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Influence of governance structure on green stormwater infrastructure investment

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ABSTRACT

Communities are faced with the challenge of meeting regulatory requirements mandating reductions in water pollution from stormwater and combined sewer overflows (CSO). Green stormwater infrastructure and gray stormwater infrastructure are two types of water management strategies communities can use to address water pollution. In this study, we used long-term control plans from 25 U.S. cities to synthesize: the types of gray and green infrastructure being used by communities to address combined sewer overflows; the types of goals set; biophysical characteristics of each city; and factors associated with the governance of stormwater management. These city characteristics were then used to identify common characteristics of “green leader” cities—those that dedicated > 20% of the control plan budget in green infrastructure. Five “green leader” cities were identified: Milwaukee, WI, Philadelphia, PA, Syracuse, NY, New York City, NY, and Buffalo, NY. These five cities had explicit green infrastructure goals targeting the volume of stormwater or percentage of impervious cover managed by green infrastructure. Results suggested that the management scale and complexity of the management system are less important factors than the ability to harness a “policy window” to integrate green infrastructure into control plans. Two case studies—Philadelphia, PA, and Milwaukee, WI—indicated that green leader cities have a long history of building momentum for green infrastructure through a series of phases from experimentation, demonstration, and finally—in the case of Philadelphia—a full transition in the approach used to manage CSOs.

1. Introduction

The connection of impervious surfaces directly to streams via stormwater infrastructure has resulted in a consistent decline in the ecological integrity of urban aquatic ecosystems (Meyer et al., 2005; Shuster et al., 2005; Walsh et al., 2005a; Schueler et al., 2009). A range of stormwater control measures (SCMs), also referred to as stormwater best management practices (BMPs), can be installed in suburban and urban areas to help mitigate stream water-quality degradation. For the past few decades, urban stormwater control has focused on large, centralized conveyance-based systems. These "gray" infrastructure systems use pipe networks to direct stormwater to a receiving waterway or store and slowly release stormwater using large ponds or storage tanks. Over the last decade, there has been growing recognition that static large-scale infrastructure may not meet current and future needs as urban areas continue to grow and as climate change alters expected precipitation regimes (Ahern, 2011; Palmer et al., 2015). Green stormwater infrastructure has been suggested as a more resilient option to supplement or replace gray infrastructure (e.g., pipes and storage tanks) because it is more flexible and multi-functional in the face of future extreme weather events (Grimm et al., 2016; Moore et al., 2016). We use the term ‘green stormwater infrastructure’ to include practices that manage stormwater runoff at the source where it is generated through the promotion of on-site storage, infiltration, and evapotranspiration. This includes SCMs such as bioretention, infiltration trenches, tree box filters, green roofs, and permeable pavement.

The debate over the use of gray or green infrastructure for stormwater management continues (Palmer et al., 2015). City managers are grappling with how to balance costs with meeting water-quality requirements for Federal National Pollutant Discharge Elimination System (NPDES) permits, calling for improved control of stormwater and an 85% reduction in combined sewer overflows (CSO) into local waterways (US EPA, 1994). Combined sewer systems are those in which one pipe carries both stormwater and wastewater. When the capacity of

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the combined sewer system is exceeded during storms, CSOs occur, i.e., excess stormwater with mixed sewage is discharged directly to local waterways. For cities with combined sewer systems, meeting reduction targets will require investing millions, and in some cases billions, of public dollars in water infrastructure in the coming decades. The U.S. Environmental Protection Agency (EPA) estimated capital investments of $48.0 billion are needed over the next 20 years for publicly owned treatment works to address CSOs and meet water-quality objectives of the Clean Water Act (US EPA, 2016). Of the $48.0 billion in documented needs, 20 communities indicated $4.2 billion is needed specifically for green infrastructure projects.

Common gray infrastructure solutions to reduce CSOs include the construction of large-scale projects such as underground tunnel or tank storage systems, upsized pipes, and sewer separation. In contrast, green infrastructure solutions require investments in multiple small-scale projects, in which amended soils and vegetation capture and infiltrate stormwater at the source where it is generated. Green stormwater infrastructure solutions include practices such as bioretention (e.g., bioswales and rain gardens) and retention basins. There is an increasing trend in implementing decentralized approaches to water management in local communities, such as green stormwater infrastructure like rain gardens (Walsh et al., 2005b; Gleick, 2003). But widespread adoption of these approaches remains limited due to institutional and organizational barriers, including fragmented responsibilities, lack of coordination among city authorities, limited institutional capacity, resistance to change, and lack of market incentives (Roy et al., 2008; Keeley et al., 2013; Brown et al., 2013; Chaffin et al., 2016). Perceived risk and lack of experience installing green stormwater infrastructure remains another barrier (Oolorunkiya et al., 2012). Even with these uncertainties, several U.S. cities have incorporated a city-wide green infrastructure program to address CSOs (e.g., Philadelphia, PA, Green City Clean Waters Program and Milwaukee, WI, Fresh Coast Green Solutions). The green infrastructure program in Milwaukee was motivated by the need for measures beyond what gray infrastructure could provide, as the city had already invested millions in storage tunnels (Keeley et al., 2013). The green infrastructure program in Philadelphia sparked from experimentation in green infrastructure pilots, billing, and organizational structure (Fitzgerald and Laufer, 2017). These cities have committed to substantial financial investments in green infrastructure approaches.

In this study, we set out to identify “green leader” cities that are planning to invest substantially in green infrastructure to address CSOs and examined if there are common structural aspects of governance in communities that are investing substantially in green stormwater infrastructure to address CSOs. Support for green infrastructure was gauged based on financial commitments for green approaches to address CSOs outlined in control plans. We gathered data on green infrastructure implementation from 25 U.S. cities with combined sewer systems. We characterized two factors associated with governance of the combined sewer system: 1) scale and complexity of system management and 2) the regulatory setting in which stormwater management decisions are made. Two case studies are presented as examples of development of gray and green infrastructure programs in the two cities with the largest proportional investment of green infrastructure in the long-term CSO control plan.

2. Background

Numerous factors influence local managers' decisions to implement green or gray infrastructure approaches to address CSOs. To explore the factors influencing governance decisions, we examined some of the socio-political drivers of stormwater infrastructure transitions from gray to green approaches in U.S. cities. The water management regime and governance can be characterized according to its structural dimensions, including institutions, vertical and horizontal flows of influence, and policy arenas (Pahl-Wostl, 2007). Fragmented responsibilities can be an important impediment to sustainable, watershed-scale stormwater management because responsibilities are spread across multiple jurisdictions and among different levels of government (Roy et al., 2008). Therefore, we hypothesized that cities that are able to integrate green stormwater infrastructure at the city-scale will have sewer authorities operating at smaller geographic scales (i.e., city versus county) with low municipal complexity (i.e., fewer municipalities in service area). The lack of a legislative mandate can also be an impediment to watershed-scale changes to the types of SCMs installed for stormwater management. Therefore, we characterized the regulatory setting, specifically if there was a Federal consent decree in each of the study cities to examine the timing of regulatory change, CSO control planning, and the initiation of green infrastructure programs in each city. A Federal consent decree is a binding agreement between the EPA and the sewer authority that establishes the terms, compliance schedule, and cost commitment to address CSOs in that community.

The integration of green stormwater infrastructure as a strategy to improve urban water quality provides a unique opportunity to relate municipal adaptability or the lack of adaptability to stormwater governance, since green stormwater infrastructure is a relatively new innovation in U.S. cities. City-scale integration of green stormwater infrastructure can be viewed as a technological transition. Geels (2002) defines a technological transition as a major change in the way societal functions are fulfilled. The control of urban stormwater can be used as the societal function while the shift from large, centralized gray treatment systems to smaller, distributed green infrastructure systems can be viewed as the transition. Growth of new policies and initiatives can be fostered when the problem, solution, and political streams all converge (Kingdon, 1984). This convergence and the opening of a “policy window” together can allow policy entrepreneurs to gain support and launch new ideas, resulting in major agenda change that occurs quickly during a "spasm of reform" (Kingdon, 1993). Thus, we frame the development of a city’s CSO long-term control plans, hereafter referred to as the control plan, as the opening of a policy window in which green infrastructure can be infused under certain conditions. We examined on a broad scale whether green infrastructure is integrated during that window in 25 communities, and we then focused on two case studies of green infrastructure program development in Milwaukee, WI, and Philadelphia, PA.

3. Methods

3.1. Study cities

The majority of cities with combined sewer systems in the United States are located in the Northeast, Upper Midwest, and Pacific Northwest (Fig. 1). To span the range of geographies associated with combined sewer systems, 25 study cities were selected, including the top 10 cities with the greatest number of CSO outfalls (Fig. 1). All study cities have large combined sewer systems serving 50,000 people or more, representing about 24% of all communities with large CSO systems. No small CSO systems (serving less than 50,000 people) were included in this analysis. The city set included eleven cities with small combined sewer service areas of $< 100\,km^2$, nine with medium-sized combined sewer service areas of $101–250\,km^2$, and five with large CSO service areas of $> 250\,km^2$. The annual average CSO volume ranged from a maximum of 30 billion gallons in New York City, NY, to a minimum of 700 million gallons in Albany, NY (Table 1).

3.2. Data sources

There was no national system to track milestones related to CSO control plans and consent degrees, rather each EPA region developed their own tracking system (US EPA, 2015). Therefore, we used existing literature and municipal reports as the primary data sources for this analysis. The EPA's CSO Control Policy indicates that communities with