EVALUATING PUBLIC AMENITIES OF STORMWATER MANAGEMENT

DEMONSTRATION PROJECTS IN PHILADELPHIA, PA

By

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ABSTRACT OF THE THESIS

Evaluating Public Amenities of Stormwater Management Demonstration Projects in Philadelphia, PA

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Green stormwater infrastructure mimics natural infiltration processes and has the potential to function as a public amenity. This study evaluates public amenities at 20 stormwater management projects built within Philadelphia in the past five to ten years. “From Stormwater Management to Artful Rainwater Design” (Echols and Pennypacker 2008) served as the foundation for a rubric which scores site designs based on a Likert-like rating system (1 - 5) in six amenity categories: Education, Recreation, Aesthetics, Safety, Publicity, and Best Management Practices. Scoring was conducted on site, after taking photos and producing simple sketch diagrams in plan and section. Data reveals a correlation between Education and Recreation public amenities (73%). For each stormwater project neighborhood and site scale data are interpreted to affect the total score of public amenity. Drawing on technical, theoretical and city planning documents, this thesis exposes how stormwater management sites in Philadelphia function as public amenities, thereby informing the conceptual design process.

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

LIST OF FIGURES / ILLUSTRATIONS

Chapter 1 - Introduction

Ecology, Functionality, Publicity: Three Spheres of Stormwater Design and Research

Landscape Architects, Planners and Urban Designers are framing site amenity as a new realm of stormwater management research. Site amenities encompass experience, community involvement and work to craft public awareness of the hydrologic cycle. Civil Engineers and Environmental Scientists have focused primarily on the quantity and quality of runoff managed by green stormwater infrastructure. Quantity aspects deal with the amount of stormwater systems can hold/ infiltrate, whereas quality relates to water pollution and generation of urban habitat and species diversity. The construction of new stormwater management systems offers the possibility for multiple disciplines to work together by merging public amenities, quantity and quality (Figure 1).

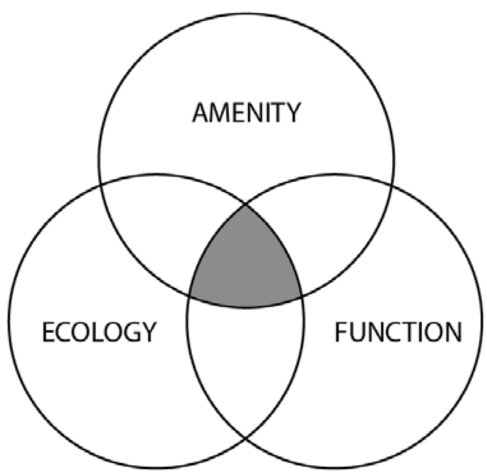


Figure 1. Three spheres of stormwater management research, overlapping in sustainable design strategies

Throughout the 20th century, quantity of runoff was the primary concern influencing engineered stormwater management systems (Novotny 2008). In recently constructed green stormwater infrastructure (GSI), quantity has played a major role in research and design. Researchers must be certain that runoff management methods are safe and functional before siting GSI in a dense urban environment. However, the idea that bio retention systems, vegetated swales and constructed wetlands are new technologies is invalidated by Frederick Law Olmsted's plan for the Back Bay Fens of 1887. New technologies exist primarily in quantifying flow and pollutant discharge rates; or through structural designs such as dry wells, flow splitters and porous paving.

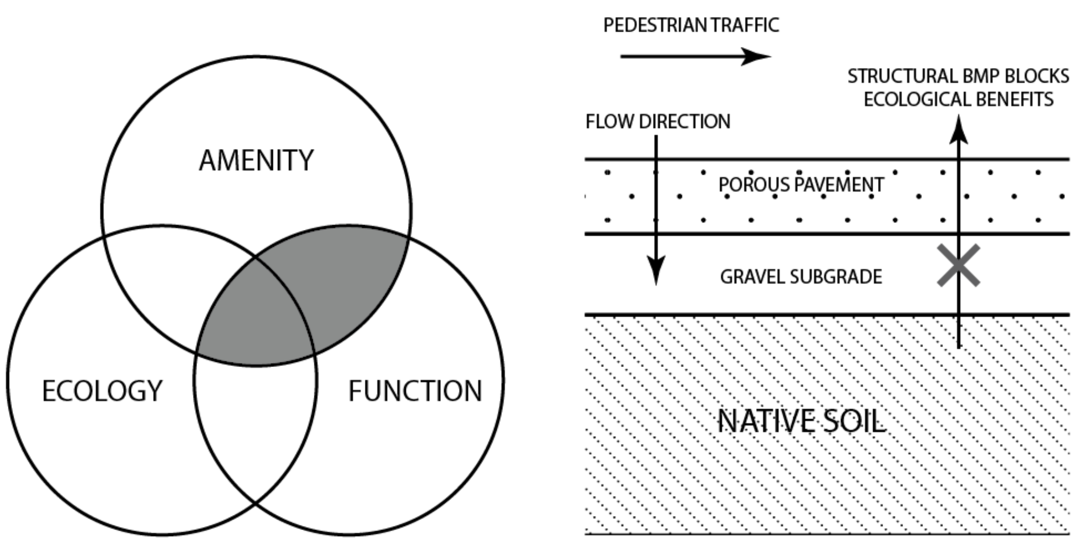


Figure 2. Porous pavement structural BMPs support function and amenity categories by do not actively address site ecology.

Researchers continually look for advances in the functionality of stormwater systems, and have found that the type of stormwater BMP affects a wide range of possible stormwater outputs including pollutant load, water quantity infiltrated and total suspended sediments removed (Davis et al. 2009, Weiss et. al. 2005). For example, the permeable paving system shown above will infiltrate less stormwater than a constructed stormwater wetland or bioswale, and will not allow for pollutant removal especially concerning metals such as copper, lead and zinc.

Similarly, ecological benefits have comprised a large portion of stormwater management system research, and continue to garner funding for new investigations. The benefits to ecosystem biodiversity have been confirmed across multiple research institutions. There is a clear advantage for plant-life, vertebrates and invertebrates which dwell within stormwater management systems, over traditionally "green" urban areas. Ecology shares important overlaps with overall functionality of GSI, in that softer technologies promote higher ecological benefits in terms of creating habitat and promoting biodiversity. Due to the structural nature of permeable surface design, habitat cannot be incorporated into the a-biotic systems (Figures 3 and 4).

Figures 3 and 4. Permeable playground and basketball court at Herron Playground.

Bridging a high level of public amenity with high functioning GSI is not straightforward. Creating GSI within urban areas is complicated by numerous factors including existing infrastructure, financial gain through property development and balancing active / passive recreational space. If stormwater management systems are to be integrated at the community and even household scale, there is a need to reverse "not in my backyard" notions (Figures 5 and 6). How a stormwater management system is perceived by local residents plays a large role in its overall success. The work of Echols and Pennypacker (2008), Peter Stahre (2008) and Herbert Dreiseitl (2005) concentrates on stormwater management system designs which create spaces where the public can come to learn about, interact with or celebrate water.

Figures 5 and 6. Stormwater management sites in Philadelphia are integrated into a neighborhood context and reverse conventional notions of landscape

Reconnecting Water Flow and Design

Throughout history, gardens have been places that display water. The Water Ladders of ancient Persian Gardens, the enclosed courtyards in Moorish Spain, and the Italian Renaissance Gardens all highlight the flow of water. It could be postulated that Villa D'Este was one of the highest expressions of water-sculpture within the garden: whether playfully sprayed out of multiple fountains, quietly dripping in wet grottos, or powering water organs and musical instruments, water was a fundamental part of experiencing the landscape. Nobility respected the impact of water in the landscape, for example entire rivers were diverted to fill the canals of Versailles. The history of water in the garden is a sequence of endless invention and intrigue, each culture harnessing and displaying water within social and environmental context.

Current landscape architectural practices have broken with historic traditions of using water in the landscape. Providing positive drainage in order to de-water specific areas of the site has become paramount to public safety. Topography is molded and natural streams are sent through culverts to ensure there is no standing water on site. Some of these methods of construction may no longer be valid in light of burgeoning sustainable site design initiatives and environmental goals. However, allowing water to simply flow towards the path of least resistance can generate innovative landscape design. Pooling in certain areas, leaving other spots relatively dry, runoff can be treated as a site amenity, instead of something to be swept under the landscape carpet (Figure 7).

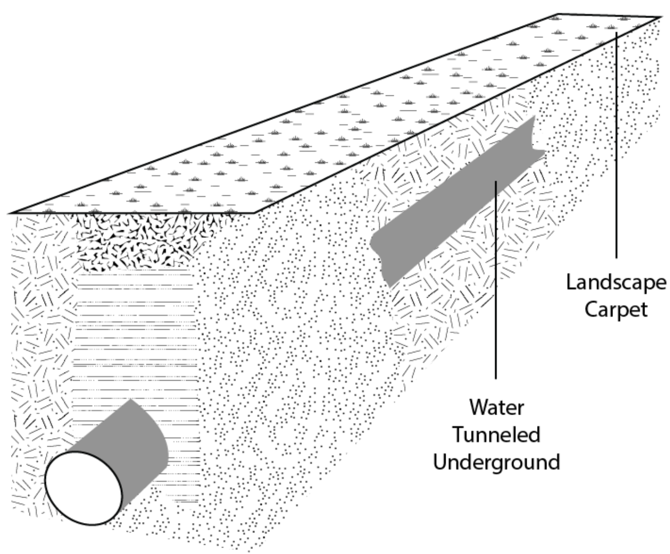


Figure 7. Drains and culverts keep water out of view in current landscape architecture.

This portion of the introduction will give case studies on the work of three water artists, to explore ground-breaking ways in which water can be displayed. John Wilkes (2007), Herbert Dreiseitl (2005) and Peter Stahre (2008) allow processes within water to shape the form of its conveyance structures. These three designers incorporate aspects of ecology, function, and amenity into their designs. Each designer brings out characteristics of water through sculpture, changing water from a passive medium to a communicative device.

John Wilkes

Working since the 1970s, John Wilkes is the founder of the Healing Water Institute in Essex, England. His primary research goal is to discover and reveal flow properties of water. Examining the links between the movement of water throughout the landscape and within the human body have led Wilkes to a holistic view of water flow. Wilkes believes that the flow of water is directly connected to its quality. Water which has been "energetically polluted," sent through pumps or other devices, needs to be returned to natural flow patterns (Wilkes 2007). His book *Flowform Research* 1970 – 2007 (2007) describes his process for understanding the intricacies of water. The book is at the forefront of scientific and cultural understandings of water and combines non-traditional ideas with scientific phenomena. He delves into the physical properties of water, such as viscosity, boiling and freezing point, thermal energy, and conductance to lend an understanding of water's flexibility. These same processes are responsible for shaping the movement of different flow patterns in water. For example, in a river system, due to different flow vortexes, several layers or paths inside of the water column may not mix until being emptied into a larger basin. When designing the slope of a stream channel to remove suspended solids, such factors must be taken into account. Similarly, flow processes have been replicated in many other natural forms, including plants and jellyfish, who exhibit spiral arrangement patterns similar to those predicted by the Reynolds number, viscosity or by drawing a paintbrush across the surface of a color - treated liquid. In his research, the interconnectedness of water is shown in a flow diagram, with the highest opportunity for life at harmonic flow patterns.

John Wilkes began researching the movement of water as a student at the Institute for Flow Sciences in Herrieschreid, Germany. A source of early inspiration came from a trip to Australia, where he observed Ayers Rock, which changes color during precipitation and exhibits patterns of natural erosion channels, carved by water streams descending the side of the rock. From this visit he developed ideas regarding symmetrical and asymmetrical flow patterns within water. Experimenting with varying widths of water channels he created “figure eight” flow, a rhythmic pattern which Wilkes considered a symbol of the abundant life-force within water (Figures 8).

Figure 8. Sketch based on Wilkes’ figure 8 flow patterns. Drawing a paintbrush through colored liquid presents similar patterns on the surface of the water

Wilkes developed Flowform systems which have been combined with stormwater management sites, such as wet ponds or constructed wetlands, these systems increase water purification (Figure 10). “The combination of lagoons and reed-beds with Flowform cascades is an efficient way of establishing a biological wastewater treatment system.” John Wilkes’ Flowform systems have augmented the natural water cleansing processes of ponds and wetlands and have been implemented in Sweden and Holland. “Flowform cascades improve water quality in combination with filters in grey-water systems . One example has been set up in a small community\ in New South Wales, Australia, using a gravel filter and a reed bed in connection with a Flowform cascade” (Wilkes 2007). The recirculating flowform systems remove the necessity for fountains or other turbulent structures to prevent mosquito habitat. The opportunity exists for entire stormwater management features to mimic John Wilkes’ Flowform structures.

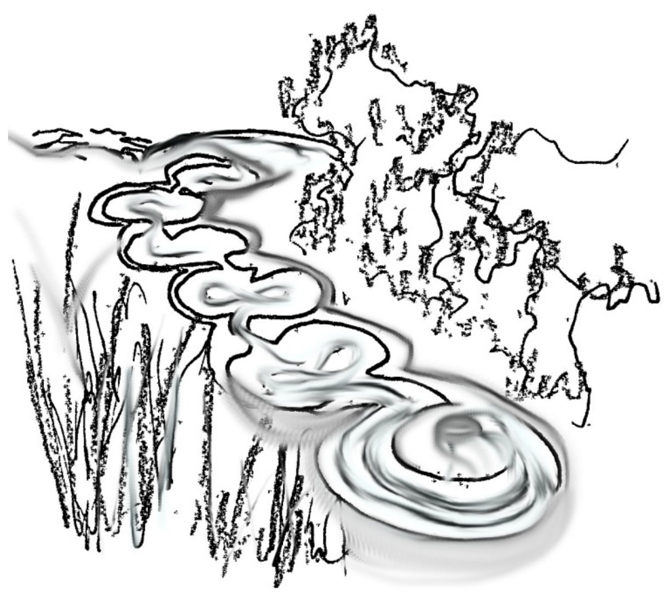
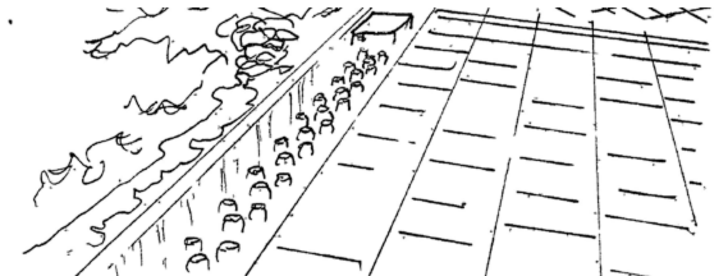


Figure 9. Sketch representation of Wilkes’ flowform basins, water passing in figure eight flow pattern towards larger stormwater management site in the distance

Peter Stahre

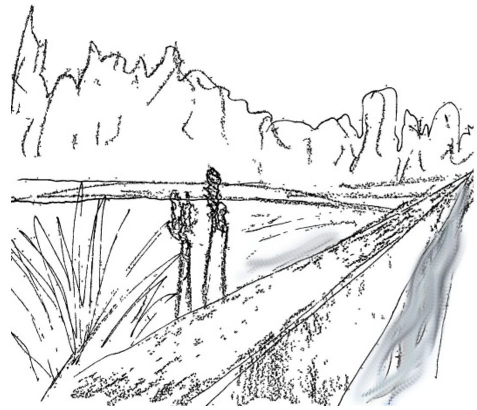
Peter Stahre's work in stormwater management in the city of Malmo, Sweden has influenced a new ways of thinking about stormwater management. Peter Stahre lists positive values associated with stormwater management including: aesthetics, biology, habitat, ecology, recreation, public relations, education and economy. Peter Stahre has analyzed added benefits of stormwater systems by examining eighteen different green stormwater infrastructure sites throughout the city of Malmo, Sweden. Urban drainage projects included multiple structural stormwater BMP typologies: pools, wetlands, meandering creeks, reed beds, canals, permeable paving, and eco-corridors.

Stahre's work in justifying the added benefits of green infrastructure is rooted in case studies. Of the projects Stahre describes, Augustenborg stands out as a model of stormwater management. Ground plane modifications branching off of a central open drainage canal conduct stormwater over a series of urban spaces, inciting comparisons with the stormwater flow pathway to a small constructed stream. Receiving areas of the central drainage corridor include a miniature wetland which features native grasses and low mow areas, a water-drop runnel (Figure 10), a double pond, a cube canal, a vegetated swale along a historic stream, and a meandering delta. Each portion of the stormwater flow pathway is activated by the surrounding community and spaces invite visitors to explore or play in the runoff stream. For example, the "cube canal" contains cube shaped stepping stones, extending about 300 feet at a 5% slope. People are invited to play on the cube stones in the canal, and children frequently jump over the watercourse. Similarly, the rain drop runnel hosts sculptural concrete raindrops which alter the flow of water inside of the runnel, creating intricate patterns on the surface of the water, reflecting light and dazzling onlookers. Multiple stormwater amenities require a high level of safe management techniques to ensure that constructed areas remain socially active. For example the double pond contains separate layers for flood events and uses a filter pump to prevent mosquitoes, it is planted with purple loosestrife to keep back algae.



Figures 10. Sketch of water droplet runnel on Augustenborg stormwater management pathway

Stormwater management systems in Augustenborg connect along a central trail and work to fulfill functional, ecological and amenity spheres of stormwater management (Wilkes 2008). Compare this system to one which water is put underground for none to enjoy, where automobiles rule the surrounding landscape, the difference in character is obvious. Current structural BMPs largely neglect the trail of water, preferring instead to use the landscape as a sponge in order to infiltrate or soak up surface runoff. However, the stormwater trail is a powerful aesthetic design tool for communicating the movement of water to the general public (Figure 11). Likening the movement of water and people within a dense urban setting draws upon larger symbolic concepts of energy and the passage of time. The evolution of stormwater management systems depend on a visceral connection to water in the landscape (Figure 12).



Figures 11 and 12. Sketch of cube canal and double pond on Augustenborg stormwater management pathway

Herbert Dreiseitl

Sculptor and water artist Herbert Dreiseitl is working at the forefront of GSI design research. His process takes into account natural flow systems of water, and works to expose intricate flow regimes in urban landscape. Years of photographing and videotaping water under different conditions has allowed Dreiseitl to form a holistic approach to incorporating water in urban design. Dreiseitl's work is more in the vein of other design visionaries such as Lawrence Halprin, in that he has crafted unique system based on individual research. In Waterscapes, Dreiseitl quotes Leonardo Da Vinci, "Take thought when you are speaking of water that you first recount your experiences and only afterwards your reflections" Leonardo Da Vinci quoted by Dreiseitl 2005). For Dreiseitl, water is a meditative medium, and he greatly detests public plazas which spray and shoot water in "a vulgar display of power," preferring instead to create trails and pathways where water can express its own unique qualities. "Fountains are usually created as a response to a design brief which includes the client's budget, time limitations, desired life, durability, maintenance availability, water supply and especially the chosen site" (Dreiseitl 2005). Many of the greatest fountains in the world today would be otherwise bankrupt if it were not for strategic thinking about reducing flows, to conserve energy on site. For example the World Trade Center Memorial, with its large baroque plumes would quickly exhaust its yearly operating budget on electricity costs alone, if it were not for a water-comb design which significantly reduced flow rates, and volume of water within the system. The design for Tanner park incorporates passive recreation with water collection in order to create an unconventional town square (Figure 13).

Figure 13. Sketch of Herbert Dreiseitl's design for Tanner Park. A rectilinear, meandering boardwalk allows passive exploration of stormwater management basin where water naturally pools

Multiple factors can influence the shape and trail of water without the need of mechanized systems such as: setting, containment, movement, lighting, wind, sound color and depth (Dreiseitl 2005). Dreiseitl works to expose the difference between types of water, such as black water, which has a concealed velocity due to a constant unbroken surface plane, versus white water which is infused with oxygen spheres, allowing for light to bounce into the surroundings, such as in rapids or waterfalls. By drawing on a large pallet of intrinsic water-related phenomena, Dreiseitl has found that “the joy of effectively working with water, by knowing and understanding the medium, is the reward for study and diligence” (Dreiseitl 2005). Dreiseitl’s experimental process is outlined in the example of water running over a polished surface, it is the expectation that water would flow straight down the surface, but instead water takes a curvilinear pathway, preferring this pathway due to its innate viscosity (Figure 14). Through such experiments Dreiseitl demonstrates how rivers and streams meander through a valley.

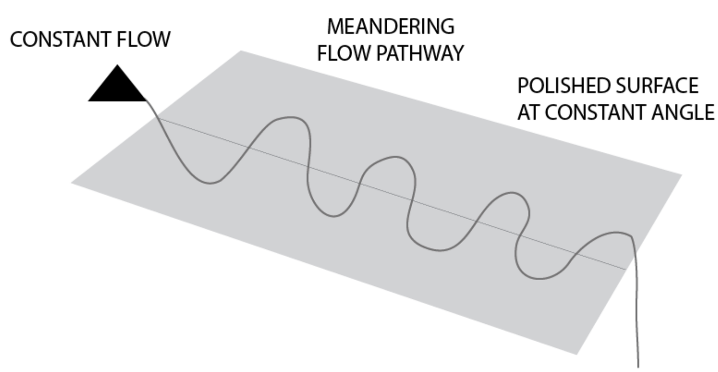


Figure 14. Diagram of water flowing over plished surface at constant flow rate and angle

New ways of managing runoff on site overlap with Dreiseitl’s philosophy of water flow. “The principal problem in Central Europe is not a general shortage, but a shortage of water of outstanding quality, and the pollutions of waterways, which goes far beyond the point at which streams or rivers can clean themselves” (Dreiseitl 2005). In America, the collective disregard for water has yielded an entire classification system based on public safety and exposure to surface waters. Dreiseitl’s stance on public interaction with water is based within the following categories: “global and local, citizen involvement and participation, commitment, sustainable technologies, and multifunctionality” (Dreiseitl 2005). Overall, Dreiseitl’s interaction with stormwater can be summed up by his description of precipitation, “you have to start watching what happens when it rains, the weather front approaches as a trailing curtain in the sky, and the threads of rain dance in the wind like a fine veil” (Dreiseitl 2005). As a student of John Wilkes, Dreiseitl’s method of designing with water in the landscape breaks with traditions and looks to reveal flow patterns.

The designers mentioned in this section focus on several aspects of improving publicity at stormwater management sites. The gaps most notably exist between levels of communication of water related phenomena on site, and what site characteristics individual designers have chosen to reveal. John Wilkes and Herbert Dreiseitl explore the innate properties of water, while Peter Stahre’s designs are more rooted in the flow of water, the passage of water form one space to another. However, in all three cases there is evident a need to address water on a more personal level, by landscape modifications. Their designs seek to redefine urban landscapes as places which reflect collective interaction with water.

Theoretical Approaches Guiding Planning and Design of Stormwater Management Systems

Theoretical approaches to stormwater management have been closely tied to landscape design and planning. Stormwater management theory is directed at designers, such as those mentioned above, or at planners and policy makers looking towards the future of urban centers. The latter group’s work will be represented in the following section Renaissance of Stormwater Management in Philadelphia. Kristina Hill describes the history of stormwater management approaches beginning with Geddes' definition of urban centers in 19th century England, which inspired the work of Ebenezer Howard, as he re-imagined urban centers as "Garden Cities of Tomorrow." Soon afterwards Olmsted constructed the Backbay Fens, a landscape amenity incorporated as a park in Boston's Emerald necklace system. These areas used natural systems to control flooding and pollution affecting Boston. The timeline continues with the cognitive mapping work of Kevin Lynch and prototype-GIS overlays of Ian McHarg. Each of these mapping systems broke with traditional ways of viewing landscape and was centered on process and interaction of supposedly separate elements. At the same time the idea of biodiversity in urban centers was being uncovered by Herbert Sukopp, whose sectional drawings came to represent ecological balance between urban areas and surrounding naturalized areas. This work was followed by Anne Spirn's "catalytic frameworks" and Nassauer's "cues to care," each addressing an interactive element of people and landscape (Hill 2009). Uncovering and describing ecological phenomena as indicators of environmental health is important in establishing a landscape approach to stormwater management.

Eco-Revelatory Design

Within the field of landscape architecture, eco-revelatory thinking has been responsible for influencing innovative stormwater management designs. Ecorevelatory design is a movement within the field of landscape architecture in which public spaces are crafted to highlight ecological processes. Researchers have found that in a contemporary context, ecorevelatory design is exhibited primarily within landscapes which host stormwater management systems (Gortz-Reaves 2010). Drawing on resources which are normally overlooked by designers, ecorevelatory design uses expressive and imaginative "design language." Landscape architect Peter Walker elaborates on the communication aspects of ecorevelatory design, "novels are written to express ideas and give people the possibility of discussing these ideas. Why shouldn't a garden be designed for exactly the same purpose?" (Gortz-Reaves 2010). This integral movement within the discipline further challenges the design of stormwater management systems asking, how can landscapes become a tool for communicating aspects of the hydrologic cycle including infiltration, runoff and evaporation to the general public?

Sprin, Treib, Nassauer

Anne Spirn has lead stormwater management design thinking in landscape architecture through *The Granite Garden, The Language of Landscape*, and "The poetics of city and nature: Towards a new aesthetic for urban design." These three texts share common themes with eco-revelatory design such as: landscape process, art, and narrative. Anne Spirn is working towards a "new aesthetic of landscape and urban design, an aesthetic that encompasses both nature and culture, that embodies function, sensory perception, and symbolic meaning, and that embraces both the making of things and places and the sensing, using and contemplating of them." Spirn is concerned with what it means to live and be within a space and draws upon Heideggerian concepts of building, thinking and dwelling. In *The Granite Garden*, she conveys how bio-remediation of stormwater has happened in park/ open space settings, drawing on Olmsted's Back Bay Fens and the Mt. St. Clemens Sewer System (Spirn 1985). In "The Poetics of City and Nature" larger ideas about urban runoff are balanced with small, site scale design interventions: “At the Portland, Oregon Auditorium Fountain, the progression from small source, to tributaries, to downstream waterfalls is telescoped into a small space. The treatment of water is varied and dynamic; the fountain permits and even invites human participation” (Spirn 1988). Lawrence Halprin’s design of this plaza is juxtaposed with earlier patio designs of the Alhambra, to show how the intricacies of water can be expressed in built structures and how water brings out the intricacies of its container (Figures 15 and 16).

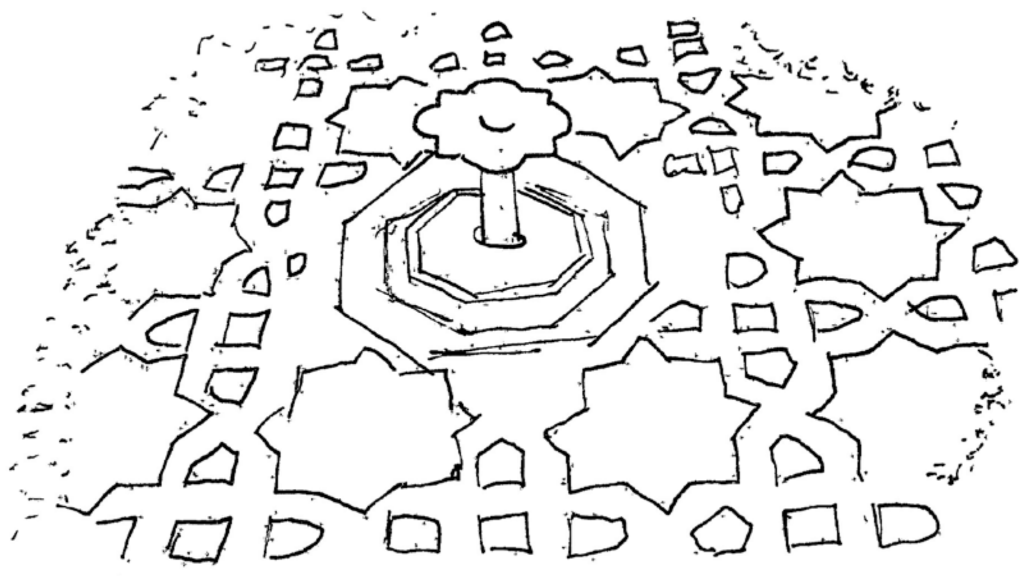


Figure 15. Sketch of central court at Alhambra

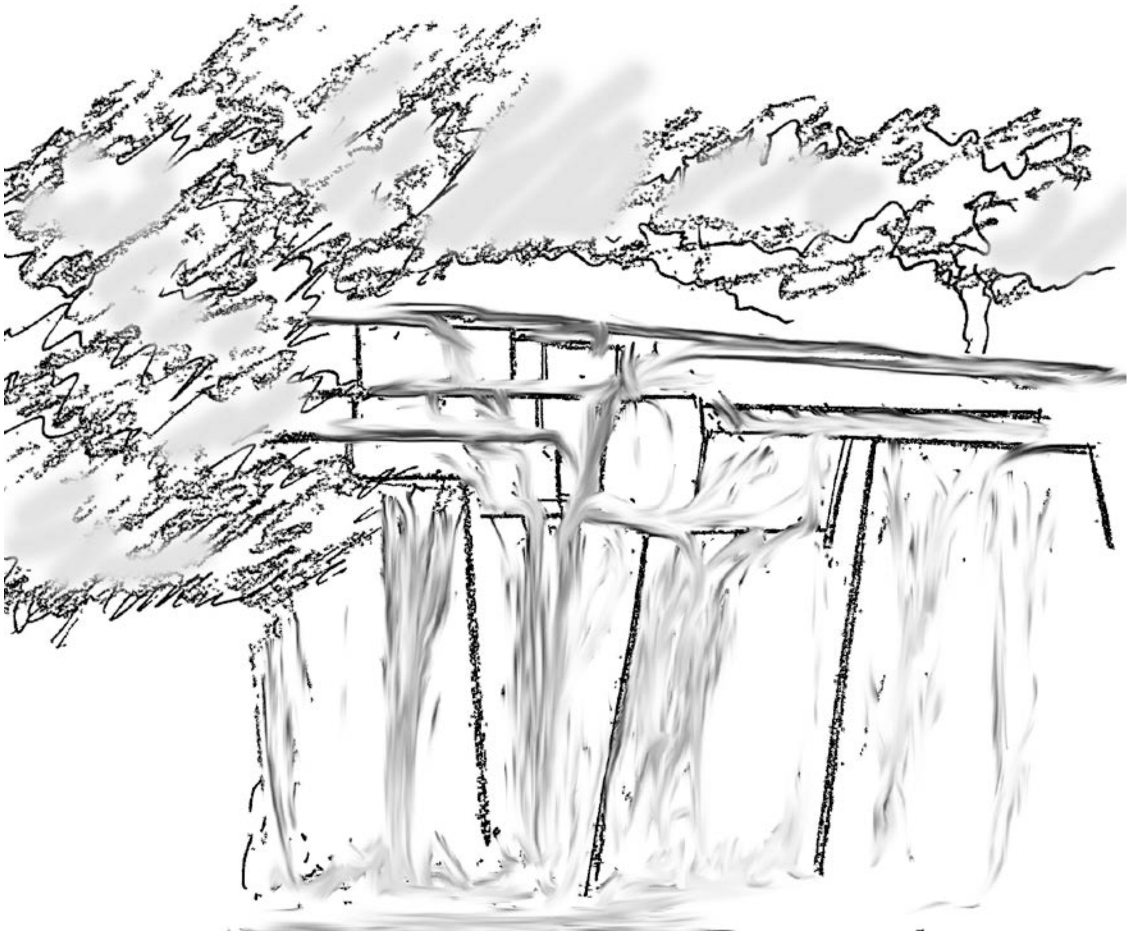


Figure 16. Sketch of Lawrence Halprin's Portland Oregon Auditorium Fountain.

Theoretical values of Marc Treib and Joan Nassauer dovetail Anne Spirn's personal connection to place. Marc Treib divides landscape architectural works into ecological, social or formal constructs and is concerned with mixing these aspects to craft public response to constructed environments. Treib wonders how we assign value to landscapes, and believes that "human occupation and use are the content of landscape design, and nature / ecological process create the matrix in which we create new terrains" (Treib 2001). Louisville Waterfront Park and the Koenig-Urmi garden (Figure 17) are two examples of sites which "give form to natural processes" (Treib 2001). Similarly Joan Nassauer understands that some of the most visually incoherent ecosystems may allow for the highest ecological benefits. By delving into the psychology governing landscape management Nassauer uncovers new strategies for maintaining stormwater management systems. Visually most stormwater systems that were analyzed for this study possessed little to no barrier physical barrier preventing entry or denoting landscape care. Management of stormwater systems can serve as a public amenity or public nuisance depending upon the diversity of public involvement.

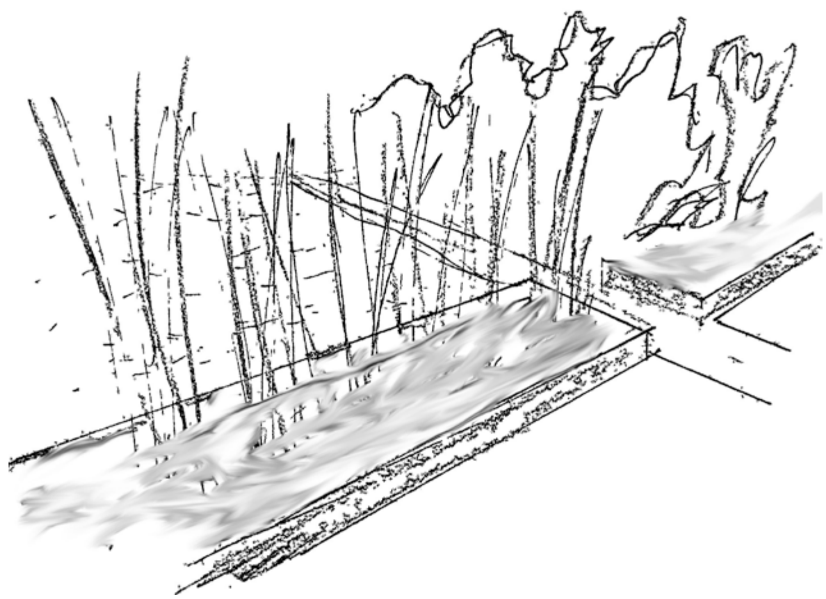


Figure 17. Sketch of Koenig Urmi Garden stormwater cells host wet site tolerant plantings.

Functional / Watershed Wide Approaches

Stuart Echols has used stormwater management theory to address functional considerations regarding the difference between current management practices of conveyance, detention and retention with natural drainage systems. Figure 18 shows a weir (structural stormwater BMP) which aims to return stormwater management processes to natural drainage methods. Stuart Echols predicts changing hydrograph patterns within the urban landscape stemming from the intervention of structural stormwater management BMPs . Theoretical considerations have been closely tied to functional water management.

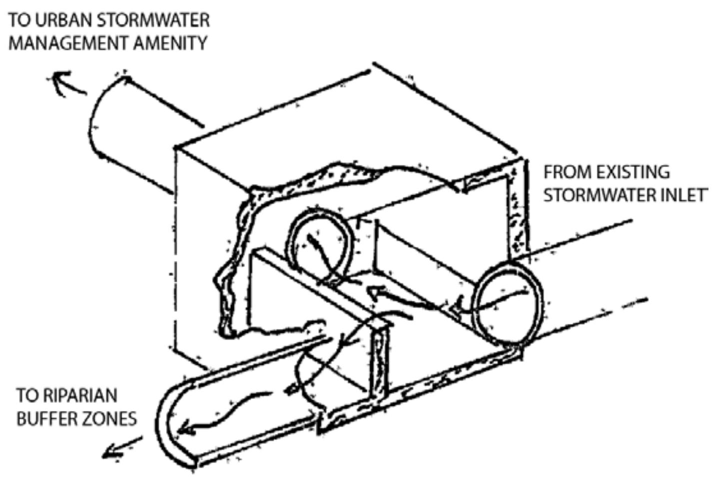


Figure 18. Detail of flow spitting structural stormwater management BMP. A small weir inside the construction diverts stormwater to adjacent areas, mimicking natural flow patterns

Vladimir Novotny (2008) expresses the changing paradigms of stormwater management, beginning with first paradigm stormwater management (roadway conveyance) and ending with fifth paradigm systems (surface retention areas in urban landscapes). Second (structural conveyance, Figure 19), third (wastewater treatment) and fourth (end of pipe controls) paradigm stormwater systems create a redundant cycle forcing, “planners and engineers to implement ever increasing imperviousness, larger interceptors and tunnels, longer transmission distances for water and wastewater, and lining, fencing off and burying urban streams” (Novotny 2008). Novotny rebukes current engineering practices, stating that combined sewers have the capability of overflowing when water volume is as low as six times dry weather events. He instead calls for, “landscape design which will emphasize the interconnected ecotones with a viable interconnected surface water system” (Novotny 2008). This thesis argues that the additional criteria of public amenity is necessary if stormwater management is to progress towards the fifth paradigm.

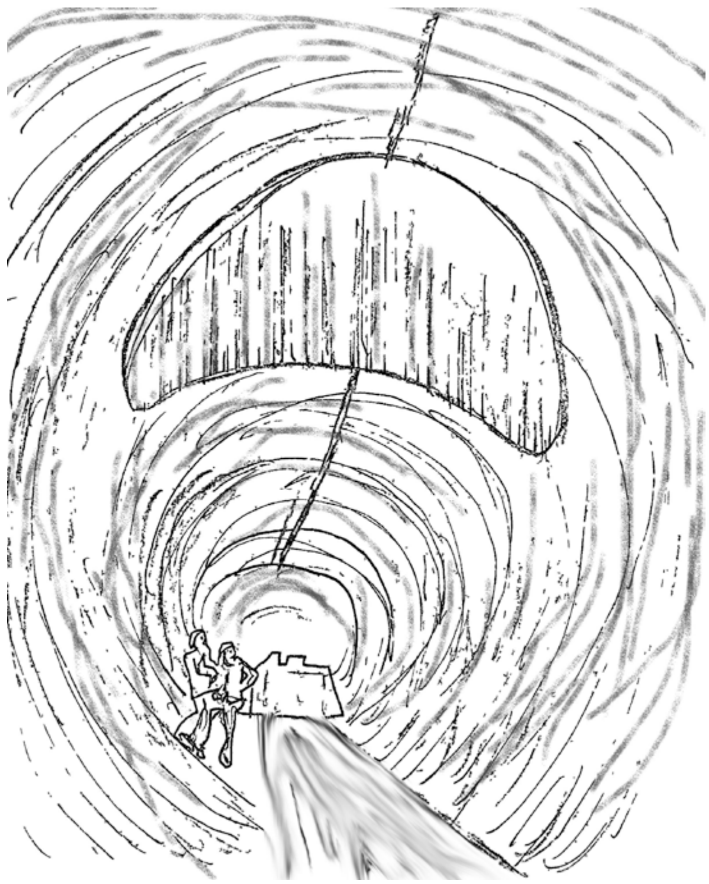


Figure 19. Sketch of large structural conveyance tunnel

Kristina Hill’s work (2009) also fits into the category of watershed - wide planning in describing multiple frameworks in which to view stormwater management including: regulatory, geography and site based. She argues that over anything else, position within the watershed is the most important indicator of the type of structural stormwater BMP that should be constructed, the three areas of the watershed which she defines are upland, network and shoreline. Hill cites Viewlands cascade as one of the first urban stormwater management projects started in Seattle, Washington (Figure 20). Receiving runoff from over 26 acres of developed land, the project works to solve larger water-shed wide issues. The work of landscape architects in the Pacific Northwest spurred the growth of stormwater management throughout other urban centers.

Figure 20. Sketch of Viewlands cascade stormwater management system located in Seattle, WA.

Echols and Pennypacker, Artful Rainwater Design and Categories of Public Amenity

Stuart Echols and Eliza Pennypacker (2008) of the Pennsylvania State University Stuckeman School of Architecture have conducted research which defines five aesthetic and public amenity values of stormwater systems. They have grouped public amenities into the following categories: Education, Recreation, Aesthetics, Publicity and Safety. This work has given landscape architects new vocabulary for describing stormwater management design. Echols and Pennypacker believe that “addressing the amenity aspect provides a useful strategy for ensuring that stormwater management ‘starts at the source,’ as so many experts have advised” (Echols and Pennypacker 2008). Small scale replicable interventions that are implemented on the household basis can combine to solve larger ecological and functional problems associated with stormwater management, but also add intrigue to individual residences and institutions. Similarly, “traditional end of pipe, out of sight solutions will not work. Instead the new paradigm of small, safe, integrated BMPs that manage runoff close to the source creates new design opportunities.” (Echols and Pennypacker 2008).

Echols and Pennypacker (2008) seek to fashion a design language in regards to stormwater management and public amenities, giving landscape architects the vocabulary to begin thinking about stormwater in new and challenging ways. New ways of addressing stormwater management design detailed in “From Stormwater Management to Artful Rainwater Design,” are based on twenty hand-picked projects, each of which received ASLA or AIA awards, and integrate stormwater management as a site amenity and deal with runoff through innovative urban drainage methods.

Echols and Pennypacker have coined the term “Artful Rainwater Design” to refer to stormwater management systems which merge ecological, functional and public amenity components. Public stormwater amenities are defined as “a feature focused on the experience of stormwater in a way that increases the landscape’s attractiveness or value” (Echols and Pennypacker 2008). Predictions show that stormwater management will become increasingly necessary within future landscape systems, to the point where water gardens and runoff collection systems are commonplace throughout residential areas. When people are asked to “live with rain” in a daily context, there will be a reversal of public attitudes of stormwater as a commuter’s hassle to stormwater as a poetic, sculptural element (Spirn 1985). Figure 21 is the Waterworks Garden in Renton, Washington, a visual representation of what Echols and Pennypacker mean by Artful Rainwater Design. Echols and Pennypacker’s study is founded in the fact that, “no methodical study of the goals objectives and techniques for the amenity component of artful rainwater design exists” The publication of their findings in Landscape journal has made peripheral design considerations more prominent within the discipline.

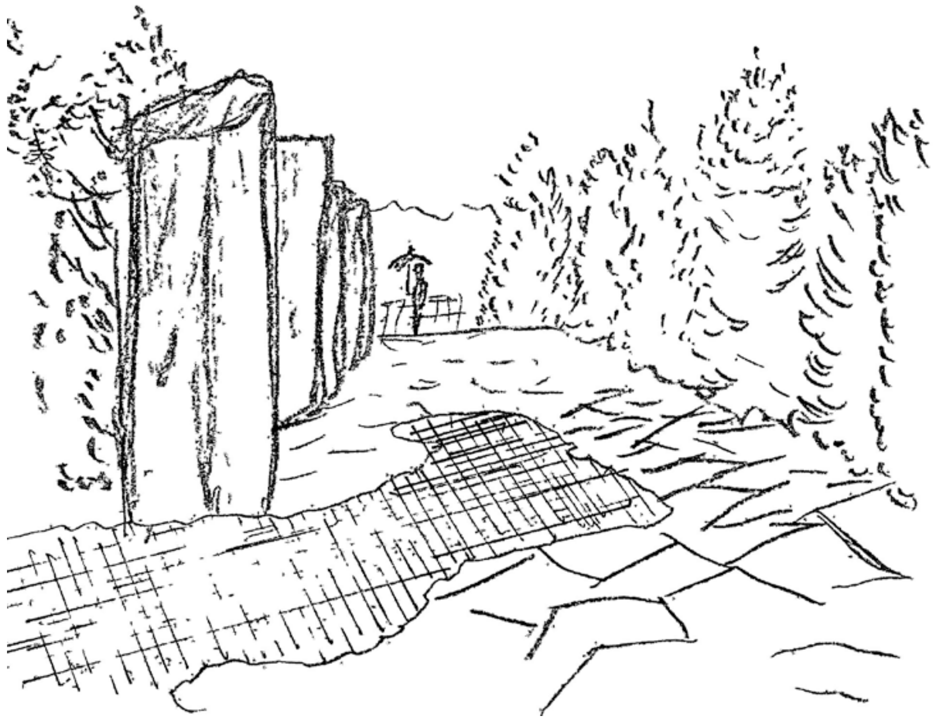


Figure 21. Sketch of Waterworks Garden in Renton, Washington

When examining a built stormwater systems, using Echols and Pennypacker's (2008) catalogue, it comes to light "that knowledge of a project's design intent in combination with design critique can result in understanding the experiential impact of a design." The catalogue formed by Echols and Pennypacker is an "articulation of amenity goals and objectives, and design techniques used to achieve them" (2008). Echols and Pennypacker's catalogue was integral to creating the design evaluation rubric which is central to this study. The main design goals included in Echols and Pennypacker's study include: Education (favorable conditions for learning), Recreation (favorable conditions for play and / or relaxation), Safety (freedom from exposure to danger or risk), Public relations (semiotic expression of values of the designer and / or owner), and Aesthetic richness (beauty or pleasure as a result of design composition).

Visual Assessment of Landscapes Adapted to Stormwater Infrastructure

Jared Buffington (2012) has described design techniques that link stormwater management systems and visual assessment of landscape spaces. This work forms an integral link between Echols and Pennypacker's article with earlier theories of Steven Kaplan begun in the 1980s. Mystery, coherence, legibility and complexity are four categories which have been widely regarded as fundamental descriptors of visual landscape assessment. In an early article for Landscape Journal Gimblett, Itami and Fitzgibbon (1985) expand on the mystery principle, relating various design techniques to the level of mystery present at a site. Mystery is influenced through screening, distance of view, spatial definition and physical accessibility. Creating a site within the landscape which draws people closer, inviting further exploration is a powerful cognitive tool. Legibility has also been discussed by Kevin Lynch (1960) in *The Image of the City* as a fundamental element of urban design. Legibility not only functions to build cognitive maps of the city, it also forms "a distinctive [...] environment, (which) not only offers security but also heightens the potential depth and intensity of human experience" (Lynch 1960). Stormwater management features, otherwise buried or underground have the potential to be, "public images, the common mental pictures carried by large numbers of a city's inhabitants: areas of agreement which might be expected to appear in the interaction of a single physical reality, a common culture, and a basic nature" ((Lynch 1960),

In a related work, Fry, Tveit, Ode and Velarde (2009) explain the ecology of the visual landscape, describing the difference and balance of human ecological indicators and environmental indicators. Commenting on the functional and ecological aspects of landscape research, Fry et. al. (2009) state that, “in many ways this data driven development of landscape indicators has been a diversion, allowing us to neglect the important questions relates to what indicators are meant to indicate.” Ecological indicators such as benthic macro invertebrates cannot be easily understood by a general public, we must reconsider how ecological indicators can be merged with social cues of built spaces. On the other hand, “aesthetic experiences occur where intentional actions towards landscapes can directly or indirectly affect ecological functions” (Fry et. al. 2009).

At the core of visual landscape assessment lies evaluation of indicators and application of meaning. By projecting meaning onto a space it becomes a place. Echols and Pennypacker’s categories of public amenities found in stormwater management systems embody the idea of connecting place to meaning. When a stormwater management system becomes more than a functional landscape object, it will begin to engage the public in ways that previous stormwater management system permutations have not. The phenomena of a space transitioning to place is documented by Spartz and Shaw (2011) in their study of the University of Wisconsin Madison Arboretum. Based on community interviews / surveys he found that the Arboretum had multiple meanings, including: society, sanctuary, nature and activity. Interpretation of place matched local plant communities found on site.

Italo Calvino’s Invisible Cities, Themes of water

Rain is a symbol of change both culturally and ecologically. Rain dances and celebrations used by indigenous cultures show the deep rooted connection and dependence on clean water. Rainwater generates a healthy harvest, and conditions for prosperity. However, when scaled out of proportion, floodwaters can be just as destructive, as times of extreme drought. Where will inspiration be generated when imagining new water infrastructure for cities? Looking towards functional codes and documents will influence a structured sameness in the design of new stormwater management systems. Influence of rain garden design needs to begin outside of the three spheres of functionality, ecology and amenity and start with deeper inspiration. Therefore we may look towards literary inspiration to generate a cultural understanding of water. Italo Calvino's *Invisible Cities* (1978) draws on multiple short narratives to describe imagined urban areas, a number of which draw on themes of water and infiltration.

The first invisible city Calvino describes is Isaura a "city of a thousand wells." He describes Isaura as sitting on top of a giant aquifer ("a deep subterranean lake"), from which the townspeople draw water. This resource has sparked two distinct forms of religion within the town, "The city's gods according to some live in the depths, in the black lake that feeds the underground streams. According to others the gods live in the buckets that rise, the pump handles, the blades of the windmills, the slender arches of the aqueducts" (Calvino 1978). This dichotomy of beliefs within the town created a vertical split in philosophy, townspeople are either portrayed as sending their prays down towards the lake, or up towards the sky. In this opposition of beliefs, the city of Isaura "exists." The townspeople praising modern mechanical inventions for gathering water would fall in the functional sphere of the stormwater diagram, whereas the townspeople who praise the aquifer would be categorized within the ecological sphere. The ability to gather resources and the need for more resources, are two practical questions every city must come to terms with. Calvino's tale of Isaura dovetails with current beliefs regarding the city's spread and ever increasing search for water resources. As the below ground aquifers dry up, new reservoirs are sited, to allow for access to healthy, clean drinking water.

Armilla is the second water-city which Calvino constructs for readers: "the water pipes that rise vertically where the houses should be and spread out horizontally where the floors should be: a forest of pipes that end in taps, showers, spouts, overflows" (Calvino 1978). This imaginary scene is symbolic of the trust we put each day into grey infrastructure systems. Even after peeling back the skin and other accouterments of the city, readers are left with a semblance of a place. He imagines water nymphs bathing at the end of each pipe, the city becomes a votive offering to aquatic sprites. Calvino evokes images of a modernized Villa D'Este as water leaps from hundreds of taps, "In the sun, the threads of water fanning from the showers glisten, the jets of the taps, the spurts, the splashes" (Calvino 1978). Sinks showers and plumbing fixtures, normally involved with carrying waste, are re-interpreted as urban fountains, the movement of water is day-lighted, "Accustomed to traveling along underground veins, they found it easy to enter into the new aquatic realm, to burst from multiple fountains, to find new mirrors, new games, new ways of enjoying the water" (Calvino 1978). Calvino is personifying water-flow and restructuring drainage patterns according to its "preference." Expanding these stories to modern times it is possible to see how each city has become an extreme representation of the second / third stormwater management paradigms. Many cities philosophically treat water in the same way as Isaura and Armilla. Urban residents may only perceive water as something associated with waste. Similarly, planners and civil engineers may only look towards functional or ecological aspects. If landscape architects are to address water resource management in an innovative way, designs must draw on the innate properties of water.

Evolution of Stormwater Management Systems

Stormwater management techniques have gone through multiple permutations over the past century. Vladimir Novotny (2008) describes five paradigms of stormwater management, for our purposes we will focus on three structural stages which span multiple paradigms. In its earliest phases stormwater was channeled in traditional grey infrastructure. Runoff quickly flowed in vast quantities into the surrounding lakes and water bodies causing flooding and pollution of various areas throughout the cities. While this allowed for increased development within urban centers, poorly draining portions of the cities, also seemed to be areas that hosted high crime and low income, whereas dry land within the headwaters commanded higher property values.

With the passing of the Clean Water Act traditional methods of water disposal were questioned, engineers came together to understand how stormwater could slowly be released from a municipality, in order to reduce flooding and pollution of the surrounding waters. Engineers began to think outside the pipe, as long horizontal planes of grassy swales and detention basins made it possible for stormwater to slowly enter the surrounding and underlying systems. However, as accurately designed as these systems were, they did nothing to address the quality of stormwater runoff. Similarly, detention basins required a minimum of a half an acre of land to be functional and therefore could not fit into an urban context. Lastly, the management needs associated with large grassy areas created a considerable burden for municipalities. The nature of detention basins and grassy swales being wet sites, does not support grass growth under mower compaction. Eventually such sites increase total suspended solids in the system.

Third phase stormwater management systems include tree trenches, vegetated swales, rain gardens, bio-infiltration basins, constructed stormwater wetlands, permeable paving surfaces and various infiltration structures (dry wells, catch basins, rain barrels). These were based in the context that wet site areas acted as the kidneys of larger ecosystems, finally water quality could be addressed. By increasing infiltration, water quality and quantity could be addressed. Structural stormwater BMPs of the third phase are found at all sites in this study.

Renaissance of Stormwater Management in Philadelphia

Philadelphia is the largest city in the Delaware River Estuary, its ecological impacts are apparent down river and in the Delaware Bay (Figure 22). The region has historically been home to multiple types of fish and wildlife, which are now threatened or endangered due to water pollution. Historically, Philadelphia has gone through a similar process as other large urban centers in dealing with stormwater management, beginning with the Clean Water Act in 1974. The central aim of the Clean Water Act is “to restore and maintain the chemical, physical, and biological integrity of the nation's waters by preventing point and nonpoint pollution sources” (PWD 2012). By putting strict regulations on point source pollution, the quality of many major waterways significantly improved. By 1978 the Pennsylvania Department of Environmental Protection had worked to pass Act 167 which made counties responsible for developing a watershed management plan. Act 167 focused on the planning process and called for new land use designations. In 1978 stormwater management was largely happening through detention and retention basins (second phase stormwater management systems); Act 167 also began a process of properly siting detention basins within municipalities, however very few detention basins were installed in Philadelphia due to high urban density. Advances in water quality monitoring made it clear that one of the biggest contributors to the ongoing pollution of the nation's waters was non-point source pollution, which is addressed under section 303d of the Clean Water Act. Section 303d calls for the implementation of Total Maximum Daily Loads or TMDLs, which outline the highest possible pollution concentration for surrounding water bodies. In 1990, discharges from Municipal Separate Storm Sewer Systems (MS4s), were required to obtain National Pollutant Discharge Elimination System (NPDES) permits (PWD 2012). MS4s carried runoff from local roads or households, and these systems were directly connected nonpoint source pollution. These initial steps were integral in defining the problem surrounding water quality management and Philadelphia was on track to cleaning up surrounding rivers and streams.

Figure 22. Philadelphia compared to other cities within the Delaware River Watershed. Geographic Information obtained via Pennsylvania Spatial Data Access (PASDA).

By 1994 it was clear that in addition to non-point source pollution, the other largest contributor to poor water quality was combined sewer runoff. Combined sewers which host wastewater and stormwater usually drain towards the treatment plant, however during large rainfall events combined sewers overflow into surrounding water bodies, creating a high level of contaminants in these areas. Philadelphia Water Department (PWD) defines a CSO as “a wastewater collection system owned by a municipality which transports wastewater from homes, businesses and industry, stormwater from storm drains on or city streets and property roof leaders through a single pipe system to a Water Pollution Control Plant" (PWD 2012). In Philadelphia there are over 3000 miles of CSO and outfalls are distributed throughout each watershed: Cobbs Creek – 34 outfalls, Delaware – 54 outfalls, Pennypack – 5 outfalls, Schuylkill – 40 outfalls, Tacony / Frankford – 31 outfall (Figure 23). Areas with high impervious cover, increased water velocity within combined sewers, meaning that flows as low as 6 times dry weather flows will result in a CSO event (EPA 2012). Philadelphia's environmental legislature responded to problems with CSO events by passing the Nine Minimum Controls (NMCs) in 1994. The NMCs primarily focus on monitoring and developing controls for CSOs.

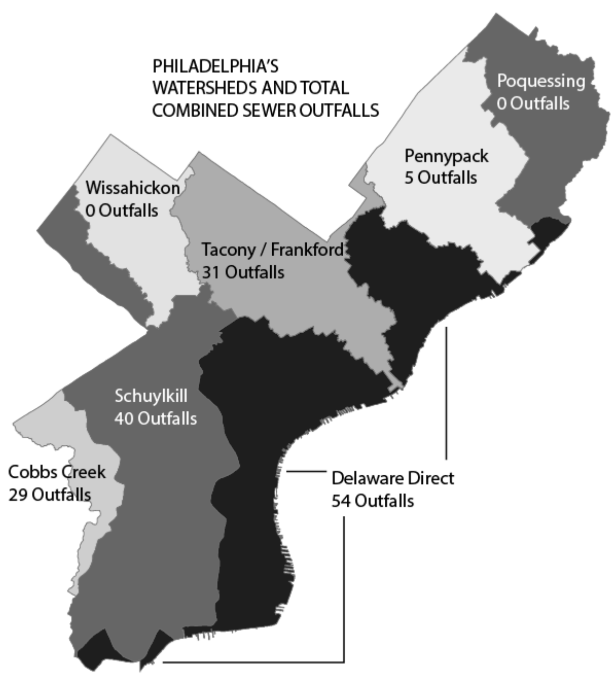


Figure 23. Watersheds in Philadelphia and associated Combined Sewer Overflows. Geographic Information obtained via Pennsylvania Spatial Data Access (PASDA).

In 1997 the Philadelphia Water Department created the Long Term Control Plan for managing CSOs. The plan called for capital improvement projects to be installed throughout Philadelphia, in order to treat stormwater before entering the combined sewer system. In 1997, $47 million were allocated towards capital CSO improvement projects (today this has increased to roughly $1.6 billion) (PWD 2012). Seventeen capital improvement projects were built in 1997 and worked to address dry weather overflows. However, most capital improvement projects were usually out of the public view. The Long Term Control Plan (LTCP) was recently updated to incorporate green stormwater infrastructure "which focuses our program on specific benefits to the residents of the city of Philadelphia by restoring environmental amenities for our constituents and greening our city" (PWD 2012). This way of approaching stormwater management is known as the "triple bottom line" which uses green infrastructure to address environmental, social and economic benefits (Figure 24).

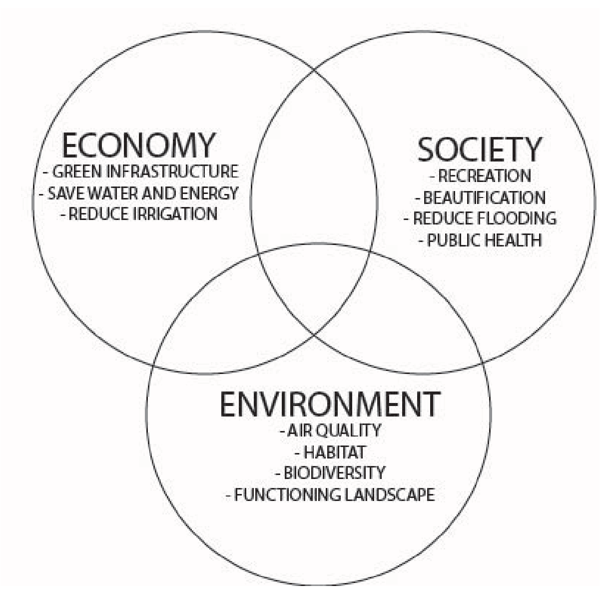


Figure 24. Representation of triple bottom line advantages of installing stormwater systems

Planning for Emerald Status

Drawing upon aspects found in the Long Term Control Plant, planners at PWD developed Green City, Clean Waters which was to become Philadelphia's comprehensive water resource management plan. The Green City, Clean Waters vision includes: large scale implementation of green stormwater infrastructure to manage runoff, requirements and incentives to reduce impact of stormwater on existing sewer infrastructure, a large scale street tree program, improving recreational opportunities along existing streams and waterfronts, preservation of open space, converting vacant and abandoned lands to open space, restoring streams habitat and implementing infrastructure based controls when necessary. Green City, Clean Waters takes a holistic approach to water management by recycling rainwater to recharge underground aquifers. The main criteria for Green City, Clean Waters is the concept of the Greened Acre, which is defined as an acre of impervious cover within a combined sewer overflow zone which flows into green stormwater infrastructure, that manages the first inch of runoff (Figure 25). By 2015 Philadelphia plans to create 450 Greened Acres throughout the city, currently there are only 13.9.

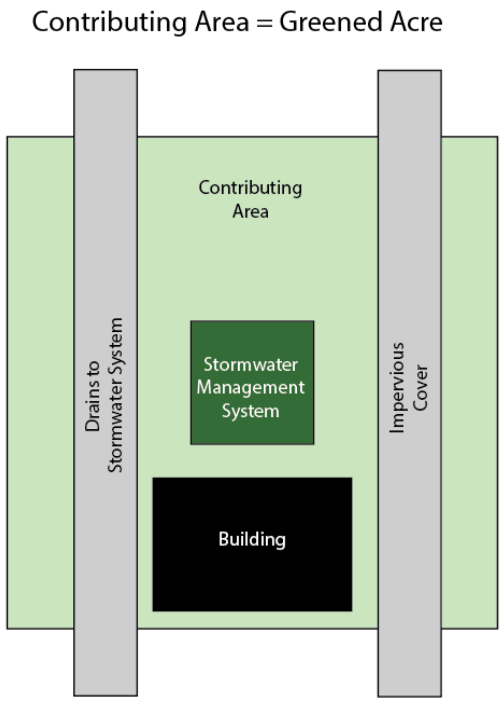


Figure 25. Diagram of Greened Acre, showing relationship of contributing area to stormwater site and impervious surfaces

Within the past five years Philadelphia has taken measures to achieve "Emerald" status, in that it meets the following requirements: long term intervention plans, retention standards, using green infrastructure to reduce some portion of the existing impervious surfaces, incentives for private party actions, guidance for other affirmative assistance to accomplish green infrastructure within the city, and a dedicated funding source for GI (NRDC 2011). A compilation of grants and incentives has totaled nearly three billion dollars' worth of investment in low impact development and green infrastructure over the next 25 years (PWD 2012). Philadelphia's process for planning, locating, designing and installing stormwater management systems, known as the Integrated Watershed Management Plan (IWMP), looks at functional aspects of environmental stewardship. The process involves three steps, a preliminary reconnaissance survey, a watershed work plan and assessment, and watershed plan implementation (PWD 2011). These steps have been very effective in producing demonstration projects throughout the five separate Philadelphia watersheds including: Cobbs Creek, Wissahickon, Delaware Direct, Tacony, and Schuylkill. The Philadelphia Water Department's long term control plan lists over fifty projects that have been developed or are in construction as demonstrations for mitigating stormwater management issues. "PWD's implementation commitment for each watershed with a completed IWMP includes a substantial commitment to demonstration projects in the first five years of the implementation planning cycle" (PWD 2011). When these demonstration projects are viewed in conjunction with wide ranging legislative efforts, it is apparent that Philadelphia is capable of living up to its "Emerald City" status.

Additionally, PWD has started to change stormwater management billing rates in order to promote private investment in green stormwater infrastructure. In 1996 the citizen advisory council suggested that stormwater billing be allocated 80% to impervious surfaces and 20% to total land area, instead of being traditionally connected to meter size. As Philadelphia's stormwater management costs have increased it seems fair to allocate billing according to a parcel's contribution to stormwater. When originally proposed technological limitations prevented this type of billing method, however with the advent of GIS and other mapping systems, PWD was able to bill according to land cover. This new methods of billing primarily affects businesses and PWD has set up an online tool to help business owners calculate their total stormwater bill. Associating a dollar amount with stormwater allows researchers to answer economic questions such as: how long does it take for stormwater management areas to become financially independent and essentially pay for themselves? Balancing savings with costs of maintenance and repair remains of high importance to civil engineers in understanding the efficiency of green stormwater infrastructure.

Green City, Clean Waters and similar plans coming from the Mayor's Office of Sustainability (Greenworks Philadelphia) have inspired planners to speculate on the future of Philadelphia. Green 2015 is a planning document created by Penn Praxis (2010) that works to target stormwater management projects within neighborhoods that lack open space. Philadelphia hosts "62 acres of paved recreation centers, 426 acres impervious of schoolyards and 558 acres of vacant lots within the city" (Penn Praxis 2010). Greening these sites will allow for open space in underserved areas of Philadelphia. By evaluating the design of public amenities at stormwater management sites, this study dovetails with open space criteria found in Green 2015.

Aesthetic Considerations of the Philadelphia Stormwater Management BMP Manual

Multiple planning documents and public programs have been instrumental in implementing green stormwater infrastructure as a response to issues of water quality. While the need for more comprehensive stormwater management sites was made explicit by the Clean Water Act, and remains the same for all urban centers, Philadelphia's response to environmental challenges, in framing them as opportunities for creating improved public spaces remains unique. However, beyond planning and EPA regulations, the final document in guiding the design and construction of stormwater management projects is the Philadelphia Stormwater Management BMP Manual. While the manual focuses primarily on structural stormwater management BMPs it also addresses the aesthetic design of stormwater management sites: “Aesthetics and visual characteristics should be a prime consideration. Plant form, texture, color, bloom time and fragrance are important to the overall feel of the site. Plants can be used to enhance and frame desirable views or screen undesirable views” (PWD 2012). Such criteria directly affect the design of the site, however remain fairly underrepresented when considering the large emphasis put on functionality of stormwater sites. The Stormwater BMP Manual struggles with protecting sites, allowing public access and keeping areas aesthetically pleasing: “Stormwater Management Project (SMP) elements […] are generally not aesthetically pleasing. Designers are strongly encouraged to integrate aesthetically pleasing landscape design with SMPs” (PWD 2012). Largely, BMP manuals read like catalogs, allowing for designers to pick a specific stormwater management system that may be best suited to a site. Modular stormwater management designs are essentially an infiltration “holy grail” and cannot be actualized due to site-specific changes in topography, managed runoff and impervious cover. Aesthetic guidance is limited to putting a “planted veneer” over structural stormwater BMPs. Therefore, Philadelphia Stormwater BMP manual seems more related to safety, and ensuring people do not accidentally enter the stormwater system, than providing a unique public experience. Drawing on ideas expressed by Echols and Pennypacker,

Goals for this Study

Stormwater management systems have the potential to generate a public forum on water. A new conversation on water will include traditional ideas about quantity and quality, but also express new ideas concerned with flow and access. The work of John Wilkes has shown how common ideas about water can be continually re-imagined and the limits of current knowledge coincide with curiosity. As stormwater management systems are incorporated into cities and municipalities on a larger scale, will the opportunity to draw upon intricacies of water flow present itself? To what extent do current structural stormwater management BMPs become public amenities? By examining multiple recently constructed stormwater management systems in Philadelphia this study explores the ability of stormwater systems to express ideas connected with water flow, quality, quantity and the hydrologic cycle.

Data across twenty stormwater management sites was gathered at three levels, neighborhood, site and design scale (Figure 26). These scales allow for comparisons to be drawn between stormwater systems based on structural BMP typology, public engagement, context and amenity. Design techniques were evaluated based on a rubric developed from Echols and Pennypacker's "From Stormwater Management to Artful Rainwater Design." A rubric allows for a non-subjective evaluation of public amenity at stormwater management sites. By comparing different stormwater interventions, this study addresses themes in water design including: legibility of water flow, tradeoffs between function and amenity, and components of aesthetic quality. Reflecting on the design of recently constructed stormwater management sites will inform the process of implementing future green infrastructure and expand the landscape architect's sources of inspiration in working with runoff.

Figure 26. Data is collected at three scales, neighborhood, site and design scale.

Are stormwater management systems twenty-first century fountains? If stormwater management systems are overly engineered and a level of publicity is not brought into the design, structural BMPs are will replicate the lifecycle of earlier paradigms of stormwater management. If landscape architects continue to seek new ways in which public amenities can be incorporated into stormwater management system, future stormwater management systems will continually evolve.

This thesis asks: How is aesthetics integrated with the design of existing stormwater systems? Can we quantify the level of public amenity offered at different stormwater sites throughout Philadelphia? Will evaluation of sites based on Echols and Pennypacker's design techniques be useful in creating cross comparisons? By taking a methodical approach to answering these questions this study will influence the design of future stormwater management systems. This introduction has expressed a broad range of knowledge ideas, and philosophies concerning stormwater management. To show how the research within this thesis fits into the literature review, Figure 27 has set up a map to categorize areas of study / inquiry.

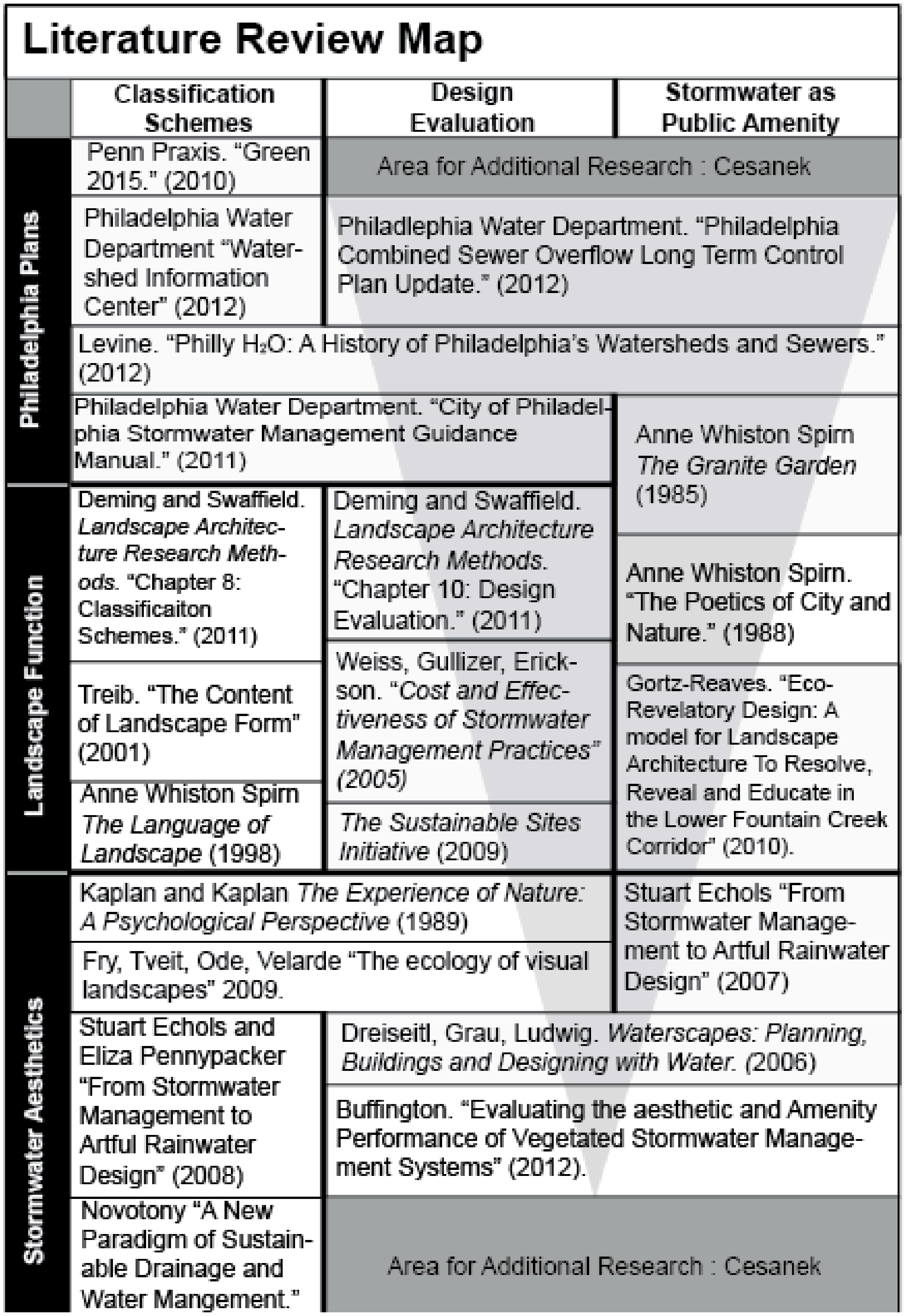


Figure 27. Diagram of literature map shows where this research fits into the existing body of knowledge surrounding stormwater management

Chapter 2 - Methods

Introduction to Study Set and Research Methodologies

Twenty stormwater management sites in four separate watersheds (Delaware Direct, Wissahickon, Tacony/ Frankford, and Schuylkill) generate the study set for this thesis. Figure 28 shows the sites visited for this study in relationship to all constructed stormwater management sites. A list of sites, addresses and adjacent facilities can be found in figures 29, 30 and 31 (these figures do not include the Traffic Triangle at 47th and Greys Ferry or the Vacant Lots in the Kensington Neighborhood). All sites examined in this study are considered public stormwater demonstration sites by PWD. Publicly accessible sites infer that amenities are associated with some part of the design, allowing for further evaluation. Twenty sites were deemed an adequate study set in that it coincided with the number of sites informing Echols and Pennypacker's study. Data was collected on sites at three different scales: neighborhood scale, site scale, and within site. The scope of this research covers design evaluation, categorization and classification methodologies, which Deming and Swaffield (2010) cite as complementary approaches in constructing new knowledge in landscape architecture. Throughout this study evaluation informs site category, similarly, parameters for evaluation and category change between scale of inquiry. Design Evaluation, Categorization and Classification Schemes have been widely used throughout landscape architecture, this chapter begins with a formal definition of these methodologies before explaining how each research method was employed at neighborhood, site and within site scales.

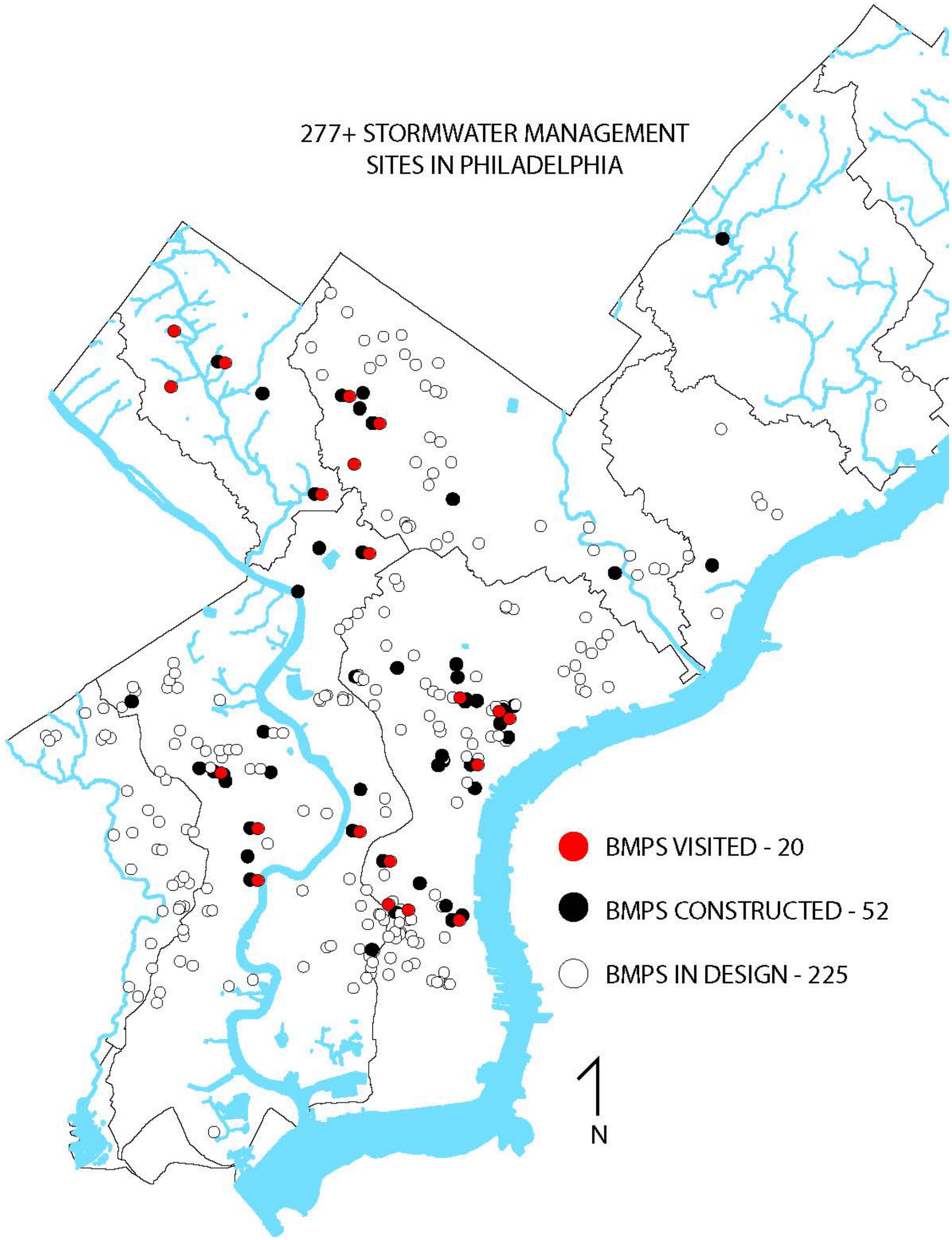


Figure 28. Map of stormwater management sites within Philadelphia. Geographic Information obtained via Pennsylvania Spatial Data Access (PASDA).

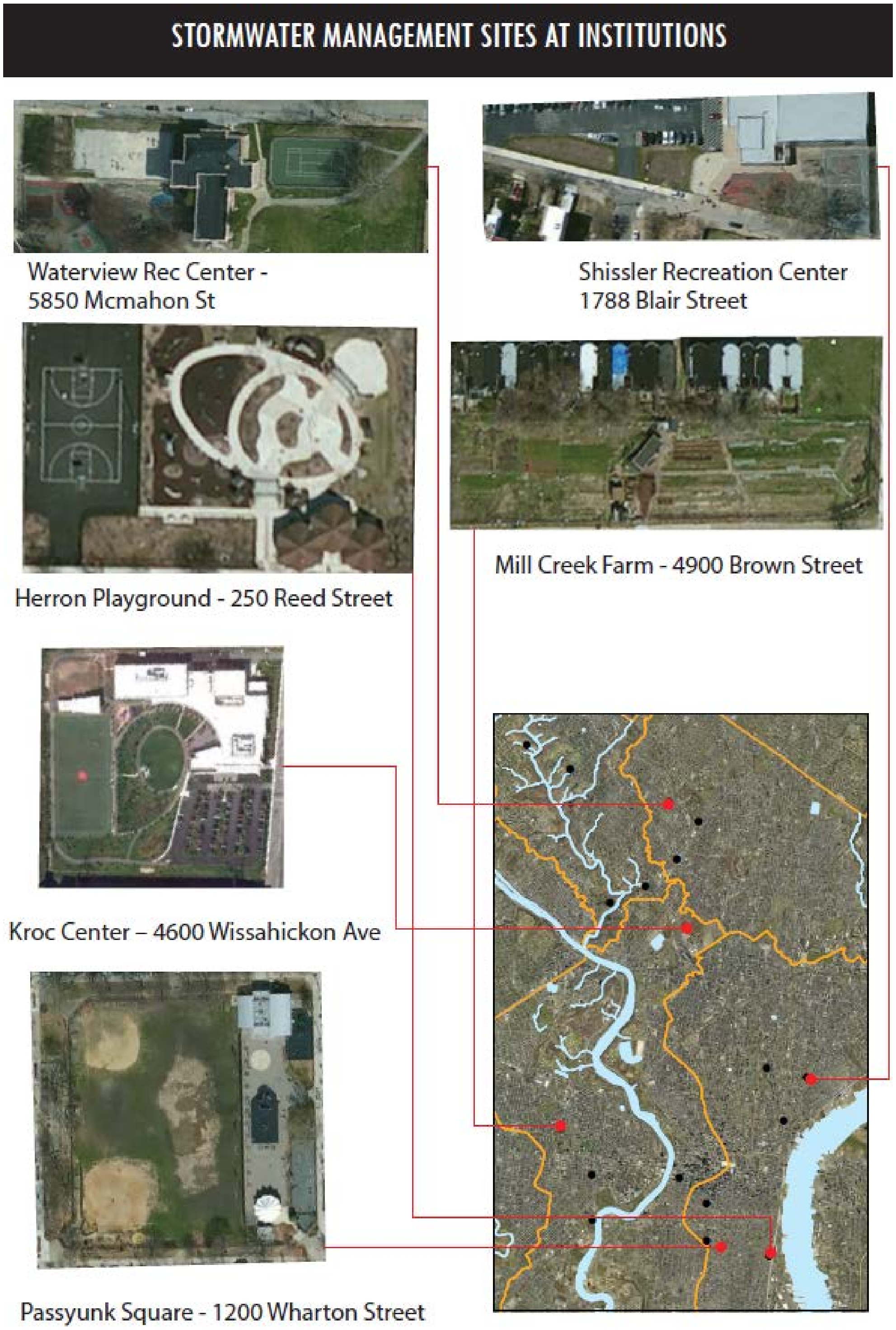


Figure 29. Stormwater management sites located at Public Institutions. Geographic Information obtained via Pennsylvania Spatial Data Access (PASDA).

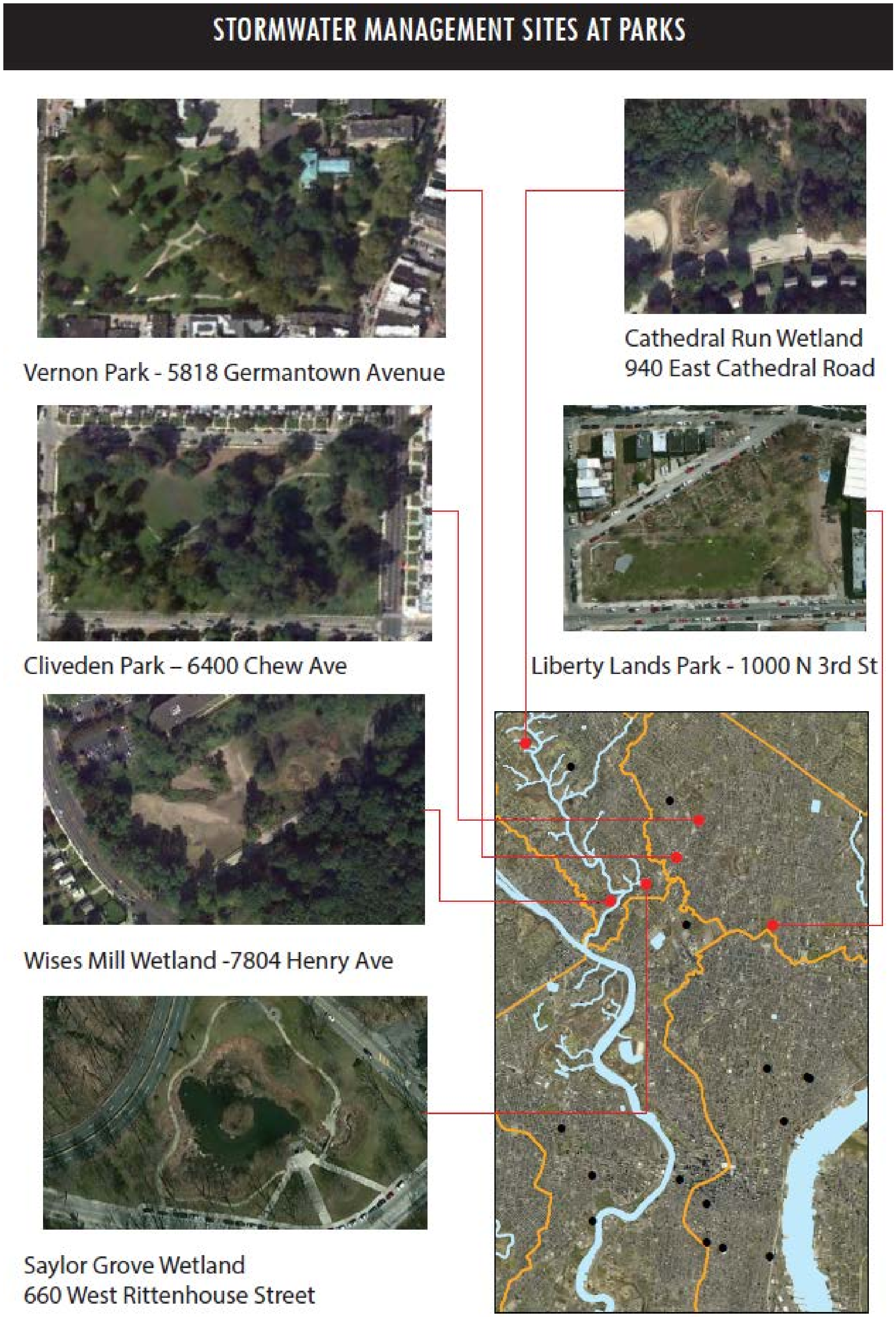


Figure 30. Stormwater management sites located at Parks. Geographic Information obtained via Pennsylvania Spatial Data Access (PASDA).

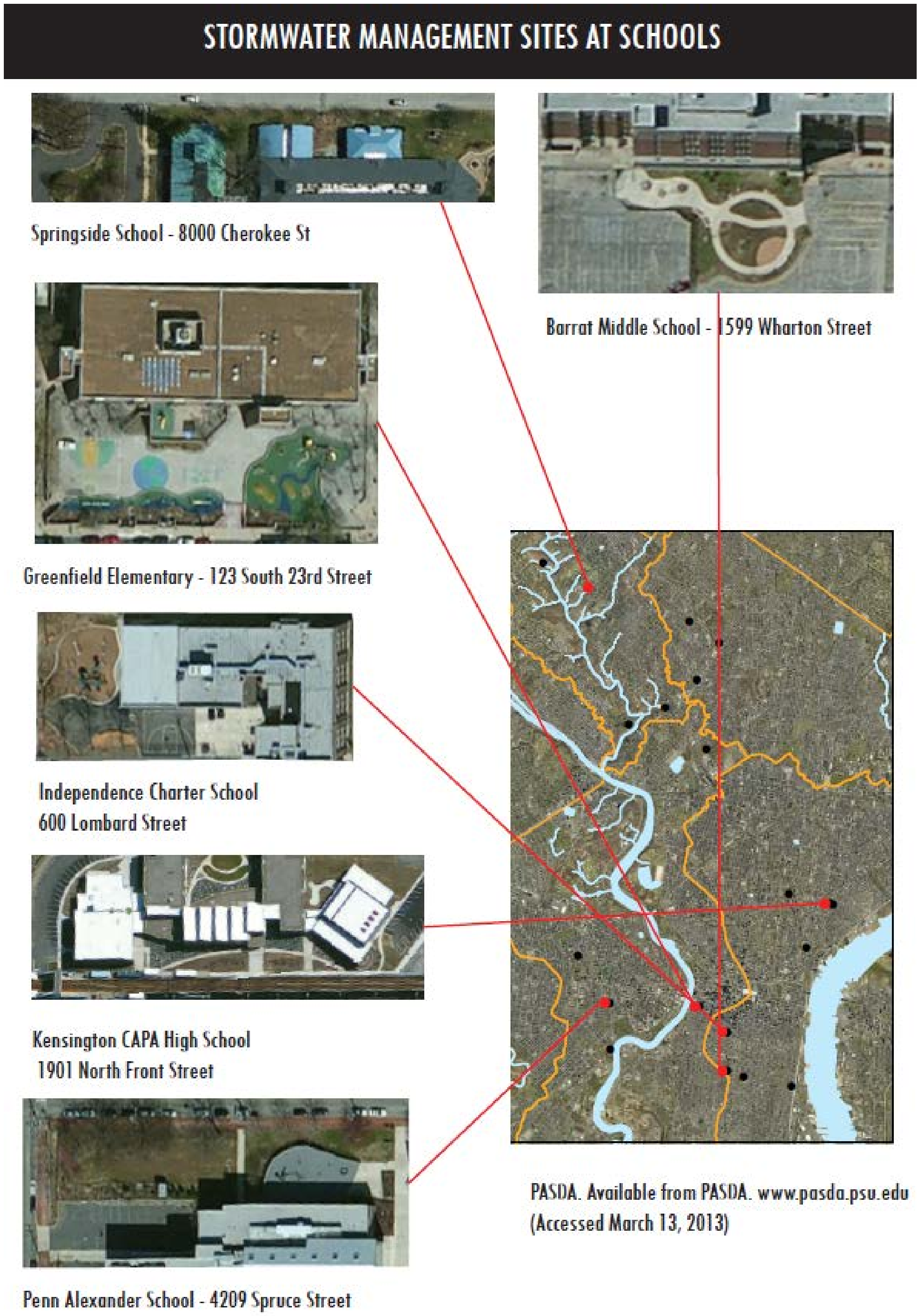


Figure 31. Stormwater Management Sites Located at Schools. Geographic Information obtained via Pennsylvania Spatial Data Access (PASDA).

Design Evaluation Research Methodology

Design evaluation refers to the work of considering, measuring, and judging the merit and value of a range of competing design options. “The ability to rapidly evaluate design ideas, throughout their development within the design process, is an essential element in the goal to increase design productivity, impact, quality and value” (Echols and Pennypacker 2008). Design evaluation is important in maintaining a standard of quality and is an important part of the process of site design and construction: “developing a plan, implementing the plan, and evaluating the plan is a dynamic, iterative process that helps move communities toward achievement of their goals” (EPA 2008).

Stormwater management design evaluation has thus far looked at the functionality and life cycles of such systems. Research Universities including Rutgers (Christopher Obropta), Villanova (Robert Travers), and University of New Hampshire (Thomas Ballestero) are on the cutting edge of understanding the science of infiltration. Evaluation of stormwater systems for research is done primarily by environmental engineering or civil engineering departments, with occasional interdisciplinary studies with soil sciences and hydrology. This type of research lends greater understanding to rain gardens. Most recently Thomas Ballestero has been working with subsurface gravel wetlands, high functioning infiltration systems that are capable of draining major roadways.

Landscape Architects, along with Environmental and Physical Planners have developed a spatial understanding of stormwater management system design. By organizing communities and developers to install rain gardens Landscape Architects have worked to increase publicity surrounding stormwater management: “Stormwater management projects may have goals for increasing knowledge and awareness and changing attitudes among groups such as residents, business owners, and municipalities" (EPA 2008). However, these changes can be harder to track, and evaluation usually encompasses a methodology of extensive surveys, interviews and other forms of personal contact. However these projects fill an important gap between construction of rain gardens and perceived water quality results, "social indicators especially behavior changes are important intermediate benchmarks in a successful stormwater management projects when many years are needed to measure a water quality response" (EPA 2008). Greater public awareness will help to spread the effects of stormwater management throughout watersheds.

The Social Indicator Planning and Evaluation System (SIPES) is one way in which Landscape Architects and Planners can quantify change in perception of a region's stormwater management plans: "SIPES was developed initially as an evaluation tool for NPS projects to assess changes in a target audience's awareness, attitudes, capacity, constraints and behavior over time" (Genskow and Prokopy 2011). Sipes consists of multiple phases of engaging the community surrounding the development of a stormwater management plan. By creating an iterative process SIPES can help watershed partnerships reach goals of improving overall water quality. It is important for the public to remain engaged with every step of the planning process, to ensure that all options are being weighed/ all input is being met. SIPES is composed of linear and cyclical planning processes, in which the public voice remains the highest indicator of successful stormwater management planning.

A similar public evaluation method was employed by Whilliam Whitmore, Edward Cook and Frederick Steiner (1995) in their paper "Public Involvement in Visual

Assessment: The Verde River Corridor Study." In working to improve landscape conditions around the water body, Researchers used classification and evaluation techniques similar to those crafted by Echols and Pennypacker. This study focuses on visual assessment of the Landscape, one of the primary ways people experience the outdoor environment. In this study, three types of visual assessment were performed including expert evaluation, public evaluation and public nomination. For the purposes of this thesis the expert evaluation is defined as "evaluation of visual quality by a trained expert incorporating knowledge from design ecology and resource management" (Deming and Swaffield 2010). The expert evaluation "engaged skilled observers to evaluate a landscape on the basis of their education and training. Whose observations result in a statement of landscape quality" (Whitmore et. al. 1995). In Whitmore et. al.'s study the expert analysis was used to delineate sites into certain categories including "natural, cultural, or a combination of natural and cultural. Further description of landform, vegetation patterns, water forms, rock formation, color, texture, harmony, variety, contrast, adjacent scenery, scarcity and cultural modification." This evaluation categorized sites into visual assessment parameters including legibility, complexity, spatial definition and mystery. These four categories of landscape are defined by Whitmore et. al. as:

- Legibility - "definition and contrast. Allow the viewer to recognize and make sense of the various landscape elements" (Whitmore et. al. 1995)
- Coherence - "arrangement of three dimensional space that creates order and unity of aesthetic elements" (Whitmore et. al. 1995)

- Complexity - “number intricacy and relative distribution of landscape elements discernible to the viewer” (Whitmore et. al. 1995)
- Mystery - “promise of additional information; visually inviting, information not readily apparent” (Whitmore et. al. 1995)

Whitmore et. al. (1995) categorized 522 photos into 29 landscape typologies for public assessment. This type of assessment was primarily visual because, “The perception of scenic beauty is considered to be an interactive process between the viewer and the environment” (Lynch 1960). It was found that the landscapes along the Verde River which the public held in higher esteem were natural areas whose, “naturalness is increased by irregular shorelines and overhanging vegetation” (Whitmore et. al. 1995). Whitmore et. al.’s study examines “the informational process of the landscape that allows for discovery of new information and maintenance of spatial orientation” (1995).

The Sustainable Sites Initiative (SITES) is another common way landscape architects have been evaluating design. SITES is an approach to understanding the ethical contribution of landscapes to the surrounding environment and society and was “initially designed to expand forward thinking provided by LEED into built landscape space” (SITES 2009). It is an interdisciplinary effort created by the American Society of Landscape Architects, the United States Botanic Garden and the Lady Bird Johnson Wildflower Center. The goal of SITES is to “promote sustainable land development and management practices” (SITES 2009). Landscapes are scored based on nine aspects of planning, design, construction and management, chapters include:

1. Site selection
2. Pre-design assessment and planning

3. Water
4. Soil and vegetation
5. Materials selection
6. Human health and well-being
7. Construction
8. Operations and maintenance
9. Monitoring and innovation

The scope of this research will examine chapters relating to water, soils / vegetation and human health / well-being. The sustainable sites evaluation of stormwater management, as well as other categories influenced the general methodology of the study.

The water chapter of SITES evaluates water use on site and is a requirement for a landscape to be eligible for SITES status. For each site a designed and baseline water requirement are calculated based on types of plantings, irrigation systems and water from non-potable sources. The difference in the baseline water requirement is subtracted from the designed water requirement and divided by the baseline to understand the reduction in potable water use. Other categories give points depending on what level the design meets the objective. For example credit 3.5 is worth 5 - 10 points and involves managing stormwater onsite. This requirement was created based on stormwater management models such as SWMM and WinTR-55. These allow users to provide calculations of initial and final target water storage capacities based on Curve numbers. Higher Curve Numbers indicate lower storage capacity, while lower Curve Numbers indicate higher storage capacity. The existing site condition is then combined with the percent improvement in water storage capacity to yield a point value for stormwater management credits.

Evaluation of other aspects is integral to the sustainable sites initiative and does not solely require an understanding of technical concepts. For a site to be awarded "Sustainable Sites" status there must be multiple people and organizations involved with the documentation of the design, a single landscape architect could not rectify all the elements of this procedure. In the Water chapter an evaluation that closely adheres to this study is the stormwater site amenities credit 3.7. This credit is worth 1 - 3 points and calls for documenting "that the rainwater falling on the site is treated as an amenity through the way it is received, conveyed and made accessible to site users" (SITES 2009). The scoring system for stormwater features as public amenity is as follows: "1 point - 50% visible, 2 points - 75% visible and contact with stormwater is possible, 3 points - 100% visible and stormwater is intended for full contact such as swimming" (SITES 2009). Essentially this stormwater management credit functions to keep the stormwater systems above ground, and functioning within the public sphere.

Public assessment, environmental modeling, visual observation, expert analysis are all ways in which landscape architects strive to quantify the environment around themselves. The most objective evaluations take the longest, as infiltration experiments and readings are conducted over a series of multiple years, whereas the most subjective evaluations can happen rapidly, but differ in their goals.

Cataloging and Categorization Research Methodologies

The basic definition of a catalogue is “a collection of items which is identified and brought together on the basis of some shared quality and is then sorted, grouping like with like” (Deming and Swaffield 2010). The basis for any catalogued system, can be thought of before or after actual site selection and must be combined with a several scales of interpretation in order to generate a classification scheme. Deming and Swaffield (2010) site Hans Obrist as a basic example of cataloging of sites. His lengthy site list entitled “Un Jardin peut en chacher un autre” is a catalogue of imaginary garden types, arranged alphabetically, from Agglomeration Garden – Zen Garden. Cataloging is integral in lending structure to a new set of ideas. The Big Green Map is PWD’s catalogue of stormwater management sites, sites are spatially defined and icons indicate structural BMPs found on site. The Big Green Map catalogue was integral in beginning this research, and allows for the public to visit and experience a stormwater management sites which may go otherwise unnoticed. Categorization is the first level of refinement which must happen before items are placed into a larger classification scheme. Categorization techniques create specific groups with criteria which break down projects from the larger catalogue. Echols and Pennypacker’s study “From Stormwater Management to Artful Rainwater Design,” gives design techniques which act as criteria for different categories (2008). A categorization of design techniques as relating to site goals, and public amenities is achieved through rigorous description and analysis.

Classification Scheme Research Methodology

Classification schemes work to arrange information in a hierarchical order. The most prevalent example of a classification system exists within the field of biology and delineates a kingdom phylum, class, order, family, genus and species for each organism. Creating classes or groups of objects allows researchers and designers create a bottom up structure from a seemingly random set of variables. At a larger scale, examining classification schemes can bring a new understanding to a generalization. Theoretical and practical values govern the nature of how a classification scheme is ordered (Echols and Pennypacker 2008). “Simple or complex, universally accepted to highly controversial, classification reflects concepts, variables, and are thus an integral part of an implicit or explicit frame of reference” (Pedhazur and Schmelkin 1991). The goal of classification schemes is to broaden the view of a certain topic, to create an in-depth understanding of the process leading to a specific point. Points of this research touch on classification schemes but an overall classification scheme of stormwater management sites in Philadelphia was outside the scope of this study. However, the possibility exists for future researchers to combine this study with newer versions to produce a coherent classification scheme of sites throughout Philadelphia (for more information on future studies see chapter 4).

Neighborhood Scale Data Collection

For each site GIS analysis was conducted to collect information available within the surrounding half mile. A half mile radius was chosen according to open space initiatives set forth by Green 2015. Spatial analysis was completed using information available on PASDA's website for the city of Philadelphia. GIS analysis fits into larger geographic frameworks for understanding the role of stormwater management systems within the watershed (Hill). Similarly, GIS analysis was used to understand the meaning attributed to a site from the surrounding community (Spartz 2011).

Population

Population data was calculated based on residential housing acreage of the surrounding half mile. A half mile radius requires a finer grained analysis than using a fraction of census blocks. Total residential land use within the half mile was calculated for high, medium and low density development. Using data made available by the Trust for Public Land (2011), average density for high, medium and low residential areas were calculated based on percentages of the population average for Philadelphia. Average people per acre were multiplied by total square acreage of high, medium and low residential land uses, then combined to calculate total population within a half mile. Population density is visualized through bar graphs. Population density is an integral part of public stormwater demonstration sites in that this is PWD's perspective audience.

Land Use

GIS mapping techniques were used to visualize spatial orientation and calculate total area of residential, institutional and park /open space land use within a half mile of all twenty stormwater management sites. Figure ground representations of surrounding land uses informed categorization of green infrastructure sites according to integration into existing urban fabric. Surrounding institutional land use was sorted into three categories: institution on site, large localized institution, and diffuse institution. Within each category, institutional acreage was arranged form high to low. Surrounding park / open space acreage is categorized as gateway or island depending on the layout and amount of existing green spaces. Lastly, existing residential acreage figure ground images allows for categorization of site as either urban, neighborhood or outside of a neighborhood context. This level of GIS analysis further informs site description. The proximity of the site to surrounding amenities influences the character and meaning derived from the landscape (Spartz and Shaw 2011).

Site Scale Data Collection

Published online resources were used to derive site scale research. Major sources for site scale research included PWD's Watersheds Website and the Temple Villanova Sustainable Stormwater Initiative website. For quantitative studies of runoff areas and greened acre calculations, data was gathered from maps made available through PASDA.

Diversity of Public Engagement

Data concerning public engagement was conducted for all twenty sites, with varying levels of confidence in each category of inquiry. Information was gathered concerning: level of volunteer involvement, fundraising efforts behind construction, level of PWD involvement, and partners. Volunteers were ranked as present of absent. PWD involvement was ranked on a high, medium or low level. Fundraising and grants were listed as well as local partnerships involved with the project. This mode of site scale research will work to inform categorization of sites based on level of public involvement (high, medium, low). For example, sites which were constructed between the collaboration of PWD and a single contractor yield low diversity of public involvement, whereas sites which garner public support from multiple institutions, had a variety of grants and partners involved with the undertaking, and most importantly receive support from volunteers would yield a high diversity of public involvement.

Cost per Square Foot

In order to gather information on cost per square foot, the boundaries of each stormwater management system were measured using GIS, based on aerial photography available through PASDA. Construction costs were reported for 12 out of 20 total sites via Temple Villanova Sustainable Stormwater Initiative. Information on primary contractors was collected for all twenty sites. Information on construction costs are compared with structural BMP technology on site to gain an understanding of which stormwater management systems are most sustainable. Current studies have shown that street trees are the most sustainable stormwater management device in that they cause the least disturbance to the ground plane. Green street programs which involve tree trenches and a variety of other stormwater management projects turn everyday streets into areas of high infiltration. However, street trees were not part of structural BMPs considered for this study, stormwater management sites within this are singular demonstration projects and encompass the blank slate of a schoolyard, park or public institution. Data is represented through bar graphs, with delineations between high and low cost per square foot.

Structural BMPs Onsite, Area Drained and Greened Acres

Information on primary / secondary stormwater management systems on site was collected from a modified Big Green Map (PWD) made available through PASDA as of January 2013. This allowed for comparisons between sites and surroundings and showed which structural BMPs most closely relate to stormwater amenities. Secondary site typologies were designated by immediate surrounding land use and were restricted to the following categories: park, open space, school, institution, or other.

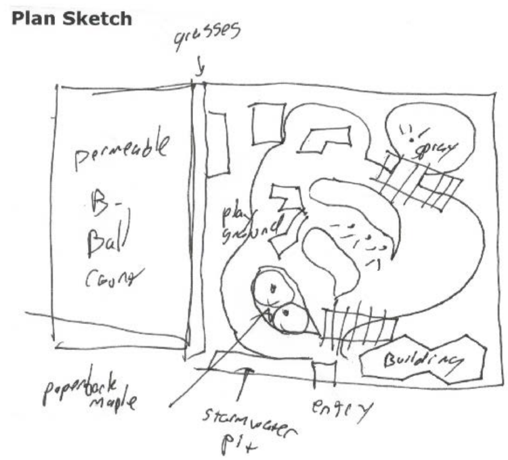
Total area each site drains was calculated using topographic GIS Analysis, as well as information on existing ground cover / inlet structures. This information was then augmented by research on TVSSI's website and other technical information provided by PWD and similar organizations. Greened acres were calculated for each of the twenty sites by measuring total contributing area for stormwater projects within the CSO. Also, this information derived a ratio of drainage area size to stormwater management feature size, allowing for an understanding of structural BMPs management capacities. Site drainage areas and greened acres are displayed as bar diagrams contrasting high and low measurements.

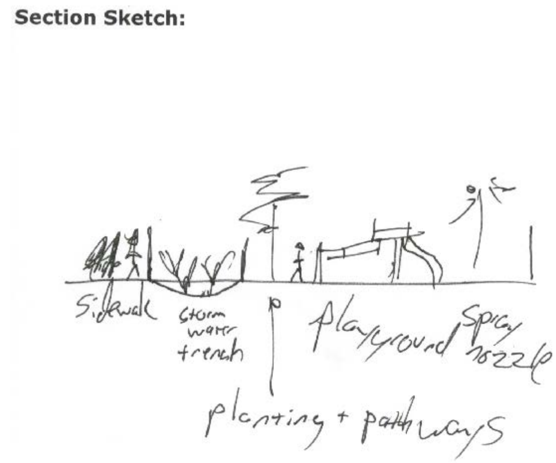
Circulation Diagrams

Circulation diagrams were made for each of the twenty sites according to aerial images made available through PASDA. Diagrams include stormwater management vegetation, dense vegetation, water, buildings, spray grounds, and structural stormwater BMPs each signified by a different color. Enclosed, looing, destination or gateway circulation categories were made based on pedestrian / vehicular circulation through site. Circulation diagrams rely heavily on organizing elements onsite, Kevin Lynch's work regarding legibility of the urban environment and cognitive mapping (1960) was integral into realizing this portion of the study.

Design Evaluation - On Site Scale

Site evaluations were conducted through a combination of on-site visits and further in-depth website-based investigation. Site evaluations were conducted based on types of design features present, and it was not necessary for users to be present to generate associated point values. However, for a majority of site visits users were present and observed interacting with the site as they would on a day to day basis. Seventeen sites were evaluated during the summer of 2012, an additional seven sites during the winter of 2012-2013 (four of the original study sites were dropped, due to public demonstration project criteria). Site visitations were scheduled according to weather patterns, with a preference for visiting in rainy conditions. Site inventory included sketching and note-taking of processes/ social actions happening on site. Water flow on site was explored through section drawings. General site layout and inventory was done through plan and section drawings (Figure 32 and 33). Labeling drawings allowed for an understanding of plant species, water and pedestrian circulation.

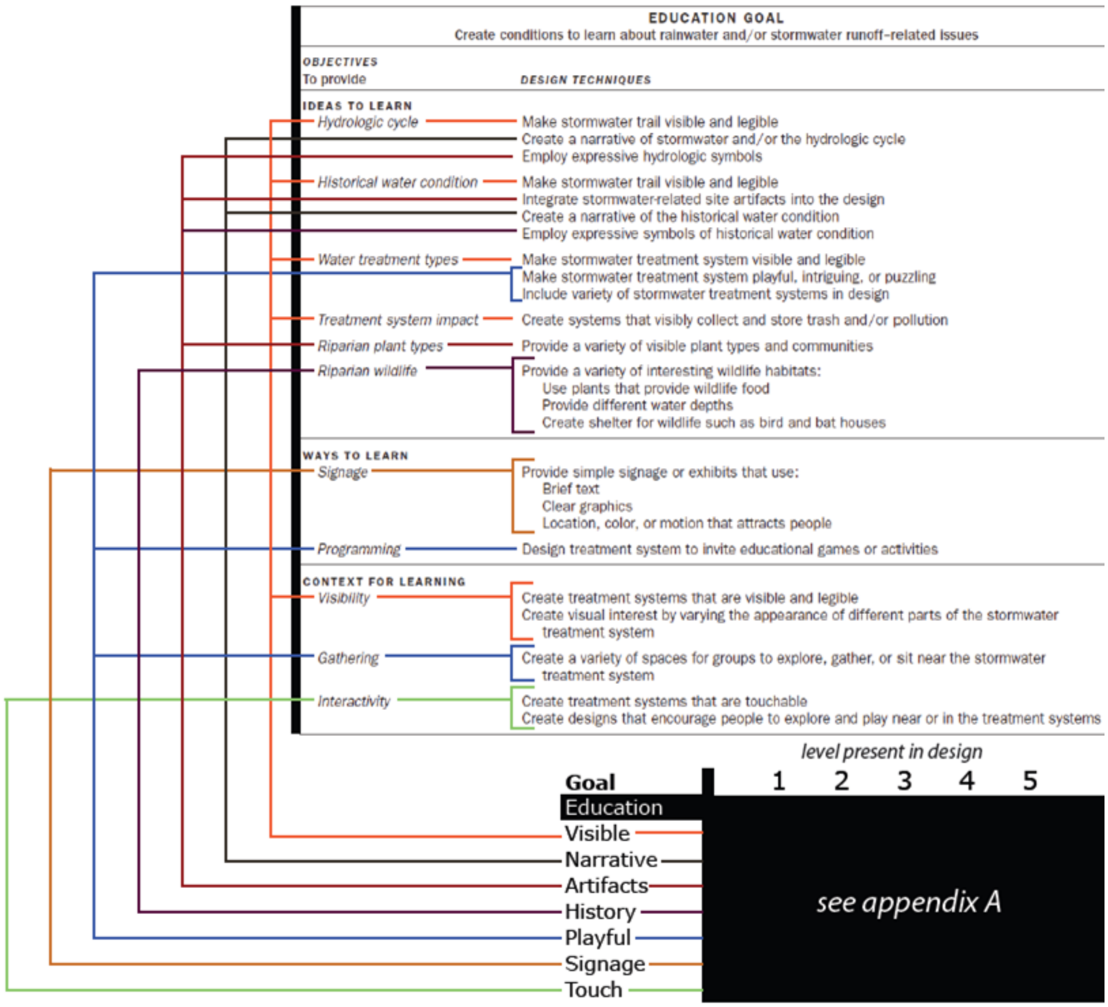




Figures 32 and 33. Plan and section sketch done onsite of Herron Playground

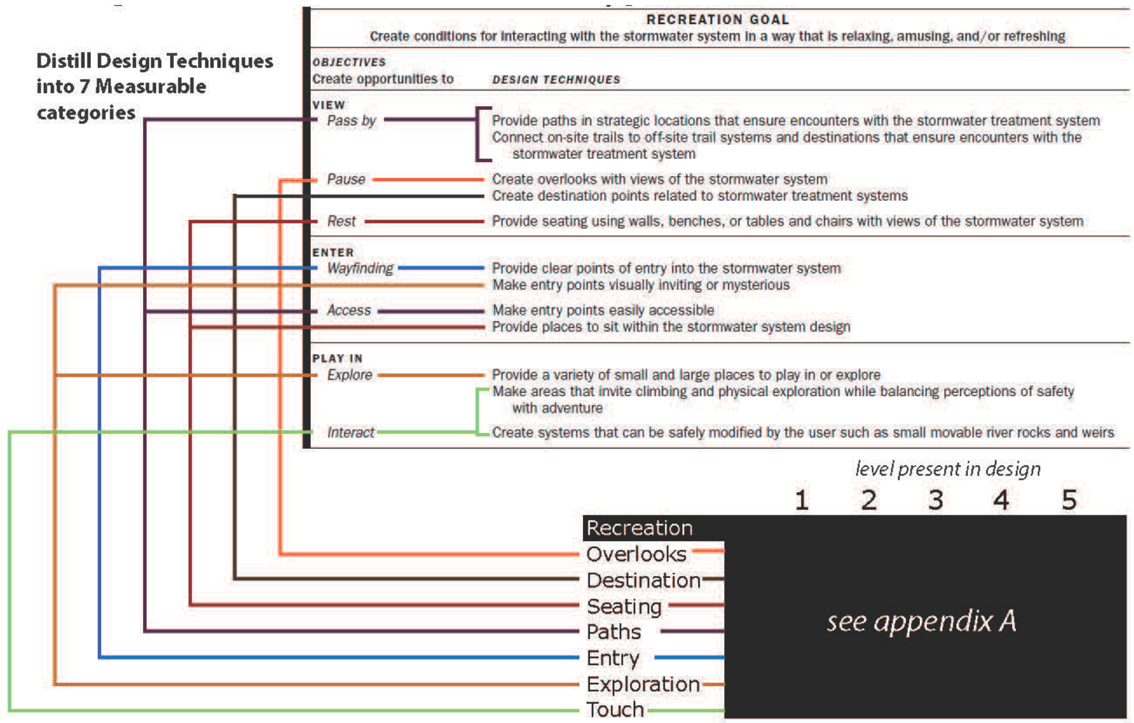
Evaluation of Public Amenities

An evaluation rubric was created to gauge the level of design techniques which offer specific site amenities. Echols and Pennypacker's article "From Stormwater management to Artful Rainwater Design" (2008) outlined five categories of public amenities: education, safety, publicity, aesthetics and recreation. In order to evaluate these categories each needed to be translated into measurable criteria. Figures 34 - 38 show how design techniques provided by Echols and Pennypacker were grouped to create criteria. It was important to omit second-level classification schemes applied to Echols and Pennypacker's Public Amenities (Ex. "Ideas to Learn" "Ways to Learn") to focus on material design considerations. Since there are no median precedents for design considerations, each criterion was ranked on a "Likert-like" ranking system (1 - 5 points). Sites were scored based on the level that design techniques adhere to criteria. Appendix A details each criteria and offers vocabulary for scores from 1 - 5.



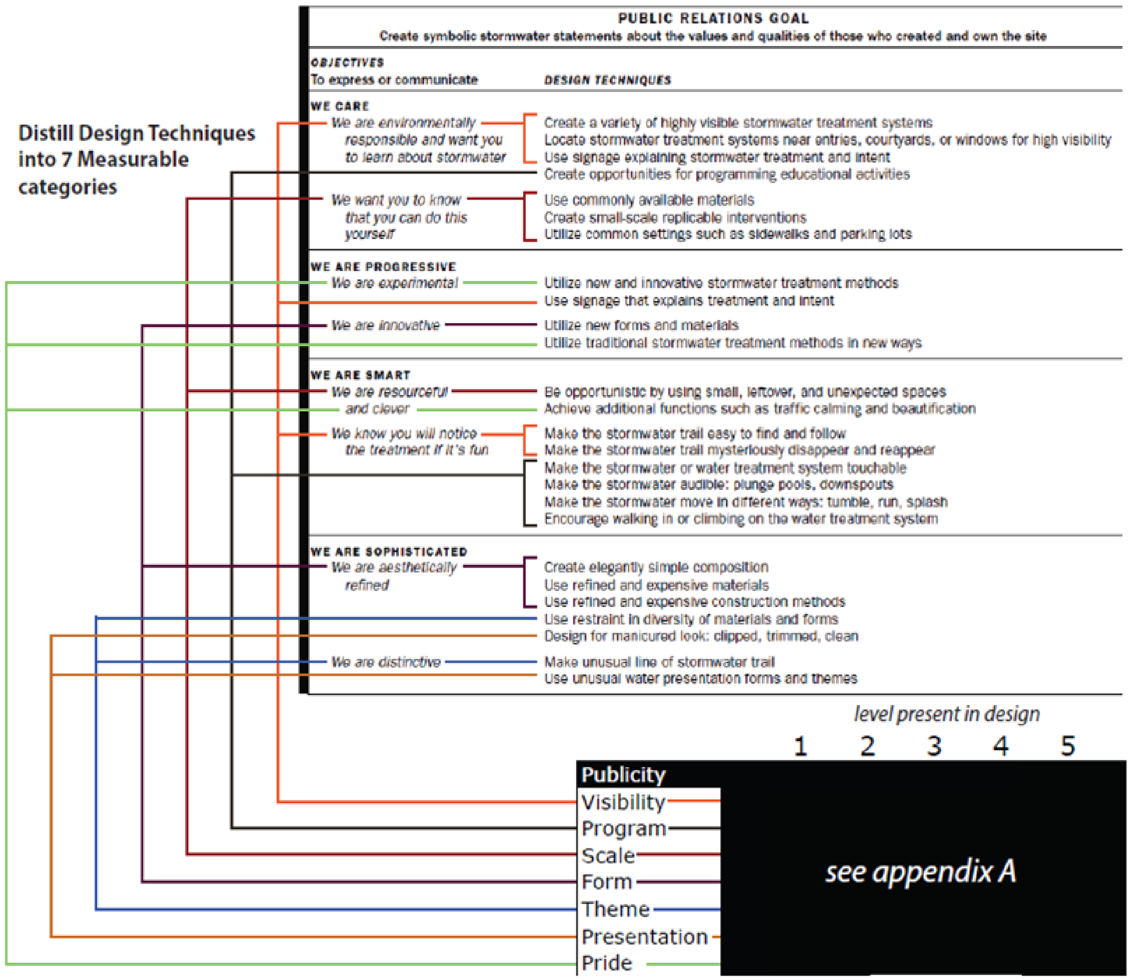
Source: Echols and Pennypacker "From Stormwater Management to Artful Rainwater Design" (2008).

Figure 34. Education amenity evaluation rubric founded on design techniques from Echols and Pennypacker (2008)



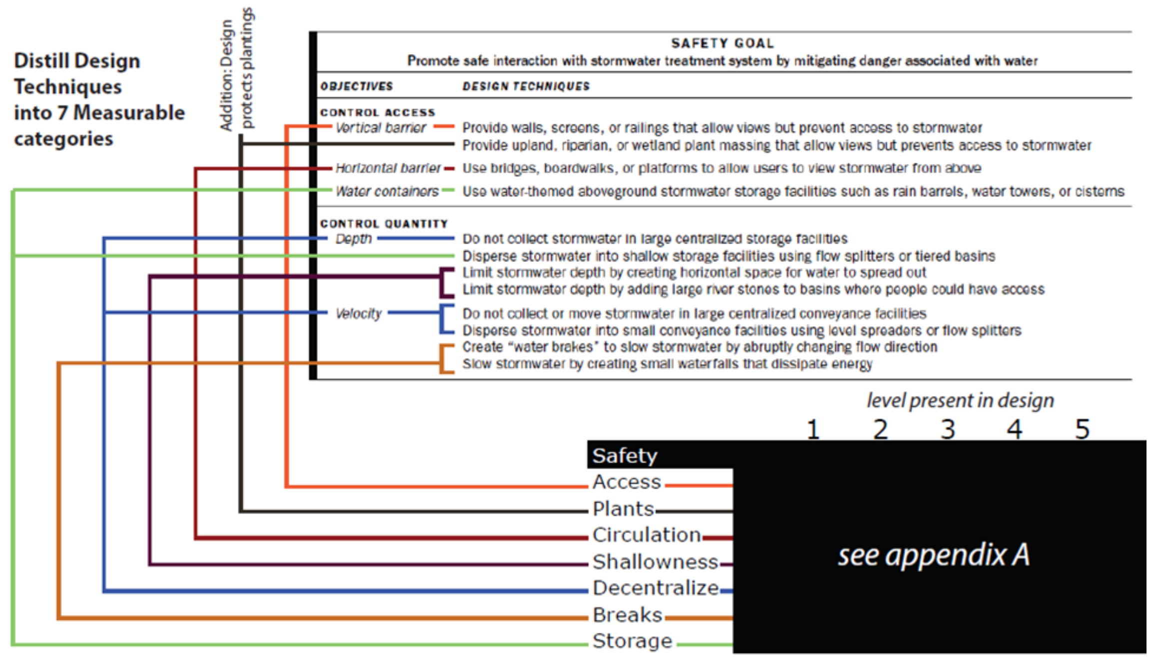
Source: Echols and Pennypacker "From Stormwater Management to Artful Rainwater Design" (2008).

Figure 35. Recreation amenity evaluation rubric founded on design techniques from Echols and Pennypacker (2008)



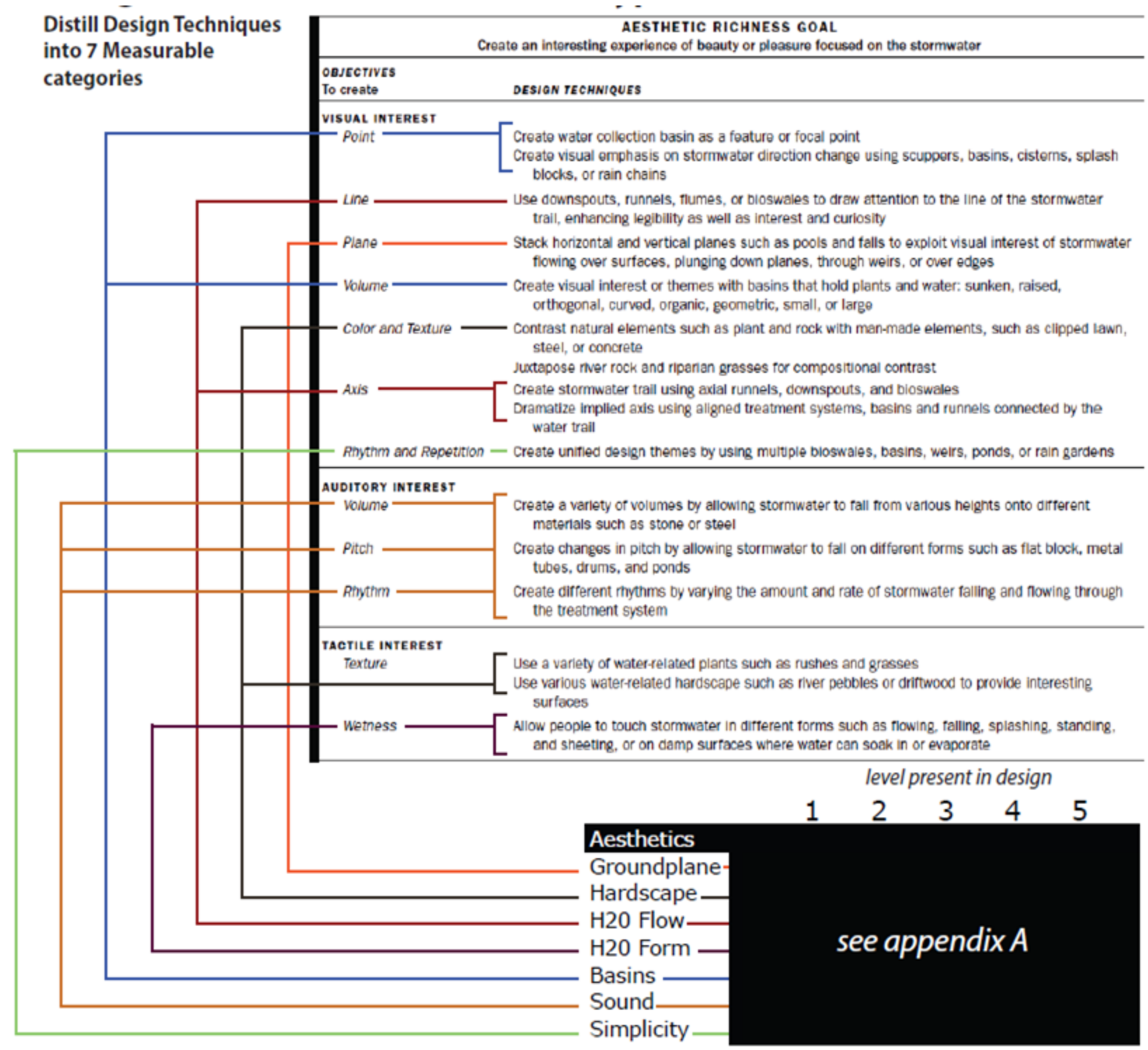
Source: Echols and Pennypacker "From Stormwater Management to Artful Rainwater Design" (2008).

Figure 36. Publicity amenity evaluation rubric founded on design techniques from Echols and Pennypacker (2008)



Source: Echols and Pennypacker "From Stormwater Management to Artful Rainwater Design" (2008).

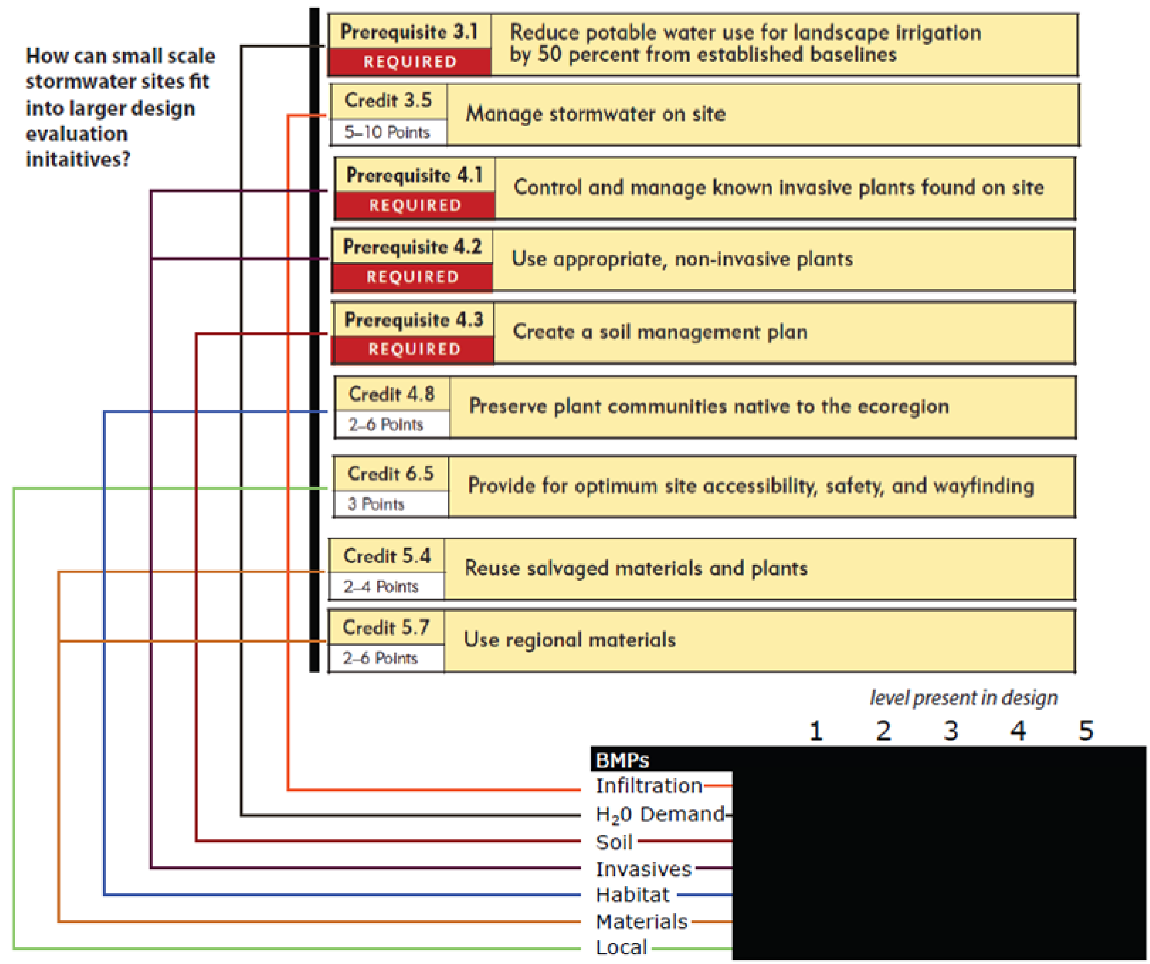
Figure 37. Safety amenity evaluation rubric founded on design techniques from Echols and Pennypacker (2008)



Source: Echols and Pennypacker "From Stormwater Management to Artful Rainwater Design" (2008).

Figure 38. Aesthetics amenity evaluation rubric founded on design techniques from Echols and Pennypacker (2008)

In addition to Echols and Pennypacker's public amenity categories, BMPs were included as an amenity generated through discussions with Jean Marie Hartman. The BMP category is based widespread construction methods including: re-used materials, native plants, xeriscaping and site remediation processes. BMPs address issues of ethics and efficiency in stormwater site construction which were not present in other categories. As increased sustainable methods are used in landscape architecture a new aesthetic surrounding sustainable techniques has been generated and incorporated into parks in Philadelphia. Criteria for the BMP category were derived from the sustainable sites initiative, primarily drawing upon chapters dealing with water, plants and soil and public integration of project (Figure 39). BMPs were successfully measured for each site and added a new layer to the understanding of this study.



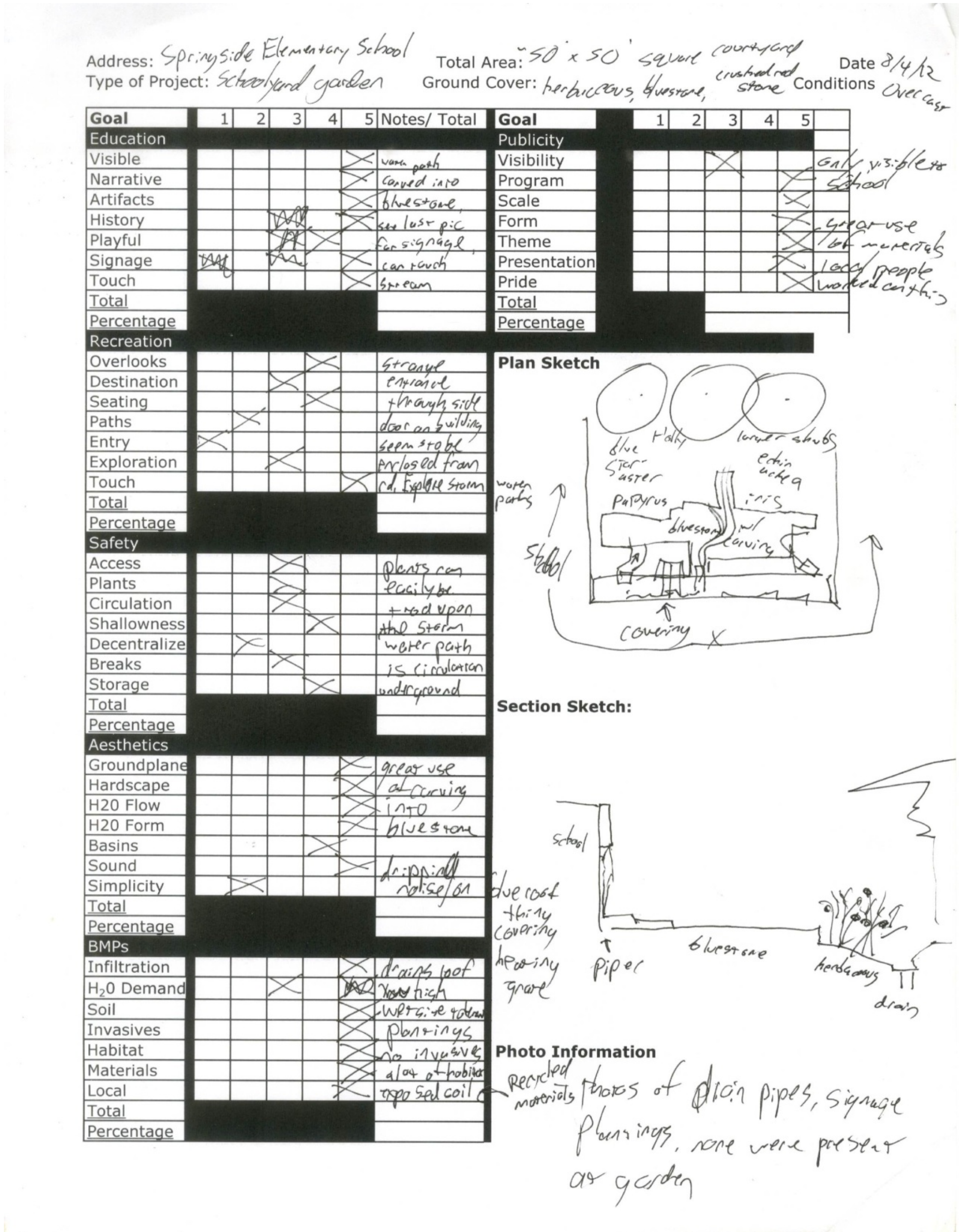
Source: Sustianable Sites Initative Handbook (2009).

Figure 39. BMP amenity evaluation rubric founded on design techniques from Sustainable Sites Initiative (2009)

With data relating to design considerations this study builds an understanding of which design techniques and construction methods most highly contribute to public amenities. It is intended that each site will score highest and lowest relating to a specific amenity. Sites were scored on seven different criteria and allow for a maximum of 35 points and minimum of 7 points to be gained.

Generating Site Scores

Evaluation was done on site over the course of 1 - 2 hours and included the following steps: site walk, observation of water flow and sketching plans / sections. Figure 40 shows an example of a field note log used to prepare sketches, detail information about photographs and record scores associated with design criteria. Date, site conditions, approximate area of site, and ground cover were recorded at each site. Stormwater management criteria were scored from 1 - 5 in the order displayed on the field log sheet, totaling and double checking scores on site. In all cases stormwater management features were incorporated with surrounding public institutions, school, parks or amenities. A general understanding of the layout of each site was derived from exploring surroundings. Walking each site included following designated trails, water trails and exploring obstacles which limit public entry. Photographs were taken of important site design features and individuals interacting with stormwater management systems.



Address: Springside Elementary School Total Area: ~50' x 50' square courtyard Date 8/4/12
Type of Project: Schoolyard garden Ground Cover: herbaceous, bluestone, crushed red stone Conditions Overcast

Goal	1	2	3	4	5	Notes/ Total
Education						
Visible					X	water path
Narrative					X	carved into
Artifacts					X	bluestone,
History			X		X	see last pic
Playful			X	X		for signage,
Signage	X		X			can touch
Touch					X	stream
Total						
Percentage						
Recreation						
Overlooks				X		strange
Destination			X			entrance
Seating				X		through side
Paths		X				door on building
Entry	X					seem stable
Exploration			X			enclosed from
Touch					X	rd, Explore storm
Total						
Percentage						
Safety						
Access			X			plants can
Plants			X			easily be
Circulation			X			tread upon
Shallowness				X		the storm
Decentralize		X				water path
Breaks			X			is circulation
Storage				X		underground
Total						
Percentage						
Aesthetics						
Groundplane					X	great use
Hardscape					X	of carving
H20 Flow					X	into
H20 Form					X	bluestone
Basins				X		
Sound					X	dripping
Simplicity		X				noise/on
Total						
Percentage						
BMPs						
Infiltration					X	drains roof
H_20 Demand			X		X	[illegible] high
Soil					X	wet site tolerant
Invasives					X	plantings
Habitat					X	no invasive
Materials					X	a lot of habitat
Local					X	[illegible] soil
Total						
Percentage						

Goal	1	2	3	4	5	
Publicity						
Visibility			X			only visible to
Program					X	school
Scale					X	
Form					X	great use
Theme					X	of materials
Presentation					X	local people
Pride					X	worked on things
Total						
Percentage						

Plan Sketch

Section Sketch:

Photo Information

Recycled materials photos of drain pipes, signage plantings, none were present at garden

Figure 40. Example of evaluation rubric used to generate amenity score at Springside School

Categorization of Sites according to Score, Representation and Correlation

In order for sites to fit into larger classification schemes projects are given a ranking based on expression of public amenity. The thirty five point scoring system was broken down into 4 equal intervals to gauge if public amenity is: present (28 - 35 points), strongly implied (21 - 27 points), latent (14 - 20 points) or not present (7 - 13 points). Breaking sites down into four distinct groups allows for certain sites to be grouped based on public amenity, and shows which site designs apply to multiple public amenities. Representation of site scores before ranking, was done with bar charts, showing highest lowest and middle ranging scores. Correlations between public amenities were used to show degree of overlap between data at neighborhood, site and design scale measurements.

Chapter 3 – Results

Data for twenty stormwater management projects is reviewed within this section according to strategies defined in Chapter 2. The methodology outlines three scales of data collection including: Neighborhood Scale, Site Scale and Design Scale. The large amount of data considered within this study creates the need to present pre-categorized figures in this section.

Neighborhood Scale Results

Neighborhoods scale (1/2 mile radius around stormwater management site) data collection, evaluation and categorization is conducted based upon the methods and inquiries outlined in Chapters 1 and 2, it includes: population, institutional land use acreage, park / open space land use acreage, residential land use acreage. Sites are grouped based on shared neighborhood characteristics.

Population Categorization

Total population within a half mile radius (1.57 square miles) of all twenty stormwater management sites is presented in Figure 41. Population levels reveal the level and type of site use by the surrounding community. This section will compare population levels across all sites. (Figure 41). The population level is the highest at the Penn Alexander School. This is due to the proximity to the University of Pennsylvania and Drexel Campuses, each with high-density student housing. It is unclear whether the students at each campus view this space as a public stormwater amenity; instead it is much more likely that a local professor, whose children may attend Penn Alexander School, will use its permeable playgrounds, infiltration fields and community garden areas. Similar to Penn Alexander School, there are over 2000 residents who live within a half mile of Saylor Grove Stormwater Wetland. Although this area has one of the highest population densities, it's residential and park / open space land use distinctions are roughly equal. Such conditions began with Ebenezer Howard's Garden-City Movement and evolved through multiple permutations such as Frank Lloyd Wright's Broadacre City. Saylor Grove Stormwater Wetland acts as a gateway to the larger Fairmount Parks System. Wises Mill Stormwater Wetland, 47th and Grays Ferry, Traffic Triangle and the Kroc Center all have surrounding population counts of less than 750. Each of these sites is outside of a neighborhood context, and does not directly enlist users for management. Average population across all sites was 1187 people, and most closely fits with Mill Creek Farm, Springside School and Vacant Lot Sites. Average population count sites were all within a neighborhood context, but not a dense urban context. Overall population difference across all sites was 1803, indicating a broad range of site contexts.

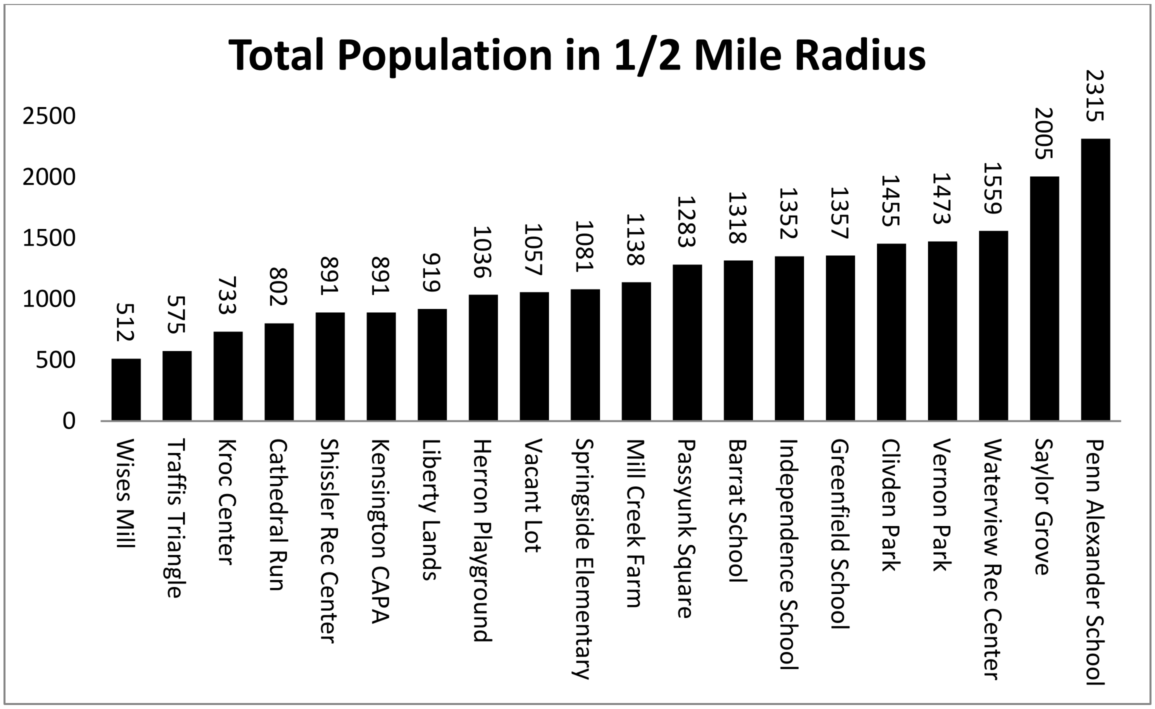


Figure 41. Total population within ½ mile radius of stormwater management site

Institutional Land Use Categorization

Figures 42, 43 and 44 categorize sites by surrounding institutional land use. As seen in figure 42 the stormwater management project at Springside School is located within 60.5 acres of surrounding institution. Springside School stormwater management BMP, hosts a relatively small amount of runoff, and does more to reflect the values of the local institutions surrounding the site. Greenfield School is located on a smaller institutional site, with 16 acres of institution within a half mile. However, Greenfield school manages more stormwater and has a larger planting area than Springside School. The low amount of institutional land use at Greenfield School reflects a highly efficient and diverse group of associated surrounding institutions. Sites located on institutional land use include schools and recreation centers.

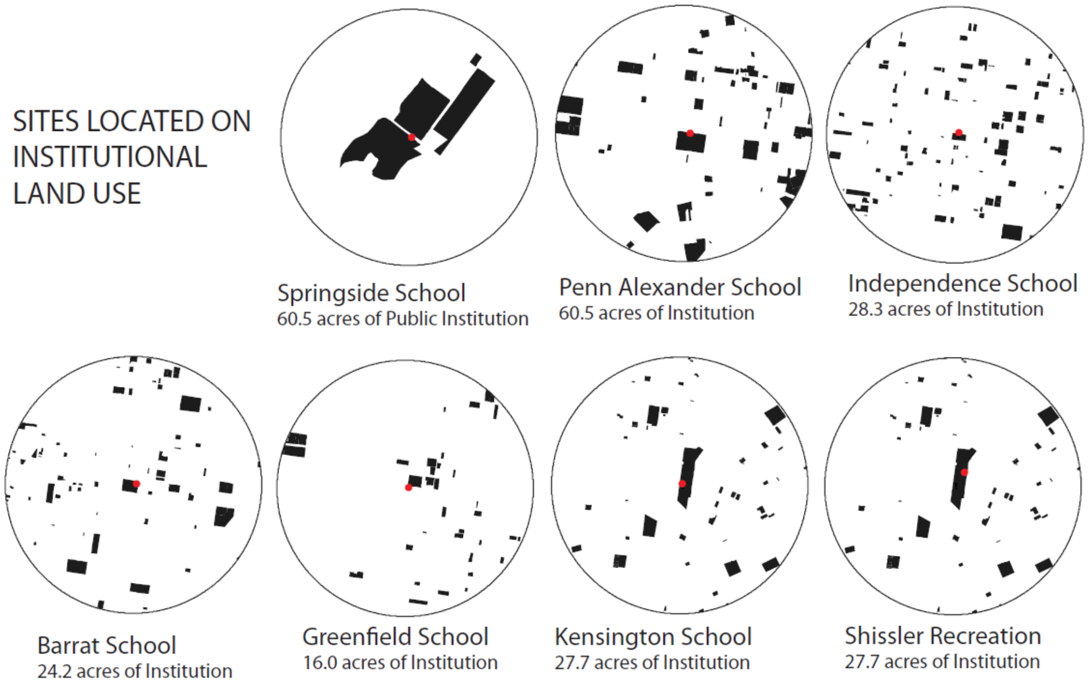


Figure 42. Stormwater Management Sites Located on Institutional Land Use

Figure 43 shows sites surrounded by large localized institutions. These larger areas include hospitals, open spaces, or other public service institutions which take up a large portion of the surrounding land use. Most notably Wises Mill stormwater wetland hosts a nearby medical complex and the Vacant Lots are bordered by multiple public administration buildings. It is unclear whether these institutions take part in the maintenance of the sites, or conduct visits / tours of stormwater management features. The Kroc Center is somewhat removed from surrounding institutions, and is located over a half mile north of Wissahickon Charter School (a stormwater management project not reviewed within this study). The stormwater management features at the Kroc Center are fully enclosed within a commercial property and it is unclear whether partnerships exist for other institutions to tour and manage the stormwater BMPs.

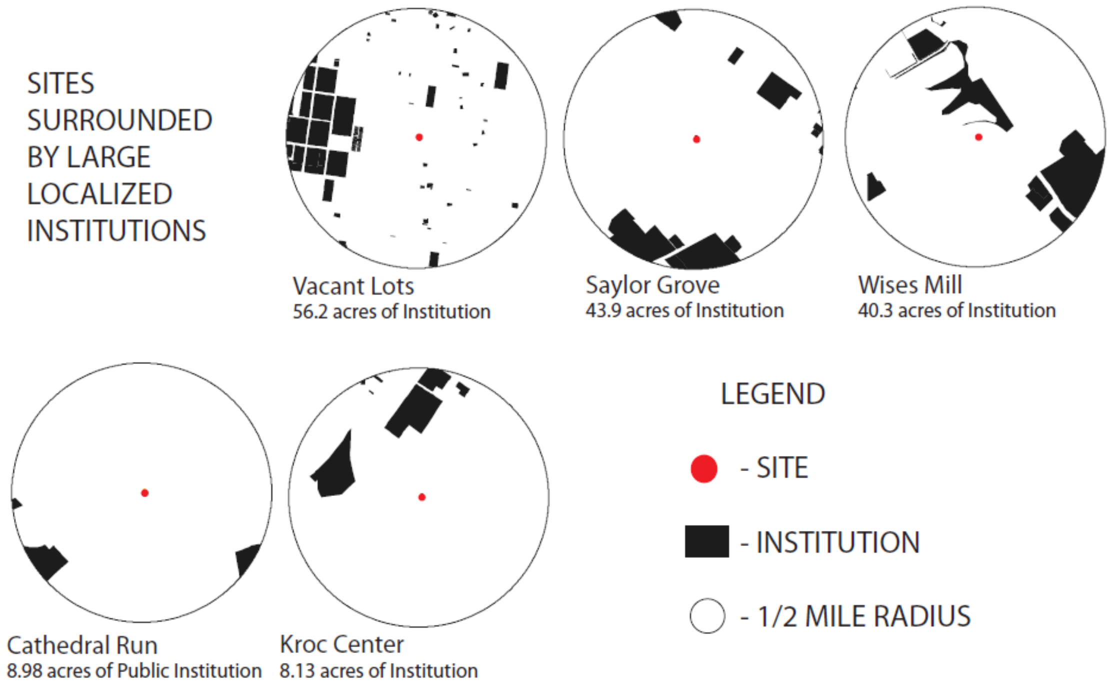


Figure 43. Stormwater Management sites surrounded by large localized institutions

Figure 44 shows a diffuse arrangement of surrounding institutions. Sites including Liberty Lands, Herron Park and Clivden Park have a low amount of surrounding institutional land use whereas, Vernon Park, Waterview Recreation and Mill Creek Farm have a more dense concentration of public institutions within a half mile. Areas around Mill Creek Farm and Passyunk Square are closest to the median of all sites.

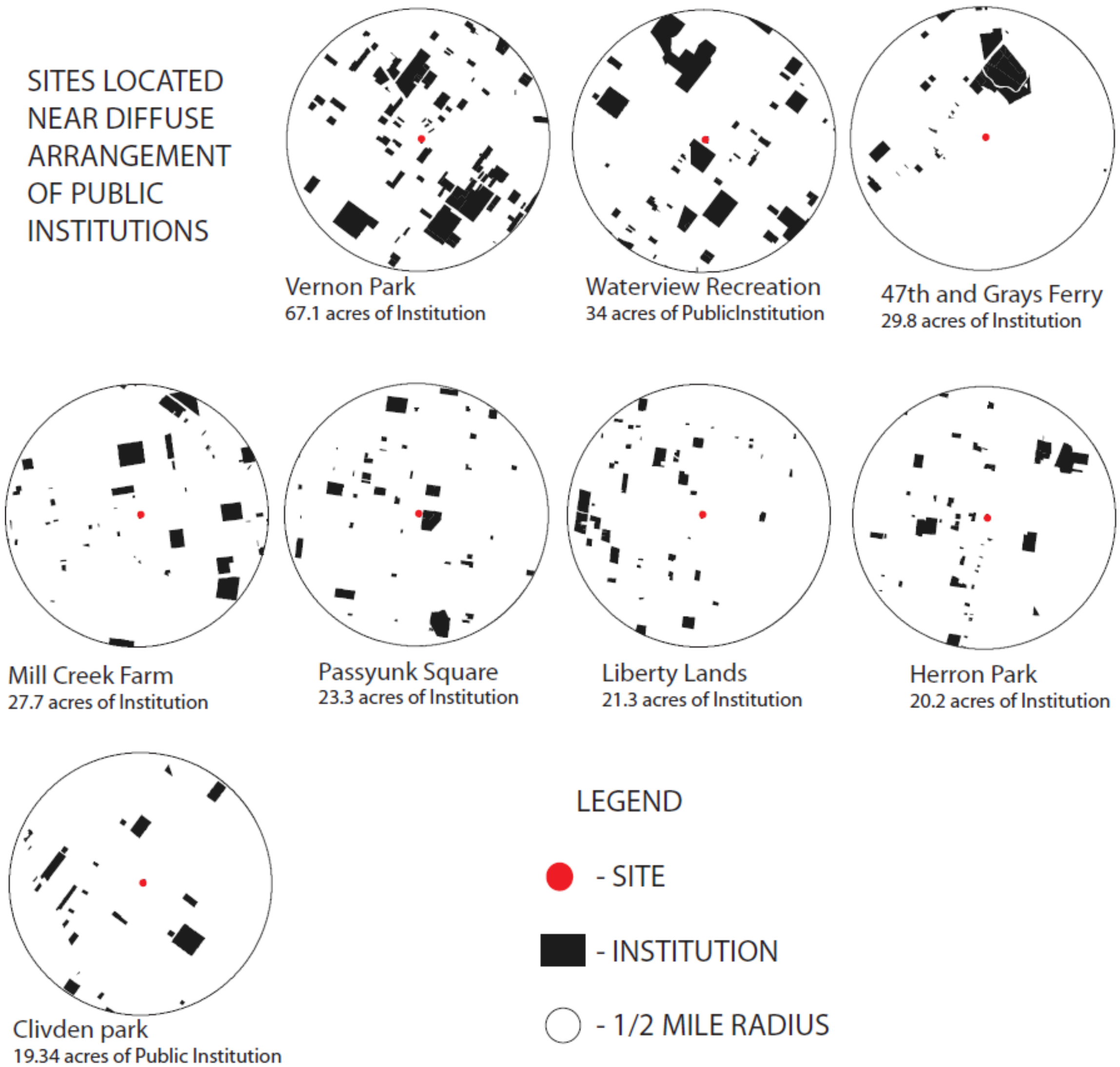


Figure 44. Stormwater manaement sites near diffuse arrangement of public institutions

Park / Open Space Land Use Categorization

Figure 45 depicts sites which are gateways to parks or larger open space areas. Cathedral Run, Wises Mill and Saylor Grove are stormwater management wetlands which function as trailheads to the Fairmount Parks System. The stormwater management BMPs at Clivden Park Vernon Park and Liberty Lands Park function on a much smaller scale and create entryways to confined park areas. These open spaces are an asset to their surrounding communities, and stormwater management projects denote a sense of arrival at each site.

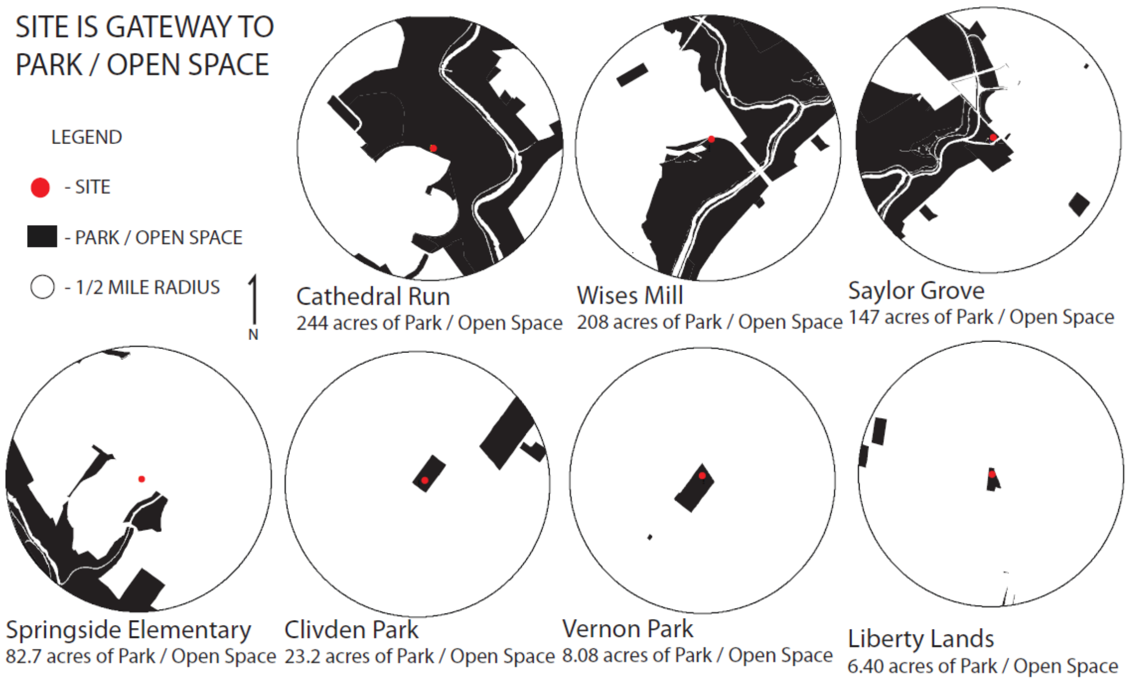


Figure 45. Stormwater sites which funciton as gateways to larger parkk / open space areas

Figure 46 shows thirteen stormwater management sites which are isolated from surrounding park/ open space land uses. All sites function as important islands of green space within a dense matrix of urban development, especially at Barrat School, Independence School, Penn Alexander School and Waterview Recreation Center. These neighborhoods are primarily impervious, and it is unclear whether local residents identify parks within their neighborhood. Vacant Lot Stormwater Management Sites could be considered as part of a larger open space / park network, but the nature of zoning regulations within these areas has not officially classified such sites as park / open space. Through site visits it was clear that through cleaning and greening vacant lots, park / open space is defined and utilized for the surrounding community. However, development prices prevent the official protection and delineation of these areas as open space / park land use.

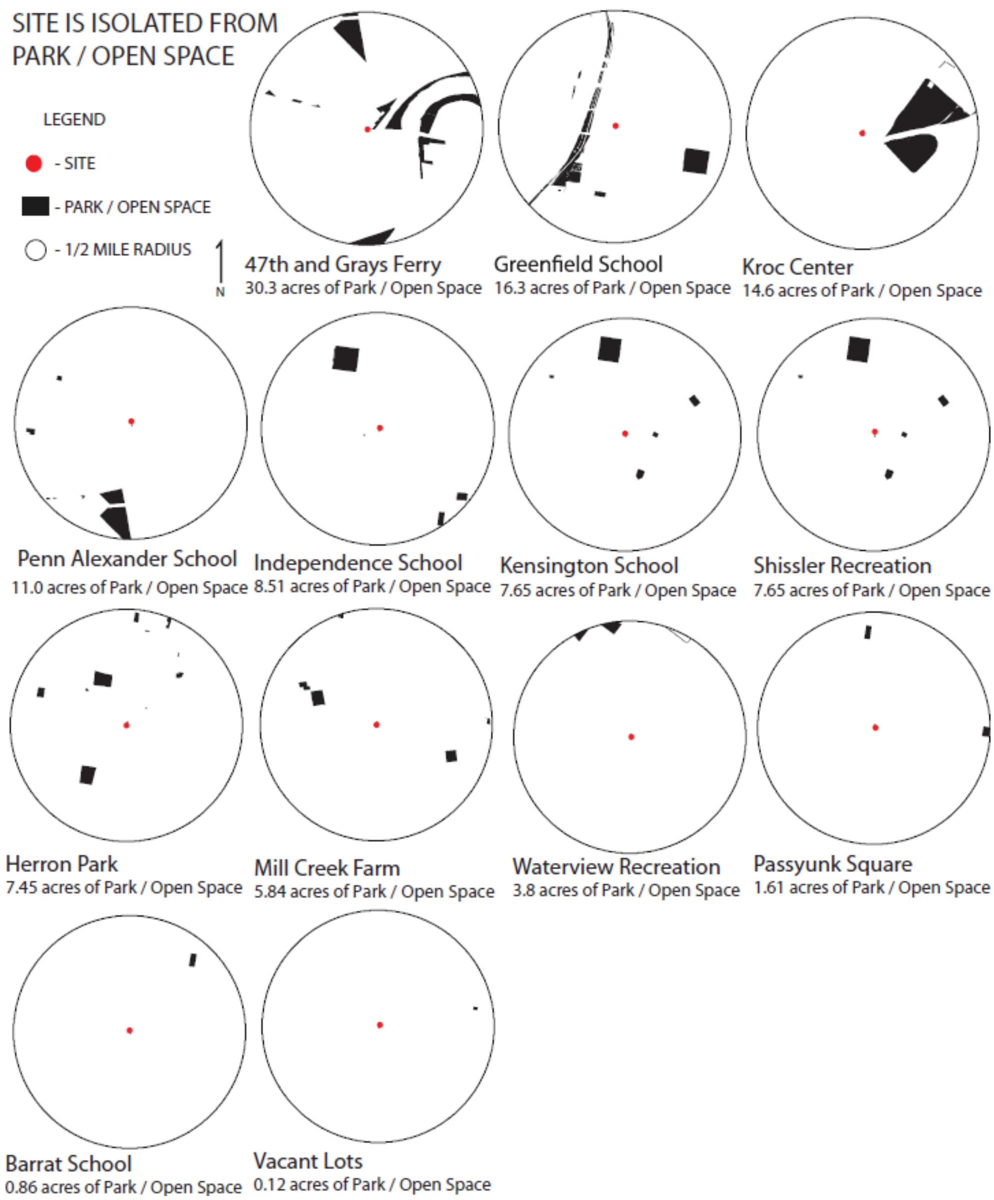


Figure 46. Stormwater management sites which are isolated form existing park / open space

Residential Land Use Categorization

Figures 47, 48 and 49 group sites by surrounding residential land use within urban, neighborhood and outside developed areas. Sites associated with high population counts such as Penn Alexander School and Waterview Recreation Center are located within a dense urban context, hosting over 200 acres of residential land use within a half mile. Stormwater sites within an urban context are inherently smaller in size, an exclude large flow rates associated with stormwater wetlands. Seven sites fall within a neighborhood context, and host an average of 134 acres of surrounding neighborhood land use. Cluster arrangement of houses within neighborhood context is evident, infrastructure and transportation corridors divide areas along several axes. Figure X displays six sites outside of residential context, each site is surrounded by parkland, institutional or other land use categories. Kroc Center, 47th and Grays Ferry Traffic Triangle and Wises Mill Park have the lowest surrounding residential use of sites outside of residential context, users will primarily access these sites via automobile, as opposed to sites which are integrated into the surrounding neighborhood that residents may pass by on the daily commute or take their dogs to.

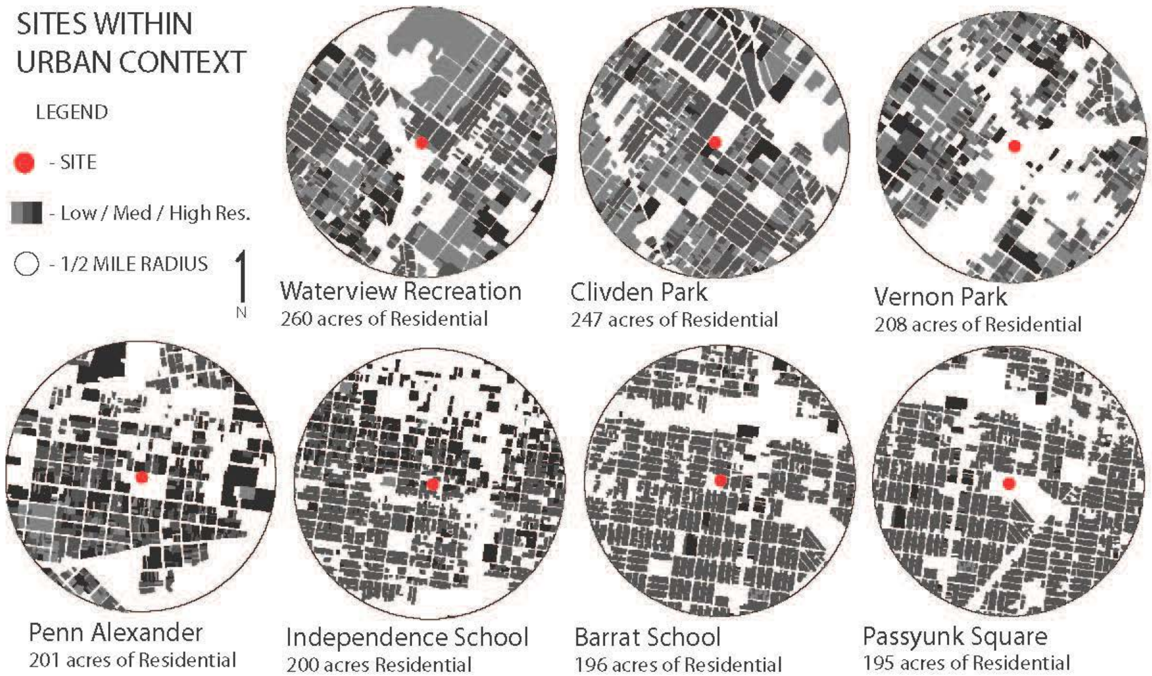


Figure 47. Stormwater sites with high residential land use fall within urban context.\

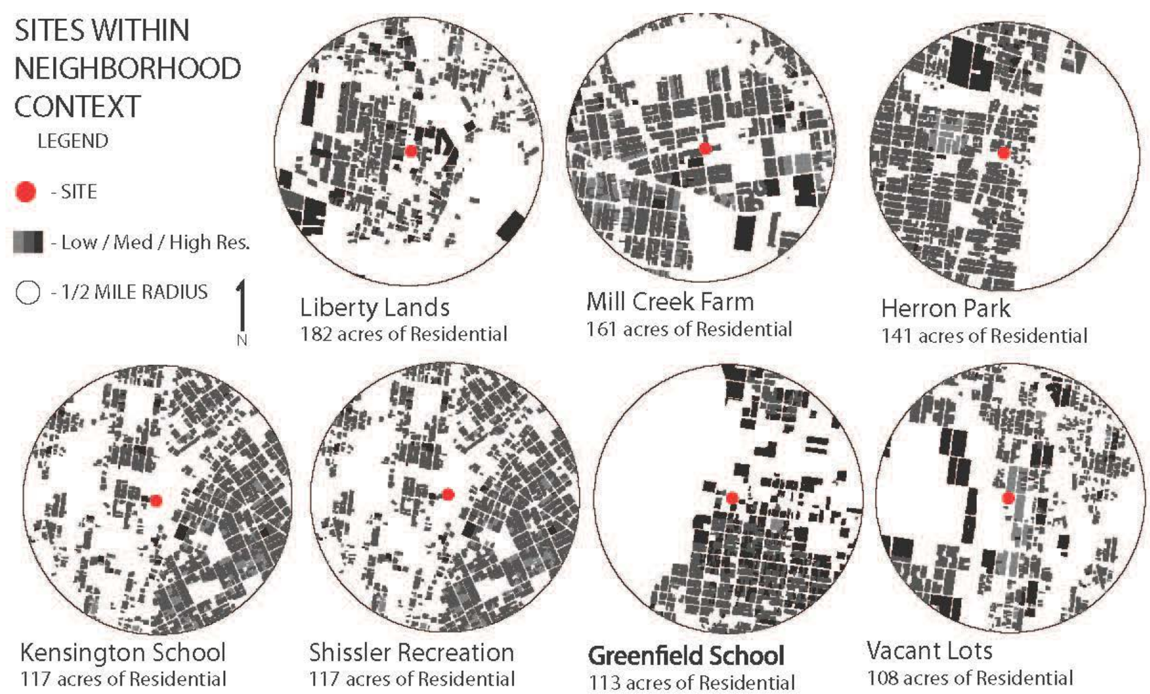


Figure 48. Stormwater sites with average surrounding residential land use fall within neighborhood context

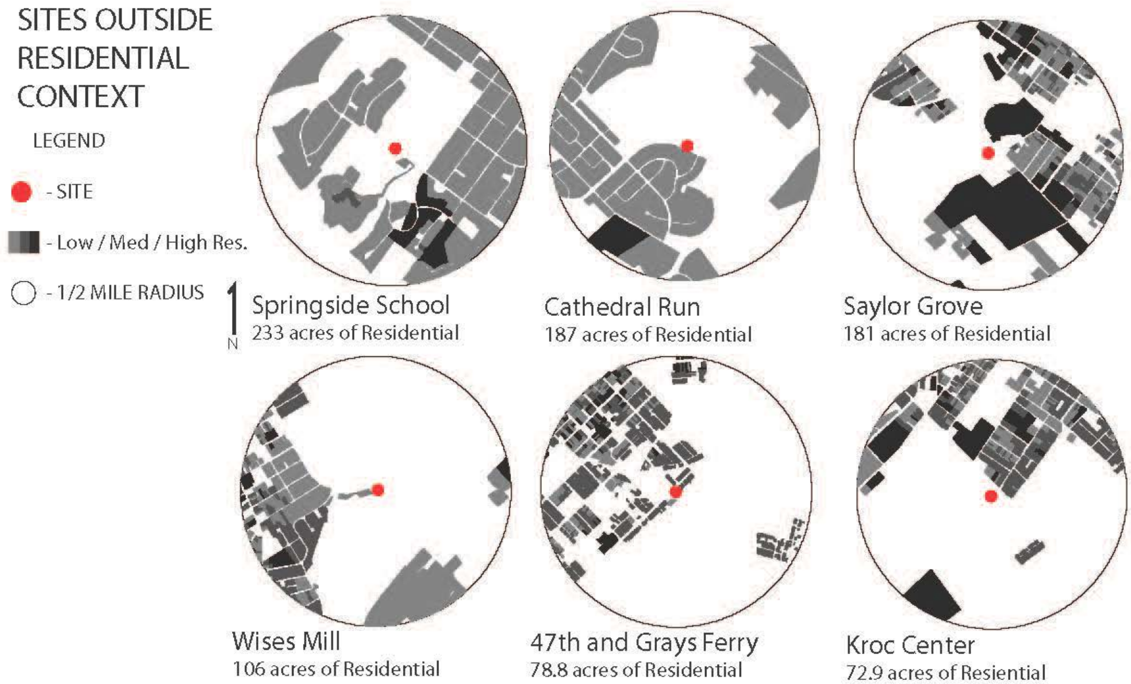


Figure 49. Stormwater sites with low surrounding residential land use fall outside of residential context

Site Scale Results

Site scale data collection, evaluation and categorization covers diversity of public involvement, primary / secondary stormwater management BMP, construction cost per square foot, size, combined sewer area relationship, greened acres, ratio of size of system to total area contributing runoff, and site circulation patterns.

Diversity of Public Involvement

Figure 50 depicts stormwater management sites with a high diversity of public involvement. Vernon Park, Saylor Grove, Shissler Recreation, Kensington School, Liberty Lands, Greenfield School and Columbus Square all have a local volunteer group that works to maintain the stormwater management site. Fundraising for these sites was conducted by multiple public agencies and accomplished through a variety of grants including the growing greener grant at greenfield school and the Philadelphia urban renewal project at Liberty Lands. All sites have a high level of PWD involvement, but also collaborated with multiple public organizations. Vernon Park Stormwater Site is a prime example of multiple public agencies which have joined together in order to implement the onsite rain garden, install flow channels through the existing pavement, and disconnect the downspouts from the adjacent park center. A full list of the organizations that contributed to Vernon Park can be found on the Tacony-Tookany Frankford Watershed Partnership website which also hosts videos and other media displaying the community interaction with the park and stormwater management system.

	Vernon Park	Saylor Grove	Shissler Recreation	Kensington School	Liberty Lands	Greenfield School	Columbus Square
Volunteer	✓	✓	✓	✓	✓	✓	✓
Fundraising	TTF LOVE	PADEP PWD	PWD	PWD	PWD PURP	PADEP GROW	PWD
PWD Involvement	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
Partners	MANY	PADEP FPC CIP	19125 MURAL PARKS	19125 KCDC PARKS	PHS NLNA PADEP	HSA GREEN	PSCA PHS PCPO

Figure 50. Stormwater Management Sites which host a high diversity of public involvement

Figures 51 and 52 show medium and low diversity of public involvement at stormwater management sites. Springside School, Clivden Park, Barrat School and Mill

Creek Farm host volunteers, but are limited in the scope of fundraising, contributing to a medium diversity of public involvement score. Similarly, Wises Mill, Independence School, Penn Alexander School and 47th and Grays Ferry Traffic Triangle have a high level of partnering institutions, but lack volunteers and have a singular source of fundraising. Lastly, Stormwater sites with a low diversity of public involvement are primarily driven by PWD or private organizations (Kroc Center). Cathedral Run, Waterview Recreation Center, Vacant Lots and Herron Playground consult with only one other organization other than PWD.

	Springside School	Clivden Park	Wises Mill	Independence School	Barrat School	Mill Creek Farm	Penn Alexander School	Traffic Triagnle
Volunteer	✓	✓			✓	✓		
Fundraising	SWP	BANK	FPC	PWD	PWD	PWD	GROW	PADEP
PWD Involvement	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
Partners	RECY LEVY PHS	PWD PHS FCP	WISSA FPC PWD	GREEN INDEP PWD	PWD BARRAT	PWD	UPENN PADEP HSA	PHS CITY PADEP

Figure 51. Stormwater sites with a medium level of diversity of public involvement

	Cathedral Run	Waterview Center	Kroc Center	Vacant Lots	Herron Playground
Volunteer					
Fundraising	CITY	PWD	KROC	PWD	PWD
PWD Involvement	HIGH	HIGH	LOW	MED	HIGH
Partners	FPC PWD	PWD PHS PARKS	SALV ARMY	PWD PHS	PWD PCPD

Figure 52. Stormwater sites with a low level of diversity of public involvement

Primary and Secondary Structural Stormwater Management BMPs

Figure 53 shows primary and secondary structural BMPs found at all twenty stormwater management sites. Since few green streets were evaluated in this study, stormwater planters and bump outs were not common on sites. Stormwater wetlands including Cathedral Run, Wises Mill and Saylor Grove all incorporated vegetated swales as part of site design. Rain gardens were among the most widely implemented structural BMPs at stormwater sites, followed by porous paving, vegetated swales, and infiltration / storage trenches. Tree trenches and cisterns were implemented at two sites. Independence School hosts a secondary stormwater management feature which slows down runoff in the form of a small concrete runnel, which displays water flow before moving into the porous paving/ infiltration and storage trench areas.

	CATHEDRAL RUN	SPRINSIDE SCHOOL	CLIVDEN PARK	WATERVIEW REC	VERNON PARK	SAYLOR GROVE	WISES MILL	KROC CENTER	VACANT LOT	SHISSLER REC	KENSINGTON SCHOOL	LIBERTY LANDS	GREENFIELD SCHOOL	INDEPENDENCE SCHOOL	BARRAT SCHOOL	COLUMBUS SQUARE	HERRON PLAYGROUND	MILL CREEK F ARM	PENN ALEX SCHOOL	TRAFFIC TRIANGLE
Tree Trench				2′					2′											
Stormwater Planter																1′				
Stormwater Bumpout																				
Rain Garden		1′	1′		1′			1′				2′	2′		1′					
Infiltration/ Storage Trench									1′	1′	1′						2′			1′
Porous Paving				1′						2′			1′	1′		2′	1′		1′	
Vegetated Swales	2′		2′			2′	2′											1′	2′	
Stormwater Wetland	1′					1′	1′													
Disconnected Downspout		2′			2′															
Cistern								2′				1′								
Other														2′						

Figure 53. Primary and Secondary Structural Stormwater Management BMPs at each site

Cost Per Square Foot Evaluation and Categorization

Cost per square foot was calculated for twelve out of twenty stormwater management sites (Figure 54). Stormwater sites with construction costs over $10 per square foot are displayed in Figure 55 with a photo and relative cost per square foot. Herron Playground was one of the most expensive stormwater management sites, hosting multiple vegetative swales, a permeable basketball court and permeable playgrounds. The total cost of construction and design was over $1 million as the site incorporates the latest in motion sensing and touch activated playground / sprayground equipment. Stormwater sites which host construction costs less than $5 per square foot are depicted in figure 56. Vacant Lots were not depicted within this figure, but have the lowest stormwater management construction cost, at $1.70 per square foot. These sites use a simple clean and green approach to make the space usable and are considerably less than construction costs of sites with structural stormwater BMPs such as rain gardens, stormwater wetlands, infiltration trenches and cisterns. Overall, size of the site played a large role in determining construction costs per square foot. Larger sites such as Wises Mill and Saylor Grove which have total construction costs of $750,000 and $300,000, are some of the most efficient structural BMPs.

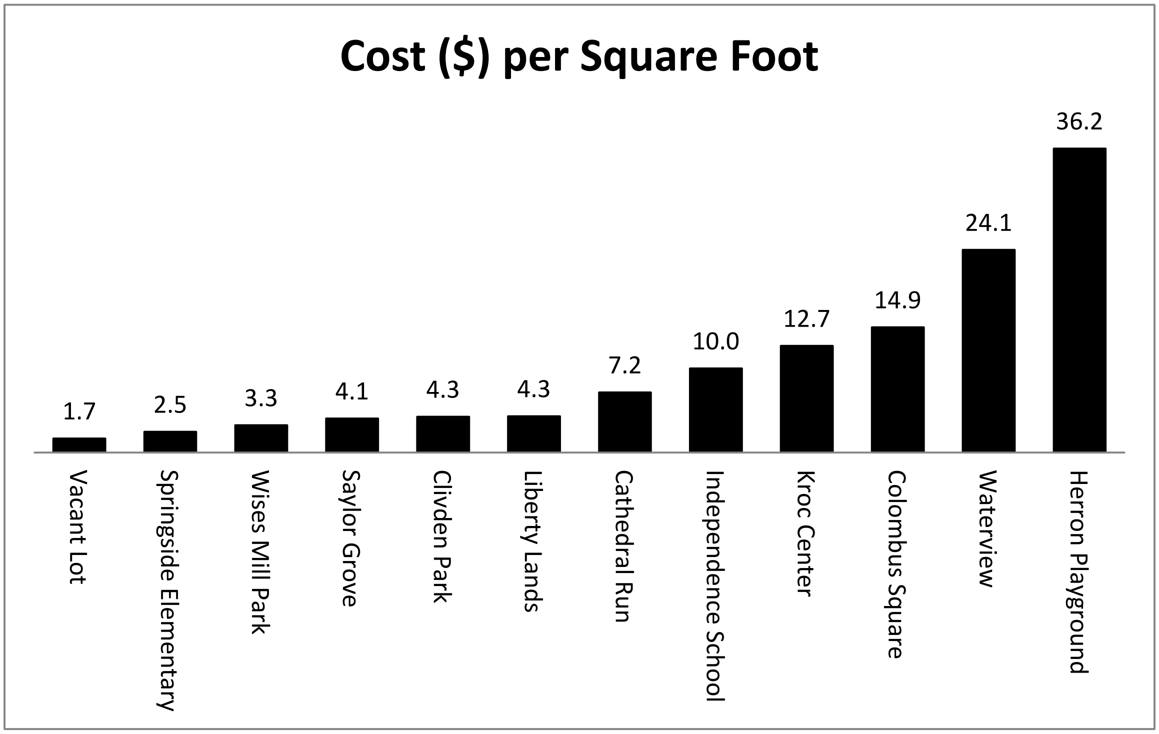


Figure 54. Cost in dollars per square foot at twelve stormwater management sites

Figure 55. Stormwater management sites with construction costs greater than $10 per square foot

Springside Elementary	Wises Mill Park	Saylor Grove	Clivden Park	Liberty Lands
$2.50 / sq. ft.	$3.30 / sq. ft.	$4.10 / sq. ft.	$4.30 / sq. ft.	$4.30 / sq. ft

Figure 56. Stormwater management sites with construction costs less than $5 per square foot

Stormwater Management Site Combined Sewer Area, Greened Acres, Ratio of Contributing (Drained) Area to System Size

Figure 57 shows stormwater management sites in relationship to combined sewer area. Cathedral Run, Springside School, Wises Mill, Saylor Grove and Kroc Center stormwater sites fall outside of the combined sewer area. The calculations of Greened acres for these sites will not contribute to benchmarks set forth by the Green City, Clean Waters and the CSO Long Term Control Plan.

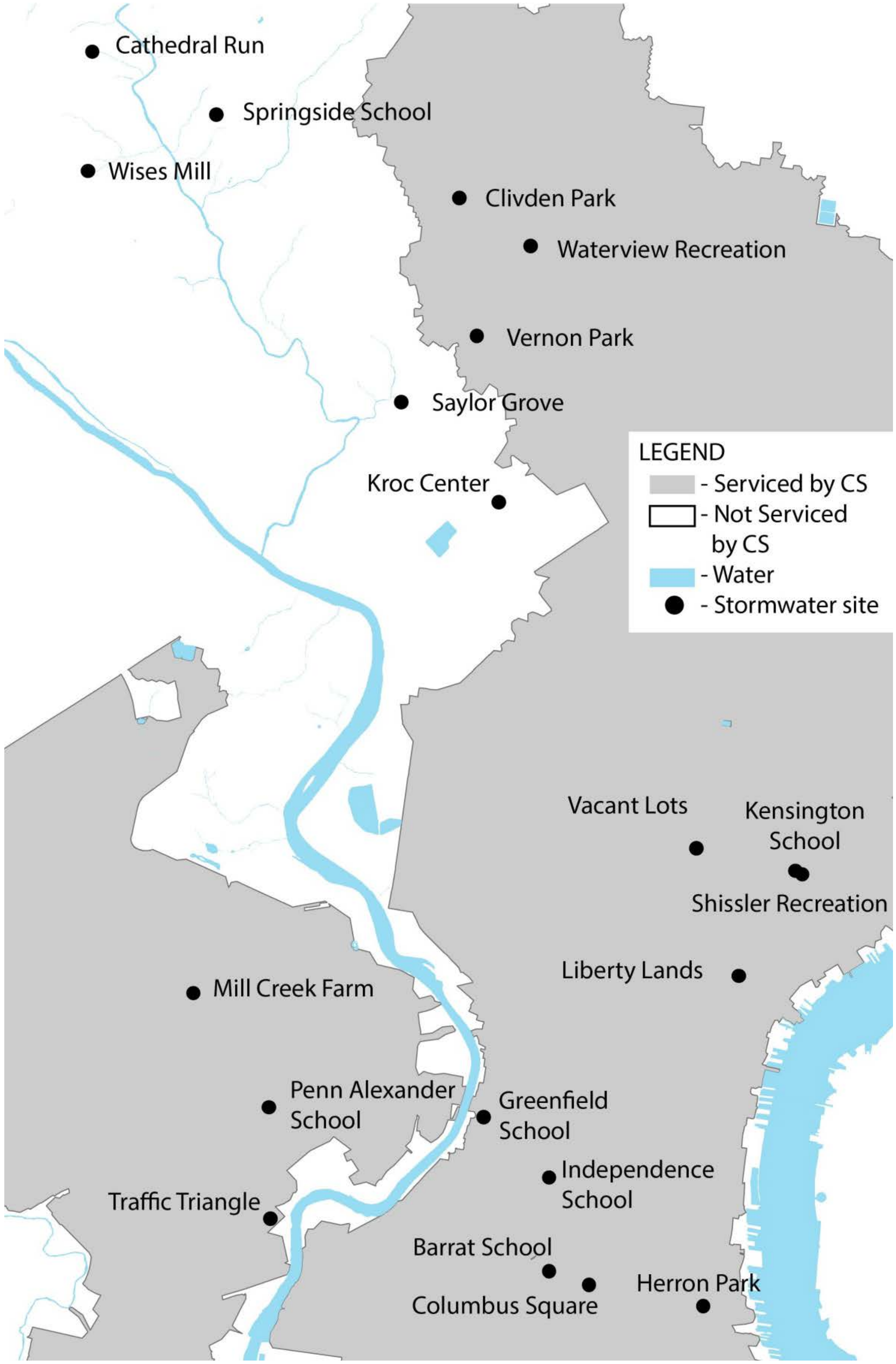


Figure 57. Combined sewer service area in relationship to stormwater management sites.

Mapping data obtained through PWD and Pennsylvania Spatial Data Access (PASDA).

Contributing area for Cathedral Run, Saylor Grove and Wises Mill was collected from data made available on the Temple-Villanova Sustainable Stormwater Initiative Website. Figures 58 - 60 show groupings of sites with high, medium and low ratios of contributing area to site size. All images are at a scale of 1” is 450’. In Figure 58 it is evident that the three constructed stormwater wetland sites have the highest ratio, responsible for water being present at all three sites. On the other hand, Liberty Lands has a Ratio of 17.67 but relatively little water is present on site due to a large cistern which captures stormwater beneath the surface. Vernon Park and Columbus Square employ infiltration trenches, stormwater planters and rain gardens to capture stormwater from a relatively large area within a condensed system. Figure 59 shows stormwater sites which have contributing area to system size ratios closest to average of 5.87 (average calculated excluding very large ratios found in stormwater wetlands). Clivden Park, 47th and Grays Ferry Traffic Triangle and Shissler Recreation all contain infiltration trenches or large basins to hold runoff. Whereas Penn Alexander School and Waterview Recreation Center use permeable paving systems, due to smaller ratios of contributing area to system size. Lastly, Figure 60 shows Stormwater Management Sites which concentrate flows from comparatively small areas into large stormwater management systems, these sites have ratios of contributing area to system size of less than three. Herron Playground and Greenfield School permeable paving systems cover a large area and manage stormwater which lands on or runoff onto these surfaces. However, permeable paving systems take up more surface area than infiltration trenches, cisterns or other structural BMPs which concentrate stormwater flow. In comparing construction cost to ratio of stormwater system it is interesting to note that higher cost systems such as Kroc Center (Ratio of 3.84) and Herron Playground seem to manage comparatively less stormwater.

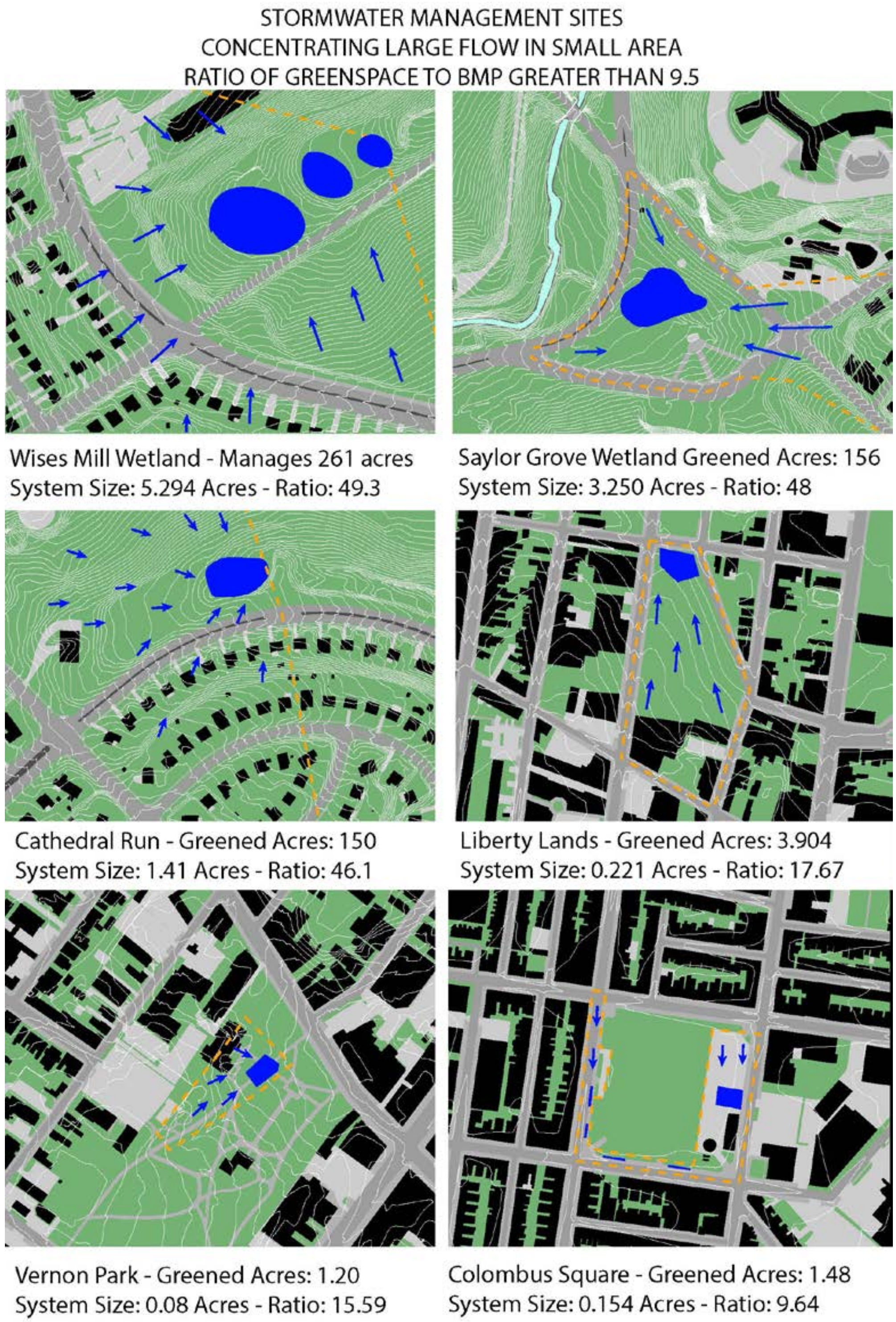


Figure 58. Sotrmwater management sites with high ratio of drained area to system size

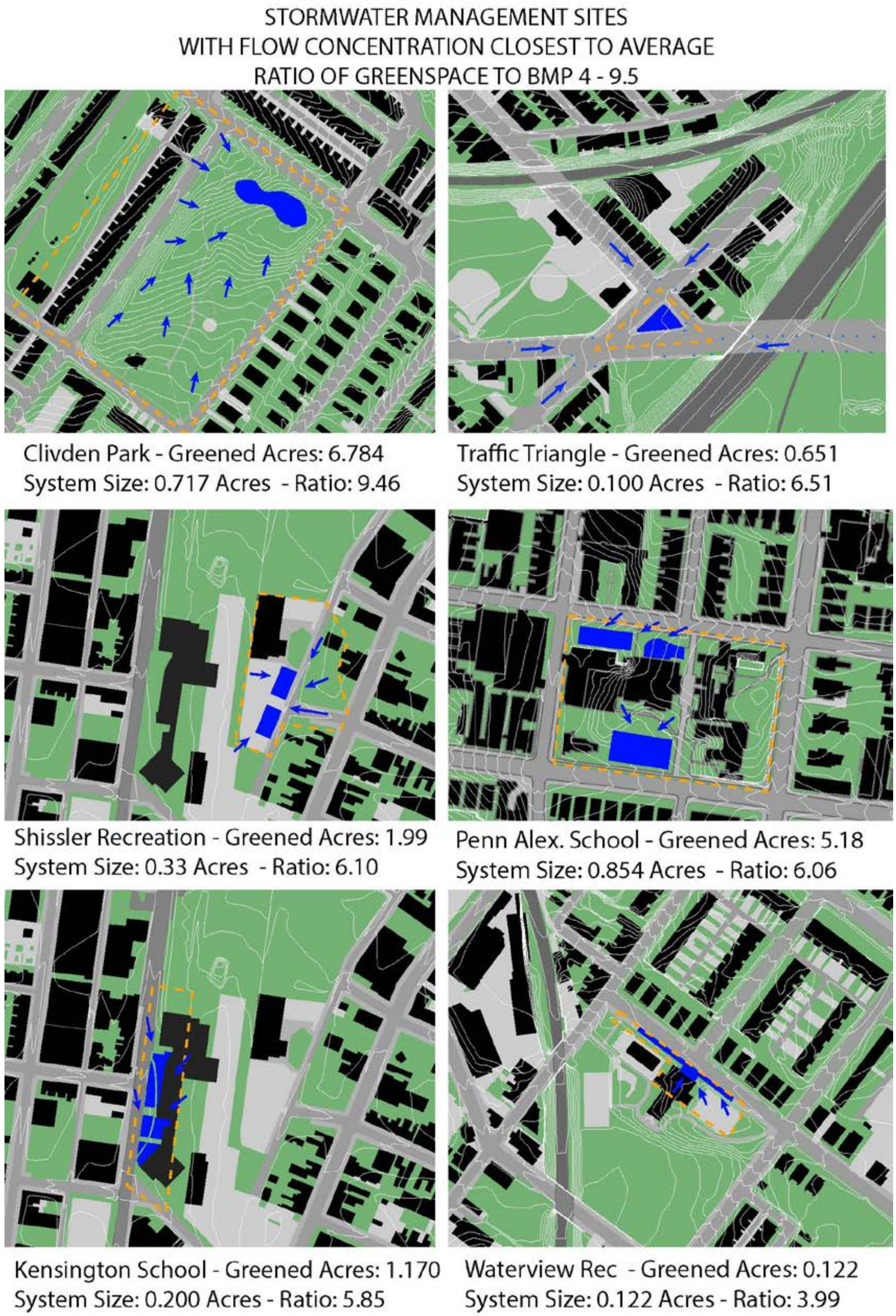


Figure 59. Stormwater sites with average ratio of drained area to system size

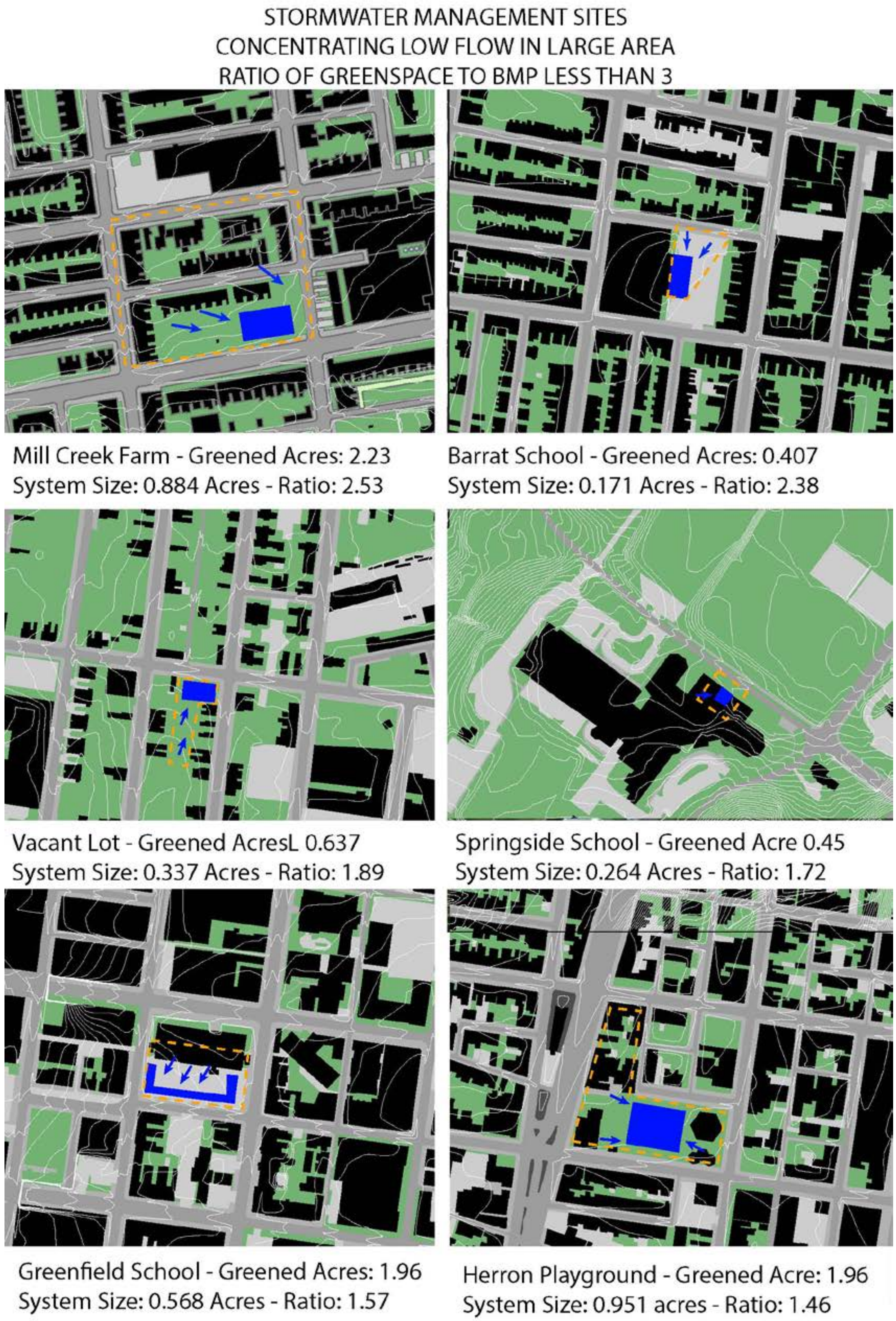


Figure 60. Stormwater management sites with low ratio of drained area to system size

Circulation Categorization

In moving towards design scale analysis, the last site scale parameter this section will discuss is pedestrian circulation onsite. Figures 61 and 62 show four categories of site circulation including Destination, Gateway, Enclosed and Circular / Looping. Stormwater Sites which are destinations exist within a larger context or are associated with another amenity. For example Waterview Recreation Center's Sprayground or Vernon Park's Visitor Center are community destinations attached to stormwater management systems. Vacant Lots and Urban Farms are also thought of as community destination areas with associated stormwater management features. Stormwater sites that act as gateways to parks or recreation centers are evident at multiple sites. This definition of gateway category differs than neighborhood gateways seen in GIS Scale analysis. Here, stormwater sites are gateways to buildings, parks, baseball fields or neighborhoods (Kensington School and Shissler Recreation, Clivden Park, Columbus Square and Retrofitted Traffic Triangle respectively). Figure 61 shows stormwater management sites with enclosed circulation patterns. At Greenfield School, Independence School and Herron Playground the user enters past an infiltration trench / rain garden to move around the inside of the stormwater site. At Springside Elementary it is not clear whether users are meant to enter the site from the roadway, the stormwater management feature is primarily accessed from the building. Stormwater management sites with looping circulation patterns can be found at Barrat School, Kroc Center and the Three Stormwater Wetlands. At the Kroc center users pass through a series of seven rain gardens as they make their way around the property. Stormwater Wetlands accomplish looping circulation through a different site layout, the main stormwater feature exists at the center of the site, with trails ordering the edges.

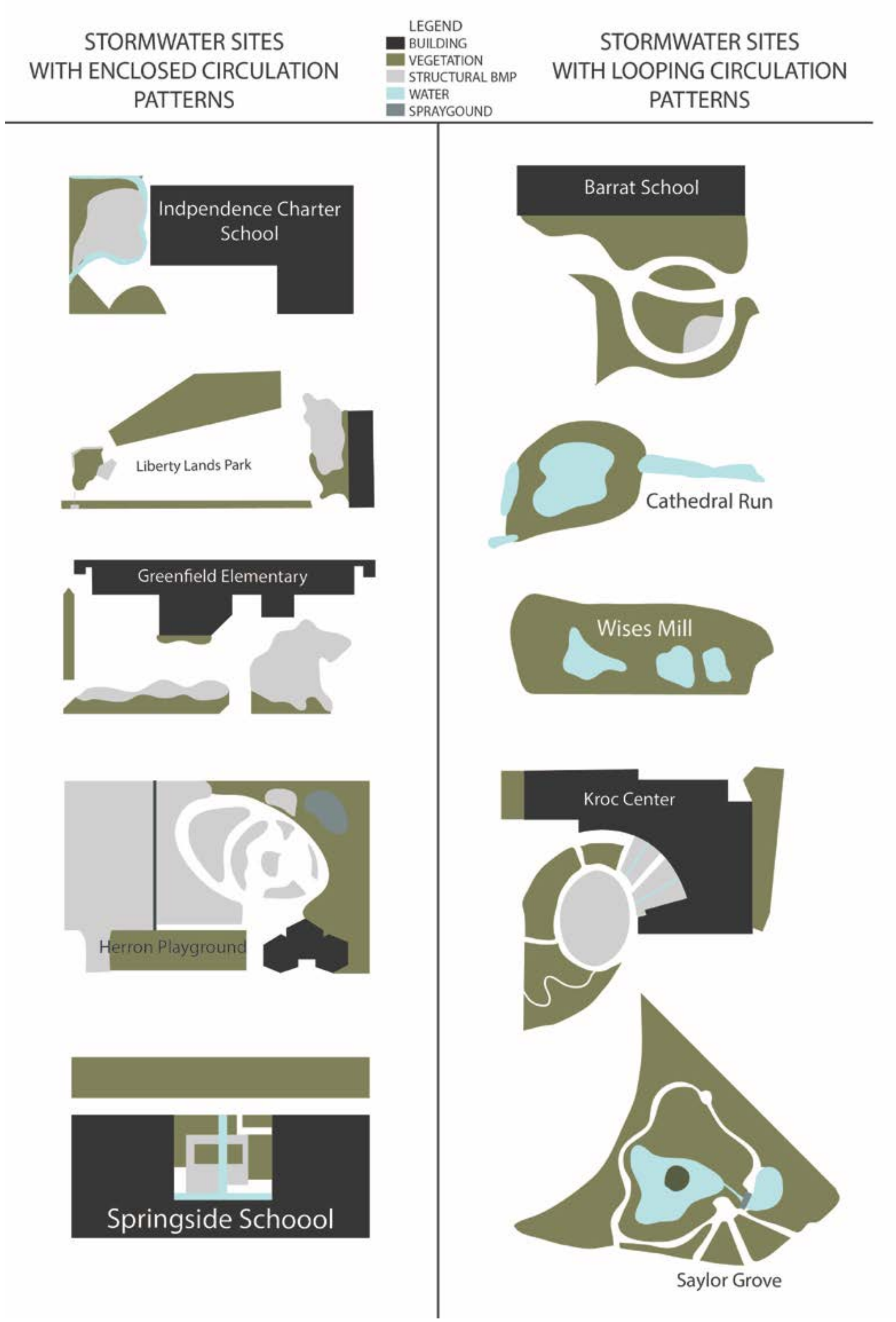


Figure 61. Stormwater management sites with enclosed and looping circulation patterns

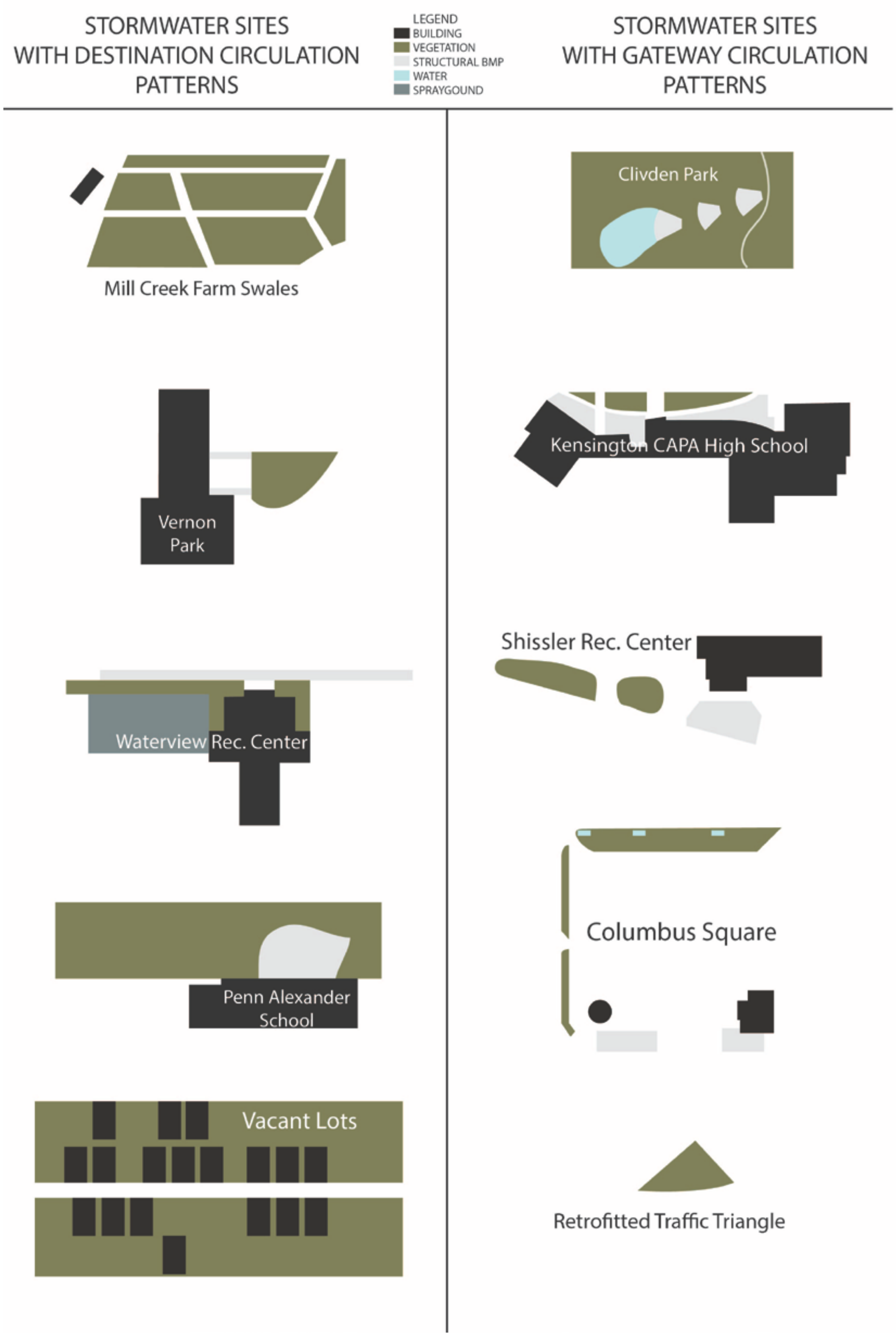


Figure 62. Stormwater management sites with destination and gateway circulation patterns

Design Scale Results

Design scale results were compiled for all twenty stormwater management sites and evaluated stormwater management systems according to: sustainable SITES initiative chapter 3.7 (public amenity of stormwater system), five public amenity categories outlined by Echols and Pennypacker including additional BMP category (education, recreation, aesthetics, safety, publicity), and visual assessment categories outlined by Kaplan and Kaplan (mystery, complexity, coherence, and legibility). Public amenities were scored on a range of 7 to 35 points as outlined in chapter 2 and are criteria are recombined to generate visual assessment categories. Sustainable SITES Initiative Criteria measurements were conducted based on photographs of each site and not part of original field notes. These measurements are included as a commentary on existing methods of scoring public amenities at stormwater management systems.

Sustainable SITES Initiative Public Amenity Evaluation

Stormwater management projects were scored according to the Sustainable SITES Initiative Chapter 3.7 which allocates 1 - 3 points based on the degree that the stormwater management feature is seen as a public amenity. Figure 63 shows results for Sustainable SITES Initiative Chapter 3.7 Criteria and overall score. The criteria include: the visibility of water onsite (50%, 75% or 100%), whether users can touch stormwater onsite, and whether users are able to user stormwater areas for contact purposes such as swimming. No sites allowed for swimming within the stormwater management system, and therefore could not score 3 points. Vacant lots scored the lowest out of all stormwater sites in that water directly seeps into the ground and no portion of the stormwater system can be publicly observed. The six sites which gained 2 out of 3 total points allowed for users to touch stormwater within a project which allowed for 100% visibility, these include (Springside School, Clivden Park, Saylor Grove, Kroc Center and Independence School).

	CATHEDRAL RUN	SPRINSIDE SCHOOL	CLIVDEN PARK	WATERVIEW REC	VERNON PARK	SAYLOR GROVE	WISES MILL	KROC CENTER	VACANT LOT	SHISSLER REC	KENSINGTON SCHOOL	LIBERTY LANDS	GREENFIELD SCHOOL	INDEPENDENCE SCHOOL	BARRAT SCHOOL	COLUMBUS SQUARE	HERRON PLAYGROUND	MILL CREEK FARM	PENN ALEX SCHOOL	TRAFFIC TRIANGLE
50 % VISIBLE				●								●						●	●	●
75% VISIBLE		●			●					●	●		●		●	●	●			
100% VISIBLE	●		●			●	●	●						●						
TOUCH		●	●			●		●						●						
CONTACT																				
SITES SCORE	2	2	2	1	1	2	1	2	0	1	1	1	1	2	1	1	1	1	1	1

Figure 63. SITES Chapter 3.7 score for all stormwater management sites

Evaluation of Public Amenity Categories at Stormwater Management Sites

Figure 64 shows stormwater management site designs in which public amenities are not present, latent, strongly implied or present within the project. There are two main goals of displaying stormwater amenity scores: 1) to determine which category each site best fits into, and thereby understand which designs best host a specific public amenity 2) to generate a comparative analysis across sites. This section will focus on explaining intricacies within these two goals as derived from Figure 64.

According to evaluation parameters outlined in methods section, a stormwater management site hosts a public amenity only when scoring from 28-35 points. Figure 64 shows that BMP public amenities are most widespread, and present at Penn Alexander School, Shissler Recreation, Passyunk Square, Greenfield School, the Kroc center and Springside School. Aesthetics, safety and education categories were the second most prevalent stormwater amenity category, present at four sites. Publicity and Recreation categories were less prevalent across all sites. Springside Elementary School, Kroc Center and Greenfield School host three or more public amenities. At all three sites, BMP and Publicity amenities are present. Conversely, Traffic Triangle, Cathedral Run, Vacant Lots, Mill Creek Farm, Barrat School, Vernon Park, Kensington School, Wises Mill and Liberty Lands did not produce scores that indicate public amenities are present.

Total scores across all stormwater management sites are split into five categories: 35 – 70 points, 71 – 105 points, 106 – 140 points, 141 – 175 points and 176 - 210 points. No sites scored within he firs tand lowest category, whereas the majority of site scores fell within the third (average category). Only Springside School scored within the highest category thoughout all stormwater sites. Within the subset of sites which scored between 106 – 140 points, BMP public amenity was found at Penn Alexander and Shissler, while saftey public amenities were present at Waterview Recreation. The presence of public amenities within the average point range indicate that tradeoffs were present within the deisgn of the site. For example, at Penn Alexander School, a relatively large site which hosts a range of topographical variation, there is a high possibility of exposing water onsite as a meandering trail or interactive pond / basin. However, to maintain maximum use of all spaces onsite, structural BMPs including a green “infiltration field” and permeable playgorund were sited. Similar tradeoff are present at shissler recreation center, where large stormwater management infiltration trenches are the primary structural BMP onsite and allow for relatively low amount of recreation / publicity amenities.

The Traffic Triangle at 47th and Grays Ferry and the Stormwater Courtyard at Springside School represent the low and high extremes of score evaluation. Publicity of stormwater management widely varies at each site, the traffic triangle bound on three sides by highly trafficed roadways, allows for passive interaction with the stormwater system, occasionally crawing the attention of passing motorists. Whereas at Springside School, the stormwater trail can be modified onsite, recylcled materials convey water into a native plant gove that users can feel and interact with, lastly stormwater onsite can be heard dripping from a large artistic gutter system installed to capture rooftop runoff.

Average total public amenity score across all sites is 139.5, fitting most closely to Shissler Recreation Center. As stated above a balance between all amenities is achieved throughout the site by trading off certain public amenity aspects to highlight others.

It is important to note that Herron Park, while designed as an active recreation facility, was not evaluated as a recreational stormwater amenity. Criteria for a recreational stormwater amenity include users being able to interact with stormwater onsite, connecting with surrounding trials and multiple other aspects that promote the synthesis of public circulation with stormwater circulation. As shown in circulation diagrams, users are enclosed onsite by a series of fenced off infiltration trenches (Figure 61). Alternatively, Greenfield School, contains a similarn enclosed circulation pattern and employs similar structural BMPs, pervious paving is the primary water infiltration device used. However, a series of mounds which allow for climbing on the stormwater management system and pattern of porous paving which mimics the sotrmwater trail define an experience which closely adheres to recreational amenity criteria derived from Echols and Pennypacker (Figure 65).

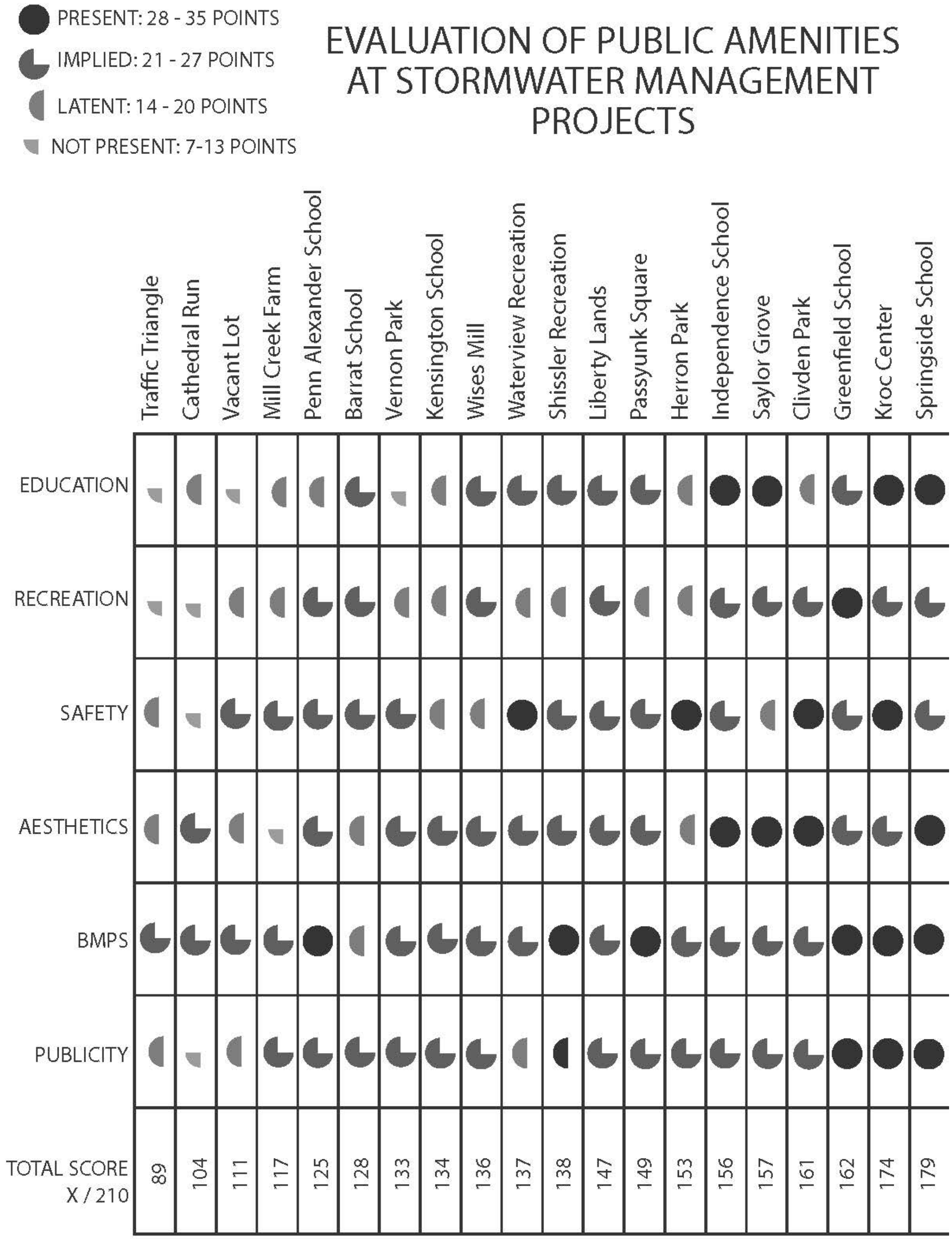


Figure 64. Evaluation of stormwater management amenities with total score for each site

Figure 65. Series of mounds at Greenfield School yeilding high recreation amenity score

Comparing Total Scores

Total scores for individual categories of public amenities at stormwater management sites are shown in Figures 66 – 71. The data represented within this section further describes trends within categories and expands on results found within the previoius section, “Evaluation of Public Amenity Categories at Stormwater Management Sites.”

Education amenity scores have a range of 21 points and an aveage of 20.7 points. Average score indicates that majority of sites exhibited latent education amenity. Highest scoring educational sites included Saylor Grove and Springside school, each scoring 32 points. The Traffic Triangle at 47th and Grays Ferry yeilded the lowest educaitonal score with a total of 11 points.

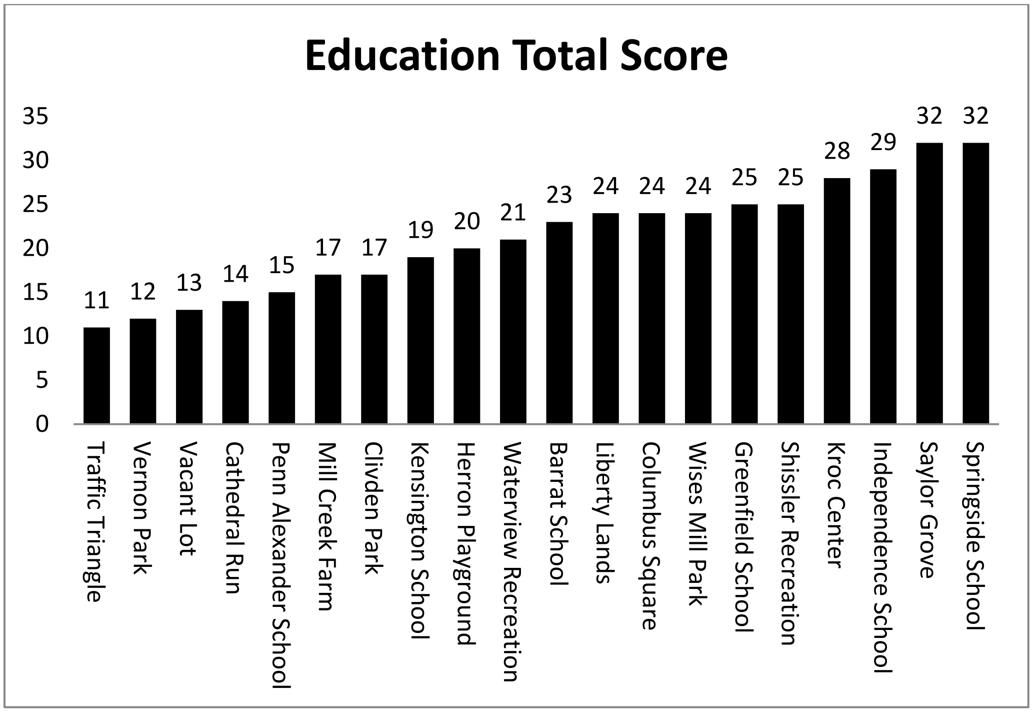


Figure 66. Total education amenity score at twenty stormwater management sites

Recreation Scores in figure 67 have a range of 21 points and an average of 20.1 points. Average score indicated that majority of sites exhibited latent recreation amenity. Highest scoring recreational sites included Greenfirld School, with a total score of 29 points. The Traffic Trangle at 47th and Grays Ferry yeilds the lowest recreational amenity score with a total of 8 points.

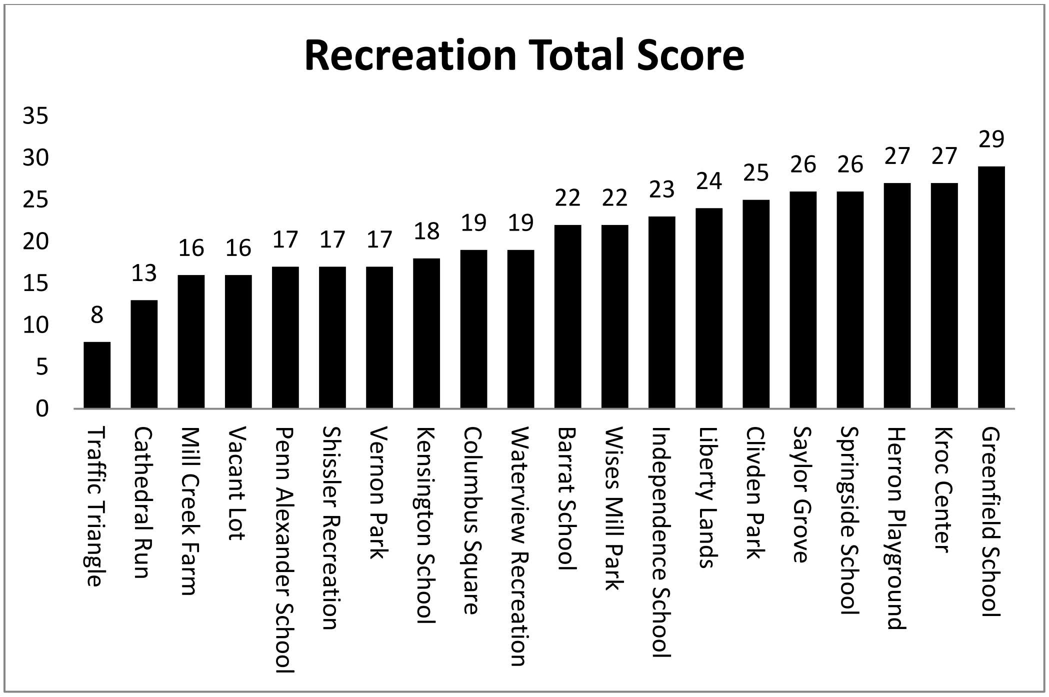


Figure 67. Total recreation amenity score at twenty stormwater management sites

Safety amenity scores have a range of 19 points and an aveage of 22.9 points (Figure 68). Average score indicates that majority of sites exhibited implied safety amenity. Waterview Recreation Center is the highest scoring recreation site with a total of 31 points. Cathedral Run yeilded the lowest safety amenity score at 12 total points.

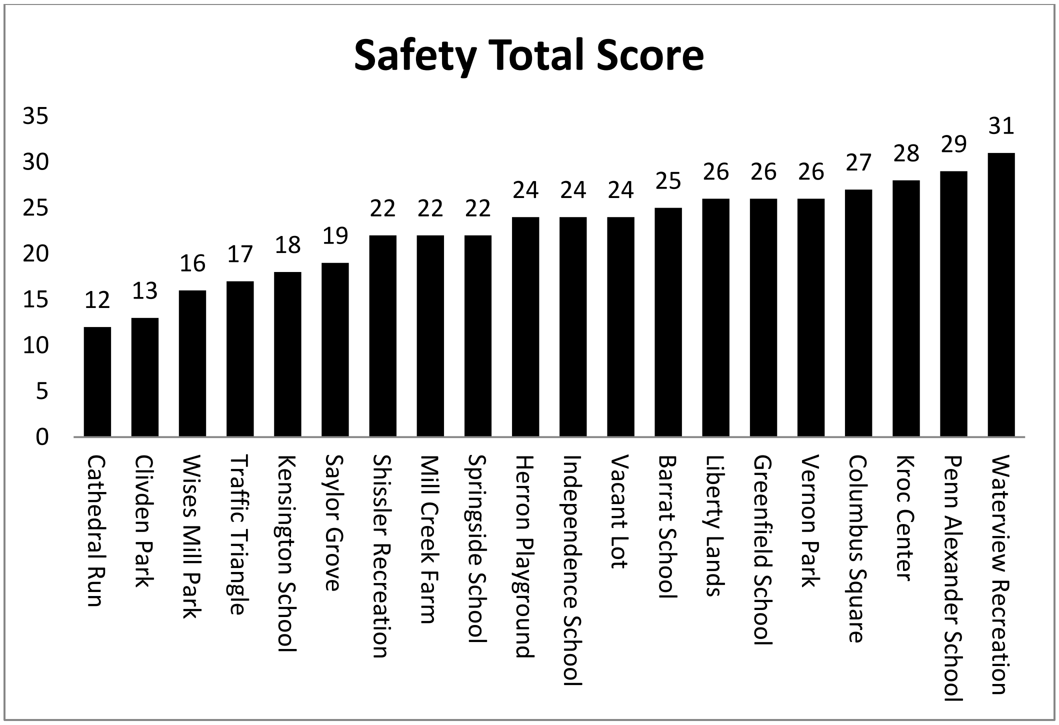


Figure 68. Total safety amenity score at twenty stormwater management sites

Aesthetics amenity scores have a range of 22 points and an aveage of 23 points (Figure 69). Average score indicates that majority of sites exhibited implied education amenity. Clivden Park is the highest scoring aesthetic amenity site with a total of 35 points (maximum points possible, maximum total score throughout all categories). Waterview Recreation and Mill Creek Farm yeilded the lowest aesthetic score at 13 total points.

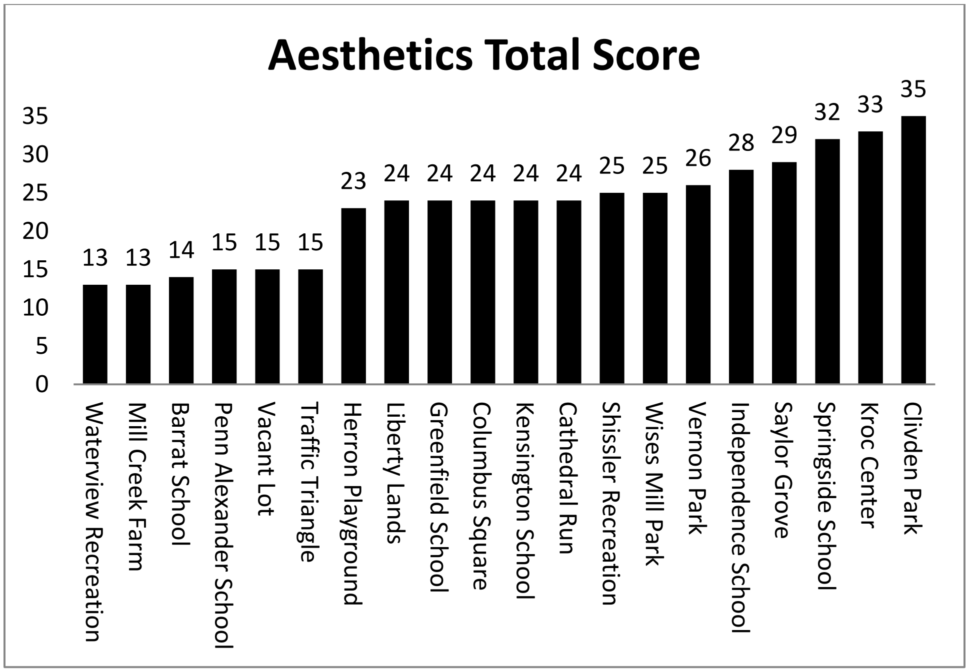


Figure 69. Total aesthetics amenity score at twenty stormwater management sites

BMP amenity scores have a range of 14 points and an aveage of 26.3 points (Figure 70). Average score indicates that majority of sites exhibited implied BMP amenity. Springside School is the highest scoring BMP site with a total of 33 points. Barrat School yeilded the lowest BMP score at 19 total points.

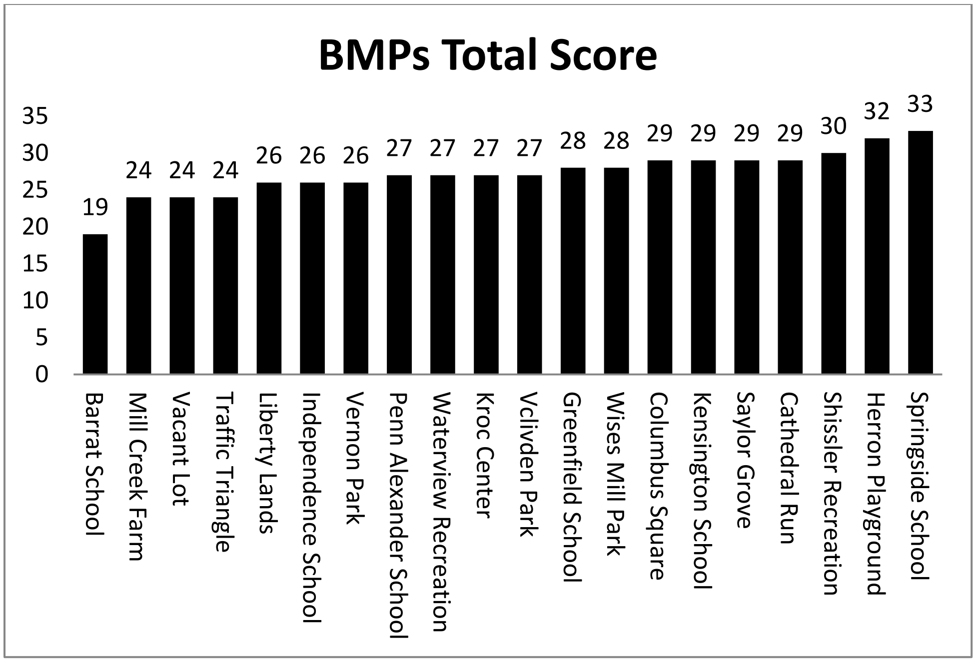


Figure 70. Total BMP amenity score at twenty stormwater management sites

Publicity amenity scores have a range of 23 points and an aveage of 26.9 points. Average score indicates that the majority of sites exhibited implied publicity amenity. Springside Elementary is the highest scoring publicity amenity site with a total of 34 points. Cathedral Run stormwater wetland yeilded the lowest pulicity score at 12 total points.

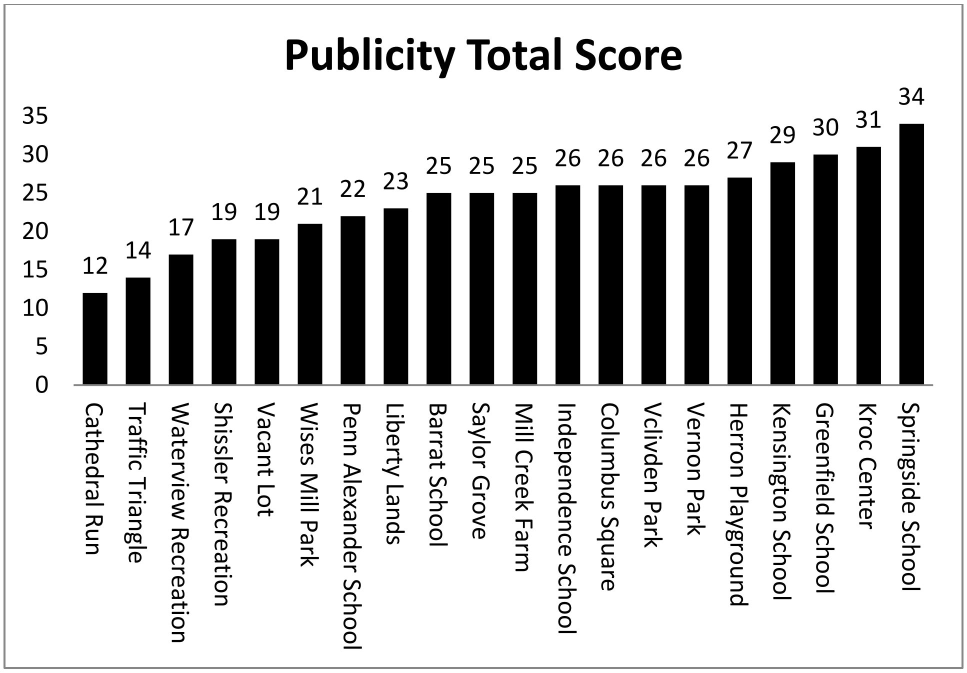


Figure 71. Total Publicity amenity score at twenty stormwater management sites

In comparing ranges aross categories it was found that BMP amenity yeilded lowest range of scores, whereas publicity amenity yeilded the highest range of scores. These two categories also had the highest average across all amenities. It can be concluded that education, recreation, safety and aesthetics categories are more polarizing than BMP categories when comparing scores across all sites.

Chapter 4 – Conclusions

Conclusions are drawn from correlations between vayring data sets. This chapter will introduce comparisons between neighborhood scale, site scale and design scale results by using correlations. Correlations measure the dependence between two measured datasets, for the purposes of this research all correlations above 30% are deemed significant. The chapter concludes with an explanation of general reccomendations to landscape architects when considering how stormater systems will look and go on to explain how this thesis might inform future studies. This chapter will conclude with a reflection on data collection and design evaluation as a means to bringing legibility to an urban center.

Correlations and Comparisons

Correlations and comparisons are representative of general trends across the data and are not meant to posit factual evidence. Correlations are most useful to this study because they do not require that each data set be at the same scale or have the same slope between data points. Relationships of each data point to the data set mean are combined to determine correlation. Correlation yeilds a percent value and can be either positive or negative, showing if these data sets are related (positive) or inversely related (negative). Each data point within scatter grams represents an individual site. This section is used to understand general trends across sites, however specific site examples are cited to further explain conclusions / comparisons. It is noted that for correlations and scatter graphs to be significant additional research must be done for extreme variables

Population Correlation

Population was correlated with site scale and design scale datasets (Figure 72). It was found that a 39.2 % correlation existed between population and cost per square foot. Areas which host higher populations are associated with more costly stormwater management sites (Figure 73). This correlation can be linked into the work of Weiss et. Al. (2005) who have found that stormwater wetlands are some of the most cost effective stormwater management systems. Increased engineering within structural BMPs as in permeable paving systems, sub surface cisterns, tree trenches, under-drains and structural soils require additional cost, but similarly, cause the least disturbance to the existing urban ground plane (Figure 74). Similarly population had a negative correlation with aesthetics, due to the fact that many permeable pavement systems hide the water trail, generating low scores within water flow and form categories.

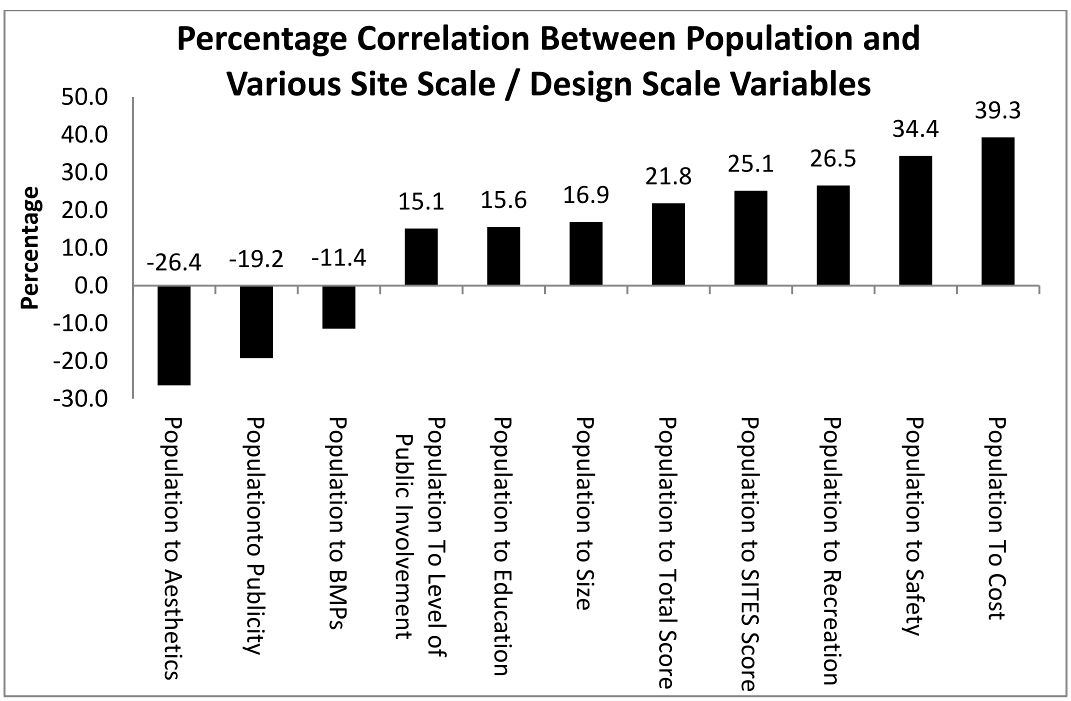


Figure 72. Correlation between population and site / design scale measurements.

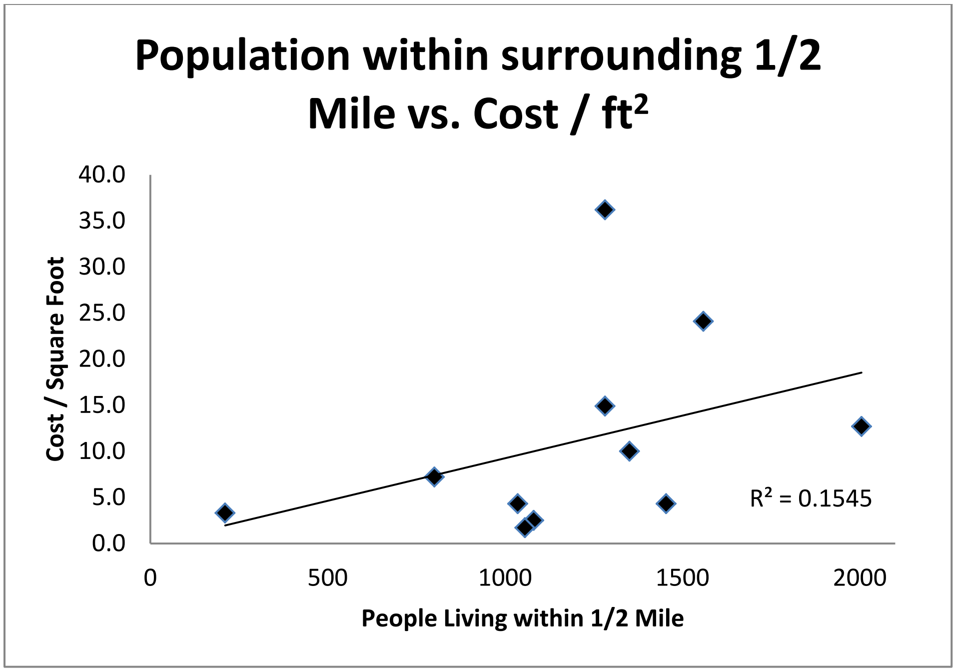


Figure 73. Scatter chart indicating positive corelation between population and cost per square foot.

Figure 74. Waterview recreation center employs structural stormwater management systems in conjunciton with a sprayground area. Out of all sites waterview recreation has one of the highest surrounding populations and costs per square foot.

Park / Open Space Land Use Correlation

Positive correlations between landuse and site / design evaluation parameters were best linked to park / open space (Figure 75). Park / open space within the surrounding half mile was highly correlated with contributing area. Cathedral Run, Saylor Grove and Wises Mill stormwater wetlands were all located in or near existing park / open space, and were responsible for slowly releasing runoff from large residential areas. The stormwater wetland located at the entrance to a public park or open space is the urban form of the detention pond. Similarly, all three stormwater wetlands were larger in size than most other projects, showing a 65.8% correlation between surrounding park / open space and total area of stormwater BMP. Lastly, park / open space had a 30% correlation with recreational amenities found onsite (Figure 76). Echols and Pennypacker include connection to existing trails as part of design techniques contributing to a recreational stormwater amenity. This correlation is reflected in the design of Wises Mill stormwater wetland, which acts as a gateway to the Fairmount Park System (Figure 77).

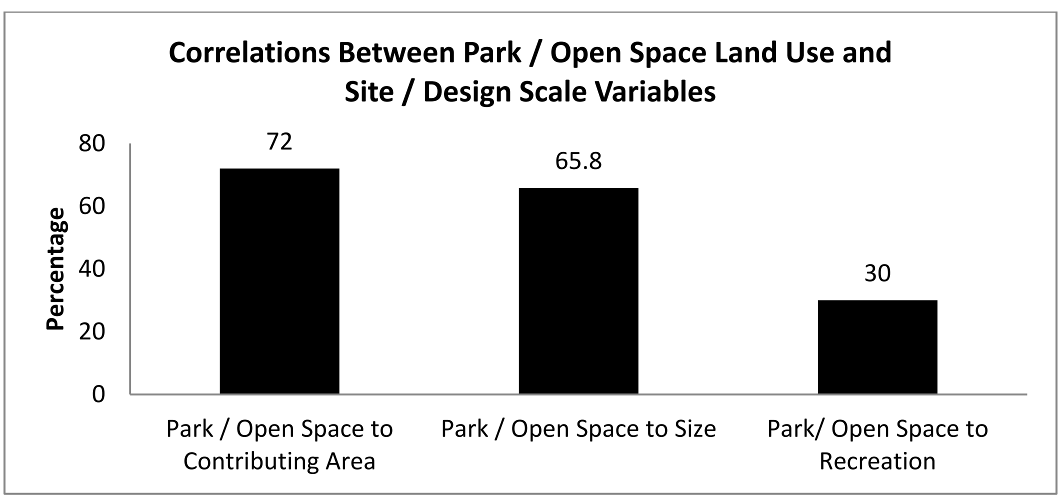


Figure 75. High correlation between surrounding park / open space vs. contributing area, size and recreation amenity score

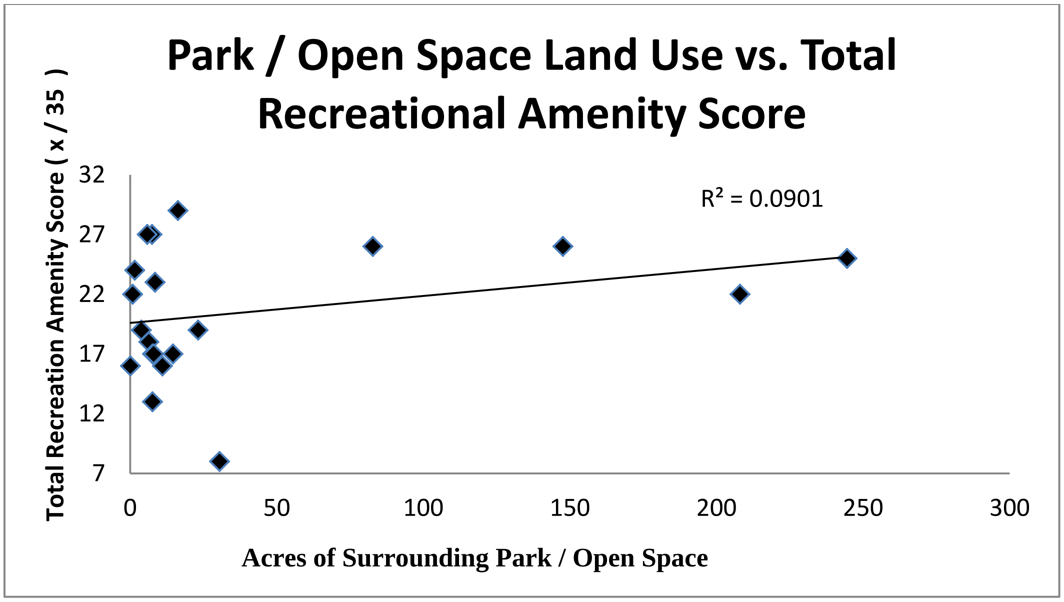


Figure 76. Scatter graph showing positive correlation between park / open space and recreation amenity score

Figure 77. Wises Mill stormwater wetland, high scoring recreational amenity due to proximity to surrounding trails and park pathways

Public Involvement Correlation

Level of public involvement within the site design process showed highest correlation with aesthetic and educational stormwater amenities (Figure 78). Public involvement to aesthetic amenity is plotted as a scattergram in figure 79. Volunteer activity, fundraising organizations, PWD involvement and partners generate designs which fulfill techniques cited by Echols and Pennypacker. Stormwater management sites such as Saylor Grove, Springside Elementary School and Vernon Park employ appropriate symbols / signage to engage visitors with public organizations (Figure 80). In this sense stormwater management areas are understood as passive meeting grounds, where members of a community can exchange ideas, or learn how to become involved with their local watershed partnership. Additionally, sites which had a high level of diversity in public involvement, had a negative correlation with cost per square foot. Public involvement inherently brings a low amount of engineering to the site, as volunteers are called upon to do plantings or lends their skills with a simple curb-cutting wet-saw, the project cost generally diminishes. Similarly, stormwater projects which host a high diversity of public involvement are inversely correlated with a safety amenity. This is due to the fact that the general public will not be installing permeable pavements or other standard structural BMPs. Instead the majority of projects implemented are site specific designs, which may or may not entirely adhere to code specifications.

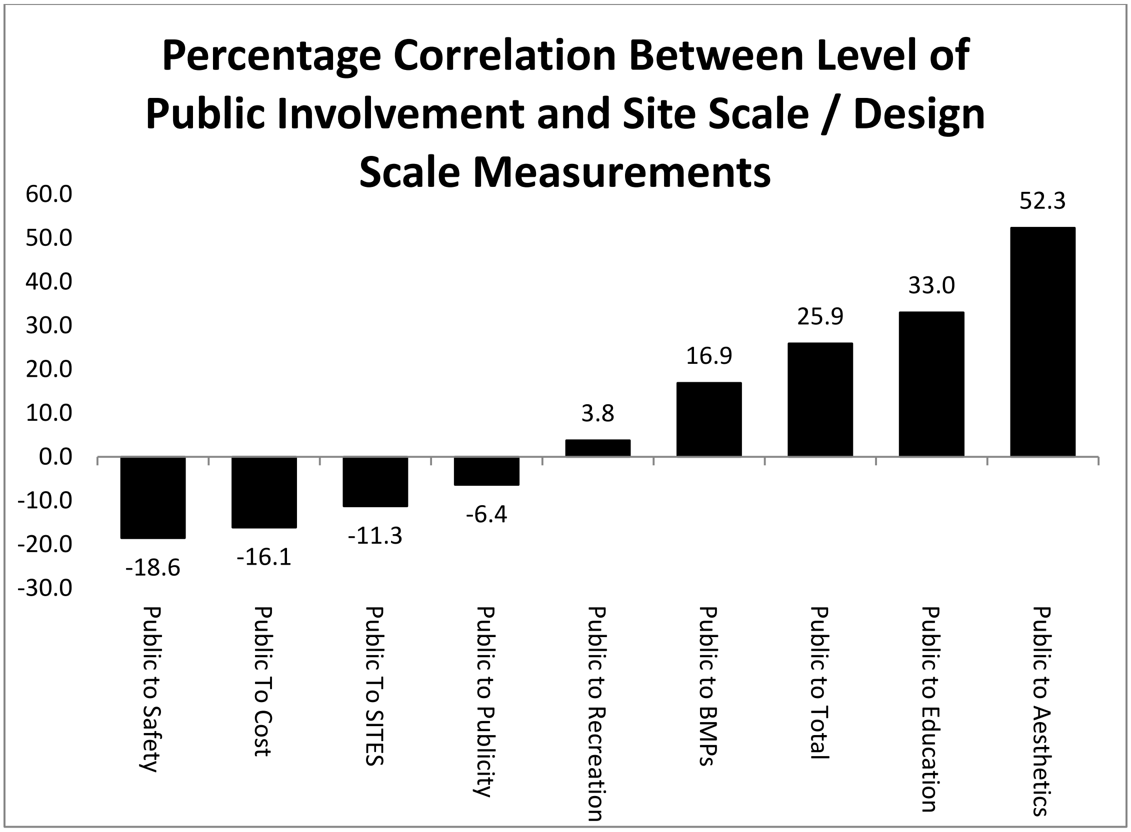


Figure 78. Correlation between diversity of public involvement and site / design scale measurements

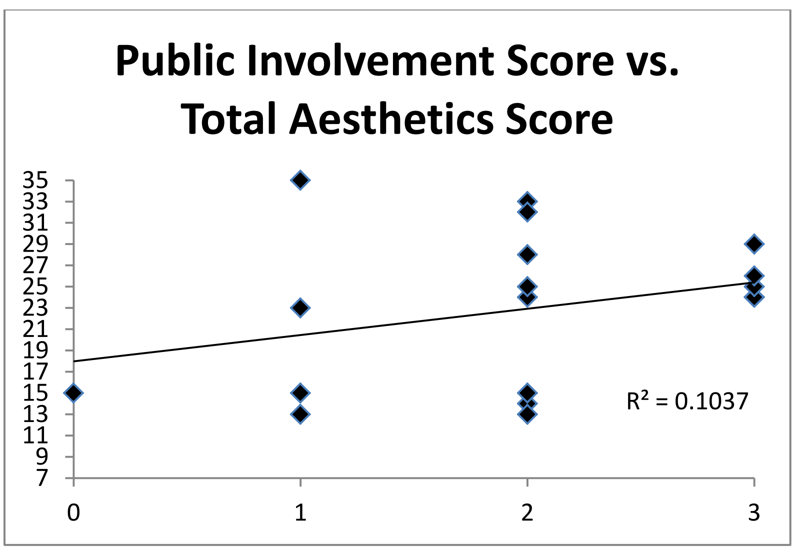


Figure 79. Scatter graph showing positive correlation between diversity of public involvement and high aesthetic amenity score

Figure 80. Saylor grove stormwater wetland had a high diversity of public involvement and generated a high score in the aesthetic amenity category

Cost per Square Foot Correlation

Cost per square foot had the highest correlation with safety and recreational stormwater management amenity categories (Figure 81). Correlations between cost / square foot and total score at site did not reveal significant results (10% correlation), and it was determined that cost / square foot had higher overlap with the six specific public amenity categories. Cost per square foot was most highly related to safety for similar reaons that diversity of public involvement was inveresely related to these two categories. Highly engineered components such as permeable pavement systems cost more on a square foot basis than nautral systems. Similarly, it was found that stormwater sites which scored highest for recreationgl amenities had a 39.9% correlation with Recreation. Sites such as herron playground, independence school represent high cost, high recreational score sites and can be found within the upper right of the scattergram in figure 82. On the other hand sites which had lower costs genreally had lower aesthetic scores (Figure 83). The extereme example of this is the Kroc center a multi-million dolar site, which had one of the highest aesthetic scores / total scores across all public amenity categories. However, due to the metrics used for this study, the expanse of the Kroc Center in relationship to the investment made the cost per square foot relatively lower than other sites such as Herron Playgorund (Figure 84). In order to draw futhrer conclusions from this data it would be nessecary to look at total cost of the site in comparison with amenities.

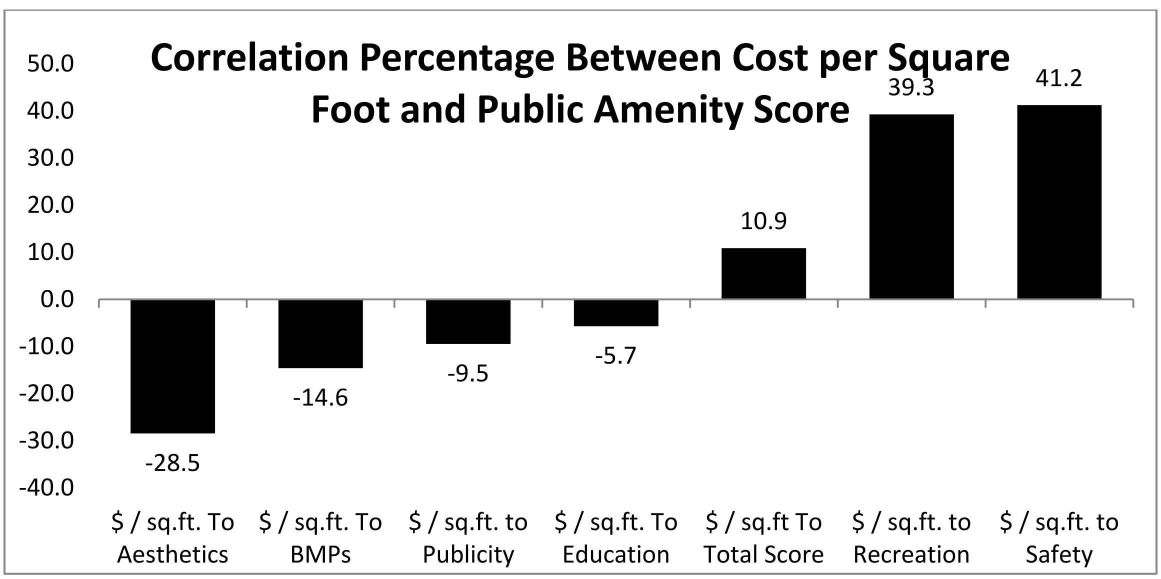


Figure 81. Correlation between cost per square foot and public amenity score

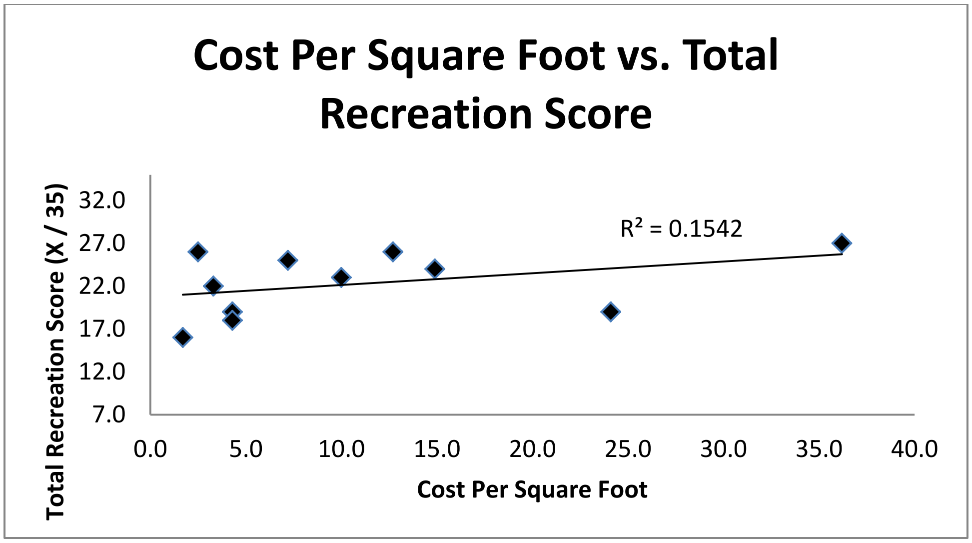


Figure 82. Scatter graph showing positive correlation between cost per square foot and total recreation amenity score

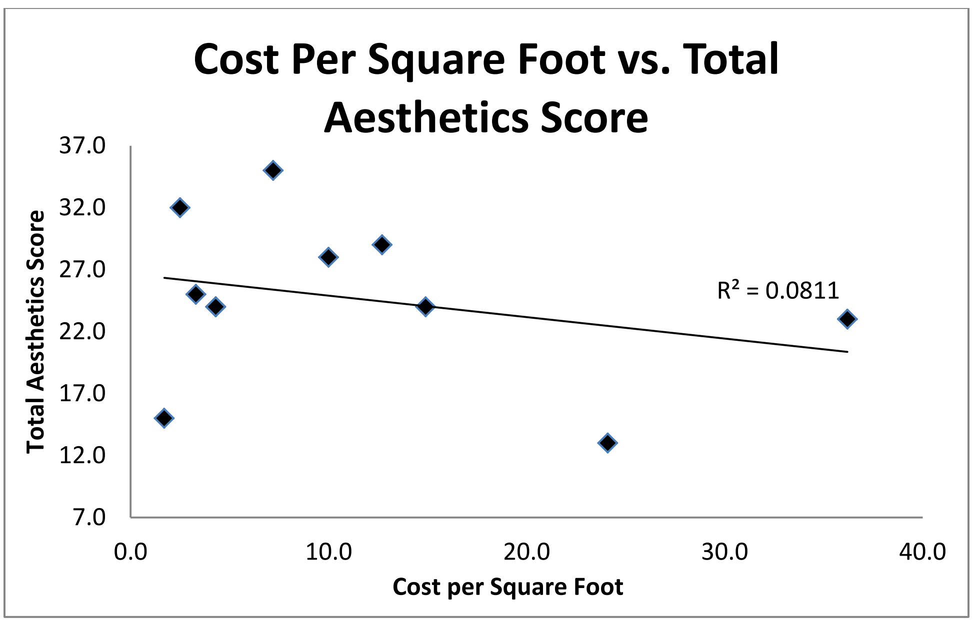


Figure 83. Scatter graph showing negative correlation between cost per square foot and total aesthetic amenity score

Figure 84. Fences surround stormwater system at herron playgorund, detracting form aesthetic amenity score while contributing to cost per square foot

Ratio of Drained area to System Size Correlation

The ratio of drianed area to system size was useful in predicting inf water would be present on site (Figure 85). All stormwater management wetlands had water present on site, however it is determined that site-specific structural BMPs are what govern the presence / absense of water. For example, Liberty lands has a relatively large ratio of drained area to system size, but due to the presence of a large underground cistern stormwater is only present onsite within the adjacent rain garden. The ratio had the strongest inverse correlation with safety amenity (Figure 86). All stormwater management wetlands and sites with similar high-drainage areas require the presence of large centralized pools over three feet in depth to pond high runoff volumes (Figure 87). Such volumes are considered a safety hazard towards the surrounding public, especially at sites which are installed near neighborhoods and urban areas. However, concerning aesthetic public amenities, it is not possibly for a sotmrwater site to score highly within this parameter if no water is flowing onsite. Accordingly, a high correlation between aesthetics and ratio of drianed area to system size was found within this study. However, the ability of designers to work with water creatively can allow for relatively small drained areas, and small amounts of water to play out in interesting ways across the landscape. For example at Springside elmentary school the combination of cretively cut splash guards and bluestone bricks, leading into a natural rain garden hosts no specific pools or basins of water nonsite. However designers were still able to modify water flow and form with site specific design techniques, most notably within the system of convuluted rain gutters designed by Stacey Levy.

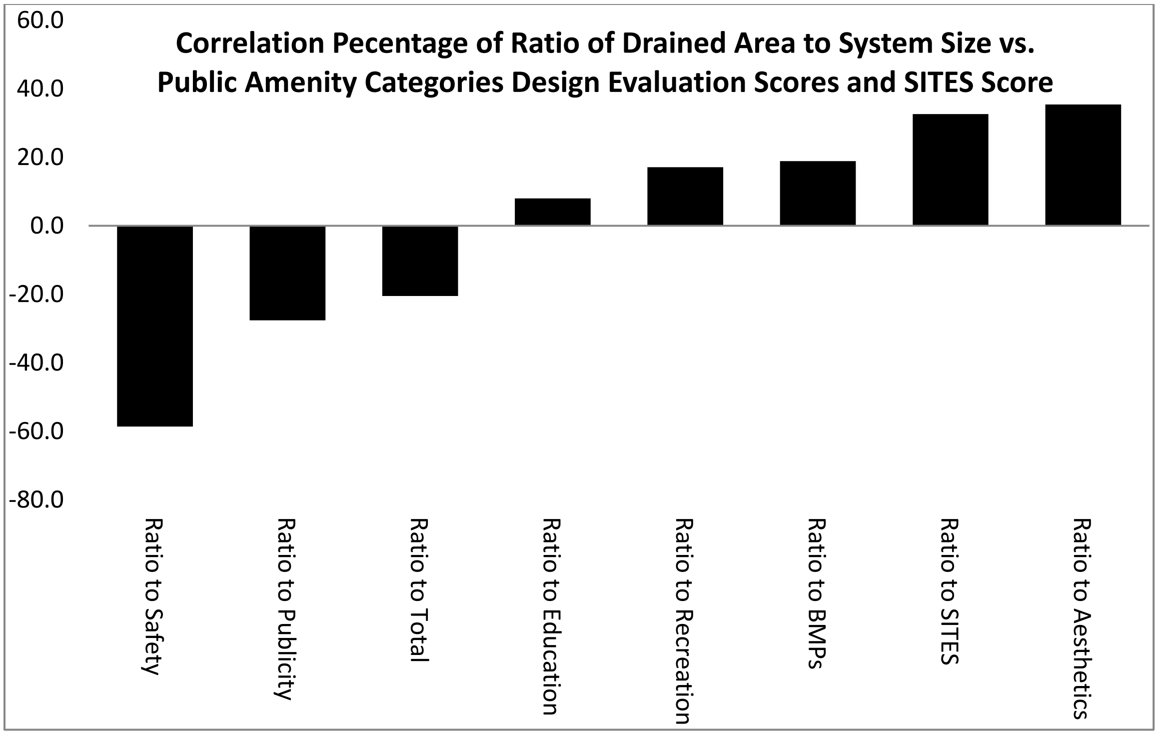


Figure 85. Correlation between ratio of drained area to system sizet and public amenity score

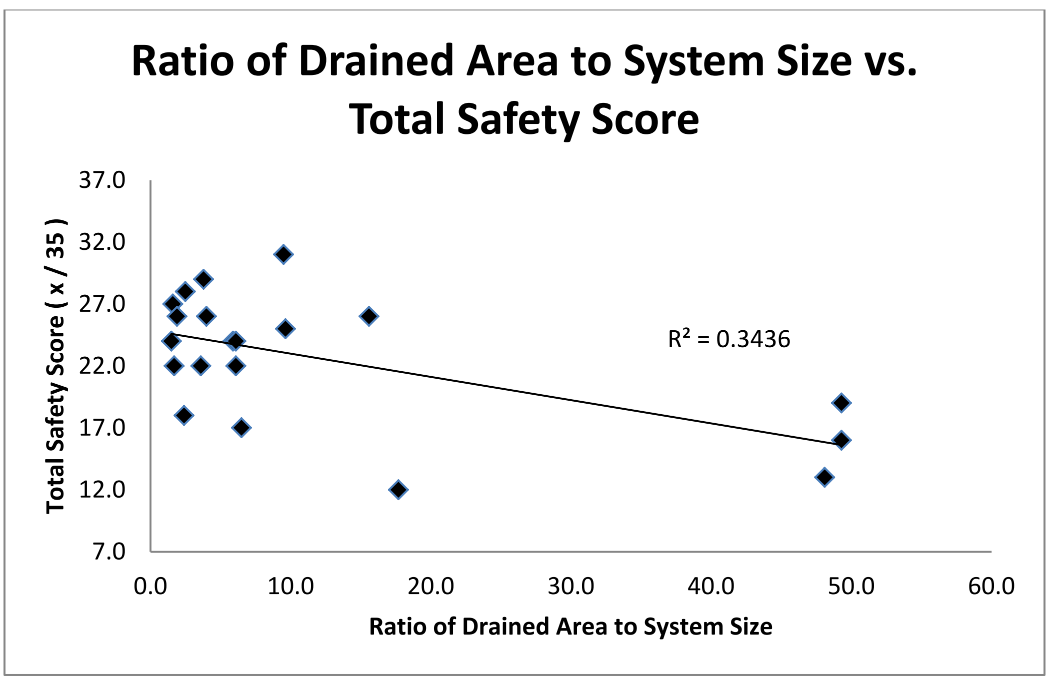


Figure 86. Scatter graph showing negative correlation between ratio of drained area to system size and total safety amenity score

Figure 87. Wises stormwater wetland controls stormwater from over 200 acres of developed land, large pools onsite yeilded a low safety amenity score

Public Amenity Design Evaluation Correlation

In comparing public amenities across stormwater management sites it was found that education and recreational public amenity categories had the strongest correlation at 73% (Figure 88 and 89). Similarly, recreation and aesthetics categories / education and aesthetics had posistive correlations over 50% (Figure 90 and 91). Designing for one of these categories shows the possibility for significant overlap in achieving goals of other public amenity categories. Low correlation was found between safety and aesthetics categories, as the presence of water and basins onsite can be mutually exclusive between these two categories. This dichotomy is represented when comparing sites such as Saylor Grove stormwater wetland and Herron Playground, the inherent “reality” of structures onsite, using plastic boulders or real boulders for seating is something which will inherently affect aesthetic score (Figure 92 and 93). The overlap between education, aesthetics and recreation indicates that more research needs ot be done on the criteria for each category. If Echols and Pennypacker’s categorical arrangement of stormwater management amenities is not meant to overlap, negative correlations would need to be achieved for each of the fifteen comparisons in Figure 88.

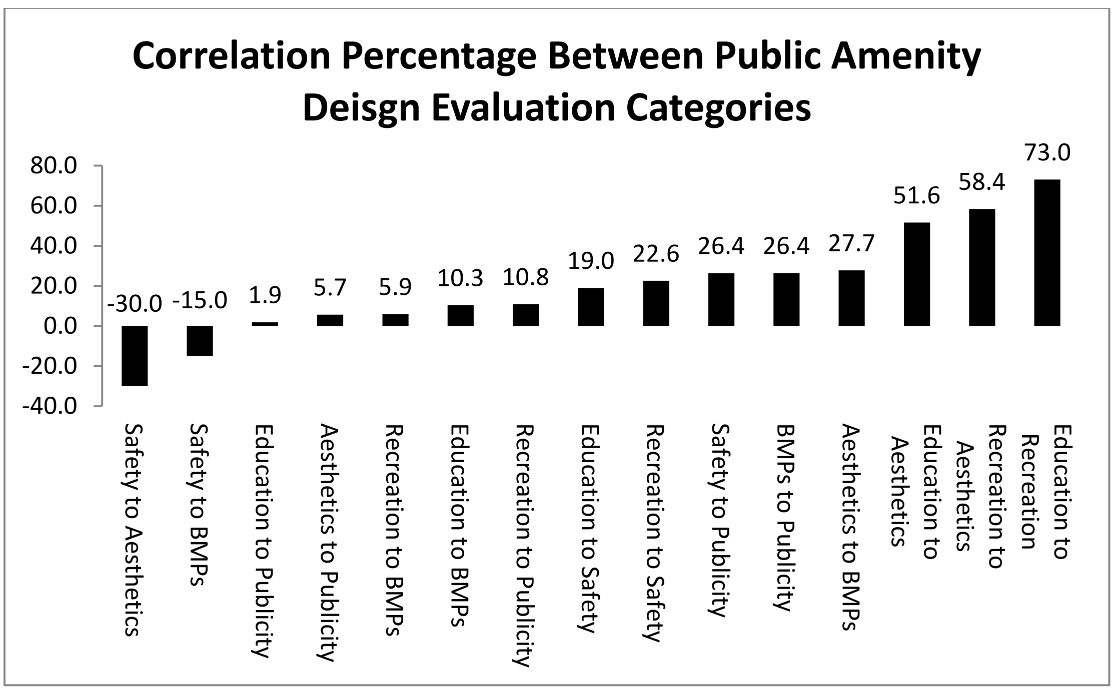


Figure 88. Correlation between public amenity design evaluation categories

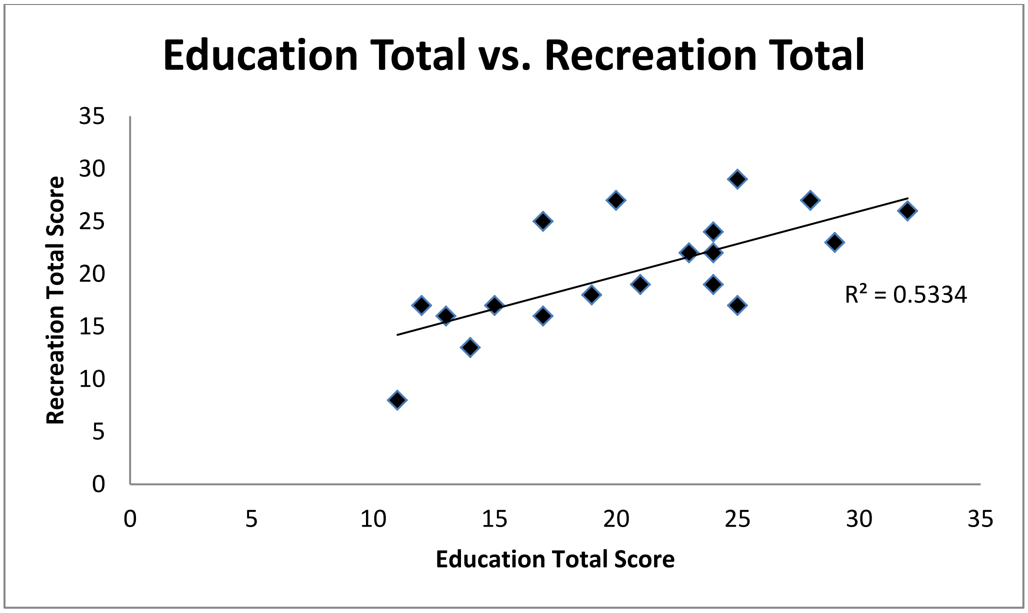


Figure 89. Scatter graph showing positive correlation between total education amenity score and total recreation amenity score

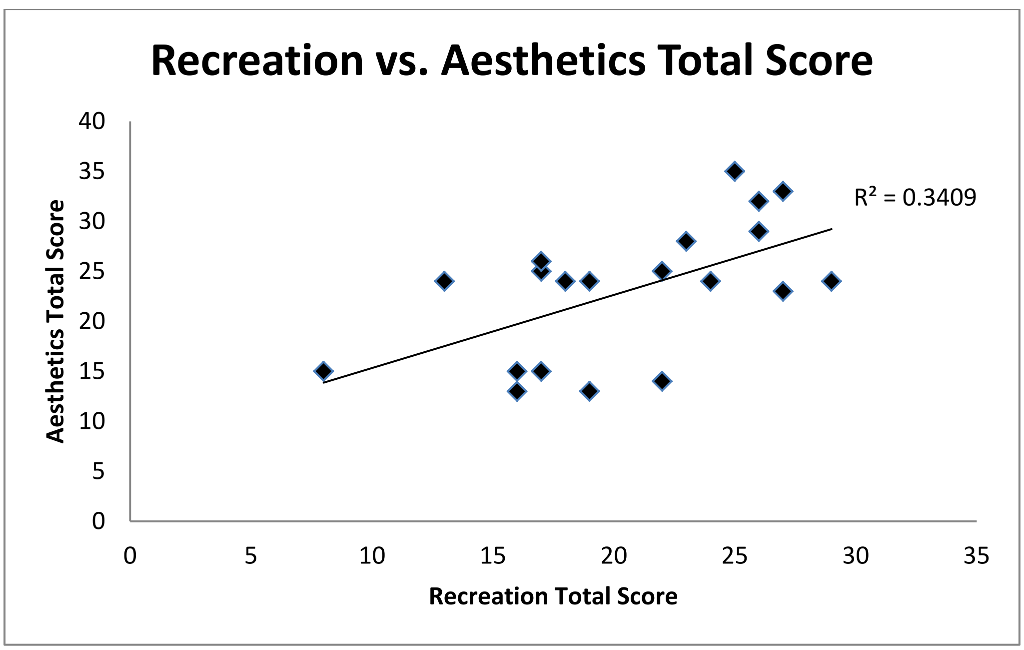


Figure 90. Scatter graph showing positive correlation between total recreation amenity score and total aesthetics amenity score

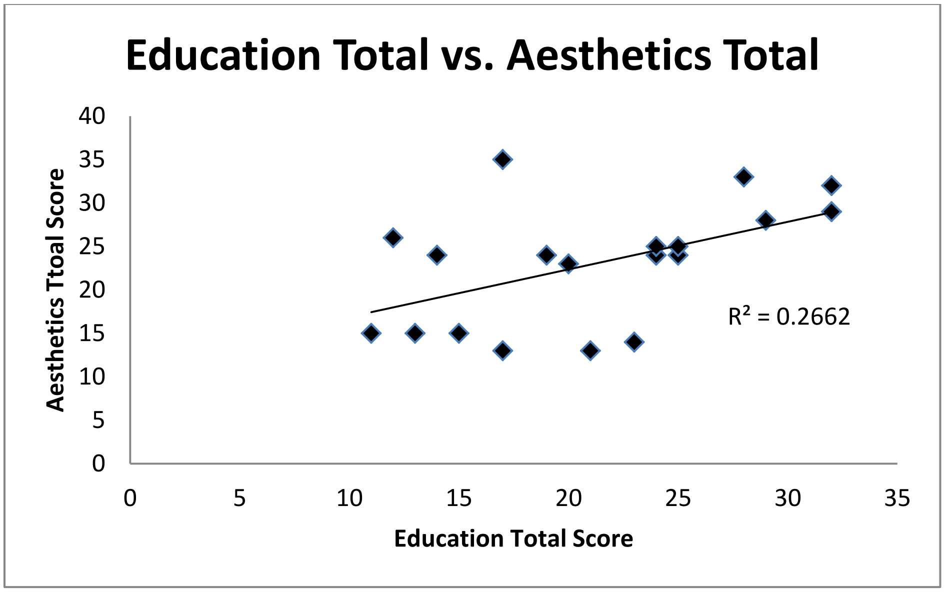


Figure 91. Scatter graph showing positive correlation between total education amenity score and total aesthetics amenity score

Figures 92 and 93. Seating structures at Saylor Grove and Herron Playground stormwater management sites promote interaction with natural or man-made elements

General Conclusions and Recommendations

From the correlations done in the previous section, it is possible to generate ideas regarding the design of future stormwater management sites. This section will give general recommendations based on what was found within the correlations chapter. It is important to note that correlations were used instead of non-linear regressions, and therefore this study assigns no predictive value to the general conclusions. These are not meant to be strict guidelines, but merely a summary of results of the previous section.

At the neighborhood scale, it was found that high surrounding populations coincide with higher, more costly systems. Similarly, high park and open space around stormwater systems is associated with higher recreational amenity scores. If stormwater management BMPs are used as gateways into surrounding parks / open space areas, the public can capitalize on recreation amenities of these sites.

At the site scale, it was found that a high level of public involvement was associated with sites resulting in high aesthetic scores. The public participation process was not taken into account in this study, and the possibility of integrating a quantitative study of public participation remains open for drawing conclusions in future studies. Figure 94 shows a perspective of the stormwater planters at Columbus square, which are part of a larger effort by the Passyunk Square Civic Association to turn Columbus Square into a neighborhood nursery, a harbor for plantings form the surrounding community.

Lastly at the design scale, a high correlation was found between aesthetics, education and recreation across all sites. This is not to say that every new site featuring an active recreational area will host education and at the same time be aesthetically pleasing to the surrounding community. If stormwater management sites are designed within the scope of a singular public amenity, they can accomplish more and connect with their intended audience in a stronger way than projects which look to accomplish high scores across multiple categories. However, it was found that sites which stimulated haptic sensations gained points throughout all categories.

Figure 94. Columbus Square stormwater management planters

Future study

This study is grounded in significant research happening regarding stormwater management throughout Philadelphia. Main Research universities including Temple, Villanova and University of Pennsylvania remain highly involved in research regarding functional and ecological spheres of stormwater management. Due to Rutgers presence in Camden, additional research can be conducted regarding social, spatial and planning parameters based on the initial data / conclusions drawn from this study. This section details how future studies can be built upon existing data.

The first step of any future research into the realm of public amenities of Philadelphia’s stormwater management projects would be to recreate the existing study and expand upon the dataset to include all 52 built stormwater management projects. This would include gathering data on structural BMPs originally outside of the intended data set. Expanding the study to encompass green streets and tree planters would allow for new criticisms to arise regarding the evaluation scheme. Similarly, if future iterations of this study generate alternative scores for stormwater management sites, it would be necessary to revise the evaluation criteria to allow for the least amount of possible variation on the results. Researchers primarily would remain landscape architecture, urban design or planning students / faculty familiar with flow processes and the intricacies of Echols and Pennypacker’s original approach. The eventual goal being to generate an evaluation scheme which is widely accepted throughout the discipline.

Once the evaluation scheme has been edited and released of any original bias relating to sites or conditions, it would be the next appropriate step to integrate the evaluation scheme with chapter 3.7 of the Sustainable SITES Initiative. Currently the chapter sits at the far end of the water design spectrum and is peripherally linked with non-critical, peripheral criteria of other chapters. Using this research the water chapter would be guided by public amenity approach to design rather than reducing base line water requirement. The current extent of stormwater management amenity evaluation criteria is limited to visibility, touch and full contact (swimming, wading, etc.). None of the stormwater sites evaluated in Philadelphia were meant for swimming (due to toxic pollutants and excess chemical loading). The current SITES criteria did not allow for any sites to score a full 3 points for this category and therefore could benefit from being updated.

Next, the stormwater management system amenities would be mapped city-wide in order to create a landscape of amenities associated with water. If Philadelphia is being converted to a waterscape, her citizens need to be aware of what each portion of the new landscape is offering. As stormwater amenities are mapped and incorporated with existing public relation documents (Big Green Map, etc.) the amenity aspect will become as much of an aspect of each site as existing function and ecology spheres. Once the projects have been mapped, stormwater management site design can be further determined by the excess or dearth of public amenity within a certain region. For example if a neighborhood in Philadelphia hosts many educational stormwater management systems, but relatively few which deal with publicity, the mapping process could be instrumental in guiding and establishing further design criteria.

Lastly, future academic studies within the realm of visual assessment would be important in garnering public involvement. Visual assessment will gauge users responses to various structural BMPs. Jared Buffington outlined a matrix of comparisons between

Echols and Pennypacker’s amenity design techniques, with Kaplan and Kalpan’s visual assessment categories (Figure 95). The chart was expanded to include all criteria evaluated within this study to assess how each site scored in relationship to mystery, legibility, coherence and complexity categories (Figure 95). Scores for individual design techniques cross over into the visual assessment categorization allowing for total score of criteria to determine if a site falls within mystery, complexity, coherence, or legibility. Each site scores highest for a single visual assessment category and is classified accordingly.

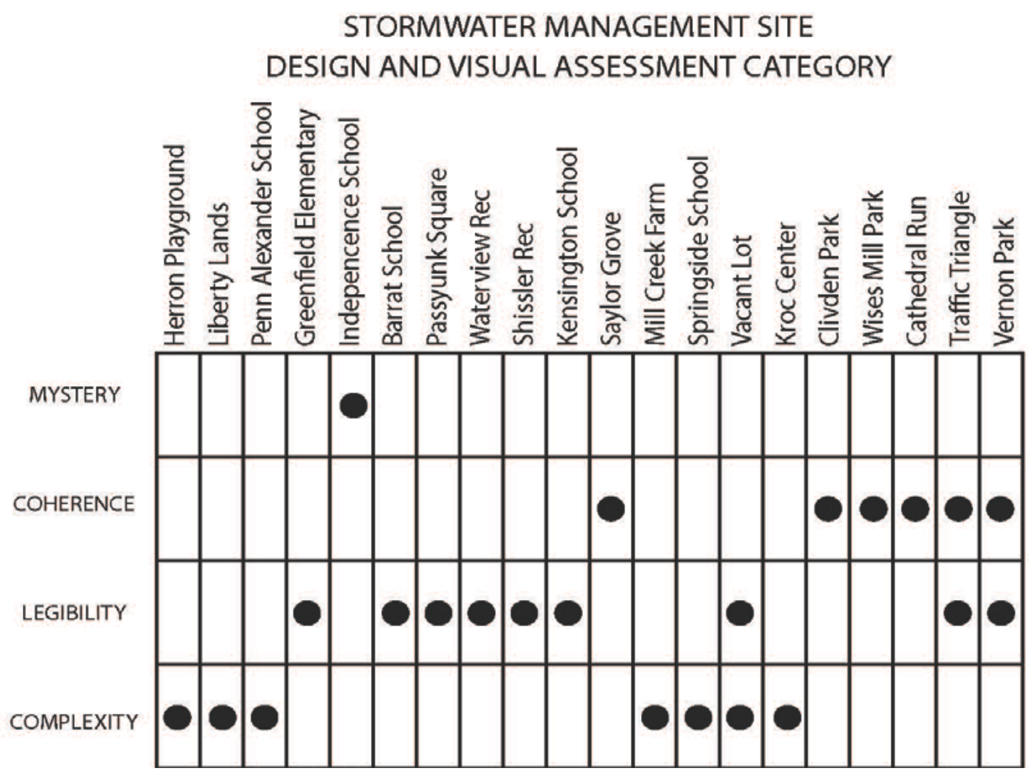


Figure 95. Future studies would expand upon the relationship of stormwater management sites to visual assessment categories

Experience / Reflection

Design evaluation and categorization are two forms of research within landscape architecture which are beginning to have broader applications throughout the discipline. By taking a quantitative approach to public amenities this thesis works to merge subjective design information with a repeatable measurement process. If this research methodology is replicated for other criteria related to public amenity, the social implications of landscape design could be more widely understood.

While conducting this thesis stormwater management knowledge was constructed through coursework and through meetings with the Lawrence Brook Watershed Partnership. Layers of understanding in functional and ecological spheres of stormwater management informed decisions throughout the process. The opportunity to construct and apply theoretical ideas on site was important in creating a physical connection to stormwater management philosophies. Similarly, stormwater sites, neighborhoods and watersheds became important geographical features in reading maps of Philadelphia. According to legibility theories of Kevin Lynch (1960), the process of collecting and finding data could be considered as separate research. Lastly, this thesis allowed for the opportunity to visit stormwater sites within neighborhoods, urban or park contexts. Each area brought about an entirely different atmosphere, creating conditions for research which were not controlled. Such conditions were necessary for understanding different interaction with the stormwater site, however this approach would not be appropriate for quantitative or functional considerations. Landscape architecture continues to benefit from physical site investigation when constructing knowledge in the field.

APPENDIX A

The Evaluation system used for scoring public amenity is presented within this appendix. Education, Recreation, Safety, Publicity, Aesthetics and BMP evaluations are explained with associated influence from Echols and Pennypacker and suggested point values. A representation of visual characteristics of scores is given for each amenity. The evaluation system is not complete and will be edited and revised as additional stormwater sites are considered.

Appendix A - Aesthetics Ranking System

Groundplane

(Echols and Pennypacker Design Techniques)

Stack horizontal and vertical planes such as pools and falls to exploit visual interest of stormwater flowing over surfaces, plunging down planes, through weirs, or over edges

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

Examples of groundplane systems which generate associated point values.

5 points – Vertical elements convey water directly onto horizontal elements

4 points – Stormwater trail cascades over multiple pools

3 points – Stormwater trail runs down a sloped hillside

2 points – Stormwater mainly flows horizontally onsite

1 point – Stormwater seeps through horizontal elements

Hardscape

(Echols and Pennypacker Design Techniques)

Contrast natural elements such as plant and rock with man-made elements such as clipped lawn, steel, or concrete

Use a variety of water-related plants such as rushes and grasses

Use various water-related hardscape such as river pebbles or driftwood to provide interesting surfaces

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of hardscape systems which generates associated point values</u>

5 points – Site materials convey story of water - related events at stormwater system

4 points – Repeated use of stormwater hardscape materials elsewhere in site, breaks impervious

3 points – Stormwater hardscape materials are located specifically at stormwater system

2 points – Single architectural follies related to stormwater, but disconnected form system

1 point – Little or no hardscape materials present

H2O Flow

(Echols and Pennypacker Design Techniques)

Use downspouts, runnels, flumes or bioswales to draw attention to the line of the stormwater trail, enhancing legibility as well as interest and curiosity

Create stormwater trail using axial runnels, downspouts and bioswales

Dramatize implied axis using aligned treatment systems, basins and runnels connected by water trail

Rubric

Point Value based on water flow system intervention present onsite.

<u>Examples of H2O flow which generate associated point values</u>

5 points – Water flows through at least 3 different areas onsite

4 points – Water flows through at least 2 different areas onsite

3 points – Water flows through main area onsite

2 points – Water flow onsite is concealed but implied

1 point - Water directly infiltrates and does not flow onsite

H2O Form

(Echols and Pennypacker Design Techniques)

Allow people to touch stormwater in different forms such as flowing, falling, splashing, standing and sheeting, or on damp surfaces where water can soak in or evaporate

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

Examples of H2O form which generate associated point values

5 points – Water flows in at least 3 different forms onsite

4 points – Water flows in at least 3 different forms onsite

3 points – Water flows in 1 dominant form onsite

2 points – People can touch damp surfaces onsite

1 point – Water flows directly into site

Basins

Create water collection as a feature or focal point

Create visual emphasis on stormwater direction change using scuppers, basins, cisterns, splash blocks, or rain chains

Create visual interest or themes with basins that hold plants and water: sunken, raised orthogonal, curved, organic, geometric, small or large

(Echols and Pennypacker Design Techniques)

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of basin systems which generate associated point values</u>

5 points **–** Stormwater enters at least 3 different basins onsite, basins have different geometry

4 points **–** Stormwater enters at least 2 different basins onsite, structural elements convey water flow

3 points **–** Stormwater enters one main basin onsite, with mixture of plantings

2 points **–** Stormwater flows throughout site, lacks centralized flow area, basins formed by plants

1 point - Stormwater does not enter any formal basins on site

Sound

(Echols and Pennypacker Design Techniques)

Create a variety of volumes by allowing stormwater to fall from various heights onto different materials such as stone or steel

Create changes in pitch by allowing stormwater to fall on different forms such as flat block, metal tubes, drums and ponds

Create different rhythms by varying the amount and rate of stormwater falling and flowing through the treatment system

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of sound systems which generate associated point values</u>

5 points – Sound of water clearly audible at multiple points on site

4 points – Sound of water clearly audible at single point on site

3 points – Sound of water audible if listening

2 points – Sound of water implied by wet areas / habitat

1 point – Sound of water not present on site

Simplicity

(Echols and Pennypacker Design Techniques)

Create unified design themes by using multiple bioswales, basins, weirs, ponds, or rain gardens

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of simplified systems which generate associated point values</u>

5 points – Site employs modular stormwater systems which connect or repeat

4 points – Site contains stormwater systems which highlight different hydrologic aspects

3 points – Site uses a single stormwater management system and repetition of materials

2 points – Multiple stormwater systems, similar materials

1 point – Multiple stormwater systems use different design languages

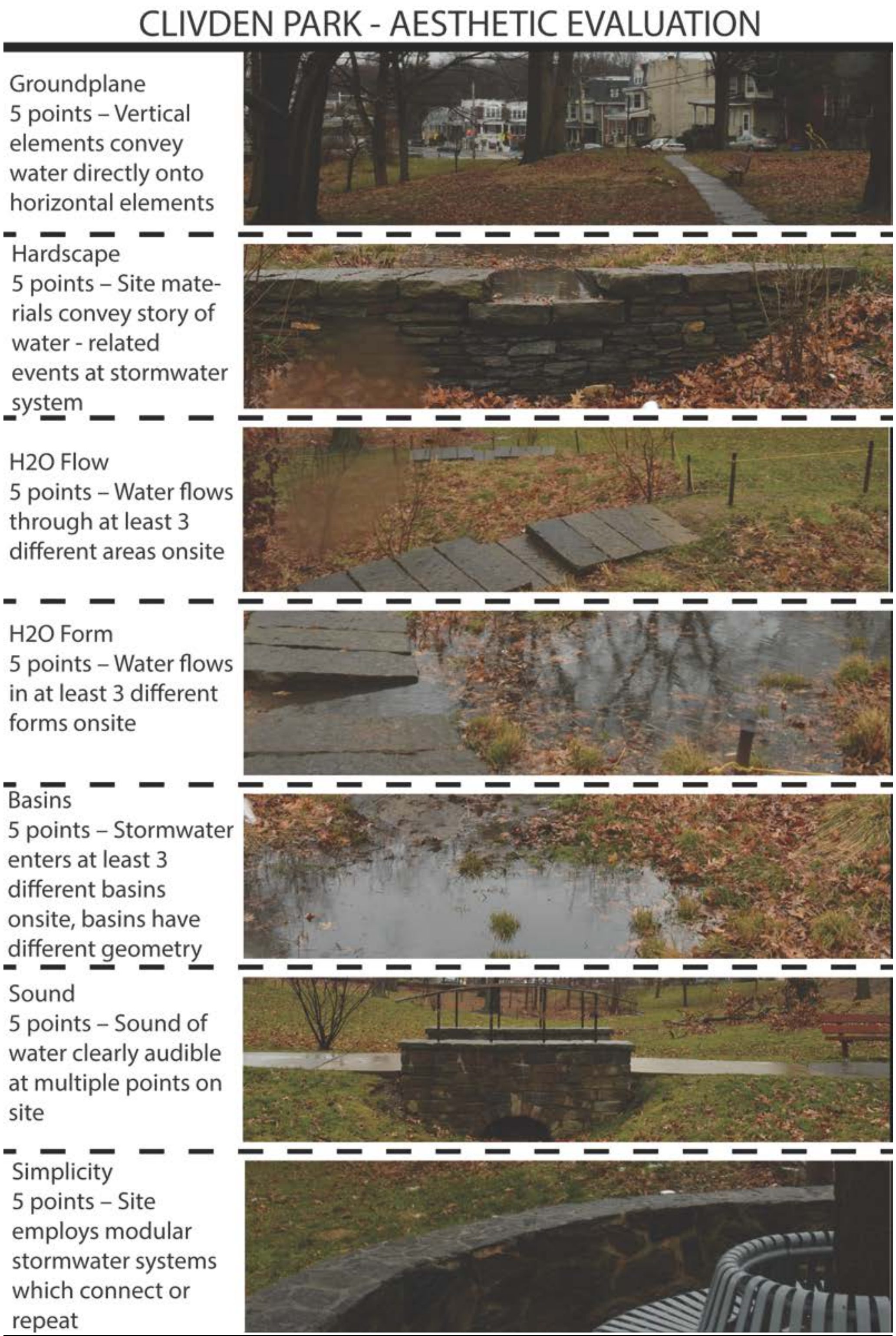


Figure 96. Clivden Park aesthetic evaluation visualization

Appendix A - Education Ranking System

Visibility

(Echols and Pennypacker Design Techniques)

Make stormwater trail visible and legible

Make stormwater treatment system visible and legible

Create systems that visibly collect and store trash and/ or pollution

Create treatment systems that are visible and legible

Create visual interest by varying the appearance of different parts of the stormwater system

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

Examples of Structural BMPs which generate associated point values.

5 points – Runnels, Basins, Disconnected Downspouts, Cisterns

4 points – Constructed Wetlands, Flow-through Planters, Vegetated Swale

3 points – Rain Gardens, Infiltration Basins, Vegetated Roof

2 points – Permeable Paving Systems, Porous Concrete / Play Surface

1 point – Under-drain systems, Infiltration Trenches

Narrative

(Echols and Pennypacker Design Techniques)

Create narrative of stormwater or hydrologic cycle

Creates narrative of historical water condition

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

Examples of narrative expression in design which generates associated point values

5 points – Precipitation enters plantings and flows offsite, bold markings, very loosely managed

4 points – Precipitation enters plantings, loosely managed, some markings

3 points –Topography generates narrative, slightly maintained plantings

2 points – Degree of wetness generates narrative, maintained site

1 point – High degree of management, stormwater directly enters subsurface treatment system

Artifacts

(Echols and Pennypacker Design Techniques)

Provide a variety of plant types or communities

Integrate stormwater related site artifacts into the design

Employ Expressive Hydrologic Symbols

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of Stormwater Artifacts which generate associated point values</u>

5 points – Recycled stormwater materials, riparian plantings, markings highlight stormwater trail

4 points – Some recycled materials used, native plantings, markings present but purely symbolic

3 points – Wet-site tolerant vegetation, historical component and markers mixed

2 points – Common ornamental vegetation, lacks recycled / historic materials

1 point – Lacks recycled / historic component, nonnative / invasive plantings present onsite

History – Perceived as natural history on site. Creation of different habitat areas generates

(Echols and Pennypacker Design Techniques)

Provide a variety of interesting wildlife habitats

Use plants that provide wildlife food

Provide Different Water depths

Create shelter for wildlife such as bird / bat houses

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of Natural History Features which generate associated point values</u>

5 points – Three or more wildlife habitat locations created by stormwater management system

4 points – Two distinct wildlife habitat locations created onsite

3 points – Stormwater Management system is wildlife habitat location

2 points – Stormwater management system is perceived /incidental habitat location

1 point – No wildlife habitat created by system, wildlife exists at periphery of system

Playful

Make stormwater treatment system playful, intriguing or puzzling

Include a variety of stormwater treatment systems in design

Design Treatment System to invite educational games or activities

Create a variety of spaces for groups to explore, gather, or sit near the stormwater treatment system

(Echols and Pennypacker Design Techniques)

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

Examples of Playful Stormwater Interventions which generate associated point values

5 points – Spray-ground near stormwater system, visitors can interact with flow of water

4 points – Scale of site can host classroom activities, large groups

3 points – Stormwater BMPs are arranged around a central play area

2 points – Permeable Playground, stormwater system is central play area

1 point – Singular structural stormwater system, not for entry

Signage

(Echols and Pennypacker Design Techniques)

Provides simple signage or exhibits that use: brief text, clear graphics, location, color, or motion attracts people

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

Examples of Signage Quality which generates associated point values

5 points – Signage provokes further exploration of stormwater system

4 points – Signage present on site has clear bold graphics, is located close to stormwater system

3 points – Signage is located on site and close to stormwater management system

2 points – Signage does not provoke interest in stormwater system

1 point – Little or no signage present onsite

Touch

(Echols and Pennypacker Design Techniques)

Create treatment systems that are touchable

Create designs that encourage people to explore and play near or in the treatment systems

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of Structural BMPs which generate associated point values</u>

5 points – Visitors can touch water onsite and are immersed in stormwater system

4 points – Visitors can walk inside of the stormwater management system

3 points – Visitors can feel texture of a variety of wet site plantings

2 points – Systems imply visitors should not enter and provide no formal pathways

1 point – Systems are fenced in or below ground preventing visitor interaction

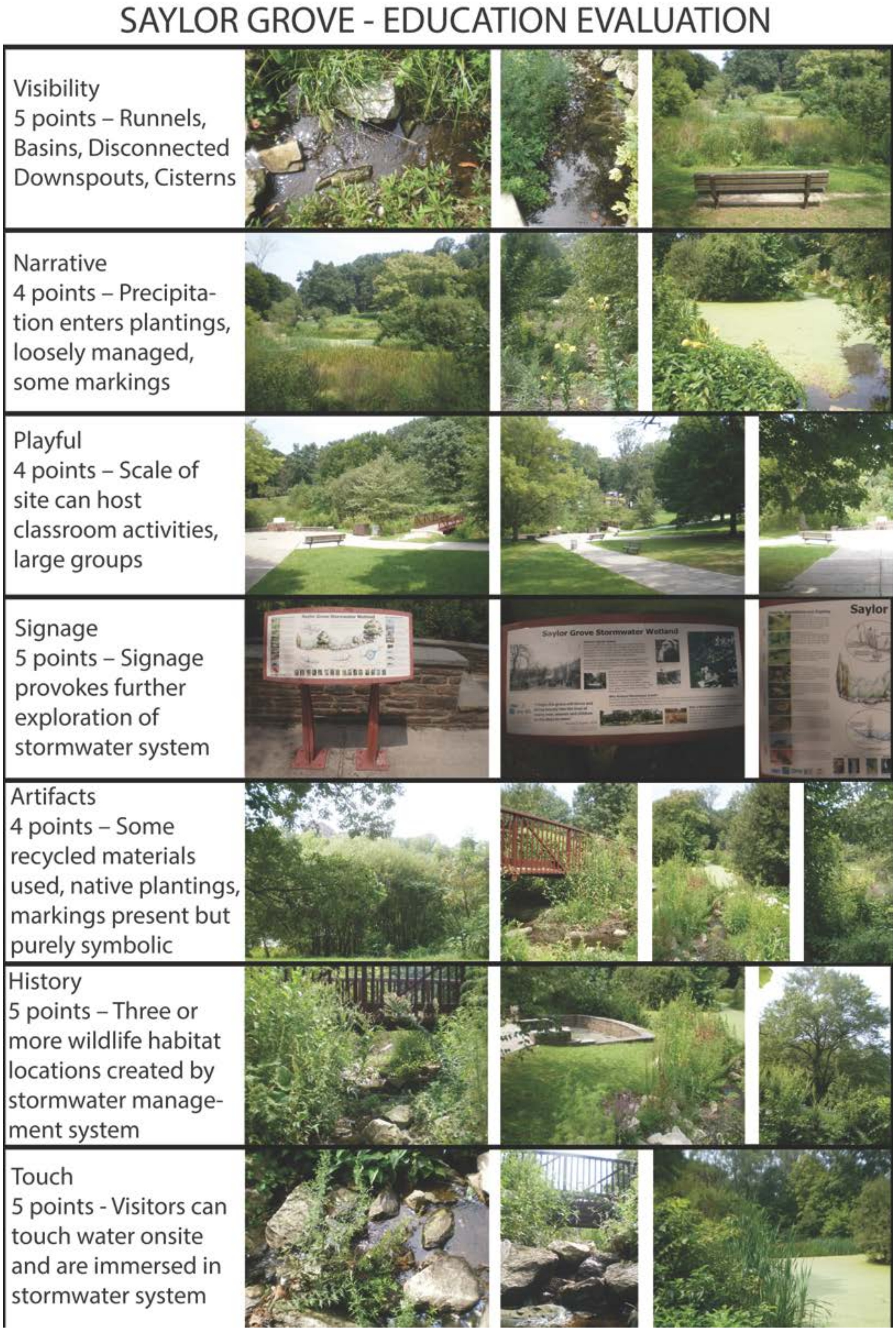


Figure 97. Saylor Grove education evaluation visualization

Appendix A - Publicity Ranking System

Visibility

(Echols and Pennypacker Design Techniques)

Create a variety of highly visible stormwater treatment systems

Locate stormwater treatment systems near entries, courtyards, or windows for high visibility

Use signage explaining stormwater treatment and intent

Make the stormwater trail easy to fang and follow

Make the stormwater trail mysteriously disappear and reappear

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

Examples of visibility systems which generate associated point values.

5 points – Stormwater system located at entry of park, junction or focal point

4 points – Stormwater system located near buildings, incorporated in structural elements

3 points – Stormwater trail visible onsite

2 points – Signage provides understanding of stormwater system

1 point – Stormwater system hidden from view

Program

(Echols and Pennypacker Design Techniques)

Create opportunities for programming educational activities

Utilize new forms and materials

Make the stormwater or water treatment system touchable

Make the stormwater audible: plunge pools, downspouts

Make the stormwater move in different ways: tumble, run, splash

Encourage walking in or climbing on the water treatment system

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of programming systems which generate associated point values</u>

5 points – Stormwater management system has existing program for community maintenance

4 points – Stormwater system is used as an educational facility for organized groups

3 points – Stormwater system engages user experience through sound, touch or movement

2 points – Stormwater system is meant to be viewed

1 point – There is little or no potential for engaging the stormwater system

Scale

(Echols and Pennypacker Design Techniques)

Use commonly available materials

Create small-scale replicable interventions

Utilize common settings such as sidewalks and parking lots

Be opportunistic by using small, leftover, and unexpected spaces

Rubric

Point Value based on water flow system intervention present onsite.

Examples of stormwater scale which generates associated point values

5 points – Stormwater system uses recycled materials, is small scale and repeatable, (rain barrels)

4 points – Stormwater system activates underused areas (vacant parks, lots, neighborhoods)

3 points – Stormwater system is appropriate scale for human interaction (creeks, pools, basins)

2 points – Stormwater system allows for other activities to happen onsite

1 point - Stormwater management system is large/ hidden, covers most of site

Form

(Echols and Pennypacker Design Techniques)

Utilize new forms and materials

Create elegantly simple composition

Use refined and expensive materials

Use refined and expensive construction methods

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of stormwater system form which generates associated point values</u>

5 points – Individual craftsmanship evident in stormwater management system

4 points – Design of stormwater flow is straightforward and elegant

3 points – Stormwater system uses innovative design materials

2 points – Stormwater system is informal, overly natural and lacks structure

1 point – Stormwater system is minimally designed and consists solely of engineering elements

Pride

(Echols and Pennypacker Design Techniques)

Utilize new and innovative stormwater treatment methods

Utilize traditional stormwater treatment methods in new ways

Achieve additional functions such as traffic calming and beautification

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of community pride on site which generates associated point values</u>

5 points – It is evident community takes pride in stormwater management system

4 points – Stormwater management systems allows for user interaction / engagement

3 points – Design of stormwater system contributes to neighborhood beautification

2 points – Stormwater system slows down passers-by, indirect interaction

1 point - Stormwater system detracts from neighborhood, contributes to clutter

Theme

(Echols and Pennypacker Design Techniques)

Use restraint in diversity of materials and forms

Make unusual line of stormwater trail

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of stormwater system theme which generates associated point values</u>

5 points – Stormwater system design conveys site theme, relating to larger context

4 points – Stormwater system design is repeated and uses a limited number of materials

3 points – Stormwater system theme based on water trail

2 points – Stormwater system relates to road or street

1 point – Stormwater system lacks common functioning theme

Presentation

(Echols and Pennypacker Design Techniques)

Design for manicured look: clipped, trimmed, clean

Use unusual water presentations forms and themes

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of stormwater presentation which generate associated point values</u>

5 points – Stormwater system opens up to users and invites people inside

4 points – Stormwater system is perceived as a coherent, legible image of urban diversity

3 points – Stormwater system has a managed controlled look

2 points – Stormwater system mixes natural and structural elements

1 point – Stormwater system is entirely natural, unmanaged and does not contain "cues to care"

Figure 98. Liberty lands publicity evaluation visualization

<u>Appendix A - Safety Ranking System</u>

Access

(Echols and Pennypacker Design Techniques)

Provide walls, screens or railings that allow views but prevent access to stormwater

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of access systems which generate associated point values.</u>

5 points – Stormwater management system is fitted with railings, walls, or screens

4 points – Smaller boundary systems exists to prevent access to stormwater system

3 points – Stormwater system is contained within a defined area

2 points – Stormwater system lacks definition onsite

1 point – Stormwater system is potentially hazardous to pedestrians

Plants

(Echols and Pennypacker Design Techniques)

Provide upland, riparian or wetland plant massing that allow views but prevents access to stormwater

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of stormwater management plant safety which generates associated point values</u>

5 points – Mixture of three riparian typologies onsite, plants are protected

4 points – Two riparian typologies onsite, plants are protected

3 points – One riparian typology onsite plants are protected

2 points – One dominant site, plants are not protected

1 point – Plants have potential to be trampled

Circulation

(Echols and Pennypacker Design Techniques)

Uses bridges, boardwalks or platforms to allow users to view stormwater from above

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of circulation which generate associated point values</u>

5 points – Bridges, boardwalks or platforms are incorporated into design

4 points – Design utilizes changes in topography to separate people from stormwater

3 points – Design utilizes topography to separate people from stormwater

2 points – Design puts people and stormwater system on the same plane

1 point - People must walk through the stormwater management system

Shallowness

(Echols and Pennypacker Design Techniques)

Limit stormwater depth by creating horizontal space for water to spread out

Limit stormwater depth by adding large river stones to basins where people could have access

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of pathways which generate associated point values</u>

5 points – Stormwater management system is primarily horizontal surface infiltration

4 points – Rain gardens and other structural BMPs allow for minimal water ponding

3 points – Water ponding onsite is limited to restricted areas

2 points – Water ponding depth is approximately 1 - 2 feet

1 point – Water ponding depth is approximately 3 -4 feet

Breaks

Create “water breaks” to slow stormwater by abruptly changing flow direction

Slow stormwater by creating small waterfalls that dissipate energy

(Echols and Pennypacker Design Techniques)

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of brake systems which generate associated point values</u>

5 points – Stormwater trail interrupted by rocks, bends or alternative flow patterns

4 points – Stormwater sheets across site, horizontal movement of water present

3 points – Initial flow velocity of water is slowed by onsite interventions

2 points – Slight reduction in water velocity onsite

1 point - Little to no reduction of water flow velocity onsite

Storage

(Echols and Pennypacker Design Techniques)

Use water themed above ground stormwater storage facilities such as rain barrels, water towers or cisterns

Disperse stormwater into shallow storage facilities for water to spread out

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of storage systems which generate associated point values</u>

5 points – Above or below ground storage facility part of structural site BMPs

4 points – Rain Gardens and other natural storage areas have a planar geometry

3 points – Small scale storage facilities are a maximum of 6” deep

2 points – Above ground stormwater storage onsite is maximum of 1’ deep

1 point – Above ground stormwater storage facility is maximum of 2’ deep

Decentralize

(Echols and Pennypacker Design Techniques)

Do not collect or move stormwater in large centralized conveyance facilities

Disperse stormwater into small conveyance facilities using level spreaders or flow splitters

Do not collect stormwater in large centralized storage facilities

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of decentralized systems which generate associated point values</u>

5 points – Runoff enters at least 4 separate small scale structural BMPs onsite

4 points – Runoff enters at least 3 separate small scale structural BMPs onsite

3 points – Runoff enters at least 2 separate small scale structural BMPs onsite

2 points – Runoff enters at least 1 separate small scale structural BMPs onsite

1 point – A singular large scale structural BMP is located onsite

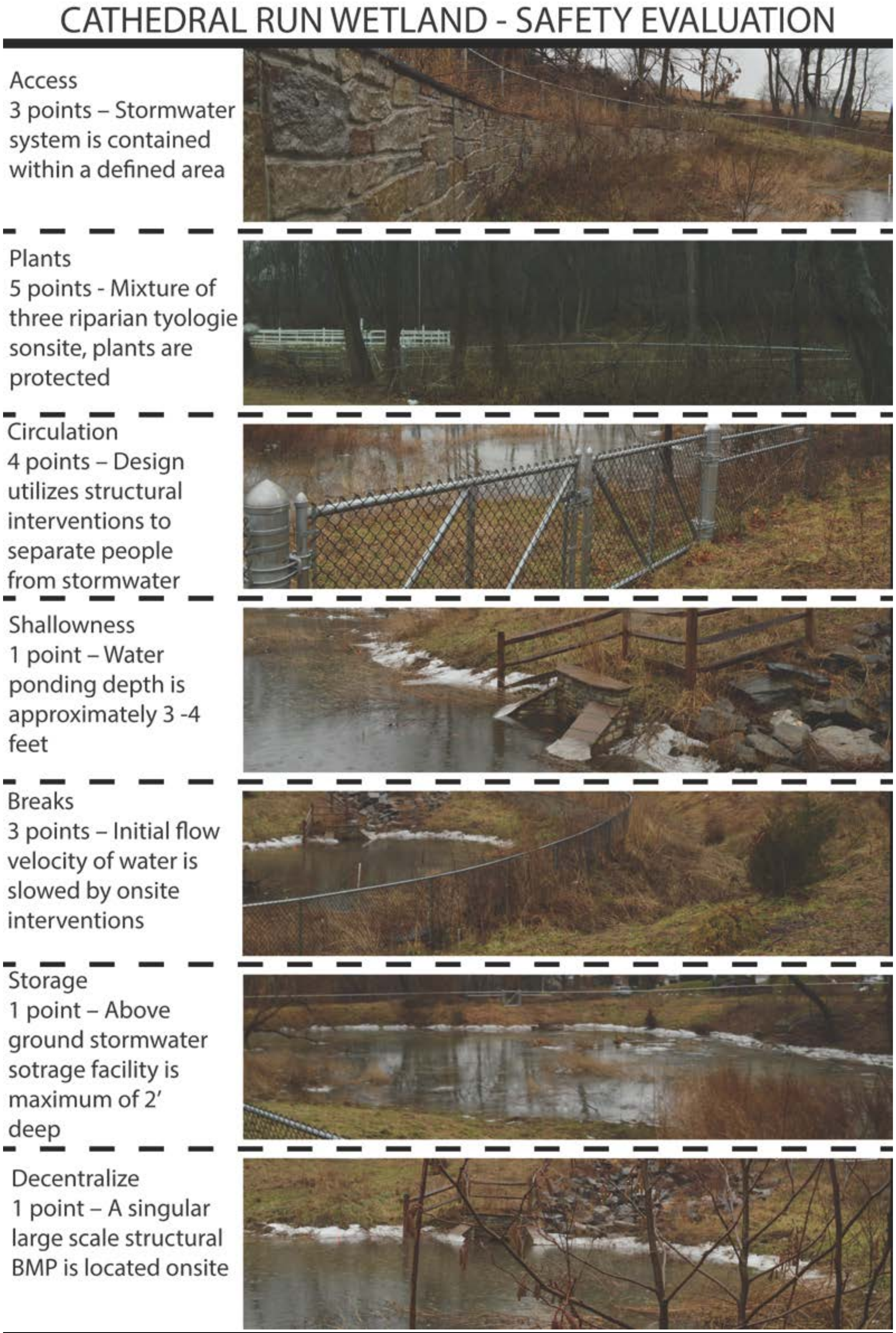


Figure 99. Cathedral Run safety evaluation visualization

Appendix A - Recreation Ranking System

Overlooks

(Echols and Pennypacker Design Techniques)

Create overlooks with views of the stormwater system

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

Examples of overlooks which generate associated point values.

5 points – Stormwater management system is direct focus of visual experience

4 points – Visual experience lets viewers look across or through stormwater management systems

3 points – Stormwater systems create enclosure of visual experience

2 points – Stormwater systems are present onsite, but not main visual focus

1 point – Stormwater system is not in view

Destination

(Echols and Pennypacker Design Techniques)

Create destination points related to stormwater systems

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of stormwater management destination which generates associated point values</u>

5 points – Stormwater system defines experience of site, strong connection to community

4 points – Stormwater system creates a gateway or entrance to a larger park / institution

3 points – Stormwater system is part of a larger park / institution

2 points – Stormwater system is not meant for public use

1 point – Stormwater system is out of sight

Seating

(Echols and Pennypacker Design Techniques)

Provide seating using walls, benches, or tables and chairs with views of the stormwater system

Provide places to sit within stormwater system design

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of seating which generate associated point values</u>

5 points – Benches of varying height/size/material, stormwater system is used as seating

4 points – Benches of varying heights/sizes /material spaced around stormwater system

3 points – Standard benches on site, offer view of stormwater system

2 points – Few benches onsite, informal seating

1 point - Site does not contain any formal/ informal seating

Paths

(Echols and Pennypacker Design Techniques)

Provide paths in strategic locations that ensure encounters with the stormwater treatment system

Connect on-site trails to off-site trail systems and destinations that ensure encounters with the stormwater treatment system

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of pathways which generate associated point values</u>

5 points – Pathway runs along stormwater system, pathway incorporated into surrounding trails

4 points – Pathway runs along stormwater system, not incorporated with surrounding trails

3 points – Pathway glances stormwater management system at least 3 times, informal paths

2 points – Pathway glances stormwater management system at least once

1 point – Pathway does not take visitors to stormwater management system

Entry

Provide clear points of entry to the stormwater system

(Echols and Pennypacker Design Techniques)

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of entry systems which generate associated point values</u>

5 points – Multiple points of entry to stormwater management system

4 points – Singular point of entry to stormwater management system

3 points – Informal entry to stormwater management system (pervious playgrounds)

2 points – Stormwater management system does not host circulation (Rain Garden / Bioswale)

1 point - Structural constraints make the stormwater management system unable to be entered

Exploration

(Echols and Pennypacker Design Techniques)

Make entry points visually inviting or mysterious

Provide a variety of small and large places to play in or explore

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of exploration systems which generate associated point values</u>

5 points – Mixture of landscape elements at multiple distances allow for mystery and exploration

4 points – Winding pathways and sinuous elements create visual buffers

3 points – Stormwater trail promotes site exploration

2 points – Stormwater management system at terminus or along central axis

1 point – Stormwater system is completely out of view

Touch

(Echols and Pennypacker Design Techniques)

Make areas that invite climbing and physical exploration while balancing perceptions of safety with adventure

Create systems that can be safely modified by the user such as small movable river rocks and weirs

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of haptic systems which generate associated point values</u>

5 points **–** Stormwater trail can be easily modified onsite, with small rocks or pebbles

4 points **–** Spraygrounds, rocks and other structural equipment engage users onsite

3 points **–** Visitors can passively interact with stormwater system, water can be touched

2 points **–** Stormwater system not meant for contact

1 point **–** Stormwater management system is out of reach of visitors

GREEENFIELD ELEMENTARY - RECREATION EVALUATION

Overlooks
4 points – Viewers look across or through stormwater management systems

Destination
5 points – Stormwater system defines experience of site, strong connection to community

Seating
5 points – Benches of varying heights and materials, stormwater system is used as seating

Paths
4 points – Pathway runs along stormwater system, not incorporated with surrounding trails

Entry
3 points – Informal entry to stormwater management system (pervious playgrounds)

Exploration
4 points – Winding pathways and sinuous elements create visual buffers

Touch
4 points – Spraygrounds, rocks and other structural equipment engage users onsite

Figure 100. Greenfield Elementary recreation evaluation visualization

<u>Appendix A - BMP Ranking System</u>

Infiltration

(Sustainable SITES Initiative Chapter Guidelines)

Credit 3.5 - Manage Stormwater Onsite

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of visibility systems which generate associated point values.</u>

5 points – Stormwater flows into system onsite and from large surrounding area

4 points – Stormwater flows into system primarily onsite and from small surrounding roads

3 points – Stormwater flows into system onsite

2 points – Some stormwater leaves site

1 point – Site allows for large amount of discharge into sewer system

H2O Demand

(Sustainable SITES Initiative Chapter Guidelines)

Prerequisite 3.1 - Reduce potable water use for landscape irrigation by 50 % from established baselines

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of programming systems which generate associated point values</u>

5 points – Plants on site are chosen to adapt to changing climate and weather patterns

4 points – Stormwater system is used as main plant irrigation system

3 points – Plants on site require no irrigation systems for upkeep

2 points – Plants required some initial watering at beginning of project

1 point – Plantings require excess watering

Soil

(Sustainable SITES Initiative Chapter Guidelines)

Prerequisite 4.3 - Create a soil management Plan

Rubric

Point Value based on water flow system intervention present onsite.

Examples of stormwater scale which generates associated point values

5 points – Evidence that soils were remediated onsite

4 points – Soil remediation happening through successive planting generations/ removals

3 points – Stormwater system is crafted to respond to soil infiltration rates

2 points – Soil onsite is being managed by outside contractor, removing chemical sediments

1 point - Little to no comprehensive soil management plan

Invasives

(Sustainable SITES Initiative Chapter Guidelines)

Control and manage known invasive plants found on site

Use appropriate, non-invasive plants

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

Examples of stormwater system form which generates associated point values

5 points – Invasive plantings are not found onsite, native plantings are abundant in design

4 points – Invasive plantings not present on site, small presence of native plantings

3 points – Invasive plantings are not present onsite

2 points – Some invasives onsite, not prevalent

1 point – Invasive starting to take over majority of the site

Habitat

Credit 4.8 Preserve plant communities native to the Eco region

(Sustainable SITES Initiative Chapter Guidelines)

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

<u>Examples of community pride on site which generates associated point values</u>

5 points – Plant communities use a combination of woody and herbaceous plants

4 points – Plant communities onsite are native and include herbaceous or woody plantings

3 points – The majority of plant communities onsite are native

2 points – Plant communities are present on a portion of the site

1 point – Plant communities do not exist onsite or are non-native

Materials

(Sustainable SITES Initiative Chapter Guidelines)

Credit 5.4 – Reuse salvaged materials and plants

Credit 5.7 – Use regional materials

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

Examples of stormwater system theme which generates associated point values

5 points – Recycled materials / regional construction is evident in design language

4 points – Recycled materials make comprise a majority of structures onsite

3 points – It is apparent that local community is involved in construction

2 points – Some recycled materials are present onsite

1 point – Stormwater system lacks common functioning theme

Local

(Sustainable SITES Initiative Chapter Guidelines)

Credit 6.5 – Provide for optimum site accessibility, safety and way finding

Rubric

Point Value based on Structural Stormwater Management intervention present onsite.

Examples of stormwater presentation which generate associated point values

5 points – Stormwater system serves a wide range of user groups and is at an important place

4 points – Stormwater system serves a wide range of user groups

3 points – Stormwater system is safe for users and is easily accessible

2 points – Stormwater system allows for minimal amount of user groups

1 point – Stormwater system is not accessible by all types of users

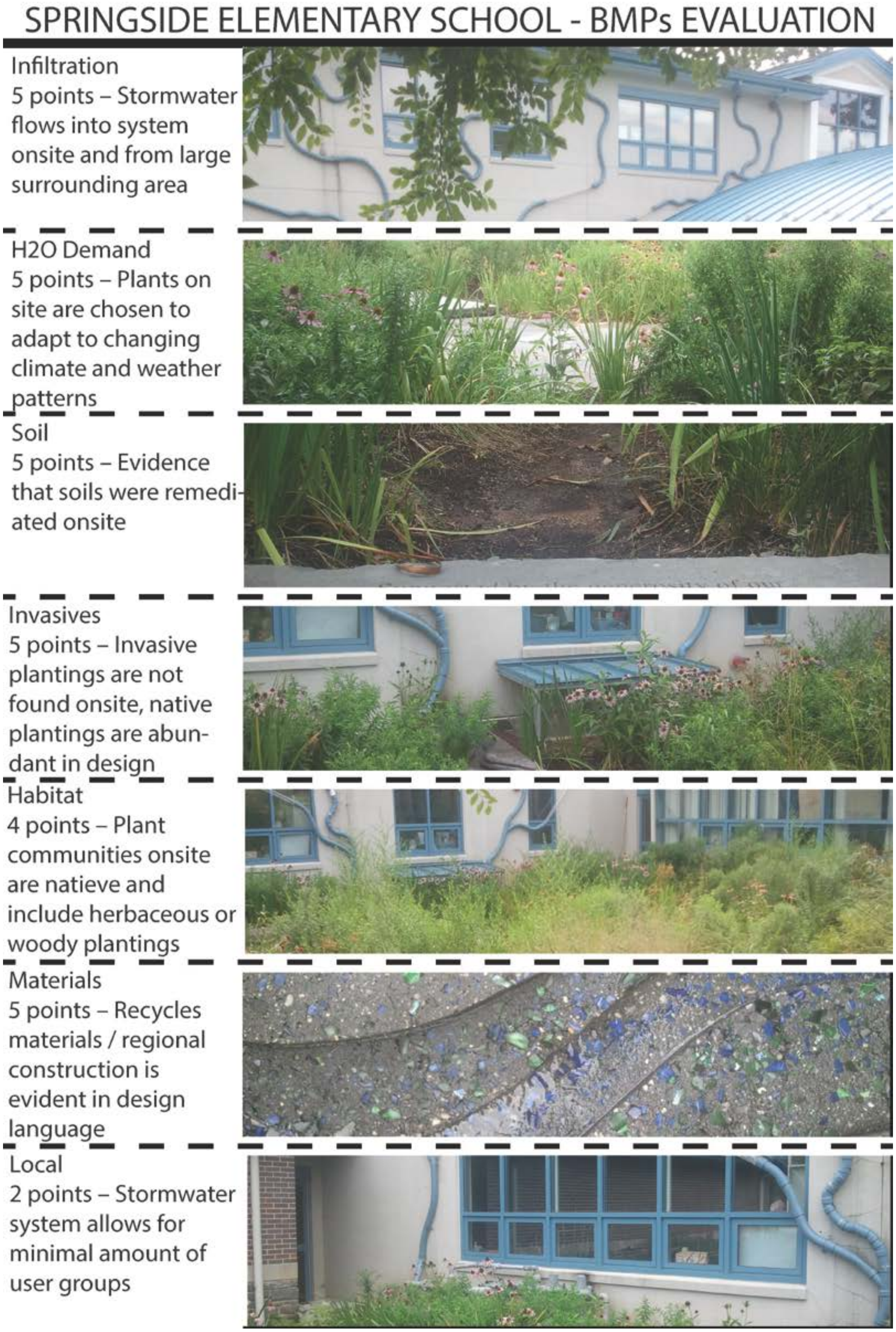


Figure 101. Springside School BMP evaluation visualization

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