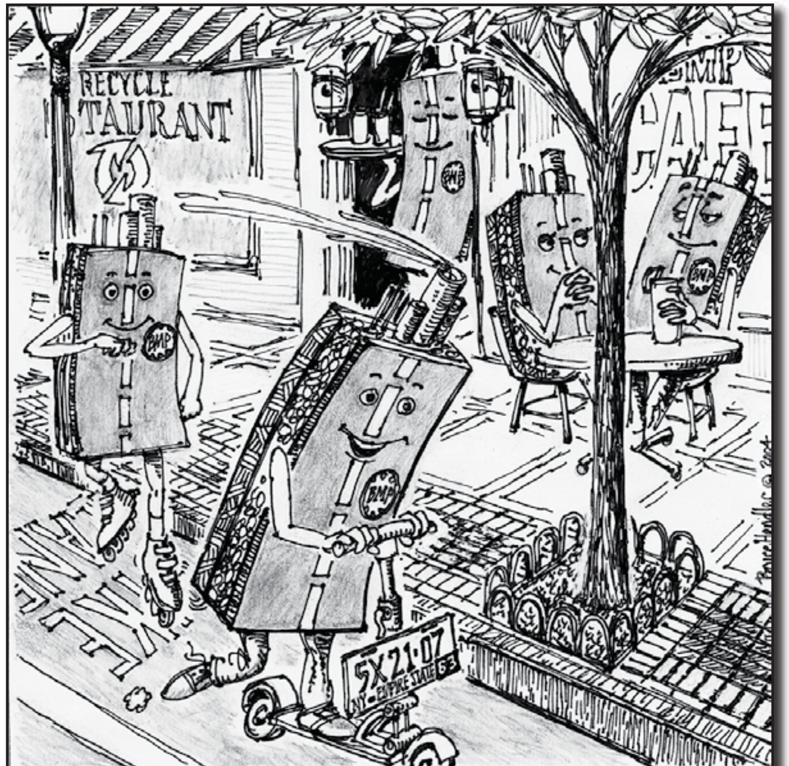
[61] Costs of PV paneled fixtures and grid connected lighting may be equivalent due to costs of cable laying and street repair.



STREETSCAPE

PART THREE: BEST PRACTICES
PAVEMENT

PA.1
MAXIMIZE PAVEMENT LIFECYCLE CITYWIDE

OBJECTIVE

Undertake a comprehensive regime of planning, budgeting, construction, maintenance, and monitoring strategies to maximize pavement lifecycle citywide. Develop a citywide pavement management system to ensure that the entire roadway system is performing as well as possible at all times. Coordinate pavement management system with other citywide infrastructure planning processes to reduce disruption and coordinate construction work, redouble the value of infrastructure investments, and minimize unanticipated future work that would lead to pavement degradation.

BENEFITS

+ Improves the durability, performance, and lifecycle of pavements.
+ Decreases construction work and costs, and energy and material inputs.
+ Reduces impact of construction on the environment and community.
+ Optimizes the effectiveness and value of public investments in infrastructure.
+ Comprehensive planning helps to minimize unanticipated future work that could lead to pavement degradation.

LIMITATIONS

– Implementation will require a substantial enhancement of the City's current capital asset management program in order to address NYC's extensive road system. Such an initiative will require long-term, dedicated funding.
– A comprehensive pavement management system will require extensive coordination with and cooperation of public and private utilities.

BACKGROUND

A pavement management system is a comprehensive strategy and integrated process for operating and maintaining a city's entire roadway system. A pavement management system oversees a comprehensive regime of planning, construction, operation, maintenance and monitoring activities, including preventative maintenance, corrective maintenance, holding maintenance, emergency maintenance, condition assessment, lifecycle cost analysis, and so on. A pavement management system is extremely beneficial because it allows stakeholders to understand and track the relationship between municipal pavement investment and the resulting level of service. This understanding will help to optimize infrastructure investments, improve operational and maintenance techniques, and ensure long-term performance of the City's roadway system. For best results, coordinate the pavement management system with other citywide infrastructure planning processes, including streetscape improvement planning **(SS.1)**, utility infrastructure planning **(UI.1)**, stormwater management planning **(SM.1)**, and landscape planning **(LA.1)**.

INTEGRATION

- **SS.1** Work with Community Groups to Enhance and Maintain Streetscape
- **PA.3** Maximize Pavement Albedo
- **PA.6** Use Recycled and Reclaimed Materials
- **UI.1** Minimize Impact of Utility Work
- **UI.2** Improve Restoration of Utility Cut Trenches
- **UI.3** Coordinate Utility Infrastructure for Easy Access and Maintenance
- **UI.4** Use Trenchless Technologies
- **SM.1** Conduct Integrated Stormwater Management Planning
- **LA.1** Optimize Citywide Landscape Planning
- **LA.4** Use Structural Soils Where Appropriate
- **LA.8** Plant Trees to Maximize Shading of Pavement
- **CP.5** Minimize Disruption and Impact of Right-of-Way Construction

TECHNICAL STRATEGIES

Develop a citywide pavement management system: Develop and implement a system to coordinate all pavement planning, construction, operations and maintenance activities. The pavement management system should encompass the following activities:

- Regular investigation of roads.
- Condition assessment and prediction of future performance.
- Selection of maintenance and rehabilitation techniques.
- Prioritization of critical maintenance and rehabilitation projects.
- Adequate budgeting for planning, design, construction, and maintenance.
- Design and construction.
- Ongoing monitoring.
- Preventative maintenance.

Develop and maintain a central database to track and integrate the following information:

- Road conditions.
- Complaints.
- Accidents.
- Community board requests.
- Maintenance needs.
- Inspection reports and evaluations.

- Condition assessments.
- Utility cut data.
- Maintenance and rehabilitation performed.

Coordinate pavement management system with other infrastructure planning processes:
- Streetscape improvement planning. **(SS.1)**
- Utility infrastructure planning and coordination. **(UI.1)**
- Integrated stormwater management planning. **(SM.1)**
- Citywide landscape planning. **(LA.1)**

Anticipate future utility infrastructure needs and plan accordingly to minimize future pavement disturbance and to reduce long-term costs:
- Consider installing laterals and additional conduit to minimize future impact and long-term costs.
- Provide the regulatory and financial mechanisms to facilitate this process.
- Coordinate with private utilities.

Practice pavement lifecycle cost analysis: Identify the best value – i.e. the lowest long-term cost that satisfies the objective being sought – for investment expenditures. Lifecycle cost analysis accounts for environmental and social impacts[62] and evaluates the overall long-term economic efficiency of competing alternative investment options.

Conduct routine pavement condition assessment.
- Coordinate data with utility condition assessment information.

Standardize pavement design, maintenance, and assessment methods:
- Ensure that all pavement stakeholders, including transportation agencies, private utility companies, design engineers and construction managers adhere to the same standards.
- Undertake research and development to take advantage of best available technology.

Plan and implement a preventative maintenance program: Preventative maintenance is a 'systematic and proactive' strategy in which cost-effective treatments are made to an existing roadway system 'to preserve the system, retard future deterioration, and maintain or improve the functional conditions of the system.'[63]

The goal of preventative maintenance is to maintain pavements in good condition prior to the development of structural damage, thereby slowing the rate of deterioration and extending the lifecycle of the pavement.[64]
- Develop a preventative maintenance plan and schedule as part of the planning and design of new roads or major reconstruction.
- Integrate preventative maintenance programs with pavement condition assessment systems.
- Establish a long-term source of dedicated funding for preventative maintenance.

Optimize corrective maintenance techniques:
- Equip maintenance crews with non-destructive testing and sensing devices to locate and analyze problems promptly.
- Use mobile asphalt hole repair units capable of treating spot repairs with minimum disturbance to traffic.
- Improve restoration of utility cut trenches. **(UI.2)**
- Use trenchless technologies. **(UI.4)**
- Ensure quick response times for sending maintenance teams out to service roads.
- Consider using an overlay to extend pavement lifecycle.
- Consider employing crack sealing to prevent water infiltration.
- Consider employing rubblization – i.e. breaking down concrete into pieces and overlaying hot mix asphalt (HMA) – to rehabilitate deteriorated Portland cement concrete (PCC) pavement.
- Utilize grouting with fly ash.
- Use recycled and reclaimed materials where possible and beneficial. **(PA.6)**

Optimize additional maintenance activities:
- Emergency maintenance treatments: actions performed during or immediately following an emergency situation.
- Holding maintenance treatments: actions to prolong use of the pavement until more substantial rehabilitation takes place.
- Pavement rehabilitation treatments: periodic actions to restore initial pavement serviceability through resurfacing, overlay, etc.
- Reconstruction: removing all surface layer materials, improving base and sub-base materials as necessary, and applying a new surface.

Use pavement management system to optimize municipal infrastructure capital investments.

62 According to the Swedish Environmental Research Institute: 'Lifecycle assessment is a tool which makes it possible to assess the environmental impact of a product, a process or an activity, through identifying and quantifying the flows of energy and material; evaluating the consumption of energy and materials as well as emissions generated, and identifying and evaluating possible measures for improving the environment.' Lifecycle analysis categorizes and evaluates all the costs of a construction alternative from 'cradle to grave', i.e. from the production of all material inputs through the end of service life and disposal. The following costs are analyzed: raw materials, energy inputs, processing, stockpiling, loading and transporting, design, construction, testing and inspection, operation, maintenance, disposal and reuse, user costs (from pollution, traffic disruption, etc), and environmental impact. Numerous lifecycle assessment studies exist for different pavement types to serve as a model, however, local circumstances must be considered to develop accurate and useful lifecycle data. The goal of using lifecycle analysis in the design of pavements is to choose the technique that will result in the lowest lifecycle costs and environmental impact, and best performance over the analysis period.

63 U.S. Federal Highway Administration, 2000. Insights into Pavement Preservation, www.fhwa.dot.gov/infrastructure/asstmgt/resource.htm

64 Studies have found that conducting periodic, low cost preventative maintenance extends the life of pavements, leads to better overall transportation service, and enables the best possible returns on pavement investments. Canadian Priority Planning BMP, page 5.

Route 9A Reconstruction – Manhattan, NY
Roadway was reconstructed with a 50-year design life, rigid pavement structure composed of high-albedo concrete. Improvements were made to subsurface utilities to prevent the need for near-term utility repair and to protect the 50-year pavement.

EXAMPLE

A recent paper by the Michigan Department of Transportation studied pavement preventative maintenance programs conducted in three states: Arizona, Montana and Pennsylvania. The study determined that for every dollar spent on preventative maintenance, an average of $4 to $10 was saved in rehabilitation costs. The study also determined that the earlier the preventative maintenance was conducted, the lower the cost and the higher the benefits. For more information see: http://www.pavementpreservation.org/publications/WIDOT_TPM.pdf

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PA.2 MINIMIZE IMPERVIOUS PAVEMENT AREA

OBJECTIVE

Reduce impervious pavement area, where appropriate, to decrease stormwater runoff and water pollution, reduce combined sewer overflows (CSOs), decrease urban heat island effect, and improve pedestrian safety.

BENEFITS

+ Can significantly decrease construction costs by reducing excavation, materials use, landfilling, etc.
+ Reduces urban heat island effect.
+ Reduces stormwater runoff, combined sewer overflows, and water pollution.
+ Promotes traffic calming.
+ Improves pedestrian safety.

LIMITATIONS

– Could result in reduced level of service (LOS) if improperly designed.
– Could impact parking availability.
– Could make it difficult to provide dedicated bicycle lanes.

BACKGROUND

New York City's public right-of-ways consist of nearly 20,000 lane miles of dark-colored, impervious pavement – approximately 1.2 billion square feet – an area nearly twice the size of Manhattan. While impervious pavements create a smooth and stable riding surface for cars, they enact significant environmental and social impact. Impervious pavements disallow rainwater from infiltrating into the ground, resulting in tremendous amounts of stormwater runoff that contains sediments, oils, toxins, heavy metals and other water pollutants.[65] Impervious pavements also absorb a large percentage of the solar energy hitting their surface, making them a leading cause of the urban heat island effect. Finally, research shows that oversized roadways increase the probability of accidents involving pedestrians since cars are more likely to travel at unsafe speeds.[66]

65 One acre of pavement produces sixteen times as much runoff as a one acre meadow. See the Stormwater Management Section for more details.

66 Institute of Transportation Engineers. 1999. *Traffic Calming: State of the Practice.* Informational Report sponsored by the FHWA. FHWA-RD-99-135. Institute of Transportation Engineers. Washington, D.C. Available at: http://www.ite.org/traffic/tcstate.htm

The Federal Highway Administration advocates that designers employ the 'flexibility' that exists within roadway design standards to achieve an optimal design for each road project relative to its unique context, and to provide environmental and social benefits. Reducing impervious pavement area and roadway width is an important objective, where feasible and appropriate. In New York City, this objective is particularly challenging, as pedestrian and commercial demands for space in the urban right-of-way are heavy. However, creative solutions for minimizing impervious pavement area are readily achievable; if properly designed, these streets enable pedestrians, bicyclists, surface mass-transit vehicles and cars to mix safely, and ensure that the flow of goods and commerce is maintained.

INTEGRATION

- **SS.2** Improve Streetscape for Pedestrians
- **SS.3** Improve Streetscape for Bicyclists
- **SS.5** Increase and Improve Right-of-Way Public Space and Green Areas
- **PA.4** Use Pervious Pavements
- **SM.1** Conduct Integrated Stormwater Management Planning
- **SM.3** Minimize Runoff from New Building Construction and Major Renovations
- **SM.4** Optimize Right-of-Way Drainage
- **LA.1** Optimize Citywide Landscape Planning
- **LA.2** Encourage Ecological Connectivity and Habitat
- **LA.3** Create Absorbent Landscapes
- **LA.7** Increase Quantity, Diversity and Density of Trees
- **LA.8** Plant Trees to Maximize Shading of Pavement

TECHNICAL STRATEGIES

Site evaluation:

- Research site history, conduct traffic counts and accident analysis. **(SA.1)**
- Determine if road geometry is oversized or is a factor in traffic accidents.
- Consider lowering design speeds or level of service, and implementing traffic calming.
- Analyze opportunities for pavement reduction.
- Consider pedestrian criteria and streetscape amenities. **(SS.2, SS.5)**
- Coordinate with area-wide bikeway initiatives. **(SS.3)**
- Coordinate with efforts to improve operation of surface mass transit. **(SS.4)**
- Discuss strategies with community board and fire department. **(SS.1)**

Develop an overall right-of-way geometry: Incorporate the following objectives:

- Pedestrian design and traffic calming objectives. **(SS.2)**
- Bicycle planning objectives. **(SS.3)**
- Surface mass-transit operation objectives. **(SS.4)**
- Improvements to right-of-way public space, green areas, or streetscape amenities. **(SS.1, SS.5, LA.3)**
- Stormwater management best practices. **(SM.4 to SM.11)**

Route 9A Reconstruction – Manhattan, NY
Lane-widths were reduced to 11' and breakdown lanes were eliminated (pullouts provided every 600') to minimize impervious pavement, allow for landscaped medians, and dedicated bike and pedestrian lanes.

Reduce right-of-way impervious pavement area, where appropriate:
- Reduce vehicle lane widths, where appropriate.[67]
- Reduce quantity of lanes, where appropriate.
- Use turning lanes and shoulders only where necessary.
- Minimize street turning radii. **(SS.2)**
- Reduce ROW parking area, where appropriate.
- Implement traffic calming measures that reduce impervious pavement. **(SS.2)**
- Increase landscaped areas by adding medians, planting strips, etc. **(SS.5, LA.3)**
- Redesign impervious medians and other features with landscaping. **(SS.5, LA.3)**
- Consider changes to sidewalks to reduce impervious pavement.
- Minimize the extent of unbroken expanses of impervious pavement.
- Increase landscaping within full-width sidewalk areas. **(SS.5, LA.3, LA.7, LA.8)**
- Use pervious pavements. **(PA.4)**

Reduce impervious pavement in parking lots: Reduce impervious pavement in parking lots by up to 30% through the following changes:[68]

Reduce impervious pavement in parking lots:
- Substitute compact cars parking stalls for 30% of all spaces.
- Share parking between businesses with different peak parking demand schedules.
- Use the smallest allowable dimensions for regular parking stalls.
- Base parking lot design on average parking needs rather than peak parking needs.
- Consider using pervious pavements, especially in overflow parking areas. **(PA.4)**

EXAMPLE

The City of Portland implemented its *Skinny Streets Program* in 1991 to reduce street widths and calm traffic. Reducing street widths has helped to enhance livability in communities, decrease stormwater runoff, and reduce construction costs of new streets.

After two decades of planning and design, the reconstruction Route 9A in Manhattan – a vital 5 mile section of roadway beginning at the Brooklyn Battery and running to West 59th Street – was completed. This southernmost section of State Route 9A was originally conceived of as an eight lane elevated urban freeway, but through an interdisciplinary design process involving planners, landscape architects, and community representatives, the final result is a six lane urban boulevard with a reduced design speed, dedicated bike lanes, and ample landscaping. A distinguishing feature of the final design is the center landscaped median that is elevated .50 m to .85 m (20 in to 34 in) above the roadway to allow for increased soil capacity and tree plantings. In addition, lane widths were reduced from 12' to 11' even though Route 9A is a truck route and high volume road. Breakdown lanes were also eliminated. According to the FHWA, the Route 9A redevelopment illustrated that a collaborative, multidisciplinary, and public planning and design process can result in the creation of a world-class street design. It should be noted that Route 9A has a high-intensity maintenance program, which is entirely paid for by New York State.

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[67] AASHTO Guidelines do not require 12' wide lanes. Lane widths can be reduced without affecting level of service or traffic volumes.

[68] Recommendations from: Environmental Protection Agency. 2001. *Our Built and Natural Environments: A Technical Review of the Interactions between Land Use, Transportation, and Environmental Quality.* EPA 123-R-01-002. EPA: Washington DC. http://www.epa.gov/livability/pdf/built.pdf (Accessed December, 2003). Page 50.

PA.3 MAXIMIZE PAVEMENT ALBEDO

OBJECTIVE

Maximize pavement albedo, or reflectivity, to reduce urban heat island effect, improve air quality, and reduce energy consumption for air-conditioning.

BENEFITS

+ Reduces urban heat island effect and energy use.
+ Reduces the production of ground level ozone, significantly improving public health and quality of life.
+ Increases pavement durability, resulting in longer lasting streets and cost savings.
+ Improves nighttime illumination by increasing the effectiveness of artificial street lighting and enhancing natural ambient lighting.

LIMITATIONS

– Could increase the cost of design and construction, especially if new equipment is required.
– Poor roadway maintenance and inadequate utility cut restoration could undermine efforts to increase pavement albedo.
– Could increase maintenance needs and cost.
– Light-colored asphalts or coatings that require routine reapplication may be impractical for high-use roads or composite pavements with a sacrificial wearing course.

BACKGROUND

According to the EPA, 'albedo' is the ability of a surface material to reflect incident solar (short wave) radiation. Albedo is expressed on a scale of 0 to 1 where a value of 0.0 indicates that a surface absorbs all solar radiation, and an albedo value of 1.0 represents total reflectivity.[69] Light-colored surfaces generally have higher albedos and dark materials have lower albedos. Conventional asphalt has an albedo in the range 0.04 to 0.12, while concrete has an albedo of around 0.5.

Increasing the albedo of paved surfaces will decrease the absorption of solar energy, thereby reducing the build-up of urban heat. The urban heat island effect has played a primary role in increasing average summertime temperatures in NYC by approximately 4 degrees Fahrenheit since 1880.[70] The urban heat island effect is likely to be compounded in the future by increasing global climate change, causing significant public health, economic, and environmental consequences. High air temperatures inflict severe stresses on humans, especially on children, the elderly and people with respiratory problems. The urban heat island effect increases the concentration of ground level ozone – a harmful eye and respiratory irritant – and also increases energy demand for air conditioning use, further increasing air pollution. Studies estimate that Los Angeles could save $90 million a year from decreased energy use and smog reduction if it increased pavement albedo citywide (to .25).[71] Researchers also estimate that a reduction in urban temperatures of approximately 3 degrees F. would produce air quality benefits equivalent to replacing a city's entire fleet of gas-powered cars with electric vehicles.[72]

INTEGRATION

- **PA.2** Minimize Impervious Pavement Area
- **PA.4** Use Pervious Pavements
- **PA.6** Use Recycled and Reclaimed Materials
- **LA.8** Plant Trees to Maximize Shading of Pavement
- **SS.7** Optimize Streetlighting and Signaling

TECHNICAL STRATEGIES

Planning

Develop a comprehensive, citywide plan to increase pavement albedo:
- Analyze the benefits and costs of increasing albedo citywide.
- Set a goal for citywide pavement albedo.
- Conduct research and development
- Determine ways to improve pavement maintenance so albedo increase is not undermined.
- Use lifecycle analysis to choose the most cost effective strategies.
- Integrate with other city planning and high performance infrastructure initiatives.
- Provide regulatory or financial incentives to encourage private sector participation.

69 Environmental Protection Agency. From Heat Island Effect Webpage: http://www.epa.gov/heatisland/resources/faq.html#7.

70 Factoring in global warming, researchers estimate that by the year 2100, temperatures in NYC could increase up to ten degrees Fahrenheit, resulting in many 90-degree days as Miami. Bloomfield, Janine, Environmental Defense Fund. *Hot Nights in the City: Global Warming, Sea-Level Rise and the New York Metropolitan Region*. New York: EDF, 1999. http://www.environmentaldefense.org/documents/493_HotNY.pdf Page. 5.

71 Heat Island Group. http://eetd.lbl.gov/HeatIsland/Pavements/Durability/

72 Stone Jr., Brian, and Rodgers, Michael O. *Urban Form and Thermal Efficiency, How the Design of Cities Influences Urban Heat Island Effect*. APA Journal Spring, 2001. Vol. 67, No. 2. http://www.wisc.edu/urpl/people/stone/UFTE.pdf

- Work with utility companies and private contractors to improve pavement maintenance techniques and to minimize pavement disruption. **(UI.1 to UI.4)**
- Increase albedo in all road resurfacing and reconstruction projects.

Design

Consider using light colored aggregate in asphalt: Using light colored aggregate increases average albedo over a pavement's lifetime. As dark asphalt binder wears away, the light colored aggregate is revealed, raising albedo and reflectivity.

Consider using high-albedo asphalt coating: Asphalt coatings allow for an albedo of over 0.5. One study found that the average summertime surface temperature of high-albedo coated asphalt was 88 degrees F, compared to 123 degrees for conventional asphalt.[73]

Consider conducting chip-sealing on low volume roads: Chip sealing is a pavement surfacing technique that uses a thin layer of asphalt covered with partially exposed light colored aggregate. Chip sealing increases albedo to as high as 0.35, compared with conventional asphalts albedo of 0.04 to 0.12.

Consider painting sections of pavement with light-colored paint: Paint bike lanes, crossing areas, intersections and other zones with light-colored paint to enhance visibility and safety, and to reduce urban heat.

Consider using Portland cement concrete where possible: The albedo of Portland cement concrete is around 0.5. Substitute Portland cement concrete for asphalt concrete wherever possible.[74] Ultra thin white-topping can be used as a rehabilitation strategy to keep the costs of design and construction to a minimum, while increasing albedo.

Consider using a tinted asphalt or white binder: Conduct research and development and consider use of best-available technologies for light colored asphalt binders.

Consider using alternative soil stabilization resins: Alternative soil stabilization resins can be used to provide walking or vehicle surfaces in light-traffic areas such as park walks, runs, and bike paths.

Maintenance

- Ensure that roadway maintenance does not diminish albedo.[75]
- Work with utility companies and private contractors to improve pavement maintenance techniques and to minimize pavement disruption. **(UI.1 to UI.4)**
- Consider fines or penalties for non-compliance.

[73] Research conducted by the Heat Island Group, using asphalt coating developed by Reed & Graham, Inc. of San Jose, California. http://eetd.lbl.gov/heatisland/pavements/lowertemps.

[74] The trend in metropolitan and urban areas is to move towards a composite pavement structure similar to NYC's design rather than a rigid pavement, due to the difficulty in repairing utility cuts in the latter. However, atypical city streets with no utilities may be a good candidate for a higher-albedo rigid pavement. See Example.

[75] According to the Downtown Brooklyn Traffic Calming Project Final Report, published by the NYC DOT, 'material and color changes to pavements are often rendered ineffective through poor roadway maintenance. Much more stringent maintenance practices are needed to maintain the effectiveness of these techniques.' http://www.nyc.gov/html/dot/html/motorist/dntnbklyntraf.html. (Accessed June 2004). Pages 45-68. Pages 72-3.

PERFORMANCE GOALS

- Increase citywide albedo to 0.25.
- Achieve an albedo of 0.3 or higher on road resurfacing and reconstruction projects.

EXAMPLE

Route 9A in Manhattan was reconstructed with a 50-year design life, rigid pavement structure composed of high-albedo concrete. Improvements were made to subsurface utilities to prevent the need for near-term utility repair and to protect the 50-year pavement. To facilitate the use of concrete, a crusher plant was constructed to create recycled aggregate and a local concrete plant was reopened to avoid long distance transportation. For this and many other reasons, Route 9A is considered a premier example of "Context Sensitive Design." See the "Precedents in NYC" section in Part I for more details.

In Georgia, the non-profit group 'Cool Communities' – which is sponsored by the US Department of Energy and Environmental Protection Agency – has formed a coalition of public and private organizations to work together to reduce urban heat island effect by promoting increased pavement albedo, among other strategies.
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PA.4 USE PERVIOUS PAVEMENTS

OBJECTIVE

Use pervious pavements, where appropriate, to increase on-site infiltration, reduce stormwater runoff and water pollution, and reduce urban heat island effect.

BENEFITS

+ Reduces runoff, combined sewer overflows, and water pollution.
+ Improves water quality through physical filtration.
+ Reduces urban heat island effect.
+ Improves urban hydrology and facilitates groundwater recharge.
+ Improves traffic safety by reducing hydroplaning and improving wet weather visibility.

LIMITATIONS

– Not appropriate for high volume roads.
– Could result in groundwater contamination.
– Difficult to use where soil is compacted.
– Requires periodic maintenance.
– Diminished infiltration rate, clogging, and flooding could result from inadequate maintenance.
– Sensitive to frost heave and clogging.

BACKGROUND

Pervious pavements are hard surfaces – often equal in strength and durability to conventional pavements – that allow stormwater to percolate through the pavement and into the ground. Using pervious pavements to encourage infiltration throughout the City will reduce runoff, combined sewer overflows, and water pollution. It will also aid in groundwater recharge and urban heat island mitigation. Two types of pervious pavements exist. The first is 'porous surfacing', which allows water to infiltrate across the entire paved surface through small openings. Types of porous surfacing include porous asphalt, porous concrete, and porous pavers. Porous asphalt and concrete are created by leaving the fine aggregate out of the paving mix, and by leaving the surface unsealed, allowing water to infiltrate. The second type of pervious pavement is 'permeable surfacing', which allows water to infiltrate through pervious joints or spaces between pavement material. Permeable surfacing typically consists of unitary brick, stone, or concrete where the joints between the pavers are filled with a porous material such as gravel. Open-grid pavement, another type of permeable surfacing, typically consists of plastic or concrete "grids" which are infilled with grass, gravel or other porous material.

INTEGRATION

- **PA.2** Minimize Impervious Pavement Area
- **SM.1** Conduct Integrated Stormwater Management Planning
- **SM.3** Minimize Runoff from New Building Construction and Major Renovations
- **SM.4** Optimize Right-of-Way Drainage

TECHNICAL STRATEGIES

Site Evaluation

- Conduct soil analysis. **(SA.2)**
- Conduct hydrologic and hydraulic analysis. **(SA.3)**
- Ensure soil is suitable for infiltration. **(SA.2, SA.3, SM.9)**
- Determine if porous surfacing (porous asphalt, porous concrete, porous pavers, etc.) or permeable surfacing (open-grid paving, interlocking paving stones, etc.) are appropriate.
- Avoid using pervious pavements near potential sources of pollution, including gas stations, truck stops, and industrial sites.
- Ensure that use of pervious pavements will not result in groundwater contamination.
- Ensure that de-icing procedures will not decrease functionality.

Planning and Design

Consider using pervious pavements in right-of-way applications:
- Low volume roads.
- Roads susceptible to flooding.
- Parking areas or shoulders.
- Sidewalks and walking paths.
- Separated bike lanes.
- Fire truck access lanes.

Use pervious pavements in other locations:
- Parking lots.
- Roads and walkways in parks.
- Back alleys and service areas.
- City facilities, including warehouses, bus depots, maintenance facilities, etc.

Design

- Provide reservoir of crushed stone or river-run pebbles below porous paving.
- Use a geotextile below reservoir basin to reduce sediment migration into sub-base.
- Ensure that traffic markings will bond to the pavement and will not require unreasonable rates of reapplication.
- Separate large expanses of impervious pavement with pervious pavements. **(PA.2)**
- Consider using BMPs in conjunction with pervious pavement installations to aid in the reduction and treatment of runoff, and to prevent flooding. **(SM.4 to SM.11)**
- Edge pervious pavement areas with filtration strips compose of river stones or other materials. **(PA.5)**
- Slope adjacent grade away from porous pavement to avoid carrying excess sediment into the porous pavement area.

Maintenance

- Perform periodic vacuum sweeping and/or jet hosing to maintain the infiltrative capacity of pervious pavements.
- Avoid sedimentation of downstream BMPs or water sources during maintenance. **(CP.3)**
- If necessary, perform periodic mowing of modular open grid pavements planted with turfgrass.
- Ensure that de-icing procedures will not decrease functionality. Avoid sand and salt applications during winter maintenance. **(SM.2)**
- Use care when snowplowing. Grid pavers and turf-pave systems require a special skid-plate on snowplows to keep the blades from digging up the pavement surface.
- If possible, analyze sediment removal rate to optimize maintenance schedule and infiltration performance.

EXAMPLE

Reconstructed sidewalks along Route 9A in Manhattan incorporate un-grouted granite pavers on top of a continuous tree trench filled with structural soil to increase stormwater infiltration and uptake by trees. Use of structural soil and increased soil volume also enables deeper root growth, and thus prevents damage to sidewalks.

Porous asphalt pavement was used on a section of Cross Island Parkway just south of Northern Boulevard to reduce periodic flooding. The asphalt looks just like conventional asphalt. Undertaking monitoring of this and other pervious pavement sites over time will help the City assess the cost effectiveness, performance, durability, and maintenance needs of using pervious pavements in highly trafficked right-of-ways.

The Sunrise Yards Department of Transportation Maintenance Facility employs two types of permeable pavements in a parking lot and fire truck route.

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PA.5 USE REDUCED-EMISSION MATERIALS

OBJECTIVE

Minimize levels of volatile organic compounds (VOCs) and overall toxicity in compounds, sealants, coatings, traffic markings, and other products or materials used in right-of-way construction. Conserve natural resources by specifying renewable or biobased materials and products.

BENEFITS

+ Reduces air pollution and the production of ground level ozone.
+ Increases health and safety of workers, reducing liability for the City.
+ Increases public health and safety.
+ Reduces water and ground pollution.
+ Reduces resource depletion.

LIMITATIONS

– Some water-based products may increase construction times.
– Some water-based products cannot be used in cold weather.

BACKGROUND

Many construction materials and paints used in the public right-of-way contain compounds, chemicals and substances that adversely impact the environment and are hazardous to human health. One of the most serious consequences resulting from use of these materials is ground-level ozone, which is formed in photochemical reactions with volatile organic compounds (VOCs) and nitrous oxides found in these materials. Aggravated asthma, reduced lung capacity, and increased susceptibility to certain respiratory illnesses are just a few of the health problems attributed to even very low levels of ground-level ozone. Ecological impacts include decreased plant resistance to insects, harsh weather and generation of other pollutants.

Another class of toxins known as hazardous air pollutants (HAPs) is found in typical infrastructure construction materials. HAPs are typically released in smaller quantities but can be even more dangerous than VOCs. Certain products and processes are evaluated in terms of their toxicity – a measure of how harmful a chemical is to human health based toxicological data. Though toxicity measurement is primarily limited to industrial processes, some of the same determinants used to rate toxicity can be applied to infrastructure materials. Limits on VOCs and other toxins can be enacted by inserting requirements into standard specifications, which will ultimately lead to increased use of reduced-emission, renewable, and biobased products.

INTEGRATION

- **SM.2** Prevent Water Pollution and Practice Source Control
- **CP.2** Protect Existing and Future Planted Areas
- **CP.3** Protect Water Sources During Construction

TECHNICAL STRATEGIES

Ensure Compliance

- Require submittal of product data sheet and Material Safety Data Sheets (MSDS) for each product proposed for use. If VOC concentration is not indicated, request information from manufacturer.
- Submit data indicating biobased material and content in product.

Applications for Asphaltic Materials[76]

Asphalt, the semi-solid residual product of petroleum refining, is used in urban areas for a variety of applications from paving to patching. Diluents or solvents used in asphaltic materials often contain high levels of VOCs. Consider the following strategies to reduce environmental impact:

Prioritize use of hot-mix asphalt: Hot-mix asphalt (HMA) has minimal emissions of VOCs and HAPs due to its high molecular weight and low vapor pressures and is preferred over high-diluent products.[77] Current City practice is to use HMA wherever possible, for resurfacing, reconstruction and repairs.

Reduce impact of prime coat: In flexible pavements, minimize impact from prime coats applied to the granular base before the asphalt course is applied:
- Limit use of cutback petroleum- based asphalt.
- Specify asphalt prime coat with lowest possible diluents to achieve lowest possible VOC emissions.

Reduce patching and sealing emissions:
- Cover asphalt container when possible.
- Specify HMA or water-based (emulsified) asphalt use when possible in warm weather.[78]

76 Asphaltic cement: is either fluxed natural asphalt or residual asphalt derived from the distillation of asphaltic petroleum.

77 Emission Inventory Improvement Program Technical Report Series, STAPPA ALAPCO EPA Emission Inventory Improvement Program. January 2001, Vol. 3, Ch. 17. Available at: http://www.epa.gov/ttn/chief/eiip/techreport/ (Accessed 10/13/04)

78 Emulsified asphalt: is a liquid mixture in which minute globules of bitumen are held in suspension in water or in a watery solution. Emulsified asphalt emissions are lower than cutback, however, some emulsified asphalts contain up to 12% solvents.

- When petroleum-based asphalt (cutback[79]) is required, use compound with lowest possible diluent concentration to achieve lowest possible VOC emissions.[80]

Applications for Concrete Materials

Concrete sidewalks, slabs, boxes, cradles and other structures found in the right-of-way are sprayed with concrete curing materials to seal them off and prevent evaporation. It is a one-time application performed during a concrete pour, and is either confined or wears off with time. Consider the following strategies to minimize VOCs:

Reduce impact of concrete curing compound:

- Specify curing compounds with lowest possible diluents to achieve lowest possible VOC emissions. Specify 160g/L limit on VOC content of concrete curing compounds, as per DDC Office of Sustainable Design Low Toxicity Material Specifications.
- Consider the feasibility of limiting VOC content to 90 g/L, as per DOD-EPA Parking Lot Requirements contract.
- Specify water-based, acrylic compound.
- In composite pavements, use the tack coat between the concrete base and asphalt-wearing course as a concrete curing compound.

Reduce impact of tack coat:

- Specify emulsified asphalt/curing compound in warm weather.[81]
- Limit cutback asphalt use.
- Specify asphalt tack coat/curing compounds with lowest possible diluents to achieve lowest possible VOC emissions (e.g. maximum of 250 grams per liter).

Reduce impact of form release agent:

- Specify low- to zero-VOC form release agent.
- Use biobased, biodegradable agent with minimum 85% soy-based oil or other biobased material.[82]

Applications for Traffic Marking Coatings

- When possible, substitute change of pavement color or texture for coated traffic markings.

79 Asphalt cutback, or liquid asphalt, is a product of fluxing an asphaltic residuum with a petroleum distillate, typically 25 to 40 percent by volume. Asphalt cutback emissions are caused by the use of diluents containing VOCs and some HAPs.

80 Rapid Cure (RC) asphalt cutback uses gasoline and napthas as diluents and produces the highest emissions, with evaporative losses estimated at 95 percent by weight of diluent. Medium Cure (MC) asphalt cutback uses kerosene as a diluent, and evaporative losses are estimated at 70 percent by weight of diluent. Slow Cure (SC) uses low volatility fuel solvents as diluents and produces the lowest levels of emissions, with evaporative losses estimated at 25% by weight of diluent.

81 Emulsified asphalt is currently prohibited from application as concrete curing compound when the weather is below 40 degrees

82 As per the June 7, 2002 Draft of the USDA Biobased Products — Definitions and Descriptions, minimum biobased content for construction materials is 85%.

- Use negligible-VOC emissive thermoplastic traffic markings (less than 50 grams per liter) for permanent markings; limit paint to temporary applications.
- Use low-VOC primer (less than 150 grams per liter) for thermoplastic reflectorized pavement markings and thermosetting adhesives.
- Consider using recycled content glass beads in thermoplastic reflectorized pavement markings. Take caution, as glass beads can shatter on impact with sharp metallic objects.
- Specify 150 g/L limit on VOC content of temporary and permanent traffic marking paint. Use paints with low levels of aromatic compounds and other restricted chemicals.
- Specify a latex, water-based emulsion marking paint when street closure does not affect traffic.
- Consider the use of high build acrylic coating (HBAC) on asphaltic pavement and pavements.[83]
- Consider water-based road marking paints in combination with reflective glass beads.

Applications for Anti-Graffiti Coatings

- Specify 250 g/L limit on VOC content
- Use water-based coatings

Applications for Biobased Filter Fabric

See PA.6, Part Vi

EXAMPLE

At the Pentagon in 1997, the Department of Defense, in partnership with the EPA, implemented a pilot construction project utilizing environmentally benign pavements and pavement accessories. Among the products used were water-based, lead-free, chromatic-free, and low-VOC content paint alternatives.
See http://www.epa.gov/opptintr/epp/pubs/eppdod1.pdf

West Virginia prohibits the manufacture, mixing, storage, use or application of cutback asphalts during the ozone season, which extends from May through September. Emulsified asphalt containing any VOC is prohibited during the same period without exception. In the District of Columbia these same restrictions are extended from April through September.

83 HBAC produces upraised markings and is appropriate for use in marking crosswalks, centerlines, etc.

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PA.6 USE RECYCLED AND RECLAIMED MATERIALS

OBJECTIVE

Use recycled and reclaimed materials in infrastructure construction to divert waste materials from landfills into productive reuse. Create policy and program mechanisms to facilitate the use of recycled and reclaimed materials. Systematically evaluate usage.

BENEFITS

+ Conserves and reduces pressure on local landfills.
+ Reduces transportation costs and air pollution.
+ Decreases the likelihood of future raw materials shortages.
+ In many cases offers significant cost savings over virgin materials, particularly if locally available or site processed.
+ Decreases the embodied energy of pavements by taking advantage of the energy already invested in the recycled / reclaimed products.
+ Some recycled / reclaimed materials improve pavement workability during construction.
+ Some recycled / reclaimed materials increase pavement strength and durability.
+ Large quantities of recycled and reclaimed materials are regionally available, and high levels of recycling are possible.[84]
+ Promotes local economic development and strengthens the market for recycled material technologies.

LIMITATIONS

– Impurities in recycled / reclaimed materials can lead to inconsistent or reduced mixture stability, strength and durability.
– Can lead to migration of lime into planting soil.
– Quality control procedures could make using certain recycled / reclaimed materials cost prohibitive in comparison to locally available and inexpensive virgin aggregates.
– Some recycled / reclaimed materials used for aggregate are more absorptive than conventional aggregate and therefore have a higher asphalt cement demand.
– In some cases, excessive use of recycled / reclaimed materials can reduce mixture stability and strength.
– Some recycled / reclaimed materials are dusty and may result in more dust generation than normal.
– Using some recycled materials in concrete could require a longer set time.

BACKGROUND

This BMP is organized into six subcategories: one recommending programmatic practices and five demonstrating material applications:

I) DEVELOP A RECYCLED MATERIALS PROGRAM

II) APPLICATIONS IN ASPHALT CONCRETE

III) APPLICATIONS IN PORTLAND CEMENT AGGREGATE

IV) APPLICATIONS IN PORTLAND CEMENT CEMENTITIOUS MATERIALS

V) APPLICATIONS IN SUB-GRADE

VI) NON-PAVEMENT APPLICATIONS

INTEGRATION

▫ **SA.1** Assess Site and High Performance Opportunities
▫ **PA.1** Optimize Pavement Lifecycle Citywide
▫ **PA.3** Maximize Pavement Albedo
▫ **UI.2** Improve Restoration of Utility Cut Trenches
▫ **LA.6** Perform Soil Berming
▫ **CP.4** Implement a Waste Management and Recycling Plan

[84] In the US, between 350 and 850 million tons of potentially usable materials are generated from the municipal, industrial, and transportation sectors each year, while the use of new materials in highway construction is estimated to be 350 million tons per year (320 M tons of which is aggregate). The Netherlands has an extremely efficient recycling program that aims to achieve closed material cycles for construction materials; for many transportation materials, the Netherlands acheves 100% recyclng. Sweden, Germany and Denmark also have high recycling efficiencies for materials utilized in pavement construction. See Eighmy, T. Taylor, and Holtz, Katherine. 2000. Scanning European Advances in the Use of Recycled Materials in Highway Construction. *Public Roads.* U.S. Department of Transportation, Federal Highway Administration, July, Vol.64. No.1. http://www.tfhrc.gov/pubrds/julaug00/index.htm (Accessed December, 2003). 2 Ibid.

I. DEVELOP A RECYCLED AND RECLAIMED MATERIALS PROGRAM

Develop a program to increase recycled materials used in street construction:[85]

- Assess amounts and types of recycled and virgin materials currently used.
- Evaluate regional supplies of recycled and virgin materials.
- Identify goals and strategies for increasing the use of recycled and reclaimed materials.
- Prioritize using affordable, locally available, and dependable materials.
- Develop a system to track recycled materials use, performance, lifecycle cost savings, environmental and economic benefits.
- Conduct and evaluate recycled materials pilot projects.
- Develop specifications and Quality Assurance/Quality Control (QAQC) for approved recycled materials.
- Conduct research and development to identify new and improved recycled materials technologies.

Evaluate engineering performance:[86]

- Recycled / reclaimed materials should meet or exceed all conventional performance criteria.
- Ensure that existing test methods and criteria are applicable to the proposed recycled/reclaimed material. If necessary, develop new tests and evaluation criteria.
- Consider modifications to the material or application to achieve performance criteria.
- If necessary, supplement laboratory tests with field evaluations.

Evaluate and minimize environmental impact:

- Ensure that using recycled/reclaimed material in a specific application will not adversely impact soil, water, air, vegetation health, etc.
- If no relevant criteria exist, develop environmental standards for recycled / reclaimed materials and applications.
- Define maximum acceptable contaminant levels in the material.
- Define maximum acceptable emission or leaching of physical and chemical constituents from the material in its application.
- Where appropriate, use mechanistic leaching tests and application-specific evaluation of impacts to soil and groundwater.[87]

85 Guidelines for starting a recycled materials program are based on: Davio, Rebecca. 2000. Lessons Learned: TxDOT's Efforts to Increase the Use of Recycled Materials. *Public Roads*. U.S. Department of Transportation, Federal Highway Administration, July. Vol. 64, No.1. http://www.tfhrc.gov/pubrds/julaug00/index.htm (Accessed December, 2003).

86 Federal Highway Administration. 1997. Turner-Fairbank Highway Research Center. 2000. *User Guidelines for Waste and Byproduct Materials in Pavement Construction*. Chapter 21. Evaluation Guidance –General Framework. FHWA-RD-97-148. U.S. Department of Transportation. FHWA: Washington, D.C. http://www.tfhrc.gov/hnr20/recycle/waste/begin.htm (Accessed December, 2003).

87 The European Union is considering adopting this as standard criteria. Eighmy, T. Taylor, and Holtz, Katherine. 2000. Scanning European Advances in the Use of Recycled Materials in Highway Construction. *Public Roads*. U.S. Department of Transportation, Federal Highway Administration, July, Vol.64. No.1. http://www.tfhrc.gov/pubrds/julaug00/index.htm (Accessed December, 2003).

- Where appropriate, use laboratory and field tests to determine if material meets environmental criteria in its application.[88]
- Evaluate environmental cost savings (reduced air pollution, reduced waste, etc).

Evaluate occupational safety and health:

- Develop standards or use existing criteria for protecting worker health and safety.
- Minimize exposure to dust, fumes, corrosive liquids, sharp edges and other harmful material properties.[89]
- Where appropriate, use laboratory and field tests to determine potential hazards to workers and to ensure acceptability.

Evaluate future recycling, reuse, or disposal of material:

- Determine potential applications for recycling or reusing the material at the end of its service in the current application.
- Consider disposal requirements and costs.
- Ensure that no adverse impacts would result from recycling or disposing of the material.

Use full cost accounting to evaluate cost-effectiveness:

- Use full cost accounting to determine if using the recycled / reclaimed material in its application is cost-competitive with conventional materials.
- Account for the all intrinsic material costs, including price of extracting and processing raw material, stockpiling, loading, and transporting.
- Account for installation costs, including design, construction, testing and inspection.
- Account for lifecycle costs, including changes in maintenance requirements and expected service life.
- Account for environmental costs, including reduced impact from avoided transportation and landfilling.

Establish and enforce quality assurance: Develop and implement application-specific quality assurance criteria for all recycled / reclaimed materials.

Partner with construction and demolition (C&D) waste processors:

- Seek to divert waste from City projects to maximize recycling rates and minimize vehicular hauling and landfilling.
- Regularly inform recycled materials suppliers of potential demand by City agencies, including job size, timing, and location.
- Develop a recycled construction materials market directory listing companies and organizations that collect, process and market these materials. Provide list of acceptable materials from each company or organization.
- Coordinate with building construction efforts.
- Make recycled construction materials market directory available on the internet.

88 Federal Highway Administration. 1997. Turner-Fairbank Highway Research Center. 2000. *User Guidelines for Waste and Byproduct Materials in Pavement Construction*. Chapter 21. Evaluation Guidance – General Framework. FHWA-RD-97-148. U.S. Department of Transportation. FHWA: Washington, D.C. http://www.tfhrc.gov/hnr20/recycle/waste/begin.htm (Accessed December, 2003).

89 Ibid.

EXAMPLE

The Sold Waste Division construction webpage for King County, Washington State is a model recycled construction materials market directory. It includes jobsite waste guidelines, a waste management plan template, sample waste recycling specifications, directory of local construction waste recyclers and more. Assistance is offered in the form of presentations to jobsite workers on recycling, site visits to assess recycling options and research on recycling options for various materials. http://www.metrokc.gov/dnrp/swd/construction-recycling/index.asp

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II. APPLICATIONS IN ASPHALT CONCRETE

Reduce the use of virgin asphalt concrete material and redirect waste material from landfills by using recycled asphalt pavement (RAP) or other recycled materials in asphalt concrete.[90] Asphalt pavement can be recycled and incorporated into new pavement using a variety of methods.[91] This BMP focuses on hot-mix asphalt (HMA) recycling, which is the most feasible and commonly used method in New York City. Recycled asphalt pavement exhibits similar performance criteria to non-recycled mixes in terms of rutting, raveling, weather resistance and fatigue cracking. Many additional waste materials, such as glass, industrial byproducts, etc, can also be used in asphalt pavement.

BENEFITS

+ Significantly reduces costs.[92]
+ Conserves non-renewable petroleum resources and virgin aggregate.
+ RAP has a longer lifecycle than conventional asphalt.
+ Improves water resistance of pavement.
+ Penetration values of the binder, or relative hardness, are significantly lower and viscosity is much higher.

LIMITATIONS

– Dedicated sources with consistent QAQC must be identified.
– Variations in RAP source and type can cause volumetric swings.[93]
– Stockpiles of milled RAP batches must be kept separate from other materials.
– Current asphalt plant technology may prohibit extensive use of RAP.
– Area asphalt purchasers may be reluctant to create a strong market for RAP.
– Asphalt handling costs are increased.

TECHNICAL STRATEGIES

Recycled Asphalt Pavement (RAP)

The percentage of RAP used in HMA depends on plant technology, RAP aggregate gradation, physical binder properties, and gaseous emission regulations. Other factors include ability to exercise systematic quality control, which is essential to obtaining a consistent, high-quality pavement containing RAP or recycled products.

90 NYC does not use a full-depth asphalt pavement, but typically calls for a 3" asphalt concrete wearing course on its roads. This mix can incorporate as much as 40% RAP, the limiting factors being plat capabilities and performance. Many commonly available waste products can be diverted back into the materials stream for asphalt pavement aggregate, bituminous mix, or mineral filler.

91 Recycling methods include full depth reclamation (FDR), cold-in-place recycling (CIPR), hot-in-place recycling (HIPR), and hot-mix asphalt (HMA) recycling.

92 It is estimated as much as 18% of the costs of HMA production are saved using a mixture containing 40% RAP. Olson, Roger C., et. al. 'Minnesota's Experience in Implementing the Use of Recycled Materials,' in *Beneficial Use of Recycled Materials in Transportation Applications: Proceedings of the Recycled Materials Resource Center Held in Arlington, VA 13-15 November 2001*, (Sewickly, PA: Air & Waste Management Association), 82.

93 Ibid.

After the existing pavement is milled and removed from the site, it is crushed down to its original components of bituminous binder and clean aggregate. Milled asphalt may be stockpiled until an appropriate use for it is identified. Once a RAP stockpile has been approved for use, the stockpile shall be dedicated solely to that use and no further RAP may be added to the stockpile. A series of tests are conducted and results of these tests are used to design an appropriate asphalt concrete blend of RAP and virgin material.

Evaluate RAP material properties:
- Obtain cooperation from C&D waste yards, recyclers, asphalt plants and contractors.
- Ensure RAP meets specified parameters:
- Adequate material properties.
- Gradation requirements.
- Viscosity and penetration requirements.
- Binder stiffness.
- Stability and flow requirements.
- Air void requirements.
- Mixes incorporating less than 20% RAP do not require a change in asphalt grade as defined by ASTM.[94]
- For mixes incorporating more than 20% RAP, incorporate a recycling or rejuvenating agent to compensate for increased binder viscosity.[95]
- Follow conventional HMA methods for placement.

Consider RAP hot mixing plant requirements:[96]
- Do not expose RAP to high temperatures in excess of 800 degrees Fahrenheit, as that can result in excessive hydrocarbon emissions. Modifications can be made to existing asphalt plants, which typically mix asphalt at 1500 degrees Fahrenheit.

Consider batch plant requirements: RAP substitution rates are limited in batch plants by the heat capacity of the plant, resulting in permissible substitution rates of 10 to 30%.
- The batch plant's dryer may have to be operated at temperatures higher than with all new materials. Modifications to the dryer and the dust collection system may be necessary to prevent damage.
- Batch Plants require an additional metering device and proportioning method for adding RAP to superheated virgin aggregate.

Consider drum plant requirements: RAP substitution rates in drum plants should be limited to 50% due to hydrocarbon emission limitations.[97]
- Drum plants require an additional metering device and proportioning method for adding RAP to the dryer-mixer in a way that does not damage the RAP. Elevated levels of moisture in this mix must be compensated for.

94 Turner-Fairbank Highway Research Center. 2000. *User Guidelines for Waste and Byproduct Materials in Pavement Construction.* Chapter 21. Evaluation Guidance – General Framework. FHWA-RD-97-148. U.S. Department of Transportation. FHWA: Washington, D.C. http://www.tfhrc.gov/hnr20/recycle/waste/rap132.htm

95 Recycling and rejuvenating agents are derived from petroleum extracts and either take the form of soft asphalt, napthenic oils and paraffinic oils.

96 http://www.tfhrc.gov/hnr20/recycle/waste/rap132.htm

97 Ibid.

- The mixing time for a drum-mix plant must be adequate to achieve an intimate blending of the new and reclaimed materials and a complete coating of all aggregate particles.

Properly stockpile RAP:
- Separate stockpiles of milled RAP from one another, since millings from different projects will have different aggregate quality and size, affecting mix consistency.
- Store RAP in conical – not horizontal – stockpiles, to prevent re-agglomeration.
- Regularly monitor the stockpile for moisture content, gradation, and bituminous content.

Consider hot-in-place recycling (HIPR): HIPR eliminates costs associated with transporting, processing, and stockpiling RAP by recycling it on-site. Conduct research and development to seek out HIPR technology that could be used successfully in NYC and overcomes the following limitations:
- Pavement reconditioning is limited to shallow depth with HIPR.
- There is no opportunity to make significant changes to the mix.
- Pavement with irregular patching (i.e. utility cuts) are not suitable for HIPR.
- Regulations prohibiting the use of propane frequently prohibit this type of street construction.

Miscellaneous Recycled Products for Asphalt Concrete

Consider air-cooled blast furnace slag (ACBFS): Referred to simply as 'slag' in many specifications, ACBFS is a by-product of iron manufacture that can be crushed and screened and then used as asphalt concrete aggregate.
- ACBFS offers advantages over conventional aggregate because it weighs less and it improves pavement stability, frictional properties, resistance to rutting, and resistance to stripping.
- ACBFS is porous and may absorb as much as 3% more asphalt cement than non-porous aggregates.
- Use ASTM and AASHTO requirements for conventional asphalt components when using ACBFS.
- Use only Ferrous metal slags. Avoid Nonferrous slags – including processed air-cooled and granulated copper, nickel, and phosphorus slags – since they have poor skid resistance due to vitreous qualities.

Consider mineral processing wastes: Called 'ore tailings' in New York City's asphalt specification, mineral processing wastes are waste rock derived from ore processing sources, and are currently permissible for use as coarse aggregate.[98]
- Use mineral processing waste from local iron ore waste rock source.

Consider fly ash as mineral filler in HMA: Utilize fly ash to achieve asphalt concrete mixtures that exhibit design properties comparable to those containing conventional fillers.

98 Ore tailings have been used in asphalt in New York since 1930, as iron ore tailings are typically trap rock or granite, both of which are of excellent quality.

Consider recycled concrete aggregate (RCA): Substitute percentage of virgin coarse asphalt concrete aggregate with RCA.

- RCA is commonly used in asphalt concrete in regions where virgin aggregate is not plentiful.
- RCA exhibits a porosity similar to ACBFS, but may also absorb more asphalt cement than non-porous aggregates.
- Standard asphalt milling/recycling operations may not be possible in asphalt concrete containing RCA aggregates.

Consider 'glasphalt' and asphalt-rubber: Asphalt concrete incorporating glass cullet as fine aggregate (glasphalt) and asphalt-rubber were attempted in New York City but discontinued for performance problems and issues related to milling asphalt containing recycled material. However, both materials have benefits that make emerging technologies worth considering.

- Glass cullet has a strong continuous market supply in New York City and has some performance benefits. However, exposed glass embedded in asphalt or concrete can crack under impact from sharp objects.
- Asphalt-rubber friction courses reduce traffic noise by between 65-85%, increase pavement lifecycle, and help resist rutting, raveling and cracking.
- Standard asphalt milling/recycling operations may not be possible with asphalt concrete incorporating these two materials. Worker health and safety may be affected during milling operations, due to fine particles of glass. More research is needed in this area.

EXAMPLE

Almost all asphalt milled from New York City roadway reconstruction and resurfacing jobs is recycled or reused as wearing courses, temporary asphalt, base or sub-base material. Although there are no requirements mandating contractors to recycle asphalt, City and private asphalt plants typically mill and recycle or reuse as much RAP as the market demands because of cost savings and prohibitions against dumping un-separated material. Non-recyclable material is transported to the Fresh Kills landfill in Staten Island for use as temporary cover. An incremental environmental improvement would be to redirect this asphalt to private asphalt recyclers. An increase in the allowable percentage of RAP would stimulate this market opportunity.

From 1990 to 1995, the NYC DOT used approximately 250,000 tons of glass cullet in roadway resurfacing projects. To date, this is by far the most aggressive glasphalt program implemented in the region.

Orlando, Florida is using one-pass HIPR on its streets, and reports that it helps reduce traffic delays caused by lane closures, and saves money.[99]

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[99] 'Orlando Recycles its Way to the Top.' *Better Roads*, July 2003.

III. APPLICATIONS IN PCC AGGREGATE

Use recycled concrete aggregate (RCA) – a coarse granular material – in the Portland cement concrete aggregate to reduce the use of virgin aggregate, minimize environmental impact, and redirect waste material from landfills. Currently, City specifications do not differentiate between recycled and conventional aggregate. As long as the RCA meets gradation requirements, passes the tests required by specification, and is clean and free of foreign matter, it can be used at the discretion of the resident engineer on site.[100]

BENEFITS

+ Using site-processed RCA is significantly cheaper than new aggregate hauled to the site, especially for large projects.
+ RCA's durability and soundness properties meet or exceed those of virgin aggregate.
+ Concrete with RCA has good resistance to freeze-thaw exposure.
+ Standard methods and equipment can be used to process RCA concrete mixes.
+ Reduces material, transportation and landfill costs.
+ Exhibits beneficial engineering performance and provides overall cost savings to projects.[101]

LIMITATIONS

– Using a high percentage of RCA may require excessive amounts of water to maintain workability, reducing concrete quality.
– Impurities may lead to inconsistent or reduced strength and durability.
– Freeze-thaw expansion of large aggregate can result in cracking.
– Free lime from unhydrated cement may increase pH of soil, affecting vegetation and tree health.
– Metal reinforcement may be difficult to remove during reprocessing.
– Appropriate test procedures for RCA applications are not standardized.
– Performance-based specifications for RCA do not exist.

[100] A number of obstacles to the use of RCA exist. Where RCA is used, excavated concrete is typically hauled to a central facility for stockpiling, processing, and crushing, screening and metal recovery operations. For it to be worthwhile for processors to separate, grade and wash RCA to meet requirements, there must be sufficient demand. In regions where virgin aggregate is rare or nonexistent, such as Texas, RCA has been used successfully in PCC concrete pavement for many years. In New York, however, where demand for post-demolition material is low, RCA is harder to move out of the recycling yards and back into the construction materials stream, making it difficult for the C&D recycler offer tipping fees lower than the landfills. Additionally, RCA must be 'handled,' that is, subjected to a series of Quality Assurance (QA) tests, thus making it less attractive than the readily available simple source.

[101] FHWA Pavement Technology Recycled Concrete Aggregate Federal Highway Administration National Review – Summary of California Recycled Concrete Aggregate Review. Available at http://www.fhwa.dot.gov/pavement/rca.htm (Accessed August 2004)

TECHNICAL STRATEGIES

Aggregates comprise around 80-85% of concrete mixtures by mass and between 60-65% by volume, and aggregates have a significant impact on the properties and performance of concrete in both the plastic and hardened state. It has been noted that RCA has relatively high QAQC demands; at least one U.S. state discontinued use of RCA because of problems with dry mixtures resulting from poor QAQC, limited construction inspection capabilities, and poor expertise. Construction agencies often forgo the process of developing specifications for use of RCA in PCC in favor of simply creating conditions that allow for its use. However, the following parameters could guide in the development of a specification for the use of RCA as a coarse aggregate in PCC.

Consider grading and proportions: Cementing material and water requirements, workability, pumpability, economy, porosity, shrinkage and durability are all affected by these three factors:

▫ Minimize void spaces in concrete by properly grading RCA and proportioning different sizes in the mix.
▫ Follow same gradation requirements as for natural aggregate materials.
▫ Consider using RCA as the sole coarse aggregate or combining it with other aggregates to obtain optimal mix properties.

Evaluate physical properties of RCA: Conduct tests measuring compliance with AASHTO and ASTM particle strength requirements, soundness (freeze-thaw) limitations, and potential freeze-thaw cycling of the aggregate (D-cracking). Special consideration should be taken when evaluating the following properties of RCA:

Evaluate aggregate shape:

▫ Develop standards for particle size and shape in specifications.
▫ Avoid flat or elongated particles, since they may reduce mix strength. Angular shaped aggregates are preferable though they may reduce workability.

Evaluate absorptivity: RCA is typically reclaimed from air-entrained concrete, meaning void contents may be as high as 9-11%. This results in a porous type, or 'thirsty' aggregate that will be highly water consumptive if preventative steps are not taken.[102] Additionally, there may still be unhydrated (and highly absorptive) cement mortar adhering to the RCA, which could further aggravate high absorption problems. Entities currently using RCA make the following recommendations for mitigating high absorptivity:

▫ Eliminate the fine portion to reduce absorptivity.
▫ Require coarse RCA to be wetted to the saturated dry surface condition prior to mixing, ensuring aggregate pores are filled with water before mixing and eliminating additional water demand.
▫ Sprinkle stockpiles to eliminate excessive water demand.

[102] Jason Harrington, FHWA. Telephone Interview by author. August 5, 2004. Written notes.

Evaluate alkali-silica reactivity (ASR): Siliceous materials in the RCA have the potential to react with alkaline pore water, resulting in an expansive gel that causes the concrete to crack and deteriorate.

- Conduct tests to measure the potential reactivity of RCA and conventional aggregates, and to ensure that ASR will not be a problem.
- Consider using supplementary cementitious materials (SCMs), such as fly ash and slag, to control ASR in PCC, resulting in a more stable mix design than conventional materials yield.

Minimize deleterious substances: Avoid clay lumps, friable particles, shale, chert, and other materials that could affect the chemical and volumetric stability, and weathering resistance of the concrete.

Consider expert recommendations:

- Perform a series of strength tests as introductory measures.
- Pilot-use of RCA in locations where risk is minimal and performance potential is high.

EXAMPLE

In the City of Los Angeles, RCA is allowed to be used in concrete to a maximum of 30% by weight of total aggregate.[103] The City of San Francisco is currently using RCA in flatwork concrete, i.e. in sidewalks, curbs, gutters and street base. The Texas Department of Transportation is currently using 100% recycled concrete coarse aggregate in some pavement designs.[104]

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104 Jason Harrington, FHWA. Telephone interview by author. August 5, 2004. Written notes.

IV. APPLICATIONS IN PCC CEMENTITIOUS MATERIAL

Use supplementary cementitious materials (SCMs) – granulated blast furnace slag (GGBFS) or coal fly ash – in Portland cement concrete to reduce the use of Portland cement, reduce environmental impact, and redirect waste material from landfills.[105]

SCMs are industrial by-products that would otherwise have to be disposed of in landfills, providing cost savings to concrete manufacturers and reducing environmental impact caused by averting disposal. SCMs are typically pozzolans, or finely divided siliceous/aluminous materials that hydraulically react with calcium hydroxide to produce cementitious compounds. Because of their fineness and spherical shape, SCMs produce a concrete with several performance advantages over conventional Portland cement concrete in certain applications and conditions, extending the life cycle of the concrete.

BENEFITS

+ Reduces embodied energy of concrete.
+ Expands production capacity.
+ Reduces emission of greenhouse gases and other air pollutants.
+ Reduces costs.
+ Reduces fuel consumption.
+ Enhances concrete properties in certain applications.
+ Reduces the environmental impact of Portland cement mining operations by decreasing demand.[106]
+ Increases pavement albedo, helping to reduce urban heat island effect.
+ Avoids exploitation of non-renewable resources used in Portland cement.

LIMITATIONS

– Properties of SCMs can vary.
– Some SCMs increase concrete set time, which could delay construction and prolong right-of-way disruption.
– Transportation and storage costs may be high.
– Future reliable source of material is questionable.

105 Although fly ash has been used as an SCM in the United States since the construction of the Hoover Dam in 1929, approximately two-thirds of the 68 million tons produced annually still gets dumped into landfills. The remaining 22 million tons finds its way into engineering applications, primarily SCM in cement production (13.4 million tons). The City of Seattle and the State of Texas provide for the inclusion of fly ash in their specifications.

106 Common complaints regarding mines include noise and visual impact, water and air pollution.

TECHNICAL STRATEGIES

Coal Fly Ash

Coal fly ash is a fine, glassy residue recovered from exhaust gases that are generated from coal combustion power plants.[107] Two classifications of fly ash exist, based on chemical composition: Class C contains over 20% calcium oxide (lime) and is referred to as high calcium fly ash, whereas Class F contains less than 10% CaO and is referred to as low calcium fly ash. When fly ash is added as an SCM during concrete mixing, it typically replaces between 15 to 35%, with substitution ratios for fly ash to Portland cement ranging between 1:1 and 1.5:1 by weight. Concrete incorporating more than 30% fly ash is known as high volume fly ash concrete (HVFAC). Few states or cities allow this substitution rate. However, according to the FHWA, HVFAC has proven in field tests to improve concrete performance beyond conventional concrete and at lower costs. However, high range water reducers must be used to achieve adequate early strength.

New York City currently uses ASTM C 150, 'Standard Specification for Portland Cement' for its cement specifications, which is recommended by the EPA's Comprehensive Procurement Guidelines for Cement and Concrete Containing Recovered Materials.[108] There are currently separate provisions for fly ash in the New York State DOT standard specifications for PCC pavement.

Consider the beneficial properties of using coal fly ash in PCC:
- Water demand is decreased in direct proportion to the amount of fly ash added to the mix.
- Workability is improved by virtue of the spherical shape of fly ash particles.
- Pumpability is improved by minimizing frictional losses.
- Strength gain increases over time to an ultimate strength exceeding conventional mixes, as silica in fly ash reacts with lime and alkali in concrete to produce additional cementitious compounds.
- Fly ash can mitigate alkali-silica reactivity (ASR), or the tendency of alkaline pore water to react with siliceous aggregates and cause expansive cracking. The alkali that could potentially cause this cracking reacts instead with fly ash to produce additional cementitious compounds. This property of fly ash permits the inclusion of recycled concrete aggregate (RCA), which may otherwise cause ASR.
- Permeability is decreased by the additional cementitious compounds and by the reduction in water content. Corrosion is decreased as well.
- Cost benefits from using fly ash rather than Portland cement can be realized immediately and will accrue as the market for fly ash grows.
- Inclusion of fly ash in New York City concrete flatwork or other exposed concrete can help mitigate the heat island effect. Higher albedo, or increased reflectivity, can be achieved with fly ash because of its light color.

[107] Around 68 Million tons of coal fly ash are landfilled annually.

[108] Environmental Protection Agency. Comprehensive Procurement Guidelines, Cement and Concrete Specifications. Available at: http://www.epa.gov/cpg/products/cemspecs.htm#state (Accessed October 2004)

Consider the limiting properties of using coal fly ash in PCC:
- Slower early strength development has been attributed to concretes incorporating fly ash. This is confirmed for Class F fly ash, however, some studies have shown that some Class C fly ashes are as effective as Portland cement in developing early strength.
- Chemical admixtures, known as accelerators, may be necessary to achieve higher early strength.[109]
- Heat of hydration is reduced making cold-weather concreting more difficult.
- Air entrainment can be difficult in certain fly ashes due to their fineness, improved workability, and the presence of additional carbon.
- Consolidated Edison does not allow fly-ash in concrete for electric vaults where drilling may need to be done.

Consider blended cement incorporating coal fly ash: Coal fly ash can be interground with Portland cement clinker and other typical cement components, to produce a mixture known as blended cement. ASTM C595 defines two blended cement products in which fly ash has been added:
- Portland-pozzolan cement (Type IP), containing 15 to 40% pozzolan.
- Pozzolan modified Portland cement (Type I-PM), containing less than 15% pozzolan.

Ground Granulated Blast Furnace Slag (GGBFS)

Blast furnace slag is a nonmetallic industrial by-product of the production of iron. Primarily composed of silicates, aluminosilicates and calcium-alumina-silicates, the majority of blast furnace slag is either air-cooled or foamed. A third type of blast furnace slag is granulated and ground into a very fine material with strong cementitious properties when activated by free lime. Ground granulated blast furnace slag (GGBFS) has been blended into Portland cements since the latter part of the 19th Century, and in 1950 was made available as a SCM in its own right.

Specify use of GGBFS: Because of resistance to new materials and misconceptions that GGBFS is a waste material, the EPA recommends including specific provisions in construction contract documents for the use of GGBFS, when appropriate.

Consider the beneficial properties of GGBFS in PCC:
- Increases pavement albedo, helping to decrease urban heat island effect.
- Improves workability because of lower relative density and increased paste volume.
- Decreases water demand because of lower relative density.
- Improves resistance to alkalis and sulfates.
- Potentially enables higher flexural strength because the shape and surface texture of the slag particles create stronger bonds in the concrete matrix.
- Freeze-thaw performance is excellent with concrete containing 25 to 65% percent GGBFS. Durability factors of 91% have been reported.[110]
- Non-corrosive to metals.

[109] In Canada, Class C fly ash is used in 'high-early strength' concrete, which is designed to gain strength rapidly enough to allow the road to be open for traffic just four hours after placement.

[110] Federal Highway Administration. Available at: http://www.fhwa.dot.gov/infrastructure/materialsgrp/ggbfs.htm (Accessed July 2005)

Consider the limiting properties of GGBFS in PCC:

- Salt scaling resistance may decrease with substitution rates greater than 25%.
- Could slow down strength gain times. Schedule pavement construction accordingly.
- May require water-reducing accelerators to achieve fast set time.
- GGBFS grade should be limited to grades 100 and 120 (grades are designated in ASTM C 989-82). Grade 80 does not provide an adequate compressive strength.

Consider blended cement incorporating GGBFS: Blended cement incorporating GGBFS is defined by ASTM C595 in two parts:

- Slag-modified Portland cement, containing less than 25% slag.
- Portland blast-furnace slag cement, containing between 25 and 70% slag.

EXAMPLES

AirTran JFK, a new transit system linking New York City's John F. Kennedy International Airport with the subway and bus, substitutes as much as 30% GGBFS for Portland cement in its cast-in-place columns and up to 40% in precast segments.

New York City is saving money and improving quality by substituting 20% GGBFS for Portland cement in concrete flatwork in the second phase of construction of the Gateway Estates Development in Brooklyn. Opportunities to increase this proportion will be explored in future phases.

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V. APPLICATIONS IN PAVEMENT SUB-BASE

Use recycled or reclaimed products in pavement sub-base layer to minimize construction waste in landfills and to improve pavement performance. New York City's roads are built over a very large land area with varying soil conditions and traffic requirements. A sub-base layer is typically incorporated in all of them, whether they are on good quality soil or on poor quality landfill. The sub-base layer is an essential component of a pavement built on poor quality soil, but it is also typically used in the construction of pavements on adequate soil, as it can prolong its service life.

BENEFITS

+ Enhances overall pavement performance.
+ In many applications, performs better than conventional materials.

LIMITATIONS

– Leaching of pollutants or free lime may occur with certain industrial by-products, making them an undesirable sub-base material.
– Quality assurance and quality control (QAQC) may be difficult to implement.

TECHNICAL STRATEGIES

With the exception of 'broken asphalt,' the NYC DOT permits the use of waste materials. The NYC DOT sub-base specifications make allowances for the use of blast furnace slag, mechanically-crushed recycled concrete, and waste glass. Current and future opportunities to increase the use of recycled or reclaimed products in the pavement sub-base layer include the following:

Recycled Concrete Aggregate (RCA)

Use of RCA is particularly advantageous in metropolitan areas such as New York City, where sources of waste concrete are plentiful, landfill space is at a premium, disposal costs are extremely high, and the need for good quality engineered aggregate exists. New York City does not limit percentage used in its specifications.

Consider benefits of using RCA in the sub-base:

- Can stabilize soft, wet soils early in construction by virtue of the porosity of aggregates.
- RCA derived from air-entrained concrete has double the absorptivity of virgin aggregates.
- Drainage is better and sub-base is more permeable than conventional granular sub-base because of lower fines content.
- RCA used in sub-base layer exhibits beneficial engineering performance and provides overall cost savings to projects.

Consider limitations of using RCA in the sub-base: The following adverse effects can be prevented by washing RCA aggregates to remove dust from the particle surface:

- Alkaline leachate may occur if there is free lime and/or unhydrated cement, raising the pH of adjacent soil and water and potentially harming plants and trees. Alkaline leachate is a particular concern in New York City because it has the potential to cause chlorosis in street trees.
- Consider using high alkaline plants if leaching is possible.
- Leachates may form precipitates that clog geotextiles and prevent free drainage from the pavement structure.

Recycled Asphalt Pavement (RAP)

RAP, which is plentiful in the City, can be crushed and blended with conventional aggregates for use as coarse and/or fine aggregate in the pavement sub-base layer.

Consider benefits of using RAP in the sub-base:

- Adhesive presence of asphalt results in a better bearing capacity over time.
- Drainage is better and sub-base is more permeable than conventional granular sub-base because of lower fines content.

Consider limitations of using RAP in the sub-base:

- Grinding or pulverizing (rather than crushing) may result in the generation of undesirable fines.
- Adhesiveness of asphalt can make placement and finish grading difficult.
- Adequate compaction must be ensured to avoid post-construction densification.
- Pre- and post-blending stockpiled aggregate can experience agglomeration and hardening, and may have to be recrushed and rescreened.

Consider moisture content when using RAP:

- The optimum moisture content for RAP blended aggregates is reported to be higher than for conventional granular material.

Air-Cooled Blast Furnace Slag (ACBFS)

Referred to simply as 'slag' in many specifications, ACBFS is a by-product of iron manufacture that is crushed and screened and then used as a sub-base material. New York City does not limit the percentage of ACBFS use in its specifications.

- Use conventional design procedures for bases containing ACBFS.

Consider the beneficial properties of using ACBFS in the sub-base:

- Lower compacted unit weight of ACBFS aggregate yields greater volume for a weight equivalent to conventional aggregates.
- High level of stability of ACBFS aggregates provides good load transfer even when placed on weak sub-grade.

Consider the limiting properties of using ACBFS in the sub-base:

- Adequate separation from water must be maintained. When ACBFS is placed in strata with poor drainage conditions or with exposure to slow-moving water, sulfurous leachates are possible.

Use Glass Cullet

Since there is a reliable, dedicated supply of recycled glass and ceramics in NYC, consider use in sub-base applications. When crushed to a fine aggregate size, glass cullet exhibits properties similar to conventional fine aggregates or sand.

- Consider opportunities to recover other vitreous products, such as porcelain toilets.
- AASHTO makes provisions for 5% inclusion (by mass) of ceramics in its standard specification for glass cullet use.

Consider the beneficial properties of using glass cullet in the sub-base:

- High level of stability in 15% additions of glass cullet were observed, yielding bearing capacities nearly equal to conventional aggregate.

Consider the limiting properties of using glass cullet in the sub-base:

- Poor durability is exhibited by large particles. The use of glass cullet for coarse aggregate is not recommended.
- Recommended limit is 20% by mass for glass cullet, as performance of sub-base layers containing more than 20% is not known.
- Deleterious substances such as labels and food residue must be controlled at the materials recovery facility. It is recommended that deleterious substances be limited to 1% by mass, of which no more than 0.05% is paper.

EXAMPLES

Caltrans reported to the FHWA that RCA used in sub-base (and base) layer has a beneficial engineering performance and provides overall cost savings to projects. The Gateway Estates Development in Brooklyn is utilizing asphalt millings, stockpiled in a DOT yard adjacent to the site, in the sub-base pavement layer.

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VI. NON-PAVEMENT APPLICATIONS

Use recycled, reclaimed or renewable materials whenever possible in miscellaneous infrastructure applications. The following are examples of opportunities in non-pavement applications.

Pipe Bedding

Water mains in the City are typically bedded on a bed of gravel or broken stone. However, there is ample opportunity to replace these materials – which must be mined, engineered, and trucked into the City – with materials diverted from the City's waste stream. Materials appropriate for recycling as pipe bedding include the following:

Consider using glass cullet: The results suggest that as long as glass cullet meets the AASHTO No. 10 (or No.8) classifications, its strength characteristics and overall engineering performance will be comparable to, or exceed those of, natural aggregates of the same gradation, regardless of the actual processing procedure (i.e., quarry crushing equipment versus recycling center operations).[112]
Benefits include:

- Offsets the cost of sophisticated crushing machines.
- Offsets the cost of hauling aggregate into the City.
- Glass cullet is hydrophobic.

Consider using recycled concrete aggregate (RCA): RCA is frequently used as pipe bedding by a number of entities. King County, Washington used RCA obtained from existing paved areas and building slabs, and reported the following benefits:

- Performance is good. .
- Cost is reduced due to elimination of new material cost, disposal and trucking fees.
- Aggregate stays drier.

Pipe Substructure

Occasionally soil conditions or other factors require placement of the water pipe on concrete saddles or on a reinforced concrete mat. Pipe valves must be placed in valve boxes or chambers, depending on size. Appurtenances to these systems such as fire hydrants and manholes require slab footings and other supporting structure. Any water or sewer main failure has serious environmental implications, and for this reason supporting structures are typically designed to extreme performance standards and often use more material. Rediversion of material from the waste stream back into the construction materials stream would soften the environmental impact of building concrete infrastructure elements with such demanding performance standards.

Consider using supplementary cementitious materials(SCMs): Consider ground granulated blast furnace slag (GGBFS) and fly ash, where appropriate (see **PA.6, part IV**).

- GGBFS is non-corrosive to metal pipes and appurtenances.

112 PennDOT Partners with Private Industry to Determine Select Properties of Glass Cullet. Accessible at http://www.dep.state.pa.us/dep/deputate/airwaste/wm/recycle/Market/penndot_glass.pdf

- Some studies show fly ash to be corrosive to metals. Fly ash should not be used anywhere near metal pipe or appurtenances.

Recycled-Content / Biobased Filter Fabric

Filter fabric is required in water main trenches to prevent migration of fines and prevent deformation of the bedding material under loading. It must be permeable enough to not limit flow of water between strata, and must also have the tensile strength required to resist loading from traffic.

Consider using recycled concrete filter fabric:

- Specify filter fabric with maximum available post-consumer recycled content.
- 100% recycled polypropylene filter fabric from the post-industrial waste stream is available (NYC currently specifies polypropylene filter fabric 'or approved equal,' but does not specify recycled content requirements).
- 100% recycled P.E.T. (primarily soda bottles) filter fabric from the post-consumer waste stream is available.

Consider using biobased filter fabric:

- Consider filter fabrics made from biodegradable materials, such as jute, for construction projects requiring temporary erosion control and stabilization.
- Jute has a negligible environmental impact, is biodegradable, and fosters growth of vegetation.
- Natural geotextiles are cheaper than synthetic geotextiles.

EXAMPLES

King County, Washington State, achieved a cost savings of $2 per ton of delivered pipe bedding by using glass cullet ($20 per ton delivered) versus pea gravel ($22 per ton). For full evaluation, see http://www.metrokc.gov/procure/green/swpglsag.htm

Recycled porcelain sinks and toilets have been successfully used by Minnesota, Seattle, California, and Pennsylvania in a number of applications as a replacement for virgin aggregate fill material. The State of California found crushed porcelain either exceeds or meets requirements for concrete aggregates.[113]

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PAVEMENT

PART THREE: BEST PRACTICES
UTILITY

UI.1
MINIMIZE IMPACT OF UTILITY WORK

OBJECTIVE

Implement administrative, regulatory and financial mechanisms to reduce the frequency and impact of right-of-way construction by private utilities, minimize delays and work stoppages, improve coordination, and reduce pavement deterioration.

BENEFITS

+ Reduces pavement degradation, improves infrastructure lifecycles, and helps maintain the value of municipal infrastructure investments.
+ Reduces maintenance and rehabilitation costs for the City.
+ Reduces work stoppages and construction delays.
+ Minimizes traffic congestion and associated emissions.
+ Reduces air and water pollution, and soil erosion.
+ Improves pedestrian and vehicular safety.
+ Enhances quality of life.
+ Reduces comprehensive costs to area residents, workers, and businesses.
+ Improves right-of-way aesthetics.

LIMITATIONS

– Proliferation of private utility companies poses a coordination challenge.
– Private utility companies may initially resist efforts to improve coordination and reduce impact.
– Costs incurred by utilities may get transferred to ratepayers.
– Alternative contracting procedures may require the allocation of additional funds.

BACKGROUND

In New York City, private utility companies provide essential services including water, gas, steam and electricity, as well as communication services including telephone, cable, and fiber optic connections. Since most of this infrastructure is located under the City's streets – and since requests for new technologies or service repair are quite frequent – private utilities perform the majority of construction and maintenance work that occurs in the public right-of-way, approximately 100,000 utility cuts per year. If left unchecked, the amount of annual utility cuts could increase significantly as infrastructure ages and as multiple service providers enter the New York market.

Executing work on private utilities usually requires fully or partially closing the road, making a cut in the pavement, and excavating a trench around the utility. This activity exacts considerable environmental, social and economic costs. Presently, New York City bears the total cost of maintaining and restoring utility cut-associated pavement failures, as well as other indirect social and environmental costs stemming from private utility construction.

Another significant complication is that construction delays and work stoppages are often caused by inadequate data and coordination between private utilities and the City. Although the private utilities are responsible for having accurate data on the condition and exact location of their infrastructure, this information is often incorrect or fails to account for actual subsurface conditions. Despite the City's effort to coordinate its sub-grade work with private utilities prior to construction (see 'alignment meetings' in the Part Two), unanticipated interferences are not uncommon. Negotiating these interferences is often difficult and results in unnecessary and costly disruption.

INTEGRATION

- **SA.1** Assess Site and High Performance Opportunities
- **PA.1** Maximize Pavement Lifecycle Citywide
- **UI.2** Improve Restoration of Utility Cut Trenches
- **UI.3** Coordinate Utility Infrastructure for Easy Access and Maintenance
- **UI.4** Use Trenchless Technologies
- **CP.1** Develop and Enforce a Site Protection Plan
- **CP.2** Protect Existing and Future Planted Areas
- **CP.3** Protect Water Sources During Construction
- **CP.5** Minimize Disruption and Impact of Right-of-Way Construction
- **CP.6** Use Cleaner Construction Equipment

TECHNICAL STRATEGIES

Employ alternative contracting methods: Encourage contractors to complete work in a timely fashion, reduce costs, and minimize overall disruption to the community.

- Give financial incentives for completion of work ahead of the contract schedule.
- Impose payment deductions for each day or hour that the contractor goes over the schedule.
- Use lane rentals.
- Use A + B bidding.
- Use incentive/disincentive (I/D) clauses.
- See "Minimize Disruption and Impact of Right-of-Way Construction" **(CP.5)** for details.

Employ Joint bidding: Stream-line roadway reconstruction – and reduce environmental, social and economic costs – by including private utility work and public work in a common contract that the City bids out.

- Conduct pre-engineering of the job. Require private utilities to identify the type, location and quantities of all existing property that may interfere with City work.

- Agree to clear methods of payment prior to construction. Determine unit prices for interference-related work to eliminate future disagreements between the contractor and utility.
- Require sealed arbitration so that if additional work arises it is negotiated in a one-time arbitrated session without impacting construction progress or stopping work.

Coordinate utility work with scheduled pavement construction and rehabilitation programs:

- Utilize additional contract requirements (Section U) applying to work performed in the presence of privately owned utility facilities.

Employ utility cut moratoriums: Disallow any excavation or utility cuts for a length of time – preferably a minimum of five years – after a street has been resurfaced, repaved or reconstructed. Grant waivers for utility cuts only under emergency circumstances. Utility cut moratoriums preserve pavement lifecycle, minimize disruption, and reduce long-term costs.

Employ pavement degradation penalties: Enact provisions that enable the City to recover costs from ongoing maintenance of utility cut repairs.

- Develop a fee schedule based on unit costs of new material, excavation, site mobilization, design, construction management, and contingencies.
- If possible, include a unit fee for social costs such as disruptions to area businesses, traffic congestion, and public health impacts.
- Grant waivers if the utility company employs trenchless construction methods or agrees to coordinate its work with City roadway work.

Give incentives or require private utilities to upgrade infrastructure during road reconstruction.

EXAMPLES

A number of cities on the west coast – including Los Angeles, San Francisco, Bakersfield, and Seattle – charge utility cut fees to recover a portion of the cost of long-term damage to pavements. Utility cut fees are typically expressed in dollars per square foot or dollars per linear foot, and are based on the age and condition of the pavement. In these cities, prices range from under a dollar to nearly $20 per square foot.

Los Angeles imposes a one-year non-emergency utility cut moratorium on newly paved city streets. Ottawa, Canada imposes three-year moratoriums. New York City is authorized by New York State's 'Coordinated Construction Act for Lower Manhattan' to employ joint bidding on infrastructure projects where speed of construction is crucial to the downtown recovery effort.

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UI.2 IMPROVE RESTORATION OF UTILITY CUT TRENCHES

OBJECTIVE

Restore utility cuts with the best available technology to minimize pavement damage and lifecycle degradation. Adopt guidelines for utility cut restoration and management.

BENEFITS

+ Reduces pavement degradation and failures.
+ Reduces maintenance and rehabilitation costs for the City.
+ Improves public safety and quality of life.
+ Reduces environmental impact of right-of-way construction.
+ Improves right-of-way aesthetics.

LIMITATIONS

– Ineffective if contractors fail to comply or perform procedures incorrectly.
– Achieving sufficient compaction of soil under and around utility components is difficult.
– Lack of consensus over best practices for utility cut restoration must be overcome.

BACKGROUND

Each year over 100,000 utility cuts are made in New York City's streets, taking a significant toll on roadway lifecycle and serviceability. The majority of pavement failures in NYC result from improperly restored utility cuts. Typically, pavement strength is reduced in a zone surrounding the utility cut – known as the 'trench influence area' – that extends up to 6 feet beyond the cut location.[114] If soil compaction in the restored trench is inadequate, the trench influence area is likely to sag or slump over time. Improperly sealed utility cuts exacerbate this problem by allowing water intrusion, which erodes and further weakens sub-grade soil. Fatigue cracking or spalling can eventually occur around the edges of the cut, ultimately resulting in pavement failure. The more utility cuts in a pavement, the more likely that the pavement will fail.

Utility trench restoration is usually performed by the private utilities or contractors that made the cut. Although the City establishes standards for repair, these standards are often undermined by hasty construction practices or ignored because the procedure is more costly and time consuming for contractors. Compaction requirements are rarely met and cuts are performed incorrectly. This best management practice examines different trench restoration techniques and advocates for future research and testing. It also calls for increased quality control and standards enforcement; the increased cost is justified by the benefits of more durable pavement restoration.

INTEGRATION

- **PA.1** Maximize Pavement Lifecycle Citywide
- **PA.6** Use Recycled and Reclaimed Materials
- **UI.1** Minimize Impact of Utility Work
- **UI.3** Coordinate Utility Infrastructure for Easy Access and Maintenance
- **UI.4** Use Trenchless Technologies
- **CP.5** Minimize Disruption and Impact of Right-of-Way Construction

TECHNICAL STRATEGIES

Develop effective design guidelines for utility cut restoration citywide:

- Include considerations for a range of traffic conditions and environments.
- Present design alternatives whenever possible.
- Include complete, comprehensive analyses.
- Provide advice based on available construction technology and local expertise.

Prevent water intrusion:

- Use an emulsion-based (tack coat) sealant applied to all exposed joint surfaces.[115]
- Adequately maintain seal and cut.

Ensure adequate compaction of trench backfill to prevent pavement failure:[116]

- Ensure backfill achieves recommended standard density for full depth of excavation.
- Employ a soil compaction testing device that can measure compaction levels beyond the first two feet below ground surface, continuously along the length, and at or around the walls of the cut. Testing device should be able to log results automatically (not manually) in a computerized form.
- Use ground-penetrating radar (GPR), which enables mapping of field density along the trench length and automatically logs data.
- Use a soil compaction meter, which is a buried sensor that determines soil density by analyzing sound waves transmitted by the compaction device. A computer console yields automated results.
- Consider other best-available technologies for measuring compaction.

[114] Impact of Utility Cuts on Performance of Seattle Streets. Seattle Transportation, City of Seattle. January 31, 2000. Available at: http://www.ci.seattle.wa.us/transportation/pdf/final-rpt_Jan31.PDF (Accessed June 2004)

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Reuse excavated material during restoration where appropriate:

- Backfill utility trenches with uncontaminated existing soil to minimize waste, reduce transportation and disposal costs, and reduce the use of virgin materials.
- Dispose of contaminated soil appropriately.

Select an appropriate utility cut type: Two common utility cut types are the T-section and the straight section cuts.[117] Although T-section cuts are the standard in NYC and other cities, recent studies question the benefits of T-sections.[118] As long-term test results for repair performance emerge, the City will be able to judge more accurately when and where each technique is appropriate.

- Regardless of cut type, minimize the volume of excavation and pavement removal in the utility cut.
- Select excavation and compaction equipment on the basis of ability to minimize volume of excavation and pavement removal.

Use flowable fill, where appropriate, to achieve a high level of compaction: Flowable fill – also known as controlled low strength materials (CLSM) and controlled density backfill (CDF) – is a self compacting and self leveling backfill material used in lieu of compacted fill. Flowable fill is typically composed of the same materials as cement concrete–water, sand, and Portland cement with varying quantities of fly ash, fine or coarse aggregates– and is batched and delivered in a form resembling highly workable concrete. Flowable fill can be poured in and around trench repairs and utility conduits like a liquid, but it sets up like a solid, resembling a high-quality compacted soil. A principle advantage of using flowable fill is its ease of use: it restores lateral stability to the trench and minimizes pavement damage without requiring extensive quality control.

Consider the following benefits of using flowable fill:

- Flowable fill may be a good solution in narrow trenches where adequate compaction is hard to achieve.
- Flowable fill may be a good solution in trenches that are close to other utilities, as compaction can be achieved without damaging the adjacent utilities.
- Flowable fill can be used in trenches to replace contaminated soil.
- Flowable fill can be engineered to allow for easy removal and manual excavation at a later date.
- By-products and waste materials can be used in flowable fills, including fly ash, foundry sand, ground granulated blast furnace slag, wood ash, glass, soil blends, and others.

When using flowable fill, take caution in the following circumstances:

- Avoid using flowable fill in cold weather. Refer to ACI 229R-99.
- Take caution when using flowable fill containing waste materials with ductile iron pipe to avoid corrosion: Encase ductile iron pipes in a polyethylene sleeve when using flowable fill.[119]
- Consider the effect of using flowable fill on drainage paths, since flowable fill will have a different permeability than surrounding soil. Adequate subsurface drainage must be achieved at the cut location.
- Consider the potential for frost heave due to thermal conductivity[120] and frost penetration to pipes.
- Consider whether the high costs of using flowable fill are justifiable based on job size, compaction requirements, job complications, etc.
- Consider future access for maintenance and repair in design.

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117 T-Section (cutback) Repairs extend the pavement cut 6' to 12' beyond the boundaries of the trench excavation for the full length of the trench. Straight section (non-cutback) repairs involve cutting the pavement directly over the trench excavation area.

118 T-Section Cuts are said to reduce water infiltration by making it more difficult to travel over a complex path. They are also thought to reduce the likelihood of pavement failure by transferring traffic loads beyond the trench area via arching action. However, recent studies claim that straight section repairs perform as well as T-sections if adequate soil compaction is achieved. Furthermore, studies point out that T-section repairs require excavating up to three times as much material as straight cut repairs. T-section cuts are also more expensive, labor intensive, and difficult to execute because they require 'surgical precision' to avoid sub-grade damage.

119 Although there is no consensus among experts, some studies show that flowable fill containing coal fly ash or other supplementary cementitious materials may corrode ductile iron pipes. Future research needs to be conducted. In the meantime, Trejo, et al., see references.

120 Todres, see references.

UI.3 COORDINATE UTILITY INFRASTRUCTURE FOR EASY ACCESS AND MAINTENANCE

OBJECTIVE

Coordinate placement of public and private utilities using common trenching and utility ducts to minimize the environmental impact of installation and maintenance.

BENEFITS

+ Ideal for urban areas where space in the right-of-way is at a premium and maintenance is frequently performed.
+ Enables different entities to synchronize work and share expenses.
+ Minimizes pavement degradation from utility cuts.
+ Minimizes the environmental impact of construction.
+ Enables easy location and identification of utilities.
+ Minimizes incorrect excavations, utility damage and interference.
+ Reduces construction delays and impacts.
+ Reduces traffic congestion and vehicular emissions.

LIMITATIONS

– Increases opportunity for utility security to be compromised.
– High construction costs may be unjustifiable in some situations.
– Identifying a liable and responsible party for maintenance of common structure may be difficult.
– Opportunities to install new utility configurations are rare.
– Conflicting interests among utility franchises may prohibit cooperation.
– Utility companies may be unwilling to bear additional costs.
– Leaks may be difficult to detect and could lead to trench failure.
– Determination of leaks may be difficult.

BACKGROUND

The subsurface of the public right-of-way is a dense, sometimes chaotically arranged assortment of private utilities and public infrastructure. As a result, utility records often contain inaccurate position and depth recordings, and abandoned and forgotten conduits are frequently encountered. Not only does this create a potential safety hazard for construction personnel and people on the street, but it also can have significant environmental impact. Accidents and unexpected interferences between utilities in the field can cause construction delays and work stoppage that can impede the flow of traffic in the right-of-way, causing increases in pollution, noise and disruption.

Though the majority of New York City's private utility structure is already in place, ongoing capital improvement projects inevitably require relocation of utilities. Utility relocations are often required on street reconstruction projects that include sub-grade work, such as water main and sewer repairs and reconstruction. It is important to create a consistent layout that predetermines location, nature, and depth of jointly installed utilities before construction to minimize redundancy of cuts and to reduce damage and work stoppage.

INTEGRATION

- **SA.1** Assess Site and High Performance Opportunities
- **PA.1** Maximize Pavement Lifecycle Citywide
- **UI.1** Minimize Impact of Utility Work
- **CP.2** Protect Existing and Future Planted Areas
- **CP.3** Protect Water Sources During Construction
- **CP.5** Minimize Disruption and Impact of Right-of-Way Construction

TECHNICAL STRATEGIES

Use markings to reduce damage to third-party utilities:

- Use accurate, uniform-colored above-ground markings indicating utility location and type.
- Consider imprinting markings on asphalt, affixing tape or stickers to the trench, etc.
- Note where excavator must begin hand digging.
- Use excavation and temporary survey markings.

Utilize common trenching: Place utilities in a coordinated configuration in the right-of-way corridor. This will reduce the impact of utility installation, expansion, relocation, and repair.

- Consider vertical stacking of telephone, electric, gas, and other 'dry' utilities.
- Avoid common trenching of water and sewer lines or other 'wet' services.[121]

[121] Common trenching of wet services can lead to cross contamination of potable water mains in the event of breakage and repair. Additionally, proximity to gas lines complicates repair operations to wet services.

- Ensure that electrical cables of different classes maintain adequate separation distances from each other and gas pipes.
- Utilize alternative contracting and insurance mechanisms to enhance cooperation and coordination among utilities.

Utilize utility ducts in new right-of-way construction or major reconstruction: A utility duct, or 'utilidor', is a subterranean supporting structure – ranging in size from a small conduit to a walk-though tunnel – that contains several adjacent utility systems and allows easy access for regular maintenance.

- Use utility ducts in urban areas where space in the right-of-way is at a premium and maintenance of utilities is frequent.

EXAMPLES

Utility Markings

New York City employs aboveground marking techniques and has a 24-hour utility location hotline to help reduce construction delays, service interruptions, and accidental damage caused to utilities by the City or private utility company during excavation.

Common Trench

In 1999, Fort Worth, Texas was approached by twelve different telecommunications companies who wanted to install conduits in downtown Fort Worth. The city, in an effort to avoid twelve separate construction jobs, requested the twelve franchises coordinate and install a common trench with common manholes. There was no city ordinance mandating cooperation, though, and the franchises were resistant. Finally, Fort Worth threatened to permit the utilities on a first-come, first-serve basis, meaning some of them would have to delay installation for up to three years. Not surprisingly, all utilities agreed to install conduits in a common trench (but refused common manholes). Currently, Fort Worth's phone company is working with the electric company to jointly install utilities in a subdivision. In this case, the cost of joint trenching will be picked up by the developer.[122]

Utility Ducts

The City of Denton, Texas states in its comprehensive plan: 'The dry utilities will be placed in a duct bank with expansion room under the sidewalk opposite the gas line.'[123] This effectively gives more critical utilities such as water, sewer, electric and gas priority in the right-of-way over the 'dry' utilities such as telephone, cable, and internet. Irving, Texas reports trenches with eight or nine companies in one trench. The NYC DDC recently took the opportunity during a water main installation in a Central Park transverse road to install stackable duct banks and manholes for the Fire Department's communication lines. The Fire Department, in turn, is leasing these vacant ducts to private, low-voltage utility lines such as telephone and telecommunications.

A typical situation in Manhattan in which active subsurface utilities are surrounded by abandoned and forgotten conduits, making coordination and repair difficult.

Nassau County, NY, which supplied the Borough of Brooklyn with water prior to Brooklyn's 1898 consolidation with New York City, is currently ducting private utilities into a discarded cast iron water main.

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UI.4
USE TRENCHLESS TECHNOLOGIES

OBJECTIVE

Employ trenchless technologies to facilitate non-destructive inspection and installation of utility infrastructure and to minimize pavement cutting and excavation during water, sewer, and other conduit work.

BENEFITS

+ Minimizes congestion and vehicular emissions.
+ Preserves pavement integrity and minimizes damage.
+ Minimizes environmental disturbance; useful in sensitive areas.
+ Accelerates project schedules.
+ Minimizes dust, noise, and other detriments to quality-of-life.
+ Minimizes impact to area businesses.
+ Usually less expensive than open-cut excavation.
+ Improves worker safety.

LIMITATIONS

– Not applicable to many right-of-way maintenance and installation procedures that require excavation.
– May be cost-prohibitive, impractical, or unsuitable for pipes that have extensive lateral connections.
– Could cause harm to unanticipated buried utilities.
– Requires a variety of new equipment.
– Equipment and technical expertise may not be locally available.

BACKGROUND

'Trenchless technologies' is an umbrella term that encompasses a total system of know-how, technologies, procedures, services, and equipment dedicated to providing an alternative to open-cut excavation.[124] Trenchless technologies minimize the environmental, social and economic costs of right-of-way construction by enabling the bulk of operations to take place underground without excavation. Recently developed trenchless technologies are particularly useful in cities where automobile traffic is high, underground utility congestion is growing, and soil contamination and erosion are a problem.

[124] Trenchless Technologies are recognized as an Environmentally Sustainable Technology (EST) by the United Nations Environment Programme (UNEP). See Trenchless Technology Systems: An Environmentally Sound Technology' UNEP-DTIE-IETC/ISTT. http://www.nodig-construction.com/praxisberichte/UNEP_Final.pdf (Accessed August 9, 2004).

Trenchless technologies can be classified into four types of applications: investigation, localized repair, on-line replacement, and new installation. Choice of trenchless technologies is influenced by a wide range of factors, including project needs, subsurface soil and groundwater conditions, pre-existing obstructions, and density of lateral utility connections. In many cases, a common trenchless technology will need to be adapted to address a particular set of site-specific conditions. Private utilities such as electric, gas, and telecommunications companies should consider using trenchless methods when possible to install and repair their own property. This will result in fewer utility cuts, a reduced rate of pavement failure, and cost savings for the City.

INTEGRATION

- **PA.1** Maximize Pavement Lifecycle Citywide
- **UI.1** Minimize Impact of Utility Work
- **CP.2** Protect Existing and Future Planted Areas
- **CP.3** Protect Water Sources During Construction
- **CP.5** Minimize Disruption and Impact of Right-of-Way Construction

TECHNICAL STRATEGIES

Minimize environmental impact when utilizing trenchless technologies:

- Assess the potential for finding contaminated soil prior to construction.
- When utilizing trenchless technologies in contaminated soils, take special care to minimize environmental impact.
- Develop a program to handle, treat and dispose of contaminated soil.
- Protect storm sewer inlets, vegetated areas, and other sensitive areas.
- See "Protect Water Sources During Construction" **(CP.3)** for more details.

Trenchless Investigation and Nondestructive Testing

Minimize ground excavation during investigation and monitoring using one or several of the following methods:

Sound inspections: To detect leaks, use ground microphones or 'hydrophones,' embedded in the pavement as a permanent monitoring system.

Conduct visual inspections: Use closed circuit television (CCTV) and other imaging technologies to inspect the flow and wall conditions of pipes.

Conduct radar inspections: Use as a remotely controlled nondestructive testing method.

Sonar inspections: Use as a remotely controlled nondestructive testing method.

Trenchless Repairs

Use trenchless technologies to repair damage that is restricted to a small part of the sewer or drain, and when it is more cost-effective to repair individual defects rather than replace or renovate the full length of the conduit. Typically, trenchless repairs are limited to gravity sewers and storm drains.

Use internal joint seals: For repair of pressure pipe joints, use synthetic rubber internal joint seals to ensure a hermetic seal around the entire leaking pipe joint. Internal Joint Seals have been used on pipes with diameters as small as 16', but are primarily intended for pipes large enough to permit human access. Using internal joint seals is a low-cost, reliable alternative to other common, more invasive pipe repairs.

Conduct pipe re-rounding: Use an expander unit – in tandem with patching and liner repair strategies – to restore a deformed pipe to its original circular section and hold pipe fragments in place until the pipe can be patched or lined.

Employ robotic methods: Use commercially available robotic equipment to repair deteriorated areas and cracks. Use in tandem with trenchless investigation techniques to obtain live video images and to control the repair operation remotely.

Trenchless On-Line Replacement

Minimize ground excavation while rehabilitating on-line conduits using the following technologies:

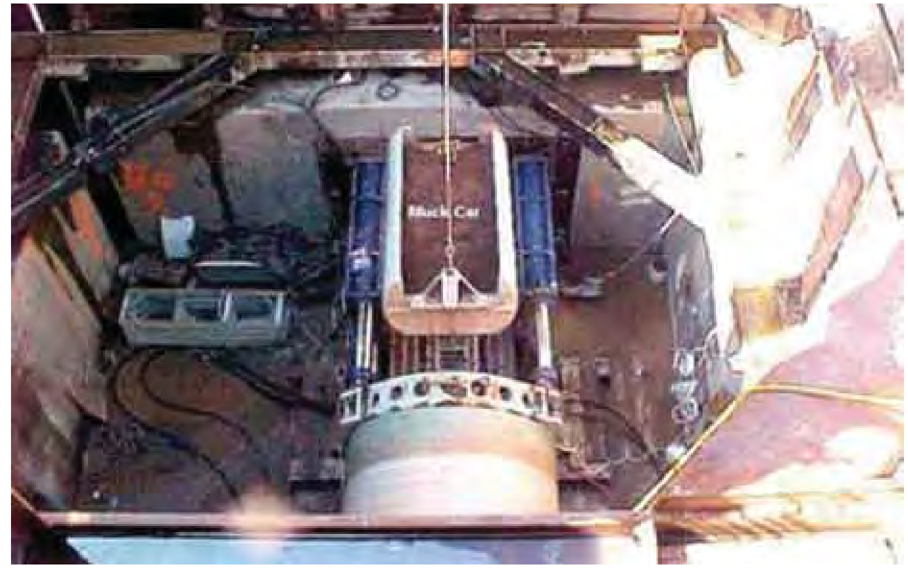
Use cured-in-place pipes (CIPP): Use various combinations of fabric and resin to perform both non-structural repairs (internal corrosion, leakage, etc) and full structural rehabilitations to sewers.[125] Also known as in-situ relining, CIPP is a relatively rapid and versatile repair method that is able to negotiate bends and accommodate a variety of diameters. CIPP is usually introduced into the sewer system from an existing manhole or access pit. Within the last three years, full-structural CIPP rehabilitation of pressure pipes has begun to come into wide use.[126]

Conduct sliplining: Conduct sliplining to make a range of repairs or full-structural rehabilitation of water or sewer pipes under gravity or pressure flow. Insert liners made of various materials into the host pipe from a launch pit to an exit pit at the end of the length to be repaired.[127] Considerations include:

- Determine an entry and exit pit.
- Use sliplining on long runs with few connections.
- Consider the reduction in cross-sectional area: some liners with an independent structure may reduce the cross-sectional area of the pipe, reducing flow capacity. However, the improved friction coefficient of the liner may enhance hydraulic performance enough to compensate for the reduction in pipe section.
- Consider the need for a close fit: where a close fit is desirable, particularly in pressure pipes (i.e. water pipes), consider re-rounding the inserted liner one time by applying heat or water pressure.
- Consider the rigidity of the liner: bends are limited to 45 degrees in close fit applications and zero degrees in other cases.
- Consider grouting of the annular space to maintain the structural integrity of the newly lined pipe.

Conduct pipe bursting: Perform pipe bursting – also known as pipe splitting or pipe reaming – to burst existing water or sewer pipes while simultaneously inserting a new pipe. A splitting tool is either drawn or pushed statically, hydraulically, or pneumatically into the existing pipe by a winched cable or drill with the replacement pipe attached to the splitting tool. The radial force applied to the old pipe causes it to shatter and embeds the fragments into the surrounding soil. Considerations include:

- Determine an entry and exit pit.
- Use pipe splitting on long runs with few bends or connections.
- Avoid pipe splitting in shallow depths that will lead to ground heaves.
- Maintain a safe clearance to adjacent utilities and underground structures.



Central Park West and West 63rd Street – New York, NY
Pipejacking performed at a busy intersection to minimize disruption and costs

Trenchless New Installation

Minimize ground excavation when installing new conduits using the following technologies:

Conduct horizontal directional drilling (HDD): Perform horizontal directional drilling in the installation of new water or sewer pipes when open-cut excavation is impossible. This technique uses a remotely controlled drill pipe that drills a pilot hole, enlarges it to the required size and then pulls the carrier pipe into place. The drill pipe also manages and removes the tunneling spoils, which may be contaminated with hazardous material. A drawback of HDD is that quality control of pipe bedding and fill is limited and difficult to inspect. For this reason, soil conditions must be fairly consistent for good performance.

Conduct pipejacking: Use pipejacking to install gravity sewers and other systems that require precise installation close to target lines and levels. Pipejacking employs hydraulic jacking from a drive shaft to install pipe segments directly behind a shield machine that performs the excavation. The pipe segments are joined in the entry pit,

[125] Typical CIPP systems include felt-based, woven hose, and membrane, which are respectively used for full-, semi-, and non-structural rehabilitations. These fabrics are often impregnated with resin pre-installation, and then cured within the host pipe to produce a new rigid structure. Resins used must meet local health and environmental approvals when used in potable water systems. Enforce a high level of quality control during the installation process to avoid collection of hazardous levels of resin at the end of the pipe.

[126] Major municipalities in Ontario, Canada, are using CIPP in water force mains.

[127] High density polyethylene (HDPE) and polyvinyl chloride (PVC) are typically the materials of choice in this process. PVC is of concern for both its effect on water and its detrimental effect on the environment. Only use PVC in non-potable water applications, if at all.

Pelham Parkway – Bronx, NY
Piperamming a 36" steel casing for a 20' water main crossing under the Pelham Parkway

forming a continuous pipe in the ground. Pipejacking guidance and control systems are very precise.

Conduct pipe ramming: Use a percussive hammer to drive the installation of pipe segments in a process similar to pipejacking.

Conduct microtunneling: To install pipe with a diameter too small for human entry, combine the pipejacking installation procedure with a laser-guided, remotely steered drill shield. Unlike other trenchless methods, microtunneling may be more expensive than open-cut excavation.

Air-spading: Use air-spading, rather than cut and cover technique, to install utilities within tree protection zone. **(CP.2)**

EXAMPLES

At a reclaimed industrial brownfield site in Chelsea, Massachusetts, contaminated soil was identified along a proposed sewer alignment during the geotechnical investigation. To minimize environmental impact and disruption to local businesses, microtunneling was used to install the infrastructure.[128] Approximately 3,000 linear feet of new 66' diameter sewer and 4,700 liner feet of 36' diameter sewer were installed successfully.

To connect New York City's Water Tunnel No. 3 into the existing system, engineers were forced to split a sewer main into two pipes and reroute it, and another water distribution main, to make way for a new water trunk main. Open-cut excavation was prohibited for part of the job that ran under a railroad. To accomplish this task, engineers used a pipe ramming method known as the 'oversize missile system,' in which a percussive hammer is mounted at the front of the pipe, pulling it into place.

New York City has used microtunneling for over a decade, including on a job that ran under the Bronx River.[129]

In 1999, the City of Ottawa, Canada, sliplined a 36' water main and avoided excavation in a busy downtown street. Total economic cost savings on this project was estimated at a minimum of $3 million.[130]

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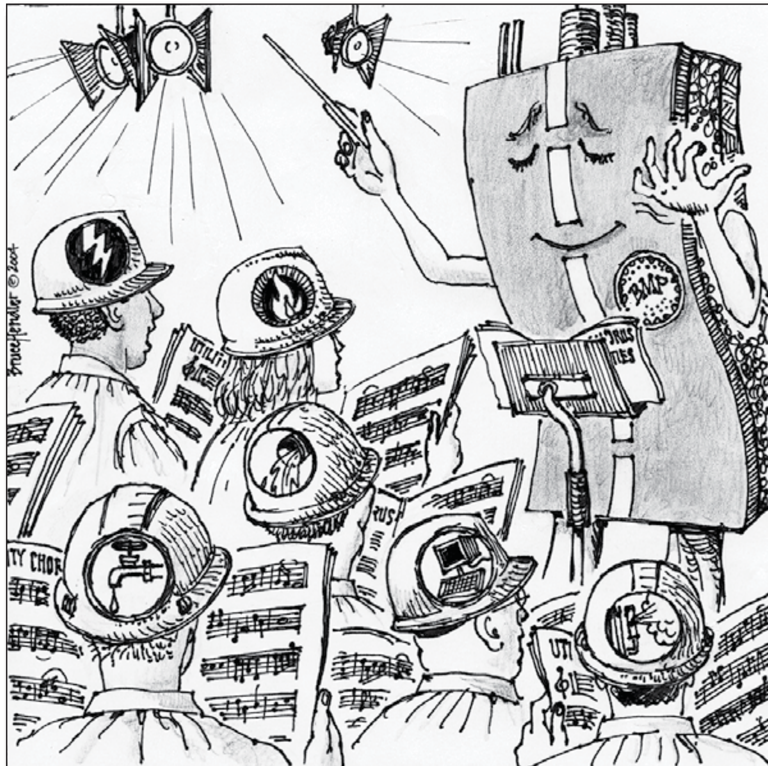

UTILITY

PART THREE: BEST PRACTICES
STORMWATER MANAGEMENT

SM.1
CONDUCT INTEGRATED STORMWATER MANAGEMENT PLANNING

OBJECTIVE

Undertake a proactive, integrated planning approach to urban stormwater management to protect property and aquatic ecosystems while at the same time accommodating land development.[131] Develop and implement watershed-based drainage master plans and associated policies that seek to reduce, treat, and control stormwater runoff as close to its source as possible. Over time, seek to eliminate combined sewer overflows, and improve water quality and urban hydrology. Prioritize initiatives that will enhance overall environmental quality, aesthetics, habitat, quality of life, and property values.

BENEFITS

+ Significantly improves water quality and minimizes combined sewer overflows.
+ Shifts cost of stormwater management to building operators and property owners, resulting in a cost savings for the City.
+ Could enable downsizing sewer infrastructure, resulting in significant cost savings for the City.
+ Ensures that future development – both public and private – will further the goal of minimizing runoff.
+ Promotes productive reuse of stormwater and minimizes use of municipal potable water.
+ Increases habitat, open space preservation, and urban landscape.
+ Improves urban hydrology.
+ Reduces the urban heat island effect.

LIMITATIONS

– Cannot succeed without extensive coordination among stakeholders and comprehensive, citywide management, planning, and budgeting.
– May require dedicated funding source.

[131] Definition of Integrated Stormwater Management from Greater Vancouver Regional District.

BACKGROUND

Integrated Stormwater Management Planning (ISMP) is a comprehensive, interdisciplinary process that coordinates the efforts of urban planners, ecologists, engineers, architects and landscape architects. The goal is to optimize rainfall capture, control, flood risk management, water quality improvement, and aquatic ecosystem protection on a regional, watershed, neighborhood, and local scale. ISMP should accommodate and inform all other land use development processes.

In the past, the sole objective of stormwater management was to remove rainfall as quickly as possible without jeopardizing safety. Today, knowledge of the environmental impact of stormwater – i.e. sedimentation, habitat degradation, turbidity, eutrophication, toxicity, oxygen depletion, trash and debris buildup, temperature increases, bacterial contamination, etc – has led to the development of improved approaches to handling the specific needs of small, large, and extreme storms.[132] The emerging consensus among stormwater management planners is to seek to eliminate runoff from small storms (the majority, or 90% of all storms); detain, treat and slowly release rainfall from large storms (once a year storms or greater); and provide conveyance or flood control for extreme storms. Experience by state and local agencies proves that retaining and treating stormwater as close to its source as possible, and eventually allowing it to infiltrate into the ground or evapotranspirate into the atmosphere, is the most cost-effective method of improving water quality and hydrology, and minimizing damage to aquatic ecosystems.

INTEGRATION

- **SA.1** Assess Site and High Performance Opportunities
- **SA.2** Conduct Soil Analysis
- **SA.3** Conduct Hydrologic and Hydraulic Analysis
- **SA.4** Survey Existing Vegetation
- **SS.1** Work with Community Groups to Enhance and Maintain Streetscape
- **SS.5** Increase and Improve Right-of-Way Public Space and Green Areas
- **PA.2** Minimize Impervious Pavement Area
- **PA.4** Use Pervious Pavements
- **SM.2** Prevent Water Pollution and Practice Source Control
- **SM.3** Minimize Runoff from New Building Construction and Major Renovations
- **SM.4** Optimize Right-of-Way Drainage
- **LA.1** Optimize Citywide Landscape Planning
- **LA.2** Encourage Ecological Connectivity and Habitat
- **LA.3** Create Absorbent Landscapes
- **LA.7** Increase the Quantity, Density and Diversity of Trees

[132] For a detailed methodology for managing the 'complete spectrum' of rainfall events, consult, Stormwater Planning: A guidebook for British Columbia. http://wlapwww.gov.bc.ca/epd/epdpa/mpp/stormwater/stormwater.html

TECHNICAL STRATEGIES

Develop watershed-based drainage master plans:

- Plan to infiltrate, retain, or reuse stormwater as close to its source as possible.
- Develop drainage network strategies to distribute stormwater to nearby locations where it can be retained and infiltrated cost-effectively.
- Develop strategies to reduce substantially and ultimately eliminate combined sewer overflows.
- Prioritize use of on-site bioengineered BMPs and other strategies that enhance overall environmental quality, aesthetics, quality of life, habitat, and property values.
- Determine high-priority or problematic drainage catchment areas.
- Seek to minimize and disconnect impervious areas. **(PA.2, PA.4)**
- Seek to maximize open space, natural habitat and landscape. **(LA.1, LA.2)**
- Undertake reforestation and watercourse restoration. **(LA.2)**
- Promote stormwater reuse.
- Use lifecycle analysis to select the most cost-effective, beneficial strategies. See City Process Section for more details.

Develop scientifically-based performance targets and guidelines:

- Develop stormwater management targets and guidelines for all project types citywide.
- Require that public and private building construction and redevelopment projects produce no post-development runoff. **(SM.3)**
- In right-of-way reconstruction or new construction projects, seek to capture and treat, and either infiltrate or retain all small storms, or 90% of annual rainfall volume. **(SM.4)**
- Seek to detain, and if possible treat, runoff generated during large, once a year storm (mean annual rainfall event) and enable slow release at the rate of a naturally vegetated watershed. **(SM.4)**
- Provide flood risk management for extreme storms.
- Prioritize implementation of stormwater management performance targets in high-priority or problematic drainage catchment areas.
- Develop special initiatives to reduce combined sewer overflows.

Integrate stormwater management planning citywide:

- Integrate stormwater management planning with all other city planning initiatives – including open space and parks development, economic development, housing redevelopment, etc – so that new projects further the goal of reducing runoff and improving water quality.

Develop stormwater demonstration projects:

- Locate demonstration projects in high-priority or problematic drainage areas
- Seek to demonstrate how optimizing stormwater management can add value to development projects through the creation of open space, attractive landscapes, etc.
- Monitor and evaluate pilot projects and seek to improve stormwater management in future initiatives.

Provide financial incentives and eliminate regulatory barriers:

- Improve zoning ordinances, construction permitting procedures, building codes, stormwater utility fees, etc to allow for, and provide incentives for, the minimization of runoff.
- Give incentives for existing facilities to reduce runoff by minimizing impervious area, constructing green roofs, constructing stormwater collection systems, and reusing runoff for irrigation, grey water, cooling tower water, cooling of steam condensate before discharge, washing, etc.

Develop and implement public education campaigns to increase awareness of the importance of watershed health.

Implement strategies to prevent water pollution and control sources. (SM.2.)

EXAMPLE

The Philadelphia Office of Watersheds was created in 1999 to oversee a multidisciplinary watershed management program aimed at abating combined sewer overflows. The Office of Watersheds has used integrated stormwater management planning to develop comprehensive, citywide strategies to reduce and control runoff. A number of projects have already been implemented, including stabilizing vacant lots, creating new parks and community gardens with bioengineered stormwater BMPs, renovating school yards to reduce impervious area and increase green space, constructing infiltration basins underneath playing fields, resurfacing basketball courts with pervious pavement, minimizing runoff from parking lots, and constructing green roofs. Future objectives for the Office of Watersheds include overhauling the city's existing stormwater ordinance, updating land development codes, providing economic incentives for eliminating runoff, and educating the general public about the importance of watershed health.

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SM.2
PREVENT WATER POLLUTION AND PRACTICE SOURCE CONTROL

OBJECTIVE

Undertake pollution prevention and source control strategies to minimize damage to water sources and aquatic ecosystems. Engage the participation of City employees, construction workers, businesses and industries, and the general public.

BENEFITS

+ Offers the most cost effective method of reducing water pollution.
+ Reduces maintenance costs and improves performance of downstream BMPs.
+ Encourages participation by citizenry.
+ Easy to implement.

LIMITATIONS

– May require dedicated funding.
– Ineffective without education and cooperation of the public, industry, construction workers, maintenance workers, business owners, building operators, etc.

INTEGRATION

- **PA.5** Use Reduced-Emission Materials
- **LA.12** Use Low-maintenance, Salt-tolerant, Native or Naturalized Species
- **LA.14** Biointensive Integrated Pest Management
- **CP.1** Develop and Enforce a Site Protection Plan
- **CP.2** Protect Existing and Future Planted Areas
- **CP.3** Protect Water Sources During Construction

TECHNICAL STRATEGIES

Prevent water pollution from right-of-way construction (CP.3):
- Prohibit concrete trucks from washing out into catch basins.
- Minimize the use of toxic materials and VOC-containing compounds in construction and maintenance. **(PA.5)**
- Control chemicals and dispose of them appropriately. **(CP.3)**
- Use catch basin inserts as temporary sediment traps during construction. **(SM.6)**
- Protect water sources during construction. **(CP.3)**

Improve streetscape maintenance practices:
- Optimize street cleaning practices.[133]
- Avoid pesticides, herbicides and insecticides. **(LA.12, LA.14)**
- Clean catch basins at least once per year during dry weather. **(SM.6)**
- Conduct maintenance of stormwater management BMPs in conjunction with maintenance cycles of other infrastructure components.
- Minimize use of detergents. Consider the use of heated water or natural cleaners.

Develop alternative strategies for de-icing traveled routes:
- Prohibit use of sodium chloride as a de-icing salt.
- Use calcium chloride mixed with sand and fine gravel.
- Consider use of calcium magnesium acetate (CMA) in lieu of road salt especially in sensitive ecological areas and on bridges.
- Use grit on less traveled paths and within park areas.
- Maintain salt spreading equipment regularly.
- Protect vegetated areas: use good de-icing salt spreading techniques. Use mix of de-icing salt and sand.
- Consider pre-treating roads to help prevent bonding of ice.

Develop 'Pollution Prevention and Control Plans' (PPCP): Develop PPCPs for City agencies whose activities may generate non-point source pollution. Also work with community boards, local businesses and industries, commercial and residential buildings to develop and implement PPCPs. Consider giving awards or other incentives to encourage participation and environmental stewardship. Encourage the following practices:
- Minimization or substitution of chemicals and hazardous materials.
- Proper material handling and storage.
- Prevention and proper handling of spills.
- Use of environmentally benign cleaning and maintenance practices.
- Minimization and containment of waste generating activities.
- Proper waste storage, treatment, and disposal.
- Promotion of recycling and composting.
- Safe vehicle fueling, cleaning and maintenance.
- Promotion of water conservation.
- Control of sedimentation and erosion.
- Maintenance and monitoring of stormwater controls, particularly after major storms.
- Proper irrigation and landscaping practices.
- Periodic sweeping and cleaning of impervious surfaces.
- Training of employees about pollution prevention.

Promote Public Education about Pollution Prevention and Control:
- Stencil catch basin inserts with messages or pictures that promote environmental awareness and seek to reduce non-point source pollution.

[133] Consult Oregon Department of Environmental Quality 'Recommended BMPs for Washing.' http://www.deq.state.or.us/wq/wqpermit/WashWater.pdf

- Develop and distribute educational material about the importance of water quality and how to prevent non-point source pollution.

Additional Pollution Prevention Practices:

- Develop a municipal tree and landscaping ordinance to increase and properly maintain open space and vegetation. **(LA.1)**
- Create absorbent landscapes. **(LA.3)**
- Increase the quantity, density, and diversity of trees. **(LA.7)**
- Encourage improved designs and maintenance strategies for impervious parking lots.
- Reduce impervious pavement on a citywide basis. **(PA.2, PA.4, SM.1)**

EXAMPLE

The Massachusetts Highway Department has designated approximately one thousand lane-miles of roadway in certain watersheds as low-salt roadways. On certain roads adjacent to cranberry bogs, such as Route 25 in the Plymouth area, Mass Highway uses magnesium acetate (CMA) as a salt alternative. Before major projected storms, Mass Highway pre-treats bridges and ramps, and posts road crews throughout the area to expedite the initial clearing operation.
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SM.3
MINIMIZE RUNOFF FROM NEW BUILDING CONSTRUCTION AND MAJOR RENOVATIONS

OBJECTIVE

Minimize, and if possible eliminate, stormwater runoff from new building construction and major renovation projects. When planning and designing buildings and sites, create a hydrologic landscape that is functionally equivalent to the pre-development hydrology.

BENEFITS

+ Significantly improves water quality and minimizes combined sewer overflows.
+ Shifts cost of stormwater management to building operators and property owners, resulting in a substantial cost savings for the City.
+ Treats stormwater as a valuable resource. Promotes the productive reuse of stormwater and reduces use of municipal potable water.
+ Cost-effectively reduces and controls stormwater as close to its source as possible.

LIMITATIONS

– Increases construction costs.
– BMPs require periodic maintenance. Improper maintenance could result in inadequate stormwater management, flooding, etc.
– Regulatory changes or financial incentives may be necessary to gain compliance by private developers.
– Enforcement, fines and transfer of liability may be necessary to ensure long-term performance and upkeep of on-site stormwater management.

INTEGRATION

- **SA.2** Conduct Soil Analysis
- **SA.3** Conduct Hydrologic and Hydraulic Analysis
- **SA.4** Survey Existing Vegetation
- **PA.2** Minimize Impervious Pavement Area
- **PA.4** Use Pervious Pavements
- **SM.1** Conduct Integrated Stormwater Management Planning
- **SM.4** Optimize Right-of-Way Drainage
- **SM.5** Use Vegetated Filters and Buffer Strips
- **SM.8** Use Detention Structures
- **SM.9** Use Infiltration Structures
- **SM.10** Use Bioretention
- **SM.11** Use Constructed Wetlands
- **LA.1** Optimize Citywide Landscape Planning
- **LA.2** Encourage Ecological Connectivity and Habitat
- **LA.3** Create Absorbent Landscapes
- **LA.7** Increase the Quantity, Density and Diversity of Trees

TECHNICAL STRATEGIES

Planning

- Modify municipal permitting process and building codes to encourage or require onsite stormwater management and reduce runoff.
- Create incentives for developers to maximize onsite stormwater management and minimize runoff.

Design

Design a hydrologic landscape that will enable zero-runoff beyond the pre-development state:

- Begin stormwater management planning as early in the process as possible.
- Minimize and disconnect impervious surface areas to reduce runoff and encourage infiltration. **(PA.2, PA.4)**
- Maximize landscaping and pervious open space. **(LA.1, LA.2, SS.5)**
- Use pervious pavements. **(PA.4)**
- Create absorbent landscapes. **(LA.3)**
- Use bioengineered and structural practices to reduce and control runoff.
- Use stormwater collection and recycling systems.
- If possible, design site so that it maintains or restores pre-development drainage patterns.
- If some runoff is unavoidable, seek to detain for the duration of the storm and allow it to slowly enter back into the municipal drainage system. If possible, treat the water quality volume prior to discharge.

Minimize stormwater runoff from buildings, especially in areas with combined sewer systems:

- Use green roofs.
- Use roof downspout controls to manage runoff from buildings on-site.
- Create absorbent landscapes. **(LA.3)**
- Use structural practices to reduce and control runoff. **(SM.8, SM.9)**
- Use stormwater collection and recycling systems.
- Reuse stormwater runoff for irrigation, indoor plumbing, janitorial uses, cooling tower make-up, cooling of steam condensate, washing of vehicles, facades, and pavement, and etc.
- Use vegetated swales, bioretention and constructed wetlands. **(SM.10, SM.11)**
- Use drywells and leaching fields for stormwater infiltration.

- Use porous pavement for stormwater infiltration. **(PA.4)**
- See *High Performance Building Guidelines* for more details.

Capture and reuse stormwater: Rather than exporting rainwater as a waste product down storm sewers, reuse it for landscape irrigation, toilet flushing, custodial work, and other uses to reduce demand for potable water.

PERFORMANCE GOALS

The following performance goals are recommended by the United States Green Building Council in LEED for New Construction and Major Renovation:

Quantity:[134] Implement a stormwater management plan that prevents the post-development 1.5 year, 24 hour peak discharge rate from exceeding the pre-development discharge rate.
Quality: Construct site stormwater treatment systems designed to remove 80% of the average annual post-development total suspended solids (TSS) and 40% of the average annual post-development total phosphorous (TP) based on the average annual loadings from all storms less than or equal to the 2-year/24-hour storm.

EXAMPLES

Seattle, Washington – High Point Redevelopment

Seattle Public Utilities, partnering with Seattle Housing Authority developed a natural drainage system for a 129 acre housing redevelopment – one of Seattle's largest redevelopments in recent history – located in the threatened Longfellow Creek Watershed. The natural drainage system integrates 22,000 linear feet of bioretention swales into the right-of-way, providing both storage and infiltration for stormwater from surrounding blocks. Once built, the natural drainage system will provide water quality treatment for the 6-month storm and attenuate the two-year, 24-hour storm to pre-developed conditions, resulting in substantially improved water quality compared to conventional drainage infrastructure.
http://www.seattle.gov/util/naturalsystems

City of Chicago

The City of Chicago has undertaken a series of innovative projects to reduce runoff and improve urban hydrology. In 2001, a 38,800 square foot green roof was installed on top of the City Hall. Chicago has also developed a ground-breaking landscaping ordinance called City Trees, which requires tree planting and landscaping for new and renovated buildings and parking areas.
http://www.lid-stormwater.net/greenroofs/greenroofs_commercial.htm
http://www.cityofchicago.org/Environment/CityTrees/LandscapeOrdinance.html

Mt. Hope Community Center – Bronx, New York
New community center minimizes runoff through the use of intensive and extensive green roofs, pervious pavements, stormwater detention, and gray water irrigation.

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SM.4
OPTIMIZE RIGHT-OF-WAY DRAINAGE

OBJECTIVE

Optimize right-of-way drainage through the use of stormwater management BMPs to reduce, detain, and treat stormwater runoff.

BENEFITS

+ More cost-effective than building end-of-pipe treatment facilities.
+ Reduces combined sewer overflows.
+ Improves water quality.
+ Improves urban hydrology and provides other environmental benefits.
+ Could result in cost savings by downsizing storm sewer infrastructure.
+ Easy to retrofit into existing public right-of-ways.

LIMITATIONS

– Increases construction costs and requires periodic maintenance.
– Existing regulatory barriers may need to be overcome to permit implementation of certain BMPs.
– Objections may result because of conventional aesthetic expectations.

BACKGROUND

In new right-of-way construction or reconstruction, seek to optimize management of small, large, and extreme storm events to minimize damage to property and aquatic ecosystems. Use localized stormwater management BMPs within or adjacent to the right-of-way to achieve the following objectives:

- **Reduce** Reduce runoff quantity through promoting infiltration and evapotranspiration so that less water enters the sewer system and is discharged into receiving waters.
- **Detain** Temporarily store runoff until after major storms to reduce peak demand on the sewer system, reduce combined sewer overflows, and minimize damage to receiving waters.
- **Treat** Remove stormwater constituents that cause water pollution.

Certain BMPs in the Guidelines accomplish only one of these objectives, while others accomplish multiple objectives. The following text describes three categories of BMPs discussed in the *Guidelines.* The primary objectives achieved by each BMP are listed in parentheses.

Pretreatment BMPs Practices that provide initial treatment and reduce velocity of stormwater before it enters downstream BMPs.
- **SM.5** Use Vegetated Filters and Buffer Strips (Treat)
- **SM.6** Use Catch Basin Inserts (Treat)
- **SM.7** Use Water Quality Inlets (Treat)

Structural BMPs Practices that use physical means to control and treat runoff.
- **SM.8** Use Detention Structures (Detain)
- **SM.9** Use Infiltration Structures (Reduce, Treat)

Bioengineered BMPs Vegetated practices that are designed to mimic natural hydrologic and ecological processes. Bioengineered BMPs rely on biological, physical, and chemical processes to reduce and treat runoff.
- **SM.10** Use Bioretention (Reduce, Detain, Treat)
- **SM.11** Use Constructed Wetlands (Reduce, Detain, Treat)

INTEGRATION

- **SA.1** Assess Site and High Performance Opportunities
- **SA.2** Conduct Soil Analysis
- **SA.3** Conduct Hydrologic and Hydraulic Analysis
- **SA.4** Survey Existing Vegetation
- **SS.5** Increase and Improve Right-of-Way Public Space and Green Areas
- **PA.2** Minimize Impervious Pavement Area
- **PA.4** Use Pervious Pavements
- **SM.1** Conduct Integrated Stormwater Management Planning
- **SM.3** Minimize Runoff from New Building Construction and Major Renovations
- **SM.5** Use Vegetated Filters and Buffer Strips
- **SM.6** Use Catch Basin Inserts
- **SM.7** Use Water Quality Inlets
- **SM.8** Use Detention Structures
- **SM.9** Use Infiltration Structures
- **SM.10** Use Bioretention
- **SM.11** Use Constructed Wetlands
- **LA.1** Optimize Citywide Landscape Planning
- **LA.3** Create Absorbent Landscapes
- **LA.7** Increase the Quantity, Density and Diversity of Trees

TECHNICAL STRATEGIES

Site evaluation

Conduct soil analysis (SA.2), and hydrologic/hydraulic analysis. (SA.3)

Evaluate site, considering the following issues:
- Drainage master plan and regulatory requirements. (SM.1)
- Size and soil characteristics of drainage catchment area. (SA.2)
- Existing storm sewer infrastructure.
- Water volume and pollutant concentrations after different sized storm events. (SA.3)
- Contribution of site's runoff to combined sewer overflows.
- Physical limit of the right-of-way and site's suitability for BMPs. (SA.1)
- Existing and future land use and right-of-way use.
- Opportunities to incorporate BMPs into adjacent landscapes, open spaces or properties. (LA.1, SS.5)
- Proximity to significant natural resources.
- Public safety and community acceptability.
- Short and long-term maintenance requirements.
- See individual BMPs for more details.

Planning

General considerations:
- Begin planning BMPs as early in the process as possible.
- Consider constructing BMPs when conducting right-of-way rehabilitation, econstruction, or new construction.
- Consider incorporating BMPs into landscaped medians, planting strips, shoulders, traffic islands, bulbouts, traffic calming features, etc.
- Consider incorporating BMPs into spaces adjacent to the right-of-way, including open spaces, parks, abandoned lots, etc. (SS.5, LA.1)
- Prioritize the use of bioengineered BMPs. See Design section.

Design systems to manage the 'entire spectrum' of rainfall events: [135]
- Seek to eliminate runoff from small rainfall events (the majority, or 90% of all storms).
- Seek to detain, treat and slowly release large storms (once a year storms or greater).
- Provide conveyance and flood control for extreme storms.
- Incorporate BMPs into drainage systems where possible.

Use lifecycle cost analysis: Analyze lifecycle costs to determine the relative cost effectiveness and environmental benefits of competing options for controlling and treating stormwater. See City Process section.

Design

Configure right-of-way to direct stormwater to BMPs:
- Design right-of-way grading, curb profile, and storm sewer infrastructure to direct stormwater towards BMPs within and adjacent to the right-of-way.

Size BMPs appropriately:
- Use data from soil analysis and hydrologic and hydraulic analysis in the determination of BMP sizing. (SA.2, SA.3)
- Seek to capture, retain, treat, and facilitate either infiltration or evapotranspiration of all small storms, or 90% of average annual storm runoff volume. The New York State Department of Environmental Conservation refers to this quantity as the 'Water Quality Volume,' while other municipalities refer to it as the highly polluted 'first flush' (typically the first 1 to 1 1⁄2 inches of rainwater).
- Seek to retain or detain, and treat runoff from large storms (once a year storms or greater), and then slowly facilitate evapotranspiration, infiltration, or conveyance. This will help reduce peak flows, combined sewer overflows, and damage to aquatic ecosystems.
- Provide conveyance and flood control for extreme storm events.

Use pretreatment:
- Use pretreatment to remove large sediments, salts, hydrocarbons and debris from stormwater as it moves towards downstream BMPs.
- Use above ground pretreatment, including vegetated filters and swales, and buffer strips. (SM.5)
- Use catch basin inserts or water quality inlets to pretreat stormwater entering the storm sewer. (SM.6, SM.7)

Prioritize the use of bioengineered BMPs:
- At a minimum, make all landscapes, 'absorbent landscapes.' (LA.3)
- In street reconstruction projects, integrate bioretention areas or constructed wetlands into existing landscaped areas, traffic calming measures, adjacent open spaces, etc. (SS.5, LA.1, SM.1, SM.10, SM.11)
- Tailor bioengineered BMPs to reduce, detain and treat runoff as necessary depending on site characteristics and stormwater management needs. (SM.10, SM.11)
- Design bioengineered BMPs to enhance streetscape aesthetics, property value, habitat, and air quality.
- See individual BMPs for details. (SM.10, SM.11)

Use structural BMPs:
- Where bioengineered BMPs are unfeasible or undesirable, use structural BMPs to reduce, detain, and treat runoff. (SM.8, SM.9)
- If surface space is limited, consider locating structural BMPs underground.
- See individual BMPs for details. (SM.8, SM.9)

[135] For a detailed methodology for managing the 'complete spectrum' of rainfall events, consult, Stormwater Planning: A guidebook for British Columbia. http://wlapwww.gov.bc.ca/epd/epdpa/mpp/stormwater/stormwater.html

Plan for maintenance:
- Establish contract language and financial incentives or penalties to ensure regular and long-term maintenance.
- Consider involving community groups in routine maintenance and upkeep. Develop flexible maintenance contracts to encourage participation. **(SS.1)**
- Develop enforceable specifications or guidelines for monitoring and maintaining BMPs.

Construction

Employ proper construction practices and sequencing: Construction practices heavily influence the longevity and performance of stormwater management BMPs.
- Mark and rope off area surrounding bmp prior to construction. **(CP.1)**
- Prevent soil compaction. **(CP.2, CP.3)**
- Use low ground pressure (LGP) equipment.
- See Construction Practices section for more details.

Avoid sedimentation during construction:
- If possible, construct BMPs after site is completely stabilized.
- Ensure that no runoff enters BMPs before the site is stabilized.
- Do not use BMPs as temporary sediment traps during construction.
- Use diversion berms, hay bales, or silt fences to protect BMPs or existing systems prior to construction.
- Ensure that truck washing occurs away from BMPs.
- Place excavated material downstream and away from BMPs.
- See "Protect Existing and Future Planted Areas" **(CP.2)** and "Protect Water Sources During Construction" **(CP.3)** for more details.

Conduct final inspection and testing: After site is stabilized, inspect and test BMPs to ensure proper operation.
- Require the submission of an as-built drawing.

Maintenance and Monitoring

Post construction testing and monitoring:
- Conduct periodic monitoring for up to two years after construction.

Monitoring and periodic inspection: Conduct periodic inspections of BMPs, especially after major storm events. Perform annual inspections. See Individual BMPs for inspection details. Always inspect for the following:
- Structural soundness.
- Obstruction of inlets, valves, etc.
- Flooding or ponding.
- Erosion, sedimentation and channelization.
- Full drainage within acceptable time period (less than 24 hours).
- Algae, stagnation or odors.
- Vandalism.

Proposed Neighborhood Green Corridor – Bronx, NY
The Neighborhood Green Corridor has the goal of transforming an oversized roadway into an attractive pedestrian thoroughfare while providing onsite stormwater management for up to a ten-year design storm, as well as a range of safety, environmental and health benefits – both locally and regionally. See example in Part I for more details.

Periodic maintenance:
- Develop and document an operations and maintenance plan.
- Establish contract language or financial mechanisms to ensure adequate maintenance.
- Perform BMP maintenance in conjunction with other planned right-of-way maintenance activities.
- Regularly clean out BMPs, especially after major storms.
- Clean pretreatment and overflow structures at least twice annually.
- Establish a dry period if performance decrease is observed.
- Take corrective action immediately if ponding or flooding occurs.
- See individual BMPs for more details.

EXAMPLE

Seattle Public Utilities recently constructed a bioengineered stormwater management demonstration project called the 'Street Edge Alternative' to test new approaches to on-site stormwater management and streetscape improvement. The reconstructed Street Edge Alternative street has 11% less impervious pavement surface than a traditional street, provides surface detention in small vegetated swales, and contains over 100 new evergreen trees and 11000 shrubs. The Street Edge Alternative street not only controls and treats 95% of stormwater from up to a two-year storm, it also cost 20% less to build than a conventional street and offers a range of social and environmental benefits.

Seattle Public Utilities is also partnering with Seattle Housing Authority to construct a natural drainage system for a 129 acre housing redevelopment – one of Seattle's largest redevelopments in recent history – located in the threatened Longfellow Creek Watershed. The natural drainage system integrates 22,000 linear feet of bioretention swales into the right-of-way, providing both storage and infiltration for stormwater from surrounding blocks. Once built, the natural drainage system will provide water quality treatment for the 6-month storm and attenuate the two-year, 24-hour storm to pre-developed pasture conditions, resulting in substantially improved water quality compared to conventional drainage infrastructure.

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SM.5 USE VEGETATED FILTERS AND BUFFER STRIPS

OBJECTIVE

Use surface pretreatment BMPs – including buffer strips and vegetated filters and swales – to remove sediments, salts, pollution, and debris, and to reduce, slow, and evenly distribute stormwater heading towards downstream BMPs.

BENEFITS

+ Provides water treatment and control for a small cost increase over conventional earthmoving.
+ Considerably easier and less expensive to maintain than downstream BMPs.
+ Improves performance and reduces maintenance costs of downstream BMPs.
+ Suitable for any soil type and site configuration.
+ Effective at roadway shoulders, medians and other right-of-way applications.
+ Efficiently improves quality and control of stormwater in small spaces.
+ Enhances aesthetics if well landscaped.

LIMITATIONS

– Requires regular maintenance to avoid build-up of litter and debris.
– Limited effectiveness in treating high volume flows.
– Vegetated filtration may become less effective in winter months.

INTEGRATION

- **SA.2** Conduct Soil Analysis
- **SA.3** Conduct Hydrologic and Hydraulic Analysis
- **SM.1** Conduct Integrated Stormwater Management Planning
- **SM.3** Minimize Runoff from New Building Construction and Major Renovations
- **SM.4** Optimize Right-of-Way Drainage
- **SM.8** Use Detention Structures
- **SM.9** Use Infiltration Structures
- **SM.10** Use Bioretention
- **SM.11** Use Constructed Wetlands
- **LA.12** Use Low-maintenance, Salt-tolerant, Native or Naturalized Species
- **LA.13** Use Water-efficient Landscape Design
- **CP.2** Protect Existing and Future Planted Areas

TECHNICAL STRATEGIES

Use buffer strips: Buffer strips are thin zones consisting of gravel or pervious pavement that filter, slow and evenly spread stormwater that is heading towards downstream BMPs.

- Use buffer strips to reduce the impact of de-icing procedures and sedimentation on downstream BMPs.
- Use buffer strips before vegetated filter strips and other BMPs to prevent channelization and erosion.
- Integrate buffer strips with the design of sidewalks, curbs and other features.

Use vegetated filter strips or swales: Vegetated filter strips are evenly sloped vegetated areas that filter stormwater by passing it in sheets towards downstream BMPs.

- Plant with low-maintenance herbaceous species that are tolerant of periodic inundation, salt and other pollutants. **(LA.12)**
- Consider the use of weirs or down gradient berms to enhance control of runoff. **(LA.6)**

Planning and Design

- Determine the volume of the design storm and size of drainage catchment area.
- If possible and feasible for the site, plan to control and treat the entire water quality design storm.
- If necessary, design an overflow or bypass structure to divert excessive volumes from large storms and prevent channelization, erosion, and flooding.
- Design pretreatment to have a gentle slope towards the downstream BMP.
- Design as much treatment length as possible in the direction of the water flow.
- If soil and site conditions are suitable, design pretreatment BMPs to infiltrate a portion of the stormwater. **(SA.2, SA.3, SS.9)**
- Use vegetation that can withstand both inundation and drought conditions. **(LA.12)**

Construction

- Ensure evenly compacted and level soil surface.
- Prevent excessive soil compaction if designed for infiltration. Use low ground pressure (LGP) excavation equipment. Mark and rope off infiltration areas prior to construction. **(CP.1 to CP.3)**

Operations and Maintenance

- Periodically mow grasses and remove successional vegetation.
- Avoid the use of herbicides and fertilizers. **(LA.12, LA.14)**
- Periodically remove excess sediment to maintain treatment capability.
- Patch bare spots and eliminate channels and rills at least twice annually.

Riverdale Country School, Lower Campus – Bronx, New York
A rock-lined infiltration trench near the playground promotes natural hydrology and provides an educational resource.

EXAMPLE

The Port Authority of New York and New Jersey recently constructed a bioretention basin with two levels of pretreatment at the Newark Liberty International Airport. Adjacent to the road is pervious paver buffer strip that removes coarse sediments, debris, and salt from runoff. A grass filter strip is located down gradient and surrounds the bioretention area, further enhancing filtration and debris removal. Any residual storm water runoff from the bioretention basin is then directed to an infiltration trench composed of gravel and topped with pea gravel. The entire treatment system represents a significant enhancement to the aesthetics and functionality of the airport's right-of-way.

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Newark Liberty International Airport – Newark, New Jersey
Pictured in the foreground is the permeable paver buffer strip followed by the grass filter strip. The diversely-planted infiltration trench is located in the middle ground.

SM.6 USE CATCH BASIN INSERTS

OBJECTIVE

Install catch basin inserts into existing catch basins to enhance onsite treatment of runoff.

BENEFITS

+ Easy to install in existing catch basins.
+ Easier to maintain than cleaning catch basins, and could be less expensive.
+ Cost effective method of improving catch basin treatment efficiency.
+ Effective at filtering sediments, debris, hydrocarbons and other pollutants.
+ Designers can choose among a variety of models based on a site's specific pollutant removal priorities.
+ Effective for use as temporary sediment control devices during construction.
+ Could be maintained by community groups, business improvement districts or private citizens.

LIMITATIONS

– Improper maintenance will result in re-suspension of sediments, hydrocarbons and other pollutants.
– May require more frequent maintenance compared to catch basin sump size.

BACKGROUND

Catch basin inserts are pre-manufactured units that mount directly into the frame of catch basins. They work by filtering debris and large sediment particles from stormwater entering into the catch basin, and can also include an oil absorbent material to remove hydrocarbons. Catch basin inserts come in three basic types: 1) Inserts consisting of a series of trays, with a sediment trap on top and varying media filters below; 2) Inserts composed of filter fabric. 3) Inserts consisting of a plastic box that filters water and traps debris. Each of these devices has a smaller volume compared to the size of the catch basin sump (up to 60% of the sump volume), requiring more frequent maintenance. However, catch basin inserts are far easier to maintain the an sumps, and they provide significant water quality improvement benefits if well maintained.

INTEGRATION

- **SM.1** Conduct Integrated Stormwater Management Planning
- **SM.4** Optimize Right-of-Way Drainage
- **SM.7** Use Water Quality Inlets
- **SM.8** Use Detention Structures
- **SM.9** Use Infiltration Structures
- **SM.10** Use Bioretention
- **SM.11** Use Constructed Wetlands
- **CP.3** Protect Water Sources During Construction

TECHNICAL STRATEGIES

Selection of catch basin inserts (CBI's):

- Consider the use of CBI's that are designed with an overflow to allow peak volumes of runoff from major storm events to bypass treatment, thus minimizing resuspension of sediments and debris.
- Select CBI's based on pollutant removal needs for the site, as well as design storm and overflow needs.
- Consider maintenance requirements when selecting CBI's.
- Use catch basin inserts as pretreatment for downstream BMPs.

Use inserts as temporary sedimentation traps during construction. **(CP.3)**

Operations and Maintenance

Maintain as frequently as possible for best results: Studies suggest that increased maintenance significantly improves catch basin insert performance. A study of 60 catch basins in Alameda County, California, found that annual sediment removed per inlet was 54 pounds for cleaning at a frequency of once annually, 70 pounds for semi-annual cleaning, and 160 pounds for monthly cleaning. For catch basins located in industrial areas, monthly cleaning increased total annual sediment collection six times compared to once a year cleaning (180 pounds versus 30 pounds).[136]

Conduct a catch basin pilot study: Identify a pilot project area and monitor the effectiveness of catch basins maintained at varying frequencies. Record and analyze the amount of material removed.

Determine optimal maintenance schedule: Analyze the costs of increased maintenance against the benefits of improved pollutant removal. Use GIS to optimize the schedule and frequency of catch basin maintenance.

Additional considerations:

- Develop and implement an operations and maintenance plan.
- Remove sediment and debris at least twice annually, but preferably after every two or three major storms, to prevent clogging and resuspension.

[136] See the Center for Watershed's Catch Basin Fact Sheet and also its article 'The Value of More Frequent Cleanouts of Storm Drain Inlets.'

- Perform more frequent maintenance for inserts that remove oil and grease.
- Perform more frequent maintenance in industrial or highly trafficked areas.
- Properly dispose of waste according to all relevant guidelines.
- Prevent cement trucks from washing out into catch basins.
- Always clean catch basin inserts after chemical, oil or other spills occur.
- Ensure proper training of individuals responsible for CBI cleaning.
- Consider working with community groups to maintain catch basin inserts.

EXAMPLE

The Port of Seattle has compared maintenance requirements and costs using catch basin inserts versus cleaning the catch basin sump directly without an insert. The study concluded that catch basin inserts allowed for much easier, faster and cheaper cleaning of catch basin sumps. It estimated that one person could clean 18 inserts in 90 minutes, while it would take two vacuum truck operators about three hours to clean 18 sumps.

A Seattle based not-for-profit organization called Planet CPR began a program called 'Grate Mates' in 1998 to encourage community volunteers to install and maintain catch-basin inserts in parking lots and other locations. A tax deduction encourages local businesses to purchase and maintain the catch basin, and the group offers an expense stipend to other volunteer groups to encourage participation. The program has resulted in the installation and regular maintenance of thousands of catch basin inserts in the Puget Sound watershed. Participants in the program remark that it is an excellent way to engage community members, especially children, in environmental stewardship.

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SM.7 USE WATER QUALITY INLETS

OBJECTIVE

Use water quality inlets – including oil and grit separators, media filters, and high-volume treatment proprietary devices – to treat the highly polluted water quality volume of the design storm.

BENEFITS

+ Standardized designs are able to be integrated into preexisting infrastructure.
+ Water quality inlets have long lifecycles if well maintained.
+ Effective at removing suspended solids, metals, hydrocarbons, phosphorus, insoluble organics, and other pollutants.
+ Suitable for any soil type and hydrogeologic condition.
+ Well suited for small spaces within or adjacent to urban right-of-ways.

LIMITATIONS

– May be costly if substantial underground construction work is required.
– Requires long-term routine maintenance.
– Damage or repeated disruption to surrounding pavements could compromise the structural integrity or performance of water quality inlets.
– Treatment during peak flows may be reduced.
– Less environmentally beneficial than bioengineered BMPs, which offer residual benefits of improving streetscape aesthetics, cleaning air, providing habitat, etc.

INTEGRATION

- **SM.1** Conduct Integrated Stormwater Management Planning
- **SM.4** Optimize Right-of-Way Drainage
- **SM.6** Use Catch Basin Inserts
- **SM.8** Use Detention Structures
- **SM.9** Use Infiltration Structures
- **SM.10** Use Bioretention
- **SM.11** Use Constructed Wetlands

TECHNICAL STRATEGIES

Oil and grit separators: Oil/Grit separators are underground structures that can be retrofitted into the existing storm sewer conveyance system, within the space of a conventional manhole cover, to remove sediments and hydrocarbons from the runoff of small drainage catchment areas. Most designs consist of three or more chambers that work to settle sediments and particulate matter, screen debris, and remove oils from stormwater.

- Use oil and grit separators to treat runoff from parking lots.

Underground media filters: Underground media filters use either sand or compost filter media to settle, filter and absorb pollutants. Most underground media filters employ these basic components:

1. Forebay - Removes large sediments and debris.
2. Sand bed - Filters water and removes fine sediments and other pollutants.
3. Underdrain - Slowly discharges treated runoff to the municipal storm sewer.
4. Overflow System - allows water to bypass filtration during large storms.

High-volume proprietary treatment devices: Many high-volume proprietary treatment devices exist, and some could be applicable to the New York City right-of-way. Treatment devices work in a variety of ways and can be selected based on pollutant removal needs and effectiveness, and available space.

- Consider undertaking a pilot program to test proprietary treatment devices in various settings.

Design

- Configure water quality inlets off-line or use flow-splitters to divert large storm volumes and to avoid excessive pollutant loading and damage.
- Select water quality inlets and sizes based on pollutant removal needs, available space, size of water quality volume and drainage catchment area, additional detention needs, and the desired discharge rate.
- Design water quality inlets to empty completely between storm events, preferably after 24 hours.
- Design water quality inlets for easy access and maintenance.
- Consider designing shutoff mechanisms for use during maintenance and for emergency shutoff.
- Use catch basin inserts as pretreatment. **(SM.6)**

Construction

- Avoid sedimentation of water quality inlets during construction. Ensure that no runoff enters until construction is completed and site is stabilized. **(CP.3)**
- Prevent cement trucks from washing out into catch basins.
- Construct water quality inlets to be completely watertight.
- Conduct a final inspection and testing to ensure that water quality inlets are functioning properly.

Operations, Maintenance and Monitoring

Periodic maintenance:

- Develop and implement an operations and maintenance plan.
- Record and analyze the amount of material removed from BMPs to optimize frequency of maintenance.
- Inspect and clean out water quality inlets several times annually (preferably at least four times per year) and after major storm events to prevent clogging and re-suspension.
- Perform more frequent maintenance for inlets that remove oil and grease.
- Perform cleaning when inlets are completely drained.
- Always clean water quality inlets after chemical, oil or other spills occur.
- Dispose of cleanout waste appropriately.

Periodic testing:

- Test filtration and discharge rates annually.
- If discharge time changes significantly, inspect components and take necessary corrective measures.
- Inspect structural components annually.

EXAMPLE

The Alexandria Department of Transportation installed and monitored a sand filter in a parking lot near Reagan National Airport in Alexandria, Virginia. The goal was to treat runoff from the lot as part of an effort to comply with the requirements of the Virginia Chesapeake Bay Preservation Act and the Stormwater Management Act. Removal efficiencies for Total Phosphorus (60 to 70%) and Total Nitrogen (32 to 52%) were high compared to other similar filter studies.

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SM.8 USE DETENTION STRUCTURES

OBJECTIVE

Use underground detention structures – made from reinforced concrete, pre-manufactured corrugated metal, plastic pipe, etc – to temporarily attenuate and store runoff during peak flow periods.

BENEFITS

+ Reduces combined sewer overflows (CSOs).
+ Reduces flooding, and lessens damage to receiving waters.
+ Improves water quality by detaining the storm's highly polluted first flush.
+ Effective for use in urban areas with high land values and limited space for surface BMPs.
+ Easy to incorporate into right-of-way retrofits.

LIMITATIONS

– Offers only minimal treatment benefits onsite.
– Requires periodic maintenance to maintain performance.
– Must be located in areas that will allow easy access for maintenance.
– Less environmentally beneficial than bioengineered BMPs, which offer residual benefits of improving streetscape aesthetics, cleaning air, providing habitat, etc.

INTEGRATION

- **SM.1** Conduct Integrated Stormwater Management Planning
- **SM.3** Minimize Runoff from New Building Construction and Major Renovations
- **SM.4** Optimize Right-of-Way Drainage
- **SM.5** Use Vegetated Filters and Buffer Strips
- **SM.6** Use Catch Basin Inserts
- **SM.7** Use Water Quality Inlets

TECHNICAL STRATEGIES

Planning and Design

- Conduct hydrologic and hydraulic analysis. **(SA.3)**
- Determine detention structure size and configuration based on available space, size of drainage area and design storm, desired discharge rate, and additional storage capacity needs. Detention structure should empty out completely between storm events, preferably after 24 hours.
- Design an overflow, splitter, or bypass structure to divert excessive volumes from large storms.
- Use pretreatment BMPs prior to detention. **(SM.5 to SM.7)**
- Install detention tanks at a slight slope to facilitate complete drainage.
- If placed under a roadway, design detention structures to withstand heavy loads from vehicles and trucks.
- Maintain a minimum distance between detention structures and adjacent buildings or properties.
- Avoid positioning detention facilities on steep slopes (greater than 15%).
- If necessary, provide water-tight access chambers and/or cleanouts to allow for easy maintenance and monitoring. Avoid designing detention systems under structures that cannot be excavated.

Construction

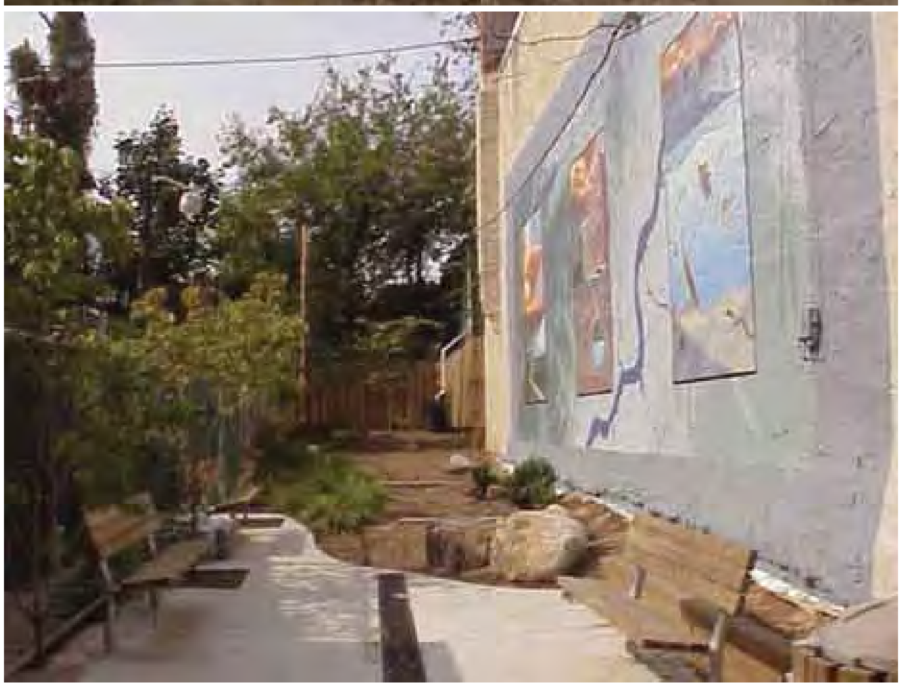
- Avoid sedimentation of detention structures during construction. **(CP.3)**
- Conduct a final inspection and testing to ensure that the detention structure is working properly.
- Use recycled and reclaimed materials. **(PA.6)**

Operations, Maintenance and Monitoring

- Develop an operations and maintenance plan.
- Periodically clean out sediments and debris. Avoid sending sediment downstream during cleaning process.
- Periodically inspect structural integrity of detention structure and inlets/outlets. Perform repairs as necessary.

EXAMPLES

The City of Philadelphia Office of Watersheds – as part of an ambitious plan to reduce combined sewer overflows – is converting vacant lots throughout the city into small 'stormwater parks.' The Office of Watersheds utilized GIS mapping to identify high-risk drainage catchment areas; they determined that converting vacant lots in certain areas into stormwater parks could incrementally reduce the frequency of combined sewer overflows. Each stormwater park contains small scale treatment and detention structures to manage the runoff from the lot, and if possible from surrounding areas. The Office of Watersheds worked with local community groups in the design of the park environment, including seating, play areas, murals and landscaping. The result



Vacant lot transformed into stormwater park - Philadelphia, PA.

is not only a cost-effective solution to managing stormwater runoff and reducing CSOs, but also the creation of valuable public open space, which improves quality of life for residents, improves environmental quality, increases property values, and encourages urban revitalization.

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SM.9 USE INFILTRATION STRUCTURES

OBJECTIVE

Use surface and underground infiltration structures – including trenches, vaults/galleries, injection wells, dry wells, leaching fields, etc – within or adjacent to the right-of-way to reduce stormwater runoff volumes and peak flows, improve water quality, and promote groundwater recharge. Infiltration can also be employed in bioengineered facilities. **(SM. 7, SM.8)**

BENEFITS

+ Effective at filtering metals, sediments, nutrients, bacteria, organics and oxygen demanding substances.
+ Effective for use in small spaces.
+ Effective for use under parking lots, ball-fields, etc. Popular with commercial and industrial developers because they use up little or no developable area.
+ Reduces run-off volumes and peak flows, resulting in reduced combined sewer overflow (CSO) events and improved hydrology.
+ May reduce the cost and size of downstream stormwater treatment facilities and infrastructure.

LIMITATIONS

– Requires long-term periodic maintenance and monitoring to prevent clogging, flooding, and premature failure.
– Potential for groundwater contamination exists and must be assessed prior to design.
– Provides no visual enhancements to the right-of-way.
– Unsuitable for some urban sites because of impermeable or contaminated soil, or potential for infiltration into adjacent infrastructure or building foundations.
– Can develop gullies and erosion if poorly designed or maintained.

BACKGROUND

Infiltration structures temporarily store stormwater and enable slow percolation into the underlying soil, physically filtering runoff in the process and enabling soil particles to absorb and biodegrade pollutants. Infiltration structures are well suited for urban sites with gentle slopes, permeable soils, relatively deep groundwater and bedrock, and a small drainage catchment area. If the possibility exists to incorporate landscaping into the infiltration structure, see "Use Bioretention." **(SM.10)**

INTEGRATION

- **SA.2** Conduct Soil Analysis.
- **SA.3** Conduct Hydrologic and Hydraulic Analysis
- **SM.1** Conduct Integrated Stormwater Management Planning
- **SM.3** Minimize Runoff from New Building Construction and Major Renovations
- **SM.4** Optimize Right-of-Way Drainage
- **SM.5** Use Vegetated Filters and Buffer Strips
- **SM.6** Use Catch Basin Inserts
- **SM.7** Use Water Quality Inlets
- **SM.10** Use Bioretention
- **SM.11** Use Constructed Wetlands
- **LA.3** Create Absorbent Landscapes

TECHNICAL STRATEGIES

Site evaluation

Conduct soil and hydrologic and hydraulic analysis, and research site's history. **(SA.1 to SA.3)** An experienced geotechnical engineer should verify the site's suitability for infiltration and should recommend a design infiltration rate. Ensure that site meets the following criteria:

- Minimum infiltration rate of 0.5 inches per hour.
- Able to drain completely in time for the next storm, preferably within 24 hours.
- Sufficient organic content and Cation Exchange Capacity (CEC) for the treatment of anticipated pollutants.
- No contaminated soils.
- Sub-grade maintains structural stability with extended saturation or head loading.
- Sufficient clearance from the top of the groundwater table, bedrock or impermeable layer to the infiltration structure bottom.
- Sufficient clearance from building foundations, roads, subsurface infrastructure, drinking water wells, septic tanks, drain fields or other elements.
- Will not violate groundwater quality standards or impact sensitive aquifers.
- Will not be harmed by de-icing procedures.

Planning and Design

Design: Infiltration structures include, but are not limited to, an excavated trench lined with permeable filter fabric and filled with large stones (between 1 and 3 inches in diameter). Runoff is conveyed in sheet flows across the top of the stones or from the outfall of a storm drain system. Additional design options include:

- A top layer of pea gravel, separated by filter fabric, to enhance sediment removal and reduce maintenance needs and costs.
- A sand filtration layer at the bottom of the trench.

- An observation well to enable easy monitoring.
- A direct access chamber to allow for easy maintenance.
- An overflow or flow splitter to divert large storm events.
- An underdrain system with a shutoff valve to enable drainage if the trench has become clogged, and to enable periodic dry periods.
- An emergency detention structure to detain excessive runoff volumes.
- A drain-rock reservoir to facilitate infiltration into subsoils.

Sizing: Size the void volume of the infiltration structure based on the size of the drainage catchment, the design storm size, additional detention requirements, and the infiltration rate of the trench media and surrounding soil. Base the trench surface dimensions on the site topography, size and shape, and drainage path. Ensure that drainage will be completed within 24 hours.

Use pretreatment: Use pretreatment to remove large sediments and debris, and to slow down and distribute runoff. Ensure that exit velocities from pretreatment are non-erosive.

- Use pretreatment buffer strips and/or vegetated filter strips if water is conveyed in sheet flows. **(SM.5)**
- If water is conveyed through piping, use catch basin inserts or water quality inlets as pretreatment. **(SM 6, SM.7)**

Cold climate considerations: If necessary, design infiltration structure so that the water volume resides below the seasonal frost line. Ensure that trench surface is kept clean of compacted snow and ice. Improve de-icing procedures in surrounding areas.

Construction

Prevent soil compaction in infiltration areas:

- Mark and rope off infiltration areas prior to construction. **(CP.1 to CP.3)**
- Use low ground pressure (LGP) excavation equipment.

Avoid sedimentation during construction:

- Construct infiltration structures after the site is completely stabilized.
- If early construction is unavoidable, excavate to within one foot of the final bottom of the infiltration structure. Complete excavation after site is completely stabilized.
- Ensure that no runoff enters infiltration area before the site is stabilized.
- Place diversion berms, sod, and/or silt fences around infiltration area. **(CP.3)**
- Do not use infiltration structures as sediment traps during construction.
- Ensure that truck washing occurs away from infiltration area.
- Place excavated material downstream and away from infiltration area.

Other construction practices:

- Prevent smearing of infiltration walls or floor. If smearing occurs, scarify with a rake or other equipment.
- Ensure that the bottom of the infiltration trench is completely flat.
- Conduct final inspection and testing after site stabilization to ensure that the infiltration structure is working properly.
- Require the submission of an as-built drawing.

Riverdale Country School, Lower Campus – Bronx, New York
Construction of recycled HDPE infiltrators below a parking lot.

Operations, maintenance and monitoring

Periodic testing:

- Conduct periodic monitoring for up to two years after construction to ensure maintenance of infiltration rate.
- Regularly inspect infiltration rate. Check observation wells 24 hours after a storm to determine if infiltration is occurring in a timely fashion.
- Inspect structural components annually.

Periodic maintenance:

- Develop and implement an operations and maintenance plan.
- Establish contract language or financial mechanisms to ensure adequate maintenance.
- Regularly remove grass clippings, weeds, sediment and debris from the top layer of aggregate to avoid clogging.
- Clean pretreatment and overflow structures at least twice annually.
- If infiltration rate is decreased significantly, establish an extended dry period to restore infiltration capacity.
- If ponding occurs, take corrective action immediately.

EXAMPLE

The Port Authority of New York and New Jersey built long, narrow infiltration structures as part of a right-of-way reconstruction at Newark Liberty International Airport. Infiltration structures located between the right-of-way and large impervious parking areas are able to control and treat stormwater runoff from both areas while taking up minimal space.

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SM.10
USE BIORETENTION

OBJECTIVE

Design shallow swales and basins with diverse landscaping in an engineered soil medium to reduce, detain, and treat stormwater runoff. Depending on site characteristics and stormwater management requirements, bioretention areas can be designed either to convey runoff into the municipal storm sewer, to infiltrate runoff, or to provide a combination of conveyance and infiltration.

BENEFITS

+ Cost-effectively reduces runoff volume and peak flows, minimizing combined sewer overflows.
+ Environmental benefits exceed those of structural BMPs. Landscaping improves air quality, reduces noise pollution, and provides habitat for urban wildlife.
+ Engages natural systems to improve stormwater management.
+ Effective at removing sediments, metals, nutrients, bacteria, and organics.
+ Applicable at many scales and spatial configurations. Ideal for the constricted spaces of the ultra-urban environment.
+ Flexible designs enable use in any soil type.
+ Low-maintenance and tolerant of urban conditions, if well designed.
+ Appropriate soil construction, microbiology, and plant life can keep soil pores open and indefinitely maintain infiltration capacity.
+ Beautifies the urban environment, enhances quality of life, and increases property values.

LIMITATIONS

– Requires periodic maintenance to ensure plant health and remove debris.
– Vegetation may become less effective at filtering pollutants during winter.
– Vegetation may become dormant and look dead during periods of drought.

BACKGROUND

Bioretention areas – similar to absorbent landscapes **(LA.3)** but more intensively engineered – are designed to capitalize on the ability of forest-shrub ecosystems to capture, take up, and treat large volumes of stormwater. During storms, runoff temporarily ponds in the bioretention depression as it percolates through the mulch layer and engineered soil mix. Plantings physically filter stormwater above ground and take up stormwater constituents through roots underground. Stormwater is also physically and biologically filtered in the engineered soil layers. Bioretention offers highly effective treatment of polluted urban runoff.

Bioretention areas can be designed to allow for partial or full infiltration, if site conditions are suitable. Alternatively, bioretention can be used for detention and filtration only, with the entire design storm volume eventually discharging to the municipal storm sewer via a perforated underdrain. Runoff from very large storm events is either diverted completely or enters an overflow structure to avoid flooding. Bioretention is an ideal BMP for highly urbanized areas because it can be designed to reduce, detain and treat runoff, and it can be retrofitted into small spaces like medians, planting strips, traffic islands, and so on. Bioretention can also be used to infiltrate and treat roof runoff.

INTEGRATION

- **SA.2** Conduct Soil Analysis
- **SA.3** Conduct Hydrologic and Hydraulic Analysis
- **SA.4** Survey Existing Vegetation
- **SS.5** Increase and Improve Right-of-Way Public Space and Green Areas
- **PA.2** Minimize Impervious Pavement Area
- **SM.1** Conduct Integrated Stormwater Management Planning
- **SM.3** Minimize Runoff from New Building Construction and Major Renovations
- **SM.4** Optimize Right-of-Way Drainage
- **SM.5** Use Vegetated Filters and Buffer Strips
- **LA.1** Optimize Citywide Landscape Planning
- **LA.2** Encourage Ecological Connectivity and Habitat
- **LA.3** Create Absorbent Landscapes
- **LA.7** Increase the Quantity, Density and Diversity of Trees
- **LA.12** Use Low-maintenance, Salt-tolerant, Native or Naturalized Species
- **LA.13** Use Water-efficient Landscape Design
- **LA.14** Practice Biointensive Integrated Pest Management
- **CP.2** Protect Existing and Future Planted Areas

TECHNICAL STRATEGIES

Site Evaluation

- Determine if site configuration allows for bioretention.
- Conduct soil analysis. **(SA.2)**
- Conduct hydrologic and hydraulic analysis. **(SA.3)**
- Ensure that de-icing procedures will not harm bioretention area. **(SM.2, CP.2, CP.3)**
- Ensure that bioretention area will receive sufficient direct sunlight to maintain vegetation health (preferably 6 hours daily).

Determine if infiltration is desired and feasible:
An experienced geotechnical engineer should verify the site's suitability for partial or full infiltration. If feasible, decide whether partial or full infiltration will be used, and determine a design infiltration rate. Ensure that site meets the following criteria:
- Ensure that subsoil infiltration rate is a minimum of 0.5 inches per hour.
- Able to drain completely in time for the next storm, preferably within 24 hours.
- Sufficient organic content and Cation Exchange Capacity (CEC) for the treatment of anticipated pollutants.
- No contaminated soils.
- Sub-grade maintains structural stability with extended saturation or head loading.
- Sufficient clearance from the top of the groundwater table, bedrock or impermeable layer to the infiltration structure bottom.
- Sufficient clearance from building foundations, roads, subsurface infrastructure, drinking water wells, septic tanks, drain fields or other elements.
- Will not violate groundwater quality standards or impact sensitive aquifers.

Planning and Design

Use pretreatment: Use pretreatment to remove large sediments and debris, and to slow down and distribute runoff. Ensure that exit velocities from pretreatment are non-erosive.
- Use pretreatment buffer strips and/or vegetated filter strips if water is conveyed in sheet flows. **(SM.5)**
- If water is conveyed through piping, use catch basin inserts or water quality inlets as pretreatment. **(SM 6, SM.7)**

Sizing:
- Determine size of bioretention area based on site configuration and available area, design storm size, and additional detention requirements. If appropriate for the site and feasible, design bioretention area to hold entire design storm, plus additional detention requirements, without overflow.
- For streets with a gradient in excess of 5%, consider the use of check dams to slow the flow of stormwater and allow for greater infiltration and uptake of water by plants.

Infiltration and conveyance considerations:
- If no infiltration is to occur, design underdrain system with enough capacity to convey the entire design storm volume without flooding or backup.
- If it is determined that infiltration is desirable and feasible, decide what percentage of water will be infiltrated vs. conveyed.
- If only partial infiltration is to occur, design the underdrain system to convey the remaining runoff to the municipal storm sewer.
- If full infiltration is desired, consider using an underdrain as an additional overflow system and emergency drainage system.
- Ensure that bioretention area is completely drained (whether through conveyance or infiltration) in time for the next storm, preferably within 24 hours.
- Provide an overflow system to convey extreme storm events.

Vegetation design:
- Use Low-maintenance, salt and pollutant tolerant, native or naturalized species. **(LA.12)**
- Plant with a diverse and dense cover to optimize treatment and to withstand environmental stresses (insects, disease, drought, flood, wind, and exposure).
- Plant bioretention area to simulate an upland forest-shrub ecosystem.
- In the heavily inundated zones, plant shrubs, herbaceous species, rushes sedges, and other species capable of wetter conditions and high pollutant uptake. Avoid planting trees in the wettest zones.
- Plant species in a random layout to simulate natural conditions.
- Make aesthetics a prime consideration in bioretention design.
- Use hardy ground cover to minimize erosion and reduce the likelihood of undesirable volunteer vegetation and the creation of walking trails.
- Provide a mulch layer to retain moisture, minimize erosion, and avoid surface sealing. **(LA.10)**
- Consider using grassed areas to enable multi-use bioretention facilities.
- Minimize the use of turfgrass. **(LA.11)**
- See "Use Healthy Plant Selection and Planting Practices" **(LA.10)** for more details.

Sub-grade design:
- Design underdrain system based on infiltration and conveyance needs.
- Consider the use of a drain-rock reservoir to enhance storage for low infiltration rate sub-soils.
- Install cleanouts at the upstream and downstream sides of the drainage pipe.
- Use at least 4' depth of engineered planting soil.
- Design soil bed to support diverse biotic communities.
- Use filter fabric on the sides of the planting soil.

Plan for maintenance:
- Establish contract language and financial incentives or penalties to ensure regular and long-term maintenance.
- If privately owned, establish a long-term maintenance agreement with owner.
- Consider involving community groups in routine maintenance and upkeep. **(SS.1)**

Provide signage to educate public about bioretention.

Construction

Prevent soil compaction:
- Mark and rope off bioretention areas prior to construction. **(CP.1 to CP.3)**
- Use low ground pressure (LGP) excavation equipment.

Avoid sedimentation during construction:
- Construct bioretention areas after the site is completely stabilized.
- If early construction is unavoidable, excavate to within one foot of the final bottom of the bioretention trench. Complete excavation after site is completely stabilized.
- Ensure that no runoff enters bioretention area before the site is stabilized.

- Place diversion berms or silt fences around infiltration area.
- Do not use bioretention areas as temporary sediment traps during construction.
- Ensure that truck washing or other cleaning occurs away from bioretention area.
- Place excavated material downstream and away from bioretention area.

Other construction practices:
- Prevent smearing of bioretention walls or bottom surface. If smearing occurs, scarify with a rake or other equipment.
- Ensure that the bottom of the bioretention trench is completely flat.
- Conduct final inspection and testing after site stabilization to ensure proper functioning.
- Require the submission of an as-built drawing.
- Irrigate bioretention landscape as necessary to establish plant health. **(LA.10)**
- See "Use Healthy Plant Selection and Planting Practices" **(LA.10)** for more details.

Monitoring and Maintenance

Post construction maintenance:
- Conduct irrigation as necessary during the first season to establish plant health.
- Conduct frequent inspections of vegetation during the first year of operation.
- Conduct periodic monitoring for up to two years after construction to ensure maintenance of drainage rate.
- See "Use Healthy Plant Selection and Planting Practices" **(LA.10)** for more details.

Periodic inspection:
- Periodically test infiltration rate. Check observation wells 24 hours after a storm to determine if infiltration is occurring in a timely fashion.
- Inspect structural components annually.
- Inspect bottom of soil bed annually.
- Inspect for sedimentation build up quarterly and after major rainfalls.
- Inspect vegetation areas twice annually for general health, erosion and scour, and invasive species propagation.
- Ensure that road de-icing procedures do not impact vegetation health. **(CP.2, CP.3, SM.2)**

Periodic maintenance:
- Develop and implement an operations and maintenance plan.
- Establish contract language or financial mechanisms to ensure adequate maintenance.
- Conduct maintenance when the bioretention area is completely dry.
- Regularly remove grass clippings, undesirable volunteer vegetation, sediment and debris.
- Clean pretreatment and overflow structures at least twice annually.
- Conduct mowing as necessary.
- Avoid the use of fertilizers, herbicides and pesticides. Conduct Biointensive Integrated Pest Management. **(LA.14)**
- Remove and recycle all green and woody waste. **(CP.4)**

Proposed Neighborhood Green Corridor – Bronx, NY
Proposed bioretention area in a prototypical Neighborhood Green Corridor that will infiltrate and treat up to a ten year design storm, as offer a range of safety, environmental and health benefits-both locally and regionally. Proposed design meets all NYC DOT & DEP standards. See example in Part I for more details.

- Undertake corrective maintenance if channelization or erosion has occurred.
- If drainage rate is decreased significantly, consider redirecting runoff temporarily to establish an extended dry period, which can help to restore infiltration capacity.
- If ponding occurs for an extended period of time, take corrective action immediately.

EXAMPLE

A recent study by the Virginia Transportation Council evaluated a number of ultra-urban stormwater best management practices including bioretention and three proprietary water quality inlets. In terms of total suspended solids (TSS) removal efficiency, the study found that the bioretention area was the most cost-effective of the BMPs monitored in the study. The bioretention BMP also had the lowest installation and maintenance costs.

The cities of Philadelphia and Seattle are currently implementing bioretention in right-of-way retrofits and large scale urban redevelopments. These cities have determined that bioretention is an extremely cost-effective approach to managing stormwater at highly impervious sites in critical watersheds.

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SM.11
USE CONSTRUCTED WETLANDS

OBJECTIVE

Use constructed wetlands – permanent pools of water that are populated by wetland plants and aquatic organisms – to reduce, detain and treat stormwater runoff.

BENEFITS

+ Provides aesthetic enhancements and educational benefits.
+ Increases property values.
+ Suitable for almost any soil type and hydrogeology.
+ Highly effective at pollutant removal.
+ Relatively low maintenance costs.
+ Provides flood attenuation and reduces peak flows.
+ Possible to fit into small spaces, particularly ones already devoted to landscaping.

LIMITATIONS

– Relatively high construction costs, compared to other BMPs.
– Requires periodic maintenance to ensure plant health and remove debris.
– If improperly designed, can become a mosquito breeding ground or drowning hazard.

BACKGROUND

Constructed wetlands contain a permanent pool of water and have sufficient volume and surface area to retain stormwater runoff for a relatively long residence time. Simulating natural wetland ecosystems, constructed wetlands are extremely effective in improving water quality through the settling of pollutants and constituents as well as biological uptake by vegetation and microorganisms. A number of design variations exist, differing in the relative amounts of shallow and deep water, and upland storage capacity. Constructed wetlands typically require more space than other BMPs, however design variations allow for wetlands in small spaces like right-of-way retrofits.

INTEGRATION

- **SA.1** Assess Site and High Performance Opportunities
- **SA.2** Conduct Soil Analysis
- **SA.3** Conduct Hydrologic and Hydraulic Analysis
- **SA.4** Survey Existing Vegetation
- **SS.5** Increase and Improve Right-of-Way Public Space and Green Areas
- **SM.1** Conduct Integrated Stormwater Management Planning
- **SM.3** Minimize Runoff from New Building Construction and Major Renovations
- **SM.4** Optimize Right-of-Way Drainage
- **SM.5** Use Vegetated Filters and Buffer Strips
- **SM.6** Use Catch Basin Inserts
- **SM.7** Use Water Quality Inlets
- **LA.1** Optimize Citywide Landscape Planning
- **LA.2** Encourage Ecological Connectivity and Habitat
- **LA.3** Create Absorbent Landscapes
- **LA.7** Increase the Quantity, Density and Diversity of Trees
- **LA.12** Use Low-maintenance, Salt-tolerant, Native or Naturalized Species
- **LA.13** Use Water-efficient Landscape Design
- **LA. 14** Practice Biointensive Integrated Pest Management
- **LA.15** Use Biotope-based Plant Arrangement Along Shade-Light Continuum
- **CP.1** Develop and Enforce a Site Protection Plan
- **CP.2** Protect Existing and Future Planted Areas
- **CP.3** Protect Water Sources During Construction

TECHNICAL STRATEGIES

Site Assessment

- Conduct soil analysis. **(SA.2)**
- Conduct hydrologic and hydraulic analysis. **(SA.3)**
- Consider whether site allows for large constructed wetlands or smaller wetland variations. In general, the larger the wetland to drainage area ratio, the better the treatment capacity.
- Locate on gently sloped sites.
- Ensure adequate base flow from drainage catchment area, groundwater, or other source to maintain a permanent pool and sustain vegetation.

Planning

Many constructed wetland design variations exist, but most have four zones consisting of varying water depths and vegetation types.[137] Beginning with the deepest zone, they are:

1) **Deep pool:** Area with standing water depth of 4 to 6 feet. Provides the main area for particle settling.
2) **Low marsh:** Area with standing water depth of 6 to 18 inches. Supports a variety of emergent wetland species.
3) **High marsh:** Shallower marsh area with standing water less than 6 inches deep. Supports a greater density and diversity of emergent wetland species than low marsh.
4) **Semi-wet zones:** Area located above the pool and marsh areas, which contains water only when inundated during storm events.

[137] Consult NYSDEC for requirements and approvals.

Constructed wetland designs differ in the configuration and proportional sizes and volumes of these four zones. Typical designs include:

- **Marsh wetlands:** Primarily consist of low and high marshes with sinuous water flow paths to increase retention time and treatment area. Marsh wetlands contain small deep pool zones and have a shallow water depth, making them more land-intensive than other designs and requiring a larger drainage catchment area to maintain base flow.
- **Pond wetlands:** Primarily consist of one or more deep pools, with surrounding or adjacent marsh zones that enhance treatment. Water flows into the deep pools first and then flows through the marsh zones. Pond wetlands are capable of controlling more runoff in a smaller space than marsh wetlands. Generally they have the highest pollutant removal rates.
- **Extended detention wetland:** Extended detention wetlands are designed to store the design storm water volume in the semi-wet zone above the permanent pond and marsh areas. Water is typically stored for between 12 and 24 hours. The semi-wet zone is planted with species that can tolerate frequent inundations and fluctuating water levels. Extended detention wetlands are the most space-efficient design.

Design

General considerations:

- Use pretreatment to extend life of wetlands and reduce maintenance costs. **(SM.5 - SM.7)**
- Include a forebay – a small pool located near the inlet – to pretreat runoff, settle out coarse particles and debris, and reduce water velocity. Including a forebay helps reduce the frequency and difficulty of maintenance.
- Design deep pool and marsh areas with an undulating topography of earth berms (6' to 18') to maximize the surface area and resident time of the flow path, and to encourage plant diversity and microbiology.
- Include a small pond or 'micropool' near the outlet to reduce clogging and ensure ease of maintenance.
- Shade the outlet area to avoid warming of water prior to discharge.
- Design wetlands with a non-clogging outlet
- Ensure wetland stages have enough capacity to accommodate the design storm without flooding and have adequate base flow to sustain vegetation
- Include an emergency spillway or overflow system to convey water from extreme storm events.
- Consider effects of cold climate in designing wetlands.
- Consider including drain in pool areas to facilitate cleaning and emergency drainage.
- Install valves at inlet and outlet to regulate flows.
- Design for easy maintenance.

Landscape considerations:

- Develop a wetland landscaping plan providing detailed information about plant types, planting and maintenance strategies.
- Develop a plan to ensure continuous base flow of water in wetland.

Riverdale Country School-Upper Campus – Bronx, NY
Constructed wetland provides bioretention accompanied by wet tolerant vegetation

- Choose diverse plant species adaptable to varying water depth, and tolerant of varying periods of inundation.
- Prioritize the use of native or naturalized perennial species that establish rapidly. **(LA.12)**
- Avoid invasive species and monoculture planting.
- If possible, use field collected plants to enhance vitality and longevity of plantings. Seed stock is preferable to clonal stock plantings.
- Alternate species of varying root depth for optimal pollutant removal.
- Consider the use of wetland mulch to enhance plant diversity and seed establishment.
- Consider habitat needs for wildlife and aquatic organisms. Allow for a diverse animal food chain to regulate mosquitoes.
- Ensure compliance with state and local environmental regulations.
- Carefully consider aesthetics.
- See "Use Healthy Plant Selection and Planting Practices" **(LA.10)** for more details.

Design wetlands for small sites: The following constructed wetland types offer high pollutant removal rates and can fit within small, existing landscaped areas in or adjacent to the right-of-way. Both designs are best when accompanied by some form of pretreatment.

- **Pocket wetlands:** Reduced size wetlands with similar features to larger designs that are often excavated down to the groundwater level to maintain a constant base flow.

- **Submerged gravel wetlands:** Constructed trenches filled with crushed rock and supporting wetland species in a permanent pool of water. Gravel wetlands were originally designed to treat wastewater, and work through physical filtration and particle removal as stormwater flows through the vegetated zone, gravel, and subsurface roots.

Construction

- Keep wetland area flooded after excavation. Avoid extended dry periods.
- Allow wetland to soak for an extended period to allow settlement.
- Drain wetland several weeks prior to planting to ensure proper grading. Modify topography as necessary to ensure successful plant growth.
- Protect plantings from wildlife during establishment period.

Maintenance

Post construction monitoring:

- Perform multiple inspections and vigilant maintenance during the first two years. This period is the most crucial to long-term wetland productivity.
- After the second growing season, inspect for adequate plant coverage and health. Undertake corrective planting or maintenance as necessary.
- Monitor stability of varying depth zones.
- Monitor to ensure base flow of water.
- Observe distribution of vegetation. Make adjustments as necessary.
- Record, map and assess data from inspections.

Periodic inspection and maintenance:

- Develop an operations and maintenance program.
- Inspect for and remove invasive vegetation regularly.
- Inspect structural components annually.
- Inspect for hydrocarbon and sediment buildup.
- Inspect inlet and outlet devices for clogging.

Assess vegetation health / distribution. Perform corrective planting or maintenance if necessary.

- Repair eroded areas.
- Remove debris from inlets 3-4 times per year and after major storms.
- Perform mowing as necessary.
- Remove sediment from forebay periodically.
- Record, map and assess data from inspections.

Staten Island Bluebelt – Staten Island, NY

EXAMPLE

The Staten Island Bluebelt is an award-winning program that provides ecologically sound and cost-effective storm water management for approximately one third of Staten Island's land area. The program preserves natural drainage corridors, called Bluebelts, including streams, ponds, and other wetland areas. Preservation of these wetland systems allows them to perform their functions of conveying, storing, and filtering storm water. In addition, the Bluebelts provide important community open spaces and diverse wildlife habitats. The wetlands located within the watershed areas act as flood control measures. By temporarily storing floodwaters, wetlands help protect adjacent and downstream property owners from flood damage. Urban wetlands are especially valuable in this regard because the impervious surfaces created by urbanization increase the rate, velocity and volume of surface water runoff. The Bluebelt program saves tens of millions of dollars in infrastructure costs (estimated at $50 million in 1999) when compared with the costs of providing miles of conventional storm sewers to the same land area. This program demonstrates how wetland preservation can be economically prudent, environmentally responsible, and socially beneficial.

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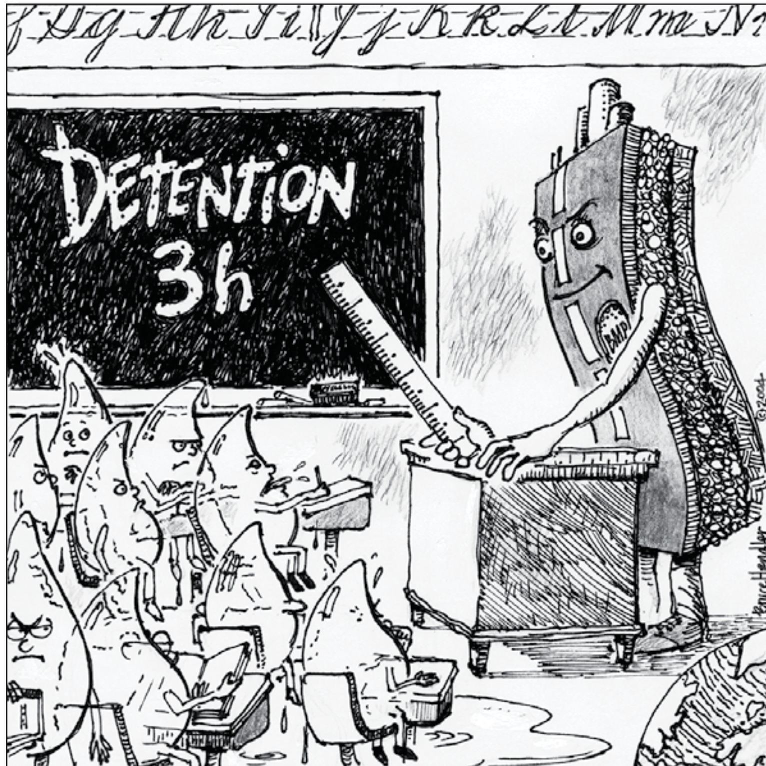

STORMWATER MANAGEMENT

PART THREE: BEST PRACTICES
LANDSCAPE

LA.1
OPTIMIZE CITYWIDE LANDSCAPE PLANNING

OBJECTIVE

Develop citywide standards, specifications, zoning regulations, processes, and policies to encourage the proliferation of high-quality, attractive, and healthy landscapes.

BENEFITS

+ Increases the sustainability of urban landscapes.
+ Reduces capital investment and maintenance costs.
+ Reduces negative impacts on water quality by protecting sensitive site areas.
+ Reduces urban heat island effect, air pollution, and public health problems.
+ Reduces economic and environmental costs associated with traditional landscape maintenance techniques.
+ Increases property values and quality of life.
+ Increases public awareness, participation, and sense of civic pride.

LIMITATIONS

– May add cost to projects.
– Requires public education (owner, contractor, agency, public) to revise current practices, attitudes and expectations about the landscape.
– BMPs are site and project specific requiring upfront coordination to identify and advance landscape opportunities.

INTEGRATION

- **SA.1** Assess Site and High Performance Opportunities
- **SA.2** Conduct Soil Analysis
- **SA.3** Conduct Hydrologic and Hydraulic Analysis
- **SA.4** Survey Existing Vegetation
- **SS.1** Work with Community Groups to Enhance and Maintain Streetscape
- **SS.5** Increase and Improve Right-of-Way Public Space and Green Areas
- **PA.2** Minimize Impervious Pavement Area
- **SM.1** Conduct Integrated Stormwater Management Planning
- **SM.3** Minimize Runoff from New Building Construction and Major Renovations
- **SM.4** Optimize Right-of-Way Drainage
- **SM.10** Use Bioretention
- **SM.11** Use Constructed Wetlands
- **LA.2** Encourage Ecological Connectivity and Habitat
- **LA.3** Create Absorbent Landscapes
- **LA.7** Increase the Quantity, Density and Diversity of Trees
- **LA.12** Use Low-maintenance, Salt-tolerant, Native or Naturalized Species
- **LA.13** Use Water-efficient Landscape Design
- **LA. 14** Practice Biointensive Integrated Pest Management
- **LA.15** Use Biotope-based Plant Arrangement Along Shade-Light Continuum

TECHNICAL STRATEGIES

Develop a municipal landscape ordinance: Develop and implement a citywide landscape ordinance that sets guidelines to encourage planting within the public right-of-way and throughout the City.

Standardize landscape specifications citywide: Develop a single set of landscape protection, planting, soils and maintenance specifications for use by all City agencies undertaking work within the public right-of-way.

Develop and maintain a tree data base: Using available citywide GIS maps, track tree planting and survival rates and areas of significant vegetation. This will assist with monitoring benefits of improved planting techniques and alert planners to tree protection/mitigation strategies that may be required for future infrastructure projects.

Develop realistic landscape budgets: During planning and budgeting for an infrastructure project, allow for sufficient funds to protect existing landscape features and supplement with additional landscape improvements.

Develop and implement public education and awareness programs: Some landscape BMPs may result in an appearance different than what is traditionally expected in a public landscape. Meadows, unpruned native shrub masses and integrated pest management techniques require education of the public, contractors and City management personnel to appreciate the benefits of a non-traditional landscape. Some BMPs will benefit from public participation in plant care to supplement City maintenance forces, encourage more innovative practices and foster greater civic pride.

Optimize planning of individual landscape projects:

- Assess site, larger environmental context and open space conditions. **(SA.1)**
- Evaluate existing or proposed right-of-way dimensions and alignment for opportunities to implement BMPs.
- Seek to increase and improve right-of-way public space and green areas. **(SS.5)**
- Plan early for site protection and budget appropriately for landscape improvements.
- Develop effective contracting methods to ensure compliance with landscape planting and maintenance requirements.
- Monitor periodically for landscape health.
- If possible, work with BIDs and engage community organizations in stewardship of public landscapes. **(SS.1)**

EXAMPLES

In 1991, the City of Chicago developed a landscape ordinance that requires, and promotes innovative standards for, landscaping in parking lots, loading dock areas, vehicular use areas, and all buildings adjacent to the right-of-way. The ordinance was strengthened in 1999 with the addition of new requirements and stricter standards. The goal of the Chicago landscape ordinance is to achieve 'a greener, more attractive city; reduced heat, noise and air pollution; and increased property values.' The ordinance requires shade tree and shrub plantings in the construction of any new building; any addition or enlargement to an existing building if the construction exceeds 1,500 square feet; any repair or rehabilitation work of an existing principal building if the expense of this work exceeds 50% of the structure's replacement cost; construction of any parking area containing five or more spaces; and repair or expansion of existing parking areas if the number of spaces are increased by more than 25%. The landscape ordinance standardizes planting practices and is integrated with all building and zoning permit applications to ensure compliance. The cumulative effect of the landscape ordinance has been transformative for the city. According to Steve Berg of the Minneapolis Star-Tribune, 'few boulevards in the world can match the flower-bedecked splendor of Michigan Avenue, and public beauty is spreading like a contagion down every street in the Loop and into the neighborhoods. No corner gas station is safe from decorative lampposts and baskets of drooping geraniums. No surface parking lot can escape a border of wrought-iron fencing and leafy canopies of newly planted trees.'[138] For more information see: http://www.newrules.org/environment/chiland.html

In 2001, OASIS (Open Accessible Space Information System) was launched as NYC's first interactive mapping website dedicated to open space and green infrastructure resources. It was developed by New York Public Interest Research Group for the USDA Forest Service and a coalition of over 40 nonprofit organizations. A recent OASIS project utilized interactive mapping and data gathered from field investigation to develop detailed information about NYC's urban forest and tree canopy coverage. Ultimately, this and other OASIS projects will help to optimize urban forest management by providing quantifiable data on the value of trees for human health and environmental quality. For more information, see: http://www.oasisnyc.net/

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LA.2
ENCOURAGE ECOLOGICAL CONNECTIVITY AND HABITAT

OBJECTIVE

On a local and regional scale, seek to maintain and enhance biodiversity and ecology. On sites within or adjacent to the public right-of-way, strengthen existing natural site patterns and make connections to surrounding site context. Use a diversity of ecotypes to repair or restore existing site systems. Minimize edge conditions that degrade habitat, encourage invasive species and alter ecological communities.

BENEFITS

+ Protects existing local plant and animal communities, prevents species extinction, and helps maintain genetic diversity.
+ Protects riparian ecosystems and potable water supply from contamination by herbicides, pesticides and fertilizers.
+ Biodiversity protects nutrients held in the biomass of native vegetation.
+ Habitat corridors containing native plants act as biofilters to absorb and cleanse storm water runoff.
+ Natural ecosystems and native or naturalized species require less long-term maintenance, fertilizer, water and herbicides than exotic landscapes. They are also far less susceptible to invasive species, pests and disease.

LIMITATIONS

– Design fees rarely cover the cost to engage in comprehensive site analysis.
– Native landscapes and management practices may not meet community expectations of a well-maintained site.

INTEGRATION

- **SA.1** Assess Site and High Performance Opportunities
- **SA.2** Conduct Soil Analysis
- **SA.3** Conduct Hydrologic and Hydraulic Analysis
- **SA.4** Survey Existing Vegetation
- **SS.5** Increase and Improve Right-of-Way Public Space and Green Areas
- **PA.2** Minimize Impervious Pavement Area
- **SM.1** Conduct Integrated Stormwater Management Planning
- **SM.3** Minimize Runoff from New Building Construction and Major Renovations
- **SM.4** Optimize Right-of-Way Drainage
- **SM.10** Use Bioretention
- **SM.11** Use Constructed Wetlands
- **LA.3** Create Absorbent Landscapes
- **LA.7** Increase the Quantity, Density and Diversity of Trees
- **LA.15** Use Biotope-based Plant Arrangement Along Shade-Light Continuum
- **CP.2** Protect Existing and Future Planted Areas

TECHNICAL STRATEGIES

Planning

- Analyze and model water and nutrient cycles and local flora and fauna species prior to design to understand the site as an integrated ecosystem.
- Engage local stakeholders in process to manage expectations and encourage education about benefits.
- Identify critical or unique habitats based on topography, water or vegetation.
- Establish link between land use mapping and development plans and environmentally sensitive areas.

Design

- Design landscaped areas to reconnect fragmented vegetation and establish contiguous networks with other natural systems both within the site and beyond its boundaries.
- Avoid major alterations to sensitive topography, vegetation and wildlife habitat.
- Preserve ecologically significant and/or sensitive vegetation, wildlife habitat and topography.
- Use plant associations found locally that will enhance biodiversity and habitat.
- Where space permits, design redundancy of multiple habitat movement corridors to adapt to dynamic nature of landscape processes.
- Design riparian corridors with adequate dimension to offer optimal protection of waterways by filtering contaminants.
- Design habitat corridors of sufficient width to allow for good vegetation layering and a diversity of species that comprise both interior and edge conditions.
- Consolidate utility corridors to minimize site disturbance.
- Integrate stormwater management BMPs to manage and treat runoff and to minimize water pollution. **(SM.5 to SM.11)**
- Consider including public space amenities. **(SS.5)**
- Consider including educational features.

Construction

- Sequence construction activities to minimize adverse impacts to existing soils, vegetation and drainage patterns. **(CP.1 to CP.3)**
- Develop and enforce a site protection plan. **(CP.1)**
- Purchase local plants. **(LA.10)**

Eibs Pond – Staten Island, NY

Maintenance

- Time mowing operations before weed seeds set. Mow herbaceous areas annually to prevent encroachment of invasive woody plants.

Monitoring

- Perform annual ecological monitoring to inform landscape management.
- Maintain records of plant and animal species to monitor changes over time. Use GIS mapping and link records to other land use mapping and decision systems.

PERFORMANCE GOAL

- Incorporate native plants in a 2:1 ratio of native plants removed.
- Ensure 50% of vegetated area is contiguous.
- Provide buffers for mapped wetlands in accordance with NYSDEC regulations. For unmapped wetlands, provide a minimum 50' buffer.
- Provide 300' wide habitat corridor.

EXAMPLE

Eibs Pond in northeastern Staten Island is a fresh water kettle-pond that was formed from glacial activity around 15,000 years ago and is home to many unusual plant communities. Although the pond had been left to neglect and disuse and its ecosystem was degraded because of stormwater runoff pollution, it had great potential to become a valuable open space amenity (17 acres in total area) to the dense surrounding community. From 2001 to 2003, the Design Trust for Public Space sponsored three fellows to work with the Parks Council, the NYC Department of Parks and Recreation, local community members and others to develop a park restoration master plan. In 2002, the fellows created a schematic design for the park's southern edge that integrated state-of-the-art stormwater filtration technology, vegetation mitigation techniques, and public amenities. In 2003, an outdoor classroom was built out of recycled plastic lumber and sustainably harvested wood. Elementary school students from nearby PS 57 participated in the reclamation and now use the park as an ecological classroom. The restoration of Eibs Pond is an important prototype for how to integrate high performance technologies with open space development and ecological restoration. The result is a remarkable space, enjoyed by all.

Eibs Pond – Staten Island, NY

Design Trust fellows' design for the south edge of Eibs Pond, integrating public amenities and stormwater filtration

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LA.3
CREATE ABSORBENT LANDSCAPES

OBJECTIVE

Design and construct landscapes that are capable of high rates of stormwater absorption, infiltration, and treatment.

BENEFITS

+ Easy to construct, cost-effective, aesthetically pleasing, and highly beneficial for the environment.
+ Reduces runoff volume, minimizing combined sewer overflows, water pollution, and aquatic ecosystem degradation.
+ Effective at maintaining soil infiltration capacity during large storm events.[139]
+ Appropriate soil construction, microbiology, and plant life can keep soil pores open and indefinitely maintain infiltration capacity.
+ Applicable at many scales and spatial configurations; ideal for small sites in highly urbanized areas, such as medians, planting strips, traffic islands, and so on.
+ Low-maintenance and tolerant of urban conditions if well designed.

LIMITATIONS

– Requires periodic maintenance to ensure plant health and remove debris.
– Vegetation may become less effective at filtering pollutants during winter.

BACKGROUND

Urban landscapes are often constructed with a thin layer of topsoil on top of a heavily compacted site, which jeopardizes long-term plant health and results in poor infiltration capacity. If properly designed and constructed, 'absorbent landscapes' perform several crucial functions to control, absorb, treat, and gradually release rainfall:[140]

- Vegetative cover provided by trees and plants intercepts a significant portion of rainfall – some of the rainfall remains on vegetation until it evaporates, and the rest is temporarily detained and eventually reaches the ground.
- Vegetation draws up water from the soil and eventually releases it into the atmosphere through evapotranspiration.
- Low-lying surface vegetation helps to minimize soil erosion and physically filter runoff.
- Soils – if un-compacted and rich in organic matter – are able to store and slowly release or infiltrate significant volumes of water.
- Vegetation works to maintain the absorptive capacity of the soil through root growth, and the death and decay of organic matter.
- Organisms in the soil – including earthworms, insects, ants, and microorganisms – depend on organic matter and help to maintain macropores in the soil.

INTEGRATION

- **SA.2** Conduct Soil Analysis
- **SA.3** Conduct Hydrologic and Hydraulic Analysis
- **SA.4** Survey Existing Vegetation
- **SS.5** Increase and Improve Right-of-Way Public Space and Green Areas
- **PA.2** Minimize Impervious Pavement Area
- **SM.1** Conduct Integrated Stormwater Management Planning
- **SM.3** Minimize Runoff from New Building Construction and Major Renovations
- **SM.4** Optimize Right-of-Way Drainage
- **LA.5** Amend Existing Soils
- **LA.7** Increase the Quantity, Density and Diversity of Trees
- **LA.12** Use Low-maintenance, Salt-tolerant, Native or Naturalized Species
- **LA.13** Use Water-efficient Landscape Design
- **LA. 14** Practice Integrated Pest Management
- **LA.15** Use Biotope-based Plant Arrangement Along Shade-Light Continuum
- **CP.2** Protect Existing and Future Planted Areas

TECHNICAL STRATEGIES

Planning

- Conduct soil analysis. **(SA.2)**
- Ensure that subsoil infiltration rate is 2' per hour or greater. Take corrective measures as necessary to ensure required infiltration rate.
- Ensure that surface soil layer has high organic content (between 10 and 25%).
- Amend existing soils as necessary to increase organic content or infiltration rate. **(LA.5)**
- If necessary, conduct hydrologic analysis to calculate stormwater runoff volume. **(SA.3)**
- If landscape needs to accommodate large runoff volumes, see "Use Bioretention" **(SM.10)** for more details.

139 According to the Stormwater Planning: a Guidebook for British Columbia, absorbent landscapes can continue to absorb rainfall during large (5 year) storms, while landscapes with disturbed or compacted soils can generate nearly as much runoff as impervious surfaces.

140 Characteristics of 'absorbent landscape' are described in detail in Greater Vancouver Regional District. 'Stormwater Source Controls Preliminary Design Guidelines Interim Report. 2004. http://www.grvd.bc.ca/sewerage/stormwater_reports.htm

Design

- If possible, design absorbent landscapes with a slight slope or as a depressed area.
- Ensure adequate soil depth for vegetation/tree health and stormwater storage/ infiltration.
- Ensure that imported or existing planting medium has an infiltration rate of at least 2' per hour.
- Provide a transition layer between the planting soil and existing subsoil to facilitate drainage.
- Maximize vegetative canopy. Use a low-maintenance, salt-tolerant, native or naturalized vegetative ground cover that will help to reduce soil erosion and physically filter stormwater. **(LA. 12)**
- Use mulch or other organic cover to retain moisture, minimize erosion and avoid surface sealing. **(LA.10)**
- Use absorbent landscapes to disconnect impervious areas. **(PA.2)**
- Use absorbent landscapes in right-of-way public spaces and green areas. **(SS.5)**
- Consider designing landscape as a 'rain garden' to enhance the visibility of its role in controlling and infiltrating stormwater. Consider incorporating educational elements into the design.

Construction

- Control erosion during construction. **(CP.2, CP.3)**
- Avoid soil compaction. **(CP.2)**
- Prevent smearing of soil. If smearing occurs, fix with a rake or other equipment.
- Insure that final constructed landscape – including subsoil, transition layer, and planting medium – meets or exceeds an infiltration rate of 2' per hour.
- Irrigate during construction and post-construction period.
- Use Healthy Plant Selection and Planting Practices. **(LA.10)**

Maintenance

- Periodically apply mulch or other organic cover.
- Monitor plant health in first year.

EXAMPLE

The City of Philadelphia Office of Watersheds is promoting the creation of absorbent landscapes within right-of-ways and on other public properties throughout the city. One recent design is for an absorbent landscape located within a traffic island on Biltmore Avenue. The project was developed in partnership with the Pennsylvania Horticultural Society and the Philadelphia Water Department, and was intended to serve as a prototype for future absorbent landscapes throughout the city.

Manhattan Avenue – Brooklyn, NY

A 1/4 acre street end is converted into a park with absorbent landscaping that will provide a small water-front promenade, sitting areas, native plantings and a kayak launch.

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LA.4
USE STRUCTURAL SOILS WHERE APPROPRIATE

OBJECTIVE

Use structural soils – an engineered mix of load-bearing rock and organic soil – in trafficked planted areas or under pavements where planting will occur, to maximize plant health and minimize pavement damage.

BENEFITS

+ Supports mature trees, which contribute shade, beauty, noise reduction, wind abatement, cooling, pollution reduction and habitat.
+ Life expectancy of trees is 4 to 5 times greater when adequate soil volume is provided for roots.
+ Withstands compaction caused by foot traffic, vehicle loads, and vibration.
+ Reduces damage to sidewalks and pavement by encouraging deeper root growth.
+ Simplifies construction, as they are suitable both as a pavement base and a root medium.

LIMITATIONS

– Structural soils may be more costly than natural or manufactured topsoil.
– Uniform blending of structural soil components requires either special equipment (pug mill) or careful monitoring (volume mixing with front-end loader).
– Pre-mixed structural soil cannot remain stockpiled for long periods of time or transported over long distances because the component parts will separate.

BACKGROUND

Urban trees are subjected to greater stress than rural or suburban trees. The scarcity of quality soil and the likelihood of soil compaction impedes drainage and inhibits access to nutrients and oxygen, leading to root death. Furthermore, limited soil space around urban street trees forces roots to push upward as they grow, causing significant damage to pavements and sidewalks. Using structural soil in trafficked planted areas or under pavements where planting will occur can significantly improve tree health and minimize pavement damage. Structural soil combines a proper soil mix for plant health with a load-bearing stone matrix or lattice to provide structural support for surrounding pavements. Structural soil prevents soil compaction, helps maintain soil macro-pores to facilitate drainage and access to nutrients and oxygen, and enables deep root growth.

INTEGRATION

- **SA.2** Conduct Soil Analysis
- **SA.4** Survey Existing Vegetation
- **SS.2** Improve Streetscape for Pedestrians
- **PA.1** Optimize Pavement Lifecycle Citywide
- **LA.5** Amend Existing Soils
- **LA.8** Plant Trees to Maximize Shading of Pavement
- **LA.9** Plant Trees in Trenches or Continuous Soil Zones
- **LA.10** Use Healthy Plant Selection and Planting Practices

TECHNICAL STRATEGIES

Planning

- Budget adequately for structural soils early in the project development process.
- Ensure that structural soils are used only at appropriate locations.

Design

Design structural soils to provide a load-bearing aggregate lattice to support a pavement: The lattice provides stability through stone-to-stone contact while providing interconnected voids for root penetration, air and water movement.

- Use gap graded angular stone rather than well-graded stone particles to ensure porosity in the matrix.
- Follow NYS or NYC DOT aggregate soundness and durability requirements for the stone particles.

Design structural soils to provide nutritional components: The objective is to coat the stones with soil and allow the nutritional material to reside within the stone matrix.

- Use a loam with a higher than normal clay and silt content.
- Provide organic matter as necessary.
- Consider use of a soil tackifier to facilitate uniform mixing, transportation and dumping.

Ensure proper compaction:

- Specify compaction to 95%-100% Standard Proctor density. Testing should follow ASTM D698-91 method D protocol or AASHTO T-99.
- Install and compact in 6 inch lifts.

Minimize the impact of lime migration into planted structural soils:

- Avoid planting ericaceous (acid-requiring) species if lime migration is likely.
- Avoid using recycled concrete aggregate adjacent to planted areas.

Design pavement and planting sections simultaneously to maximize soil volume for planting.

Provide for positive drainage between subsoil and structural soil to prevent water-logging.

Construction

- Avoid stockpiling pre-mixed structural soil for long periods or transporting it over long distances to prevent the separation of component parts.
- Achieve uniform blending of the structural soil components. Use proper equipment and monitoring.
- Test components at source prior to shipment to job site.[141]
- Perform on-site mixing of structural soils. Test mix prior to installation
- Install and compact in 6 inch lifts.

Monitoring

- Monitor structural soils and plants annually for nutrient balance and health.

EXAMPLES

Route 9A Reconstruction in Manhattan is one of the first projects to use structural soils both in the medians and sidewalks. Five and a half miles of sidewalk have continuous tree trenches filled with structural soil. Trenches are discontinuous only at driveways and are covered with ungrouted granite blocks. Completed between 1998 and 2000, the trees are thriving and there is no evidence of settlement. See photo in **LA.9**

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[141] Since structural soils are relatively new and there is on-going debate about the proper base materials and proportions in the final mix, testing of individual components as well as testing of the final mix prior to installation is essential.

LA.5 AMEND EXISTING SOILS

OBJECTIVE

Whenever possible, use existing on-site soil for planting rather than importing foreign topsoil and exporting waste soil. Amend soil on-site (stockpiled or in-situ) to compensate for poor organic or physical properties, or to improve soil infiltration rate. If necessary, remediate soil in-situ using bioremediation and phytoremediation.

BENEFITS

+ Reduces air pollution resulting from trucking soils to and from job site.
+ Reduces surface runoff and erosion by restoring the soil's water infiltration and storage capacity.
+ Reduces the need for supplemental water, fertilizers and pesticides, minimizing environmental impact.
+ Improves plant and soil health.
+ Reduces cost by minimizing importation of topsoil and removal of existing soil.
+ Reduces potential disruption to existing vegetated areas.
+ Reduces risk of importing invasive species or contaminants.

LIMITATIONS

– May not be suitable for steeply sloping sites where erosion or sedimentation may be exacerbated.
– Soils with known contaminants require further investigation to determine their capability for bioremediation.

BACKGROUND

Typically, construction techniques remove or stock-pile useful existing topsoil. However, the resulting compaction and construction vehicle traffic can reduce soil structure, with negative hydrologic and biodiversity impact. Soil health can be regained by using compost, biosolids, forest product residuals, and other renewable organic substances to increase the porosity of soil and return nutrients to the earth. This rebuilds beneficial soil life that fights pests and disease, and supplies plants with nutrients and water, reducing the need for fertilizers and pesticides. Two additional methods can be used to remediate soil in-situ:

Bioremediation Uses soil bacteria and other microorganisms to cleanse pollutants from soil and water. Bioremediation has proven successful in cleansing toxic sites contaminated with non-heavy metals such as petroleum, uranium, selenium, benzene, PCB's and herbicides. To be most effective, bioremediation must be an aerobic process that enables microorganisms to metabolize organic pollutants.

Phytoremediation A science in its infancy that uses specific plants to absorb pollutants from a contaminated soil. Phytoremediation operates through three principal mechanisms: extraction, containment and degradation. Pollutants typically remain in the plants or their leaves, which must be harvested to prevent further dispersal of toxins. Phytoremediation is useful for treating a wide variety of environmental contaminants including crude oil, solvents, pesticides, chromium and mercury and is most appropriate for relatively low concentrations located in the upper soil layers.

INTEGRATION

- **SA.2** Conduct Soil Analysis
- **SA.3** Conduct Hydrologic and Hydraulic Analysis
- **SA.4** Survey Existing Vegetation
- **LA.3** Create Absorbent Landscapes
- **LA.4** Use Structural Soils Where Appropriate
- **LA.10** Use Healthy Plant Selection and Planting Practices
- **LA.12** Use Low-maintenance, Salt-tolerant, Native or Naturalized Species
- **LA.13** Use Water-efficient Landscape Design
- **LA. 14** Practice Biointensive Integrated Pest Management

TECHNICAL STRATEGIES

Site Assessment

- Specify soil testing procedures.
- Conduct and evaluate soil tests to determine needs for soil amendment.
- Consider appropriate soil remediation techniques.

Design

Determine soil amendment procedures:

- Based on evaluation of soil test results, determine proper proportions of amendments, or suitable remediation techniques.
- Specify locally-available organic amendments, such as compost, biosolids and forest product residuals. Do not use peat moss or other non-renewable resources.
- Specify appropriate application and sequencing of amendment procedures.
- Specify testing protocol for post-application of amendments to meet target ranges.

Develop a soil management plan that identifies the following areas:

- Areas where native soil and/or vegetation will be retained in place.
- Areas where topsoil or subsoil will be amended in place.
- Areas where topsoil will be stripped and stockpiled prior to grading for reapplication.
- Areas where imported topsoil will be applied.

Construction

Use proper construction sequencing and practices:

- Do not permit delivery or installation of amendments prior to approval of test results.
- Coordinate amendment procedures and sequencing with other activities.
- Delineate areas to receive soil amendments based on Tree and Vegetation Protection and Transplant Plan. **(SA.4, CP.1, CP.2)**
- Perform amending procedures within Protection zones using hand methods; do not permit heavy equipment to encroach on in-place soils or within protection zones or use low ground pressure (LGP) operating equipment.

Ensure compliance with specifications:

- Verify that delivered materials match specified materials by requiring delivery tickets stating type, source and volume.
- Retest amended soil for conformance with specifications.

Take erosion and sedimentation control measures:

- Provide erosion/siltation barriers to protect drains/streams from sediment.
- Install temporary cover (seed, mulch or fabric) immediately after amending soil if permanent planting is delayed.
- See "Protect Existing and Future Planted Areas" **(CP.2)** and "Protect Water Sources During Construction" **(CP.3)** for more details.

Operations and Maintenance

- If necessary, re-apply certain amendments (organics) to maintain healthy soil balance.

Monitoring

- Monitor soils annually by performing soil tests or visual inspection to ensure healthy soil balance.

PERFORMANCE GOAL

Restore the landscape to the capacity of the original undisturbed soil native to the site.

EXAMPLE

Washington State has adopted guidelines by Snohomish County of Public Works Department that defines techniques of amending soils in place. A variety of methods are provided based on site conditions.

Shore Parkway Bike Path – Queens, NY
On-Site soils amended with organic matter

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LA.6
PERFORM SOIL BERMING

OBJECTIVE

Where sufficient space exists, construct earth berms to reduce unwanted noise, absorb excess fill, and to improve aesthetics and quality of life in residential neighborhoods.

BENEFITS

+ Improves air quality.
+ Reduces noise pollution.
+ Represents the lowest cost method of reducing unwanted noise. Earth berms are approximately half the cost of metal, concrete or wood noise walls.
+ Reduces excess fill, minimizing costs of transportation and disposal.
+ Earth berms are permanent and require no reconstruction and minimal maintenance.
+ Earth berms are attractive and introduce new opportunities for vegetation and habitat.

LIMITATIONS

– Requires much more land area than noise walls.
– Ineffective for noise reduction if residences are at a higher elevation than the noise source.

INTEGRATION

- **SA.2** Conduct Soil Analysis
- **SA.3** Conduct Hydrologic and Hydraulic Analysis
- **SS.5** Increase and Improve Right-of-Way Public Space and Green Areas
- **PA.6** Use Recycled and Reclaimed Materials
- **LA.1** Optimize Citywide Landscape Planning
- **CP.4** Implement a Waste Management and Recycling Plan
- **CP.5** Minimize Disruption and Impact of Right-of-Way Construction

TECHNICAL STRATEGIES

Site Assessment

- Determine if construction will generate excess excavation material suitable for vegetated berms.
- Conduct soil tests to determine if excess material is suitable for re-use in berm construction. **(SA.2)**

Planning

Determine locations for berms and other noise-mitigating measures:

- Evaluate site plan to determine optimum locations for roads, residences and intervening land mass that can accommodate earth berms.
- Consider depressing road if berms are not practical to deflect noise.
- Consider the use of berms to clarify street crossing points; ensure that visibility is not impaired.
- Consider using berms in conjunction with noise walls and vegetated buffers.
- Determine optimal heights for noise-mitigating berms or combination berm/wall configurations.
- Plan to protect dense masses of vegetation that can assist in noise mitigation. **(SA.4, CP.2)**

Design

Determine berm geometry:

- Design berms in relation to natural angle of repose and vegetative cover.
- Avoid slopes in excess of 3:1 since they are difficult to mow.
- Use flat-topped berms if installing an additional sound wall on top of the berm.

Determine proper plantings:

- Plant berms with shrub and tree masses on the road side rather than mown grass to increase sound absorption.
- Use low grasses on top of the berm to avoid scattering sound down behind the barrier.
- Select low-maintenance, native species tolerant of salt, wind and natural rainfall characteristics.

Operations and Maintenance

- Maintain vegetation including annual mowing (for native grasses) and removal of invasive species.

PERFORMANCE GOAL

Reduce noise by 3 dBA or more for earth berms and 5 dBA for combined earth berms and noise walls.

EXAMPLE

Since 1989, the Ministry of Transportation and Highways of British Columbia (MoTH) has required highway noise impact mitigation measures on all new or upgraded freeway or expressway projects. Mitigation measures must achieve an average noise reduction of 5 dBa. To assess the validity of various noise mitigation techniques involving earth berms, MoTH undertook a research project with the University of British Columbia Mechanical Engineering Department and Wakefield Acoustics, Ltd. Using a scale model of a highway section, the study found that earth berms with a steeper slope (1.5:1 and 2:1) that are located close to the noise source are the most effective configuration for noise reduction. The study also found that using highly absorbent soil admixtures such as vermiculite, perlite, wood chips or mulch could enhance noise reduction.[142]

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LA.7 INCREASE THE QUANTITY, DENSITY, AND DIVERSITY OF TREES

OBJECTIVE

Increase density of tree canopy using multiple species of native or naturalized trees. Develop strategies to plant trees in groups rather than in isolated pits. Increase tree species diversity to minimize the spread of disease and pests.

BENEFITS

+ Reduces air pollution, noise pollution and soil erosion.
+ Reduces and treats stormwater runoff via water uptake and evapotranspiration.
+ Reduces the urban heat island effect by lowering local ambient temperatures.
+ Assists in stabilizing local microclimates and moderate weather extremes.
+ Provides shading and insulation, reducing energy required to heat and cool buildings.
+ Trees planted in groups are better protected and healthier, and reduce damage and natural degradation of infrastructure by providing shelter from harsh weather.
+ Diversity of tree species protects against spread of disease and pests that can devastate monoculture plantings.
+ Improves public health and quality of life.
+ Increases property values.

LIMITATIONS

– Grouped tree plantings consume greater area than individual tree pits.

BACKGROUND

Typically, street trees stand alone, spaced regularly from each other in separate pits. In general, trees planted together are better protected and healthier. Clustered trees protect each other from wind throw and leaf scorch, and they also develop better root systems that strengthen the trees against disease, wind throw, drought and girdling. Increased leaf mass of clustered trees helps protect against erosion caused by splash and helps reduce peak runoff.

INTEGRATION

- **SA.1** Assess Site and High Performance Opportunities
- **SA.2** Conduct Soil Analysis
- **SA.4** Survey Existing Vegetation
- **PA.2** Minimize Impervious Pavement Area
- **SM.1** Conduct Integrated Stormwater Management Planning
- **SM.3** Minimize Runoff from New Building Construction and Major Renovations
- **SM.4** Optimize Right-of-Way Drainage
- **SM.10** Use Bioretention
- **SM.11** Use Constructed Wetlands
- **LA.1** Optimize Citywide Landscape Planning
- **LA.3** Create Absorbent Landscapes
- **LA.9** Plant Trees in Trenches or Continuous Soil Zones
- **LA.10** Use Healthy Plant Selection and Planting Practices
- **CP.2** Protect Existing and Future Planted Areas

TECHNICAL STRATEGIES

Site Assessment

- Assess site to determine optimal locations for mass tree plantings. **(SA.4)**
- Evaluate existing habitat. Assess viable existing species to be protected. **(SA.4)**
- Conduct soil analysis. **(SA.2)**

Planning

- Determine suitable native or naturalized tree species and local availability. **(LA.10)**
- Determine location of proposed or existing utilities to avoid interferences and excavation damage. Coordinate utility runs away from planting zones.

Design

Properly select and specify tree species:

- Select species based on future use (proximity to trucks, buses and utility corridors; proximity to curbs, street lights, or within high pedestrian traffic areas).
- Seek to increase diversity of tree species.
- See "Use Healthy Tree Selection and Planting Practices" **(LA.10)** for more details.

Determine optimal planting locations:

- Group tree species according to site conditions including soil type, available moisture, slope, aspect, salt tolerance and shade.
- Encourage owners of adjacent properties to increase tree planting over large expanses of pavement, especially parking lots.

Construction

- Monitor construction to ensure tree selection, planting, and after-care BMPs are implemented. **(LA.10)**

- Provide for and administer requirements of two-year landscape warrantee.
- Use Healthy Plant Selection and Planting Practices. **(LA.10)**
- Protect existing trees and new trees. **(CP. 2)**

Operations and Maintenance

- Provide supplemental water during establishment period and sustained drought.
- Avoid over-watering trees to conserve water and protect tree roots from rot.
- Inspect trees annually and prune dead or infected wood.
- Monitor soil health and adjust as required.
- See "Use Healthy Tree Selection and Planting Practices" **(LA.10)** for more details.

PERFORMANCE GOAL

- Provide 1 cubic yard of soil volume for every 5 cubic yards of crown volume of a mature tree. For example, major shade trees require 75-95 cubic yards of soil and minor trees require 10-30 cubic yards of soil.
- Meet or exceed the following minimum width requirements for planting soil zones:
  (a) Lawn or herbaceous planting: 3 feet.
  (b) Shrubs: 5 feet.
  (c) Single row of trees: 8 feet.
  (d) double or staggered row of trees: 12 to 18 feet.

EXAMPLE

The Village of Oak Park, Illinois has prepared an Arboricultural Standards Manual that applies to its parkways. Locations and spacing of trees allow greater number of trees to be planted than is permitted in New York City as a result of calibrating species type with spacing.

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LA.8
PLANT TREES TO MAXIMIZE SHADING OF PAVEMENT

OBJECTIVE

To reduce urban heat and air pollution, and to increase pavement lifecycle, plant trees in sufficient numbers and appropriate layouts to achieve maximum shading of pavements.[143]

BENEFITS

+ Reduces the urban heat island effect by lowering local ambient temperatures and decreasing heat absorption by pavements. Reduces building cooling loads and energy consumption during the summer.[144]
+ Increases pavement durability and extends lifecycle by reducing deformation and rutting caused by heat stress.
+ Reduces stormwater runoff through water uptake and evapotranspiration.
+ Reduces air pollution and noise pollution.
+ Improves public health, quality of life, and aesthetics.
+ Provides shelter from the sun and harmful ultraviolet rays.
+ Increases property values.

LIMITATIONS

– Increases construction costs.

INTEGRATION

- **SS.5** Increase and Improve Right-of-Way Public Space and Green Areas
- **PA.1** Maximize Pavement Lifecycle Citywide
- **PA.3** Maximize Pavement Albedo
- **LA.1** Optimize Citywide Landscape Planning
- **LA.4** Use Structural Soils Where Appropriate
- **LA.7** Increase the Quantity, Density and Diversity of Trees
- **LA.9** Plant Trees in Trenches or Continuous Soil Zones
- **LA.10** Use Healthy Plant Selection and Planting Practices
- **CP.2** Protect Existing and Future Planted Areas

[143] The USDA Forest Service estimates that clustered street trees reduce temperatures 0.4 degrees F. for every percent increase in canopy cover. Other studies suggest that mid-day air temperatures under a tree with grass ground cover can be up to 3 degrees F cooler than surrounding areas.

[144] Deciduous trees will block the sun during the summer months and allow in the sun during the winter months.

TECHNICAL STRATEGIES

Design

Properly select and specify tree species:

- Select appropriate species for local climatic conditions, salt and wind tolerance, utility obstructions, traffic control devices and available soil volume.
- Select species with appropriate branching structure and growth characteristics to maximize canopy and leaf mass.
- Select trees with mature heights in conjunction with vehicular and overhead utility clearances.
- Specify caliper size between 3-4 inches (minimum rootball diameters: 32’ for 3’ caliper; 42’ for 4’ caliper) to ensure rapid establishment and sufficient initial girth. Caliper may be downsized to 2 1⁄2’-3’ depending on specie availability and most suitable transplant size.
- Specify two year warrantee for street trees.
- See “Use Healthy Tree Selection and Planting Practices” **(LA.10)** for more details.

Determine optimal planting locations:

- Plant trees to maximize shade coverage over dark surfaces and pedestrian areas (roads, parking lots, sidewalks).
- Space trees based on specie type to maintain visibility of vehicular intersections, street light efficiency and traffic control devices. Spacing to range between 20’ to 40’ on center.
- Plant shade trees near homes and buildings to shield them from direct sun in the summer.
- Design to plant trees in trenches or continuous soil zones. **(LA.9)**
- Use structural soil where appropriate. **(LA. 4)**

Construction

Use healthy tree planting practices:

- Select locally grown species.
- Obtain disease-free certification from nursery/supplier.
- Plant trees during optimum season based on species.
- Protect plantings from construction activities **(CP.2)**.
- Perform tree planting according to best horticultural/arboricultural practices.
- Do not fertilize trees during first year.
- Enforce contractor warranty for defective installation and replacement of dead or vandalized trees.
- See “Use Healthy Plant Selection and Planting Practices” **(LA.10)** for more details.

Operations and Maintenance

- Conduct annual inspection of street trees for pest infestation or damage.
- Provide emergency water during sustained drought periods through the use of gator bags, water trucks, etc.
- Prune or remove infested trees or limbs.

- Remove tree stakes (if used) after first year.
- Monitor for plant health. **(LA.10)**

PERFORMANCE GOAL

- Reduce local ambient temperature by 5 degrees Farenheit minimum.
- Reduce peak cooling loads for residential buildings by 30% annually in conjunction with other urban heat island reduction strategies.

EXAMPLE

The Syracuse, New York Urban Forest Master Plan – developed the USDA Forest Service in cooperation with the City of Syracuse and several other organizations – is the most comprehensive assessment and innovative plan of its type. In the process of developing the master plan, organizers created a high-resolution digital urban vegetation cover map informed by extensive sampling data, conducted a 100% street-tree inventory, surveyed city residents regarding desirable and undesirable tree characteristics, and interviewed local tree experts. The master plan establishes priorities for the future management of Syracuse's urban forest, including objectives for increasing overall tree canopy cover to 30%, enhancing tree health, and optimizing environmental and social benefits. The master plan is intended to be integrated with the Syracuse Neighborhood Initiative and other urban planning and revitalization programs.

The U.S. Environmental Protection Agency, as part of its Cool Communities program, has conducted definitive research that demonstrates significant reduction in the Urban Heat Island Effect through the use of shade trees over pavements. As a result, a number of municipalities including Los Angeles, Sacramento, Baton Rouge, Chicago, and Highland Park, New Jersey have adopted best practices for street tree planting in the public right-of-way.

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LA.9
PLANT TREES IN TRENCHES OR CONTINUOUS SOIL ZONES

OBJECTIVE

Create continuous soil trenches or root paths to provide greater area for root growth, better access to air, moisture and nutrients.

BENEFITS

+ Significantly increases the lifespan of trees.
+ Enables greater absorption of stormwater runoff.
+ Provides a greater area for root growth and shares resources among individual trees.
+ Tree longevity and health preserves genetic diversity and integration with other native plantings.
+ Eliminates the need for drainage and watering systems, which offsets the costs of soil trenching.
+ Alleviates heaving of adjacent pavements and the associated cost of repair and litigation related to tripping injuries.
+ Minimizes future costs associated with remedial action and replacement of dead trees.

LIMITATIONS

– Adds construction costs for additional excavation and backfill.

BACKGROUND

As an alternative to traditional tree pits, the implementation of continuous soil trenches creates shared resources among individual trees and provides greater area for root growth and stormwater absorption. This practice can additionally prevent pavement heaving adjacent to tree pits and the associated cost of repair and litigation related to tripping injuries. Similarly, the elimination of unwarranted tree stabilization techniques protects trees from future girdling or snapping, while elimination of unnecessary tree stakes or guy wires protects pedestrians and saves installation cost.

INTEGRATION

- **SA.2** Conduct Soil Analysis
- **PA.1** Maximize Pavement Lifecycle Citywide
- **SM.4** Optimize Right-of-Way Drainage
- **LA.4** Use Structural Soils Where Appropriate
- **LA.7** Increase the Quantity, Density and Diversity of Trees
- **LA.10** Use Healthy Plant Selection and Planting Practices
- **CP.2** Protect Existing and Future Planted Areas

TECHNICAL STRATEGIES

Design

Adequately size tree trenches / continuous soil zones:
- Design sidewalks of sufficient width to accommodate tree trenches.
- Meet or exceed the following minimum width requirements for planting soil zones:
  Single row of trees: 8 feet.
  Double or staggered row of trees: 12 to 18 feet.
- Provide 1 cubic yard of soil volume for every 5 cubic yards of crown volume of a mature tree.
- Provide 75-95 cubic yards of soil for major shade trees.
- Provide 10-30 cubic yards of soil for minor trees.
- If soil space is limited or linear trenches are physically impossible, design to direct root growth toward larger soil volumes or break out zones (lawns or planting strips).

Minimize interference with streetscape elements:
- Specify structural soils under pavements. **(LA.4)**
- Coordinate placement of utilities, light poles, bus stops, driveways and hydrants to maximize continuity of trenches.
- If use of structural soils is impossible or if interference with streetscape elements is likely, design root paths to direct root growth toward larger soil volumes or break out zones (i.e. lawns or planting strips).

Select appropriate paving or plant material to cover soil trench between trees*:*
- Do not grout joints of pavers within 10 feet either side of a tree.
- Do not plant grass or shrubs within 4 feet of either side of a tree.

Construction

- Inspect subsoil after excavation to determine need for supplemental drainage.
- Install and test structural soil **(LA.4).**
- Follow healthy tree selection and planting procedures. **(LA.10)**

EXAMPLE

Seattle Washington's Department of Transportation has adopted tree planting guidelines for the public right-of-way that require continuous structural soil trenches. The additional cost of excavation and backfill is offset by eliminating drainage trenches and upgrades to the stormwater infrastructure.

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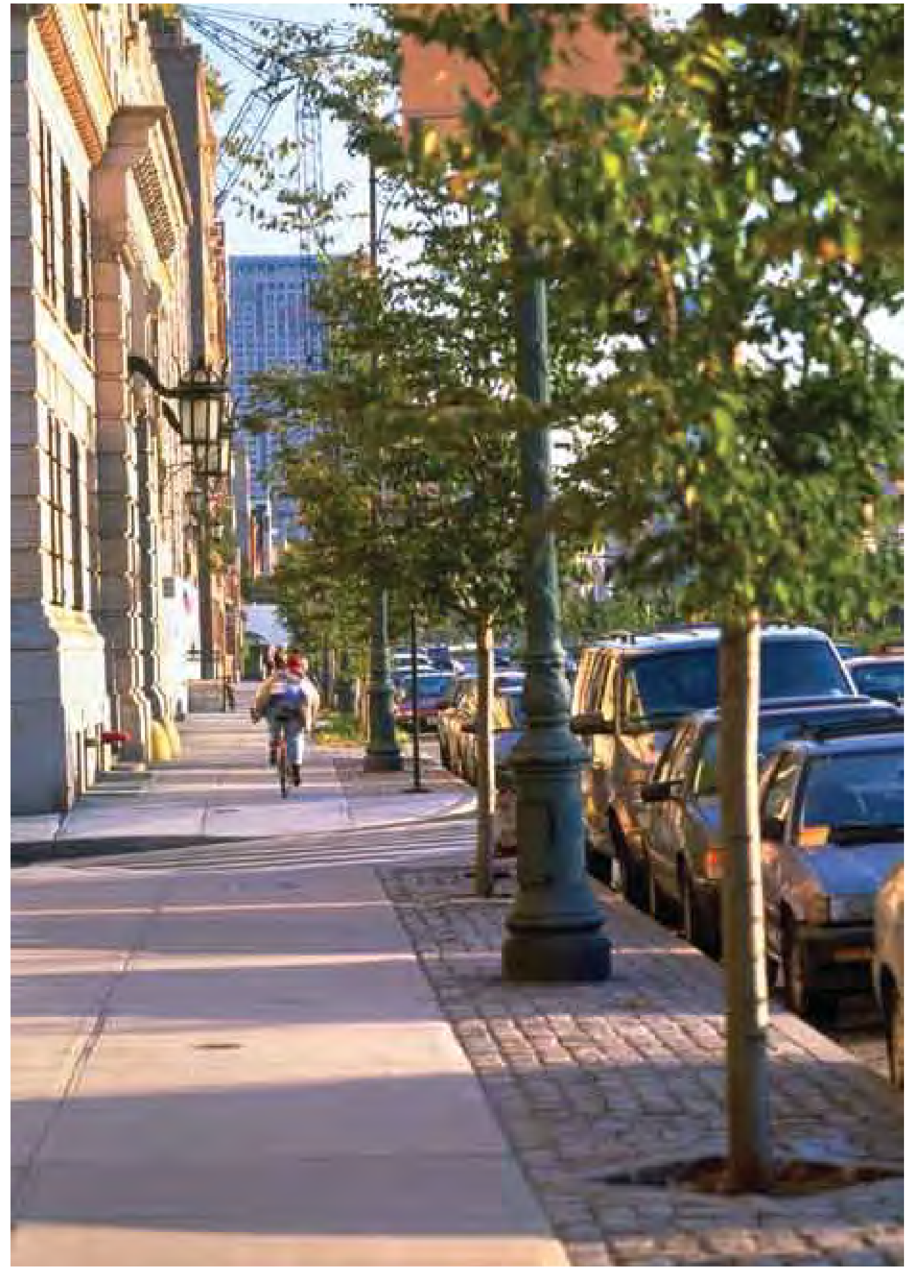

Route 9A – Manhattan, NY
Five and a half miles of sidewalk along Route 9A have continuous tree trenches filled with structural soil. Trenches are discontinuous only at driveways and are covered with ungrouted granite blocks. Completed between 1998 and 2000, the trees are thriving and there is no evidence of settlement.

LA.10
USE HEALTHY PLANT SELECTION AND PLANTING PRACTICES

OBJECTIVE

Specify, budget for and use planting techniques that promote healthy plants and trees. Purchase plants and trees that have been grown within the site's local environment and within approximately a 250-mile radius. Trees grown within the same or similar environmental conditions as the site (local ecotype trees or indigenous species) have the greatest chance for success. Document and enforce planting practices that ensure tree longevity. Select tree species that are resistant to local pest infestations.

BENEFITS

+ Increases the lifespan of trees and minimizes future costs associated with remedial action and replacement of dead trees.
+ Preserves genetic diversity and integration with other native plantings.
+ Use of local trees improves likelihood for successful transplants.
+ Use of trees from local ecotypes helps preserve local pollinators, insects, birds and mammals.
+ Elimination of unwarranted tree stabilization techniques protects trees from future girdling or snapping, protects pedestrians from protruding or sharp materials, and reduces installation cost.
+ Self-supported trees develop stronger root systems and exhibit better internal movement of hormones and sugars.
+ Mulching provides a range of benefits including: reduced weed growth; reduced need for herbicides and watering; reduced soil compaction, improved soil fertility through adding nitrogen, sulfur, phosphorous, calcium and other nutrients; and enhanced habitat for beneficial earthworms and insects that build healthy soil and increase infiltration rate.
+ Provides economic and environmental benefit by reusing yard waste that constitutes 20% of waste stream in USA.
+ Increases health of soil, improves rainwater infiltration rate and natural detention, increases evapotranspiration and plant health.
+ Reduces need for watering, herbicides, and fertilizers thereby protecting water quality.

LIMITATIONS

– Designers will have to adjust standard plant palettes to comply, and become more aware of local conditions to specify correct planting procedures.
– Nursery growers are reluctant to use bio-degradable products due to their shorter-term efficacy, and traditional practices are difficult to change.
– Landscape contractors will have to expend greater effort to protect trees during planting operations.
– Tree availability may be different at time of purchase than at time of design, thereby requiring substitutions.
– Special maintenance agreements will be required when non-standard tree protection devices are used.

INTEGRATION

▫ **SS.2** Improve Streetscape for Pedestrians
▫ **LA.5** Amend Existing Soils
▫ **LA.12** Use Low-maintenance, Salt-tolerant, Native or Naturalized Species
▫ **LA.13** Use Water-efficient Landscape Design

TECHNICAL STRATEGIES

Site Assessment

▫ Evaluate local environmental conditions – including soil, climate/rainfall, elevation, drainage, aspect, sun/shade and habitats – to help determine proper tree selection.
▫ Conduct soil analysis and assessment. **(SA.2)**

Planning

▫ Budget for maximum amount of watering to accommodate full-drought conditions.

Design

Design tree planting zones:
▫ If possible, plant trees in trenches or continuous soil zones. **(LA.9)**
▫ Locate trees a minimum of 3 feet from outside face of curb to protect from vehicular damage. Where space is limited, plant tree pits off center.

Select trees properly to ensure health and longevity:
▫ Purchase trees that have been grown within site's local environment and within approximately a 250-mile radius.
▫ Ensure trees are tagged at a nursery that grows specified local ecotypes and certifies that they are disease and pest free. Require nursery compliance with Asian Longhorned Beatle (ALB) quarantine restrictions.
▫ Specify trees with a minimum caliper of 3 inches for canopy trees or greater than 8 feet tall for minor trees. Coordinate caliper with branching height to achieve proper clearances for pedestrians or vehicles, species availability, adaptability of specie to transplant success and project budget.

- Specify trees with straight trunks, strong leader, balanced branching habit and ball sizes in accordance with American Standards for Nursery Stock.
- Specify seedling stock, not clonal stock, cultivars or horticulturally enhanced trees to avoid limiting genetic variation.
- Select species that are not hosts to Asian Longhorned Beatle or are known hosts of transmittable diseases (i.e. cedar-apple rust).
- Inspect trees at nursery grower to ensure root flare is visible or exposed prior to digging.
- Select salt-tolerant species for trees located in areas susceptible to de-icing salt runoff.

Avoid tree substitutions:
- Coordinate tree specie selection with locally available growers to avoid undesirable substitutions during construction.
- Require landscape contractor to identify nursery sources at time of bid to reduce likelihood of substitutions.

Specify optimal tree protection:
- Specify tree protection such as low fences or wicket/hoop surrounds in congested sidewalk areas.
- Do not require guys or stakes unless wind, soil conditions or safety conditions warrant their use.
- If necessary use rubber or polypropylene bands and flexible stakes, below ground tree staples or anchors.
- Omit tree wrap unless local conditions indicate susceptibility of bark to cracking from sun.

Specify soils procedures:
- Specify structural soils if appropriate. **(LA.4)**
- Specify appropriate soil amendments for backfilling. **(LA.5)**
- Specify mulching. See “Conduct Mulching” in next section.

Require and enforce two-year warrantee for trees.

Construction

Perform proper tree inspection:
- Require a state certified tree expert or ISA (International Society of Arboriculture) certified arborist to supervise tagging, delivery and planting of trees.
- Inspect trees for evidence of bark damage, pests or fungus if trees were wrapped in nursery or during transport.
- Reject damaged or loose tree balls delivered to construction site.
- Reject trees that do not have exposed root flare.

Monitor importation of plant material:
- Test imported material at plant and upon delivery to site

Perform irrigation as necessary:
- Provide supplemental water for plants during establishment period or times of sustained drought.
- Leave grass clippings in place to reduce moisture loss.

Prepare trees for planting and execute planting:
- Remove all non-biodegradable burlap or twine from rootball.
- Remove girdled roots prior to planting.
- Remove top half of wire baskets and cut remaining wires once tree has been placed in its final location and height.
- Locate trees a minimum of 3 feet from outside face of curb to protect from vehicular damage. Where space is limited, plant tree pits off center.
- Plant trees in holes 3 times the diameter of rootball with tapered sides; set ball on firm sub-grade; backfill with native soil or amended native soil, depending on soil test results; root flare must be visible.
- Do not fertilize trees at time of installation.
- Install specified tree protection. Refer to design section.
- Ensure conformance with planting specifications. Require contractors to be certified by New York State Department of Agriculture to perform work within ALB quarantine zones.
- Enforce two-year warrantee and maintenance.

Conduct mulching:
- Choose a mulch material and particle size that is appropriate to site characteristics such as slope and dimensions, aspect, soil drainage and wind exposure. If mulch is being used to improve soil structure and fertility, organic mulch is an appropriate choice. A dark color mulch on a northern aspect will help capture heat; a light color mulch on a southern aspect will help reflect heat.
- Do not create mulch ‘volcanoes’ up against tree trunks. Keep mulch 4 inches away from tree trunks.
- Spread mulch to a layer thickness of 3 to 4 inches.
- Avoid applying mulch to slopes over 33 percent.
- Maintain a mulch diameter of 4 to 6 feet around base of trees especially in lawn areas to protect from mower damage.

Operations and Maintenance

Conduct Irrigation:
- Provide supplemental water for plants during establishment period or times of sustained drought.
- Consider requiring watering schedules from contractors.
- Avoid over-watering trees to conserve water and protect roots from rot.
- Prune only to remove dead, damaged or infested limbs. Prune in accordance with American National Standards Institute (ANSI) and International Society of Arboriculture (ISA).
- Inspect trees annually to determine appropriate time to remove above-ground stabilization if used.

Practice On-Site Composting:
- Create on-site compost/mulch piles or purchase from a local municipal composting facility.

- Comply with NYSDEC regulations regarding on-site composting procedures and permits.
- Avoid composting toxic or diseased plant materials.
- Use only yard waste that has decomposed for a minimum of 6-12 months, depending on material/process.
- Apply compost at a 2:1 soil-to-compost by volume ratio. The soil should pre-tilled prior to the application of compost. Two to four inches of compost should be spread over the soil and should be tilled to a depth of eight inches of existing soil. When replenished annually, chemical fertilizers may be eliminated.

EXAMPLES

The City of Seattle Department of Parks and Recreation has published a Best Management Practices Manual that describes how it established and operates a nursery that grows native species for use in its park system. www.cityofseattle.gov

The U.S. Environmental Protection Agency has defined the recommended recovered materials content range from various types of compost, including yard waste. The Agency has also provided a database of acceptable suppliers and testing methods.

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LA.11
REDUCE USE OF TURFGRASS

OBJECTIVE

Establish a meadow or use native ground covers in lieu of turfgrass. Use lower maintenance turfgrass species where recreational activities warrant need for mown grass.

BENEFITS

+ Reduces water consumption.
+ Minimizes the need for pesticides, fertilizer and fumigants, substantially reducing maintenance costs and environmental impact.
+ Significantly reduces bacterial, chemical and nutrient loading of ground water and surface water bodies.
+ Reduces the need for supplemental irrigation and conserves potable water.
+ Eliminates the need for regular mowing, reducing maintenance costs and air pollution. Reduces damage to trees from mowing.
+ Strengthens native plant communities, habitat and local ecosystems.
+ Encourages healthy soil.
+ Reduces erosion due to deeper root systems of turfgrass alternatives.

LIMITATIONS

– Requires education and adaptation of landscape aesthetic expectations.
– May have higher initial installation costs than conventional turfgrass.
– Establishing weed-free meadows requires higher initial maintenance than traditional turfgrass.
– Availability of alternative species fluctuates annually.

INTEGRATION

SA.4 Survey Existing Vegetation
SM.5 Use Vegetated Filters and Buffer Strips
LA.12 Use Low-maintenance, Salt-tolerant, Native or Naturalized Species
LA.13 Use Water-efficient Landscape Design

TECHNICAL STRATEGIES

Design

▫ Reduce use of turf especially in shaded, steeply sloped, natural or hard to maintain areas. Replace with mulch, stone-scape, ground covers, naturalized vegetation or low-maintenance grasses.
▫ Coordinate selection of non turfgrass areas with drainage patterns; locate to optimize stormwater filtration.
▫ Select native or well-adapted species requiring minimal or no maintenance overtime. Specify a combination of pioneer and successional species.
▫ Use turfgrass only for specific functions (sports, passive recreation); specify drought-resistant, lower maintenance turfgrass species.
▫ Use water-efficient landscape design **(LA.13)**.
▫ Do not use turfgrass within 4 foot diameter (minimum) of tree trunks.

Promote public education and awareness:
▫ Conduct local outreach programs that educate the public about the benefits and care of a native landscape.
▫ Install interpretive signage at key locations to identify a distinctive turf-alternative landscape and to describe its benefits.
▫ Encourage local schools to incorporate educational programs about the native landscape and adoption of nearby public landscapes for hands-on maintenance and awareness training.

Construction

▫ Follow recommended procedures for eliminating invasive species and weed seed. **(SA.4, CP.2)**
▫ Follow recommended procedures for protecting planted areas. **(SA.4, CP.2)**
▫ Prepare soil prior to native grass/meadow/turfgrass installation to minimize use of fertilizer and pesticide.

Maintenance

▫ Where turf is used, mow grass higher than conventional mowing height to conserve water and energy.
▫ Leave grass clippings on turf to reduce moisture loss. Reduce use of fertilizer and pesticides in conjunction with selected lower maintenance species.
▫ Where 'no-mow' grass is used, mow only once per year.
▫ Where meadow grass/wildflowers are used, mow every 3-4 years. Choose mowing time to avoid disturbing wildlife and prevent spread of weed seed.
▫ Follow biointensive integrated pest management recommendations. **(LA.14)**

Monitoring

▫ Monitor meadows for encroachment of invasive species; reseed immediately after removal of invasives.

US Food and Drug Administration Headquarters – Queens, NY
Low shrubs and ground covers planted adjacent to parking lot and front entry minimize pavement and use of turfgrass, and reduce maintenance.

PERFORMANCE GOAL

- Reduce turfgrass area by 60% exclusive of active sports fields.

EXAMPLE

The State of New Jersey has developed the Municipal Environmental Resource Inventory that provides maps and data to facilitate sensitive site design in municipalities. The State's Municipal Land Use Law extends this recognition to requiring alternatives to turfgrass to protect stormwater runoff from carrying pollutants emanating from turfgrass.

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LA.12
USE LOW-MAINTENANCE, SALT-TOLERANT, NATIVE OR NATURALIZED SPECIES

OBJECTIVE

Select low-maintenance, native or naturalized plants that are tolerant of urban conditions, require less fertilizer, pest and disease control measures, and require less supplemental water than traditional/exotic landscapes. In conjunction with best management soil practices, replace chemical fertilizers with organic amendments. Combine species to avoid host pest problems. Avoid use of invasive species to reduce on-going maintenance.

BENEFITS

+ Native plants are better adapted to local climatic conditions including rainfall patterns and are more resistant to drought.
+ Native plants help preserve or enhance natural habitats and preserve genetic diversity.
+ Reduces construction and maintenance costs.
+ Curtailed use of chemicals in plant maintenance reduces risk of riparian and ground water contamination.
+ Salt-tolerant species can withstand the harmful effects of de-icing salts and require less frequent replacement.
+ Appropriate species selection avoids disease transmission from host plants and reduces long-term maintenance or replacement costs.
+ Native plants require less fertilizer and pest or disease control measures than exotic plants due to their adaptation to local site conditions.
+ Properly selected woody plants require less pruning and trimming.

LIMITATIONS

None.

INTEGRATION

- **SA.2** Conduct Soil Analysis
- **SA.4** Survey Existing Vegetation
- **LA.5** Amend Existing Soils
- **LA.10** Use Healthy Plant Selection and Planting Practices
- **LA.11** Reduce Use of Turfgrass
- **LA.13** Use Water-efficient Landscape Design
- **LA.14** Use Biointensive Integrated Pest Management
- **LA.15** Use Biotope-based Plant Arrangement Along the Shade-Light Continuum
- **CP.2** Protect Existing and Future Planted Areas

TECHNICAL STRATEGIES

Design

- Research plant disease transmission within local region to prevent planting host species.
- Coordinate new planting design with existing vegetation to be protected **(SA.4)**.
- Select species based on future use conditions (road de-icing salts, soil compaction, vegetated swale, etc.).
- Select plants according to anticipated or existing conditions including shade, moisture, soils, wind, etc.
- Select plant species based on their mature size characteristics to avoid future trimming or pruning oversized plants.
- Select native or non-invasive naturalized species that are locally available.
- Replace or augment native plant diversity during planting design process.
- Use alternatives to turfgrass **(LA.11)**.
- Write and standardize best management practice planting specifications.

Construction

- Protect existing soils and amend as required. **(LA.5, CP.2, CP.3)**
- Utilize local growers and nurseries that offer nursery-propagated native species.
- Use healthy plant selection and planting practices. **(LA.10)**

Operations and Maintenance

- Restrict mowing along roads to prevent incursion of invasive/exotic species.
- Replant denuded areas rapidly to avoid incursion of invasive/exotic species.
- Perform maintenance in accordance with “Use Biointensive Integrated Pest Management.” **(LA.14)**
- Provide supplemental water during establishment period or sustained drought.
- Improve type and spreading techniques of de-icing salts.
- Follow maintenance guidelines in “Use healthy plant selection and planting practices.” **(LA.10)**

Monitoring

- Monitor newly landscaped areas for evidence of invasive species. **(LA.10)**

PERFORMANCE GOAL

- Ensure that 70% of specified/planted species are native
- Ensure that 100% of species are locally adapted and non-invasive.

EXAMPLES

The Nature Conservancy Headquarters in Arlington, Virginia is located on 1.6 acres of land that includes a 0.5 acre native plant garden that demonstrates the process of secondary succession.
The City of Ottawa Planning and Development Design Guidelines require the planting of native, low-maintenance, salt-tolerant species along all public roads.

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Route 9A Reconstruction – New York, NY
Native plant species selected for drought and salt tolerance, pest resistance and coordinated with driver and cyclist sight lines.

LA.13 USE WATER-EFFICIENT LANDSCAPE DESIGN

OBJECTIVE

Reduce water consumption and protect water quality by designing a water-efficient landscape. Eliminate the need for irrigation through selection of drought-resistant plant species. If necessary, use irrigation systems that maximize efficient use of water in the landscape.

BENEFITS

+ Conserves local water supply.
+ Protects water resources from contaminants associated with landscape maintenance.
+ Reduces up front costs if no irrigation system is used.

LIMITATIONS

– Requires regular monitoring to ensure optimal water efficiency and minimal plant loss.

INTEGRATION

- **SA.2** Conduct Soil Analysis
- **SA.4** Survey Existing Vegetation
- **LA.5** Amend Existing Soils.
- **LA.10** Use Healthy Plant Selection and Planting Practices
- **LA.11** Reduce Use of Turfgrass
- **LA.12** Use Low-maintenance, Salt-tolerant, Native or Naturalized Species
- **LA.15** Use Biotope-based Plant Arrangement Along the Shade-Light Continuum

TECHNICAL STRATEGIES

Design

- Assess soil tests to determine amendments that will increase the soil's ability to absorb and hold water for plants. **(SA.2)**
- Consider systems for rainwater collection, storage, filtration, and reuse.[145]
- Evaluate temporary vs. permanent irrigation system if planting consists of trees only. Trees typically need supplemental water only during the establishment period.
- Group plants with similar water requirements; establish zones based on high (regular watering), medium (occasional watering) and low (natural rainfall). Coordinate zones with aesthetic/human considerations.
- Minimize turf areas. Use drought-tolerant plants along pavement to minimize radiant heat gain. **(LA.11, LA.12)**

Optimize water-efficiency of irrigation systems:

- Where required, design an irrigation system to maximize water efficiency and uniformity of distribution. Design in accordance with soils, slope, plant species, microclimate, water source and local weather conditions.
- Assess whether temporary or permanent irrigation systems are more appropriate.
- Design drip irrigation systems or efficient spray systems (turfgrass areas only) to reduce evaporation loss and to avoid applying unnecessary water on pavements.
- Specify water-conserving irrigation management methods such as check valves, pressure regulators, and moisture/rain/wind sensors.

Construction

- Enforce warranty regarding contractor responsibilities for maintenance and watering. Develop incentives and penalties to ensure compliance.
- Install irrigation system in accordance with specifications, system design criteria and water supply source (harvested rainwater, cistern, filtered greywater, or potable water supply).

Maintenance

- Maintain mulch cover to recommended depths; replenish annually.
- Do not shear shrubs; shearing promotes water-demanding new growth.
- Water plants regularly during establishment period and during periods of drought, if irrigation system is not installed. Use tree gator bags or similar to reduce labor cost.
- Consider hand-watering for medium zones during low rainfall/drought periods after establishment.
- Remove competitive weeds regularly.
- Regulate irrigation system in response to changing (seasonal, daily) need for water. Operate irrigation system at times of low evaporation.
- Repair leaks or malfunctioning components immediately to prevent water loss and plant injury.
- Avoid over-watering trees to conserve water and prevent root rot.

Monitoring

- Conduct irrigation audits every 5 years to check conformance with local requirements, distribution uniformity standards and functioning of sensors.

[145] Re-use of greywater is subject to health regulations and requires proper filtration and monitoring systems to avoid damage to soil and plants.

PERFORMANCE GOAL

- Reduce water consumption for landscape by 50%.
- For irrigation systems, design and maintain a distribution uniformity of 75 for the irrigated areas. Apply no more than 1 inch of irrigation water per week, including rainwater, to turfgrass areas.

EXAMPLE

The Capital Regional District Water Department in Victoria, British Columbia has published a Best Management Practices guide to Water conservation in the public sector. The document features strategies for designing and maintaining water efficient landscapes in the public right-of-way. http://www.crd.bc.ca/

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Sidewalk on Beach Channel Drive – Queens, NY
Drought tolerant, native grasses planted in a sidewalk planting strip buffer an adjacent day care center fence and absorb/cleanse runoff.

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LA.14
USE BIOINTENSIVE INTEGRATED PEST MANAGEMENT

OBJECTIVE

Utilize biointensive integrated pest management (BIPM) techniques to minimize the use of synthetic chemicals for control of disease, invasives and pests. Maintain and control pests, invasive species and diseases at acceptable levels using the most economical procedures that are the least damaging to people, property and the environment. Effectively manage pests and beneficial organisms in an ecological context.

BENEFITS

+ Significantly reduces human health hazards.
+ Significantly reduces the use of toxic chemicals that pollute soil, air and water supply.
+ Maintains quality habitats for fauna.
+ Reduces cost of hazardous waste disposal.
+ Reduces cost of chemicals, pesticides and fertilizers.

LIMITATIONS

– Requires education of owner, contractor, consumers, and public to understand the process and accept unconventional landscape aesthetics.
– Requires training of landscape contractors.

BACKGROUND

In recent years, increased public concern about the dangers of chemical pesticides has resulted in the development of less costly and less toxic alternatives. An integrated pest management system utilizes a suite of environmentally compatible techniques and 'bio-pesticides' (products that contain botanical insecticides derived from plants) to maintain pest populations at levels below those causing economically unacceptable damage or loss.

INTEGRATION

- **SA.2** Conduct Soil Analysis
- **SA.4** Survey Existing Vegetation
- **SM.2** Prevent Water Pollution and Practice Source Control
- **LA.10** Use Healthy Plant Selection and Planting Practices
- **LA.12** Use Low-maintenance, Salt-tolerant, Native or Naturalized Species
- **CP.2** Protect Existing and Future Planted Areas
- **CP.3** Protect Water Sources During Construction

TECHNICAL STRATEGIES

Design

- Specify pest-resistant cultivars.
- Specify locally-grown, native species.
- Specify a diversity of appropriate species.

Construction

- Prepare soil and incorporation of amendments in conjunction with invasive species elimination. **(SA.4, LA.5)**
- Protect planted areas from contamination and construction activities. **(CP.2)**
- Use healthy planting practices. **(LA.10)**

Maintenance

- Identify and understand the biology of the plants and key pests involved; recognize the damage that pests inflict and propose appropriate control measures. Timing and knowledge of control measures are the keys to successful BIPM.
- Whenever possible, employ methods that preserve, complement, and augment the biological dynamics of the local ecosystem.
- Establish thresholds of acceptable levels of damage for each landscape type based on aesthetic appearance and pest species. Educate the client, users and public.
- Utilize a combination of regulatory, genetic, biological, cultural and chemical control measures.

- Regulatory: Chemical products regulated by local, state and federal agencies.
- Genetic: Control measures based on host pest resistance and autocidal action.
- Biological: Control measures based on using natural enemies or beneficial organisms (microbial pesticides).
- Cultural: Control measures based on using best maintenance practices including pruning, sanitation, cultivation, mulching, nutrient management.
- Chemical: Use non-toxic, non-residual chemicals or alternatives such as soaps, oils and bacterial preparations. Where required, use spot treatment of chemicals. Prevent water pollution and practice source control. **(SM.2)**

Monitoring

- Monitor plants monthly to check for vigor, structure, safety and the presence of diseases, and pests as well as beneficial organisms.
- Keep records of IPM procedures to assist in on-going proactive management decision.
- Monitor and control invasive specie encroachment.

Regulatory Issues

- Comply with City, state and federal codes regarding types, use, application and disposal of chemical controls.

EXAMPLE

The Catholic University of America implemented an integrated pest management program as part of a campus wide environmental awareness initiative. The project's goals were to decrease the amount of chemicals used on campus, to decrease the potential exposure to pesticides, and to improve overall campus health and environmental sustainability. In addition to meeting all of these goals, the University saved money by reducing the amount of chemicals purchased and by reducing hazardous waste disposal costs.
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LA.15
USE BIOTOPE-BASED PLANT ARRANGEMENT ALONG THE SHADE–LIGHT CONTINUUM

OBJECTIVE

In wide planting zones, use biotope-based arrangement along the shade – light continuum. Effective shade management uses plants to block sunlight from striking the soil surface and to intercept, scatter and reflect radiant energy to protect paved surfaces from direct sunlight. This planting strategy mimics natural distribution of canopy, understory, shrub, and herbaceous layers based on sunlight/shade tolerance of individual plant species.

BENEFITS

+ Reinforces and protects habitat and promotes species migration between habitat fragments.
+ Filters and recharges stormwater runoff if located properly.
+ Reintroduces moisture into the atmosphere thus reducing nearby building cooling loads.
+ Conserves moisture and reduces urban heat island effect.
+ Reduces long-term maintenance; reduces establishment and spread of invasive species.
+ Preserves genetic biodiversity.

LIMITATIONS

– Effective biotope gradient planting requires significant width (minimum 300 feet) to create sustainable ecosystem.

BACKGROUND

A biotope is a region definable by its specific environmental parameters and ecological conditions which support the organisms living there. Using biotope-based plant groupings is an emerging practice. Where space permits, such an approach may improve vegetation hardiness and longevity, while providing enhanced habitat and an aesthetically pleasing palette of plant material.

INTEGRATION

- **SA.1** Assess Site and High Performance Opportunities
- **SA.2** Conduct Soil Analysis
- **SA.4** Survey Existing Vegetation
- **SM.1** Conduct Integrated Stormwater Management Planning
- **SM.3** Minimize Runoff from New Building Construction and Major Renovations
- **SM.4** Optimize Right-of-Way Drainage
- **LA.1** Optimize Citywide Landscape Planning
- **LA.2** Encourage Ecological Connectivity and Habitat
- **LA.12** Use Low-maintenance, Salt-tolerant, Native or Naturalized Species
- **LA.13** Use Water-efficient Landscape Design
- **LA.14** Use Biointensive Integrated Pest Management
- **CP.2** Protect Existing and Future Planted Areas

TECHNICAL STRATEGIES

Design

- Design using principles of successional landscape: arrange native or locally appropriate species along a vertical gradient from low herbaceous to high canopy trees.
- Coordinate with habitat restoration and ecological connectivity. **(LA.2)**
- Coordinate with natural drainage patterns to serve as buffer and filter along riparian corridors. **(SM.1 to SM.4)**
- Coordinate planting design with prevailing seasonal wind patterns to maximize heat evacuation in summer and heat trap in winter.
- Select native and locally appropriate, naturalized non-invasive species.

Construction

- Protect existing vegetation and soils from construction impacts. **(CP.2, CP.3)**

Maintenance

- Establish maintenance procedures for natural/naturalized areas based on best management practices for similar local ecotypes.
- Monitor management practices to ensure continued diversity; remove invasive species and replant with appropriate plant material.
- Encourage public education on the values of ecological succession and biotope diversity.

Prudential Insurance Company Headquarters – New Jersey
Plant material arranged from high to low species to mimic natural solar gradient of canopy, understory and herbaceous layers.

EXAMPLE

Germany has taken the lead in developing laws that are intended to conserve and augment significant biotopes. In 1990, Berlin adopted a law that legally protects specific natural environments and specifies compensatory mitigation measures including review of landscape plans to ensure restoration of successional biotopes.

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Chapter 2


EcoSPA
A DIVISION OF
Best Management Practices
REGISTERED
LANDSCAPE
ARCHITECT
BERM
Ask for Details
BIOINTENSIVE
PEST PURGE
RUB
BMP
Constitution SOIL AMENDMENTS
BIOTOPE

LANDSCAPE

PART THREE: BEST PRACTICES
CONSTRUCTION PRACTICES

CP.1
DEVELOP AND ENFORCE A SITE PROTECTION PLAN

OBJECTIVE

Develop, implement, and enforce a site protection plan to minimize impact of construction activity in and adjacent to the right-of-way.

BENEFITS

+ Minimizes community disruption.
+ Reduces noise and air pollution.
+ Reduces water pollution and sedimentation.
+ Reduces soil disturbance, compaction, and erosion.
+ Protects existing plants and reduces cost of additional planting and topsoil.
+ Improves contractors' awareness and sensitivity to environmental and social impacts of construction.

LIMITATIONS

– Ineffective without cooperation among contractors and construction manager/owner.
– May increase costs on projects with restricted site areas.

INTEGRATION

- **SA.1** Assess Site and High Performance Opportunities
- **SA.4** Survey Existing Vegetation
- **SM.2** Prevent Water Pollution and Practice Source Control
- **CP.2** Protect Existing and Future Planted Areas
- **CP.3** Protect Water Sources During Construction
- **CP.4** Implement a Waste Management and Recycling Program
- **CP.5** Minimize Disruption and Impact of Right-of-Way Construction
- **CP.6** Use Cleaner Construction Equipment

TECHNICAL STRATEGIES

Illustrate site protection plan(s) on all relevant site plans: Site preparation/demolition/removals plan; grading and site utilities plans, etc.

Clearly mark limits of construction and other relevant areas:
- Mark clearing limits and approved work areas.
- Identify areas of site requiring significant excavation.
- Limit excavation and soil disturbance to minimum area necessary to perform work.
- Establish construction access points.
- Prevent soil compaction. Use lightest-weight machinery possible.
- Include designated stockpile location(s) and truck access route(s).
- Indicate on plans and in specifications that protection barriers may have to be relocated and reinstalled during construction to provide temporary access.
- Specify that under no circumstances shall material, equipment or debris be stockpiled within the protection zones.

Develop a Soil Erosion and Sediment Control Plan. **(CP.3)**

Include the following considerations in the site protection plan:
- Protect topsoil from compaction, erosion and disruption. **(CP.2)**
- Protect existing trees and vegetation. **(SA.4, CP.2)**
- Protect planted areas against chemical contamination. **(CP.2)**
- Protect new plantings. **(CP.2)**
- Protect against invasive species. **(SA.4, CP.2, LA.14)**
- Minimize sedimentation and erosion. **(CP.3)**
- Prevent water pollution and control sources. **(CP.3, SM.2)**
- Use interim stormwater management to reduce and treat runoff. **(CP.3)**
- Implement a waste management and recycling plan. **(CP.4)**

Minimize noise and disruption to community. **(CP.5)**

Properly sequence major construction activities to minimize environmental impact and community disruption. **(CP.5)**

Use alternative contracting methods to minimize construction delays and work stoppages. Maintain transportation patterns. **(CP.5)**

Promote awareness and enforcement:
- Ensure that all disciplines respect the protection plan throughout the design and construction process.
- Require contractor to maintain protection barrier in good condition throughout the life of the contract.
- Develop special contract provisions to enforce site protection goals. Include both incentives and penalties.
- Enforce restrictions by imposing fines on contractor(s) who violate protection requirements.
- Post signage communicating site protection measures, including vehicle protocols, parking and site access, storage of waste and recyclables, storage of hazardous

materials and vehicle cleaning areas.
- Conduct meetings to educate workers about site disturbance and water pollution control measures.
- Meet with contractor and/or construction manager at outset to coordinate site protection measures.

Monitoring and Maintenance

- Conduct regular inspections and maintenance of site protection measures. Ensure that site protection markings are maintained.
- Inspect erosion and sedimentation control measures after heavy rainfalls (1/2' in less than 24 hours).
- Remove sediment from sediment traps when design capacity has been reduced by 50%.
- Periodically inspect hazardous materials containers and perform necessary maintenance.
- Monitor trees whose roots have been cut during construction for stability and health.
- Monitor disturbed soils over time to ensure stability and re-vegetation.
- Remove hazardous conditions.

Develop and enforce a post-construction mitigation plan.

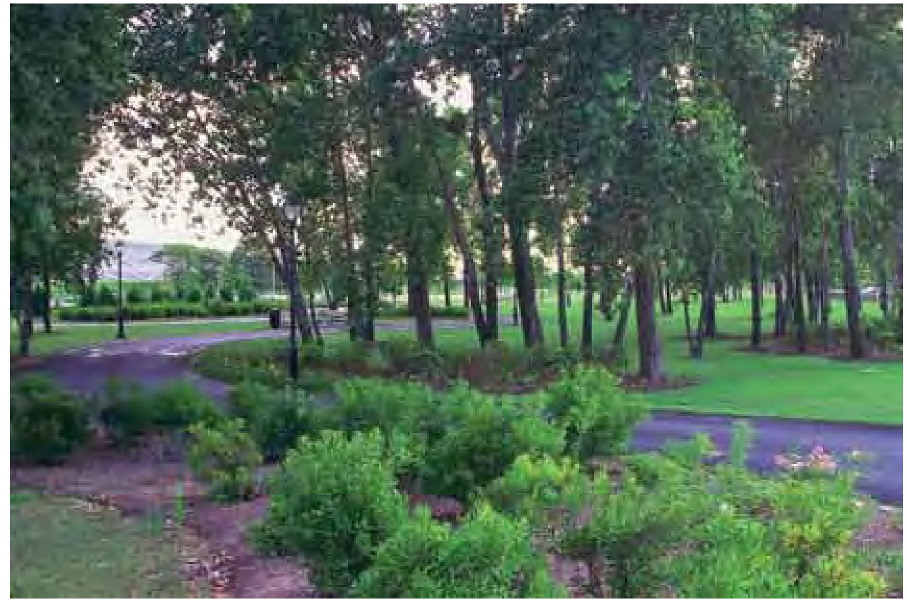
Consider the use of progress payment schedules to ensure contractor compliance: Under this type of contract, money is held back from the contractor until they complete certain tasks – including landscape maintenance, site protection measures, etc. Requires monitoring to ensure compliance.

Develop a system to impose liquidated damages on contractors that cause injury to planted areas or fail to follow protection measures.

Develop performance goals to maximize the use of local materials. Endeavor to obtain the materials within 100 miles if transported by truck and 300 miles if transported by rail or barge.

EXAMPLE

The City of Seattle Department of Parks and Recreation's Best Management Practices guide contains a chapter entitled 'Construction Site Management' that describes methods to sustain vegetation assets, avoid soil compaction and degradation, avoid physical injury to trees and protect soils and hydraulic integrity of a site during construction.



Shore Parkway Bikeway – Queens, NY
Evidence of well-executed site protection plan minimizes disturbance to existing trees.

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Vol. 45, No. 2, February 2004, p. 29
http://www.jgpress.com/archives/_free/000103.html

CP.2
PROTECT EXISTING AND FUTURE PLANTED AREAS

OBJECTIVE

Protect existing and future planted areas from soil compaction and disturbance, chemical pollution, damage from construction equipment, invasive species, and so on. Monitor and maintain vegetation protection measures.

BENEFITS

+ Maintains natural infiltration and soil porosity by reducing soil disturbance and compaction.
+ Reduces cost of additional planting and topsoil.
+ Protects existing or new plants from construction-related contaminants that alter nutrient transfer capacity of soils and introduce toxic heavy metals.
+ Preserves desirable vegetation and natural soil profile.
+ Improves quality of life and increases property value.
+ Minimizes pollution, sedimentation and erosion of receiving waters.

LIMITATIONS

– Ineffective without cooperation among contractors and construction manager/owner.
– May increase costs on projects with restricted site areas.

INTEGRATION

- **SA.1** Assess Site and High Performance Opportunities
- **SA.4** Survey Existing Vegetation
- **CP.1** Develop and Enforce a Site Protection Plan
- **CP.3** Protect Water Sources During Construction
- **CP.5** Minimize Disruption and Impact of Right-of-Way Construction

TECHNICAL STRATEGIES

Protect topsoil from compaction, erosion and disturbance:
- Protect existing topsoil or subsoil from compaction.
- Specify low ground pressure (LGP) equipment for construction operations within planted areas.
- Prohibit construction vehicles from driving or staging on future planted areas.
- If necessary, provide geotextile fabric and 12 inch gravel layer for access routes.
- Cover exposed soils immediately with erosion-control measures.
- Protect soils from chemical cleaning products and other pollutants.
- Test soils impacted by construction activity prior to planting; amend or remediate as required to meet specifications.
- Monitor disturbed soils over time to ensure stability and re-vegetation.
- Permit earthwork operations during dry weather only; soil moisture content should not exceed 20% during operations.

Minimize impact from chemical applications:
- Specify sterilants/herbicides/pesticides with short residual periods, selected specifically for the species to be eradicated and within USEPA standards of low toxicity to humans and animals. Use non-selective, non-residual herbicide, a glyphosate without surfactant if possible.
- Follow appropriate federal, state, or local environmental and health standards to assess risk when planning the use of chemical substances.
- Avoid chemical applications that can vaporize into the atmosphere, be residually absorbed by soil or plants or be leached into groundwater.
- Prohibit use of methyl bromide or other soil fumigants.
- Coordinate herbicide applications with growth characteristics of invasive species.
- Require submission of test reports, material safety data sheets, application procedures and timing of any chemical applications to vegetation.
- Specify that surrounding areas are to be protected from migration of chemical applications.
- Use biointensive integrated pest management. **(LA.14)**
- Ensure truck washing and other cleaning procedures take place away from planted areas.

Minimize impact of de-icing procedures:
- Prohibit use of sodium chloride as de-icing salt; use calcium chloride mixed with sand and fine gravel away from vegetated areas. Consider use of calcium magnesium acetate (CMA) in lieu of road salt especially in sensitive ecological areas. Use grit on less traveled paths and within park areas.
- Monitor weather, maintain salt spreading equipment and use good de-icing salt spreading techniques to reduce impact on vegetated areas. Use mix of de-icing salt and sand.

Protect existing trees and vegetation:
- Discuss tree and vegetation protection plans at the alignment meeting and take necessary steps to coordinate utility work and earthwork to reduce impact.
- Implement tree and vegetation protection plans. **(SA.4, CP.2)**
- Implement tree removal and transportation plans. **(SA.4, CP.2)**
- Illustrate protection plan(s) on all relevant site plans, including the site preparation/demolition/removals plan and on the grading and site utilities plans.
- Remove hazardous conditions from protection zone.
- Minimize, or if possible prohibit, earthmoving within protected tree or vegetation/riparian zones.
- Protect roots of preserved trees from excavation.
- If excavation is required, hand excavate within protection zone.
- Cover exposed roots with wet burlap; reinstall native soil immediately within

exposed root zone; maintain mulch cover over protected trees.

- Use micro-tunneling and other trenchless technologies, and air-spading, rather than cut and cover technique, to install utilities within tree protection zone.
- Monitor for stability and health trees whose roots have been cut during construction.
- Perform compensatory pruning in the event of root or crown damage; perform work using a certified arborist.
- Monitor vegetation for evidence of destructive pests or damage to ecosystem.

Protect new plantings:

- Coordinate soil and planting installation with other construction activities to protect from damage.
- Monitor vegetation for evidence of destructive pests or damage to ecosystem.

Protect against invasive species:

- Implement invasive species eradication plan. **(SA.4, CP.2)**
- Control invasive species in compliance with local, state and federal regulations.
- Understand invasive species' growth habit and identify optimal season(s) for eradication by hand or chemical means.
- Where possible, specify mechanical controls such as hand pulling or tarpaulin suppressant.
- If chemical application is needed, use appropriate soil sterilant or non-residual systemic herbicide as applicable to the particular specie to be eradicated and the surrounding vegetation and hydrologic conditions. See 'Protection against chemical contamination' above.
- Select native and non-invasive plants for re-vegetation. **(LA.12)**
- Monitor zones eradicated of invasive species to ensure continued control.
- Remove reappearance of invasive species by hand or with recommended herbicide.
- Specify that all parts of invasive plants are to be removed from the site and disposed of legally. Identify species to be eradicated.
- If applicable, use permanent root barriers for long term protection.
- Ensure contractor has experience and full-time supervisory personnel.

Develop a system to impose liquidated damages on contractors that cause injury to planted areas or fail to follow protection measures.

Employ a certified arborist to monitor projects that require sensitive site protection measures.

PERFORMANCE GOAL

Protect 65% or more of the existing vegetated areas beyond the construction limit zone.

EXAMPLE

The City of Seattle Department of Parks and Recreation's Best Management Practices guide contains a chapter entitled 'Construction Site Management' that describes methods to sustain vegetation assets, avoid soil compaction and degradation, avoid physical injury to trees and protect soils and hydraulic integrity of a site during construction.

Riverdale Country School, Upper Campus – Bronx, NY
Soil erosion control, tree protection and delineated construction activity zone

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CP.3
PROTECT WATER SOURCES DURING CONSTRUCTION

OBJECTIVE

Undertake conscientious construction practices to protect water sources. Implement plans for pollution prevention, chemical source control, sedimentation and erosion control, and interim stormwater management. Monitor and maintain protection of water sources.

BENEFITS

+ Minimizes water pollution.
+ Minimizes community disruption.
+ Reduces noise and air pollution.
+ Reduces soil disturbance, compaction, and erosion.
+ Improves contractors' awareness and sensitivity to environmental and social impacts of construction.
+ Helps minimize site disturbance.

LIMITATIONS

– Ineffective without cooperation among contractors and construction manager.
– May increase costs on projects with restricted site areas.

INTEGRATION

- **SA.4** Survey Existing Vegetation
- **SM.2** Prevent Water Pollution and Practice Source Control
- **CP.1** Develop and Enforce a Site Protection Plan
- **CP.2** Protect Existing and Future Planted Areas
- **CP.5** Minimize Disruption and Impact of Right-of-Way Construction

TECHNICAL STRATEGIES

Prevent water pollution and control sources:
- Reduce the use of hazardous materials.
- Minimize the use of toxic materials and VOC-containing compounds.
- Dispose of hazardous waste according to local, state or federal regulations.
- Control chemicals and pollutant sources: Store hazardous materials in a clearly marked designated area away from water sources and vegetated areas. Dispose of chemicals and pollutants according to local, state or federal regulations.
- Periodically inspect material containers and perform necessary maintenance.
- Cover soil after stripping, amending or placement.
- Prevent detergents and chemicals from entering into stormwater management BMPs and conveyance infrastructure.
- Establish and educate workers about clean-up procedures for spills.
- Ensure that truck washing occurs in designated locations and away from catch basins.
- Minimize the use and impact of herbicides/insecticides/pesticides. **(CP.2, CP.3)**
- Use biointensive integrated pest management. **(LA.14)**
- Minimize impact of de-icing procedures. **(SM.2)**

Minimize sedimentation and erosion:
- Develop a Soil Erosion and Sediment Control Plan prepared by a CPESC (Certified Professional in Erosion and Sediment Control).
- Where appropriate implement NYSDEC sedimentation and erosion guidelines for projects less than one acre.
- Incorporate erosion and sedimentation plans into contract documents.
- Limit excavation and soil disturbance to minimum area necessary to perform work.
- Stabilize soils, channels and outlets.
- Identify and protect slopes in excess of 10%, or areas of significant vegetation.
- Implement a no-construction buffer zone along water bodies.
- Use catch basin inserts or an alternate method to reduce sediment and debris entering into storm sewer.
- Identify and stabilize sediment deposits.
- Clean sediment traps when design capacity has been reduced by 50%.
- Inspect erosion and sedimentation control measures after heavy rainfalls (1/2' in less than 24 hours).
- Stockpile topsoil appropriately and protect from erosion.

Provide interim stormwater management to reduce and treat runoff:
- Develop performance targets to reduce, detain and treat runoff.
- Develop and implement interim stormwater management regime.
- Monitor stormwater management BMPs to ensure that they meet performance targets.

Use environmentally benign substances to control rodents during construction.

Monitoring and Maintenance

- Conduct regular inspections and maintenance of water source protection measures.
- Clean sediment traps when design capacity has been reduced by 50%.
- Inspect erosion and sedimentation control measures after heavy rainfalls (1/2' in less than 24 hours).
- Periodically inspect control of hazardous materials and other materials.

- Monitor disturbed soils over time to ensure stability and re-vegetation.
- After construction, evaluate the effectiveness of water source protection regime to improve future construction work.
- Re-vegetate denuded areas as soon as appropriate planting season permits.

Enforcement

- Improve construction supervision to ensure contractor compliance with erosion and sedimentation control plans.
- Encourage education of contractors about water quality issues.
- Develop incentives and penalties for compliance.
- Undertake community outreach programs to promote public awareness.

Conduct pilot projects: In a variety of settings, conduct pilot projects to develop the most effective techniques for minimizing sedimentation, erosion, and water pollution during construction.

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United States Environmental Protection Agency
"Stormwater Discharges from Construction Activities"
http://cfpub.epa.gov/npdes/stormwater/const.cfm

CP.4 IMPLEMENT A WASTE MANAGEMENT AND RECYCLING PLAN

OBJECTIVE

Implement a construction and demolition waste management plan for infrastructure construction to reduce the amount of waste entering the waste stream and increase recovery of recyclable materials.

BENEFITS

+ Conserves and reduces pressure on local landfills.
+ Decreases transportation costs and reduces pollution.
+ Reduces soil, water and air pollution.
+ Reduces use of virgin materials.
+ Promotes local economic development.
+ Strengthens the market for recycled materials.

LIMITATIONS

– May increase construction costs.
– Lack of availability of markets for recycled materials could minimize effectiveness of recycling plan.
– Ineffective without contractor compliance and agency enforcement.

INTEGRATION

▫ **CP.1** Develop and Enforce a Site Protection Plan
▫ **PA.6** Use Recycled and Reclaimed Materials
▫ **LA.6** Perform Soil Berming

BACKGROUND

More than 60% of New York City's solid waste stream consists of construction and demolition (C&D) debris generated from land clearing and excavation, as well as work performed on structures, roads and utilities.[146] Approximately 19,500 tons of fill and 13,500 tons of other C&D material are generated daily. Most of the disposal or recycling of this waste is handled by private companies. Thanks to the favorable economics of C&D waste management in infrastructure projects, many contractors have developed effective recycling routines. In doing so, they avoid landfill tipping fees and costs associated with waste transportation out of the City. Additionally many contractors save money by recycling asphalt, concrete, metals, fill, and other materials common to infrastructure from one job to the next. It is estimated that approximately 60% of fill and 40% of non-fill materials are taken to waste processors, which recycle almost 100% of C&D waste they receive.

Implementing a waste management plan will help reduce exported City waste, reduce air pollution, realize cost savings through material recovery, and create more market opportunities in the waste processing industry. In general, waste management decisions should be made in accordance with the preferred hierarchy of 1) reuse on-site, 2) recycle on-site, 2) reuse off-site and 3) recycle off-site.

TECHNICAL STRATEGIES

Regulate Management of C&D Waste in Contract Documents

Develop standard C&D waste specifications: Include the following requirements in contract documents, editable on a per project basis:

▫ Establish general waste management goals (in cubic yards).
▫ Require submittal of a C&D waste management plan.
▫ Require interim submittal of delivery receipts for recovered and waste materials sent to waste processing or landfill facilities.
▫ Specify acceptable site management practices (see "Manage Site to Reduce Waste").

Develop a C&D waste management plan: At project outset, require submittal of a plan that includes:

▫ Indication of how contractor proposes to recover a specified percentage of C&D waste for reuse and recycling.
▫ Identification of anticipated materials to be reused or recycled, and estimation of amount by weight.
▫ Identification of anticipated materials that are not reusable or recyclable.
▫ Coordination of material recovery with construction and demolition schedule.
▫ List of insured and licensed waste processors to be used, organized by location and ranked by C&D recycling rates.
▫ Indication of situations in which compliance with standard C&D waste specifications do not apply or are not possible.

Document C&D waste management efforts:

▫ File recycling and waste disposal receipts to aid in estimating the quantities generated on future projects.
▫ Fill out recycling economics worksheet for each project to track cost of implementing C&D waste management plan versus conventional waste disposal process (see King County, Washington).
▫ Generate a post-construction report documenting waste diverted (by weight, type) and money saved, for future reference on other projects.

Manage site to reduce waste:

▫ Make decisions in accordance with the waste management hierarchy of reuse on-site, recycle on-site, reuse off-site, and recycle off-site.

[146] C&D waste includes concrete, stones and dirt generated during excavation (referred to as 'fill' or rubble), asphalt, wood, metals (ferrous and non-ferrous), and miscellaneous materials (dry wall, insulation, light fixtures, carpeting, etc.)

- Return, resell or reuse substandard, rejected or unused materials.
- Review and modify storage and handling practices to reduce material loss from weather, theft, and other damage.
- Verify correct amount of material is delivered to the site.
- Consider allowing the public to remove materials for their own use.

Manage ongoing site waste:
- Require vendors to take back packaging when products are unpacked upon delivery, or when multiple deliveries make it possible to retrieve packing from a prior delivery.
- Recycle packaging materials and other miscellaneous site waste.
- Ensure waste materials do not get contaminated.
- Clearly label all recycling bins and waste containers on site.
- Post lists of recyclable and non-recyclable materials.
- Conduct regular site visits to verify that bins are not contaminated.
- Provide feedback to the crew and subcontractors on the results of their efforts.

Separate on-site when possible:
Separation of materials on-site generally yields a better price for materials and results in better recycling rates. Use the following factors to determine whether on-site separation is feasible:
- availability of space.
- volume of C&D waste.
- relative proportions of C&D waste.

Ensure high recycling rates of mixed C&D waste:
When on-site separation is not possible, the following practices will help ensure higher recycling rates of commingled waste:
- Clearly designate and label container for placement of recyclables.
- Place a separate, clearly labeled dumpster designated for waste disposal adjacent to recycling container to avoid confusion and contamination.
- When providing contractor with list of approved, area waste processors, indicate recycling rates.
- Require pre-hauling verification and approval of mixed C&D waste processor.

Employ Creative Waste Management Strategies

Promote 'zero waste' in private and public sector:
- Develop partnerships between local government entities, industry, and the public to reduce waste when possible, achieve highest and best use of all materials, and find markets for recycled materials.
- Consider giving incentives (in the form of discounts on required permits) to utilities and other entities performing work in the right-of-way that agree to implement a C&D waste management plan.

Prevent waste in design and material procurement:
- Define material efficiency as a primary design parameter.
- Consult recycled material market directory when selecting materials of construction. **(PA.6 part I)**
- Choose materials with little or no packaging.
- Request vendors deliver materials in reusable containers.

Coordinate C&D Efforts to Reduce Vehicular Miles Traveled

Encourage rail-and-barge served transfer facilities:
- Consider feasibility of managing C&D waste transfer at Marine Transfer Stations.

Maintain area lists of licensed local haulers and waste processors:
- Organize on basis of location.
- Designate materials accepted at facility.
- Designate whether facilities accept source-separated or commingled waste.

EXAMPLE

Construction Works, a program administered by the King County, Washington State Solid Waste Division, provides one-on-one technical assistance to contractors setting up jobsite recycling and waste-reduction programs. In order to participate, the contractor must agree to meet the following requirements:
- Implement six waste-prevention strategies.
- Recycle at least 60 percent of its construction waste.
- Use six or more recycled-content building materials.
- Conduct at least three activities that promote waste prevention, recycling and/or the use of recycled-content products to their employees, customers and/or the community.

In exchange for participation, the contractor receives recognition in local business and industry publications as well as awards for outstanding participants from the County.

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Thomas Outerbridge
City Green Inc. Telephone Interview by author *on* October 21, 2004 (Written notes)

CP.5
MINIMIZE DISRUPTION AND IMPACT OF RIGHT-OF-WAY CONSTRUCTION

OBJECTIVE

Employ alternative contracting strategies and creative design and construction solutions to minimize the duration of street closures, traffic diversions and detours, noise and disruption resulting from construction work in the public right-of-way.

BENEFITS

+ Avoids impeding emergency vehicles.
+ Reduces work stoppages and construction delays.
+ Minimizes traffic congestion.
+ Reduces air and water pollution, and soil erosion.
+ Reduces comprehensive costs to area residents, workers, and businesses.
+ Reduces pavement degradation.
+ Reduces maintenance and rehabilitation costs for the City.
+ Improves infrastructure lifecycles.

LIMITATIONS

None.

INTEGRATION

- **SA.1** Assess Site and High Performance Opportunities
- **SS.1** Work with Community Groups to Enhance and Maintain Streetscape
- **PA.1** Maximize Pavement Lifecycle Citywide
- **UI.1** Minimize Impact of Utility Work
- **CP.1** Develop and Enforce a Site Protection Plan
- **CP.6** Use Cleaner Construction Equipment

TECHNICAL STRATEGIES

Impose "lane rental fees" for construction work that requires street or sidewalk closing: Requiring the contractor to pay a rental fee for closing lanes of traffic and sidewalks works as an effective incentive to minimize the disruption of construction work. The fee accrues based on the amount of time the contractor obstructs or occupies part of the roadway, and is based on the estimated cost of delay and inconvenience to the road user during this period.

- Standardize lane rental rates for different road types and locations throughout the City.
- Develop a range of fees for each location based on number of lane closings, type, time of day, etc.
- Affirm the lane rental fee in the bidding contract in units of dollars per lane per time increment.
- Deduct rental fee from progress payments.

Make judicious use of Incentives/Disincentives to accelerate work: Consider the use of bonus payments for early completion of construction, or penalties for late completion.[147]

Creative design and construction phasing to reduce impact to pedestrian and business patterns:

- Schedule project phases to occur simultaneously whenever possible.
- When design and construction alternatives exist, select the method that minimizes impact to community and environment.

EXAMPLE

A recent street reconstruction project in the Hunts Point section of the Bronx sought to minimize economic losses incurred by local wholesale fruit and vegetable distribution centers. The NYC DDC decided to construct a full-depth flexible asphalt pavement to give delivery trucks interim access during construction.

Generic Lane Rental Example: A single lane closure from 7:00 am to 2:00 pm would bill at $2,000 per hour from 7:00 to 9:00 am (rush hour) and $500 per hour from 9:00 am to 2:00 pm. The total estimated rental fees proposed by the contractor can be combined with the cost of work items and used as a criterion to determine the successful bidder.

REFERENCES

None.

[147] The NYC DOT and the NYS DOT base their Incentive/Disincentive policies in part on sample provisions issued by the FHWA. The FHWA policy on bonus payments is based in part on the evaluation of National Experimental and Evaluation Program (NEEP) Project #24 which showed that I/D provisions are a valuable cost-effective construction tool.

CP.6
USE CLEANER CONSTRUCTION EQUIPMENT

OBJECTIVE

Reduce diesel emissions from construction equipment through undertaking vehicle retrofits and through using cleaner alternatives to traditional diesel fuel.

BENEFITS

+ Reduces ground level ozone formation and particulate matter emissions.
+ Improves public health..
+ Increases visibility.
+ Reduces emissions of gaseous toxins.

LIMITATIONS

– Premature wear of engine components may occur if minimum fuel specifications are not met.
– Initial diesel distillate may have slightly lower energy content, increasing costs.
– Ultra-low sulfur diesel (ULSD) fuel will initially cost more due to currently limited market presence.

INTEGRATION

PA.5 Use Reduced-Emission Materials
SM.2 Prevent Water Pollution and Practice Source Control
CP.3 Protect Water Sources During Construction

BACKGROUND

In urban areas, diesel exhaust from construction vehicles may comprise as much as 36% of the fine particulate matter **(PM2.5)** mass,[148] 10% of all nitrogen oxide (NOx) pollution,[149] and contain a variety of other toxins, causing a serious threat to public health.[150] Despite progress in emissions control of heavy-duty diesel vehicles (HDDVs) in the mining sector and for public transportation vehicles, emission control of construction equipment – referred to as 'non-road' vehicles by the EPA – has not been widely implemented.[151]

Emissions from HDDVs can be reduced using a combination of cleaner fuel technologies and emission control retrofit devices. In 2003, New York City passed Local Law 77, legislation requiring the use of cleaner, ultra low sulfur diesel fuel (ULSD), in conjunction with 'Best Available Technology' (BAT), or retrofit devices such as oxidation catalysts, filters and adsorbers. Local Law 77 is part of the same legislative family as the US EPA Clean Air Non-road Diesel rule, which will also help significantly to reduce the risk that diesel emissions pose to public health.[152]

TECHNICAL STRATEGIES

Reduce Emissions from Vehicles and Construction Equipment.[153]

Use ultra-low sulfur diesel (ULSD) fuel: ULSD is a widely available petroleum diesel that has been modified in the refinery to reduce its sulfur content. ULSD fuel is mandated by the EPA for use in non-road construction equipment by 2010.[154]

- Use ULSD alone to yield modest emission improvements.
- Use ULSD in conjunction with after-treatment technologies to reduce particulate emissions by up to 90%.
- Consider blending ULSD with other substances to produce lower-impact ULSD fuel blends, including emulsified diesel, biodiesel, oxygenated diesel, and fuel-borne catalysts.

148 United States Environmental Protection Agency, Health Assessment Document for Diesel Engine Exhaust, USEPA/600/8-90/057F, May 2002.

149 Northeast States for Coordinated Air Use Management. Construction Equipment Retrofit Project Summary Report. Available at http://www.nescaum.org/pdf/CACI/retrosumm.pdf (Accessed October 2004)

150 PM2.5 , primarily composed of carbon particles, is New York City's primary pollutant, and is associated with a variety of serious health effects including asthma and other chronic respiratory problems. For more information see http://www.epa.gov/air/urbanair/pm/index.html.

151 Examples of vehicles covered here include front-end loaders, backhoes, excavators, cranes, air compressors and generators, and many more.

152 EPA estimates that by 2030, controlling these emissions will annually prevent 12,000 premature deaths, 8,900 hospitalizations, and one million workdays lost. The overall benefits ($80 billion annually) of this rule outweigh the costs by a ratio of 40 to 1. See http://www.epa.gov/otaq/regs/nonroad/equip-hd/basicinfo.htm

153 See the Low Sulfur Design Manual by the DDC Office of Sustainable for more details. http://nyc.gov/html/ddc/html/ddcgreen/reports.html

154 ULSD fuel typically has a sulfur content of 15 ppm or less, compared to 250-500 ppm for standard on-road diesel fuel and up to 3,000 ppm for standard off-road diesel fuel.

Employ after-treatment retrofits: These devices clean the exhaust after it leaves the engine but before it exits into the atmosphere. Usage of these technologies can reduce NOx and PM emissions by as much as 90%. Following are the seven most common, commercially available options, listed by regulated pollutant they address.[155]

After-treatment retrofits addressing particulate matter (PM):
- Diesel oxidation catalysts (DOC).[156]
- Catalyzed diesel particulate filters (DPF).[157]
- Active diesel particulate filters (Active DPF).

After-treatment retrofits addressing nitrogen oxide (NOx):
- Exhaust gas recirculation (EGR).
- Lean NOx Catalysts.
- NOx adsorbers.

After-treatment retrofits addressing both PM and NOx:
- Selective catalytic reduction (SCR).

Optimize emission control with fuel/technology combinations:
- Evaluate alternative fuel and after-treatment technology combinations for each type of diesel-powered construction vehicle or equipment.[158]
- Reevaluate regularly to incorporate technological advancements.

Consider applying existing regulations to all construction equipment: The EPA distinguishes on-road from non-road (bulldozers, loaders and cranes) vehicles159 and emission standards vary between the two. Additionally, certain regulations apply only to heavy-duty diesel vehicles (HDDV).[160] As regulations become more stringent for on-road and HDDVs, they will become easier to enforce for all vehicles.
- Regulate unnecessary idling or operation on all vehicles.[161]
- Perform opacity, or smoke tests, on all equipment as part of required safety inspections.
- When feasible, use alternative fuels and after-treatment retrofits on all generators, temporary and permanent, using combinations of technology as appropriate.

[155] Refer to DDC Low Sulfur Fuel Manual (see references) for detailed emission reductions, a general description and evaluation of each technology, and current feasibility.

[156] 10 DOCs and DPFs are said to reduce toxic emissions of formaldehyde, benzene, and other known gaseous carcinogens by as much as 70%. Data for other retrofit technologies unknown. See Northeast States for Coordinated Air Use Management. Construction Equipment Retrofit Project Summary Report. Available at http://www.nescaum.org/pdf/CACI/retrosumm.pdf (Accessed October 2004)

[157] Ibid.

[158] The New York City Department of Environmental Protection recently designated use of a fuel-borne catalyst in conjunction with a diesel oxidation catalyst as a 'Best Available Technology'

[159] Regulations for non-road vehicles were first adopted in 1996.

[160] Vehicles weighing in exceedence of 8,500 lbs

[161] Currently the New York State Department of Environmental Conservation regulates idling in HDDV. This may be difficult to extend to stationary non-road vehicles, and may be impractical during maintenance, while in stopped in traffic, and in cold weather.

EXAMPLES

The Central Artery/Tunnel Project (aka 'Big Dig') in Boston Massachusetts included construction vehicle detours, designation of truck routes, idling prohibitions, dust control measures, and retrofitted construction equipment.
See http://www.epa.gov/otaq/retrofit/retrobigdig.htm.

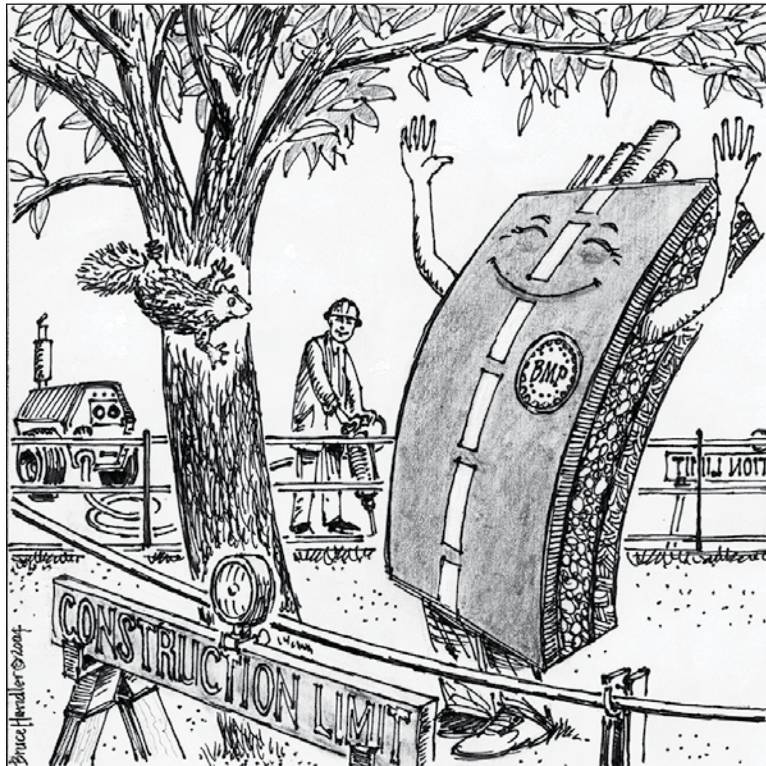
REFERENCES

DDC Office of Sustainable Design Low Sulfur Diesel Fuel Manual
June 2004
http://nyc.gov/html/ddc/html/ddcgreen/reports.html

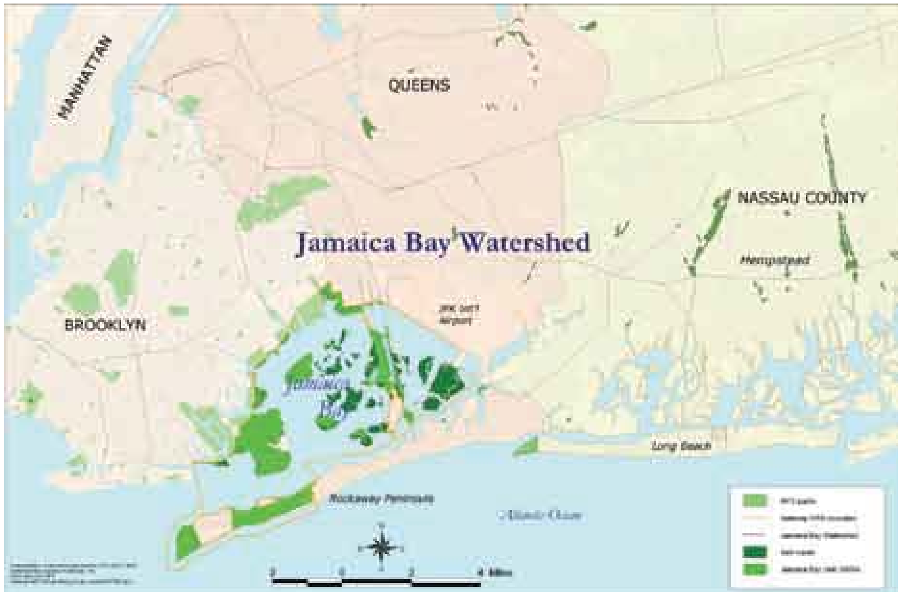
EPA Voluntary Diesel Retrofit Program Website
Designed to help fleet owners/operators, state/local government air quality planners, and retrofit manufacturers understand the diesel retrofit program and obtain information they need to create effective retrofit projects.
http://www.epa.gov/otaq/retrofit/overview.htm

EPA Non-road Diesel Equipment Home Page
http://www.epa.gov/otaq/regs/nonroad/equip-hd/basicinfo.htm

Northeast States for Coordinated Air Use Management
http://www.nescaum.org/



CONSTRUCTION PRACTICES



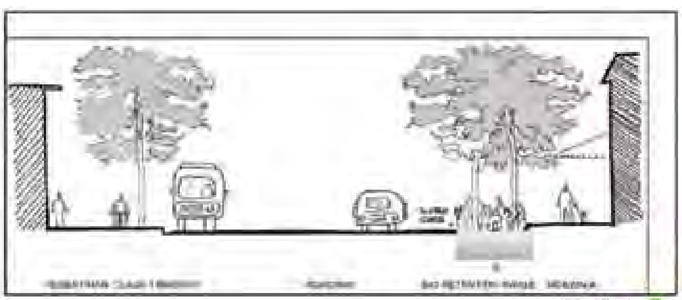
APPENDIX: GATEWAY ESTATES CASE STUDY

Concurrent with the research and development of this manual, the Guidelines development team conducted an initial high performance infrastructure planning simulation utilizing the final draft of the best management practices. This simulation addressed one of the largest segments of new infrastructure in decades: the Gateway Estates in southeast Brooklyn. Occupying 227 acres, Gateway Estates will provide over 2,000 affordable, owner-occupied one- and two-family homes; over 640,000 square feet of regional and neighborhood retail space; two new public schools; and two parks. At the behest of the Department of Housing, Preservation and Development, the DDC Infrastructure Division will install new storm and sanitary sewers, water mains, streets, streetlights, traffic signage, and signals. The project is currently in the early stages of infrastructure planning and development.

Undertaking a simulation workshop for Gateway Estates was significant given its sensitive location adjacent to Jamaica Bay, an endangered estuarine ecosystem. Part of Gateway National Recreation Area, Jamaica Bay is a habitat serving over 350 types of waterfowl and shorebirds, making it one of the best bird watching locations in the western hemisphere. In recent years, however, landfilling operations, channel dredging and water pollution, together with the hardening of the bay's shores with impervious infrastructure, have degraded and reduced salt-water marshes in the bay at an alarming rate. Given this predicament, opportunities exist to make the development of Gateway Estates a showcase of sustainable infrastructure strategies aimed at minimizing environmental impact while promoting revitalization of the area.

In the simulation, the team focused on strategies to promote landscape health and localized control and treatment of stormwater, both in the right-of-way and in the development's open spaces and parks. Other recommendations included design of alternative road geometries to promote pedestrian movement and bicycling, using recycled and reclaimed materials, coordinating utility infrastructure for easy access and maintenance, and so on. The following pages illustrate select strategies developed during the team's 2004 workshop. Throughout this planning simulation, the team tested the practicality of the Guidelines and the interdisciplinary nature of developing high performance infrastructure projects. Ultimately, the simulation helped inform the 'City Process' recommendations and enabled the team to fine-tune certain technical practices. Most importantly, the simulation demonstrated how the City could achieve meaningful social and environmental benefits through applying best management practices at Gateway Estates and on other future projects.

GATEWAY ESTATES – CASE STUDY PLAN AND SECTIONS



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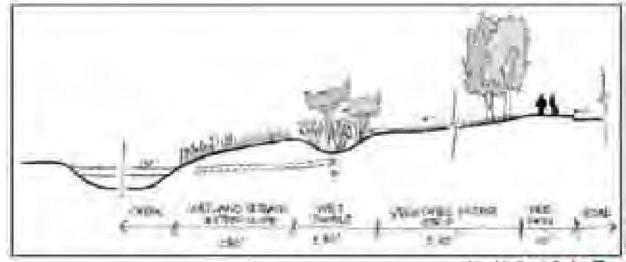

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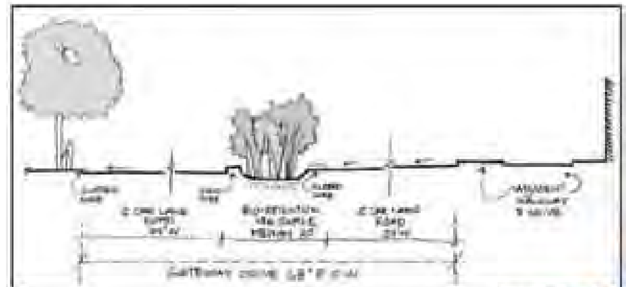

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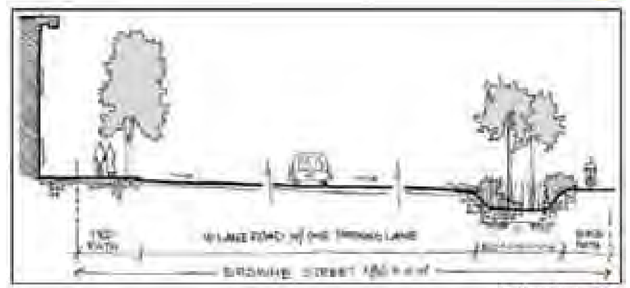

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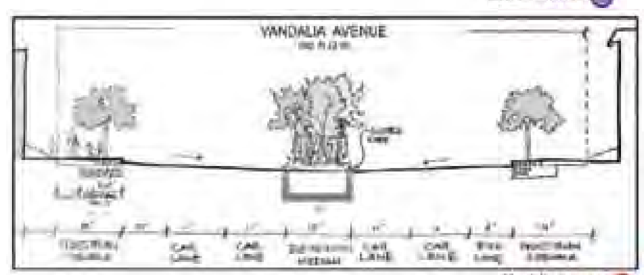

Vandalia Avenue
Section = N.T.S.

GLOSSARY

Acid rain: Acid rain is formed when sulfur dioxide and nitrogen oxides – pollutants resulting primarily from burning coal, oil, and other fossil fuels – mix with water vapor in the atmosphere to create acidic compounds. Acid rain impacts aquatic ecosystems and high altitude forests, creates haze, and contributes to the deterioration of buildings and historical monuments.

Albedo: The ratio of reflected light to the total amount falling on a surface. A high albedo indicates high reflectance properties.

Amenity: A tangible/intangible feature that enhances and adds to value or perceived value.

Asset management: A business process and a decision-making framework that covers an extended time horizon, draws from economics as well as engineering, and considers a broad range of assets. It incorporates the economic assessment of trade-offs among alternative investment options and uses this information to help make cost-effective investment decisions. For wastewater management utilities, asset management can be defined as managing infrastructure capital assets to minimize the total cost of owning and operating them, while delivering the service levels customers' desire.

Berm: A constructed, vegetated or paved embankment, somewhat dike-like in appearance, used for enclosure, separation or protective purposes.

Biodiversity: The tendency in ecosystems, when undisturbed, to have a large number and wide range of species of animals, plants, fungi, and microorganisms. Human population pressure and resource consumption tend to reduce biodiversity.

Bioremediation: A biotechnology that uses biological processes such as bacteria or plants to overcome environmental problems by removing or neutralizing contaminants or pollutants.

Bioswale: Strategically placed earthen depression that capture stormwater and filter it using native wetland plants.

Biotope: A biotope is a region definable by its specific environmental parameters and ecological conditions which support the organisms living there.

Brownfields: Abandoned, idled, or under-used industrial and commercial facilities/sites where expansion or redevelopment is complicated by real or perceived environmental contamination.

Buffer: A 'buffer' is a strip of heavily vegetated land that absorbs and filters runoff water.

Carbon dioxide (CO2): A naturally occurring greenhouse gas in the atmosphere, concentrations of which have increased (from 280 parts per million in pre-industrial times to over 350 parts per million today) as a result of humans' burning of coal, oil, natural gas and organic matter (e.g., wood and crop wastes).

Climate change: A regional change in temperature and weather patterns. Current science indicates a discernible link between climate change over the last century and human activity, specifically the burning of fossil fuels.

Coal fly ash: A byproduct of coal burning at electric utility plants.

Combined sewer overflow (CSO): Combined sewers are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe. Most of the time, combined sewer systems transport all of their wastewater to a sewage treatment plant, where it is treated and then discharged to a water body. Combined sewer overflows contain stormwater but also untreated human and industrial waste, toxic materials, and debris. This overflow is a major water pollution concern.

Composting: A process whereby organic wastes, including food wastes, paper, and yard wastes, decompose naturally, resulting in a product rich in minerals and ideal for gardening and ideal for gardening and farming as a soil conditioner, mulch, resurfacing material, or landfill cover.

Composite pavement: Pavement that has a sub-base of cement-bound material and uses less asphalt than conventional asphalt paving, offering a considerable saving.

Constructed wetlands: Engineered wetlands that simulate natural wetland and utilize natural and biological processes for wastewater treatment. Includes surface and subsurface flow constructed wetlands.

Context Sensitive Design (CSD): The art of creating public works projects that meet the needs of the users, the neighboring communities, and the environment. It integrates projects into the context or setting in a sensitive manner through careful planning, consideration of different perspectives, and tailoring designs to particular project circumstances. It uses a collaborative, interdisciplinary approach that includes early involvement of key stakeholders to ensure that transportation projects are not only 'moving safely and efficiently,' but are also in harmony with the natural, social, economic, and cultural environment. CSD requires an early and continuous commitment to public involvement, flexibility in exploring new solutions, and an openness to new ideas. Community members play an important role in identifying local and regional problems and solutions that may better meet and balance the needs of all stakeholders. Early public involvement can help reduce expensive and time-consuming rework later on and thus contributes to more efficient project development.

Curb cuts: A ramp built into a sidewalk to facilitates pedestrian or wheel chair travel between sidewalk and street elevations. In accordance to the American with Disabilities Act Standards for Accessible Design, curb ramps shall be provided wherever an accessible route crosses a curb.

Data management: A system that manages attribute and documentary product data, as well as relationships between them, through a relational database system.

Design charrette: The charrette process is a focused workshop that takes place in the early phase of the design process. All project team members meet together to exchange ideas, encouraging generation of integrated design solutions.

Ecological connectivity: The maintenance of a connected system of open space throughout an ecosystem. Not only is a contiguous line of open space maintained, but also specific natural systems are kept intact. Ecological connectivity relies on maintaining ecotones, the linkages between different ecological regions.

Ecotones: A habitat created by the juxtaposition of distinctly different habitats; an edge habitat; or an ecological zone or boundary where two or more ecosystems meet.

Ecosystems: An interactive system that includes the organisms of a natural community association together with their abiotic physical, chemical and geochemical environment.

Embodied energy: Embodied energy accounts for all energy expended for production and transportation plus inherent energy at a specific point in the life cycle of a product.

Environmental Matrix: A design tool that defines the environmental requirements for a project including (identify for infrastructure)

Environmentally preferable: Products or services that have a lesser or reduced effect on human health and the environment when compared with competing products or services that serve the same purpose. This comparison may consider raw materials acquisition, production, manufacturing, packaging, distribution, reuse, operation, maintenance, or disposal of the product or service.

Ericaceous species: Plants affiliated with the Ericacae (Heath family), typically acid-loving, low growing plants that are intolerant of alkaline soils.

Erosion: The wearing away of the land surface by running water, wind, ice or other geological agents including such processes as gravitational creep.

Evapotranspiration: A combined process of both evaporation from soil and plant surfaces and transpiration through plant canopies. Water is transferred from the soil and plant surfaces into the atmosphere in the form of water vapor.

Fill: Material used to make up the percentage of missing earth or other material so as to produce a stable site.

Flexibility in Highway Design: Design that balances the need for highway improvement with the need to safely integrate the design into the surrounding natural and human environments.

Fossil fuel: A fuel, such as coal, oil, and natural gas, produced by the decomposition of ancient (fossilized) plants and animals.

Global warming: Increase in the average temperature of the earth's surface. (See 'greenhouse effect').

Grading: Includes initial clearing, brushing or grubbing, subsequent excavating or filling of earth, stockpiling, terracing, road building, leveling and bulldozing on any property

Ground granulated blast furnace slag (GGBFS): The glassy granular material formed when molten blast-furnace slag is rapidly chilled by immersion in water with or without compositional adjustments made while the blast-furnace slag is molten. It is graded by its performance with Portland cement. Grade 80 being the lowest performer and grade 120 the highest, the quality of GGBFS will be controlled by the fineness of grind and its chemical composition

Greywater: Wastewater that does not contain sewage or fecal contamination and can usually be reused for irrigation after filtration.

Greenhouse effect: The process that raises the temperature of air in the lower atmosphere due to heat trapped by greenhouse gases, such as carbon dioxide, methane, nitrous oxide, chlorofluorocarbons, and tropospheric (ground level) ozone.

Habitat: The place where a population (e.g. human, animal, plant, microorganisms) lives and its surroundings, both living and non-living.

Heat sink: Area where heat is greatly absorbed and concentrated

Herbaceous species: Non-woody plants, typically herbs and grasses that occupy the understory and are usually grown from seed as a vegetative ground cover.

Hydro chlorofluorocarbon (HCFC): HCFCs deplete to a lesser extent stratospheric ozone, compared to chlorofluorocarbons. HCFCs are generally used to replace CFCs where mandates require CFCs to be eliminated. A total ban on all CFCs and HCFCs is scheduled effective 2030.

Hydrology: The science dealing with the properties, distribution and circulation of water.

Impervious surface: Constructed surfaces such as: rooftops, sidewalks, roads, and parking lots - covered by impenetrable materials such as asphalt, concrete, brick, and stone. These materials seal surfaces, repel water and prevent precipitation and melt-water from infiltrating soils.

Industrial ecology: A rapidly–growing field that systematically examines local, regional, and global materials and energy uses and flows in products, processes, industrial sectors and economies. It focuses on the potential role of industry in reducing environmental burdens throughout the product life cycle, from the extraction of raw materials, to the production of goods, to the use of those goods to the management of the resulting waste.

Infiltration: The passage of water through a myriad of voids in the receiving ground.

Integrated pest management: A coordinated approach to pest control that is intended to prevent unacceptable levels of pests by the most cost-effective means with the least possible hazard to building occupants, workers, and the environment.

Invasive species: Plants that are 1) non-native to the ecosystem under consideration and 2) whose introduction causes or is likely to cause economic or environmental harm by competing for space and resources. The spread of invasive species results in monoculture and hence a decrease in habitat diversity.

Life cycle: The life cycle of a product are all stages of a product's development, from extraction of fuel for power to production, marketing, use and disposal.

Life cycle assessment: The comprehensive examination of a product's environmental and economic aspects and potential impacts throughout its lifetime, including raw material extraction, transportation, manufacturing, use and disposal.

Life cycle cost: The amortized annual cost of a product, including capital costs, installation costs, operating costs, maintenance costs, and disposal costs discounted over the lifetime of a product.

Light pollution: Light pollution – excess brightness in the sky resulting from direct and indirect lighting above urban areas – has had a negative impact on the urban ecology, disrupting biological cycles in plants and animals. It has also been hypothesized that human health requires a certain amount of exposure to darkness. The amount of energy wasted in lighting the sky or outdoor and indoor spaces, which do not need it, has been estimated conservatively to reach approximately $2 billion per year in the US.

Locally manufactured material: Building materials manufactured locally the use of which reduces the environmental impacts resulting from their transportation and support the local economy. According to the LEED Green Building Rating System, a guide for green and sustainable design, manufacturing refers to the final assembly of components into the building product that is furnished and installed by the tradesmen. Per LEED, the material or product must be manufactured within 500 miles of the project.

Material safety data sheet (MSDS): Forms that contain brief information regarding chemical and physical hazards, health effects, proper handling, storage, and personal protection appropriate for use of a particular chemical in an occupational environment.

Mulch: An organic or inorganic material which is spread or allowed to remain on the soil surface to conserve soil moisture and shield soil particles from the erosive forces of raindrops and runoff. Mulch also serves to moderate soil temperature, discourages weeds and a good, organic mulch will introduce nutrients into the soil as it decomposes.

Native species: Plant species that have evolved or are indigenous to a specific geographical area. The strict definition is a species that has not been introduced by humans either accidentally or intentionally. Because native species are a part of an ecosystem where everything is interdependent, these plants are adapted to local soil and weather conditions as well as pests and diseases.

Nitrogen oxide (NOx): A product of combustion from transportation and stationary sources such as power plants. NOx is a major contributor to acid rain and to ground level ozone (the primary component of smog).

Non-destructive: Methods of conducting maintenance or testing of right-of-way systems that will not damage the system or any adjacent right-of-way components.

Non-motorized vehicles: Bicycling and walking, forms of non-motorized transportation, help reduce emissions or concentrations of air pollutants from transportation sources.

Operations and maintenance: Operations refers to how equipment or systems are run, e.g., when a system should be turned on, temperature ranges, set points for boiler pressures and temperatures, thermostat set points, etc. Maintenance refers to servicing or repair of equipment and systems. 'Preventive maintenance' performed on a periodic or schedule basis to ensure optimum life and performance is designed to prevent breakdown and unanticipated loss of production or performance. 'Corrective' or 'unscheduled' maintenance refers to repairs on a system to bring it back 'on-line.' 'Predictive' maintenance is performed on equipment monitor for signs of wear or degradation, e.g., through thermography, oil analysis, vibration analysis, maintenance history evaluation.

Ozone:
1. Stratospheric ozone: In the stratosphere (the atmosphere layer beginning 7 to 10 miles above the earth), ozone is a form of oxygen found naturally which provides a protective layer shielding the earth from ultraviolet radiation's harmful effects on humans and the environment.
2. Ground level ozone: Ozone produced near the earth's surface through complex chemical reactions of nitrogen oxides, volatile organic compounds, and sunlight. Ground level ozone is the primary component of smog and is harmful to humans and the environment.

Ozone depleting substances: Substances used in HVAC systems and fire suppression systems and extinguishers that deplete the stratospheric ozone layer. Refrigerants include CFCs, Hydro chlorofluorocarbons (HCFCs) and their alternatives including HFCs. A bromine containing substance, Halon, is used in fire suppression systems and fire extinguishers. Halon production has been banned and other substances are being phased out in the U.S.

Pervious paving: See porous pavement.

Photovoltaic panels (PVs): Photovoltaic devices use semiconductor material to directly convert sunlight into electricity. Power is produced when sunlight strikes the semiconductor material and creates an electric current.

Post-consumer recycled content: Post-consumer material is a material or finished product that has served its intended use and has been discarded for disposal or recovery, having completed its life as a consumer item.

Porous pavement: Paving specifically designed and constructed to encourage rapid infiltration and percolation of rainfall and stormwater through the entire pavement cross-section, and maintain this function over many decades, while directly supporting traffic loads. A permeable pavement surface with an underlying stone reservoir that temporarily stores surface runoff before infiltrating into the subsoil.

Pre-consumer recycled content: Pre-consumer material is material diverted from the waste stream following an industrial process, excluding reutilization of materials such as rework, regrind or scrap generated in a process and capable of being reclaimed within the same process. Synonyms include post-industrial and secondary material.

Recycling: The series of activities, including collection, separation, and processing, by which products or other materials are recovered from the solid waste stream for use in the form of raw materials in the manufacture of new products other than fuel for producing heat or power by combustion.

Renewable energy: Energy resources such as wind power or solar energy that can keep producing indefinitely without being depleted.

Right-of-way (ROW): Right of passage, as of another's property. 2. A route that is lawful to use. 3. A strip of land acquired for transport or utility construction. 4. The design area of a roadway, which includes the pavement width, vegetated strip, sidewalk and space, designated for soil erosion control.

Riparian corridors: Riparian corridor or buffer, a type of ecotone, is the zone between a river or stream, and an upland area. Both areas are home to many specialized plants and animals that respond to changes in aquatic and terrestrial influences, and which actually depend on this rapidly changing environment to function and survive.

Root paths: A narrow zone of growing medium that permits plant roots to reach a larger surrounding soil mass to draw minerals and water.

Runoff: Runoff from a rainstorm or melting snow

Sedimentation: The (unwanted) settling and depositing of loose dirt in a given area.

Shade-light continuum: The shade-light continuum is a product of the natural progression in the height of species of a specific biotope, resulting in different levels of shade and light availability. Effective shade management uses plants to block sunlight from striking the soil surface and to intercept, scatter and reflect radiant energy to protect paved surfaces from direct sunlight. This planting strategy mimics natural distribution of canopy, understory, shrub, and herbaceous layers based on sunlight/shade tolerance of individual plant species.

Structural soils: New development in planting structure design developed by Cornell's University Urban Horticulture Institute that uses crushed rock for strength, with soil filling the spaces in the gravel. Strong enough to support paving like base course, yet even when compacted to full strength, has space for plant roots to grow through.

Stormwater management: Stormwater management consists of programs to reduce, control and treat rainfall runoff as part of an effort to minimize flooding, water pollution, erosion, sedimentation, and aquatic habitat damage. Stormwater management best management practices (BMPs) are structural or bioengineered devices designed to store, treat, and either retain, convey or infiltrate runoff.

Sulfur dioxide (SO2): An air pollutant formed primarily by coal and oil burning power plants. SO2 combines with other pollutants to form acid rain.

Sustainable forest products: Wood products originating from a forest certified for Sustainable Forest Management through various agencies and verified through an independent chain of custody audit. This creates an opportunity for both suppliers and buyers of forest products to demonstrate and communicate their commitment to sustainable forest management. It creates market incentives for producers to responsibly manage forests and harvest timber, gives consumers the power to positively 'vote' for conservation when they buy certified wood products, and contributes to the preservation of forests and forest wildlife worldwide.

Traffic calming: A new approach to roadway design in the U.S. that originated from safety concerns and has a significant potential to reduce environmental impact. Outdated design standards emphasize extra wide, straight, flat roads to increase the number of vehicles and speed. Traffic calming measures reduce lane width, introduce roadside 'friction' features like street trees, and prominently defines pedestrian crossing points.

Trenchless technology: Underground construction methods that eliminate or minimize surface disruption. Trenchless methods include auger boring, directional drilling, robotic fiber-optic installation, manhole rehabilitation, micro tunneling, pipe bursting/splitting, pipe jacking, pipe fusion, pipe ramming, pipe relining, pipe inspection and cleaning systems, robotic sewer repair methods, rock drilling, utility tunneling and vacuum excavation

Urban heat island effect: The additional heating of the air over a city as the result of the replacement of vegetated surfaces with those composed of asphalt, concrete, dark-colored roofing and other heat-retaining man-made materials. These materials store much of the sun's energy, producing a dome of elevated air temperatures up to 10OF greater over a city compared to air temperatures over adjacent rural areas. Light colored rooftops and lighter colored pavement can help to dissipate heat by reflecting sunlight, and tree planting can further help modify the city's temperature through shading and evapotranspiration.

Utility infrastructure: All the physical elements that comprise the utilities, i.e. water, electricity, gas, sewage disposal, etc., and that provide for their delivery to citizens of a community.

Volatile organic compound (VOC): Volatile organic compounds (VOCs) are chemicals that contain carbon molecules and are volatile enough to evaporate from material surfaces into indoors air at normal room temperatures (referred to as off-gassing). Examples of building materials that may contain VOCs include, but are not limited to: solvents, paints adhesives, carpeting and particleboard. Signs and symptoms of VOC exposure may include eye and upper respiratory irritation, nasal congestion, headache and dizziness.

Watershed: Watershed is all the land area that drains to a given body of water.

Wetlands: Environment characterized by shallow or fluctuating water levels and abundant aquatic and marsh plants. Includes marches, swamps, bayous, bogs, fens, sloughs, and ponds.

Xeriscape: Landscape that uses drought-tolerant vegetation instead of turf to reduce the amount of water required to maintain a lawn.

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