GREEN INFRASTRUCTURE: A NEW STRATEGY FOR STORMWATER MANAGEMENT IN DOWNTOWN WICHITA

by

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A Report

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Abstract

Wichita is an historic keystone in American history Since 2002 Wichita has begun another period of urbanization and the Wichita Downtown Development Corporation (WDDC) was formed to help facilitate the needs of both the people wanting to move downtown and the developers who aim to realize the city's historic potential. With the help of the WDDC the City of Wichita adopted the Project Downtown Master Plan developed by the Boston based firm Goody Clancy in 2010.

The Project Downtown has a market driven development strategy that has little concern for ecology. The economically driven master plan gives little reason for a developer to be ecologically and socially oriented. The City of Wichita does have a rudimentary incentive focused on public infrastructure. Essentially, the City of Wichita will front the money to help develop the public infrastructure of a site to ease the total development costs. This is the key to begin defining the Project Downtown's green spaces that are socially and ecologically oriented. Green infrastructure is a method of developing land used by pedestrian, automobile, and other human needs in a way that is ecologically sensitive. The general idea of green infrastructure is to open up the barrier of an impermeable infrastructure created by urban development to the soil below. The goal is to get as close to an undeveloped footprint as possible while still meeting the needs of the humans who occupy the area.

This project looks at the Catalyst Site C-2 (chosen by the Project Downtown as an integral step of development) and designs the given program using several green infrastructure techniques. The proposed design is treated as a pilot project intended to treat 80% of the stormwater runoff developed by the building, automobile, and pedestrian space during a two year, one hour storm. This schematic design would cost roughly $536,00 designed using traditional grey infrastructure of impervious pavements that drain directly to the Arkansas River. By implementing green infrastructure the costs total roughly $533,000 saving $4,000 and greatly improving the ecological and social benefits of the design.

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3 Introduction

3.1 Background

3.1.1 Wichita History

3.1.1.1 Formation

Wichita was formed around the location at which the Arkansas River and the Little Arkansas River meet. The first European settlers came to the area in the 1850's and 1860's because of the rich wildlife resulting from the adjacency to the Arkansas and Little Arkansas rivers. The first recorded permanent settlement was in 1863 by the Wichita Native Americans. The City of Wichita was incorporated in 1870 as a village and became the county seat of Sedgwick County. A military post, Camp Breecher, provided a market for local business as well as the railroad that was introduced by 1872. By 1886 business had grown large enough to incorporate the City of Wichita as a city of first class and it became the regions principal city

3.1.1.2 Aviation

The City of Wichita first experienced substantial growth during the post-Civil War era (Figure 3.1). The two world wars also provided the city with means of growth, primarily from the new aviation business. The first plane, the Cessna Comet, was manufactured in Wichita in 1917. During the 20th century war periods aviations' affinity with Wichita designated the area as the, "air capital." The aviation business brought a large number of manufacturing jobs throughout the 1940's and led to a subsequent population boom. The Wichita Air Force Base activated in 1951 provided another boost to population and increased the entrepreneurial spirit of the City of Wichita. Other notable companies starting in the area because of these population booms are: Boeing, Beech, Lear, Cessna, Coleman, White Castle, Pizza Hut, and Koch Industries.

Figure 3.1 1936 aerial view of downtown Wichita looking southwest (Barnes Flying Service 1936).

3.1.1.3 Modern Metropolitan Urbanization

Human urbanization was a steady trend for the first 75 years as a nation. By the end of the Civil War, however, urbanization began to spike. Urban growth was a result of trains and other transportation methods. The end of the first world war marked the first peak of downtown residency in America. The rapid increase of automobile ownership allowed the average American to migrate away from the downtown (Auch, Taylor and Acevedo 2004).

After the general decentralization from metropolitan areas in America from the 60's up to 2000, Wichita began to reinvest in the downtown core. In 2002 the Wichita Downtown Development Corporation, or WDDC, was launched to facilitate revitalization of the city center.

3.1.2 WDDC

The WDDC (Figure 3.2) is, as their name suggests, the backbone of the downtown development in Wichita. In practice the WDDC works to both assist native developers of Wichita and to bring new forward thinking developers in from around the nation. WDDC contracts with the city of Wichita on an annual basis and is funded through a Self Supported Municipal Service District (SSMID). With a very hands-on approach, the WDDC has been able to sustain growth; even during the economic down of recent years. In their most recent annual report from 2011 they claim proudly, “over $60 million completed in 2011, over $94 million in progress, over $20 million initiation in 2012” (Wichita Downtown Development Corperation 2011)

The success of the WDDC has gained them trust from their array of clients; these include a handful of regular ambitious developers, the city of Wichita itself, and social groups such as the Rotary International or the Young Professionals of Wichita. Alongside this trust, the WDDC is governed by a 25-member board of directors. Any person concerned with the vitality of the Downtown may apply and be elected by the members of the organization. These traits give WDDC the ability and credit to help guide the future of the Wichita Downtown.

A recent and key tool the WDDC has in its deployment is the Downtown master plan, developed by Boston based firm Goody Clancy. This master plan was conceived from 2009-2010 through a partnership with the City of Wichita. The idea was to produce a master plan that had a high degree of input from the people affected by the project; this included citizens, business owners, and developers. The partnership yielded $500,000; the WDDC provided $175,000 in seed capital, the City of Wichita provided $225,000, and the WDDC raised an additional $100,000 through the private sector to fund a new master plan. Through a RFP, or request for proposal, process, 32 firms were considered and four finalists were selected to present to the public and Goody Clancy was eventually chosen in September 2009.

The process was expedited from then on. In October a City-to-City visit to Chattanooga Tennessee was undertaken to hold a forum between Goody Clancy and 63 local business leaders and government leaders. The goal was to enlighten project leaders of challenges involved from the viewpoint of Chattanooga, a successful city similar to Wichita.

November marked the beginning of the community data collection. In December a “Walk-Shop” was conducted. This consisted of over 100 people presenting over 800 images of what they believed to be Downtown Wichita’s greatest assets, opportunities and challenges. Initial findings were presented in January, 2010. 350 individuals were in attendance and the research presented covered housing, commercial markets,

Figure 3.2 The Wichita Downtown Development Corporation (Author 2013).

hotel industry, and retail.

In February the second annual lecture put on by WDDC featured Jim Cloar, the past chair of the Urban Land Institute. It was at this time the Master Plan Charrette was held. 140 citizens attended a seven hour planning session to explore possibilities for the future development of Wichita.

In April Goody Clancy presented their vision statement for the Wichita Downtown for community input. In September the master plan was given a formal title, "*Project Downtown.*" In November the Planning Commission adopted the master plan as well as the City Council in December.

The result of this process was a master plan that met the goals of what the city needed; a plan for economic redevelopment (Wichita Downtown Development Corperation 2011).

3.1.3 Project Downtown

3.1.3.1 Master Plan Vision

The Project Downtown is a plan that projects for 20 years of development (Figure 3.4). The plan was developed to positively impact property and business owners, cultural organizations, city and county staff, and other key stakeholders in the downtown area. The plan addresses how to foster development, who should enact this development, who it will affect, as well as when and where key developments should take place.

3.1.3.2 Master Plan Appendix

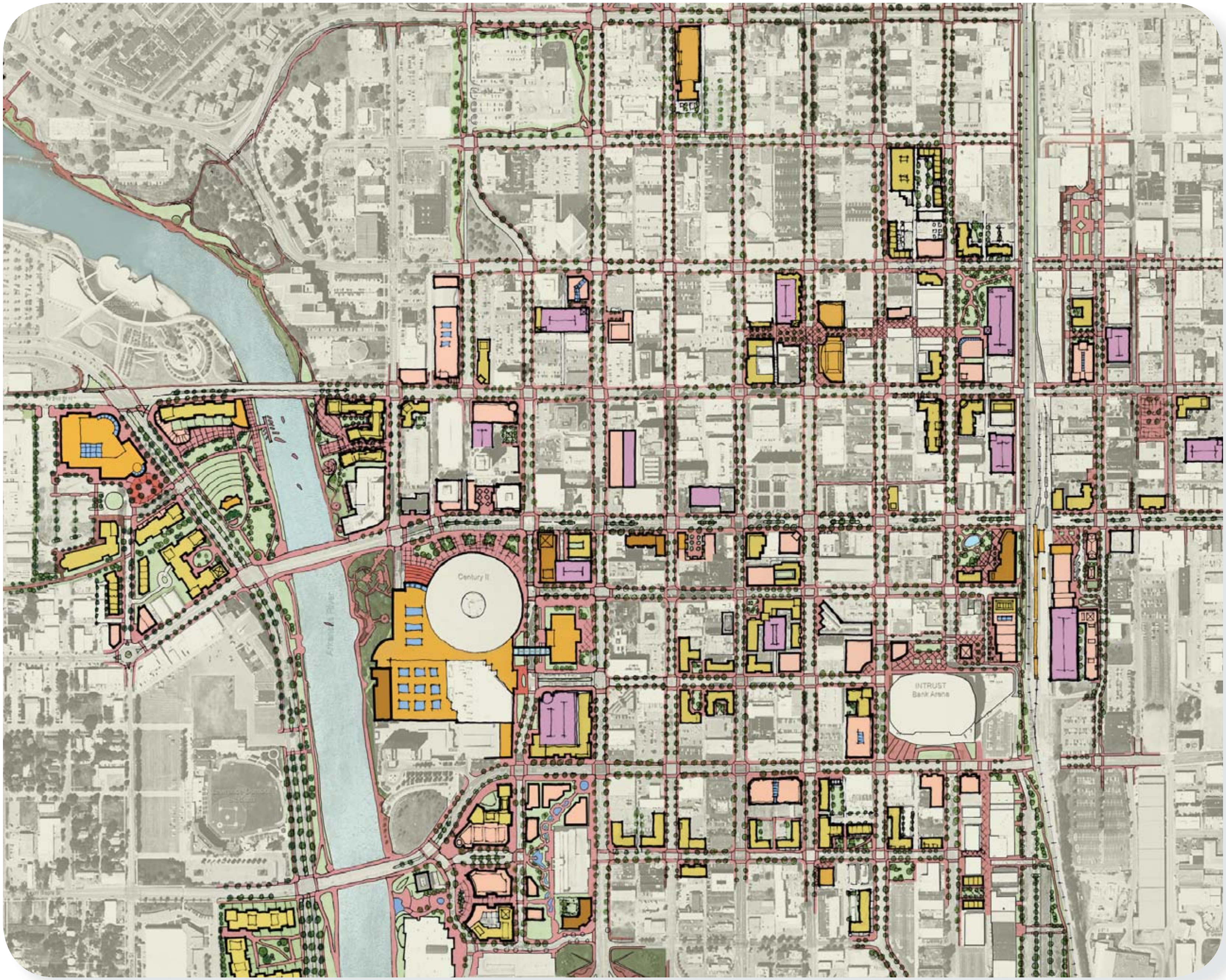
As an appendix to the Goody Clancy master plan, an additional document outlining an extensive market analysis, transportation plan, development guidelines, and an implementation matrix to measure success was included. This appendix was designed to be a fine grain planning effort to assist the master plan.

The market-based analysis of residential, office, hotel, and retail was conducted by three nationally recognized specialists: Laurie Volk of Zimmerman/Volk Associates, Sarah Woodworth of W-ZHA, and Michael Berne of MJB Consulting. The analysis conducted covered a base market analysis and a projected long-term demand. The analysis was conducted in 2010 and projected demand for the next 5 to 7 years.

The transportation analysis looked back to the 1920's when Wichita had multi modal transportation options. Modern development patterns were partially responsible for the fall of historic transport patterns (Figure 3.3). "Super-block" development began to break up the original street grid, destination developments began to fragment and grow away from the downtown core, and the mix of one-and two-way streets made streets unfamiliar to the growing personal automobile presence.

Figure 3.3 Douglas Avenue in the 1920's (Unknown photographer 1922).

Figure 3.4 Illustrative master plan concept developed by Goody Clancy (Goody Clancy 2010).



3.2 Issues

3.2.1 Lack of Master plan focus

3.2.1.1 Summary Master Plan

The Project Downtown Master Plan has always had a focus on economic development. Throughout the master plan there are periodic references to "green streets" and "green spaces" but never a strict definition. Focusing on economics has helped gain development momentum downtown but the focus on specific design suggestion never reaches levels of clarity needed to actually persuade the green development proposed in the master plan. Green infrastructure can be defined as an approach to wet weather management that use natural systems — or engineered systems that mimic natural processes — to enhance overall environmental quality and provide utility services such as storm and wastewater management. As a general principal, green infrastructure techniques use soils and vegetation to infiltrate, evapotranspire (the release of water vapor into the air after a plant uses water absorbed from the environment), and/or recycle stormwater runoff (US EPA 2012). The Project Downtown refers to green streets, corridors, and parks but not clearly enough for anyone reading to understand what is meant. A lack of clarity in definition has lead most new or redevelopments downtown to keep traditional grey infrastructure or, "the hard, engineered systems to capture and convey runoff, such as gutters, storm sewers, tunnels, culverts, detention basins, and related systems" (Odefey, et al. 2012).

3.2.2 Stormwater Stress along the Arkansas River

Development along a river is an essential pattern in civilizations. As a result urban density is also found along rivers. The Arkansas River cuts through Wichita and is the western border of the metropolitan area. Urban areas, such as the downtown of Wichita, tend to have a high degree of impermeable surfaces. These surfaces are composed of roofs, pedestrian, and automobile pavement. Ground surface that is converted to impermeable materials for human infrastructure increases the amount and rate of runoff in a storm event. This can lead to higher peak flow rates and increase the chance of flooding. Wichita has a spotted history of flooding along the Arkansas River (Table 3.1) An additional issue with high flow rates is an increased rate of erosion. Erosion can cause issues in areas directly related to the impervious areas (Figure 3.5) as well as stream stability further downstream.

Figure 3.5 The Arkansas Riverfront downtown (Author, 2013)

Table 3.1 Flooding along the Arkansas River near Wichita (USGS 2013).

Date	Notes
5/18/1877	Flood reached 21 ft, Wichita's flood stage is 12 ft.
6/8/1923	7.06 in of rain. Millions of dollars of damage reported
4/23/1944	6.03 in of rain. Damage estimated $5 million
July/1951	Estimated $2,868,000 in damages
5/16/1957	The Cowskin floodway diverted 1/3 of peak flow
8/31/1998	170 homes affected, $4 million in damages

Another issue related to development along a river is contamination from urban development. Total suspended solids, or TSS, is listed as a conventional pollutant in the U.S. Clean Water Act. These solids are produced by human waste, automobile emissions, and other pollution producing outlets. Normally these wastes are sent to a water treatment facility. However, if there is an overflow or development that drains to a river without first passing through a treatment facility these solids are sent directly into the stream. An area of high TSS content can come under scrutiny from the EPA and fines can ultimately be issued if the standards of the Clean Water Act are not met.

3.3 Thesis

3.3.1 Project Statement

Green infrastructure is usually more socially, economically, and ecologically successful when compared to traditional grey infrastructure (Benedict and McMahon 2002). Using GIS, or geospatial information systems, to uncover areas in the Downtown of Wichita that are most suitable for green roofs, rain gardens, rainwater harvesting, porous or pervious pavements, and vegetated swales will show new developers and existing landowners where green infrastructure should be implemented. Modifying the existing investment policy developed by Goody Clancy to promote green infrastructure in these suitable areas will grow a local precedent and encourage other landowners and developers to use green infrastructure improving the overall aesthetic quality of the Wichita Downtown.

An extended explination of the ArcGIS process is outlined in appendix 9.3.

3.3.2 Solution Development

The primary goal of this project is to discover the most ideal sites to implement green infrastructure in downtown Wichita in order to better capitalize on their public investment policy. Investing in green infrastructure will meet the aesthetic and social goals of the Project Downtown master plan. The suitability of 5 different green infrastructure options will be assessed to determine where, in the downtown, will have the most successful use of the SSMID funds. Once the areas with the highest concentration of suitable green infrastructure types have been discovered, using a qualitative and quantitative analysis developed using geospatial data, site specific design options will be explored. A quantitative cost of implementation can be compared to the qualitative social, economic and ecologic benefits of each design. Together the analysis, design, and comparison will clearly define areas that Downtown Wichita can better implement their public infrastructure investments. The WDDC, who normally acts as the facilitator for new development downtown, can use these refined investment opportunities to promote green infrastructure with quantitative data to ensure success. Existing landowners can also be notified if they possess property that has a high amount of suitability so that green infrastructure can also begin implementation in the private sector.

4 Research

4.1 Defining Green Infrastructure

4.1.1 Grey Infrastructure

Grey infrastructure is an approach to stormwater management that uses hard engineered surfaces to convey water from human environments. The structure is generally composed of gutters, storm sewers, tunnels, culverts, and detention basins. All of these components either drain to a water treatment facility or body of water (Figure 4.1). In older cities, sewage and storm sewers are combined and can cause overflows into adjacent rivers. Fortunately Wichita does not have a combined sewer system; however, storm water is still directed to a treatment facility. Though Wichita does not run a risk of a combined sewer system overflow, treating stormwater can be redundant for non-potable uses and a source of unnecessary costs (Odefey, et al. 2012).

4.1.2 Green Infrastructure

Green infrastructure is a natural or engineered ecological system that acts as living infrastructure. The process of implementing green infrastructure brings natural vegetation and soils into an urban community's inherently grey infrastructure. The primary function of green infrastructure is to manage stormwater by infiltration into the ground and onsite collection but green infrastructure also provides additional social, economic, and environmental benefits not commonly found in traditional infrastructure (Figure 4.2). A community that is invested in the protection of natural water resources, such as the Arkansas River, will find that modifying the urban environment by bringing in more vegetation and soil and opening up impervious surfaces will have a substantial positive impact (University of Louisville 2009).

Figure 4.1 Gray infrastructure stormwater management strategy (Author 2013)

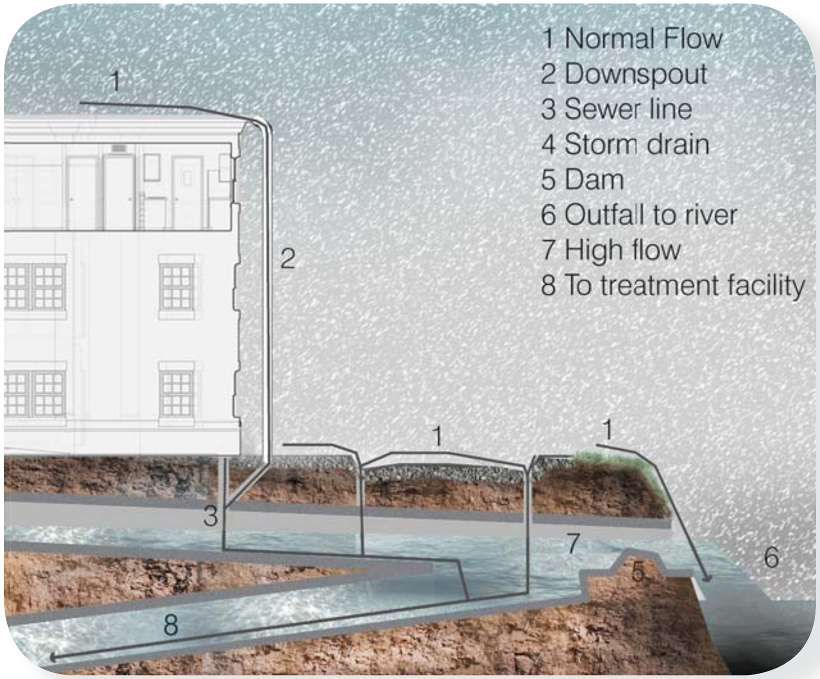
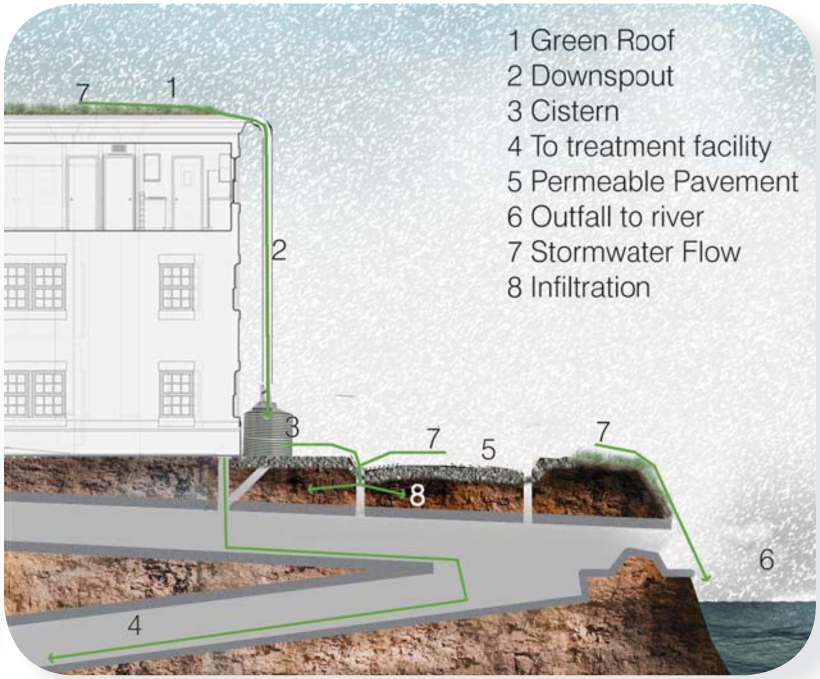


Figure 4.2 Green infrastructure stormwater management strategy (Author 2013)



4.1.2.1 Water Management

The main function of green infrastructure is to divert water away from sewer systems. This is primarily accomplished in two ways. The first method of water management is by means of vegetation and soil absorption and the other is stormwater harvesting. Using stormwater to water native plantings can cut irrigation costs severely and stormwater harvesting can cut costs on other small landscape, and non-potable reliant uses.

4.1.2.2 Water Treatment

Another function of green infrastructure related to water management is water treatment. Contaminates that are conveyed across the impermeable surfaces go to a water treatment facility in a standard gray infrastructure system. When green infrastructure allows that contaminated water to pass through vegetation and soil, some or all of the contaminates can be absorbed and treated naturally. This can lead to water treatment cost decreases and cleaner water.

4.1.2.3 Green Infrastructure Theory

A review of a journal article by Mark A. Benedict and Edward T. McMahon (2002) titled Green Infrastructure: Smart Conservation for the 21st Century was key in developing a suitability concept central to this project. The main concept of this article was that successful green infrastructure approaches can be designed following a set of seven principles:

Principle 1: Green infrastructure should function as the framework for conservation and development.

Principle 2: Design and plan green infrastructure before development.

Principle 3: Linkage is key

Principle 4: Green infrastructure functions across jurisdictions and at different scales.

Principle 5: Green infrastructure is grounded in sound science and land use planning theories and practices

Principle 6: Green infrastructure is a critical public investment.

Principle 7: Green infrastructure engages key partners and involves diverse stakeholders.

Green Infrastructure: Smart Conservation for the 21st Century (Benedict and McMahon 2002) also addresses urban sprawl and its relation to ecosystem fragmentation. Benedict and McMahon suggest that green infrastructure can become a sort of ecosystem bridge that can be introduced into fragmented areas to improve water management capabilities, ecosystem repair, and increase social; cultural; and didactic abilities.

4.2 Green Infrastructure Benefits

4.2.1 Water Quality

By allowing stormwater to filter through vegetation and other natural materials such as soil and gravel the concentration of pollutants in stormwater is reduced (Figure 4.3). Stormwater that drains to open water bodies like the Arkansas River contains sediment picked up from the urban environment. Vegetation acts as a filter to trap the urban sediment and the vegetation and other microorganisms work to breakdown the filtered pollutants that are captured. Natural water treatment also reduces the need for costly water treatment plants (University of Louisville 2009).

4.2.2 Reduction and Delay of Stormwater Runoff

When water passes through vegetation and soil, all or a portion of that water sinks into the ground (Figure 4.4). This infiltration reduces the volume of water sent to wastewater infrastructure in a combined sewer system. The effect of this is a reduction of the peak flow occurrence in the combined sewer systems from a storm and the reduction of a chance for a combined sewer overflow (EPA 2010). Porous ground cover also helps by allowing stormwater to reach soil that a traditional impervious groundcover would block.

Figure 4.3 Diagram of stormwater filtration (Author 2013)

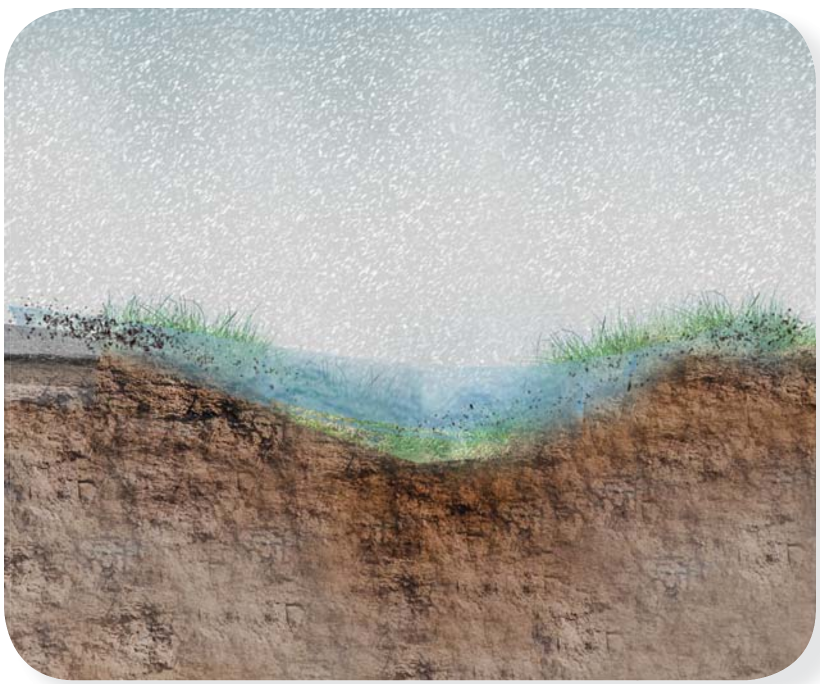
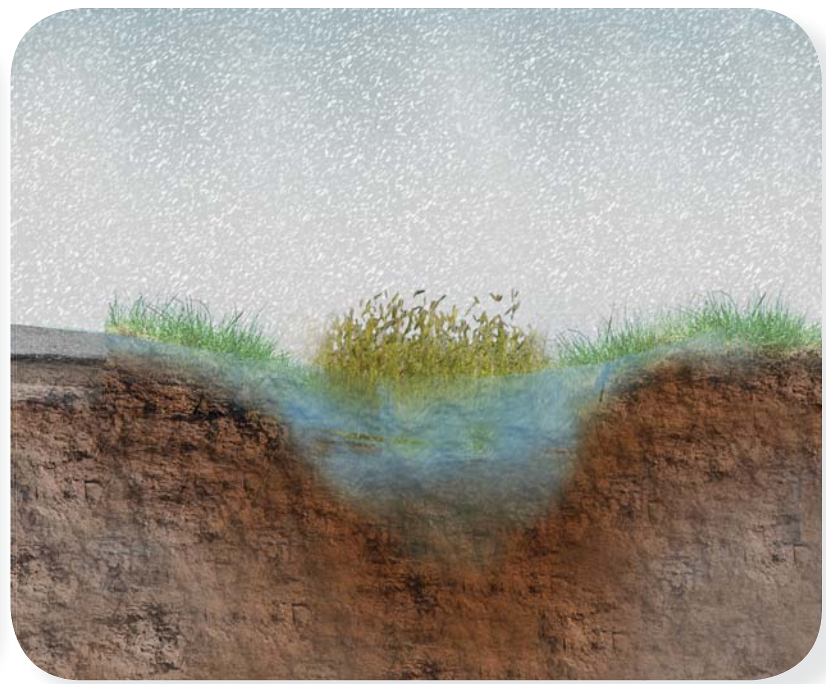


Figure 4.4 Diagram of stormwater infiltration (Author 2013)



4.2.3 Air Quality

Vegetation is a natural way to sequester carbon dioxide and other air pollutants (Figure 4.5). By implementing green infrastructure into the urban environment, the volume of plant material will be boosted resulting in more carbon sequestration (University of Louisville 2009). The temperature reduction provided by increased vegetation cover in urban areas also reduces the ground-level ozone pollution from industrial facilities and electric utilities (EPA 2012).

4.2.4 Energy Demand Reduction and Efficiency

The urban heat island effect and ground-level ozone pollution is reduced by green infrastructure. These benefits come from a lowered reliance on air-conditioning and the power plant emissions energy production creates. Buildings that have vegetation on them also receive a second form of insulation from the combination of plant material, and growing medium (Figure 4.6). Also, by diverting stormwater from management plants, wastewater treatment costs are reduced (University of Louisville 2009).

Figure 4.5 Diagram of carbon sequestration (Author 2013)

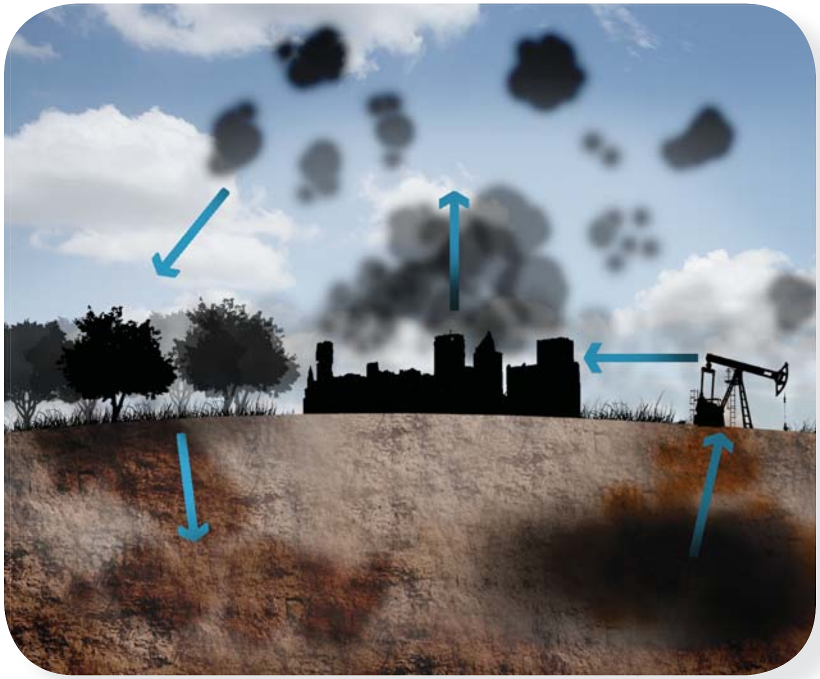


Figure 4.6 Diagram of solar absorption and building insulation (Author 2013)

4.2.5 Economic Savings

Maintenance work on traditional grey infrastructure is often costly. Grey infrastructure is typically comprised of cast-in-place concrete that must be destroyed and rebuilt for repairs. Permeable pavers, soil, and some vegetation, can simply be moved for maintenance and then replaced once complete; generating little to no extra cost. The operation of a waste water management facility that the grey infrastructure drains to is also a costly component of traditional infrastructure. The city of Wichita Public Works & Utilities Sewage Treatment Division operates and maintains four Wastewater Treatment Facilities: The Lower Arkansas River Water Quality Reclamation Facility has design capacity to treat 54.4 million gallons per day (MGD) of wastewater and is discharged into the Arkansas River; the Four Mile Creek Water Quality Reclamation Facility is designed to treat 3.0 MGD of wastewater and discharges into Four Mile Creek; the Cowskin Creek Water Quality Reclamation Facility is designed to treat 2.0 MGD and the discharge from this facility is received by two ponds that are available for recreational fishing to the public; the Mid-Continent Water Quality Reclamation Facility is designed to treat 3.0 MGD and also drains into Cowskin Creek (City of Wichita 2013). By diverting stormwater away from waste water treatment facilities the amount of water to be treated can drop dramatically. The reduction of stormwater and water pollutants was proven by the Jordan Cove Urban Watershed project in Connecticut, 2009 that looked at a control site developed in 1988, a new traditionally developed site, and a new site developed with green infrastructure. The site developed using better management practices (green infrastructure as well as clustered development) had much less storm and pollutant particulate runoff from nonpoint sources (Bedan and Clausen 2009). An additional benefit of managing stormwater is the reduction of large stormwater flows into the Arkansas River. Lowering peak flows can reduce flood associated stormwater damages (University of Louisville 2009).

4.3 Green Infrastructure Design Strategy

Once a community has decided to implement green infrastructure with a strong guiding policy, locations that are most suitable to support green infrastructure must be determined. Using design as a means for validating the implementation of green infrastructure is known as, “value engineering” (University of Louisville 2009). Value engineering compares the cost and value of green infrastructure verses traditional infrastructure. If green infrastructure is more cost effective then areas that are most ideal can be chosen for the best value to cost. The first step of value engineering is to identify factors that can be considered such as food capacity, water treatment, allowable/ desired runoff, on-site water requirements, groundwater recharge needs, landscape amenity opportunity, habitat needs, and recreational needs. The second step is to develop a project schematic using traditional forms of infrastructure, and estimate initial and lifecycle costs. Third, develop an alternative using green infrastructure, then estimate cost and lifecycle costs. Fourth, compare costs and value to determine best value. The cost and benefit analysis is not entirely monetary, and can be assessed through public forum and review, as a fair amount of green infrastructures create value through ecological and social means (University of Louisville 2009).

4.4 Green Infrastructure Policy Strategy

4.4.1 Stormwater Regulations

Local stormwater codes are usually driven by the EPA and NPDES permits. Requiring a project to manage all or a significant part of its stormwater on-site has the highest success rate. Communities such as Olympia, Washington and Lenexa, Kansas require developers to manage a specific amount of stormwater; relative to the amount of impervious surface of the project. Other communities like Alachua County, Florida, and Chicago, Illinois chose to manage the amount of site disturbances and reduce the total amount impervious surface created. EPA case studies show that stormwater codes lead to better water quality, but no stormwater regulations addressed a community's entire water demand. The deficit comes from the majority of existing developments existing under grandfathered codes that have little environmental consideration. Philadelphia predicts that only 20 percent of its land has been affected by stormwater codes because and because of grandfathered codes, vacant properties, public lands, streets and waterfronts will need to be managed through other policy approaches (EPA 2010).

Stormwater management regulations are closely related to land use regulations. Stafford County, Virginia for example, implemented stringent infiltration and filtration practices into their stormwater codes but neglected any large scale land use planning policies. The ideal urban density was not reached because of this oversight and as a result a high percentage of county land has been converted to parking lots. 95 percent of new commercial development manages stormwater on-site through infiltration but the rate of impervious surface growth is also very high (Stafford County 2013).

Lenexa, Kansas is a prime precedent for implementation of an array of land use strategies that are based on local needs, establishing different development densities, capitalizing on open space opportunities, preserving ecological buffers, and minimizing development disturbance. Green infrastructure works best when planned and implemented on a large-scale and Lenexa has accounted for this. The city directs development away from existing natural habitats and buys land in those areas to protect the natural flood mitigation, stream ecology, water quality, and recreational amenities. The land use policy in Lenexa also supports higher density development with a mix of uses to reduce the impermeable footprint of the urban area (Lenexa, Kansas 2013).

4.4.2 Review and Revision of Local Codes

Local policies such as landscaping and parking requirements should not be a barrier toward the implementation of green infrastructure. The local policies should complement stormwater standards making it easier for developers to meet multiple requirements simultaneously. If local codes are also written to support water quality goals, it is easier to meet stormwater regulations (EPA 2010).

Chicago's Department of Environment initiated a Green Urban Design process to address issues of eight different city agencies and developed a framework to align their ordinances toward a green ideal. One notable discontinuity was a landscape ordinance that required a prescriptive placement of vegetation rather than placement based on ecological function. By not addressing ecological function into plantings, performance based landscapes were difficult to create (City of Chicago 2013). Philadelphia developed a group similar to Wichita's WDDC deemed the Developer Services Committee. The purpose of this committee is to streamline the permit review, inspection, and approval process. The Philadelphia Water Department wanted to ensure successful stormwater regulation by requiring projects to get concept approval for water, sewer, and stormwater use before zoning permits are issued (Philedelphia Water Department Office of Watersheds 2011). By placing the importance of stormwater consideration early in the project development, Philadelphia has experienced higher success rates in green infrastructure implementation because more standard and tested implementation strategies can be used (City of Philedelphia 2002).

4.4.3 Demonstration and Pilot Projects

Demonstration and pilot projects are becoming more common ways to introduce green infrastructure into development programs and related agency policies. Providing an example of green infrastructure on a testing ground has the benefit of reduced physical and political complications. A well-choreographed example of green infrastructure can be demonstrated to partnerships, agencies, and staff to work out the logistics of implementing green infrastructure practices, form design, construction and maintenance, or basic permitting protocols.

Seattle Public Utilities, for example, found that their Natural Drainage Systems program success was due to carefully designed pilot programs that tested design, installation, and performance prior to citywide implementation. Pilot programs have also shown that the higher cost of green infrastructure verses traditional infrastructure can be lowered after a pilot project phase. These cost decreases can be seen the Chicago's Green Alley Program. The initial costs of the Green Alley Program were 150-200 percent more than traditional ally retrofit, but costs now almost match traditional infrastructure (Center for Neighborhood Technology 2013).

In Olympia, Washington a pilot program went poorly resulting in a revised program. Green Cove Basin, the healthiest stream in the jurisdiction, had its adjacent land set under very strict development standards. The developers in the area did not fully agree with the standards set in place and because the standards were hard to understand, many developers found loopholes in the regulations. The result was poorly developed neighborhoods and homeowner dissatisfaction. Olympia had to revise their development requirements to focus more on street design and public areas to improve the stormwater runoff going into Green Cove Basin (EPA 2010). In this example the pilot project contained the regulation issues, allowing a revision before more development was conducted under faulty codes.

4.4.4 Capital and Transportation Projects

The surface created by roads, railways, sidewalks, and alleys make up the majority of the impervious surface in urban development. The size of these infrastructure systems is so large, an equally large portion of funding is allocated to repair, maintain, and improve them. Eight of the twelve case studies conducted by the EPA (EPA 2010) showed that the value of leveraging funding efforts of traditional infrastructure to green infrastructure into standard transportation projects was valuable.

The City of Seattle created a new Sustainable Infrastructure Initiative to evaluate its $650 million annual investment into capital projects such as bridge building and road construction. The interdisciplinary committee founded by the Sustainable Infrastructure Initiative reviews development projects and proposes ways that green infrastructure can implemented. Santa Monica, California has a similar method to Seattle but functions more efficiently because Santa Monica is smaller and reviewed by one person who can personally conduct inspections of new capital development plans (City of Santa Monica n.d.). Portland's Green Street program has a formal process of overlaying multiple bureau project plans and scheduled capital improvement projects to identify how multiple levels of public and private development can work together to maximize the investment of green infrastructure (City of Portland 2004). Chicago has a more refined approach; the Green Alley Program. 3,500 acres throughout Chicago needed improvements and repairs, opening up a significant portion of the impervious downtown susceptible to change. By investing in green infrastructure, the Green Alley Program was able to change low traffic areas in disrepair to allow infiltration instead of the traditional piped alley infrastructure.

Ecologically sensitive land important to water quality protection can be purchased for protection. Lenexa, Kansas's Rain to Recreation program spends tens of millions of public dollars to protect sensitive landscapes integral to water quality. By purchasing sensitive lands, new development cannot introduce impermeable surfaces and eventually disrupt the natural water treatment cycle. Purchasing sensitive lands also provides long term recreational assets. Alachua County Forever in Florida has a similar program for purchasing sensitive lands but adds an extra step to consider how green infrastructure can be used to improve the protected landscapes (EPA 2010).

4.4.5 Education and Outreach

An education and outreach program is designed for persons who occupy a site that has a green infrastructure implementation so the didactic opportunities of green infrastructure are maximized. Educational signage and design are used to explain the economic, ecologic, and social value of stormwater management to the general public. The explanation is done through signage, brochures, and other outreach materials. Portland, Oregon has developed the stormwater cycling tour and Chicago has developed a how-to guide for downspout disconnection and rain barrel implementation. In Olympia, Washington the "Gardening with a Sound Mind" informs homeowners of the importance of the protection of the Puget Sound by use of native plantings (City of Olympia 2012). In Lenexa, Kansas the Rain to Recreation program funds a public speaker to the schools, community groups, residents, businesses, and other professionals (EPA 2010).

4.4.6 Stormwater Fees

Stormwater fees are intended to generate revenue that is dedicated toward the growing investment needed to control combined sewer overflows and stormwater runoff. By creating a tax for properties that generate more stormwater runoff, general taxes are not considered, "wasted" on green infrastructure.

San Jose, California's Santa Clara County Tax Collector's Office collects the Storm Sewer Service Charge through the annual property tax roll. These fees are for commercial, multi-family residential and industrial properties. The tax is based on lot size and percentage of imperviousness. Using GIS the data can be collected and calculated for larger parcels. The stormwater runoff fees are usually added to water, sewer or utility bills (EPA 2010).

4.4.7 Stormwater Discounts

By implementing a fee for stormwater runoff generation, an inverse incentive can be created to reward exemplary use of green infrastructure to manage generated stormwater runoff. These incentives often help promote implementation of green infrastructure in retrofit situations. By decreasing impervious surface or using green infrastructure, developments in Portland, Philadelphia, and Seattle receive fee discounts and tax credits toward development fees. A reduction of development fees generates less revenue for the city but money is saved by not having to treat unnecessary stormwater. Table 4.1 was developed by the EPA to outline a framework for setting goals and developing a process to implement fee discounts. Discounts can be awarded for both the management of stormwater, occasionally water pollutant reduction, or impervious surface reduction. Credits can vary based on the type of green infrastructure used and the goals of the community in which they reside. Portland, Oregon has specific credits for sites with eco-roofs or trees over 15 feet tall (EPA 2010).

Table 4.1 Fee discount development (EPA 2010)

Goal of Discount	Mechanism for Fee Reduction	Process for Implementation
Reduce Imperviousness	• Percent fee reduction • Per-square-foot credit	• Percent reduction in imperviousness • Square feet of pervious surfaces
On-Site Management	• Percent fee reduction • Quality/Quantity credits (performance-based)	• List of practices with associated credits • Total area (Square feet) managed
On-Site Management	• Percent fee reduction • Performance-based quantity reduction	• Percent reduction in imperviousness • Performance-based • Total area (square feet) managed • Practices based on pre-assigned performance values
Use of Specific Practices	• Percent fee reduction • One time credit	• List of practices with associated credits

4.4.8 Other Incentives

In general, incentives can be a creative tool local governments can use to encourage green infrastructure on private property. These incentives can work to influence beyond the restrictions of regulatory authorities that are not up to date on the wet weather management practices such as green infrastructure and other best management strategies. The EPA developed several types of local incentives:

- Fee Discount: Requires a stormwater fee based on impervious surface area. If a property owner can reduce need for municipal services by reducing impervious area, fees are proportionately reduced.
- Development Incentives: These incentives are offered during the development permit application process. These are awarded for zoning upgrades, expedited permitting, and reduced stormwater requirements for example.
- Rebates & Installation Financing: This provides funding, tax credits or reimbursements to property owners that implement green infrastructure. The awards should be given to implementations relevant to site-specific stormwater needs to improve success rates.
- Awards & Recognition Programs: Monetary awards can be granted to public outreach and exemplary examples of green infrastructure implementation.

By promoting creative use of green infrastructure in private developments, more stringent and costly stormwater regulations can be avoided. In Chicago the Green Permit Program fast tracks award reviews for projects that are seeking to meet Leadership in Energy and Environmental Design (LEED) criteria (City of Chicago 2013). In Portland, Oregon the Eco-roof Floor Area Ratio Bonus allows development to exceed the growth limitations by adding a proportionately sized eco-roof. The Eco-roof Floor Area Ratio Bonus has helped generate $225 million in additional private development and added 120 eco-roofs because of the new development.

Green infrastructure installation rebates can be another effective method for private implementation. Seattle's Residential RainWise Program provides additional funding for rain garden and stormwater retention cisterns in residential projects (City of Seattle 2009). Santa Monica, California gives $160,000 a year to Landscape Grants to property owners that use native planting to reduce water consumption and aid stormwater infiltration. The Chicago Green Roof Grants helped the former industrial city add 2.5 million square feet of green roofs across the city. This generic grant awards $5,000 to residential and small commercial buildings that meet criteria based on, location, visibility, and environmental impact to maximise investment benefit (EPA 2010).

5 Suitability Analysis

5.1 Work Flow

The depth of analysis capable in GIS can become complicated and results can become hard to replicate. To ensure a coherent analysis model for both the creator and the users, a systematic workflow must be developed. The workflow used for this project relies on an initial model concept (Figure 5.1), and then appropriate data is gathered. Once all of the necessary data has been collected, the actual analysis model can be built (Figure 5.2). The model builder then verifies each step in the process to make sure each output from one tool fits into the next. After the model has been assembled and run the results can be analyzed further to determine if any errors have occurred. Errors can result from faulty data or improper use of tools. Errors are usually denoted in the model run log, and from there the faulty tool or data can be located and fixed.

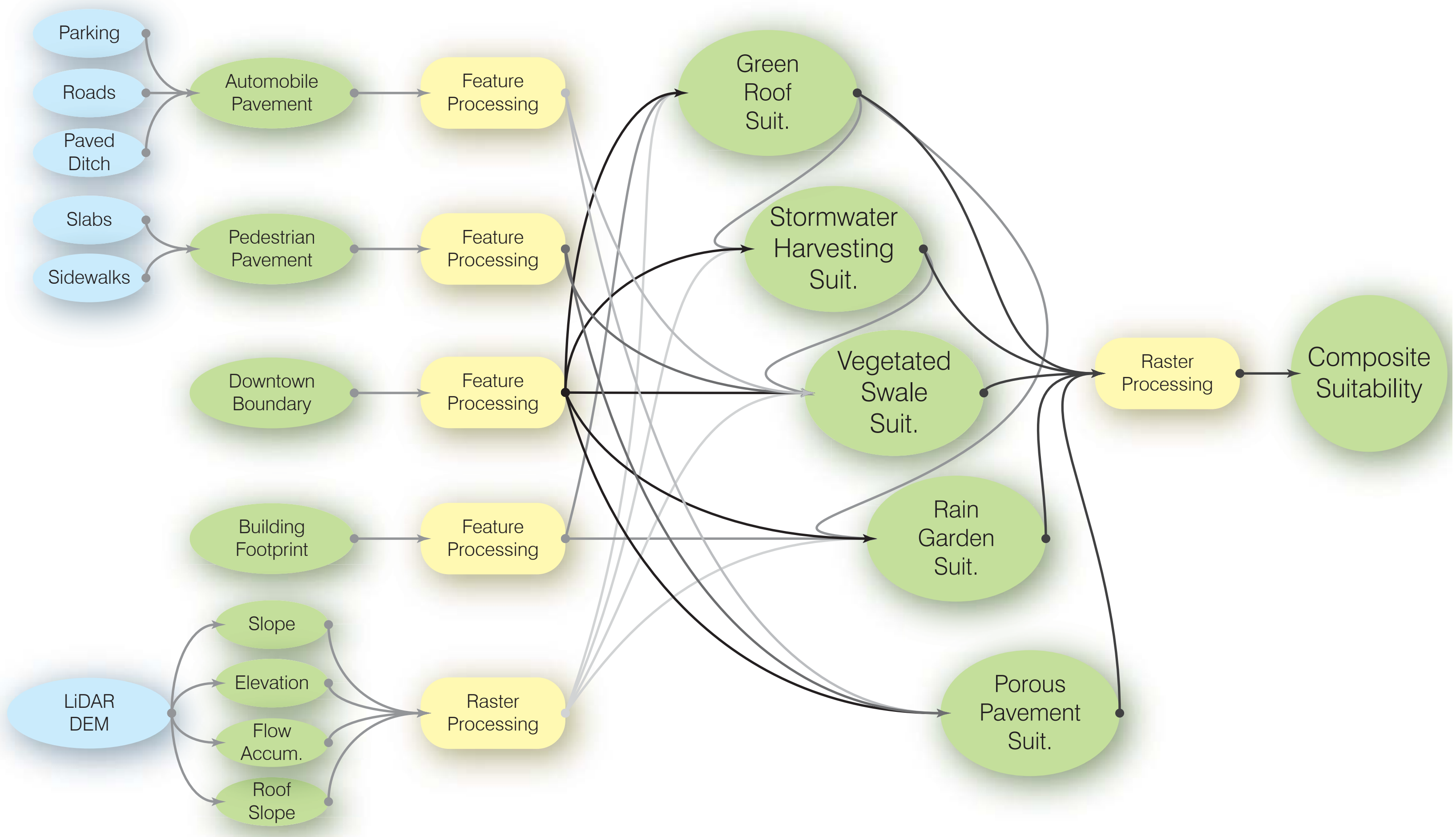
The suitability analysis was run for green roofs, stormwater harvesting, vegetated swales, rain gardens, and porous pavement. These BMP's have been selected because they all can be implemented in a downtown scenario and work to manage smaller watersheds created in a downtown environment. This decision was made from review of chapter 7 of the University of Louisville's Environmental Responsibility Handbook of Land Use (University of Louisville 2009)

Figure 5.1 Original analysis concept (Author 2013)

5.2 Data Gather

For this project the majority of data needed was provided by the City of Wichita. The physical shapefiles for the building footprint, pedestrian pavement, and vehicular pavement as well as the Light Detection and Ranging (LiDAR) .LAS data used to generate the digital elevation model all came from the GIS department at the City of Wichita. The remaining data, such as stream shape and information as well as the 4-band aerial imagery was downloaded from the United States Geological Survey (USGS) archives. Miscellaneous data that was not included in the data gathered such as roof types and exterior conditions were visually assessed both on site and using Google Earth Street View.

Figure 5.2 Green infrastructure suitability model (Author 2013)



5.3 Standard Tools

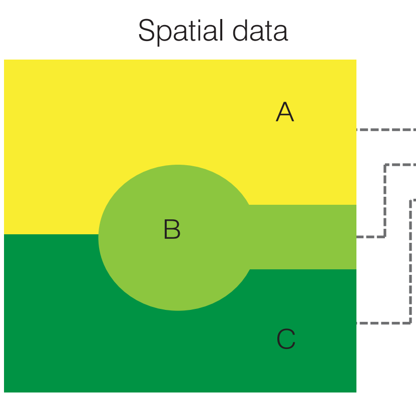
The data gathered can exist in two forms: a feature or a raster. Each serves a different purpose for analysis. Simply put features are point, vector, or polygon shapes that can have an extensive set of tabular data associated with the separate points, vectors, or polygons. Raster datasets on the other hand exist as pixel based .TIFF's, where each pixel is coded with an integer that represents a set of data.

5.3.1 Feature editing

The physical form of a feature's tabular data is associated with a spatial shape. If a feature is comprised of 100 different polygons, the associated tabular data would have 100 rows of information. The columns of the tabular data are named based on the type of information relevant to that feature (Figure 5.3).

A feature's spatial component can be edited because the tabular data is associated with each individual object; a point, line, or polygon. A large set of feature data can be clipped down, erased by other data, or merged with other data. Individual pieces can be extracted out and the tabular data can be added to or simplified. Features are more malleable than raster data.

Figure 5.3 Feature dataset (Author 2013)



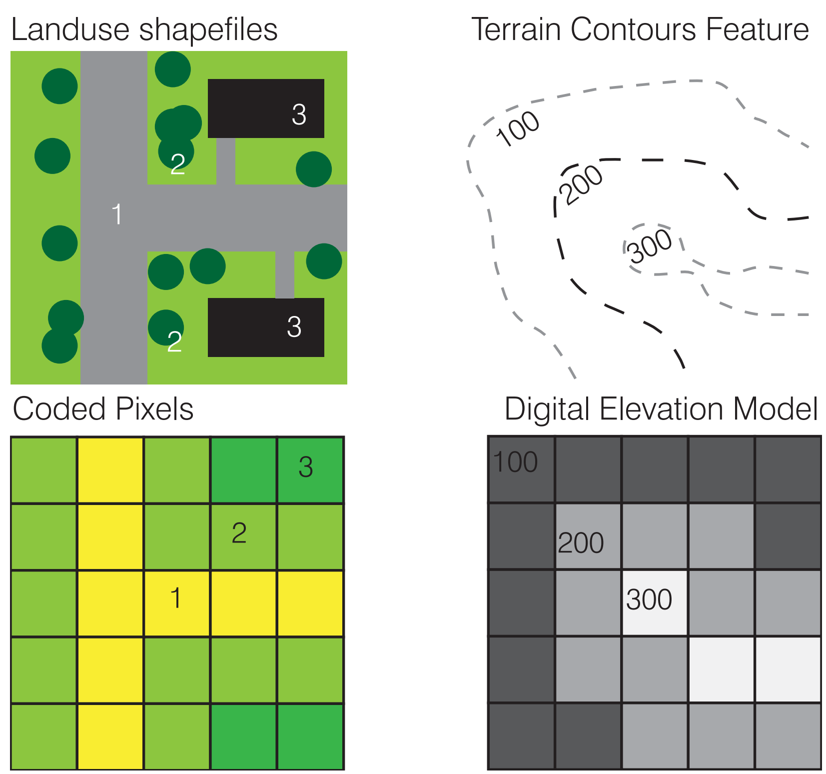
Tabular data

ID	Area	Land use
A	1,000	R1
B	1,500	
C	1,000	R2

5.3.2 Raster Processing

A raster is essentially a pixel based image (Figure 5.4). The main difference between a raster and a feature is that a raster can only store one set of data. This set of data can have different values represented by integers that are represented by different colors, visually. Each integer is coded to represent a specific value. For example in a digital elevation model a raster value of 1 could represent a pixel with an elevation of 1 meter, a raster value of 2 would represent 2 meters. On the other hand a land use raster could represent the raster value of 1 to be coded with information such as pedestrian pavement and a raster value of 2 could represent park space. Rasters can become convoluted because of the dual meaning of the visual representation. It is usually best to process a raster as a final step in model building to avoid this confusion.

Figure 5.4 Raster dataset (Author 2013)



5.4 Complete Permeability Analysis

The first model demonstrated is intended to serve two purposes. First was to imagine a downtown with entirely pervious surfaces. The only factors considered in suitability were the type of pavement. The second purpose was to test the weighted overlay and weighted sum analysis methods as well as assemble the composite pavement shapefiles.

5.4.1 Factors

The purpose of green infrastructure is to open up the impermeable surface of an urban area. To conceptualize a downtown that has a 100% implementation of green infrastructure all of the existing impervious surface (sidewalk, parking lot, and road) will be given a suitability of 2. The areas that are already pervious or vegetated (parks, areas with tree canopy, and areas with porous pavement) will be given a suitability of 1. The footprint of existing buildings will be removed along with the Arkansas River.

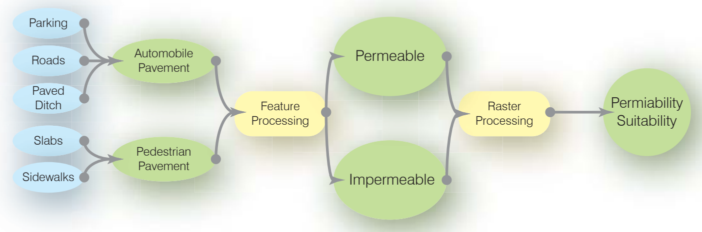
The factors used in the suitability analysis can be viewed in table 5.1 and the model in figure 5.5. The results of the model can be seen in Figure 5.6.

Table 5.1 General suitability factors

Suitability Rating					
Suitability Scale		0	1	2	3
		No Development	Moderate	High	Very High
Weight	Analysis Layer	Exclusionary	Least Favorable	←-----------→	Most Favorable
2	Permeable	-	-	Yes	-
1	Impermeable	-	Yes	-	-

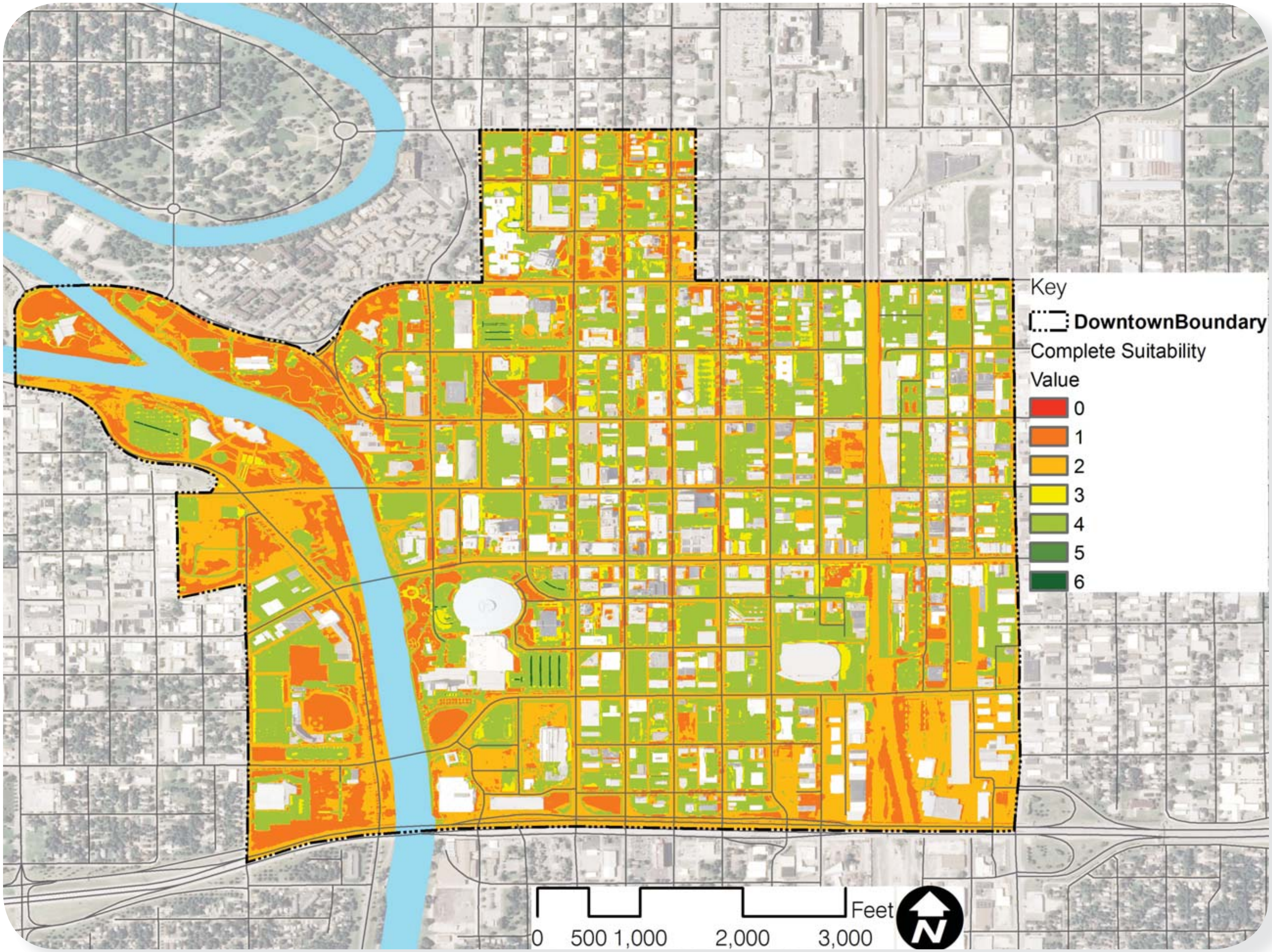
5.4.2 Model

Figure 5.5 General suitability model



5.4.3 Results

Figure 5.6 General suitability model result



5.5 Green Roofs

A green roof attempts to cover a building with vegetation and soil either partially or completely. The standard design of a green roof consists of a base layer of water proofing, a drainage medium, a vegetation barrier, the growing medium (soil), and finally the vegetation. The main benefit of a green roof is the cooling nature of evaporation. The water that is not drained from the roof collects in the vegetation and the soil and, like sweat on the skin, evaporates from the wind and sun to cool. The growing medium must be a special lightweight, normally engineered soil, and the structure of the roof must be assessed to determine a roof's weight bearing capacity. The plants selected must be suitable for the location on the roof (University of Louisville 2009). Typically sedums or other hardy plants are used, but in some cases native plantings can be used and given a strong enough structure and sufficient growing medium, even a tree can be planted. Plants with a slow to moderate growth pattern are ideal as well because they tend to keep in balance and not die while the root system is dormant in the winter (University of Louisville 2009).

5.5.1 Factors

A large factor for green roof success is its footprint area and depth. Structural support is important as the load of a green roof can be too heavy in some cases. Green roofs function best with a growing media depth of 4-5" (Hutchinson, et al. 2003). Due to a current lack of structural data a visual assessment was used to assess each building. New buildings will be given a suitability factor of 2 and older buildings will be given a suitability factor of 1. The visual assessment of structure will not be used to exclude any buildings from the analysis because, as it may be expensive, the physical structure of a roof can be improved to support a green roof.

Another major factor for green roof implementation is roof slope. A shallow slope allows a green roof to retain more water and generally function better. Slopes of 1-2% are best and receive a suitability of 3. Roofs in-between 2-7% slope have a moderate functionality and receive a suitability of 2. Any roof that is not pitched and under greater than 8.1% will receive a suitability of 1 (Getter, Rowe and Andersen 2007).

Sun availability is integral to the success of a green roof. Generally a green roof needs full sun access when it is comprised of native plantings or sedums (MSU 2004). Research is being done at K-State on the shade tolerance of certain sedums and native plantings in an attempt to discover methods to apply green roofs to predominantly shaded areas. To assess solar accesses buildings above 10 stories will receive a suitability of 3, buildings from 9-3 stories will receive a suitability of 2 and buildings 2-1 stories will receive a suitability of 1.

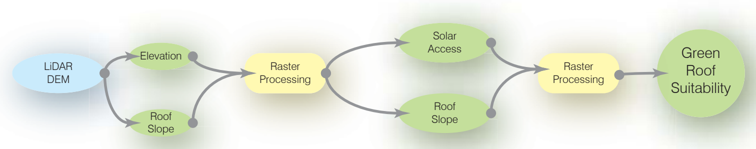
The factors used in the suitability analysis can be viewed in table 5.2 and the model in figure 5.7. The results of the model can be seen in Figure 5.8.

Table 5.2 Green roof suitability factors

Suitability Rating					
Suitability Scale		0	1	2	3
		No Development	Moderate	High	Very High
Weight	Analysis Layer	Exclusionary	Least Favorable	←-----------→	Most Favorable
1	Structure	-	Old	New	-
2	Roof Slope	0-1, Pitched	>8.1%	2.1-8%	1.1-2.0%
2	Solar Access	-	> 10 stories	9-3 stories	1-2 stories

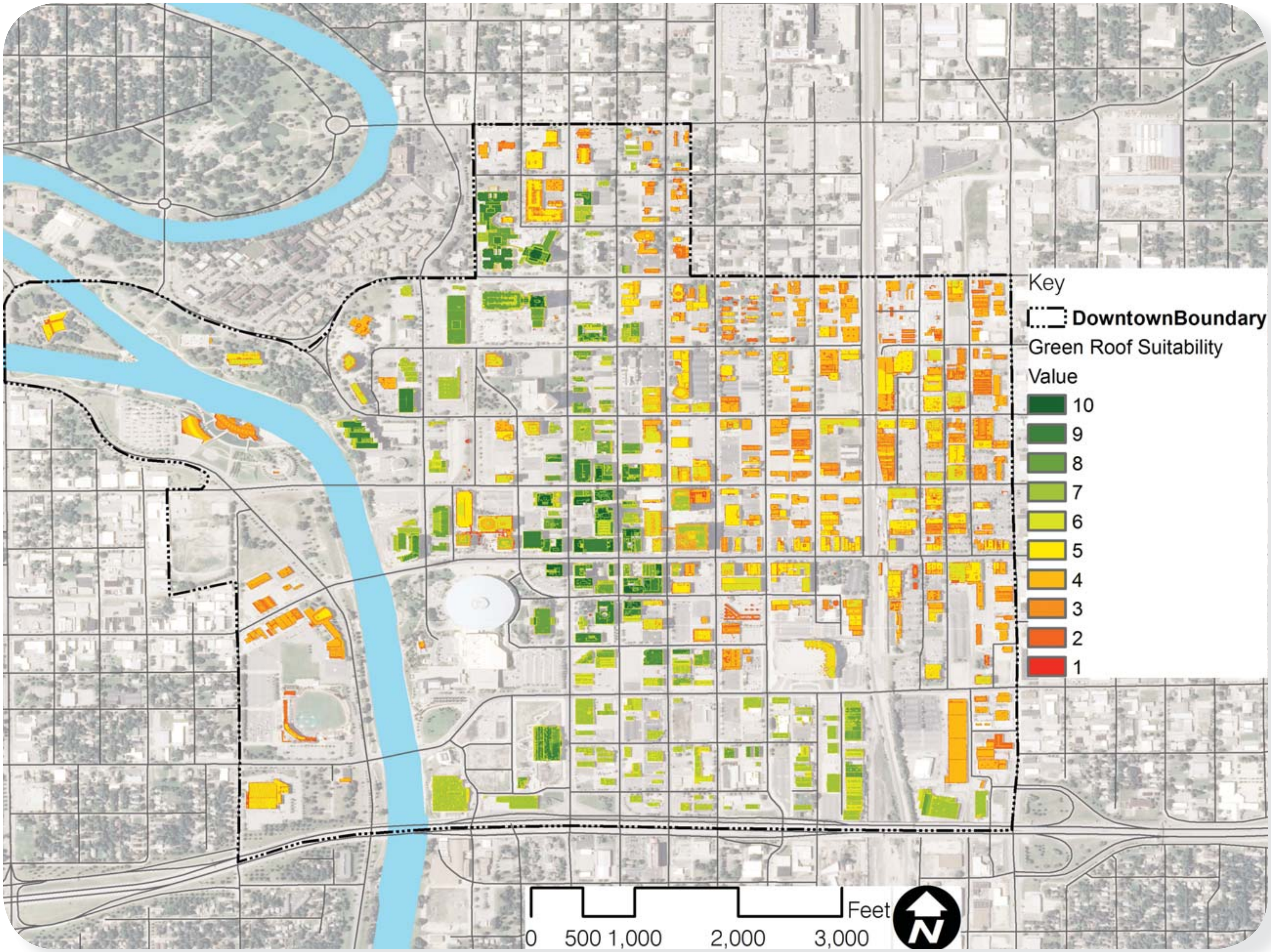
5.5.2 Model

Figure 5.7 Green roof suitability model



5.5.3 Results

Figure 5.8 Green roof suitability model result



5.6 Rainwater Harvesting

Also know as rainwater tanks or rain barrels, cisterns collect and store rainwater. The water collected normally comes from rooftops through gutters. A more efficient method is to first filter stormwater through a green roof and then downspout to a cistern. The cistern is beneficial because it either directly stops untreated rainwater from entering the stormwater infrastructure or delays the time by holding the water temporarily. The stored water can be used for a multitude of purposes such as watering gardens, washing cars, urban agriculture, or other home uses such as toilet flushing (University of Louisville 2009).

5.6.1 Factors

The main factors for rain water harvesting are the volume of rainwater delivered to the system, the proximity to a downspout or a green roof system, and the proximity to a vegetated swale, or rain garden (City of Portland Environmental Services n.d.).

The volume of stormwater sent to a rainwater harvesting system is determined by the size of the roof that the rainwater harvesting system is receiving stormwater from. Roofs up to 3,000 square feet will receive a suitability of 1, roofs with 3,001-11,000 square feet will receive a suitability of 2, and roofs with square footage greater than 11,001 will receive a suitability of 3.

To maximize the benefits of a green roof, areas that are located within five feet of roofs that are highly suitable for a green roof will receive a suitability of 2. (City of Portland Environmental Services n.d.)

Once a rainwater harvesting system reaches capacity, the excess stormwater will overflow. To catch this rainwater overflow, areas that are located within ten feet of the highest suitable areas for vegetated swales or pocket wetlands will receive a suitability of 2. (City of Portland Environmental Services n.d.)

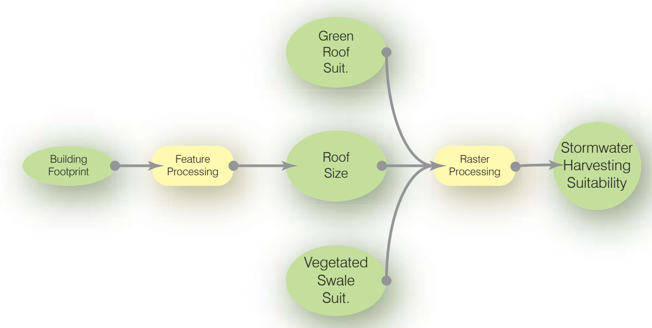
The factors used in the suitability analysis can be viewed in table 5.3 and the model in figure 5.9. The results of the model can be seen in Figure 5.10.

Table 5.3 Rainwater harvesting factors

Suitability Rating					
Suitability Scale		0	1	2	3
		No Development	Moderate	High	Very High
Weight	Analysis Layer	Exclusionary	Least Favorable	←-----------→	Most Favorable
3	Roof Size	-	0-3000 sqft.	3001-11000 sqft.	>11001 sqft.
2	G.R. Proximity	-	-	<5′	-
2	V.S. Proximity	-	-	<10′	-

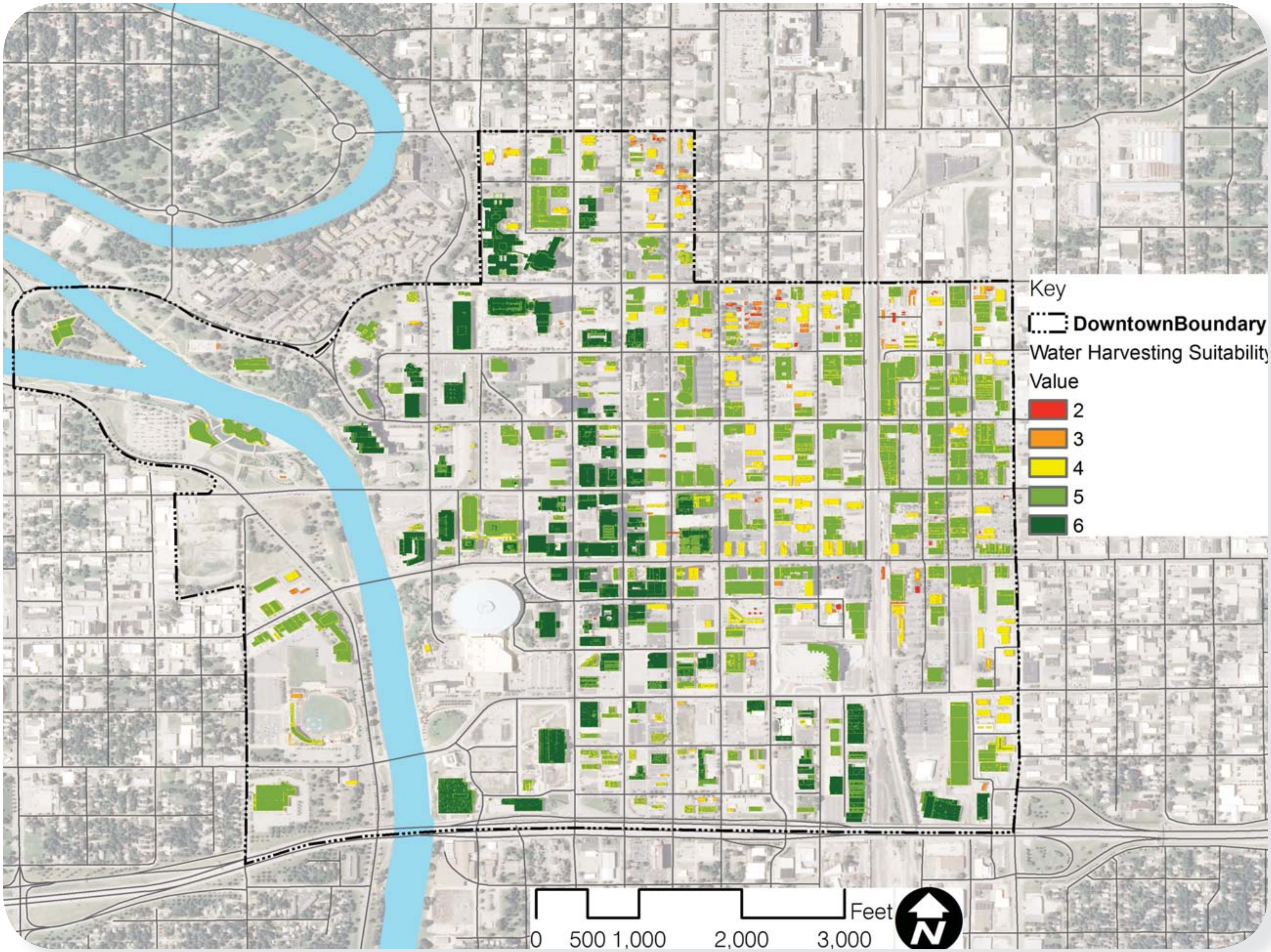
5.6.2 Model

Figure 5.9 Rainwater harvesting suitability model



5.6.3 Results

Figure 5.10 Rainwater harvesting suitability model result



5.7 Rain Garden

Rain gardens usually work alongside green roofs or adjacent to roofs that cannot support a green roof. A rain garden can also be referred to as a bioretention basin. The design of a rain garden is typically a planted topographic depression that is designed to absorb rainwater that drains from impervious surfaces such a roofs, parking areas, walkways, and areas of compacted soils. Rain gardens help to decrease erosion, water pollution, flooding, and increase recharge of groundwater because they help absorb rainwater close to where it falls (University of Louisville 2009).

5.7.1 Factors

The major factors of a rain garden include water volume, the ability for soil to drain water, depth to water table, location to building foundation, and slope.

Rain gardens are most useful when they receive a large volume of stormwater (Iowa Stormwater Partnership 2008). The water volume sent to an area will be determined using the flow accumulation tool from the hydrology toolset in ArcGIS. Areas accumulating the most water will receive a suitability of 3, areas accumulating moderate amounts of water will receive a suitability of 2, and areas accumulating the least amount of water will receive a suitability of 1.

Rain Gardens must be able to percolate the stormwater that they receive quickly in order to maximize their efficiency (Iowa Stormwater Partnership 2008). Soils that are compacted will receive a suitability of 1, soils that are moderately well drained will receive a suitability of 2, and well drained soils will receive a suitability of 3.

Rain gardens should be located away from building foundations to avoid structural damage. Areas within 10 feet of a building footprint will be excluded, areas 11-40 feet will receive a suitability of 1, and areas outside of 41 feet will receive a suitability of 2 (Iowa Stormwater Partnership 2008).

Another major factor for rain garden implementation is ground slope. A shallow slope allows a rain garden to retain more water and generally function better (Iowa Stormwater Partnership 2008). Slopes of 1-2% are best and receive a suitability of 3. Slopes between 2-7% have moderate functionality and receive a suitability of 2. Any slope under 25% will receive a suitability of 1.

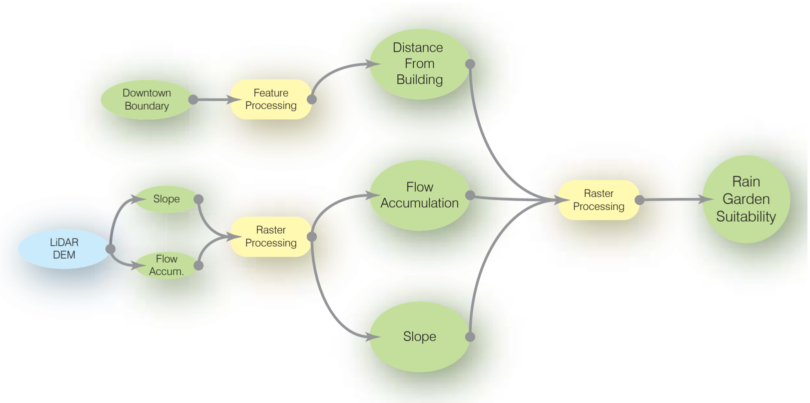
The factors used in the suitability analysis can be viewed in table 5.4 and the model in figure 5.11. The results of the model can be seen in Figure 5.12.

Table 5.4 Rain garden factors

Suitability Rating					
Suitability Scale		0	1	2	3
		No Development	Moderate	High	Very High
Weight	Analysis Layer	Exclusionary	Least Favorable	←-----------→	Most Favorable
3	Flow accumulation	-	Low	Medium	High
3	Distance from building	<10’	11-40’	>41’	-
1	Slope	-	<25%	2-7%	1-2%

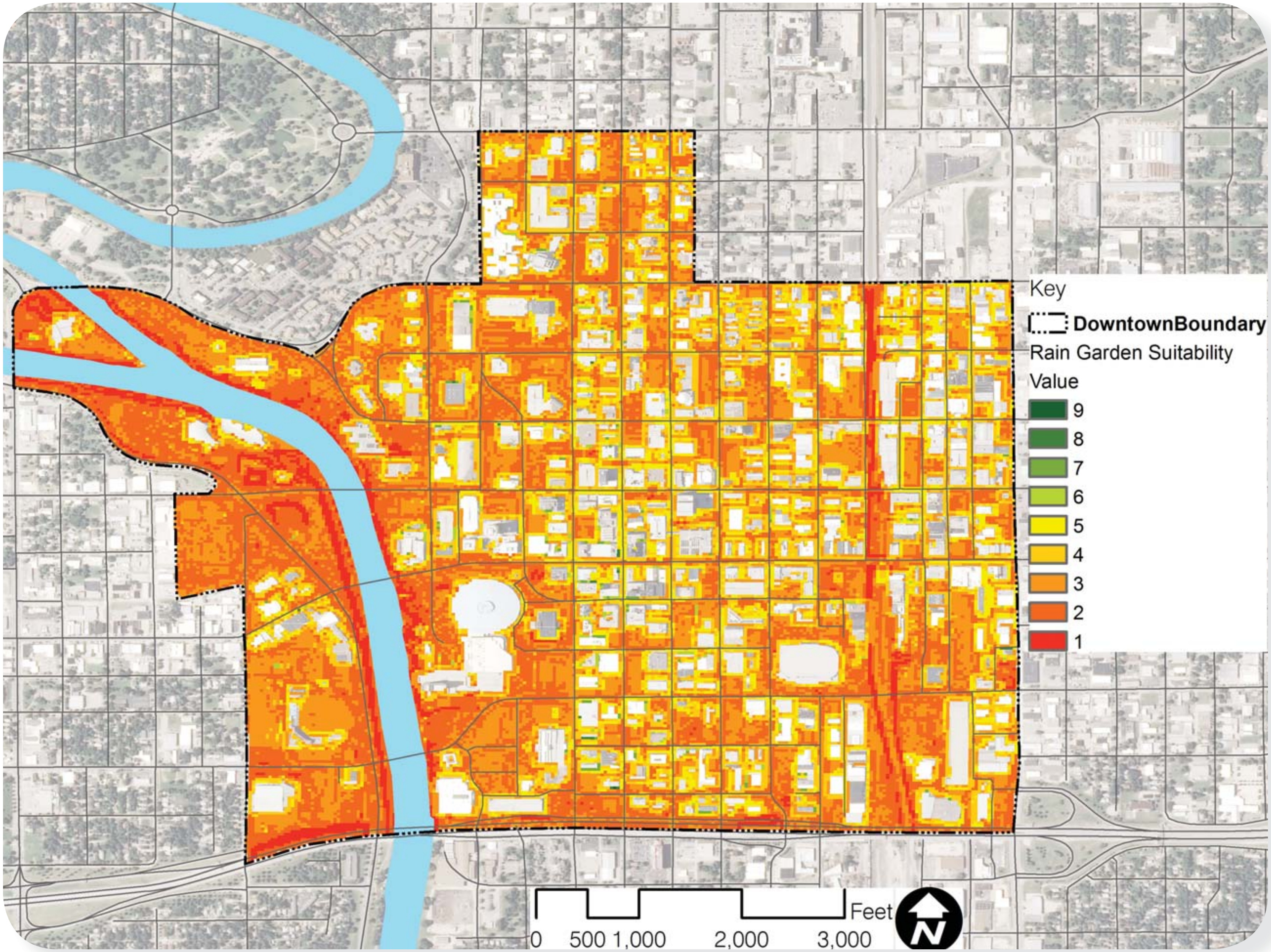
5.7.2 Model

Figure 5.11 Rain garden suitability model



5.7.3 Results

Figure 5.12 Rain garden suitability model result



5.8 Vegetated Swales

Vegetated swales, also known as bioswales, are a wide shallow channel that is covered on the sides and bottom by a dense cover of vegetation. This vegetation is normally native in nature and is flood tolerant. The design of a vegetated swale promotes infiltration; helps reduce the flow velocity of stormwater runoff, and traps runoff particulates, pollutants, and silt. Though these can exist naturally in areas with low development, bioswales are generally engineered in the urban environment. The design of a vegetated swale is generally linear so their application usually goes best along parking lots to increase their ability to pick up harmful automobile pollution before the stormwater runs off into grey infrastructure and contaminates untreated water (University of Louisville 2009).

5.8.1 Factors

The major factors for the implementation of vegetated swales are the length of the swale, the slope of the swale, and the underlying soils ability to percolate water.

One of the most influential factors for a vegetated swale is its length. Swales that are 2-5 meters are less effective and swales longer than 15 meters have no added benefit in pollutant removal (Abu-Zreig, et al. 2003). Areas with linear distance between 5 and 15 meter will receive a suitability of 2.

Another major factor for vegetated swale implementation is ground slope. A shallow slope allows a vegetated swale to retain more water and generally function better (Abu-Zreig, et al. 2003). Slopes of 1-2% are best and receive a suitability of 3. Slopes in-between 3-5% have moderate functionality and receive a suitability of 2. Any slope under 25% will receive a suitability of 1.

Vegetated swales must be able to percolate the stormwater that they receive quickly in order to maximize their efficiency (Abu-Zreig, et al. 2003). Soils that are compacted will receive a suitability of 1, soils that are moderately well drained will receive a suitability of 2, and well drained soils will receive a suitability of 3.

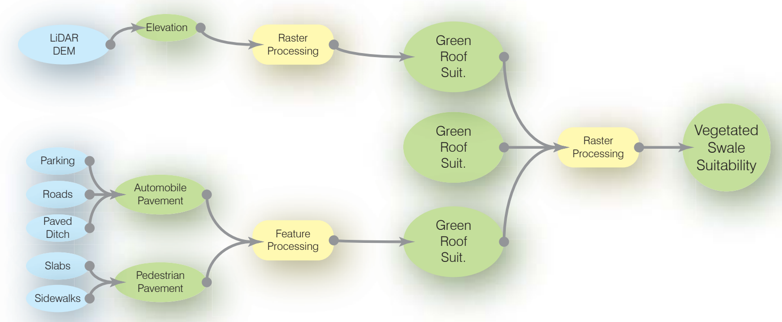
The factors used in the suitability analysis can be viewed in table 5.5 and the model in figure 5.13. The results of the model can be seen in Figure 5.14.

Table 5.5 Vegetated swale suitability factors

		Suitability Rating			
Suitability Scale		0	1	2	3
		No Development	Moderate	High	Very High
Weight	Analysis Layer	Exclusionary	Least Favorable	←-----------→	Most Favorable
1	Distance G.R.	-	>5'	-	<4.9'
2	Ground slope	0%	>5.1%	2.1-5.0%	0.1-2.0%
3	Linear Run	-	2-5 m	6-15 m	-

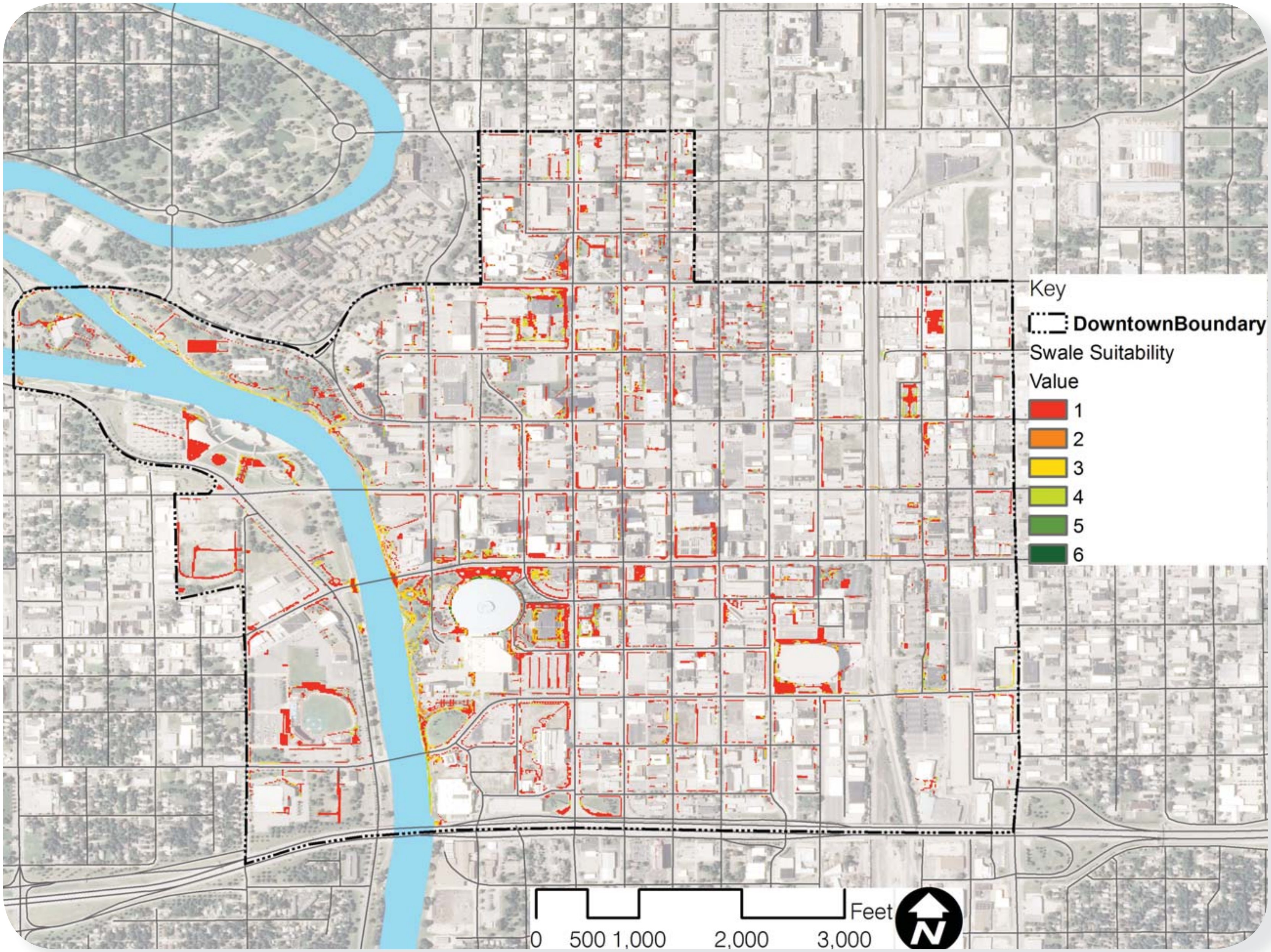
5.8.2 Model

Figure 5.13 Vegetated swale suitability model



5.8.3 Results

Figure 5.14 Vegetated swale model result



5.9 Porous Pavements

The purpose of porous and pervious pavements is to allow rainwater to infiltrate through to the soil below. These paving techniques can be used for roads, parking lots, and walkways. The effect of porous paving is a decreased flow velocity of stormwater runoff as well a groundwater recharge. Typical construction methods include porous asphalt or concrete, paving stones, and bricks (University of Louisville 2009).

5.9.1 Factors

Suitability for permeable pavements is based mainly on soil type, precipitation pattern, and adjacency to other green infrastructures. Compacted soils are the least effective at percolating stormwater and receive a suitability of 1, soils that are moderately well drained receive a suitability of 2, and well drained soils receive a suitability of 3 (Bean, Hunt and Bidelspach 2007).

The storm intensity factor will be determined with the hydrology toolset. Porous pavements function best when they experience a medium runoff intensity and volume (Hunt, Stevens and Mayes 2002). Because permeable pavement are most effective at a medium runoff intensity, pavements that have the least flow accumulation and the most flow accumulation will receive a suitability of 1. Pavements that receive a moderate amount of flow accumulation will receive a suitability of 2.

Permeable pavements that are located next to swales allow excess runoff to be managed in large storm events (Rushton 2002). Pavements that are connected to suitable vegetated swales will receive a suitability of 3, pavements that are 1-3 feet away from suitable vegetated swales will receive a suitability of 2, and pavements that are more than 4 feet from suitable swales will receive a suitability of 1.

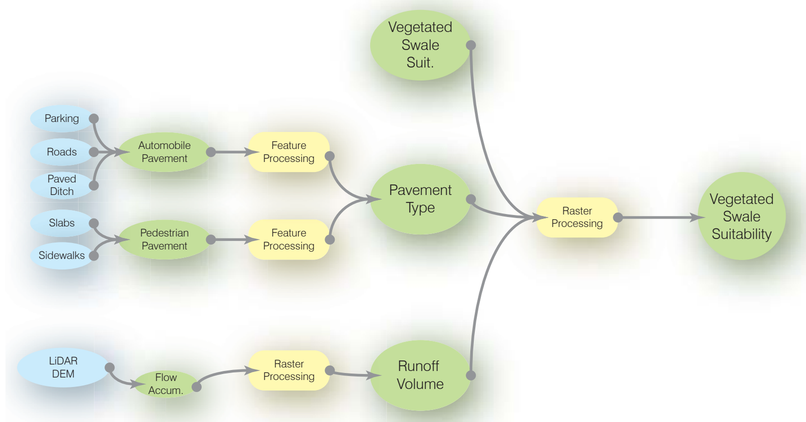
The factors used in the suitability analysis can be viewed in table 5.6 and the model in figure 5.15. The results of the model can be seen in Figure 5.16.

Table 5.6 Porous pavement suitability factors

Suitability Rating					
Suitability Scale		0	1	2	3
		No Development	Moderate	High	Very High
Weight	Analysis Layer	Exclusionary	Least Favorable	←-----------→	Most Favorable
2	Pavement Type	-	Road	Sidewalk	Parking Lot
3	Runoff volume	-	High, Low	Medium	-
1	Swale location	-	>4' away	1-3' away	Connected

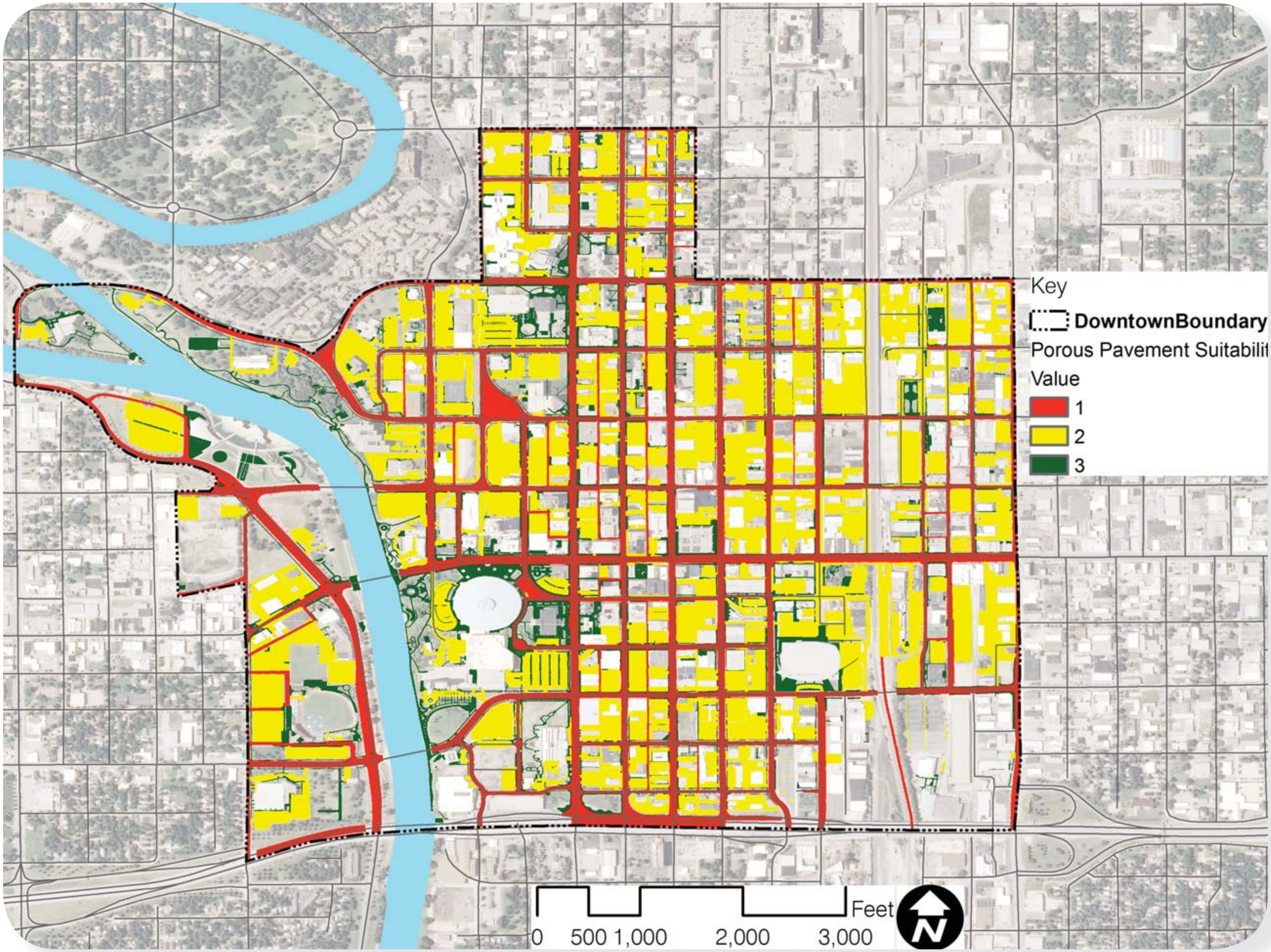
5.9.2 Model

Figure 5.15 Porous pavement suitability model



5.9.3 Results

Figure 5.16 Porous pavement suitability model result



5.10 Composite suitability

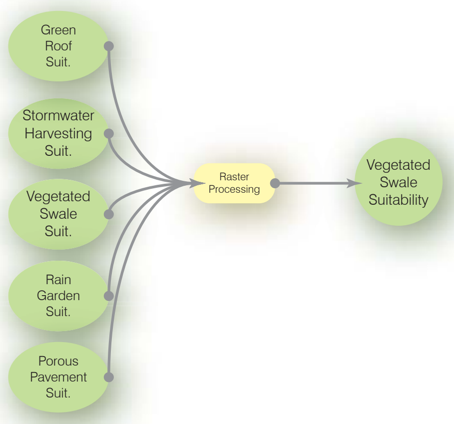
5.10.1 Factors

The composite suitability model is a weighted sum using the results from the green roof, stormwater harvesting, vegetated swale, porous pavement, and rain garden suitability models. The output of the model shows where suitability stacks on top of one another, or where linkages between different green infrastructures can be made.

The model used in the suitability analysis can be viewed in figure 5.17 and the resultant analysis map in figure 5.18

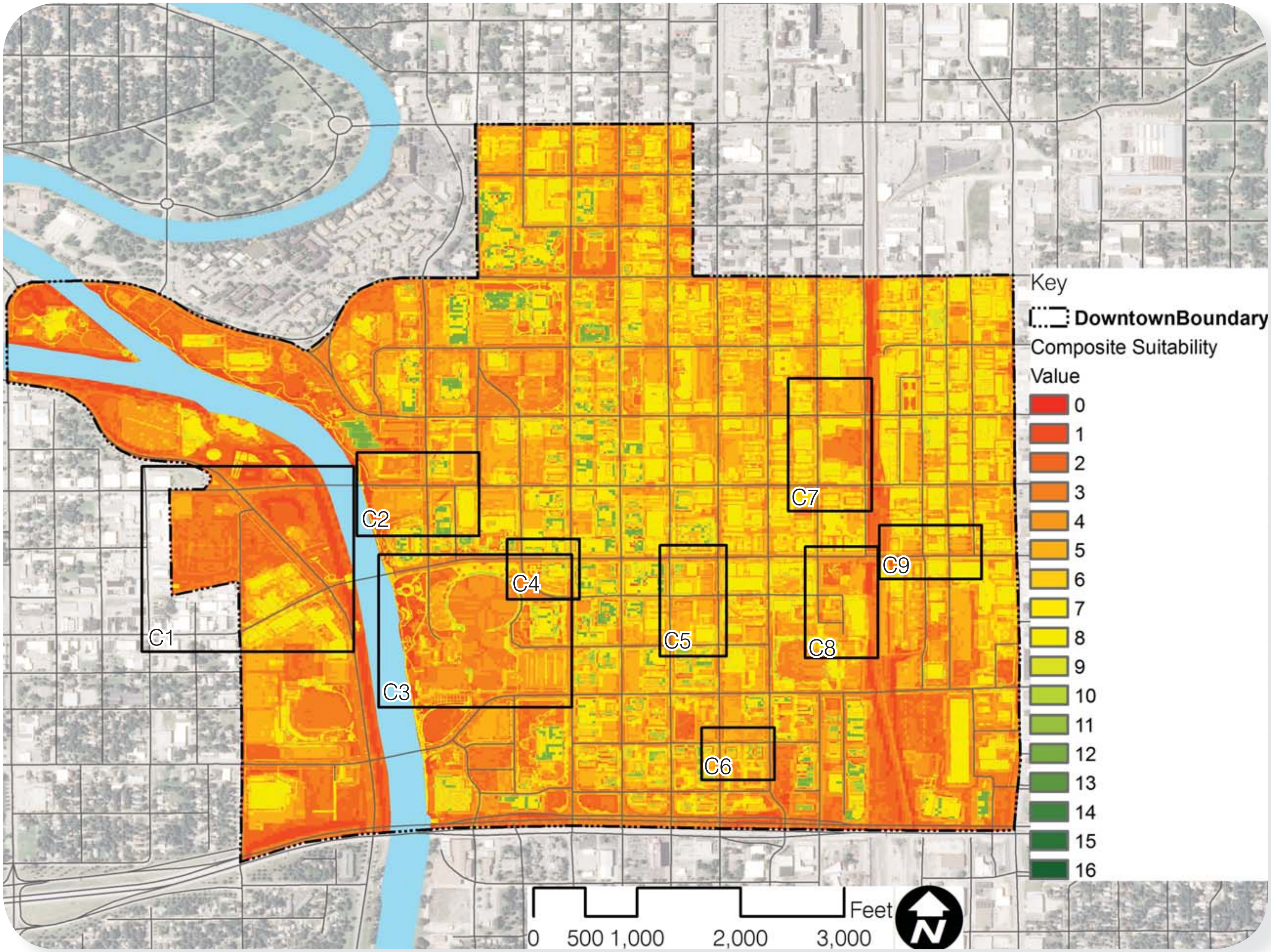
5.10.2 Model

Figure 5.17 Composite suitability model



5.10.3 Results

Figure 5.18 Composite suitability model result



5.11 Site Selection

5.11.1 Model Result Summary

The results found in the suitability map align with the original prediction made. A majority of the highly suitable sites are found in areas that occupy large areas of pedestrian and automobile pavements and are in lower areas.

All of the other highly suitable sites exist on newer developments with pedestrian zones containing buildings and large flat roofs. One of the most notable sites is the Century II plaza along Douglas Ave. The reason these sites are more suitable is because buildings with large footprints tend to have more pedestrian and automobile pavements associated with them.

The areas of moderate suitability tend to be large parking lots with little flow accumulation and are not close to other suitable areas; the north east section of the downtown.

The areas of lowest suitability are the vegetated areas, generally to the west of the Arkansas River. The composite suitability map shows the most notable string of suitability is along Market Street.

5.11.2 Rational for site selection

The catalyst sites identified in the Project Downtown are publicly owned parcels that offer greater control over the private development and public infrastructure that is created on site. Choosing a site that is suitable for green infrastructure as the location for a pilot project will both decrease the costs of green infrastructure implementation and increase the ability to design stormwater management.

Ideally the catalyst sites chosen in the Project Downtown would have aligned with areas that were evident to be of high suitability for green infrastructure. All of the identified sites were on existing, and relatively new pedestrian areas. Catalyst site C-3 (Century II) was considered but was too new and too large for consideration. To meet the goal of showing a pilot project, site C-2 was chosen as it was an empty parking lot (Figure 5.19). Because catalyst site C-2 has a relevant program defined in the Project Downtown, developing this site would be the most effective method to demonstrate green infrastructure implementation using groundwork laid by the Project Downtown.

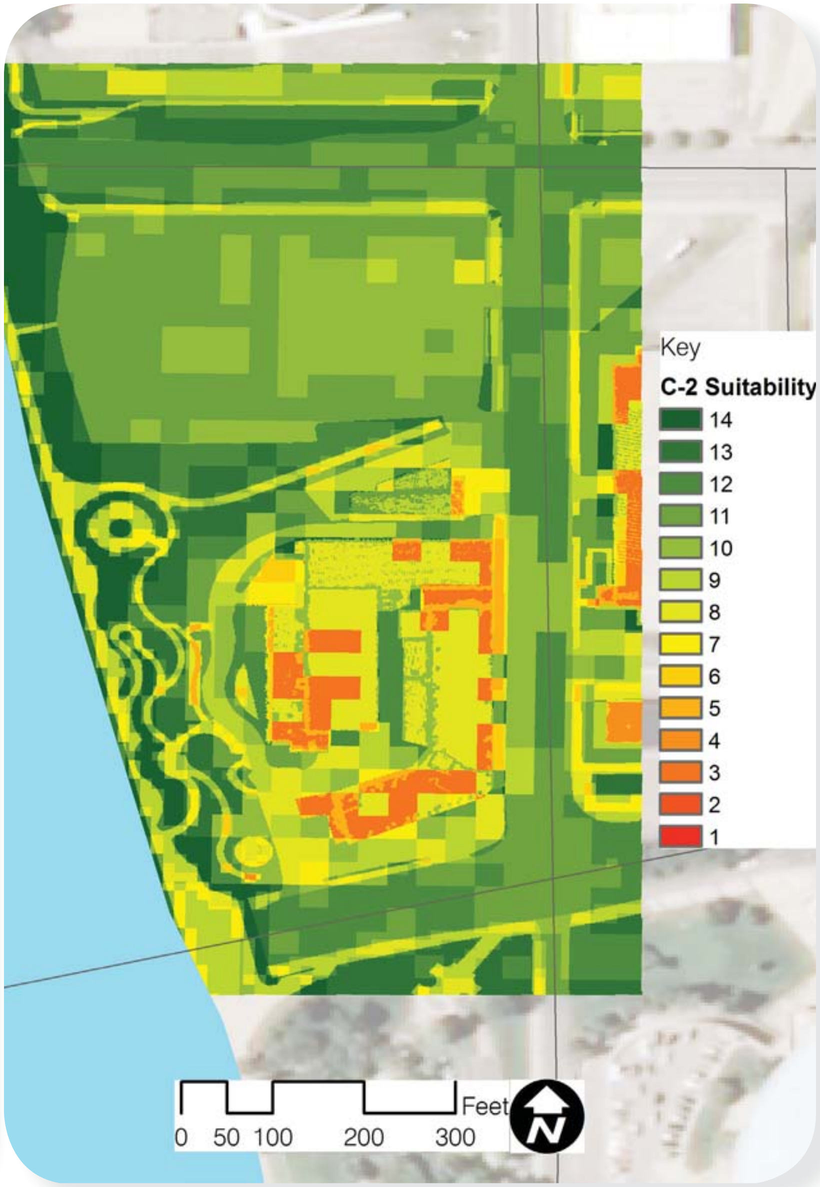
5.11.3 Catalyst Site C-2

“This large city-owned parcel sits north of the Broadview Hotel and includes a riverfront recreational path. The city’s partial ownership of the lot southeast of First and Waco streets (former rail corridor) as well as the public parking structure to the east side of Waco reinforce investment opportunity on and around this site” (Goody Clancy 2010).

When the green infrastructure suitability model is rerun on a just catalyst site C-2, the results are recalculated and are relative to the site boundary. Running the results on a smaller scale provide a refined analysis that can direct design decisions. The western vegetated edge shows high suitability. The parking lot shows higher suitability for green infrastructure on the west side. The new renovations to the south show the least suitability and will not be modified (Figure 5.20).

Figure 5.19 Catalyst site C-2

Figure 5.20 Catalyst site C-2 site specific suitability model



6 Project Proposal

6.1 Inventory

6.1.1 Parking lot

Currently the parcel to be developed is occupied by a large surface parking lot (Figure 6.1). During phases of construction in the area the lot was used to house excess equipment and construction materials and other than large events the lot is seldom at capacity.

The lot houses 220 standard perpendicular parking spots, 12 motorbike stalls, and 8 handicapped stalls. The parking lot creates a general drainage towards the south west and is entirely impermeable. There is a small staircase on the western end of the lot that leads to the riverfront walk.

Figure 6.1 Existing parking lot (Author 2013)

6.1.2 Adjacent buildings

The Drury Hotel received a $29 million historic renovation in August of 2011 (Figure 6.2). This renovation relocated the entrance toward the riverfront and added a skywalk to the parking garage across the street. The hotel contains 200 rooms and suites.

The parking garage connected by skywalk to the east of the Drury Hotel. Currently the main use of this garage is for hotel patrons and is sold at $8 per day.

The lot south east of the First and Waco intersection is planned to be a residential development currently being called Corner 365. This development is being choreographed by the Garvey Center and is scheduled for completion in 2013.

Figure 6.2 The Drury hotel (Author 2013)

6.1.3 Riverfront

In June of 2011 riverfront improvements leading to the Keeper of the Plains were completed (Figure 6.3). Located west of the Drury Hotel, the improvements include a meandering pedestrian path that is ADA accessible, improved lighting, and a small gathering space.

Figure 6.3 Existing riverfront engagement (Author 2012)

6.2 Analysis

According to the Project Downtown, the catalyst site C-2 is a key location for creating a cohesive riverfront. New development adjacent relies on this location to create a unified community. The existing lot does not capitalize on the properties potential.

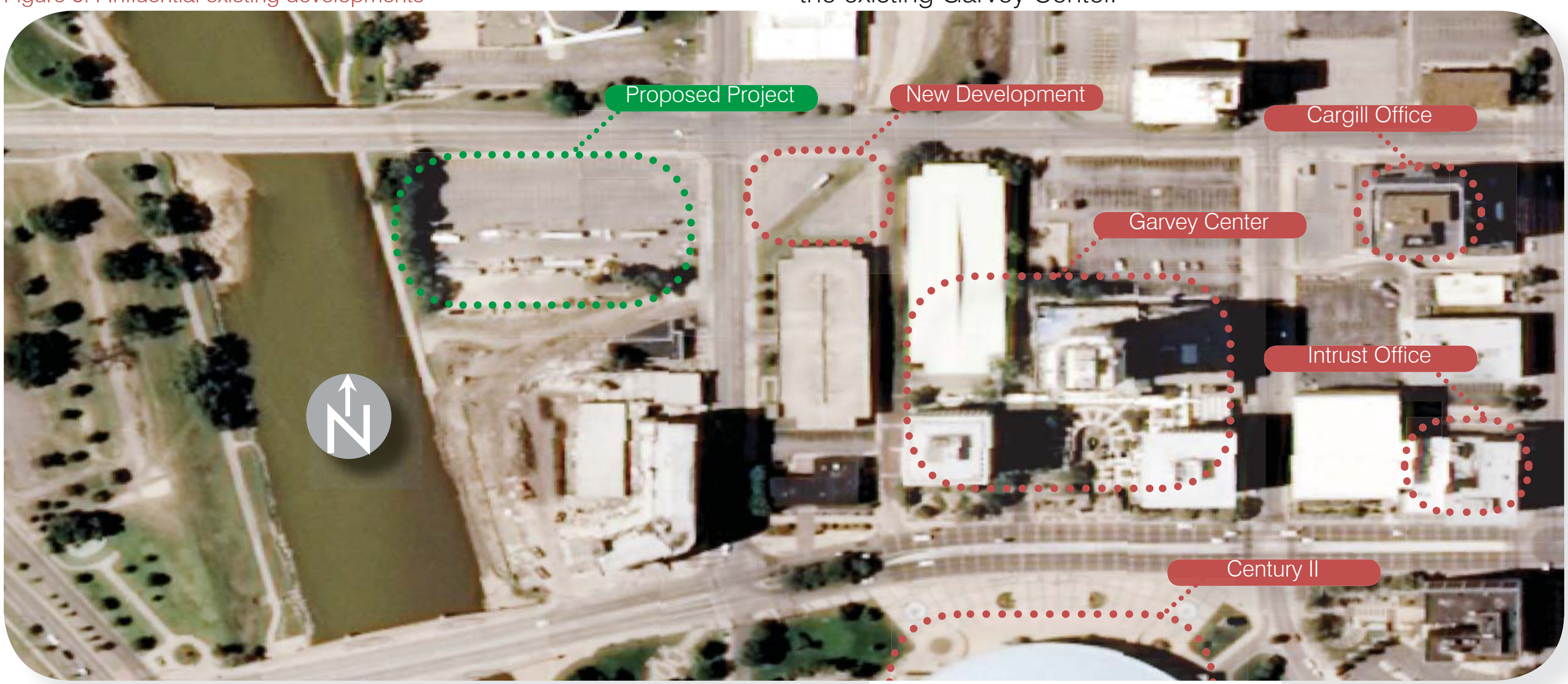
The recent riverfront park improvements west of the Drury Hotel are a precedent for riverfront engagement. The existing Garvey Center provides a substantial mix of office, housing, and retail spaces. Other important developments nearby are the Century II convention center, the Cargill office, and the INTRUST Bank offices (Figure 6.4).

The market analysis conducted for the Project Downtown suggests that a residential focused development on the catalyst site C-2 may be most beneficial after other areas downtown have developed. Currently the existing land value may not be sufficient to support the cost of a project program that meets a high standard of design. The interim use of the site could potentially be an area designated for small public boating facilities such as kayaks and canoes. A simple automobile reliant activity such as this could provide a more frequent use of the existing lot.

6.2.1 Project Downtown Program

The program developed by the Project Downtown master plan calls for a mixed use development that is housing and retail dominant. The building can house 130 dwelling units and should be constructed three to five stories tall. The development should be river oriented and improve pedestrian access to surrounding amenities. There is also opportunity for a possible institutional use for the incoming development to the east and the existing Garvey Center.

Figure 6.4 Influential existing developments



6.3 Program

6.3.1 Development strategy

6.3.1.1 Building Design

My interpretation of the program suggested by the Project Downtown can contain 100-150 dwelling units that are primarily double loaded (Figure 6.5). A parking garage with 50 spaces per story is contained within the footprint. The garage would be concealed within by the building facade.

On the western facade a space has been pulled out to house a major retail or institutional use (Figure 6.5).

6.3.1.2 Site Design

The site has been designed to create a pedestrian front to the river (Figure 6.6 & 6.7). The riverfront will also contain a majority of the stormwater management to capitalize on the didactic nature of this pilot project. An additional 5000 sq/ft private fenced garden will be created in the interior of the building. A recreational space will be created on the roof of the parking garage for the residents. The garage roof will act as a private balcony and contain a green roof that both manages stormwater and acts a visual focal point (Figure 6.6 & 6.9).

6.3.2 Green Infrastructures Utilized

The design of the site takes the original green infrastructure concept into consideration (Figure 5.1). Generally stormwater is collected by green roofs then runoff is collected in a cistern. The Cistern is used to water the constructed wetland in dry times, and inversely the wetlands take on overflow from the roof in large storms. Water collected in the private garden and generated by the pedestrian and automobile pavement is also conveyed to the wetland. The area of developed land is 1.66 acres. The remainder of the parcel for stormwater management is 0.89 acres.

6.3.3 Stormwater runoff calculations

Ideally the green infrastructure system devised would be able to manage 80% of the two year, one hour storm. Using the rational method this is estimated to be 3.626 Acre inches per hour (Table 6.1).

Table 6.1 Rational method calculations

Total Acreage	2.55
Percent developed	65
Percent vegetated	35
Developed runoff coefficient	.5
Vegetated runoff coefficient	.1
Weighted runoff coefficient	.36
Rainfall intensity	3.95
Peak stormwater runoff[1]	3.626

$$^{1}Peak\ runoff = Weighted\ runoff\ coeddicient * Rainfall\ Intesity * Total\ Acrage$$

6.4 Design

Figure 6.5 Conceptual building design (Author 2013)

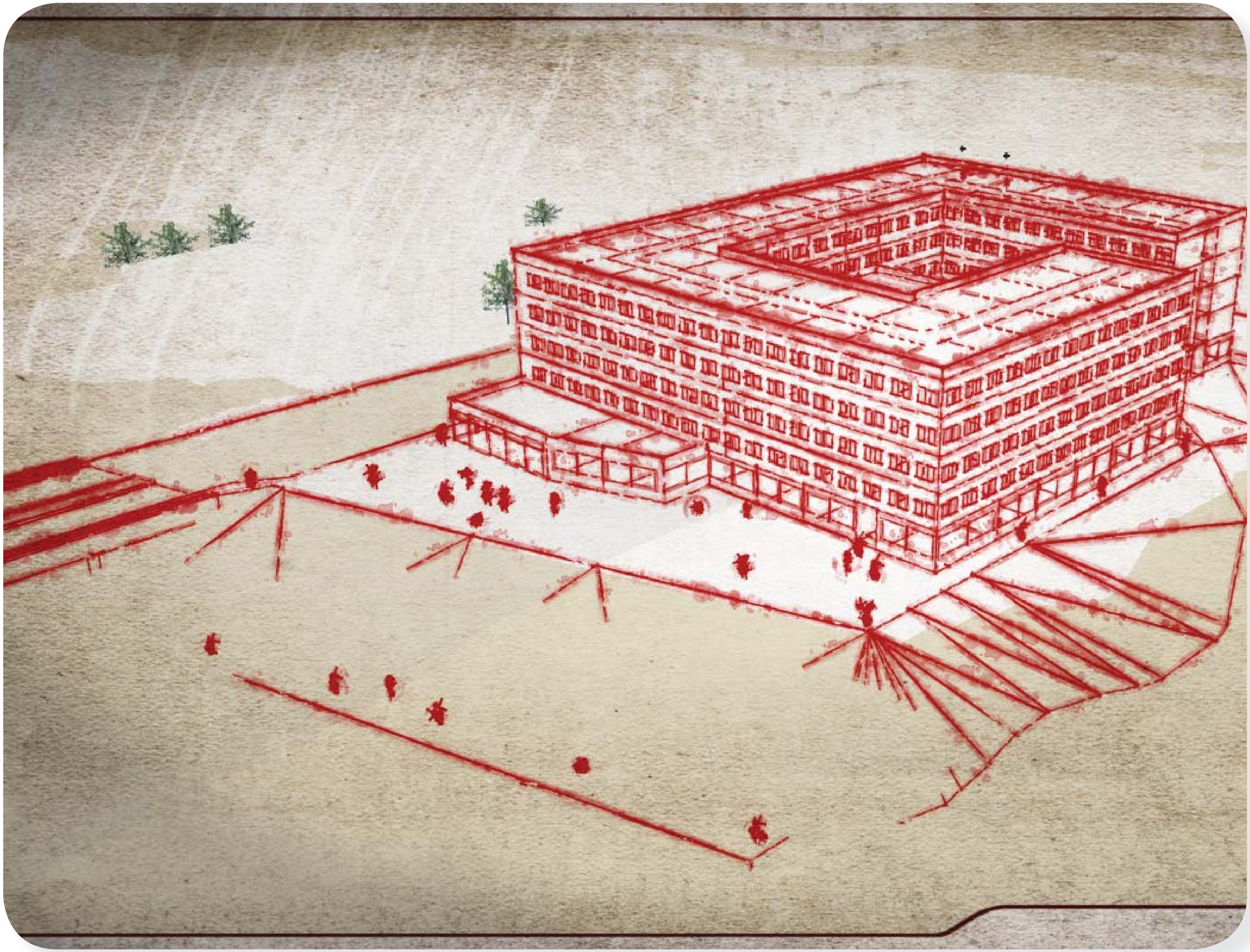


Figure 6.6 Aerial view looking north (Author 2013)

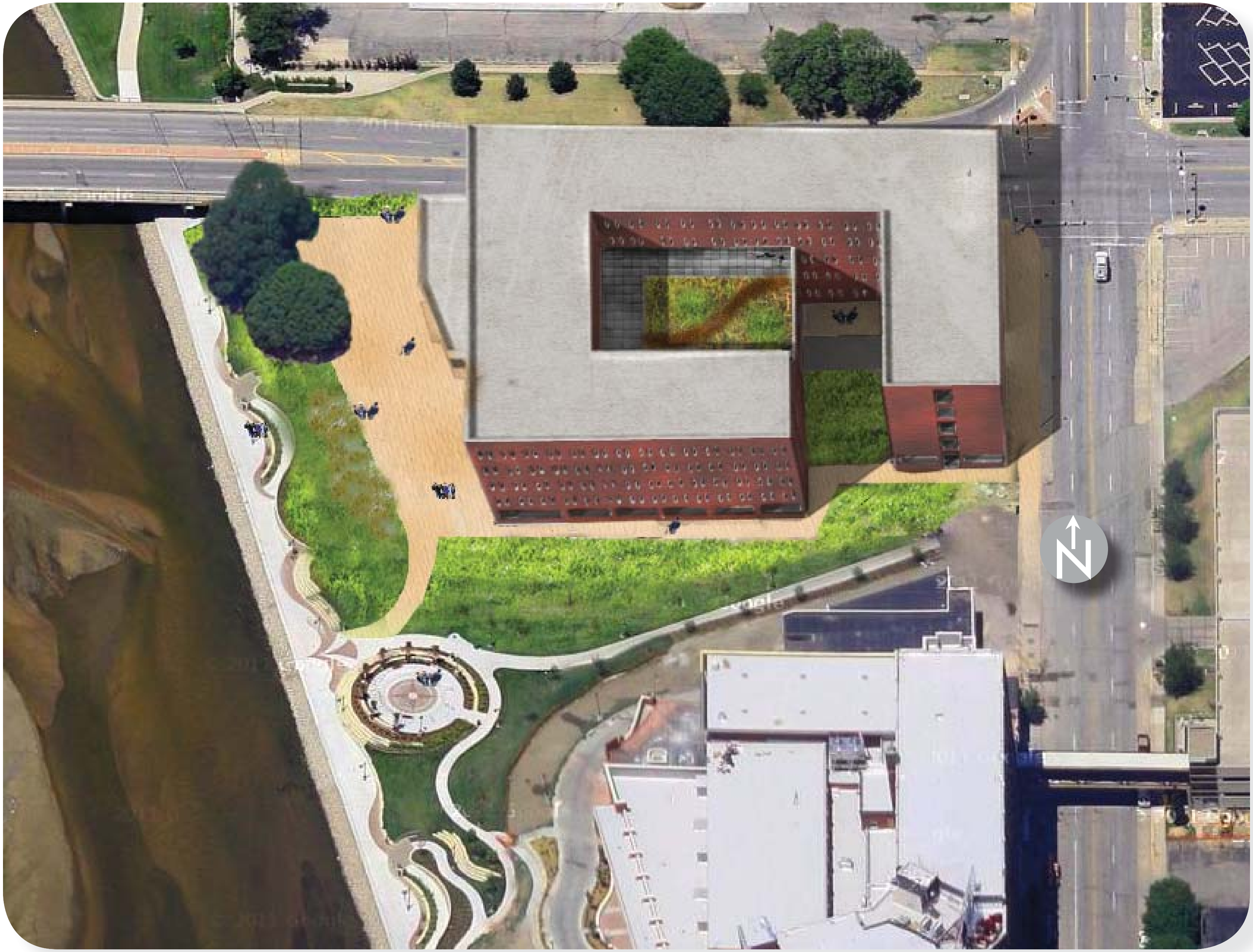


Figure 6.7 Perspective viewing site from the West Bank (Author 2013)

Figure 6.8 Schematic design using gray infrastructure (Author 2013)

Figure 6.9 Schematic design using green infrastructure (Author 2013)

6.5 Cost to Benefit Analysis

6.5.1 Green Values National Stormwater Management Calculator

The National Green Values Calculator (GVC) is a tool used to compare the performance, costs, and benefits of green infrastructure to conventional stormwater practices. This online calculator was developed by the Center for Neighborhood Technology (CNT). CNT has been around since the late 1970's and is a multi-disciplinary organization focused on the issues of, transportation, community development, energy usage, water management, and climate change (Center for Neighborhood Technology 2013).

The GVC is focused on runoff volume reduction and does not account for peak flows. Volume reduction is calculated through standardized equations for infiltration, evapotranspiration, and reuse. The GVC is intended for small, single site applications equivalent to the C-2 catalyst site. The specific methodology used in the GVC can be downloaded from the calculator home page (http://greenvalues.cnt.org/national/calculator.php) and a similar cost analysis method has been included in section 9.2 of the Appendix of this document.

The land use results of the GVC run on the schematic design Figure 6.12 can be seen in Table 6.2, Figure 6.10 and 6.11. The Construction costs (Table 6.3) show that green infrastructure costs slightly more by about $7,000. The annual maintenance estimate (Table 6.4) shows that green infrastructure cost less by about $1,000. The estimated 100 year life cycle costs show green infrastructure having a savings of $32,000. A breakdown of stormwater managed per BMP can be seen in table 6.6. The explicit results from the GVC can be seen in appendix 9.1.

6.5.2 Schematic Design

Table 6.2 Land use calculations per design

	Grey	Green
Conventional Roof	51,201	48,641
Green Roof	0	2,560
Pavement	16,384	0
Permeable Pavement	0	16,384
Lawn	45,235	0
Native vegetation	0	45,235
Rain garden	0	2,000
Total Impervious	**67,585**	**48,641**
Total Pervious	**45,235**	**61,619**

Figure 6.10 Traditional infrastructure land use (Author 2013)

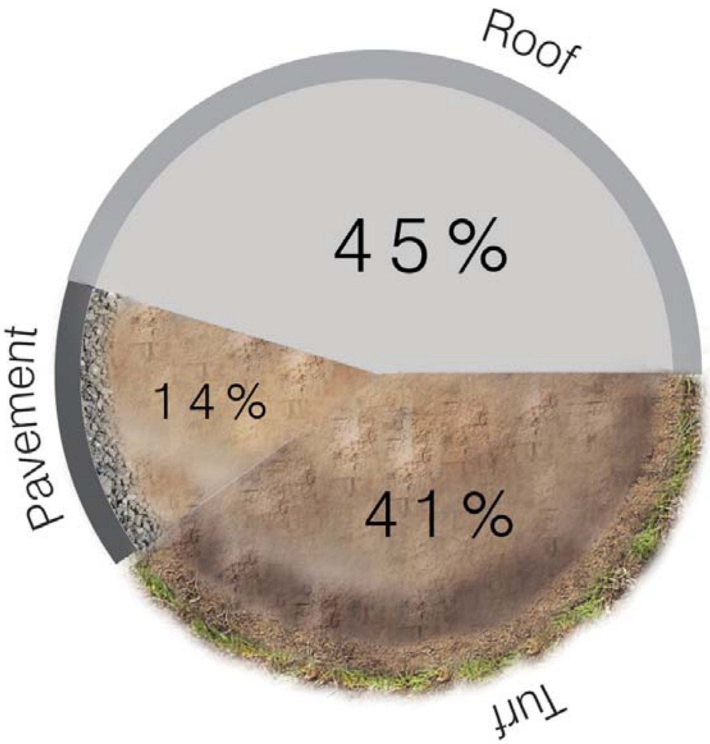


Figure 6.11 Green infrastructure land use (Author 2013)

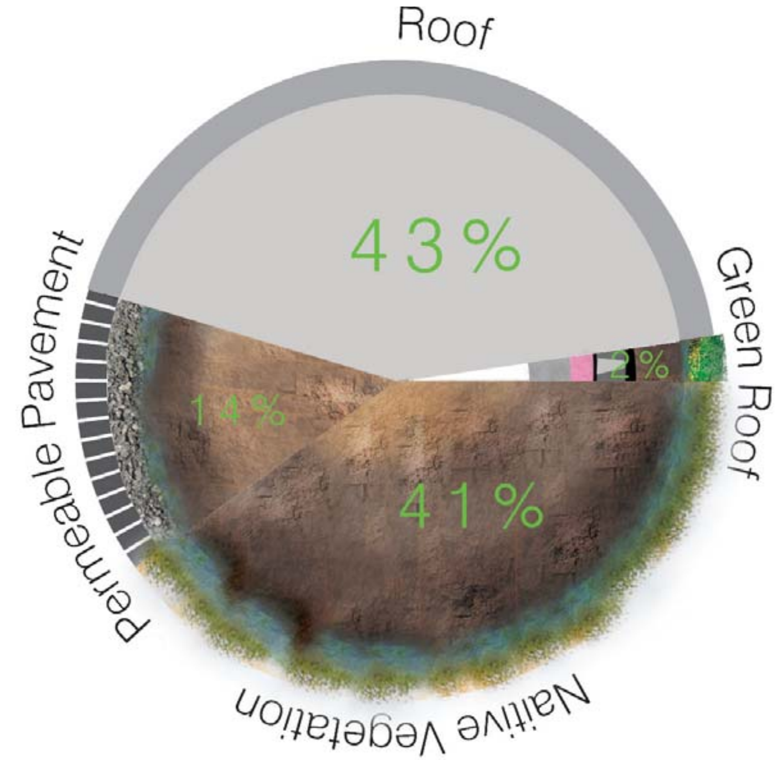


Figure 6.12 Section from east to west (Author 2013)

6.5.3 Material Costs

Table 6.3 Construction cost estimation

	Gray ($)	Green ($)
1 Concrete sidewalk	85,033	
2 Storm Sewer	54,295	
3 Standard Roof	384,008	364,807
4 Green Roof		40,321
5 Pavers		116,326
6 Turf	9,499	
7 Native Plants		4,324
8 Rain garden		14,000
9 Downspout		70
10 Cisterns		290
Total	532,835	540,138

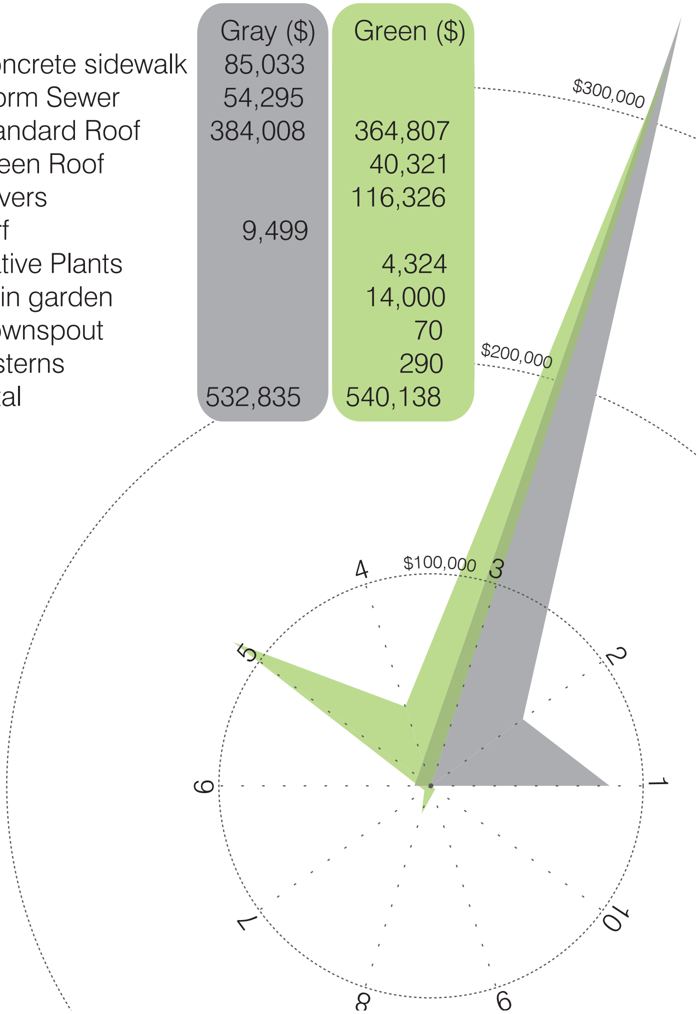


Table 6.4 Annual maintenance cost estimation

	Gray ($)	Green ($)
1 Concrete sidewalk	475	
2 Storm Sewer	141	
3 Standard Roof	2,560	2,432
4 Green Roof		64
5 Pavers		590
6 Turf	4,071	
7 Native Plants		2,612
8 Rain garden		680
9 Downspout		1
10 Cisterns		14
Total	7,247	5,942

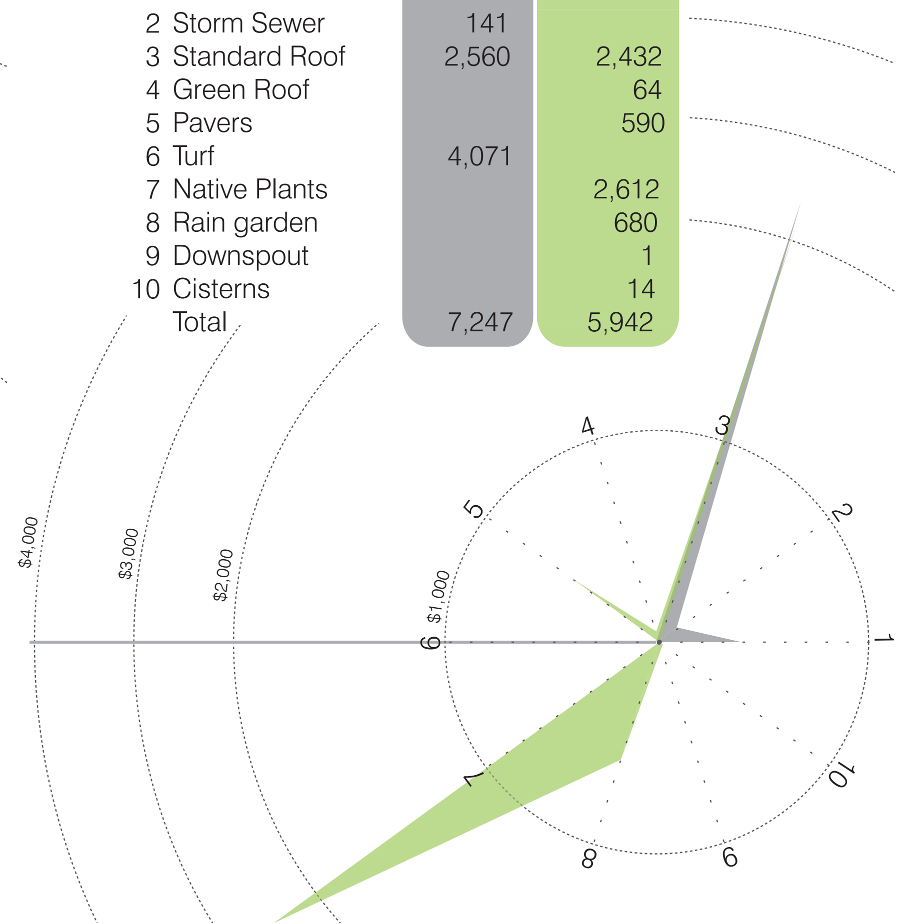
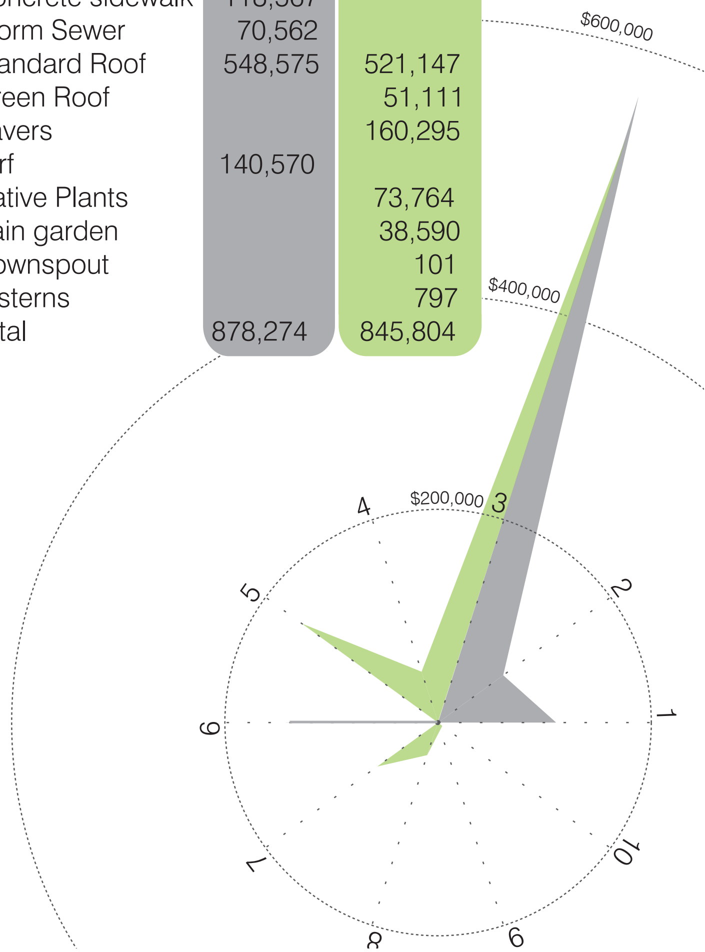


Table 6.5 Life cycle cost estimation (100 years)

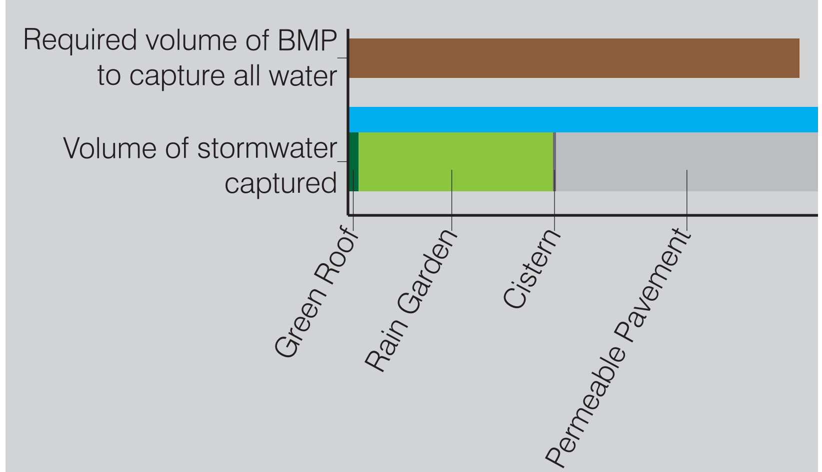
	Gray ($)	Green ($)
1 Concrete sidewalk	118,567	
2 Storm Sewer	70,562	
3 Standard Roof	548,575	521,147
4 Green Roof		51,111
5 Pavers		160,295
6 Turf	140,570	
7 Native Plants		73,764
8 Rain garden		38,590
9 Downspout		101
10 Cisterns		797
Total	878,274	845,804



6.5.4 Stormwater Reduction

Table 6.6 Stormwater management per BMP

Required volume capture from whole site (ft³)	4,701
Volume captured by BMP's (ft³)	4,891
Green roof (ft³)	107
Rain garden (ft³)	2,027
Cistern (ft³)	27
Permeable pavement (ft³)	2,731
Percent captured (%)	104
Decrease of impervious area (%)	28



7 Findings

7.1 Feasibility

7.1.1 Cost Analysis

The results of the cost analysis are favorable. When running a cost calculation scenario through the GVC using the exact schematic design, the result developed 224,339 ft^3 of water to capture. The GVC also predicted that 4,701 ft^3 of green infrastructure would be necessary to manage the predicted runoff. seen in table 6.6. Using green infrastructure was found to be more cost effective strictly considering implementation and life cycling. Though the savings were not dramatic, only about $7,000, the effectiveness of a pilot project is worth exploring.

Ideally the cost analysis would be conducted using a methodology developed using local statistics. For this analysis stormwater calculations using the rational method were reasonable. However, specific calculations for cost of green and gray infrastructure implementation were not available as the city has no precedent for a study of this nature. The infrastructure cost estimates developed using Green Values Stormwater Toolbox Calculator are reasonable.

The positive results of this analysis also align with the findings from the American Society of Landscape Architect's Green Infrastructure Survey. This study questioned ASLA members for evaluations of their projects that implement green infrastructure (Table 7.1, 7.2, and 7.3). The response was 479 case studies from 43 states, the District of Columbia, and Canada. 55 percent of the studies were designed to meet local ordinance, 88 percent of local regulators were supportive of green infrastructure implementation and 68 percent of the projects received local funding (Odefey, et al. 2012).

Table 7.1 Project types reported form EPA survey (Odefey, et al. 2012)

Institutional/ Educational	21.5%
Open space/ park	21.3%
Other	17.6%
Transportation Corridor/ Streetscape	11.9%
Commercial	8.6%
Single family Residential	5.5%
Government Complex	4.2%
Multi Family Residential	3.7%
Open Space Garden	2.9%
Mixed use	1.8%
Industrial	1.1%

Table 7.2 Green Infrastructure Implementation method (Odefey, et al. 2012)

Retrofit of existing property	50.7%
New development	30.7%
Redevelopment project	18.6%

Table 7.3 Did green infrastructure increase costs? (Odefey, et al. 2012)

Reduced costs	44.1%
Did not influence costs	31.4%
Increased costs	24.5%

7.1.2 Benefit Analysis

Again there is no precedent for green infrastructure or substantial BMP's in downtown Wichita. The results of the benefit analysis show that it is relatively easy to manage all of a large storm event without increasing the costs of a project.

Green infrastructure also finds its benefit in the value of bringing vegetation to an urban area. Vegetation helps foster a sense of community in an urban area. The ecological benefits, along side the cultural and economic benefits prove that green infrastructure is a viable substitute for traditional infrastructure.

7.2 Moving Forward

7.2.1 Policy

The developed pilot project shows that for no extra cost 80% of the stormwater generated by catalyst site C-2 on a two year one storm can be managed on site. It is recommended that the SSMID policy should be modified to promote green infrastructure implementation through strategies outlined in section 3.5.3 in this document.

A review and revision of local codes should be conducted to promote green infrastructure implementation outlined in section 4.4.2 of this document. First stormwater fees should be created to tax sites that develop more stormwater than they manage. Alongside these fees, stormwater discounts should be created as an incentive to manage stormwater onsite.

In the new stormwater regulations developed by the City of Wichita Volume 3 section 8.0 and sub heading 7.0 the document outlines performance bonds (Public Works 2012). These are set up to cover the costs that the city may incur from improper stormwater management or if a developed site does not manage stormwater as it had planned when applying for a building permit. There appears to be no benefit for managing stormwater only penalties.

Another opportunity for incentives toward implementing green infrastructure could be in the Community Improvement District (CID) policy (City of Wichita 2010). The CID is meant to promote the construction of infrastructure that is not publicly of privately feasible. The City Council holds petition for approval of these funds and can push for green infrastructure.

Private investment can be fostered further by planning and developing demonstration projects such as this report and using them as a method to educate developers and outreach to the community for support.

7.2.2 Phasing

The composite suitability analysis conducted in section 4.10 of this document delineates areas that should receive funding for green infrastructure implementation. Areas that have the largest concentrations of suitability such as the Market street corridor should be planned first. This corridor should be linked to adjacent areas that have not seen recent development. The final phase of green infrastructure implementation would be the more recently developed sites such as the Century II convention center.

The sequence of projects should promote a stormwater management linkage through adjacent developments to maximize green infrastructure potential. Using the composite model methodology developed by this project can reveal potential linkages within a specified boundary.

7.2.3 Conclusions

The Downtown Wichita, with help from the WDDC and the Goody Clancy master plan, has experienced steady growth. The SSMID tax incentive adopted from the Project Downtown provides an opportunity to rethink infrastructure investment strategies.

Many of the gaps created by unclear definition of public space can be solved by green infrastructure strategies. Analysis of suitability in the downtown shows where to best invest in green infrastructure. By strategically implementing green infrastructure in highly suited locations using public investment, a standard for stormwater management precedent can be built. The implications of increasing downtown permeability will help protect the Arkansas River downstream.

Designing and analyzing a catalyst site using a program defined in the Project Downtown with the National Green Values Calculator showed that the cost of managing 100% of the stormwater generated on site does not increase development costs. This analysis shows that the ecological and social value of bringing vegetation to the downtown and reducing the amount of impermeable surfaces comes with no extra cost. Another economic benefit, not examined in the GVC is the ability for the added vegetation of green infrastructure to increase property value. This benefit would be validated through increased implementation and analysis over time.

A more detailed methodology, with calculations specific to Wichita, would need to be conducted to be certain if costs are not increased. This level of analysis was not possible for this project as no precedent currently exists however a more detailed cost estimation developed for the Piedmont area (Hathaway and Hunt 2007) can be found in appendix 9.2.

Wichita should use this report as a starting point to modify existing stormwater regulations and generate new ideas to promote green infrastructure. The benefits of implementing green infrastructure outweigh the costs.

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9 APPENDICIES

9.1 Cost Calculations for Site C-2

9.2 Calculations for 2 Acre Watershed

9.3 GIS Capabilities

9.1 Cost Calculations for Site C-2

Construction costs	Gray ($)	Green ($)
Concrete sidewalk	85,033	0
Conventional stormwvater storage	54,295	0
Standard Roof	384,008	364,807
Green Roof	0	40,321
Permeable Pavements (Pavers)	0	116,326
Turf	9,499	0
Native Plants	0	4,324
Rain garden	0	14,000
Downspout disconnection	0	70
Cisterns	0	290
Total	**532,835**	**540,138**

Annual maintainance cost	Gray ($)	Green ($)
Concrete sidewalk	475	0
Conventional stormwater storage	141	0
Standard Roof	2,560	2,432
Green Roof	0	64
Permeable Pavements (Pavers)	0	590
Turf	4071	0
Native Plants	0	2,612
Rain garden	0	680
Downspout disconnection	0	1
Cisterns	0	14
Total	**7,247**	**5,942**

Lifecycle costs (100 year)	Gray ($)	Green ($)
Concrete sidewalk	118,567	0
Conventional stormwater storage	70,562	0
Standard Roof	548,575	521,147
Green Roof	0	51,111
Permeable Pavements (Pavers)	0	160,295
Turf	140,570	0
Native Plants	0	73,764
Rain garden	0	38,590
Downspout disconnection	0	101
Cisterns	0	797
Total	**878,274**	**845,804**

9.2 Calculations for 2 Acre Watershed

9.2.1 Bioretention

Item	Unit	Cost $
Excavation	Sf	0.25
Soil amendment -sand	Sf	0.50
Mulch	Sf	0.75
Plants	Sf	1.00
Plant installation	Sf	0.50
Under drain	Per	50.00
Under drain installation	Per	200.00

9.2.2 Cistern/ rainwater harvesting

Item	Unit	Cost
Site preparation	Sf	1.39
Hose and Accessories	Per	15.00
Modify gutters	Per	30.00
Rain Barrel		
Rain Barrel	Per	150.00
Rain barrel installation	Per	100.00
Cistern		
550 gallon	Per	564.00
1000 gallon	Per	874.00
2500 gallon	per	1349.00
Cistern installation	Per	568.20
Concrete pad	Sf	3.58
Attachments	Per	90

9.2.3 Green Roofs

Item	Unit	Cost
Impermeable layer	Sf	1.00
Drainage layer	Sf	1.50
Soil	Sf	0.60
Soil installation	Sf	1.25
Plants	Sf	6.00
Plant installation	Sf	3.00

9.2.4 Impervious Removal

Item	Unit	Cost
Surface removal	Sf	1.50
Removal of underlying gravel	Sf	0.25
Hauling and disposal	Sf	0.40
Purchase of load soil	Sf	1.00
Fill void with soil	Sf	0.25
Re-grading	Sf	0.30
Grass seed application	Sf	0.30

9.2.5 Pervious Pavement

Item	Unit	Cost
Excavation	Sf	0.25
Hauling	Sf	0.25
Fine Grading	Sf	0.36
Gravel Under layer	Sf	0.75
Pavement Installation	Sf	8.00

9.2.6 Swales

Item	Unit	Cost
Excavation	Sf	0.09
Hauling	Sf	0.21
Grading	Sf	0.36
Grass	Sf	0.29

9.2.7 Pocket Wetland

Item	Unit	Cost
Excavation	Sf	0.25
Hauling	Sf	0.25
Grading	Sf	0.36
Plants	Sf	2.00
Plant Installation	Sf	0.30
Outlet Structure	Per	50.00

9.3 GIS Capabilities

9.3.1 Data Processing

GIS data processing is an important step in the history of spatial mapping and analysis. On the surface a geographic information system, or GIS, is simply a map of information. The real value of GIS is the tabular data associated with the visual map representation. Not only can different maps be combined or overlaid upon one another to create a qualitative visual spatial analysis, but GIS also possesses the ability to produce results in a qualitative tabular output.

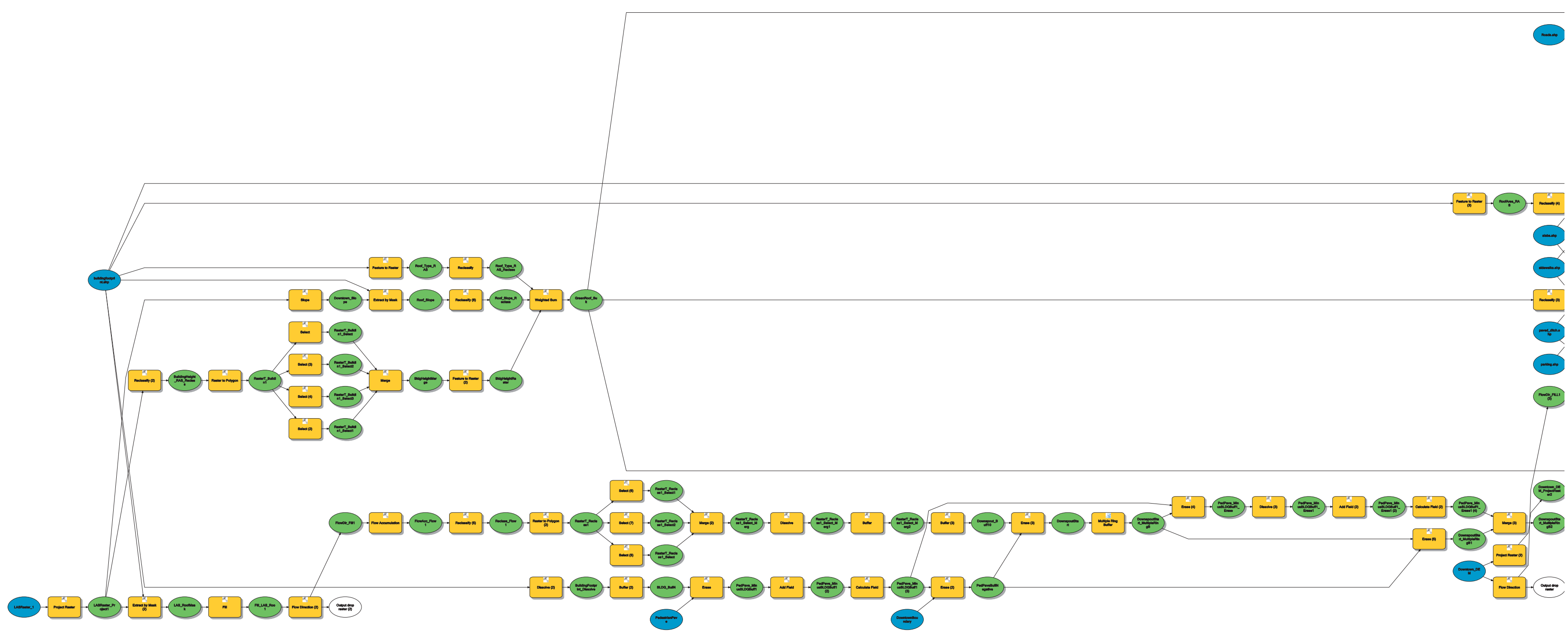
9.3.2 Data Modeling

9.3.2.1 Python Scripting, Visualized

Python is a general-purpose programming language that has a focus on code readability. Because python is a dynamic programming language, it can execute scripts when run rather than after script compilation, It can be used in third party programs; such as ArcGIS.

The benefit of being able to visualize these scripts is accessibility. Each python script is represented as a tool that has its own description and input factors. This simplicity makes utilizing and describing analysis methodology easier; as

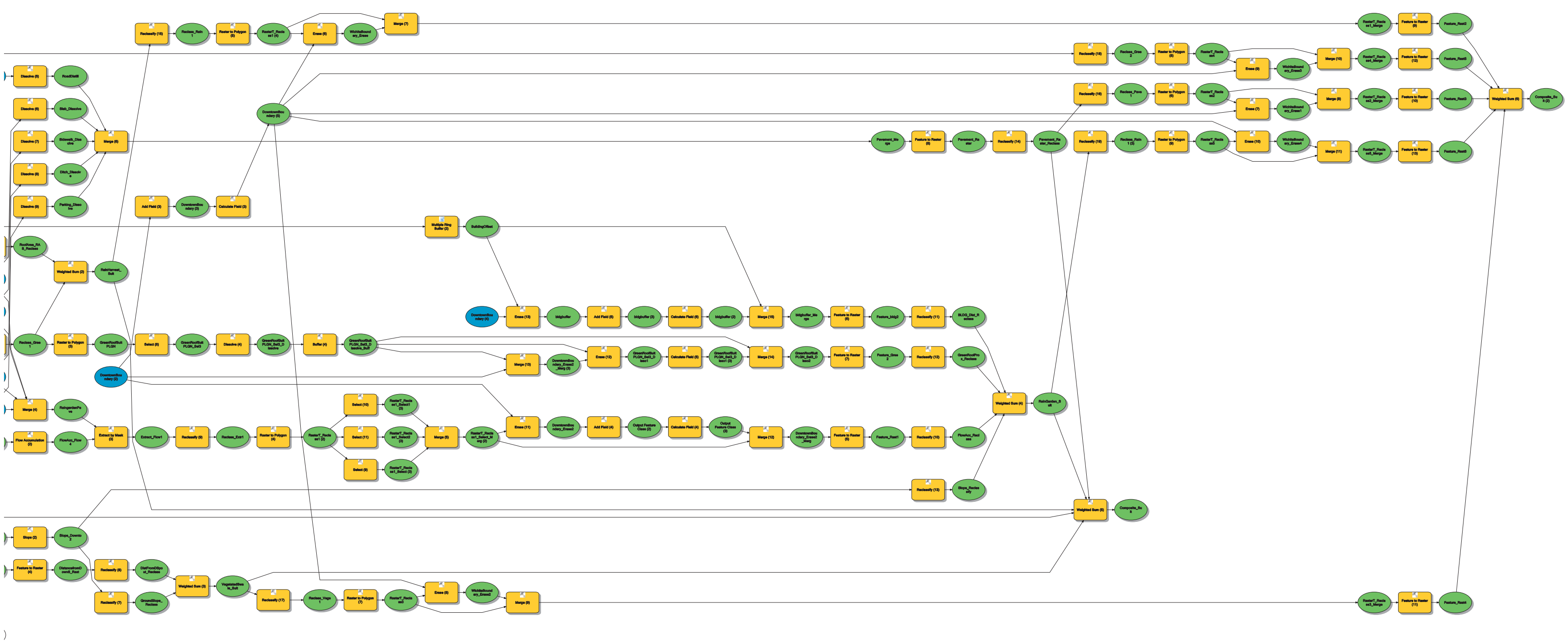
Figure 9.1 ArcGIS suitability model used for this report (Author 2013)



demonstrated in this project.

9.3.2.2 Testing ability/ reproducible results

This project has attempted to cut out as many subjective factors as possible to identify the costs and benefits of green infrastructure implementation. The scientific nature of this project needed the ability to test hypotheses of suitability with reproducible results. Should the results be found favorable by the City of Wichita, or other entities as well, and implementation of green infrastructure commences, the methodology used should not be exclusive to this project.



GREEN INFRASTRUCTURE

A NEW STRATEGY FOR STORMWATER MANAGEMENT IN DOWNTOWN WICHITA

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