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Analysis, Implementation, and Applicable Design of Low Impact Developments for Stormwater Management in Austin, Texas

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Analysis, Implementation, and Applicable Designs of Low Impact Developments for Stormwater Management in Austin, Texas

by

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Dedicated to the memory of Dr. Kent Butler whose work in sustainable practices inspired the subject of this report; may he never be forgotten.

Abstract

Analysis, Implementation, and Applicable Designs of Low Impact Developments for Stormwater Management in Austin, Texas

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This paper serves as a "kicking-the-tires" analysis of low impact developments as a method of stormwater management. Specifically, this paper examines the feasibility, benefit, and current practice of low impact developments in Austin, Texas. Merits, strengths, and weakness are comparatively determined primarily on the basis of the impact and efficiency of design, particularly relating to ability to handle water volume and potential to improve water quality. By examining case studies and "applied" examples the potential of low impact development application is considered for the expected, potential, and/or alleged benefits of low impact implementation.

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EXECUTIVE SUMMARY

Traditional stormwater drainage systems and low impact developments both have areas of strength and weakness. Traditional designs benefit from efficiency in design and have the ability to move massive amounts of water at a time, though they seldom need to. However, traditional systems lack the ability to filter out pollutants and can lead to degradation of the urban water quality, by emptying polluted runoff directly into urban waterways.

LID projects, on the other hand, benefit from high levels of specific site analysis and a through pre-development phase. Low impact developments are very efficient at naturally filtering pollutants from stormwater runoff and increasing permeable cover in urban environments.

In the application and utilization of LID in Austin, Texas the first issue that must be addressed is the detailing and specific mention within the comprehensive plan, design, and supporting technical and environmental documents (via policies, ordinances, etc.) for the standards, use, and implementation practices for LID.

Chapter 1 Introduction

Growing up in the Texas countryside where the neighborhood road and driveway were loose gravel and most everything else was some variation of a grassy field I knew exactly where the water went when it rained: straight into the ground. But in our cities the answer to “Where does the water go when it rains?” is less direct. With acres of parking lots, seamless impervious street networks, and footprint after footprint of poured concrete foundation the urban water cycle resembles a labyrinth much more than it does the traditional circle pattern depicted in textbooks.

So where does the “city rainwater” go? Most of it will, at some point or another, end up going down a storm drain. After that it depends on the city you live in, for Austin, Texas most of the storm drains empty into urban creeks. After its labyrinth worthy journey across parking lots, down streets, and through gutters the water, now heavy with pollutants (everything from antifreeze to aluminum cans) empties into the creek. In most cases the water will not undergo any type of filtration or other cleaning process before it enters the creek. Currently the City of Austin helps manage this problem by sponsoring a volunteer program in which citizens can take part in a “Storm Drain Marking” program where “volunteers place markers on the drains as a visual reminder that the storm drains run directly to our creeks.”[1] However, as cities have began to emphasize the importance of urban watersheds, and the urban water networks (including creek ways) that support

[1] *Storm Drain Marking*, Watershed Protection Department, City of Austin. http://www.austintexas.gov/department/storm-drain-marking.

these watersheds "green alternatives" to the traditional management of storm water runoff have been on the rise. At the forefront of the green redevelopment movement are advocates of low-impact development (LID) who proposes a slight "deconstruction" of the existing urban water labyrinth to allow for more natural water movement and filtration through the urban environment. This project examines the potential low-impact developments have to positively (or negatively) impact[2] the storm drain to creek system in Austin, Texas.

This paper serves as a sort of "kicking-the-tires" analysis of low impact developments as a method of stormwater management. Specifically, this paper examines the feasibility, benefit, and current practice of low impact developments in Austin, Texas. In the first portion of this paper I will give will define the terminology used throughout this report and will review the history and related background information comparing

Top: A drainage pipe from a roof directs stormwater onto an impervious street. Bottom Left: Bioswales with curb cuts allow for runoff to be naturally filtrated. Bottom Right: A tree box filter. Sources: See Photo Index.

[2] "Positive impact" in this case refers to a reduction of non-point source pollution entering the storm drains and subsequently draining into the creeks (i.e., how well can low-impact developments serve as a filtration method before the water enters the creeks.)

low impact developments to traditional stormwater management practices, including the goals, implementation processes of the respective development types, and the distribution of publicized low impact development projects in Texas. Using a SWOT analysis I will evaluate the effectiveness of an informally low impact development in Austin, Texas (The Triangle). These components of have been organized into three sections, Background, Best Management Practices, and Systems Design Analysis and Action Items. My analysis will be reinforced by case studies centralized on mitigating stormwater runoff and I will propose general recommendations (for the best management practices and systems design) for Austin's stormwater management system.

SECTION 1:

BACKGROUND

Chapter 2 Terminology and Background Information

For the purpose of this paper the terminology (technical and otherwise) has been simplified as to be applied generally in diverse analyses. Below are the common terms and their definitions that are used widely in this paper. Note: this is not to suggest that these are the only terms that can be used to describe the process, nature, or development types mentioned below, rather it is to avoid confusion that the terms have been simplified to their most common deriviatives.

Definitions:

LOW IMPACT DEVELOPMENT (LID)
US Department of Housing and Urban Development (HUD)

An approach to land development that uses various land planning and design practices and technologies to simultaneously conserve and protect natural resource systems and reduce infrastructure costs. LID still allows land to be developed, but in a cost-effective manner that helps mitigate potential environmental impacts.

LID STORMWATER MANAGEMENT SYSTEM
US Department of Housing and Urban Development (HUD)

A stormwater management system that reduces development costs through the reduction or elimination of conventional storm water conveyance and collection systems.

LID systems can reduce the need for paving, curb and gutter, piping, inlet structures, and storm water ponds by treating water at its source instead of at the end of the pipe. However, developers are not the only parties to benefit from the use of LID storm water management techniques. Municipalities also benefit in the long term through reduced maintenance costs.

STORMWATER DRAINAGE SYSTEM (TRADITIONAL)

Office of Design in the Iowa Department of Transportation

The function of stormwater drainage systems is to collect and convey storm runoff to a discharge point. A stormwater drainage system can be as simple as a ditch that outlets to a stream or as complex as a system comprising numerous intakes, manholes, and pipes along with ditches, stormwater retention or detention basins, and pump stations.

STORMWATER HARD INFRASTRUCTURE

This refers to the infrastructure building components of the traditional stormwater drainage system, which are manmade and typically non-naturally occurring. Typically these are impervious in construct and are designed for large-scale municipal stormwater management

Above: Assorted components of modern stormwater drainage management systems. Sources: See Photo Index.

projects that include a high level of raw material and process redundancy.

History:

TRADITIONAL/CONVENTIONAL

Conventional stormwater drainage systems date back to the earliest human settlements. However, they increased in use and efficiency during the Bronze Age (Balyan, 2010) when technological advancements lead to new urban construction and a solution was needed to drain the stormwater from the now altered natural drainage flow of cities. Modern stormwater systems are designed for controlling flow volume and reduce the risk of downstream flooding[3] during storm events resulting in a large underground network with high redundancy in design (multiple inlet points, and a circuit-type style). Due to the subterranean nature of stormwater systems and their close proximity to existing city sewer lines[4] many cities have opted to create a "combined" system where rather than flow to an external water body (such as a creek, bay, or wetland) the stormwater is directly discharged into the wastewater line where it continues on to a water treatment facility[5]. The "other" traditional method, is a "separate" system[6], the separate system usually runs parallel to a city's sewer system, however rather than be processed at a water treatment facility the drainage pipe will outlet in a nearby water body, usually a creek or directly into the bay if the city is coastal. Separate systems and

[3] Rosner, Larry. "Stormwater Infrastructure for Water Quality Management." Cockrell School of Engineering. University of Texas at Austin. 8 Apr. 1999. *University of Texas at Austin*. Web. 3 May 2012.

[4] Not relevant for new developments where no existing water or wastewater lines exist.

[5] Fang, Chhetri, and Thompson. *Synthesis of Storm Drainage Design.* 2010. Print.

[6] Fang, *Synthesis of Storm Drainage Design*

combined systems were both designed to handle large volumes of water, filtering that water to insure environmental protection through the water quality prior to discharge is not part of the design[7].

LOW IMPACT DEVELOPMENT

In the mid 1980's faced with the pressure of developing new land for economic development but to maintain and improve the county's environmental sensitivity, Prince George County, Maryland, used bioretention technology to help address the limitations posed by conventional stormwater management systems in what became America's first municipally supported low impact development project (LID Center, 2007). By the early 1990's Prince George County's LID initiative had blossomed into two documents8 detailing the utility, practice, implementation, and benefits of utilizing LID practices to retrofit and/or replace conventional stormwater drainage systems (HUD, 2003). Produced by the Programs and Planning Division of the Prince George County Environmental Resource Department these two documents would become the basis and support for many LID projects across the country.

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[7] Rosner, Larry. "Stormwater Infrastructure for Water Quality Management." Cockrell School of Engineering. University of Texas at Austin. 8 Apr. 1999. *University of Texas at Austin*. Web. 3 May 2012.

[8] The documents are: *Low-Impact Development Design Strategies An Integrated Design Approach* (EPA 841-B-00-003) and *Low-Impact Development Hydrologic Analysis* (EPA 841-B-00-002). Together these documents detail how LID can achieve storm water control through the creation of a hydrologically functional landscape that mimics the natural hydrologic regime. Source: U.S. Department of Housing and Urban Development Office of Policy Development and Research, *The Practice of Low Impact Development,* Section 2.1: Introduction to Storm Water Management. (2003).

Chapter 3 Goals of Low Impact Developments

The design goals of low impact development are formulated to "emphasize conservation and [the] use of existing natural site features integrated with distributed, small-scale stormwater controls to more closely mimic natural hydrologic patterns."[9] The purpose of this is to allow natural filtration of stormwater, both direct and runoff (point and non-point), so that pollutants can be removed before reaching the water table (either through ground seepage or transport via a traditional stormwater drainage system directly into a water body).

[9] Hinman, Curtis, and Puget Sound Action Team. *Low Impact Developments: A* Technical *Guidance Manual for Puget Sound*. Ed. Bruce Wulkan. Tacoma: Washington State University, 2005. *Puget Sound Action Team*. Web. 28 Nov. 2011. <http://www.psp.wa.gov/downloads/LID/LID_manual2005.pdf>.

With a strong focus on water quality it is clear that LID is a response to the traditional volume-centric stormwater management systems, which despite the effectiveness of traditional systems at removing water from the urban environment there are major flaws when it comes to systematic solutions to water quality. As professional engineer Dr. Larry A. Rosner[10] explains in his lecture *Surface Water Hydrology* (1999), "Simply reducing pollutants in the runoff to the Maximum Extent Practicable (MEP) will probably not result in significant improvement to the ecological condition of the receiving waters…flow management must also be taken into account." It becomes an issue of scaling; large traditional systems are designed to accommodate peak flows and flood events and therefore the MEPs of these systems are still too high to benefit[11] a small urban waterway (such as a creek). "Small storms account for most of the runoff [that storm drainage systems are managing] and are affected most by urbanization[12]…85 percent of the storms in east Texas are less than 1 inch of rainfall and 85 percent of the storms in west Texas are less than 0.65 inches."[13] The implication of this is that rather than having one mega stormwater system, it is very plausible that a series of small developments could be more effective[14] for mitigating runoff from the most common

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[10] Dr. Larry A. Roesner, P.E., *Surface Water Hydrology.* CE 394K. University of Texas at Austin. April 8, 1999. Lecture.

[11] Removing macro and micro-level pollutants.

[12] This means that the drainage that would naturally remove the small storm event runoff is most greatly impacted by urbanization, i.e. urban development is more apt to handle large rainfall events such as floods.

[13] Rosner, Larry. "Stormwater Infrastructure for Water Quality Management." Cockrell School of Engineering. University of Texas at Austin. 8 Apr. 1999. *University of Texas at Austin*. Web. 3 May 2012.

[14] Effective refers to both the transport of water from the streetscape and filtration of separate stormwater systems.

source, small storms. It is this niche of more heavily polluted[15] initial runoff from small storms that low impact development is most apt to fill.

[15] Initial runoff is more highly polluted because it is the "first sweep" of both the macro and micro pollutants that have built up on the street surface, in curbs, in gutters, etc. between rainfall events.

Chapter 4: Implementation Methodology Comparison

The implementation approaches taken by the different stormwater management development types contrast primarily in regards to the pre-development[16] and installation[17] processes.

Pre-Development

The pre-development process for LID is a multi-step process beginning with a careful site analysis. In the site analysis everything from soil type to slope stability[18] is assessed to determine the best placement and type of LID for the site. In some cases after the site analysis has been completed a series of scenarios[19] will be created to test "best fits" though projective modeling, and also to acquire public input on the various possibilities of the project. Depending on the sponsor of the LID project public input may or may not play a large part in the pre-development process. While public entities such as city planning departments or State departments of transportation may seek actively seek public input and participation[20] (especially if the project is a "pilot" project in the community) private developers are less likely to seek input. However, developers that are

[16] Pre-development refers to the visioning, design, public participation processes, etc. that occur prior to on site installation.
[17] Installation refers to the on-site work to complete the pre-approved project.
[18] LID Manual, Site Analysis for Puget Sound
[19] *LID in a CSO District Technical Report*. EPA SWMM Scenarios.
[20] Participation can range from a call for approval to a charrette (or component of a design charrette) to create design standards for the project site.

seeking to utilize LID in their developments are very likely to seek input from city officials and LID field experts to ensure a smooth process void of unnecessary and costly regulatory delays[21]. The last step of pre-development for LID projects is approving the final site design.

Pre-development for traditional systems is much more streamlined. Depending on the geophysical situation of the site an environmental expert may be called in to consult on the project, however most often the "expert" is a stormwater design professional engineer[22]. Unless a variance is needed the private developer will typically not consult with city officials[23] or the public and the subterranean aspect of the traditional system makes aesthetic design concepts generally irrelevant.

Installation

While LID may be more taxing on the pre-development end it becomes much more streamlined in the installation process. Due to the extensive site analysis and pre-approval of designs (via the public[24] input) installation goes relatively quickly. The development process is minimally invasive, usually consisting mostly of placing pervious pavers and/or planting vegetation.[25][26]

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[21] EPA. *The Practice of Low Impact Development.*
[22] EPA. *The Practice of Low Impact Development.*
[23] EPA. *The Practice of Low Impact Development.*
[24] Public input includes the input by public officials (city councils, planning departments, permitting, etc.)
[25] University of Florida, *Bioswale Factsheet.*
[26] The intrusiveness of a project will vary depending on type, scale, density, and site-specific conditions.

However, low impact developments are almost always (except perhaps for large paving projects and bioretention ponds) less invasive than the installation of a traditional system.

Traditional systems, on the other hand, require excavation for the placement of pipes and drains[27]. The installation typically progresses systematically and is (if possible) integrated or joined with existing stormwater infrastructure to complete the circuit.[28]

While both approaches have their advantages and disadvantages, the differences can be attributed to the function that each model and type of development was designed to provide. Traditional stormwater drainage systems are designed to have the capacity to manage high volumes of water on an extremely large scale (city-wide, for example). Low impact developments, on the other hand, are designed to be self-sufficient and site-specific systems typically built to manage the runoff from frequent but small storm events.[29]

See Tables 1 and 2 for flow chart of the general process for both LID and traditional stormwater management systems.

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[27] A traditional system in this example is assumed to be in a new, greenfield-type, development where existing infrastructure does not already exist, i.e. not in an ETJ where water/wastewater lines have already been extended.

[28] Fang, Chhetri, and Thompson. *Synthesis of Storm Drainage Design*. N.p.: n.p., 2010. Print.

[29] Conclusion has been drawn from Rosner's *Surface Water Hydrology* Lecture in conjunction with the LID Manual for Puget Sound.

Collaboration	Ordinance Review and Outreach	Site Review and Analysis
■ Uses experts such as landscape architects, engineers, hydrologists, geologists, and biologists to collaborate, perform site analysis, and identify innovative solutions. ■ Encouages collaborative effort among all site design professionals to maximize natural resource benefits.	■ Proactively seeks public officials' input in pre-development meetings to identify project opportunities. ■ Works with the community to include its interests in project design. ■ Conducts resource analysis first to determine what the site offers. Reviews the ordinances to determine potential barriers to proposed designs. Design must meet ordinances or developer obtains a variance.	■ Analyzes the land use ordinances to identify resource opportunites and constraints. ■ Reviews all inputs to create multiple land design options for consideration ■ Works together with public officials to gain flexibility in the design phase.

Source: US Department of Housing and Urban Design, 2003

Table 1: Low Impact Development Process

Collaboration	Ordinance Review and Outreach	Site Review and Analysis
■ Usually uses an engineering team and one or two other experts. ■ Uses experts sequentially, i.e., conducts one phase of development process and then passes project details to the next expert.	■ Limits interaction with public officials to permitting meetings. ■ Does not actively seek out public's inupt on design options. ■ Meets existing ordinances. ■ Uses pre-development meetings to review preliminary site plans.	■ Analyzes the land use ordinances to identify regulatory barriers. ■ Conducts review with the goal of developing one design plan. ■ Meets the regulatory requirements.

Source: US Department of Housing and Urban Design, 2003

Table 2: Traditional Stormwater Drainage Management Process

Chapter 5 LID in Texas

The majority of LID projects in Texas have predominantly occurred in the Texas Triangle core cities (Austin/San Antonio, Dallas/Fort Worth, and Houston), with a few projects in the outlying areas[30]. While LID projects can be utilized in any urban (or rural) environment, an analysis of the map suggests that LID in Texas is being applied in areas that experience higher and more frequent levels of annual rainfall[31] (note from the map how there is a lack of LID projects mapped in West Texas). However, rainfall is not the only factor, because far east area of Texas, which experiences the most annual rainfall (as a general trend, flash events may exceed the average) lacks LID projects, which suggest some other factor must be driving the distribution of LID projects.

Narrowing the map analysis utilizing Tobler's First Law of Geography[32], the places where LID is *not* occurring are excluded from further analysis, and instead the analysis shifts to what the places that *do* have LID have as a common factor. The immediate answer is cities that have high population concentrations.[33] The high populations imply an intensified demand for basic infrastructure (streets, buildings, etc.), which would increase the amount of impervious cover in these areas.

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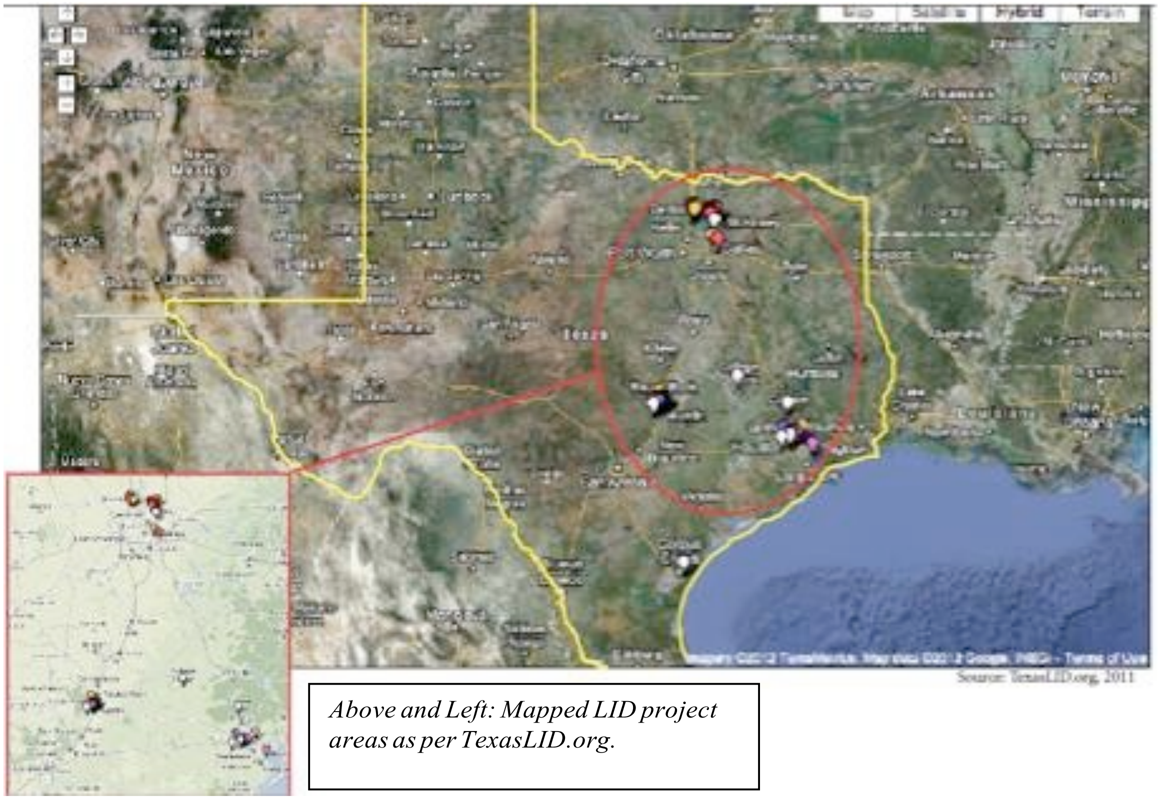
[30] TexasLID.org, map analysis.

[31] Based on NOAA's 1981-2010 Climatic Normals, there is a consistent trend of East Texas receiving over 100 days of rain per year at about 50 inches/year. West Texas enjoys an average rainfall of 60 days per year and just over an approximate 20 inches/year. Data source: http://www.currentresults.com/Weather/Texas/average-yearly-precipitation.php

[32] Tobler W., (1970) "A computer movie simulating urban growth in the Detroit region". *Economic Geography*, 46(2): 234-240. Tobler's Law: "Everything is related to everything else, but near things are more related than distant things." The same could be applied to phenomena (in our case, the why LID projects occur in one generalized area).

[33] Confirmed via reference to the 2010 US Census Data.



Above and Left: Mapped LID project areas as per TexasLID.org.

The increased impervious cover would likely cause an increase of pollution to urban waterways via stormwater runoff, thus creating a need for some sort of filtration system to protect the water quality and natural environment of the area(s). If, in these cities, LID was determined to be a more desirable solution[34] to managing the stormwater runoff (as compared to the cost of retrofitting and/or modifying the existing infrastructure) then this could explain the disproportionate amount of projects in the central Texas area.

Note on Mapping LID in Texas

[34] "More desirable" in terms of cost effectiveness, perceived and/or realized impact, and/or alignment with existing city policies and/or initiatives.

Mapping Texas' low impact developments is extremely difficult. Low impact developments are diverse in scale, type, and sponsoring sector[35]. It should be noted that while the map above is accurate and up to date it is by no means fully comprehensive, especially in regards to smaller, privately created low impact developments. However, the map (above) and its parent organization TexasLID.org have been selected as source material to analyze the distribution of large scale public and private low impact developments due to the highly reputable co-creator/collaborators in the creation of the site. TexasLID.org pulls its data (which it uses to subsequently create maps) from four main sources; the Ecosystem Design Group at the Lady Bird Johnson Wildflower Center[36], the Center for Research in Water Resources (CRWR) based out of the University of Texas at Austin's Bureau of Engineering Research[37], the Texas Commission on Environmental Quality[38], and lastly information from private developers on their LID projects. The map itself is created from the LID Project Database[39] for the State of Texas derived from detailed case studies on LID projects throughout the state.

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35 Sponsoring sector refers to whether or not a project was funded by a municipality or if it was a private development.

36 Lady Bird Johnson Wildflower Center, 4801 La Crosse Avenue, Austin, Texas, 78739. Phone: 512-232-0100. http://www.wildflower.org/

37 CRWR, Pickle Research Campus, Building 119, 10100 Burnet Road, Austin, Texas, 78758. Phone: 512-471-3131, Fax: 512-471-0072. http://www.crwr.utexas.edu/

38 TCEQ, 12100 Park 35 Circle, Austin, Texas, 78753. Phone: 512-239-1000. http://www.tceq.texas.gov/

39 The LID Project Database is a shared initiative of the collaborators of TexasLID.org. No information was given as to specifically which supporting agency/entity (or combination of supporting agencies) is responsible for updating and QA/QC of the data.

SECTION 2:

BEST MANAGEMENT PRACTICES

Chapter 6 Case Studies

In examining the environmental effectiveness and economic significance of low impact developments compared to traditional stormwater drainage systems (both in filtration ability and infrastructural costs) the Environmental Protection Agency (EPA) collected data from seventeen low impact developments and redevelopments for assessment. These case studies from throughout North America (most of which are from the mid and northern United States and upwards into Canada) are inclusive of new LID projects; LID retrofits on existing hard stormwater infrastructure, as well as modeling studies. By examining these studies we can have a better image of how wide-scale low impact developments would integrate into the Austin's geographic and socio-political environment.

Case Study 1: Bellingham, Washington[40]

When two parking lots in the City of Bellingham, Washington needed to be upgraded the city decided to install rain gardens, rather than install underground vaults,[41] as a cost effective solution to manage the stormwater runoff from the parking lots. Upon completion of the parking lot rain gardens, (as an example the City Hall parking lot utilized 3 out of a total of 60 spaces to create the 550 cubic foot rain garden catchment basin) costs were compared to estimates for what the traditional vaults would have cost,

[40] Original study in the EPA's document, *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices*, EPA 841-F-07-006, December 2007.

[41] There is no evidence to suggest that vaults were the only option for the City of Bellingham, however as they are a viable alternative to LID/ rain gardens this case study was considered.

given a project of similar scale. Below is the table of the cost comparison of actual cost for the rain garden versus estimated costs of a conventional vault installment.

Project	Conventional Vault Cost	Rain Garden Cost	Cost Savings	Percent Savings
City Hall	$27,600	$5,600	$22,000	80%
Bloedel Donovan Park	$52,800	$12,800	$40,000	76%

Table 3: Comparison Table for Bellingham's Parking Lot Retrofits.[42]

Relevance to Austin

Due to Austin's lack of an extremely efficient and well integrated public transit system, most commercial areas are complete with individual parking lots to accommodate their patron's need to use an automobile to get to and from their establishment. Therefore the utilization of rain gardens as a retrofit to traditional stormwater runoff management systems in parking lots could prove to be a highly effective (both cost and environmental) solution to handle the polluted runoff from a parking lot. Additionally, this case exemplifies how little space is needed to accommodate the LID project, by taking only 3 parking spaces out of the 60 total in the City Hall example for Bellingham, Washington the user access, general productivity and/or functionality of the building are unhindered. Applying this model to a commercial, rather than a civic, building we can assume similar results and success without a cost or detriment to the establishment, especially when considering the high saving percentage that is created by transforming the parking spaces into rain gardens.

Case Study 2: Fredericksburg, Virginia[43]

[42] EPA 841-F-07-006, *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices*, December 2007. Table 5

In the Central Park area (an area dominated by commercial development) in the City of Fredericksburg, Virginia sought to include LID components, namely bioswales and bioretention areas into the area. Using a cost analysis study the City created a side-by-side analysis of the cost additions and reductions for what it would cost to redesign several existing sites (listed in table). Though in five out of six examples the cost of LID exceeded the cost of traditional infrastructure, the study argues for the low impact development, citing that the increased cost is still "comparable" to traditional stormwater management systems.

Name	Total BMP Area (ft²)	Total Impervious Area Treated (ft²)	Percent of Impervious Area Treated	Cost Additions[a]	Cost Reductions[b]	Change in Cost After Redesign
Breezewood Station Alternative 1	4,800	64,165	98.4%	$36,696	$34,785	+ $1,911
Breezewood Station Alternative 2	3,500	38,775	59.5%	$24,449	$21,060	+ $3,389
Olive Garden	1,780	31,900	59.1%	$14,885	$11,065	+ $3,790
Kohl's, Best Buy, & Office Depot	14,400	354,238	56.3%	$89,433	$80,380	+ $9,053
First Virginia Bank	1,310	20,994	97.7%	$6,777	$1,148	+ $5,629
Chick-Fil-A[c]	1,326	28,908	82.2%	$6,846	$12,540	– $5,694

Table 4: Site Information and Cost Additions/Reductions Using LID versus Traditional Designs[44]

Relevance for Austin

Though this case study was purely a model based study and was not actually implemented, the general findings that low impact developments are, at the very least,

[43] Original study in the EPA's document, *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices*, EPA 841-F-07-006, December 2007.
[44] EPA 841-F-07-006, *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices*, December 2007. Table 6.

comparable in costs to traditionally implemented stormwater management designs did convince the developer (according to the document and case study) to begin implementing LID into the site plans of future developments.[45]

In regards to applicability to Austin, Texas, this case study is of particular interest because many of the commercial sites that the model was applied to are corporations with branches in Austin (Kohl's, Chick-fil-A, etc.) therefore the same cost-comparable designs devised in the Virginia study could be duplicated (with minimal modifications) in Texas. Also, this case study demonstrates the very important issue that LID is not always immediately less expensive to traditional stormwater drainage designs, but (as indicated by the willingness of the developer to begin implementing LID) that the environmental and aesthetic impact they have on a project makes up for the slight increase in cost[46].

Case Study 3: Sherwood, Arkansas[47]

The Gap Creek Subdivision in Sherwood, Arkansas was originally planned to contain on 1.5 acres of open space, however by redesigning the site under the principles of low impact development the amount of open space (for the same amount of area) increased to 23.5 acres. The two primary LID practices that allowed for this open space

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45 The level and type of LID implemented in future commercial development projects was not discussed and could not be determined upon further research as details for the developer were not disclosed in the EPA document.

46 It should be noted that it was not the objective of the EPA case study to demonstrate that LID costs more, rather the goal was to demonstrate that LID and traditional designs are in the same cost "ballpark" and that differences in cost should not (and would not) deter a developer or municipality from implementing LID in commercially zoned sites.

47 Original study in the EPA's document, *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices*, EPA 841-F-07-006, December 2007.

saving site design were the identification and preservation of natural drainage areas[48] (based on site analysis), and the relocation of trees to be closer to the street.[49] By preserving open space the developer was able to spend approximately $4,800 less in development costs (as compared to land development cots using non-LID methods) and each lot sold for roughly $3,000 more resulting in a $2.2 million profit for the developer.

Total Cost of Conventional Design	Gap Creek LID Cost	Cost Savings	Percent Savings	Savings per Lot
$4,620,600	$3,942,100	$678,500	15%	$4,800

Table 5: Cost Comparison for Gap Creek Subdivision[50]

Relevance to Austin

This case study examines how LID can be used to lower developer cost and include the green initiatives of cities to reach a "happy median." While this case study does indicate that the developer was able to sell the lot for more it is important to note that when the cost to the developer is low the overall housing "package" cost is lower for the consumer[51]. In this regard LID may actually contribute to increasing the affordability of housing in urban areas, a positive externality of adding LID into the urban form and fabric of a city.

48 By preserving natural drainage areas it reduced the need in both space and cost to provide alternative drainage methods.

49 There is no indication that the trees were converted into tree box filters.

50 EPA 841-F-07-006, *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices*, December 2007. Table 7.

51 The typical ratio of consumer price to developer cost is 5:1, meaning that the consumer will pay approximately five times what the developer paid to "package" the property. Kahn, Terry. *Land Development*, Spring 2011. University of Texas at Austin School of Architecture.

The Gap Creek case study is particularly relevant for Austin in consideration of how much population growth the city is expected to have within the coming years. Much of this growth will occur on the outskirts of the city's core or in the city's extraterritorial jurisdiction (ETJ); therefore it is very likely that a large amount of the development will occur in new or expanding subdivisions. What Gap Creek demonstrates is that by including LID elements into the site design and layout of the development the developer can increase their profit margins while the city and natural environment benefits from increased filtration of pollutants and runoff before it can enter an urban waterway or contaminate the water table. By incentivizing LID and/or advocating it's cost effectiveness the city could improve its urban water quality and create a more environmentally effective stormwater management system (as compared to the city's current initiative[52] of simply labeling the storm drains to raise awareness of pollutant run off into urban creek ways).

52 *Storm Drain Marking*, Watershed Protection Department, City of Austin. http://www.austintexas.gov/department/storm-drain-marking. Details the city's current initiative.

Chapter 7 Austin, Texas: Current and Potential Stormwater Management Policies

Austin Tomorrow Comprehensive Plan

Austin's current acting comprehensive plan is the Austin Tomorrow plan that was adopted in 1979[53]. As discussed in the history portion of this report formal LID did not come into existence until the mid 1980's, with the first published work on the impact, implications, and benefits of its utilization as a stormwater management tool coming about in the early 1990's. Therefore it goes without saying that there is no reference to the use or applicability to low impact developments in Austin, Texas. Additionally, as the times have changed so too has the emphasis on environmental friendliness, looking at the Austin Tomorrow Plan most of the policies in the Environmental Management section[54] is primarily concerned with acquisition of natural or environmentally sensitive land and development restrictions. There is essentially no discussion of how to make developments work with nature as is accomplished with the implementation of LID projects.

Imagine Austin Comprehensive Plan

Much has changed for the city of Austin since the adoption of the Austin Tomorrow Plan in 1979 and Austin has recognized the need for revised policies and a

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[53] City of Austin. Austin Tomorrow Comprehensive Plan. 1979.
[54] City of Austin. Austin Tomorrow Comprehensive Plan. 1979. Pages 33-50.

new city comprehensive plan. Currently Austin is in the process of adopting a new comprehensive plan[55], the Imagine Austin Plan[56], however this plan does not address the use, application, or implementation of LID within the city. However, within the City Facilities and Services section, under the "Key Challenges for the Future" subsection, bullet point four[57], lists "Reducing the volume of stormwater runoff and improving the quality of groundwater infiltration," as a key priority. Additionally, under the subsection "Wastewater, Potable Water, and Drainage Policies," policy CFS P8[58], states the need to "Reduce pollution in all creeks from stormwater runoff, overflow, and other non-point sources." Furthermore, in the Conservation and Environment Section, under Conservation and Environmental Policies, policy CE P11[59] states the need to, "Integrate development with the natural environment through green building and site planning practices such as tree preservation and reduced impervious coverage and regulations. Ensure new development provides necessary and adequate infrastructure improvements." However, despite all of these policies that seem to so strongly allude to the use of low impact development strategies, the plan does not explicitly indicate that such developments be integrated into the urban form.

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[55] As of the publication of this report the Imagine Austin Plan has been submitted to the Austin City Council for approval, but no adoption, determination, or revisions have yet to be formally decided upon.
[56] City of Austin, Imagine Austin Comprehensive Plan, Planning Commission Recommended Draft, April 2012.
[57] City of Austin, Imagine Austin Comprehensive Plan, Planning Commission Recommended Draft, April 2012. Page 145.
[58] City of Austin, Imagine Austin Comprehensive Plan, Planning Commission Recommended Draft, April 2012. Page 147.
[59] City of Austin, Imagine Austin Comprehensive Plan, Planning Commission Recommended Draft, April 2012. Page 138.

This ambiguity in the plan pertaining to the use of LID could either enable its use or completely cripple it in that if someone were to propose a commercial redesign (see the Virginia case study) and point to the Imagine Austin policies CFS P8, and CE P11 as supporting policies they may be able to complete the project including the LID. However, by that same token if someone were to object the redesign they would be able to point to the exact same policies used to support the projects to effectively sideline them by indicating that nowhere in the policies does it allow for LID and that alternatives to LID can accomplish the goals outlined in the polices. Regardless of how useful, effective, or even existent, the alternatives may be the ambiguity in the plan would most like (at the very least) lead to a delay in development while clarification is sought. If the delay is significant enough then the project may be scrapped all together despite its potential benefits and clear alignment with the goals of the policies.

Chapter 8 Suggestions for City of Austin Best Management Practices for Stormwater Management through Low Impact Development

Policy Changes and Adoptions

The City of Austin should, first and foremost, clarify its policies for the use and implementation of low impact developments as an environmental preservation/water quality tool for stormwater management and/or as an accepted urban design practice. Without clear identification for the acceptable use of LID in the public realm it is unlikely that the wide spread use of this type of development will be implemented, despite its cost effectiveness and ability to naturally filter pollutants from stormwater runoff.

LID Options for Austin, Texas

The quickest type of LID for Austin to implement on a citywide scale would be the use of permeable paving options in lieu of traditional asphalt paving or poured concrete on sidewalks and in parking lots. This would most likely begin with new construction where the existing properties only have to make changes if they wish to modify, expand, or in any other way alter their parking or pedestrian ways (implemented the same way that urban form changes or zoning changes are implemented). The extent for which this should be used can fluctuate on use type and the environmental sensitivity of the area. Take for example a sidewalk; traditionally the sidewalk is one long (essentially continuous) ribbon of smooth poured concrete. One degree of variation would be the change it in the least intrusive way, this could be something as simple as when the joints or line breaks that are put into the concrete to prevent it from cracking are placed in by the mason to instead allow for several inches of permeable surface, such as granite gravel, packing sand, (etc.) to allow for periodic permeability in the surface. Inversely the maximum degree of variation would be to nix the traditional sidewalk all together and replace it instead with a completely permeable pedestrian path made of granite gravel, or a synthetic permeable surface that would not cause problems for the various users of the path (including children, elderly, and women with strollers, and bearing in mind ADA accessibility and usability).

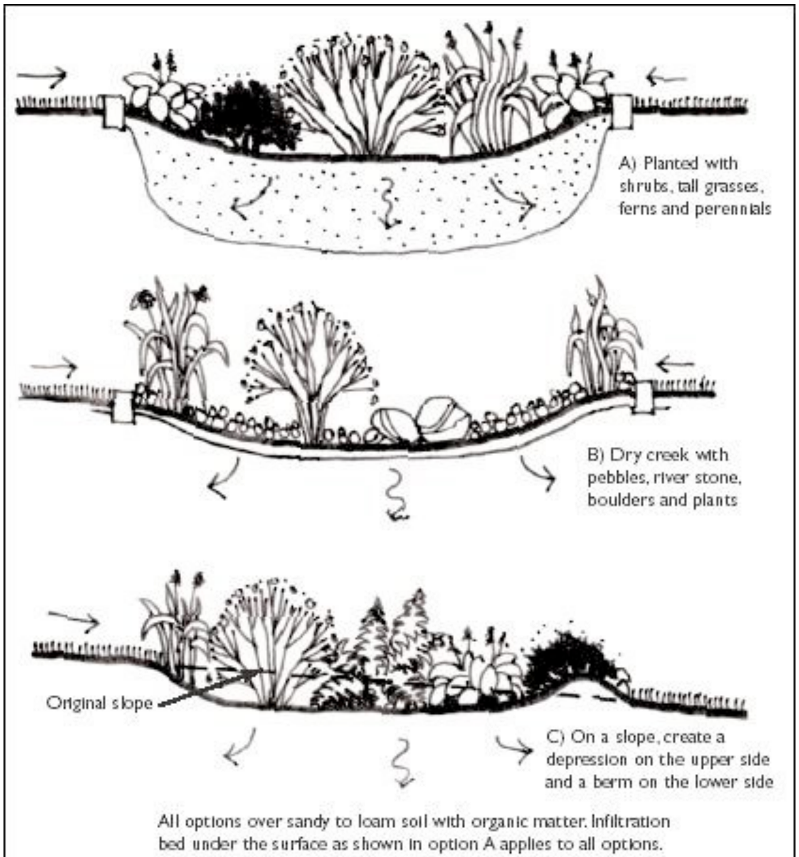


Figure 1: Types of rain gardens. Source: See photo index.

The next most likely LID option for Austin is the use and implementation of rain gardens. The city has already started to utilize "pilot" rain gardens[60] to raise general awareness about the environmental benefit to LID stormwater management. Rain gardens are a practical LID for Austin because they are more

[60] The gardens are located at the corner of Barton Springs Road and South First Street at the Texas One Center, which houses a several city departments including the planning and urban design departments.

isolated and can be used to retrofit parking lots that may have more spaces that needed and could sacrifice a few for the LID project (recall the Bellingham, Washington City Hall case study where three parking spaces were converted into effective rain gardens saving the city money when the existing drainage infrastructure needed replacement and upgrading). Rain gardens can maximize the utility of residual spaces within the city; however given the climatic conditions of Austin (namely the proneness to drought) careful thought should be given to the plant selection for the species that are to occupy the rain garden. Drought resistant, Texas native plants are recommended such as succulents (resistant to drought) or Texas locals like bulbine. Also rain gardens that feature more geologic features (rocks, gravel, sands, etc.) may be beneficial in some areas of Austin due to the hot summers and low rainfall. However, depending on the location and the amount of involvement that the property owner wants to have in the garden plants can be rotated depending on the season. Like permeable pavers the degree of variation will differ between sites, properties, location, and land use and can range from little maintenance to highly involved, elaborate designs.

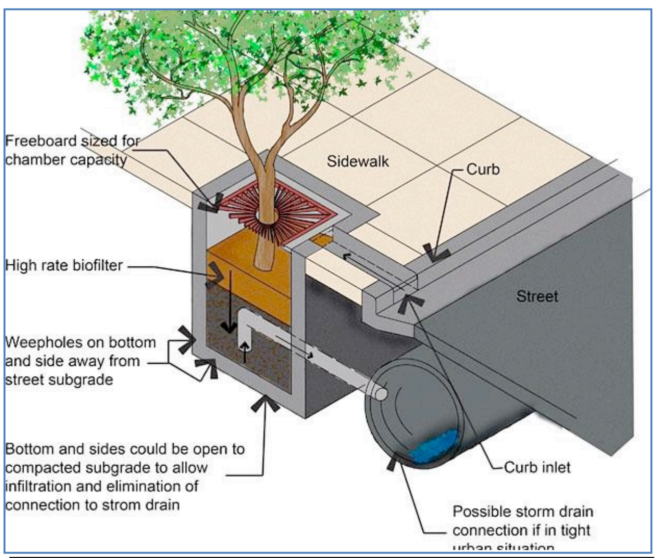


Figure 2: Inner workings and installation of a tree box filter for a tight urban environment. Source: See photo index.

Tree box filters and bioswales have the same Achilles heel. While both can be very effective at filtering pollutants and creating a buffer between the auto-centric right of way and the pedestrian areas, they also require a certain[61] amount of space to be safely implemented. Many rights of way (ROW) in the City's downtown and frequently used streets do not have an adequate pedestrian ROW, or shoulder in the road to allow for tree box filters or swales to serve as the buffer. However, the streets that do have enough space to safely support this urban forestry and green swales could greatly benefit from both the stormwater management and the aesthetic improvement of a site. However, like in the case of rain gardens special attention must be given to the species selection when installing a swale or tree box filter. Overall climatic conditions, rainfall, as well as site-specific conditions[62] should be considered in the pre-development process so that the swale/filter is most successful. Also it is important to remember that the trees used in the tree-box filter will almost always outgrow their boxes and need to be replaced with younger, smaller trees throughout the life of the installment. The type and size of the swale should be determined by what the ROW can support and what species are a "best fit" for the site-specific and overall climatic situation for the development.

[61] "Certain" is variable and contingent on the type of species used, size of total right of way, and expected full grown-out size of the swale and/or tree.
[62] A site -specific condition may include limited sunlight due to tall buildings in the city's downtown, or limited and/or partial exposure to sunlight throughout the day.

SECTION 3:

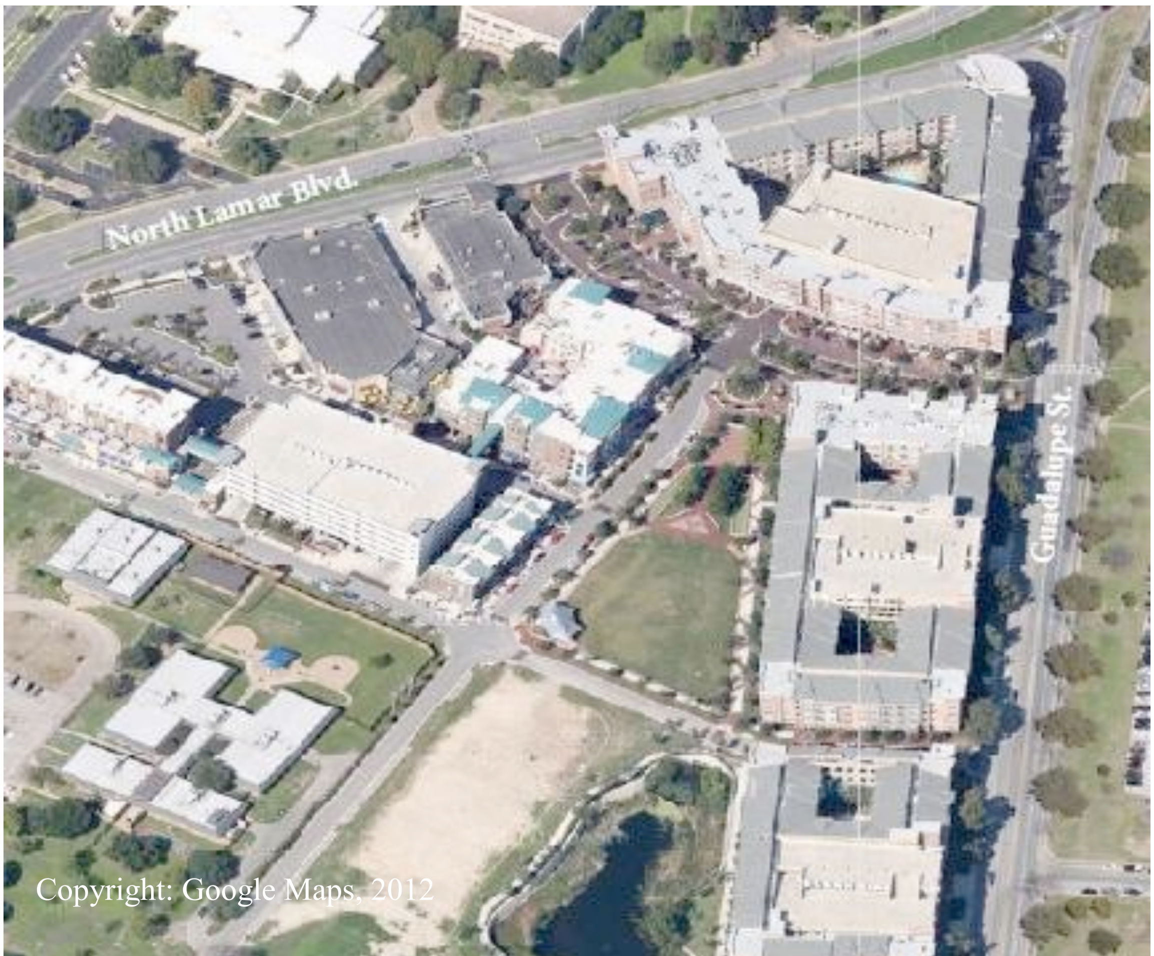
SYSTEMS DESIGN AND ACTION ITEMS

Chapter 9 SWOT Analysis of Applied LID[63]

In theory, low impact developments are a near perfect solution to the issue of urban stormwater management. They increase pervious cover, filter pollutants, require little maintenance, cost less than traditional systems, and enhance the "curb appeal" of cities; at least on paper. However, when applied the effectiveness of LID can be less than the glowing reviews that the advocates had promised. While it typically maintains at least some aspect of all its key strengths, in practice LID is far from a perfect system. There are areas of weakness such as incomplete designs that externally seem like a well thought out low impact site plan, but actually stop short of meeting the goals of a true LID. In application LID projects reveal the opportunities for growth and continued improvement of LID as a development tool, but also bring to light shortfalls that may threaten its use a first-choice alternative to traditional stormwater drainage system. In this SWOT analysis, I examine the strengths, weaknesses, opportunities, and threats of applied low impact developments, using the Triangle, in Austin, Texas as a case study.

[63] All photos herein (of the Triangle) are the property of the author, except where otherwise specified.

Brief Background



Above: Oblique aerial imagery of the Triangle Development, Austin, Texas.

The Triangle is a mixed-use development located north of the University of Texas at Austin campus at the "Y" of Guadalupe Street and North Lamar Boulevard. Though the development is not officially a low impact development many concepts of LID have been utilized in the site design and landscape architecture. However, looks can be deceiving, and though many aspects of The Triangle could be classified as “honest-to-goodness” low impact designs, many components of the site miss the mark. It is because of these “close misses” that the site was chosen as a representative of applied LID in Austin, Texas; because the site context implies and could have applied to it low impact development.

This SWOT analysis of The Triangle differs from a traditional SWOT analysis in that rather than taking the site as a holistic unit, the analysis is on the design and design implications of the site. Strengths, weaknesses, opportunities and threats all refer to aspects and application of the design and does not suggest anything about the overall functionality, utility, enjoyment, (etc.) of The Triangle.

Strengths

The biggest strength of The Triangle is the preservation of open space on both large[64] and small[65] scales. Perhaps the strongest LID feature on site is the large bioretention pond for general drainage; the pond is home to a variety of flora and fauna. Another asset of the triangle is wide spread use of permeable pavers on walkways, driveways, pedestrian paths, and crosswalks. These LID components of the Triangle are implemented on a variety of scales, from a small planter at the end of a parking space to a rolling plaza of permeable bricks and grass.

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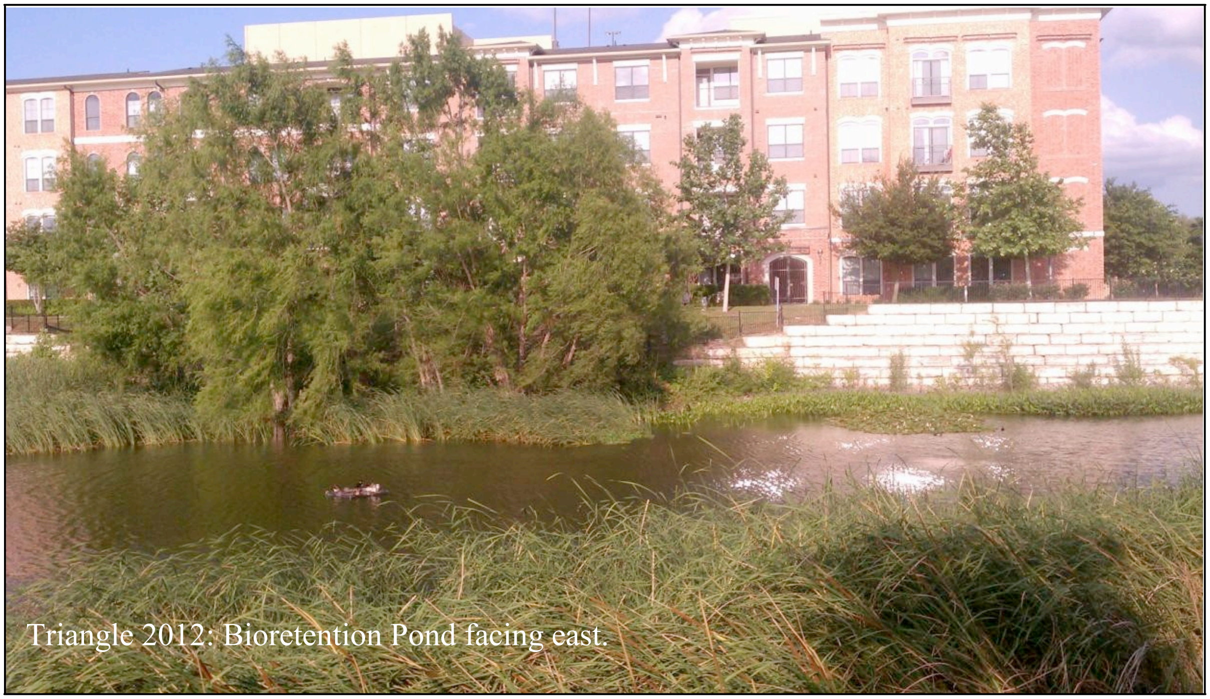
[64] Large scale in this case refers to the bioretention pond and the large grassy “malls”.

[65] Small scale refers to the variety of planters (trees), green medians, and demi-

bioswales.



Triangle 2012: Bioretention Pond facing east.

Above: Images of low impact developments utilized in the Triangle Mixed-Use Development in Austin, TX. Photos by Shannon Wade, Spring 2012.

The benefit of these permeable surfaces is that it allows the runoff that has no escape in the parking lot (see “Weaknesses”)[66] to filter back into the ground before it can reach a creek or stream.

Weaknesses

The weaknesses of the Triangle design may seem minimal, but when compared to the opportunities they are substantial. For the most part the flaw in the design is a lack of follow through. For example, large vegetated planters are placed in the center and along the peripheries of the main parking areas (excluding parking garages), however there are no curb cuts in the planters to allow the runoff from the parking lot to enter planter. Therefore, the planter is prevented from becoming an active bioswale and the opportunity to filter the initial runoff is lost.

Street trees that are near the major streets (Guadalupe and Lamar) have similar weaknesses. Here, almost every aspect of the design (the tree planter) is identical to that of a tree box filter, however, the planter does not collect or filter any water other than what happens to naturally fall into the grate. Changes could easily be made to the street tree design to help direct runoff water through the tree box, therefore maximizing the effectiveness and utility of the tree.

Lastly, many storm gutters (collecting and directing the rain from the roof), empty either straight into the below ground storm drain connection pipe (essentially functioning as another inlet point) or empty directly onto the pavement. If these gutters were simply redirected to empty into a depressed planter or one with small retaining walls as to

[66] This is in reference to the lack of curb cuts in planters.

prevent overflow on to the sidewalk, the non-point roof runoff could be filtered before entering the storm drain system. Alternatively the gutters could empty into rain collection cisterns[67], as another form of green infrastructure.

Missed opportunity to create a tree box filter.

Non-optimal parking lot drainage.

Opportunities

The Triangle is a unique case study in that it already has a lot going for it in regards to low impact development components. Most of what could be done to improve the LID within The Triangle would be to do a sort of mutual retrofit where the existing LID is retrofitted in order to become optimized LID[68] and the existing traditional stormwater infrastructure is restructured so that rather than collecting direct runoff flow it can take advantage of the filtration potential of the permeable cover.

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[67] Rain cisterns are in the same class as LID (green infrastructure) but is not in the same family of tools, because the goal of a cistern is to save and reuse water, while LID is to filter and transport (with the exception of bioretention which is designed to store).

[68] Optimized LID: For example, inserting a curb cut into a currently closed planter in order to create a bioswale.

The opportunities for The Triangle's LID are greatest along the border of the development, along the highly trafficked Guadalupe Street and North Lamar Boulevard. This is because the more a road is traversed by automobiles the more pollutants are gradually deposited, and therefore the more highly polluted the initial run off will be and the greater impact LID could have.[69]

Vegetated "swale" on top of, but not part of, a traditional storm drain inlet. There is an opportunity to redesign to optimize the proximity the two development types have to one another.

Threats

The biggest threat to creating an enhanced LID environment at The Triangle is the perception that it is as "green" as it seems. That is to say, that not all at The Triangle is what it appears, case in point: the "permeable" pavers that cover the development. While many, if not most of the pavers are genuine. However along the periphery, where there is

[69] The literature suggests that once water enters the traditional drainage system, no longer able to be filtered by LID, that there will be no opportunity for that water to be filtered later on in the process. This mean that it is just as critical to put LID on heavily polluted streets, as it is to implement it closer to areas that are environmentally sensitive.

the greatest opportunity to impact the surrounding environment, the pavers that appear permeable are in fact stained and stamped concrete, an impervious cover. Without close inspection it can be difficult to tell, however once damaged the difference becomes exceedingly obvious.

Development that appears to be LID without the benefit is a threat to the future implementation of more LID, because there is no perceived need. Using false LID in conjunction with real LID should be avoided so that the efficiency and level of repair[70] can be properly assessed at LID project sites.

[70] Looking at the paver diagram and it may be difficult for someone not familiar with concrete stamping practices to tell what is LID and what is not, because the two will require different maintenance needs when the two are in close proximity it can be difficult to determine if/what needs repair.

Chapter 10: Planning Recommendations

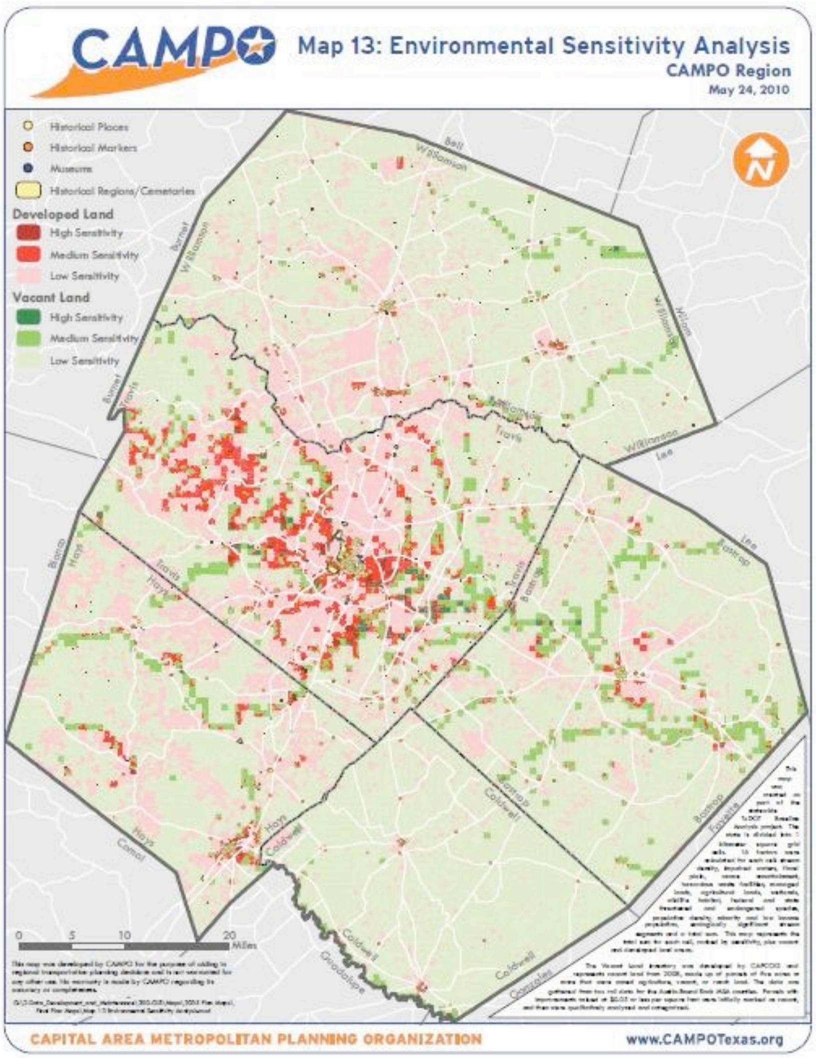
In order to better assess situations when LID would have the greatest environmental impact and to determine if/when a specific development could/should/would qualify to apply LID within the site design planning standards should be created within the City. One of the main goals[71] of low impact development is to reduce the amount of non-point source polluted runoff from entering urban waterways and because one of the most likely origins is the built up pollutants on streets both environmental sensitivity and transportation land uses should be considered equally to strategically place LID within the city to have the greatest impact. Therefore, I recommend that the City of Austin create an overlay district that (using data on environmentally sensitive areas, particularly those regarding urban waterways and transportation volume, type, etc.) that would allow for LID projects without any special permitting, assuming that the site design does not jeopardize public health and safety and complies with proper requirements (city, state, or federal). By allowing for permit free zones within the city the use of low impact developments would be encouraged and it is more likely that a private developer would incorporate low impact components into the site design. Additional measure could be taken to further encourage[72] or restrict[73] the use of LID within designated areas in the city.

[71] See Chapter 3, "Goals of Low Impact Development"

[72] For example, a developer-oriented incentive might be something like allowing for narrower streets in new developments if LID is used (recall the Gap Creek Case Study). Narrowing the streets would reduce the overall development cost to the developer making it an attractive option.

CAMPO, the Capital Area Metropolitan Planning Organization, has generated a map[74] in their 2035 Regional Transportation Plan[75] detailing the environmental sensitivity of Travis County in relation to major arterial streets.

Figure 3: CAMPO Environmental Sensitivity Analysis Map



Environmental Sensitivity Analysis from the CAMPO 2010 Regional Plan shows environmentally sensitive areas and their proximity to major roadways. Austin, TX.

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73 Standards or restrictions could be put in place as to what qualifies as LID (for example, a development like the Triangle has aspects of LID, but hasn't utilized them to their fullest potential). These standards may make the implementation too taxing for some developers, effectively restricting the application of LID in certain areas. Also, "LID Free" zones could be created where no LID projects are allowed if so desired.

74 CAMPO. *CAMPO 2035 Regional Transportation Plan*. 24 May 2010. Map 13: Environmental Sensitivity Analysis of the CAMPO Region. P 60.

75 CAMPO. *CAMPO 2035 Regional Transportation Plan*. 24 May 2010.

A map similar to the CAMPO map could be utilized in determining sensitive areas where LID should be implemented to provide security to the environmental quality, and more precisely the water quality, of the area.

Next, I would recommend that the City of Austin create planning policies (either through general urban design guidelines or more structured form-based code) to speak to the visual application of low impact developments. Currently the City uses the Texas Environmental Criteria Manual as the primary planning guide for water quality management in Austin. While the manual is very detailed in regard to calculations for base pollutant loads and acceptable degrees of standard deviations,[76] as well as in what circumstance specific ordinances may or may not be applied it does little to detail requirements for site design. This lack of documentation detailing specific standards to how to apply and what qualifies as a low impact development is problematic because, as seen in the example of The Triangle, there are many ways a seemingly low impact development could fall short.

However, perhaps the greater issue is that once again the documentation provided by the City of Austin fails to specifically mention low impact development[77] despite high levels of similarity between the City's goals and the goals of low impact development. Therefore I also recommend that either documentation be created detailing the acceptable use and standards for LID in Austin, or, the current documentation be revised or appended to include the applicability of LID.

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[76] City of Austin, *Texas Environmental Criteria Manual*. Section1: Water Quality Management

[77] Based on a review of the *Criteria Manual*.

Chapter 11 Conclusion

Compared to traditional stormwater drainage systems LID is comparable in cost, with many case study examples of LID being less expensive to install than a traditional system upgrade, retrofit, or total new installment. Low impact developments can be utilized with any type of development at any level of establishment, though many in Texas go along with high populations in areas with at least moderate amounts of annual precipitation (in both days and inches).

Traditional stormwater drainage systems and low impact developments both have areas of strength and weakness. Traditional designs benefit from efficiency in design and have the ability to move massive amounts of water at a time, though they seldom need However, traditional systems do not filter out pollutants and can lead to a degradation of the urban water quality. LID projects, on the other hand, benefit from high levels of specific site analysis and a through pre-development phase. Low impact developments are very efficient at naturally filtering pollutants from stormwater runoff and increasing permeable cover in urban environments.

In the application and utilization of LID in Austin, Texas the first issue that must be addressed is the detailing and specific mention within the comprehensive plan (via policies) to the use and implementation for LID. However, once the policy matter has been sorted the type and scale of LID options for Austin will vary based on the site-specific needs and restrictions of the project. Permeable paving options would be the easiest form of LID to implement on a wide scale basis. Rain gardens would be the second most applicable due to the ability to construct a rain garden in a small “pocket” of space and to allow the systems to exist in a more isolated manner, though “chain linking” rain garden projects is recommended for optimum efficiency and greatest impact. Tree box filters and bioswales are both good options of LID for Austin; however these two types will face greater restriction due to limitations of the ROW and site context. In all LID cases that involve vegetation special attention should be paid in the species selection, as Austin is very prone to droughts, succulents and native Texas species are therefore recommended for best results. Also, LID projects that focus on the use of geologic features such as rocks, gravel and sands (rather than vegetation) are highly recommended for Austin given the environmental conditions and climatic trends. The most impactful move the city could make to further the use of low impact developments that are consistent with named City goals would be to create documentation detailing the use and application of LID as a feasible development type in Austin, Texas.

In conclusion, low impact developments have proven (through cost analyses and case studies as well as environmental reports) to be a cost effective, environmentally friendly form of stormwater management and should be incorporated into the City of Austin’s stormwater management, comprehensive plan, and supporting technical[78] and urban design standards documentation.

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[78] This applies to any document that is relevant to the technical aspect of stormwater management for the City of Austin and includes, but is not limited to environmental analysis process documentation, form based code, and overlay districts within the city and its ETJ.

APPENDIX A: LID OPTIONS FOR AUSTIN, BY TYPE

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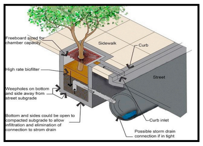

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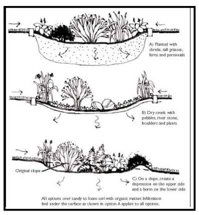

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This Master's Report was typed by the author.