Analysis of the Implementation of City-Wide Retrofit Sustainable Urban Drainage Solutions to Address Combined Sewer Overflow. Case Studies: New York City, Philadelphia, and Cleveland

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Introduction

Ambitious requirements for reducing combined sewer overflows (CSOs), and an expectation of more frequent and more severe flood events, have led large cities in the northeast United States to turn to Sustainable Urban Drainage Solutions (SUDS) to collect and treat stormwater runoff at the source. Over the past decade, New York City, Philadelphia, and Cleveland have developed long term CSO control plans to help improve the water quality of receiving water bodies. These cities are examples of how certain implementation programs have evaluated and utilized SUDS as a cost-effective means to improving the water quality in streams while other programs have prioritized gray infrastructure as a more advantageous way of managing CSOs. The implementation of differing technologies is a result of the types of city/local government agency organization and their jurisdictions, regulatory requirements, specific program goals, and performance results. Implementing an integrated solution, including SUDS, can enhance the performance of the gray infrastructure and improve water quality in receiving streams.

New York City, Philadelphia, and Cleveland have programs to invest between $2.4 and $5.3 billion over 20 to 25 years to implement long-term control plans. These investments are being used to meet ambitious CSO reduction goals. Each city is using SUDS in different ways according to its existing collection system infrastructure, ongoing urban development plans, available open space, and differing community needs. Each program prioritizes publicly owned properties for retrofits when available, targets CSO drainage areas, and requires coordination with other city-wide agencies.

This paper provides an overview of the regulations guiding the implementation of these programs, summarizes the long-term control plans and CSO reduction goals for each of these cities, identifies the different types of SUDS technologies being implemented, provides an update on how each city's long-term goals are being met, and offers examples of the many benefits gained by investing in combined solutions that include both green and gray infrastructure.

Background on US Regulations

Aging infrastructure throughout the United States is introducing a need for repair and replacement of collection systems. The high costs of upgrading the current infrastructure along with more stringent regulations on water quality compliance are leading cities to consider and invest in new technologies and integrated management solutions for system improvements.

The water bodies of the United States are regulated by the US government, specifically the Environmental Protection Agency (USEPA) and are enforced through regional EPA offices and state agencies. The first law to address water pollution was the Federal Water Pollution Control Act of 1948. The enforcement techniques for the Federal Water Pollution Control Act were ambiguous and failed to significantly improve water quality in US water bodies. The law was significantly revised in 1972, and included a much more detailed framework for regulating pollutant discharges. The new law introduced strict pollution reduction requirements from point and nonpoint sources. The law set forth maximum pollution discharge limits to the receiving waterbodies and over the years has greatly improved the water quality of lakes, rivers and streams across the US. To further insure improvements to receiving water body quality, the EPA established the Combined Sewer Overflow (CSO) Control Policy in 1994. The policy outlines a consistent nationwide approach for controlling discharges from CSOs. These increasingly stringent regulations have required city and state agencies to reevaluate the water quality and volume of CSOs at their discharge locations.

The combination of an increasingly changing environment with more intense and frequent storm events along with more stringent regulations, has pushed cities throughout the United States to develop integrated solutions to reduce CSOs and increase resilience where possible. SUDS technologies have been combined with traditional gray infrastructure to provide the cost-effective and highest-performance solutions. New York City, Philadelphia and Cleveland are only a few of the many cities across the United States to evaluate and implement these integrated solutions.

New York City, New York: PlaNYC / Green Infrastructure Plan

The New York City Department of Environmental Protection (NYCDEP) provides clean drinking water and wastewater treatment to over 8 million citizens. The NYCDEP has control of the revenue and budget for all water infrastructure in New York City including water supply, wastewater treatment and stormwater management. This includes the management of 14 wastewater treatment plants, 96 pumping stations and 422 CSO discharge locations. Sixty percent of the city's sewer system is combined and 40 percent is separated.

In 2007, New York City Mayor Bloomberg initiated PlaNYC, a city-wide plan for "a greener, greater New York". It outlined goals for land use, water, transportation, energy, air and climate change. The water initiatives were twofold: improve water quality and improve the water network. The goal to improve water quality was to improve CSO capture rate to over 75%, decrease bacterial levels, increase dissolved oxygen and ensure that over 90% of the city's tributaries and 98% of the waterways are open for recreational use. Implementation methods included developing long-term control plans for existing collection systems, expanding the wet-weather capacity of the wastewater treatment plants, utilizing proven solutions to prevent stormwater from entering the system, and to implementing, tracking and analyzing SUDS on a broad scale.[10]

The SUDS initiative led to the development of the NYC Green Infrastructure Plan, which includes a $5.3 billion investment in SUDS and gray upgrades. Analyses indicated that approximately $1.5 billion could be saved compared to using only gray infrastructure. The CSO volume reduction target is approximately 3.8 billion gallons (14.4 billion litres) per year.

The overall goal is to capture rainfall from 10% of impervious surfaces in CSO areas through SUDS and other source controls.[4]

To achieve these aggressive goals, the NYCDEP is prioritizing combined sewer drainage areas and implementing green infrastructure technologies wherever possible. New York City is using a number of SUDS technologies including "cookie cutter" bioswale standard designs within the right-of-way, and other site-specific SUDS technologies such as rain gardens, pervious pavements and underground storage systems through coordination with other city agencies in parks, schools and housing properties.

To date, New York City has installed thousands of right-of-way rain gardens and other SUDS technologies in the priority CSO areas but the city is behind in achieving its goals. The 2015 goal was to manage 1 inch of runoff from 1.5% of the impervious surfaces in combined sewer areas. By the end of 2015, DEP had only managed approximately 0.6% with the SUDS technologies implemented. A contingency plan was agreed upon to encumber additional funds to reach the remaining goals. The DEP plans to have over $1 billion allocated to the Green Infrastructure program over the next 10 years. A number of challenges have prevented the city from reaching this goal. Challenges include population and infrastructure density limiting the available space within the right-of-way to locate these systems, siting constraints due to Department of Transportation clearance requirements, underground utility conflicts and unfavorable soil conditions[5].

Philadelphia, Pennsylvania: Green City, Clean Waters

Philadelphia, Pennsylvania is located along the mid-Atlantic region of the eastern shore of the United States. The water utility agency for Philadelphia is the Philadelphia Water Department (PWD) which provides drinking water and wastewater services to over 1.5 million citizens. As in New York City, PWD controls the water supply, wastewater treatment, and stormwater facilities throughout Philadelphia, including the control of revenue and budget. The aging collection system comprises approximately 60% combined sewers and 40% separated sewers.

In 2011, the Philadelphia Water Department implemented the Green City, Clean Waters plan to use SUDS technologies to reduce stormwater pollution entering the combined sewer system. The plan extending for 25 years, includes an overall investment of $2.4 billion, of which $1.67 billion of which is dedicated to SUDS technologies, $345 million to wet-weather treatment plant upgrades, and $420 million is left for adaptive management (i.e. either SUDS or traditional gray infrastructure). The overarching water quality goal of the program is to eliminate the pollutants that would otherwise be removed from 85% by volume of the sewage collected in the combined sewer system during rain events.

Since the inception of the plan, Philadelphia has utilized stormwater tree trenches, rain gardens, wetlands, pervious pavement and other SUDS to manage stormwater at the source. As of 2016, five years into the program, the city has established 837.7 "greened acres," exceeding the initial target. The overall program has led to a reduction of over 1.5 billion gallons (5.6 billion litres) of CSOs with the implementation of these "greened acres" and other gray infrastructure improvements. A total of 441 SUDS sites have been installed. Even

though Philadelphia is currently on track to achieve their goals, the city has encountered challenges similar to those in New York City. Coordination and approval with utility agencies is an ongoing challenge on most projects.[8]

Other notable achievements of the Philadelphia Green City, Clean Waters Program are these:

- Public Green Stormwater Infrastructure Projects include the typical design and installation by PWD or other partnering agencies.
- The Incentivized Stormwater Infrastructure Projects consists of voluntary stormwater management projects on private properties as a direct result of PWD sponsored incentives including the stormwater billing and credit program and grants.
- (Re)Development Green Stormwater Infrastructure incorporates on-site stormwater management projects during the development or redevelopment of properties to comply with the City of Philadelphia's Stormwater Regulations.

Northeast Ohio Regional Sewer District: Project Clean Lake

Cleveland, Ohio is located within the Great Lakes region along Lake Erie. The Northeast Ohio Regional Sewer District (NEORSD) has responsibility for both regional wastewater and stormwater for Cleveland and 61 suburban communities. Unlike the NYCDEP and PWD, NEORSD is not a City, but a regional utility with a service population of approximately 1.4 million people and an area of 355 square miles (920 square kilometers). Each municipality is responsible for its own "local" sanitary sewer and storm sewer system, in total more than 6,000 miles (10,000 kilometers) of sewers, and each has its own method for generating revenue to operate and maintain their assets. The NEORSD regional wastewater system consists of three wastewater treatment plants and more than 300 miles (480 kilometers) of large-diameter trunk/interceptor sewers and 400 miles (640 kilometers) of regional stormwater conveyance. In addition, NEORSD has responsibility for compliance with CSO regulations within its service area. The collection system is approximately 23% combined and 77% separated and includes 126 permitted CSOs.

As a Great Lake, Lake Erie is considered a "sensitive receiving water" by the EPA and is subject to more stringent water quality regulations, including a goal to capture 98% of all combined sewage. In 2011, NEORSD entered into a consent decree with the US EPA, US DOJ, Ohio EPA, and Ohio Attorney General, to control an additional four billion gallons (15 billion litres) of CSO annually in order to achieve the 98% CSO capture goal. The plan was estimated to cost $3 billion over a 25-year period, which included the use of SUDS with gray infrastructure.

NEORSD developed a Green Infrastructure Plan that outlined the goal of capturing a minimum of 44 million gallons (166 million litres) of CSO in a typical year that would otherwise be discharged. The consent decree also required an investment of $42 million, of the $3 billion investment, to be allocated for SUDS to achieve this goal. The SUDS to be installed within NEORSD combined sewer areas were required to provide the NEORSD with permanent access and sufficient control over the infrastructure proposed, engage public participation wherever possible and must be completed within 8 years of the 2011 consent decree. Other considerations included methods of measuring performance, prioritizing

environmental justice considerations, including low income or minority areas, and operation and maintenance.

NEORSD has been implementing SUDs technologies since the inception of the Green Infrastructure program. Differently than New York City and Philadelphia, NEORSD has prioritized fewer large scale SUDS technologies to meet their green infrastructure goals compared to thousands of smaller SUDS systems. Notable large scale public engagement projects include a Complete and Green Streets project in partnership with the City of Cleveland which controls 4.8 million gallons (18 million litres) of stormwater in a typical year (Fleet Avenue) resulting in a 500,000 gallon (1.8 million litre) capture of CSOs, and the Urban Agriculture Innovation Zone (UAIZ) Project which includes amenities such as an outdoor classroom for community events and education programs. The UAIZ controls 12.4 million gallons (46.9 million litres) of stormwater in a typical year resulting in a 1.6 million gallon (6 million litre) capture of CSO annually. Additionally, NEORSD has developed a Green Infrastructure grants program to support more projects in the combined sewer areas to control stormwater, a Member Community Infrastructure Grants Program (MCIP) to address local water quality issues, and contributes to a Water Resource Restoration Sponsor Program to implement SUDs policies through restoration and protection.

Due to the stringent goals outlined by the EPA, the jurisdictional limitations as a separate utility, and considering the long term operation, maintenance and staffing needs over the 50 to 100 year project life cycle, NEORSD has found gray infrastructure to be the most cost-effective option to capture CSOs in Cleveland. NEORSD's future goals include more investment in gray technologies with the installation of seven large scale storage tunnels.

SUDS Technologies

Similar SUDS technologies are used in the implementation of Philadelphia and New York's long-term control plans. They range from large scale site development projects to smaller "cookie cutter" technologies that can be implemented quickly across large areas. Large scale site development SUDS include constructed stormwater wetlands, infiltration basins, underground storage facilities and tiered systems that may incorporate a number of different SUDS technologies in series.

Smaller systems typically installed at large scales include right-of-way bioswales or rain gardens, stormwater bumpouts or green streets and stormwater tree trenches. These smaller systems are usually installed along the right-of way and collect stormwater runoff from adjacent impervious roadways and sidewalks.

The SUDS technologies used in these two cities are similar in concept but may have its own terminology. For example, typical rain garden designs are referred to as right-of-way bioswales and stormwater greenstreets in New York City and stormwater planters and bumpouts in Philadelphia.

The SUDS technologies implemented by NEORSD are fewer in number but larger in size. NEORSD is unable to utilize the right-of-way or public spaces for available green infrastructure opportunities, and therefore, have installed nine large-scale SUDS systems that manage millions of gallons of water on an annual basis.

Lessons Learned

Through the development of these city's long term control plans, it is apparent that an integrated approach to SUDS and traditional technologies can be a cost-effective option in meeting water quality requirements for certain cities. Philadelphia and New York City rely on their jurisdiction as a city department to install SUDS technologies in a cost-effective way, while Cleveland, as a separate utility responsible for addressing wastewater and stormwater generated by other agencies has developed a different approach to implement and maintain green infrastructure. Many other cities across the United States are implementing versions of these combined approaches as they plan for the success and reliability of their infrastructure.

Although SUDS technologies are being implemented at a large scale across the US, it is important to understand their limitations. SUDS can be very effective and relied upon for smaller storms, typically less than 1" (2.54 centimeters) in depth, and can deliver water quality benefits in those smaller storms. For the larger volume and intense storm events, which need to be controlled in many CSO programs, tunnels and other gray storage solutions prove to be cost effective solutions. Additionally, the life-cycle costs of the implementation of SUDS technologies must be considered. Considerations should include anticipated owners, operations and maintenance costs and staffing needs and training programs required to keep these systems functioning properly. The thousands of SUDS technologies installed across cities such as New York City have resulted in a significant maintenance effort which may not be feasible for all city agencies or utilities. When evaluating the installation of SUDS technologies other costs and benefits should be considered including stormwater management, groundwater recharge, improved air quality, community aesthetics, public engagement and education opportunities and required funding for long term operation and maintenance.

Conclusion

In the development of the long-term control plans for each city, SUDS, in combination with traditional infrastructure, has proven to improve water quality benefits to the community. Traditional infrastructure remains critically important for hydraulic control of the largest storms that cause CSOs. SUDS, meanwhile, are well suited to handle smaller storms, provide a great aesthetic amenity for the community, and improve water quality for non-point source stormwater.

These large-scale urban areas are a testament to the ability of agencies to adopt new technologies. As agencies across the world strive to comply with ever-increasing CSO compliance standards and changing weather patterns, SUDS are becoming an important method to enhance the performance of traditional infrastructure and achieve greater water quality benefits.

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