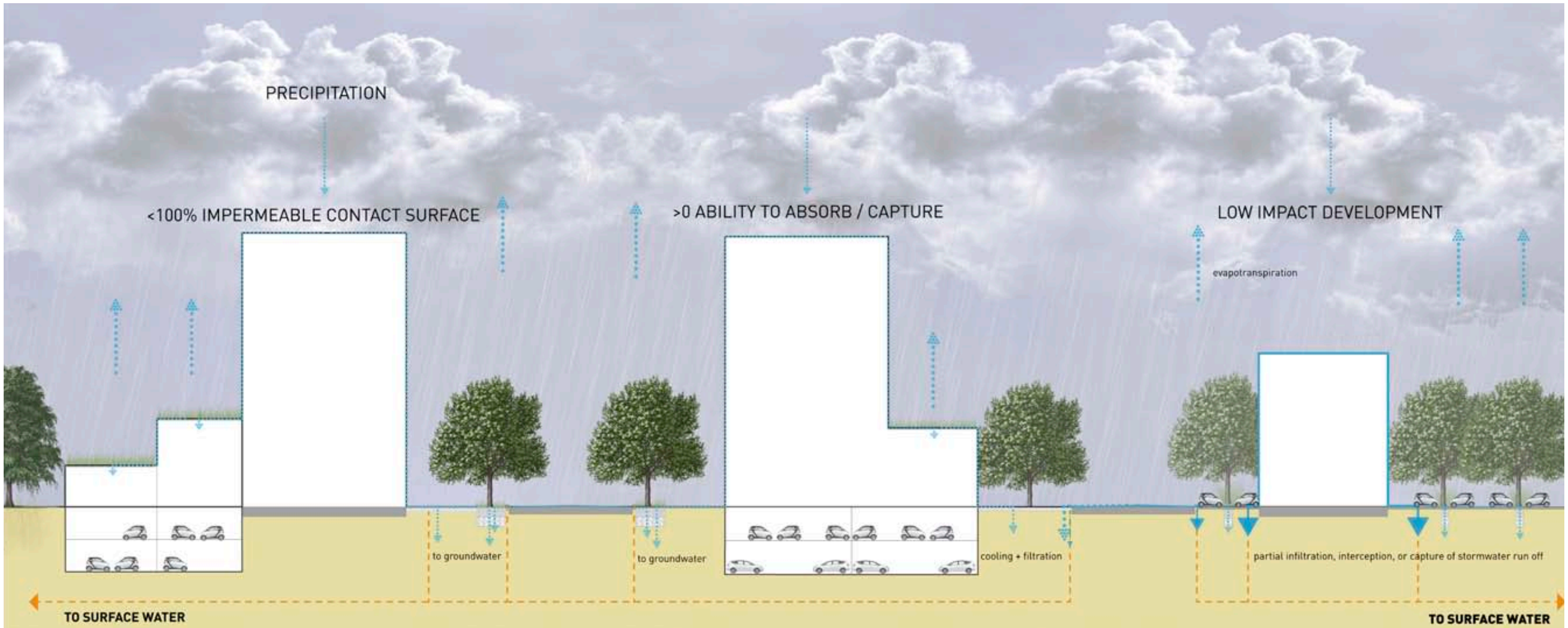

Low Impact Development and Decisions:

A framework for comparison of spatial configurations
low impact development in the design of a district

nelly fuentes | MDS | spring 2013

Low Impact Development and Decisions:

A framework for comparison of spatial configurations low impact development in the design of a district

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Abstract:
This study analyzes the quantifiable impacts of low impact development features, sometimes referred to as green infrastructure, across three alternative proposals for the development of a city district along the edge of a lake and a creek. Low impact development is defined as a stormwater management approach designed to capture water before it goes into stormwater drains or directly into bodies of water in order to allow the water to infiltrate groundwater sources or evapotranspirtate back into the atmosphere. The study applies Carl Steinitz's Framework for GeoDesign to the three alternative proposals and the existing conditions as a means of comparison in order to understand an informed decision based approach to design.

Statement:

Time Magazine predicts "resiliency" as the environmental buzzword for 2013, particularly as it relates to cities[1]. Yet the conversation about the impact cities and the environment have on each other comes not as a new thing. The discussion about sustainable cities or green cities can be traced back to the start of the 20th century in Ebenezer Howard's Garden Cities[2]. The buzz around this topic merely grows louder and garners more public visibility with each natural disaster that strikes such as Hurricane Sandy in 2012 and Hurricane Katrina in 2005.

Had *Time Magazine* been writing specifically about discourse in design, they might have included words like "green infrastructure" or "low impact development" as part of their predicted buzzwords.

For Austin, the conversation starts with what quantifying the benefits of green infrastructure does to allow stakeholders to make decisions about design and models of development. Imagine Austin, the City of Austin's comprehensive plan adopted in 2012, indicates one of the priorities of the comprehensive plan to be the use of "green infrastructure to protect environmentally sensitive areas and integrate nature into the city.[3]" As an urban design student coming from the landscape architecture program, I am particularly interested in studying the way we build our cities with respect to the environment and landscape systems. By that I mean, where do we position ourselves within bio-physical processes?

Frederick Steiner and Danilo Palazzo point to a definition of urban design posed originally by Matthew Carmona and Steve Tiesdell that is useful in un-packing this complex question. Carmona and Tiesdell "define urban design 'as the *process* of making *better* places for people *than would otherwise be produced*' (emphasis in original).[4]"In this case, we might view the "what otherwise might be produced" as the development that might occur which comes strictly from codes and regulations, or negotiations around such policy. Urban design negotiates between policy and design. That policy is linked with landscape systems because it determines where we build on the land, how much of it we build over, where our flows of resources and waste go and how fast they move. In a sense, this parallels the study of ecosystems.[5] Palazzo and Steiner advocate for integrating

1 Walsh, Brian . "Adapt or Die: Why the Environmental Buzzword of 2013 Will Be Resilience Read more: http://scienAdapt or Die: Why the environmental buzzword of 2013 will be resilience." January 08, 2013. http://science.time.com/2013/01/08/adapt-or-die-why-the-environmental-buzzword-of-2013-will-be-resilience/ (accessed January 10, 2013).

2 Howard, Ebenezer. *Garden Cities of To-morrow.* (Being the third edition of "To-morrow: a peaceful path to real reform"). London, 1902. http://hdl.handle.net/2027/mdp.39015055593399.

3 City of Austin. "Imagine Austin, Comprehensive Plan." Austin, June 15, 2012 ftp://ftp.ci.austin.tx.us/npzd/Austingo/web_IACP_full_reduced.pdf

4 Palazzo, Danilo, and Dean Frederick R. Steiner. Urban Ecological Design: A Process for Regenerative
Places. Island Press, 2011.

5 Palazzo and Steiner, 2011, pg. 2

an understanding and application of urban ecology as a basic component of urban design. They write,

> Urban ecology is more than understanding nature in cities. It also involves the integration of humans and nonhumans in functional and just ecosystems…Many parallels exist between urban design and urban ecology. Both involve making connections and revealing relationships. Both are fields of studies searching for an integrated approach between different disciplines. Urban ecology requires an integrated framework "to assess the environmental implications of areas in the face of change" (Alberti 2008, xiv). Urban design is an integrated discipline traditionally allied with architecture and city planning (Lang 1994). Ecology involves the reciprocal relationships between all organisms with other organisms as well as their environments. Marina Alberti (2008, xiv) argues that "cities are hybrid phenomena –driven simultaneously by human and biophysical processes." These phenomena cannot be fully understood by just studying their component parts separately; "thus urban ecology is the study of the ways that human and ecological systems evolve together in urbanizing regions" (Alberti 2008, xiv). Urban ecological studies synthesize the diverse dimensions of urban systems dynamics into a coherent theoretical framework. Within these frameworks, urban planners and designers can find tools and aids for analysis, policies and designs. At a minimum, the designer may begin with the precautionary principle –that is, first do no harm to the environment or to people. Furthermore, the designer helps to mitigate human impacts on the natural environment. More ambitiously, the designer helps to orchestrate our relationships with other living organisms in the built environment.[6]"

Several points come from this work. The first of which is the need to assess the impacts of changes in the built environment on biophysical systems. <u>This study focuses on modeling environmental impacts of different types of development that could be proposed for the design of a district in Austin in order to assess the advantages and disadvantages of each in comparison to the set, specifically with respect to the hydrologic cycle</u>.

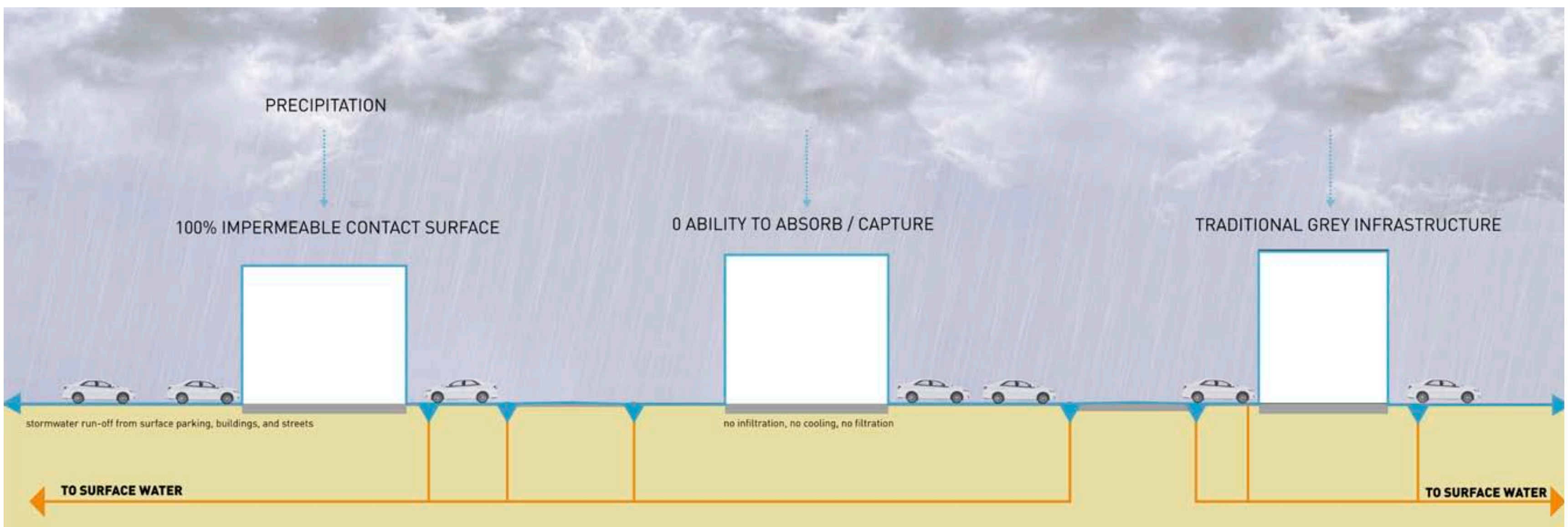
There are many biophysical processes in the landscape which can be engaged at the urban scale such as the cycling of carbon, nutrient flows or energy flows. The water cycle resonates strongest because Austin is a city built between creeks along the Colorado River. Creeks and the river are not only a part of our geomorphological history but our cultural one as well. Water is also one of the landscape systems that is regulated in Austin at the urban scale. Specifically, how closely to the water one can build to, the ratio of impervious to pervious cover on the site, the amount of stormwater that must be captured and handled on site and the rate at which it can return to a body of water.

This study could potentially provide stakeholders with a way to think through these types of decisions by looking at where the designer can insert themselves into the hydrologic cycle and the impacts of those choices. The study asks questions of certain choices that designers can make that feed back into hydrologic cycle by impacting how much run-off a site generates, how much of that run-off it can capture and how much is lost into storm drains which outflow into lakes or creeks. Part of these

6 Palazzo and Steiner, 2011, pg. 3

choices relate to the volume of water directed into traditional grey infrastructure such as concrete pipes and basins or how much of that water is directed into features referred to as “green infrastructure” or low impact development.

HYDROLOGIC CYCLE



EXISTING DEVELOPMENT CONDITIONS

The Hydrologic Cycle and Infrastructure:

The un-interrupted hydrologic cycle traces precipitation down from the atmosphere until it comes into contact with a surface. The surface is essentially the built environment. If that surface is permeable, like soil or growing media, the water will be absorbed and temporarily captured. That water will either infiltrate down into groundwater (or the aquifer) or the water will be taken up by plant roots and released back into the atmosphere through evapotranspiration. If that surface is impermeable like a tree leaf, the water will temporarily be captured and released into the atmosphere through evaporation. Water not captured or absorbed will flow over the ground until it reaches an open body of water like a lake or a creek. The University of Arkansas' Community Design Center identifies 17 ecosystem services that come from this cycle, including climate regulation, disturbance regulation, water regulation, pollination, habitat and water supply (regulation)[7]. Water is just one resource that results from a function of the environment. "The environment functions instrumentally as an essential input into a wide range of human and natural goods and services including 'agricultural output, human health, recreation, and more amorphous goods such as quality of life.[8]'"

Current models of urban development have interrupted the hydrologic cycle by covering the ground with impermeable surfaces, creating an excess of run-off which is piped directly into a body of water. The impermeable surfaces make it nearly impossible for precipitation to recharge the groundwater source. It necessitates infrastructure to convey it away from buildings, streets and parking lots. This infrastructure is usually a network of concrete pipes and basins that drain into bodies of water, sometimes the same source of a community's drinking water. As it goes into the pipes, the water picks up pollutants from surfaces such as poly-hydrocarbons, bacteria, petroleum based products, sediment, heavy metals and fertilizer.[9]

Grey infrastructure, as this infrastructure is sometimes referred to in reference to its materiality, is often single purpose. Grey infrastructure is produced by humans for human use.

Brett Frischmann identifies three assumptions about traditional infrastructure that might begin to understand the role of infrastructure in development. First assumption, the government has a role in providing infrastructure. Second assumption, the infrastructure is accessible to anyone who is part of the community and wishes to use the resource are free to do so in equal terms. Third assumption, "traditional infrastructures generate significant spillovers that result in larger social gains"[10].

7 University of Arkansas Community Design Center. *Low Impact Development: A Design Manual for Urban Areas*, 2010.

8 Frischmann, Brett M. *Infrastructure: The Social Value of Shared Resources*. Oxford University Press, USA, 2013.

9 University of Arkansas Community Design Center, 2010, pg. 10

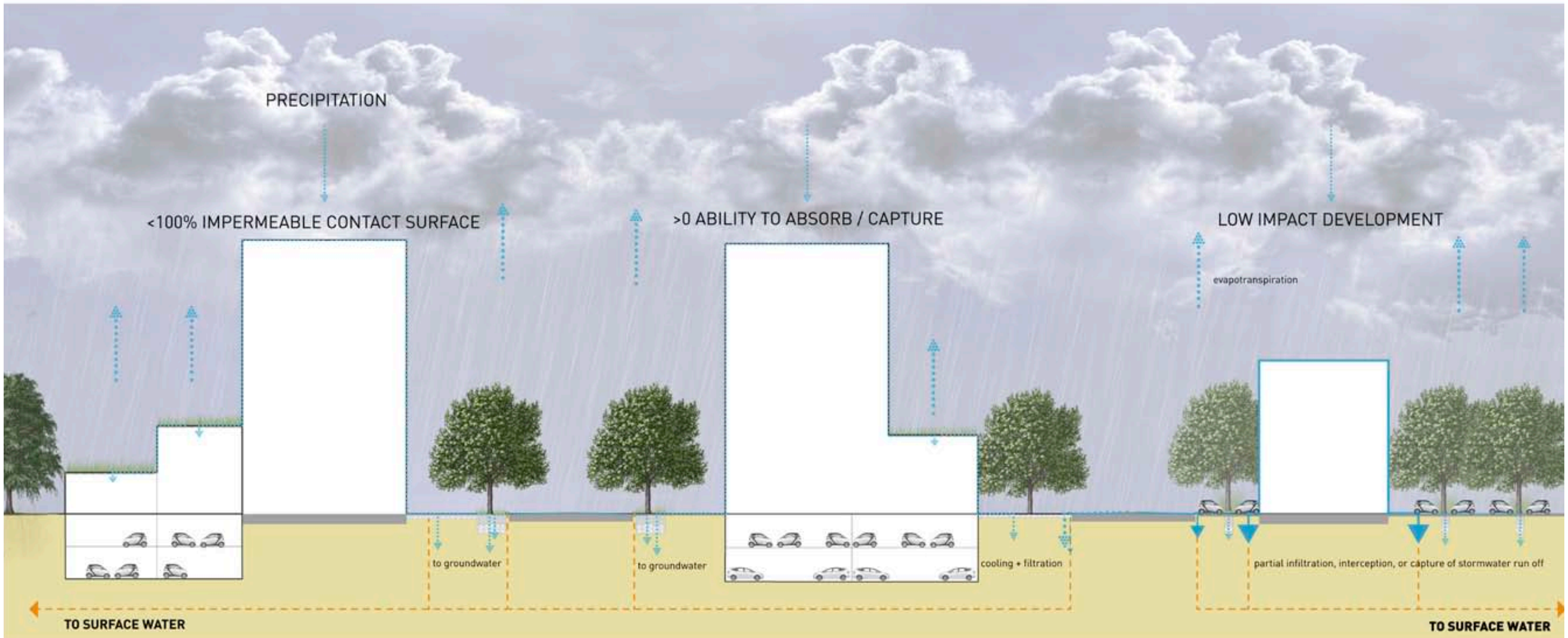
10 Frischmann, 2013, pg. 5

These assumptions will come up again later when I discuss stakeholders and decision making, but I introduce them now as a definition of infrastructure which can be used to compare grey infrastructure to low impact development, or green infrastructure.

Low impact development “is an ecologically-based stormwater management approach favoring soft engineering to manage rainfall on site through a vegetated treatment network... using techniques that infiltrate, filter, store and evaporate stormwater runoff close to its source.[11]” Low impact development provides us with an alternative to traditional concrete pipes and basins by temporarily capturing water before it goes into grey infrastructure and give it time to infiltrate and recharge groundwater sources or disperses it over vegetation to be cooled and cleaned. Instead of allowing surface pollutants to be conveyed into our drinking water, low impact development take’s advantage of vegetation’s ability to treat water through phytoremediation, phytovolatization, phytoextraction, phytostablization and phytodegradation. This means vegetation has the ability to mitigate contaminated soil water and air to uptake, eliminate, sequester or degrade contaminants and keep them away from resources like drinking water or the air we breathe. Referring back to Frischmann, the effects of phytoremediation resulting in cleaner air, cleaner soil and cleaner water are some of the spillover benefits of this type of infrastructure which are available to members of the community. If less pollutants from one district make their way into the drinking water, the overall quality of the water body increases, not just the district’s water.

The premise of this study is that designers can insert themselves into the hydrologic cycle and work within the biophysical by making choices about the types of infrastructure networks an urban development relies on as well as choices regarding the size and materiality of the built environment. The size and materiality of the built environment has a direct relationship to the amount of stormwater run-off produced on site and the type of infrastructure will determine what volume of water is conveyed into bodies of water through traditional pipes or what volume might be allowed to infiltrate and recharge the aquifers or groundwater sources. Essentially, what kind of surface will precipitation come into contact with, how and to where will run-off flow.

11 University of Arkansas Community Design Center, 2010, pg. 22



HYBRID CONDITION

Low Impact Development

Some of the choices available to designers today include green roofs, parkspace that doubles as dedicated bio-filtration areas, permeable pavers, rain cisterns and rain gardens. These features have in common the ability to absorb a quantity of volume and temporarily retain it long enough for it to infiltrate to ground water or slowly disperse it over the landscape in times of low amounts of precipitation. The metric to pay attention to in terms of understanding stormwater capture capacity is the volume of these systems, often subsurface, and a coefficient which indicates a substrate's ability to hold water. For example, if sandy soils are used as substrate they typically have the capacity to devote 30% of their volume to temporary water capture. Of the soil's entire volume, about 30% of that is air pockets between particles which is where water starts to fit in. It is important to note that not all soils have the same capacity to absorb water and should be tested as it will play a role in the success or failure of the infrastructure. For the purpose of this project, it is assumed that existing soils were removed or engineered to perform as desired in terms of water capture capacity. Using a .3 water capture capacity comes from conversations with Dr. Michael Barrett at the Center for Research in Water Resources.

Green Roofs

The literature reviews for green roofs in Central Texas show that green roofs, when designed to certain specification can retain large volumes of water (relative to their surface area and depth) and can significantly cool buildings[12]. In one experiment, a green roof with built in monolithic (not modular) structure with decomposed granite and perlite substrate mixed with small size organic matter and spun plastic filter fabric had the capacity of retaining 88% of medium to large rain events[13]. The study showed that depending on construction typologies, a green roof can retain between 44% and 88%[14]. For the purpose of this study, green roofs are assumed to be designed to the standards of the higher preforming roofs (88%) for the purpose of running an analysis. The volume of water capture capacity is determined by taking this number and multiplying it by a depth of 6 inches and the surface area of the green roof. In terms of who gets to decide to use a green roof as a storm water best management practice it is up to the individual owner of the building to choose to make that investment. A city can incentivize it with development bonuses but the long term management of the system is the responsibility of the individual.

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12 Simmons, Mark, Brian Gardiner, Steve Windhager and Jeannie Tinsley. "Green Roofs Are Not Created Equal: The Hydrologic and Thermal Performance of Six Different Extensive Green Roofs and Reflective and Non-reflective Roofs in a Sub-tropical Climate - Springer." Accessed January 24, 2013. http://link.springer.com.ezproxy.lib.utexas.edu/article/10.1007/s11252-008-0069-4/fulltext.html.

13 Simmons et al., 2008, pg. 3

14 Simmons et al., 2008 pg. 1

Park space

Park space being used as dedicated areas of bio-infiltration assume that soils have been un-compacted and amended to a depth of two feet. Typically features of an area designated as a best management practice (bmp) for bio-infiltration will have .7-1 m of a sand/soil/organic media and vegetation[15]. As bio-infiltration becomes a more widely accepted BMP throughout the country, more and more bodies of regulation come up with standards for construction and installation. Some of the design objectives of these features deal with base flow and groundwater recharge; pollution prevention and removal; erosion control and peak flow reduction, as well as infiltration and evapotranspiration rates[16]. The City of Austin has studied the relationship of vegetation type and water yield, meaning the water that actually makes it into the ground. The study found that the larger the canopy cover, the less water actually made it into the ground because of amount of surface area tree canopy has to intercept water before it hits the ground. Additionally, trees have a higher evapotranspiration rate than grasses.

This becomes important in terms of setting an ecological goal for parkland. What I mean by this is that beyond the ability to keep water out of grey infrastructure, parks have the ability to increase the water yield of a site (into the aquifer or groundwater recharge) by maintaining a particular canopy ratio. According to the study, the ideal canopy cover over land meant to increase water yield is 20% or less[17]. It has the ability to perform more than just one function, it can keep water out of grey infrastructure and get more water into the recharge zone by taking on specific formal qualities. The defining of a more specific goal begins to set up spatial constraints on the design of the park.

These constraints should be weighed against other programmatic and political issues surrounding the context of the site. For example, in a city where groundwater recharge takes political priority, is it in their best interest to allow a land owner to replace trees removed from the site as a result of construction on the same land that is designated as stormwater management? Conceptually, replacing lost trees and keeping stormwater out of storm drains seem like two things that are in the interest of the environment, but is recharging the aquifer any less so? Low impact development features such as parks dedicated as bio-infiltration areas can have multiple benefits but still require decisions in terms of the limits of those benefits might be.

The decision to make land dedicated park space can be one taken at the individual level or the larger collective level. That is to say individuals can choose to build or not build on their land, or use a part of their land as dedicated park space in order to get some development bonus like additional height. Cities, districts,

15 Davis, A., W. Hunt, R. Traver, and M. Clar. “Bioretention Technology: Overview of Current Practice and Future Needs.” *Journal of Environmental Engineering* 135, no. 3 (2009): 109–117. doi:10.1061/(ASCE)0733-9372(2009)135:3(109).

16 Davis et al., 2009, pg. 111

17 McCaw, Matt. Water yield as a function of canopy cover on the City of Austin Water Quality Protection Lands. Austin, 2002.

or another form of collective action can choose to dedicate or buy land and dedicate it as public park space as part of the configuration of urban development.

Permeable Pavement

Permeable pavement, with maintenance can infiltrate at a rate of up to 50 inches per hour. Without maintenance, the infiltration rate goes down to 3 to 4 inches per hour[18]. According to research performed by the Interlocking Concrete Pavement Institute, permeable pavement can reduce 100% of run-off from a 3 inch rain event with a subgrade of sandy soil and 1 foot depth of thick open-graded aggregate.[19] When put over structural soil boxes, concrete pavers allow for urban street trees to grow beneath the pavement with less stress than traditional tree wells. While permeable pavers are not appropriate for all regions due to climatic concerns, they are appropriate to Central Texas as temperatures rarely go below freezing, requiring streets and sidewalks to be salted.

Additionally, permeable pavers may not be appropriate for streets with high traffic or industrial loads. While new concrete paver modules are developed to try and handle more weight, pressure, and use, permeable pavers might be more appropriate to distinguish streets where pedestrian and bicycle modes of transportation are privileged.

18 Interlocking Concrete Pavement Institute, Permeable interlocking concrete pavement for design professionals, Canada, 2008.

19 Interlocking Concrete Pavement Institute, 2008, pg. 4

For the purposes of this study it is assumed that the permeable pavers are used primarily in sidewalks and are set on one foot of thick open-graded aggregate. This set up sits on top of structural soil when the sidewalks have trees integrated in their design.

Rain Gardens

Rain gardens are perhaps the low impact development feature that more people have encountered and have an idea of what one might look like. One might picture a depressed area in the topography planted with mesic plants that can function with both high amounts of water and low amounts of water. What makes rain gardens an interesting point of discussion when looking at low impact development's viability as infrastructure is that the decision of where, when and how to build a rain garden can become a bit ambiguous.

For example, a city might encourage homeowners to construct a rain garden in their front or back yard to handle water coming off of their roof. Generally this construction can be a simple depression in the topography of a site and using existing soils. This model limits the effectiveness of a rain gardens as stormwater infrastructure to areas where soils have a higher infiltration capacity otherwise water would remain ponded in the depressed area long enough to breed mosquitos[20]. However, if

20 Calkins, Meg. The Sustainable Sites Handbook: A Complete Guide to the Principles, Strategies, and Best Practices for Sustainable Landscapes. 1st ed. Wiley, 2012.

the rain gardens took on standards of construction and could rely on engineered or amended soils when faced with native soils with a low infiltration rate and water capture capacity, perhaps rain gardens can become part of a larger set of ecological infrastructure.

Referring back to Frischmann's three assumptions of infrastructure, the third assumption is the spill over benefits from the infrastructure result in larger social gains[21].In terms of a rain garden, the spill over benefits from rain gardens can be seen in their ability to become habitat, their ability to reduce the pollutants going into storm drains, and arguably their ability to increase the aesthetic appeal of an area. The third criteria is obviously subjective to aesthetic preferences, but in terms of the first two one is actually able to count species living in a rain garden and compare it to pre-rain garden conditions. It is also possible to calculate the amounts of pollutants the vegetation takes out of the water. Frischmann's second assumption of infrastructure, anyone who is part of the community and wishes to participate may do so freely, becomes a point of discussion[22]. An increase in wildlife species as a result of rain gardens might mean more pollinators are now available to the area beyond the boundary of the rain garden.

In the case of many species, pollinators are a critical component of propagation and more pollinators in the area could increase their chances of becoming a self-regenerating plant community as opposed to one that has to be planted from store-bought seed or pots from a nursery.

Yet it is Frischmann's first assumption about infrastructure that really begins to test the viability of rain gardens to come stormwater infrastructure. Frischmann's first assumption of infrastructure says that "government plays a significant and widely accepted role in ensuring the provision of many traditional infrastructures.[23]" This could mean that the government might play a role in the funding of such projects or in setting standards for their construction. This differs from the first model of rain gardens where individuals go out and manipulate existing topography then vegetate the area to something that suggests standards for construction and maybe even standards for plantings. One might look at governing bodies' role in provisioning new types of low impact development infrastructure in potentially three stages with varying degrees of participation. The first might be to work with experts in soils, vegetation and hydrology to test for construction and vegetation standards ideal for the local area. The second stage might be to distribute this information to both the professional community and stakeholders. Part of this distribution of information could be done as part of a series of workshops or demonstration projects in public places. The

21 Frischmann, 2013, pg. 5

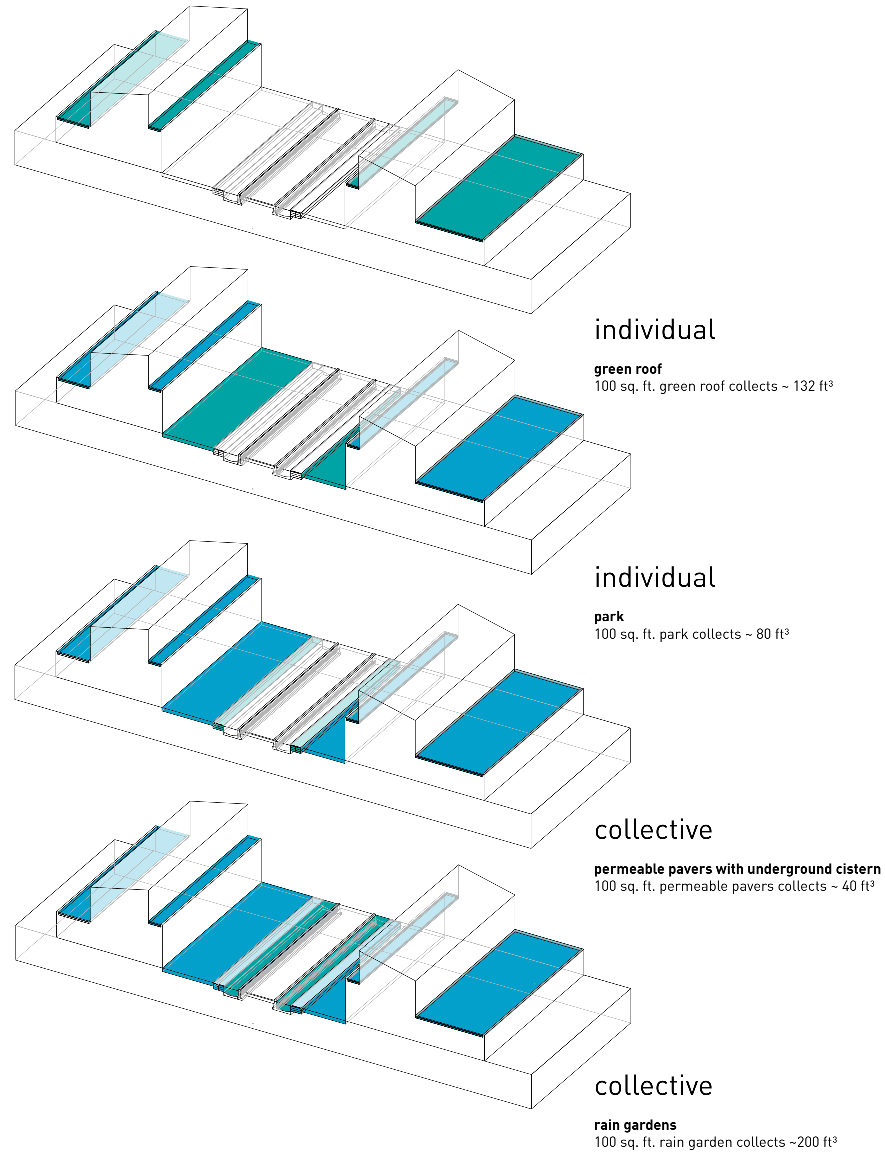
22 Frischmann, 2013, pg. 5

23 Frishmann, 2013, pg. 4

third way the governing body might participate in ensuring this type of infrastructure is to take steps to integrate it into urban development practice. This might mean finding the funds to subsidize the individuals constructing this type of infrastructure on their sites, or incentivizing the use of low impact development through density or height bonuses in response to zoning. Another way governing bodies might provide low impact development features to the community is by integrating it into the public spaces provided by that governing body.

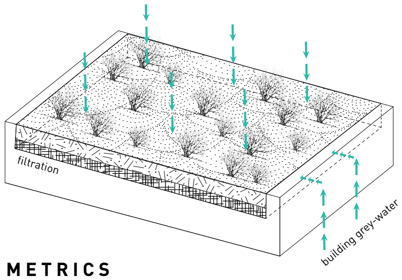
This last method is how this study proposes the integration of rain gardens into the district's stormwater management system. Rain gardens are placed along streets and rights of way as part of the sidewalk configuration. Doing so not only defines the governing body's role in the provisioning of infrastructure as the provider of said infrastructure but also brings Frischmann's second assumption in to play. Frischmann's second assumption states that "all members of a community wishing to use the resource may do so on equal terms.[24]" Anyone walking in the district can walk on the sidewalks with rain gardens, enjoy their aesthetic quality and stand under the shade of the trees. The same can be said about the sponge parks, larger rain gardens bordering the creek that can be in habited on trails and seating areas.

This study also sets the standard depth and construction of rain gardens at a 5ft. depth of planting media and aggregate to be able devote 40% of its volume to stormwater. They are at 5ft. deep because medium to tall trees are integrated into their design as part of the street scheme.

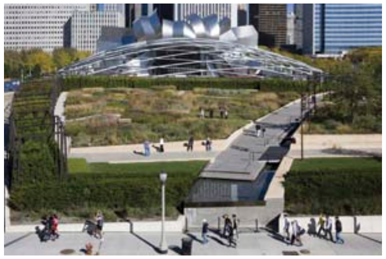


24 Frischmann, 2013, pg. 4

Green-Roofs



ASLA Headquarters, Michael Van Valkenburgh Associates

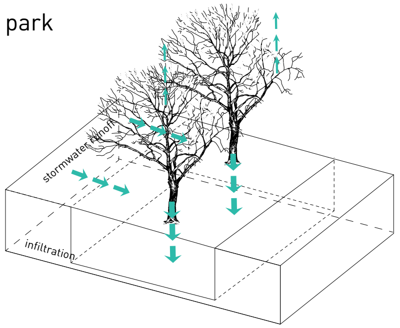


Lurie Garden, Kathryn Gustafson

METRICS

Water Capture
[1.5 ft. depth * surface area (sq. ft.) *
88 % retention capacity]
= total absorb/capture volume in $ft.^3$

park



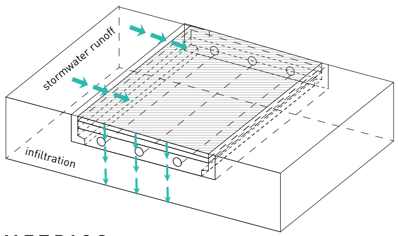
Levinson Plaza by Mikyoung Kim

Central Warf Plaza by Reed Hilderband

METRICS

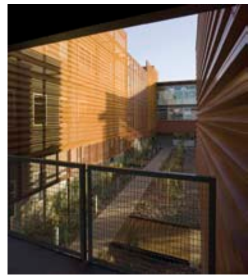
Water Capture
[2 ft. depth * surface area (sq. ft.) *
30-35 % retention capacity]
= total absorb/capture volume in $ft.^3$

permeable surfaces



METRICS

Water Capture
[1 ft. depth * surface area (sq. ft.) *
30-40 % retention capacity]
= total absorb/capture volume in ft.^{3}

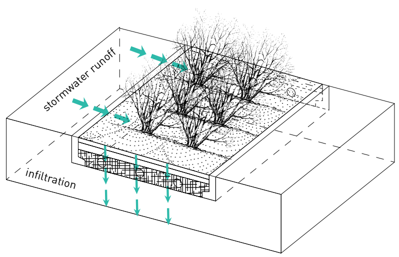


ASU Polytechnic Academic District
RSP Architects and Lake Flato Architects

1315 Peachtree Street / Perkins+Will

1315 Peachtree Street / Perkins+Will

Bio-Filtration (Rain Gardens + Sponge Parks)



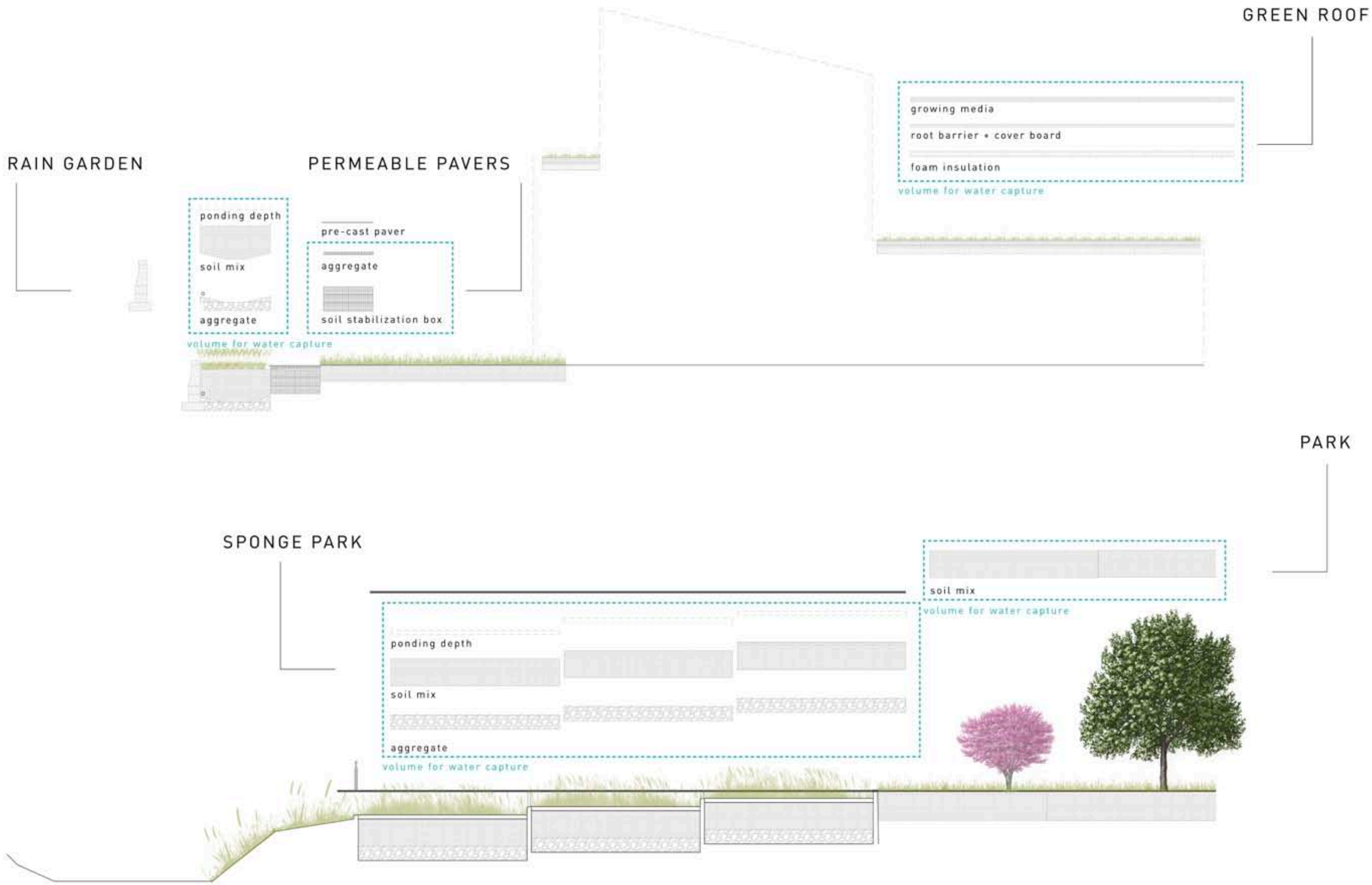
METRICS

Water Capture
[5 ft. depth * surface area (sq. ft.) *
40 % retention capacity]
= total absorb/capture volume in ft.^{3}

Rain Garden, City of Portland, Oregon.

Sponge Park by D-Land Studio

1111 Lincoln Road by Herzog & de Meuron, landscape by
Raymond Jungles


GREEN ROOF
growing media
root barrier + cover board
foam insulation
volume for water capture
RAIN GARDEN
PERMEABLE PAVERS
ponding depth
soil mix
aggregate
volume for water capture
pre-cast paver
aggregate
soil stabilization box
PARK
soil mix
volume for water capture
SPONGE PARK
ponding depth
soil mix
aggregate
volume for water capture

Center for Neighborhood Technology's The Value of Green Infrastructure: A guide for recognizing its economic, environmental and social benefits

Several cities have studied the integration of low impact development or green infrastructure into urban conditions. One such study done by the Center for Neighborhood Technology, CNT, begins to engage the question of putting a value on the multiple benefits of green infrastructure and trying to convey that value to those who are stakeholders and decision makers.

CNT defines green infrastructure as "a network of decentralized stormwater management practices, such as green roofs, trees, rain gardens and permeable pavement, that can capture and infiltrate rain where it falls, thus reducing stormwater runoff and improving the health of surrounding waterways.[25]"This definition is very similar to the University of Arkansas Community Design Center's definition of Low Impact Development which this study has adopted. Additionally, CNT's definition of green infrastructure shares similarities with the Environmental Protection Agency's definition of green infrastructure. The "EPA intends the term "green infrastructure" to generally refer to systems and practices that use or mimic natural processes to infiltrate, evapotranspirate (the return of water to the atmosphere either through evaporation or by plants), or reuse stormwater or runoff on the site where it is generated. Green infrastructure can be used at a wide range of landscape scales in place of, or in addition to, more traditional stormwater control elements to support the principles of LID.[26]"

Definitions of green infrastructure or low impact development are important to consider because they tell us what is and what is not considered part of this type of infrastructure and might begin to give indications of how such infrastructure is supposed to work.

CNT considers green roofs, tree plantings, bio-retention and bio-infiltration areas, permeable pavement and water harvesting to be part of the palette of green infrastructure. This palette informed the choices of this study of what to count as green infrastructure. One notable exception to this are tree plantings, which as a result of both design choices and the limited ability to assess the health and size of a tree in the future, trees became part of the planting palette of rain gardens (bio-infiltration areas) and as such are not counted as individual features. This also avoids double counting benefits. More on this choice will be discussed in a later section.

Each component of what CNT considers green infrastructure is then valued in one of two ways. First, what

25 Center for Neighborhood Technology, The Value of Green Infrastructure: A guide for recognizing its economic, environmental and social benefits. Chicago. 2008. Accessed October 2012 http://www.cnt.org/repository/gi-values-guide.pdf

26 United States Environmental Protection Agency, OW. "Low Impact Development (LID)." Accessed February 2013. http://water.epa.gov/polwaste/green/.

is the benefit of the feature in terms of stormwater reduction. Then other spill over benefits are considered and assessed. These benefits include reduced energy use, improved air quality, reduced atmospheric carbon dioxide and reduced heat island effect. Benefits alluded to but not assessed numerically included improved aesthetics, increased recreational opportunities, reduced noise pollution, improved community cohesion, improved habitat and cultivated public education opportunities.

The benefits that CNT does asses provide metrics in two forms. The first form comes in a unit of performance, i.e. gallons captured, kilowatts per hour reduced. The second form is an economic reading of those benefits in terms of prices. For the purposes of this study, the former metrics are used in terms of making choices about the built environment and only those pertaining to volumes of stormwater. That is to say, what determined the quantity and size of the low impact development features is their ability to temporarily capture or absorb storm water, not their ability to sequester carbon or reduce energy. This study recognizes that low impact development features have the potential to provide more than one benefit, but for the sake of analysis chose to focus on the benefit of stormwater run-off reduction on which to base spatial configurations. In a study with a different focus and set of skills, the monetary benefits and costs would be assessed and perhaps used to make a different kind of informed choice.

The Center for Neighborhood Technology used research numbers from the Chicago area to perform their study. Part of the challenge of this study was to find equivalent data for the Austin area. The models for calculating the volumes of stormwater reduction assume the construction of the features to be similar in nature with soils engineered to have higher infiltration rates than the existing conditions. The calculations apply data from peer reviewed low impact development research available at the time. The modified calculations are as follows.

<u>Green Roofs</u>

CNT Model:

[annual precipitation (inches) * GI area (SF) *

% retained] * 144 sq inches/SF * 0.00433 gal/cubic inch

= total runoff reduction (gal)

Austin Model:

[.5 ft. green roof depth * green roof surface area (sq. ft.) * 88% retention capacity[27]]

= run-off reduction capacity in ft^3.

<u>Bio-infiltration area(s)</u>

CNT Model:

[annual precipitation (inches) * (feature area (SF) +

drainage area (SF)] * % of rainfall captured] *

144 sq inches/SF * 0.00433 gal/cubic inch

= total runoff reduction (gal)

27 Simmons et al., 2008, pg. 4

Austin Model:

Rain gardens and sponge parks:

[5ft. rain garden depth * rain garden surface area (sq. ft.) * 40% retention capacity[28 29 30]]

= run-off reduction capacity in ft^3.

Park space:

[2ft. rain garden depth * rain garden surface area (sq. ft.) * 35% retention capacity[31 32 33]]

= run-off reduction capacity in ft^3.

Permeable Pavement

CNT Model:

[annual precipitation (inches) * GI area (SF) *

% retained] * 144 sq inches/SF * 0.00433 gal/cubic inch

= total runoff reduction (gal)

28 Michael Barrett, Research Center for Water Resources, Austin, conversation 2013

29 Davis, Allen P., Robert G. Traver, and William F. Hunt. "Improving Urban Stormwater Quality: Applying Fundamental Principles." Journal of Contemporary Water Research & Education 146, no. 1 (2010): 3–10. doi:10.1111/j.1936-704X.2010.00387.x.

30 United States Environmental Protection Agency, 2013

31 Michael Barrett, Research Center for Water Resources, Austin, conversation 2013

32 Davis, Allen P., Robert G. Traver, and William F. Hunt. "Improving Urban Stormwater Quality: Applying Fundamental Principles." Journal of Contemporary Water Research & Education 146, no. 1 (2010): 3–10. doi:10.1111/j.1936-704X.2010.00387.x.

33 United States Environmental Protection Agency, 2013

Austin Model:

[1ft. substrate depth * permeable paver surface area (sq. ft.) * 40% retention capacity[34 35 36]]

= run-off reduction capacity in ft^3.

One thing to note about the CNT models for calculating benefits as well as the modified Austin models is that they simply point to a number for stormwater run-off volume reduction from traditional stormwater infrastructure loads. That number needs to be measured against a standard of performance to determine whether or not the features are working well.

The Center for Neighborhood Technology's work does not indicate a particular standard for success other than more stormwater run-off reduction is better than less. The Environmental Protection Agency regulates federal projects on sites greater than 5000 sq. ft. in terms of keeping the pre-development and post-development hydrology the same. The volume of water leaving the site after construction cannot be greater or moving faster than the volume of water of pre-development conditions. Some governing bodies have minimum standards of performance when it comes to meeting stormwater capture volumes.

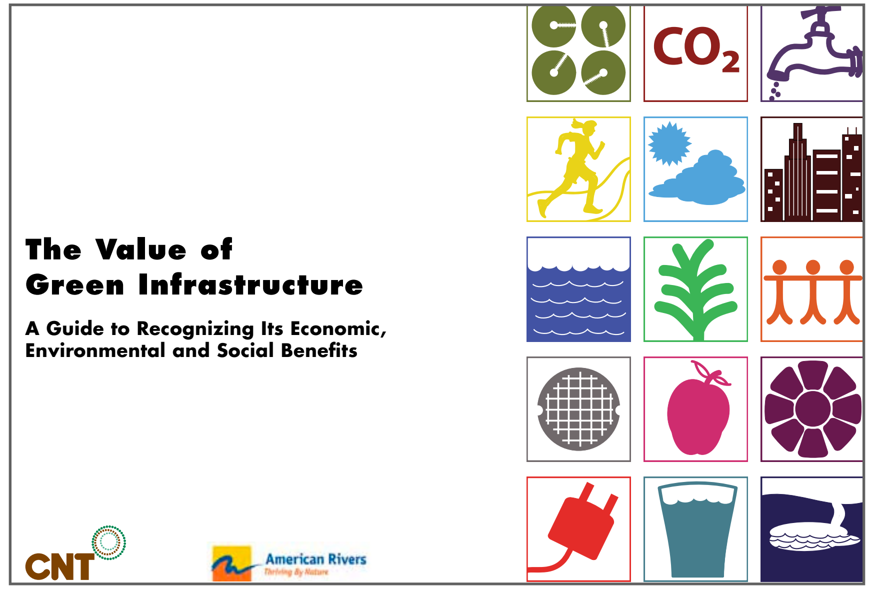
34 Michael Barrett, Research Center for Water Resources, Austin, conversation 2013

35 Davis, Allen P., Robert G. Traver, and William F. Hunt. "Improving Urban Stormwater Quality: Applying Fundamental Principles." Journal of Contemporary Water Research & Education 146, no. 1 (2010): 3–10. doi:10.1111/j.1936-704X.2010.00387.x.

36 United States Environmental Protection Agency, 2013

In the City of Austin, the minimum amount of stormwater captured on-site is dependent on the ratio of pervious cover to impervious cover. Each site is required to capture .5" + .1" for every 10% increase in impervious cover over 20%[37]. A 1000 sq. ft. site with 100% impervious cover would be required to capture .5"+ .1"(8) = 1.3" of water on site. The volume of that water is .10833 ft. multiplied by the surface area of 1000 ft^2 which equals 108.33 ft^3. The amount of stormwater captured by infrastructure on site, green or grey, must equal or surpass that volume in order for the site to be in compliance with code. This will become important when discussing the methods of study and the values which inform some of the evaluation criteria in the next section.

37 City of Austin Environmental Criteria Manual, Section 1: Water Quality Mangement, Austin, 2012



Green Infrastructure Benefits and Practices

This section, while not providing a comprehensive list of green infrastructure practices, describes the five GI practices that are the focus of this guide and examines the breadth of benefits this type of infrastructure can offer. The following matrix is an illustrative summary of how these practices can produce different combinations of benefits. Please note that these benefits accrue at varying scales according to local factors such as climate and population.

Benefit	Reduces Stormwater Runoff				Increases Available Water Supply	Increases Groundwater Recharge	Reduces Salt Use	Reduces Energy Use	Improves Air Quality	Reduces Atmospheric CO_2	Reduces Urban Heat Island	Improves Community Livability					Improves Habitat	Cultivates Public Education Opportunities
	Reduces Water Treatment Needs	Improves Water Quality	Reduces Grey Infrastructure Needs	Reduces Flooding								Improves Aesthetics	Increases Recreational Opportunity	Reduces Noise Pollution	Improves Community Cohesion	Urban Agriculture		
Practice										CO_2								
Green Roofs	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Maybe	Yes	Yes
Tree Planting	Yes	Yes	Yes	Yes	No	Maybe	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Yes
Bioretention & Infiltration	Yes	Yes	Yes	Yes	Maybe	Maybe	No	No	Yes	Yes	Yes	Yes	Yes	Maybe	Maybe	No	Yes	Yes
Permeable Pavement	Yes	Yes	Yes	Yes	No	Maybe	Yes	Maybe	Yes	Yes	Yes	No	No	Yes	No	No	No	Yes
Water Harvesting	Yes	Yes	Yes	Yes	Yes	Maybe	No	Maybe	Maybe	Maybe	No	No	No	No	No	No	No	Yes

Yes Maybe No

CNT © 2010 3

Center for Neighborhood Technology, The Value of Green Infrastructure: A guide for recognizing its economic, environmental and social benefits. Chicago. 2008. Accessed October 2012 http://www.cnt.org/repository/gi-values-guide.pdf

Study Methods: Using Carl Steinitz's A Framework for GeoDesign to make informed decisions about potential changes to a site.

Now that a scope of choices for low impact development features has been established, the designer needs a framework to work through those choices and have the ability to make an informed decision about the configurations of space that are possible. This study will use Carl Steinitz's framework for GeoDesign to compare three change scenarios for a district in Austin on the shores of Lady Bird Lake to existing conditions. The differences of the sites The Steinitz Framework asks 6 questions about the landscape and gives us 6 models to answer those questions[38].

The first question: "how should the study area be described?"

The second question: "how does the study area operate?"

The third question: "is the current study area working well?"

The fourth question: "how might the study area be altered?"

The fifth question: "what differences might the changes cause?"

The sixth question: "how should the study area be changed?"

38 Steinitz, Carl. A Framework for Geodesign: Changing Geography by Design. ESRI Press, 2012, pg. 25-34.

The six questions can be answered with the six models the Steinitz framework provides.

The REPRESENTATION model answers the first question: "how should the study area be described?" This model begins with data available to describe the existing conditions on site. The data looks at the physical, ecological and social specifics of the site. How many buildings are on site? What is their square footage. What is the square acreage of surface parking lot? What types of vegetation are found? The data found in the representation model are things one can count and identify.

The PROCESS model answers the second question: "how does the study area operate?" This model looks at the pieces of the representation model and studies how they are linked to each other in terms of function and structure. For the purpose of this study, the process model considered the function and structure of the hydrologic cycle.

The EVALUATION model answers the third question "is the current study area working well?" For this model it is important to consider the values of the stakeholders and decision makers. Additionally there might be standards set in place which determine the success or failure of a study area. For example, in Austin, the City mandates a particular level of success in terms of stormwater capture. A site must meet a required volume of stormwater capture in order to be considered successful or preforming well. Identifying areas that are preforming well help the designer understand what areas might need more intervention than others. Palazzo and Steiner's precautionary principle comes to mind –first do no harm. If an area is already working well, the designer should make sure it at minimum it keeps that level of success.

The CHANGE model answers the fourth question "how might the study area be altered?" This model investigates changes that can be made to the existing conditions. Like the representation model, the change model looks at new data that can be used to represent the site. What has changed with respect to the pieces the study started out with?

The IMPACT model answers the fifth question "what differences might the changes cause?" What does the process model look like with the new conditions coming from the alterations of the change model?

The DECISION model answers the sixth question "how should the study area be changed?" The decision model, like the evaluation model, is dependent on the values of the stakeholders and decision-makers at which form part of the investigation. What is the threshold that gives the designer the go-ahead or not?

As part of the design process, the framework is run-through three times. The first time reveals a general sense of what is happening with the site and what decisions might be considered. The first run through is the designer studying the site and asking: "what is there?"; "what can I observe about how it works?"; "is it working well?"; "what can I change?"; "will that make a difference?"; "what decisions can I make?" During this run-through, the designer gets a general sense of what the challenges and opportunities on site might be.

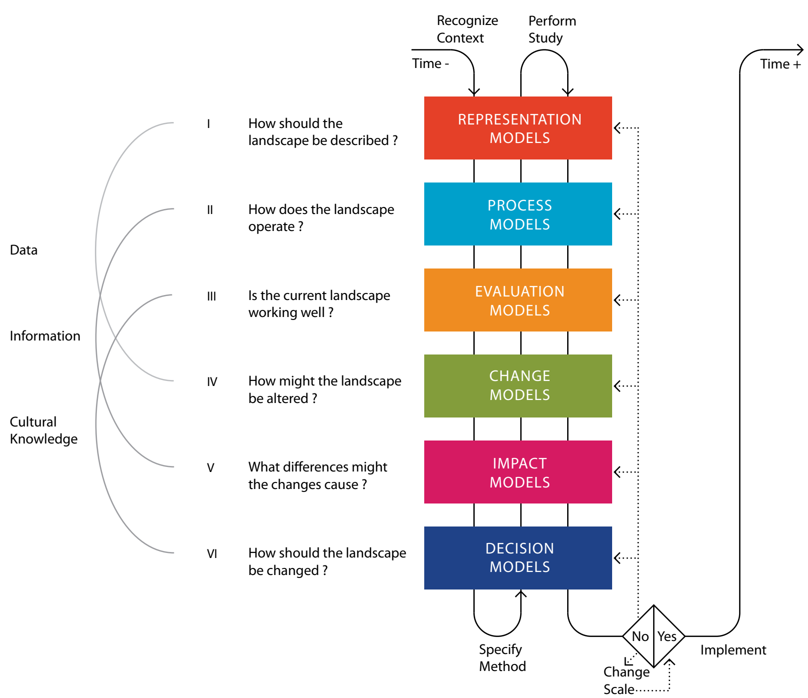
During the second run-through of the framework, the designer asks the questions in the other direction, with the intent of teasing out and testing the design study method. This pass is the most important pass as it is what makes the framework a decision driven framework rather than a data driven framework[39]. Starting at the decision model the designer might ask, what kinds of decisions should be made? Who will be making them? Are there existing standards that should be met based on existing values or regulations? With this in mind, the designer makes appropriate changes to the impact model in order to inform the decision model. Changes to the impact model might include a shift in scales in order to better understand a system or the transformation of a system to be more complex with more pieces. The data presented in the change model is altered to inform the impact model. The same applies to the evaluation, process and representation models. The additional data to make the models work is added or created.

The third pass of the Steinitz framework is the design study method applied to the project. This will result in a yes, no or maybe decision[40]. If the decision is no, the models are revisited

39 Steinitz, 2012, pg. 28
40 Steinitz, 2012, pg. 31

and the sequence begins again. If the answer is maybe, the size and scale of the study might shift before the models are revisited and the sequence begins again.

The intent of this study is not to get to a yes, no or maybe but rather compare what three difference scenarios might result in using the framework as an analytical tool.



Framework for Landscape Planning
Carl Steinitz, Landscape Journal 9:2 (1990)

FUENTES

contact surface
-permeable surface
-impermeable surface

(nouns)

- buildings — studio I SDAT I Imagine Austin
- parking spaces — studio I SDAT I Imagine Austin
- vegetated space — studio I SDAT I Imagine Austin I CNT
- LID BMPS — studio I SDAT I Imagine Austin I CNT I Lit Reviews

hydrology
ability to absorb/capture run-off
-required water quality capture volume
-25 yr, 50 yr, 100 yr storm event volume
(verbs)

- flow over ground — studio I lit review
- no flow (capture) — studio I lit review
- flow into ground — studio I lit review

required wqcv
-meets or does not meet required capture volume

(adjectives/verbs)

- meets required wqcv — studio I SDAT I Imagine Austin
- 25-yr 24-hr storm capture — studio
- 50-yr 24-hr storm capture — studio
- 100-yr 24-hr storm capture — studio

L I D BMPs
-green roofs, rain gardens, parks, sponge parks, cisterns
(+/-nouns)

- buildings — studio I SDAT I Imagine Austin
- parking spaces — studio I SDAT I Imagine Austin
- vegetated space — studio I SDAT I Imagine Austin I CNT
- LID BMPS — studio I SDAT I Imagine Austin I CNT I Lit Reviews

hydrology
ability to absorb/capture run-off
-required water quality capture volume
-25 yr, 50 yr, 100 yr storm event volume
(verbs)

- flow over ground — studio I lit review
- no flow (capture) — studio I lit review
- flow into ground — studio I lit review

individual vol / collective vol
-meets or does not meet required capture volume, 25 yr, 50 yr, 100 yr storm event volume

- meets required wqcv — studio I SDAT I Imagine Austin
- 25-yr 24-hr storm capture — studio
- 50-yr 24-hr storm capture — studio
- 100-yr 24-hr storm capture — studio

	Fuentes	CNT	Studio	SDAT	Imagine Austin	Lit-Review
REPRESENTATION	**contact surface** -permeable surface -impermeable surface (nouns)	*(representation)* *-current stormwater infrastructure*	**existing conditions** -building typologies -pathways -open space -zoning -views	*(representation)* *-current models of development*	**who we are today** -historic context -population -housing and neighborhoods -landuse -transportation -economy	**experiment conditions** -materials -dimensions -location -source
PROCESS	**hydrology** ability to absorb/capture run-off -required water quality capture volume -25 yr, 50 yr, 100 yr storm event volume (verbs)	*(process)* *-models for stormwater calculation*	**objectives** -connect to lake front -connect to neighborhoods -encourage redevelopment	*(process)* *perceptions of mobility,sustainability ,livability, economic viability*	*(process)* *-measuring of current "building blocks for success"*	**results** -coefficients for infiltration
EVALUATION	**required wqcv** -meets or does not meet required capture volume (adjectives/verbs)	*(evaluation)* *-success is found in reduction of stormwater quality and quantity volumes going into*	**quality of life** -liveability -walkability -mobility -density -transparency -intimacy	**community values** -nature in the city -culture -recreation -weirdness -community -creatitivty -diversity	*(evaluation)* *-identification of areas lacking or low in "building blocks" as areas for potential intervention*	
CHANGE	**L I D BMPs** -green roofs, rain gardens, parks, sponge parks, cisterns (+/-nouns)	**green infrastructure** -green roofs -tree plantings -bio-retention -permeable pavement	**existing conditions** -building typologies -pathways -open space -zoning	**Green Infrastructure** -stormwater streetscapes -water receiving landscapes -active recreation -wide riparian buffers	**vision for complete community** -liveability -mobility and interconnectedness -values -prosperity -education -creativity -nature and sustainability	**applied experiment conditions** -materials -dimensions -location -construction
IMPACT	**hydrology** ability to absorb/capture run-off -required water quality capture volume -25 yr, 50 yr, 100 yr storm event volume (verbs)	**ecosystem services** -reduce stormwater run-off -reduce energy use -reduce criteria pollutants	**objectives** -connect to lake front -connect to neighborhoods -encourage redevelopment	*(impact)* *-ranking of area according to indicators of mobility, livability,*	**conservation and environment** -protect Austin's watersheds, waterways and supply -reduce impact of development in sensitive areas -improve regional planning and coordination	**results** -coefficients for infiltration
DECISION	**individual vol / collective vol** -meets or does not meet required capture volume, 25 yr, 50 yr, 100 yr storm event volume (adjectives/verbs)	**valuation of benefit** - avoided stormwater treatment costs -avoided energy use	**quality of life** -liveability -walkability -mobility -density -transparency -intimacy	**guiding principles** -water as resource -development	**nature and sustainability** -sustainable, compact and walkable development -resource conservation/ efficiency -extensive green infrastructure	

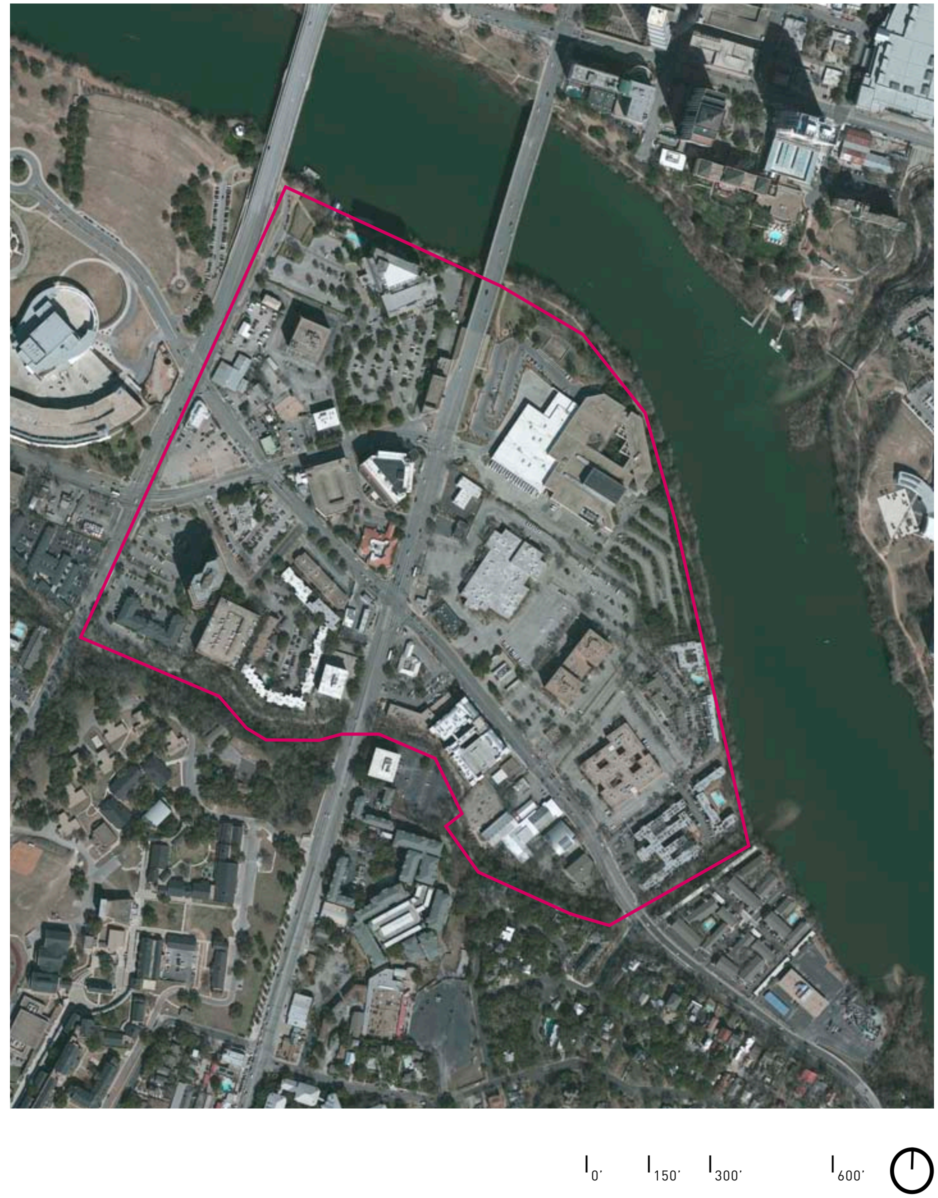
framework references

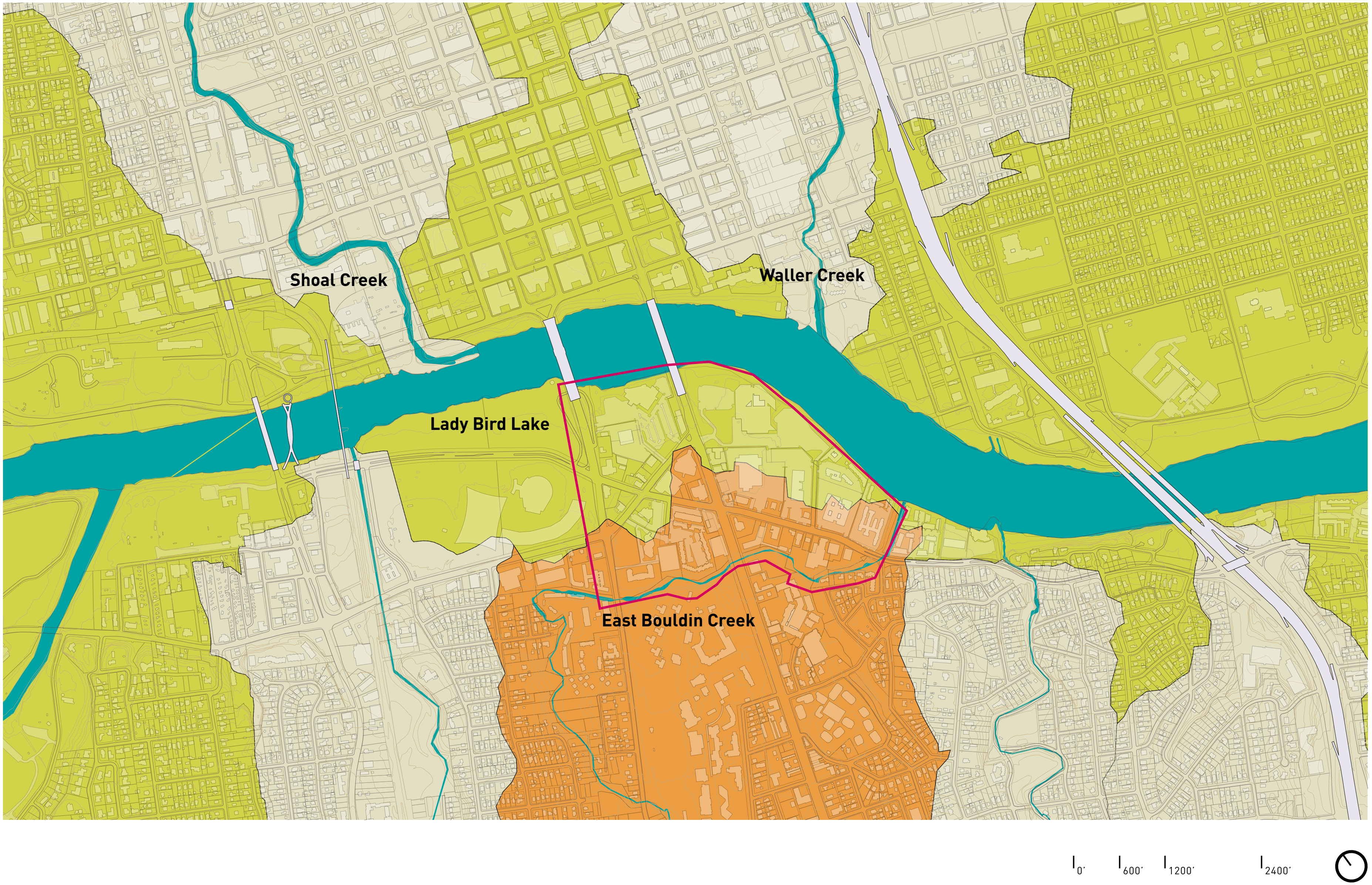
Study Site: South Shore Central in Austin, Texas

The site of the study to which the Steinitz framework will be applied is located in Austin just south of Lady Bird Lake, bounded by East Bouldin Creek and South First Street. Directly south of the creek is an escarpment where the topography on the other side of the creek rises about 24 feet. The site straddles the Town Lake and East Bouldin Creek watersheds.

I worked in collaboration with Dean Almy's urban design studio, The Texas Urban Futures Lab, which also studied models of urban development on this site. The spatial configurations analyzed come from the Texas Urban Futures Lab's work. The studio studied issues related to density, mobility, transportation planning, zoning restrictions as well as green infrastructure. This study presents the parts of the studio's work that relate to stormwater management and low impact development.

Because the studio set the incorporation of green infrastructure into the design and identity of the district as a priority, the public spaces within the district often serve dual purpose, providing areas of passive recreation as well as stormwater management. More about the choices made by the Texas Urban Futures Lab will be discussed as each scenario is presented in the next sections.





watershed map

site context

Beyond this study and studio, the City of Austin acknowledges this site as the next critical piece of urban development after the Waller Creek District. In November of 2011, the City of Austin wrote a grant proposal to the American Institute of Architects, requesting assistance from the AIA's Sustainable Development Assessment Team in hosting a series of public participation workshops and design charettes[41]. The work and ideas were presented in October of last year.

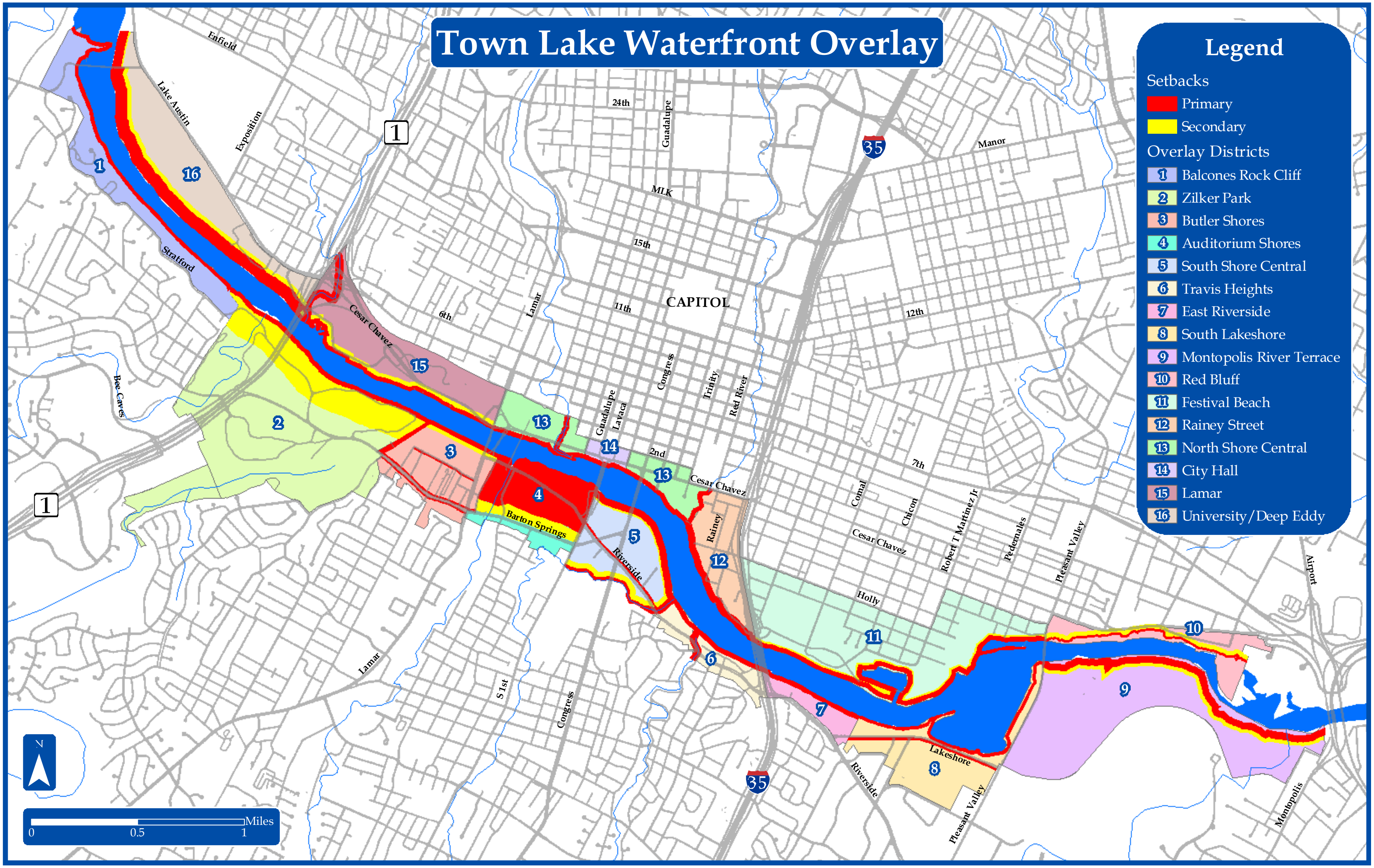
The SDAT Report contains guiding principles that played a key role in informing the values of the study, particularly in terms of the evaluation and impact models. The SDAT report plays a key role because of its engagement with stakeholders at both the city government level and the citizen level[42].

The SDAT report is one of the multiple efforts on behalf of the city to study this area. Other studies include the 1985 Town Lake Corridor Study, the 1986 Waterfront Overlay, the 2008 Waterfront Task Force Report. The 1986 Waterfront Overlay holds significant political presence with stakeholders even after its 1999 re-write. The 1986 overlay sets up the 16 sub-districts around Town Lake (the Colorado River) and defines development regulations.

41 American Institute of Architects, Sustainable Development Assessment Team Report, Austin, November 2012.

42 AIA SDAT Report, 2012, pg. 6

AIA Communities by Design
ENVISION. CREATE. SUSTAIN.



Waterfont Overlay Commision Districts Map http://www.austintexas.gov//sites/default/files/files/Boards_and_Commissions/Waterfront/waterfront-overlay-districts-map.pdf

These development regulations include height and impervious cover limitations. The work of the Texas Urban Futures Lab tests the development regulations of the 1986 overlay and begins to push against them, particularly in terms of height. Public park space and accessible green roofs are some of the trade-offs for adding height.

The SDAT report presents three critical guiding principles as part of their strategy for developing recommendations for Austin[43]. The first of those critical guiding principles lists the consideration of "Water as a Resource." Recommendations based on that principle state that "All landscapes should be functional." Examples of functional landscapes provided include landscapes that "catch, convey, clean and distribute water [which] include rain gardens, multi-functional retention ponds, swales in urban streetscapes, and stormwater planters." The low impact development features proposed by the Texas Urban Futures Lab are keeping with the spirit of these recommendations.

Other recommendations for green infrastructure from the SDAT report include[44]

-establishing Lady Bird Lake and its waterfront as a culturally valuable and performative

landscape as well as the heart of Austin

-Improve human health and well-being through restorative effects of exposure to natural systems and through opportunities for active recreation.

-Establish urban agriculture to provide connection to the land, an understanding of natural systems, and access to healthy eating

-Protect all water sources

-Build active water management systems such as greywater and blackwater systems at the site scale and reclaimed water and living systems at the district scale

-Preserve and restore ecological function through redevelopment

-Establish wide riparian buffers to support healthy habitat, and promote biodiversity and soil conservation

-Maintain water balance by considering the flows that enter and leave the side and manage these flows to work with natural systems

-Improve soil health by reducing soil compaction and capping, decreasing run-off to lessen erosion and pollution flows, and promoting nutrient cycling through maximized planting.

-Design landscapes as "water receiving landscapes" to encourage water management and cleansing functionality

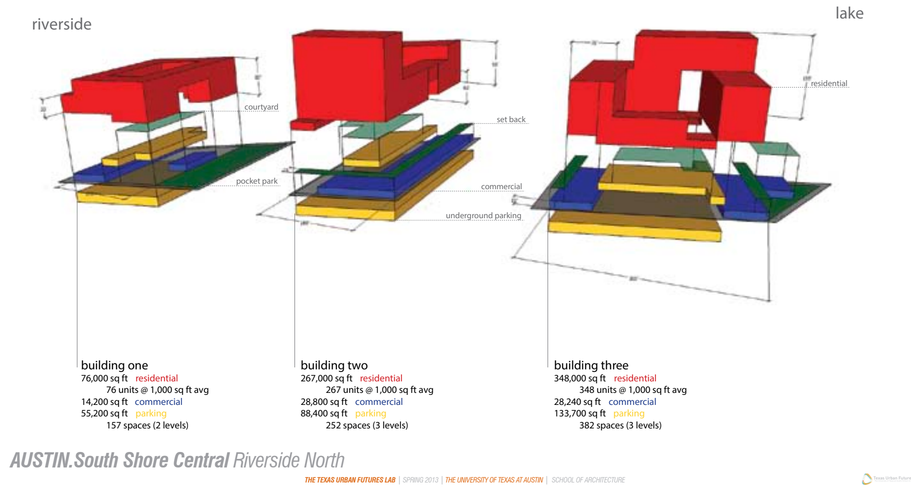
Many of these recommendations manifest themselves in the change scenarios proposed by the Texas Urban Futures Lab through their choices in low impact development features. For example, the land at the edge of the lake remains as dedicated public park space with sponge park outfalls that receive the overflow from the rain gardens along the streets and right of

43 AIA SDAT Report, 2012, pg. 22

44 AIA SDAT Report, 2012, pg. 35

ways. East Bouldin Creek is protected by what is referred to as a sponge park which is essentially a large, tiered rain garden that receives water over flow from the rain gardens and helps re-vegetate the banks of the creek which are currently banked with concrete for much of the length of the site. The sponge park has a light weight bridge and grated decking supported by piers to allow visitors to inhabit pieces of the sponge park without damage to vegetation or compaction of soils. It is expected that these sponge parks and rain gardens will become areas for wildlife such as bees, butterflies and birds. The seating and access will provide visitors with an opportunity to observe and learn more about these creatures.

Currently, the site is linked to a special project. Several departments in the city are working with a HUD grant to develop an analytic Geographic Information Systems (GIS) based model to assess the economic and demographic impacts of development scenarios on site[45]. This project is known as the Sustainable Places Project. Members of the departments working on the Sustainable Places Project worked in collaboration with the Texas Urban Futures lab, specifically looking at building prototypes proposed by the studio, in conjunction with projected returns on investments based on development mixes and expected rents. This type of information about building typologies and expected returns on investments, in addition to the spatial needs for stormwater capture, influenced the configurations of urban space developed by the Texas Urban Futures Lab.



Building Typology Study by Texas Urban Futures Lab

45 “Lady Bird Lake Waterfront Special Project: South Shore Central.” Accessed March 23, 2013. http://www.austintexas.gov/department/lady-bird-lake-waterfront-special-project.

The Representation Model: Existing Conditions

The existing conditions on site consist largely of building and surface parking lot coverage. Approximately 83% of the site is covered by some sort of impervious surface. The ratio of surface parking lot square footage to building square footage is a little over 2:1. One parcel, the City of Austin's One Texas Center, has a devoted rain garden to capture water from the parking lot. This is the only evidence of a feature such as those described by the low impact development literature. Currently, the site does not have dedicated public park land. According to the parcel ownership map, the land directly adjacent to the river belongs to the groups that own the Hyatt Hotel (parcel 1) and the Austin American Statesman (parcel 2). Currently there is enough room for the Lady Bird Lake Hike and Bike Trail to go through until it reaches the edge of the Austin American Statesman property. The property with private condos on the lake does not currently have a public trail on its property. The hike and bike trail must direct back through the Statesman property, cross the crocket property (parcel 19) and continue on Riverside Dr. This breaks the continuity of the trail along the lake and disorients those who are not familiar with the diversion.

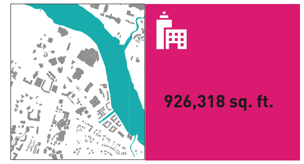
As part of the study of existing conditions, the trees on site were surveyed and cataloged according to species and diameter at breast height. The overall composition of species is distributed largely amongst four species: Live Oaks (*Quercus fusiformis*), Southern Red Oaks (*Quercus falcata*), Pecans (*Carya illinoinensis*) and Cedar Elms (Ulmus crassifolia) with the exception of the lake front which is largely Bald Cypress (*Taxodium distichum*). Using the National Tree Benefit Calculator[46], the values of the trees were assessed in terms of gallons of stormwater intercepted, energy savings in terms of kilowatt hours saved, and carbon sequestered per year by the pound. The Tree Benefit Calculator also assess the value of the trees in dollar figures associated with the benefits.

Although this data reflects a similar approach to quantifying green infrastructure benefits as the Center for Neighborhood Technology's study, it did not make it into this study's final representation model for two reasons. The first reason is that the data is based on value per year and as will be explained, the data that feeds into the process model is based on a per-storm event approach. The second reason is that models for projecting tree growth to the accuracy of a field survey are not able to capture the nuances of the growing conditions of the trees. That is to say, there is no local research that shows the growth model for a tree growing in a rain garden irrigated with grey water in comparison to one growing by a creek or a lake or one that is planted in a courtyard. As will be discussed in the explanation of future scenarios, the Texas Urban Futures Lab did use the existing conditions tree survey to locate heritage trees to protect.

46 Casey Trees and Davey Tree Expert Co., National Tree Benefit Calculator, http://www.treebenefits.com/calculator/

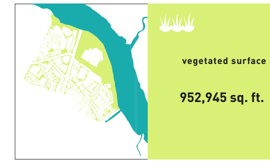
existing conditions

0' 100' 200' 400'

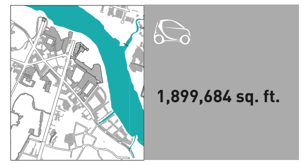


buildings

parks



vegetated surface



surface parking lots

trees

sidewalk cisterns

rain gardens

green roofs

sponge parks

grey stormwater management

topography

representation

The Process Model: Existing Conditions

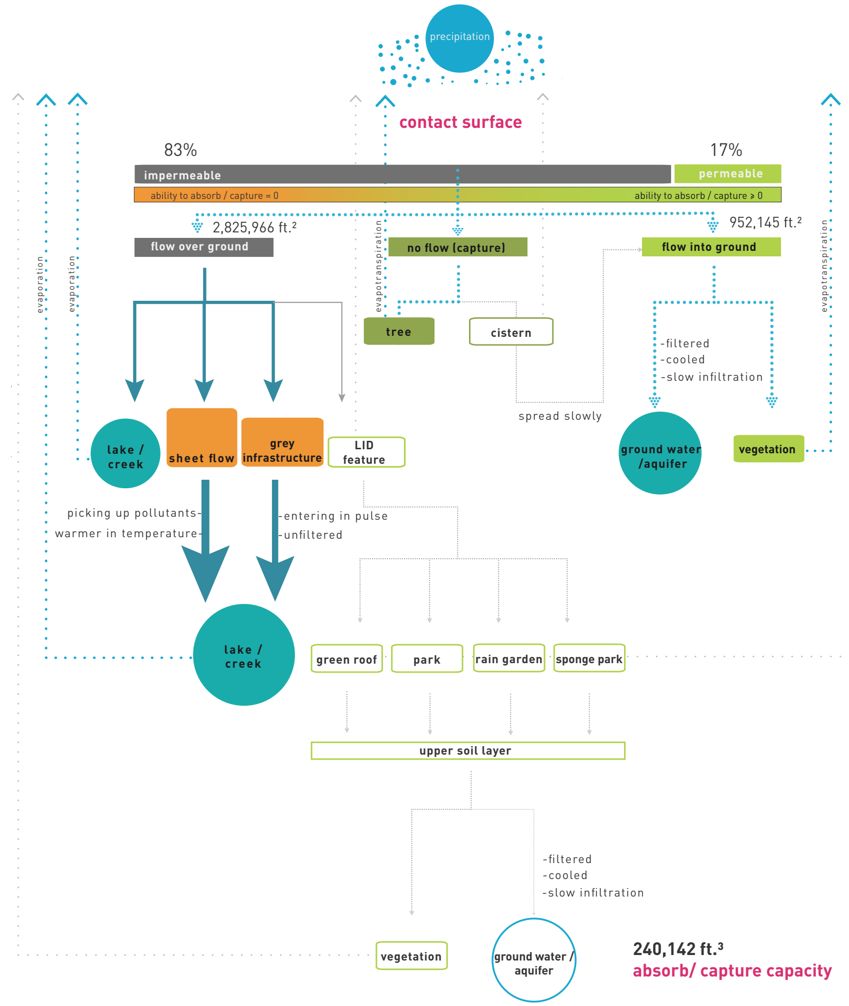
The process models are an abstraction of the sites hydrology and study the way water flows on site during rain events. For the sake of analysis, the data from the representation model is categorized into impermeable and permeable surfaces. Precipitation can either flow over the ground, flow into the ground or be captured resulting in no flow. Flow over the ground either directly into a body of water, as sheet flow or from being piped by conventional stormwater infrastructure. If water is being captured, it is being intercepted by a tree or flowing into a cistern. Water flow that is going into the ground is either going into ground water recharge or being taken up by vegetation and evaportranspirated. Another option for water flowing over the ground is its conveyance into a low impact development feature such as a green roof, park, rain garden or sponge park.

The amounts of required water capture required for each individual parcel is calculated by using the ratio of impermeable surface to permeable surface. For this study, impermeable surfaces are counted by the square footage of buildings and surface parking lots. Impermeable surface is the remaining parcel space not covered over by one of the two types of cover mentioned. For the purposes of this study, vegetated area is considered area for stormwater infiltration.

Calculations for the process model can be found as an appendix item. (Appendix item 1)

existing conditions

0' 100' 200' 400'



The Evaluation Model: Existing Conditions

Each individual is assessed on whether or not it is able to capture the required stormwater on site as required by the city of Austin. In addition to the City of Austin's standard of performance, this study and the Texas Urban Futures Lab is interested in the entire district's ability to absorb the stormwater volume of the 24-hour 25 year, 50 year, and 100 year storm events. This capture capacity is studied at the district level because as mentioned, the city regulates a minimum amount of water at the individual site level but we are interested in thinking about low impact development as viable infrastructure at a larger scale.

The evaluation model indicates that most of the parcels are not preforming to City of Austin standards and the district is not able to meet any of the stormwater capture volumes for the three rain events. The individual parcel's inability to meet stormwater requirements can be attributed to two reasons. The first reason a parcel might not be meeting requirements is because it may have been developed before regulations were put in place. This would exempt it from having to follow any performance standards until the owner decided to re-develop the land. Any additions must be brought up to code standards. The second reason why a parcel might not be performing up to city standards is because the owner and the city might have reached a fee-in-lieu agreement where the owner or developer of the land would pay a certain amount of money into a fund which the city would use for stormwater management. The problem with this set up is that on this particular site, for many parcels, if the water is not managed on site it is going directly into the Lady Bird Lake or East Bouldin Creek, which essentially means all of that untreated stormwater is going into the city's drinking water supply.

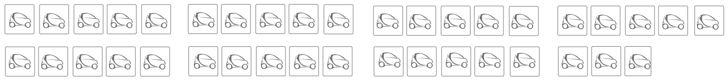
The amount of stormwater run-off generated by the 25 year storm event is equal to 216,524 $ft.^3$ According to the NPR, the average Austinite uses 13,368 $ft.^3$ of water per year[47]. The amount of water lost to stormwater run-off is equal to the amount of water 150 Austinites would use in a year. The 50 year storm event results in a loss of the amount of water 161 Austinites would use in a year, and the 100 year storm event is equivalent to losing the amount of water 222 Austinites would lose in year.

47 "The Top 25 Water Users in Austin." StateImpact Texas. Accessed May 2, 2013. http://stateimpact.npr.org/texas/2011/10/27/the-top-25-water-hogs-in-austin/.

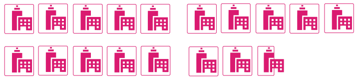
existing conditions

0' 100' 200' 400'

= 50,000 sq. ft. parking lot

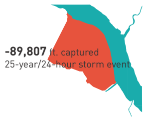


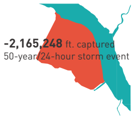
= 50,000 sq. ft. building

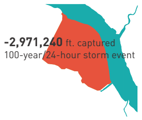


= 50,000 sq. ft. vegetation

= 50 trees







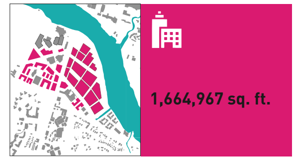
South Shore Central Alternative 1

The Change Model

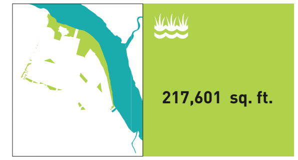
The change model for scenario 1 sees the greatest change in terms of adding approximately 55% more building space and taking away approximately 75% of the surface parking lot area. This scenario also introduces a configuration of low impact development features that include parks, rain gardens, green roofs and sponge parks. In this scenario, the largest amount of low impact development square footage comes in the form of green roofs, with almost 300,000 sq. ft. of building roof designated as green roof space. The ratio of impermeable surface to permeable surface has gone down from 80% percent impermeable to 73% impermeable and 27 % permeable.

south shore central alternative 1

0' 100' 200' 400'

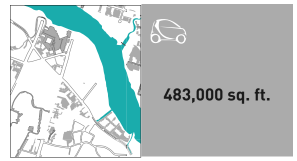


buildings

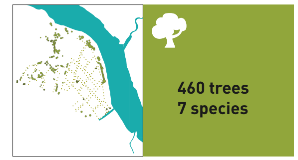


parks

vegetated surface

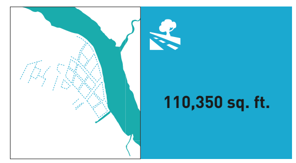


surface parking lots



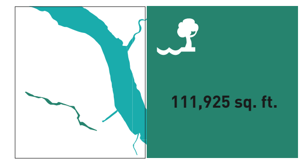
trees

sidewalk cisterns



rain gardens

green roofs



sponge parks

grey stormwater management

topography

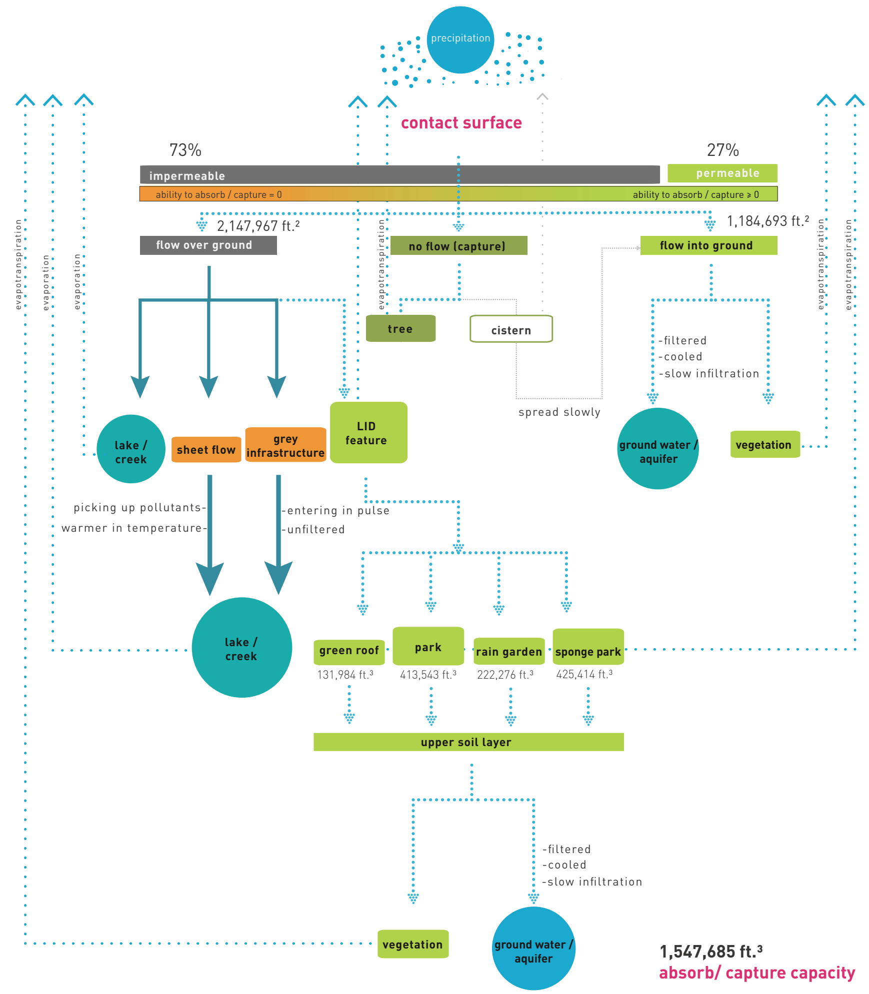
The Impact Model

The new ratios of impermeable to permeable cover and the addition of low impact development features allow for more water to be captured on site, meaning more individual parcels can meet their stormwater capture requirements. Additionally, more water is being directed away from sheet flow and grey infrastructure flow into low impact development features with the capability of cooling and cleaning the water that goes into them. Parks and Sponge parks are accounting for more than half of the district's absorb/capture capacity. This was calcuated by taking new measurements of each parcel's impermeable to permeable cover ratio and calculating the new values for required stormwater capture. The volume of required stormwater capture was subtracted from the estimated water capture capacity of the parcel's low impact development features such as green roofs or park space if the parcel had any. The district's ability to capture water was calculted by summing the amount of stormwater loss to run-off (not captured by an LID feature) and subrtacting it from the capacity for stormwater capture of the collective spaces.

Calculations for the impact model can be found as an appendix item. (Appendix item 2)

south shore central alternative 1

0' 100' 200' 400'

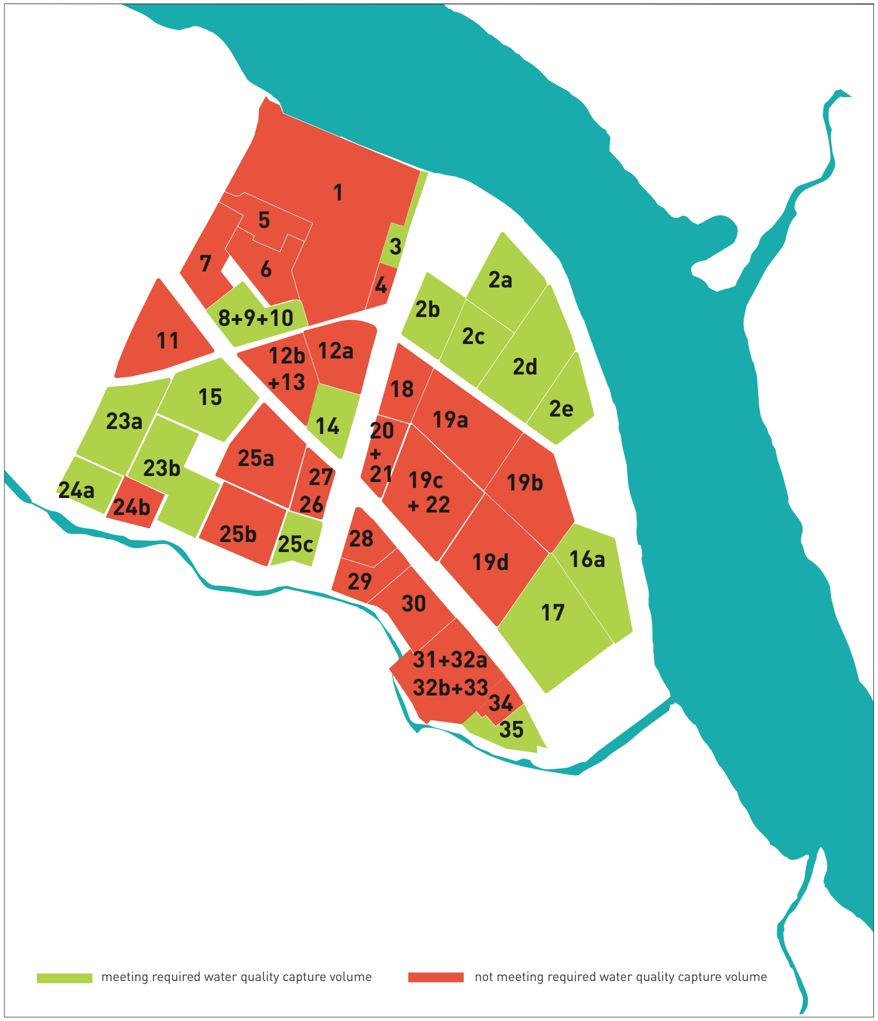


impact

The Decision Model

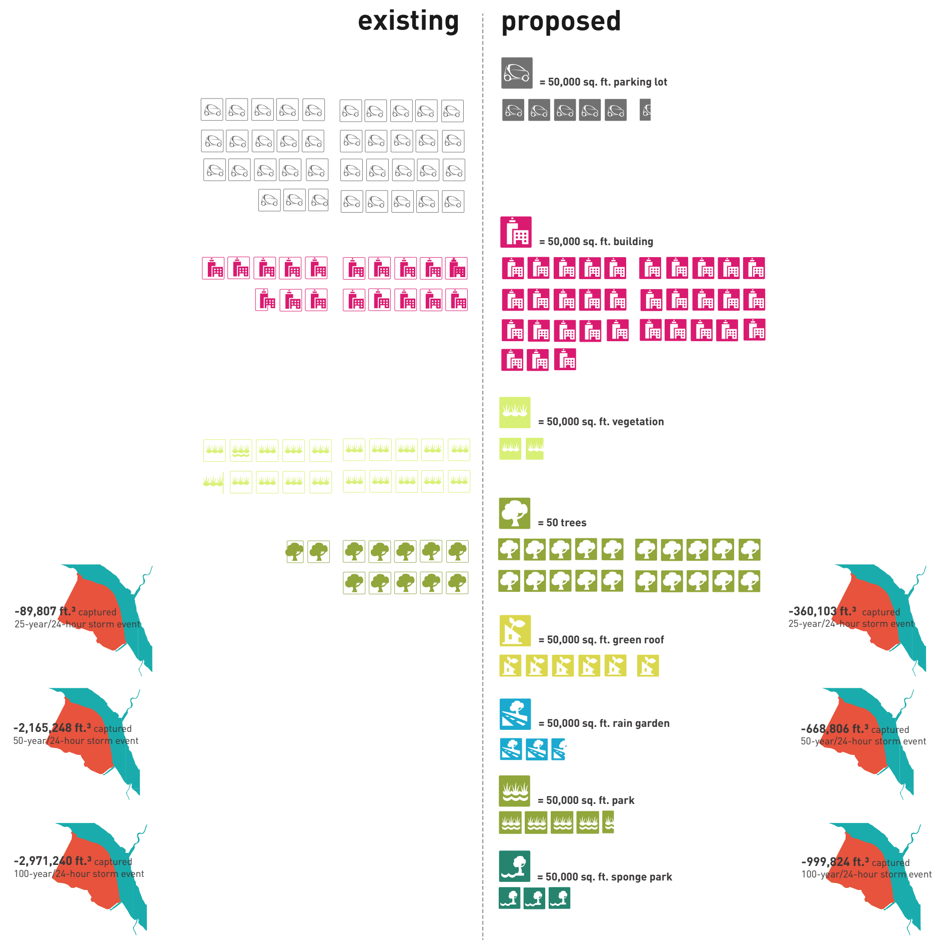
The decision model, like the evaluation model indicates which parcels are performing relative to the City of Austin's standards. In this configuration, parcels have been subdivided or combined. Ownership has not changed, so they are still comparable to the existing models but the new configuration of parcels means that owners may have to worry about the performance of more than one site. In South Shore Central Scenario 1, more parcels are performing at the individual ownership level than they were in the existing condions.

While more individual parcels are performing at city code standards, the district is still not able to capture any of the three storm events. However, the amount of water lost in run-off has significantly been reduced. The amount of water lost in the 25 year storm event is only 17% percent of what is lost in the 25 year storm event with existing conditions. That means that instead of losing the amount of water 150 people use in a year, the amount lost in scenario 1 is equal to the yearly water consumption of 26 people. In the 50 year storm event the amount of water loss is equal to 50 people which is a 70% reduction from existing conditions and the 100 year storm event sees water loss reduced by 67% which is equal to the water used by 74 people.



south shore central alternative 1

0' 100' 200' 400'



decision ?

South Shore Central Alternative 2

The Change Model:

South Shore Central Scenario 2 increases the amount of building square footage by about 60% and decreases the amount of surface parking by about 70% from the existing conditions. Much of that newly permeable space is dedicated as park space. Additionally, the amount of green roof square footage has increased to about 365,000 sq. ft. The overall ratio of the district's impermeable to permeable space is now at 70% impermeable to 30% permeable. It is also important to note that in this alternative, the existing property lines are respected. The Texas Urban Futures Lab was urged by the city to not engage in land swap negotiations between owners. However, the studio did merge some properties that they considered otherwise unlikely to develop at a smaller parcel size.

south shore central alternative 2

The Impact Model:

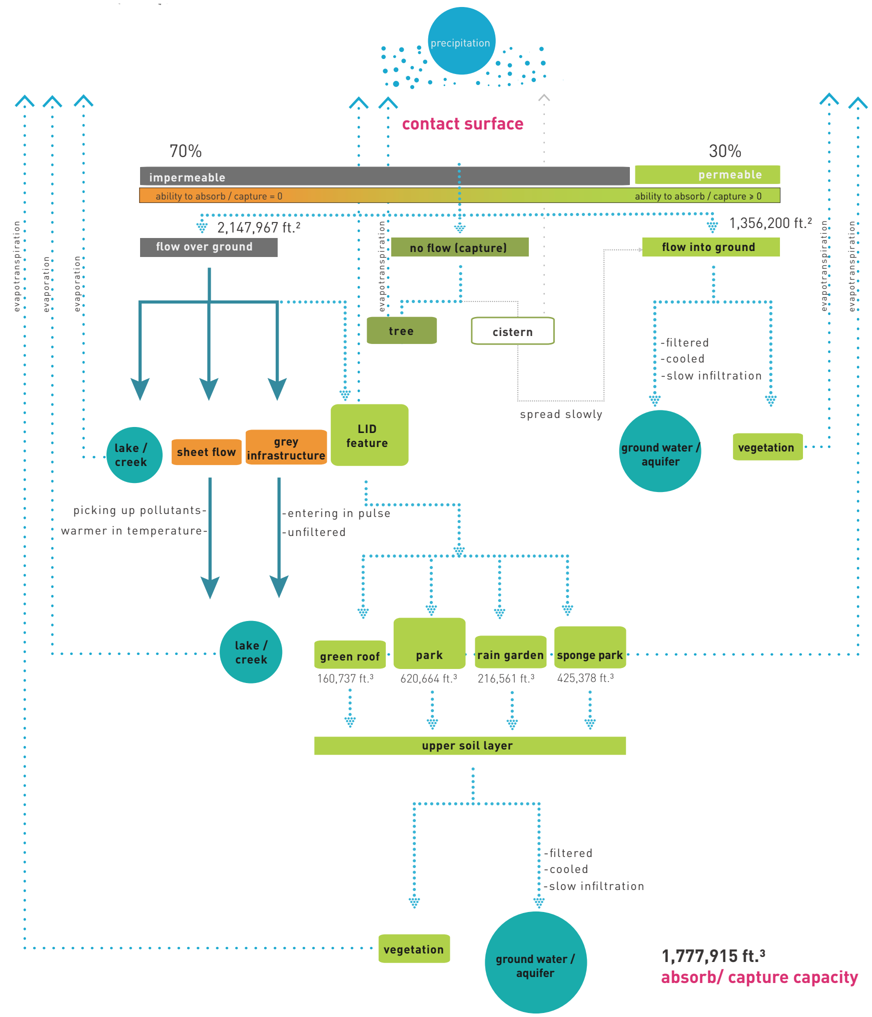
The increases in low impact development features, particularly in terms of park space mean, that even more water is being directed away from traditional grey infrastructure and has a chance to be cooled, filtered and infiltrated into groundwater sources. Park space alone is capturing about 620,000 $ft.^3$ of stormwater run-off. In comparison to the existing process model, this impact model shows less water being piped into the bodies of water and more areas where water is given time to infiltrate. This was calcuated by taking new measurements of each parcel's impermeable to permeable cover ratio and calculating the new values for required stormwater capture. The volume of required stormwater capture was subtracted from the estimated water capture capacity of the parcel's low impact development features such as green roofs or park space if the parcel had any. The district's ability to capture water was calculted by summing the amount of stormwater loss to run-off (not captured by an LID feature) and subrtacting it from the capacity for stormwater capture of the collective spaces.

Calculations for the impact model can be found as an appendix item.

(Appendix item 3)

south shore central alternative 2

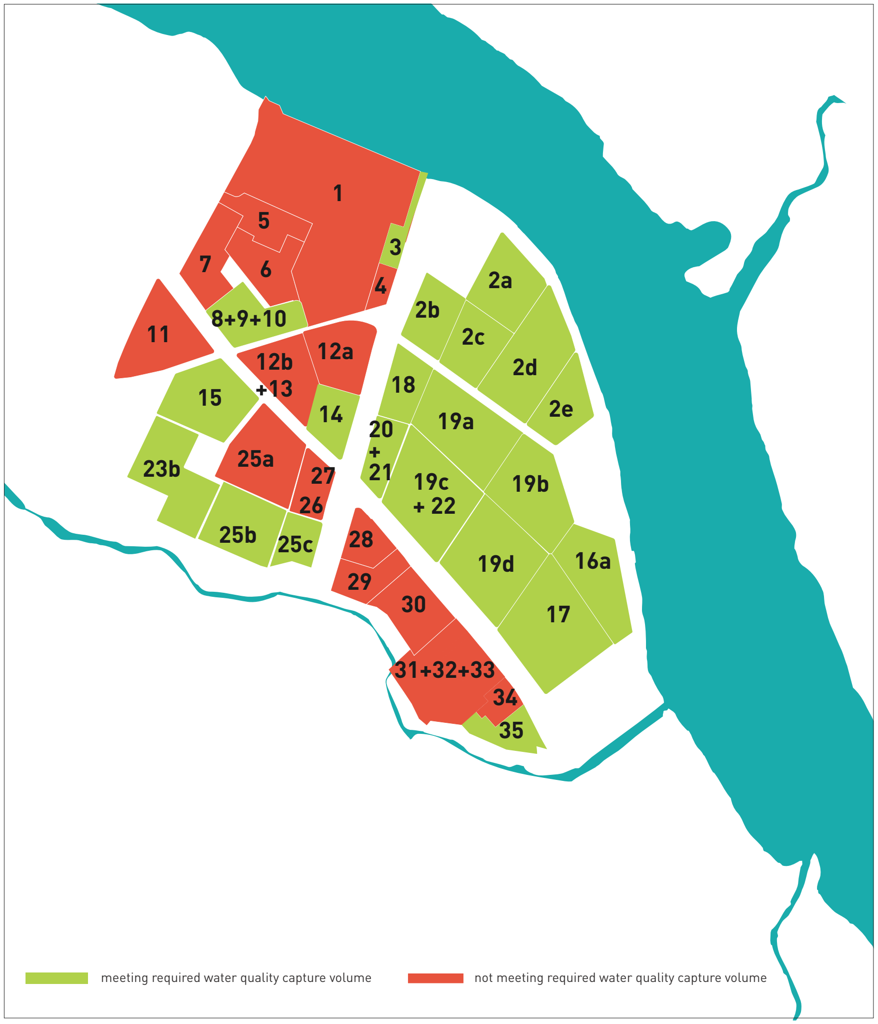
0' 100' 200' 400'



The Decision Model:

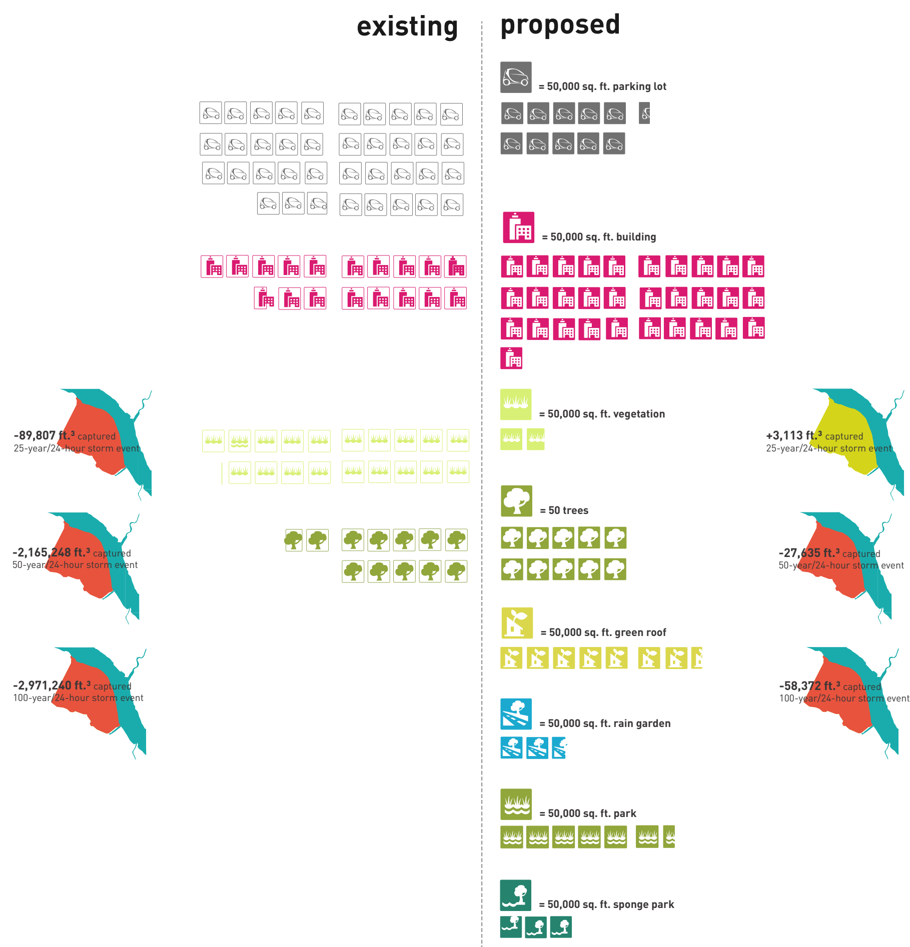
In terms of individual parcel performance, more parcels are able to meet City of Austin required stormwater capture volume standards. One thing to make not of in this map is that at this point in time, some of the parcels remain unchanged from existing conditions. This is either a result of deliberate choice on behalf of the studio to respect what is there as is in the case of parcel 7 and parcels 29 and 30. These parcels are the site of recent development, or development that has recently broken ground. Since the Texas Urban Futures Lab has adopted a pragmatic approach to the site's development, it chooses to respect these sites. Other parcels such as parcel 1 were still in development at the time South Shore Central Alternative 1 and South Shore Central Alternative 2 were presented at midterm reviews.

In this alternative, the district is able to capture the 25 year storm event through low impact development infrastructure. Additionally, the loss of water in the form of run-off has decreased to only losing the amount of water 2 people would use of the course of the year during the 50 year storm event. In the 100 year storm event, the amount of water lost in run-off is equivalent to the amount of water 4 people would use. That is approximately a 98% reduction of loss from existing conditions during the same rain event.



south shore central alternative 2

0' 100' 200' 400'



decision ?

South Shore Central Alternative 3

The Change Model

South Shore Central Alternative 3 aligns itself very closely to the SDAT recommendations in terms of impermeable cover to permeable cover ratios. The percentage of impermeable cover has gone down to 60%, a figure presented as part of the recommendations made in the report. One of the most significant changes is that the amount of surface parking square footage has dropped by approximately 85% to about 274,000 sq. ft. Much of that previously impervious cover has been devoted to sponge park area. This alternative also sees the inclusion of a new typology of low impact development feature, permeable pavement combined with underground cisterns. The amount of rain gardens have increased to almost 200,000 sq. ft. along the sidewalks. Part of this increase in rain gardens has come from the addition of private gardens along parts of buildings where the ground floor is residential. These small private gardens would be constructed in similar fashion to rain gardens to increase the amount of low impact development infrastructure. Compared to other alternatives, this scenario sees the least amount of building space devoted to green roofs.

south shore central alternative 3

0' 100' 200' 400'

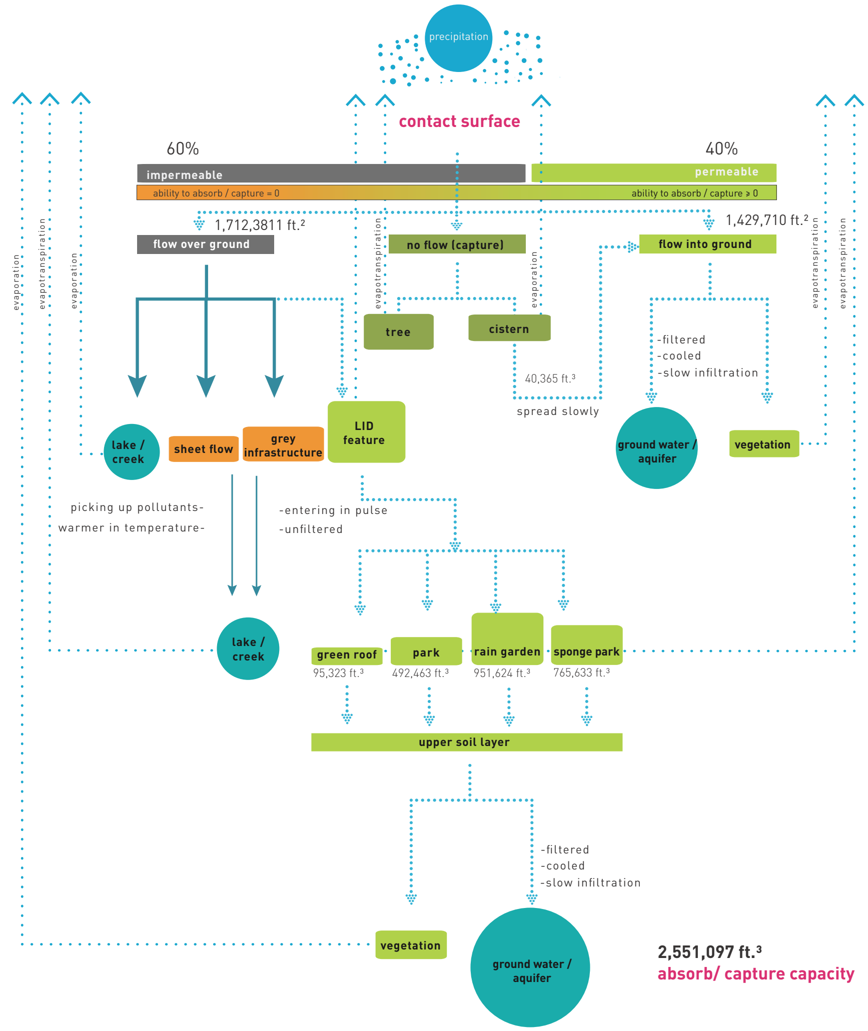
The impact model

The impact model indicates that the increase of rain garden square footage has increased that particular infrastructure's capture capacity to almost 1 million cubic feet of water per rain event. The sponge park is right behind it in terms of water capture with the capacity to capture about 765,000 ft.[3] The overall absorb capture capacity of the site is 2,551,097 ft.[3] This means the rain gardens along sidewalks account for almost 40% of stormwater capture. This was calcuated by taking new measurements of each parcel's impermeable to permeable cover ratio and calculating the new values for required stormwater capture. The volume of required stormwater capture was subtracted from the estimated water capture capacity of the parcel's low impact development features such as green roofs or park space if the parcel had any. The district's ability to capture water was calculted by summing the amount of stormwater loss to run-off (not captured by an LID feature) and subrtacting it from the capacity for stormwater capture of the collective spaces.

Calculations for the impact model can be found as an appendix item.

(Appendix item 4)

south shore central alternative 3



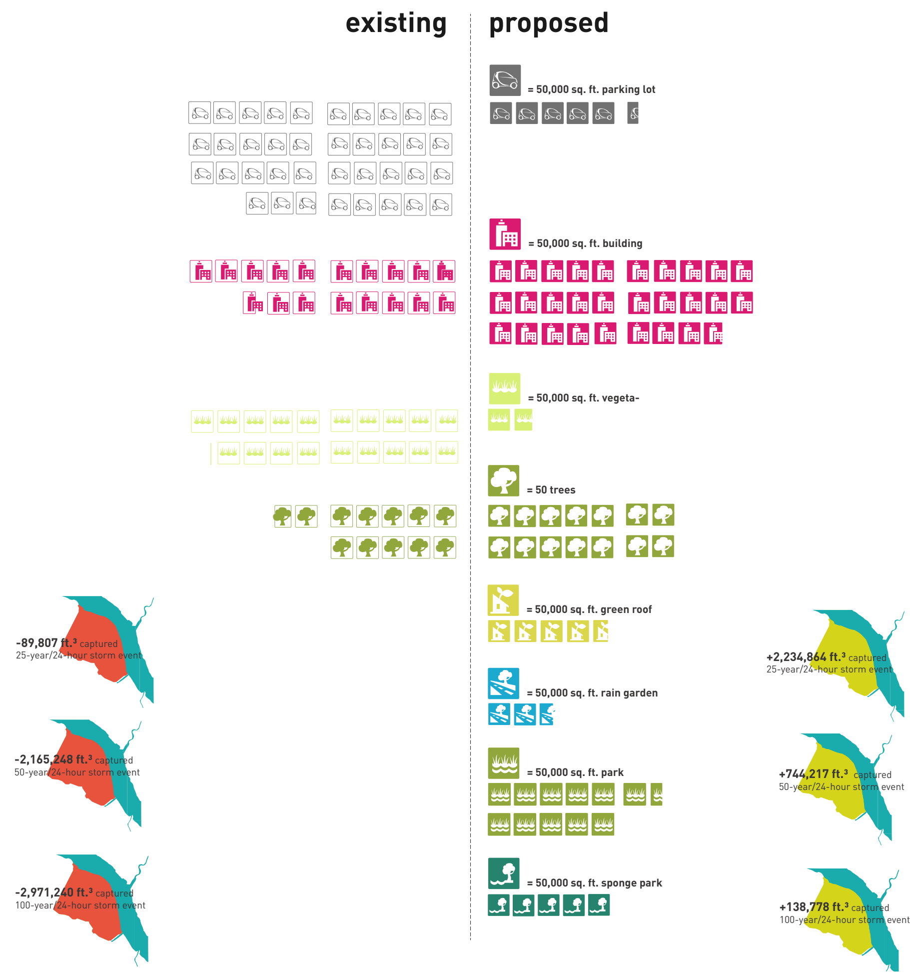
2,551,097 ft.³
absorb/ capture capacity

impact

The decision model

In this alternative, any parcel that was changed is able to meet City of Austin standards. Additionally, the district is able to capture the volumes of the three storm events. This ability to capture more water correlates with this scheme's increased amounts of low impact development features in the public space rather than the private space. The sponge park along the back of the creek almost doubled in size, increasing the protection afforded to the creek. The amount of green roofs, a choice that depends on decisions made by individuals, is actually less than the amounts in the other scenarios.

south shore central alternative 3



decision ?

Discussion

In comparing the alternatives, perhaps a closer look at the subtext will help facilitate the discussion. In South Shore Central Alternative 1, green roofs were the most prevalent low impact development feature used. The second most common feature used is park space. This scenario engages the problem of low impact development's viability as infrastructure with a solution that sets the decision making capabilities largely with the individual owners. The individual owners get to decide to have a green roof or not as well as decide to build or not. The governing body's role in this alternative can be engaged at the policy level, which might revisit the Waterfront Overlays and decide on new rules for impermeable to permeable cover ratios. As the rules stand right now, many sites with the exception of the ones edging the lake and creek are allowed an impermeable cover ratio as high as 95%. The overlay reduced the amount impermeable cover on the parcels edging the bodies of water through buffers where less than 15% impermeable cover is allowed. However, parcel 29 and 30, recent construction, set up a precedent for building within the creek's buffer zone.

South Shore Central Alternative 2 also sees green roofs and park space become the most prevalent choice of low impact development. In this scenario, the use of park space as stormwater management is heavily favored. The Texas Urban Futures Lab begins to engage the relationship between public space and stormwater infrastructure. As a general rule larger parks, particularly those fronting the lake and creek are seen as completely public and belonging to the city. In the current model of development, the city has negotiated with landowners to varying degrees of success regarding public access of the land that fronts the lake. Parcel 2, the Austin American Statesman, has a portion of their land accessible to the general public as a space to watch the bat colony that lives under Congress Bridge. The space is a bit ambiguous and terminates abruptly when it reaches the edge of the property and parcel 16 begins. The creek has no public access and very little in the way of private access. In alternative 2, the lake front, turns into clearly delineated city park space that connects with the boardwalk the city has begun construction on. The creek gets similar treatment at a smaller scale. One could see the governing bodies of the district take a more active role in the provision of low impact development infrastructure in this alternative by imagining its role in the construction and management of these larger public parks in partnership with the individual land owners.

Ultimately, the studio chose to present South Shore Central Alternative 3 as their proposal for the site. In their view, that scenario offered the best urban design strategies to accomplish their goals regarding mobility, density, accessibility, and sustainability. This scenario privileges the use of low impact development features in the public spaces which most likely would be provided by the initiative of the governing body, be it the City of Austin or the management of an entity that represents the district. The infrastructure is deployed systematically along streets and rights of way as well as along the bodies of water which border the site. The sponge park peels away from the creeks buffer and begins to make a connection with the streets that front it. This portion of the sponge park acts more like the sponge parks originally conceptualized by dlandstudio. In that conceptualization, the end of the street coming up to a body of water would turn into a small park space that caught the water from the street before it went into the body of water with all of the contaminants.

Before deciding which alternative, if any, is best for this site in Austin, the comparison of the three alternatives reveals the importance of identifying who gets to make decisions about low impact development and at what scale. The three alternatives pose three different mixes of decision makers, distinguishing the roles of those who get to make decisions about private space and those who get to make decisions about public space. Looking back to Frischmann raises interesting questions. While green roofs are able to reduce the amount of stormwater run-off of the district, they do not engage two of the three assumptions posed by Frischmann.

The government does not play a role in deciding to build one or not. It can incentivize but ultimately cannot decide yes or no. Also, members of the community cannot freely participate in this type of infrastructure either. Physics and policy deter one person from piping water onto their neighbors green roof even if such an arrangement could be agreed upon. While there are spill over benefits of individuals having green roofs, can they still be considered infrastructure if they do not meet two of the assumptions that might hold otherwise true for infrastructure?

This notion begins to bring the question of scale and accessibility into questions of infrastructure. At what scale does low impact development have to occur for it to be considered infrastructure? If it's there but not at a public scale then what is it? What benefits are coming from it and where are those benefits going? Who bears the burden and who reaps the rewards? Who can decide build or don't build with regards to low impact development? These are questions the comparison of alternatives begins to ask.

Imagine Austin 2012 and Urban Development:

Placing the work back into the larger context of urban development in Austin, the analysis reveals several parallels with some of the indicators found in Imagine Austin. Imagine Austin is the city's most recently adopted comprehensive plan which outlines strategies and opportunities for urban growth for the next 30 years. The last comprehensive plan Austin adopted was in 1979[48]. Within Imagine Austin, chapter 4 outlines what are referred to as building blocks that outline conservation and environmental policies. These building blocks are indicators the city of Austin and the entities that went through the public participation process wish to see in Austin as it continues to develop. While it is not yet clear how all of the indicators get measured nor what measure constitutes a level of success, the indicators point back to a system of values the city of Austin and some of its citizens consider important to urban design.

Among the issues important to Imagine Austin which the South Shore Central development might tie into with respect to the use of Low Impact Development Infrastructure include:

-Protect Austin's watersheds, waterways, and water supply within Central Texas, one of the fastest growing regions in the country.

-Reduce the impact of development in environmentally sensitive watershed areas, particularly in areas affecting Barton Springs or the Edwards Aquifer

-Improve regional planning and coordination to provide adequate water-related infrastructure and protect environmentally sensitive areas.

-Balance growth and protection of our natural resources to create a future that is sustainable.

The use of low impact development features in this new phase of urban development for the city can protect watersheds and water supply by reducing the amount of un-treated run-off going into Lady Bird Lake. Reduction of stormwater run-off has been demonstrated in all three alternatives. Analysis of the alternatives also seems to indicate which areas of planning and what type of coordination might occur to deploy low impact development features throughout urban development. Two areas in particular, identifying decision makers and testing of what scale of low impact development might constitute infrastructure, beg further investigation. One typology of low impact development, the sponge park, in combination with policy relating to impermeable cover ratio and creek buffers might yield a growth of viable creek habitat but also open up their accessibility to people for recreation and educational purposes.

The alternatives from the Texas Urban Futures Lab offer up possibilities of what urban development in Austin might look

48 "Austin Comprehensive Plan Process Frames Big Choices for Future." Accessed March 15, 2013. http://www.statesman.com/news/news/special-reports/austin-comprehensive-plan-process-frames-big-choic/nRyCd/.

like and how it might begin to fit itself back into a biophysical process important to the city at large. Engaging in low impact development as an alternative to traditional grey stormwater infrastructure can begin to integrate some of the benefits of the hydrologic cycle, such as cleaner water and more wildlife habitat, back into the urban fabric. The degree to which low impact development can be considered infrastructure is a question still left open ended as some of the issues surrounding it are not quite clear. The definition of who gets to decide what part is still a question the city of Austin has to work through.

While the Steinitz framework does provide a means with engaging the process of decision making grounded in information and allows for comparison of different spatial configurations, feedback loops into the framework could use further investigation. For example, in the representation (and possibly change) model, have all the forms of what low impact development might look like been accounted for? Is the unit for counting low impact development features accurate enough to feed into the process model? Has the process model captured all of the nuances of the hydrologic cycle that are critical to the biophysical process? Is the reading of the process model accurate enough to inform the evaluation model? Are there other standards of health, safety and general welfare that need to influence the evaluation model that have not yet been made into policy? For example, the City of Austin has a metric by which to indicate compliance or non-compliance of stormwater management code but is that metric strict enough to ensure long-term sustainability? It is in these questions where study work might find its next iteration and move forward.

Low Impact Development and Decisions:

A framework for comparison of spatial configurations low impact development in the design of a district

Appendix

										Pervious Cover			Green Roofs			Parks			
Parcel	Area in Sq ft.	Building in Sq. ft.	Parking Lot Sq. Ft	Imp. Cover (Building/ area)	Imp2 (Imp. Cover x 10 to get 10% increments)	Required Inches Captured =0.5+0.1*(Imp2-2)	Required Ft. Captured = Req. In. Cap*0.0833333	Req. Cap Cubic Ft. = Area * Req. Ft. Cap.	Vol. in Gal = Req. Cap Cubic Ft. *7.48052	area in sq. ft.	GR Gallons Captured = (6in*area*0.3 efficiency)*144* 0.00433	Cubic Ft. Captured = (6in*area*0.5 efficiency)*144*	Green Roof area in sq. ft.	GR Gallons Captured = (6in*area*0.88 efficiency)*144*0.0 0433	Vol. not captured by Green Roof	Park Space sq. Ft.	Gallons Captured by Park = (24in*area*0.4 efficiency)*144* 0.00433	Gal. Needed to be accounted for	
1	414,034.00	51,920.00	236,820.00	0.70	6.97	1.00	0.08	34,412.50	257,423.42	125,294.00	234,369.94	31,330.81	0.00	0.00	257,423.42	0.00	0.00	257,423.42	0.0
2	795,709.00	201,717.00	300,614.00	0.63	6.31	0.93	0.08	61,753.62	461,949.17	293,378.00	548,781.15	73,361.61	0.00	0.00	461,949.17	0.00	0.00	461,949.17	0.0
3	22,870.00	2,648.00	11,486.00	0.62	6.18	0.92	0.08	1,749.58	13,087.79	8,736.00	16,341.21	2,184.51	0.00	0.00	13,087.79	0.00	0.00	13,087.79	0.0
4	16,081.00	9,660.00	3,838.00	0.84	8.39	1.14	0.09	1,526.86	11,421.69	2,583.00	4,831.66	645.90	0.00	0.00	11,421.69	0.00	0.00	11,421.69	0.0
5	50,590.00	0.00	50,590.00	1.00	10.00	1.30	0.11	5,480.58	40,997.60	0.00	0.00	0.00	0.00	0.00	40,997.60	0.00	0.00	40,997.60	0.0
6	68,655.00	0.00	68,655.00	1.00	10.00	1.30	0.11	7,437.62	55,637.28	0.00	0.00	0.00	0.00	0.00	55,637.28	0.00	0.00	55,637.28	0.0
7	66,564.00	0.00	66,564.00	1.00	10.00	1.30	0.11	7,211.10	53,942.76	0.00	0.00	0.00	0.00	0.00	53,942.76	0.00	0.00	53,942.76	0.0
8	42,801.00	0.00	42,801.00	1.00	10.00	1.30	0.11	4,636.77	34,685.47	0.00	0.00	0.00	0.00	0.00	34,685.47	0.00	0.00	34,685.47	0.0
9	13,220.00	0.00	13,220.00	1.00	10.00	1.30	0.11	1,432.17	10,713.35	0.00	0.00	0.00	0.00	0.00	10,713.35	0.00	0.00	10,713.35	0.0
10	18,714.00	0.00	18,714.00	1.00	10.00	1.30	0.11	2,027.35	15,165.63	0.00	0.00	0.00	0.00	0.00	15,165.63	0.00	0.00	15,165.63	0.0
11	65,299.00	12,022.00	42,455.00	0.83	8.34	1.13	0.09	6,172.22	46,171.43	10,822.00	20,243.20	2,706.13	0.00	0.00	46,171.43	0.00	0.00	46,171.43	0.0
12	119,145.00	72,892.00	11,798.00	0.71	7.11	1.01	0.08	10,036.12	75,075.40	34,455.00	64,450.14	8,615.76	0.00	0.00	75,075.40	0.00	0.00	75,075.40	0.0
13	8,575.00	0.00	6,320.00	0.74	7.37	1.04	0.09	741.04	5,543.37	2,255.00	4,218.11	563.88	0.00	0.00	5,543.37	0.00	0.00	5,543.37	0.0
14	31,102.00	18,648.00	6,910.00	0.82	8.22	1.12	0.09	2,907.38	21,748.73	5,544.00	10,370.38	1,386.32	0.00	0.00	21,748.73	0.00	0.00	21,748.73	0.0
15	69,797.00	12,159.00	37,726.00	0.71	7.15	1.01	0.08	5,902.01	44,150.07	19,912.00	37,246.59	4,979.16	0.00	0.00	44,150.07	0.00	0.00	44,150.07	0.0
16	316,645.00	89,361.00	108,601.00	0.63	6.25	0.93	0.08	24,412.95	182,621.55	118,683.00	222,003.67	29,677.67	0.00	0.00	182,621.55	0.00	0.00	182,621.55	0.0
17	172,283.00	56,757.00	92,878.00	0.87	8.69	1.17	0.10	16,776.65	125,498.08	22,648.00	42,364.44	5,663.32	0.00	0.00	125,498.08	0.00	0.00	125,498.08	0.0
18	35,750.00	0.00	35,750.00	1.00	10.00	1.30	0.11	3,872.92	28,971.42	0	0.00	0.00	0.00	0.00	28,971.42	0.00	0.00	28,971.42	
19	453,593.00	117,826.00	309,356.00	0.94	9.42	1.24	0.10	46,938.31	351,122.94	26411	49,403.36	6,604.29	0.00	0.00	351,122.94	0.00	0.00	351,122.94	
20	7,831.00	0.00	7,831.00	1.00	10.00	1.30	0.11	848.36	6,346.16	0	0.00	0.00	0.00	0.00	6,346.16	0.00	0.00	6,346.16	0.0
21	8,772.00	0.00	8,772.00	1.00	10.00	1.30	0.11	950.30	7,108.74	0	0.00	0.00	0.00	0.00	7,108.74	0.00	0.00	7,108.74	0.0
22	15,495.00	8,334.00	0.00	0.54	5.38	0.84	0.07	1,081.87	8,092.98	7161	13,395.08	1,790.67	0.00	0.00	8,092.98	0.00	0.00	8,092.98	
23	219,666.00	60,761.00	99,594.00	0.73	7.30	1.03	0.09	18,854.56	141,041.91	59311	110,944.78	14,831.21	0.00	0.00	141,041.91	0.00	0.00	141,041.91	
24	109,213.00	22,231.00	43,706.00	0.60	6.04	0.90	0.08	8,225.07	61,527.81	43276	80,950.35	10,821.52	0.00	0.00	61,527.81	0.00	0.00	61,527.81	
25	264,166.00	89,710.00	83,946.00	0.66	6.57	0.96	0.08	21,075.47	157,655.51	90510	169,304.39	22,632.78	0.00	0.00	157,655.51	0.00	0.00	157,655.51	
26	18,153.00	0.00	18,153.00	1.00	10.00	1.30	0.11	1,966.57	14,711.00	0	0.00	0.00	0.00	0.00	14,711.00	0.00	0.00	14,711.00	
27	3,176.00	0.00	3,176.00	1.00	10.00	1.30	0.11	344.07	2,573.80	0	0.00	0.00	0.00	0.00	2,573.80	0.00	0.00	2,573.80	0.0
28	37,366.00	8,028.00	21,038.00	0.78	7.78	1.08	0.09	3,356.32	25,106.98	8300	15,525.65	2,075.48	0.00	0.00	25,106.98	0.00	0.00	25,106.98	
29	43,931.00	16,691.00	18,835.00	0.81	8.09	1.11	0.09	4,058.77	30,361.74	8405	15,722.06	2,101.74	0.00	0.00	30,361.74	0.00	0.00	30,361.74	
30	70,086.00	19,077.00	39,225.00	0.83	8.32	1.13	0.09	6,610.65	49,451.08	11784	22,042.68	2,946.69	0.00	0.00	49,451.08	0.00	0.00	49,451.08	
31	10,887.00	0.00	10,887.00	1.00	10.00	1.30	0.11	1,179.42	8,822.71	0	0.00	0.00	0.00	0.00	8,822.71	0.00	0.00	8,822.71	0.0
32	102,651.00	34,689.00	35,761.00	0.69	6.86	0.99	0.08	8,437.10	63,113.93	32201	60,233.90	8,052.13	0.00	0.00	63,113.93	0.00	0.00	63,113.93	
33	21,233.00	13,178.00	6,051.00	0.91	9.06	1.21	0.10	2,133.24	15,957.75	2004	3,748.60	501.12	0.00	0.00	15,957.75	0.00	0.00	15,957.75	
34	23,483.00	0.00	23,483.00	1.00	10.00	1.30	0.11	2,543.99	19,030.37	0	0.00	0.00	0.00	0.00	19,030.37	0.00	0.00	19,030.37	
35	40,575.00	8,009.00	14,094.00	0.54	5.45	0.84	0.07	2,856.29	21,366.54	18472	34,552.98	4,619.08	0.00	0.00	21,366.54	0.00	0.00	21,366.54	
Totals	3,778,111.00	926,318.00	1,899,648.00	29.12	291.24	39.62	3.30	329,949.81	2,468,196.15	952,145.00	1,781,044.35	238,091.79	0.00	0.00	2,468,196.15	0.00	0.00	2,468,196.15	

collective park area in sq. ft.	0	park capture in gallons	0
collective sponge park area in	0	sponge capture in gallons	0
total capture in gallons	1,796,382.94		
required wqcv in gallons	-671,813.21	required wqcv in cubic ft.	-89807.98953
25 yr capture in gallons	-16,197,249.36	25 yr capture in cubic ft.	-2165248.295
50 yr capture in gallons	-19,094,119.96	50 yr capture in cubic ft.	-2552501.956
100 yr capture in gallons	-22,226,516.72	100 yr capture in cubic ft.	-2971240.755

Rain Gardens			25 yr Storm	25 yr Gal	50 yr Storm	50 yr Gal	100 yr Storm	100 yr Gal		Total Rain Capture	Gallons captured over R	25 yr	50 yr	100 yr
Rain Garden Area sq ft.	Rain Gal. Captured = (61.5 in *Rain Garden Area sq ft *0.4 efficiency)*144*0.0 0433		7.64 in over 24 hrs = 0.636667 ft.	cubic ft to gal.	8.87 in over 24 hrs = .7391667 ft.	cubic ft. to gal	10.2 in over 24 hrs. =.85	cubic ft to gal		Green Roofs + Parks + Rain Garden Rain Capture + pervious cover	Gallons Captured above Req. WQV			
0.00	0.00		263601.7847	1971878.422	306040.1455	2289339.429	351928.9	2632611.175		234,369.94	-23,053.47	-1,737,508.48	-2,054,969.48	-2,398,241.23
0.00	0.00		506601.6619	3789643.864	588161.5957	4399754.58	676352.65	5059469.525		548,781.15	86,831.98	-3,240,862.71	-3,850,973.43	-4,510,688.37
0.00	0.00		14560.57429	108920.6672	16904.74243	126456.2638	19439.5	145417.5685		16,341.21	3,253.42	-92,579.46	-110,115.05	-129,076.36
0.00	0.00		10238.24203	76587.37425	11886.5397	88917.49798	13668.85	102250.1058		4,831.66	-6,590.03	-71,755.72	-84,085.84	-97,418.45
0.00	0.00		32208.98353	240939.9455	37394.44335	279729.8814	43001.5	321673.5808		0.00	-40,997.60	-240,939.95	-279,729.88	-321,673.58
0.00	0.00		43710.37289	326976.3186	50747.48979	379617.6123	58356.75	436538.8355		0.00	-55,637.28	-326,976.32	-379,617.61	-436,538.84
0.00	0.00		42379.10219	317017.7215	49201.89222	368055.7388	56579.4	423243.3333		0.00	-53,942.76	-317,017.72	-368,055.74	-423,243.33
0.00	0.00		27249.98427	203844.0523	31637.07393	236661.7643	36380.85	272147.676		0.00	-34,685.47	-203,844.05	-236,661.76	-272,147.68
0.00	0.00		8416.73774	62961.575	9771.783774	73098.02396	11237	84058.60324		0.00	-10,713.35	-62,961.57	-73,098.02	-84,058.60
0.00	0.00		11914.58624	89127.30065	13832.76562	103476.2799	15906.9	118991.8836		0.00	-15,165.63	-89,127.30	-103,476.28	-118,991.88
0.00	0.00		41573.71843	310993.0322	48266.84634	361061.1094	55504.15	415199.9042		20,243.20	-25,928.23	-290,749.83	-340,817.91	-394,956.70
0.00	0.00		75855.68972	567440.004	88068.01647	658794.5586	101273.25	757576.5721		64,450.14	-10,625.26	-502,989.86	-594,344.41	-693,126.43
0.00	0.00		5459.419525	40839.29695	6338.354453	47414.18725	7288.75	54523.64015		4,218.11	-1,325.26	-36,621.18	-43,196.07	-50,305.53
0.00	0.00		19801.61703	148126.3923	22989.5627	171973.8836	26436.7	197760.2631		10,370.38	-11,378.35	-137,756.01	-161,603.50	-187,389.88
0.00	0.00		44437.4466	332415.208	51591.61816	385932.1315	59327.45	443800.1763		37,246.59	-6,903.48	-295,168.62	-348,685.54	-406,553.59
0.00	0.00		201597.4222	1508053.549	234053.4397	1750841.437	269148.25	2013368.867		222,003.67	39,382.12	-1,286,049.88	-1,528,837.76	-1,791,365.19
0.00	0.00		109686.9008	820515.0549	127345.8566	952613.227	146440.55	1095451.463		42,364.44	-83,133.64	-778,150.61	-910,248.78	-1,053,087.02
0.00	0.00		22760.84525	170262.9581	26425.20953	197674.3084	30387.5	227314.3015		0.00	-28,971.42	-170,262.96	-197,674.31	-227,314.30
0.00	0.00		288787.6945	2160282.125	335280.841	2508075.036	385554.05	2884144.782		49,403.36	-301,719.58	-2,110,878.76	-2,458,671.68	-2,834,741.42
0.00	0.00		4985.739277	37295.92238	5788.414428	43300.34989	6656.35	49792.9593		0.00	-6,346.16	-37,295.92	-43,300.35	-49,792.96
0.00	0.00		5584.842924	41777.52919	6483.970292	48503.46945	7456.2	55776.25322		0.00	-7,108.74	-41,777.53	-48,503.47	-55,776.25
0.00	0.00		9865.155165	73796.49051	11453.38802	85677.29813	13170.75	98524.05879		13,395.08	5,302.10	-60,401.41	-72,282.22	-85,128.98
1,000.00	15,338.59		139854.0932	1046181.341	162369.7923	1214610.479	186716.1	1396733.52		126,283.38	-14,758.53	-919,897.97	-1,088,327.10	-1,270,450.14
0.00	0.00		69532.31307	520137.8586	80726.61281	603877.0416	92831.05	694424.5261		80,950.35	19,422.54	-439,187.50	-522,926.69	-613,474.17
0.00	0.00		168185.7747	1258117.052	195262.7105	1460666.611	224541.1	1679684.189		169,304.39	11,648.87	-1,088,812.67	-1,291,362.23	-1,510,379.80
0.00	0.00		11557.41605	86455.48192	13418.09311	100374.3138	15430.05	115424.7976		0.00	-14,711.00	-86,455.48	-100,374.31	-115,424.80
0.00	0.00		2022.054392	15126.01832	2347.593439	17561.21967	2699.6	20194.41179		0.00	-2,573.80	-15,126.02	-17,561.22	-20,194.41
0.00	0.00		23789.69912	177959.3201	27619.70291	206609.74	31761.1	237589.5438		15,525.65	-9,581.34	-162,433.67	-191,084.09	-222,063.90
0.00	0.00		27969.41798	209225.7906	32472.3323	242909.9312	37341.35	279332.7155		15,722.06	-14,639.68	-193,503.73	-227,187.87	-263,610.66
0.00	0.00		44621.44336	333791.5995	51805.23734	387530.114	59573.1	445637.766		22,042.68	-27,408.40	-311,748.92	-365,487.43	-423,595.09
0.00	0.00		6931.393629	51850.42867	8047.307863	60198.04741	9253.95	69224.35805		0.00	-8,822.71	-51,850.43	-60,198.05	-69,224.36
0.00	0.00		65354.50422	488885.6759	75876.20092	567593.4385	87253.35	652700.4297		60,233.90	-2,880.03	-428,651.77	-507,359.54	-592,466.53
0.00	0.00		13518.35041	101124.2906	15694.72654	117404.7158	18048.05	135008.799		3,748.60	-12,209.15	-97,375.69	-113,656.11	-131,260.20
0.00	0.00		14950.85116	111840.1411	17357.85162	129845.7562	19960.55	149315.2935		0.00	-19,030.37	-111,840.14	-129,845.76	-149,315.29
0.00	0.00		25832.76353	193242.5042	29991.68885	224353.4283	34488.75	257993.7842		34,552.98	13,186.45	-158,689.52	-189,800.44	-223,440.80
1,000.00	15,338.59	0.00	2,405,398.60	17,993,632.31	2,792,653.84	20,890,502.90	3,211,394.35	24,022,899.66	0.00	1,796,382.94	-671,813.21	-16,197,249.36	-19,094,119.96	-22,226,516.72

Parcel	Area in Sq ft.	Building in Sq. ft.	Parking Lot Sq. Ft	Imp. Cover (Building/area)	Imp2 (Imp. Cover x 10 to get 10% increments)	Required Inches Captured =0.5+0.1*(Imp2-2)	Required Ft. Captured = Req. In. Cap*0.0833333	Req. Cap Cubic Ft. = Area * Req. Ft. Cap.	Vol. in Gal = Req. Cap Cubic Ft. *7.48052	Pervious Cover: area in sq. ft.	Pervious Cover: GR Gallons Captured = (6in*area*0.3 efficiency)*144*0.00433	Pervious Cover: Cubic Ft. Captured = (6in*area*0.5 efficiency)*144*	Green Roofs: Green Roof area in sq. ft.	Green Roofs: GR Gallons Captured = (6in*area*0.88 efficiency)*144*0.00433	Vol. not captured by Green Roof	Parks: Park Space sq. Ft.	Parks: Gallons Captured by Park = (24in*area*0.4 efficiency)*144*0.00433	Gal. Needed to be accounted for
1-existing	414,034.00	51,920.00	236,820.00	0.70	6.97	1.00	0.08	34,412.50	257,423.42	125,294.00	234,369.94	31,330.81	0.00	0.00	257,423.42	0.00	0.00	257,423.
2a	88354.2	71,630.70		0.81	8.11	1.11	0.09	8,178.08	61,176.27				0.00	0.00	61,176.27	5,558.70	79,023.90	-17,847.
2b	155,001.50	36,104.70		0.23	2.33	0.53	0.04	6,883.76	51,494.10				12,944.90	42,617.01	8,877.09	93,317.10	1,326,619.78	-1,317,742.
2c	61,905.70	31,082.70		0.50	5.02	0.80	0.07	4,137.87	30,953.39				0.00	0.00	30,953.39	17,827.40	253,438.88	-222,485.
2d	102,921.90	71,921.70		0.70	6.99	1.00	0.08	8,566.52	64,082.02				13,791.90	45,405.49	18,676.52	8,392.20	119,305.66	-100,629.
2e	104,904.20	63,768.60		0.61	6.08	0.91	0.08	7,936.65	59,370.28				10,329.70	34,007.29	25,362.99	8,665.60	123,192.39	-97,829.
3-existing	22,870.00	2,648.00	11,486.00	0.62	6.18	0.92	0.08	1,749.58	13,087.79	8,736.00	16,341.21	2,184.51	0.00	0.00	13,087.79	0.00	0.00	13,087.
4-existing	16,081.00	9,660.00	3,838.00	0.84	8.39	1.14	0.09	1,526.86	11,421.69	2,583.00	4,831.66	645.90	0.00	0.00	11,421.69	0.00	0.00	11,421.
5	50,590.00	0.00	0.00	0.00	0.00	0.30	0.02	1,264.75	9,460.98	50,590.00	94,631.63	12,650.45		0.00	9,460.98		0.00	9,460.
6-existing	68,655.00	0.00	68,655.00	1.00	10.00	1.30	0.11	7,437.62	55,637.28	0.00	0.00	0.00	0.00	0.00	55,637.28	0.00	0.00	55,637.
7-existing	66,564.00	0.00	66,564.00	1.00	10.00	1.30	0.11	7,211.10	53,942.76	0.00	0.00	0.00	0.00	0.00	53,942.76	0.00	0.00	53,942.
8+9+10	42,402.00	30,766.00		0.73	7.26	1.03	0.09	3,623.88	27,108.52	11,636.00	21,765.84	2,909.68	6,974.00	22,959.70	4,148.82		0.00	4,148.
11	93,018.90	60,508.00		0.65	6.50	0.95	0.08	7,367.80	55,115.00				3,923.60	12,917.23	69,306.29		0.00	69,306.
12+13 Existing	135,420.90	91,274.00	0.00	0.67	6.74	0.97	0.08	10,991.68	82,223.52	11,636.00	21,765.84	2,909.68	0.00	0.00	0.00	0.00	0.00	73,455.
14	30,295.45	47,017.00		1.00	10.00	1.30	0.11	3,282.01	24,551.11		0.00		11,201.25	36,876.61	-12,325.50		0.00	-12,325.
15	80,496.80	48,492.00		0.60	6.02	0.90	0.08	6,053.42	45,282.71				0.00	0.00	45,282.71	18,145.00	257,953.90	-212,671.
16a	97,443.90	55,571.60		0.57	5.70	0.87	0.07	7,067.06	52,865.29				27,872.50	91,761.44	-38,896.15	19,294.00	274,288.44	-313,184.
16b	98,533.00	84,644.30		0.86	8.59	1.16	0.10	9,517.01	71,192.21				16,593.80	54,629.87	16,562.34		0.00	16,562.
17	94,267.90	90,477.30		0.96	9.60	1.26	0.10	9,896.47	74,030.73				30,977.10	101,982.36	-27,951.63		0.00	-27,951.
18	55,530.80	42,599.70		0.77	7.67	1.07	0.09	4,938.24	36,940.63				4,597.40	15,135.49	21,805.13		0.00	21,805.
19a	82,364.30	81,692.80		0.99	9.92	1.29	0.11	8,866.84	66,328.55				14,191.50	46,721.05	19,607.50		0.00	19,607.
19b	64,922.60	53,209.00		0.82	8.20	1.12	0.09	6,057.15	45,310.60				4,422.50	14,559.69	30,750.91		0.00	30,750.
19c+22	81,155.60	40,953.70		0.50	5.05	0.80	0.07	5,441.70	40,706.72				10,448.60	34,398.73	6,307.99	25,046.40	356,066.03	-349,758.
19d	86,739.60	69,639.20		0.80	8.03	1.10	0.09	7,971.75	59,632.86				16,202.60	53,341.97	6,290.89		0.00	6,290.
20+21	70,679.30	63,613.50		0.90	9.00	1.20	0.10	7,068.10	52,873.10				11,403.20	37,541.45	15,331.65		0.00	15,331.
23a	76,178.50	30,391.00		0.40	3.99	0.70	0.06	4,437.04	33,191.40				17,676.06	58,192.87	-25,001.47		0.00	-25,001.
23b	103,778.00	55,197.00		0.53	5.32	0.83	0.07	7,194.20	53,816.34				17,276.39	56,877.07	-3,060.73	6,922.48	98,411.78	-101,472.
24a	31,726.50	31,243.00		0.98	9.85	1.28	0.11	3,396.74	25,409.41				8,304.96	27,341.46	-1,932.04		0.00	-1,932.
24b	22,756.80	22,053.00		0.97	9.69	1.27	0.11	2,406.67	18,003.14				2,507.98	8,256.72	9,746.42		0.00	9,746.
25a	122,995.40	75,685.00		0.62	6.15	0.92	0.08	9,381.96	70,181.97				2,954.38	9,726.37	60,455.60		0.00	60,455.
25b	63,103.30	74,422.00		1.18	11.79	1.48	0.12	7,779.41	58,194.05				17,276.39	56,877.07	1,316.99		0.00	1,316.
25c	26,874.40	25,647.00		0.95	9.54	1.25	0.10	2,809.11	21,013.60				6,633.75	21,839.55	-825.95		0.00	-825.
26+27	30,548.50	20,342.00		0.67	6.66	0.97	0.08	2,458.88	18,393.69				5,276.18	17,370.17	1,023.52		0.00	1,023.
28	44,524.90	32,754.00		0.74	7.36	1.04	0.09	3,842.62	28,744.80				15,462.91	50,906.76	-22,161.96		0.00	-22,161.
29-existing	43,931.00	16,691.00	18,835.00	0.81	8.09	1.11	0.09	4,058.77	30,361.74	8405	15,722.06	2,101.74	0.00	0.00	30,361.74	0.00	0.00	30,361.
30-existing	70,086.00	19,077.00	39,225.00	0.83	8.32	1.13	0.09	6,610.65	49,451.08	11784	22,042.68	2,946.69	0.00	0.00	49,451.08	0.00	0.00	49,451.
31+32a+33	29,618.30	27,745.00		0.94	9.37	1.24	0.10	3,052.54	22,834.58				5,915.49	19,474.89	3,359.70	7,320.00	104,062.99	-100,703.
32b	27,130.30	26,517.00		0.98	9.77	1.28	0.11	2,888.01	21,603.79				4,736.75	15,594.26	6,009.53	7,115.00	101,148.66	-95,139.
34-existing	23,483.00	0.00	23,483.00	1.00	10.00	1.30	0.11	2,543.99	19,030.37	50590	94,631.63	12,650.45	0.00	0.00	19,030.37	0.00	0.00	19,030.
35-existing	40,575.00	8,009.00	14,094.00	0.54	5.45	0.84	0.07	2,856.29	21,366.54	18472	34,552.98	4,619.08	0.00	0.00	21,366.54	0.00	0.00	21,366.
Totals	3,022,462.45	1,664,967.50	483,000.00	29.97	299.70	41.97	3.50	253,165.29	1,893,808.01	299,726.00	560,655.47	74,948.98	299,895.78	987,312.57	851,380.44	217,603.88	3,093,512.42	-2,168,676.

collective park	147080	park capture in gallons	2090926.932	Cubic feet Water Vol	279517.2033
collective sponge park	111,925	sponge capture in gallons	3182308.906		425414.2368
collective rain garden	108,402	rain garden capture in gallons	1662704		222271.9334
total capture	11,577,420.30	Cubic feet Water Vol	1547681.123		
			0		
required wqcv	9,683,612.29		1294514.974		
25 yr	-2,691,396.41		-359788.563		
50 yr	-4,988,593.26		-666880.136		
100 yr	-7,472,560.62		-998939.376		

Individual				25 yr Storm	25 yr Gal	50 yr Storm	50 yr Gal	100 yr Storm	100 yr Gal		Total Rain Capture	Gallons captured over R	25 yr	50 yr	100 yr
	Rain Gal. Captured = (61.5 in *Rain Garden Area sq ft *0.4 efficiency)*144*0.00433		7.64 in over 24 hrs = 0.636667 ft.	cubic ft to gal.	8.87 in over 24 hrs = .7391667 ft.	cubic ft. to gal	10.2 in over 24 hrs. =.85	cubic ft to gal		Green Roofs + Parks + Rain Garden Rain Capture + pervious cover	Gallons Captured above Req. WQV				
23,053.47	0.00	0.00		263601.7847	1971878.422	306040.1455	2289339.429	351928.9	2632611.175		234,369.94	-23,053.47	-1,737,508.48	-2,054,969.48	-2,398,241.23
-17,847.64	0.00	0.00		98684.34	738210.1791	114571.9473	857057.7428	131751.275	985568.0477		79,023.90	17,847.64	-659,186.28	-778,033.84	-906,544.15
-1,317,742.69	0.00	0.00		39413.3163	294832.1009	45758.63198	342298.3617	52619.845	393623.8029		1,369,236.80	1,317,742.69	1,074,404.70	1,026,938.43	975,612.99
-222,485.49	0.00	0.00		39413.3163	294832.1009	45758.63198	342298.3617	52619.845	393623.8029		253,438.88	222,485.49	-41,393.22	-88,859.48	-140,184.92
-100,629.14	0.00	0.00		65526.97731	490175.8643	76076.44118	569091.3398	87483.615	654422.9317		164,711.16	100,629.14	-325,464.71	-404,380.18	-489,711.77
-97,829.39	0.00	0.00		66789.0423	499616.7667	77541.69133	580052.1728	89168.57	667027.2713		157,199.68	97,829.39	-342,417.09	-422,852.50	-509,827.59
-3,253.42	0.00	0.00		14560.57429	108920.6672	16904.74243	126456.2638	19439.5	145417.5685		16,341.21	3,253.42	-92,579.46	-110,115.05	-129,076.36
6,590.03	0.00	0.00		10238.24203	76587.37425	11886.5397	88917.49798	13668.85	102250.1058		4,831.66	-6,590.03	-71,755.72	-84,085.84	-97,418.45
-85,170.65	0.00	0.00		32208.98353	240939.9455	37394.44335	279729.8814	43001.5	321673.5808		94,631.63	85,170.65	-146,308.32	-185,098.25	-227,041.95
55,637.28	0.00	0.00		43710.37289	326976.3186	50747.48979	379617.6123	58356.75	436538.8355		0.00	-55,637.28	-326,976.32	-379,617.61	-436,538.84
53,942.76	0.00	0.00		42379.10219	317017.7215	49201.89222	368055.7388	56579.4	423243.3333		0.00	-53,942.76	-317,017.72	-368,055.74	-423,243.33
-17,617.02	0.00			26995.95413	201943.7748	31342.14641	234455.5531	36041.7	269610.6577		44,725.54	17,617.02	-157,218.24	-189,730.01	-224,885.12
42,197.77	0.00	0.00		59222.06401	443011.8342	68756.47335	514334.174	79066.065	591455.2806		12,917.23	-69,306.29	-430,094.60	-501,416.94	-578,538.05
60,457.68	0.00	0.00	0.00	86218.01814	644955.6091	100098.6198	748789.7271	115107.765	861065.9382		21,765.84	-23,516.88	-623,189.77	-727,023.89	-839,300.10
-12,325.50	0.00	0.00		19288.11129	144285.1023	22393.38551	167514.1682	25751.12987	192631.842		36,876.61	12,325.50	-107,408.49	-130,637.56	-155,755.23
-212,671.18	0.00	0.00		51249.65617	383374.0779	59500.55402	445095.0843	68422.28	511834.234		257,953.90	212,671.18	-125,420.18	-187,141.19	-253,880.34
-313,184.59	0.00	0.00		62039.31548	464086.3402	72027.286	538801.5535	82827.315	619591.3864		366,049.89	313,184.59	-98,036.45	-172,751.67	-253,541.50
16,562.34	0.00	0.00		62732.70951	469273.2882	72832.31245	544823.5699	83753.05	626516.3656		54,629.87	-16,562.34	-414,643.42	-490,193.70	-571,886.50
-27,951.63	0.00	0.00		60017.26109	448960.3219	69679.69256	521240.3338	80127.715	599396.9746		101,982.36	27,951.63	-346,977.96	-419,257.97	-497,414.61
21,805.13	0.00	0.00		35354.62784	264471.0007	41046.51818	307049.3002	47201.18	353089.371		15,135.49	-21,805.13	-249,335.51	-291,913.81	-337,953.88
19,607.50	0.00	0.00		52438.63179	392268.2339	60880.94783	455421.1479	70009.655	523708.6244		46,721.05	-19,607.50	-345,547.18	-408,700.10	-476,987.57
30,750.91	0.00	0.00		41334.07697	309200.3895	47988.624	358979.8616	55184.21	412806.5866		14,559.69	-30,750.91	-294,640.70	-344,420.17	-398,246.90
-349,758.05	0.00	0.00		51669.09239	386511.679	59987.51704	448737.821	68982.26	516023.1756		390,464.76	349,758.05	3,953.09	-58,273.06	-125,558.41
6,290.89	0.00	0.00		55224.24091	413106.0386	64115.02389	479613.7185	73728.66	551528.7157		53,341.97	-6,290.89	-359,764.07	-426,271.75	-498,186.75
15,331.65	0.00	0.00		44999.17789	336617.2502	52243.78494	390810.6781	60077.405	449410.2297		37,541.45	-15,331.65	-299,075.80	-353,269.23	-411,868.78
-25,001.47	0.00	0.00		48500.33706	362807.7414	56308.61046	421217.6867	64751.725	484376.5739		58,192.87	25,001.47	-304,614.87	-363,024.82	-426,183.71
-101,472.51	0.00	0.00		66072.02793	494253.1263	76709.24179	573825.0174	88211.3	659866.3939		155,288.84	101,472.51	-338,964.28	-418,536.17	-504,577.55
-1,932.04	0.00	0.00		20199.21558	151100.6361	23451.17231	175426.9635	26967.525	201731.1101		27,341.46	1,932.04	-123,759.18	-148,085.51	-174,389.65
9,746.42	0.00	0.00		14488.50359	108381.5408	16821.06876	125830.3413	19343.28	144697.7929		8,256.72	-9,746.42	-100,124.82	-117,573.62	-136,441.07
60,455.60	0.00	0.00		78307.11233	585777.9199	90914.10393	680084.7728	104546.09	782059.1172		9,726.37	-60,455.60	-576,051.55	-670,358.40	-772,332.74
1,316.99	0.00	0.00		40175.7887	300535.7909	46643.85802	348920.3128	53637.805	401238.6731		56,877.07	-1,316.99	-243,658.72	-292,043.25	-344,361.61
-825.95	0.00	0.00		17110.04362	127992.0235	19864.66156	148597.9981	22843.24	170879.3137		21,839.55	825.95	-106,152.47	-126,758.45	-149,039.76
1,023.52	0.00	0.00		19449.22185	145490.293	22580.43393	168913.3877	25966.225	194240.8654		17,370.17	-1,023.52	-128,120.13	-151,543.22	-176,870.70
-22,161.96	0.00	0.00		28347.53451	212054.2988	32911.3234	246193.8129	37846.165	283108.9942		50,906.76	22,161.96	-161,147.54	-195,287.05	-232,202.23
14,639.68	0.00	0.00		27969.41798	209225.7906	32472.3323	242909.9312	37341.35	279332.7155		15,722.06	-14,639.68	-193,503.73	-227,187.87	-263,610.66
27,408.40	0.00	0.00		44621.44336	333791.5995	51805.23734	387530.114	59573.1	445637.766		22,042.68	-27,408.40	-311,748.92	-365,487.43	-423,595.09
-100,703.30	0.00	0.00		18856.99421	141060.1223	21892.86107	163769.9851	25175.555	188326.2427		123,537.88	100,703.30	-17,522.24	-40,232.10	-64,788.36
-95,139.13	0.00	0.00		17272.96671	129210.7729	20053.81432	150012.9591	23060.755	172506.439		116,742.92	95,139.13	-12,467.86	-33,270.04	-55,763.52
-75,601.26	0.00	0.00		14950.85116	111840.1411	17357.85162	129845.7562	19960.55	149315.2935		94,631.63	75,601.26	-17,208.51	-35,214.13	-54,683.66
-13,186.45	0.00	0.00		25832.76353	193242.5042	29991.68885	224353.4283	34488.75	257993.7842		34,552.98	13,186.45	-158,689.52	-189,800.44	-223,440.80
	0.00														
-2,747,672.45	0.00	0.00	0.00	1,907,463.21	14,268,816.70	2,214,553.74	16,566,013.56	2,546,611.85	19,049,980.91	0.00	4,641,480.46	2,757,504.74	-9,627,336.25	-11,924,533.10	-14,408,500.45

										Pervious Cover existing			Green Roofs			Parks	
Parcel	Area in Sq ft.	Building in Sq. ft.	Parking Lot Sq. Ft	Imp. Cover (Building/area)	Imp2 (Imp. Cover x 10 to get 10% increments)	Required Inches Captured =0.5+0.1*(Imp2-2)	Required Ft. Captured = Req. In. Cap*0.0833333	Req. Cap Cubic Ft. = Area * Req. Ft. Cap.	Vol. in Gal = Req. Cap Cubic Ft. *7.48052	area in sq. ft.	GR Gallons Captured = (6in*area*0.3 efficiency)*144*0.00433	Cubic Ft. Captured = (6in*area*0.5 efficiency)*144*	Green Roof area in sq. ft.	GR Gallons Captured = (6in*area*0.88 efficiency)*144*0.00433	Vol. not captured by Green Roof	Park Space sq. Ft.	Gallons Captured by Park = (24in*area*0.4 efficiency)*144*0.00433
1-existing	414,034.00	51,920.00	236,820.00	0.70	6.97	1.00	0.08	34,412.50	257,423.42	125,294.00	234,369.94	31,330.81	0.00	0.00	257,423.42	0.00	0.00
2a	62,262.86	52,409.00		0.84	8.42	1.14	0.10	5,923.99	44,314.50		0.00		16,744.98	55,127.58	-10,813.08	90,302.81	1,283,767.84
2b	28,593.00	26,033.00		0.91	9.10	1.21	0.10	2,884.24	21,575.62		0.00		8,676.43	28,564.41	-6,988.79	7,094.32	100,854.66
2c	39,681.17	26,312.00		0.66	6.63	0.96	0.08	3,184.69	23,823.17		0.00		8,676.43	28,564.41	-4,741.24	8,222.00	116,886.00
2d	74,367.78	66,657.00		0.90	8.96	1.20	0.10	7,413.94	55,460.14		0.00		17,944.22	59,075.70	-3,615.56	81,225.56	1,154,723.33
2e	34,933.23	21,324.00		0.61	6.10	0.91	0.08	2,650.33	19,825.84		0.00		26,814.81	88,279.34	-68,453.49	4,531.00	64,413.86
3-existing	22,870.00	2,648.00	11,486.00	0.62	6.18	0.92	0.08	1,749.58	13,087.79	8,736.00	16,341.21	2,184.51	0.00	0.00	13,087.79	0.00	0.00
4-existing	16,081.00	9,660.00	3,838.00	0.84	8.39	1.14	0.09	1,526.86	11,421.69	2,583.00	4,831.66	645.90	0.00	0.00	11,421.69	0.00	0.00
5	50,590.00	0.00	0.00	0.00	0.00	0.30	0.02	1,264.75	9,460.98	50,590.00	94,631.63	12,650.45		0.00	9,460.98		0.00
6-existing	68,655.00	0.00	68,655.00	1.00	10.00	1.30	0.11	7,437.62	55,637.28	0.00	0.00	0.00	0.00	0.00	55,637.28	0.00	0.00
7-existing	66,564.00	0.00	66,564.00	1.00	10.00	1.30	0.11	7,211.10	53,942.76	0.00	0.00	0.00	0.00	0.00	53,942.76	0.00	0.00
8+9+10	42,402.00	30,766.00		0.73	7.26	1.03	0.09	3,623.88	27,108.52	11,636.00	21,765.84	2,909.68	6,974.00	22,959.70	4,148.82		0.00
11	93,018.90	60,508.00		0.65	6.50	0.95	0.08	7,367.80	55,115.00		0.00		3,923.60	12,917.23	42,197.77		0.00
12+13 Existin	108,966.00	30,766.00	66,564.00	0.89	8.93	1.19	0.10	10,834.98	81,051.28	11,636.00	21,765.84	2,909.68	0.00	0.00	81,051.28	0.00	0.00
14	31,765.00	24,304.00		0.77	7.65	1.07	0.09	2,819.46	21,091.01		0.00		14,591.00	48,036.28	-26,945.27		0.00
15	80,496.80	48,492.00		0.60	6.02	0.90	0.08	6,053.42	45,282.71		0.00		0.00	0.00	45,282.71	18,145.00	257,953.90
16a	78,280.62	58,480.00		0.75	7.47	1.05	0.09	6,830.35	51,094.54		0.00		37,518.70	123,518.51	-72,423.97	13,527.00	192,303.29
16b	71,807.63	66,060.00		0.92	9.20	1.22	0.10	7,300.19	54,609.20		0.00		10,532.66	34,675.49	19,933.71	13,132.15	186,689.96
17	98,048.59	85,403.00		0.87	8.71	1.17	0.10	9,568.13	71,574.57		0.00		13,967.67	45,984.16	25,590.41	10,924.00	155,298.38
18	30,295.45	47,017.00		1.00	10.00	1.30	0.11	3,282.01	24,551.11		0.00		11,201.25	36,876.61	-12,325.50		0.00
19a	97,662.75	80,404.02		0.82	8.23	1.12	0.09	9,141.90	68,386.17		0.00		17,696.99	58,261.78	10,124.39	7,655.98	108,839.37
19b	107,827.58	93,487.94		0.87	8.67	1.17	0.10	10,486.35	78,443.33		0.00		32,699.22	107,651.90	-29,208.57	7,808.06	111,001.38
19c+22	100,503.12	60,990.00		0.61	6.07	0.91	0.08	7,595.07	56,815.11		0.00		1,475.76	4,858.47	51,956.64	34,387.65	488,863.66
19d	210,092.48	95,783.30		0.46	4.56	0.76	0.06	13,234.25	98,999.06		0.00		27,818.71	91,584.36	7,414.70	8,304.70	118,061.74
20+21	22,868.60	21,868.00		0.96	9.56	1.26	0.10	2,394.05	17,908.72		0.00		3,950.02	13,004.19	4,904.53		0.00
23a	76,178.50	30,391.00		0.40	3.99	0.70	0.06	4,437.04	33,191.40		0.00		17,676.06	58,192.87	-25,001.47		0.00
23b	103,778.00	55,197.00		0.53	5.32	0.83	0.07	7,194.20	53,816.34		0.00		17,276.39	56,877.07	-3,060.73	6,922.48	98,411.78
24a	31,726.50	31,243.00		0.98	9.85	1.28	0.11	3,396.74	25,409.41		0.00		8,304.96	27,341.46	-1,932.04		0.00
24b	22,756.80	22,053.00		0.97	9.69	1.27	0.11	2,406.67	18,003.14		0.00		2,507.98	8,256.72	9,746.42		0.00
25a	122,995.40	75,685.00		0.62	6.15	0.92	0.08	9,381.96	70,181.97		0.00		2,954.38	9,726.37	60,455.60		0.00
25b	63,103.30	74,422.00		1.00	10.00	1.30	0.11	6,836.19	51,138.24		0.00		17,276.39	56,877.07	-5,738.82		0.00
25c	26,874.40	25,647.00		0.95	9.54	1.25	0.10	2,809.11	21,013.60		0.00		6,633.75	21,839.55	-825.95		0.00
26+27	30,548.50	20,342.00		0.67	6.66	0.97	0.08	2,458.88	18,393.69		0.00		5,276.18	17,370.17	1,023.52		0.00
28	44,524.90	32,754.00		0.74	7.36	1.04	0.09	3,842.62	28,744.80		0.00		15,462.91	50,906.76	-22,161.96		0.00
29-existing	43,931.00	16,691.00	18,835.00	0.81	8.09	1.11	0.09	4,058.77	30,361.74	8405	15,722.06	2,101.74	0.00	0.00	30,361.74	0.00	0.00
30-existing	70,086.00	19,077.00	39,225.00	0.83	8.32	1.13	0.09	6,610.65	49,451.08	11784	22,042.68	2,946.69	0.00	0.00	49,451.08	0.00	0.00
31+32a+33	29,618.30	27,745.00		0.94	9.37	1.24	0.10	3,052.54	22,834.58		0.00		5,915.49	19,474.89	3,359.70	7,320.00	104,062.99
32b	27,130.30	26,517.00		0.98	9.77	1.28	0.11	2,888.01	21,603.79		0.00		4,736.75	15,594.26	6,009.53	7,115.00	101,148.66
34-existing	23,483.00	0.00	23,483.00	1.00	10.00	1.30	0.11	2,543.99	19,030.37	50590	94,631.63	12,650.45	0.00	0.00	19,030.37	0.00	0.00
35-existing	40,575.00	8,009.00	14,094.00	0.54	5.45	0.84	0.07	2,856.29	21,366.54	18472	34,552.98	4,619.08	0.00	0.00	21,366.54	0.00	0.00
Totals	2,809,977.47	1,527,065.26	549,564.00	30.92	309.16	42.92	3.58	240,965.09	1,802,544.19	299,726.00	560,655.47	74,948.98	365,227.67	1,202,397.27	600,146.91	326,617.70	4,643,280.80

collective par	147080	park capture	2090926.932	vol. in cubic ft.	279515.1123
collective spo	111,925	sponge capture	3182308.906		425411.0545
Collective rair	105623	rain garden capture in gallons	1620121		216577.7753
total capture	13,299,690.38	Cubic feet Water Vol	1777915.91		237671.7989
			0		
required wqc	11,497,146.20		1536950.001		205459.4761
25 yr	68,175.04		9113.707689		1218.320444
50 yr	-2,062,022.30		-275653.2036		-36849.32025
100 yr	-4,365,412.47		-583572.7049		-78011.99919

Gal. Needed to be accounted for	Individual Rain Garden Area sq ft.	Rain Gal. Captured = (61.5 in *Rain Garden Area sq ft *0.4 efficiency)*144*0.00433		7.64 in over 24 hrs = 0.636667 ft.	25 yr Storm cubic ft to gal.	25 yr Gal 8.87 in over 24 hrs = .7391667 ft.	50 yr Storm cubic ft. to gal	50 yr Gal 10.2 in over 24 hrs. =.85	100 yr Storm cubic ft to gal	100 yr Gal	Green Roofs + Parks + Rain Garden Rain Capture +	Total Rain Capture Gallons Captured above Req. WQV	Gallons captured over R	25 yr	50 yr	100 yr
257,423.42	23,053.47	0.00	0.00		263601.7847	1971878.422	306040.1455	2289339.429	351928.9	2632611.175		234,369.94	-23,053.47	-1,737,508.48	-2,054,969.48	-2,398,241.23
-1,294,580.92	-1,294,580.92	0.00	0.00		39640.71096	296533.1312	46022.63586	344273.248	52923.43457	395894.8108		1,338,895.42	1,294,580.92	1,042,362.29	994,622.17	943,000.61
-107,843.45	-107,843.45	0.00	0.00		18204.22182	136177.0454	21134.99611	158100.7611	24304.05306	181806.955		129,419.07	107,843.45	-6,757.97	-28,681.69	-52,387.88
-121,627.24	-121,627.24	0.00	0.00		25263.69146	188985.5492	29330.99948	219411.1282	33728.9945	252310.4179		145,450.41	121,627.24	-43,535.14	-73,960.72	-106,860.01
-1,158,338.89	-1,158,338.89	0.00	0.00		47347.51203	354184.0107	54970.18727	411205.5853	63212.61385	472863.2222		1,213,799.03	1,158,338.89	859,615.02	802,593.45	740,935.81
-132,867.35	-132,867.35	0.00	0.00		22240.83685	166373.0248	25821.48278	193158.1184	29693.24831	222120.9378		152,693.20	132,867.35	-13,679.83	-40,464.92	-69,427.74
13,087.79	-3,253.42	0.00	0.00		14560.57429	108920.6672	16904.74243	126456.2638	19439.5	145417.5685		16,341.21	3,253.42	-92,579.46	-110,115.05	-129,076.36
11,421.69	6,590.03	0.00	0.00		10238.24203	76587.37425	11886.5397	88917.49798	13668.85	102250.1058		4,831.66	-6,590.03	-71,755.72	-84,085.84	-97,418.45
9,460.98	-85,170.65	0.00	0.00		32208.98353	240939.9455	37394.44335	279729.8814	43001.5	321673.5808		94,631.63	85,170.65			
55,637.28	55,637.28	0.00	0.00		43710.37289	326976.3186	50747.48979	379617.6123	58356.75	436538.8355		0.00	-55,637.28	-326,976.32	-379,617.61	-436,538.84
53,942.76	53,942.76	0.00	0.00		42379.10219	317017.7215	49201.89222	368055.7388	56579.4	423243.3333		0.00	-53,942.76	-317,017.72	-368,055.74	-423,243.33
4,148.82	-17,617.02	0.00	0.00		26995.95413	201943.7748	31342.14641	234455.5531	36041.7	269610.6577		44,725.54	17,617.02			
42,197.77	42,197.77	0.00	0.00		59222.06401	443011.8342	68756.47335	514334.174	79066.065	591455.2806		12,917.23	-42,197.77	-430,094.60	-501,416.94	-578,538.05
81,051.28	59,285.44	0.00	0.00	0.00	69375.05632	518961.4963	80544.03863	602511.2919	92621.1	692853.991		21,765.84	-2,785.27	-497,195.66	-580,745.46	-671,088.15
-26,945.27	-26,945.27	0.00	0.00									48,036.28				
-212,671.18	-212,671.18	0.00	0.00		51249.65617	383374.0779	59500.55402	445095.0843	68422.28	511834.234		257,953.90	212,671.18	-125,420.18	-187,141.19	-253,880.34
-264,727.27	-264,727.27	0.00	0.00		49838.6866	372819.2919	57862.42652	432841.0389	66538.52581	497742.7731		315,821.81	264,727.27	-56,997.48	-117,019.23	-181,920.96
-166,756.24	-166,756.24	0.00	0.00		45717.54678	341991.023	53077.80705	397049.5972	61036.48338	456584.6346		221,365.44	166,756.24	-120,625.58	-175,684.15	-235,219.19
-129,707.97	-129,707.97	0.00	0.00		62424.30356	466966.2513	72474.25493	542145.1135	83341.30405	623436.2918		201,282.54	129,707.97	-265,683.71	-340,862.57	-422,153.75
-12,325.50	-12,325.50	0.00	0.00		19288.11129	144285.1023	22393.38551	167514.1682	25751.12987	192631.842		36,876.61	12,325.50	-107,408.49	-130,637.56	-155,755.23
-98,714.98	-98,714.98	0.00	0.00		62178.65184	465128.6486	72189.0547	540011.6675	83013.33988	620982.9492		167,101.15	98,714.98	-298,027.50	-372,910.52	-453,881.80
-140,209.95	-140,209.95	0.00	0.00		68650.26194	513539.6574	79702.55655	596216.5683	91653.44309	685615.4141		218,653.28	140,209.95	-294,886.38	-377,563.29	-466,962.13
-436,907.01	-436,907.01	0.00	0.00		63987.01755	478656.1645	74288.55682	555717.035	85427.64886	639043.2358		493,722.12	436,907.01	15,065.96	-61,994.91	-145,321.11
-110,647.04	-110,647.04	0.00	0.00		133758.9514	1000586.511	155293.368	1161675.145	178578.6113	1335860.874		209,646.10	110,647.04	-790,940.41	-952,029.05	-1,126,214.78
4,904.53	4,904.53	0.00	0.00		14559.68238	108913.9953	16903.70693	126448.5178	19438.30924	145408.661		13,004.19	-4,904.53	-95,909.81	-113,444.33	-132,404.47
-25,001.47	-25,001.47	0.00	0.00		48500.33706	362807.7414	56308.61046	421217.6867	64751.725	484376.5739		58,192.87	25,001.47	-304,614.87	-363,024.82	-426,183.71
-101,472.51	-101,472.51	0.00	0.00		66072.02793	494253.1263	76709.24179	573825.0174	88211.3	659866.3939		155,288.84	101,472.51	-338,964.28	-418,536.17	-504,577.55
-1,932.04	-1,932.04	0.00	0.00		20199.21558	151100.6361	23451.17231	175426.9635	26967.525	201731.1101		27,341.46	1,932.04	-123,759.18	-148,085.51	-174,389.65
9,746.42	9,746.42	0.00	0.00		14488.50359	108381.5408	16821.06876	125830.3413	19343.28	144697.7929		8,256.72	-9,746.42	-100,124.82	-117,573.62	-136,441.07
60,455.60	60,455.60	0.00	0.00		78307.11233	585777.9199	90914.10393	680084.7728	104546.09	782059.1172		9,726.37	-60,455.60	-576,051.55	-670,358.40	-772,332.74
-5,738.82	-5,738.82	0.00	0.00		40175.7887	300535.7909	46643.85802	348920.3128	53637.805	401238.6731		56,877.07	5,738.82	-243,658.72	-292,043.25	-344,361.61
-825.95	-825.95	0.00	0.00		17110.04362	127992.0235	19864.66156	148597.9981	22843.24	170879.3137		21,839.55	825.95	-106,152.47	-126,758.45	-149,039.76
1,023.52	1,023.52	0.00	0.00		19449.22185	145490.293	22580.43393	168913.3877	25966.225	194240.8654		17,370.17	-1,023.52	-128,120.13	-151,543.22	-176,870.70
-22,161.96	-22,161.96	0.00	0.00		28347.53451	212054.2988	32911.3234	246193.8129	37846.165	283108.9942		50,906.76	22,161.96	-161,147.54	-195,287.05	-232,202.23
30,361.74	14,639.68	0.00	0.00		27969.41798	209225.7906	32472.3323	242909.9312	37341.35	279332.7155		15,722.06	-14,639.68	-193,503.73	-227,187.87	-263,610.66
49,451.08	27,408.40	0.00	0.00		44621.44336	333791.5995	51805.23734	387530.114	59573.1	445637.766		22,042.68	-27,408.40	-311,748.92	-365,487.43	-423,595.09
-100,703.30	-100,703.30	0.00	0.00		18856.99421	141060.1223	21892.86107	163769.9851	25175.555	188326.2427		123,537.88	100,703.30	-17,522.24	-40,232.10	-64,788.36
-95,139.13	-95,139.13	0.00	0.00		17272.96671	129210.7729	20053.81432	150012.9591	23060.755	172506.439		116,742.92	95,139.13	-12,467.86	-33,270.04	-55,763.52
19,030.37	-75,601.26	0.00	0.00		14950.85116	111840.1411	17357.85162	129845.7562	19960.55	149315.2935		94,631.63	75,601.26	-17,208.51	-35,214.13	-54,683.66
21,366.54	-13,186.45	0.00	0.00		25832.76353	193242.5042	29991.68885	224353.4283	34488.75	257993.7842		34,552.98	13,186.45	-158,689.52	-189,800.44	-223,440.80
-4,043,133.89	-4,603,789.36	0.00	0.00	0.00	1,768,796.20	13,231,515.34	2,053,562.14	15,361,712.69	2,361,480.60	17,665,102.86	0.00	6,406,333.54	4,633,344.25	-6,569,691.53	-8,628,587.16	-10,854,878.52

										Pervious Cover existing			Green Roofs			Parks		
Parcel	Area in Sq ft.	Building in Sq. ft.	Parking Lot Sq. Ft	Imp. Cover (Building/area)	Imp2 (Imp. Cover x 10 to get 10% increments)	Required Inches Captured =0.5+0.1*(Imp2-2)	Required Ft. Captured = Req. In. Cap*0.0833333	Req. Cap Cubic Ft. = Area * Req. Ft. Cap.	Vol. in Gal = Req. Cap Cubic Ft. *7.48052	area in sq. ft.	GR Gallons Captured = (6in*area*0.3 efficiency)*144*0.00433	Cubic Ft. Captured = (6in*area*0.5 efficiency)*144*	Green Roof area in sq. ft.	GR Gallons Captured = (6in*area*0.88 efficiency)*144*0.00433	Vol. not captured by Green Roof	Park Space sq. Ft.	Gallons Captured by Park = (24in*area*0.4 efficiency)*144*0.00433	Ga ac
1+5	396,405.00	152,705.00		0.39	3.85	0.69	0.06	22,635.53	169,325.55		0.00	0.00	0.00	0.00	169,325.55	243,700.00	3,464,501.59	
2a	74,914.00	50,563.00		0.67	6.75	0.97	0.08	6,086.43	45,529.67		0.00	0.00	9,510.00	31,308.69	14,220.98	1,225.00	17,414.91	
2b	44,208.00	26,973.00		0.61	6.10	0.91	0.08	3,352.95	25,081.80		0.00	0.00	10,986.00	36,167.95	-11,086.15	0.00	0.00	
2c	59,478.00	31,817.00		0.53	5.35	0.83	0.07	4,138.37	30,957.12		0.00	0.00	13,677.00	45,027.22	-14,070.10	0.00	0.00	
2d	101,066.00	59,277.00		0.59	5.87	0.89	0.07	7,466.40	55,852.53		0.00	0.00	10,292.00	33,883.17	21,969.36	8,216.00	116,800.76	
2e	45,258.00	23,745.00		0.52	5.25	0.82	0.07	3,110.20	23,265.90		0.00	0.00	9,013.00	29,672.47	-6,406.56	0.00	0.00	
3+4	38,957.00	12,374.00	11,486.00	0.61	6.12	0.91	0.08	2,962.26	22,159.22		0.00	0.00	0.00	0.00	22,159.22	7,555.00	107,403.81	
6-existing	68,655.00	0.00	68,655.00	1.00	10.00	1.30	0.11	7,437.62	55,637.28	0.00	0.00	0.00	0.00	0.00	55,637.28	0.00	0.00	
7-existing	66,564.00	0.00	66,564.00	1.00	10.00	1.30	0.11	7,211.10	53,942.76	0.00	0.00	0.00	0.00	0.00	53,942.76	0.00	0.00	
8+9+10	70,882.00	26,372.00	13494	0.56	5.62	0.86	0.07	5,094.21	38,107.37		0.00	0.00	6,974.00	22,959.70	15,147.67	1,788.00	25,418.67	
11	89,853.00	48,159.00		0.54	5.36	0.84	0.07	6,259.57	46,824.86		0.00	0.00	19,652.00	64,698.03	-17,873.17	10,100.00	143,584.19	
12a-existing	64,880.00	34,746.00		0.54	5.36	0.84	0.07	4,517.50	33,793.24		0.00	0.00	0.00	0.00	0.00	0.00	0.00	
12b+13	65,430.00	38,146.00	0.00	0.58	5.83	0.88	0.07	4,814.58	36,015.57		0.00	0.00	0.00	0.00	36,015.57	7,677.00	109,138.20	
14	37,762.00	20,901.00		0.55	5.53	0.85	0.07	2,685.80	20,091.17		0.00	0.00	9,726.00	32,019.80	-11,928.62	0.00	0.00	
15	84,459.00	36,278.00		0.43	4.30	0.73	0.06	5,134.64	38,409.77		0.00	0.00	0.00	0.00	38,409.77	23,295.00	331,167.68	
16a	87,966.00	45,567.00		0.52	5.18	0.82	0.07	5,996.40	44,856.17		0.00	0.00	1,983.00	6,528.40	38,327.77	11,960.00	170,026.42	
16b	128,359.00	65,572.00		0.51	5.11	0.81	0.07	8,673.30	64,880.83		0.00	0.00	6,711.00	22,093.86	42,786.97	29,359.00	417,375.06	
17	129,920.00	71,677.00		0.55	5.52	0.85	0.07	9,221.08	68,978.47		0.00	0.00	14,432.00	47,512.82	21,465.65	16,771.00	238,420.83	
18	40,836.00	27,503.00		0.67	6.73	0.97	0.08	3,312.82	24,781.58		0.00	0.00	9,044.00	29,774.53	-4,992.95	0.00	0.00	
19a	111,343.00	67,299.00		0.60	6.04	0.90	0.08	8,391.82	62,775.19		0.00	0.00	9,740.00	32,065.89	30,709.30	12,438.00	176,821.79	
19b	98,087.00	72,438.00		0.74	7.39	1.04	0.09	8,488.67	63,499.68		0.00	0.00	10,475.00	34,485.64	29,014.03	5,205.00	73,995.61	
19c+22	114,995.00	61,832.00		0.54	5.38	0.84	0.07	8,027.54	60,050.16		0.00	0.00	9,192.00	30,261.77	29,788.39	22,442.00	319,041.22	
19d	125,106.00	84,604.00		0.68	6.76	0.98	0.08	10,177.98	76,136.58		0.00	0.00	9,241.00	30,423.09	45,713.49	8,677.00	123,354.45	
20+21	34,004.00	21,500.00		0.63	6.32	0.93	0.08	2,641.77	19,761.78		0.00	0.00	9,870.00	32,493.87	-12,732.09	0.00	0.00	
23a	83,663.00	42,605.00		0.51	5.09	0.81	0.07	5,641.99	42,205.01		0.00	0.00	0.00	0.00	42,205.01	10,559.00	150,109.45	
23b	99,639.00	60,740.00		0.61	6.10	0.91	0.08	7,552.64	56,497.66		0.00	0.00	0.00	0.00	56,497.66	5,660.00	80,464.01	
24a	33,511.00	12,364.00	7,626.00	0.60	5.97	0.90	0.07	2,503.61	18,728.28		0.00	0.00	0.00	0.00	18,728.28	3,031.00	43,089.47	
24b	24,242.00	8,300.00	6,035.00	0.59	5.91	0.89	0.07	1,800.63	13,469.67		0.00	0.00	0.00	0.00	13,469.67	4,597.00	65,352.13	
25a	98,056.00	66,940.00		0.68	6.83	0.98	0.08	8,029.73	60,066.56		0.00	0.00	19,437.00	63,990.21	-3,923.65	2,603.00	37,004.91	
25b	69,125.00	39,157.00	4,308.00	0.63	6.29	0.93	0.08	5,350.21	40,022.32		0.00	0.00	0.00	0.00	40,022.32	8,098.00	115,123.24	
25c	28,181.00	13,920.00		0.49	4.94	0.79	0.07	1,864.52	13,947.61		0.00	0.00	2,670.00	8,790.14	5,157.48	2,415.00	34,332.26	
26+27	32,457.00	15,193.00		0.47	4.68	0.77	0.06	2,077.51	15,540.84		0.00	0.00	6,255.00	20,592.62	-5,051.78	0.00	0.00	
28	44,136.00	23,753.00		0.54	5.38	0.84	0.07	3,082.82	23,061.06		0.00	0.00	17,715.00	58,321.07	-35,260.01	0.00	0.00	
29-existing	43,931.00	16,691.00	18,835.00	0.81	8.09	1.11	0.09	4,058.77	30,361.74	8405	15,722.06	2,101.74	0.00	0.00	30,361.74	0.00	0.00	
30-existing	70,086.00	19,077.00	39,225.00	0.83	8.32	1.13	0.09	6,610.65	49,451.08	11784	22,042.68	2,946.69	0.00	0.00	49,451.08	0.00	0.00	
31+32a+33	36,450.00	16,179.00		0.44	4.44	0.74	0.06	2,259.50	16,902.23		0.00	0.00	0.00	0.00	16,902.23	3,535.00	50,254.46	
32b	33,732.00	15,600.00		0.46	4.62	0.76	0.06	2,143.30	16,032.99		0.00	0.00	0.00	0.00	16,032.99	3,217.00	45,733.70	
34-existing	23,483.00	0.00	23,483.00	1.00	10.00	1.30	0.11	2,543.99	19,030.37	50590	94,631.63	12,650.45	0.00	0.00	19,030.37	0.00	0.00	
35-existing	40,575.00	8,009.00	14,094.00	0.54	5.45	0.84	0.07	2,856.29	21,366.54	18472	34,552.98	4,619.08	0.00	0.00	21,366.54	0.00	0.00	
Totals	2,940,654.00	1,438,576.00	273,805.00	23.78	237.82	35.48	2.96	216,214.68	1,617,398.24	89,251.00	166,949.35	22,317.96	216,595.00	713,070.94	870,534.06	454,123.00	6,455,928.82	

collective park	615440	park capture	3683895.828
collective sponge park	211,437	sponge capture	6011685.04
collective Rain Garden	90,707	rain garden capture	1391317.665
collective Stoop Garden	104,441	stoop garden capture	1601977.887
collective sidewalks	67250	sidewalk capture	301908.384
total capture	20,326,733.92		91253700.95
required wqcv	18,709,335.68		83992643.87
25 yr	6,321,574.51		28379722.6
50 yr	4,066,824.95		18257376.19
100 yr	1,628,756.02		7312046.052

appendix item 4

Gal. Needed to be accounted for	Individual Rain Garden Area sq ft.	Rain Gal. Captured = (61.5 in *Rain Garden Area sq ft *0.4 efficiency)*144*0.00433		7.64 in over 24 hrs = 0.636667 ft.	25 yr Storm cubic ft to gal.	25 yr Gal 8.87 in over 24 hrs = .7391667 ft.	50 yr Storm cubic ft. to gal	50 yr Gal 10.2 in over 24 hrs. =.85	100 yr Storm cubic ft to gal	100 yr Gal	Green Roofs + Parks + Rain Garden Rain Capture +	Total Rain Capture Gallons Captured above Req. WQV	Gallons captured over R	25 yr	50 yr	100 yr
-3,295,176.03	-3,295,176.03	0.00	0.00		252377.9821	1887918.543	293009.3757	2191862.495	336944.25	2520518.201		3,464,501.59	3,295,176.03	1,576,583.04	1,272,639.09	943,983.39
-3,193.93	-3,193.93	0.00	0.00		47695.27164	356785.4334	55373.93416	414225.822	63676.9	476336.324		48,723.60	3,193.93	-308,061.83	-365,502.22	-427,612.73
-11,086.15	-11,086.15	0.00	0.00		28145.77474	210545.0308	32677.08147	244441.5615	37576.8	281094.0039		36,167.95	11,086.15	-174,377.08	-208,273.61	-244,926.05
-14,070.10	-14,070.10	0.00	0.00		37867.67983	283269.9363	43964.15698	328874.7556	50556.3	378187.4133		45,027.22	14,070.10	-238,242.71	-283,847.53	-333,160.19
-94,831.40	-94,831.40	0.00	0.00		64345.38702	481336.9545	74704.6217	558829.4167	85906.1	642622.2992		150,683.93	94,831.40	-330,653.02	-408,145.48	-491,938.37
-6,406.56	-6,406.56	0.00	0.00		28814.27509	215545.7611	33453.20651	250247.3804	38469.3	287770.368		29,672.47	6,406.56	-185,873.29	-220,574.91	-258,097.90
-85,244.59	-85,244.59	0.00	0.00		24802.63632	185536.617	28795.71713	215406.9379	33113.45	247705.825		107,403.81	85,244.59	-78,132.80	-108,003.12	-140,302.01
55,637.28	55,637.28	0.00	0.00		43710.37289	326976.3186	50747.48979	379617.6123	58356.75	436538.8355		0.00	-55,637.28	-326,976.32	-379,617.61	-436,538.84
53,942.76	53,942.76	0.00	0.00		42379.10219	317017.7215	49201.89222	368055.7388	56579.4	423243.3333		0.00	-53,942.76	-317,017.72	-368,055.74	-423,243.33
-10,270.99	-10,270.99	0.00	0.00		45128.23029	337582.6293	52393.61403	391931.4776	60249.7	450699.0858		48,378.37	10,270.99	-289,204.26	-343,553.11	-402,320.72
-161,457.36	-161,457.36	0.00	0.00		57206.43995	427933.9182	66416.3455	496828.8008	76375.05	571325.089		208,282.22	161,457.36	-219,651.70	-288,546.58	-363,042.87
0.00	33,793.24	0.00	0.00		41306.95496	308997.5027	47957.1355	358744.3112	55148	412535.717		0.00	-33,793.24	-308,997.50	-358,744.31	-412,535.72
-73,122.62	-73,122.62	0.00	0.00	0.00	41657.12181	311616.9328	48363.67718	361785.4544	55615.5	416032.8601		109,138.20	73,122.62	-202,478.74	-252,647.26	-306,894.66
-11,928.62	-11,928.62	0.00	0.00		24041.81925	179845.3098	27912.41293	208799.3631	32097.7	240107.4868		32,019.80	11,928.62	-147,825.51	-176,779.57	-208,087.69
-292,757.91	-292,757.91	0.00	0.00		53772.25815	402244.4526	62429.28032	467003.48	71790.15	537027.6529		331,167.68	292,757.91	-71,076.77	-135,835.80	-205,859.97
-131,698.65	-131,698.65	0.00	0.00		56005.04932	418946.8916	65021.53793	486394.9149	74771.1	559326.709		176,554.83	131,698.65	-242,392.07	-309,840.09	-382,771.88
-374,588.09	-374,588.09	0.00	0.00		81721.93945	611322.6025	94878.69845	709742.0013	109105.15	816163.2567		439,468.92	374,588.09	-171,853.69	-270,273.08	-376,694.34
-216,955.18	-216,955.18	0.00	0.00		82715.77664	618757.0215	96032.53766	718373.3186	110432	826088.7846		285,933.65	216,955.18	-332,823.37	-432,439.67	-540,155.13
-4,992.95	-4,992.95	0.00	0.00		25998.93361	194485.5429	30184.61136	225796.589	34710.6	259653.3375		29,774.53	4,992.95	-164,711.02	-196,022.06	-229,878.81
-146,112.49	-146,112.49	0.00	0.00		70888.41378	530282.1971	82301.03788	615654.5599	94641.55	707968.0076		208,887.68	146,112.49	-321,394.52	-406,766.88	-499,080.33
-44,981.58	-44,981.58	0.00	0.00		62448.75603	467149.1685	72502.6441	542357.4793	83373.95	623680.5005		108,481.26	44,981.58	-358,667.91	-433,876.22	-515,199.24
-289,252.83	-289,252.83	0.00	0.00		73213.52167	547675.2131	85000.47467	635847.7508	97745.75	731189.0378		349,302.99	289,252.83	-198,372.23	-286,544.76	-381,886.05
-77,640.96	-77,640.96	0.00	0.00		79650.8617	595829.864	92474.18917	691755.0216	106340.1	795479.2449		153,777.54	77,640.96	-442,052.32	-537,977.48	-641,701.70
-12,732.09	-12,732.09	0.00	0.00		21649.22467	161947.4581	25134.62447	188020.061	28903.4	216212.4618		32,493.87	12,732.09	-129,453.59	-155,526.19	-183,718.59
-107,904.43	-107,904.43	0.00	0.00		53265.47122	398453.4228	61840.90362	462602.1164	71113.55	531966.333		150,109.45	107,904.43	-248,343.98	-312,492.67	-381,856.89
-23,966.34	-23,966.34	0.00	0.00		63436.86321	474540.724	73649.83082	550939.0325	84693.15	633548.8024		80,464.01	23,966.34	-394,076.72	-470,475.02	-553,084.79
-24,361.19	-24,361.19	0.00	0.00		21335.34784	159599.4962	24770.21528	185294.0908	28484.35	213077.7499		43,089.47	24,361.19	-116,510.02	-142,204.62	-169,988.28
-51,882.46	-51,882.46	0.00	0.00		15434.08141	115454.9547	17918.87914	134042.5338	20605.7	154141.351		65,352.13	51,882.46	-50,102.83	-68,690.40	-88,789.22
-40,928.57	-40,928.57	0.00	0.00		62429.01935	467001.5278	72479.72994	542186.0694	83347.6	623483.3888		100,995.13	40,928.57	-366,006.40	-441,190.94	-522,488.26
-75,100.92	-75,100.92	0.00	0.00		44009.60638	329214.7407	51094.89814	382216.4074	58756.25	439527.3033		115,123.24	75,100.92	-214,091.50	-267,093.17	-324,404.06
-29,174.78	-29,174.78	0.00	0.00		17941.91273	134214.837	20830.45677	155822.6485	23953.85	179187.254		43,122.39	29,174.78	-91,092.44	-112,700.25	-136,064.86
-5,051.78	-5,051.78	0.00	0.00		20664.30082	154579.7156	23991.13358	179466.1546	27588.45	206375.952		20,592.62	5,051.78	-133,987.09	-158,873.53	-185,783.33
-35,260.01	-35,260.01	0.00	0.00		28099.93471	210202.1236	32623.86147	244043.4482	37515.6	280636.1961		58,321.07	35,260.01	-151,881.06	-185,722.38	-222,315.13
30,361.74	14,639.68	0.00	0.00		27969.41798	209225.7906	32472.3323	242909.9312	37341.35	279332.7155		15,722.06	-14,639.68	-193,503.73	-227,187.87	-263,610.66
49,451.08	27,408.40	0.00	0.00		44621.44336	333791.5995	51805.23734	387530.114	59573.1	445637.766		22,042.68	-27,408.40	-311,748.92	-365,487.43	-423,595.09
-33,352.24	-33,352.24	0.00	0.00		23206.51215	173596.7783	26942.62622	201544.8543	30982.5	231765.2109		50,254.46	33,352.24	-123,342.31	-151,290.39	-181,510.75
-29,700.70	-29,700.70	0.00	0.00		21476.05124	160652.0309	24933.57112	186516.0775	28672.2	214482.9655		45,733.70	29,700.70	-114,918.34	-140,782.38	-168,749.27
19,030.37	-75,601.26	0.00	0.00		14950.85116	111840.1411	17357.85162	129845.7562	19960.55	149315.2935		94,631.63	75,601.26	-17,208.51	-35,214.13	-54,683.66
21,366.54	-13,186.45	0.00	0.00		25832.76353	193242.5042	29991.68885	224353.4283	34488.75	257993.7842		34,552.98	13,186.45	-158,689.52	-189,800.44	-223,440.80
		0.00														
-5,585,394.76	-5,718,550.87	0.00	0.00	0.00	1,872,217.36	14,005,159.41	2,173,633.51	16,259,908.97	2,499,555.90	18,697,977.90	0.00	7,335,949.11	5,718,550.87	-6,669,210.29	-8,923,959.85	-11,362,028.79