

ANALYZING THE BENEFITS OF REDUCING PARKING: IMPROVING PUBLIC TRANSPORTATION TO  
REDUCE PARKING DEMAND AND INCREASE SPACE FOR GREEN INFRASTRUCTURE IN  
MANHATTAN, KANSAS

by

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A REPORT

submitted in partial fulfillment of the requirements for the degree

MASTER OF LANDSCAPE ARCHITECTURE

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College of Architecture, Planning and Design

KANSAS STATE UNIVERSITY  
Manhattan, Kansas

2013

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## **ABSTRACT**

Climate change and declining ecological health of urban environments are global issues of growing concern. In order to mitigate these issues we must reduce Greenhouse Gas emissions and increase green infrastructure solutions. One way of doing this is through improving public transportation and decreasing parking areas. In this study, Manhattan, Kansas was used to illustrate how improvements to public transportation can reduce parking demand and to show how excess parking can be transformed into green space to improve the ecological health of the city.

First a review of literature and case studies related to increasing ridership of public transportation, reducing parking demand, and calculating ecologic and economic benefits was done. Then ArcGIS was used to analyze the existing public transportation in Manhattan, Kansas. Improvements to the existing transit system were developed and potential increase in ridership was calculated. ArcGIS was then used to analyze existing parking in Manhattan, Kansas. Excess Parking was determined based on current parking demand and predicted transit ridership. A suitability study was then done in ArcGIS to determine which parking areas should be converted into green space. The suitability map assisted in choosing four specific parking areas to redesign in detail to incorporate additional green space and tree cover.

It was estimated that improving Manhattan's bus system could double its ridership. It was also estimated that with improved public transit and parking planning, 30% of Manhattan's parking could be eliminated. Converting 30% of Manhattan's parking into green space would decrease runoff and pollutants from parking lots. Ecological valuation methods were used to calculate the benefits of converting parking into green space. It was found that integrating green space into parking lots would decrease stormwater runoff, mitigate the heat island effect, store carbon, improve air quality and may have social benefits as well.





# ***ANALYZING THE BENEFITS OF REDUCING PARKING***

*Improving Public Transportation to  
Reduce Parking Demand and Increase  
Green Space in Manhattan, Kansas*

***Jena Biondolilo***

## *ANALYZING THE BENEFITS OF REDUCING PARKING*





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**LANDSCAPE ARCHITECTURE MASTER REPORT**

**KANSAS STATE UNIVERSITY**

**PROFESSOR TIM KEANE**

**MAY 2013**

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# ONE

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## INTRODUCTION

PROJECT SUMMARY

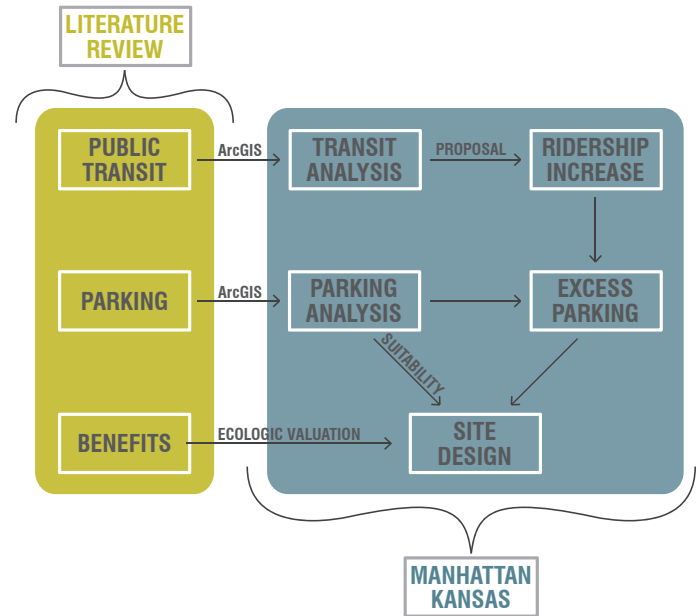
DEFINITION OF TERMS

DILEMMAS

RESEARCH QUESTION

Climate change and declining ecological health of urban environments are global issues of growing concern. In order to mitigate these issues we must reduce Greenhouse Gas emissions and increase green infrastructure solutions. One way of doing this is through improving public transportation and decreasing parking areas. In this study, Manhattan, Kansas was used to illustrate how improvements to public transportation can reduce parking demand and to show how excess parking can be transformed into green space to improve the ecological health of the city.

The following process is summarized in *Figure 1-1*. First a review of literature and case studies related to increasing ridership of public transportation, reducing parking demand, and calculating ecologic and economic benefits was done. Then ArcGIS was used to analyze the existing public transportation in Manhattan,



**Figure 1-1 Process Diagram**

The literature review defines analysis done using ArcGIS. The ArcGIS analysis of existing public transportation and parking influences the site designs. The literature provides methods for calculating the benefits of the proposed designs.

Kansas. Improvements to the existing transit system were developed and potential increase in ridership was calculated. ArcGIS was then used to analyze existing parking in Manhattan, Kansas. Excess Parking was determined based on current parking demand and predicted transit ridership. A suitability study was then done in ArcGIS to determine which parking areas should be converted into green space. The suitability map assisted in choosing four specific parking areas to redesign in detail to incorporate additional green space and tree cover.

It was estimated that improving Manhattan's bus system could double its ridership. It was also estimated that with improved public transit and parking planning, 30% of Manhattan's parking could be eliminated. Converting 30% of Manhattan's parking into green space would decrease runoff and pollutants from parking

lots. Ecological valuation methods were used to calculate the benefits of converting parking into green space. It was found that integrating green space into parking lots would decrease stormwater runoff, mitigate the heat island effect, store carbon, improve air quality and may have social benefits as well.

## 1.1

### PROJECT SUMMARY

***Carbon Sequestration***

A natural process of trees and other plants that separates carbon dioxide from the atmosphere and stores it above ground stems and foliage and below ground in roots and soil.

***Green Infrastructure***

The combined structure, position, connectivity and types of green spaces which together enable delivery of multiple benefits as goods and services. It is necessary for the efficient functioning, socially, economically and ecologically, of a given geographical area. Examples of green infrastructure include bio-swales, constructed wetlands, rain gardens, and green roofs. (Forest Research, 2010)

***Greenhouse Gas (GHG):***

Gases, naturally occurring or produced by industrial activities and automobiles, that

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contribute to global warming. Greenhouse gases include carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), and ozone (O<sub>3</sub>), as well as, several classes of halogenated substances that contain fluorine, chlorine, or bromine. (US EPA, 2012)

***Heat Island Effect:***

Occurs when urban areas are warmer than the surrounding rural areas as a result of increased impermeable surfaces and decreased vegetation. (Heat Island Effect | US EPA, 2013)

***Impermeable Surface:***

A surface such as concrete or asphalt that does not allow runoff to percolate into the soil resulting in greater runoff rates.

***Low Impact Development (LID):***

“An ecologically-based stormwater management

approach favoring soft engineering to manage rainfall on site through a vegetated treatment network.” (University of Arkansas, 2010)

***Runoff:***

Precipitation, snow melt, or irrigation water that does not infiltrate into the ground, flows downhill, and appears in uncontrolled surface streams, rivers, drains or sewers. (USGS Water Science School, The, 2013)

***Urban Ecology:***

An interdisciplinary field that integrates social and ecological aspects of urban areas. Key concepts in Urban Ecology suggest that humans are part of urban ecosystems. Urban ecologists look to better understand the link between humans and the natural environment. (Marzluff et al. 2008)

## 1.2

### DEFINITION OF TERMS



Figure 1-2 **Parking in Manhattan**

### ***Global Dilemmas***

Climate change, air quality, and degraded ecological processes within urban environments are global issues of growing concern. America's over-reliance on the automobile contributes to climate change and leads to large sums of space and money allocated to roads, parking, and other vehicle amenities. Parking lots contribute to increased stormwater runoff, pollution in streams and the heat island effect. Steps can be taken at a local scale to help mitigate these global issues.

### ***Local Dilemmas***

There is an opportunity to improve public transportation in Manhattan, Kansas. Although Manhattan implemented a fixed route bus system starting in 2012, the city is not meeting its full potential for public transportation. A preliminary study of transit in towns similar to Manhattan shows that city's transit system is lacking in

route coverage, frequency and annual ridership. The dominance of parking in Manhattan, Kansas also presents an opportunity for improvement. There are several areas in Manhattan with a high concentration of parking as seen in *Figure 1-2*. Not only do these parking lots decrease aesthetic value and pedestrian accessibility, they contribute to ecological issues including the heat island effect and increased stormwater runoff. By decreasing the amount of parking in Manhattan, more green space could be implemented to be used for storm water management, heat island mitigation, and carbon sequestration.

*What are the ecological benefits of improving public transportation and reducing parking demand?*

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***Research Questions***

How can improvements to public transportation and parking planning reduce greenhouse gas emissions and parking demand?

What are the ecological benefits of reducing parking?

***Project Statements***

Making improvements to the bus system in Manhattan, Kansas would increase ridership.

Increased ridership would reduce parking demand and greenhouse gas emissions.

Excess parking could be transformed into green space to be used for stormwater management, heat island mitigation, carbon storage and sequestration and air pollution abatement.

**1.4****RESEARCH QUESTION**



## TWO

2.1

### BACKGROUND KNOWLEDGE

2.2

DRIVING FORCES

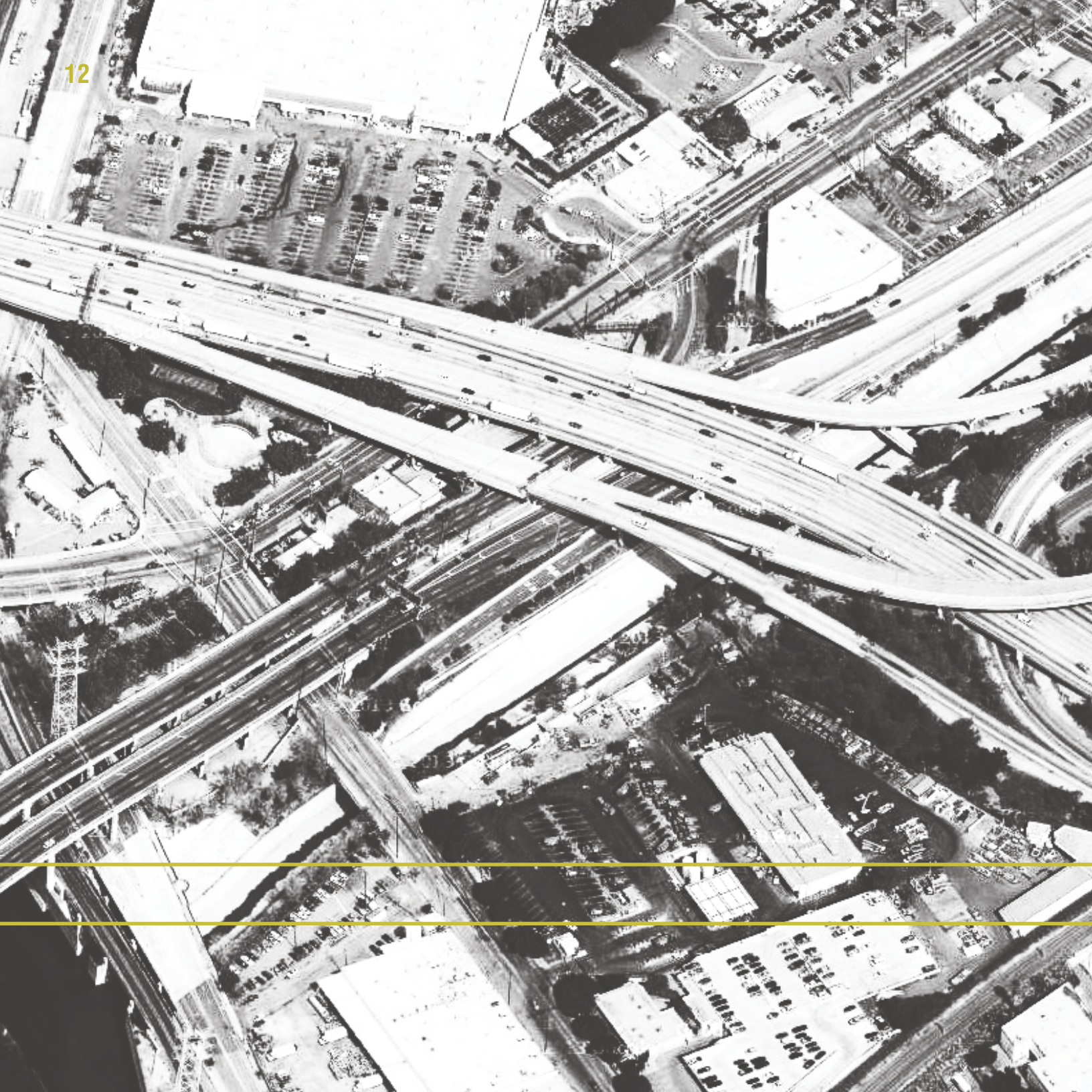
2.3

LITERATURE REVIEW

2.4

CASE STUDIES

EXISTING CONDITIONS





### Figure 2-1 Planning for Cars

*This is an aerial image of Los Angeles, California. It exemplifies the dominance of space and infrastructure dedicated to cars in American cities.*

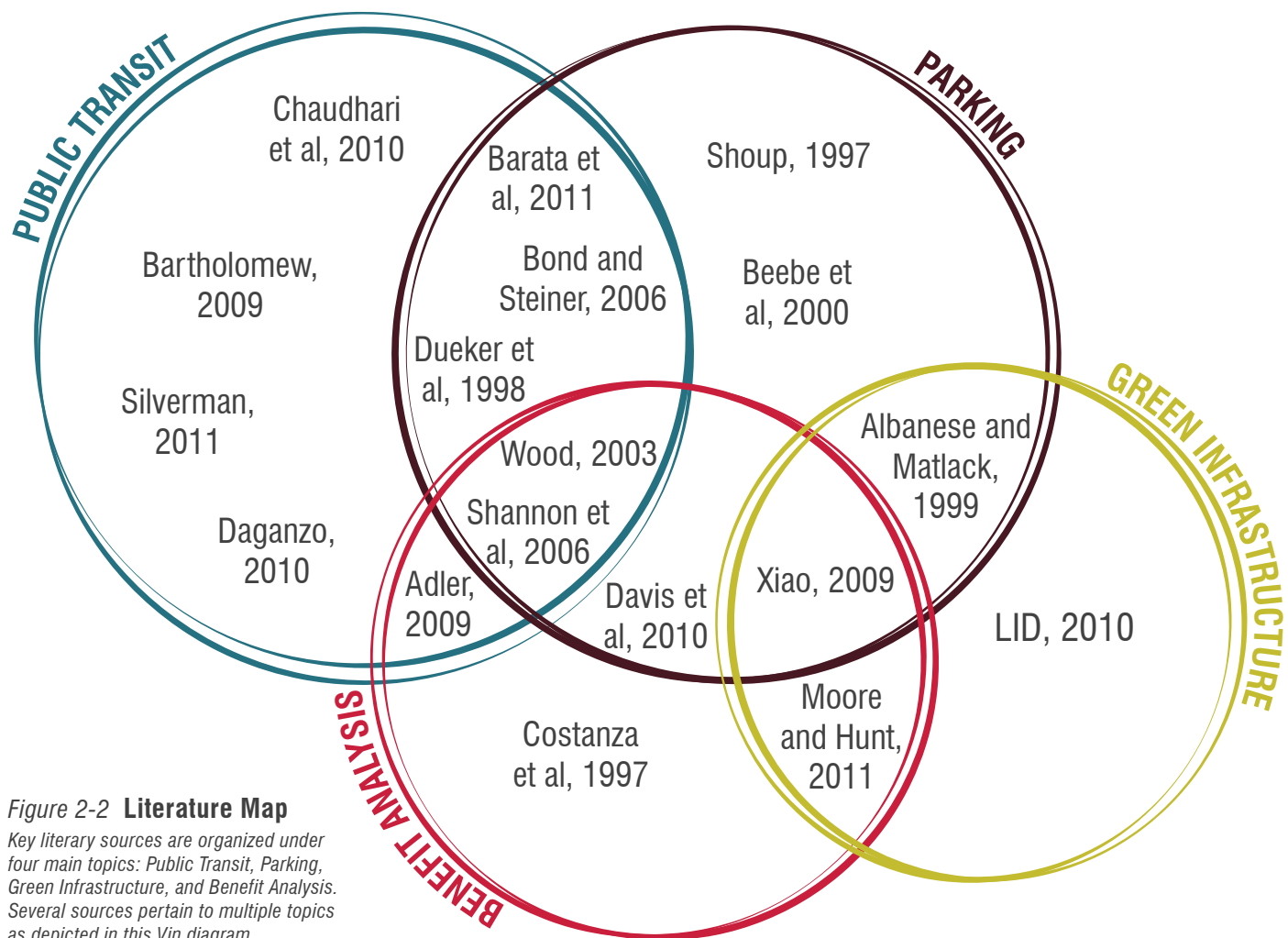
Prior to the invention of the automobile, transit, especially across long distances, was somewhat limited. People depended on trains or even slower modes of transportation. At first, the automobile increased mobility significantly but over time, as development planning catered to the car as shown in *Figure 2-1*, mobility began to decrease as a result of increased traffic and decreased walkability. Today, many urban areas in America have excessive vehicular traffic and lack accessibility for pedestrian and other non-automobile travelers. In recent years public transit has been on the rise. Cities must invest in public transit as a means of increasing accessibility and mobility, as well as a way of addressing environmental issues. Some of these environmental issues include, global climate change, depletion of the earth's natural resources, and declining ecological health in urban areas.

Preliminary research reveals that public transportation can reduce greenhouse gases which in turn helps to mitigate climate change. An increase in public transportation can also reduce the amount of space allocated toward parking. Parking can be replaced with green space which can then be used for low impact development, decreasing the effects of heat island, and carbon sequestration. The following research focuses on the ecologic benefits of improving public transit and reducing parking.

A wide breadth of literature was reviewed related public transportation, parking planning and analyzing the benefits of increasing green space. The review of literature provided background knowledge on related topics and defined the research questions, project statements, and analysis methods.

## 2.1

### DRIVING FORCES



**Figure 2-2 Literature Map**

Key literary sources are organized under four main topics: Public Transit, Parking, Green Infrastructure, and Benefit Analysis. Several sources pertain to multiple topics as depicted in this Vin diagram

To ensure a comprehensive review of literature my search was divided into four main topics: public transit, parking, green infrastructure, and benefits analysis. Key sources and topics can be seen in the literature map in *Figure 2-2*.

### ***Improving Public Transit***

Public transportation improves the ecological health of urban areas by decreasing car dependence and parking demand which can reduce green house gas emissions and free up space for green infrastructure (Mostafavi and Doherty 2010, Topos 2010, Mashayekh et al. 2012, Shannon et al. 2006). Newman (2006) argues that transit is the central means of creating a sustainable community. Sustainable transport is not dependent on developing more sustainable automobile technology but rather, overcoming car dependence (Newman 2006). An estimated 90% of trips in the United States

are made by private vehicles compared to 58% in the United Kingdom (Adler 2009). The American Planning Association states that, “the economic superpowers of the 21st century will be determined by the investments made during this decade, particularly in transportation” (Renne 2010, 61).

### ***Reducing Emissions***

Currently, there is international concern about changing climate. The Intergovernmental Panel on Climate Change suggests a 50%-85% reduction in global CO<sub>2</sub> emissions from the 2000 levels by 2050 to limit global mean temperature rise to 2.0-2.4°C (Mashayekh et al. 2012). Similarly, Bartholomew (2009) states that global CO<sub>2</sub> emissions must reduce 60%-80% of the 1990 levels to stabilize the climate. Personal vehicle use in urban areas accounts for 21% of human generated CO<sub>2</sub> emissions in the United

## 2.2

## LITERATURE REVIEW

States (Bartholomew 2009). Improved vehicular efficiency technologies help to reduce the total CO2 emissions but they are not enough. It is necessary to reduce the demand for personal transportation (Mashayekh et al. 2012). Public transportation is estimated to be 65% more energy efficient than single passenger motor vehicles (Quirk 2011). There is a plethora of sources that emphasize the importance of public transit to mitigate greenhouse gas emissions and climate change including: Bartholomew (2009), Grabow et al. (2012), Mashayekh et al. (2012), Quirk (2011), Sharma and Mathew (2011) and Silverman (2011).

### ***Increasing Ridership***

The success of public transit to mitigate global climate change is dependent on ridership. Higher ridership means less vehicular trips taken, which leads to reduced green house gases (GHG) in

the atmosphere and less land allocated to the automobile in urban areas. Understanding what leads to increased ridership is an important part of transit design. There is extensive literature on the subject of ridership and public transportation including: Bartholomew (2009), Bond and Steiner (2006), Daganzo (2010), Oldread (2011), Taylor and Haas (2002), and Taylor et al. (2009). Common themes throughout literature related to transit ridership include the need for public transportation to be competitive with the automobile, and the ways in which parking planning can increase ridership.

People gravitate toward automobiles rather than public transportation because public policy and investment decisions have made the automobile the superior travel method (Bartholomew 2009). Additionally, Quirk (2011) states that, “the car has proved highly attractive to consumers, given the

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convenience, privacy and flexibility it provides.” For public transportation to be competitive with personal vehicle transit, it must be accessible, convenient and cost comparable. “Even in an automobile-dependent city, people will give up their cars if viable alternatives are provided” (Shannon et al. 2006, 250-251). According to Bartholomew, (2009) transit design and policy is focused on mobility rather than accessibility. To increase accessibility, transit stops should be located within 1/4 mile of origins or destinations. Environments that are more accessible to pedestrians tend to have higher transit use (Bartholomew 2009).

Daganzo (2010) describes how transit route network design and frequency can influence ridership. “Transit systems must uniformly cover the service region in space and time with well-spaced transit stops and frequent reliable service”

(Daganzo 2010, 334). For transit systems to be able to compete with automobiles, they must be equally convenient. Waiting and transfer times associated with public transit should be similar to the time automobile users spend walking to and from cars and looking for parking, which is approximately ten minutes. In-vehicle-transit time of public transportation and personal automobile trips should also be similar (Daganzo 2010).

“Networks should provide good service between every pair of points in the city throughout the day, and be easily understood by the public” (Daganzo 2010, 334). To achieve good transportation services throughout that city, Daganzo (2010) proposes a hybrid system for a successful transportation network. This hybrid system includes double coverage in the center of a city and single coverage on the periphery of a city. A double coverage system is a grid pattern with two

## 2.2

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perpendicular directions of travel at every stop while a single coverage system is a hub-and-spoke layout with only one direction of travel at each stop. The hybrid system is more convenient than a single coverage system but not as costly as a double coverage system.

Chaudhari and Ye (2010) describe a method used to analyze public transit at Auburn University. “Tiger Transit” was started at Auburn University in 1997 to serve student commuters and address parking issues on campus. Initially the transit system was successful in decreasing automobile use and parking demand on campus but over time, although public transit increased, ridership did not and parking, once again, became an issue. By 2007 the transit system served only 70% of the universities students. A route assessment was required to improve the effectiveness of “Tiger Transit.” Chaudhari and Ye (2010) used

GIS to analyze the existing route effectiveness and determine the success of route modification. The analysis revealed that the bus stops were located too close to each other resulting in long travel times and service gaps, some student housing was not serviced by transit, and some routes overlapped. Chaudhari and Ye (2010) then modified the routes in GIS, based on experience, data, and intuition, to better serve students. An analysis of new routes showed that the system could serve 90% of the student population, as well as several commercial locations, with fewer buses.

A survey done by Shannon et al. (2006) revealed that travel time is the biggest reason why people do not take public transportation. People overestimate travel time of public transit by 45% and underestimate travel time of cars by 16% (Shannon et al. 2006). Shannon et al. (2006)

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suggests providing easy access to trip planning advice and timetables to address inaccurate perceptions of travel times associated with public transportation.

The final aspect of public transportation that must be considered for it to be competitive with the automobile is cost. “Frequent service draws passengers, and high fares drive them away” (Taylor et al. 2009, 60). Bartholomew argues that people tend to favor fixed costs rather than incremental costs. A fixed cost refers to a set price to use a service many times such as the cost of buying a car or the cost of an annual transit pass. An incremental price is something paid again and again such as fuel or single pass transit tickets. “People seek to maximize the use of transportation modes that are based predominantly on fixed costs and minimize the use of incremental cost options” (Bartholomew

2009). Currently 53% of car costs are fixed while most public transportation costs are incremental (Bartholomew 2009). To increase ridership, transit systems should have fixed price options such as monthly and annual passes.

Shannon et al. (2006) surveyed students and employees of the University of Western Australia about their commuting habits. The survey revealed that saving money is a main reason why students that commute by automobile would switch to alternative modes of transportation. A subsidized transit pass would be the most effective strategy for increasing alternative transit methods. Studies show that transit passes increase student ridership from 71-200% in the first year (Shannon et al, 2006).

Creating public transportation systems that are viable alternatives to automobiles is an

## 2.2

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important way to increase ridership; reducing the availability and increasing the price of parking is another. According to Dueker et al. (1998) parking pricing strategies is one of the most effective ways to increase ridership. Shoup (1997) argues that an over-supply of free parking gives people an incentive to drive rather than take public transit. “Zoning requirements for overly-abundant off-street parking and failure to charge appropriately for curb parking result in extra air pollution, higher oil consumption, traffic congestion, and sprawl” (Shoup 1997, 1).

### ***Reducing Parking Demand***

In the same way that reducing available parking increases ridership, increased ridership reduces the demand for parking. Zhang et al. (2012) predicts that parking requirements could be reduced by around 20% and up to 50% in areas with good transit. Excessive parking can have

negative effects on the local economy, quality of life and the environment.

Poor parking planning often leads to excessive parking. Planners often rely too heavily on national parking planning data rather than looking at local usage patterns and parking prices (Revell and Rich 2001). For example, the number of parking spaces for a business is usually based on the need for a day of peak demand, such as the day after Thanksgiving (Davis et al. 2010). Factors such as shared parking and public transit are not always accounted for. Poor parking planning can cause gridlocked traffic, urban businesses unable to compete with suburban companies, and municipal credit ratings to suffer (Revell and Rich, 2001). Excessive parking also increases stormwater runoff and negatively impacts local streams (Albanese and Matlack 1999).

Davis et al. (2010) analyzed parking supply and demand in Tippecanoe County, Indiana. The analysis revealed that the parking supply in Tippecanoe County is exceeding demand at the county-wide scale. The ratio of the area of parking lot space to park space is 3:1 in urban areas. There are 1.7 parking spaces per person of driving age and 2.2 parking spaces per registered vehicle in Tippecanoe County. Davis et al. (2010) estimated the ecosystem service value (ESV) lost as a result of the presence of parking lots in the county. Hypothetically, if all the parking lots in Tippecanoe County were replaced with wetlands, the ESV of these areas would be \$22.5 million which is equivalent to a 38.4% increase to the county's total ESV. Davis et al. (2010) also performed a Long-term Hydrologic Impact Assessment (L-THIA) to determine the effect that the county's parking lots have on stormwater runoff. The L-THIA for Tippecanoe County

indicates a more than 900% increase in runoff due to parking lots.

While there is often an excess of parking at a large scale, universities around the world also have issues with a lack of parking. For example, demand for parking is currently exceeding supply on the University of Western Australia campus. In order to put a cap on parking spaces the university hopes to reduce the number of drivers to campus by promoting active modes of commuting such as public transportation. Shannon et al. (2006) argues that reducing the dependence on private vehicles, through increasing alternative modes of transportation, would reduce parking demand, allowing existing parking lots to be developed for other university amenities. A survey concerning commuting patterns of students and staff to the university revealed that 21.5% of staff and 46.8% of

## 2.2

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students currently take active modes (i.e. public transit, walking, biking) and that an additional 30% would potentially switch to active modes. If 30% of car drivers switched to alternative modes of commuting to campus, the University of Western Australia could reduce its current parking by over 1000 spaces. This would solve the universities parking issues and reduce the negative effects that expansive parking can have on the environment.

The University of Coimbra in Portugal is improving parking management to address issues such as underpriced and overcrowded parking lots. The university aims to balance supply and demand of parking, bring in revenue to cover parking costs and improve attractiveness of alternative transportation. Barata et al. (2011) performed a parking flows modeling analysis which revealed that parking demand exceeds

capacity on campus. Barata et al. (2011) argues that universities are particularly well suited for alternative transportation systems as solutions for parking problems. A survey revealed that car drivers would be willing to switch to public transit if waiting times were reduced. “If fewer cars are travelling to the campus, then fewer parking spaces are required, lower maintenance costs are incurred, and the land currently dedicated for parking can be converted to other, possibly more rewarding, uses” (Barata et al, 2011, 412).

### ***Opportunities for Green Infrastructure***

As argued by Davis et al. (2010), Shannon et al. (2006), and Barata et al. (2011), parking area that is reduced as a result of increased public transit ridership, can be transformed into other, more productive uses such as green infrastructure. *Low Impact Development a design manual for*

*urban areas* (LID) by the University of Arkansas Community Design Center is a key reference to use when designing and implementing different types of green infrastructure.

Parking that is transformed into green space can improve ecological health in four main ways: decreasing runoff, decreasing air temperatures storing carbon and improving air quality. Stormwater management is crucial to the health of urban streams. Walsh et al. (2005) describes the Urban Stream Syndrome which refers to the consistently observed, ecological degradation of stream draining urban land. Urban development increases runoff rates and has caused destruction of river habitat and impacted hydrology. Albanese and Matlack (1999) suggest integrating runoff detention basins into parking to minimize the negative impacts of parking on local streams. Not only do stormwater detention basins regulate

runoff hydrology and quality, they can provide habitat (Moore and Hunt 2011). Increasing green space and plant diversity would provide habitat for birds and other organisms.

Large areas of pavement, such as parking lots, contribute to the heat island effect. One of the main ways to reduce air temperatures in urban areas is through increased permeability and vegetation. Transforming parking space into green space will inevitably reduce the heat island effect.

The final way that converting parking to green space can improve ecological health in urban environments is through carbon storage and sequestration. All vegetated land sequesters carbon but forest land and grassland are most efficient. Grasses store carbon below ground in their roots and the soil while trees store carbon

## 2.2

### LITERATURE REVIEW

both below ground and above ground in their foliage. Carbon sequestration restores degraded soils, enhances biomass production, purifies surface and ground water, and reduces CO<sub>2</sub> in the atmosphere (Lal 2004).

### ***Analyzing the Benefits***

Additional literature was gathered to inform methods of quantifying the benefits of improving public transportation and reducing parking demand. Wang and Zhao (2007) express the importance of analyzing ecological benefits of urban green spaces, “More attention should be paid to plants, including species, amount, planting structure and arrangement, in order to ensure the maximum ecological benefit to be produced by green spaces and to improve the urban ecological environment as much as possible” (Wang and Zhao 2007, 213).

The Long-term Hydrologic Impact Assessment (L-THIA) can be used to estimate stormwater runoff and pollutants reduced as a result of land use change (Harbor 1994). Nowak and Crane (2002) study the carbon storage capacity and sequestration rates of trees in different American cities. Nowak (2004) gives a value of \$22 (USD 2012) for every ton of carbon stored. Akbari (2002) discusses the cooling effect of trees resulting from evapotranspiration and shading. Akbari also quantifies the average energy savings of buildings that are shaded by trees. Escobedo and Nowak (2009) estimate the effect trees have on improving different air pollutants.

Costanza et al. (1997) has gathered many studies that aim to give values to ecosystems services. Through the synthesis of all the studies, Costanza et al. (1997) estimated the average ecosystem service value of different land types. For example,



wetlands are worth \$14,785 (1994 USD) per hectare per year while cropland is only worth \$92 (1994 USD) per hectare per year, and urban land has no ecosystem service value. Davis et al. (2010) describes a method of using Costanza et al.'s (1997) ecosystem economic valuation by biome to determine ecosystem service value (ESV). Davis et al.'s (2010) method can be used to estimate the ESV lost or gained as the result of land use change.

## 2.2

### LITERATURE REVIEW

Case Study Name	Location	Parking	Public Transit	Benefit Analysis	Methods	Source
Auburn University	Auburn, AL					Chaudhari and Ye, 2010
University of Coimbra	Coimbra, Portugal					Barata et al, 2011
University of Florida	Gainesville, FL					Bond and Steiner, 2006
University of Western Australia	Perth, Australia					Shannon et al, 2006
Tippecanoe County	Indiana					Davis et al, 2010
Green Travel Plan	Newbury, England					Wood, 2003

**Methodology Case Studies**

The literature review process revealed several relevant case studies including Auburn University, the University of Coimbra, the University of Florida, the University of Western Australia, Tippecanoe County, Indiana, and the corporate headquarters’ green travel plan in Newbury, England. These precedents were used as examples in five different ways: parking, public transit, economic and ecologic analyses, and specific research methods. The areas of study involved with each precedent are summarized in the precedent matrix in *Table 2-1*.

**Table 2-1 Case Study Matrix**

*Case studies from the literature are used to inform different aspects of the research including: public transit, parking, benefit analysis, and methods. Several case studies contain information about multiple aspects.*

**Bus System Case Studies**

In addition to case studies found in the literature, seven case studies were chosen to represent a range in quality and success of transit systems in cities similar to Manhattan, Kansas. The seven cities chosen are Blacksburg, Virginia, Ames, Iowa, Iowa City, Iowa, Auburn, Alabama, Tuscaloosa, Alabama, Gainesville, Florida, and Lawrence, Kansas. Comparison of the seven case studies provided a base for understanding what bus system characteristics tend to lead to greater ridership. For the cities with high ridership, such as Ames, Gainesville and Blacksburg, it will be important to understand the strategies responsible for such high ridership. The synthesis of data gathered for each case study will inform a set of guidelines for improving Manhattan’s bus system to increase ridership. Data gathered for each case study is summarized in *Table 2-2*.

General Information						Bus System Information					
city	university	population	students	Area (sq. mi.)	houses/sq. mile	year started	service days	annual ridership	ridership/population	# of routes	# of stops
Ames	Iowa State University	59,042	31,000	22	868	1977	sun-sat	5,447,289	92	15	101
Gainesville	University of Florida	125,326	50,000	49	832	1985	sun-sat	10,698,984	85	33	128
Blacksburg	Virginia Tech	42,620	30,000	19	704	1983	sun-sat	3,300,000	77	12	217
Auburn	Auburn University	54,566	25,134	40	513	1997	mon-fri	2,077,714	38	19	193
Iowa City	University of Iowa	68,947	30,500	24	1078	1971	mon-sat	1,964,000	28	20	391
Lawrence	University of Kansas	88,727	30,000	29	1167	1957	mon-sat	666,777	8	18	57
Tuscaloosa	University of Alabama	91,605	33,602	67	622	1941	mon-fri	200,340	2	6	115

Table 2-2 **Bus System Comparison**

*This table summarizes data about city size, bus system, and bus fares for each city. Ridership/population refers to the average number of trips per person per year.*

				Bus Fares					
stops per sq. mi.	# of vehicles	average frequency	population serviced	single ride	Day pass	10-ride pass	monthly pass	semester pass	discount for students
5	84	30 min	na	\$0.60/1.25	na	\$6/12	\$20/40	\$80/160	yes- free, \$115 semester
3	114	35 min	na	\$0.75/1.50	\$3	na	\$17.50/35	\$60	yes- \$0.75, \$17.50 monthly
11	44	30 min	na	\$0.25/0.50	na	na	\$4/8	\$18.75/37.50	yes- pre-paid
5	42	18 min	na	na	na	na	na	na	yes- free
16	85	36 min	na	\$0.75/\$1	\$2	\$8.50	\$27/32	\$100	yes- \$60 semester
2	73	36 min	na	\$0.50/1	\$1.35/2.75	\$5/10	\$17/34	na	yes- free
2	16	47 min	na	0.5/1	na	na	na	na	yes- free

2.3

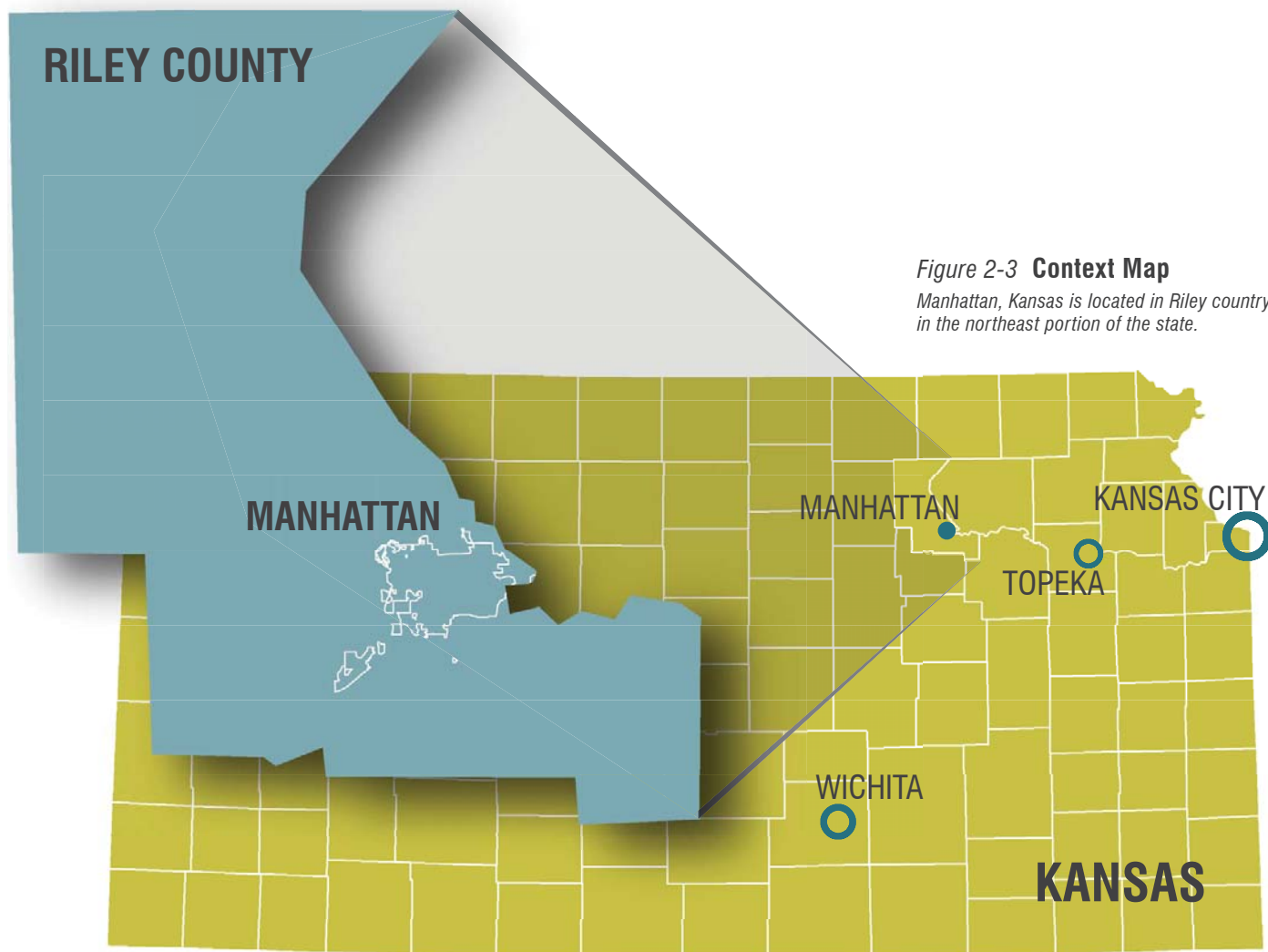
CASE STUDIES

***Manhattan, Kansas***

Manhattan is located in the Flint Hills region of Riley County, Kansas, as seen in *Figure 2-3*. It is best known as the home of Kansas State University and nearby United States Army post, Fort Riley. Manhattan was established in 1855. The extension of rail lines in the late 1800's spurred growth in the Manhattan area.

Today, the city is approximately nineteen square miles and has a population of nearly 54,000 people. In recent years, Manhattan has experienced significant growth. The city's population has increased nearly 17% since 2000. Manhattan is expected to continue to grow due to the expansion of Fort Riley and the National Bio and Agro-Defense Facility currently being built. Manhattan's city planners and officials must strategize for the city's rapid growth to maintain it's accessibility and character.

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**Figure 2-3 Context Map**

*Manhattan, Kansas is located in Riley county in the northeast portion of the state.*

## 2.4

### SITE DESCRIPTION

***Kansas State University***

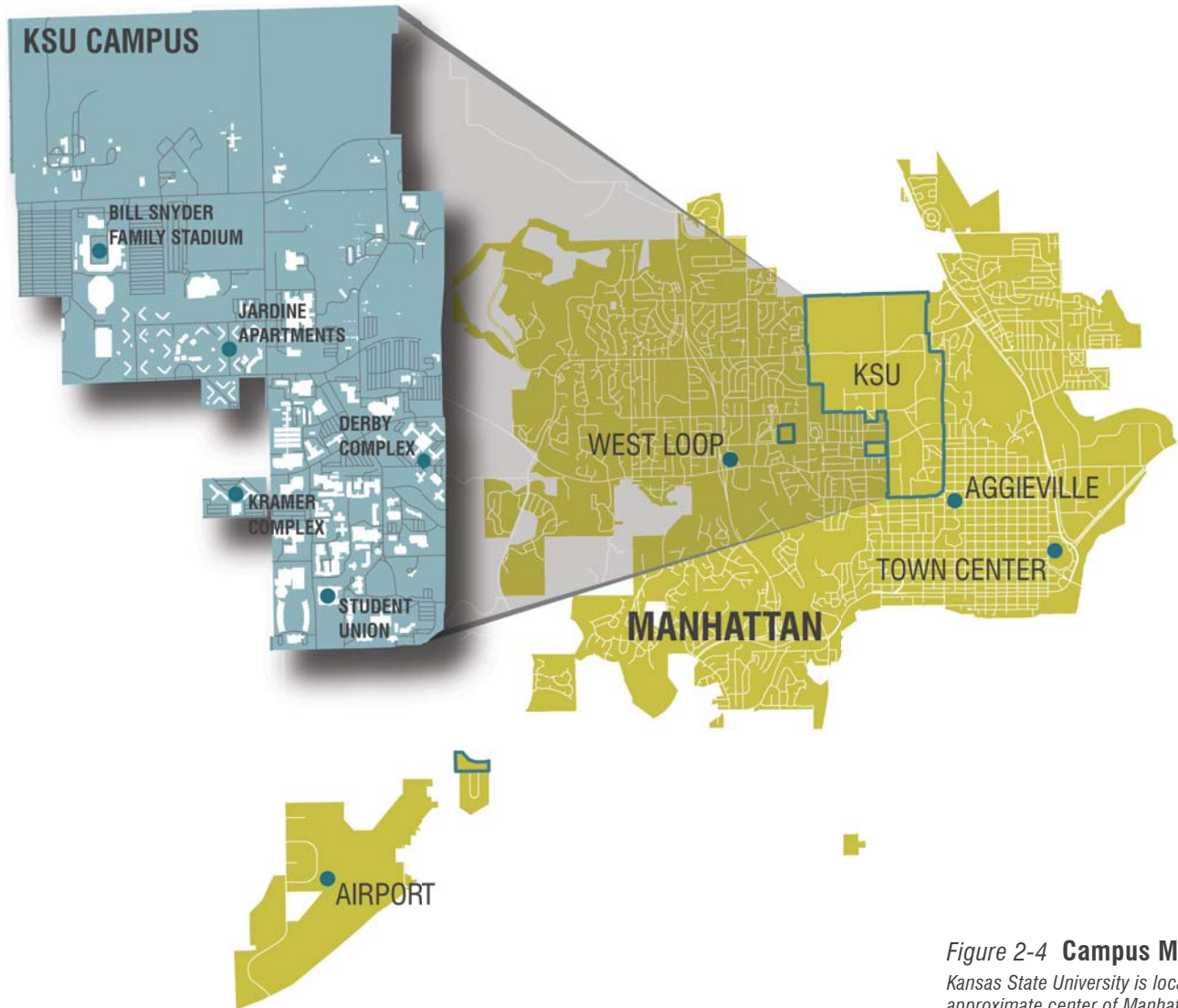
Kansas State University accounts for a significant portion Manhattan's population and economy. Kansas State University was founded in 1863. Nearly 24,000 students attend Kansas State. *Figure 2-4* shows the Kansas State Campus in relation to the rest of the city.

Manhattan is home to several other colleges including Manhattan Area Technical College, and Manhattan Christian College. All together, approximately 30-40% of Manhattan's population is made up of college students. Therefore, student life is an important part of the city's culture.

Manhattan's high student population and rapid growth provide an opportunity to implement sustainable transportation planning techniques including public transit and innovative parking design strategies.

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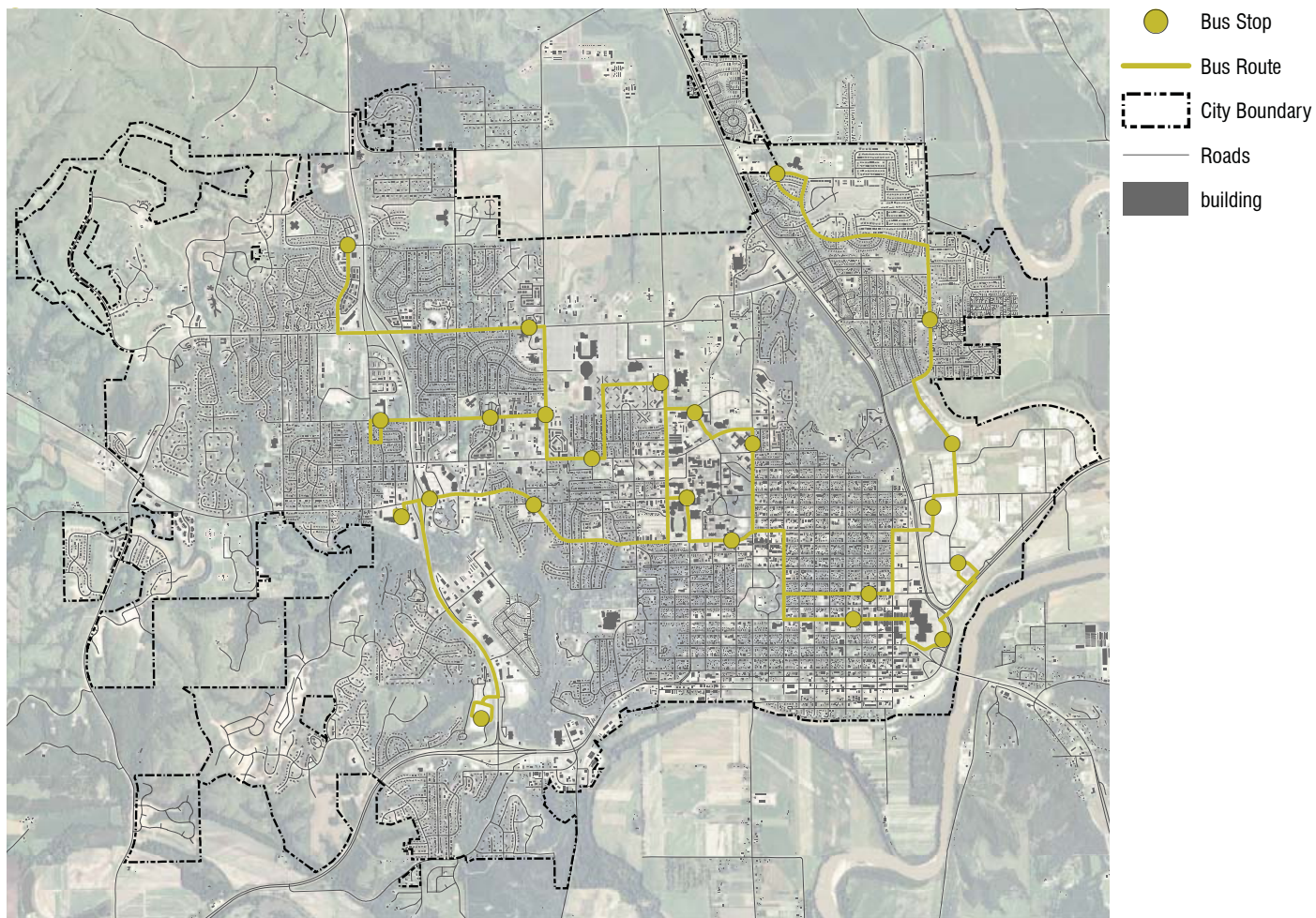




**Figure 2-4 Campus Map**  
*Kansas State University is located in the approximate center of Manhattan, Kansas.*

## 2.4

### SITE DESCRIPTION



**Figure 2-5 ATA Fixed Route**

*Manhattan's fixed route bus system consists of five routes and 28 stops.*

### ***ATA Bus System***

The Flint Hills Area Transportation Agency (ATA) began in 1970 as a demand response service for primarily Manhattan, Fort Riley and Junction City. The fixed route system was not implemented until 2012 and consists of four routes and 28 bus stops as shown in *Figure 2-5*. There is a fifth route, the Jardine Route, which circulates through campus and is free for students. Buses arrive at each stop every 43 minutes on average and cost \$1.00 per trip.

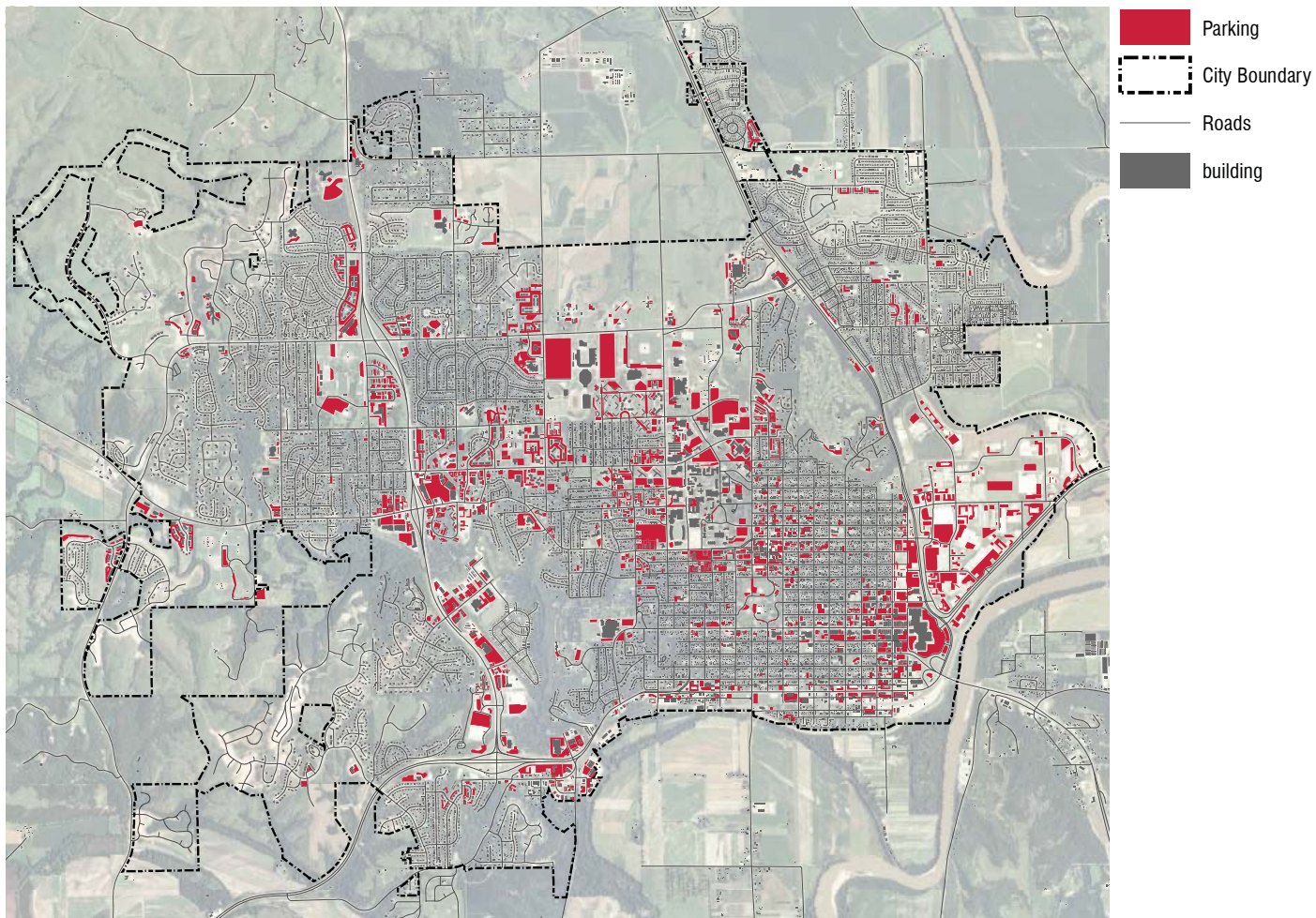
The predicted annual ridership of the ATA bus system is 209,793 based on current ridership rates. This means that each person in Manhattan takes four bus trips a year on average. It is

estimated that 32% of Manhattan's population is currently being serviced by the fixed route system. The percent serviced was calculated by using United States Census data in ArcGIS to determine the number of people living within walking distance (1/4 mile) of bus stops.

## 2.4

### SITE DESCRIPTION





**Figure 2-6 Manhattan Parking**

*Seven percent of Manhattan's total area is devoted to parking.*

### ***Parking in Manhattan***

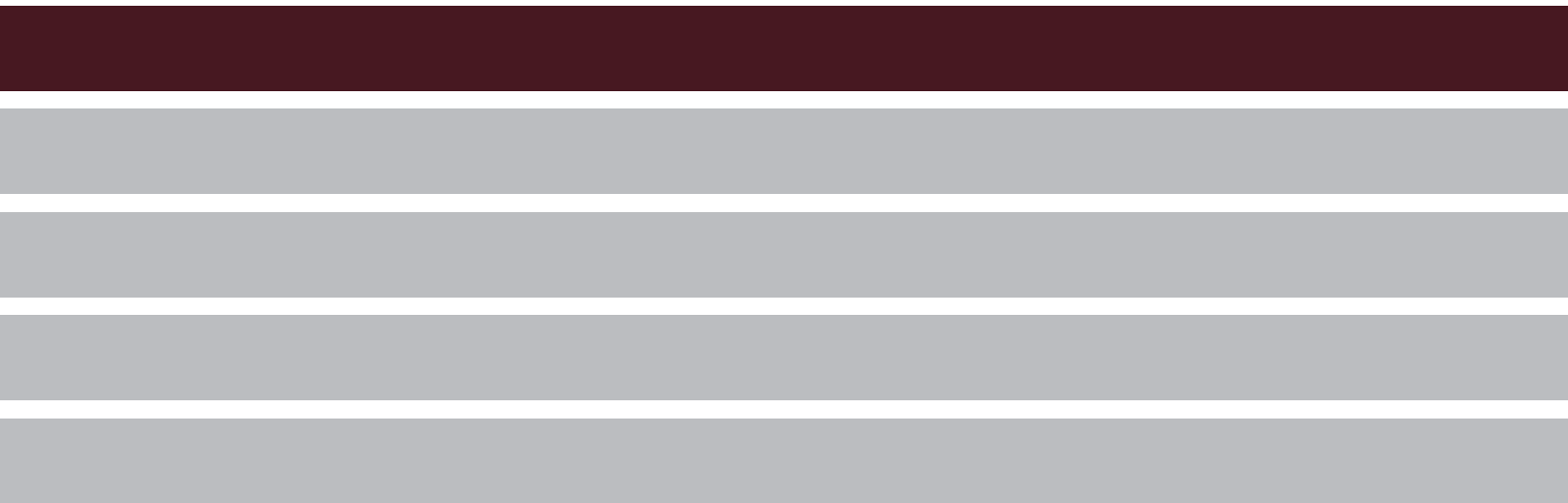
There is an estimated 612 acres of parking in Manhattan, Kansas which is equal to approximately one square mile or 463 football fields as showing in *Figure 2-6*. There are 69 thousand parking spots in Manhattan, 56,300 of which are dedicated to non-residential uses.

According to Article VII of Manhattan's zoning regulations, business and commercial establishments must have one parking space for every 200 square feet of floor area. Business and professional offices must have one parking space for every 300 square feet of floor area. Multi-family residential is required to have one to two parking spots per bedroom.

Parking regulations in Manhattan, Kansas require that 5% of parking areas must be landscaped open space. Every parking space must be within seventy feet of landscaped open space. There must also be at least one tree within every 5000 square feet of parking.

## **2.4**

### **SITE DESCRIPTION**



# THREE

3.1

## METHODS AND FINDINGS

3.2

PUBLIC TRANSIT ANALYSIS

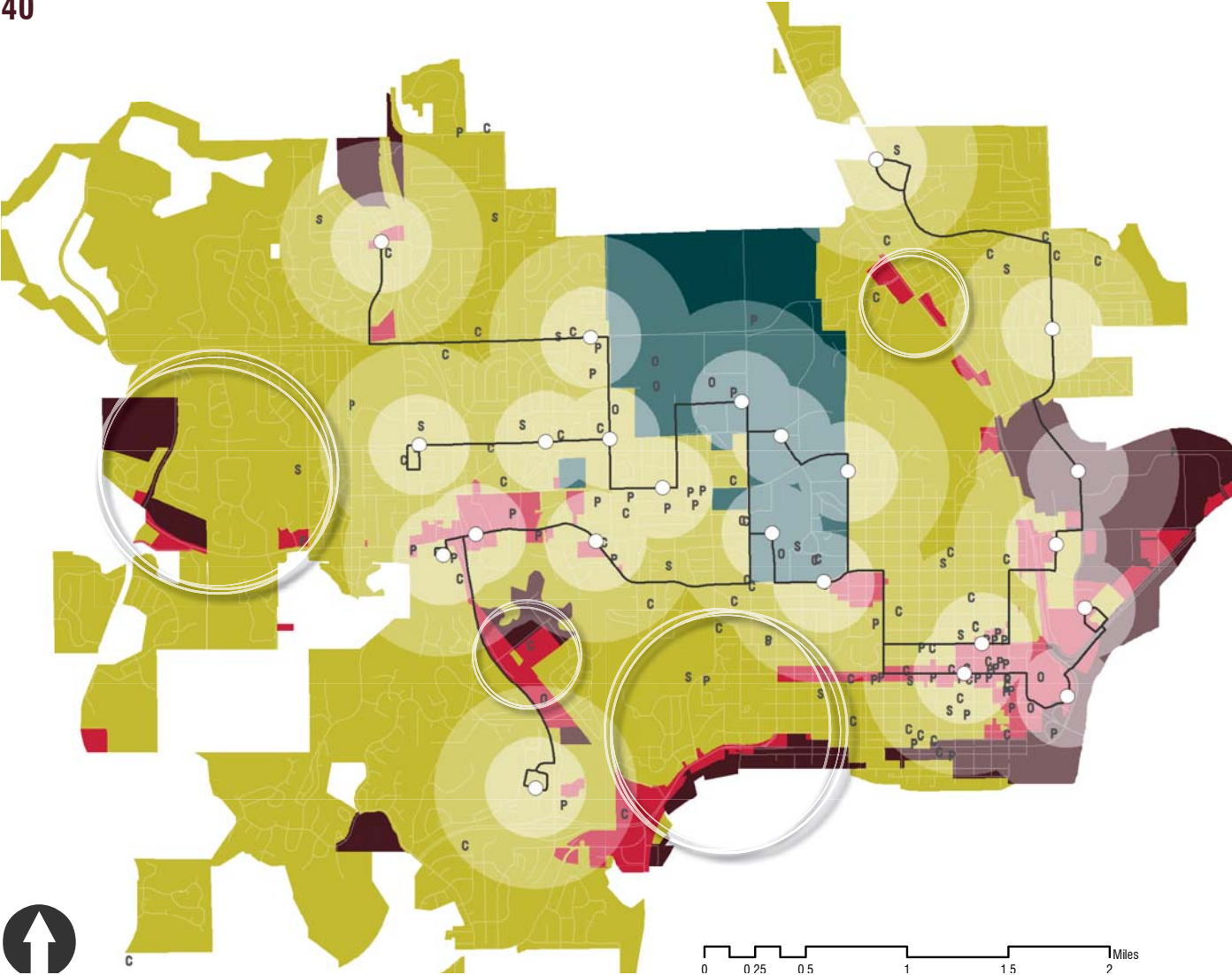
3.3

IMPROVED TRANSIT PLAN

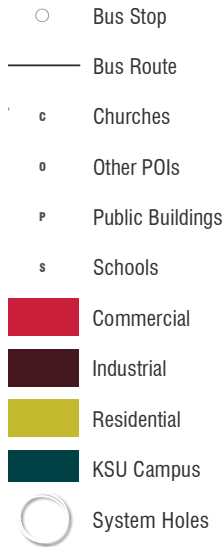
3.4

PARKING ANALYSIS

SITE SELECTION







**Figure 3-1 Existing Bus System**

*Land use, points of interest, and exiting bus stop buffers are layered to reveal holes in the existing bus system and show opportunities for additional bus stops.*

### ***Existing Route Coverage***

To analyze the existing bus system, routes and stops were layered with land use and various points of interest including public buildings, schools, and churches, in ArcGIS. The Multi-Ring Buffer tool in ArcMap was used to create quarter and half mile radii around each bus stop. The quarter mile radius represents walking distance. Layering the bus stop buffers with land use and points of interest revealed holes in the existing transit system as seen in *Figure 3-1*. There are several residential areas and a few commercial areas and points of interest that are lacking access to the bus system.

### ***Existing Student Access to Campus***

Currently there are 11,500 parking spots on the Kansas State University Campus. In 2012, Kansas State University Parking Services sold approximately 14,000 campus parking passes

## 3.1

## PUBLIC TRANSIT ANALYSIS

which means campus parking demand exceeds supply by approximately 2,500 spots. Because students are the primary users of the existing ATA bus system and demand for parking on campus exceeds supply, it is important to analyze how students travel to campus. Once an understanding of where, throughout the city, students are in need of bus access is gained, improvements can be made to improve student ridership. If more students have the opportunity to ride the bus to campus, parking demand on campus could be reduced.

The Weighted Overlay tool in ArcMap was used to determine which areas are lacking access to campus. Factors included in the Weighted Overlay were rented units per square mile, median age, bus stop buffers and a campus buffers as shown in *Figure 3-2*.

Because most university students rent houses and apartments rather than own them, areas with higher levels of renters were given a higher value. Areas with a median age of 19 to 24 were given a higher value because most Kansas State University students are between the ages of 19 and 24. Students who are within walking distance of existing bus stops are already being serviced by the ATA bus, therefore, are not in need of an additional stop. Areas outside the quarter mile bus stop buffers are given higher ratings. Similarly, students that live within walking distance of campus do not need to take the bus so a quarter mile buffer around campus was given the lowest rating while areas outside the buffer are given higher ratings. Rented units per square mile, median age, bus stop buffers and a campus buffers are combined into a single map to reveal areas most in need of additional bus stops as seen in *Figure 3-3*.

*areas with high rates  
of rented units per  
square mile*

*areas with median  
ages of 19-24*

*areas outside  
walking distance to  
the KSU campus*

*areas outside  
walking distance to  
existing bus stops*

*areas with high  
concentrations  
of students*

*areas currently  
lacking access  
to campus*

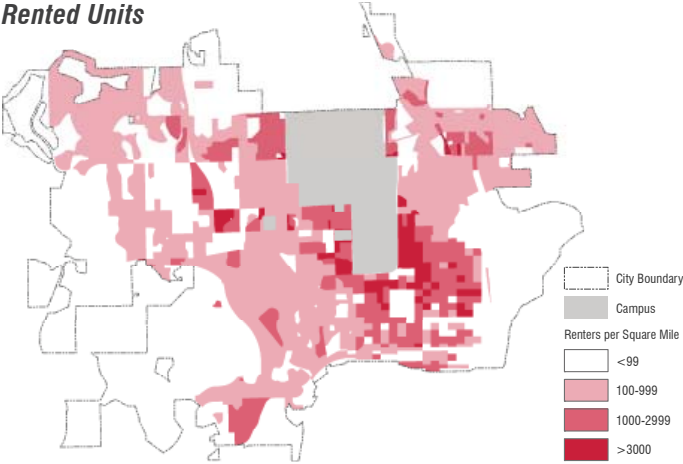
*areas in need of  
increased access  
to campus*

**Figure 3-2 Factors of Access to Campus**  
Concentration of renters and median age are used to determine where students live. Proximity to campus and existing bus stops are used to determine which areas are lacking access to campus.

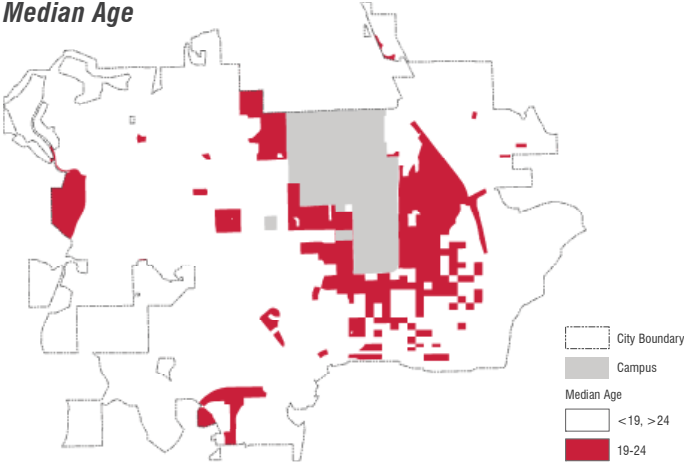
### 3.1

## PUBLIC TRANSIT ANALYSIS

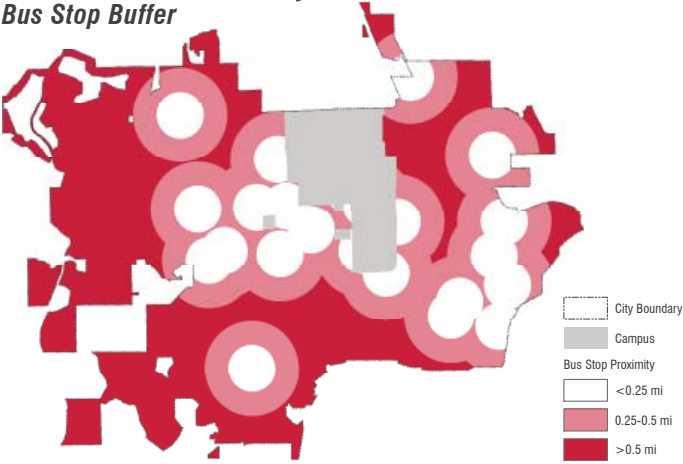
***Rented Units***



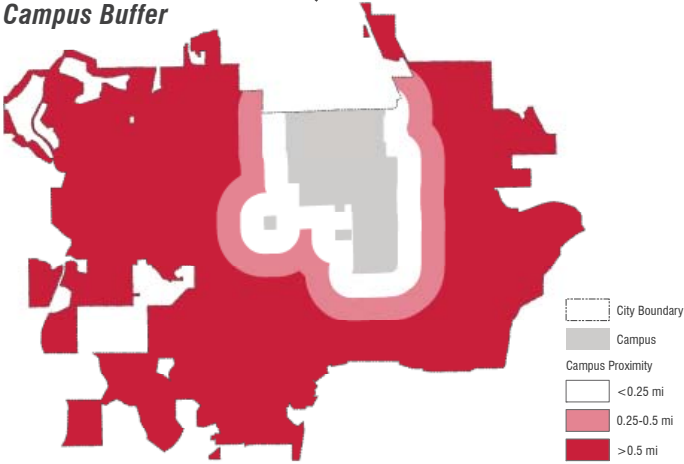
***Median Age***

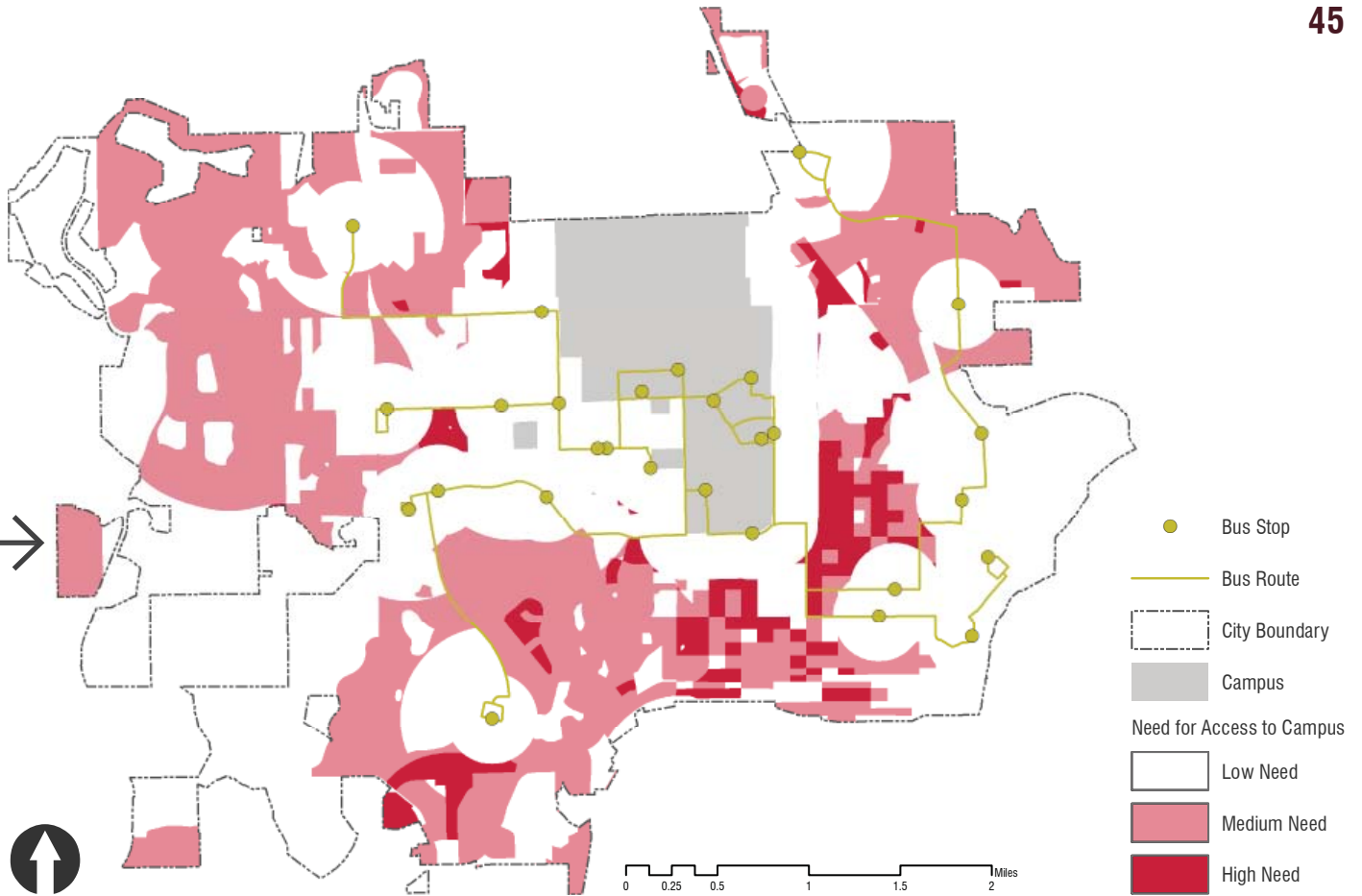


***Bus Stop Buffer***



***Campus Buffer***





**Figure 3-3 Student Access to Campus**

*Areas in red are most in need of additional transit stops, while areas in pink are in less need of additional transit stops.*

## 3.1

## PUBLIC TRANSIT ANALYSIS

General Information						Bus System Information					
city	university	population	students	Area (sq. mi.)	houses/ sq. mile	year started	service days	annual ridership	ridership/ population	# of routes	# of stops
Ames	Iowa State University	59,042	31,000	22	868	1977	sun-sat	5,447,289	92	15	101
Gainesville	University of Florida	125,326	50,000	49	832	1985	sun-sat	10,698,984	85	33	128
Blacksburg	Virginia Tech	42,620	30,000	19	704	1983	sun-sat	3,300,000	77	12	217
Auburn	Auburn University	54,566	25,134	40	513	1997	mon-fri	2,077,714	38	19	193
Iowa City	University of Iowa	68,947	30,500	24	1078	1971	mon-sat	1,964,000	28	20	391
Lawrence	University of Kansas	88,727	30,000	29	1167	1957	mon-sat	666,777	8	18	57
Tuscaloosa	University of Alabama	91,605	33,602	67	622	1941	mon-fri	200,340	2	6	115
Manhattan (existing)	Kansas State University	53,678	23,800	15	1179	2012	mon-sat	209,793	4	5	28

**Table 3-1 Comparison of Existing Transit to Case Studies**  
*Most of the case studies have greater ridership, route coverage, frequency, and fixed cost options than Manhattan’s bus system.*

				Bus Fares					
stops per sq. mi.	# of vehicles	average frequency	population serviced	single ride	Day pass	10-ride pass	monthly pass	semester pass	discount for students
5	84	30 min	na	\$0.60/1.25	na	\$6/12	\$20/40	\$80/160	yes- free, \$115 semester
3	114	35 min	na	\$0.75/1.50	\$3	na	\$17.50/35	\$60	yes- \$0.75, \$17.50 monthly
11	44	30 min	na	\$0.25/0.50	na	na	\$4/8	\$18.75/37.50	yes- pre-paid
5	42	18 min	na	na	na	na	na	na	yes- free
16	85	36 min	na	\$0.75/\$1	\$2	\$8.50	\$27/32	\$100	yes- \$60 semester
2	73	36 min	na	\$0.50/1	\$1.35/2.75	\$5/10	\$17/34	na	yes- free
2	16	47 min	na	0.5/1	na	na	na	na	yes- free
1.866667	15	43 min	17,363	\$0.50/1	na	na	\$30	na	yes- free on campus

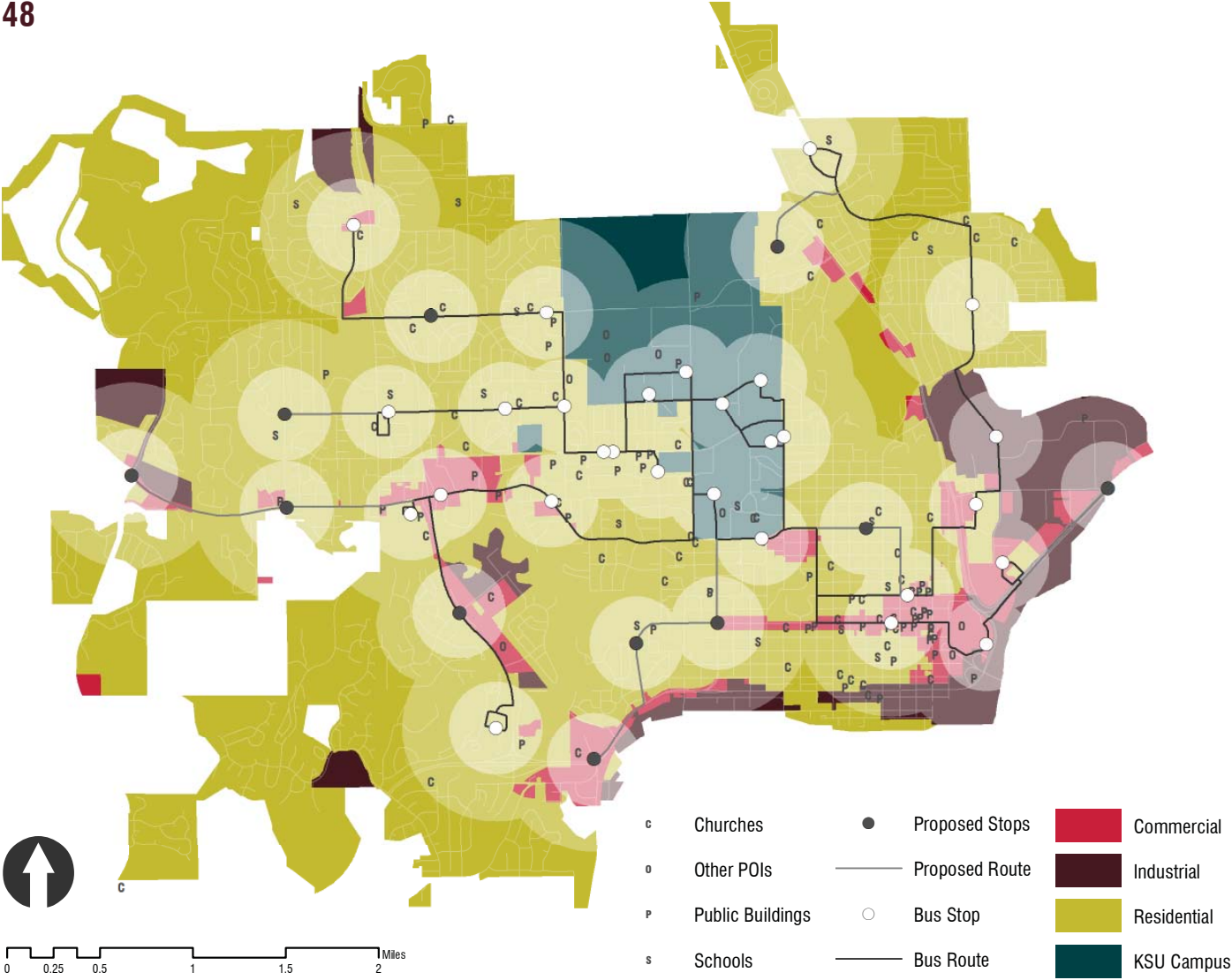
**Comparison to Case Studies**

Once Manhattan’s bus system was analyzed using ArcGIS, it was compared to the seven selected case studies. The case studies’ and Manhattan’s bus systems are summarized in *Table 3-1*. Manhattan’s current system ranks at or near

the bottom in ridership, route coverage and frequency. Although the cost per ride is similar to the case studies, Manhattan’s system offers less fixed cost options. Comparing Manhattan to the case studies reveals ways in which the ATA bus system could be improved.

3.1

PUBLIC TRANSIT ANALYSIS





### ***Proposed Improvements to Transit***

Improvements to Manhattan's current bus system can be made to increase ridership and therefore, decrease parking demand. Increased route coverage, frequency, and fixed price options lead to increased ridership. (Bartholomew 2009, Daganzo 2010). A proposed transit improvement plan was developed to serve as an example of the benefits of improving the existing system.

The improved plan aims to fill in holes of the existing system, increase the number of students with access to campus, and to improve Manhattan's rank among the case studies. The

proposed improvements include one new route, eleven additional bus stops, five on the new route and six added to existing routes, three additional vehicles, and new fixed cost options such as a ten-ride pass and a semester pass.

### ***Increased Accessibility***

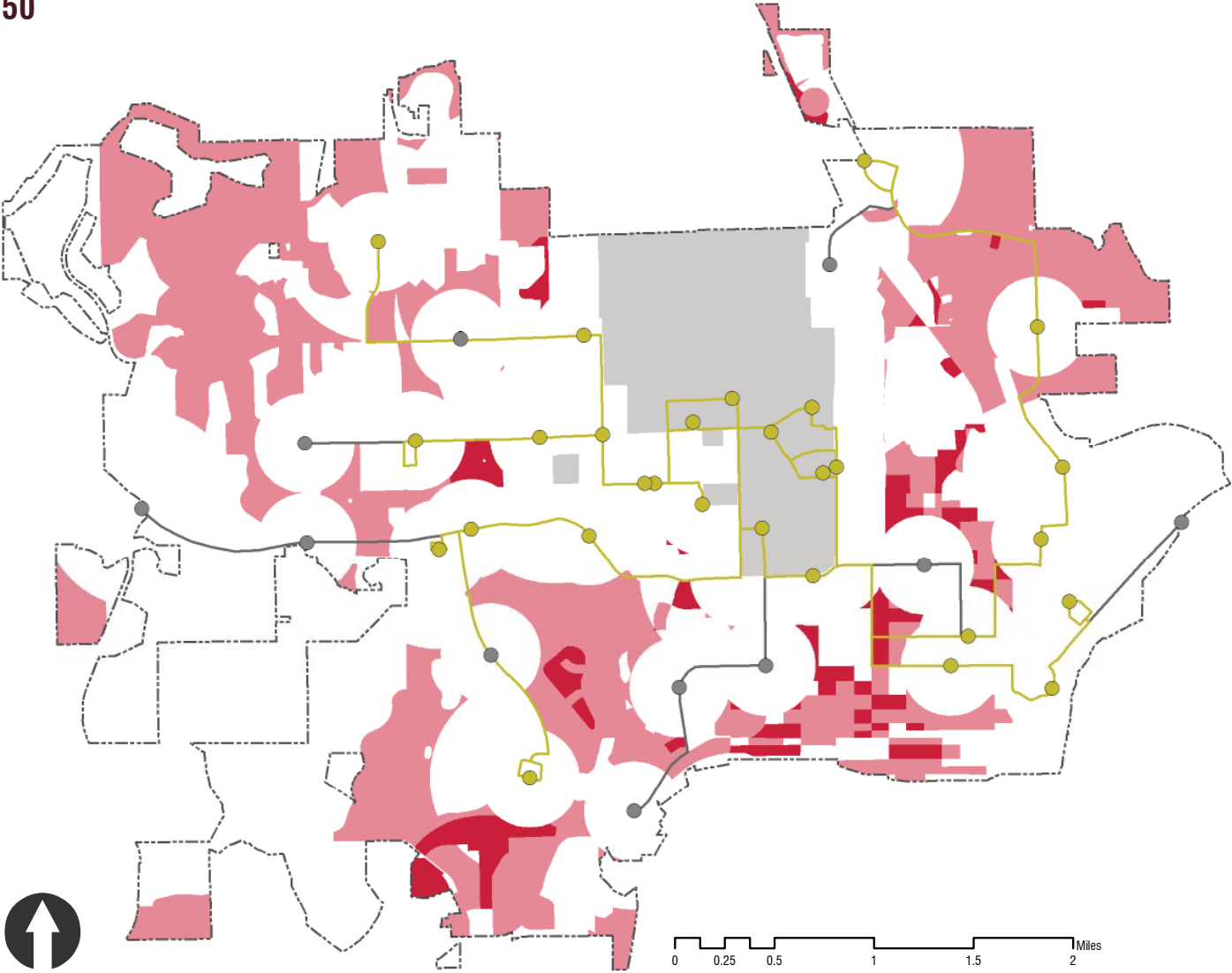
The improved route coverage that would result in the implementation of the proposed transit plan can be seen in *Figure 3-4*. The improved plan also decreases the number of students lacking access to campus and shown in *Figure 3-5*.

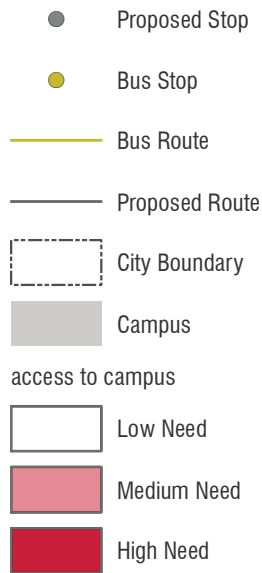
### ***Figure 3-4 Proposed Bus System***

*The proposed bus system fills most of the holes in the existing system. It provides access to additional residential and commercial areas.*

## **3.2**

## **IMPROVED TRANSIT PLAN**





**Comparison to Case Studies**

Implementing the proposed improvements to public transportation would make Manhattan’s transit system more comparable to the seven case studies as seen in *Table 3-2*. The improved design increases route coverage by almost 40% and increases average frequency by 25%. The proposed bus system ranks nearly average in stops per square mile, average stop frequency, and fixed cost options among the other bus systems studied. It is estimated that the proposed changes would double the ridership of Manhattan’s bus system.

**Figure 3-5 Improved Access to Campus**

*The proposed bus system provides a greater opportunity for students to take public transportation to campus.*

3.2

IMPROVED TRANSIT PLAN

General Information						Bus System Information					
city	university	population	students	Area (sq. mi.)	houses/sq. mile	year started	service days	annual ridership	ridership/population	# of routes	# of stops
Ames	Iowa State University	59,042	31,000	22	868	1977	sun-sat	5,447,289	92	15	101
Gainesville	University of Florida	125,326	50,000	49	832	1985	sun-sat	10,698,984	85	33	128
Blacksburg	Virginia Tech	42,620	30,000	19	704	1983	sun-sat	3,300,000	77	12	217
Auburn	Auburn University	54,566	25,134	40	513	1997	mon-fri	2,077,714	38	19	193
Iowa City	University of Iowa	68,947	30,500	24	1078	1971	mon-sat	1,964,000	28	20	391
Lawrence	University of Kansas	88,727	30,000	29	1167	1957	mon-sat	666,777	8	18	57
Tuscaloosa	University of Alabama	91,605	33,602	67	622	1941	mon-fri	200,340	2	6	115
Manhattan (existing)	Kansas State University	53,678	23,800	15	1179	2012	mon-sat	209,793	4	5	28
Manhattan (proposed)	Kansas State University	53,678	23,800	15	1179	2012	mon-sat	419,586*	8*	6	39
improvement percentage	na	na	na	na	na	na	0%	100%	100%	20%	39%

\*estimation based on improved coverage, increased frequency and increase fixed cost options

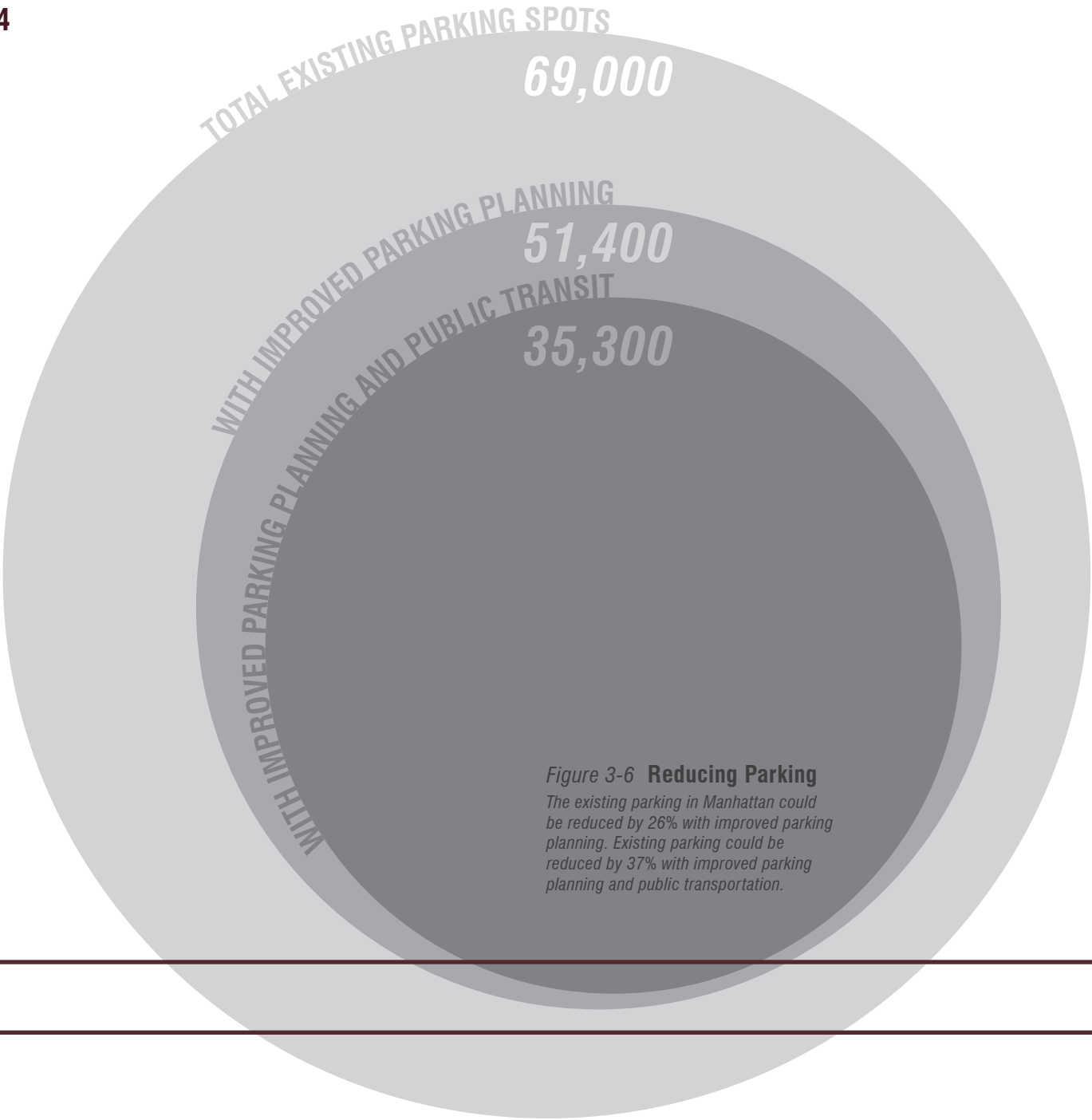
Table 3-2 Comparison of Improved Transit to Case Studies

The proposed transit plan ranks near the middle in ridership, route coverage, frequency, and fixed cost options.

				Bus Fares					
stops per sq. mi.	# of vehicles	average frequency	population serviced	single ride	Day pass	10-ride pass	monthly pass	semester pass	discount for students
5	84	30 min	na	\$0.60/1.25	na	\$6/12	\$20/40	\$80/160	yes- free, \$115 semester
3	114	35 min	na	\$0.75/1.50	\$3	na	\$17.50/35	\$60	yes- \$0.75, \$17.50 monthly
11	44	30 min	na	\$0.25/0.50	na	na	\$4/8	\$18.75/37.50	yes- pre-paid
5	42	18 min	na	na	na	na	na	na	yes- free
16	85	36 min	na	\$0.75/\$1	\$2	\$8.50	\$27/32	\$100	yes- \$60 semester
2	73	36 min	na	\$0.50/1	\$1.35/2.75	\$5/10	\$17/34	na	yes- free
2	16	47 min	na	0.5/1	na	na	na	na	yes- free
1.866667	15	43 min	17,363	\$0.50/1	na	na	\$30	na	yes- free on campus
2.6	18	32 min	23,765	\$0.50/1	na	\$4.50/9	\$30	\$100	yes- free on campus, discounted semester pass
39%	20%	25%	37%	0%	0%	100%	0%	100%	50%

3.2

IMPROVED TRANSIT PLAN



**Figure 3-6 Reducing Parking**

*The existing parking in Manhattan could be reduced by 26% with improved parking planning. Existing parking could be reduced by 37% with improved parking planning and public transportation.*

### ***Potential to Reduce Parking***

To determine the amount of parking that could be reduced in Manhattan, Kansas, the existing parking was analyzed and the number of drivers in Manhattan was estimated. The following calculations are approximations. There is an estimated 612 acres of parking in Manhattan, Kansas. This means that 7% of Manhattan's total area is used for parking lots. There are 69 thousand parking spots in Manhattan, 56,300 of which are dedicated to non-residential uses.

Based on the population of people of driving age (16+ years old) and the average vehicles per household from the United States Census Bureau, it is estimated that there are 38,700 drivers living in Manhattan. There are 17,600 more non-residential parking spots than drivers in Manhattan. This means that if every driver left home in their vehicle and parked somewhere in

Manhattan other than residential parking lots, close to 17,600 non-residential parking spots would be left vacant.

As suggested by Zhang et al. 2012 and supported by Davis et al. 2010, Wood 2003, Bond and Steiner 2006, and Shannon et al. 2006, Manhattan's parking demand could be reduced by an additional 20% with improved public transit. Combining the existing excess parking with the additional excess parking resulting from improvements to Manhattan's bus system totals 25,000 excess parking spots. This concludes that with improved public transit and parking planning, at least 30% and up to 40% of Manhattan's parking could be eliminated. The potential to reduce parking in Manhattan is diagrammed in *Figure 3-6*.

## **3.3**

### **PARKING ANALYSIS**

***Benefits of Reducing Parking***

Eliminating 30% of Manhattan's parking would free up more than 180 acres of space to be used for various ecologic and social amenities. Converting the entire 30% of eliminated parking into green space would decrease the average annual runoff volume from parking lots by 90 acre-feet and potentially more if Low Impact Development strategies such as bioswales, rain gardens, and bio-retentions were implemented.

Reducing runoff can save money by reducing the need for additional stormwater infrastructure such as storm drains and levees. Reducing runoff can mitigate damages and associated costs caused by flooding. Reducing runoff volume would also reduce nonpoint source pollutants. A summary of reductions in runoff and pollutants as a result of converting 30% of parking into green space can be referenced in the *Appendix*.

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Costanza et al. (1997) developed a method for determining the Ecosystem Service Value (ESV) of different land types. Davis et al. (2010) references Costanza et al. (1990) to determine the ESV lost as a result of parking. Pre-development, what is now Manhattan, Kansas would have been primarily tallgrass prairie. Costanza et al. (1997) assigns grassland a value of \$136 (USD 2012) per acre per year. Over time, approximately 612 acres of what was once grassland became parking. Therefore, the ESV lost as a result of parking is \$83,232 per year.

If 30% of Manhattan's parking was converted back to grassland the ESV regained would be \$24,480 per year. If 30% of parking was converted to forest, the ESV of this land would be \$101,914 per year. If 30% of parking was converted to wetland, the ESV would be \$1,555,380 per year which is more than eighteen

times more than the ESV lost as a result of parking. A detailed summary of Costanza et al.'s (1997) ecosystem services values for grassland, forest, and wetland can be seen in the *Appendix*.

### 3.3

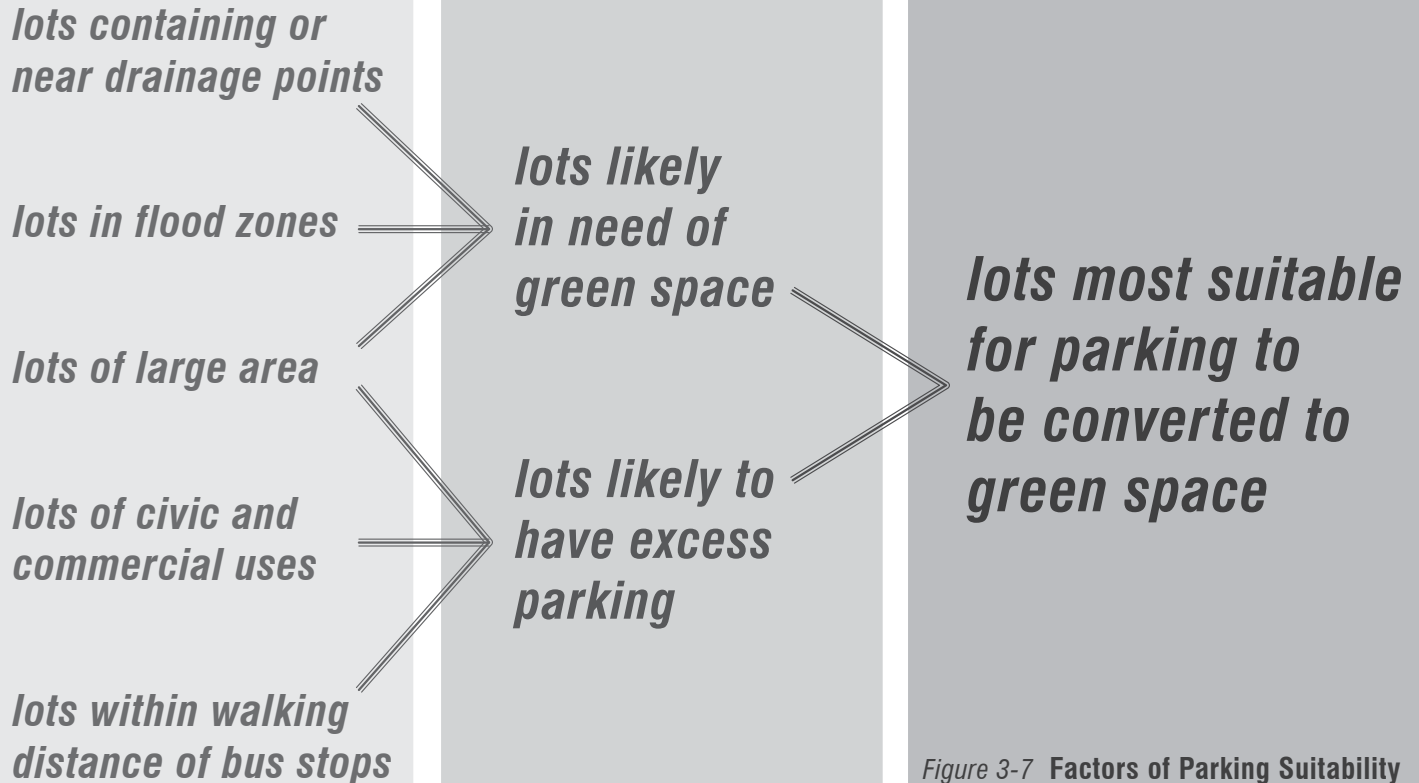
## PARKING ANALYSIS

### ***Parking Suitability***

To determine which parking areas should be converted to green space, a suitability analysis was done using ArcGIS. Parking lots that are likely to have excess parking and are in need of additional green space are most suitable to be converted into green space as seen in *Figure 3-8*.

Factors that were used to determine which areas are likely have excess parking were parking use, proximity to bus stops and lot size. Parking lots used for civic and commercial purposes were given a higher suitability value than residential parking lots. Parking lots within walking distance of a bus stop were given a lower suitability value than parking lots outside walking distance of bus stops. Parking lots of very large area are more likely to have an oversupply of parking and are therefore given a higher suitability value.

Factors that were used to determine which lots might be in need of additional green space were drainage points created using ArcHydro and flood zones. Parking lots that have drainage points in or near them have a greater opportunity to catch runoff through Low Impact Development strategies; therefore, these parking lots were given a higher suitability value. Parking lots within flood plains are more suitable to be converted to green space to reduce flood risks. Larger lots are also more suitable because they have great expanses of impermeable pavement which contributes to high runoff rates and the heat island effect. All five factors, use, size, bus stop proximity, drainage points, and flood zones were combined using the Weighted Overlay tool in ArcGIS to create a parking to green space suitability map as diagrammed in *Figure 3-7*.

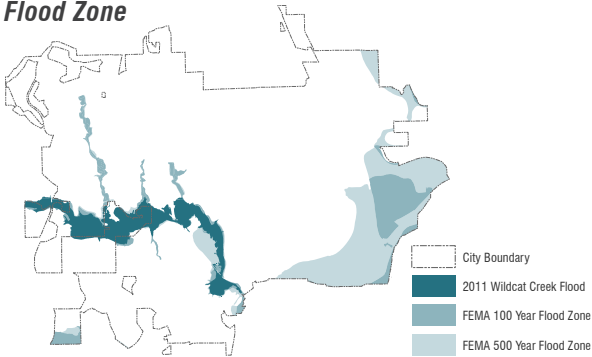


**Figure 3-7 Factors of Parking Suitability**  
Drainage points and floods zones were used to determine lots likely in need of green space. Lot use and bus stop proximity were used to determine lots likely to have excess parking. Lot size was used for both.

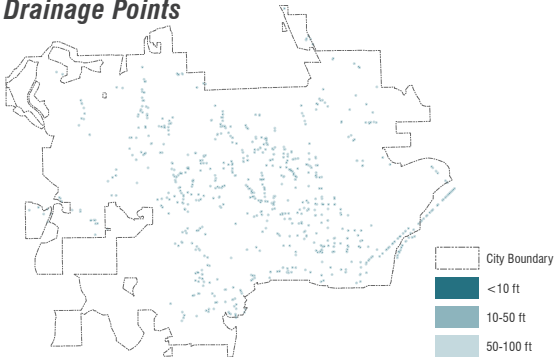
## 3.4

### SITE SELECTION

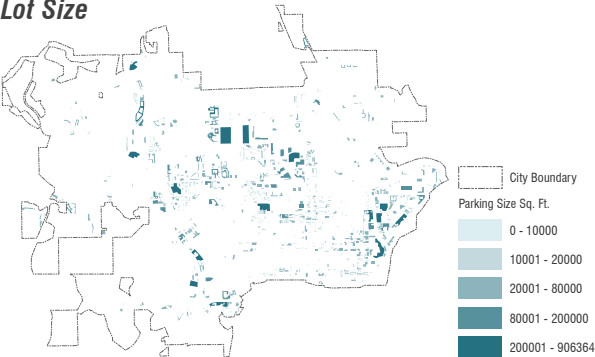
*Flood Zone*



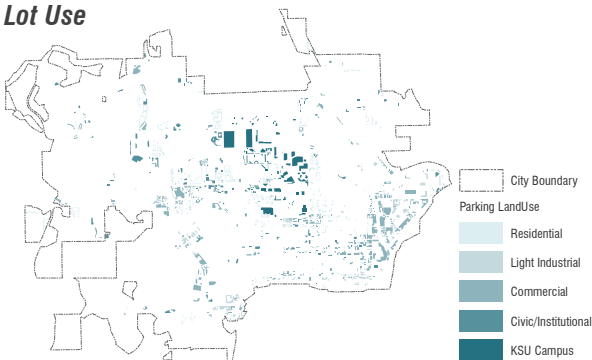
*Drainage Points*



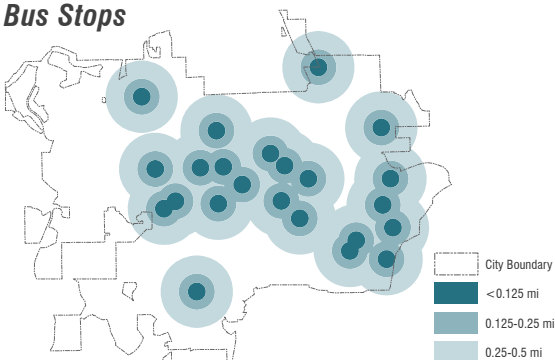
*Lot Size*

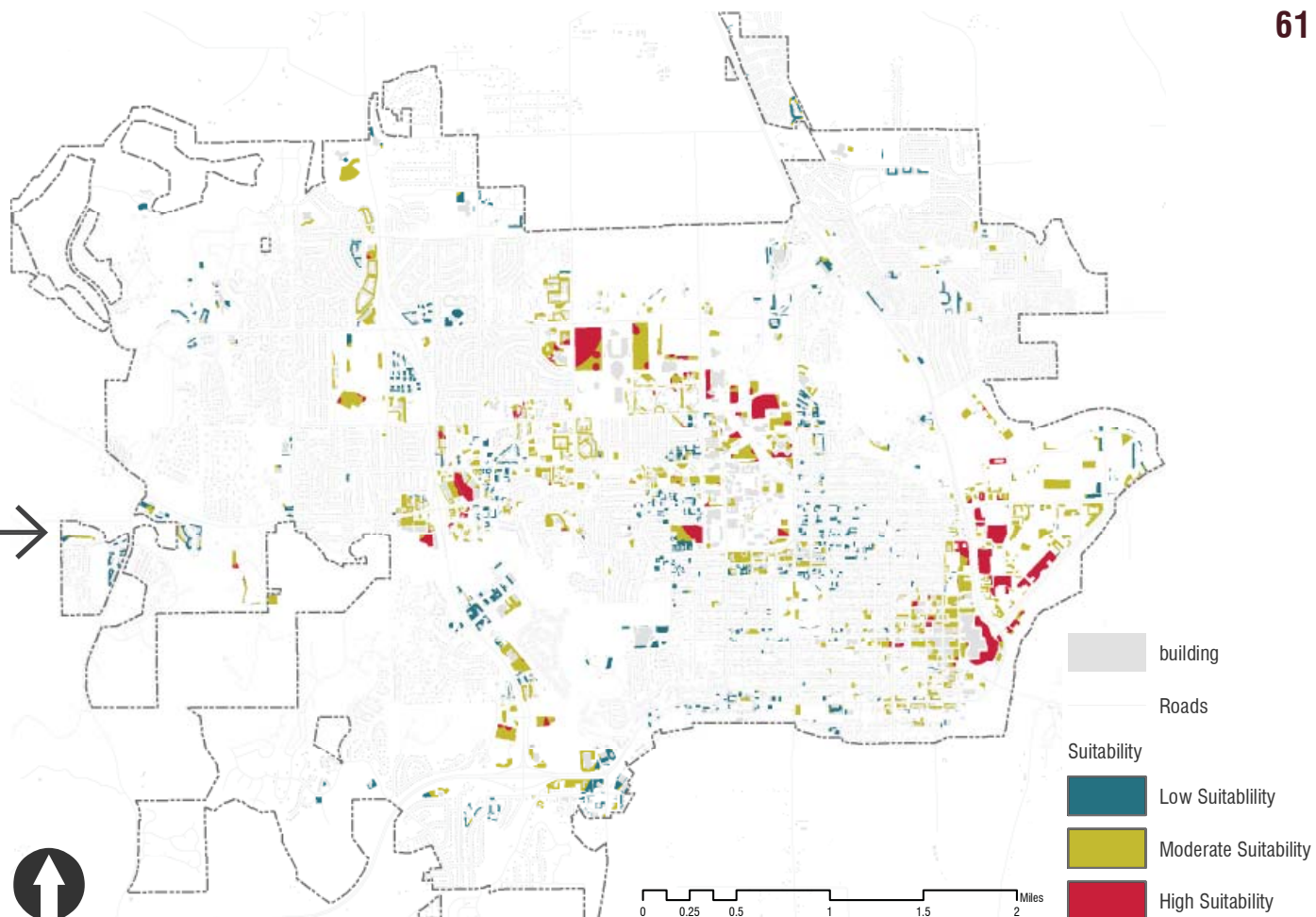


*Lot Use*



*Bus Stops*



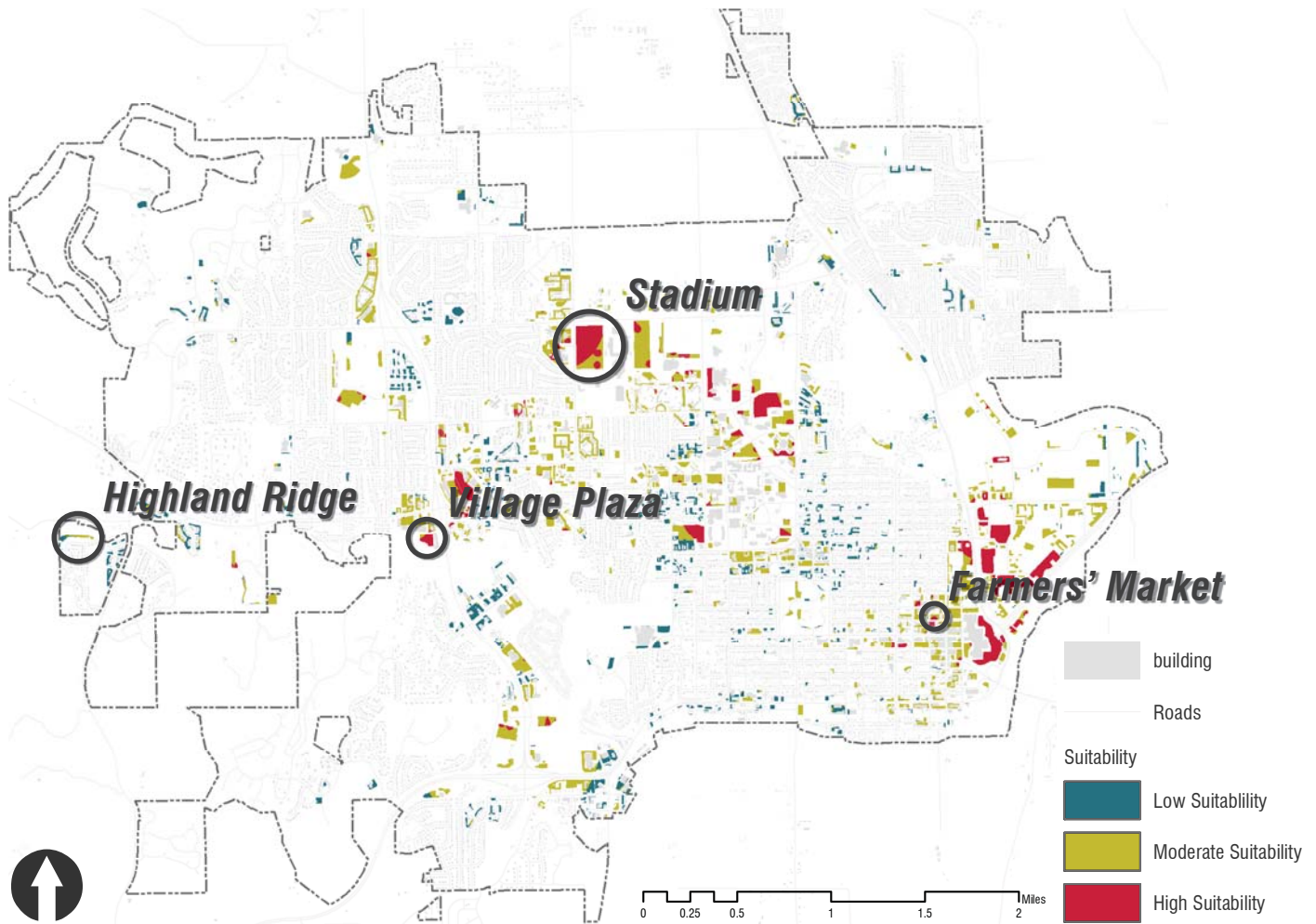


**Figure 3-8 Parking to Green Space Suitability**

*Areas in the darkest red are in most need of additional transit stops, while areas in light red or pink are in less need of additional transit stops.*

## 3.4

### SITE SELECTION



**Figure 3-9 Site Selection**

*Four sites were chosen to design in detail*

### ***Sites Chosen***

Four specific sites were chosen to redesign in detail to show how converting approximately 30% of a parking lot to green space can have ecological benefits. The four sites were chosen based on the parking to green space suitability map made in ArcGIS. Other considerations that influenced site selection were having sites of a variety of sizes and uses, having sites from a range of locations across Manhattan and having sites with minimal existing green space and vegetation. The four sites chosen can be seen in *Figure 3-9*.

The first site is the west parking lot at Bill Snyder Family Stadium. The second site is located on the western edge of Manhattan at Highland Ridge apartments. This site is not rated as high suitability according to the parking to green space suitability map, but it was chosen to show that

even some residential parking can be converted into green space. It is also located in the Wildcat Creek flood zone.

The third site is located at Village Plaza shopping center. The final parking lot is located downtown at the site of the Downtown Farmers' Market of Manhattan. Inventory and analysis of existing conditions was done for each site. Then designs were developed to maximize green space, trees, and stormwater management on each site. Finally, benefits, such as runoff reductions, carbon storage, and reduction in local air temperature, that would occur as a result of implementing the proposed designs were calculated.

## **3.4**

### **SITE SELECTION**





# FOUR

4.1

## DESIGN SOLUTION

4.2

STADIUM

4.3

HIGHLAND RIDGE

4.4

VILLAGE PLAZA

FARMERS' MARKET



**Figure 4-1 Storm Drain**

*The runoff from the site drains to the northwest corner of the lot and flows into two storm pipes*

### ***Site Description***

The stadium lot is part of the Kansas State University campus. The lot is located to the west of Bill Snyder Family Stadium at the corner of Kimble Avenue and College Avenue. It is approximately 25 acres making it the largest parking lot in Manhattan. Runoff on the site drains diagonally across the parking lot into two storm pipes at the northwest corner of the site as seen in *Figure 4-1*.

The stadium parking lot is left almost entirely unused during most days of the year as seen in *Figure 4-2*; however, it is used when there is an event at Bill Snyder Family Stadium or Bramlage Coliseum. Events held at the stadium and coliseum include Kansas State University basketball and football games, large lectures, and graduations. During many of these events, the parking lot is used at maximum capacity and

traffic is monitored by campus employees. During several Saturdays in the fall, the stadium parking lots are completely filled with tailgaters attending Kansas State University football games.

Except for narrow turf strips on the edges of the parking lot, there is no green space within site. This causes high runoff rates during storm events. The lack of trees on site makes shade limited for users and contributes to the heat island effect. It is necessary for the proposed design to maximize green space and shade, while providing enough parking to accommodate large events. Creating a pleasant environment for tailgaters is also an important consideration for this site.

## **4.1**

### **STADIUM**









**Figure 4-2 Stadium Lot**  
*The stadium lot is left almost completely unused except during large events.*



College Ave.

narrow bioswale

tailgating  
space

runnel

wide  
bioswale

Bill Snyder  
Family Stadium

0 100 200  
Feet





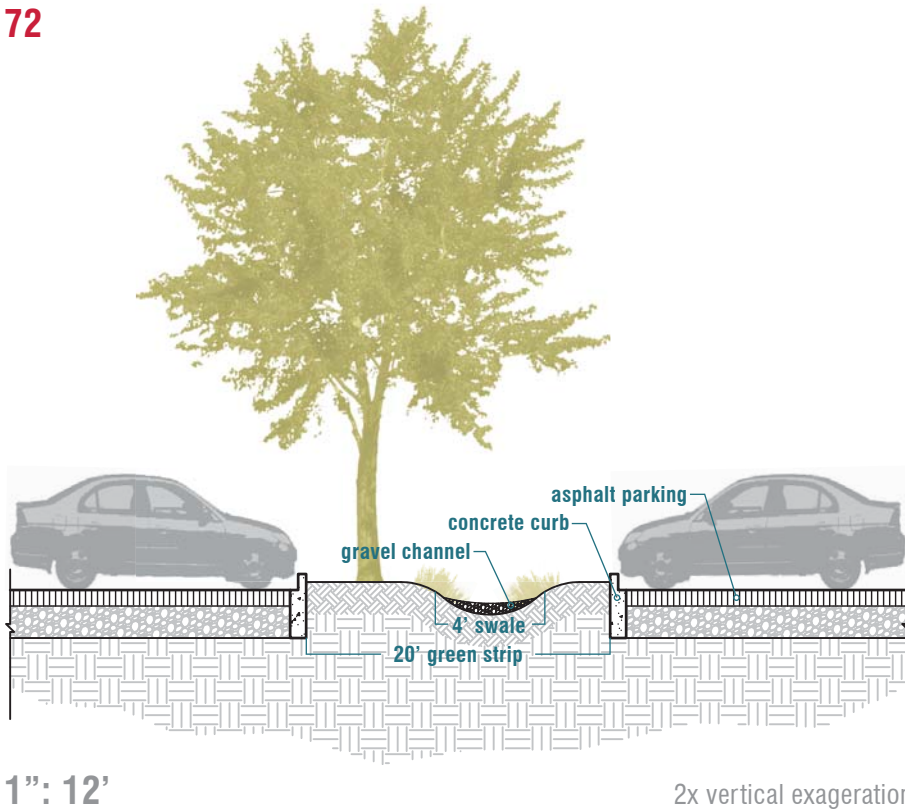
**Figure 4-3 Stadium Lot Plan**

The design concept for the stadium lot is a network of green spaces that follow the existing drainage.

**Design Description**

The proposed design for the stadium parking lot more than doubles the amount of green space on site by integrating a network of green strips throughout the parking lot as seen in *Figure 4-3*. The green spaces are strategically placed to make use of existing drainage patterns. In the proposed design, runoff continues to drain diagonally across the site but instead of flowing directly into the storm drain at the northwest corner of the site, it flows through a series of bioswales that lead to a large detention basin. The swales start narrow toward the southeast portion of the site and widen as they near the a detention basin. The bioswales slow runoff allowing some of it to infiltrate into the ground. A narrow bioswale within a twenty foot wide green strip can be seen in Section A in *Figure 4-4*. Section B in *Figure 4-5* illustrates a wider bioswale that is near the detention basin.

**STADIUM**



**Figure 4-4 Section A (left)**

Narrow four foot wide, gravel lined swales are located within the twenty foot wide planting strips. These swales catch runoff from the parking lot and allow it to slow before it enters the larger bioswales.

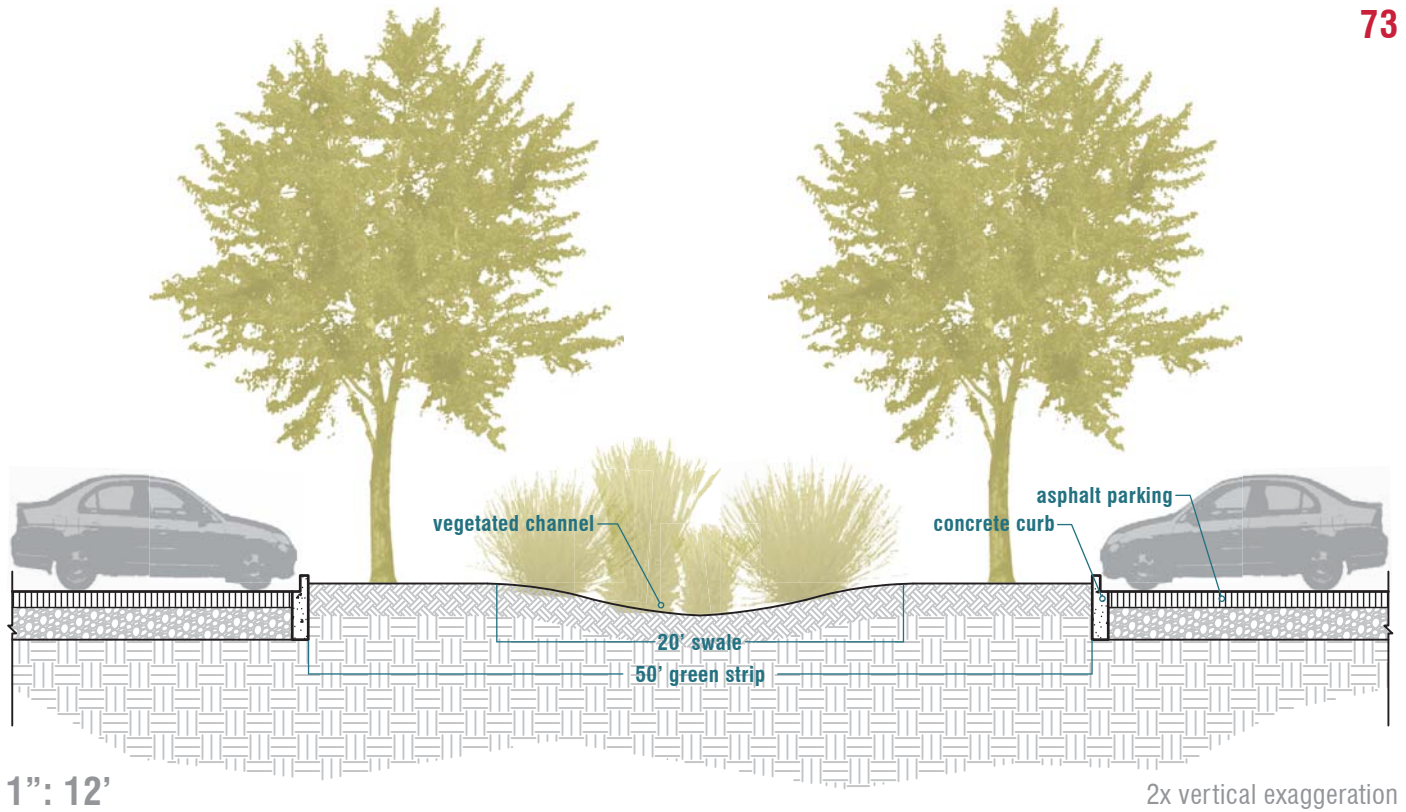
**Figure 4-5 Section B (right)**

Within the 40-50 foot wide planting strips, there are 15-20 foot wide vegetated bioswales. These swales allow water to collect and infiltrate.

The detention basin can hold up to 2.6 acre-feet or about 8.5 million gallons of water. This means that the proposed design can hold 100% of the runoff volume of a two year, one hour storm. During larger storms, when the detention basin begins to overflow, excess water will be allowed to flow into the existing storm drains. A section

of the retention basin can be seen in *Figure 4-6*. Although the flow line cuts across the site, main circulation paths were maintained. The bioswales are connected across circulation paths with narrow runnels that are covered by metal grates so the can be driven over. These runnels allow water to flow from one bioswale to the next. The





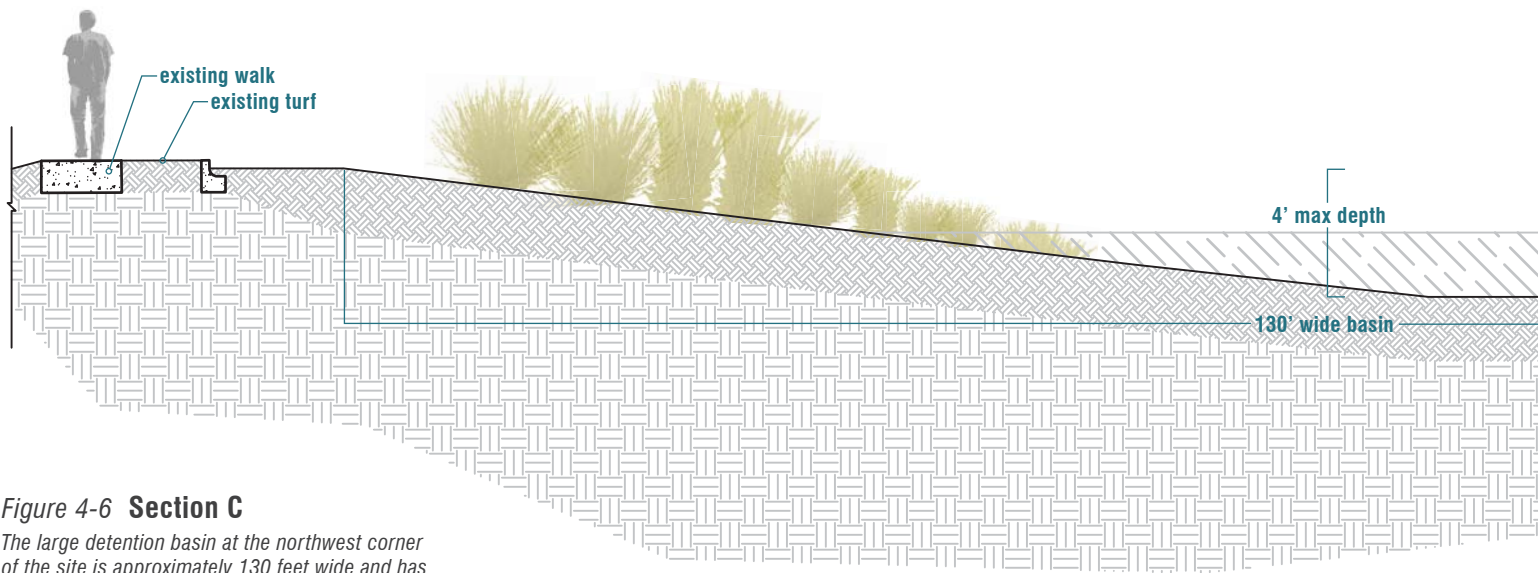
grates can be easily removed to clear away debris that may collect in the runnel.

The edges of all the green spaces are lined with 211 additional trees. Not only do these trees provide shade to create a more comfortable environment for tailgaters, they have several

ecological benefits. Combined, the proposed trees will store 50-70 tons of carbon, in addition; they will sequester approximately two tons of carbon annually (Nowak and Crane 2002). This is equal to savings of approximately \$1300 and an additional \$40 per year (Nowak 2004).

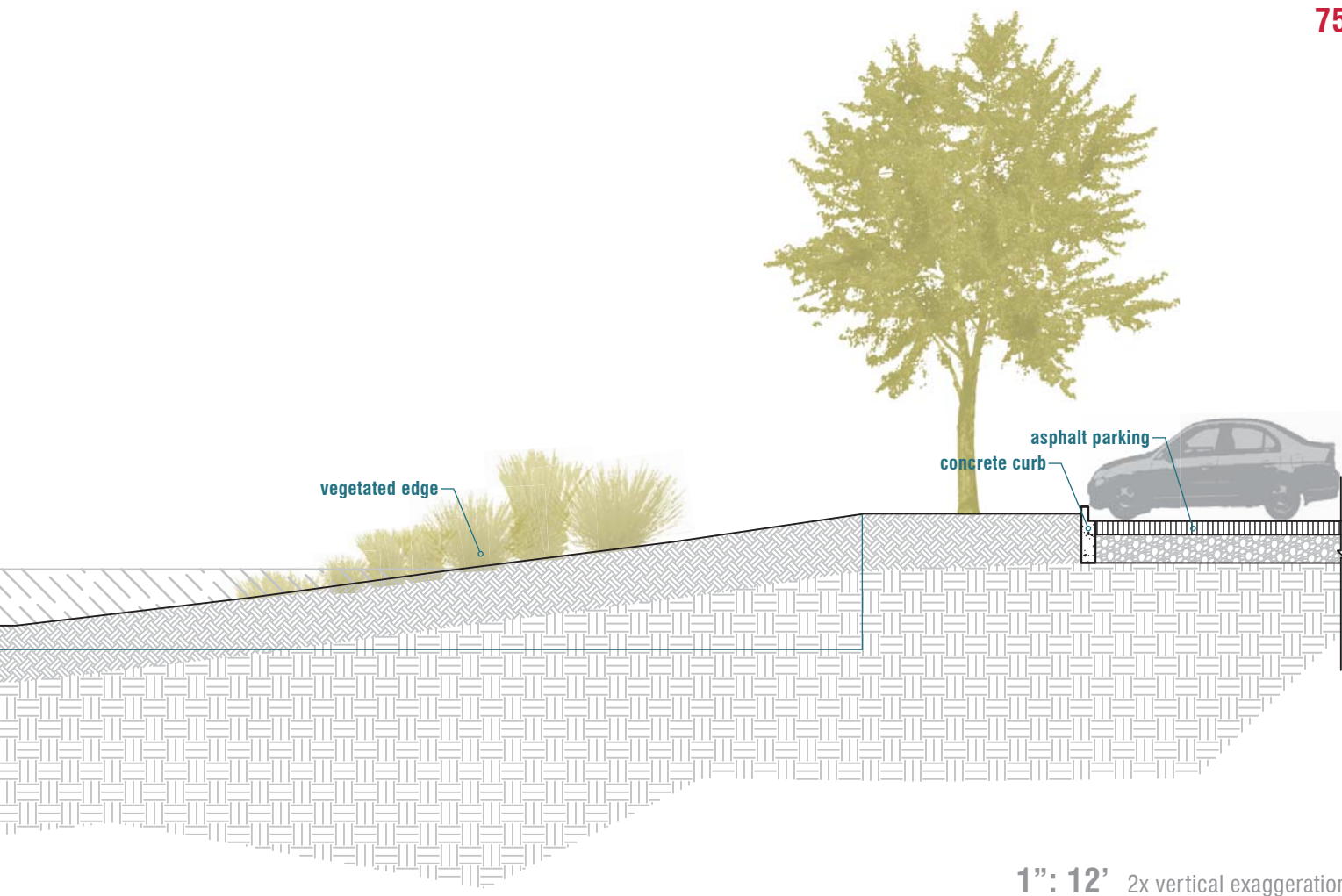
## 4.1

### STADIUM



**Figure 4-6 Section C**

*The large detention basin at the northwest corner of the site is approximately 130 feet wide and has an average depth of approximately two feet.*



4.1

STADIUM





### Figure 4-7 Tailgating at the Stadium

*This perspective depicts what tailgating could be like with the new design for the stadium parking lot.*

Trees can reduce local air temperatures and decrease energy use by providing shade and through evapotranspiration. It is estimated that the proposed trees would lead to a reduction in average maximum air temperatures within the parking lot by nearly one degree Celsius. The trees account for direct A/C energy savings of almost \$18,000 and indirect A/C energy savings of about \$6000 totaling approximately \$24,000 in A/C energy savings over their lifespan (Akbari 2002). The A/C savings account for the regional cooling effect of evapotranspiration, as well as, the shade trees provide to adjacent buildings.

The ability of trees to reduce air temperatures which slows the formation of smog and to remove NO<sub>2</sub> which is an ozone precursor, reduces smog. The estimated smog saving of planting 211 additional trees is estimated to be over \$32 thousand (Akbari 2002). Smog savings refers to

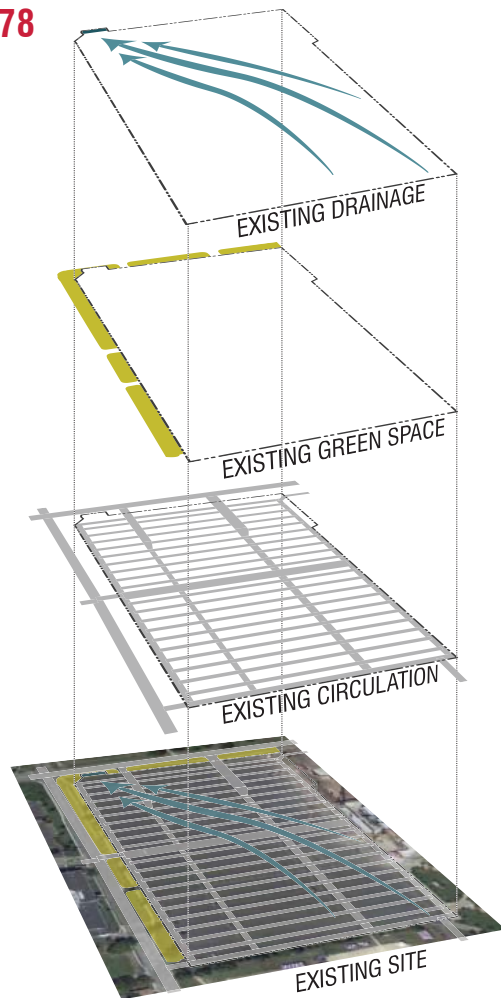
the decrease in energy cost and medical costs that results from a reduction in smog levels. Although smog is not an issue in Manhattan, Kansas, it is important to understand the benefit trees can have on smog when applied to other cities. The existing and proposed conditions of the site are compared in *Figure 4-8* and *Figure 4-9*.

In addition to environmental benefits such as carbon storage, heat island mitigation, and air pollutant abatement, the proposed design provides social benefit. Open areas within the green spaces that are not being used for bioswales or detention basins serve as amenities to tailgaters. These areas will be designed with semi-permanent charcoal grills and picnic tables, as seen in *Figure 4-7*.

## 4.1

## STADIUM

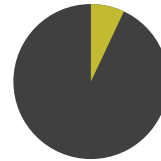
78



**Figure 4-8 Existing Site**  
Currently, the site is almost entirely pavement and provides very little shade.

### Permeable Surfaces

7%



### Parking Spots

2,660



### Annual Runoff

21  
ac-ft

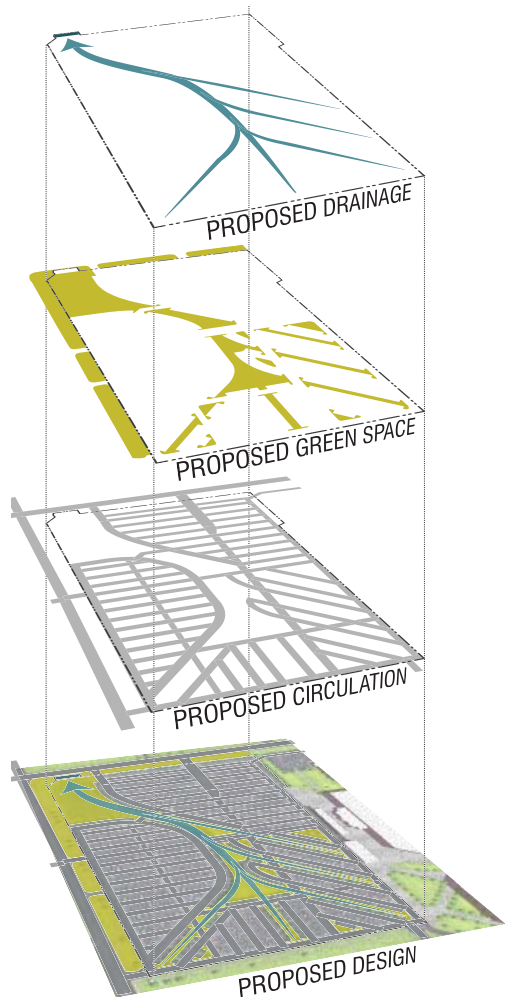


### Number of Trees

15





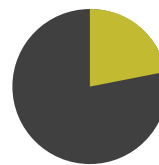


**Figure 4-9 Proposed Site**  
*The proposed design maximizes green space and shade while providing enough parking for large events.*

## Permeable Surfaces

79

22%



## Parking Spots

2,014



## Annual Runoff

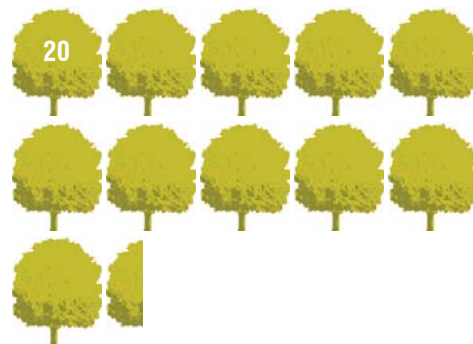
18

ac-ft



## Number of Trees

226



4.1

STADIUM







**Figure 4-10 Retaining Wall Pipe (top)**

*Runoff from the parking lot flows into a pipe which lets out into the open space on the other side of the retaining wall.*

**Figure 4-11 Existing Swale (bottom)**

*There is an existing drainage swale on the west edge of the site the catches runoff from the adjacent neighborhood and leads directly into Wildcat Creek.*

**Site Description**

Highland Ridge is a new multi-family residential development off of Scenic Drive on the western edge of Manhattan, Kansas. The focus parking lot services four buildings to the west of Scenic Drive and just south of Wildcat Creek. The parking lot is a 3.5 acre strip located between the buildings and Wildcat Creek. There are retaining walls along the northern and western edges of the site as seen in *Figures 4-10 and 4-11* respectively.

Most of the runoff from the parking lot flows into a drain near the center of the lot. The drain leads to a pipe that lets out on the other side of the retaining wall to flow into Wildcat Creek as shown in *Figure 4-10*. There is also a drainage swale along the western edge of the site that collects runoff from the adjacent neighborhood and leads directly into Wildcat Creek.

In recent years, due partially to changes in land use, Wildcat Creek has caused damaging floods in Manhattan, Kansas. The Highland Ridge parking lot is located within the 2011 Wildcat Creek flood line. The flood line rises to the very edge of the buildings. To help mitigate damage caused by flooding, a large detention basin exists below the retaining wall to catch runoff. The existing detention basin also serves as flood storage to prevent the flooding of Highland Ridge Apartments. It is important for the proposed design to address storm-water management and flood risk while continuing to provide adequate parking for residents.

**4.2****HIGHLAND RIDGE**







**Figure 4-12 Highland Ridge Lot**

*The Highland Ridge parking lot is located between the apartment building and open space adjacent to Wildcat Creek.*





recreation  
facilities

existing retaining wall

bioswale

narrow bioswale

existing parking

apartment  
building

proposed parking

narrow bioswale

Highland Ridge Dr

existing  
drainage  
swale

single-family  
residential

Harland Dr



### Figure 4-13 Highland Ridge Plan

The proposed design for Highland Ridge relocates the northern most row of parking to the south of the buildings to allow space for a bioswale to the north of the parking lot.

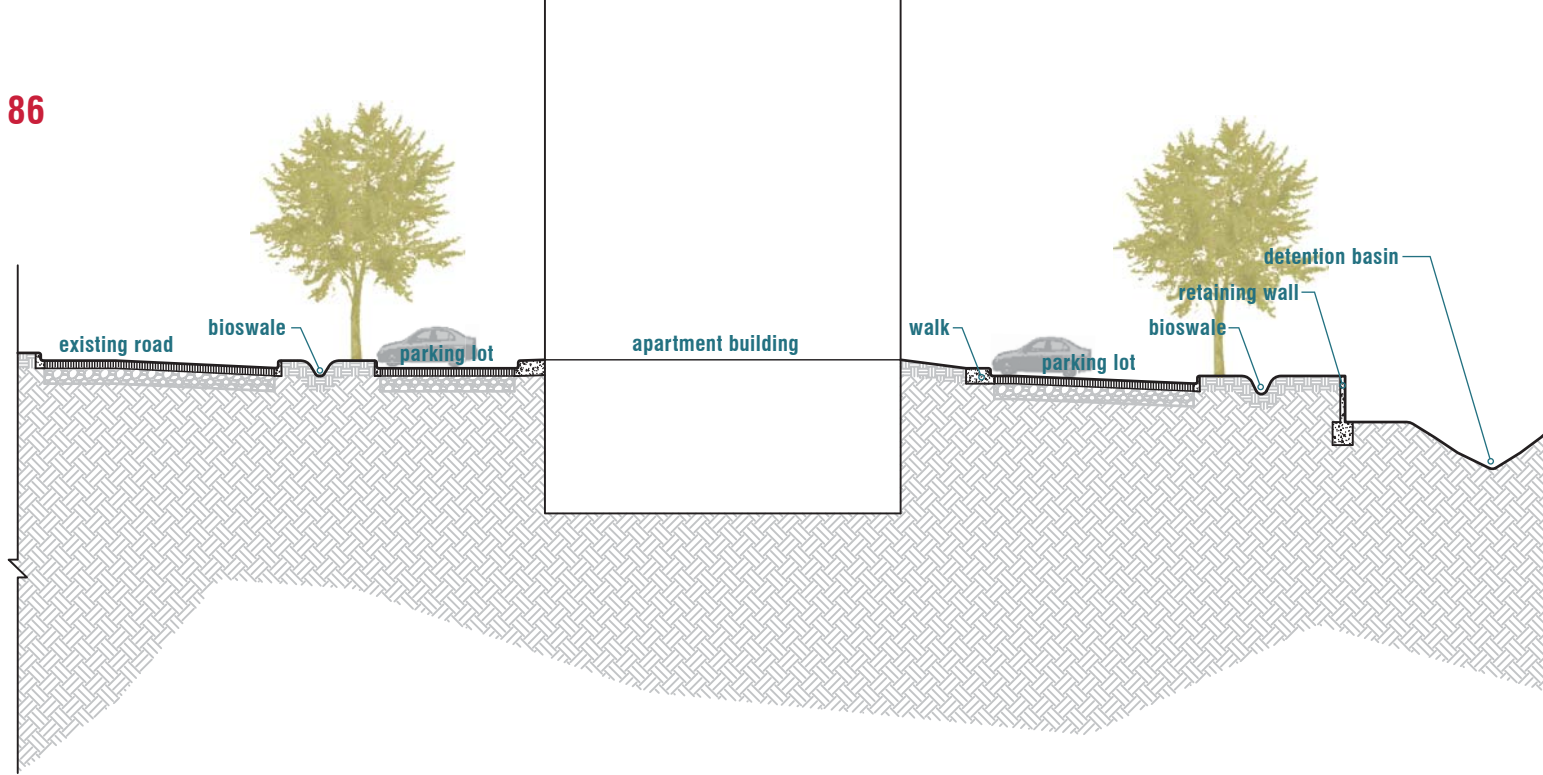


### Design Description

In the proposed design for the Highland Ridge parking lot, the vegetated area does not increase, it is just rearranged within the site; the proposed design does however, increase the number of trees and improves stormwater management on site. One row of parking is removed to allow space for a bioswale. Parking is added to the front of the buildings to maintain sufficient parking for residents as seen in *Figure 4-13*.

Runoff from the north parking lot is allowed to flow into the bioswale through curb cuts. The existing pipe that carries runoff from the parking lot to the open space beyond the retaining wall is used to connect the bioswale to a detention basin on the other side of the retaining wall. Runoff from the southern parking lot flows into a narrow bioswale at the edge of the site. This bioswale connects to a smaller detention basin.

## HIGHLAND RIDGE

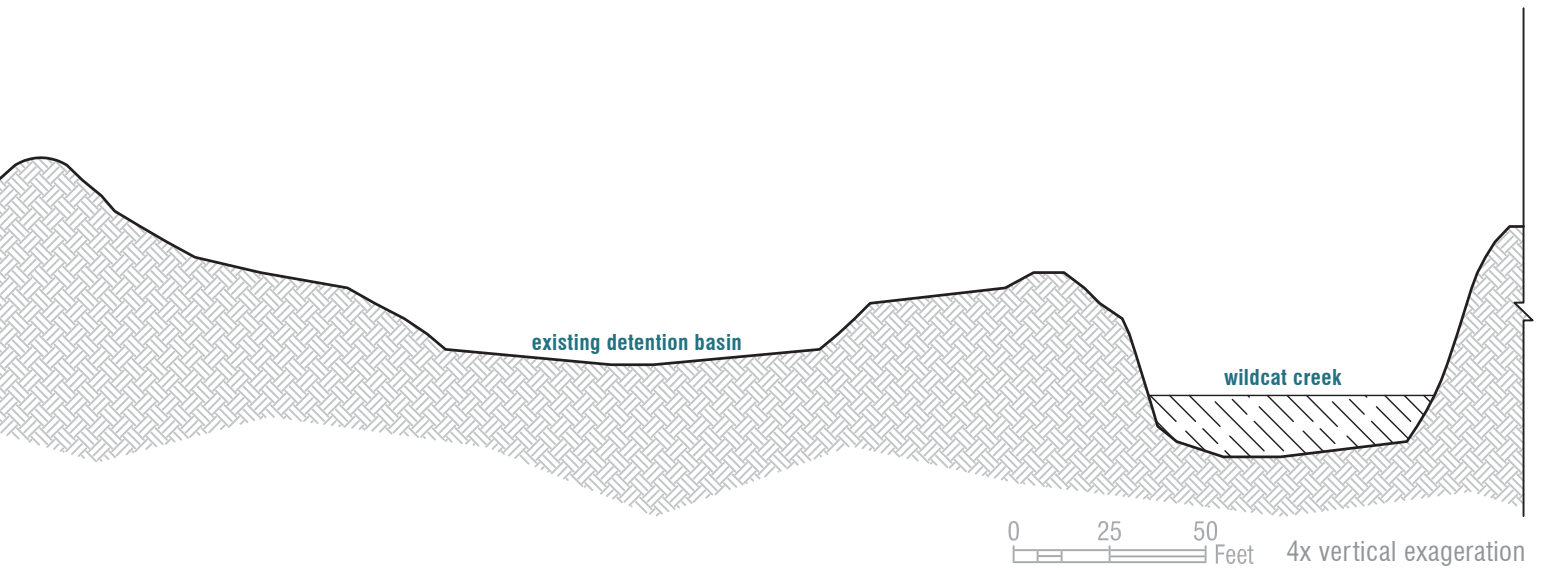


The proposed bioswales are similar to the narrow ones used in the stadium lot which can be seen in *Figure 4-4*. The proposed detention basins can hold a combined volume of 0.22 acre-feet of water which is the amount of runoff produced by a one year, one hour storm. During larger storm events the proposed detention basins can

overflow into the large existing basin. Not only will the proposed bioswales reduce runoff, they will provide extra flood storage for Wildcat Creek to protect the apartment buildings from flood damage. The bioswales and detention basins are shown in the section in *Figure 4-14*. A view of how the northern bioswale and detention basins

### Figure 4-14 Highland Ridge Section

The proposed design for Highland Ridge relocates the northern most row of parking to the south of the buildings to allow space for a bioswale to the north of the parking lot.



might look during a storm event is illustrated in *Figure 4-15*.

The proposed design for Highland Ridge incorporates 39 additional trees. These additional trees will store 10-14 tons of carbon and will sequester an additional 0.3-0.5 tons of carbon

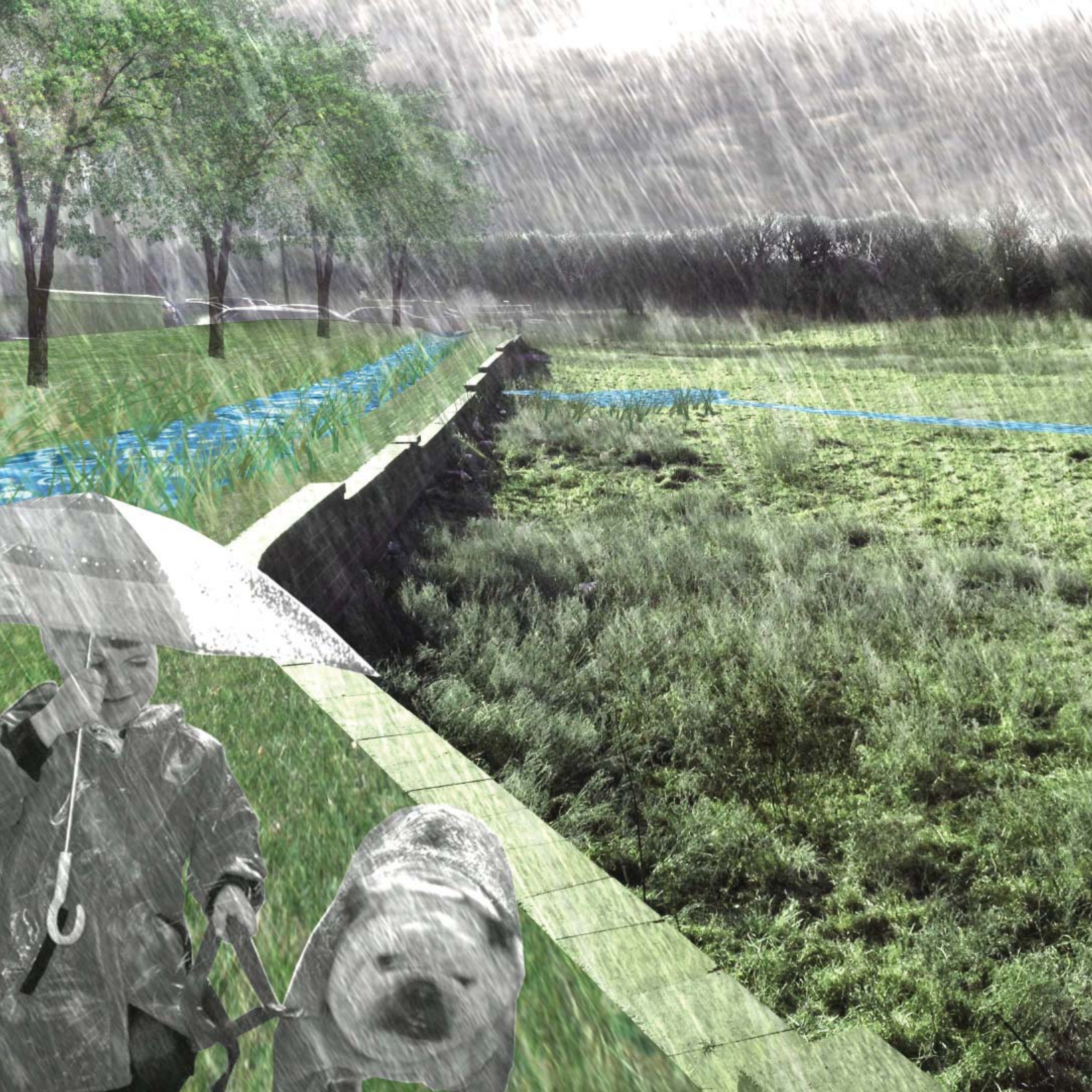
annually (Nowak and Crane 2002). This is equal to savings of almost \$300 and an addition \$9 per year (Nowak 2004).

It is estimated that the proposed trees will lead to a reduction in local average maximum air temperatures by over one degree Celsius. The

## 4.2

### HIGHLAND RIDGE









#### **Figure 4-15 Storm at Highland Ridge**

*During heavy storm events, the bioswale overflows into a detention basin below the retaining wall. Once the small detention basin is full, runoff overflows into the large existing detention basin.*

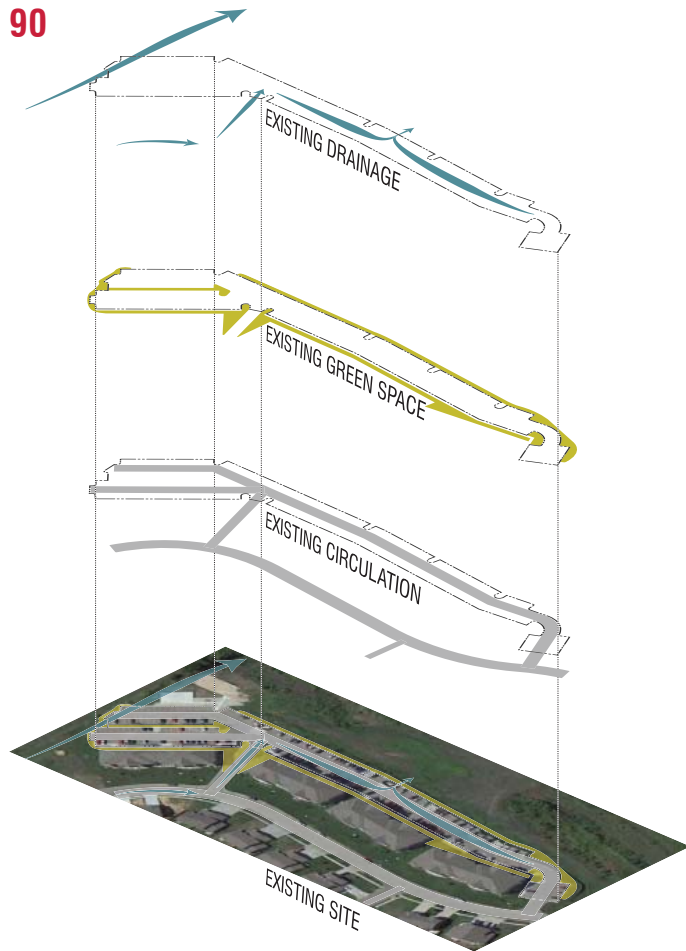
**89**

trees account for direct A/C energy savings of over \$3000 and indirect A/C energy savings of over \$1000 totaling almost \$4500 thousand in A/C energy savings over their lifespan (Akbari 2002). The estimated smog saving of planting 39 additional trees is estimated to be \$6000.

A summary of the existing site conditions can be seen in *Figure 4-16*. The proposed design changes are shown in *Figure 4-17*. Although the area of green space remains nearly the same in the proposed design volume of runoff held and the number of trees increases significantly in the proposed design. The proposed design also increases flood storage reducing the risk of flood damages.

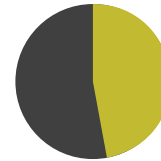
## **HIGHLAND RIDGE**

90



## Permeable Surfaces

47%



## Parking Spots

221



## Annual Runoff

1.7  
ac-ft



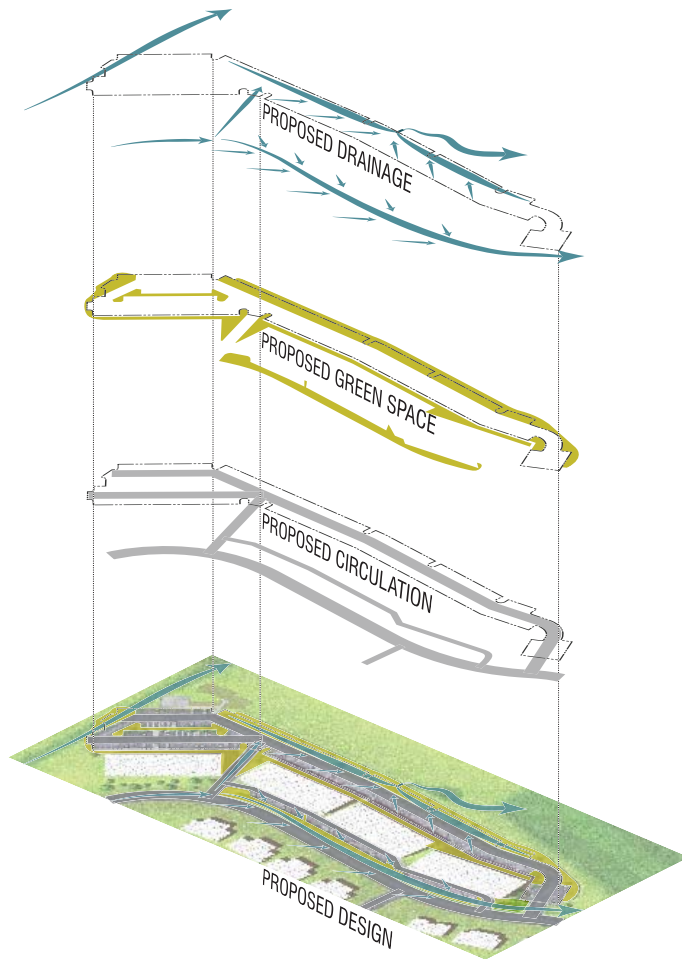
## Number of Trees

39



**Figure 4-16 Existing Site**

The existing site is susceptible to flooding from Wildcat Creek.

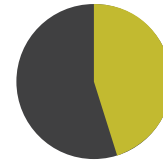


**Figure 4-17 Proposed Site**  
*The proposed design does not increase green space  
 but it increases ecological benefits.*

## Permeable Surfaces

91

45%



## Parking Spots

151



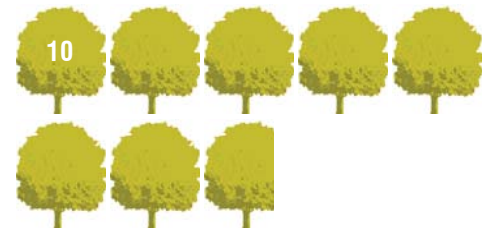
## Annual Runoff

1.7  
ac-ft



## Number of Trees

78



4.2

HIGHLAND RIDGE





**Figure 4-18 Village Plaza Lot**

*Because this parking lot is only used by four businesses, it is not being used to its full capacity.*

### ***Site Description***

Village Plaza is located on the southwest corner of Anderson Boulevard and Seth Child Road. The focus parking lot is 3.4 acres and is located behind Ray's Apple Mart. There is a small strip mall directly adjacent to the parking lot on the east side. Most of the spaces in the strip mall are vacant. The parking lot primarily serves four

---



small businesses and is not used at full capacity as shown in *Figure 4-18*.

The parking lot is surrounded by open space to the south and the west. There are eight small planters within the parking lot. Except for the southern and western edges, there is very little shade on site.

The Linear Trail runs along the south of the site. The Linear Trail is a pedestrian and bicycle path that winds along the southern and eastern edges of Manhattan. The parking lot serves as an entrance to the Linear Trail. The access point to the Linear Trail is located at the southern corner of the site; it is hidden and unmarked as shown in *Figure 4-19*.

## 4.3

### VILLAGE PLAZA





**Figure 4-20 Storm Drain**

*A storm drain exists at the southern corner of the site near the entrance to the Linear Trail.*





**Figure 4-19 Linear Trail Entrance**

*The Linear Trail access point on site is hidden, unmarked, and poorly maintained.*

Wildcat Creek winds just beyond the Linear Trail to the south of the site. Similar to the Highland Ridge parking lot, the Village Plaza lot is located within the 2011 Wildcat Creek flood line. The runoff on site flows into a drain located near the entrance to the linear trail which can be seen in *Figure 4-20*.

The proposed design must provide shade to accommodate users and mitigate the heat island effect. It must also catch runoff during storm events. The Linear Trail access point provides an opportunity to create a main entrance to the trail.

## 4.3

### VILLAGE PLAZA



Ray's Apple  
Mart

bioswale

bioswale

tree  
planter

runnel

detention  
basin

Linear Trail  
entrance

small  
businesses

vacant  
spaces



0 50 100  
Feet





### Figure 4-21 Village Plaza Plan

A storm drain exists at the southern corner of the site near the entrance to the Linear Trail.

#### Design Description

The proposed design replaces two existing rows of parking with bioswales and 26 additional spots with tree planters. The design also includes a detention basin and improved Linear Tail entrance at the south end of the site as seen in *Figure 4-21*. The bioswales are similar in design to the narrow swales in the stadium lot design shown in *Figure 4-4*. The bioswales collect runoff from the parking lot slow it, and allow some of it to infiltrate into the ground and excess it to flow into the detention basin.

The detention basin has a volume of nearly 0.4 acre-feet which means it can hold all of the runoff from a two year, one hour storm, and over 75% of the runoff from a ten year, one hour storm. During larger storm events, the detention basin can overflow into Wildcat Creek located south of the site.

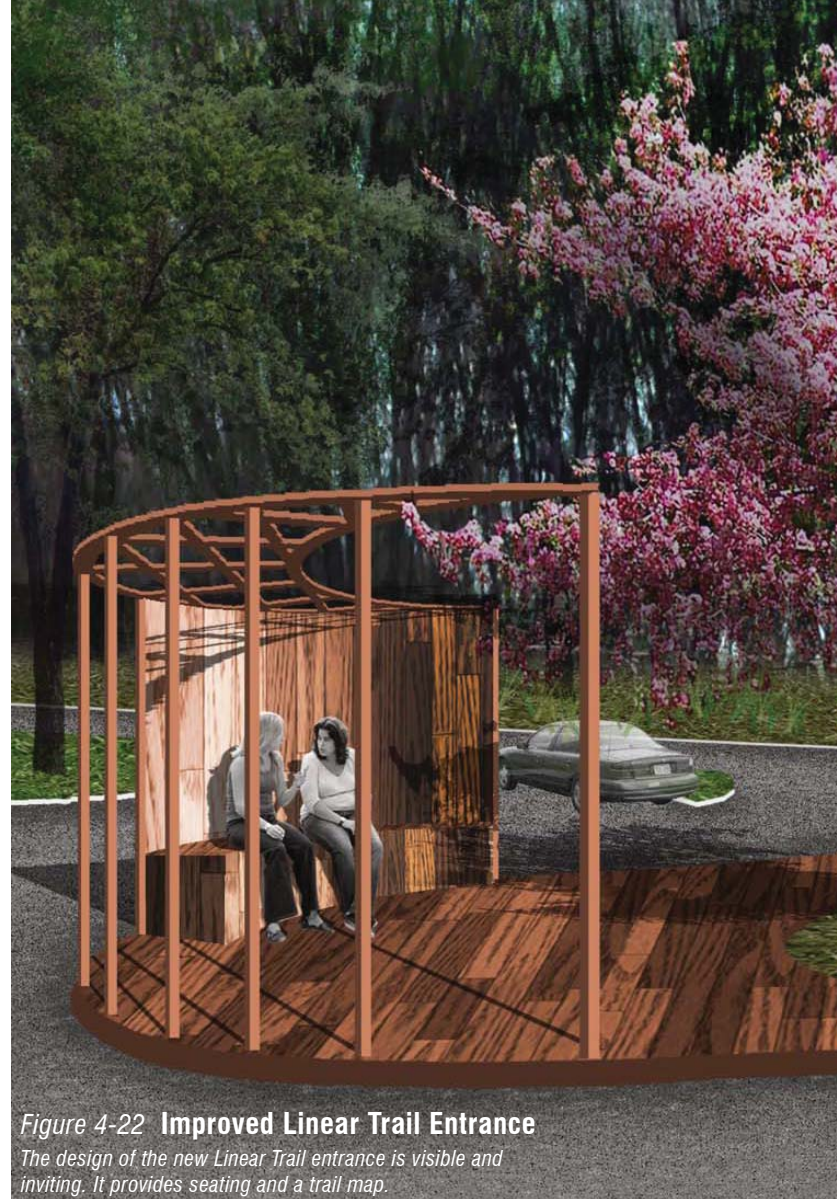
Because the existing site is lacking shade within the parking lot, 55 trees are added to the proposed design. These additional trees will store 14-17 tons of carbon and will sequester an additional 0.4-0.6 tons of carbon annually (Nowak and Crane 2002). This is equal to savings of approximately \$340 and an addition \$10 per year (Nowak 2004).

It is estimated that the proposed trees will lead to a reduction in average maximum air temperatures by nearly two degrees Celsius. The trees account for direct A/C energy savings of over \$4000 and indirect A/C energy savings of almost \$2000 totaling approximately \$6000 thousand in A/C energy savings over their lifespan (Akbari 2002). The estimated smog saving of planting 55 additional trees is estimated to be nearly \$8500.

## 4.3

### VILLAGE PLAZA

In addition to environmental benefits such as carbon storage, heat island mitigation, and air pollutant abatement, the proposed design provides a new entrance to the Linear Trail. The improved trail entrance is near the detention basin and provides amenities such as shade structures, benches, and a trail map as depicted in *Figure 4-22*.



**Figure 4-22 Improved Linear Trail Entrance**

*The design of the new Linear Trail entrance is visible and inviting. It provides seating and a trail map.*

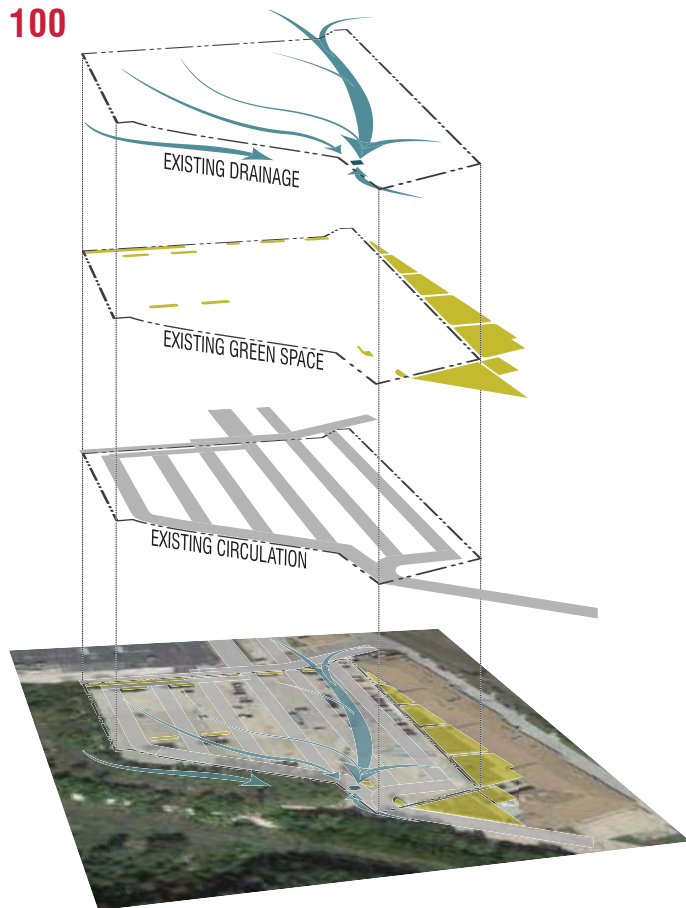




**4.3**

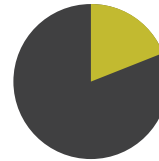
**VILLAGE PLAZA**

100



## Permeable Surfaces

19%



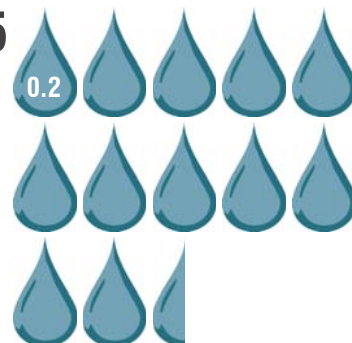
## Parking Spots

338



## Annual Runoff

2.5  
ac-ft



## Number of Trees

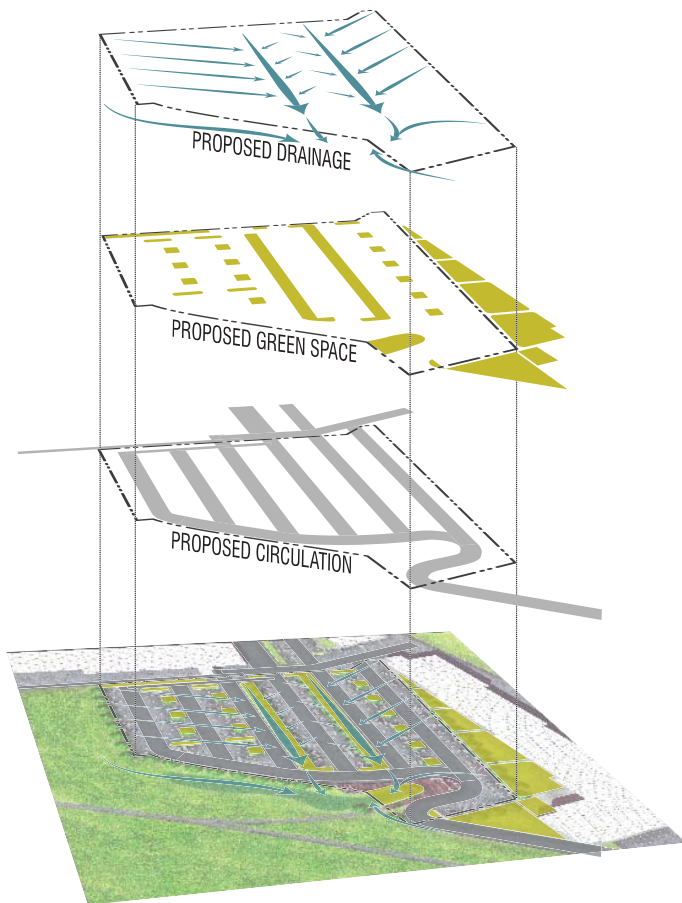
43



**Figure 4-23 Existing Site**

Currently, the site is not being used at full capacity and lacks shade.

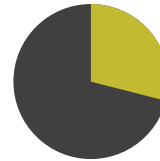




**Figure 4-24 Proposed Site**  
*The proposed design improves stormwater management on site and increases tree cover.*

### Permeable Surfaces

29%



101

### Parking Spots

231



### Annual Runoff

2.2  
ac-ft



### Number of Trees

98



4.3

VILLAGE PLAZA

**Site Description**

The final site is located in downtown Manhattan at the corner of Humboldt Street and 5th Street. It is bordered by small offices to the east, dense single-family homes to the north as seen in *Figure 4-25*, new apartments to the west as seen in *Figure 2-27*, and the Riley County Courthouse to the south.

The lot is free public parking most of the week but serves as the Downtown Farmers' Market of Manhattan, Kansas seasonally on Wednesday evenings and Saturday mornings. The Farmers' Market parking lot is less than an acre making it the smallest lot of the four chosen sites. It is also in the most urban location of the four sites.

*Figure 4-25* **Farmers' Market Lot**

*This view is from the southern edge of the parking lot looking north.*







Sidewalks and narrow turf strips line the parking lot on the south and west edges. There is one tree on site located at the southeast corner of the lot. There is no green space within the actual parking lot. The lot's runoff flows off site into street gutters; then eventually flows into the storm drain shown in *Figure 4-26*.

The farmers' market is an important consideration for the proposed design. It is important to provide shade to vendors and other users of the farmer's market. It is also necessary to continue to provide free public parking to employees and users of nearby offices and businesses.

**Figure 4-26 Street Drain**

*Currently the parking lot's runoff flows off site into street gutters and eventually into storm drains such as this.*

## 4.4

## FARMERS' MARKET



FREE MUNICIPAL  
PARKING  
→

DOWNTOWN  
**FARMERS' MARKET**  
SATURDAY 8to1

ONE WAY →







*Figure 4-27 Farmers' Market Entrance*

*This parking lot serves as both public parking and the downtown farmers' market.*





single-family  
residential

5th St

bioswale

small  
offices

bioswale

existing  
tree

Humboldt St

0 50 100 Feet





**Figure 4-28 Farmers' Market Plan**

*The proposed plan for the farmers' market parking lot increase green space and shade considerably.*

**Design Description**

The design for the farmers' market parking lot has eight times more green space than the existing site. The proposed green spaces include one in the center of the parking lot and additional green space on the edges as seen in *Figure 4-28*.

The central green space includes a vegetated bioswale, that collects runoff from the site. Excess runoff overflows into another bioswale located at the south of the site. The bioswales can hold half of the total runoff volume for a one year, one hour storm. During larger storm events, excess runoff will overflow into the existing storm drain at the southwest corner of the site.

There is only one existing tree on site so 29 additional trees are proposed to provide shade to vendors and users of the farmers' market. Not only will increasing tree cover create a

more comfortable environment, it will increase ecological benefits. The additional trees will store 5-7 tons of carbon and will sequester an additional 0.2 tons of carbon annually (Nowak and Crane 2002). This is equal to savings of approximately \$130 and an addition \$4 per year at maturity (Nowak 2004).

It is estimated that the increased tree density will lead to a reduction in local average maximum air temperatures by nearly four degrees Celsius. The proposed trees account for direct A/C energy savings of over \$2000 and indirect A/C energy savings of almost \$1000 totaling over \$3000 thousand in A/C energy savings over their lifespan (Akbari 2002). The estimated smog saving of planting 29 additional trees is estimated to be nearly \$4500.

**4.4****FARMERS' MARKET**



**Figure 4-29 The Downtown Farmers' Market**

*On Wednesday evenings and Saturday mornings, the site is transformed from a parking lot to a farmers' market.*



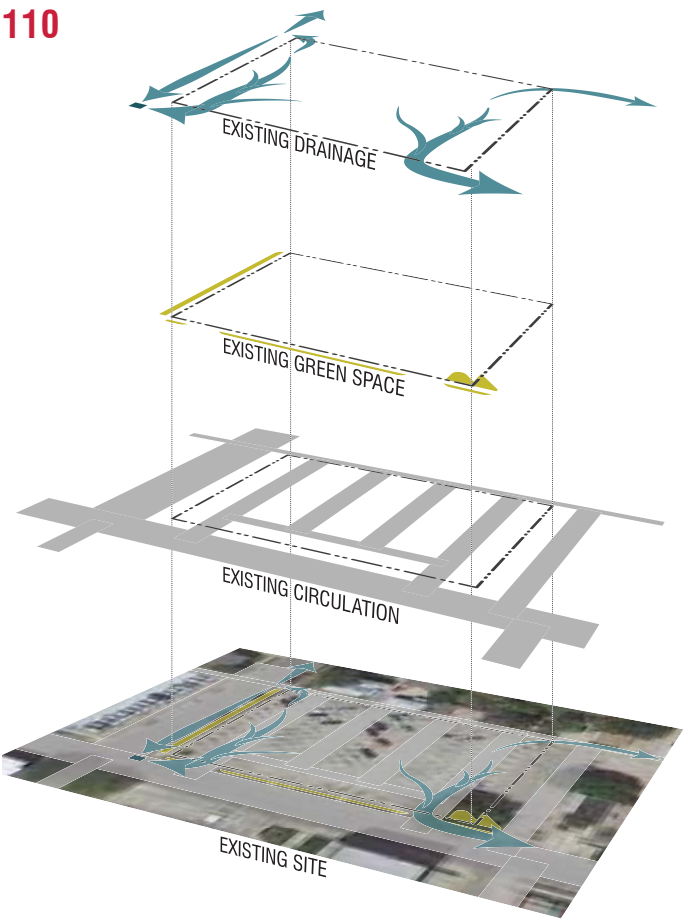


In addition to providing environmental benefits such as carbon storage, heat island mitigation, and air pollutant abatement, the proposed design serves as a public parking lot that can be transformed into an active public space as depicted in *Figure 4-29*.

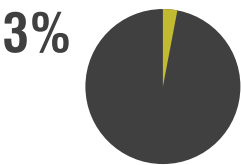
The existing site has very little permeable surfaces and only one tree as seen in *Figure 4-30*. The proposed design significantly increases permeable surfaces and trees and reduces average annual runoff as seen in *Figure 4-31*.

## 4.4

### FARMERS' MARKET



Permeable Surfaces



Parking Spots



Annual Runoff



Number of Trees

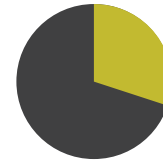


Figure 4-30 Existing Site  
The existing site contains hardly any green space or trees.

## Permeable Surfaces

111

30%



## Parking Spots

53



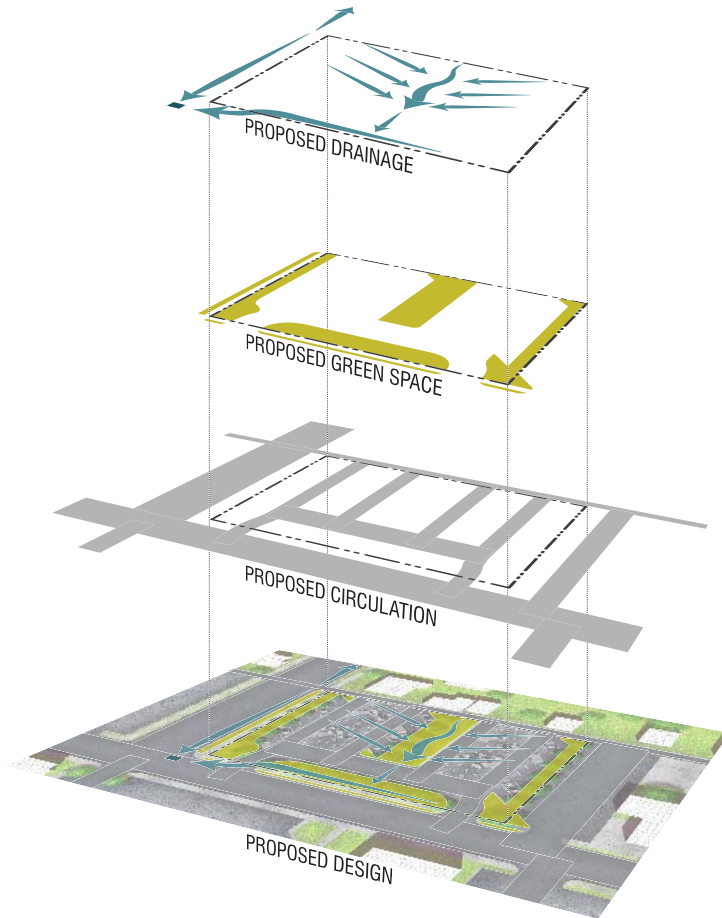
## Annual Runoff

0.5  
ac-ft



## Number of Trees

30

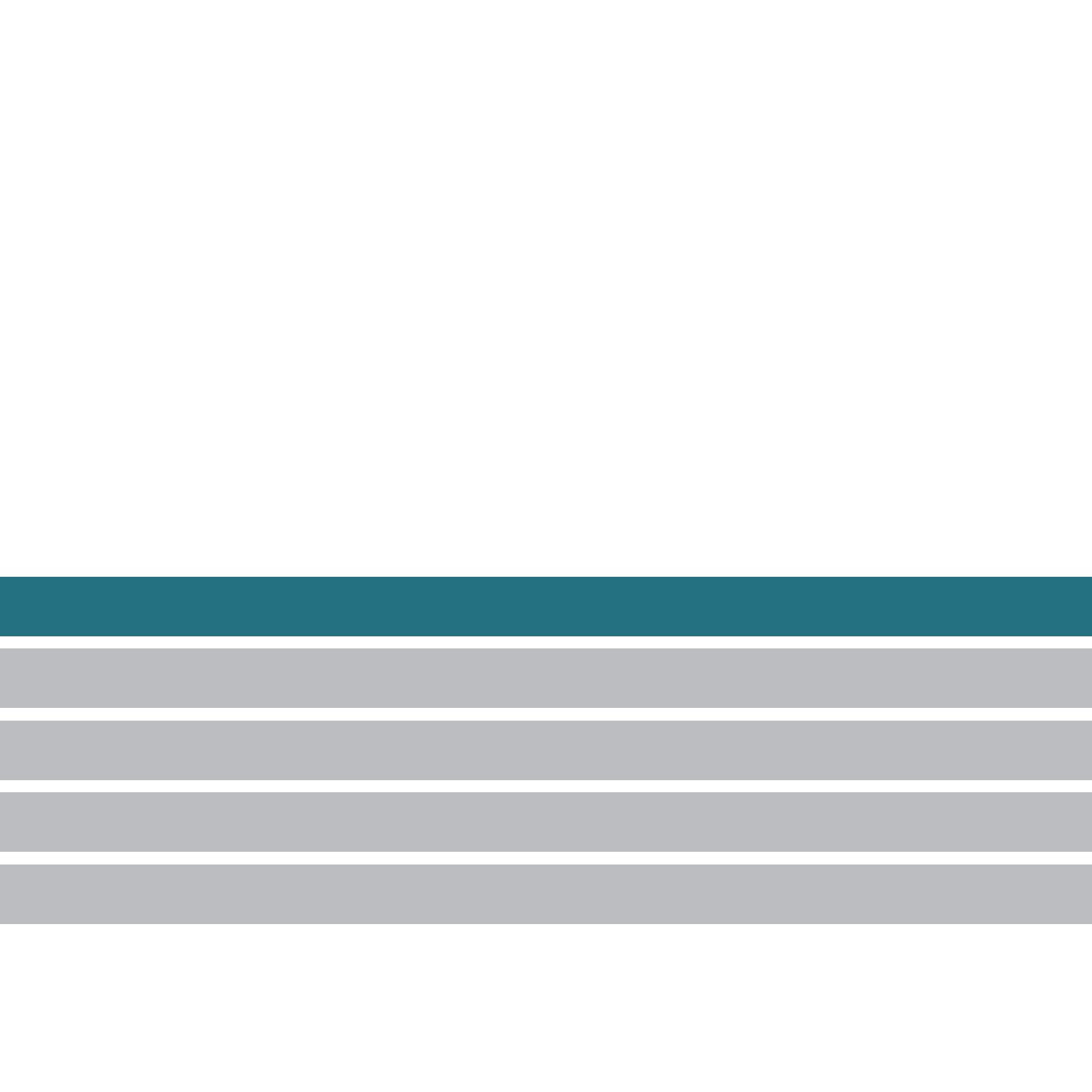


**Figure 4-31 Proposed Site**

The proposed design significantly increases green space and tree cover.

4.4

FARMERS' MARKET





# FIVE

5.1

## SUMMARY AND CONCLUSION

5.2

RESEARCH SUMMARY

5.3

LIMITATIONS AND FUTURE RESEARCH

5.4

RESOURCES

FIGURE CITATIONS

The primary purpose of this report was to emphasize the connections between public transportation and parking demand, reducing parking and increasing green space, and increasing green space and ecological benefits. These connections are diagrammed in *Figure 5-1*. Urban and suburban areas in America are designed primarily for the automobile. This leads to an overwhelming amount of land and

resources dedicated to automobile infrastructure such as streets and parking lots. Expansive parking contributes to increased stormwater runoff, pollution in streams and the heat island effect.

Nearly 7% of Manhattan, Kansas' total area is covered by paved parking. Steps must be taken to reduce the amount of parking in Manhattan



in order to improve the ecological quality of the city. One way to reduce parking demand is by increasing ridership of public transportation. Although Manhattan implemented a fixed route bus system started in 2012, it is not meeting its full potential for public transportation. The current bus system is lacking in route coverage, frequency and annual ridership compared to bus systems in other university cities of similar size.

Making improvements to Manhattan’s bus system would increase ridership. Increasing ridership would reduce greenhouse gas emissions and reduce parking demand. Excess parking could be transformed into green space to be used for stormwater management, heat island mitigation, carbon storage and sequestration, and air pollution abatement.



**Figure 5-1 Research Connections**

*Improving public transit can reduce parking demand.  
Excess parking can be converted into green space.  
Increasing green spaces can improve the ecological health of an urban environment.*

## 5.1

### SUMMARY OF RESEARCH

A study of relevant literature revealed the benefits of improving public transportation and ways to increase ridership including, increasing route coverage, route frequency and cost. Literature was also used to define methods of calculating the benefits of reducing parking and increasing green space such as, reduced runoff, carbon storage and sequestration, reduced air temperatures and money saved as a result. Case studies were also used to define methods, as well as, to determine which factors lead to high public transit ridership.

Currently, the ATA bus system has five routes totaling 28 stops with an average frequency of approximately 43 minutes. The price to use the ATA bus system is \$1 per ride or \$30 for a monthly pass. The proposed improvements to the existing system included one additional route, eleven new stops, increased frequency by 25%,

and additional fixed cost options. It was predicted that making these improvements could increase ridership by 100%.

There are approximately 56,300 non-residential parking spots within Manhattan. It was estimated that there are only 38,700 divers living in Manhattan which means that there is currently an excess of approximately 17,600 parking spots in Manhattan. It was assumed that improving the existing bus system could decrease parking demand by an additional 20%. Therefore, with improved public transit and parking planning, 30% of Manhattan's parking could be eliminated.

A suitability map was created using ArgGIS to determine which areas were most suitable to eliminate parking and implement additional green space. Four specific parking lots were chosen to redesign in detail. All four designs

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eliminated approximately 30% of parking and replaced it with green space as summarized in *Table 5-1*.

The green spaces include bioswales and stormwater detentions which reduce on site runoff volumes. Each proposed design increases tree cover which increases carbon storage and reduces local air temperatures. The ecological benefits due to increased green space and tree cover were analyzed for each site. Monetary values for each benefit were calculated when possible. The reduction in stormwater runoff rates for the sites can be seen in *Table 5-2*. The improvements to air quality resulting from each design are compared in *Table 5-3*. Cooling effects and estimated energy savings resulting from each design can be seen in *Table 5-4*. Finally, *Table 5-5* summarizes the volume of carbon storage and sequestration from the trees on each site.

The benefit analysis gives validity to the ideas presented in this report. This research can be used to convince city municipalities and planners to make better decisions when it comes to transit and parking. Like a domino effect, one smart decision can lead to another. Improving public transportation can decrease parking demand, reducing parking can increase green space, and increasing green space has countless benefits, not only ecologic benefits, but economic, and social benefits as well. This is a strategy that can be adapted in cities big and small across America.

# 5.1

## SUMMARY OF RESEARCH

Site Conditions

	Stadium	Highland Ridge	Village Plaza	Farmers' Market
Total Area (acres)	25.5	3.5	3.4	0.8
<b>PARKING</b>				
Existing Site (spots)	2661	221	338	81
Proposed Design (spots)	2014	151	231	53
Decrease (%)	24	32	32	35
<b>GREEN SPACE</b>				
Existing Site (acres)	1.84	1.63	0.64	0.03
Proposed Design (acres)	5.67	1.57	0.98	0.24
Increase (%)	210	0	50	750
<b>TREE COVER</b>				
Existing Site (trees)	15	39	43	1
Proposed Design (trees)	226	78	98	30
Increase (%)	1410	100	130	2900

Table 5-1 Improved Site Conditions (left)  
Each proposed design eliminates approximately 30% of the existing parking on site. The design for the farmers' market lot has the greatest increase in green space and tree cover while the Highland Ridge design has the least.

Table 5-2 Stormwater Runoff (right)  
Runoff rates were calculated using the Rational Method. The detention capabilities of each design were determined by calculating the volume of the detention basins. The farmer's market design reduces runoff the most.

Stormwater Runoff

	<i><b>Stadium</b></i>	<i><b>Highland Ridge</b></i>	<i><b>Village Plaza</b></i>	<i><b>Farmers' Market</b></i>
Detention Volume (ac-ft)	2.6	0.22/4	0.36	0.03
<b>1 YR- 1 HR STORM</b>				
Existing Site (ac-ft)	2.4	0.21	0.29	0.08
Proposed Design (ac-ft)	2.09	0.22	0.26	0.06
<b>Decrease (%)</b>	<b>13</b>	<b>-5</b>	<b>10</b>	<b>25</b>
<b>2 YR- 1 HR STORM</b>				
Existing Site (ac-ft)	2.94	0.26	0.35	0.1
Proposed Design (ac-ft)	2.55	0.27	0.32	0.07
<b>Decrease (%)</b>	<b>13</b>	<b>-4</b>	<b>9</b>	<b>30</b>
<b>10 YR- 1 HR STORM</b>				
Existing Site (ac-ft)	4.33	0.39	0.52	0.14
Proposed Design (ac-ft)	3.76	0.4	0.47	0.11
<b>Decrease (%)</b>	<b>13</b>	<b>-3</b>	<b>10</b>	<b>21</b>
<b>25 YR- 1 HR STORM</b>				
Existing Site (ac-ft)	5.15	0.46	0.61	0.17
Proposed Design (ac-ft)	4.47	0.47	0.55	0.13
<b>Decrease (%)</b>	<b>13</b>	<b>-2</b>	<b>10</b>	<b>24</b>
<b>Detention Capabilities (storm size)</b>	<b>2 yr- 1 hr</b>	<b>1 yr- 1 hr/ 100+yr</b>	<b>2 yr- 1 hr</b>	<b>1/2 of 1 yr- 1 hr</b>

5.1

SUMMARY OF RESEARCH

Table 5-4 **Cooling Effects** (top right)

The additional trees create a cooling effect due to evapotranspiration and shading. This can lead to lower energy uses in adjacent buildings.

Table 5-5 **Carbon Storage** (bottom right)

As determined based on the study by Nowak and Crane (2002), one tree at maturity can store an average of 1/4 ton of carbon. According to Nowak et al. (2004), one ton of carbon stored is worth \$22 (USD 2012).

Table 5-3 **Air Pollution Improvement** (left)

A study by Escobedo and Nowak (2009) was used to determine the percent improvement of different air pollutants resulting from additional trees. Akbari (2002) defines how to calculate smog savings.

	Stadium	Highland Ridge	Village Plaza	Farmers' Market
Trees Added	211	39	55	29
Tree Cover (%)	6.3	10.0	12.4	16.3

**SMOG SAVINGS**

Smog Savings (USD)	32,494	6,006	8,470	4,466
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**POLLUTANT IMPROVEMENT**

PM10 Improvement (%)	0.340	0.540	0.670	0.880
O3 Improvement (%)	0.140	0.220	0.270	0.360
SO2 Improvement (%)	0.090	0.140	0.170	0.230
CO Improvement (%)	0.001	0.002	0.002	0.003
NO2 Improvement (%)	0.090	0.140	0.170	0.230



Cooling

	<i><b>Stadium</b></i>	<i><b>Highland Ridge</b></i>	<i><b>Village Plaza</b></i>	<i><b>Farmers' Market</b></i>
Tree Density (trees/sq. mi.)	5,302	7,091	10,377	22,308
Trees Added	211	39	55	29

**COOLING EFFECT**

Reduction in Local Average Maximum Temperature (°C)	0.9	1.2	1.8	3.8
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**A/C ENERGY SAVINGS**

Direct Savings (USD)	17,935	3,315	4,675	2,465
Indirect Savings (USD)	6,330	1,170	1,650	870
<b>Total Savings (USD)</b>	<b>24,265</b>	<b>4,485</b>	<b>6,325</b>	<b>3,335</b>

Carbon

	<i><b>Stadium</b></i>	<i><b>Highland Ridge</b></i>	<i><b>Village Plaza</b></i>	<i><b>Farmers' Market</b></i>
Tree Increase (trees/acres)	211/1.6	39/0.35	55/0.42	29/0.13

**CARBON STORAGE**

Volume Stored (tons)	53-66	10-14	14-17	5-7
Savings (USD)	1166-1452	220-308	308-374	110-154

**CARBON SEQUESTRATION**

Volume Stored (tons/yr)	1.7-2.2	0.3-0.5	0.4-0.6	0.2
Savings (USD/yr)	37-48	7-11	9-13	4

***Limits of Transit Analysis***

Due to the breadth of the research done, and the time frame of the project, the analysis and proposal of public transportation in Manhattan, Kansas was done relatively quickly. With additional time spent on this portion of the project, the analysis of public transportation in Manhattan would have been more thorough, leading to a more successful proposed transit plan. For example, the transit analysis did not include information about commuters. It also did not look at the possibility of regional transit.

If additional time had been spent on designing the proposed transit system to maximize its success, ridership could have been increased even more, and additional parking could have been eliminated. Once the parking suitability map was created and specific sites were chosen, the proposed transit system could have been

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reworked to have bus stops located within the chosen parking lots. This would have strengthened the connection between public transportation and parking.

### ***Limits to Parking Analysis***

One limit of the parking analysis is that it is difficult to calculate exactly how much improving Manhattan's bus system would reduce parking demand. Relevant literature and case studies were used to determine a range of 20-40% reduction in parking demand due to improved public transit. Although this range was helpful for presenting possibilities and estimating benefits, it would have been useful to have a more accurate and site specific calculation for determining an exact amount of reduced parking. It would also have been helpful to predict the amount parking demand would decrease as a result of implementing a portion of the

suggested improvements to public transportation compared to implementing all of the suggested improvements.

The parking to green space suitability analysis takes into account five factors and gives an idea of which parking lots would be best suited to be partially converted into green space. The suitability map would be more thorough if additional factors had been accounted for. For example, the current suitability analysis does not account for buildings adjacent to parking. Parking lots surrounded by buildings would be more suitable to be converted to green space because the cooling effect of the trees would have a greater impact on energy savings. Another factor that could have been considered for parking to green space suitability is proximity to other parking lots. Parking lots that are in close proximity to other parking lots have a greater

## **5.2**

### **LIMITATIONS AND FUTURE RESEARCH**

ability to be converted to green space because there are opportunities for shared parking.

***Limits to benefit analysis***

Currently, studies related to calculating the benefits of increasing green space and tree cover focus on large scale improvements including city wide, and regional areas. It is difficult to define methods for determining the ecological benefits at the site scale. The methods used for determining the ecological benefits of each specific site were based on information gathered from several studies performed at much larger scales. Equations and rates had to be adjusted to be used for the site specific scale. This created a high margin of error when calculating specific values. The site specific ecological benefits are therefore presented as approximations and ranges. More research related to ecological benefits at a small scale is required to more

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accurately calculate the ecological benefits of the four site designs.

Almost all the benefits calculated (carbon storage and sequestration, cooling, and air quality improvement) were given monetary values. Reduction in stormwater runoff was also calculated for each design but the associated monetary value was not calculated. Although reducing runoff can save on the cost of stormwater infrastructure and can reduce costs resulting from flood damages, it is very difficult to assign a specific monetary value to reducing runoff due to all the factors involved.

### ***Future Research***

The research and findings of this report could continue to be developed. Multiple design scenarios could be developed such as incorporating bus stops into the designs of the

parking lots. Design scenarios could include other best management practices besides bioswales, such as permeable paving and rainwater harvesting, to compare the ecological benefits of implementing different designs. Currently, the benefit analysis focuses on ecological benefits. Future research could include the analysis of social benefits resulting from increasing green space within parking lots.

The intent of this research was to be site specific while presenting ideas and defining methods that could be used in other cities. It would be beneficial to perform a similar study in other cities including a large urban city to compare the findings.

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## RESOURCES

**Figure 1-1:**

Biondolilo, Jena. 2013. Process Diagram. Adobe Illustrator diagram.

**Figure 1-2:**

Biondolilo, Jena. 2013. Parking in Manhattan.

Source data: Riley County GIS. "Road." <http://gis.rileycountyks.gov/website/rileyco/layerframes.htm>. Accessed 2012. Jena Biondolilo. "Parking." Created 2013.

**Figure 2-1:**

Google Earth. Las Angeles, California. Accessed 2013.

**Figure 2-2:**

Biondolilo, Jena. 2013. Literature Map. Adobe Illustrator diagram.

**Figure 2-3:**

Biondolilo, Jena. 2013. Context Map. Adobe Illustrator diagram.

**Figure 2-4:**

Biondolilo, Jena. 2013. Campus Map. Adobe Illustrator diagram.

**Figure 2-5:**

Biondolilo, Jena. 2013. ATA Fixed Route.

Source data: Riley County GIS. "Road," "Building," "ctybnd," "Aerial\_2008." <http://gis.rileycountyks.gov/website/rileyco/layerframes.htm>. Accessed 2012. Jena Biondolilo. "Bus Route," "Bus Stop." Created 2013.

**Figure 2-6:**

Biondolilo, Jena. 2013. Manhattan Parking.

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**Figure 3-1:**

Biondolilo, Jena. 2013. Existing Bus System.



Source data: Riley County GIS. "Road," "Zoning," "Public Buildings," "Schools," "Churches." <http://gis.rileycountyks.gov/website/rileyco/layerframes.htm>. Accessed 2012. Jena Biondolilo. "Bus Stop," "Bus Route," "Bus Stop Buffer," "Other Points of Interest," "System Holes." Created 2013.

**Figure 3-2:**

Biondolilo, Jena. 2013. Factors of Access to Campus. Adobe InDesign diagram.

**Figure 3-3:**

Biondolilo, Jena. 2013. Student Access to Campus.

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**Figure 3-4:**

Biondolilo, Jena. 2013. Proposed Bus System.

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**Figure 3-5:**

Biondolilo, Jena. 2013. Improved Access to Campus.

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**Figure 3-6:**

Biondolilo, Jena. 2013. Reducing Parking. Adobe InDesign diagram.

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**Figure 3-7:**

Biondolilo, Jena. 2013. Factors of Parking Suitability. Adobe InDesign diagram.

**Figure 3-8:**

Biondolilo, Jena. 2013. Parking to Green Space Suitability.

Source data: Riley County GIS. “ctybnd,” “rlco\_fema,” “WildcatCreekFloodedArea2011,” “Road,” “Building.” <http://gis.rileycountyks.gov/website/rileyco/layerframes.htm>. Accessed 2012. ArcHydro. “Drainage Points” Created 2013. Jena Biondolilo. “Parking,” “Bus Stop Buffer,” “Parking Suitability.” Created 2013.

**Figure 3-9:**

Biondolilo, Jena. 2013. Site Selection

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Biondolilo. “Parking Suitability.” Created 2013.

**Figure 4-1:**

Biondolilo, Jena. 2013. Storm Drain (Bill Snyder Family Stadium, Manhattan, KS). Digital photograph.

**Figure 4-2:**

Biondolilo, Jena. 2013. Stadium Lot (Bill Snyder Family Stadium, Manhattan, KS). Digital photograph.

**Figure 4-3:**

Biondolilo, Jena. 2013. Stadium Lot Plan. AutoCAD Civil 3D and Adobe Photoshop rendering.

**Figure 4-4:**

Biondolilo, Jena. 2013. Section A. AutoCAD Civil 3D

**Figure 4-5:**

Biondolilo, Jena. 2013. Section B. AutoCAD Civil 3D

**Figure 4-6:**

Biondolilo, Jena. 2013. Section C. AutoCAD Civil 3D

**Figure 4-7:**

Biondolilo, Jena. 2013. Tailgating at the Stadium. Adobe Photoshop Montage.

Source Data: “Grill Master Tim. 2009. Photograph by flickr user Tobyotter (Tony Alter). Accessed 2013. Reproduced from flickr, <http://www.flickr.com/photos/78428166@N00/3847107240/>,” “Fourth of July. 2010. Photograph by Kathy Bacon. Courtesy of Kathy Bacon. Accessed 2013. Reproduced from “Reflections...By Kathy.” <http://edshunnybunny.wordpress.com/2010/07/06/one-word-describes-our-fourth-of-july-crowded/>.” Biondolilo, Jena. 2011. Wheelbarrow Race. (Stillwater, OK). Digital photograph.”

**Figure 4-8:**

Biondolilo, Jena. 2013. Existing Site. Adobe Illustrator diagram.

**Figure 4-9:**

Biondolilo, Jena. 2013. Proposed Site. Adobe Illustrator diagram.

**Figure 4-10:**

Biondolilo, Jena. 2013. Retaining Wall Pipe (Highland Ridge, Manhattan, KS). Digital photograph.

**Figure 4-11:**

Biondolilo, Jena. 2013. Existing Swale (Highland Ridge, Manhattan, KS). Digital photograph.

**Figure 4-12:**

Biondolilo, Jena. 2013. Highland Ridge Lot (Highland Ridge, Manhattan, KS). Digital photograph.

**Figure 4-13:**

Biondolilo, Jena. 2013. Highland Ridge Plan. AutoCAD Civil 3D and Adobe Photoshop rendering.

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**Figure 4-14:**

Biondolilo, Jena. 2013. Highland Ridge Section. AutoCAD Civil 3D section.

**Figure 4-15:**

Biondolilo, Jena. 2013. Storm at Highland Ridge. Adobe Photoshop Montage.

Source Data: "Child Walking his Dog in the Rain. Photograph by corbis images user Dann Tardif. Accessed 2013. Reproduced from corbis images, <http://www.corbisimages.com/stock-photo/rights-managed/PE-031-0431/child-walking-his-dog-in-the-rain#>."

**Figure 4-16:**

Biondolilo, Jena. 2013. Existing Site. Adobe Illustrator diagram.

**Figure 4-17:**

Biondolilo, Jena. 2013. Proposed Site. Adobe Illustrator diagram.

**Figure 4-18:**

Biondolilo, Jena. 2013. Village Plaza Lot (Village Plaza, Manhattan, KS). Digital photograph.

**Figure 4-19:**

Biondolilo, Jena. 2013. Linear Trail Entrance (Village Plaza, Manhattan, KS). Digital photograph.

**Figure 4-20:**

Biondolilo, Jena. 2013. Storm Drain (Village Plaza, Manhattan, KS). Digital photograph.

**Figure 4-21:**

Biondolilo, Jena. 2013. Village Plaza Plan. AutoCAD Civil 3D and Adobe Photoshop rendering.

**Figure 4-22:**

Biondolilo, Jena. 2013. Improved Linear Trail Entrance. Adobe Photoshop Montage.



**Figure 4-23:**

Biondolilo, Jena. 2013. Existing Site. Adobe Illustrator diagram.

**Figure 4-24:**

Biondolilo, Jena. 2013. Proposed Site. Adobe Illustrator diagram.

**Figure 4-25:**

Biondolilo, Jena. 2013. Farmers’ Market Lot (Downtown, Manhattan, KS). Digital photograph.

**Figure 4-26:**

Biondolilo, Jena. 2013. Street Drain (Downtown, Manhattan, KS). Digital photograph.

**Figure 4-27:**

Biondolilo, Jena. 2013. Farmers’ Market Entrance (Downtown, Manhattan, KS). Digital photograph.

**Figure 4-28:**

Biondolilo, Jena. 2013. Farmers’ Market Plan. AutoCAD Civil 3D and Adobe Photoshop.

**Figure 4-29:**

Biondolilo, Jena. 2013. The Downtown Farmers’ Market. Adobe Photoshop Montage.

**Figure 4-30:**

Biondolilo, Jena. 2013. Existing Site. Adobe Illustrator diagram.

**Figure 4-31:**

Biondolilo, Jena. 2013. Proposed Site. Adobe Illustrator diagram.

**Figure 5-1:**

Biondolilo, Jena. 2013. Research Connections. Adobe Illustrator diagram.

**Table 2-1**

Biondolilo, Jena. 2013. Case Study Matrix.

Source Data: Chaudhari and Ye 2010, Barata et al. 2011, Bond and Steiner 2006, Shannon et al. 2006, Davis et al. 2010, Wood 2003.

**Table 2-2**

Biondolilo, Jena. 2013. Bus System Comparison.

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**Table 5-1**  
Biondolilo, Jena. 2013. Improved Site Conditions.

**Table 5-2**  
Biondolilo, Jena. 2013. Stormwater Runoff.

**Table 5-3**  
Biondolilo, Jena. 2013. Air Pollution Improvement.

Source Data: Escobedo and Nowak 2009, Akbari 2002.

**Table 5-4**  
Biondolilo, Jena. 2013. Cooling Effects.

Source Data: Akbari 2002.

**Table 5-5**  
Biondolilo, Jena. 2013. Carbon Storage.

Source Data: Nowak and Crane 2002, Nowak 2004

**Table A-1**  
Biondolilo, Jena. 2013. L-THIA Results.

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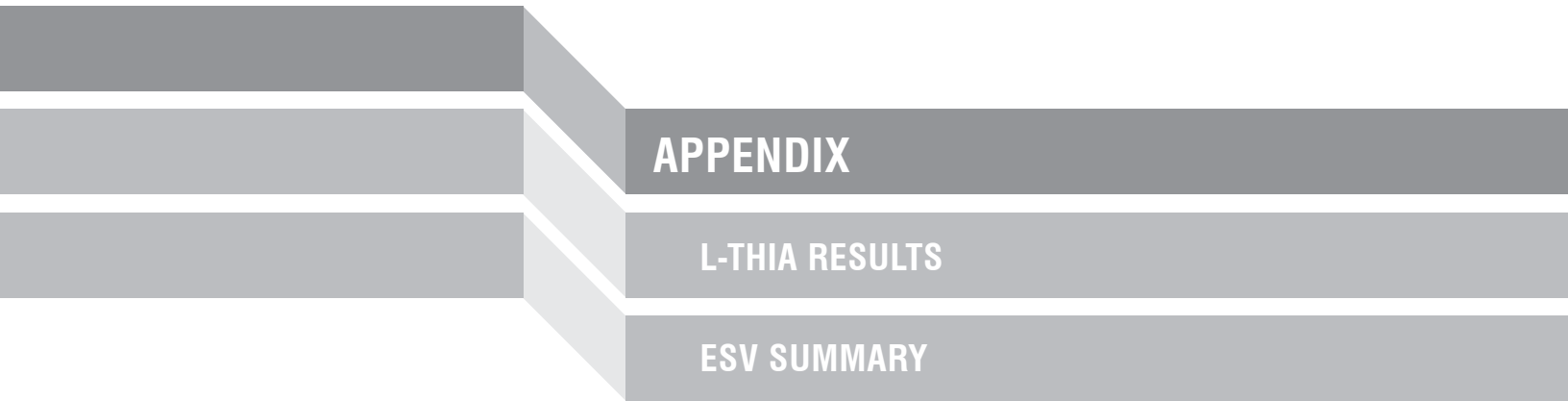
**Table A-2**  
Biondolilo, Jena. 2013 ESV Summary. Adapted from Costanza et al. 1997.

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	<b>APPENDIX</b>
	L-THIA RESULTS
	ESV SUMMARY

**Existing Parking**  
**30% Converted to Green Space**

Average Annual Runoff	
Volume (ac-ft)	Depth (in)
322	6.5
232	4.6

**Existing Parking**  
**30% Converted to Green Space**

Annual Nonpoint Source Pollutants						
Nitrogen (lbs)	Phosphorous (lbs)	Suspended Solids (lbs)	Lead (lbs)	Copper (lbs)	Zinc (lbs)	Cadmium (lbs)
1178	280	48823	10	12	157	0.8
824	196	34175	7	8	110	0.6

**Existing Parking**  
**30% Converted to Green Space**

Annual Nonpoint Source Pollutants (Continued)						
Chromium (lbs)	Nickel (lbs)	BOD (lbs)	COD (lbs)	Oil & Grease (lbs)	Fecal Coliform (mil of coliform)	Fecal Strep (mil of Coliform)
8	9	20232	102046	7916	27590	71975
5	7	14162	71431	5541	19312	50382

**Table A-1 L-THIA Results**  
*The Long Term Hydrologic Impact Analysis (L-THIA) was used to predict the reduction in average annual runoff and nonpoint source pollutants produced by parking lots in Manhattan if 30% of parking areas was converted to green space.*

**Ecosystem Service Value (Costanza et al. 1997)**

	Gas Regulation	Climate Regulation	Disturbance Regulation	Water Regulation	Water Supply	Erosion Control	Soil Formation	Nutrient Cycling	Waste Treatment
<b>Grassland</b>	4	0	nd	2	nd	17	1	nd	51
<b>Forest</b>	nd	82	1	1	2	56	6	211	51
<b>Wetland</b>	78	nd	2647	9	2216	nd	nd	nd	2436

	Pollination	Biological Control	Habitat/ Refugia	Food Production	Raw Materials	Generic Resources	Recreation	Culture	<b>Total Value (\$acre<sup>-1</sup> yr<sup>-1</sup>)</b>
<b>Grassland</b>	15	13	nd	39	nd	0	1	nd	<b>\$136</b>
<b>Forest</b>	nd	1	nd	25	80	9	38	nd	<b>\$566</b>
<b>Wetland</b>	nd	nd	177	149	62	nd	335	514	<b>\$8,641</b>

**Table A-2 ESV Summary**

*This table is adapted from the Summary of Average Global Value of Annual Ecosystem Services table by Costanza et al. (1997)*





***Special thanks to my major professor, Tim Keane, and my committee members, Hyung Jin Kim and Jeff Peterson.***

