Integrated Stormwater Management in New York City: Implementation of Citywide Green Infrastructure Measures

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UCCRN Case Study Docking Station (2024)
DOI: 10.7916/84dx-en06

Keywords	Integrated Stormwater Management, Nature-based Solutions, Green Infrastructure
City Population (Metropolitan Region)	8,230,290
City Area (Metropolitan Region)	778.2 km^2
City GDP (per capita)	1.59 trillion USD
Climate Zone	Cfa (humid subtropical)
ARC3.3 Linkage	Urban Planning, Design, and Architecture Element

Introduction. New York City, like approximately 860 other cities in the United States, is largely serviced by a combined sewer system [CSS]. Nearly 40 million people live in these municipalities. A CSS carries all household wastewater from sinks, toilets, showers, washing machines, dishwashers, etc., and combines it with stormwater runoff from roofs, streets, sidewalks and parking lots, mixing it in one pipe that transports the wastewater and stormwater to treatment plants. The NYC CSS is comprised of 14 wastewater treatment plants. At the plants, sludge and wastewater are separated. The wastewater is treated and released back into the waterways whereas the sludge remains on site and reemerges as fertilizer and heating energy after an extensive treatment process. New York City's sewer system is one of the most extensive in the country, handling and processing around 1.3 billion gallons of sewage and stormwater each day. The combined design capacity of all of NYC's wastewater treatment plants is 1.8 billion gallons.

During dry weather, the NYC CSS handles the volume released into its pipes as designed. During wet weather, however, and particularly during heavy rainstorms, the additional rainwater volume outstrips the wastewater treatment plants' capacity. When it rains and the wastewater volume exceeds the designed volume of the treatment plants, a built-in protection feature, an outfall pipe connected to its respective combined sewer overflow [CSO] shed, releases a combination of untreated sewage and stormwater directly back into the waterways. About 450 sewer outfalls dot the coastlines of NYC with an additional 250 in New Jersey to create a combined 700 outfalls into the New York/New Jersey estuary. These outfalls act as relief valves during CSO rain events to protect the functioning of the wastewater treatment plants and to prevent a backup of wastewater into streets and homes.

In 2012 New York City's Department of Environmental Protection [NYCDEP] and New York State's Department of Environmental Conservation [NYSDEC] signed an agreement to reduce combined sewer overflows (CSO) using a hybrid gray and green infrastructure approach. As part of the agreement, NYCDEP developed ten water body-specific Long Term Control Plans [LTCPs] and one citywide open waters LTCP with the goal of identifying necessary CSO controls to achieve, in each specific case, water quality standards in alignment with the Clean Water Act.

The urgency to address the continued pollution of NYC waterways is spurred by climate-related factors that will put further stress on the physical health of the City's water bodies and the City population. NYC will see a climate change-induced increase in temperature as well as in precipitation (NPCC 2019 Report). Infiltrating rainwater before it enters the sewer system through green infrastructure measures such as rain gardens, bioswales or permeable surfaces is the most promising strategy to address these additional climate stresses, as it mitigates CSO and flood risk without expanding gray infrastructure at a very high cost. Additionally, capturing rainwater in rain barrels and larger storage tanks diverts runoff from roofs and can be used to irrigate private and public green infrastructure such as green roofs and gardens, much needed for cooling the city without drawing from NYC's drinking water.

The citywide Green Infrastructure [GI] plan is part of the LTCPs and is being led by the city's GI Office. It seeks to reduce CSO by 1.67 billion gallons per year by 2030. GI measures such as green roofs, rain gardens, infiltrati n basins and permeable pavement have been, and continue to be, implemented through the right-of-way program on streets and sidewalks, on publicly owned land, such as schools, public housing or parks, and on private land, defined as incentivized and regulated infrastructure.

This case study looks at the in-progress implementation of NYC's Green Infrastructure plan to reduce rainwater overflow. .

Context and Drivers: Every year in New York City around 20 billion gallons of untreated raw sewage and polluted runoff are diverted from the City's wastewater treatment plants during CSO events and directed into the water along the shoreline of the City, as the designed capacity of the system is reached quickly when it rains. Data from Notify NYC, NYC's official source for information about emergency alerts, shows that in 2019 there were 179 days when a CSO advisory was issued indicating a CSO event. CSO events occur unevenly across the City. Depending on the particularities of a specific CSO shed, the outfall pipe might be activated with as little as a 0.05" rainfall (CSO Shed: NCB-083). In other words, some CSO sheds have almost reached their full capacity to handle drainage of wastewater during dry weather and future climate change-induced increases in precipitation will put further stresses on an already overloaded system.

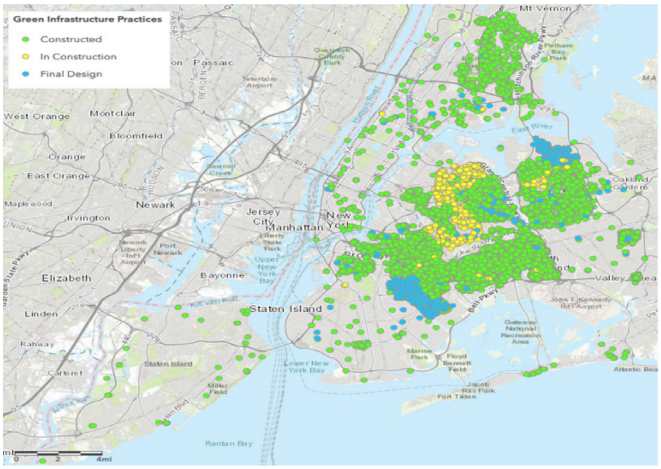

Fig 1: *DEP Infrastructure Program Map of NYC. The relevant colors in the map include GI assets; green=constructed, yellow=under construction, blue=final design phase*

Source: NYC OpenData, State of NJ, Esri, HERE, Garmin, USGS, NGA, EPA, NPS, last modified April 13, 2022

Description and Performance. New York City's Green Infrastructure program aims to reduce combined sewer overflows into NYC's waters while mitigating the urban heat island effect through urban greening and providing more native habitats for birds and pollinators throughout the city. The plan, introduced in 2010, has the overarching goal of allowing NYC to be able to manage 1" of stormwater runoff with green infrastructure across 10% of the impervious surfaces within the combined sewer area of the city by 2030. NYC's streets, sidewalks and other public, as well as private properties, are retrofitted with GI assets. The most widely implemented is the standard rain garden. Other GI measures include permeable playgrounds at parks and public schools and green roof installations incentivized through a DEP grant program on private properties. More than 11,050 GI assets have been installed or are currently under construction since 2012. To ensure a reliable performance of GI assets over time the program staff is performing maintenance and has set up a rain garden stewardship program, run by NYCDEP, to engage citizens directly or through environmental organizations at a level that matches their experience and availability.

Key Issues. The installation of rain gardens in the public right of way faces some challenges: necessary maintenance to ensure proper performance, conflict with the density of city infrastructure below the streets and sidewalk surfaces (gas, cable, freshwater lines), as well as high bedrock and high water table levels in some areas of the city. Where sidewalk space is very limited and maintenance difficult, mainly in industrial areas, the city is installing infiltration basins which result in a reduced cooling effect but require less maintenance. Additionally, acceptance of rain gardens and bioswales is facing challenges due to different aesthetic expectations and unsightly litter. Steady opposition has mounted in some communities where bioswales are now installed. During a storm, the bioswale fills with runoff water being led into the swale from the street and forms a pond until runoff infiltrates, typically within 48 hours. During this time, residents complain about the unsightly appearance, standing brown water often mixed with litter.

Increasing proper and regular maintenance of rain gardens from weekly to bi-weekly weekly is necessary to address the litter problem and proper performance. Community members also criticized a lack of outreach prior to installations of GI assets which contributed to a lack of acceptance. Some adjustments have been made to offer residents options from swales that look like a patch of grass to hiding the swales under a permeable concrete surface. This solution, however, eliminates the additional benefit of plants helping to cool their immediate surrounding environment through evapotranspiration.

Fig 2: *ROW rain garden installations at Denton Place, Brooklyn*

The program as initially laid out depends heavily on GI asset installations on private properties with approximately 50% of the land targeted by the city for GI installations being privately held. To date, however, most GI assets have been installed on public properties. In order to reach the stated goal of the GI plan by 2030, the program will need to increase its focus on incentivizing GI assets on privately owned land. A second important aspect for the initiative will be to keep NYC's goal of equity and sustainability in mind by expanding the measures in an equitable, collaborative, and inclusive manner, and at the same avoiding the triggering of "green gentrification;" the tendency that GI benefits lead to market pressures that

displace long-time residents from their neighborhoods.

Future Prospects. The GI program has made positive progress in the last eleven years despite unanticipated challenges. Reaching its stated goal in 2030 will require achieving missed milestones and an increased focus on GI measures on private properties. Currently, DEP's grant program and DEP's Private Property Retrofit program both focus on private properties 50,000 square feet and larger. As a result, there remains significant unrealized potential to capture water and divert roof runoff from the sewer system in many smaller catchment areas and in ways that are cost-effective on small private properties. These strategies could significantly contribute to a further reduction of CSO if widely implemented.

The opposition to the installation of GI assets in some areas could potentially be reduced if community outreach happened early on in the process to lay the groundwork for wider acceptance and collaborative decision-making among all stakeholders. The engagement of community volunteers in stewardship programs to maintain GI assets in systematic ways could further strengthen acceptance and care for the assets while helping to address the magnitude of maintenance needs to ensure proper performance. Well-maintained rain gardens and bioswale, in particular, could address some of the initial opposition towards their installation.

Fig 3: *Brooklyn Grange Sunset Farm, Brooklyn. Partially funded by DEP'S GI Grant Program.*

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Acknowledgments

We thank Lili Boenigk and Kirsten Ondris for providing valuable feedback on this case study.

Additional Data

• **Gross National Income (GNI):** 80,300 USD (High Income)

• **Population Density:** 10,612 people/km^2

• **Gini Coefficient:** 35.1

• **Human Development Index (HDI):** 0.927 (Very High)

• **Type of Climate Intervention:** Both
