DESIGN AND IMPLEMENTATION PROCESSES
OF LOW IMPACT DEVELOPMENT IN THE
DALLAS - FORT WORTH AREA

by

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ABSTRACT

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In 1999, the EPA published The Stormwater Phase II rule, which instituted the implementation of "techniques, measures or structural control to manage and improve the quality of stormwater runoff" otherwise known as Best Management Practices (BMP) (EPA, 1999). These strategies are designed to address one or more of three factors; flow control, pollutant removal, and pollutant source removal. As part of the list of techniques associated with BMP's, one in particular has become a more strategic approach that mimics predevelopment hydrology (EPA, 2009). This approach is known as Low Impact Development. Low Impact Development (LID) practices have emerged as the new alternative to conventional planning strategies.

The purpose of this research is to evaluate the design and implementation processes of LID in order to gain clear understanding about the effects and integration of low impact principles in urban environments, specifically the Dallas - Fort Worth (DFW) area. The research

concentrates on how various design and construction disciplines, such as landscape architecture and engineering, approach a design or construction using Low Impact Development. Additionally, what are the influences that have helped designers choose LID practices over conventional planning strategies?

This research concentrates on various LIDs practices implemented using qualitative methods (Taylor et al ,1998). The research primarily utilizes interviews and site observations on existing LID's in selected sites in DFW (Marcus et al, 2001). The researcher reviews and documents the various types of LID practices and uses those practices as a basis for qualitative analysis through the use of interviews with designers of LIDs. To analyze what design and construction techniques and processes have been used, the thesis conducts interviews with different individuals that have designed and implemented LID in the Dallas -Fort Worth area. In addition to the interviews, a site observation has been conducted at Texas A&M Agrilife Research and Extension Center in Dallas, TX. This ongoing research project is documented to further understand and illustrate the problems and issues involved in the construction process associated with LID practices. While at Texas A & M, documentation about the construction processes of LID was obtained through passive field observation techniques (Marcus et al, 2001). *Rogers' Diffusion of Innovation Theory* is used to analyze the interviews to find the commonalities and differences in the interview responses (Rogers, 2003).

In conclusion, LID practices have become more abundant in the continuously expanding Dallas- Ft Worth area. The framework for this evolving alternative to conventional planning strategies has start gaining wider audience across design disciplines. This research illustrates that the decision to choose low impact development over traditional methods lies solely with each individual that is involved in the design and construction process. This research also evaluates the differences in design and implementation of LID practices among the disciplines of landscape architecture and engineering. The significance of this topic is important to landscape architects because it particularly involves the one area upon which a designer has a direct influence; the environment in which we inhabit. The American Society of Landscape Architects mission statement is "to lead, to educate, and to participate in the careful stewardship, wise planning, and artful design of our cultural and natural environment" (ASLA, 2012).

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INTRODUCTION

1.1 Background

Low Impact Development practices (LID) is a new approach that has begun to be implemented as an improved solution to BMP's in the Dallas - Fort Worth area. LID practices are part of a larger group that are used to insure development would not increase stormwater volume, degrade water quality, which could eventually cause damage to lakes, rivers, streams and coastal areas. The larger group of practices are called Best Management Practices (BMP's). These practices have been implemented since the Clean Water Act in 1972. In comparison to BMP's, LID takes a different approach to managing the flow of water from new development. BMP's use a structural approach to control stormwater versus LID that uses a variety of natural and manmade built features that reduce the rate of runoff, filter out pollutants, and promotes the infiltration of water back into the ground. LID originated in Prince George County, Maryland Department of Environmental Resources in 1990 (Prince George County, 1990). LID started in Maryland and has been used there for more than ten years. This fairly new practice has started to take hold as a new innovation for not only landscape architects but engineers as well.

1.2 Research Objectives

Even though there has been a significant number of resources and research regarding the LID practices in North America (EPA, 2012), there is almost no resource that has shown the effect and the value of the design and implementation in the Dallas - Fort Worth area because the design practice has only been implemented in the past three years. The objective of the research is to analyze the design and construction processes related to Low Impact Development

practices, particularly in the DFW area in order to assess their adaptation, effectiveness and value. It is imperative to first understand what individuals are involved in implementation of LID practices and then what influences the designer to choose this type of strategy in order to inform future landscape decisions.

1.3 Research Questions

The research questions for this study are:

1. How are the design processes in Low Impact Development different from conventional methods?
2. How are the implementation processes different in Low Impact Development practices opposed to conventional methods?
3. What is the value of Low Impact Development in the Dallas- Fort Worth area?
4. What individuals are involved in the implementation of LID practices in the Dallas - Fort Worth area and how do their varying view influence the design and implementation of LID?

1.4 Research Methods

The research uses qualitative analysis to assess adaptation, effectiveness and value of LIDs in the Dallas - Fort Worth area. The research primarily utilizes interviews (Taylor et al, 1998) and site observations on existing LID's in selected sites in DFW (Marcus et al, 2001). *Rogers' Diffusion of Innovation Theory* is used to analyze the interviews to find the commonalities and differences in the interview responses (Rogers, 2003).

The names of the designed or implemented projects as well as key practitioners are obtained from a database created by a grant awarded by Texas Commission for Environmental

Quality (TCEQ). This grant was awarded to a joint partnership between Ecosystem Design Group, Center for Research in Water Resources located at University of Texas in Austin, and TCEQ (www.texaslid.org, 2012). This database shows the LID projects that have been designed in the delimitated area. The database also provides information about what type of LID practice has been designed on a particular site.

This research primarily utilized face-to-face interviews to gain a better understanding of the different design and implementation processes among various practitioners. Landscape architects and engineers are interviewed solely on the basis of gaining a better understanding of what design procedures are being implemented. The first set of questions asked by the researcher was dealing with LID practices. The second set of questions asked the value question of Low Impact Development. These questions were asked to gain a better understanding of the interviewees perceptions and understanding of LID practices. These questions also addressed the commonality of the use of particular techniques of LID.

This research also utilized passive observations techniques influenced by Marcus, 2001 to systematically document design and implementation processes of LIDs. This observation occurred at a LID research project site at Texas A&M Agrilife Research and Extension Center in Dallas, TX that is supported by a competitive TCEQ, RFP 319 research grant for 2010-2013 (Grant recipients Jaber, F. project lead from TAMU; Ozdil, T. R. project principal partner from UTA) . The grant was part of the publication titled “Upper Trinity Watershed Green Building Infrastructure for Stormwater Management.” The grant was awarded on May 15, 2010. Three other project observations are also conducted in other LID sites. These sites are the following: Rayzor Ranch, Denton, TX, and North Texas Orthopedic, Flower Mound, TX.

1.5 Definitions of Terms

A.S.L.A.: American Society of Landscape Architects (ASLA, 2012).

B.M.P.: Best Management Practices. This definition is defined by the EPA as "an approach that integrates the control of stormwater peak flows and the protection of natural channels to sustain the physical and chemical properties of aquatic habitat." (EPA, 2004).

Bioretention: Bioretention utilizes soils and both woody and herbaceous plants to remove pollutants from storm water runoff (Medell et al, 2010).

Dry Wells: Gravel or stone filled pits that are located to catch water from roof downspouts or paved areas (EPA, 2004).

Filter Strips: Bands of dense vegetation planted immediately downstream of a runoff source designed to filter runoff before entering a receiving structure or water body (EPA, 2004).

Evapotranspiration:The process of transferring moisture from the earth to the atmosphere by evaporation of water and transpiration from plants (EPA, 2004).

Grassed Swales: Shallow channels lined with grass and that are used to convey and store runoff (EPA, 2004).

Infiltration Trenches: Trenches filled with porous media such as bioretention material, sand, or aggregate that collect runoff and exfiltrate it into the ground (EPA, 2004).

Integrated Management Practices (I.M.P.): IMP's are techniques used to control stormwater. Included in this category are bioretention, rain water harvesting, vegetated swales (EPA, 2004).

i.S.W.M: Is a cooperative initiative that assists municipalities and counties in achieving their goals of water quality protection, streambank protection, and flood mitigation, while also helping communities meet their construction and post-construction obligations under state stormwater permits (NCTCOG, 2009).

Green Infrastructure: Green infrastructure refers to a strategically managed network of natural and open spaces that provides ecological benefits for human and wildlife populations in urbanized areas (Benedict and McMahon 2006; Sandstrom 2002).

Low Impact Development (L.I.D.): This definition is defined by the EPA as "innovative practices that manage stormwater close to its source by minimizing a site's predevelopment hydrology and use design techniques that infiltrate, evapotranspirate, and reuse runoff." (EPA, 2004).

MS4s: Operators of regulated small municipal separate storm sewer systems. Examples are state departments, transportation, universities, local sewer districts, hospitals, military bases, and prisons (EPA, 2004).

Permeable Pavement: Asphalt or concrete rendered porous by the aggregate structure (EPA, 2004).

Permeable Pavers: Manufactured paving stones containing spaces where water can penetrate into the porous media placed underneath (EPA, 2004).

Stormwater: Stormwater runoff is generated when precipitation from rain and snowmelt events flows over land or impervious surfaces and does not percolate into the ground (EPA, 2004).

1.6 Significance and Limitations

This research focuses on the design and implementation of LID practices as a new technical innovation for stormwater management in the Dallas- Fort Worth area only. It evaluates the adoption of these practices by professionals within this area only. Interviews are conducted one-on-one with the designers of LID practices in this region and their experiences. The significance of this research is to evaluate what design professionals are using and implementing LID practices. The research also evaluates what influences their choice to design and implement LID practices.

1.7 Summary Chapter Outline

The focus of this chapter was to introduce the research proposed by this thesis by giving a quick background on LID and its relationship to stormwater management, This chapter set the objective of the research as to analyze the design and construction processes of LID, specifically in the Dallas - Ft Worth area and identify the questions to be addressed in the following chapters. Moreover, it explain briefly some of the key terminology, and methodological underpinnings of the research with foreseen significance and limitations of the research. The following chapters of the research will introduce natural will further detail these issues. Chapter two of this thesis will discuss and review different literatures relating to stormwater management. Chapter three will discuss the methodology behind the research. Chapter four analyzes the interviews and site observations related to the research. Chapter five will summarize the findings of the research and discusses future research on the topic of LID.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature review provides a background for water resource management and techniques used for managing stormwater due to its relationship to LID. The literature documents citations in order to understand the water cycle from its simplest form to its most complex. The research documents different types of stormwater techniques ranging from local levels to requirements at the national level. These technologies that are reviewed are not only used by engineers but landscape architects as well.

2.1.1 Natural Systems: Understanding the Hydrologic Cycle

Since the largest amount of water is held in the oceans, the largest amount of water in atmosphere comes from the world's oceans. The sun, which drives the water cycle, starts the hydrologic cycle by heating water in the ocean. Some of this water evaporates as vapor and dissipates into the air. Rising air currents take the vapor into the atmosphere along with water gained by evapotranspiration. Evapotranspiration is water which is transpired from plants and evaporated from the soil. The vapor rises into the air where cooler temperatures cause it to condense into clouds. These clouds are then moved by air currents around the globe. As the air particles and clouds collide, grow and fall from the sky, then precipitation occurs. Some precipitation falls as snow and can collect as ice caps and glaciers. This accumulation can store frozen water for thousands of years. Snowpacks in warmer climates often thaw and melt when spring finally arrives. The melted water from the snowpacks flows over the land as snowmelt. Most of the precipitation falls back into the oceans or onto land where it flows over the ground as surface runoff. The runoff, partially, enters small streams and then into lakes and then eventually into the oceans. Runoff and seepage of ground water accumulates and is stored as freshwater in lakes. Not all of the runoff flows into rivers. Part of the runoff enters the ground as infiltration. Some water infiltrates the ground and replenishes aquifers. Some infiltration stays close to the ground surface and will potentially seep back into surface-water bodies as ground-water discharge. The cycle repeats over and over again until it is hard to distinguish the beginning and the end (USGS, 2010).

Evaporation drives the water cycle. Evaporation from the oceans is the primary mechanism supporting the surface- to- atmosphere portion of the water cycle. Since the ocean has the largest surface area, evaporation mostly occurs in these areas around the globe. On a larger scale, the amount of water evaporating is about the same as the amount of water delivered to the Earth as precipitation. Most of the water that evaporates from the ocean falls back into the oceans as precipitation. Evaporation is more prevalent over the oceans and precipitation is more prevalent over land. Most of the water that evaporates from the oceans returns back to the oceans as precipitation. The process of evaporation is so large that without precipitation runoff, and discharge from aquifers, oceans would become nearly empty (USGS, 2010).

The hydrological cycle is important to the topic of LID because it explains the natural flow of water and how it relates to certain LID techniques. LID techniques try to mimic certain natural processes. To be able to understand the hydrologic cycle, it is first imperative to also understanding the way in which LID techniques function in relation to the water cycle.

2.1.2 The Clean Water Act and the National Pollution Discharge Elimination System

Stormwater pollution has two main ingredients. The first ingredient is the increased volume and rate of runoff from impervious surfaces. The second ingredient comprises the concentration of pollutants in the runoff. Both ingredients are directly related to development in urban and urbanizing areas. Combining these ingredients causes changes in hydrology and water quality. The end result is a variety of problems, including habitat modification and loss, increased flooding, decreased aquatic biological diversity, and increased sedimentation and erosion (Pitt, et al, 1995, 260).

The Clean Water Act (CWA), enacted in 1972, is the cornerstone of early legislation for protection of surface water quality in the United States. Under the CWA, the EPA has implemented pollution control programs. The Clean Water Act uses regulatory and nonregulatory tools that sharply reduce direct pollutant discharge into waterways and wastewater treatment facilities, as well as manage polluted runoff. These tools are used to achieve the goal of restoring and maintaining the chemical, physical, and biological integrity of the waters within the borders of the United States (Edelman,1973).

Mandated by Congress under the Clean Water Act, the National Pollution Discharge Elimination System (NPDES) Stormwater Program is a comprehensive two-phased program for addressing the non-agricultural sources of stormwater discharges which adversely affect the quality of the water within the United States. This program uses a permitting mechanism to require the implementation of controls designed to prevent harmful pollutants from being carried away into local water bodies. Under this program industrial, municipal, and other facilities must obtain permits if they allow their discharges to go directly into any clean water sources (Edelman,1973).

Part of the permitting phase for NPDES is the EPA's stormwater program referred to as the Phase I Program. Phase I was originally created in 1990 under the CWA. This program relies heavily on the NPDES for permit coverage to address stormwater runoff from the following sources: (a.) medium and large municipal separate storm sewer systems (MS4's) serving populations of 100,000 or larger, (b) construction activity disturbing five acres of land or greater and (c)ten categories of industrial activity. This program requires medium and large cities or certain countries with populations of 100,000 people or more to obtain NPDES permit coverage for their stormwater discharges.

The second phase of the EPA's stormwater program is referred to as the Phase II Program. The Phase II rule is the second step by the EPA to preserve, protect, and improve the nation's water resources from polluted stormwater runoff. The Phase II program expands upon a previous Phase I program by requiring additional operators of MS4s in urban areas and operators of small construction sites to implement programs and practices to control polluted stormwater runoff. As part of the permitting process, permittees are required to submit an application that includes the following (a) source identification information, (b) precipitation data, (c) existing data on the volume and quantity of storm water discharges,(d) a list of receiving water bodies and existing information on impacts on receiving waters, and (e) a field screening analysis for illicit connections and illegal dumping. The purpose of Phase II is to further reduce adverse impacts to water quality and aquatic habitat by initiating the use of controls on the unregulated sources of stormwater discharge. Stormwater discharge has the greatest likelihood of causing environmental degradation.

Stormwater pollution is classified as either point or non-point source pollution. Point source pollution is defined by the EPA as "any single identifiable source of pollution from which pollutants are discharged, such as a pipe, ditch, ship or factory smokestack." Factories and sewage treatment plants are two types of point sources described by the EPA. Industrial companies, including oil refineries, pulp and paper mills along with chemical, electronics and automobile manufacturers are allowed a certain amount of discharge into local waters (EPA, 2001).

Nonpoint source is defined by the EPA as "pollution that enters a water body from diffuse origins on the watershed and is not transported via discernible, confined or discrete conveyances." The sources, given by the EPA, are as follows: agriculture, mining, construction, urban development, and silviculture. Categories of pollutants are sediments, mineral pollutants (ie heavy metals), nutrients (ie nitrogen and phosphorus), pesticides, biodegradable pollutants, thermal pollution, radioactivity, and microbial pollution (Litwin et al, 1978, 2348).

A journal article from the Water Pollution Control Federation dated 1978, the author describes that different factors that affect the extent of nonpoint source pollution. Land use and management practices, hydrologic and topographic characteristics, and vegetative cover affect this extent of pollution. The author states that "anything that influences the accumulation and generation of pollutants on land surfaces or the mechanisms which transport pollutants from the land surface to streams has a direct impact on nonpoint source pollution" (Litwin, Donigan, 1978, 2348).

The Clean Water Act and NPES is important to the topic of LID because it explains the necessity for stormwater control measures in coordination with state and local agencies. It also explains how the increase of development has called out of necessity better stormwater control measures and permitting processes. In turn, NPES was created to access and mitigate that development by the permitting process. Also, the topic of nonpoint and point source pollution is important to the topic of LID because it explains the sources of pollution to not only industrial but commercial sites as well.

2.2 Methods of Stormwater Management

2.2.1 Conventional Design of Stormwater

In Grigg's words " Stormwater systems consist of the minor stormwater system that uses gravity to drain water from points of generation to points of disposal." He goes on to explain that the stormwater system is called "stormwater and flood control" because it is not practical to use piped stormwater systems to handle the largest flows. He states that the "minor" and "major" subsystems rely on different components. This approach is often referred to as "risk based " (Griggs, 2002, 43).

The minor system is called the "initial" or convenience system. It uses gutters, small ditches, culverts and storm drains, and detention ponds to capture the water. Griggs points out that even though the minor system contains small facilities , it requires large pipes downstream. The major system drains bigger floods and rare flood events. The major system is adjacent to streets, large channels, creeks and rivers. It may not be used for years, but it captures the rare flood events that can potentially flood a building. Major systems include flood hazard areas zoned to restrict development (Griggs, 2002, 44).

Griggs also explains that stormwater systems handle the large amount of water and function only during rainfall events. There are two paths that stormwater can take. The first path is from a grassy field to a contaminated runoff, the second path is from industrial sites. The volume of water that flows off these types of sites can vary.

When talking about minor systems, the storm event that is used to plan for these systems is the range of 2-25 years. Two years would apply to the residential areas and the 25 years would apply to the commercial zones. The major systems are generally planned for the 100 year event. This policy was enacted under the influence of the Flood Insurance Act (Griggs, 2002).

See Figure 2.1 and 2.2 for graphical representation of typical stormwater design.

The following principles for planning stormwater are given by the ASCE - American Society of Engineers (Griggs, 2002):

- Drainage does not understand boundaries
- Storm drainage is a subsystem of the water system
- Every urban area has two drainage systems, a major and a minor
- Runoff routing is a "space allocation problem"

The topic of conventional design of stormwater is important to the topic of LID because it gives a background and explanation to the elements of design when it comes to controlling stormwater on a specific site. It also explains the controls measures associated with the amount of flooding that can occur from stormwater. Conventional stormwater techniques are part of the literature review because they offer information on typical engineering guidelines relating to stormwater design.

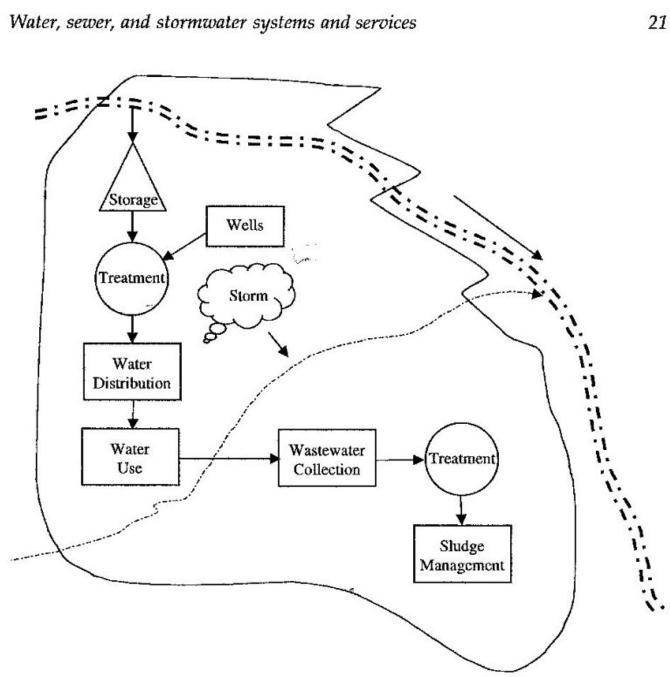
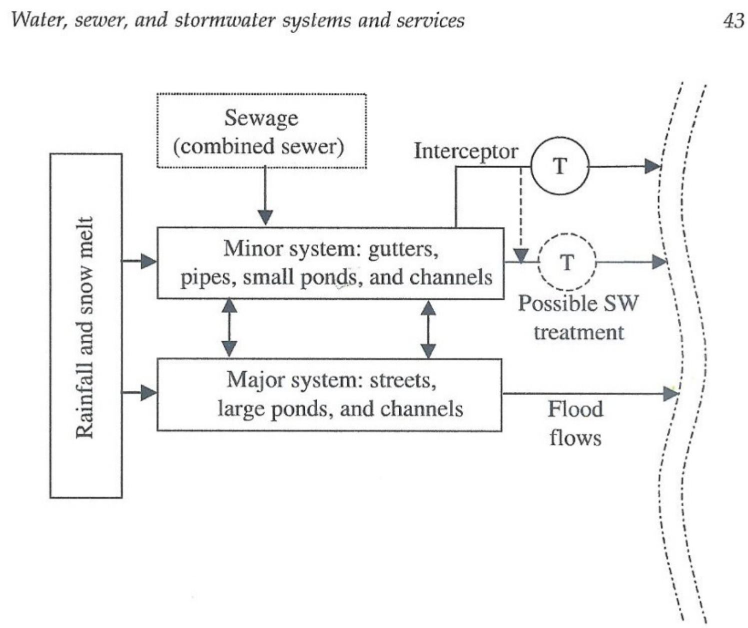


Figure 2.1 Integrated Urban Water Systems (Griggs, 2002, 21)



<u>Figure 2.2 Typical Stormwater Systems</u> (Griggs, 2002, 43)

<u>2.2.2 iSWM Manual</u>

iSWM criteria manual was developed to help provide "guidance and framework for incorporating effective and environmentally sustainable stormwater management into the site development and construction processes" (NCTCOG, 2010,1). The manual also tries to encourage a greater regional uniformity in development plans for stormwater management systems. The iSWM manual was created with the following goals. First, to control runoff within and from the site to minimize flood risk to people and properties. Secondly, to access discharges from a site to minimize the downstream effect of bank and channel erosion. Thirdly, to reduce pollutants in stormwater runoff in order to protect the water quality and provide assistance to communities in meeting the regulatory requirements (NCTCOG, 2010, i).

The iSWM program has four types of documentation and tools. These four tools (steps) are the iSWM Design Criteria Manual, iSWM Technical Manual, iSWM Tools, and iSWM Program Guidance. The first tool, iSWM Criteria Manual provides a description of the development process. The second tool, iSWM technical manual provides technical guidance. This second tool "includes equations, descriptions of methods, and fact sheets, which are necessary for design" (NCTCOG, 2010, i). The third tool, iSWM Tools, includes a web-served training guides, that could be useful during design. The fourth tool, iSWM Program Guides, includes "reference documents that help guide programmatic planning rather than technical design" (NCTCOG, 2010, i). See Figure 2.3 and 2.4 for iSWM Flow Chart and iSWM Development Chart.

This document created by the North Central Council of Governments in 2010 has been integrated into the ordinances for the City of Dallas, Denton, Mansfield, Benbrook, and Ft Worth. iSWM is a document that helps developers design sites that address stormwater concerns. The document's purpose is to help provide guidance and a framework for effective and environmentally sustainable stormwater management. The main focus of the manual, in regard to design, is the concern over water quality and stream bank protection, flood mitigation and conveyance. This literature has an important relationship to LID because it tries to address the effects of stormwater not only on site but also downstream.

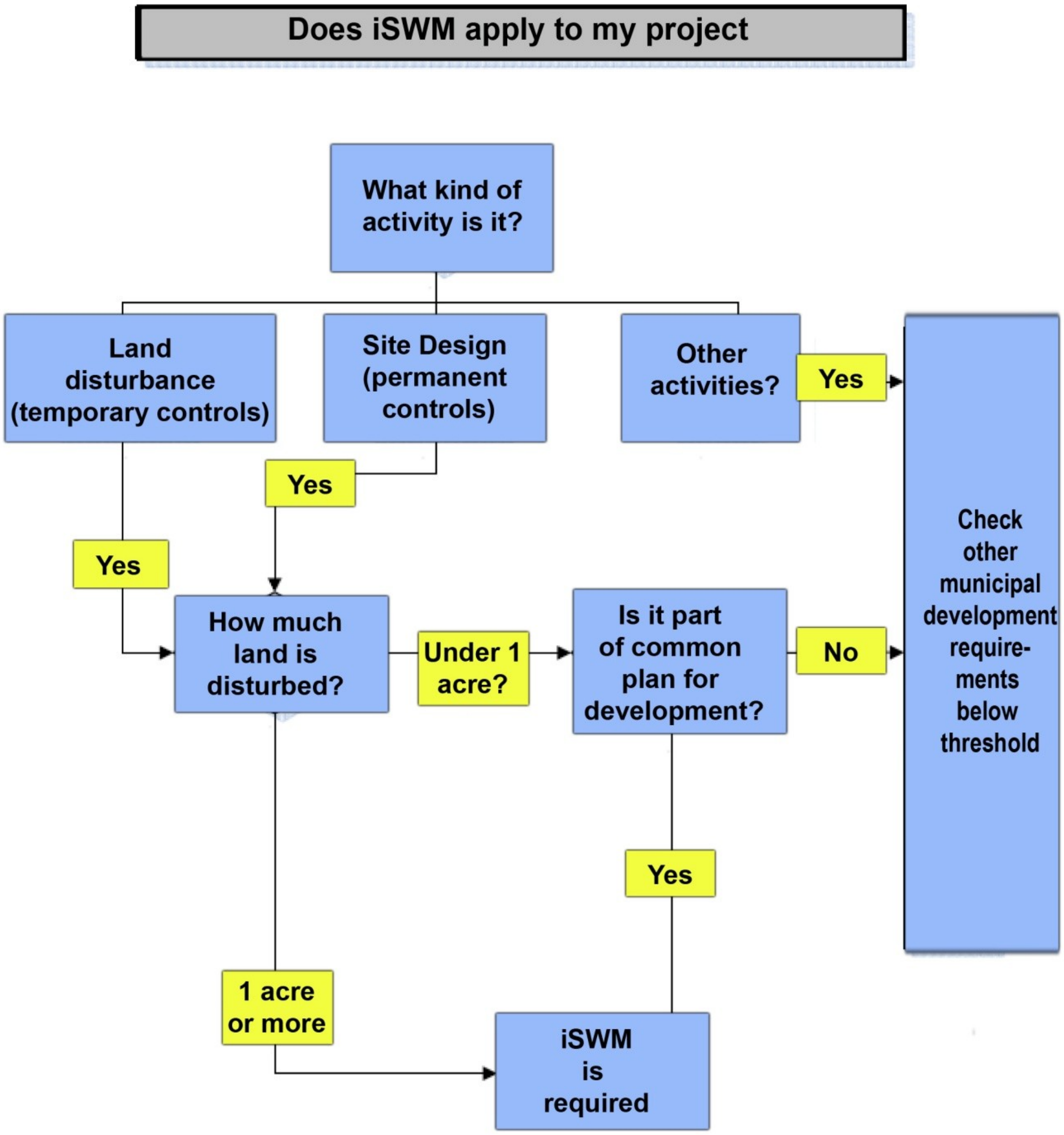


Figure 2.3 iSWM FLOW CHART
(Source: NCTCOG, 2010)

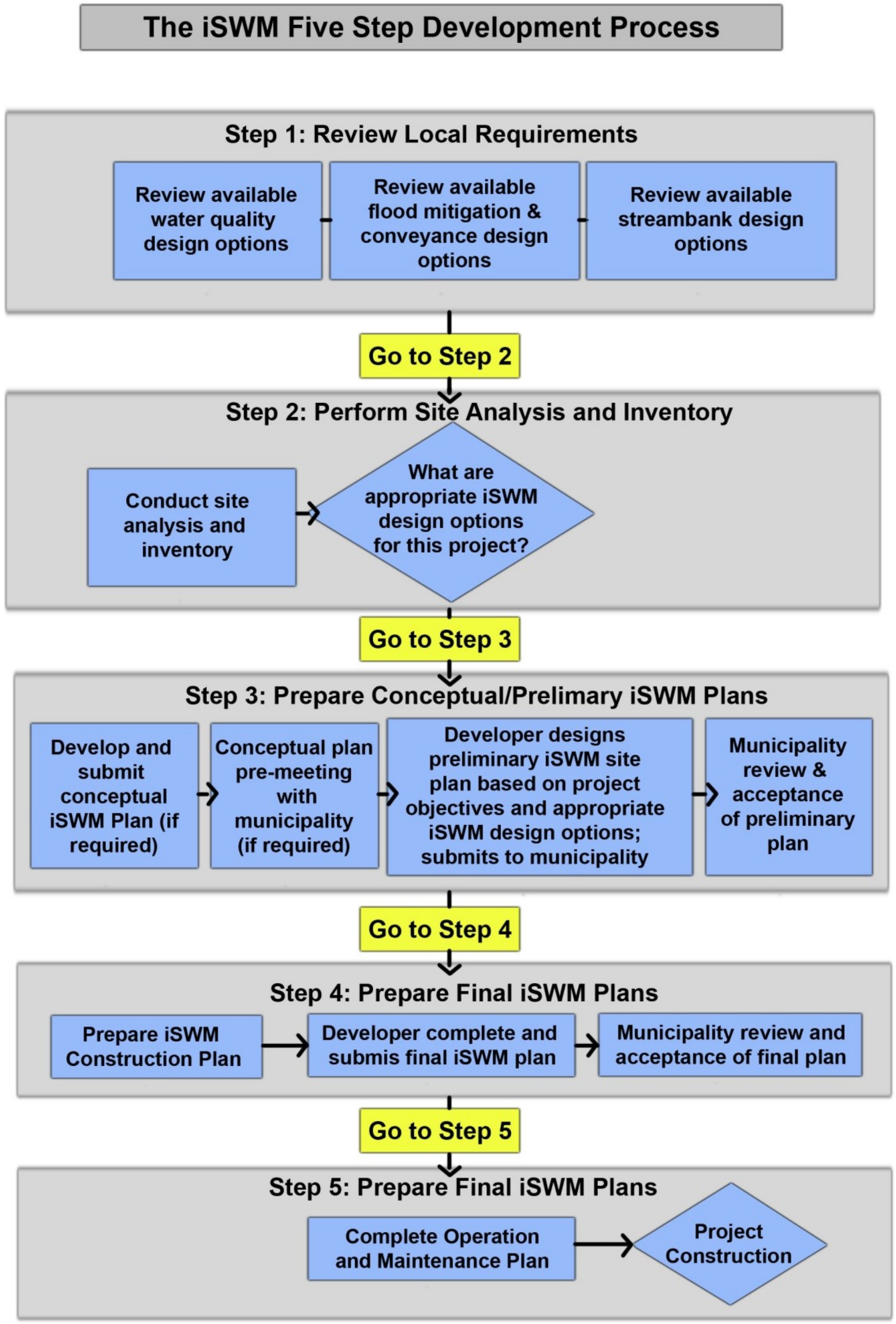


Figure 2.4 iSWM DEVELOPMENT CHART
(Source: NCTCOG, 2010)

2.2.3 Best Management Practices

Over the past twenty years, the rate of land development has been two times greater than the population growth. With the increasing amount of development taking place, concerns over the increasing amount of impervious surface caused the development of Best Management Practices. These practices would insure that development would not increase stormwater volume, or degrade water quality, which could eventually cause damage to lakes, rivers, streams and coastal areas (EPA, 2004).

A stormwater best management practice (BMP) is 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. BMP's can be either engineered or can be part of a constructed system. They potentially can improve the quality and/or control the quantity of runoff such as detention ponds and constructed wetlands. BMP's can also be used as pollution prevention practices designed to limit the generation of storm water runoff or reduce the amounts of pollutants contained in the runoff. Using one type of BMP is not effective to address all types of storm water problems. Each type of BMP has certain limitations based on drainage area served, available land space, cost, pollutant removal efficiency, as well as a variety of site-specific factors. Site specific factors include soil types, slopes, and depth of groundwater. It is important to understand each of these factors in order to appropriately select the correct BMP or group of BMP's for a particular location. (EPA, 2004).

Stormwater BMP's may be organized into two major groups. These two groups are structural BMP's or non-structural BMP's. Structural BMP's are described as the following (See Figure 2.5 a for examples of Structural BMP's) :

- infiltration systems such as infiltration basins and porous pavement.
- detention systems such as basins and underground vaults

- retention systems such as wet ponds
- constructed wetland systems
- filtration systems such as media filters and bioretention systems
- vegetated systems such as grass filter strips and vegetated swales
- minimizing directly-connected impervious surfaces (EPA, 2004).

Non-Structural BMP's are described as the following:

- automotive product and household hazardous material disposal
- modified use of fertilizers, pesticides and herbicides
- lawn debris management
- animal waste disposal
- maintenance practices such as catch basin cleaning, street and parking lot sweeping, road and ditch maintenance
- illicit discharge detection and elimination
- low impact development and land use planning (EPA, 2004, 5-2).

The theory behind effective stormwater management is using a management systems approach versus an approach that focuses on individual practices. For example, the pollutant control achievable from any given management system is viewed as the sum of the parts. This sum takes into account the range of effectiveness associated with each single practice, the costs of each practice, and the resulting overall cost and effectiveness. Some individual practices may not be very effective by themselves but in combination with others, may provide a key function in highly effective systems. The Phase II rule promotes system-building by stating the minimum requirements in general terms. By stating the minimum requirements allows the use of situation specific appropriateness for sets of practices that achieve the minimum measures (EPA, 2004).

Box Culvert Retention Pond

Figure 2.5 Best Management Practices
(Source: North Carolina State University, Jan 2012)

2.2.4 Low Impact Development Practices

Low Impact Development (L.I.D.) is a stormwater management strategy concerned with maintaining or restoring the hydrologic functions of a site to pre-development levels. These strategies are focused towards achieving natural resource protection objectives and fullfilling environmental regulatory requirements. LID utilizes a variety of natural and built features that reduce the rate of runoff, filter out pollutants, and promote the infiltration of water into the ground. By reducing the amount of pollution going into the groundwater, LID improves the quality of receiving surface waters and helps to stabilize flow rates into nearby natural streams (EPA, 2000). In Figure 2.6 Schusler graphs the stream flow rate versus time to show the effects of pre-development and post development.

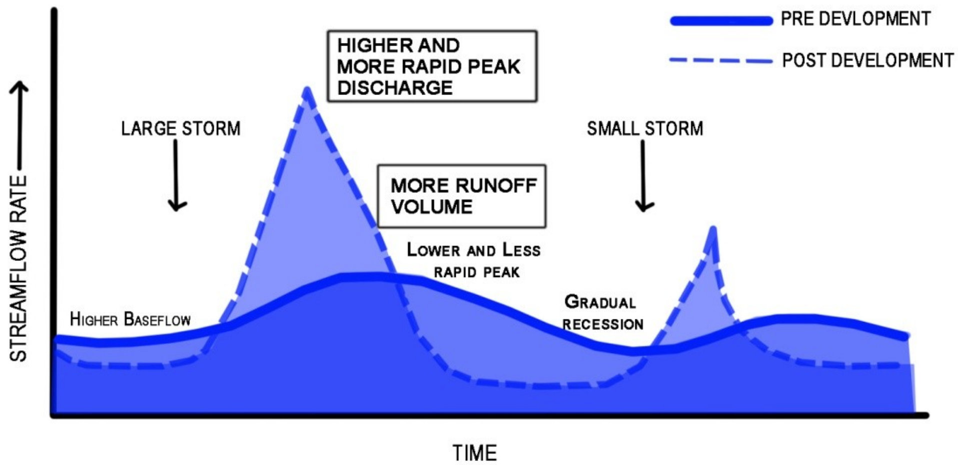


Figure 2.6 Changes in Stream Hydrology as a Result of Urbanization by Schulser
(Source: EPA, 2000)

LID originated in Prince George County by the Maryland Department of Environmental Resources in 1990. The LID effort began with the development and use of bioretention cells. A bioretention cell is created by replacing existing soil with a highly porous soil mixture. The area is then graded to form a shallow depression and planted with specialty selected vegetation. The vegetation must be able to sustain long periods of saturating conditions as well as pollutants contained within the runoff. As it rains, the bioretention areas collect the runoff and then filter out the pollutants as the water passes through the soil medium (EPA, 2000).

LID embodies a set of overall site design strategies as well as highly localized, small scale, decentralized control techniques originating at the source of the stormwater runoff. These source control techniques are known as Integrated Management Practices (IMP's). IMP's can be integrated into several different sources including building design, infrastructure, and landscape architecture. Instead of collecting runoff in a piped or channelized network, LID uses an ecological rather than an engineering approach. IMP's are to be designed in a small portion in each lot. To eliminate the need for a centralized BMP structure, IMP's are designed near the main source of impact. LID uses a decentralized approach that disperses flows and manages runoff closer to where it originates. Because LID embraces an array of useful techniques for controlling runoff, designs can be adjusted and reconfigured according to local regulatory requirements. The appropriateness of using LID practices is dependent on site conditions. It is not based strictly on spatial limitations. No matter what stage or size of a project, the principles of LID can be implemented and incorporated (EPA, 2000).

In a report December 2007, Prince George County, MD, the Department of Environmental Resources describes the goals of LID to be the following:

- Improve technology for environmental protection
- Provide economic incentives that encourage environmental sensitivity
- Develop environmentally sensitive planning to its potential
- Encourage education for the public
- Help build communities based stewardship to the environment
- Reduce construction and maintenance cost for stormwater infrastructure
- Mimic or replicate hydraulic features and maintain ecological/biological integrity of streams

In this same report from Prince George County in 2007, the department identifies five fundamental concepts of low impact development. The first step is using hydrology as the integrating framework. The second step is thinking micromanagement. The third step is controlling stormwater at the source. The fourth step is to use nonstructural methods of stormwater control methods. The fifth step is to create a multifunctional landscape.

The main objective in using the LID approach is to reduce the hydrologic impact of development and to incorporate techniques that maintain or restore the hydrologic and hydraulic functions. An optimal site design for LID would be to minimize the volume of runoff and to preserve existing paths of water flow. Using this design strategy would minimize infrastructure requirements. LID designs can significantly reduce development costs through site design by reducing impervious surfaces, curbs and gutters. Smart site design also decreases the use of storm drain piping, inlet structures and therefore eliminating or decreasing the size of large stormwater ponds. In some situations, the amount of lot area can be obtained by using LID techniques, in turn increasing returns to developers. Reducing site development infrastructure can also potentially reduce associated project bonding and maintenance costs (EPA, 2000)

When discussing LID practices, it is equally important to understand the time of concentration. The time of concentration (Tc) refers to the amount of time it takes for water to travel from the farthest point to the watershed outlet. By trying to achieve predevelopment hydrology, negative impacts associated with development can be decreased. The idea of detention and retention of rainfall are the key components of increases of Tc. With the increase of amount of impervious surfaces within a given site, altering drainage patterns, the contribution of total land area decreases (EPA, 2000).

Several studies were conducted by the EPA to "analyze the effectiveness of various LID practices based on hydrology and pollutant removal capabilities"(EPA, 2000, i). Among all the strategies, bioretention areas, grassy swales, permeable pavements and vegetated roof tops were the most common studied. The EPA concluded that these techniques reduced the amount of "Effective Impervious Area (EIA) in a watershed. The EPA defines EIA as "the directly connected impervious area to the storm drain system that contributes to increased watershed volumes and runoff rates"(EPA, 2000, i). The EPA states that there are documented case studies that conclusively link urbanization and increased watershed imperviousness to hydrologic impacts on streams (EPA, 2000, i).

Figure 2.7 Low Impact Development Practices

2.2.4.1 Database of LID practices in Dallas - Ft Worth area

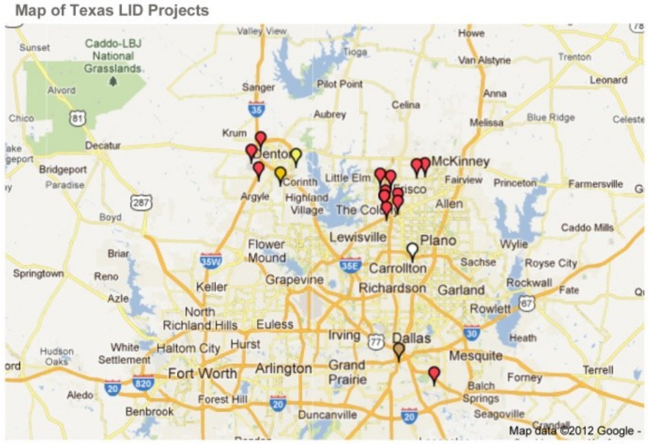
The following is the database created by a grant from TCEQ to compile a database listing LID projects that are located in Texas. The database was created by a joint partnership by Ecosystem Design Group located at the Lady Bird Johnson Wildflower Center in Austin, Center for Research in Water Resources located at the University of Texas at Austin, and Texas Commission on Environmental Quality (TCEQ), Ecosystem Design Group, Center for Research in Water Resources, Texas Commission on Environmental Quality, 2010). The database can be found online at www.texaslid.org.

PROJECTS

CALL for PROJECTS

TexasLID.org has developed a two-fold LID project database for the entire state of Texas. The first phase of this project is an interactive Texas LID map. The second phase involves the development of project Case Studies which will highlight varying applications of LID projects in detailed summaries.

Map of Texas LID Projects



Search Texas LID Projects

Land Use: ▾ **Region:** ▾

Search

View & search all projects

Phase I: LID Mapping

TexasLID.org has developed a LID mapping project to document various types of LID projects across the state. The database contains a list of LID practices (such as bioretention, permeable pavements, swales etc), their geographic location, and their watershed. The map allows users to search for LID projects across Texas by practice, region, watershed or a combination.

If you are interested in adding your LID project - completed or in construction - to our map, please email us at info@texaslid.org with the information listed below and we will add your project to our mapping database.

- Project Name
- Location
- Land Use Type (residential, commercial, mixed use)
- LID Practice(s)

Phase II: LID Case Studies

LID projects from the LID mapping project will be highlighted and developed into Case Studies. This resource will be accessible for researchers, practitioners, and municipal officials to search for information that will help facilitate future project implementation and LID research across Texas. For example, the Case Studies will contain both quantitative and qualitative information such as water quality monitoring results, runoff reductions, project costs, and ordinance revision and development. We invite you to submit projects that document the success or failure of using LID tools and techniques for managing stormwater and site drainage.

To submit your case study, contact us at info@texaslid.org for the Case Study Submission Form!

Figure 2.8 Map of LID projects in DFW area
(Source: www.texaslid.org)

2.2.4.2 Specific LID practices

2.2.4.2.1 Rainwater Harvesting

The main purpose for harvesting rainwater is for human use. Most captured rain water can be used to provide water to landscapes, raingardens, livestock, pets and wildlife. The first use for rainwater is in the landscape. In the landscape, drip irrigation can be implemented by a gravity fed system. The second use is that the rainwater can be used for human consumption. The water can be disinfected and used as potable or non-potable water. The third reason to use rainwater harvesting is to replenish groundwater and reduce stormwater runoff (Medell et al, 2010).

In order to build a rainwater harvesting system, it is first important to gather and interpret precipitation data. In addition to gathering rainfall data of precipitation distribution for the area must be determined (Medell et al, 2010). The following rainfall precipitation data must be considered when planning a Rainwater Harvesting System. First is the annual and monthly amount of rainfall. This amount is determined by average annual total and monthly totals of rainfall in the area.

The second is median annual and monthly amount. "Using the median rainfall data typically results in a much more conservative determination of potential water supply" (Medell et al, 2010). The third is intensity of rainfall. Typically, rainfall is measured in inches per hour. Rainfall can vary greatly throughout the United States. The fourth is frequency. The rainwater system should be sized according to the "probable intensity and frequency of rainfall" (Medell et al, 2010).

To calculate the amount of water that can be harvested in a given area, there are four essential variables; the size of the catchment area, the amount of local rainfall, system efficiency, and design safety factor. See Figure 2.10 for images of rainwater collection systems at Texas Agrilife Research and Extension Center.

Catchment Calculation - One Rainfall event (Medell et al, 2010).

Harvested water (in gallons) = catchment area (ft^2) x rainfall depth (in) x 0.623 x runoff coefficient x safety factor

Catchment Calculation - Annual or monthly basis (Medell et al, 2010).

Harvested water (in gallons) = catchment area (ft^2) x rainfall depth (in) x 0.623 x rainfall depth(in)

Figure 2.9 Green Roof/Rainwater Collection
(Source: www.texaslid.org, 2012)

Figure 2.10 Rainwater Collection at Texas Agrilife Research and Extension Center
Dallas, TX

2.2.4.2.2 Bioretention Areas

Biorentention is a specific area that is used for collection of rainwater runoff from roofs, parking lots and other impermeable surfaces. In general, bioretention areas were found to be effective in reducing runoff volume and the first flush (first 1/2 inch of stormwater) (EPA, 2000). Pollutant loadings are contained in this first flush from impervious surfaces and contain grease, oil, nutrients (nitrogen and phosphorus), sediments and heavy metals. Pollutant loadings and water quality impacts from development have been well documented in numerous studies.

Bioretention facilitates capture rainwater runoff to be filtered through a prepared soil medium (Prince George County, 2012). Once the soil pore space capacity of the prepared soil medium is reached, stormwater begins to pool at the surface of the soil medium. The main function of a biorentention area is to serve as natural hydrology of infiltration, retention, and evapotranspiration. The chemical, biological, and physical properties of soils, plants and microbes are used to remove pollutants from stormwater through the four processes of settling, chemical reactions in the soil, plant uptake and biological degradation in the root zones (Medell et al, 2010). Runoff is directed to the biorentention area as a sheet flow. Bioretention can be designed in different shapes, but the most functional shape is as a bowl or contained within a series of berms. One factor that is important to remember about bioretention/rain gardens is the that they must be maintained regularly to help remove sediments effectively.

Bioretention areas can be built out of a variety of soils. These soils can range from sand to clay. The most important aspect of the soil is that it contains a mixture of high-permeability soil and organic matter. The size of the rain garden is heavily dependent upon the size of the catchment area. See Figure 2.11 and 2.12 for images of bioretention/rain garden. Before installation, the EPA suggests the following criteria for a bioretention area (EPA, 2000, 5):

PH Range	5.5-6.5
Organic Matter	1.5-3.0%
Magnesium	35lbs/acre
Phosphorus	100lbs/acre
Potassium	85lbs/acre
Soluable salts	<500ppm

<u>Sizing Calculation for Bioretention Area</u> (Prince George County, 2012):

Volume per sq ft = Water Depth x 0.623

Suface area of Rain Garden = <u>Volume of runoff (gallons)</u>
Volume per sq ft (gallons per ft

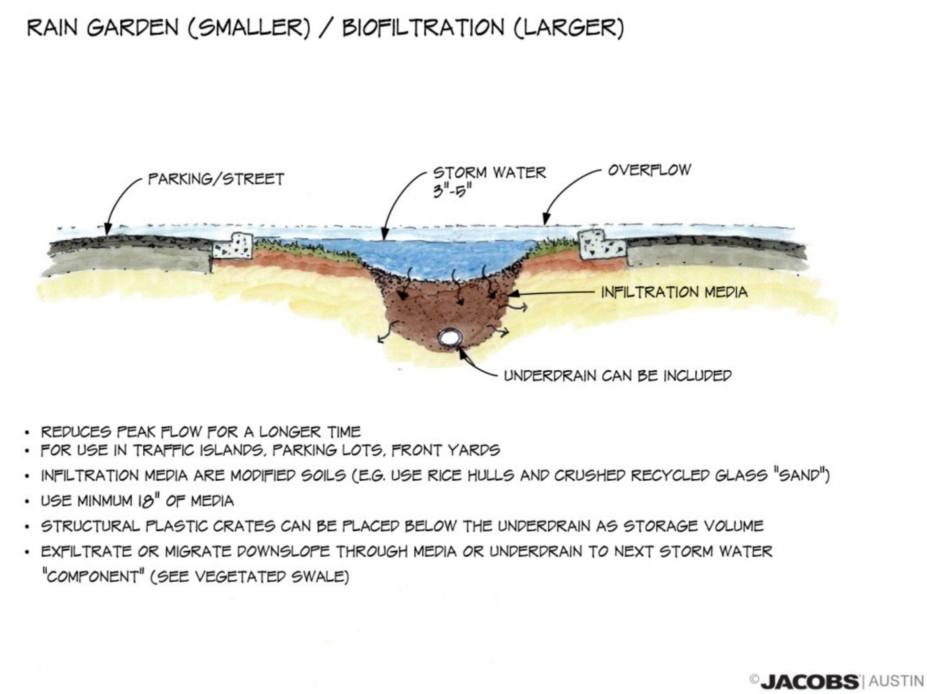


Figure 2.11 Diagram of Rain Garden/Bioretention
(Source: www.texaslid.org)

Figure 2.12 Rain Garden and Bioretention Area
(Source: Dr. Fouad Jaber, Texas Agrilife Research and Extension Center, 2012)

2.2.4.2.3 Green Roofs

Green roofs are an important part of the process for reducing the stormwater runoff from industrial, commercial and residential buildings because they reduce the amount of peak flows from stormwater runoff from building roofs. Green roofs include layered drainage systems and vegetation over a waterproof membrane (Cook, 2007). They use plant material and specifically designed light weight soil mixtures to absorb, filter, and detain precipitation. In contrast to traditional asphalt or metal roof systems, green roofs are much more effective at absorbing and storing precipitation, facilitating evapotranspiration and reducing peak flows. Green roofs may also reduce the introduction of pollutants by using the plants as filters (Cook, 2007).

There are two types of green roofs: intensive and extensive. Intensive green roofs contain a soil depth of one foot to provide a soil medium for plant growth of large trees and shrubs. This type of green roof contains a multi-layer construction complete with irrigation and drainage systems. Intensive green roofs add a considerable load (80-150 pounds per square foot) to the building. This type of green roof is designed to be accessible and used as a building amenity. The second type of green roof, extensive, the soil depth can range from 1 to 5 inches. Extensive green roofs are primarily built for environmental benefits and are not built as a building amenity. They provide many of the same benefits as an intensive roof but the cost of maintenance and construction is less (Cook, 2007).

2.3 Summary

The focus of this chapter is to give an overview of the practices involved in designing for stormwater management. The chapter explains how the first legislation, Clean Water Act, that was enacted in 1972 is the predecessor of legislation for stormwater management in the United States. It also shows how this early legislation was enacted in order to deal with stormwater and set up guidelines for development to respond to stormwater management in the future. Later techniques, Best Management Practices, were developed by the EPA as a response to rapid growth and development in cities. Instead of BMP's, LID has been documented as the latest innovation to be used to treat stormwater through ecological means.

Reviewing literature relating to LID is important because it helps to understand the path that water takes from point of origin all the way downstream. The literature explains not only the natural processes of water but constructed designs of stormwater management. The literature also provides examples of the manuals that have been written that provide guidelines for developing sites.

CHAPTER 3

RESEARCH METHODS

3.1 Introduction

The methodological underpinnings of this research informed by qualitative data collection and analysis techniques described by Taylor and Bogdan in Introduction to Qualitative Research Methods, Third edition (Taylor et al,1998). There are two types of data collection methods are utilized in the research. First, interviews are conducted for collection of data for finding the professionals that have designed and implemented LID practices in the Dallas- Fort Worth area (Taylor et al, 1998). In addition to that, passive observation techniques are utilized at specific sites that have implemented LID techniques (Marcs et al, 2001). The method for analyzing this data from the interviews is through Diffusion of Innovation theory (Rogers, 1995).

3.1.1 Place and Population

This thesis is using data collection through one-on-one interviews. Designers were chosen by obtaining information from the database that was started and maintained by a joint partnership by Ecosystem Design Group located at the Lady Bird Johnson Wildflower Center in Austin, Center for Research in Water Resources located at the University of Texas at Austin. and Texas Commission on Environmental Quality (TCEQ) (Ecosystem Design Group, Center for Research in Water Resources, Texas Commission on Environmental Quality, 2010). The sample included primarily individuals from two different design disciplines; engineering, and landscape architecture. Research also benefited from the feedback of couple of city officials who were involved with the design and implementation of LIDs.

3.1.2 Person to person interviews

Structured one-on-one interviews are used to collect information about the respondent's experiences relating to the design and implementation of LID practices. Qualitative analysis is used to identify design professionals (Taylor et al, 1998). Landscape architects, engineers and architects were chosen for this sample because they were identified by the database as the principle designer on projects that were constructed in the Dallas - Fort Worth area. The one-on-one interviews allowed the respondents to offer their perspectives on the design and construction process and to share their experiences of LID practices. The questions that were asked were specifically and purposefully designed in order to yield data that could be used for analysis. This analysis could show certain themes of commonalities and differences in the way that professionals design and implement LID practices. The technique used for the data analysis part of the research was Roger's Diffusion of Innovation.

3.1.3 LID Site Observations

The researcher used passive observations techniques to document the design and implementation processes at Texas A&M Agrilife Research and Extension Center in Dallas, TX and also to document existing LID practices in the Dallas - Fort Worth area (Taylor et al , 1998). The researcher systematically visited various LID sites in DFW to view and document examples of bioretention areas, bioswales, filter strips, and permeable paving systems. The researcher documented and observed changes in the areas between dry and wet spells. LID practices that had been implemented were documented. The areas observed were given by interviewees as examples of designed and implemented LID practices. These sites included:

- Rayzor Ranch in Denton, TX designed by Dunaway and Associates,
- North Texas Orthopedic in Flower Mound, TX designed by Environs Group/ G & A Consultants

3.2. Research Design

The design of the research uses one-on-one interviews as the main source of collecting data from individuals that have designed and implemented LID practices. The research uses Rogers to identify and access the adoption of LID within these interviews. The researcher uses Rogers to categorize the interviewees into one of the five categories of adoption. Rogers identifies each individual as belonging to one of the five different categories based on the time that it takes the adopter to accept and/or adopt the innovation. These five groups are innovator, early adopter, early majority, late majority or laggard. The key to the adoption of the innovation is based not only on the individual but also the communication channels and the society in which the individual inhabits.

3.2.1 Research Questions

1. How are the design processes in Low Impact Development different from conventional methods?
2. How are the implementation processes different in Low Impact Development practices opposed to conventional methods?
3. What is the value of Low Impact Development in the Dallas- Fort Worth area?
4. What individuals are involved in the implementation of LID practices in the Dallas - Fort Worth area and how do their varying view influence the design and implementation of LID?

3.2.2 Design of Profile and Interview Questions

The profile and interview questions are designed so that the researcher could find and identity the similarities and differences among the interviewees responses relating to design and implementation of LID practices. The profile questions were designed intentionally to categorize the respondents into categories of engineer (PE), landscape architect (LA), city official (CO) or other. The interview questions were designed so that each interviewee could share their thoughts and ideas about their first hand experiences with the design and implementation of LID practices.

<u>3.2.3 Profile Questions</u>

A series of profile questions was asked to include the respondents name, educational and professional background, professional experience, and familiarity of Low Impact Development Practices. These questions were asked in order to classify each one in the appropriate design field; landscape architecture or civil engineering as well as their experience relating to Low Impact Development practices.

1) Please state your name
2) What is your educational background?
3) What is your professional background or area of "expertise" (i.e. a civil engineer, architect, or landscape architect)?
4) How long have been working in your profession?
5) How long have you been designing and/or implementing Low Impact Development practices?

<u>3.2.4 Interview Questions</u>

1. Based on your design and/or implementation experience, what is Low Impact Development (LID)?
2. Specifically, what Low Impact Development practices have you designed and/or implemented in the past?

3. In your area of expertise, what is the difference in the design processes between LID and conventional techniques (ie, typical landscape or stormwater design/installation, Best Management Practices, Sustainable Sites Initiative, Green Printing)?

4. Do you feel that one type of LID practice was more effective in regards to design than the other? Please elaborate.

5. In your professional experience, what is the difference in the implementation processes between LID and conventional techniques?

6. What were the positive and negative results that emerged during construction?

7. In your expert opinion, what is the value of Low Impact Development practices?

3.3 Data Analysis Theory and Procedure

3.3.1 Rogers Theory of Innovation

The interview transcripts were analyzed specifically to understand why and when the respondents made the choice to choose LID. This decision-making process can be linked to Rogers Innovation Theory (Rogers, 1995). The key elements in diffusion research are innovation, communication channels, time, and social system. The key elements are defined as follows:

a) Innovation: "An idea, practice, or object that is perceived as new by an individual or other unit of adoption"

b) Communication channels: "The means by which messages get from one individual to another"

c) Time: "The length of time required to pass through the innovation decision process"

d) Social system: "A set of interrelated units that are engaged in joint problem solving"

Rogers explains that innovation occurs through a five step process. The process is strictly a decision-making process that occurs through a sequential communication channel over a period of time. Rogers categorizes the five stages as: awareness, interest, evaluation, trial, and adoption (Rogers, 1995). Rogers describes the five step process of innovation as follows:

1. Knowledge -The individual is first exposed to an innovation but lacks information about the innovation. During this stage there is no inspiration to find out more information about the innovation.
2. Persuasion - The individual is interested in the innovation and seeks information about the innovation.
3. Decision - The individual takes the concept of change and weighs the advantages/disadvantages of using the innovation. The individual then decides whether to adopt or reject the innovation.
4. Implementation - The individual applies the innovation to a varying degree depending on the situation. In this stage the individual determines the usefulness of the innovation and may search for further information about the innovation.
5. Confirmation - The individual finalizes his/her decision to continue using the innovation and may decide to use it to its full potential (Rogers, 1995, 169)

3.3.2 Roger's Five Factors of Innovation

Rogers (2003) describes "the adoptability" of innovations based on several characteristics. The five characteristics of innovation are the following:

- relative advantage which describes "how the innovation has improved over a previous generation"(p15).
- compatibility which describes the "the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters"(p15).
- complexity which describes " how difficult the innovation can be adopted"(p15).
- trialability which is the "ability to test or trial an innovation"(p15).
- observability "which is the extent of the innovation being able to be observed" (p15).

3.3.2.1 Relative Advantage

Rogers' (2003) characteristic of relative advantage relates" how the innovation has improved over the previous generation" (p,16). This characteristic explains how LID has become a new innovation in relation to an older and previously used innovation of Best Management Practices. Best Management Practices is an older type of innovation that engineers have used in the past for control of stormwater management.

3.3.2.2 Compatibility

Rogers' (2003) characteristic of compatibility describes "the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters" (p16). This definition describes how potential designers perceive the new concept and idea of LID. It also explains how this innovation is adopted by future users.

3.3.2.3 Complexity

Rogers' (2003) characteristic of complexity deals with the difficulty of adopting the innovation. Understanding this concept further, Rogers explains that the higher the level of complexity then the reduced rate of adoption (p.16). Using this concept, the researcher looked at which designers adopted the innovation quicker than others. Being able to compare the complexity of the innovation versus earlier innovations is also key to the adoption.

3.3.2.4 Trialabilty

Rogers' characteristic of trialabilty relates to the ability to test or trial an innovation. This characteristic relates to the application of the innovation. Experimentation with the innovation must occur to yield a higher adoption rate.

3.3.2.5 Observability

Rogers' characteristic of observability measures the extent to which an innovation can be observed. Again, the idea of experimentation with the innovation must occur to yield a higher adoption rate. The idea of being able to be observed is imperative for adoption.

3.4 Methodological Significance and Limitations

The significance to using Roger is that it can theoretically explain why this innovation has been adopted through design professionals quicker than other professionals. It also explains what individuals have adopted new innovations and the reasoning for the adoption. The characteristics of adoption can also be applied to the individual professions as well. It also helps define how the innovation reached where it is today and also who the change agents might be.

The limitation of using this type of methodology is the fact that it does not take into account the span of time relating to adoption. It is often hard to tell who the change agents might be in society. It is equally as hard to understand how the previous technology was improved upon as well.

3.5 Summary

Rogers was applied to this research because of the innovation of LID. Rogers describes that a new innovation will travel within a social system through communication and time. Diffusion of Innovation describes which type of people will adopt the new innovation relative to the time element. The adoptability of an innovation, as previously described, depends on five characteristics which are relative advantage, compatibility, complexity, trialability, and observability. All of these characteristics involved are called the innovation decision-making process. This involves a process which the individual goes through from initial understanding of a type of innovation, to forming an opinion toward the innovation, to making a decision whether to adopt or reject, to implementing the new idea, to confirmation of the innovation. The rate of adoption is key in the new innovation being implemented or being forgotten (Rogers, 2003).

Through out the process of site observations, the researcher gained knowledge by visualization of the different types of LID practices that had been implemented in the Dallas - Ft. Worth area. Also through site observations the researcher was able to confirm and compare findings from the interviews. When visiting each site, the researcher documents what type of LID practices have been designed and how well they have been implemented based on aesthetics and functionality.

CHAPTER 4

ANALYSIS AND FINDINGS

4.1 Introduction

The two types of protocol used in this research is one-on-one interviews and passive observations. They are conducted to understand and gather data relating to the design and implementation of LID practices (bioretention, rainwater harvesting, filter strips and bioswales) in existence in the DFW area. Qualitative analysis is used to understand and record the individual types of LID practices and how they are being used at each site. In regards to the interviews, transcripts are analyzed using Rogers Innovation Theory regarding five attributes of innovation (Rogers, 2003). The five attributes of innovation affect adoption rates regarding new innovations and practical applications of those new innovations. The data showed that the understanding and application of the innovation was consistent for all landscape architects. On the other hand, data showed that the application was different for the engineering professionals. Overall, the data showed that as a whole, professionals have a positive outlook for LID practices in the DFW area.

4.2 Analysis of the Interviews

Interviews were recorded using a Olympus Digital Voice recorder. All of the digital files were sent via file transfer via www.verballink.com. Employees of Verbalink (www.verbalink.com, 2012) transcribed the interviews and uploaded them to their server for the researcher to retrieve. The researcher read the interviews that were transcribed and double checked their accuracy.

The researcher read these interviews for themes and commonalities among the interviewees relating to Roger's five attributes of innovations. Commonalities between the interviewees relating to their adoption of the innovation revealed similar characteristics in the rate of adoption, but some differences appeared as to why and how the innovation was adopted initially.

The interview questions were analyzed to obtain certain similarities and differences in regards to types of responses. Each question was analyzed for significant similarities according to type of designer, whether the individual was an engineer (PE), landscape architect (LA), city official (CO) or other.

Each interviewee was initially sought out by the interviewer for their involvement in projects in the DFW area. The researcher targeted an equal number of professionals in each field of landscape architecture and engineering. Other interviewees fell into the group of city official or informed leader. The number of professionals that were originally contacted by the researcher was 14. The number of professionals that responded to the researchers inquiry for an interview was 11.

4.2.1 Analysis of In depth Profile Questions

During the interview, a set of background profile questions were asked to gain an understanding of the type of designer and profession that the individual was grouped within. The profile questions are asked so that the researcher can become familiar with their professional background as well as their experiences with LID.

Specifically, one of the profile questions inquires about the number of years each interviewee has been designing and implementing LID practices. Even though the data shows varying years of experience, each interviewee has been designing and implementing LID for more than three years. Most of the landscape architects replied that they had always strived to practice low impact design. LA#1 states "We intuitively practice low impact development when we do our job, but it’s become called LID within the last few years, with the real emphasis on storm water and then of course, not only storm water, but trying to conserve water. In the landscape we're really looking at doing away with a lot of grass areas in the traditional form." See Figure 4.1 to see comparison of years experience:

Profile Question:

How long have you been designing and/or implementing Low Impact Development practices?

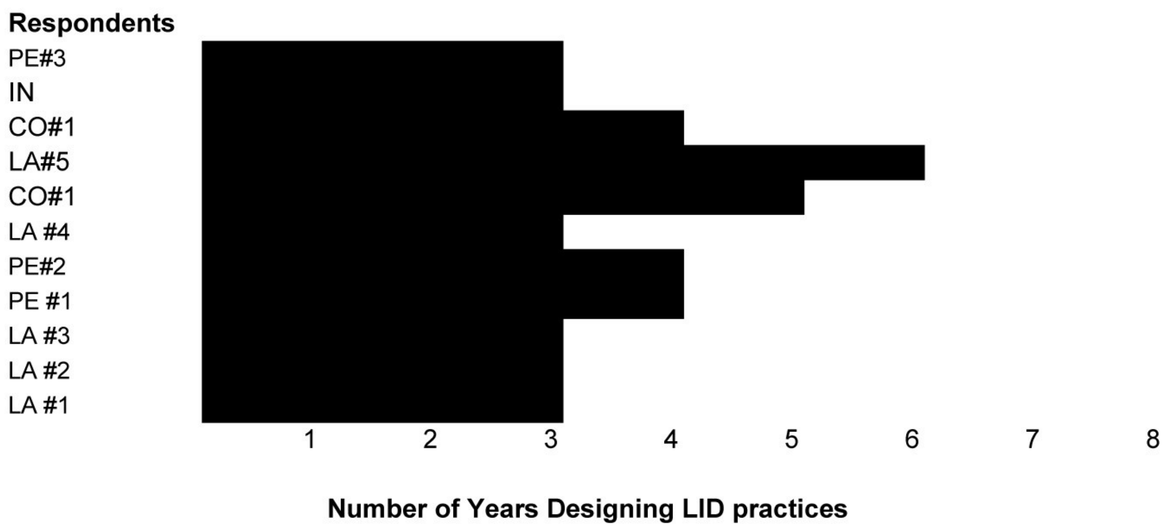


Figure 4.1 - Number of Years Designing LID practices

4.2.2 Analysis of In depth Interview Questions

Interview Question:

Based on your design and/or implementation experience, what is Low Impact Development (LID)?

In response to the first question, respondents answers varied as to the definition of LID. Various landscape architects stated that definition to LID was "....reducing the amount of storm water runoff, and cleaning up storm water runoff,"... "using the landscape to serve a purpose of filtering out storm water, filtering out pollutants, cleaning storm water, and basically capturing it onsite as near to the source as possible." LA #1 stated that "we intuitively practice low impact development when we do our job.....that we should always take the site into account and design the landscape to be a system of the environment....... It is an environmental response to storm water management." The engineers that were interviewed responded differently to the first question. PE #2 stated that "low impact development is trying to not just move water, to get it from one area to the next and to flood somewhere else but use of infiltration. It's the key to low impact development, so it's trying to think a little bit more about the water seeping through and to use that to your advantage, especially for storm water treatment" PE#2......."My definition would be how can we get the objective of the client designed in a manner that least impacts the environment, or from my perspective, water resources component." See Figure 4.2 below for commonalities between respondents.

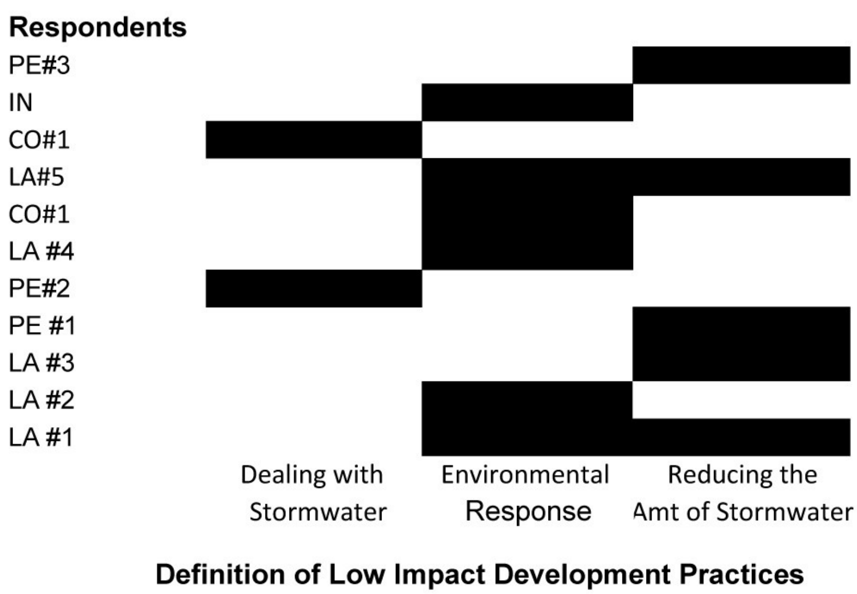


Figure 4.2 - Definition of Low Impact Development

Interview Question:

Specifically, what Low Impact Development practices have you designed and/or implemented in the past?

A common theme among landscape architects, engineers and city officials is their involvement with the design and implementation of bioretention, filter swales, and bioswales. PE# 1 replied that "it gets difficult with the clay soils we have. So it’s been more we’ve used filter strips, bioretention areas, detention, which basically settles out all the particulates but still lets some of the finer stuff go through. That’s primarily been it here recently. Sometimes we get into maybe more grass than would otherwise .... try to reduce the amount pavement. Increase and preserve as much as the grassy areas..... we put in structural channel improvements to protect against erosion that was occurring, and we planted willows in the bank to try to green it up a little bit which kind of hides the structure component but it looks more natural and it functions in a more natural capacity."

LA #4 replied "my big thing that I think I really excel at is, I have a background in horticulture and I really get into the creation of .... I do use adaptive plants, but using adaptive plants and native plants to use less water, to create habitat and to actually help clean and manage storm water. But we design a lot of community parks and on all of those community parks, we’re looking at aspects of just creating small rain gardens that people can see that the runoff from the roof of the building goes into a garden and creates a butterfly garden. So they understand that connection between water and plants and habitat." See Figure 4.3 for commonalities among the respondents:

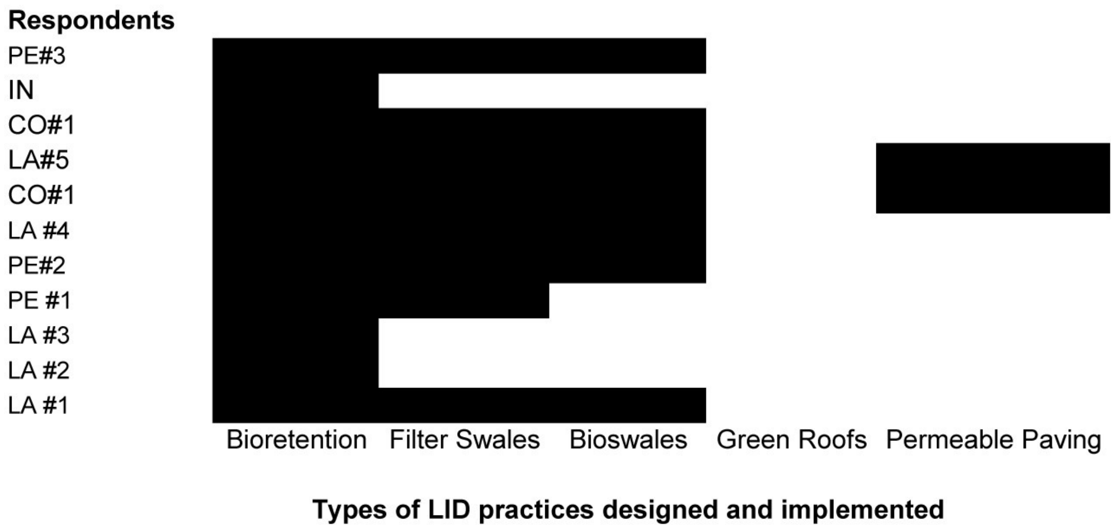


Figure 4.3 - Types of LID practices designed and implemented

Interview Question:

In your area of expertise, what is the difference in the design processes between LID and conventional techniques (ie, typical landscape or stormwater design/installation, Best Management Practices, Sustainable Sites Initiative, Green Printing)?

Responses to the third question brought about varying responses by different design disciplines. LA #4 states that "You can't just have the lone designer making all the decisions. You have to bring in a team of experts. That's what this requires, is everybody has their own field of expertise, we can't know it all. So we just need to learn to work together in that collaborative process." LA #1 response to the question was "So if it's done right, you're really not putting more landscape probably than you would have, but you're putting it in smarter and it's working with the site rather than just icing on the cake. When you integrate all that together and it works together...... in theory you save money on storm drains, which you should if you do it right, you accomplish your landscape and you've cleaned the water." LA #2 response was "....bioretention and rain gardens, but I would say bioretention, some rain gardens, and then enhanced grassy swells." PE # 1 responded to the question by stating "Not really a lot of difference in the processes. The technique itself is what drives the process. ....it's a lot of concrete going on, but if you're using something else it incorporates more green and more impervious, there is a process that goes with that. It's really the process is not that different, but it's just what technique are you going to use with your project...... I love to do the new, but there are people that they want to do tried and true. They don't want to venture off into something that's unknown, especially when they're spending hundreds of thousands of dollars on it. They want to go with something they're familiar with. So that's as big a part of the process is getting them familiar with or at least comfortable enough that you could use the LID practice." See Figure 4.4 for commonalities between the responses.

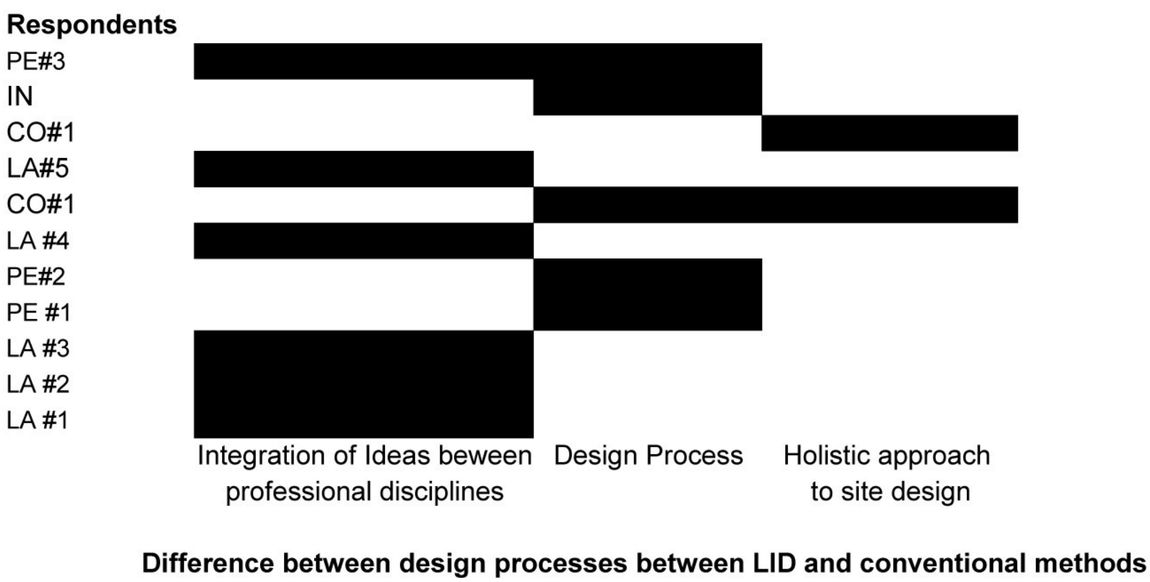


Figure 4.4 - Differences in design processes

Interview Question:

Do you feel that one type of LID practice was more effective in regards to design than the other? Please elaborate.

The responses to fourth question is also varied. Landscape architects responses varied from LA #1 responding "the bioretention I've done is in order to take advantage of landscape strips that are required by the city, ... minimize the size of retention ponds, because we can take the volumes within the bioretention, and subtract from our retention calculations, and thereby take up less land with the retention ponds" to LA #6 stating that "there is a higher cost as far as removing the dirt, putting in all the sub structure and putting it back, but there is no concrete, there's no expensive hardscape issues like outlet structure, or pilot flume, or anything like that, so the final cost are very very close, and the developer gets more land." LA #1 states that ".... here is the way I try and put people at ease with iSWM is you have to almost every city in Texas you'd have to do a landscape plan of some type at some type of percentage. The real strength of iSWM is you're integrating H&H or hydraulics and hydraulic, your engineering, your site planning, your landscape architecture are all working together." PE #1 states that "I'm not sure about effective. The storm water detention pond is certainly more familiar. Most clients are familiar enough with detention. Whether or not they use it .....they know what it is. Bioretention, they're not that familiar with it, but I think from an effective standpoint the storm water detention pond is probably, at least in this situation, the most bang for the buck on that site."

Interview Question:

In your professional experience, what is the difference in the implementation processes between LID and conventional techniques?

The fifth question had very similar answers from both engineers and landscape architects. LA #4 states that "Well, there's some education there that has to go on. I can give one example.... the special event center. We have rain planters and the contractor had to build them like four times to understand that water was going be held in there and that there needed to be some freeboard for water to accumulate and large rock that pours the water for water to stand in." LA #1 states to the question....."yeah, well I think to be a little bit redundant I think to do LID appropriately your landscape architect has to team up with an engineer and the two have to work together and not in conflict. But if they're working independent you're not going to get the product and the beauty of a firm like ours, where we have all of this in house that we've come together as a team and approach it as a team, ...if you have a situation, where you have an architect is over here, engineer is a different consultant, landscape architect is a different consultant, there could potentially be a problem." PE #2 states that "I'm all for it.....I love to do the new, but there are people that they want to do tried and true. They don't want to venture off into something that's unknown, especially when they're spending hundreds of thousands of dollars on it. They want to go with something they're familiar with. So that's as big a part of the process is getting them familiar with or at least comfortable enough that you could use the LID practice."

Interview Question:

What were the positive and negative results that emerged during construction?

Responses to this question were somewhat similar in nature. LA # 5 response .."sometimes there's a high dollar amount, because this might be the first time they've been involved in a project like that. So there is a learning curve.......we lost thousands of dollars in the design fees, because there was a big learning process.. but we have more than made up for that.. by now having it systematized..... having a library of details that we can start applying to different sites. So now we actually make a profit on all of those, after we pass the learning curve." PE #1 response "On the other project, the construction aspect if you're using live plantings, obviously, you have to take care and there's a certain window that you have to get them planted. To some degree if you're working with contractors that aren't familiar with what you're doing you kind of have to watch over them a little bit, maybe educate them as well."

Interview Question:

In your expert opinion, what is the value of Low Impact Development practices?

To be expected, the seventh question had varying responses. LA #4 responded by saying ..."The health and social value of people understanding that the land outside their doorstep or in the park that they're in every day is actually a dynamic ecosystem that makes the world that they live in a healthier place for them. I mean those things are values that I think we could call priceless...... That we're all kind of being better stewards of the environment and we can't have one project alone that solves our problem, but if everybody would take that approach, we would start to make the world a better place. So I think those are valuable." LA #5 response.. is "....of course living in Flower Mound, Highland Village, Lewisville with Lake Lewisville on the north and Grapevine Lake on the south were pretty stinking close to some direct release of storm water so for me that's a big, a big part of it is the environmental issue of it." PE #1 response.. "I think the value... There's a number of different components from a storm water management standpoint, which is what I get into..... especially in creeks. You want to try to preserve the creek area as much as you can or the area around it, the buffer area because it's a water quality habitat for the little critters that live in the creek. And a lot of times – and developers I think are coming to realize this – but what you provide LID say in a subdivision or even in ________, for instance, it's an amenity."

4.3 Rogers Theory of Innovation

An innovation is described by Rogers as" an idea, practice, or object that is perceived as new by an individual or other unit of adoption." Rogers goes on to explain that it matters little whether or not an idea is new as measured by the lapse of time since its first use or discovery.

When speaking about adoption of innovation, it is imperative to understand the characteristics of innovation. Rogers describes "the adoptability" of innovations based on several characteristics. The five characteristics of innovation are relative advantage, compatibility, complexity, trialability, and observability.

4.3.1 Relative Advantage in Relation to LID practices

Relative advantage can be correlated to the adoption of LID practices because of the advantages that it has over previous technologies, ie BMP's. BMP's have been in existence since the 1970's and newer studies conducted by the EPA have shown that LID, even though they are classified within the same system, are more effective for the overall health of our water systems (EPA, 2006). Through the interviews, the researcher found that designers chose LID over conventional techniques either because they were forced by the City or made the decision as a responsible choice to improve stormwater at the source. PE #2 states "Yeah, the big rains there is not much you can do, you gotta allow for that but if you could treat 90% of your rain events, that's a lot better then what we are doing now and that's where you're going to have some benefits to LID ." Rogers also states that the degree of relative advantage may be measured in economic terms. Through the interviews, data was collected that showed that this was correct. " Respondents described that LID practices can actually be cheaper and more efficient than previously used BMP's . LA#1 states " So if it's done right, you're really not putting more landscape probably than you would have, but you're putting it in smarter and it's working with the site rather than just icing on the cake. When you integrate all that together and it works together, in theory you save money on storm drains, which you should if you do it right, accomplish your landscape and you've cleaned the water."

4.3.2 Compatability in Relation to LID practices

Compatability can be correlated with the adoption of LID practices, especially with certain interviewees. Rogers described compatibility as the degree to which an innovation is perceived consistent with the existing values, past experiences, and needs of potential adopters (Rogers, 2005). During the interviews, the landscape architect professionals responded to the question of how long they had been implementing LID practices as a practice they had been doing all along.

LA #1 response to the question as "We intuitively practice low impact development when we do our job, but it's become *LID* in the last few years, with the real emphasis on storm water and then of course, not only storm water, but trying to conserve water." PE # 2 states "But the difference is that neither cities, are willing to take the step forward in saying that they are requiring LID. We're saying we recommend it, but we're not requiring it.....They are not willing to step out on that ledge and say we prefer it...... or we recommend it. Nor or there any point systems set up to encourage that system. "

<u>4.3.3 Complexity in Relation to LID practices</u>

Complexity can be correlated with the adoption of LID, in regards to professionals, because of the simplicity of the innovation. PE #2 states "There's nothing wrong with concrete curb and gutters....... but why not allow a parking lot for instance..... lets allow the water to go in to a swale and a median. I love this application to go into a median, and we use the medians instead. Typically the medians are crowned so why not drop them down and allow for the water to be percolated." Each interviewee expressed that when it comes to the implementation of the technology there has been some complications. LA #4 states " Implementation.....Well, there's some education there that has to go on. I can give one example, the special event center. We have rain planters and the contractor had to build them like four times, to understand that water was going be held in there and that there needed to be some freeboard for water to accumulate and large rock that pours the water for water to stand in." In contrast PE #2 states that "LID is more complicated. It does take a lot because you have to know the soil conditions, what type of soils are you using. If your using native soils you have to get that geotech information so you know what that permeability rate is to allow for infiltrations. If your using modified soils, some kind of you know soils that brought in, you have to know what those soils conditions are and it's a little more complicated as far as an engineer is concerned."

4.3.4 Trialability in Relation to LID practices

Trialability can be correlated with the adoption of LID especially when it comes to adoptability not only to professionals but the public as well. The data obtained from the interviews revealed that the most difficult part of the implementation process was the problems that arose. Rogers states that new ideas can be tried on the installment plan will generally be adopted. This applies to LID in the fact that each professional after designing and implementing the first time, could repeat the process the second time much easier. LA #5 states "..... we lost thousands of dollars in our design fees, 3 - 4 maybe 5 thousands dollars in the design fees, because there was a big learning process. But we have more then made up for that. By now having it systematized.... having a library of details that we can start applying to different sites. So now we actually make a profit on all of those, after we pass the learning curve."

4.3.5 Observability in Relation to LID practices

Observability can be correlated to the innovation of LID especially when it comes to implementation of these techniques. Responses from the interviews showed that during construction there seemed to be a learning curve not only to the designers but the contractors as well. LA #5 states that "So you have to be very specific in the implementation and I usually make it that I'm on site multiple times, and that they have to supply testing of the soils and things like that. So do you put that into your fees. So your fees would be maybe a little bit higher to cover that foreseeable problem. LA #5 also states that "That’s means and methods to the general contractor but those are the suggestions that I have in my drawing and ultimately the landscape contractor is responsible for the guarantee on the plant material that helps with the evaporation or of pulling the moisture out of the bi retention for the most part that works out to where they do that consistently." PE #4 states "Where you going to go see it? There is nothing to say there is a bioswale, there is a rain garden, there is a porous pavement. There is you know there’s those appearances, that’s the other thing, there is nothing out there that you can easily go see 'hey I like the way this looks” and so I think that’s those all of those factors are really stacked up against

LID.

4.4 Analysis of Passive Observations

Using qualitative analysis, LID site observations was used to understand the different types of LID practices that were currently being designed in the Dallas - Fort Worth area (Marcus et al, 2001). The researcher was able to obtain, from the interviewees, specific sites that were designed with these types of criteria. These sites were visited along with documentation of the types of LID practices that were designed and implemented onsite. Documentation included images of current site conditions in relationship to the individual LID practices and construction plans from the individual designers. The following examples are sites that have been implemented and designed by the interviewees.

4.4.1 Passive Observations - Texas A&M Agrilife Research and Extension Center Dallas, TX

During the research of this thesis, the researcher was able to observe and document the design and bid process for Texas A & M Agrilife Research and Extension Center in Dallas, TX. The grant was part of a Competitive Research Grant from TCEQ, RFP 319 (for 2010-2013). Dr. Jaber is the project lead at Texas Texas A&M and Dr. Taner R. Ozdil's role is Project Principal Partner/Collaborator UTA. The project was name as "Upper Trinity Watershed Green Building Infrastructure for Stormwater Management" and the grant was awarded on May 15, 2010.

The design process involved research team to develop some preliminary ideas and concepts in the earlier phases, and the client, Texas A&M, hiring an engineering firm to help them design a detention swale/bioretention area and a permeable paver system in the parking lot in mid 2011. These two types of LID practices were desired practices by Dr. Fouad Jaber for future research. Jaber along with his research team, plans on using these two areas as an example for the public. This example, described by Jaber, "will help people become familiar with LID and incorporate them in everyday applications" (Jaber, 2011).

The design process for the Research Center involved Dr. Jaber working with a team of engineers from Alan Plummer and Associates in Fort Worth, TX. The project engineer, Daniel

Applegate, PE; worked with Dr. Jaber to come up with possible solutions for designs for a permeable paving system and bioswale/dentention basin. See Figure 4.5 for aerial map and location of LID practices. Location A is where the proposed construction of the permeable pavers is to be located and Location B is where the proposed construction of the bioswale is to be located. Daniel Applegate when interviewed about the project, made the following statement "The good news about this project is it gave me more in-site to even more details of really what makes a good LID component and how they function and why they function." Both Dr. Jaber and Applegate worked together to find a solution that would be serve as an example for future education to the public.

During the implementation process, the researcher observed certain positive and negative that became apparent during the bid process of the project. The bid process was first started on February 9, 2012. See Figure 4.6 for construction document dated 4/2/2011. When the bids came back to A & M, the construction amount was too high. After the bids came back too high, Alan Plummer and Associates were asked by Dr. Jaber to scale back the project. Both Dr. Jaber and Applegate agreed that the permeable paver system in the proposed parking lot had to be scaled back. The engineer had to re-evaluate the areas that had been designed to see what could be done to eliminate high construction costs. See Figure 4.7 for construction document dated 03/2012. Currently the project has been redesigned and is waiting for approval from Texas A & M University in College Station, TX. The other two LIDs are in the planning stages to be designed and implemented later in 2012. See Figure 4.8 for Bioswale plan.

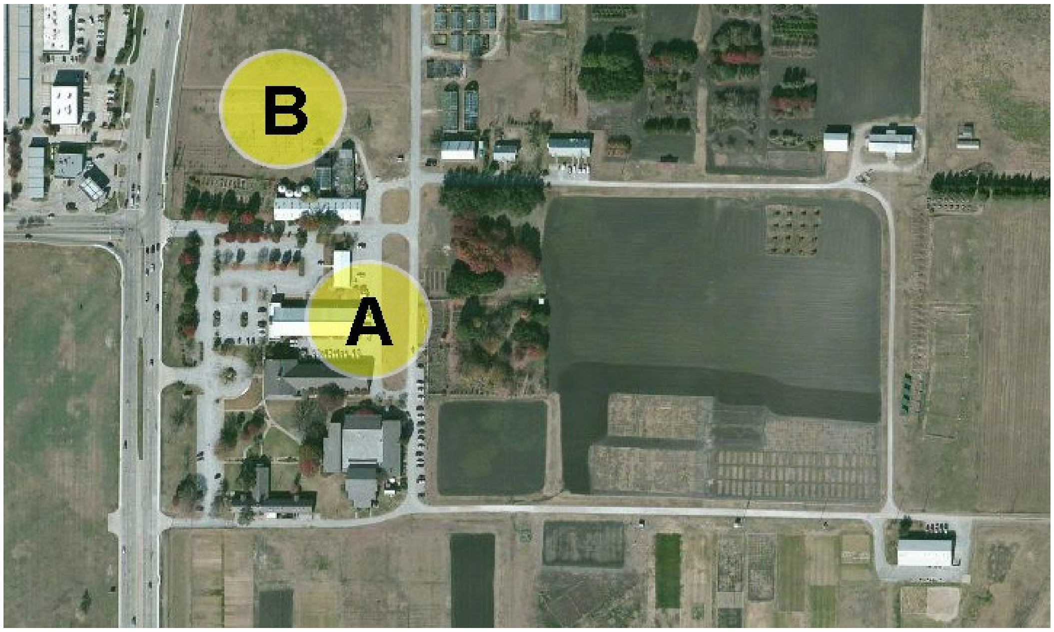


Figure 4.5 Preliminary Site Plan
Texas A&M Agrilife Research and Extension Center Dallas, TX
(Source: www.dfwmaps.com)

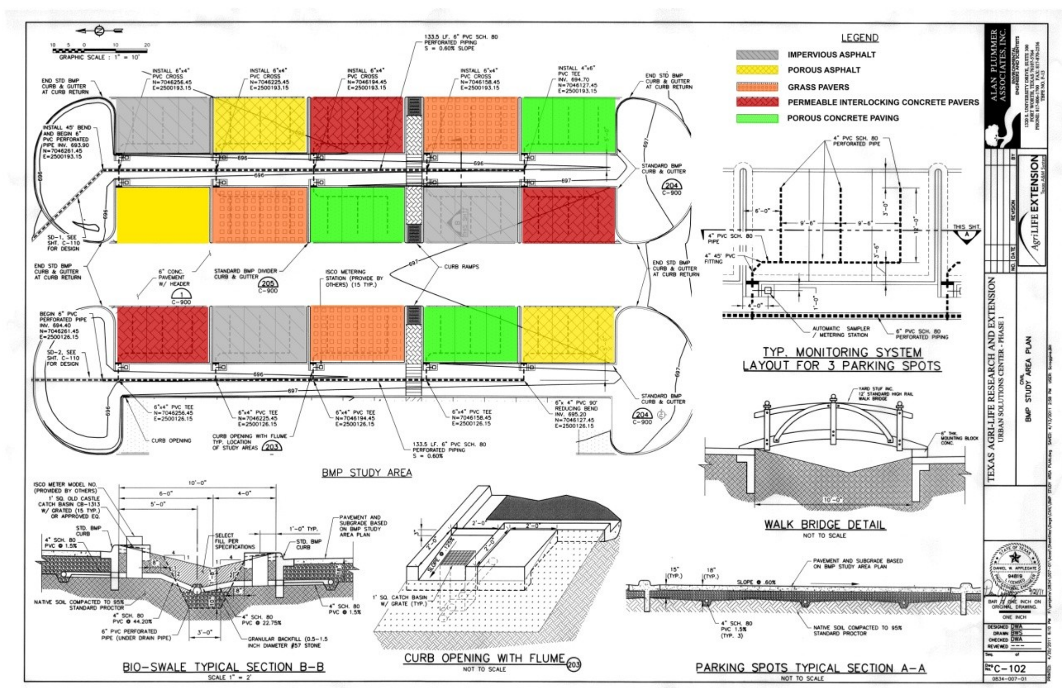


Figure 4.6 Updated Permeable Paving System

Engineering document produced on 4/2/2011 from Plummer and Associates, 2012

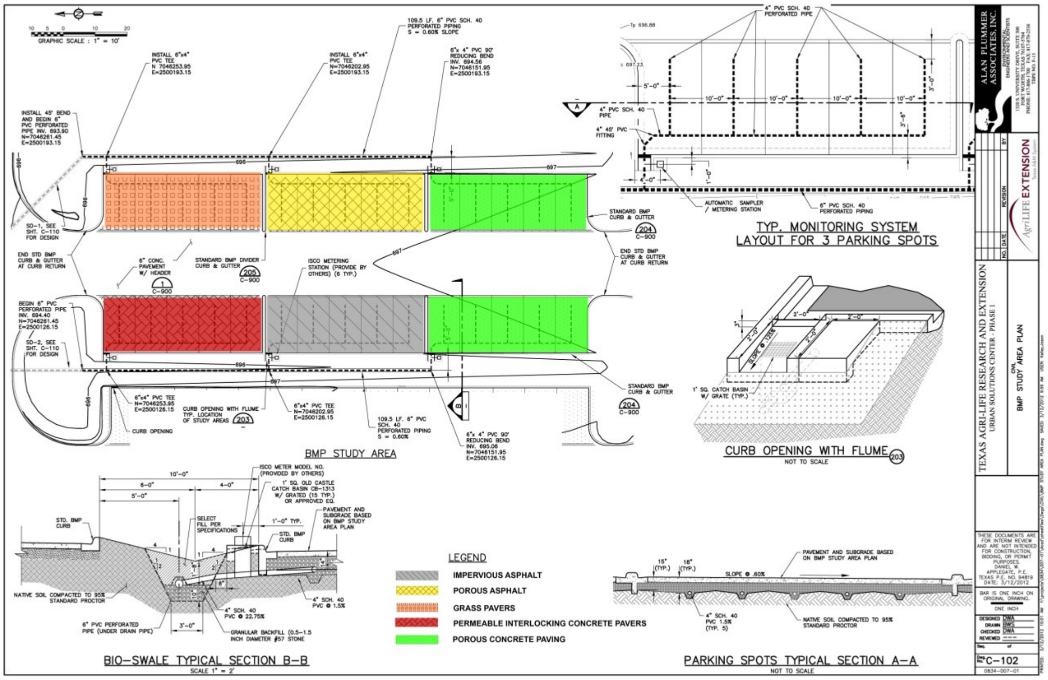


Figure 4.7 Permeable Paving System

Engineering document from 3/2012 from Plummer and Associates, 2012

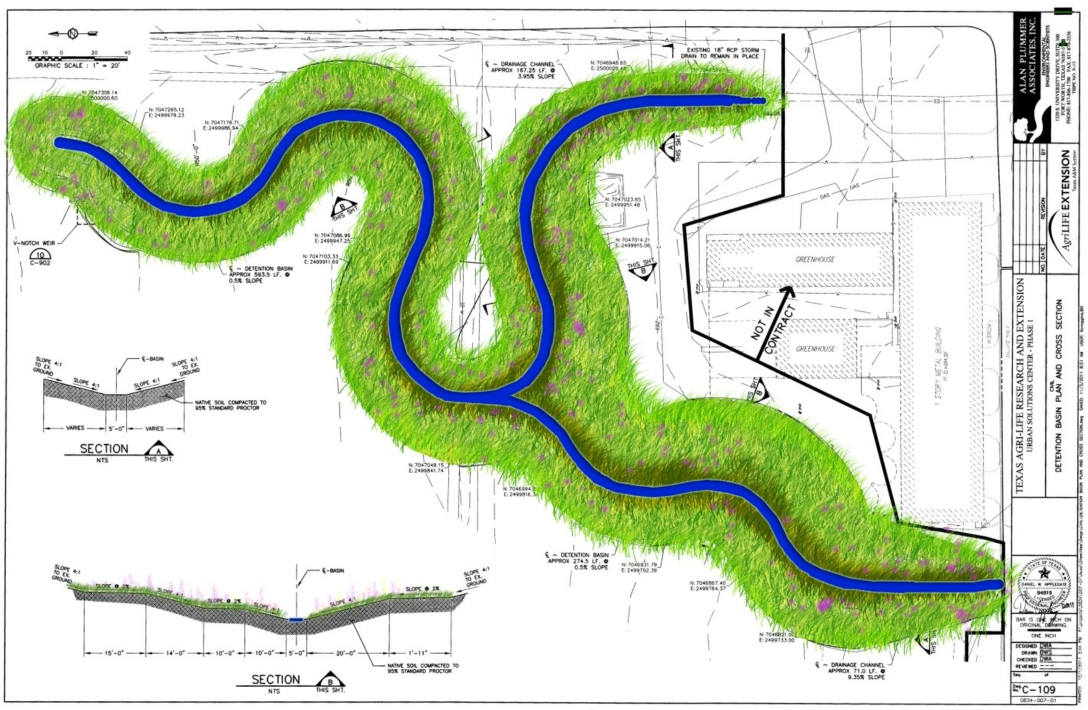


Figure 4.8- Bioswale,

Engineering document from 3/2012 from Plummer and Associates, 2012

4.4.2 Passive Observations - Razyor Ranch Denton, TX

The second site observed was Rayzor Ranch in Denton, TX. This site was designed and implemented by Dunaway and Associates of Fort Worth, TX. This site had three types of LID practices designed within its borders. These three types are bioretention, bioswales, and filter strips. The site is about 1-11/2 years old and appears to well maintained. See Figure 4.9 for site map of LID practices that have been implemented.

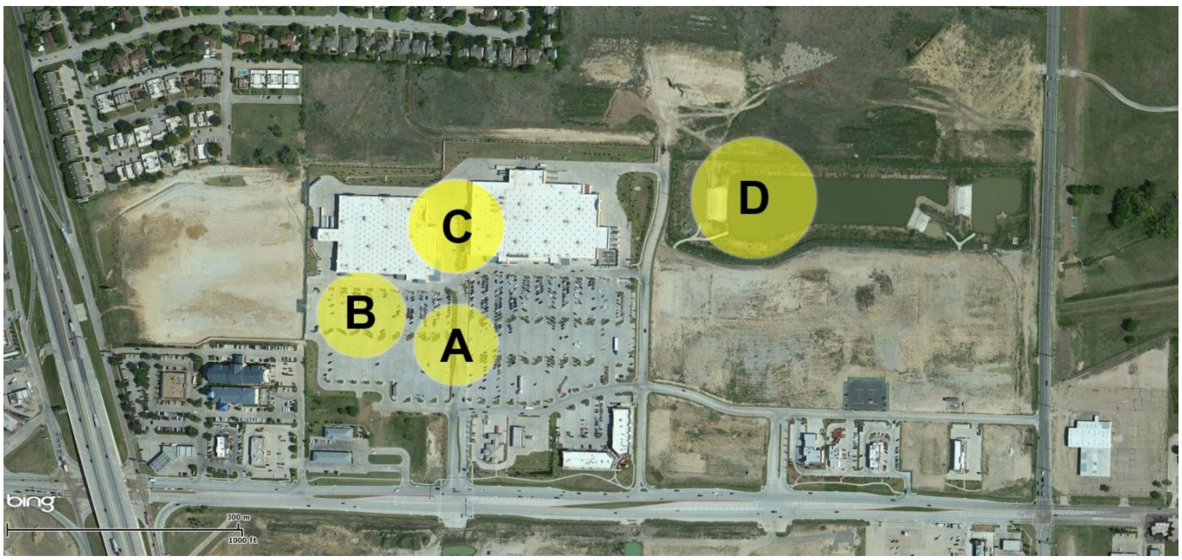


Figure 4.9 Aerial Map of Rayzor Ranch
(Source: www.dfwmaps.com)

On the aerial map, Location A is Filter strips that have been designed to capture parking lot stormwater runoff. Location B is the bioswales that have been constructed to also capture and treat parking lot stormwater runoff. See Figure 4.9 for image for Location A and Location B of constructed LID practices. Location C is the bioswale/detention area that captures large quantities of stormwater runoff from the building and concrete paving. Location D is the detention pond for the large quantities of runoff that do not infiltrate back into the ground after a large storm event. See Figure 4.9 for image for both Location C and Location D.

In regards to existing site conditions, the LID practices in Area A, B and C were in good condition and well maintained. In regards to plant material Area A contained perennial grasses, Area B contained turf grass, and Area C contained a mix of turf grass, perennial grasses, small ornamental trees and large canopy trees. At the time of the site visit Areas A, B and C were completely dry. In contrast to the other areas, Area D was completely full of water since it was designed to be a detention pond. See Figure 4.10 - Figure 4.12 for images of LID practices.

Figure 4.10 LID practices constructed at Rayzor Ranch

Figure 4.11 LID practices constructed at Rayzor Ranch

Figure 4.12 LID practices constructed at Rayzor Ranch

4.4.3 Passive Observations - North Texas Orthopedic   Flower Mound, TX

The second site that was observed was North Texas Orthopedic in Flower Mound, TX. This site was designed by Environs Group located in Lewisville, TX.   This site had two types of LID practices designed and implemented on the site. The first LID practice was bioretention. The site is about 8 months old. The plants in the bioretention area are growing and the area looks to be well maintained. See Figure 4.13 and Figure 4.15 for aerial map location and images relating to site.

In regards to existing site conditions, the plants in Area B and C were in good condition and well maintained. In regards to plant material Area C contained a mix of perennial grasses, shrubs and large canopy trees and Area B contained turf grass and small ornamental trees. At the time of the site visit Areas B and C were completely dry. In contrast to the other areas, Area A was completely full of water since it was designed to be a detention pond.

Figure 4.13 Site Plan - North Texas Orthopedic - LID practices map

Figure 4.14 North Texas Orthopedic

Figure 4.15 LID Practices

4.5 Summary of LID Site Observations

When visting each site the researcher evaluted existing site conditions, which included overall health of plants and maintenance of the LID practices. Each site was documented through photographs and compared to the proposed site plan that was given to the researcher by the original designers.

Each site that was observed seem to have a slighty different design then what was called out for on the original site plan. The design elements that varied were either plant variety or shape of the individual LID practices. For example, the planting plan for North Texas Orthopedics called for a variety of plants in the bioretention area but when during the site evaluation it appeared that some of the planting material died or was never planted. Rayzor Ranch designed each filter swale in the parking lot areas to be turf grass but during the observations the reseracher noticed that the turf was declining and in poor health.

4.6 Summary

This chapter systematically review the findings from both interviews and observations in DFW area. Then, it analyzed the results from Rogers Innovation theory to not only understand the design and implementation processes but also document the adaptation of LIDs by landscape architects, engineers, and other practitioners involved. Although it is not always explicit, different respondents answers seem to differentiate depends on their professional backgrounds. The data also revealed polarizing opinions on the definition and the value of LID. Another common theme among the respondents expressed was the lack of adoption is lagging behind other parts of the United States.

In reference to the LID site observations, each individual site was documented not only for implementation of LID practices but aesthetics as well. The researcher specifically used the observations taken at Texas A&M to understand completely and holistically the design and implementation component applied to the innovation LID. This analysis of findings further synthesized in the following chapter within the context of research questions by summarizing them in to commonalities and themes in order to further elaborate adaptation, effectiveness and value of LID practices in DFW area.

CHAPTER 5

CONCLUSIONS

5.1 Introduction

The objective of the research was to study the design and construction processes related to Low Impact Development practices, particularly in the DFW area in order to assess their adaptation, effectiveness and value. The research was critical in understanding not only the processes but also the individuals/practitioners involved in the implementation of LID practices and then what influences the designer to choose this type of strategy in order to inform future landscape decisions. The following section summarizes the findings of the research, provides remarks regarding each research questions, expands on the value of LID's for landscape architecture and suggest future research questions for further exploration in this area particular area.

5.2 Research Summary

Diffusion Theory by Rogers explains different rates of adoptions for different groups of people. This theory explains the adoption rate of different types of LID practices versus others. This theory also explains why the adoption rate of LID practices has come about within the past few years. In the study, the research appears that adoption has begun with designers that perceive the innovation as compatible with certain views that they may already have. Based on the study, other designers have adopted the innovation based on the belief that it is a much improved innovation from the previous which is the Best Management Practices. The innovation is able to be observed and also has the component of being able to be tried.

Through the interviews, the data showed that the definition of LID varied from landscape architects to engineers. The responses from the interviewees varied not only because of their educational background but their experiences with design and implementation of LID practices.

Through the interviews, the research showed the fact that the amount of design professionals that have designed LID practices is small. The design professionals, landscape architects and engineers, that were interviewed have designed LID practices and are very familiar with the types of LID practices. An important part of the interview process was that this small group of professionals that have designed LID are willing to share their design and implementation experiences throughout the interviews. These professionals were not only willing to answer my questions but also show me the LID projects that they have designed and implemented.

The data seems to show that the way in which a designer approaches an LID practice is completely different. The definition of an LID practice is completely different between the disciplines of landscape architecture and engineering. The approach is different because of their backgrounds, design and aesthetics versus quantity and practicality. Because of this difference in perspective, it appears that engineers are not concerned about the aesthetic appearance of an LID practice but is more concerned about the functionality.

Through the interviews a common theme appeared which was that economic factors played a part in LID practices only when it came to the implementation stage of design. Designers expressed that construction costs were higher only because of the lack of education from the contractor on the components of LID. Both design disciplines agreed that it was a struggle to obtain buy in from the developers because "of the unknown" with LID practices. Engineers expressed that developers always want to go with the tried and true but it is a process to get them to try something new. In regards to implementation, respondents agreed that the maintenance issue is still ongoing as well

Inconsistencies in the responses pertaining to the design processes between LID and conventional methods showed differentiating opinions . Engineers thought that the process drove the design, where the landscape architects expressed that they believed that it was an integration of ideas between disciplines. Engineers expressed that their background is in numbers and quantities versus landscape architects who expressed that it is a coordination between landscape architects and engineers. One of the landscape architects mentioned that it is our job to make it look good but the engineers to make it work.

5.3 Responses to Research Questions

How are the design processes different in Low Impact Development practices opposed to conventional methods?

To answer this question, the data shows that the process is different in many different ways. Each design discipline had differentiating responses to this question. Landscape architects answered by relating it to how a professional must coordinate and work with other disciplines to achieve a successful product . Most engineers responses were how the professional must address how the water is treated when leaving a site . There was some overlap on some of the answers when it came to professionals in a multi-disciplinary firm. Some other professionals agreed that it is a way you think about a site holistically instead of site specific.

How are the implementation processes different in Low Impact Development practices opposed to conventional methods?

All professionals agreed that the implementation processes of LID practices are very different than conventional methods. Landscape architects and engineers agreed that during the construction phase of each of the projects that they have worked on has been a challenge. Starting with the construction bids and pre-bid meetings, they had all paid close attention to the cost of construction and the processes leading up to construction. They expressed that it was necessary to closely watch the implementation stage of LID practices and watch if the construction was being done correctly. They found that they were having to charge a slight bit more for construction observation on the forefront of a project.

What is the value of Low Impact Development?

Each of the interviewees had varying responses to the questions. Most engineers thought of as a question that had to do with a stormwater approach versus with landscape architects thought of it as environmental approach to water management. Not to anyone's surprise, engineers responses were more analytical for the most part whereas landscape architect's saw LID something that had aesthetic value. They both agreed that there is a value to LID, whether it be with numbers or benefits to our environment. Both professions agreed that they continue to design and implement LID practices continuously.

5.4 Discussion on the Adaptation of LID

Rogers states that with the adoption of a new innovation, there are certain types of individuals who adopt innovations at different rates. An innovator is the first to adopt because their interest in new ideas lead them out of a local circle of peer networks (Rogers, 2003). An early adopter is more of an integral part of the society in which he lives in comparison to the innovator. An early adopter is respected and looked up to by his peers and is discretionary about new ideas. An early majority adopts new ideas just before the average amount of society. The late majority adopts new ideas just after the early majority. The last type of adopter is laggards who are the last to adopt new ideas (Rogers, 2003).

. The innovation of LID has been easy to adopt because it is so familiar to the type of design that they have been implementing, some landscape architects in this research even argued that they have been designing and implementing low impact strategies years before the concept of LID concept in its current definition under Also using Rogers theory, the early adopters are those engineers that were interviewed. The respondents that were engineers openly admitted that it is an innovation that they wished they could have started designing earlier. They also admitted that understanding that it is a collaborative approach is an important step in the design process. From the data, the interviewees admitted that working together will help LID practices be more successful in the future.

5.5 Conclusion

In conclusion this research revealed many similarities and differences among the professions of landscape architecture and engineering. They both agreed, though, that this is a better approach to mitigating and controlling water from damaging streams, lakes and valuable water resources. They also expressed that it is an education process with developers and contractors that must be done in order to create a site that can address water issues properly. They also stated that in order for developers to be more flexible to try LID practices, local governments should use incentive based approaches. As one engineer responded to the value question....."At the end of the day, it is all about economics."

Based on the research, the awareness that has been raised is the fact that landscape architects and engineers need to have a common language when it comes to LID practices. This common language is in regards to design, aesthetics and function of the individual components of LID. Another topic that has brought up is the fact that the process should be a collaboration between the two disciplines instead of a singular process. The data showed that this collaboration of disciplines helps bring about a better end product. Another awareness that is realized is the fact that in order for LID to be implemented, the desire from either the developer or city needs to be present.

5.6 Implications to the practice of Landscape Architecture

This data has relevance to the study of landscape architecture because it is important to understand the gravity of LID as an area of practice and as an innovation. This innovation slowly has been adopted throughout the professions of landscape architecture and engineering. It seemed to gain momentum within the past couple of years, especially after the greater acceptance of sustainability and green design practices in response to concerns with the limitation of resources in especially urbanized areas. The LID practices start gaining greater acceptance within city guidelines and ordinances (See such as City of Frisco TX, Fort Worth, TX and etc ordinances and guidelines). One of the respondents is not only a landscape architect but a city official as well. New ordinances were set in place in the city in which he is employed to provide incentives for those engineers and landscape architects who "think outside the box."

Knowing this growing interest and acceptance in various fronts provides a new area of understanding but also practice for landscape architects to take the profession to the next decade. To be able to move forward with this new innovation, each discipline is aware of what steps need to be taken in order for a more fluid process to take place.

5.7 Future Research

Although this research fulfilled its intended scope within the limitations outlined in the earlier chapters it also posed additional questions that would be relevant to landscape architecture profession and scholarship. Future research areas may include revisiting the innovation of LID sites in two years from now to see if it continues to gain momentum in the Dallas Fort Worth Area. Along the same line visiting individual LID sites to see the conditions of the individual practices would also be a critical information for designers and practitioners. Another research area could be how LID relates to newer innovations that are related to water resource management like green printing and Sustainable Sites Initiative. Other research that could be applicable to this topic would be to see what other groups are designing and implementing LID practices.

The following questions could be a starting point for future research:

1. In what capacity the cities and municipalities implementing LID in their Code of Ordinances?
2. What incentives are cities giving to developers to use LID practices within the specific sites?
3. What are the regional differences for LID practices?
4. What are the professional opportunities for Landscape Architects to further their knowledge in regards to LID?
5. What are the research opportunities to be able to study the ecological impact that LID practices can have on an urban scale?

APPENDIX A

IRB APPROVAL

UT Arlington

Informed Consent Document

PRINCIPAL INVESTIGATOR

Alice Cameron Holmes, Masters Program in Landscape Architecture
Contact: alice.holmes@mavs.uta.edu Phone:972.849.4772

FACULTY ADVISOR

Dr. Taner Ozdil, School of Architecture, Assistant Professor of Landscape Architecture
Contact: tozdil@uta.edu Phone:817.272.5089

TITLE OF PROJECT

Design and implementation processes of low impact development in the Dallas - Forth worth area.

INTRODUCTION

You are being asked to participate in a research study about Low Impact Development practices. Your participation is voluntary. Refusal to participate or discontinuing your participation at any time will involve no penalty or loss of benefits to which you are otherwise entitled. Please ask questions if there is anything you do not understand.

PURPOSE

The purpose of this research is to evaluate the implementation processes of LID in order to gain clear understanding about the effects and integration of low impact principles in urban environments, specifically the Dallas - Ft Worth area. One of the questions that this thesis is trying to answer is how each of the three design disciplines; landscape architecture, architecture, and engineering, approach a design for Low Impact Development. Also, what are the influences that have helped designers choose LID practices over conventional planning strategies.

DURATION

Participation in this study will last approximately 1 hour.

NUMBER OF PARTICIPANTS

The number of anticipated participants in this research study is 30.

PROCEDURES

The interview will be audio recorded. After the interview, the tape will be transcribed, which means they will be typed exactly as they were recorded, word-for-word, by the researcher. The tape will be destroyed after transcription. There will be no future use for these tapes.

1

IRB Approval Date: MAR 09 2012

IRB Expiration Date: MAR 09 2013

UT Arlington
Informed Consent Document

CONTACT FOR QUESTIONS

Questions about this research study may be directed to Dr. Taner Ozdil, Asst Professor of Landscape Architecture. His contact information is Contact: tozdil@uta.edu Phone:817.272.5089

Any questions you may have about your rights as a research participant or a research-related injury may be directed to the Office of Research Administration; Regulatory Services at 817-272-2105 or regulatoryservices@uta.edu.

As a representative of this study, I have explained the purpose, the procedures, the benefits, and the risks that are involved in this research study:

____

Signature and printed name of principal investigator or person obtaining consent **Date**

CONSENT

By signing below, you confirm that you are 18 years of age or older and have read or had this document read to you. You have been informed about this study's purpose, procedures, possible benefits and risks, and you have received a copy of this form. You have been given the opportunity to ask questions before you sign, and you have been told that you can ask other questions at any time.

You voluntarily agree to participate in this study. By signing this form, you are not waiving any of your legal rights. Refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. You may discontinue participation at any time without penalty or loss of benefits, to which you are otherwise entitled.

____

SIGNATURE OF VOLUNTEER **DATE**

IRB Approval Date: MAR 09 2012

IRB Expiration Date: MAR 09 2013

APPENDIX B

INTERVIEW LETTER

February 13, 2012

John Doe
1092 Somewhere Drive
Hometown, TX 76999

Dear Mr./Mrs. John Doe:

A few days from now you will receive a phone call requesting your participation in an interview for an important research project. The interview concerns your design process and involvement in Low Impact Development Practices.

I am writing in advance because we have found many people like to know ahead of time that their participation is being requested. This study is important because it will help landscape architects, engineers and architects in their efforts in the future. The interview will take approximately 60 minutes of your time.

Thank you for your time and consideration. It is only through the generous support of people like you that our research can be successful.

Sincerely,

A. Cameron Holmes
Graduate Student
Program in Landscape Architecture
The University of Texas at Arlington

2708 Meadow Glen Dr
Flower Mound, TX 75022

APPENDIX C

INTERVIEW EMAIL

February 13, 2012

Dear Mr./Mrs. John Doe:

Your participation in an important research project will help landscape architects, engineers, and architects in their efforts in the future. I am completing my Masters of Landscape Architecture degree at the University of Texas at Arlington. My thesis topic is *Design and Implementation Processes of Low Impact Development Practices In the Dallas - Ft Worth Area.* The reason that I am working on this particular topic is because I believe that it is a topic that needs to be further explored and examined for its use in the Dallas- Fort Worth Area.

I would like to request your participation in this research via an interview. The interview will take approximately 60 minutes of your time.

Are you available to be interviewed at one of the following dates and times:

March xx, 2012 xx:xx am

March xx, 2012 xx:xx pm

Feel free to call or email me if you have any questions. Thank you for your time and consideration. It is only through the generous support of people like you that our research can be successful.

Sincerely,

A. Cameron Holmes
Graduate Student
Program in Landscape Architecture
The University of Texas at Arlington

2708 Meadow Glen Dr
Flower Mound, TX 75022
email: alice.holmes@mavs.uta.edu
cell: 972-849-4772

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BIOGRAPHICAL INFORMATION

Alice Cameron Holmes grew up in Atlanta, Georgia. She married John Holmes in 2000 and moved to North Carolina where she attended North Carolina State University. Before completing her undergraduate degree in Bachelor of Science in Horticulture, John's job relocated them to Dallas. She graduated with her undergraduate degree from University of Texas at Arlington in 2008. She loves to be outdoors and hiked part of the Appalachian Trail from Georgia to West Virginia in 1995.