GOWANUS CANAL AND BAY ECOSYSTEM RESTORATION PROJECT
BROOKLYN, KINGS COUNTY, NEW YORK

LITERATURE SEARCH
FOR THE
WETLAND CREATION GENERAL INVESTIGATION REPORT

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1.0 INTRODUCTION

This Literature Search was conducted by the United States Army Corps of Engineers (USACE), New York District (District), as part of the Wetland Creation General Investigation Report (Report) for the Gowanus Canal and Bay Ecosystem Restoration Project (Project), in Brooklyn, New York (Figure 1). This Project was authorized by the United States House of Representatives Committee on Transportation and Infrastructure Resolution, dated 15 April 1999 (Docket Number 2596), to determine the feasibility of environmental restoration and protection relating to water resources and sediment quality within the New York Port District, including but not limited to creation, enhancement, and restoration of aquatic, wetland, and adjacent upland habitats. The Port District is centered on the New York-New Jersey Harbor, and is located within the Hudson-Raritan Estuary.

The USACE entered into a Feasibility Cost Sharing Agreement on 8 January 2002 with the New York City Department of Environmental Protection (NYCDEP), the non-Federal sponsor for the Project. The Feasibility Phase began 1 February 2002.

1.1 PROJECT DESCRIPTION

The Project area includes the Gowanus Canal, Channel, Bay, and immediate surrounding upland areas (Figure 1). The Gowanus Bay extends from the Bay Ridge Channel in Upper Bay, New York Harbor, to the beginning of the Gowanus Creek Channel. The Gowanus Creek Channel is a Federally maintained waterway that extends from the Gowanus Bay, 0.8 miles northeast, to the Hamilton Avenue Bridge. The Gowanus Canal is not a Federally maintained waterway, and extends from the Hamilton Avenue Bridge, north approximately 1 mile to its terminus at the mouth of the Flushing Tunnel, located south of Butler Street. The Gowanus Canal and Channel are located in a highly developed section of Brooklyn. The focus area for the Report is the Gowanus Canal proper, and areas immediately surrounding the Canal to the nearest hardened shoreline (Figure 2).

The Gowanus Canal was constructed in 1881 to accommodate industrial users and commercial shippers to the Brooklyn waterfront. As a result, the canal has been subject to over a century of heavy industrial use and is now characterized by poor water quality, contaminated sediments, deteriorating bulkheads, a poor benthic community structure, extensive filling, hardened shorelines, and unpleasant odors. Despite dramatic improvements in water quality over the last several decades, there continue to be episodic discharges of untreated sewage associated with periods of heavy precipitation beyond the capacity of the combined storm and sanitary sewer outfalls (CSOs). CSOs convey human pathogens, a variety of industrial wastes, and floatable materials into the waterways. Non-point source pollution from lawns, roads, broken septic tanks, construction sites, and other disturbed areas provide additional sources of contaminants to the Canal, including sediment, fertilizers, pesticides, bacteria, viruses, salt, oils, grease, and heavy metals (NYCDEP 2003).

1.2 GOALS

The goal of this Project is ecosystem restoration for the purpose of providing habitat for fish, wildlife, and benthic invertebrates, increasing biodiversity and productivity in the Canal, and removing suspended solids and pollutants/contaminants that are dissolved or transported in water prior to their deposition or infiltration into the Gowanus Canal. The goal of the Report is to present a feasibility level review of the potential for creating wetlands in the Gowanus Canal. Created wetlands are one type of stormwater management practice, and will hereafter be included under a more general description in Section 2.0 as Management Practices. These management practices, in addition to providing habitat and increasing biodiversity and productivity, could be used for containing, maintaining, and treating sources of contamination and sedimentation to the Canal prior to entering the waterway. These constructed wetland systems would be located either at the upper limits of the tidal range, to intercept urban runoff and CSO discharges, or completely within the Canal, handling daily tidal exchange.

This Literature Search focuses on wetland creation opportunities, and other stormwater management practices that could be used in an urbanized and heavily polluted waterway. The following sections include a description of the management practices and vegetation identified during this Literature Search. The Conceptual Designs will explore in more detail those management practices or wetland creation opportunities identified that could potentially be used in the focus area for the Report. The Report will link potential management practices or wetland creation opportunities with the specific wetland creation sites identified.

Figure 1. Project Location for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York.

Figure 2. Focus Area for the Wetland Creation General Investigation Report, Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York.

2.0 MANAGEMENT PRACTICES

Wetland creation is one of a variety of management practices, techniques, and systems available that are designed to remove suspended solids and pollutants/contaminants that are dissolved or transported in water prior to their deposition or infiltration into the waters down gradient (i.e., Gowanus Canal), while also providing habitat for fish, wildlife, and benthic invertebrates, and increasing local biodiversity and productivity. The following sections briefly describe the management practices identified. In addition, Table 1 provides more detailed information on each management practice, including the size of the area required for treatment, minimum vertical distance required, approximate construction costs, maintenance requirements, advantages and disadvantages, and applicable situations for use of each management practice. Table 2 links each management practice with pollutant removal capabilities, and Table 3 summarizes the articles identified during this Literature Search.

2.1 STORMWATER WETLANDS

Stormwater wetlands are shallow, constructed wetlands designed to capture stormwater runoff and allow it to infiltrate through vegetation and soils. Vegetation within the wetland acts to reduce stormwater runoff velocity and trap sediments and pollutants as the runoff flows through the wetland. Stormwater wetlands also provide habitat for wildlife and add an aesthetically pleasing element to public places. Types of stormwater wetlands include shallow wetlands, extended detention wetlands, pond/wetland system, and pocket wetlands. Determining which type of stormwater wetland would best fit at a particular site is primarily based on site topography, size of site, underlying substrate, depth to water table, and availability of water to feed the wetland. More specific details on stormwater wetlands are presented in Table 1.

Stormwater wetlands are one of the most effective management practices at reducing pollutant levels in stormwater runoff (Hunt and Doll 2000). Stormwater wetlands are capable of removing pollutants by means of sedimentation, filtration, adsorption onto soil particles, microbial activity (i.e., nitrification and denitrification), and plant uptake (Hunt and Doll 2000). These pollutant removal mechanisms effectively reduce levels of suspended sediments, phosphorous, nitrogen, nitrate-nitrogen (N-N), trace metals (zinc, lead, and copper), and bacteria. Pollutant removal capabilities for stormwater wetlands are presented in Table 2.

Thirteen documents were identified that provide information regarding stormwater wetlands as a method of stormwater management. The documents provide general information on creating stormwater wetlands and on their ability to improve water quality, reduce runoff velocity, and remove pollutants and sediment. These data are summarized in Table 3.

2.2 STORMWATER PONDS

A stormwater pond is a land depression created for the detention or retention of stormwater runoff, which is maintained as a permanent pool of water to enhance pollutant removal. A

vegetative buffer surrounding the pond helps remove pollutants and provides habitat for wildlife. There are several types of stormwater ponds, including micropool extended detention ponds, wet ponds, wet extended detention ponds, dry extended detention ponds, a multiple pond system, and pocket ponds. There are few limitations for the location of stormwater ponds, however the site must be large enough to accommodate heavy volumes of stormwater runoff and contain a permanent pool of water. More specific details on stormwater ponds are presented in Table 1.

Stormwater ponds are considered moderately to highly capable of sediment and pollutant removal when compared with other management practices (Osmond et. al. 1995). Ponds are most effective at reducing suspended sediments and soluble nutrients. Although highly effective at removing lead, stormwater ponds are not as effective at removing other trace metals, such as zinc or copper. Studies have shown variable rates of bacterial uptake (Claytor and Schueler 1996). Pollutant removal capabilities for stormwater ponds are presented in Table 2.

Seven documents were identified that provide information regarding stormwater ponds as a method of stormwater management. The documents provide general information on creating stormwater ponds and on their ability to improve water quality, reduce runoff velocity, and remove pollutants and sediment. These data are summarized in Table 3.

2.3 INFILTRATION PRACTICES

There are several types of infiltration practices, including basins, trenches, and wells, that are designed to capture and temporarily store stormwater before allowing it to infiltrate into the soil. Infiltration practices require permeable soils that allow water to leave the storage basin and penetrate the underlying soil (Osmond et. al. 1995). Infiltration devices can be small enough to be implemented in or adjacent to urban areas. One advantage of infiltration devices is that they provide significant groundwater recharge, providing a medium through which surface water can percolate through to ground water (Osmond et. al. 1995). More specific details on infiltration practices are presented in Table 1.

When compared with other management practices, infiltration devices can be highly effective at removing suspended sediments and pollutants. Suspended sediments settle out of stormwater runoff, filling in pore spaces, and pollutants adhere to the sediments, effectively removing them from the water column. However, over time, infiltration devices can become clogged with sediment, making them less effective. Maintenance may be required to restore sediment and pollutant removal efficiencies. Infiltration devices are highly effective at reducing soluble nutrients phosphorus and nitrogen, and trace metals, such as lead, zinc, or copper. Pollutant removal capabilities for infiltration practices are presented in Table 2.

Five documents were identified that provide information regarding infiltration practices as a method of stormwater management. The documents provide general information on implementing infiltration practices and on their ability to improve water quality, reduce runoff velocity, and remove pollutants and sediment. These data are summarized in Table 3.

2.4 POROUS PAVEMENT

There are two types of porous pavement: modular block porous pavement and porous asphalt. Both are composed of a permeable pavement surface with an underlying stone reservoir designed to remove pollutants, minimize surface runoff, and to reduce imperviousness. This type of management practice is often considered an infiltration practice due to its ability to store surface runoff before it infiltrates into the subsoil. However, it is also considered an alternative to conventional pavement and is recommended for low traffic parking lots or roadways because of its ability to reduce imperviousness (Osmond et. al. 1995). More specific details on porous pavement are presented in Table 1.

Porous pavement acts as a conveyance layer to the underlying aggregate chamber, which functions as an infiltration device. Similar to other infiltration devices, pollutant removal is achieved through adsorption by soil, filtration, and microbial decomposition. Porous pavement systems have been shown to have high removal rates for suspended sediments, although this often leads to clogging of the subsoil and subsequent failure of the infiltration device. Furthermore, the systems have been shown to have high removal rates of nutrients, organic matter, and trace metals that are largely due to a transfer to groundwater (Osmond et. al. 1995). Pollutant removal capabilities for porous pavement are presented in Table 2.

Three documents were identified that provide information regarding porous pavement as a method of stormwater management. The documents provide general information on limiting factors for using porous pavement and on their ability to improve water quality, reduce runoff velocity, and remove pollutants and sediment. These data are summarized in Table 3.

2.5 FILTERING PRACTICES

Filtering practices are designed to capture and temporarily store stormwater and then pass it through a filter bed of sand, organic matter, or another acceptable treatment media (NYSDEC 2001). There are several types of filtering practices, including surface sand filters, underground sand filters, perimeter sand filters, organic filters, and pocket sand filters. Determining which type of filtering practice would best fit at a particular site is primarily based on site topography, size of site, and the underlying substrate. More specific details on filtering practices are presented in Table 1.

Filtering practices are highly effective at reducing the amount of suspended sediments from stormwater runoff (Claytor and Schueler 1996). However, most filtering devices are only moderately effective at reducing soluble nutrients, trace metals, and bacteria. Pollutant removal capabilities for filtering practices are presented in Table 2.

Four documents were identified that provide information regarding filtering practices as methods of stormwater management. The documents provide general information on limiting factors for using the filtering practices, and their ability to improve water quality, reduce runoff velocity, and remove pollutants and sediment. These data are summarized in Table 3.

2.6 FILTER STRIPS

Filter strips are designed to treat stormwater runoff from adjacent surfaces and remove sediments and pollutants through filtration and infiltration. Filter strips rely on a vegetated surface to reduce runoff velocities and filter sediments and pollutants from stormwater runoff. Filter strips are most suited for use in areas adjacent to roads, parking lots, or other similar types of impervious surfaces, which often distribute runoff in sheet flow across the surface. More specific details on filter strips are presented in Table 1.

Filter strips are highly effective at reducing the amount of suspended sediments from stormwater runoff (Claytor and Schueler 1996). However, filter strips are only moderately effective at reducing levels of trace metals and soluble nutrients. Pollutant removal capabilities for filter strips are presented in Table 2.

Five documents were identified that provide information regarding filter strips as a method of stormwater management. The documents provide general information on limiting factors for using filter strips and on their ability to improve water quality, reduce runoff velocity, and remove pollutants and sediment. These data are summarized in Table 3.

2.7 SUBMERGED GRAVEL STRIPS

Submerged gravel strips are designed as a single cell or a series of cells that are filled with crushed rock or gravel, supporting a wetland vegetation cover crop. In this wetland design, stormwater runoff is directed into the underlying gravel layer, rather than entering the system via surface or sheet flow. Wetland plants are rooted in the surface layers of submerged gravel strips (Schueler and Holland 2000). The gravel substrate acts as a filtration device while the plants take up pollutants through their roots. The bottom of the wetland is sealed with a liner which is then covered with a layer of muck, preferably extracted from an adjacent wetland to introduce denitrifying bacteria into the system (Schueler and Holland 2000). Submerged gravel strips are most suited for use in areas adjacent to roads, parking lots, or other similar types of impervious surfaces, which distribute a significant volume of stormwater runoff. More specific details on submerged gravel strips are presented in Table 1.

Submerged gravel strips are highly effective at reducing the amount of suspended sediments, total phosphorus, total nitrogen, and nitrate-nitrogen in stormwater runoff (Schueler and Holland 2000). However, this practice is only moderately effective at removing trace metals. Few documented studies have analyzed the capacity of submerged gravel strips to remove bacteria. However, a study by Schueler and Holland (2000) demonstrated a removal rate of 78 percent. Pollutant removal capabilities for submerged gravel strips are presented in Table 2.

Three documents were identified that provide information regarding submerged gravel strips as a method of stormwater management. The documents provide general information on limiting factors for using submerged gravel strips and on their ability to improve water quality, reduce runoff velocity, and remove pollutants and sediment. These data are summarized in Table 3.

2.8 BIO-RETENTION

Bio-retention is a relatively new practice that incorporates soils, vegetation, and landscaping to treat urban stormwater runoff and enhance stormwater quality by collecting it in shallow depressions and allowing it to filter through a combination of soils and vegetation. This practice is designed to capture sheet flow from impervious areas and treat it by using a combination of microbial soil processes, infiltration, evapotranspiration, and plants. Bio-retention areas are best suited for use in commercial parking lots, specifically when implemented as median strips and islands within parking lots. More specific details on bio-retention are presented in Table 1.

There is considerable variation in the effectiveness of pollutant removal from bio-retention areas. However, proper design and maintenance may improve their performance (USEPA 2004). Bio-retention areas are highly effective at reducing the amount of suspended sediments in stormwater runoff; however, this may result in clogging of the filtering medium (Hunt 1999). This method is moderately effective at removing total phosphorus, total nitrogen, and trace metals. Pollutant removal capabilities for bio-retention areas are presented in Table 2.

Five documents were identified that provide information regarding the implementation of bio-retention areas for the purpose of stormwater management. The documents provide general information on limiting factors for using bio-retention areas and on their ability to improve water quality, reduce runoff velocity, and remove pollutants and sediment. These data are summarized in Table 3.

2.9 OPEN VEGETATED CHANNELS

Open vegetated channels are earthen channels vegetated with a dense growth of hardy grass designed to convey stormwater runoff, remove pollutants, and reduce runoff velocity. Determining which type of channel would best fit at a particular site is primarily based on volume of stormwater runoff received in the area. Open vegetated channels can be designed as a drainage channel, grassed channel, dry swale, or wet swale. The drainage channel design is typically used to convey large volumes of water during major flooding events. A grassed channel achieves greater pollutant removal than the drainage channel because it is designed to have a broader bottom, lower slopes, and denser vegetation. A dry swale is an open drainage channel or depression, explicitly designed to detain and promote the filtration of stormwater runoff into an underlying soil media. A wet swale is similar to a dry swale except that it is designed to retain water or intercept groundwater for water quality treatment (Claytor and Schueler 1996). Open vegetated channels are most suited for use in areas within residential communities, adjacent to parking lots, and as highway median strips. More specific details on open vegetated channels are presented in Table 1.

All types of open vegetated channels are considered highly capable at reducing the amount of suspended sediments in stormwater runoff. However, pollutant removal capabilities may vary based on the design of the channel. Pollutant removal capabilities for open vegetated channels are presented in Table 2.

Five documents were identified that provide information regarding the implementation of open vegetated channels for the purpose of stormwater management. The documents provide general information on the design of each type of channel and on the ability of open vegetated channels to improve water quality, reduce runoff velocity, and remove pollutants and sediment. These data are summarized in Table 3.

Table 1. Summary of Management Practices for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York.

Practice	Size (% of Drainage Area)	Minimum Vertical Distance	Construction Costs	Maintenance Requirements	Advantages	Disadvantages	Applicable Situation
Stormwater Wetlands (shallow wetland, extended detention wetland, pond/wetland system, pocket wetland)	3-5%[6]	6-8 inches[8]	Cost per acre is moderate.[7]	Maintenance costs are generally about 2% per year of the construction costs.[5]	Highest pollutant removal option. Ideal site for educational purposes.[1]	Most land-intensive.[1] Potential breeding ground for mosquitos.[3]	Wetlands may be created in almost any area large enough to accommodate the amount of water draining from adjacent surfaces.
Stormwater Ponds (micropool extended detention pond, wet pond, wet extended detention pond, multiple pond system, pocket pond)	2-3%[6]	Maximum of 8 feet, with an average of 4-6 feet.[8]	Construction costs can be somewhat high.[1]	Maintenance consists of mowing, annual inspections, sediment removal.[8] Costs are approx. 3-5% of the construction cost per year.[3]	Traditional, aesthetically pleasing. Also useful for recreational purposes and wildlife habitat.[3]	Relatively land-intensive. Safety issues.[1]	*Not feasible in Project area because ponds typically require a larger area.*
Infiltration Practices (basin, trench, well)	2-3%[6]	N/A	Relatively low design and construction cost.[1]	Must be maintained regularly to prevent clogging.[3]	Introduces surface water to ground water. Not very land-intensive or highly visible, can be used in residential or commercial areas.[3]	Limited application (sandy soils only). High potential for clogging.[1] Water table must be at least two feet under the bottom of the device.[3]	Sites with permeable soils and reasonably deep water tables.[3]
Porous Pavement (porous asphalt, modular block)	N/A	N/A	N/A	Must be maintained frequently to function properly. Quarterly vacuuming and/or jet hosing is needed to maintain porosity.[3]	Diversion of surface runoff to groundwater recharge, providing water quality and quantity benefits.[1]	Asphalt or concrete porous pavement has a high failure rate due to clogging, however, modular block porous pavement tends to remain effective for longer periods.[3] Can only be used on non-sanded surfaces.[8]	Intended for low vehicle traffic areas, i.e., spillover parking.[4] May be most beneficial in watersheds with large areas of impervious surfaces.[3]

Table 1. Summary of Management Practices for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Practice	Size (% of Drainage Area)	Minimum Vertical Distance	Construction Costs	Maintenance Requirements	Advantages	Disadvantages	Applicable Situation
Filtering Practices (surface sand filter, underground sand filter, perimeter sand filter, organic filter, pocket sand filter)	Surface sand: 2-3%; Underground sand: None; Perimeter sand: 2%; Organic: 2-3%; Pocket Sand Filter: 2%[7]	Surface sand: 5-8 feet; Underground sand: 5-6 feet; Perimeter sand: 2-3 feet; Organic: 5-8 feet; Pocket Sand Filter: 5 feet.[6]	Surface sand: Moderate; Underground sand: High; Perimeter sand: Moderate; Organic: High; Pocket Sand Filter: Moderate.[7]	Surface sand: annual cleanout; Underground sand: semi-annual cleanout; Perimeter sand: annual cleanout; Organic: annual cleanout; Pocket Sand Filter: annual cleanout.[6]	Sand filters: Can fit in high land-cost situations. Remove pollutants found in parking areas. Organic: effective sediment and trace metal removal, however, poor pollutant removal capability.	Sand filters: Most expensive per square feet of device. Maintenance can be cumbersome. Organic: annual cleanouts are required for maintenance.[6]	Surface sand: Parking lots, ultra-urban or retrofit; Underground sand: ultra-urban or retrofit, parking lots; Perimeter sand: parking lots, ultra-urban or retrofit; Organic: parking lots; Pocket Sand Filter: ultra-urban or retrofit, parking lots.[6]
Filter Strips	N/A	N/A	Reasonably low construction cost.[1]	Must be maintained regularly or filter strips will fail.[3]	Can provide groundwater recharge.[3]	Large land requirement. Not effective alone, needs other practices to reduce peak discharges or heavy stormwater runoff.[3]	Works best when adjacent to impervious areas where runoff is evenly distributed.
Submerged Gravel Strip	3-5%[6]	2-4 feet[6]	High (based on cost per impervious acre treated).[6]	Wetland cleanouts may be necessary.[6]	Effective pollutant removal. Generally small land requirement.[1]	Construction costs could be high.[1] Tends to clog as sediment accumulates.[2]	Parking lots, ultra-urban or retrofit.
Bio-Retention	5%[6]	4 feet[6]	Relatively expensive[7] Low[6]	Landscaped[6]	Aesthetically pleasing. Can double to meet landscape and water quality objectives.[1] Small land requirement (i.e., 5 acres or less). Larger areas tend to clog.[7]	Very new practice with little data to prove effectiveness.[1] Plants must be removed if soil clogs or becomes polluted.[1]	Urban sites with large areas of impervious surfaces; ideal for treating runoff from parking lots.[6] Generally applied to small sites in a highly urban areas.[7]

Table 1. Summary of Management Practices for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Practice	Size (% of Drainage Area)	Minimum Vertical Distance	Construction Costs	Maintenance Requirements	Advantages	Disadvantages	Applicable Situation
Open Vegetated Channels (drainage channel, grassed channel, dry swale, wet swale)	Drainage or grassed channel 6.5%; dry or wet swale: 10-20%[6]	N/A	Generally inexpensive.[3]	Easy to maintain by mowing and trimming.[3]	Highly effective in preventing erosion and controlling sediment in stormwater runoff and aesthetically pleasing.[3]	Remove only small amounts of pollutants.[3]	Open vegetated channels are designed to rapidly drain stormwater during storm events, typically from residential areas.[6]

Notes:

[1] Hunt III, W.F. 1999.
[2] Australian Wetlands Pty Ltd. 2004.
[3] Osmond, et. al. 1995.
[4] NYSDEC. 2001.
[5] USEPA. 1999.
[6] Claytor and Schueler. 1996.
[7] USEPA. 2004.
[8] Caraco, D., and R. Claytor. 1997.

Table 2. Pollutant Removal Capabilities of Management Practices for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York.

Practice	Total Suspended Solids (TSS)	Total Phosphorus (TP)	Total Nitrogen (TN)	Nitrate-Nitrogen	Trace Metals (copper, lead, zinc)	Bacteria (fecal coliform)	Other Info
Stormwater Wetlands	80%[4]	51-75%[4]	26-50%[4]	40-45%[1]	Variable: 26+%[4]	N/A	Soluble nutrients: 26-50%[4]
Stormwater Ponds	70%[4]	51-75%[4] Phosphorus – mod to high.[2]	26-50%[4]	20%[1]	Metals: lead – high[2], zinc – moderate[2] Variable: 26+%[4]	0-75%[4]	Soluble nutrients: 51-75%[4]
Infiltration Practices (basins, trenches, wells)	Limited data suggests it is initially high – but this causes system to become clogged and thus fail.[1]	76+%[4]	51-75%[4]	Very little is removed.[1]	51-75%[4]	N/A	Soluble nutrients: 51-75%[4]
Porous Pavement (porous, modular block)	High[2]				High[2]		Shown to have high removal rates largely due to transfer to groundwater.[2]
Filtering Practices (Surface sand filter, Underground sand filter, Perimeter sand filter, Organic sand filter, Pocket sand filter)	80-95%[4]	40-65%[4]	35-45%[4]	Negative[4]	35-90%[4]	40-80%[4]	Hydrocarbons – 80%[4]
Filter Strips	70%[4]	10%[4]	30%[4]	Zero[4]	N/A	N/A	Reduce pollutants such as sediment, organic matter, and many trace metals by filtering action of the vegetation. Can remove more than 60% of the particulates and up to 40% of the plant nutrients.[2]

Table 2. Pollutant Removal Capabilities of Management Practices for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Practice	Total Suspended Solids (TSS)	Total Phosphorus (TP)	Total Nitrogen (TN)	Nitrate-Nitrogen	Trace Metals (copper, lead, zinc)	Bacteria (fecal coliform)	Other Info
Submerged Gravel Strip	80%[4]	80%[4]	65%[4]	75%[4]	N/A	Results from a study in Florida showed a 78% removal rate.[3]	
Bio-Retention	Initially high but will result in clogging.[1]	65-87%[5] 70-83%[3]	52-67%[5]	Total nitrogen appears high, but Nitrate-Nitrogen may be negative.[1]	43-97%[5]	90%[3]	There is considerable variation in the effectiveness. However, proper design and maintenance may improve their performance.[5]
Open Vegetated Channels (Drainage channel, Grass channel, Dry swale, Wet swale)	80-90%[4]	20-65%[4]	40-50%[4]	50-80%[4]	N/A	N/A	There is considerable variation between pollutant removal capabilities for each channel design.[4]

Notes:

[1] Hunt III, W.F. 1999.
[2] Osmond et. al. 1995.
[3] Schueler, T.R. and H.K. Holland. 2000.
[4] Claytor and Schueler. 1996.
[5] USEPA. 2004.

Table 3. Literature Search Summary for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York.

Author or Agency	Report Title	Analyses	Data Utility
Australian Wetlands Pty Ltd. 2004	Stormwater Wetlands	General descriptions, associated benefits, and limitations of management practices.	Stormwater wetlands, submerged gravel strips.
Caraco, D., and R. Claytor. 1997	Stormwater BMP Design Supplement for Cold Climates	General descriptions and detailed designs, maintenance requirements, associated benefits and limitations of management practices.	Stormwater wetlands, stormwater ponds, infiltration practices, filtering practices, open vegetated channels.
Claytor and Schueler. 1996	Design of Stormwater Filtering Systems	General descriptions and detailed designs, costs, pollutant removal capabilities, associated benefits and limitations of management practices.	Stormwater wetlands, stormwater ponds, filtering practices, filter strips, submerged gravel strips, bio-retention, open vegetated channels.
Hunt III, W.F. 1999	Urban Stormwater Structural Best Management Practices (BMPs)	General descriptions, pollutant removal capabilities, associated benefits, and limitations of management practices.	Stormwater wetlands, stormwater ponds, infiltration practices, filter strips, bio-retention.
Hunt III, W.F., and B.A. Doll. 2000	Designing Stormwater Wetlands for Small Watersheds	General descriptions, pollutant removal capabilities, design criteria, plant selection, costs, and limitations of stormwater wetlands.	Stormwater wetlands.
Mastey, Stephen. 1997	Design Strategies for Stormwater Wetlands to Maximize Plant Diversity	General descriptions, design strategies, and study of effects of plant diversity.	Stormwater wetlands, stormwater ponds.
NYSDEC. 2001	New York State Stormwater Management Design Manual	General descriptions and detailed designs, associated benefits and limitations of management practices.	Stormwater wetlands, stormwater ponds, infiltration practices, porous pavement, filtering practices, filter strips, open vegetated channels.
Ormond et.al. 1995	Wetland Management	General descriptions, associated benefits, and limitations of management practices.	Stormwater wetlands, stormwater ponds, infiltration practices, porous pavement, filter strips, open vegetated channels.
Phillips, Veronika	Anatomy of a Constructed Wastewater Wetland	General descriptions and site requirements, plant considerations, and pollutant removal capabilities.	Stormwater wetlands.

Table 3. Literature Search Summary for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Author or Agency	Report Title	Analyses	Data Utility
Schueler, T.R., and H.K. Holland. 2000	The Practice of Watershed Protection	Over 150 journal articles with varying information regarding wetland creation and other stormwater management practices.	Stormwater wetlands, stormwater ponds, infiltration practices, porous pavement, filtering practices, filter strips, submerged gravel strips, bio-retention, open vegetated channels.
United States Environmental Protection Agency, Office of Water. 1999	Storm Water Technology Fact Sheet: Bioretention	General descriptions, design criteria, operation and maintenance, costs, pollutant removal capabilities, associated benefits and limitations of bio-retention.	Bio-retention.
United States Environmental Protection Agency, Office of Water. 1999	Storm Water Technology Fact Sheet: Storm Water Wetlands	General descriptions, design criteria, operation and maintenance, costs, pollutant removal capabilities, associated benefits and limitations of stormwater wetlands.	Stormwater wetlands.
United States Environmental Protection Agency, Office of Water. 2004	Post-Construction Storm Water Management in New Development and Redevelopment: Bioretention	General descriptions, applicability, costs, siting and design considerations, maintenance and cost considerations, limitations, and effectiveness of bio-retention.	Bio-retention.
United States Environmental Protection Agency, Office of Water. 2004	Post-Construction Storm Water Management in New Development and Redevelopment: Stormwater wetlands	General descriptions, applicability, costs, detailed design criteria and drawings, limitations and effectiveness of stormwater wetlands.	Stormwater wetlands.
United States Environmental Protection Agency, Office of Water. 2004	A Handbook of Constructed Wetlands	General descriptions and designs, hydrology, substrates, vegetation, construction plans, operation and maintenance.	Stormwater wetlands.

3.0 VEGETATION

The role of vegetation in constructed wetland and other stormwater management practices is to physically slow the flow of water, allowing suspended sediments to deposit out of the water column, provide a medium for the breakdown of organic material and assimilation of nutrients, metals, and other contaminants by microbes, and fix or uptake pollutants via the root systems (Claytor and Schueler 1996).

There are several factors that need to be considered in the design of a planting plan and selection of species for created wetlands and other stormwater management practices. In general, native plant species should be used instead of exotic or foreign species, even if contaminant removal efficiencies are lower in native species. Vegetation should be selected that can tolerate the hydrologic condition, inundation, salinity, and sun conditions expected for the created wetland. Also, the layout of species in the planting plan should appear random and natural. In management practices with different cover classes (i.e., tree, shrub, herbaceous), all cover classes should be represented in the planting plan. Additionally, urban stressors, such as wind, sun, exposure, insect and disease infestation, and drought, should be considered in the planting plan layout. Lastly, in highly visible sites, aesthetics and visual characteristics, and traffic and safety issues, should also be considered (NYSDEC 2001). Specific information detailing characteristics of vegetation typically used in stormwater management practices is presented in Table 4.

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York.

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
Trees and Shrubs								
Red Maple *(Acer rubrum)*	Deciduous Tree.[1]	Regularly to never inundated.[1]	Yes.[1] 4–6 days.[5]	Tidal fresh water.[3] High.[5]	High. Food (seeds and browse).[1,2,5]		Partial sun.[5]	Rapid growth. Tolerates acidic soils.[1] High metals and oil/grease tolerance. High resistance to insect/disease. Shallow roots.[5]
Speckled Alder *(Alnus rugosa)*	Deciduous Shrub.[1]	Regularly to periodically inundated.[1]	Yes.[1]		High. Cover, browse for deer, seeds for birds.[1]			
Smooth Alder *(Alnus serrulata)*	Deciduous Tree.[1]	Regularly to infrequently inundated.[1]	Yes.[1]	Tidal fresh water.[3]	High. Food, cover.[1]			Rapid growth. Stabilizes streambanks.[1]
Shadowbush, Serviceberry *(Amelanchier canadensis)*	Deciduous Shrub.[1]	Periodically to never inundated.[1]	Yes.[1] 2–4 days.[5]	High.[5]	High.[1,5] Nesting, cover, food. Birds and mannals.[1]		Partial shade.[1]	Common in forested wetlands and upland woods.[1] High resistance to insect/disease.[5]
Groundsel Tree *(Baccharis halimifolia)*	Deciduous Shrub.[3]	Infrequently flooded.[3]	Some.[3]	Tidal fresh to salt water.[3]				
River Birch *(Betula nigra)*	Deciduous Tree.[1]	Regularly to infrequently inundated.[1]	Yes.[1] 4–6 days.[5]		Low. Good for cavity nesters.[1]		Full sun[1] to partial sun.[5]	Bank erosion control.[1] High resistance to insect/disease.[5]
Gray Birch *(Betula populifolia)*	Deciduous Tree.[5]	Xeric to hydric.[5]	4–6 days.[5]	High.[5]	High.[5]		Partial sun.[5]	High oil/grease tolerance.[5]
Hackenberry *(Celtis occidentalis)*	Deciduous Tree.[1]	Infrequently to never inundated.[1]	Some.[1]		High. Food and cover.[1]		Full sun to partial shade.[1]	
Buttonbush *(Cephalanthus occidentalis)*	Deciduous Shrub.[1]	1 ft. deep to never inundated.[1]	Yes.[1]	Tidal fresh water.[3]	High. Ducks and shorebirds. Seeds, nectar and nesting.[1]		Full sun to partial shade.[1]	Will grow in dry areas.[1]

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
Sweet Pepperbush *(Clethra alnifolia)*	Deciduous Shrub.[5]	Mesic to wet mesic.[5]	2–4 days.[5]	High.[5]	Medium.[5]		Sun to partial sun.[5]	High resistance to insect/disease.[5]
Silky Dogwood *(Cornus amomium)*	Deciduous Shrub.[1]	Regularly to infrequently inundated.[1]	Yes.[1] 1–2 days.[5]	Tidal fresh water.[3] Low.[5]	High.[1,5] Songbirds, mammals.[1]		Shade tolerant.[1]	Drought tolerant. Good bank stabilizer.[1]
Red Osier Dogwood *(Cornus stolonifera)*	Deciduous Shrub.[5]	Mesic to hydric.[5]	2–4 days.[5]	High.[5]	High.[5]		Sun or shade.[5]	High metals, oil, grease tolerance. Needs consistent moisture levels.[5]
White Ash *(Fraxinus americana)*	Deciduous Tree.[1]	Infrequently to never inundated.[1]	No.[1] 2–4 days.[5]	Moderate.[5]	Low[5] to high.[1] Food.[1]		All conditions.[1]	Well drained soils.[1] High metals and oil/grease tolerance. High resistance to insect/disease.[5]
Black Ash *(Fraxinus nigra)*	Deciduous Tree.[1]	Regularly to infrequently inundated.[1]	Irregular-seasonal saturation[1]		High. Food (seeds, sap), cover, nesting for birds and mammals. Fruit persist in winter.[1]		Full sun.[1]	Rapid growth. Susceptible to wind/ice damage and disease.[1]
Green Ash, Red Ash *(Fraxinus pennsylvania)*	Deciduous Tree.[1]	Periodically to infrequently inundated.[1]	Yes.[1] 4–6 days.[5]	Tidal fresh water.[3] Moderate.[5]	Moderate. Songbirds.[1]		Full sun to partial shade.[1]	Rapid growing streambank stabilizer.[1] High metals and oil/grease tolerance. High resistance to insect/disease.
Maidenhair Tree *(Ginko biloba)*	Deciduous Tree.[5]	Mesic.[5]	2–4 days.[5]	High.[5]	Low.[5]		Sun.[5]	Avoid female species – offensive odor from fruit.[5]
Honey Locust *(Gleditsia triacanthos)*	Deciduous Tree.[5]	Mesic.[5]	2–4 days.[5]	High.[5]	Low.[5]		Sun.[5]	Select thornless variety.[5]
Witch Hazel *(Hamamelis virginiana)*	Deciduous Shrub.[1]	Periodically to infrequently inundated.[1]	No.[1] 2–4 days.[5]	Moderate.[5]	Low. Food for squirrels, deer, ruffed grouse.[1]		Prefers shade.[1]	Ornamental.[1]

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
Inkberry *(Ilex glabra)*	Deciduous Shrub.[5]	Mesic to wet mesic.[5]	2–4 days.[5]	High.[5]	High.[5]		Sun to partial sun.[5]	High oil/grease tolerance. High resistance to insect/disease.[5]
Winterberry *(Ilex verticillata)*	Deciduous Shrub.[1]	Regularly to infrequently inundated.[1]	Yes.[1] 2–4 days.[5]	Tidal fresh water.[3] Low.[5]	High.[1,5] Cover and food (fruit) for birds. Berries last into winter.[1]		Full sun to partial shade.[1]	Moderate oil/grease tolerance. High resistance to insect/disease.[5]
High-tide Bush *(Iva frutescens)*	Deciduous Shrub.[3]	Infrequently flooded.[3]	Yes.[3]	Tidal fresh to salt water.[3]				Grows on mounds next to ditches; upper border.[3]
Common Juniper *(Juniperus communis)*	Evergreen Shrub.[5]	Dry mesic to mesic.[5]	1–2 days.[5]	Moderate.[5]	High.[5]		Sun.[5]	High metals and oil/grease tolerance.[5]
Eastern Red Cedar *(Juniperus virginiana)*	Coniferous Tree.[1]	Periodically to never inundated.[1]	No.[1] 2–4 days.[5]	High.[5]	High to very high.[1,5] Fruit for some birds.[1]		Full sun to partial shade.[1]	Common in wetlands, shrub and bogs and edge of stream.[1] High oil/grease tolerance. High resistance to insect/disease.[5]
Larch, Tamarack *(Larix latricina)*	Coniferous Tree.[1]	Regularly to periodically inundated.[1]	Yes.[1]		Low. Nest tree and seeds.[1]		Full sun.[1]	Rapid initial growth. Acidic boggy soil.[1]
Common Spice Bush *(Lindera benzoin)*	Deciduous Shrub.[1]	Regularly to infrequently inundated.[1]	Yes.[1] 2–4 days.[5]	Tidal fresh water.[3] High.[5]	Very high. Songbirds.[1]		Shade (rich soils).[1]	Tolerates acidic soils. Good understory species. Deep root system.[1]
Sweetgum *(Liquidambar styraciflua)*	Deciduous Tree.[1]	Periodically to never inundated.[1]	Yes.[1] 4–6 days.[5]	High.[5]	Moderate to high.[1,5] Songbirds.[1]		Sun to partial shade.[1]	Tolerates acid to clay soils.[1] Fruit is a maintenance problem.[5]
Tulip Tree *(Liriodendron tulipifera)*	Deciduous Tree.[1]	Infrequently to never inundated.[1]	No.[1]		Moderate. Seeds and nest sites.[1]		Full sun to partial shade.[1]	Rapid growth. Well drained soils.[1]

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
Bayberry *(Myrica pensylvanica)*	Deciduous Shrub.[1]	Periodically to never inundated.[1]	Yes.[1] 2–4 days.[5]	Tidal fresh to slightly brackish water.[3] High.[5]	High.[1,5] Nesting, food, cover. Berries last into winter.[1]		Sun to partial sun.[5]	Roots fix nitrogen. Tolerates slightly acidic soils.[1] High resistance to insect/disease.[5]
Blackgum or Sourgum *(Nyssa sylvatica)*	Deciduous Tree.[1]	Periodically to never inundated.[1]	Yes.[1] 4–6 days.[5]	Tidal fresh water.[3] High.[5]	High.[1,5] Songbirds, egrets, herons, raccoons, owls.[1]		Sun to partial shade.[1]	Can be difficult to transplant.[1]
Tupelo *(Nyssa sylvatica vari biflora)*	Deciduous Tree.[1]	Regularly to infrequently inundated.[1]	Yes.[1]	Tidal fresh water.[3]	High. Seeds and nest sites.[1]			Ornamental.[1]
Sycamore *(Platanus occidentalis)*	Deciduous Tree.[1]	Periodically to never inundated.[1]	Yes.[1] 4–6 days.[5]	Moderate.[5]	Low to medium.[1,5] Food, cavities for nesting.[1]		Sun.[5]	Rapid growth.[1] Shallow rooted, subject to windthrow. Fruit is a maintenance problem.[5]
Black Cherry *(Prunus serotina)*	Deciduous Tree.[1]	Infrequently to never inundated.[1]	No.[1]		High. Food.[1]			Moist soils or wet bottomland areas.[1]
Eastern Cottonwood *(Populus deltoids)*	Deciduous Tree.[1]	Periodically to infrequently inundated.[1]	Yes.[1] 4–6 days.[5]	Yes.[2] High.[5]	Moderate to high.[1,5] Cover, food.[1]		Sun.[5]	Shallow rooted, subject to windthrow. Invasive roots. Rapid growth.[1] High metals and oil/grease tolerance.[5]
Red Choke Berry *(Pyrus arbutifolia)*	Deciduous Shrub.[1]	Regularly to infrequently inundated.[1]	Yes.[1] 1–2 days.[5]	High.[5]	Moderate to high.[1,5] Songbirds.[1]		Partial sun.[1]	Bank stabilizer.[1] High metals and drought tolerance.[5]
Swamp White Oak *(Quercus bicolor)*	Deciduous Tree.[1]	Regularly to infrequently inundated.[1]	Yes.[1] 4–6 days.[5]	High.[5]	High. Mast.[1]		Full sun to partial shade.[1]	One of the fastest growing oaks.[5]
Scarlet Oak *(Quercus coccinea)*	Deciduous Tree.[5]	Mesic.[5]	1–2 days.[5]	High.[5]	High.[5]		Sun.[5]	

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
Pin Oak *(Quercus palustris)*	Deciduous Tree.[1]	Regularly to never inundated.[1]	Yes.[1] 4–6 days.[5]	High.[5]	High.[1,2,5]		Sun.[5]	Tolerates acidic soils. Gypsy moth target. Prefers well-drained sandy soils.[1]
Willow Oak *(Quercus phellos)*	Deciduous Tree.[5]	Mesic to wet mesic.[5]	4–6 days.[5]	High.[5]	High.[5]		Sun.[5]	Fast growing oak. High resistance to insect/disease.[5]
Red Oak *(Quercus rubra)*	Deciduous Tree.[5]	Mesic.[5]	2–4 days.[5]	Moderate.[5]	High.[5]		Sun to partial sun.[5]	High oil/grease tolerance.[5]
Black Locust *(Robinia pseudo-acacia)*	Deciduous Tree.[5]	Mesic to xeric.[5]	2–4 days.[5]	High.[5]	Low.[5]		Sun.[5]	Fruit is a maintenance problem. Shallow rooted, subject to windthrow.[5]
Swamp Rose *(Rosa palustrus)*	Deciduous Shrub.[1]	Regularly to periodically inundated.[1]	Irregular, seasonal, or regularly saturated.[1]	Low.[1]	High. Food (hips) for birds and mammals. Cover.[1]		Full sun.[1]	Easy to establish.[1]
Black Willow *(Salix nigra)*	Deciduous Tree.[1]	Regularly to infrequently inundated.[1]	Yes.[1]	Tidal fresh water.[3]	High. Browsing and cavity nesters.[1]		Full sun.[1]	Rapid growth, stabilizes streambanks.[1,2]
Elderberry *(Sambucus canadensis)*	Deciduous Shrub.[1]	Regularly to never inundated.[1]	Yes.[1]	Tidal fresh water.[3]	Extremely high. Food and cover, birds and mammals.[1]		Full sun to partial shade.[1]	
Bald Cypress *(Taxodium distichum)*	Deciduous Tree.[1]	Regularly to periodically inundated.[1]	Yes.[1] 4–6 days.[5]		Low.[5] Little food value, good perching site for waterfowl.[1]		Sun to partial sun.[5]	NY is north of normal range. Tolerates drought.[1] Not well documented for planting in urban areas.[5]
Eastern Hemlock *(Tsuga canadensis)*	Coniferous Tree.[1]	Infrequently to never inundated.[1]	Yes.[1]		Moderate. Mostly cover and some food.[1]		All conditions.[1]	Tolerates acidic soils.[1]

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
American Elm *(Ulmus americana)*	Deciduous Tree.[1]	Periodically to never inundated.[1]	Irregular-seasonal saturation[1]		High. Food (seeds, browsing), cover, nesting for birds and mammals.[1]		Sun to full shade.[1]	Susceptible to disease (short-lived). Tolerates drought and wind/ice damage.[1]
Slippery Elm *(Ulnus rubra)*	Deciduous Tree.[1]	Regularly to infrequently inundated.[1]	Yes.[1]	No.[1]	High. Food (seeds, buds) for birds and mammals (browse). Nesting.[1]		Shade tolerant.[1]	Rapid growth. Drought tolerant.[1]
Northern Wild Raisin *(Viburnum cassinoides)*	Deciduous Shrub.[5]	Mesic.[5]	2–4 days.[5]	High.[5]	High.[5]		Sun to partial sun.[5]	High metals, oil/grease tolerance. High resistance to insect/disease.[5]
Arrowwood Viburnum *(Viburnum dentatum)*	Deciduous Shrub.[1]	Regularly to periodically inundated.[1]	Yes.[1] 2–4 days.[5]	Tidal fresh water.[3] High.[5]	High.[1,5] Songbirds and mammals.[1]		Sun to partial shade.[1]	High metals and oil/grease tolerance. High resistance to insect/disease.[5]
Nannyberry *(Viburnum lentago)*	Deciduous Shrub.[5]	Mesic.[5]	2–4 days.[5]	High.[5]	High.[5]		Sun to partial sun.[5]	High metals and oil/grease tolerance. High resistance to insect/disease.[5]
Herbaceous Plants								
Sweet Flag *(Acorus calamus)*	Herbaceous.[1]	1 ft. deep to regularly inundated.[1]	Up to 3 in.[1]	Tidal fresh water.[3]	Low.[1]			Tolerates dry periods. Not a rapid colonizer. Tolerates acid conditions.[1]
Redtop *(Agrostis alb*a)	Perimeter.[1]	Regularly to infrequently inundated.[1]	Up to 25% of season.[1] 1-2 days.[5]	High.[5]	Moderate to high.[5] Rabbits and some birds.[1]		Shade.[5]	Establishes quickly but not highly competitive.[1]
Creeping Bentgrass *(Agrostis palustris)*	Emergent.[2]	Infrequently inundated.[3]	Yes.[5]	Tidal fresh to brackish water.[3]			Full sun.[3]	Well-drained soils.[2]
Creeping Bentgrass *(Agrostis stolonifera)*	Perimeter.[3]	Infrequently inundated.[3]	Yes.[3]	Tidal fresh to brackish water.[3]				

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
Big Bluestem *(Andropogon gerardi)*	Perimeter.[1]	Periodically to infrequently inundated.[1]	Irregular or seasonal inundation.[1]		High. Seeds for songbirds, food for deer.[1]		Full sun.[1]	
Bushy Beardgrass *(Andropogon glomeratus)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Up to 1 ft.[1]				Full sun.[1]	
Broomsedge *(Andropogon virginicus)*	Perimeter.[1]	1 ft. deep to regularly inundated.[1]	Up to 3 in.[1] 1–2 days.[5]	Low.[5]	High.[1,5] Songbirds and browsers. Winter food and cover.[1]		Full sun[5] to partial shade.[1]	Tolerates fluctuating water level.[1] Tolerates drought.[5]
Smooth Brome *(Bromus inermis)*	Emergent.[5]		Fair.[5]	Fair.[5]			Partial shade.[5]	
Blue Joint *(Calamagrotis canadensis)*	Emergent.[1]	1 ft. deep to periodically inundated.[1]	Regular or permanent inundation up to ½ ft.[1]	Tidal fresh water.[4]	Moderate. Food for game birds and moose.[1]		Partial shade.[1]	Well-drained soils.[2]
Sedges *(Carex spp.)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Up to 3 in.[1]	Varies.	High. Waterfowl and songbirds.[1,2]			Many wetland and upland species.
Coontail *(Ceratophyllum demersum)*	Sub-mergent.[1]	Permanent pool 1-6 ft. deep.[1]	Yes.[1]	Tidal fresh water.[3]	Low food value. Good habitat and shelter for fish and invertebrates.[1]		Shade tolerant.[1]	Free floating submerged aquatic vegetation (SAV).[1]
Crownvetch *(Coronilla varia)*	Emergent.[5]		Low.[5]	Fair.[5]				Rapid growth. Requires liming.[5]
Tufted Hairgrass *(Deschampsia caespitosa)*	Perimeter.[1]	Regularly to infrequently inundated.[1]	Yes.[1] 2–4 days.[5]	High.[5]	High.[1]		Full sun.[1]	May become invasive.[1] High metals, insect, and disease tolerance.[5]

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
Salt Grass *(Distichlis spicata)*	Perimeter.[3]	Infrequently inundated.[3]	Yes.[3]	Salt to brackish marshes.[3]				Spread from rhizomes.[3]
Waterweed *(Elodea canadensis)*	Sub-mergent.[1]	Permanent pool 1-6 ft. deep.[1]	Yes.[1]	Tidal fresh water.[3]	Low.[1]	High nutrient, copper, manganese and chromium removal.[1]		Good water oxygenator. [1]
Tall Fescue *(Festuca arundinacea)*	Emergent.[5]		High.[5]	Good.[5]				Fast establishment, good growth rate.[5]
Red Fescue *(Festuca rubra)*	Perimeter.[5]	Infrequently inundated.[5]	Fair.[5]	Salt to brackish marshes.[3]				Fair heat and cold tolerance.[5]
Fowl mannagrass *(Glyceria striat*a)	Perimeter.[1]	Periodically to infrequently inundated.[1]	Irregular or seasonal inundation.[1] 1–2 days.[5]	Low.[5]	High.[1,5] Food for waterfowl, muskrat, and deer.[1]		Partial to full shade.[1,5]	
Marsh Hibiscus *(Hibiscus moscheutos)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Up to 3 in.[1]	Tidal fresh to salt water.[3]	Low. Nectar.[1]		Full sun.[1]	Tolerates periodic dryness.[1]
Blue Flag Iris *(Iris versicolor)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Regular or permanently up to ½ ft. or saturated.[1]	Fresh to moderately brackish water.[1]	Moderate. Food for muskrat and waterfowl. Cover for marshbirds.[1]		Full sun to partial shade.[1]	Tolerates clay. Slow growth.[1]
Soft Rush *(Juncus effusus)*	Emergent.[1]	1 ft. deep to periodically inundated.[1]	Up to 3 in.[1]	Tidal fresh water.[3]	Moderate[1] to high.[2]			Tolerates wet or dry conditions.[1]
Black Grass *(Juncus gerardii)*	Perimeter.[3]	Infrequently inundated.[5]	Yes.[3]	Salt to brackish marshes.[3]				

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
Rice Cutgrass *(Leersia oryzoides)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Up to 3 in.[1]	Tidal fresh to slightly brackish water.[3]	High. Food and cover.[1]		Full sun; tolerant of shade.[1]	Shoreline stabilization.[1]
Duckweed *(Lemna* spp.*)*	Submergent /Emergent.[1]	Permanent pool 6 in. to 6 ft. deep.[1]	Yes.[1]	Tidal fresh water.[3]	High. Food for waterfowl and fish.[1]	High metals removal.[1]		
Sea Lavender (*Limonium carolinianum*)	Perimeter.[3]	Infrequently inundated.[3]		Salt marsh.[4]				
Cardinal flower *(Lobelia cardinalis*)	Perimeter.[1]	Periodically to never inundated.[1]	Some. Tolerates saturation up to 100% of season.[1]	Tidal fresh water.[3]	High. Nectar for hummingbird, oriole, butterflies.[1]		Partial shade.[1]	
Ryegrass *(Lolium spp.)*	Emergent.[2]			No.[2]	Moderate.[2]			Establishes easily.[2]
Annual Rye *(Lolium multiflorum)*	Emergent.[5]		Good.[5]	Fair.[5]			Fair to good shade tolerance.[5]	
Birdfoot deervetch *(Lotus corniculatus*)	Perimeter.[1]	Periodically to never inundated.[1]	Infrequent inundation.[1] 1–2 days.[5]	High.[5]	High.[1,5] Food for birds.[1]		Full sun.[1]	Nitrogen fixer.[1] High metals tolerance; low oil/grease tolerance.[5]
Spatterdock *(Nuphar luteum)*	Emergent.[1]	6 in. to 1 ft. deep.[1]	Up to 3 ft.[1]	Tidal fresh water.[3]	Moderate for food but high for cover.[1]			Fast colonizer. Tolerant of fluctuating water levels.[1]
Switchgrass *(Panicum virgatum)*	Perimeter.[1]	1 ft. deep to never inundated.[1]	Up to 3 in.[1] 2–4 days.[5]	Yes.[2] High.[5]	High.[1,5] Food (seeds), cover for waterfowl and songbirds.[1]		Sun or shade.[5]	Tolerant wet/dry conditions.[1] Can spread fast and reach 6 ft high.[5]
Arrow arum *(Peltandra virginica)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Up to 1 ft.[1]	Tidal fresh to slightly brackish water.[3]	High. Food for wood ducks.[1]		Full sun to partial shade.[1]	

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
Reed Canarygrass *(Phalaris arundinacea)*	Emergent.[5]		Yes.[5]	Poor.[5]	High.[5]		Poor shade tolerance.[5]	Shallow roots, rhizomatous.[5]
Common Reed *(Phragmites australis)*	Emergent.[2]	Regularly to infrequently inundated.[3]	Yes.[4]	Tidal fresh to brackish water.[3]	Moderate. Cover for wetland wildlife species.[4]		Full sun.[4]	Rapid spread by rhizomes. Exotic that can become invasive.[2]
Timothy *(Phleum pratense)*	Emergent.[2]		Poor.[5]	No.[2]	Moderate. Food (seeds) and cover for songbirds.[4]			Establishes easily. Tolerates wet or dry conditions.[2]
Kentucky Bluegrass *(Poa pratensis)*	Emergent.[5]		Fair.[5]	Low.[5]			Fair shade tolerance.[5]	Moist, well drained soils.[5]
Smartweed *(Polygonum spp.)*	Emergent.[1]	1 ft. deep to periodically inundated.[1]	Up to 1 ft.[1]	Varies.	High. Food (seeds), cover for waterfowl, songbirds.[1,2]			Fast colonizer. Avoid weedy aliens such as *P. perfoliatum*.[1]
Pickerelweed *(Pontederia cordata)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Up to 1 ft.[1]	Tidal fresh to slightly brackish water.[3]	Moderate. Ducks. Nectar for butterflies.[1]		Full sun to partial shade.[1]	
Long-leaved Pond Weed *(Potamogeton nodosus)*	Rooted submerged aquatic.[1]	Permanent pool 6 in. to 6 ft. deep.[1]	Up to 1–6 ft. depending on turbidity.[1]	<0.5 ppt[1]	High. Food (seeds, roots) for waterfowl, aquatic furbearers, deer and moose. Habitat for fish.[1]			Rapid spread. Flowers float on surface (August – September).[1]
Pond Weed, Sago *(Potamogeton pectinatus)*	Sub-mergent.[1]	Permanent pool 1-6 ft. deep.[1]	Yes.[1]	Tidal fresh to brackish water.[3]	Extremely high. Waterfowl, marsh and shorebirds.[1]	Removes heavy metals.[1]		
Arrowhead, Duck Potato *(Saggitaria latifolia)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Up to 1 ft.[1]	Yes.[2]	Moderate. Tubers and seeds eaten by ducks.[1]	High.[2]		Aggressive colonizer.[1]

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
Perennial Glasswort *(Salicornia virginica)*	Emergent.[2]	Infrequently inundated.[3]		High.[3]			Full sun.[3]	Native to many cold climates, particularly in salt marshes.[2]
Lizard's Tail *(Saururus cernuus)*	Emergent.[1]	6 in. to 1 ft. deep.[1]	Up to 1 ft.[1]	Tidal fresh water.[3]	Low, except wood ducks.[1]		Shade tolerant.[1]	Rapid growth.[1]
Hardstem Bulrush *(Scirpus acutus)*	Emergent.[1]	6 in. to 1 ft. deep.[1]	Up to 3 ft.[1]	Fresh to brackish water.[1]	High. Cover, food (achenes, rhizomes) for ducks, geese, muskrat, fish. Nesting for bluegill and bass.[1]			Quick to establish. Good for sediment stabilization and erosion control.[1]
Wool Grass *(Scirpus cyperinus)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Irregularly to seasonally inundated.[1]	Tidal fresh water.[3]	Moderate. Cover, food.[1]		Requires full sun.[1]	Can tolerate acidic soils, drought. Colonizes disturbed areas, moderate growth.[1]
Common Three-Square *(Scirpus pungens)*	Emergent.[1]	6 in. to 1 ft. deep.[1]	Up to 6 in.[1]	Tidal fresh to brackish water.[2]	High. Food, cover for waterfowl and fish.[1]	High metals removal.[1]		
Soft-stem Bulrush *(Scirpus validus)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Up to 1 ft.[1]	Tidal fresh to brackish water.[3]	Moderate. Good cover and food.[1]	High.[1,2]	Full sun.[1]	Aggressive colonizer.[1,2]
Giant Burreed *(Sparganium eurycarpum)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Yes.[1]	<0.5 ppt[1]	High. Food (seeds, plant) waterfowl, beaver and other mammals. Cover for marshbirds, waterfowl.[1]		Partial sun.[1]	Rapid spread. Good for shoreline stabilization.[1]
Smooth Cordgrass *(Spartina alterniflora)*	Perimeter.[3]	Regularly to infrequently inundated.[3]	Yes.[3]	Salt and brackish marshes.[3]			Full sun.[3]	
Big Cordgrass *(Spartina cynosuroides)*	Perimeter.[3]	Infrequently inundated.[3]	Yes.[3]	Tidal fresh to salt water.[3]				

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
Salt Hay Grass (also Saltmeadow Cordgrass) *(Spartina patens)*	Perimeter.[3]	Regularly to infrequently inundated.[3]	Yes.[3]	Salt and brackish marshes.[3]	Moderate: Food source for livestock.[4]			Spread by rhizomes.[3]
Prairie Cordgrass *(Spartina pectinata)*	Perimeter.[3]	Infrequently inundated.[3]		Tidal fresh to brackish water.[3]			Full sun.[4]	Rapid spread by rhizomes. Best suited to large areas. Can become invasive.[4]
Seaside Arrow Grass *(Triglochin maritimum)*	Perimeter.[3]	Infrequently inundated.[3]	Yes.[3]	Tidal fresh to salt water.[3]				
Cattail *(Typha sp.)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Up to 1 ft.[1]	Tidal fresh to brackish water.[3]	Low. Except as cover.[1]	High.[1,2]		Aggressive species; may out-compete other species.[1,2]
Wild Celery *(Valisneria americana)*	Sub-mergent.[1]	Permanent pool 1-6 ft. deep.[1]	Yes.[1]	Tidal fresh to slightly brackish water.[3]	High. Food for waterfowl. Habitat for fish and invertebrates.[1]			Tolerant of turbid water and high nutrient loads.[1]
Wild Rice *(Zizania aquatica)*	Emergent.[1]	6 in. to 1 ft. deep.[1]	Up to 1 ft.[1]	Tidal fresh to slightly brackish water.[3]	High. Food for birds.[1]		Prefers full sun.[1]	

Notes:

ft. = foot (feet)
in. = inches
ppt = parts per thousand

[1] NYSDEC 2001
[2] Caraco, D., and R. Claytor. 1997.
[3] Tiner, R.W. 1987.
[4] eNature.com. 2004.
[5] Claytor, R.A., and T.R. Schueler. 1996.

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