5-2011

# Urban Design and Stormwater Management: An Integrated Approach to Public Hardscape Design

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# URBAN DESIGN AND STORMWATER MANAGEMENT: AN INTEGRATED APPROACH TO PUBLIC HARDSCAPE DESIGN

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A Thesis
Presented to
the Graduate School of
Clemson University

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In Partial Fulfillment
of the Requirements for the Degree
Master of City and Regional Planning

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by
Jared Barton Draper
May 2011

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Accepted by:
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## Abstract

Among the hierarchy of motivations, Maslow identifies the social as one of the levels that generates drive in individuals (Maslow, 1970). The urban environment is a place that has great opportunity for social interaction with design and planning of public spaces. Public spaces serve an important function in society and the design of these spaces can attract or repel a population. As specific elements are incorporated in public space and especially public hardscape design, designers should not neglect the issue of sustainability. According to the Brundtland Commission, sustainability includes the "policies and strategies that meet society's present needs without compromising the ability of future generations to meet their own needs" (World Commission of Environment and Development, 1987). Implementation of public spaces can provide for the current and future population's need for social interaction. In planning and designing these spaces the protection of natural resources must be considered for posterity. The urban built environment has had enormous impacts on the natural world. Multiple cities across the United States operate with a combined sewer and wastewater system. Use of this type of combined system creates the risk of overflow of polluted stormwater and untreated sewage into local rivers and streams during heavier rains (Paul & Meyer, 2001). Pollution alone due to runoff can be detrimental to the ecosystems that depend on local water bodies, but the additional risk of combined sewer systems and the dangers

that can result in larger storms presents the question of what steps can be done to reconcile the urban environment with the preexisting natural world? Designers must consider factors such as stormwater runoff when creating buildings, streets and public spaces. Through water quality policies, enacted by the EPA, regulations have been written and implemented to reduce the pollution that is discharged into local water bodies. Stormwater management practices have been developed to not only reduce runoff, but treat the water as well. However, there is more than can be done with public spaces and their design to recreate natural hydrological conditions while creating an attractive and vibrant place. The impacts of impervious surfaces and stormwater have eye-opening consequences. According to the King County, Washington stormwater services, stormwater impacts include contamination of local waterbodies, killing fish and harming wildlife, flooding, and potential groundwater shortages due to impervious surface (King County, 2010). Technology has improved and impervious surface materials have become porous pavements. This literature review will attempt to identify the state of the art in respect to public hardscape design, building materials and stormwater management practices. It is the goal of this research to discover how a new, more sustainable public hardscape can become the standard for design through the integration of stormwater management practices, effective use of permeable materials and thoughtful design.

# Dedication

I wish to dedicate this Thesis to my parents and and my soon to be wife. To my parents, thank you for your support in pursuing graduate school. I appreciate how you have influenced me to always strive for excellence in everything that I do. Thank you for encouraging me to learn but also for teaching me valuable lessons that I would never have learned in a classroom. To my soon to be wife, Lizzy, thank you for your encouragement during the times that this research was difficult and the end seemed far away. Thank you for believing in what I was capable of and knowing that what I was doing was important, even when I might not have seen it. I dedicate this work to you.

# Acknowledgments

I would like to extend a thank you to my committee for all of the help that they provided during this process. Thank you for supporting my research and allowing me the freedom to spend my time investigating something that I am passionate about. A special thanks, also, to my classmates for the encouragement when research and writing was difficult. It has been a blessing to work with all of you and to bounch ideas off of one another as we prepare to enter the planning field.

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# CHAPTER 1: INTRODUCTION

## I: Problem Statement

According the latest National Water Quality Inventory report, "about 44% of assessed stream miles, 64% of assessed lake acres, and 30% of assessed bay and estuarine square miles were not clean enough to support uses such as fishing and swimming" (EPA, 2009). Water bodies across the nation are facing problems due to urbanization and specifically stormwater runoff. Large amounts of impervious surfaces and buildings have contributed to an increased amount of runoff and in turn increase pollution. Pollution during storms can also be attributed to combined sewer overflows that carry both raw sewage and stormwater in the same piping. During storms these systems have been designed to overflow, allowing untreated sewage along with stormwater to flow into local water bodies (Paul & Meyer, 2001: 215). In a report by the EPA, it is estimated that around "850 billion gallons of untreated wastewater and stormwater are released as combined sewer overflows each year in the United States" (EPA, 2004). With the state of our national water bodies and pollution caused by combined sewer overflows, best practices should be investigated with regard to stormwater runoff in all elements of the urban fabric. Public hardscapes contribute to urban runoff and creative and environmental design should be applied in such areas designed and used by the public. However, design alone often may neglect environmental issues that are associated with public spaces, specifically stormwater management. Advancements in stormwater management practices as well as new technology in paving materials provide opportunity for progress in public space design within urban environments. Research in the realms of urban design, stormwater management practices, and permeable paving materials may identify the possibility of integration for urban public spaces.

## II: Background

Urbanization has increased the amount of impervious or hardened surfaces that are found within cities. Increased impervious surface area can lead to urban flooding and pollution that flows into local water bodies (NCNERR, 2007). Both flooding and pollution pose threats to the natural environment and public health. The displacement of polluted stormwater due to runoff can have extreme negative consequences on native fish and wildlife that depend on local water bodies (EPA, 2006). The pollutants picked up and carried by urban stormwater runoff can affect the ground water or drinking water quality (Gaffield et al., 2003). This risk to the public health can be mitigated with appropriate stormwater management practices and environmental impacts incorporated into design.

Potential threats of urban stormwater runoff have, in part, caused legislation such as the Clean Water Act along with its amendments and the creation of the

National Pollutant Discharge Elimination System permitting program. However, within the urban environment, there are needs of the public for spaces to interact and gather. Such public spaces often take forms with the urban context that rely on impervious surfaces, creating public hardscapes. The design of public space is essential in inviting the public use of the space, and many physical and social attributes should be considered (Carr et al., 1992; Childs, 2004; Whyte, 1980). With the growing need to address urban stormwater runoff, the design of public hardscapes may be able to incorporate stormwater management practices to reduce the impact of urban stormwater runoff on the natural environment, while protecting the public's health, safety and welfare (Gaffield et al., 2003). Through this research, the potential for integration of stormwater best management practices and permeable paving materials with public hardscape design will be investigated.

## III: Research Questions

1. *How have successfully-designed public hardscapes integrated (if at all) stormwater management practices and permeable paving materials?*

2. *What has promoted or impeded such integration in these spaces?*

3. *How can such integration be improved?*

## IV: Objectives

1. *To identify examples of successfully designed public hardscapes which have integrated stormwater management and permeable paving materials.*

2. *To understand how this type of integration has been promoted or impeded (e.g. by public policies, costs, lack of communication between disciplines, etc.).*

3. *To improve standards of professional practice by identifying ways to overcome barriers and promote improved stormwater management methods in the design of public hardscapes.*

## V: Purpose

Public space is a vital component of the urban environment. It is a space that gives opportunity for social interaction. However, urban design should not neglect environmental issues, such as stormwater management. Since the location of public space can be found within an urban context, the potential for increased runoff pollution is heightened due to the impervious nature of the urban setting. Research that seeks to integrate stormwater best management practices and permeable paving material technology with urban design is important for the United States in order to reduce the impacts that urban development is having on natural systems. The threat of pollution due to stormwater runoff is increased in cities that are served by a combined sewer and wastewater system, which can be found in over 700 cities across the nation (EPA, 2008). Public space itself should not be abandoned, but it is worth investigating how urban design can not only create an attractive and useful place, but also how the integration of stormwater management methods and permeable materials can enhance the quality of a place, as well as diminish the negative impacts.

# CHAPTER 2: COMBINED SEWER SYSTEMS

## I: Combined Sewer Systems

At the introduction of combined sewer systems (CSS) in the 1850s, the idea was progressive and allowed cities to move away from the primitive ditches that were being used. A CSS would help to dry streets and keep both stormwater runoff and sewage underground in a network of pipes (Tibbet, 2005). Although a drastic improvement to the previous system, during a larger storm, these combined systems would be filled with both sewage and stormwater runoff and would spill over into various parts of the city and local waters. This spillover came to known as combined sewer overflow (CSO). As development continues in the urban context, the impact on a city's CSS can be significant. Repairs and expanding the capacity of such a system may be costly but are needed in order to protect water bodies from harmful pollutants that can result from CSO.

## II: Combined Sewer Overflow

The EPA has attempted to control CSOs and published a final policy in 1994. According to the EPA, "CSOs consist of mixtures of domestic sewage, industrial and commercial wastewaters, and storm water runoff" (EPA, 1994b). During a large storm, there can be a multitude of pollutants that can be carried by a CSO, including suspended solids, toxic pollutants, oil and grease. Through the control policy mandated by the EPA in 1994, municipalities were charged with drastically reducing or eliminating CSOs (EPA, 1994b; Tibbets, 2005). Dangers to the environment and human health had been part of the reasoning in taking action against CSOs according to the control policy (EPA, 1994b). Even with the regulations that were set up by the EPA in 1994, pollution continues to be dumped into local water bodies. Hundreds of billions of gallons of polluted wastewater and stormwater were reported to have entered local waters in 2004 (EPA, 2004). Removing the CSS can mitigate the impacts of CSO altogether; however, such a process is costly. As population grows in many of the cities that continue to use CSSs, the risk of CSO may increase as well.

## III: Reducing the Burden on CSS

One approach that can be taken is to reduce the stormwater runoff that reaches combined systems, removing part of the load that the system has to carry. Section 319 of the Water Quality Act, 1987, established funds that can aid in the control of nonpoint source pollution. Originally this was established to reduce pollution from agricultural lands and sprawling communities (River Network, 2011b). However, in more recent years, the funds have been available to urban areas to help with stormwater programs (River Network, 2011a). The reality is that as long as cities across the United States continue to use CSSs, wet weather will also continue to pollute local waters. Public hardscapes may be a starting point in the concern of stormwater runoff, especially with financial backing through section 319. With appropriate design and stormwater management practices, these public realms can relieve CSSs and help to reduce the likelihood and frequency of CSOs in the urban environment. If public hardscapes were to be used to treat and retain stormwater runoff, reducing the burden on the city's CSS, these urban spaces must still be aesthetically pleasing and utilized by the public. The threats that are posed by CSO are not insurmountable, but will take thoughtful planning and design of the urban environment, including public spaces.

# CHAPTER 3: HARDSCAPE DESIGN

## I: Introduction

In approaching the literature on urban design with regard to squares, plazas and other public hardscapes it will be essential to begin with a brief history. The history of public space shows that this element of the urban fabric has not been a recent phenomenon and has stood the test of time. Following the history, the term public space will be defined for the purpose of this research. Furthermore, hardscapes will be defined to narrow the type of public spaces that will be considered. These definitions are key to the following sections that will discuss specific design characteristics of public space. Public space design observed in this research involves two different classifications: social character and physical design. First, the social character of public space is vital to the continued use and vibrancy that is experienced by users. Social characteristics can often attract or repel local populations from using a public space. However, it is not only the social character that appeals to the potential user; therefore, the physical design of a public space will be considered as the second classification of design. Physical design that is aesthetically pleasing will often engage the interest of the local population. For this reason, specific physical design attributes will be investigated along with social attractors, to build a comprehensive standard for design of squares, plazas, and other public hardscapes.

## II: History

Since the creation of the urban environment, there has been a public gathering or public space to encourage or provide a setting for social interaction. It has taken many forms through history, including some of the earliest forms: the Greek agora and the Roman forum. These spaces were central to the city and designed for meeting and gathering of the local people and in some cases were used as a marketplace. The Greek agora and Roman forum were intimately tied to vitality and "richness of public life" (Carr et al., 1992: 53). Location and design invited the population into the gathering space as a destination or simply a thoroughfare in which to engage with their community. Over time, the centrality of public spaces for cities has dissipated. There have been changes in use of public space in Western culture. While such spaces still exist, the creation of motorized travel, especially the personal automobile, has lessened their value. Now, with an auto dominated society and sprawling suburbs, a greater number of trips are taken with the car. Social interaction is not taking place on the trip as much as it is at the destination (Moughtin, 1999: 131).

In the United States, public spaces have gone through both acceptance and rejection. Streets became one of the major places for public interaction in the seventeenth and eighteenth centuries. Later, the acceptance of the common green and town square added to the amount of designated public space, but later generations would not be so quick to use these spaces. Suburbanization and issues within cities caused a decline in public life, and marked a possible movement toward a reduced need for public space (Carr et al., 1992: 3-5). It is during this time of greater private life that public space experienced a degree of rejection from the people of America. However, in recent decades resurgence occurred in the public realm and the urban environment once again was revitalized with public life. Carr et al., 1992, mentions that hundreds of new public spaces were built in the second half of the twentieth-century along with restoration of older existing public spaces (1992: 7). Public space appears to have its place in our society, even though it was pushed aside for a period of time. New and old public spaces should address the questions of the present day that deal with sustainability and environmental accountability.

## III: Public Space/Public Realm/Public Domain

The terms public space, public realm and public domain will be used synonymously throughout this review. The public realm or public space is comprised of two parts: the public components of the physical space and the manner in which community decisions are made for the public space (Lang, 2005: 7). Urban design is involved in both parts of the public realm. The physical elements utilized for public spaces are the products of urban design, but the purpose for the creation of the space directly influences the process of urban design. The position taken by Lang is that the public realm includes those areas to which the public has access to, even if that access is restricted at certain times. It consists of both indoor and outdoor spaces, which include public buildings, arcades, streets, squares, plazas, and parks (Lang, 2005: 7). The scope of this research will address only the outdoor public spaces. The problem with public space is that there is an increasing amount of property within the urban setting that is being privatized. Therefore, the definition of the public realm carries with it a certain degree of ambiguity. The control or lack of control of pubic space will follow political ideas and direction. Lang goes on to describe the public realm as a "set of behavior settings" (Lang, 2005: 8). According to Lang, a behavior setting consists of a behavior pattern, a pattern of built form (milieu), and a time period (Lang, 2005: 8). Public space is intimately connected with the people that use and interact with the physical environment. It is defined by the people who are part of the public domain, as well as the activities that occur, the design features of the space, the buildings that frame the space, and the access to the space.

## IV: What is a hardscape

Hardscapes are the focus of this research on public spaces. The term hardscape is defined as a place that uses a form of pavement or solid material for its foundation and does not have a majority of green space. They include public squares, plazas, and streets. The scope of this research will exclude streets due to time constraints. In defining hardscapes in this way, city parks and other green open spaces will be excluded. Further defining a hardscape as a particular place that has been altered from its natural state due to grading and laying of pavements such as concrete, asphalt, etc.; it will be found that a hardscape often changes the natural hydrology of a particular place. Public hardscapes serve the same function as public spaces often by blending into the urban environment through the use of paving materials. This type of public space does not exclude natural attributes such as vegetation or small green space components, but are characterized by change of the natural state and use of pavements.

## V: Social Character

Design of public spaces may be lacking with respect to the integration of stormwater management methods and permeable pavements. In creating public hardscapes that are capable of dealing with stormwater in an efficient and environmentally sensitive manner, the appeal of the space itself should not be forgotten. The social character of public space will be investigated to understand the implications that it has on the appeal and attractiveness of a place. This research makes use of the understanding of Carr and his associates that, "interaction of people and places and how this affect the ways settings function," is a key component of public space (Carr, et. al., 1992: 85). Local populations have both needs and rights in public spaces. No matter how public spaces address the needs of stormwater or what choice of pavement that is used, overlooking the public's needs and rights may result in an abandoned space.

## VI: Public Space Social Needs

It is of first importance to design and plan public hardscapes for the people who are going to be using the spaces. Many spaces are created without serving the real needs of the local population. The public realm can often be the centerpiece that is needed for the city. In many cases, the identity of the city itself is found in the public square or plaza. Such focal points not only bring the local community into interaction, but also prompt the visitor that they have truly "arrived" (Moughtin, 1999: 90). Cities are filled with public spaces, some of which have been designed for social interaction, and others that have become a public space due to the interaction that occurs. Carr states some public spaces are, "proposed, built, and assessed with assumptions about what should be done in them" (Carr et al., 1992: 87). Therefore, in planning new public hardscape designs, it is vital that the needs of the people take first importance. Local populations will desire different things from their specific public hardscapes, however, according to the literature, there are basic needs that must be fulfilled in order to have successful public space design.

### A). Comfort

Spaces that are used the most are places that are comfortable to access and remain within. This idea of comfort includes sunlight, natural features, and safety from crime and traffic. Le Corbusier mentions sunlight as one of the first things of importance when designing public space (Le Corbusier, 1934). Sunlight not only serve the purpose of warmth and visibility within the space, but also contribute to safety. Along with other lighting, sunlight offers protection for groups or individuals that may feel vulnerable. Through increased visibility there is opportunity to see others and for a great population to see the events that occur within the public space. Sunlight and safety create a sense of comfort within a space much like the presence of natural features. Trees and other vegetation can offer shelter from overbearing sunlight or become a barrier to wind (Carr et al., 1992: 92-94). Natural features additionally offer an aesthetic appeal and provide stormwater management functions that will be discussed in more detail in later sections.

**B). Relaxation**

The busy life within an urban environment may take its toll on local citizens. Public hardscapes can be the escape that is needed for individuals who have not stopped since their morning coffee. The need for relaxation is not often incorporated within public hardscape design, but including seating, chance for retreat, and natural and water features can offer the restoration that is needed to unwind and recharge. Seating is a basic need in public space and has been observed to attract people (Whyte, 1980: 28). Once people have a place to sit, further relaxation can come from the separation from the street and the presence of natural and water features within the public space. Trees and other natural features enhance the sense of retreat, while water is a feature that comes in contrast to the urban environment and can accent public space (Carr et al., 1992: 103). The need for relaxation is substantial due to the nature of the urban environment and is a need that proper planning and design can, in part, fulfill through public hardscapes.

**C). Engagement**

Design of public spaces must recognize the users of the spaces and how the individual interacts with the space. According to Crankshaw, there are elements that should be incorporated into design in order to enhance the experience of the public realm for the local resident or the visitor (Crankshaw, 2009). The need for engagement can be identified in two ways for public spaces, passive and active engagement. Passive engagement consists of the events and activities that happen within and around the public hardscape. This is the need for an individual or group to encounter or see something within the setting. Passive engagement reveals that one of the greatest attractors to public spaces is other people. Whyte discusses the great fascination that people have with watching other people (Whyte, 1980: 13). Passive engagement also includes the opportunity to shop and eat in or around the public space, where street performers, formal events and ordinary people can be easily seen. Natural and water features often engage the public and do not require participation (Carr et al., 1992: 108). Active engagement is often the object of passive engagement and is associated with the experience that transpires with the people in the public space or the space itself. In small public spaces, the proximity to others often encourages social interaction and connection (Alexander et al., 1977). A variety of activities can occur within public space and are available to all ages. From entertainers to young children, the active engagement of public space is a need that not only attracts the participants but the observers as well. "Their active qualities may be among the most important influences on the staying power of places, separating the ones that are boring and not worth a second visit from those of enduring interest" (Carr et al., 1992: 125).

## VII: Public Space Social Rights

The key element in public spaces is the public. Since public spaces are planned and designed for anyone and everyone, there are certain rights that the public should have concerning public spaces. The question that should be asked when analyzing public hardscapes or developing a new space is: Can people act and use the public space for their individual purposes (Carr et al., 1992: 137)? The following rights have been adapted from their original terms presented by Lynch, but the larger ideas remain the same (Lynch, 1981).

### A). Access

The ability to use a space begins with the ability to access that space. Public hardscapes should be concerned with physical access and visual access in their planning phase. Physical access may seem apparent for those who are fully capable of walking up steps or over curbs, but access should be granted to all, despite any type of disability. Many groups of people may be excluded from public space if not considered by the designer, such as the elderly, people with disabilities, and the extremely young to name a few (Carr et al., 1992: 138). Along with providing adequate entries into public hardscapes, a connection to adjacent sidewalks further promotes access and invites a larger population to enter (Whyte, 1980). Visual access should also be granted to the public. This part of access is related to the comfort and safety of a hardscape because the ability to be seen can deter crime. Visual access should also identify the public hardscape as a space for a public purpose (Carr et al., 1992: 144). The right to access is further discussed as a physical component to public hardscape design, but remains an important right of the public.

**B). Freedom of Action**

Not every person desires to use public spaces in the same manner. The right to freedom of action implies the ability to participate or not participate in whatever activity that person wishes. Having this right does not mean that public hardscapes should be designed at an enormous and irrational scale to allow all activities to happen simultaneously. Rather, spaces should be planned to offer opportunity for a multitude of activities with the recognition that the space will be shared by its users. Restrictions to this freedom are often due to lack of attention to the comfort and accessibility of the space. This lack of attention can produce the perception of an unsafe place for women and the elderly and an unavailable or accessible place to all groups. The influence physical design has on freedom of action is tremendous (Carr et al., 152-154). Each space is designed for a specific population and location, and the right to freedom of action may increase the number of users in each space.

**C). Change**

Lynch comments that the, "ability of a place to evolve and change over time is an important quality of good environment" (Lynch, 1972). The desire of this research is to focus upon what can be done to address the environmental issue of stormwater within public hardscapes, but will not neglect the importance of creating a good environment for the sake of improved results. Therefore, it is recognized that public hardscapes should change in both temporary and permanent ways over time. Temporary changes include decorations, picnic tables, and potential objects necessary for recreation. Public hardscapes that can endure temporary changes allow a greater range of events that the public can participate in while using the space. Permanent changes are also important to public hardscapes. These changes include murals and playground construction that offer an opportunity for passive or active engagement in public hardscapes (Carr et al., 1992: 169-175). Changes can occur seasonally or daily but the frequency of change is not as important as the capability for change.

The individuals and groups that interact within it will use public space uniquely. Often, the public realm is important as an extension of a financial investment. Developers use the improvement of public space as an extension of their own development. This decision may be voluntary and seen as an investment, or involuntary but implemented due to public pressure (Lang, 2005: 10). Thus, the public realm plays a powerful role as a functional as well as aesthetically appealing space. Public spaces such as squares and plazas should not only be designed well, but should be numerous throughout an urban environment to provide for the full range of inhabitants. Each should be designed with the users in mind; in order to create a large enough space that will not exclude parts of the public, yet not too large that social interaction is omitted (Moughtin, 1999: 87). Community life was once found in the public space of the city. It was a focal point in which business and social interaction took place, a true functional component of the city (Moughtin, 1999: 88).

## VIII: Physical Design

"The single most important function of an element in the city is the symbolic meaning attached to it" (Moughtin, 1999: 88). Public squares are places that include not only lighting, statues, public buildings, and natural features, but serve as a place that people can gather and socialize (Moughtin, 1999: 123).

Le Corbusier listed the basic urban design elements as "the sun, sky, trees, steel, and cement, in that order of importance" (Le Corbusier, 1934). The uses of all of these elements mentioned by Le Corbusier are common in the public realm. Public space is not only concerned with the use of these design elements, but should be designed with the public's values in mind. It is the desire of urban design to create space that can reflect what the public is and what it hopes for itself through the built environment (Moughtin, 1999: 14). Cities and their populations are different and the design of public space should be based upon the character and culture of a specific location. However, there are physical design guidelines that should be followed when creating a public hardscape.

Urban design attempts to create the public realm as part of the larger city or town. Through this, there is recognition of the order that comes with the urban setting. Each detail of development, whether a public space or a new structure that frames the public realm, must fit into the larger setting as part of the whole (Moughtin, 1999: 26). By designing space and place as part of a larger entity, the city becomes a unified place rather than individual pieces. Along with designing public hardscapes to fit into the existing urban fabric, each should also be designed to attract public use. This is not always the apparent reason in creating public spaces, especially when there is neglect for the amount of seating or shelter from sun and wind (Carr, et. al., 1992: 15). Often it may be the multiple architecture firms that are involved that cause several authentic, but not cohesive developments and public hardscapes. Despite the unique developments that fill the city, the public domain can still be used to bring the city together.

The location and the culture of public space will often shape the character of the place. Urban design should be careful not to neglect the locality when designing public hardscapes. However, there are attributes that are, to a degree, universal in successful public space design that should be identified and utilized in public hardscape implementation. Not all public space attributes are transferable from one location to another due to multiple factors, but those certain characteristics can be adapted for any location to improve the design and appeal to public use. Elements of urban design apply to both the structures that are built, large or small, as well as the space that is created, directly or indirectly, by the combination of buildings. It is the focus of this part of the literature review to understand what factors of physical design can be identified as factors of successful or good design, with respect to varying locations, cultures, and climates.

**A). Portal**

The entrance of the public realm is vital to the use of that space. The beginning of the public domain creates a first impression that has the potential to invite or reject the public (Moughtin, 1999: 98). While the portal to public space should create an inviting impression, it should also be seamless within the urban environment (Childs, 2004: 147). The doorway to public spaces play a duel role of creating a distinct place while not causing the visitor or local population to feel excluded from the space.

**B). Enclosure**

The sense of enclosure is the staple of this of the square, plaza or urban public hardscape. It can be compared to an outdoor room that is framed by the buildings that are surrounding it (Moughtin, 1999: 99). The frame does not have to enclose the space completely. There may be opportunities to move from the public hardscape into connected areas. Childs mentions the importance of corners, "Weak corners will diffuse and strong corners will reinforce the sense of enclosure" (Childs, 2004: 138). Effective public hardscape design must not only consider the design of the space itself, but the surroundings of the space in tandem. Framing public space can produce a room-like feel for the visitor, addressing needs such as comfort and relaxation (Carr et al., 1992: 92;98). Land uses within the framing buildings can create vitality and attract people to not only use public spaces, but also local businesses (Childs, 2004: 133). The sense of enclosure is further explained in regards to building heights and continuity.

i). <u>Building Height</u>

Heights of the surrounding buildings can change the perception of enclosure for the user of the square. A relationship between the size of the square itself and the buildings that frame the space should be established. Relative uniformity is also a key issue with regard to the heights of the buildings along any specific side of the square. There are many different opinions about heights of buildings and what proportional relationships should exists. According to Sitte, the height of the principal buildings should be considered the minimum dimension of the public space (Sitte, 1945; Collins and Collins, 1986: 182). Essex County Coucil provides another proportion which they find to be a compatible relationship of 1:4, height to width (County Council of Essex, 1973: 65). Although these authors provide favorable dimensions, there is no set rule of proportion and successful squares can and have been created while straying from such dimensions. However, it should be necessary to take account of the proportion when creating an enclosed square.

ii). Building Continuity

For the purpose of the enclosed square, the types of buildings that surround it have great importance. Repetition of building and house types can enhance the sense of enclosure if these similar types are facing the public space (Moughtin, 1999: 102). There may be exceptions to continuity if there is a dominated square, which has a building or group of buildings as a focal point of the space (Zucker, 1959: 11). However, in either case, the sense of enclosure is important. The placement and appearance of the buildings create a more cohesive frame to the public hardscape.

**C). Seating**

The creation of a room-like public space is a beginning step in physical design, but a room without seating may often be found empty. Planning for seating is essential for successful public space design and without it, public space, no matter how aesthetically appealing are at risk of being under-utilized. William H. Whyte reminds researchers, planners and designers of the obvious but entirely true fact that, "People tend to sit most where there are places to sit" (Whyte, 1980: 28). Opportunities to settle should be placed along the frame of public spaces, benches, chairs, places to lean, to attract those that enjoy watching others who interact within the space (Childs, 2004: 123). Two important levels of seating must exist within public hardscapes for the public to use. Primary seating describes the chairs, benches, tables that are usually the first spaces to be sat in and enjoyed. However, the amount of secondary seating should match or exceed the amount of primary seating. Secondary seating includes options that are not initially viewed as seating, such as walls, edges of planter beds, street light bases, etc. (Childs, 2004: 157). The existence of seating is a must for public hardscapes and should provide primary seating while planning for a substantial amount of secondary seating.

**D). Access**

Public hardscapes will not be used if access is denied. Access is not only a right of the public for public space, but it is also a design feature that can and has been forgotten. Public spaces can be connected to other parts of the urban environment. The pedestrian path, much like public hardscapes, in theory, should be accessible to all but is not always the case. Good planning for the sidewalks and a destination such as a square or plaza should incorporate the needs of the elderly, very young, people with disabilities, and those with wheelchairs or pushing strollers (Crankshaw, 2009: 168-169). Physical access may take on many forms, but should be "without barriers to entry and well connected to paths of circulation," according to Childs (2004: 144). It is in the interest of public spaces to provide access to the entire population and design accordingly. The accessibility of the public realm should also extend to the bicyclist. A major hindrance to bicycle transportation is the lack of parking for this mode of transport. Bike parking areas should fit into the design of the pedestrian path. Close attention should be paid to where bike racks are placed, in order to avoid obstructing the pedestrian path or create conflict between cyclists and walkers (Crankshaw, 2009: 169).

**E). Lighting**

Lighting is an important feature of any public realm and is responsible for a feeling of safety and visibility or insecurity and dim views. Multiple factors are included when planning for the lighting of any space. Lighting includes both sunlight and artificial lighting. Access to sunlight is an important component to any public space. However, artificial light can provide many benefits and are necessary for use beyond daylight hours (Childs, 2004: 159). Each factor such as pole height, illumination type, power, and shape of the fixture, can affect the quality of light. While lighting is essential to create a feeling of security, an area should not be over illuminated and cause excessive light pollution, waste of energy, and nuisance to neighboring communities or businesses (Crankshaw, 2009: 181).

### F). Vegetation and Trees

Various types of plants are important design features within public spaces. Appropriate landscaping can create a sense of place. With plants that have human scale, a connection with the natural environment can be established along with a feeling of confidence to use the public space (Miller, 2009: 71). Trees especially serve a functional role in downtowns as well as in public space. Spacing and size of the trees are important to the effectiveness of trees in an urban environment (Crankshaw, 2009: 183-184). Trees can provide shading, wind protection, as well as aesthetic quality to urban spaces.

## IX: Conclusion

Design only works when it is created for the people who are going to actually be using the public space. Good design is based upon the input of the community that will utilize the specific public space the most. The number of activities that can occur within the public realm is limitless, however, public space can be arranged to accommodate the runners, nearby churches, social groups, dog walkers, and many others (Miller, 2009: 62-63). Safety within the public realm increases the likelihood that the space will be used. Although there is usually a degree of enclosure that comes with a public space, there can also be open views to provide a heightened sense of security (Miller, 2009: 63-65). According to Whyte, the most used and safest places are those where more women are found. This is due to the finding that women are often more cautious and discriminating when going to a place alone than men, therefore being in public space alone represents an acknowledged sense of security (Whyte, 1980: 18). Public hardscape planning and design should provide for the social and physical needs of the community. Although there are a multitude of public hardscapes across the nation, frequently the design of public hardscapes ignores the issue of stormwater runoff that is associated with their impervious nature. The literature has described components of public space that attract users and create successful spaces. The following explores stormwater best management practices that when integrated into design would address runoff consequences without hindering public space design.

# CHAPTER 4:   STORMWATER MANAGEMENT

## I:   Introduction

During rain storms, water that falls onto impervious surfaces flows to the nearest storm drain or local water body.  This water can come from events other than a rain storm, such as a snow melt or street wash water, all of which are defined as stormwater (EPA, 1990: 47995).  For the purpose of this research, the type of stormwater runoff that will be addressed will be non-point source pollution. Non-point source pollution "has been recognized as the leading threat to surface water in the United States" (EPA, 1994).  Throughout this research, stormwater runoff, will be synonymous with non-point source pollution.

Stormwater runoff problems are nothing new to local land-use decision-makers. However, the principal concern about runoff has always been safety, with the focus on directing and draining water off of paved surfaces as quickly and efficiently as possible. Once off the road and out of sight, stormwater has been largely out of mind—downstream consequences be damned (or dammed). Regulations have been expanded in recent years to include consideration of flooding and erosion, yet these factors fall far short of a comprehensive and effective approach to mitigating the water quality impacts of development (Arnold & Gibbons, 1996).

The Environmental Protection Agency (EPA) has worked hard since the agency's creation to reduce the externalities of development and the population has on the environment. Stormwater runoff is often not thought of once it is out of sight, but the consequences associated continue long after it moves off of impervious surfaces (Arnold & Gibbons, 1996). With the focus of this research on public hardscapes in relation to stormwater management, it is imperative to identify the role of the EPA along with the regulations and standards that exist for stormwater management. This section will introduce stormwater best management practices (BMP) that have been created and tested by the EPA and are now considered standard methods for stormwater management.

As mentioned previously, porous pavements are an accredited stormwater BMP recognized by the EPA. For this reason, the following will not incorporate porous pavements, since previous explanations exists. However, the number of stormwater BMPs is large and for the scope of this research must be narrowed. Based on the focus of public hardscapes, structural BMPs will be the category to be researched. According to the EPA, "Structural BMPs include engineered and constructed systems that are designed to provide for water quantity and/or water quality control of storm water runoff" (EPA, 2006). Design of public spaces focuses the need for physical features that will effectively deal with stormwater, such as structural BMPs. Based on previous literature on successful public space design, the structural stormwater BMP field will be narrowed even further. Two subcategories of structural BMPs, vegetative systems and wet ponds, will be the focus of the following research. The selection of vegetative systems has been based upon reading the literature on successful public space design. A quote from William H. Whyte to Lyden B. Miller in regards to the Conservatory Garden brings this reasoning to light: "I should have thought of horticulture when I made my list of elements for successful urban places. You must make it part of the mix from now on" (Miller, 2009). The reasons for wet ponds to be a focus for research is based upon the appeal that water has on people in public spaces (Carr et al., 2003: 103, 108). Narrowed stormwater BMPs, based upon public space design principals, will allow thorough discovery of BMP operation and if there is potential to integrate these management methods into public hardscape design.

## II: Best Management Practices (BMP)

The EPA defines a BMP as a "technique, measure or structural control that is used for a given set of conditions to manage the quantity and improve the quality of storm water runoff in the most cost-effective manner" (EPA, 2006). These practices are created for specific purposes of performance, effectiveness and efficiency when dealing with stormwater runoff (Strecker et. al., 2001: 144). These measures are ways to monitor the water that moves through the BMP or BMP system as well as the ability to reduce pollutants carried by stormwater.

Specific to this research, vegetative systems and wet ponds will be explored for the purpose of integration into public hardscape design, along with permeable materials. Both vegetative systems and wet ponds incorporate the process of infiltration. According to Shaver, benefits from infiltration include, "groundwater recharge, low stream flow augmentation, water quality enhancement, and reduction in the total runoff volume" (Shaver, 1986: 270). A component of successful public space design is openness and visibility (Carr et al., 2003: 94), which in many cases would allow for increased surface area for rainfall. Due to an increased surface area, the need for stormwater BMPs that address infiltration is vital for a sustainable form of public hardscape design.

## III: Need for Stormwater Management

### A). Urban Environment

Urban areas are defined by a large percentage of impervious surfaces that are used to move higher densities quickly and efficiently. However, these impervious surfaces generate problems when dealing with stormwater since the natural hydrology of the area is disturbed due to urban developments. The creation of cities alters the natural hydrology in a series of steps, from clearing vegetation, installing roads, re-grading surfaces, and the building of actual structures (Booth, 1991: 99). The changes to water pathways from urban construction have led to important issues regarding stormwater along with creation and implementation of best management practices (BMP).

**B). Stormwater Impacts**

Stormwater is moved from urban areas where pollutants such as solids, oxygen-demanding substances, nitrogen and phosphorus, pathogens, petroleum hydrocarbons, metals, and synthetic organics are carried into storm drains and disposed of in local water bodies (Horner et al, 1994). These pollutants cause environmental damage to the receiving water bodies of the urban area, as well as the surrounding ecosystems that depend on adjacent waters. According to the EPA, "13 percent of impaired rivers, 18 percent of impaired lake acres and 32 percent of impaired estuaries are affected by urban/suburban stormwater runoff", as of 2005 (U.S. EPA, 2005: 1). The EPA discusses the consequences of urban stormwater runoff as short and long-term water quality impacts as well as physical impacts (U.S. EPA, 2006). Damages are caused by the increased runoff that occurs due to the increased amount of impervious surfaces within a city. A result is a drastic increase in the amount of water that is moved during peak flow periods. Peak flow is multiplied in cities with compact development and in some cases can create "entirely new peak runoff events" (Booth, 1991: p. 101). Increased amount of runoff and frequency of peak flow events causes a greater volume of contaminated stormwater to be discharged into receiving waters. Stormwater discharge can displace natural habitats along with contaminating drinking water for downstream users (U.S. EPA, 2006). Growing urban environments will create a growing need to address stormwater issues to insure that unnatural pollutants do not devastate receiving waters.

## IV: Legislation/Regulations for stormwater BMPs

### A). Clean Water Act (1972)

The Clean Water Act of 1972 was the improved Federal Water Pollution Control Act that had been implemented in 1948. Through the Clean Water Act, the Environmental Protection Agency (EPA) was given authority to set the limits on industrial waste as well as create standards for water quality controls. By implementing this act, any pollutant discharge was prohibited from a point source into navigable waters unless the National Pollutant Discharge Elimination System (NPDES) permit was obtained and allowed such discharge (U.S. EPA, 1990: 47990). Within the Clean Water Act, Section 301 sets the basis for treatment standards implemented on all those individuals, groups, or organizations that have pollutant discharge (Federal Water Pollution Control Act, 1972). With this Act in place, the standards for water quality before it was released into local receiving bodies were improved. As changes in water quality standards occurred, the need for enforcement and regulation was also addressed within the Clean Water Act of 1972. In Section 402, the NPDES was created in order to permit those individuals, groups or industries that discharged pollutants. A permit must be acquired from the NPDES for anyone discharging pollutants based upon the clean water legislation. Although the Clean Water Act gives the EPA authority over the NPDES permitting program, it also delegates permitting power to individual states to regulate water quality and pollutant discharge. However, the EPA continues to oversee the process that is carried out by the states and has the final ruling on regulations (Federal Water Pollution Control Act, 1972). The changes made under this act required a new way of addressing pollutant discharge that affected local water bodies. New techniques needed to be utilized to combat the status quo of water pollution. Regulation through the NPDES permitting program was vital to identifying the sources of pollution but management methods were the next step needed to further protect local receiving waters.

**B). National Urban Runoff Program (1978-1983)**

The EPA formed the National Urban Runoff Program (NURP) to gain a better understanding of the quality of stormwater runoff produces in urban commercial and residential areas. The findings of this program were staggering, showing that the discharge of suspended solids in stormwater sewers were near the magnitude of suspended solids that were discharged from a municipal secondary sewage treatment plant (U.S. EPA, 1990: 47991). With these findings, it was clearly seen that poor water quality was still an issue. Water quality continued to be a major concern when addressing the public health as well as environmental conditions. The NURP provided evidence from 28 projects across the nation to show that stormwater was truly one of the leading causes of pollutant discharge into local receiving waters.

**C). Water Quality Act (1987)**

Amendments made to the Clean Water Act continued to influence developers and municipalities when dealing with stormwater runoff externalities. Specific to stormwater management, the amendment of 1987, Water Quality Act, provided funding for States to plan and implement controls for nonpoint source stormwater runoff. The EPA was given authority to oversee the States through the distribution of grant money based upon program approval as well as periodic evaluation (U.S. Fish & Wildlife Service, 2010). Section 319 of the Water Quality Act deals with funding for specific projects that attempt to reduce the impact of non-point source pollution. In recent years, this section has provided funding for cities that are creating and implementing stormwater programs, some of which are to reduce the burden on combined sewer systems (River Network, 2011). The continued effort by the federal government and the EPA evolved water control legislation and developed more strict regulations for industries, municipalities, and developers. However, adhering to the this legislation is still not mandated and allows municipcalities to avoid potential issues of stormwater control.

**D). National Water Quality Inventory (1988)**

This assessment of water quality across the United States was carried out under the Clean Water Act, Section 305b. This inventory, taking place in 1988, showed the leading causes of poor water quality across the nation were due to agriculture, urban areas, construction sites, land disposal and resource extraction (U.S. EPA, 1999: 47991). It was through this assessment that the NPDES, under the EPA, implemented phase I for stormwater management only two years later.

**E). EPA Stormwater Phase I (1990)**

Phase I of the stormwater program was issued in 1990 by the National Pollutant Discharge Elimination System (NPDES). Under the authority of the EPA, this phase addressed moderate or large municipal separate storm sewer systems (MS4s), construction sites that had impacts on 5 acres or more, and ten categories of industrial uses (U.S. EPA, 2005: 1). Through the work of phase one, larger urban areas and construction sites were under more strict regulations in order to comply with stormwater quality standards. Since the coverage of this phase included larger areas, such as MS4s defined as 100,000 populations or greater (U.S. EPA, 2005: 1), the pollutant discharge could be reduced in higher density locations. Stormwater management extended not only to point sources, but to non-point source runoff as well. Non-point source runoff is a leading cause of surface water pollution and Phase I began to address it (EPA, 1994). This phase also set up the application process that would be necessary for obtaining a permit from the NPDES. It was recognized by the EPA that methods of stormwater management should be utilized and in phase one, the use of alternative paving materials, public education, and vegetative practices were encouraged (U.S. EPA, 1990: 47994). Best management practices would be the result of stormwater management phases, and now the EPA and NPDES have compiled a list of BMPs, as well as a design manual, for the use of urban and suburban areas.

**F). EPA Stormwater Phase II Final Rule (2005)**

The EPA followed up phase I of the stormwater program with a second phase that encompassed urbanized MS4s as well as smaller construction sites. By extending the permitting program of the NPDES to smaller location, the EPA has a wider range of municipalities and developments that must meet the stormwater management standards (U.S. EPA, 2005: 1). The programs and practices that are recommended by the NPDES to reduce and control stormwater runoff have been created to meet water quality standards set by the Clean Water Act. It is the belief of the EPA that through the use of BMPs, there will be financial, recreational and health benefits to the public. Other benefits that may not be as measurable may also be a result of BMP implementation (U.S. EPA, 1999: 68722). However, even though there has been a reduction in the amount of pollutants in local receiving waters, there is still work to be done. Although stormwater is not the only cause for pollutants in water bodies, it has done its fair share of damage and continues to do so.

## V: Types of Stormwater BMPs

### A). Vegetative Systems

Vegetative features are beneficial to public spaces because they provide a sense of natural amenity and can relax the user population. The function of a vegetative stormwater BMP is far more than the aesthetic or natural appeal, but has the ability to reduce stormwater runoff as well as treat water before soil infiltration. "Bioretention systems are designed to mimic the functions of a natural forest ecosystem for treating storm water runoff" (EPA, 2006). As rainfall begins to accumulate on the ground, it is directed into a bioretention area where the stormwater infiltrates into the soil. This process of bioretention and biofiltration removes pollutants by multiple processes, including adsorption, filtration, volatilization, ion change and decomposition (Prince George's County, MD, 1993). Utilization of a vegetative system BMP gives stormwater the opportunity to be filtered and cleaned and can be and excellent source for groundwater recharge (EPA, 2006).

Every public space should not be designed identically, but should incorporate the local community's location, culture and climate. The same is true for a vegetative BMP. There are a variety of vegetative components that are utilized based on the needs of specific locations. These components include "grass buffer strip, grass filter strip, vegetative swales, ponding area, organic mulch layer, planting soil bed, sand bed, and plants" (EPA, 2006: 5-8). Multiple components create numerous options for implementation as well as a combination of several components. Location and climate will usually determine the species of plants that vegetative systems will utilize, thereby creating a unique landscape for each location and their use of this structural BMP.

**B). Wet Ponds**

The second type of structural BMP explored for this research is the wet pond. Wet ponds are one type of retention system that is defined by its ability to capture stormwater runoff and retain it until future runoff replaces it. Unlike a dry pond, the water remains in the wet pond which serves as a place for a large quantity of runoff, and also treats the quality of that water during retention. Water treatment and storage are the designed purpose for a wet pond, but it may also provide "aesthetic value and aquatic and terrestrial habitat for a variety of plants and animals" (EPA, 2006: 5-14). Pollution that is carried by runoff enters a wet pond by design, however; through a settling process, the runoff is cleaned and able to infiltrate and replenish groundwater supplies if the wet pond does not have a bottom liner (EPA, 2006). Wet ponds may be one of the most effective pollutant removal retention systems due to the consistent pool of water and shallow depths (Yousef et al., 1986: 348). Application of wet ponds for the urban environment may fulfill both a stormwater management function along with aesthetic value for public spaces.

## VI: Problem in stormwater BMP

It is obvious that there is more attention being paid to the quality of water bodies across the United States as well as the world. Clean water is desired by most and steps are being taken to achieve better water quality through stormwater management methods. With these methods, it is vital that each strives to achieve true sustainability, through "technical reliability, environmental safety, economic effectiveness, and social equity" (Delleur, 2003: 572). Through the changes that have been made in regulations concerning stormwater, their has been a shortfall in creating a "comprehensive and effective approach to mitigating the water quality impacts of development" (Arnold & Gibbons, 1996) For this reason, stormwater management is not an issue to be addressed in the present and forgotten for the future. Best management practices must be usable and available in order to continue improving the quality of receiving waters. Progressive action may call for more than solitary BMP implementation by developments and municipalities rather than satisficing on stormwater standards. More attention should be paid to integration of stormwater management tools, drainage system, and treatment tools (Delleur, 2003: 572).

Improvement of water quality for the public realm may take cooperation and coordination across disciplinary lines. In speaking of the relationship between civil engineers and bioenvironmental scientist, Herricks emphasizes, "Neither discipline can operate with complete independence in the present climate of environmental concern (Herricks, 1986: 93). Although the relationship being discussed is not between urban designers, planners, and civil engineers, it does stress the importance of disciplinary integration to create a better solution for growing concerns. Herricks goes on to say, “Neither group should become so involved with their responsibilities that the other group is ignored” (Herricks, 1986: 93). Public hardscapes are spaces that can encourage social interaction and create vibrancy within a community when properly designed. However, greater attention should be paid to sustainability with respect to stormwater management. To perpetuate change in public space design, not only with designer need to integrate stormwater BMPs and permeable pavements, but integration among disciplines must occur to develop a more complete and sustainable standard for public hardscape design.

# CHAPTER 5: PERMEABLE MATERIALS

## I: Introduction

An approach to the sustainability of public hardscapes in terms of stormwater management must address the actual hardscape materials that can be utilized. There has been an extensive use of impervious surface materials in the past for our national highways system, sidewalks, and public hardscapes. In recent history, there has been great progress in developing paving materials that reduce negative environmental impacts. The following will investigate the potential that porous pavements have in aiding in stormwater management as well as being integrated into public hardscape design. Porous pavements are defined by the ability for water to move completely through them, which is a quality that is will well serve a public hardscape (Cahill, et al., 2003: 26). Specifically, three types of porous pavements will be identified and researched in detail: porous asphalt, pervious concrete, and interlocking concrete. Although these are not the only types of porous pavements, these three were selected because each has substantial literature available.

## II: Why Porous Pavements

Porous pavements are not a new creation, but in recent years the use of this material has seen an increase. According to Ferguson, the promise that porous pavements can make is part of the appeal that this permeable material takes advantage of. Clean water is one of the promises that are made since "porous pavement infiltrates and treats rainwater where it falls" (Ferguson, 2005: 10). The immediate infiltration of rainwater reduces the amount of runoff that is produced and the ability to capture and treat stormwater on a larger surface and allows the land to work at its full potential in stormwater management (Ferguson, 2005: 10). Due to the abilities of porous pavements, the EPA has recognized these types of pavements are credible practices that will fulfill stormwater management standards (EPA, 2006).

The promise goes beyond just cleaner water, as if that was not a good enough reason, to the reduction of cost associated with porous pavements. Although the costs are similar in regards to the pavement itself, porous pavement can save developers money when having to purchase additional land for stormwater management purposes (Ferguson, 2005:22). Some addressed the issue that the stone or aggregate layer for porous pavements is more expensive, but this material eliminates the costs for stormwater piping that is necessary for impervious pavements (Cahill, et al., 2003: 27).

The impact that stormwater runoff has on the natural world is significant, but the use of porous pavements can reduce externalities associated with paved areas. Construction of a site will not have to excavate land as extensively with porous pavements because it is part of the design of this material to “fit into the natural layout and topography of the site” (Cahill et al., 2003: 27). In this way the pavement is less intrusive on the natural environment and mimics the events that occurred before the porous pavement was laid (Ferguson, 2005: 25). Protection of native ecosystems should not be neglected in rural lands or an urban environment and as urban public hardscapes are implemented, attention should be paid to the need to preserve the natural resources that exist in that location.

## III: Porous Pavement Hydrology

**Table 1: Surface Infiltration**

| SURFACE TYPE | RATE (INCH/HOUR) | REFERENCE |
|---|---|---|
| Unbound aggregate | | |
| 1″ uniform size | 50,000 | AASHTO, 1986: AA-18 |
| 1/2″ uniform size | 15,000 | AASHTO, 1986: AA-18 |
| 1/4″ uniform size | 2,500 | AASHTO, 1986: AA-18 |
| Open-Jointed blocks with 0.08″ to 0.2″ aggregate fill (Interlocking concrete) | | |
| Initially built | 9.2 | Borgwardt, 1999 |
| 6 years after construction | 4.1 | Borgwardt, 1999 |
| Open-celled grids with cells in 10%+ of surface areas | | |
| With 0.1″ to 0.2″ aggregate fill | 40+ | Pratt et al., 1995 |
| Porous concrete | | |
| Properly constructed | 670 to 900 | Wingerter and Paine, 1989: P-1 & P-3 |
| Over-vibrated during construction | 1.25 to 24 | Wingerter and Paine, 1989: P-1 & P-3 |
| Porous asphalt | | |
| Immediately after construction | 170 to 500+ | St. John & Horner, 1997: XVI; Thelen & Howe, 1978: 13; Wei, 1986: 6-11 |
| After 3 to 4 years | 15 to 39 | Wei, 1986: 6-28 & 7-28 |
| After 4 years of winter sanding | 1.4 | St. John & Horner, 1997 |
| Dense Concrete | < 0.00002 | Rollings & Rollings, 1996: 149 |
| Dense Asphalt | 0.00006 to 6 | Rollings & Rollings, 1996: 149 |
| *Source: Ferguson, 2005: 124-125* | | |

The table above displays the infiltration rate for surface water and the type of material used. One of the most staggering findings is the difference between the dense asphalt and concrete and the porous asphalt and concrete. Even after aging and improper construction, the porous pavements exponentially outperform the dense materials (Ferguson, 2005: 124-125).

**Table 2: Runoff Coefficients**

| SURFACE TYPE | RUNOFF COEFFICIENT | REFERENCE |
|---|---|---|
| Aggregate | | |
| Range of gradiations | 0.3 to 0.7 | USFAA, 1965 |
| Open-Jointed blocks (Interlocking) | | |
| With 0.8" to 0.2" aggregate fill | 0.3 to 0.5 | Borgwardt, 1999 |
| Open-celled grids (Interlocking) | | |
| With topsoil and Kentucky bluegrass | 0 to 0.27 | Day et al., 1981 |
| Porous asphalt | | |
| Newly installed | 0.12 to 0.4 | St. John & Horner, 1997 |
| 3 to 4 years after installation | 0.18 to 0.29 | Wei, 1986 |
| Dense Concrete | 0.75 to 0.97 | Chow et al., 1988; Leeden et al., 1990 |
| Dense Asphalt | 0.73 to 0.95 | Chow et al., 1988; Leeden et al., 1990; St. John & Horner, 1997 |
| *Source: Ferguson, 2005: 124-125* | | |

Runoff coefficients are a measure of surface runoff over rainfall. This ratio is measured between values of 0 and 1 and is shown above for porous pavements and dense pavements. The runoff coefficient may be difficult to observe for porous pavements in smaller storms due to the high surface infiltration rate that was described previously. However, Ferguson states, "the coefficients for most porous pavements are below 0.5, which means that they are hydrologically more similar to grass than to dense pavements" (Ferguson, 2005: 125). With hopes of creating public hardscapes that imitate natural land features including hydrology, porous pavements should be considered in the design of such spaces.

## IV: Porous asphalt

### A). How it works

Porous asphalt was created in the 1970s at the Franklin Institute in Philadelphia. It differed from other asphalt pavement because the fine stone particles were screened and reduced in order to allow water to flow through (Cahill, et. al., 2003: 27). Early testing on porous asphalt used a minimum standard of strength, that the asphalt should be able to bear medium traffic capacity (Ferguson, 2005: 463). The actual layer of asphalt is created to allow water to pass through it to reach the second level of stone aggregate, or loosely compacted particles. This aggregate, possibly gravel like material, usually has a void space of around forty percent (Cahill, et. al., 2003: 27). Porous asphalt pavement is made in the same manner that conventional pavement is created. Both can be mixed in a plant and both appear to the untrained eye to be the same. However, with a lower concentration of fines in porous asphalt, water moves easily from the surface into the clean washed aggregate level. It is important that the stone aggregate level be clean washed since dirt could back up or stop infiltration into the soil. A thick layer of stone aggregate, eighteen to thirty-six inches deep, is dependent on site specific qualities, but also reduced the occurrences of cracking or creation of potholes that come with conventional asphalt. Below the stone aggregate level, a non-woven geotextile is placed that allows water to infiltrate into the soil but prevents the soil from rising into the aggregate. The stone level serves as a underground detention basin rather than stormwater remaining on the surface (Cahill, et. al., 2003: 28-33).

Failures in stormwater infiltration BMPs often are a result of construction or design errors that may include: compacting sub grade soils, poor erosion control or the use of poor materials (Cahill, et. al., 2003: 35). Although the chance of error does exist in the construction phase, porous asphalt is also has one of the shortest construction periods of all pavements (Asphalt Pavement Alliance, 2010a: 8).

**B). Economic**

Asphalt is the most affordable option for porous pavements (Cahill, et. al., 2003: 39). Life cycle cost analysis is a process to determine the cost of implementation for any asphalt project. It considers the initial cost, discounted future rehabilitation costs, and salvage costs.  The final life cycle cost is the sum of these costs (Asphalt Pavement Alliance, 2010a: 9-10).

**C). Environmental**

Suitable soil is important the infiltration process of stormwater and porous asphalt.  Some of the most important factors that should be considered are: soil type, infiltration rate, depth of bedrock, and depth of water table.  According to Cahill, the location of the infiltration system must be considered early in the project to avoid placing it in a location with poor soils or near a stream or wetland.  The author goes on to state that infiltration performs better in upland soils rather than in the lowest point, which is often used (Cahill, et. al., 2003: 33). Conditions of the soil must be observed before construction to understand what to prepare for with porous asphalt and the stone bed layers.  Slower infiltration rates should not be disregarded but rather seen as a longer period in which the water will be infiltrated leading to better water quality (Cahill, et. al., 2003: 33).

Asphalt has the ability to be recycled which is a benefit to its use.  The Asphalt Pavement Alliance reports that around 90 percent of asphalt that is removed is also reused in other asphalt pavements.  Since the asphalt can be recycled as well as the stone aggregate that is beneath it, asphalt is a more sustainable product that other types of pavements (Asphalt Pavement Alliance, 2010a: 9).

### D). Stormwater Management

Porous asphalt can be used as an effective stormwater management tool. Since the built environment alters the natural hydrology of any location, stormwater paths are changed and can result in damages to built structures and local ecosystems. Porous asphalt is a successful alternative that can be designed and implemented with consideration of the natural landscape (Asphalt Pavement Alliance, 2010b). A good rule of design when dealing with stormwater is to use the ratio of 5:1, impervious area to infiltration area. For example, if there were a five acre parking lot, it would require at least one acre of stone bed for infiltration purposes (Cahill, et. al., 2003: 33).

### E). Sustainability

The idea of perpetual pavement is not a new one. With this process the life span of paved surfaces can be extended beyond twenty years to fifty or more years (Perpetual Bituminous Pavements, 2001). Asphalt proves to be one of the most sustainable materials for design and construction since removed asphalt is usually recycled. The removal of the top layer of perpetual pavement can be done once every 15 to 20 years (Asphalt Pavement Alliance, 2010b).

## V: Pervious concrete

### A). How it works

Precipitation that falls in an urban area often meets an impervious surface and becomes runoff that carries pollution caused by the urban environment into local waters where stormwater is released. Pervious materials such as pervious concrete allow rainwater to percolate into the soil rather than stopping the infiltration process (NRMCA, 2010a). This process can occur through pervious concrete because there is no sand or other fines that fill the space between the aggregate (Ferguson, 2006). When implemented correctly, pervious concrete has a strength of around 3,000 psi, which can bear the weight of a fire truck, despite the void space present for water infiltration (Tennis, Leming and Akers, 2004: 3). The strength of pervious concrete is one of its advantages, however, in regards to public hardscapes, the weight that they surface will bear drastically decreases in comparison to a parking lot or street.

**B). Economic**

Pervious concrete acts as a detention area for stormwater and therefore can serve as a substitute for other stormwater BMPs. This can reduce the cost of labor, construction and materials for a particular site. However, without natural features that are found in other stormwater management methods, the site may lack in aesthetic appeal. Stormwater impact fees can be reduced with the use of pervious concrete or other forms of porous pavements since these materials reduce the amount of stormwater as well as filter out pollution (NRCMA, 2010b).

Life cycle cost is low for pervious concrete due to its strength and local production. While the initial installation costs may exceed other pavements, such as asphalt, there are fewer repairs that need to be made as well as an overall longer lifespan (NRCMA, 2010b). Proper installation and design are key factors, but when carried out can result in a pervious concrete that lasts 20-40 years with little maintenance (NRCMA, 2010c). Pervious concrete is much like other porous pavements in that it saves money in addition land acquisition costs (Ferguson, 2005: 422). Another cost that can be reduced is from the distributing companies. Since the mixing of pervious concrete can be done on site, the potential for over ordering and overproduction is reduced while adding to the local economy through local workforce (NRCMA, 2010b).

**C). Environmental**

Pervious concrete is an efficient tool in managing stormwater runoff in the urban environment. Managing stormwater takes 2 approaches to reduce the impact on the natural surroundings. First, stormwater management practices can reduce the total amount of runoff that is created by capturing the initial precipitation or the "first flush" (NRMCA, 2010a). The other approach is to reduce the pollution that is carried by the runoff through treatment methods before the water is released into local waters. Pervious concrete pavement is an efficient tool in both reducing the total amount of runoff as well as treating stormwater to reduce pollution that is carried. As water passes through pervious concrete and into the soil, there is a replenishing effect of groundwater as well as aquifers (NRMCA, 2010a).

Usage of pervious concretes has been recognized by the U.S. Green Building Council as a material that can earn a credit in the Leadership in Energy and Environmental Design (LEED) rating system. Pervious concrete is often a lighter color that other concretes, resulting in a reduction of the heat that is absorbed and the heat island effects. Due to the relatively open pore design of pervious concrete, trees and other plants that are used in urban environments have greater access to air and water, increasing the utility of pervious concretes for sidewalks and paved urban areas (NRMCA, 2010a).

**D). Stormwater Management**

The use of pervious concrete can help meet the standards that have been placed by clean water legislation (Tennis, Leming and Akers, 2004: 1). The use of this material is identified as a stormwater management practice due to its ability to retain water as well as percolate it into the soil. Pervious concrete that is five inches in depth and has 20% void space can retain one inch of stormwater within its voids. This capacity is increased to three inches of stormwater when the concrete surface layer is placed on top of a six-inch layer of open-graded gravel or crushed rock subbase (Tennis, Leming and Akers, 2004: 5). The capacity of a porous material is one of the major reasons that they have been added as a successful stormwater management tool. The ability to capture precipitation is part of its porous nature and has been found to have flow rates of between 3 and 8 gal/ft2/min (Tennis, Leming and Akers, 2004: 5).

**E). Sustainability**

While pervious concrete is one of the longest lasting porous pavements, it also shares qualities with other forms of pervious materials. The durability of these porous materials is one of their greatest qualities, especially in regards to weather conditions. While dealing with stormwater is one of the main purposes of porous pavements, these materials also clear snow and ice at a faster rate than impervious surfaces (Tennis, Leming and Akers, 2004: 6).

## VI: Permeable interlocking concrete pavement

**A). How it works**

Interlocking concrete incorporates two categories, open-jointed paving blocks and open-celled paving grids. Open-jointed paving blocks infiltrate stormwater at the joints in between solid units or blocks. The void space between blocks if the permeable area of this type of porous pavement and can be left empty of filled with porous aggregate or soil (Ferguson, 2005: 324). Open-celled paving grids differ from open-jointed paving blocks in that the units or blocks are actually made to be porous. This allows increased surface water infiltration because not only will water pass through the blocks, but will also infiltrate at the joints (Ferguson, 2005: 381). The following will refer to interlocking concrete as a general term that captures both categories and will clarify when there are differences in performance.

**B). Economic**

Interlocking concretes are an effective paving material for numerous types of projects. However, there is an initial cost that is higher than other types of pavements. While the initial cost is high, the long lifetime of interlocking concrete as well as its stormwater managements benefits counteract initial costs with future replacement and repair savings (Ferguson, 2005: 324, 384).

**C). Environmental**

Benefits from interlocking concrete are based around the impact that it has on stormwater and the decreased amount of runoff. Less stormwater runoff leads to a reduced amount of pollution entering local water bodies (ICPI, 2010). Local water bodies are often at the mercy of stormwater management practices. Simultaneously, while protecting local water bodies from pollution due to runoff, interlocking concrete can reduce the urban heat island, which has several other externalities associated with economic and environmental aspects (ICPI, 2010).

## VII: Maintainance

**A). Porous Asphalt**

Although there is recommended maintenance with porous asphalts, infiltration still occurs when maintenance is ignored. Cahill suggests that porous asphalt be vacuum-swept twice a year to function at its optimal level (Cahill, et. al., 2003: 37). A need for maintenance is different than with dense asphalt, since no coating can be applied, which removes the possibility to sand porous asphalt during winter months (Ferguson, 2005: 483; Cahill, 2003: 37). Freezing conditions have been observed with porous asphalt and findings have shown that this form of pavement can withstand such conditions. When dealing with snow and ice, it should be noted that porous asphalt could be snowplowed as well as salted. Despite conditions, particle debris may clog pores of asphalts and will require maintenance.

**B). Pervious Concrete**

Maintenance for pervious concrete hinders on the location of the pavement. In coastal regions where sand may clog concrete, it has been found that "pressure washing with clean water and immediate brooming" can restore infiltration rates (Ferguson, 2005: 426). The maintenance process changes for other areas of the nation, where organic debris may be the cause of clogging, such as the Pacific Northwest. In a region that may suffer from organic debris, the plan for maintenance may come before the laying of pervious concretes. Organic particles can be pressure washed out of the pores of pervious concrete, but much more effort is required. Due to this extra time, a maintenance plan that frequently checks and washes concrete can reduce prolonged build up and retain the water treatment capabilities of the pavement (Ferguson, 2005: 426).

**C). Interlocking Concrete Pavement**

The maintenance required for interlocking concrete can be extremely simple. Needs for maintenance occurs when small particles clogs the aggregate in the joints. Ferguson mentions that the process to remove the clogged aggregate can be done with a vacuum sweeper. This device can remove the top layer of the aggregate in the joints, which is the layer most likely to be affected by particles due to sanding or runoff particles (Ferguson, 2005: 334-335). Like other paving materials, interlocking concrete will require maintenance, but the process can be simple and effective for restoring the infiltration capabilities of this type of porous pavement.

# CHAPTER 6: LITERATURE REVIEW SUMMARY

## I: Overview

The design of public hardscapes do not have to take on the negative characteristics that are often associated with other impervious areas. The opportunity to mitigate stormwater runoff issues within the design phase of a hardscape has great potential due to the knowledge and availability of stormwater best management practices and permeable pavements (EPA, 2006; Ferguson, 2005). However, the integration of public hardscape design, stormwater management, and permeable pavements is not readily addressed within the literature.

## II: Addressing Stormwater in Public Hardscapes

The physical and social characteristics of success spaces have been discussed at length in the literature. However, there is little mention of the type of pavement that is used or that has the potential to be used. Considering that public hardscapes are within the urban fabric, the lack of attention to stormwater management is surprising. The potential threats posed by increased surface runoff due to impervious surfaces are pressing and every element of the urban environment produces a consequence. This research seeks to identify public hardscapes that have implemented stormwater management practices or permeable pavements, or both, in the creation of an urban public realm. The gaps within the literature suggest that such integration has not been adequately accomplished or documented.  However, this research displays how this integration is taking place along with what may impede such integration.

# CHAPTER 7: METHODOLOGY

## I: Introduction

Public spaces, especially hardscapes, within the urban environment have not traditionally produced designs with environmental elements such as urban stormwater management as a concern. Successful designs of public hardscapes incorporate both social and physical characteristics that have been documented as attracting people to utilize the space (Carr et al., 1992, Childs, 2004; Whyte, 1980). Public hardscapes have traditionally fit into the urban context and taken on the nature of impervious surface. However, with growing attention to the externalities of urban stormwater runoff, design of public hardscapes will need to alter its approach in order to protect against externalities.

The need for improvement in regulation on urban stormwater runoff has been recognized by the Environmental Protection Agency and led to the writing and implementation of the Clean Water Act, 1972 and its amendments that followed. Urbanization has led to an increase in impervious surface due to the construction of residential, commercial, industrial, and other types of uses. Impervious surfaces are also seen in the creation of road networks, parking lots and public hardscapes within cities. However, the increase in impervious surface can be one of the causes of urban flooding or increased pollution that is deposited into nearby water bodies (NCNERR, 2007). Stormwater runoff picks up a variety of pollutants that can be harmful to native ecosystems as well as the human population, especially when the city operates on a combined sewer system. Pollution carried to local water bodies can destroy plant life, fish, and other wildlife (EPA, 2003). Public health is also at risk with poor urban stormwater management. The infiltration of stormwater runoff into ground and drinking water can put the public at risk of water-borne illness and disease (Gaffield et al., 2003). The potential threats of weak or non-existent stormwater management have been well documented. Public hardscape designers should not neglect the need to incorporate stormwater management practices into successful public space design. Some of these techniques for stormwater management will be investigated through this research. Especially those methods that not only collect stormwater but also allow it to infiltrate into the soil, which have been shown to remove pollutants from stormwater while reducing runoff (Gaffield et al., 2003). Improving water quality and reducing stormwater runoff quantity are goals that can be achieved through stormwater best management practices and permeable pavements and integrated into public hardscape design.

## II: Research Questions

1. *How have successfully designed public hardscapes integrated (if at all) stormwater management practices and permeable paving materials?*

2. *What has promoted or impeded such integration in these spaces?*

3. *How can such integration be improved?*

## III: Methodology

The objectives of this research were to identify examples of successfully designed public hardscapes which have integrated stormwater management and permeable paving materials, understand how this type of integration has been promoted or impeded (e.g. by public policies, costs, lack of communication between disciplines, etc.), and improve standards of professional practice by identifying ways to overcome barriers and promote improved stormwater management methods in the design of public hardscapes. In order to achieve these objectives, multiple case studies of public hardscapes with stormwater management practices within design, were completed. The case studies included potential field analysis/direct observation, document analysis, and interview components.

### A). Criteria

Selecting the sites for this research went through a type of screening process as described by Yin to narrow the field of candidates (Yin, 2003: 78). The first screening tool was be the size of the city in which the hardscape is found. Public hardscapes within large cities are the unit of analysis for this research. Potential city candidates were narrowed to those with a population exceeding 500,000 according to information from the 2000 Census. Twenty-nine cities fell within this parameter and were organized by region. Regions were determined by annual precipitation across the nation. Annual precipitation maps allowed the nation to be classified into five regional categories: Northwest, Mountain West, Midwest, South/Southeast, and Northeast (NationalAtlas.gov, 2009; NCDC, 2010). The following table displays how the largest twenty-nine cities in the United States are classified into five regions.

**Table 3: U.S. Cities with Population Over 500,000**

| NORTHWEST | MOUNTAIN WEST | MIDWEST | SOUTH/ SOUTHEAST | NORTHEAST |
|---|---|---|---|---|
| San Francisco | Los Angeles | Chicago | Houston | New York City |
| Seattle | Phoenix | Detroit | Dallas | Philadelphia |
| Portland | San Diego | Indianapolis | San Antonio | Baltimore |
| | San Jose | Columbus | Jacksonville | Boston |
| | El Paso | Milwaukee | Austin | Washington DC |
| | Denver | Oklahoma City | Memphis | |
| | | | Nashville | |
| | | | Charlotte | |
| | | | Fort Worth | |

*Source: Demographia, 2005; Nationalatlas.gov, 2009; NCDC, 2010*

Furthermore, public hardscapes were identified due to the purpose of this research being to identify practices of integrating stormwater management practices with public hardscape design. Public hardscapes may include public squares, plazas, pedestrian streets or other forms. Each public hardscape investigated had evidence of stormwater management techniques used in the design. This information was gathered from articles, journals, public space websites or other academic data sources. The final criteria for case studies was the date of construction or redevelopment of the public hardscape occurring after 1987, based on the Water Quality Act that addressed nonpoint source pollution due to runoff (Water Quality Act, 1987).

**B). Field Analysis/Direct Observation**

The opportunity for field analysis/direct observation was, to a degree, limited by distance and specific travel plans. However, in those sites that direct observation occurred, the following evaluation matrix or case study checklist was used to assess the quality of public space design, existence and degree of stormwater management practices, and the existence and degree of permeable pavements.

**Table 4: Case Study Checklist**

| PUBLIC HARDSCAPE FEATURE | PRESENCE | DEGREE/TYPE/QUANTITY/ NOTES |
|---|---|---|
| | | |
| Primary Observation Site | | |
| Physical Elements | | |
| Entrance | | |
| Enclosure | | |
| Building heights | | |
| Building continuity | | |
| Seating | | |
| Primary | | |
| Secondary | | |
| Lighting | | |
| Vegetative/Natural Features | | |
| Social Characteristics | | |
| Comfort/Saftey | | |
| Relaxation | | |
| Engagement | | |
| Passive | | |
| Active | | |
| Stormwater BMP | | |
| Permeable Pavement | | |
| Combined Sewer System | | |

**C). Document Analysis**

Some details concerning stormwater management practices and permeable pavements were difficult to assess based upon appearance alone. Document analysis not only improved the quality of analysis for each space but also helped to fill in any gaps that may exist with observation alone. Document analysis was particularly useful for those spaces that could not be reached directly. The same case study checklist was used for hardscapes that were not part of the field analysis. Academic articles were used in conjunction with any available data pertaining to each public hardscape and its stormwater management functionality.

**D). Interviews**

Finally, interviews were conducted in an effort to address issues that may have arisen during the planning or design phase of public hardscapes. Questions were focused on what has promoted or impeded integration of stormwater management and permeable pavements into public hardscape design and how integration can be improved. Interviews were conducted with individuals that are involved with the specific public hardscapes that were observed or analyzed as case studies. Subjects of interviews included: design professionals, landscape architecture firms, public services representatives, and non-profit organizations.

**E). Potential Case Study Candidates**

In the table below, a preliminary list of public hardscape candidates was compiled. Many of these hardscapes were found to have available documentation that can be used for analysis. However, not all of these candidates met the essential criteria for this research. Some of the hardscapes did meet the criteria, while others were not on the list and were added after additional research.

**Table 5: Potential Case Study Candidates**

| PUBLIC HARDSCAPE NAME | CITY, STATE | REGION |
|---|---|---|
| Jamison Square Park | Portland, OR | Northwest |
| Urban Center Plaza | Portland, OR | Northwest |
| Pioneer Courthouse Square | Portland, OR | Northwest |
| Civic/Morrison Pedestrian Street | Portland, OR | Northwest |
| Mint Plaza | San Fransisco, CA | Northwest |
| Guadelupe River Park | San Jose, CA | Northwest |
| Buckingham Fountain | Chicago, IL | Midwest |
| Republic Sqaure Park | Austin, TX | South/Southeast |
| Symphony Square | Austin, TX | South/Southeast |
| High Line Park | New York, NY | Northeast |
| Liberty Plaza | New York, NY | Northeast |
| Paley Park | New York, NY | Northeast |
| Welcome Park | Philadelphia, PA | Northeast |

Although there were many potential cases for this research, not all candidates had sufficient documentation about stormwater management or background information to include in this research. It was important that each case selected for research had documents for analysis and to solidify that the hardscape was infact utilizing stormwater management practices or permeable paving materials. One objective of this research is to identify if such an integrated practice exists and use interviews and document analysis to investigate what or who promotes and impedes such integrated planning and design. Therefore, the public hardscapes that met the criteria for this research and were used as case studies include: Mint Plaza, San Fransisco; High Line, New York City; Civic-Morrison Pedestrian Street, Portland; and Urban Center Plaza, Portland.

# CHAPTER 8: FINDINGS

## I: Introduction

In order to answer the research questions posed; a case study approach was taken. Multiple sites were selected as case studies based upon public hardscape design criteria, utilization of stormwater best management practices, and size of city. Originally, it was the hope of this research to identify public hardscapes in different climatic regions in the United States because of the differences in annual precipitation trends (NationalAtlas.gov, 2009; NCDC, 2010). However, public hardscapes that included stormwater BMPs and were located in cities with a population of greater than 500,000, were not found in all regions. Therefore, case study site selection was narrowed to hardscapes within two regions, Northwest and Northeast. In total, four public hardscapes were selected due to the integration of stormwater BMPs into public space design.

Initial action was to analyze documents that pertained to each of the public hardscapes. Documentation included websites, articles, and project profiles. Through document analysis, information about the history, design, stormwater BMPs, public use and design team was gathered. For some spaces, all of the information above was available, but for others, information was limited because of vague or general project reports or inaccessible project related data. Data collected through document analysis was accompanied by primary observation of three of the four hardscapes along with interviews with agencies or firms associated with each specific case study.

Primary data was collected at three of the four case studies, the Civic and Morrison Pedestrian Street, the High Line, and the Urban Center Plaza. First hand observation allowed detailed notes about public space design along with recognition of stormwater BMPs in use. During primary data collection, notes were taken for each component described in the case study checklist. Each of the three hardscapes that were visited was documented through photoreconnaissance. The one case, Mint Plaza in San Francisco, that primary data was not collected was treated differently than the other cases. In order to complete the case study checklist and take notes on specific components, photographs published by firms and organizations associated with the hardscape were utilized. Photo analysis was a useful method for Mint Plaza and provided sufficient information for the study of this public hardscape. Both primary observation and photo analysis helped to identify successful public space design features as well as stormwater BMPs.

Finally, interviews assisted in understanding how integration of public space design and stormwater management practices was initiated. Several potential interviewees were contacted. There were multiple potential interviews for each of the four case studies. For all cases in this research, each agency or firm that was involved in the planning, designing, construction, or maintenance of the hardscape was contacted. However, after repeated attempts of contacting agencies and firms, both through email and phone calls, some were not open to or available for an interview. Although there was not a 100% response rate, interview data was collected from a minimum of one respondent associated with each hardscape in this research. Interview questions were designed to identify

## II: Integrated Public Hardscapes

1. *How have successfully designed public hardscapes integrated (if at all) stormwater management practices and permeable paving materials?*

Public spaces across the United States draw local populations along with visitors daily due to successful design. The field of public spaces is narrowed when speaking specifically of hardscapes. Hardscapes by definition produce more stormwater runoff due to their impervious nature. The issue of stormwater management is seldom integrated into public hardscape design; however, the public hardscapes identified within this research provide progressive and practical examples from a few areas within the United States. The four hardscapes were observed, either through primary observation or photo analysis. Both methods helped to identify these four hardscapes as public spaces that were not only successfully designed but incorporated stormwater BMPs.

Each of the case study sites were selected based upon specific criteria concerning public space design, size of city, and stormwater management practices. To understand each space a brief review of the site is included, based upon document analysis. A checklist of features is included with each case study as well. The checklist includes elements of successful public space design according to the literature reviewed. The checklist also identifies stormwater best management practices, including permeable paving materials within each hardscape. Along with the checklist that displays if a feature is present or absent, the checklist also includes notes that provide more details and observations of the site pertaining to a specific element of design or stormwater management practices. Multiple sites were measured through primary observation and photoreconnaissance and provide more in-depth notes for each space. Details and observations were limited for cases that were only investigated through document analysis.

## III: Case Study Analysis

### A). Mint Plaza, San Francisco, CA


Formerly known as Jessie Street, Mint Plaza was first put in motion in April of 2007 when legislation was approved to transform the street between Fifth and Mint Streets into an exclusive public pedestrian realm. The transformation of the 290 feet of street into a public hardscape was accomplished in just under two years from concept to completion of construction. Martin Building Company, a developer that has worked in San Francisco over the past decade, donated a large portion of the funds to plan and construct Mint Plaza.

Mint Plaza is a publically owned space that is open twenty-four hours a day. The creation of the space was finished by a local developer but was donated to the city. Future repairs and improvements will be funded and implemented by Friends of Mint Plaza, a non-profit 501(c)(3) created to oversee the condition of Mint Plaza. With no entrance fee or cover charge, the small public plaza has hosted small events such as live music and festivals and plans to expand the types of programming hosted by Mint Plaza.

The design of Mint Plaza was created with the public use as an apparent focus. A sense of enclosure due to the restored historic architecture and a variety of restaurants and cafes lining the plaza add to the appeal for the public. Ample lighting and seating add to the comfort and relaxation of the plaza. People that dine at the surrounding restaurants and cafes can enjoy indoor or outdoor seating in the plaza. While primary seating within the plaza is sufficient due to those tables and chairs used by adjacent businesses and moveable chairs in the plaza, secondary seating is also available throughout the plaza. Finally, the opportunity for engagement, both active and passive, can be found in Mint Plaza with occasional live music or festivals. The design of the plaza is attractive and can be used by multiple

groups or multiple purposes.

Although the design of Mint Plaza is appealing to the public eye and can be used for a variety of activities, the design of the plaza goes beyond what is seen at a glance. The plaza captures rainwater and directs stormwater into two on-site rain gardens that feed into underground infiltration systems. Rain gardens and landscaping throughout the plaza serve a dual purpose of visual appeal as well as stormwater filtering service. In the transformation of Jessie Street into Mint Plaza all concrete and asphalt were replaced with aggregate stone pavers. Capturing and retaining stormwater on-site relieves the combined sewer and stormwater management system used by the city of San Francisco.

i). <u>Design Team</u>

Developer: Martin Building Company

Landscape Architect: CMG Landscape Architecture

Design Engineer: Sherwood Design

Management & Maintenance: Friends of Mint Plaza

**Table 6: Mint Plaza Case Study**

| PUBLIC HARDSCAPE FEATURE | EXISTENCE | DEGREE/TYPE/QUANTITY/ NOTES |
|---|---|---|
| | | |
| Primary Observation Site | | |
| Physical Elements | | |
| Entrance | X | Pedestrian street that was transformed from an ordinary street. Entrances from both sides of the space |
| Enclosure | | |
| Building heights | X | Building heights are sufficient to create a room-like feeling. Since the space is only a linear corridor, buildings over two stories bring a stronger feeling of enclosure. |
| Building continuity | X | Each building is unique, but not in contrast with the parallel building. |
| Seating | | |
| Primary | X | Many opportunities for sitting. Moveable chairs allow for larger groups to be accommodated in a variety of places within the plaza. |
| Secondary | X | Ledges and bases of structural beams could be utilized as seats when chairs were occupied or even for the opportunity to retreat from other seating areas. |
| Lighting | X | Lighting is provided by both buildings lining the plaza along with additional lights through the center of the plaza. |
| Vegetative/Natural Features | X | Trees create shade throughout the space. Rain gardens provide a natural component as well as stormwater function. |
| Social Characteristics | | |
| Comfort/Saftey | X | Roomlike quality creates both comfort and feeling of safety. |

| PUBLIC HARDSCAPE FEATURE | EXISTENCE | DEGREE/TYPE/QUANTITY/ NOTES |
|---|---|---|
| Relaxation | X | Seating alone provides a great atmosphere for people to take a break from work or any other activity. |
| Engagement | | |
| Passive | X | Space provided for performers as well as small area for a stage. Passerbys can enjoy the entertainment without being part of it. |
| Active | X | Does not have a large amount of open space for some activities, there is enough space for some activities (kids juggling the soccer ball, chess/ checkers on a nearby table, etc.) |
| Stormwater BMP | X | Rain gardens/bioretention and trees |
| Permeable Pavement | X | Aggregate stone paving, newly installed with the completion of the plaza. |
| Combined Sewer System | X | |

The observations for Mint Plaza were taken through photograph analysis. Since this was not a space that primary observation was possible due to travel limitations, photographs from the hardscape's website along with images posted on the landscape architect's firm website were utilized.

**B). High Line, New York City, NY**

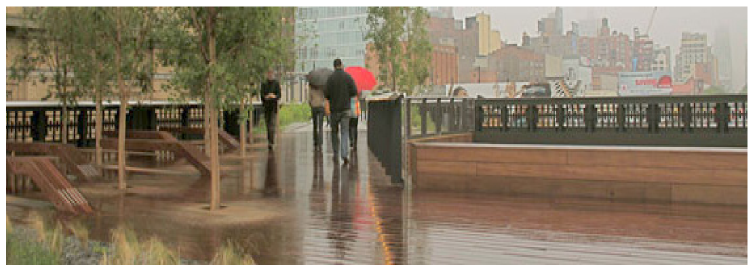
In the 1930s, an effort to remove freight trains from the streets of Manhattan produced the public-private partnership that is responsible for the High Line,

part of the project called the West Side Improvement. The High Line functioned as an elevated rail system that moved freight safely 30 feet above the streets, avoiding pedestrians and other transportation within the city. Wise planning suggested that the High Line would be more effective if it connected directly with the industries that used the line. Therefore, the rail purposefully went directly through factories and industrial buildings allowing for easy loading and unloading. In the mid 1980s, a group of property owners lobbied to destroy the High Line since the rail was no longer in use. Opposition to the rails demolition was found in court and years later in 1999, the Friends of the High Line was founded with a mission to advocate for the reuse of the elevated rail as a public space.

Friends of the High Line is a non-profit organization that has played a crucial role in the planning, design, and construction of the public park. The non-profit is responsible for the maintenance, operation, and public programming for the High Line. Over 70 percent of the operation the Friends of the High Line provide budget for the public park. It is the hope of this organization

that through their work to create a successful public space, the surrounding community will also benefit in a variety of ways. The High Line is open to the public from 7:00 AM to 8:00 PM daily with five access points, two with elevators to ensure access to people with physical disabilities. The expansion of the park has come in phases with the first section opened in June 2009 and the second section set to open in the spring of 2011.

As a linear park, the High Line provides connection between places for the visitor. However, the park was designed with more than just the pedestrian moving from one place to another. The park offers seating along both sides and has kept the historic railroad nature of the park by placing many of the seats on fixed wheels along the railroad lines. Seating is both primary and secondary in a variety of places along the High Line and special seating is offered in a viewing area with theatre style seating. Visitors may be engaged in the views of the New York skyline or glimpses of the bay. Public art has been a focus of the High Line and the park gives opportunities for local artists to display or perform in a variety of spaces along the hardscape. In the future, there are plans to add concessions from entrepreneurial food vendors for those that use the park. Since the park is elevated, the issue of access was addressed by providing elevators from street level so that the park is truly open to anyone. The park closes at eight in the evening daily. Although it does not remain open around the clock, the lighting for the park is sufficient for making park patrons feel comfortable and safe. As a public hardscape, the High Line is attractive and useful along with showing true creativity and innovation as it captures its original purpose through thoughtful design.



The High Line is a unique hardscape due to the height it sits above street level. During the design process, the issue of stormwater runoff was addressed with detailed planning and careful construction. This park acts as a green roof and is made up of several layers that allow stormwater to flow into plant beds while reducing runoff into the streets below. Drains are located in strategically placed low points that allow rainwater to flow into plant beds along the park as well as on the streets below. The planks that are used for the High Line are open-jointed concrete, which increases the amount of rainwater that can reach plant beds while reducing the total amount of surface runoff.

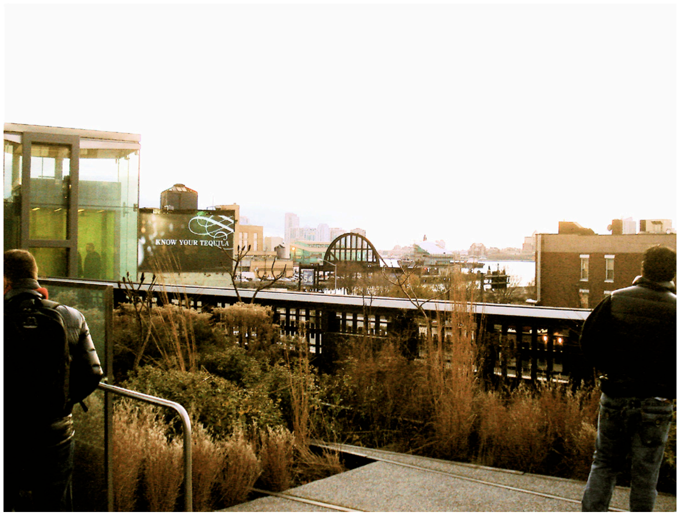
i). Design Team

Architect: James Corner Field Operations, Diller, Scofidio & Renfro

Structural Engineer: Buro Happold

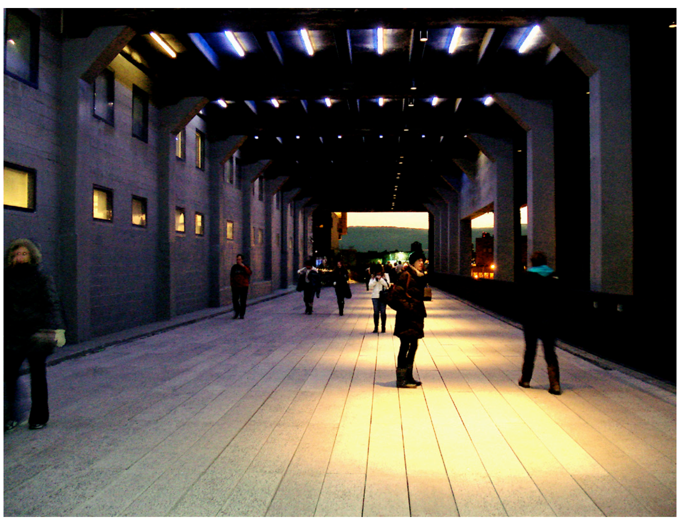
Environmental Engineer: GRB Environmental

Management & Maintenance: Friends of the High Line ii). <u>Photo Reconnaissance</u>




**Picture 1: High Line View**

Beautiful views of the water and New York City are offered throughout the High Line.



**Picture 2: Public Art Space**

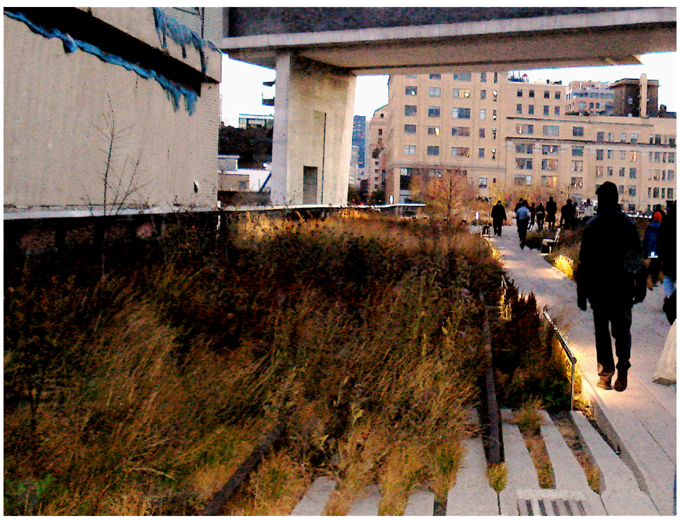
Lighting and space make for a great area for various artists to utilize this hardscape.


**Picture 3: Open Space**

Truly an area to relax, stroll, sit, read, or enjoy time with friends.

**Picture 4: Primary Seating**

Seating is not only used for sitting, as in this photo. Seats keep the railroad theme.



**Picture 5: Bioretention**

Larger bioretention area, allowing stormwater runoff to be captured and treated.

**Picture 6: Theater**

This addition to the High Line allows visitors to watch the street life, and is exceptional for viewing festivals or parades.

**Picture 7: Rain Garden**

A closer look at a rain garden, showing that runoff is easily passed from the pavement into the retention/infiltration area.

**Picture 8: Seats/Lighting**

Although this space is not open 24 hours a day, evening lighting is important for those taking advantage of the High Line after work for leisure or exercise.

**Table 7: High Line Case Study**

| PUBLIC HARDSCAPE FEATURE | EXISTENCE | DEGREE/TYPE/QUANTITY/ NOTES |
|---|---|---|
| | | |
| Primary Observation Site | X | Visited site in November, 2010 |
| Physical Elements | | |
| Entrance | X | Multiple entrances from the street, including an elevator for those that may have physical disabilities. |
| Enclosure | | |
| Building heights | X | Interesting sense of enclosure because it is an elevated linear park, however, the buildings in New York City along the High Line still create a room-like feeling. |
| Building continuity | | Buildings along the hardscape were built at various times in history and lack this element. |
| Seating | | |
| Primary | X | Several benches are scattered throughout the space. Many of the seats have unique characteristics that connect with the train/rail atmosphere of the hardscape. Also includes stadium seating in one area of the High Line. |
| Secondary | | Lacks a sufficient amount of secondary seating. Although a few people sat on the ground along the hardscape, this was not common during observation. |
| Lighting | X | Lighting is excellent throughout this hardscape. There is ample natural light during the day and in the evening hours, artifical light still allows the visitor to experience all of the features along the High Line. |

| PUBLIC HARDSCAPE FEATURE | EXISTENCE | DEGREE/TYPE/QUANTITY/ NOTES |
|---|---|---|
| Vegetative/Natural Features | X | Although the High Line is elevated above the street, plants, grasses and trees are present in the entirety of the hardscape. These plants give the natural impression even as the visitor is raised above street level. |
| Social Characteristics | | |
| Comfort/Saftey | X | Linear hardscapes may seem threatening, but this public space is monitored by the Friends of the High Line during all operating hours. |
| Relaxation | X | Even though someone might not escape the sounds of the street, this hardscape provides a chance to get away from the stress that may occur during the day. Offers great views. |
| Engagement | | |
| Passive | X | Supports public art, in various forms (music, painting, drawing, acting). |
| Active | X | A small theatre space is built into the High Line and allows the public to watch the events of the street through a viewing window. |
| Stormwater BMP | X | Bioretention and grass swales. Stormwater is filtered down to street level to water plants. |
| Permeable Pavement | X | Open-jointed concrete |
| Combined Sewer System | X | |

**C). Civic & Morrison Pedestrian Street, Portland, OR**

The Civic and the Morrison are neighboring buildings that many residents of Portland call home. The Civic is a larger condominium building standing at

16-stories, while the Morrison is a small 5-story apartment complex. While both serve as housing for a variety of people, the space that separates the two has allowed access to the public in the form of a pedestrian street. This public hardscape allows pedestrian through traffic to flow freely without having to travel around either building. This public hardscape is accompanied by the ground level of the Civic containing a variety of retail. Pedestrians and residents can enjoy a variety of seating options when between the buildings along with sunlight and plants. Both buildings have access to the pedestrian street, which offers stairs and ramps so that it may not hinder any vistor from the public space.

Through the center of the pedestrian street runs a form of stormwater management that allows the stormwater runoff to be reduced and infiltrate into the soil.  By using a bioswale, the pedestrian street between the Civic and the Morrison has the ability to treat and reduce the stormwater runoff that enters the area.  In an area such as Portland, where the amount of rain is substantial, incorporating stormwater management practices into public hardscapes such as

a pedestrian street reduces the pollution that is carried by runoff.  The hardscape between the Civic and the Morrison is unique and used by residents of the two buildings.  However, it is open to the public and can be used in a variety of ways, from relaxing, shopping and eating to treating stormwater before it becomes a threat to local waters.

i). <u>Design Team</u>

Landscape Architect: Mayer/Reed

ii). Photoreconnaissance

**Picture 9: Entrance**

Entrance allows access to all people, but excludes automobiles. This pedestrian street is easily seen from multiple areas.

**Picture 10: Thoroughfare**

As a pedestrian street, it connects two streets, but provides pedestrians a space of their own away from traffic.

**Picture 11: Rain Garden**

Stormwater management runs like a spine through the pedestrian space.

**Picture 12: Seating**

Primary seating is available with multiple benches scattered through the hardscape.

**Picture 13: Bioretention**

Another look at the rain garden/bioretention area shows that runoff flows into space without barriers.

**Picture 14: Secondary Seat**

Raised rain gardens may serve as secondary seating for those that prefer it to the benches.

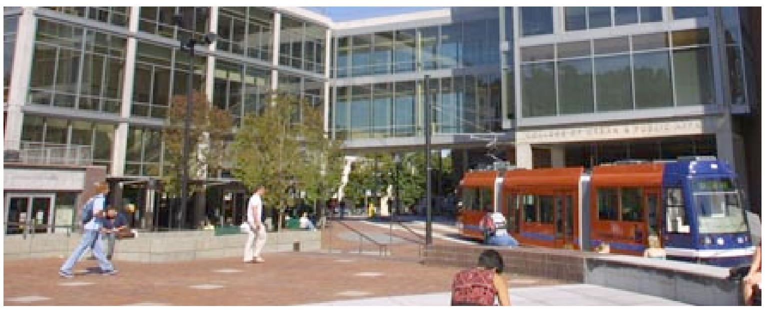
**Table 8: Civic/Morrison Case Sutdy**

| PUBLIC HARDSCAPE FEATURE | EXISTENCE | DEGREE/TYPE/QUANTITY/ NOTES |
|---|---|---|
| | | |
| Primary Observation Site | X | Visited March, 2011 |
| Physical Elements | | |
| Entrance | X | Two entrances, both accessible for people with physical disabilities. |
| Enclosure | | |
| Building heights | X | Great sense of enclosure. One building is 5 stories, while the opposite is 16 stories in height. |
| Building continuity | X | There are only two boundary buildings along the pedestrian street. This creates a sense of uniformity. |
| Seating | | |
| Primary | X | Adjacent uses put out seating daily, especially the restaurants and cafes along the hardscape. There are benches that are placed along the buildings. |
| Secondary | X | Multiple opportunities for secondary seating exist. The rain gardens are built up and have ledges that are perfect for siting within the hardscape. |
| Lighting | X | During the day, the space is lit with natural lighting, but shading is provided by the buildings. Artificial lights allow the space to be used at night and keep a comfortable and vibrant quality. |
| Vegetative/Natural Features | X | Rain gardens, shrubs and trees are consistent along the pedestrian street. |
| Social Characteristics | | |

| PUBLIC HARDSCAPE FEATURE | EXISTENCE | DEGREE/TYPE/QUANTITY/ NOTES |
|---|---|---|
| Comfort/Saftey | X | The adjacent buildings are mixed use and combine retail, office and residential. The pedestrian street has a neighborhood atmosphere based on observation. Lighting and multiple eyes on the street improve safety. |
| Relaxation | X | It appeared the space was ideal for relaxation for residents as well as those visitors to the retail areas, or those just passing through. Seating added to this component. |
| Engagement | | |
| Passive | X | Window shopping would be extent of passive engagement. |
| Active | | Not space for many active engagement opportunities. |
| Stormwater BMP | X | Rain garden/bioretention and trees. The stormwater management system creates a sort or ridge or backbone along the entire pedestrian street. |
| Permeable Pavement | | Not used |
| Combined Sewer System | X | |

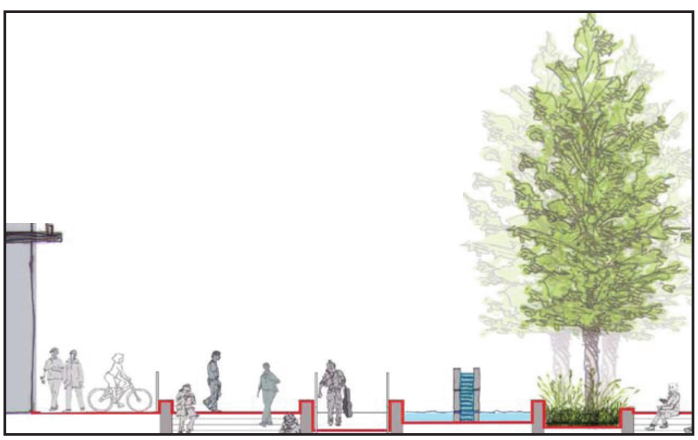
**D). Urban Center Plaza, Portland, OR**

Within the urban core of Portland, Oregon, Portland State University (PSU) is home to a plaza that bridges the campus with the rest of downtown. The university is an urban campus but with the creation of the Urban Center Plaza, the mixing of students with professionals and residents has the opportunity to increase. The plaza is the only place in the city that the streetcar and Green Line of the MAX, Portland's lightrail system, intersect. Buses that operate in the public transit system of the city also have stops adjacent to the plaza. The opportunity for transportation is a key element to the Urban Center Plaza and attracts a variety of populations to the hardscape.



The physical traits of the space correspond with that found through the literature about public space design. This attractive space has plenty of seating in multiple forms. Some benches are found in the plaza, but concrete stadium seating is also available. Other than primary seating, steps throughout the hardscape can easily be utilized as secondary seating opportunities. Lighting is provided within the space but also from adjacent uses. Surrounding the plaza, PSU's bookstore and newly built recreation center make up part of the clearly defined boarders. Seattle's Best Coffee makes up another piece of the boarder and most likely benefits from the popularity of the plaza. With the opportunity for a variety of ways of transit possible, the Urban Center Plaza has frequent traffic through the space, but many that take advantage of the surrounding uses can relax or interact with friends within the plaza.

Construction of the space began in 1998 and was completed in 2000. The plaza was redesigned as part of the Montgomery Green Street Initiative, through the work of Environmental Services for the City of Portland and the Portland Development Commission. This redesign of the plaza would not significantly change the shape or function of the plaza, but integrate stormwater BMPs into its original design. Many of the features of



the plaza were not changed with the resdesign, but a few significant stormwater components were added.  Stormwater planters were an addition to the space along with planting trees near the stairs.  Vegetative additions to the barren plaza not only aided in stormwater runoff control, but inhanced the aesthetic appeal of the plaza (Miller, 2009: 71).  The Urban Center Plaza, like many other public hardscapes within the urban context, experiences stormwater runoff from surrounding streets as well as the impervious surfaces within the plaza. Through redesign of the plaza and integration of stormwater BMPs, the impact of pollution into local waters and storm surge into combined sew systems can be reduced.

i). <u>Photoreconnaissance</u>

**Picture 15: Water Feature**

During rain events, water feature is active and acts as a calming feature.

**Picture 16: Seating and Trees**

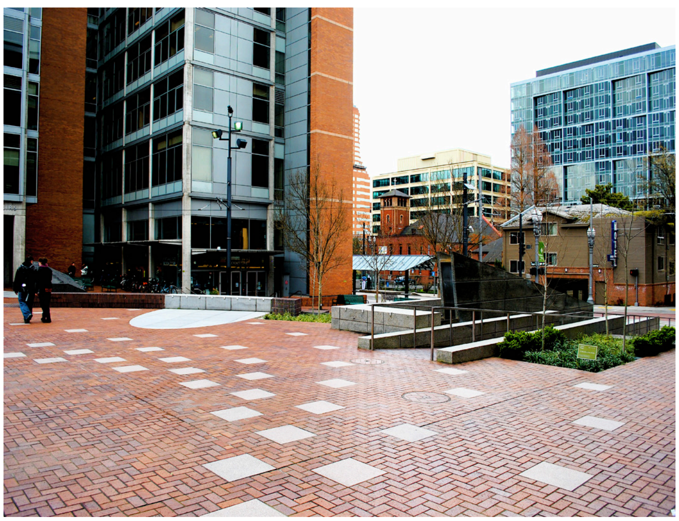
Multiple benches throughout the plaza. This photo captures the streetcar line running through the plaza.

**Picture 17: Ramp Access**

Access to this space may be reached by people with disabilities as well as those without.

**Picture 18: Rain Garden**

Placement of the rain garden allows stormwater runoff to be retained before flowing down the stairs.



**Picture 19: Open Space**

Open space provides opportunity for active and passive engagement.

**Picture 20: Water Feature 2**

A second water feature is used in a similar way as a calming device during rains.

**Picture 21: Stairs/Seating**

Stairs may be utilized as secondary seating for visitors. Adjacent to the stairs are tiered rain gardens.

**Picture 22: Light Rail**

The multiple transportation options increase the access to the plaza and create an environment for both students and Portland residents to enjoy.

**Picture 23: Streetcar**

The streetcar line runs through the center of the plaza, with a stop within the plaza as well. Increasing opportunity for potential visitors.

**Table 9: Urban Center Plaza**

| PUBLIC HARDSCAPE FEATURE | EXISTENCE | DEGREE/TYPE/QUANTITY/ NOTES |
|---|---|---|
| | | |
| Primary Observation Site | X | Visited March, 2011. |
| Physical Elements | | |
| Entrance | X | Multiple entrances for this plaza. Wheelchair accessible. Only place in the city that the light rail and streetcar lines intersect. Bus stop is also on one side of the plaza. |
| Enclosure | | |
| Building heights | X | The heights of the buildings are not overwhelming and actually make the space feel bigger than it really is. |
| Building continuity | X | Continuity is excellent. All of the surrounding buildings are owned and used by Portland State University and have the same style of architecture and materials used. |
| Seating | | |
| Primary | X | Primary seatin is scattered throughout the plaza in the forms of benches. |
| Secondary | X | Steps can be used as secondary seating in several places in the plaza. There is also a ampitheater that allows for both primary and secondary seating. |
| Lighting | X | Plenty of natural light, there may be a lack of shade during the summer months. Artificial lighting is provided throughout the hardscape as well as by surrounding buildings. |

| PUBLIC HARDSCAPE FEATURE | EXISTENCE | DEGREE/TYPE/QUANTITY/ NOTES |
|---|---|---|
| Vegetative/Natural Features | X | The rain gardens provide a great accent to the plaza and during redevelopment, the plaza added several trees that also increase the vegetative quality of the plaza. Water feature is also part of the space and is most active after rain. |
| Social Characteristics | | |
| Comfort/Saftey | X | Since the plaza is part of Portland State University, it has a campus atmosphere. However, this plaza is a place where students and residents of Portland mix. It is a comfortable space and is patroled by university security officials. |
| Relaxation | X | The steps of space make for great space to relax as well as any of the surround benches. Bookstore and recreation center are adjacent uses that could also be part of the relaxing nature of the plaza. |
| Engagement | | |
| Passive | X | Street performers have plenty of space and passerbys can enjoy anything from music, to painting/drawing, acting, etc. |
| Active | X | The space is large enough for visitors to use the space for active engagement. |
| Stormwater BMP | X | Rain gardens/bioretention, water feature, trees. All are not only part of the stormwater management features, but also the aesthetic quality. |
| Permeable Pavement | | Bricks, not completely sure of stormwater management function. |
| Combined Sewer System | X | |

## IV: Case Study Summary

Each of the four public hardscapes have integrated stormwater BMPs into its design, creating not only a space that is attractive to the public but has sustainable qualities in regards to stormwater runoff. The data collected for each of these four hardscapes is evidence that public spaces successfully design, according to the literature on public space design, have integrated stormwater BMPs, especially vegetative practices, into the planning and design of the hardscape. Although there is evidence of integration of stormwater BMPs into public hardscape design, the data collected shows limited use of permeable paving materials. In large cities across the nation, only a limited number of public hardscapes with stormwater management measures in place were found. The primary observation and photo analysis of these four public hardscapes answers the research question by showing that some public hardscapes are both successfully designed and integrating stormwater BMPs, however, the examples found are few and suggests that this type of integration into design is not common practice.

## V: Planning for integrated hardscapes

2. *What has promoted or impeded such integration in these spaces?*

Each case study included document analysis that was available for each public hardscape as well as a minimum of one interview with an agency associated with the planning or implementation of the space. Interviews were conducted with design professionals, landscape architecture firms, public services representatives, and non-profit organizations. In order to answer this research question, interviewees were asked about mandated criteria for the design of their specific public hardscape as well as and pushback involved with the project. The interviews also inquired about funding of the projects and whether or not the city has a combined sewer system. Through the responses given by interviewees and the information gathered through document analysis; programs, agencies, difficulties and successes were identified that both promote and impede integration of stormwater BMPs into public hardscape design.

**A). Promote Integration**

Since there are several public hardscapes that have been constructed recently without the integration of stormwater BMPs, it was intriguing to ask what or who promoted such a practice. According to the interviews there were conducted, there were two major issues or groups that promoted the integration of stormwater management measures into public hardscape design: innovative design firms and problems with combined sewer systems. These issues and groups were catalysts for the integration of public hardscape design and stormwater BMPs to occur. Another issue that was raised during some of the interviews was compliance with water quality standards set by the NPDES.

Water quality compliance is significant for federal funding and therefore is not a minor issue, however, it was not mentioned by all of those interviewed like design firms and problems with combined sewer systems. A majority of the interviewees also mentioned that the city itself was in support of the integration, even if they were not able to fully fund the project.

i). Innovative Design Firms

Public space design has often been placed in the hand of design firms that understand what is attractive and appealing to the public that may use the space. Through history, public spaces and hardscapes specifically have been planned and designed without stormwater runoff control as a necessary component. However, the interviews of various agencies, including but not limited to design firms, commented that the innovation of the designers often brought various stormwater BMPs into the conversation of how a public hardscape should be implemented. The analysis of the documents associated with each public space provides evidence of how innovative designers placed stormwater BMPs into the projects without taking away from the appeal of the public space. Efforts by design firms to integrate stormwater management components is essential in the planning and design phase of public hardscapes and such firms can be one of the agents that promotes a more sustainable design.

ii). Problems with Combined Sewer Systems (CSS)

In all four of the case study sites, the cities operated on a combined sewer system (CSS). Problems with CSS usually occur when there are heavy rains and cause an overflow. Overflows can result in stormwater runoff along with raw sewage flowing into local water bodies (EPA, 1994b). All interviewees noted CSS when asked about what promoted integration of stormwater management components into the project. While public hardscapes do not make up a majority of the impervious surfaces within cities, the containment and treatment of stormwater runoff on site reduces the burden that may be placed on CSS. One interviewee noted that, "Although the benefit may seem small, polluted stormwater runoff from surrounding streets often flows into public spaces and can be infiltrated without returning to the street or storm drain". The pressing problems caused by dated CSS is an important reason for integrating stormwater BMPs into public hardscape design and even further into other urban designs. The cost of replacing piping for CSS can be a costly venture. According to Environmental Service for the City of Portland, using vegetative systems, permeable paving techniques, and other "green stormwater management systems", the city could save over $40 million over solutions using piping alone (Saltzmann and Marriott, 2009). The savings coupled with the benefit of using stormwater BMPs in public space design to reduce the load for CSS, were proven to be motivation for integration. As CSS continue to be utilized in many cities across the country, the use of public space design to deal with a portion of stormwater runoff may be one identifiable solution.

**B). Impede Integration**

While design firms and the threats associated with CSS were important in promoting the integration of public space design and stormwater BMPs, interviewees identified obstacles to inserting stormwater runoff controls in various forms. As a result of interview questions regarding impediments to integration, developers' skepticism and funding were determined to be the two limited barriers.

i). <u>Developers' Skepticism</u>

The planning process of many of the projects were said to have a small degree of pushback from developers. One interviewee commented that developers may have felt as though they had another requirement to meet. However, since these public hardscapes were implemented, many of the cities have created stormwater management manuals for new and redevelopment projects. Developers' skepticism was limited and interviewees agreed that after the initial discussion about incorporating stormwater BMPs into public space design, developers were on board with the projects in their entirety.

ii). Funding

The cost of public hardscape projects depends on a variety of variables. Constructions of vegetative and paving stormwater BMPs are comparable to construction costs of piping needed for traditional stormwater runoff control. Interview questions did not ask specifically about the percentage of funding that came from each source. However, questions did identify parties that may have impeded the process of integration into design. Three of the projects were funded through public/private partnerships and difficulty came due to the uniqueness of the hardscapes. The public hardscapes that were selected for case study are innovative and funding for innovative projects often are in need of educating those willing to invest in it. Much like with developers, those that were weary of integration quickly became proponents of the project when understanding the benefits and sustainable qualities. Although funding may be an impediment for many public hardscape projects, it may not specifically be due to vegetative and paving stormwater BMPs. If opposition comes concerning these practices, the cases presented in this research suggest that education may the tool to overcome such barriers.

## VI: Improving stormwater design in public hardscapes

3. *How can such integration be improved?*

The case studies of this research proved the existence of public hardscapes that incorporate stormwater management practices within large cities across the United States. Through the literature and interviews with design professionals, landscape architecture firms, public services representatives and non-profit organizations, multiple suggestions came forward on ways to improve the integration of public hardscape design and stormwater BMPs.

Improvement of the integration of stormwater BMPs in public hardscape design is an area with seemingly limitless opportunity. Through analysis of the literature and interviews, it was gathered that improvement would come through stormwater regulations, education of those parties involved as well as dedication from design firms and professionals to implementing stormwater BMPs into design.

The literature suggests that improved stormwater regulation and legislation has been one way of making municipalities aware of stormwater management issues. Further regulations that are mandatory for municipalities could be a catalyst for the integration of stormwater BMPs into public hardscapes. Through the passing and enforcement of stormwater management regulations, both locally and nationally, steps will be taken to improve runoff control. Improving the public hardscape design through incorporating stormwater BMPs can accomplish both successful design along with meeting standards for regulation.

Education is a critical need in order for integration to be fully accepted and used in public hardscapes. Interviewees listed parties such as public officials, developer organizations, neighborhood organizations, and the public as a whole that are in need of awareness about stormwater management. All of these parties can play a role in the improvement of integration not only in public hardscapes, but also in streetscapes, neighborhood streets, new and redevelopments and many more. The awareness of these groups begins with education and hopefully will move each to being more than aware, rather involved.

The other improvement to integration will come from design firms and professionals. This begins with students and interns being exposed to stormwater management issues, in an environment where they can ask questions and test strategies and solutions in an academic atmosphere. Public hardscape designers should not only practice their own techniques but also be aware of colleague and competitor's techniques that are unique and successful. This idea corresponds with one that was stated in an interview response, commenting that design firms must continue to learn about sustainable practices in order to produce sustainable products.

Finally, improvement to integration of stormwater BMPs into public hardscape design will come through improvement in the two, education and dedicated designers, separately. As stormwater BMPs are created and built upon, dedicated designers and an educated public will hopefully implement the use of those techniques. Public space design will also continue to change with fresh ideas and attractive designs that will be utilized as cities grow and the need for public spaces with them. Education, dedicated designers, and the evolution of stormwater BMPs and public space design have the potential to improve the integration of public hardscape design and stormwater BMPs and hopefully generate a standard for a new sustainable public hardscape.

# CHAPTER 9: CONCLUSIONS

## I: Introduction

Through an investigation of public hardscapes in the United States, it has been observed that the integration of stormwater BMPs and permeable paving materials is limited in public hardscape design. However, through case study analysis, primary observation, document analysis, and interviews it is clear that integration within public hardscapes has not been entirely forgotten. The burden that stormwater runoff places on combined sewer systems is evident and relief from any area of the urban environment is beneficial. With knowledge of the literature and the results of the case studies in mind, the following suggest implications for practice, limitations of this research and avenues for future research.

## II: Implications for Practice

Evidence that stormwater best management practices are being incorporated into public hardscape design has been exposed and analyzed through this research. However, the innovations documented in the case studies within this research are a minority within the United States. The impact of stormwater will increasingly become an issue that should be addressed as our urban environments continue to be covered by impervious surfaces and major cities operate on combined sewer systems. The implications for practice, derived from this research, include the definition of preliminary standards for the planning and design of public hardscapes and the provision of information necessary for an urban public hardscape best practice.

In order for a sustainable standard for planning and design of public spaces to be effective, multiple groups must be involved. First, there is a need for awareness about stormwater management, from the public to the developer to elected officials. Once awareness is spread, policies and regulations should be created and put in place to ensure that the future of urban environments is prepared for issues regarding stormwater runoff. Many cities across the nation have already began working on stormwater control programs and have utilized funding from section 319 of the Water Quality Act (River Network, 2011b). After the creation of policies, a level of enforcement is necessary to not only insure that new developments and redevelopments are implementing stormwater BMPs, but to evaluate stormwater control programs. Public hardscapes are only a small piece of the larger picture, however, if stormwater runoff can be retained and treated within public hardscapes, the burden on combined sewer systems can be reduced and the impact of polluted runoff from nearby streets can be dissipated. Through the review of public space design and stormwater management techniques, along with an in depth look at innovative integrated spaces within the United States, a sustainable standard for hardscape planning and design is not only possible, but attainable.

Public hardscapes are not a new idea and have been used throughout history as a place for people to interact, gather, and just relax. Over time, hardscapes have changed and adapted to places and cultures, while in many cases improving in appeal and aesthetics. Through this research it is clear that there are components of public space design that are important in creating a great hardscape. The case studies in this research are only an example of what could be produced through a hardscape best practice. A best practice for hardscapes would include the physical and social features that the literature and previous case studies have identified as essential. Researchers such as William H. Whyte have completed compelling investigations in to public spaces and his findings along with others are vital in best practice (Whyte, 1980, Sucher, 2003, Carr et al., 1992). Best practice does not stop with the physical and social form of public hardscapes, but would integrate stormwater BMPs into both planning and design. The stormwater BMPs described in this research and observed in the four case studies serve a dual purpose. These stormwater BMPs provide an aesthetic and natural appeal to the space while functioning as an infiltration and treatment agent for stormwater runoff. Finally, hardscape best practice would consider permeable paving materials as an affordable and effective alternative to impervious materials traditionally used. The benefits of permeable paving materials have been thoroughly documented and can improve stormwater management without sacrificing in attractiveness or cost. A best practice for urban hardscapes incorporates elements of public space design, stormwater BMPs, and permeable paving materials without imposing drastic additional costs or reducing aesthetic appeal. This research is merely a starting point for integrating public hardscape design and stormwater BMPs in the urban context. Results of this research create a framework for a hardscape best practice and lend themselves to further research.

## III: Research Limitations

Much of this research was dependent upon primary observation, document and photo analysis, and interviews. Primary observation has the advantage of experiencing each of the hardscapes first hand. The benefit of seeing how interaction occurred and how specific parts of the space may be used in unique ways. However, threats that arise from primary observation occur in the duration of time that each hardscape was observed. Variables such as weather, events in other parts of the city, or time of day may have impacted the interaction or ways that the space was being used during the time observed. In order to remedy this threat, observation may be recorded at various times over the course of a week. However, the time limitations for this project as well as travel expenses deterred further observation of each public hardscape.

Interviews also pose a limitation to research. The hope of this research was to interview multiple agencies, organizations or firms that were associated with each public hardscape that was selected for research. Although multiple candidates were contacted, on several occasions, for interviews the response rate was weaker than hoped for and expected. Repeated attempts often resulted in voicemails and unanswered emails. A greater response rate may have developed a more complete and detailed story from each of the case studies. Despite low response rate, interviews were conducted with at minimum one representative involved in the planning and design of the hardscapes selected.

## IV: Future Research

In researching public hardscapes, especially those within large urban cities, it has become apparent that hardscapes within cities have only recently initiated efforts to address stormwater management. Stormwater management is an important topic for practitioners as more and more emphasis is placed on sustainability. With this as the current state, there is increasing opportunity for research of stormwater BMP integration into public hardscape design not only with vegetative and permeable paving materials, but other practices that exist and have yet to be created.

More opportunities for research exist in the use of these spaces as educational tools for the community. In one of the interviews, it was noted that public spaces that utilize stormwater management methods have the capability of informing the public that use those spaces in regards to this issue. Many of the parks in the Portland area describe special features of the public area through the use of small signs and informational displays. The impact of this kind of educational tool would be interesting to investigate in further detail.

## V: Final Thoughts

Public hardscapes are not the only area of the urban environment that will need to incorporate stormwater best management practices for cities to move toward sustainability. However, public spaces and hardscapes are important to not only physically, but socially as well. If planners, designers and other agencies are dedicated to creating and implementing sustainable standards and promoting best practices, the impact of stormwater runoff due to urban areas can be reduced. Problems associated with combined sewer systems must be addressed because the threats that are posed by overflows are dangerous for the health of a city's population along with the wildlife that uses local waters. Stormwate BMPs are efficient in not only reducing stormwater runoff through infiltration, but treating water due to retention. Various methods can be applied to public spaces to add both a functional and aesthetic quality. Permeable paving materials are included in stormwater BMPs and if considered can replicate impervious materials at comparable prices with substantial benefits. Literature supports the need for useful and appealing public spaces within the urban environment. As seen through this research, only a few spaces have incorporated stormwater BMPs into design, but any progress is beneficial and hopefully, a new standard will be accepted in order to integrate public hardscape design with stormwater management techniques.

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