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Urban Stormwater Governance: The Need for a Paradigm Shift

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Abstract Traditional urban stormwater management involves rapid removal of stormwater through centralized conveyance systems of curb–gutter–pipe networks. This results in many adverse impacts on the environment including hydrological disruption, groundwater depletion, downstream flooding, receiving water quality degradation, channel erosion, and stream ecosystem damage. In order to mitigate these adverse impacts, urban stormwater managers are increasingly using green infrastructure that promote on-site infiltration, restore hydrological functions of the landscape, and reduce surface runoff. Existing stormwater governance, however, is centralized and structured to support the conventional systems. This governance approach is not suited to the emerging distributed management approach, which involves multiple stakeholders including parcel owners, government agencies, and non-governmental organizations. This incongruence between technology and governance calls for a paradigm shift in the governance from centralized and technocratic to distributed and participatory governance. This paper evaluates how five US cities have been adjusting their governance to address the discord. Finally, the paper proposes an alternative governance model, which provides a mechanism to involve stakeholders and implement distributed green infrastructure under an integrative framework.

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Introduction

While providing numerous socioeconomic and cultural benefits to humans, urbanization causes significant adverse impacts on the environment. Two major impacts include the destruction of biodiversity and the disruption of hydrology. The former results from the removal of vegetation and topsoil, which damages plant species and soil organisms in addition to micro and macro habitats. The latter results from the removal of vegetation, gradation and compaction of soil, and construction of impervious structures. These activities reduce the hydrologic functions of the landscape such as interception, evapotranspiration, retention, and infiltration of rainwater. As a result, the volume of rain water that causes stormwater (e.g., the portion of rainwater that flows over the land) increases, which in turn increases the peak, rate of flow, and frequency of flooding (Chow 1964; Debo and Reese 2003; National Research Council 2009). This leads to an increased potential for property damage, public safety threat, and social inconvenience. Urban stormwater also carries numerous pollutants from urban areas and discharges into receiving waters. Examples include sediments, viruses, bacteria, nutrients, pesticides, oil, grease, and heavy metals (US Environmental Protection Agency (US EPA) 2003).

In addition to stormwater problems, the disrupted hydrology also causes other multiple environmental problems. The decreased infiltration diminishes groundwater recharge, which results in reduced baseflow in the downstream rivers and causes water scarcity for freshwater ecosystems. The altered flow, increased wet weather flow and decreased base flow, alters the sediment transport pattern and geomorphology of the downstream water bodies, adversely affecting their ecosystem structures and functions (Leopold 1968; National Research Council 2009; Niemczynowicz 1999; Paul and Meyer 2001; Walsh et al. 2012). The decreased water content in the subsurface due to decreased infiltration, soil porosity, and groundwater table, results in deficiency of water for plant uptake causing further loss of surface vegetation. The loss of vegetation alters energy inputs into the urban streams and affects stream biota (Vannote et al. 1980). More over, the diminished water/air content in the soil affects presence of soil organisms, which prefer water-filled pores (e.g., bacteria and protozoa) and air-filled pores (e.g., fungi and arthropods) (National Research Council 2012). The decrease in moisture/air content in soil can lead to the loss of these organisms. Since such soil organisms (e.g., bacteria, fungi, plant roots, and burrowing worms) impact the soil structure, the loss of these organisms alters the biophysical processes as well as the hydraulic conductivity and infiltration rate of the soil (National Research Council 2012).

Clearly, the principal causes of urban stormwater management problems are hydrological disruption and devegetation, which mutually exacerbate one another and create other socio environmental problems. By damaging natural ecosystem structures (e.g., vegetation, soil structure, and channel form), the two activities lead to a reduction of ecosystem functions and an exhaustion of ecosystem services, which are the services provided by ecosystems to humans such as food, habitat, flood control, and community esthetics (Millennium Ecosystem Assessment 2005; Ruhl et al. 2007). This results in socio-ecological disconnection in cities (Karvonen 2011).

Stormwater management was originally meant to address the problem of urban flooding from storm events. Therefore, conveyance system of pipes and gutters, called gray infrastructure, was constructed to collect and remove stormwater quickly out of urban areas (Delleur 2003; Novotny and Brown 2007; Novotny et al. 2010). Although gray infrastructure greatly addressed urban flooding and associated problems (Burian et al. 2000; Porse 2013), it did not address the environmental problems associated with devegetation and hydrologic disruption. To address these problems, decentralized methods that manage stormwater on-site using vegetation and soil and mimicking natural hydrology are now available and have begun to be applied. This approach is known as green infrastructure (GI), which consists of a range of low impact development (LID) measures including green roofs, permeable pavements, rain gardens, vegetated swales, planter boxes, and rain barrels. The approach is called Sustainable Urban Drainage System (SUDS) in Europe and Water Sensitive Urban Design (WSUD) in Australia. In addition to treating stormwater on-site, green infrastructure provides several ancillary benefits including restoration of biodiversity (Wong and Brown 2009), revival of ecosystem structures and services (Andersson et al. 2014), and enhancement of water quality (Novotny et al. 2010). It helps to re-establish the socio-ecological connectivity (Tzoulas et al. 2007) and achieve urban sustainability (Foster et al. 2011). The approach is also cost-effective when compared to gray infrastructure (Foster et al. 2011; Shaver et al. 2009).

Several cities in Europe and Australia have been using the approach for decades (Keeley et al. 2013). In the US, many cities have encouraged the use of the approach for over a decade (US EPA 2010). The US EPA is also increasingly promoting its use (US EPA 2014). However, the approach is not yet widespread. Studies cite current governance as a major barrier to mainstreaming the technology (Ellis et al. 2010; Rijke et al. 2013). Scholars have termed the governance barriers with different names such as socio-institutional barriers (Clune and Braden 2007; Brown and Farrelly 2009; Rijke et al. 2013), organizational barriers (Cettner 2012; Keeley et al. 2013), and administrative inertia (Brown 2005, 2008). However, a comprehensive evaluation of the governance is still lacking (Van de Meene et al. 2011). Therefore, there is a critical need for exploring the issues and formulating appropriate strategies to solve them. This research contributes toward addressing this need.

The approach used in this study was largely exploratory. Five US cities (Portland, Oregon; Seattle, Washington; Philadelphia, Pennsylvania; Chicago, Illinois; and Syracuse, New York) were selected for the study. Their stormwater governance was evaluated using city codes and other published materials. For each city, an assessment of the use of gray infrastructure versus green infrastructure was considered, and governance barriers to the full implementation of green infrastructure were identified. This paper presents a set of identified issues and proposes a new stormwater governance model conducive to green infrastructure.

Stormwater Governance: Issues and Implication

Although governance is a broad notion with no unanimous definition, it has some universal functions and attributes at its core. It provides a framework for decision making (Porse 2013) to regulate human interactions in a shared environment (Oakerson 2004). It refers to “collective action” accomplished for public purpose (Heaney 2007) within a defined jurisdiction and comprises a broader scope than government (Feiock 2004; Evans 2005). In addition to government, it encompasses societies, individuals, private sectors, laws, regulations, institutions, and formal and informal organizations (Tortajada 2010; Porse 2013). In other words, governance regulates the works of people both inside and outside government (Oakerson 2004). As Bovaird and Löffler (2009) outline, governance is "the way an organization works with its partners, stakeholders, and networks to influence the outcomes of public policies." Bishwas and Tortaza (2010) determine accountability, transparency, participatory, and decentralized decision making as common essential attributes of modern democratic governance. For the purpose of this paper, we define stormwater governance as the organizational authority that formulates as well as implements stormwater policies and programs. As such, the paper focuses on leadership mechanism and functional jurisdiction of its various components, not on policies, regulations and programs.

Currently, urban stormwater governance in the US has a hierarchical structure consisting of federal, state, and local governments. At the federal level, the US Congress enacts laws (e.g., Clean Water Act), which the US EPA enforces through standards and regulations. Under the federal guidelines, states can enact and implement more stringent standards on city or county governments, which carry out the stormwater management activities. City or county governments implement the federal and state laws and can also enforce their own discretionary standards and regulations as long as their minimum standards comply with the state and federal standards. Within a city, a designated agency governs all activities related to stormwater through its technocratic administration.

Major Issues of Stormwater Governance

Major issues identified by the study are presented as follows.

Intrinsic Issues

Existing urban stormwater governance inherently lacks many of the essential attributes of governance discussed earlier. The approach is highly centralized and dominantly technocratic, in which engineers of a designated city agency centrally manage stormwater through a command-and-control approach. The technocrats are trained for, experienced with, and inclined to design, construct, maintain, and repair gray infrastructure, not green infrastructure. This approach in part instills into their minds a reluctance to implementing a green infrastructure (Brown 2008). Although cities solicit public input in program development and implementation process, as per Stormwater Phase II Rule, technical complexities of gray infrastructure may often discourage the public to actively participate in the process. Even if citizens participate and provide their opinions, it is very likely that the opinions appear technically less important to the technocrats and are disregarded in the final decision. Since landowners do not have to pay for the stormwater management costs directly from their pocket, because the budget comes from the city's general revenue funds, they perceive stormwater management as city's responsibility, not theirs. Hence, there is no incentive for the landowners to participate in the governance. Due to this, the public may not show much concern to stormwater governance activities, which potentially leads to lack of transparency. Thus, traditional governance lacks the essential attributes of modern democratic governance outlined by Bishwas and Tortaza, cited earlier.

Decoupled Governance of Intercoupled Functions

Urban stormwater is an integral part of an urban water system and is a subsystem of urban environmental system. However, it is governed not as a subsystem (Brown 2005; Wilkinson et al. 2013), but as an isolated and independent undertaking. Its governance, in general, does not encompass other urban activities that impact hydrology, such as city planning, land use policy decisions, development control, and building construction (Niemczynowicz 1999). The mutually functioning urban vegetation and urban stormwater are also governed separately. The three components of urban water system, stormwater, waste water, and water supply, are generally governed separately through different agencies. Although the idea of Integrated Water Management and/or Sustainable Water Management has come into discussion among scholars for decades, it has not yet made any considerable advancements (Biswas and Tortajada 2010; Foster and Ait-Kadi 2012). As a result, viability of Integrated Water Management (Biswas 2004) and Sustainable Water Management (Biswas and Tortajada 2010) has come into question, despite being strongly advocated as efficient approaches by experts.

Runoff from Private Parcels: Responsibility Versus Authority Dilemma

Under current governance regime, a major predicament for city government to implement green infrastructure is associated with managing stormwater runoff from private land, which occupies the majority of a city area. The CWA requires a National Pollutant Discharge Elimination System (NPDES) permit for a discharge of pollutants by a person from a point source into navigable waters. Since municipal separate storm sewer systems (MS4s) are point sources, it is mandatory for a city to obtain NPDES permit for a MS4. Unfortunately, the cities cannot enforce the permits on private parcels, which are major sources of MS4 discharges, since the statutory definition does not consider stormwater as a pollutant and land parcels as point sources. Thus, the CWA for a city is a liability, not a tool to manage stormwater. In other words, the statute gives cities responsibility but not authority to control stormwater from a private property. City governments also cannot enforce other regulatory measures to install green infrastructure because of the exclusive constitutional right given to private property owners. The Fifth Amendment prohibits both physical and regulatory taking of private property for public purpose "without just compensation." But the constitution, as Ruhl et al. (2007) observe, does not further define what it means by just compensation. Additionally, the Fourteenth Amendment guarantees "due process" and prohibits government control of private property without legislative authorization, which is a very complex process in itself. Therefore, implementing green infrastructure on private land by the conventional centralized governance through a command-and-control approach is very challenging.

Pro Gray Mindset

Social mindset favoring gray infrastructure is another obstacle for the governance to implement green infrastructure on private lands (Brown and Farrelly 2009; Niemczynowicz 1999; Wilkinson et al. 2013). The long-established practice of gray infrastructure has made people accustomed to unrestrained access to city maintained gray systems to discharge runoff from their property without paying the direct costs. Due to this, green infrastructure appears costlier, hence uncompetitive, to the residents, even when they would result in lower costs in the long run (Goddard 2012). This may encourage landowners to oppose implementation of green infrastructure on their land. As a consequence, policies and programs supporting green infrastructure on private parcels are likely to lose political support, because politicians, in general, do not want to put their political career at risk by supporting the policies opposed by their voters.

Mismatch of Political and Hydrologic Boundary

Jurisdictional boundaries of political entities, such as cities, counties, and residential districts, rarely match with those of hydrologic units. This mismatch results in fragmented governance of a single hydrologic unit such as a watershed. Although this incompatibility does not limit any governance entity from implementing source control measures within its jurisdiction, it inhibits the implementation of the measures across the whole hydrologic unit and integrate them to function as an integrated system, unless all the governances entities within the hydrologic boundary coordinate to formulate consistent policies and collaborate to implement them. Since, more often than not, different governing entities have conflicting visions, priorities, and goals (Keeley et al. 2013), formulating consistent policies and implementing them is politically and socially complex.

Need for a Regime Change

Governance is not a static concept (Grigg 2011). For effective functioning, it needs to be continuously updated to incorporate growing scientific knowledge as well as changing socio-technical context. However, stormwater governance has essentially remained unchanged since the inception and spread of gray infrastructures in the nineteenth and twentieth century, despite significant changes in technology, public perception, and other contexts. A change in governance regime is, therefore, required to address the problems inherent in the current governance discussed earlier, as well as to incorporate the changes discussed below.

Shift in Perceptions and Attitudes

In recent decades, there has been a fundamental shift in the way stormwater is perceived. It is now regarded as a freshwater resource (Marsalek et al. 2007; Novotny et al. 2010; Karvonen 2011; Cettner 2012) rather than a nuisance (Wong and Eadie 2000; Marsalek et al. 2007). Understanding of the importance of ecological health for urban livability has also increased significantly (Wilkinson et al. 2013). Cities are designing and implementing strategies for hydrological restoration of urban watersheds. Adoption of ecological principles for urban design is on the rise (Hill 2007; Wu 2014) leading to the emerging sustainability paradigm of urban development (Novotny and Brown 2007; Wu 2014), which sets maintaining or mimicking hydrological integrity of landscapes as a central theme.

Technological Innovation

The changed perception and attitudes founded on the increased understanding of ecological value of stormwater has resulted in the innovation of green technology, which is fundamentally different from gray technology in many aspects including objectives, materials, design, construction, and maintenance. Gray is largely an artificial method requiring highly skilled engineers to govern, whereas green is largely a natural approach involving soil and vegetation, and requiring collaboration among experts from multiple disciplines including hydrologists, soil scientists, plant biologists, and landscape designers. Since the two approaches are substantially different and the old governance cannot address many aspects of the new approach, as illustrated in the previous sections, a new governance approach is warranted.

Evolving Goals and Objectives

Historically, the only objective of stormwater management was to control flood by draining stormwater through hydraulically efficient conveyance systems (Wong and Eadie 2000; Novotny et al. 2010; Grigg 2013). The engineers were concerned only with technical performance and economic efficiency (Delleur 2003). Now, stormwater management has become a highly integrated (Fletcher et al. 2014) and multi-objective (Wong and Eadie 2000; Grigg 2013; Fletcher et al. 2014) undertaking that includes flood control, water quality control, visual amenity, recreational value, and ecological protection (Zhou 2014). The other objectives include restoration of infiltration in the urban landscape, recharge of groundwater, and maintenance of more natural flow regimes in the receiving water bodies (Walsh et al. 2012; Fletcher et al. 2014). To achieve these multiple objectives, a governance approach with wider scope is required.

Altered Management Hierarchy

Traditional approach to stormwater management relies on collecting stormwater from individual parcels to central system that conveys and discharges into receiving waters. Most of the components of gray infrastructure are in the public domain under city control. Accordingly, management responsibility is on the city government. Conversely, in the new approach, management tendency is to promote flow distribution instead of collecting it, and the system components have to be installed on the private properties as well. Thus, the management reverses from central collection to distribution. For landowners, the "out-of-sight ought-of-mind" undertaking in the old approach now becomes a responsibility, requiring their involvement in decision making as well as implementation.

Change in Actors of Governance

In traditional approach, a designated city agency is the only actor of governance. Since green approach requires on-site management, it shifts some of the governing responsibilities from government to the private landowners (Novotny et al. 2010), who generate stormwater by changing their land features. Thus, actors of governance are expanded from a government agency to multiple stakeholders including landowners, business owners, community organizations, other city agencies, and outside government agencies. This alters the decision making structure of governance. Instead of dominantly discretionary decision making by city engineers who design and maintain a gray approach, a green approach requires harmony among decisions of all stakeholders involved in the process including landowners (Ellis et al. 2010).

Are the Frontrunner Cities on the Right Path?

Stormwater Governance in Five US Cities

Recently, some US cities have been implementing green infrastructure with encouraging results (Novotny et al. 2010; US EPA 2010; Foster et al. 2011; Chen and Hobbs 2013). Among those, governance of five cities (Portland, Oregon; Seattle, Washington; Philadelphia, Pennsylvania; Chicago, Illinois; and Syracuse, New York) were studied to explore changes, if any, adopted to implement green infrastructure. A recent study (Chen and Hobbs 2013) shows that these cities are among the leader cities in the US for implementing green infrastructure. They are adopting strategies including incentives for private party involvement, dedicated funding, long-term green infrastructure plans, and stormwater retention standards.

To analyze the stormwater governance, the city functions that have major impacts on hydrology were grouped into following five categories: (1) city planning; (2) development control; (3) water, wastewater, and stormwater management; (4) roads and streets; and (5) parks and open spaces. The functional jurisdictions of city agencies were then analyzed based on these categories. City codes were studied in order to identify the governance structures and functional jurisdictions of the respective agencies. In cases where the city codes did not provide sufficient information, other sources, such as official web sites and reports, were used. The findings are summarized in Table 1.

Seattle, Washington

In Seattle, planning, zoning, and development control responsibilities are assigned to the Department of Planning and Development (DPD) (Seattle Municipal Code 2014, §3). The Seattle Public Utilities (SPU) is responsible for the management of stormwater, water, solid waste, and wastewater. SPU and DPD share the inspection and response responsibilities. All activities in the city right-of-way are the responsibility of the Seattle Department of Transportation (SDOT). The Department of Parks and Recreation implements stormwater codes in its jurisdiction. King County is responsible for wastewater treatment (SPU 2014). The city also participates in regional programs, such as the Stormwater Outreach for Regional Municipalities (STORM) and the Puget Sound Start Here (PSSH) regional

Table 1 Functions affecting stormwater and responsible city agencies

City functions	City and responsible city agency				
	Seattle, WA	Portland, OR	Philadelphia	Chicago, IL	Syracuse, NY
City planning	Department of Planning and Development	Bureau of Planning and Sustainability	City Planning Commission	Department of Planning and Development	City Planning Commission
Development control	Department of Planning and Development	Bureau of Development Services	License and inspection	Department of Planning and Development	Department of Neighborhood & Business Development
				Department of Building	
Water (w) wastewater (ww) and stormwater (sw)	Seattle Public Utilities: w, ww, sw	Water Bureau: w	Philadelphia Water Department	Department of Water	Department of Water: ws
	King County: ww treatment	Bureau of Environmental Services: ww, sw		Department of Bldg	Department of Public Works
					Department of Engineering
Roads/streets	Seattle	Bureau of Transportation	Department of Streets: Projects in right-ofway	Department of Street & Sanitation: sanitation, plantation in medians	Department of Engineering: street grades
	Department of Transportation			Department of Transportation: design/construct roads	Department of Public Works: Plan & design of streets
Parks	Department of Parks & Recreation	Bureau of Parks (also regulates)	Department of Parks and Recreation	Chicago Park District	Department of Parks Recreation & Youth
Others	Office of Sustainability	Office of Neighborhood Involvement	Mayor's Office of Transportation and Utility	Sustainability Council chaired by Mayor	Department of Community Development

campaigns. The SPU is a member of Water Supply Forum, a regional organization of public water systems and local governments from King, Pierce, and Snohomish counties (SPU 2014). The SPU engages the public through community advisory councils and green infrastructure partnerships. It conducts academic programs in schools for K-12 youths, and organizes annual watershed forums and public tours for community people. For community participation for cleanup, the SPU also sponsors programs such as "Adopt-a-Street" and "Adopt-a-Drain."

Portland, Oregon

In Portland, the Bureau of Planning and Sustainability (BPS) develops, modifies, and updates comprehensives plans and land use plans (the City Code of Portland 2014, §3). The BPS establishes and updates sustainability principles, climate change mitigation/adaptation practices, and other sustainability policies. The Bureau of Development Services (BDS) implements and enforces planning, zoning, and building regulations, and controls construction and land modification activities. The Bureau of Environmental Services (BES) is the lead agency for sewage and stormwater collection and treatment. The water supply system is under the Portland Water Bureau (PWB). The Bureau of Parks is responsible for the construction and maintenance of parks and golf courses. For public participation, the BES conducts watershed specific as well as citywide public activities including Clean Rivers Education programs for K-12 students, community stewardship programs, and community activities. The BES also participates in the Regional Coalition for Clean Rivers and Streams. It collaborates with the Port of Portland, which manages stormwater in approximately 5500 acres within the city's urban service boundary. It also works with neighborhood associations, streamside property owners, and Army Corps of Engineers. For public participation, the city has instituted the Development Review Advisory Committee, which consists of representatives from 17 stakeholders such as communities, professionals, and business organizations. The committee provides public inputs into the development review process.

Philadelphia, Pennsylvania

In Philadelphia, the City Planning Commission (CPC) prepares the physical development plan and zoning code, which is implemented by the Department of License and

Inspection (DLI) (Philadelphia Code 2014, §5). The Philadelphia Water Department (PWD) is responsible for water supply, stormwater management, and wastewater management services that include wastewater treatment. Construction and maintenance in streets and right-of-ways are under the jurisdiction of the Department of Streets (DOS). Facility construction and maintenance in parks fall under the responsibility of the Department of Parks and Recreation. The PWD encourages stakeholder involvement through programs such as education, outreach, and cleanup. It collects public inputs on goal setting, and mobilizes the community to identify vacant land appropriate for green infrastructure installation (PWD 2014). The PWD collaborates with outside government agencies for shared jurisdictions. For example, the city collaborated with Delaware, Montgomery, and Chestar counties for Darby-Cobbs Creek in 2004 (PWD 2014). The city is working with EPA to use the city as a "learning laboratory" for green infrastructure (Chen and Hobbs 2013).

Chicago, Illinois

The Department of Planning and Development (DPD) is responsible for city planning and land use policies and regulations in Chicago (Chicago Municipal Code 2014, §2). The Department of Building regulates construction activities and approves and enforces the stormwater management plan for development projects. Stormwater and wastewater management are shared between the Department of Water Management (DWM) and the Metropoltan Water Reclamation District (MWRD), which is a state agency. The DWM collects the stormwater and wastewater through its combined sewer system and routes to the MWRD's interceptor sewers, after which the flow comes under the responsibility of MWRD for storage, treatment, and discharge. The Department of Streets and Sanitation (DSS) performs cleaning and sanitation works for public ways. It is also responsible for planting trees on parkways and medians. The Chicago Department of Transportation (CDOT) is responsible for the construction works on local transportation projects, and controls activities on the right-of-way and public sidewalks. It also supervises the dredging, deepening, and widening of waterways. All the parks and open spaces are the responsibility of the Chicago Parks District (CPD). The DWM coordinates with city departments and agencies to integrate green infrastructures into City projects. For example, in coordination with MWRD, Chicago Public Schools (CPS), and CDOT, the DWM identified 39 green projects for 2014. It also involves community non-profit organizations including the Metropolitan Planning Council, Chicago Wilderness, Space to Grow, and the Center for Neighborhood Technology.

Syracuse, New York

In Syracuse, the City Planning Commission (CPC) prepares and maintains a comprehensive development plan for the city including all lands located within three miles of the city's jurisdictional boundary (the Charter of the City of Syracuse-1960, 2014, §5). The CPC also prepares a zoning plan subject to the City Council's adoption. The Department of Neighborhood and Business Development (NBD) formulates and approves building code of the city. The NBD also coordinates neighborhood development activities. The Engineering Department (ED) performs engineering and survey services for the construction activities. The Department of Public Works (DPW) is the lead department for collection, treatment, and disposal of wastewater and stormwater. It is also responsible for the construction, repair, and cleaning of city streets and bridges. The Department of Parks and Recreation (DPR) constructs facilities in the city's parks. The CPC works in collaboration with other outside agencies, such as Syracuse-Onondaga County Planning Agency, which comprises representatives from both the CPC and the County Planning Agency. This coordinates all the planning activities affecting the County and the City.

Summary of the Findings

The study of the five cities elucidated the following facts:

1. Each city in this study has a dedicated centralized agency (utility, department, or bureau) designated to function as the lead agency for stormwater management. The agency governs stormwater predominantly through a command-and-control approach. Therefore, the overall governance is dominantly centralized and technocratic.
2. The major functions, such as city planning, zoning, development control, and construction and maintenance works in parks and right-of-ways that have major impacts on landscape hydrology and stormwater management are not under the jurisdiction of the lead stormwater management agency. This leads to fragmented governance, which are prone to conflicting policies and programs.
3. Some cities share stormwater management responsibilities with other government agencies (e.g., county or state agencies). Examples include Chicago and Seattle, where the city bears the responsibility of the collection system but not the treatment work. The treatment work is the responsibility of MWRD in Chicago, and Metropolitan King County in Seattle. The agencies sharing such responsibilities have been working in collaboration to accomplish their designated task.

4. The problem of incongruence between political and hydrological boundary remains unaddressed. Although cities collaborate with other local governments in shared regional watersheds (e.g., Seattle participates in STORM and PSSH), the collaboration is voluntary, which lacks decision making and enforcement authority.
5. As required by Stormwater Phase II Rule, cities encourage public participation in stormwater management activities through programs such as education, outreach, and cleanup campaigns. They also solicit public comments on major public projects and policy formulation. However, since incorporating public suggestions in the final decision making is at the discretion of the agency leadership, it is likely that public suggestions are not implemented. This may discourage the public to participate.
6. There is no formal community-level governance mechanism to involve individual landowners and other local stakeholders (e.g., community organizations, neighborhood groups, and business organizations) in the development of policies, programs, and management needed to implement green infrastructure. Existing subdivisions, such as residential districts and wards (e.g., Chicago), neither have any such mechanisms and responsibilities nor are they delineated by their hydrological boundaries.
7. The city agencies have taken initiatives to motivate their staff to implement green infrastructure through approaches such as training, enactment of new regulations, and adoption of new manuals. These initiatives are important to shift mindset of agency staff as well as developers.
8. Currently, green infrastructure implementation is predominantly limited to public land. However, it is estimated that 65–75 percent of land is private residential property (Rodrigue 2013), where cities cannot enforce the programs due to constitutional protection of private property from uncompensated governmental takings. Many incentives (e.g., fee discount, development incentives, rebates, and installation financing) and other programs (e.g., education, outreach, and cleanup) offered to private landowners have produced encouraging results. However, they have not been sufficient to make green infrastructure a common practice on private parcels.

The findings reveal that though initiatives taken by the cities have shown positive results, the general problems associated with governance discussed earlier remain in place preventing the mainstreaming of green infrastructure.

The Road Ahead: Two-Tier Model of Stormwater Governance

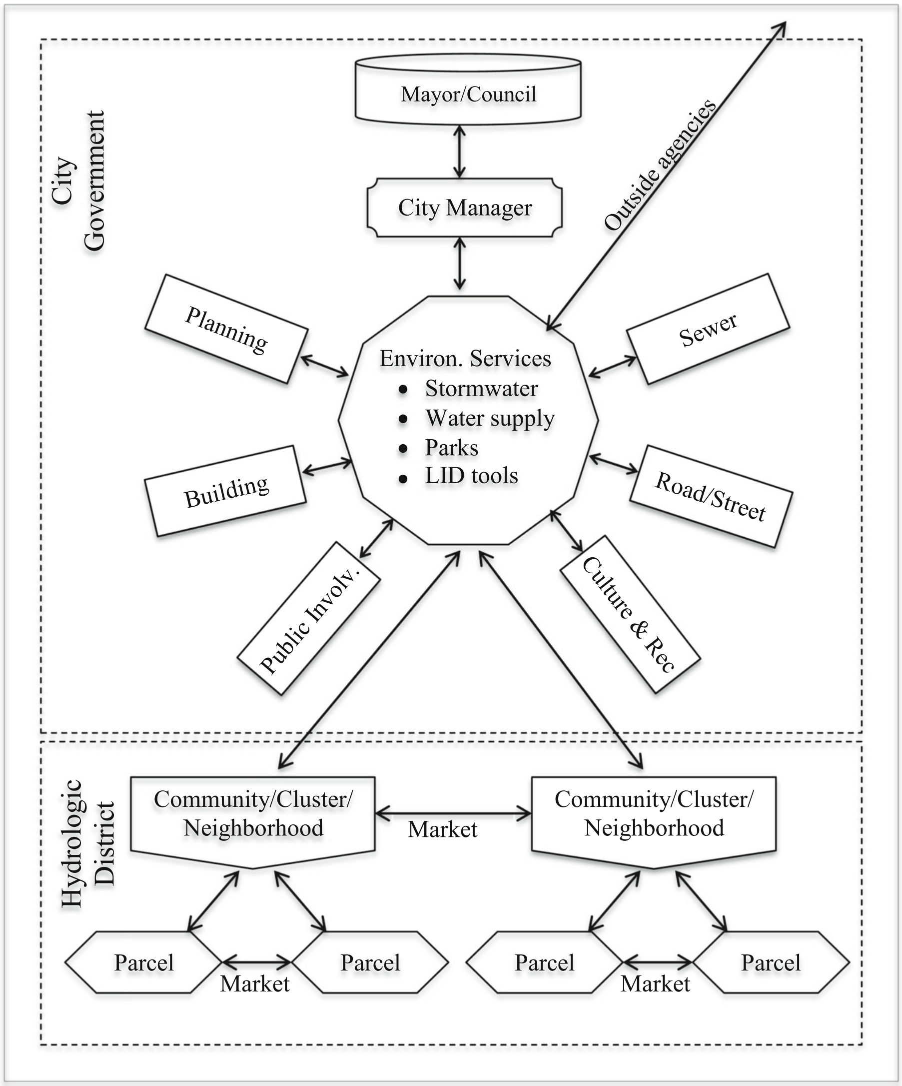
Designing a new governance approach is a critically challenging task. In the governance literature, three governance approaches are commonly identified: hierarchical, market, and network (Van de Meene et al. 2011). As a legacy of the past, we have a hierarchical approach, which is not appropriate for green infrastructure implementation because of multiple barriers outlined previously. Since the stormwater programs need to be in compliance with federal, state, and city standards, some degree of hierarchical oversight is, however, required. Markets for stormwater can be established by distributing allowances of runoff or impervious area to each landowner within a hydrologic boundary and permitting those allowances to transfer through a free trade. However, as stormwater is largely a local issue having small market only within a hydrological boundary, it is likely that it cannot be governed totally by market alone. Yet some degree of market is desirable among local landowners (Parikh et al. 2005). The market can greatly increase if price tag can be put on other ecosystem services (e.g., air purification, community esthetic, and carbon sequestration) as well.

Network governance emerges from a wide range of self-organized stakeholders (Kjær 2004; Lemos and Agrawal 2006; Provan and Kenis 2007; Van de Meene et al. 2011). Since it stimulates collaborative actions among stakeholders (Rijke et al. 2013), it is viewed as a favorable approach to govern multi-stakeholder systems (Provan and Kenis 2007) such as stormwater. However, some governmental oversight is required, otherwise the self-organized network may tend to function without regard to government policies and regulatory compliance and subsequently risk accountability as noted by Kjær (2004).

Hence, any one of the three approaches cannot sufficiently address governance issues alone. As such, a hybrid model that utilizes some attributes of each of the three approaches is required to better address the governance needs (Lemos and Agrawal 2006). Therefore, a two-tiered hybrid model consisting of a local hydrological district and a city level agency is proposed (Fig. 1).

A local hydrological district, similar to school and fire districts, would serve as a neighborhood-level mechanism to involve landowners and other stakeholders within its jurisdiction determined by hydrological boundary. The jurisdiction of such a district would encompass all local land features, under public property regime, that can be utilized for stormwater management. Examples include community parks, open spaces, ponds, and road side rain gardens. The governing body would have democratically

Fig. 1 Proposed two-tier urban stormwater governance model



elected representatives from all the stakeholders who own land or businesses within its jurisdiction. The body would coordinate planning and implementation with individual landowners, other local stakeholders, and city government. Since its jurisdictional boundary would be defined by the local hydrological boundary, the hydrologic district would help address the problem of mismatch between political and hydrological boundaries. It should be noted that several neighborhood-level governances (e.g., Homeowners' Associations and Neighborhood Associations) are successfully conducting many governance functions across US cities (Chaskin and Greenberg 2013). Although they may not necessarily fit the proposed hydrologic districts defined by hydrologic boundaries to govern stormwater, their successful functioning shows that hydrological districts would be viable. The viability of such governance is further justified from the fact that thousands of other districts, whose intended goal lies in the domain of environmental protection and enhancement, such as soil conservation, resource conservation, and flood control districts, are currently working across the US under different government agencies. Scholars have also suggested similar mechanism, called ecosystem services district, at local level to govern natural resources (Heal et al. 2001; Lant et al. 2008). These districts could be rearranged under the hydrologic districts to bring governance of all interdependent activities of environmental domain under the same umbrella.

Based on the city, state, and federal requirements, the proposed city level agency would enforce standards and monitor the performance of the hydrologic districts. Since management of stormwater requires sufficient knowledge of quality as well as quantity control, the city agency would also provide resources including technical expertise, training, and outreach materials to all of its hydrological units. This would minimize the transaction cost for the hydrological districts. Due to the fact that most cities have already been funding stormwater management, resources to local hydrologic districts would require minimal additional cost. The savings from the avoided cost of gray infrastructure-related works would provide the balance.

The city would determine the required level of stormwater control needed for each hydrologic district based on modeled pre-development hydrology. Each hydrological district would then distribute the stormwater control responsibility to its landowners in commensurate with the land's stormwater generation potential determined by an independent third party engineering consultant using hydrologic modeling. If a landowner can control more stormwater than the required quantity, the landowner would be allowed to sell that additional quantity in the form of tradable credits to any other landowner, within the hydrologic district, who cannot control stormwater from his land to the required level due to cost or space reasons. Thus, a market can be created among the landowners within the jurisdiction of a hydrologic district. The potential benefits from the allowance trading would provide incentive for a landowner to pay for the third party to evaluate the stormwater generation potential of his/her land and install green measures. Hydrologic district would also function as a clearing house to facilitate the trading of stormwater credits within its jurisdiction. Similar markets can also be established in the similar fashion among hydrologic districts within the regional watershed.

At the city level, an agency, potentially named the Department of Environmental Services, would govern stormwater, water supply, parks, open spaces, and LID tools (Fig. 1). It would also provide leadership to the hydrologic districts within the city and coordinate with other city and outside agencies. Based on the city, state, and federal requirements, the agency would enforce standards on and monitor the performance of the hydrological districts. Since cities have already established separate agencies, such as utilities, bureaus, or departments, to govern the five functions that have direct or indirect impact on stormwater, some of the functions would need to be rearranged. For example, each city has a dedicated department for parks and recreation except in Chicago where recreation is not under the jurisdiction of the Chicago Park District. Since parks and open spaces can be instrumental in stormwater management, the proposed model would bring them under the Department of Environmental Services, which would be responsible for managing stormwater as well as controlling activities, across the city jurisdiction, that impact hydrology. As such, the Environmental Services would prepare and adopt the hydrological map of the urban jurisdiction. The recreational and cultural activities would be grouped into a separate agency named Culture and Recreation Department. Since gray and green differ in nature and functioning as well as the expertise required, a separated department (Department of Sewer) is proposed for governing gray infrastructures. The Department of Sewer would be responsible for sanitary sewers, combined sewers, large size storm sewers (e.g., collectors), and wastewater treatment plants. Small storm sewers would be under the jurisdiction of hydrologic district. The collaboration between the Environmental Services and the Planning Department would be redefined to match planning and land use zoning with the hydrological map. The Department of Building, which controls the construction of building and associated infrastructures (e.g., driveways and parking lots), would work in collaboration with the Environmental Services to regulate any addition of impervious areas. Similarly, the Street Department would work with the Environmental Services for road alignment, grading, and management of stormwater runoff within the right-of-way. If managing runoff within right-of-way using green infrastructure is technically infeasible, the excess runoff would be routed to a green infrastructure beyond its right-of-way operated by hydrologic district or a private owner through allowance market. If managing stormwater using green infrastructure within hydrologic district is infeasible, the runoff would be conveyed through storm sewer maintained by the hydrologic district to the collector sewer maintained by the Department of Sewer for a fee. The Environmental Services would function as a focal agency to establish horizontal (e.g., with other city departments, environmental advocacy groups, and civic organizations) and vertical (e.g., with hydrologic districts, and upper management in the city, state, and federal agencies) coordination to perform its stormwater management functions. Since each hydrologic unit is defined according to the hydrologic characteristics, an umbrella organization that integrates all the hydrologic units can be instituted at the watershed scale. This can assure the implementation of watershed scale measures subsequently reducing fragmented governance.

The governance problems discussed in this paper also prevail in cities of other developed countries, such as Australia (Brown 2005; Brown and Farrelly 2009; Roy et al. 2008). A comparative study of urban stormwater management in the US and Australia by Roy et al. (2008) identified problems including fragmented responsibilities, lack of institutional capacity, lack of legislative mandate, lack of market incentives, and resistance to change as major barriers not only in US cities but also in Australian cities. This supports the rationale for the use of the proposed model in cities of the developed countries other than the US.

In developing countries, cities suffer from a lack of financial resources and technical expertise to a greater extent than cities of developed countries. Since green infrastructure is less demanding than gray from both the technical and cost perspectives, it would be more suitable in those cities. With the establishment of a city agency as a facilitator, the proposed model would be appealing. Successfully functioning neighborhood organizations (called Tol Sudhar Samiti in Nepali language) in the City of Butwal in Nepal reveal not only viability but also necessity of such governance model in developing countries. For years, hundreds of such organizations have been working citywide as neighborhood stewards. Currently, the city provides guidance; each household pays a flat monthly fee and provides at least one volunteer for three hours on the first Saturday of every month for activities such as neighborhood cleanup (S. Gyawali, vice president of Indreni Tol Sudhar Samiti, telephone interview, August 23, 2015). According to Gyawali, the household which cannot send a volunteer pays a fine. If neighborhood groups are rearranged according to hydrological boundaries, and the city provides knowledge, guidance, and technical support, these organizations would be able to work as the hydrologic districts of the kind proposed in the two-tier model.

Conclusion

This paper has three main areas of focus. First, it has identified the problems inherent in traditional stormwater governance that prevent wide scale adoption of green infrastructure. Second, it has examined the stormwater governance of five US cities, which have been implementing green infrastructure for some years, to see how they are addressing the governance problems. Finally, the paper proposes a new governance model to address the problems.

Traditional urban stormwater governance was adopted to govern highly engineered and centralized gray infrastructure. As such, the approach is highly technocratic and centralized, which functions through enforcement of government regulations. In contrast, green infrastructure uses natural processes and is distributed throughout the landscape. It involves a wide range of stakeholders in the governance process, including individual parcel owner, business organizations, social organizations, and government agencies, since the generation of stormwater is characterized by the hydrological processes in the landscape controlled by their activities. Therefore, the governance needs to be highly collaborative and coordinated between them. The existing discord between political and hydrological boundaries needs to be addressed to restore and enhance the watershed health. In addition, the existing fragmentations of governance within a watershed, due to presence of multiple authorities with multiple (sometimes conflicting) visions and goals, have created significant problems. This also needs to be addressed.

The survey of the cities revealed that the current practice of public involvement in cities is merely limited to participation in education, outreach, and cleanup programs. In cases when public comment is requested by government or regulatory agencies, as required by Stormwater Phase II Rule, the decision authority is, however, not required to implement these comments. The coordination is also limited within government agencies. The collaboration with stormwater generators and other local stakeholders out of the government office is lacking.

The proposed two-tier model can address the problems existing in the traditional stormwater governance. The local hydrologic district is a neighborhood-level body with the hydrological boundary as its jurisdictional boundary. The governing body would consist of representatives from land owners, community, civic organizations, environmental organizations, and businesses. The city agency would enforce regulatory standards and provide technical expertise, administrative support, and other resources to the hydrologic district. The agency would function as an umbrella organization at the city level, integrating the functions of all of the hydrologic districts. The hydrologic district would also work as a local ecosystem services district. In addition, markets for stormwater trading can be established among parcels within a hydrologic district as well as among hydrologic districts within a regional watershed.

The proposed model would provide opportunity for distributed governance, ensure public involvement, and foster collaboration among stakeholders. This would also help revive the decline in civic institutions (Emerson et al. 2012). Since the decision authority would be solely on the hydrologic district, integration of these hydrologic districts at watershed level would minimize the fragmented governance. However, additional research is needed to identify methods for appropriate and effective integration. Additional research is also required to define the authority, logistics, and the procedures of formation of the governing body, which may be unique to each city. If for no other reasons, the hydrologic conditions are location-specific, case-specific research is needed to define the spatial scale of the hydrologic district. With minor adjustments to incorporate a city's socio-political context, the model could be used globally, in developed as well as developing countries.

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