REDESIGNING RIVER DES PERES: TO IMPROVE, PROTECT, AND MAINTAIN

by

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A REPORT

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Abstract

During a 75-year building boom starting in the early to mid 1900's we built most of the stormwater and sewage infrastructure that sustains us today. As these infrastructural systems begin to meet their life expectancy, and with our cities being impacted by flooding, rapid urbanization, and water quality concerns there is a need for designers to begin rethinking these infrastructural systems. With rapid urbanization cities are seeing increased peak flow discharge volumes within their river systems and combined sewer overflow occurrences.

The River des Peres located in the City and County of Saint Louis, Missouri, is an urban waterway that is affecting the natural ecosystem and community well-being. The main stem of the River des Peres is a heavily degraded concrete trapezoidal channel that in 1988 became a National Historic Civil Engineering landmark for its sewerage and drainage works. Which leads to the question of why a historic civil engineering landmark, such as the River des Peres, is such a wreck today? In compliance with the Clean Water Act the Metropolitan St. Louis Sewer District is proposing to implement enhanced green infrastructure and stormwater/sewer storage tanks to reduce the amount of Combined Sewer Overflow (CSO) occurrences in the River des Peres watershed.

However, through review of literature, site inventory and analysis, a watershed stormwater BMP plan, and corresponding site design developments it has been found that return frequency flow can be reduced as much as 56% in the watershed, reducing the need for storage tanks and reducing CSO occurrences. Through the incorporation of stormwater best management practices (BMPs) the River des Peres responds to recurrence flow, wildlife habitat, and to the well-being of the community.

REDESIGNING RIVER DES PERES:
to improve, protect, and maintain.

Cover Photo: river des peres iron, TmQ.st.louis (2009)

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INTRODUCTION

DILEMMA

A community is dependent on the human services and structures that infrastructure provides. Such services and structures include transportation assemblies, communication lines, and stormwater/sanitary sewer systems. Today we are reaching a period of deteriorating infrastructure, rapid urbanization and decreasing water quality. Most of America's vital systems "were constructed decades ago, during a 75-year building boom, and are nearing the end of their intended lifespan" (Clemmitt, 2007, 793). If cities continue to delay the need for re-examining these systems and resources, they will encounter infrastructural system and resource failures.

For example, many cities still use combined sanitary sewer and stormwater systems. In heavy rain, combined sewer systems (CSOs) consistently overflow causing wastewater and stormwater to be discharged, untreated, into river and stream systems. These systems are most common in urban areas.

Urban river and stream systems are impacted by modifications due to land development. Wetlands, critical wildlife habitat, and riparian buffers have been eliminated and/or degraded due to the construction of stream channel infrastructure, the straightening of stream channels, the armoring of the stream banks, and the implementation of concrete culverts.

Currently, stream channelization is the most prevalent stream construction project, and its effects are showing with the loss and degradation of riparian vegetation, the increase in flooding events, and the increase in threatened and endangered species. Most stream construction projects incorporate the use of concrete and other hard structures which modify "the natural corridor characteristics, causing its progressive degradation" (Pagliara & Chiavaccini, 2005). Stream channelization projects create an influx of impervious surfaces removing infiltration, and inevitably increasing the flood frequency of the stream.

In many urban areas channelized streams and rivers become dumping grounds for waste, causing raw sewage and toxic stormwater to mix with industrial waste (Millay, 2006). The dilemma with channelized stream systems leads to the following question: How can urban streams perform additional natural processes —such as, physical, chemical, biological, and nutrient cycling— outside their basic service as a stormwater/sanitary sewer system?

THESIS

There are many urban waterway design solutions that seek to revive and improve ecological processes. Through the implementation of stormwater best management practices (BMPs), river water quality, river corridor aesthetic, and wildlife habitat will improve. Project goals, as adapted from Ann Riley (1998) include:

- *Lowering the flood frequency rate of the river through the inclusion of stormwater BMPs.*
- *Enhancement of wildlife habitat by the inclusion of native fauna and flora through the re-vegetation of the stream bank, stormwater BMPs, and wet meadows.*
- *Enhance the local identity of waterway by integrating public art into the inner and middle stream buffer.*
- *Fix the infrastructural performance problems of the site, including, stormwater and sanitary overflows.*
- *Encourage growth in areas damaged by previous engineering projects such as trapezoidal channel lining.*

The process of providing solutions to the dilemma and completing the goals listed above began by completing a literature review.

RELEVANCE TO LANDSCAPE ARCHITECTURE

Understanding the concepts of recurrence flows, wildlife habitat, and human ecology is relevant to landscape architects in the field of hydrology and ecology. Redesigning stream systems in urban areas will lead to increased awareness and education about the mistreatment of hydrologic systems. Designing new systems with knowledge of urban ecology and green infrastructure can increase water quality and biodiversity in a project area. Using the knowledge gained from generating and researching the goals used to produce this Master's project will help spur better landscape architectural projects surrounding urban waterways.

LOCATION

Located in Saint Louis, Missouri, the River des Peres watershed is situated along the eastern border of Saint Louis County and the western border of Saint Louis City, with the Meramec River to the south, and the Mississippi river to the east. Today the River des Peres watershed covers 71,146 acres of the City and County of St. Louis, as shown in figure 1.1.

In 1988 the River des Peres became recognized by the American Society of Civil Engineers (ASCE) as a National Historic Civil Engineering landmark. ASCE added the project "for the calculations involved, the large-scale trench dewatering methods; and the soil stabilization procedures" (University City, 2010). However this civil engineering landmark or "river" has become heavily channelized and degraded over the years, becoming an eyesore for much of the community. The main channel of the River des Peres is more of a combined sanitary and stormwater sewer system than an actual river. The water quality of the "river" is impacted by toxic runoff from industrial and commercial areas, high amounts of chloride from roadways, and low volumes of dissolved oxygen becoming a

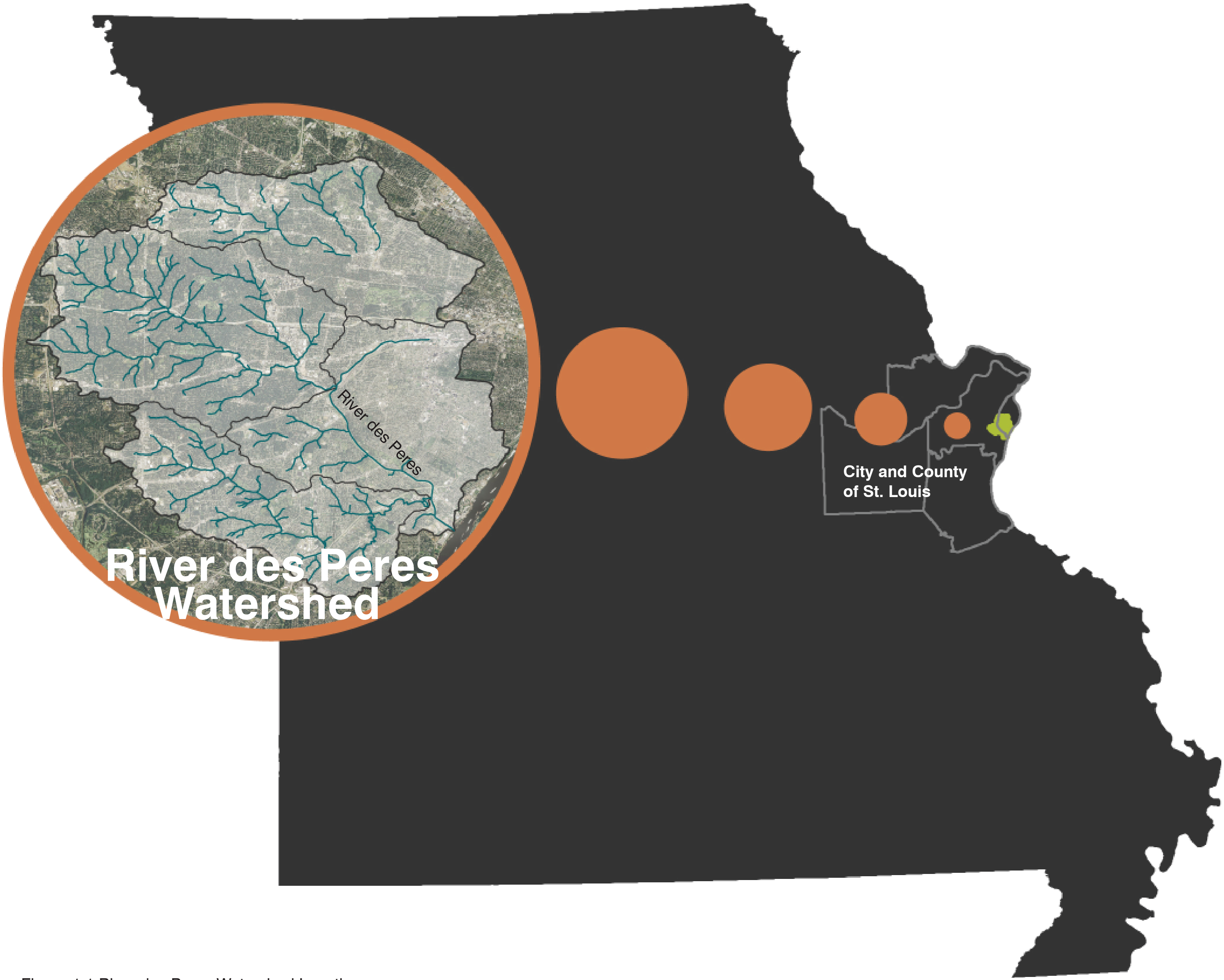


Figure 1.1 River des Peres Watershed Location

river that is uninhabitable for wildlife. A question that arises is how can this historic civil engineering landmark be such a wreck? Regardless of the current condition the intent of this mater's project is to provide sustainable solutions.

PROJECT PROCESS

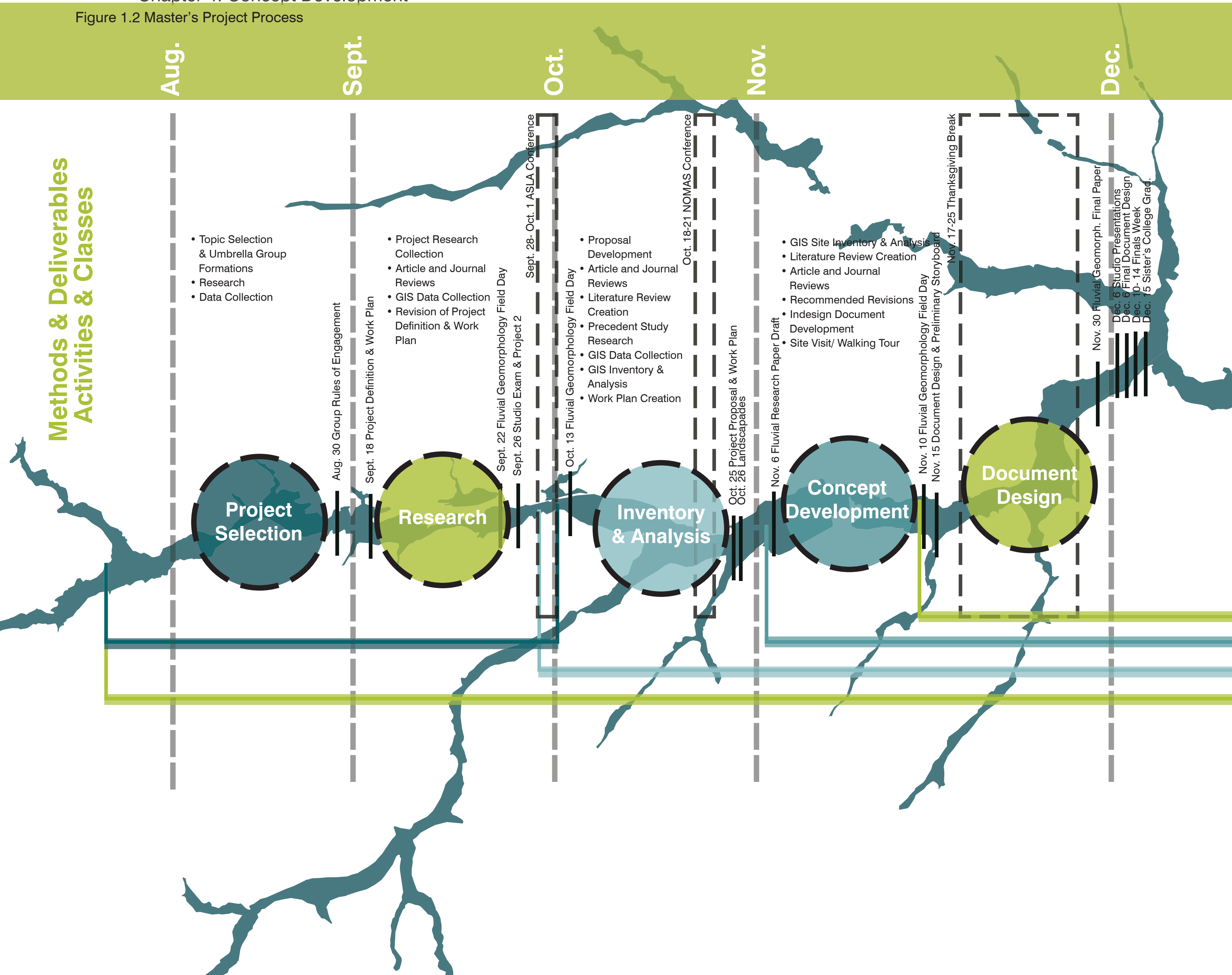
The process and development of this project started with research pertaining to Urban Ecology and Green Infrastructure in relation to streams and rivers. Articles and journal reviews were collected and analyzed to gain a better understanding of water quality and the use of stormwater BMPs. The process, as shown in figure 1.2, then focused on establishing a watershed and individual site inventories and analyses to help accomplish the goals listed in the thesis. Through inventory and analysis, watershed stormwater BMP and wet meadow plans were developed with corresponding peak flow reductions for the River des Peres and its tributaries, including Deer Creek and Gravois Creek. Through schematic and conceptual design these flow reductions led to the development of new stream channel designs and open space visions. These open spaces were chosen through a walking tour with the River des Peres Watershed Coalition. These specific project sites vary in the level of channel restoration required, surrounding land use, scale, and stakeholders.

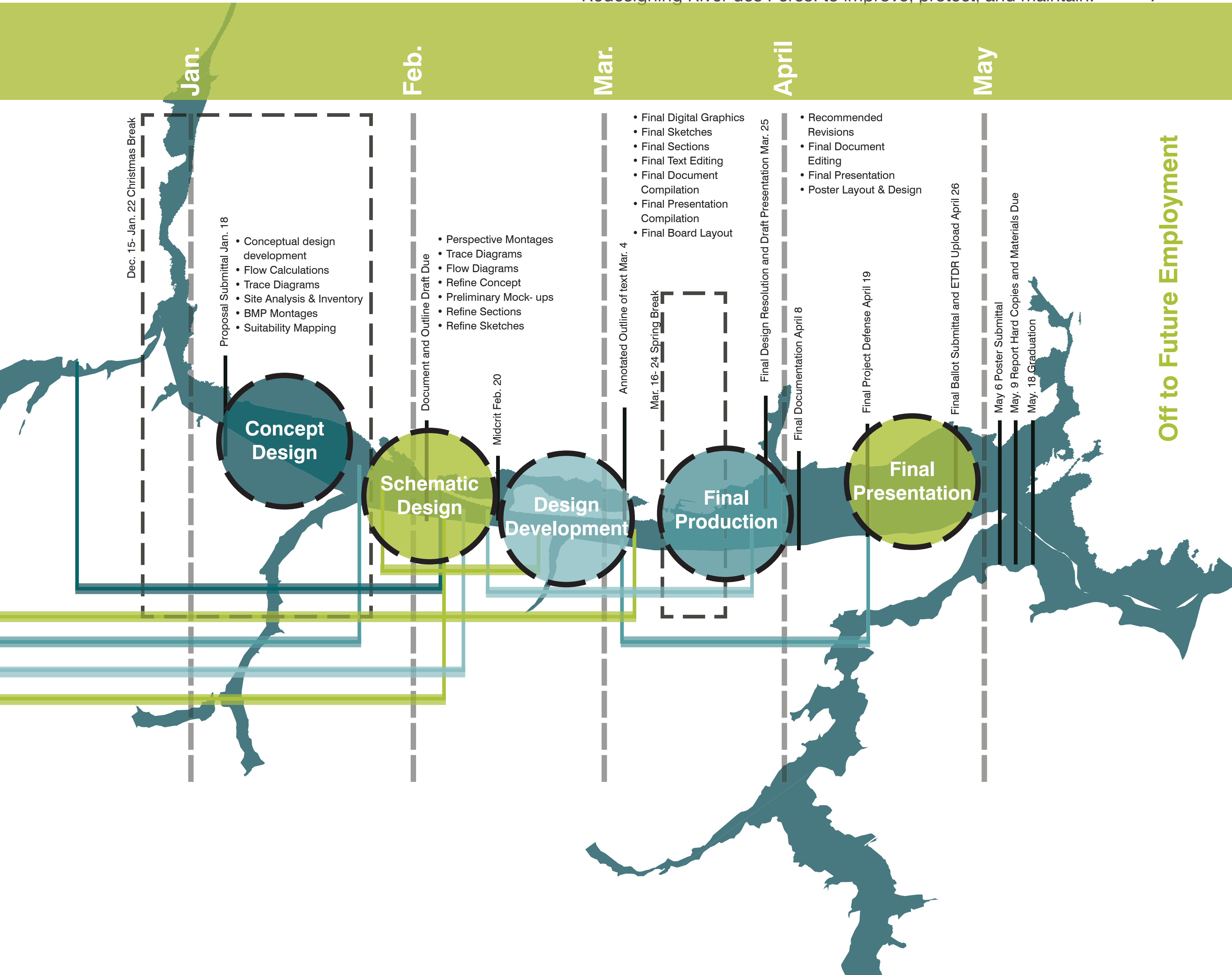
Stakeholders include the River des Peres Watershed Coalition, the Federal Emergency Management Agency, the Metropolitan St. Louis Sewer District, the County of St. Louis, St. Louis University, the Great Rivers Greenway, DG//RE Studio, Missouri Department of Transportation (MODOT), and the College of Architecture, Planning and Design at Kansas State University. Utilizing these agencies and community organizations allows for community involvement and were necessary in collecting River des Peres data.

The design approach for each of these sites includes restoring the hydrograph, floodplain, and river channel. A hydrograph is the measurement of a stream flow over a period of time. Restoring the hydrograph involved reducing the peak discharge volume after a rain event. A floodplain is the land adjacent to a channel at bankfull elevation, which is inundated on the average of about 2 out of 3 years. Restoring the floodplain occurred by lowering the land adjacent to a channel down to meet with the bankfull elevation. A river channel is the dimensions of a river that contain the bankfull discharge and consists of river banks and bed material. Restoring the river channel involved designing a channel that correctly contains the bankfull discharge. Restoring the hydrograph, floodplain, and river channel are important to combat stormwater, flooding, and ecosystem impacts in the River des Peres watershed.

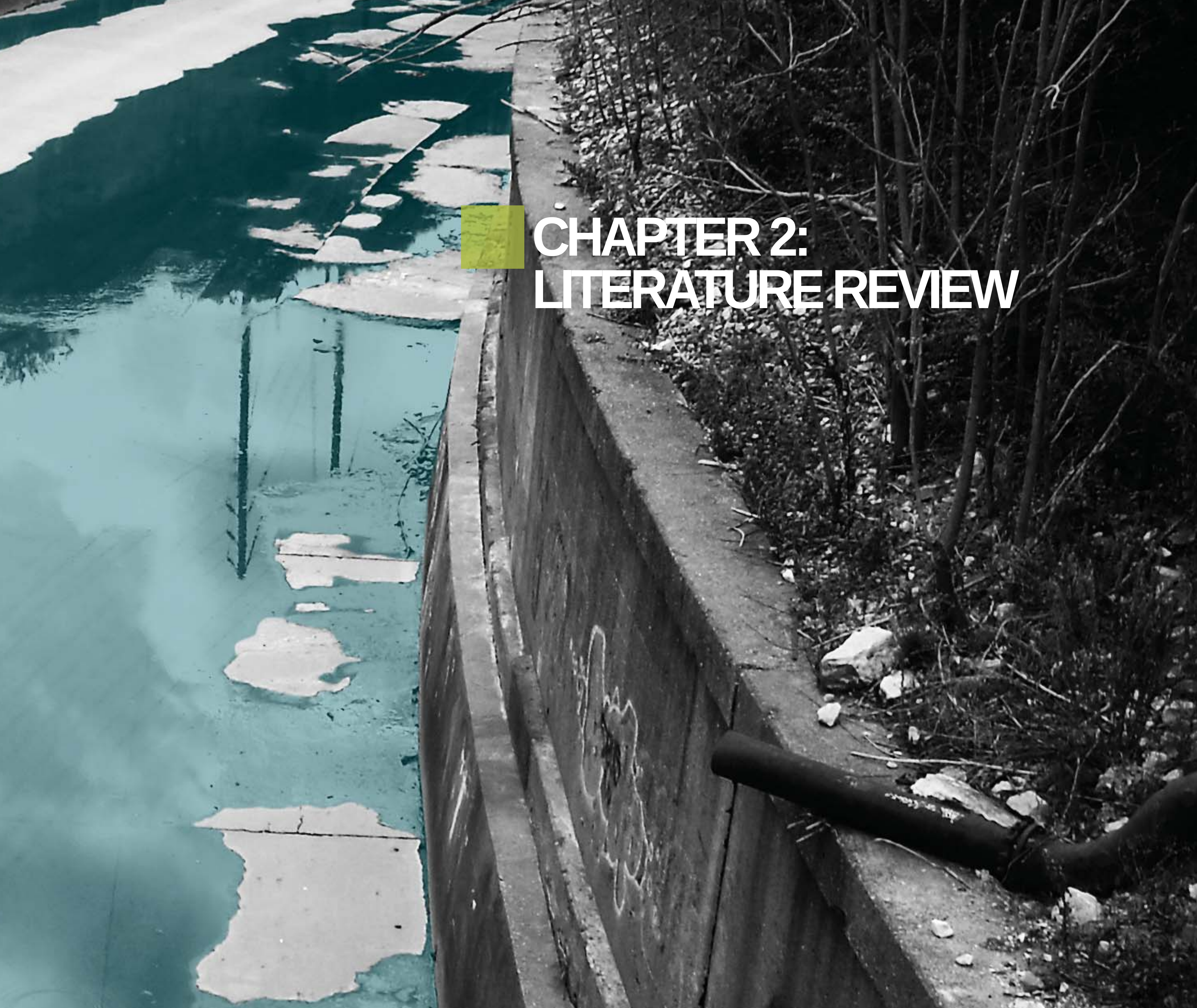
By utilizing these design approaches ecological performance benefits were calculated for each project site location. Benefits include flood storage, dissolved oxygen, water infiltration, carbon sequestration, reclaimed soil, and concrete reuse. These performance benefits are primarily ecological services, which are the multitudes of processes that our natural ecosystem provides.

Figure 1.2 Master's Project Process




Jan.
Feb.
Mar.
April
May
Dec. 15- Jan. 22 Christmas Break
Proposal Submittal Jan. 18
• Conceptual design development
• Flow Calculations
• Trace Diagrams
• Site Analysis & Inventory
• BMP Montages
• Suitability Mapping
Document and Outline Draft Due
• Perspective Montages
• Trace Diagrams
• Flow Diagrams
• Refine Concept
• Preliminary Mock- ups
• Refine Sections
• Refine Sketches
Midcrit Feb. 20
Annotated Outline of text Mar. 4
• Final Digital Graphics
• Final Sketches
• Final Sections
• Final Text Editing
• Final Document Compilation
• Final Presentation Compilation
• Final Board Layout
Mar. 16- 24 Spring Break
Final Design Resolution and Draft Presentation Mar. 25
• Recommended Revisions
• Final Document Editing
• Final Presentation
• Poster Layout & Design
Final Documentation April 8
Final Project Defense April 19
Final Ballot Submittal and ETDR Upload April 26
May 6 Poster Submittal
May. 9 Report Hard Copies and Materials Due
May. 18 Graduation
Concept Design
Schematic Design
Design Development
Final Production
Final Presentation
Off to Future Employment

River des Peres, TTmQ.st.louis (2009)



CHAPTER 2: LITERATURE REVIEW

LITERATURE REVIEW

The research conducted helped provide clarity to the subject matter of urban ecology and green infrastructure along with the goals addressed in the thesis. There were five subjects relating to urban ecology and green infrastructure that were important to explore before the design process. These subjects include defining urban ecology and green infrastructure, stream effects, urban stream restoration principles, human amenities, and urban streams and wetland precedent studies. Figure 2.1 shows a visual representation of the literature reviewed and a group literature map located in Appendix B shows the literature conducted within the Urban Ecology and Green Infrastructure Master's project group for spring 2013.

WHAT IS URBAN ECOLOGY?

While there are many definitions of Urban Ecology, *Urban Ecology: an International Perspective on the Interaction between Humans and Nature*, however, provides the best explanation as it relates to the goals established in my thesis. The editors state that urban ecology is "the study of ecosystems that include humans living in cities and urbanizing landscapes. It is an emerging, interdisciplinary field that aims to understand how human and ecological processes can coexist in human-dominated systems and help societies with their efforts to become more sustainable" (Marzluff et al., 2008, vii). A principle of urban ecology looks at the interaction between humans and the environment. Ecosystems are dependent upon change, such as stream movement. Humans, however, alter ecosystems changing their biological function, water quality, native flora and fauna habitat, and air quality. Addressing the integrity of the bioregion is integral to social and ecological health.

WHAT IS GREEN INFRASTRUCTURE?

Green Infrastructure is structures strategically implemented that work to conserve ecological values and functions. Green infrastructure "uses vegetation, soils, and natural processes to manage water and create healthier urban environments" (EPA, 2012). The role of green infrastructure is to repurpose landscape elements to "simultaneously yield ecological benefits such as ground water recharge, phytoremediation, habitat creation, and a contiguous recreation framework for people" (SWA et al., 2011, 7). Green infrastructure structures include: landscape infiltration, rainwater harvesting, rain gardens, bioswales, permeable paving, green roofs, and land conservation.

STREAM EFFECTS

Continuing themes of waterway projects include the drainage of wetlands for land reclamation, increasing river channel widths for flood control, and implementation of artificial channel banks for erosion control. Streams in urban areas are threatened by channelization, land use development, and combined sewer overflow systems.

Channelization of Streams as a Threat

Human-engineered streams or stream channelization is often constructed to control flooding and to provide bank stabilization. Channelization involves the use of concrete, rip-rap, or stones to line the bank as an erosion reducer.

Conventional flood-control channel designs are "based on the objective of constructing a channel for a selected volume of storm flows" (Riley, 1998, 161). The three most common channel designs are the box culvert, the rectangular channel, and the trapezoidal channel. Figure 2.2 shows diagrams of the most common flood control channel designs. A box culvert takes the entire stream section and places it underground in a reinforced concrete box. A rectangular channel and a trapezoidal channel consist of a flat concrete bottom with high angled or straight walls. "The design philosophy behind a traditional flood-control project is to enlarge a natural stream channel by widening and/or deepening it and to smooth the stream-channel banks and straighten the course of the stream" (Riley, 1998, 162). This design philosophy removes the flood plain function from the river creating an increase in peak flow discharges during rain events. Most channelization projects do not consider environmental impacts. Stream impacts due to channelization include (Riley, 1998, 102-103):

- *The destruction of riparian vegetation, thus, exposing water surface areas to high temperatures, increasing bank erosion, siltation and nutrients, and removing critical aquatic feeding and breeding grounds.*
- *Streams cut-off from oxbows and meanders, thereby increasing flow rates and removing the aspect of backwater habitats.*
- *Reduction in water table levels, and decreased infiltration and rainwater interception, thereby reducing stream discharge and increasing peak discharge during rain events.*

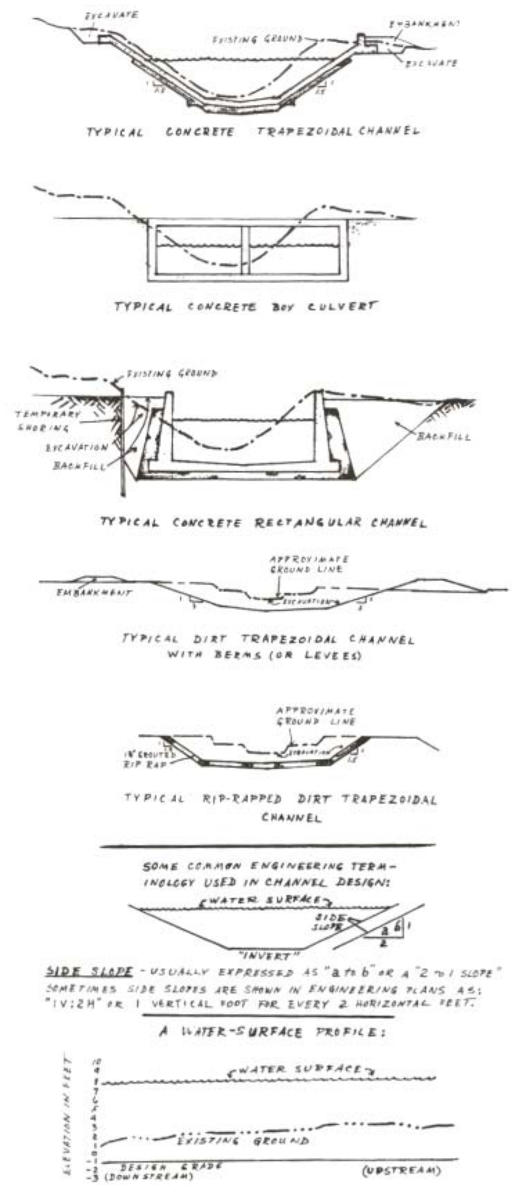


Figure 2.2 Common Flood Control Channel Designs, adapted from Ann Riley (1998, 164).

How can urban streams perform additional natural processes —such as, physical, chemical, biological, and nutrient cycling— outside their basic service as a stormwater/sanitary sewer system?

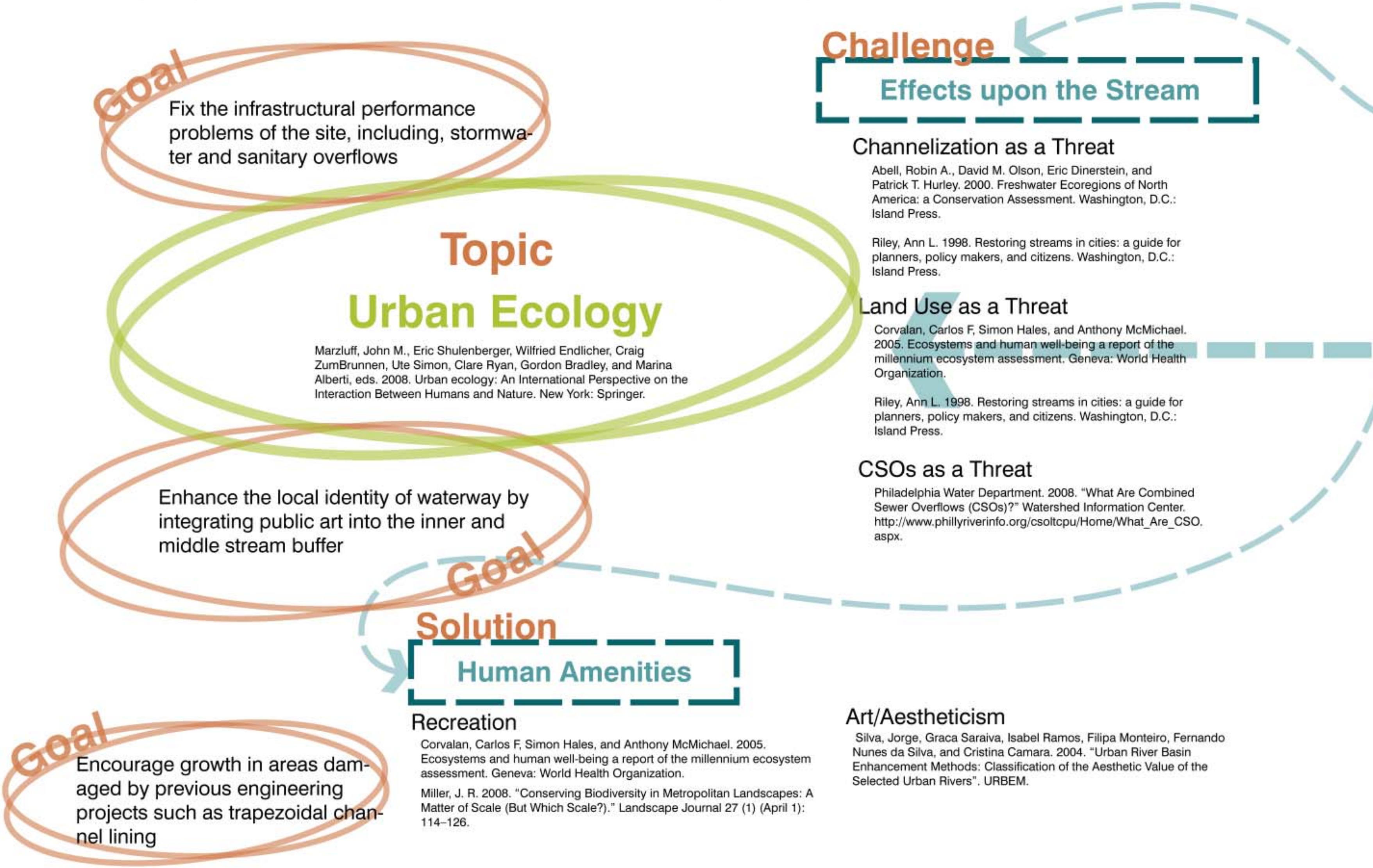


Figure 2.1 Visual Representation of the Reviewed Literature

Solution

Urban Stream Restoration

Riley, Ann L. 1998. Restoring streams in cities: a guide for planners, policy makers, and citizens. Washington, D.C.: Island Press.

Wetlands

Corrigan, Jay R., Kevin J. Egan, and John A. Downing. 2007. "Aesthetic Values of Lakes and Rivers." http://economics.kenyon.edu/corrigan/publications/Aesthetic%20Values%20of%20Lakes%20and%20Rivers.pdf.

Corvalan, Carlos F, Simon Hales, and Anthony McMichael. 2005. Ecosystems and human well-being a report of the millennium ecosystem assessment. Geneva: World Health Organization.

Hach Company. "Important Water Quality Factors." Accessed October 11, 2012. http://www.h2ou.com/h2wtrqual.htm.

Riparian Vegetation

Belt, G.H., and J. O'Laughlin. 1994. "Buffer Strip Design for Protecting Water Quality and Fish Habitat." 1994 Apr 01 9 (2) (April 1): 41–44.

EPA. 2012. "EPA - Stormwater Menu of BMPs." Accessed October 10, 2012. http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=browse&Rbutton=detail&bmp=50

Ewel, John J., and Francis E. Putz. 2004. "A Place for Alien Species in Ecosystem Management" 2 (7): 354–360.

Riley, Ann L. 1998. Restoring streams in cities: a guide for planners, policy makers, and citizens. Washington, D.C.: Island Press.

Bioswales/Rain Gardens

Xiao, Qingfu, E. Greg Mcpherson, Center for Urban Forest Research, and USDA Forest Service. 2009. "Testing a Bioswale to Treat and Reduce Parking Lot Runoff." http://www.fs.fed.us/psw/programs/uesd/uep/products/psw_cufr761_P47ReportLRes_AC.pdf.

enhancement of wildlife habitat by the inclusion of native fauna and flora through the re-vegetation of the stream bank, stormwater BMPs, and wetlands

Goal

Topic

Green Infrastructure

EPA. 2012. "What Is Green Infrastructure?." Accessed October 10, 2012. http://water.epa.gov/infrastructure/greeninfrastructure/gi_what.cfm.

SWA Group (Firm), Ying-Yu Hung, Gerdo Aquino, Charles Waldheim, Julia Czerniak, Adriaan Geuze, Matthew Skjonsberg, and Alexander Robinson. 2011. Landscape infrastructure: case studies by SWA. Basel: Birkhäuser.

Goal

Lowering the flood frequency rate of the river through the inclusion of stormwater best management practices (BMPs)

Solution

Precedent Studies

Two-Stage Channels

Witter, Jonathan D., Jessica L. D'Ambrosio, and Andy Ward. 2011. "Considerations for Implementing Two-stage Channels". University and the Ohio NEMO Program. http://greatlakeswater.uwex.edu/sites/default/files/library/outreach-and-education/implementing-fv.pdf.

Buffalo Bayou Promenade

SWA Group (Firm), Ying-Yu Hung, Gerdo Aquino, Charles Waldheim, Julia Czerniak, Adriaan Geuze, Matthew Skjonsberg, and Alexander Robinson. 2011. Landscape infrastructure: case studies by SWA. Basel: Birkhäuser.

Cheonggyecheon Stream

Robinson, Alexander, and H. Myvonwynn Hopton. 2011. "Cheonggyecheon Stream Restoration Project". Landscape Architecture Foundation. http://lafoundation.org/research/landscape-performance-series/case-studies/case-study/382/pdf/.

Qunli National Urban Wetland

Yu, Kongjian. 2011. "Stormwater Park for a Water Resilient City." Munchen (77): 72–77.

Zhang, Yi, Shweta Singh, and Bhavik Bakshi. "Accounting for Ecosystem Services in Life Cycle Assessment, Part I: A Critical Review." Environmental Science Technology. 44. no. 7 (2010): 2232-2242. http://pubs.acs.org/doi/abs/10.1021/es9021156?ai=54taf=R (accessed November 25, 2012).

Bishan Park

CNA. Channel News Asia. "A natural river in Bishan Park." Last modified 2012. Accessed November 25, 2012. http://www.channelnewsasia.com/stories/singaporelocalnews/view/1183121/1/.html.

Holmes, Damian . World Landscape Architecture. "Kallang River Bishan Park." Last modified 2012. Accessed November 25, 2012. http://worldlandscapearchitect.com/kallang-river-bishan-park-singapore-atelier-dreiseitl/.

Root River

SEWRPC. 2012. "Root River Watershed Restoration Plan." Southeastern Wisconsin Regional Planning Commission. http://www.sewrpc.org/SEWRPC/Environment/Root-River-Watershed-Restoration-Plan.htm.

USDA, and NRCS. 2008. "Rapid Watershed Assessment: Root River." United States Department of Agriculture and Natural Resources Conservation Service. Assessed January 16, 2013. http://www.ia.nrcs.usda.gov/technical/RWA/root.pdf.

Swan River

BRWG. 2009. "Swan River Restoration Project." Blue River Watershed Group. http://blueriverwatershed.org/overview/swan-river-restoration-project/.

- *Alteration and/or loss of wetlands in the project site and downstream from channelization, causing a reduction and/or elimination of wildlife that depend upon the wetlands as a critical habitat.*

Studies done in the United States have shown that "only 2 percent of the nation's 5.1 million kilometers of rivers and streams remain free-flowing" (Abell et al., 2000). In the United States the result of human intervention upon streams is confounding: 67 percent of freshwater mussels and 65 percent of crayfish species are rare or imperiled, while 37 percent of freshwater species are at risk of extinction, and 35 percent of amphibians that depend on aquatic habitats are rare or imperiled (Abell et al., 2000). Channelization, however, is not the only factor affecting stream systems.

Land Use near Stream Systems as a Threat

Land development is the modification of the natural landscape ecology into other land functions, typically unnatural. These land functions include: agriculture, commercial, industrial, mixed use, residential, recreation, and vacant lands. Table 2.1 shows the potential impacts of urbanization on a watershed. The effects of development can be seen in the declining natural sinuosity and native vegetation of the river, increased sedimentation, and decreased water quality from urban runoff. Urban runoff heading directly to the stream risks inorganic and organic chemicals entering waterways (Corvalan, Hales & McMichael, 2005).

Frequently land development and structures are built too close to the stream bank reducing stream movement, and creating restoration challenges. "For example, an urban stream may need to adjust its slope [by] forming a wider meander, but such a meander adjustment isn't possible because a concrete wall is in the way" (Riley, 1998, 154).

Combined Sewer Overflow Systems as a Threat

A combined sewer overflow system (CSOs) "is a wastewater collection system owned by a municipality which transports wastewater from homes, businesses, and industry, and stormwater from storm drains on our city streets and [housing developments into] a single-pipe system to a Water Pollution Control Plant" (Philadelphia Water Department, 2008). During dry weather and small rain events CSOs can adequately transport wastewater and stormwater to the control plant. However, during heavy rain events CSOs exceed capacity resulting in polluted waters entering nearby river and stream systems. CSOs impact rivers and streams producing high levels of bacteria, ammonia, and chloride to enter the streams, thus, reducing levels of dissolved oxygen for aquatic life.

URBAN STREAM RESTORATION PRINCIPLES

Stream restoration is the modification "of a stream's width, depth, or meander to help restore balance between the sediment load the stream must move and the flow velocities needed to move that load through the system" (Riley, 1998, 29). Stream restoration objectives also involve decreasing high velocity flows, and cleansing and filtering of water. Wetlands, riparian buffers, and bio-swales each assist in river restoration.

Wetlands as a Benefit

Wetlands are areas of high soil saturation that provide water retention, filtration, infiltration, and treatment. There are two types of wetlands, tidal and non-tidal. Tidal wetlands are in

Table 2.1 Potential Impacts of Urbanization on a Watershed

Change in Land or Water Use	*Possible Hydrologic Effect*
Transition from pre-urban to early-urban state: Removal of trees or vegetation, construction of scattered city-type house & limited water & sewage facilities.	Decrease in transpiration & increase in storm flow. Increased sedimentation of streams.
Drilling of wells.	Some lowering of water table.
Construction of septic tanks & sanitary drains.	Some increase in soil moisture & perhaps a rise in water table. Perhaps some waterlogging of land & contamination of nearby wells or streams from overloaded sanitary drain systems.
Transition from early-urban to middle-urban stage: Bulldozing of land for mass housing; some topsoil removal; farm ponds filled in.	Accelerated land erosion and stream sedimentation and aggradation. Elimination of smallest streams by filling or culverting.
Mass construction of houses; paving of streets; building of culverts.	Decreased infiltration resulting in increased storm water and flood flows & lowered ground-water levels. Flooding at channel constrictions (culverts) on remaining small streams. Occasional overtopping or undermining of banks of artificial and natural channels.
Discontinued use and abandonment of some shallow wells.	Rise in water table.
Diversion of nearby streams for public water supply.	Decrease in flow between points of diversion & disposal. Fish and other aquatic life decline or are extinguished. Riparian areas degrade or disappear.
Untreated or inadequately treated sewage discharged into streams or disposal wells.	Pollution of streams or wells. Death of fish & other aquatic life. Inferior quality of water available for supply & recreation at downstream populated areas.
Transition from middle-to late-urban stage: Urbanized of area completed by addition of more houses & streets, & of public, commercial, & industrial buildings.	Reduced infiltration & lowered water table. Streets & gutters act as storm drains, creating flashy and higher flood peaks & lower base flow of local streets.
Larger quantities of untreated waste discharged into local streams.	Increased pollution of streams & concurrent increased loss of aquatic life. Additional degradation of water available to downstream users.
Abandonment of remaining shallow wells because of pollution.	Rise in water table.
Increase in population required establishment of new water supply & distribution systems, construction of distant reservoirs, diverting water from upstream sources within or outside basin.	Increase in local stream flow if supply is from outside basin. Decrease in local stream flow if supply includes local sources also. Wide-scale loss of river systems for fish, wildlife, and recreation.
Channels of streams put in artificial channels & culverts	Increased flood damage if culverts are undersized, and increased backup flows. Increased downstream flood flows if channelized or culverted. Changes in channel geometry & sediment load. Aggradation and/or degradation up- and downstream of project or structure. Stream-channel stability problems and loss of floodplain storage.
Construction of sanitary drainage system & treatment plant for sewage and improvement of storm drainage system to move water to rivers, bays, lakes, etc.	Removal of additional water from area, further reducing infiltration recharge of aquifer. Degradation of stream channels used as stormwater conveyance systems.
Drilling of deeper, large-capacity industrial wells.	Lowered ground-water level, decreasing pressure of artesian aquifer: perhaps some local overdrafts & land subsidence. Overdraft of aquifer may result in salt water encroachment in coastal area and in pollution or contamination by inferior or brackish waters.
Increased use of water for air conditioning.	Overloading of sewers & other drainage facilities. Possibly some recharge to water table, owing to leakage of disposal lines.
Drilling of recharge wells.	Raising of ground-water (level) surface.
Wastewater reclamation and utilization.	Recharge to ground-water aquifers. More efficient use of water resources.

Adapted from : J.H. Feth (1973)

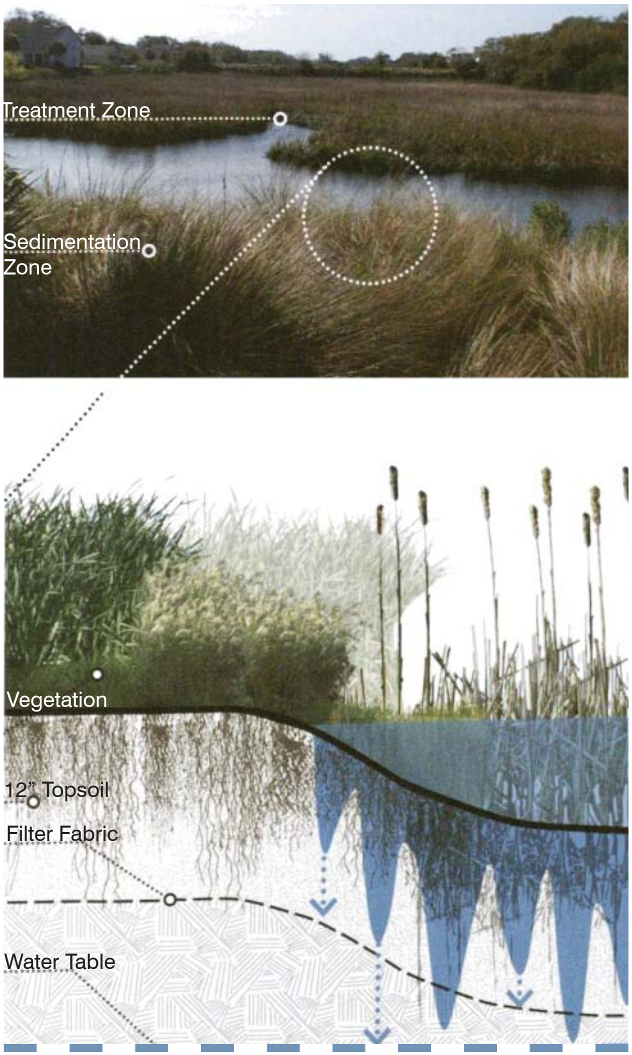


Figure 2.3 Constructed Wetland. Adapted from UACDC (2010)

relation to ocean coastlines, while non-tidal wetlands are found in the floodplains of rivers and streams. There are three types of non-tidal wetlands: marshes, wet meadows, and swamps. Wet meadows or prairies are commonly found in the central Midwest of the United States.

Stormwater runoff in developed land areas carry harmful chemical and toxic elements, including heavy metals, phosphates, nitrates, and percholorethylene (PCE). Well functioning wetlands as shown in figure 2.3 "can remove excess nutrients from sewage runoff, preventing damage to ecosystems downstream" (Corvalan et al., 2005, 30). Bacteria, pollutants within the water, and temperature play a significant role in the amount of dissolved oxygen in the stream.

Toxic when mixed with water, ammonia, a cleaning agent, can damage the gills of fish, and high levels can produce fish kills. Also toxic to fish, Benzene, Cadmium and PCE, are products of industrial waste. Phosphates increase food supply by stimulating the growth of plants, but, in large quantities Phosphates cause algae to reproduce, consuming the supply of dissolved oxygen in the water. Nitrite, a form of nitrogen, can "produce a serious illness (brown blood disease) in fish" (Hach, 2012). Each pollutant can cause serious damage to an aquatic ecosystem.

Another benefit of wetlands is aesthetic quality and human well-being. "When policymakers are provided with estimates of the aesthetic value of a lake or river, the value of the biodiversity it supports, and the value of the recreational opportunities it provides, these benefits can be compared against the cost of government policies aimed at maintaining or improving water quality" (Corrigan, Egan & Downing, 2007, 3). The relationship between the ecosystem and development should consider the economic benefit of implementing wetlands, and the psychological benefit that nature has on the well-being of the community. Riparian vegetation, additionally, is beneficial in providing aesthetic, psychological well-being, and water quality.

Riparian Vegetation as a Benefit

Riparian vegetation along the bank of a stream is composed of over-story, understory, groundcover, and emergent aquatic species. Over-story vegetation consists of tall trees with a water table near the root depth, and is commonly found on the upper and middle banks of the stream. Understory vegetation consists of large shrub species, and is also found on the upper and middle stream bank. Groundcover, such as, low shrubs, grasses, sedges, and forbs are found amongst the over-story and understory vegetation. Aquatic vegetation characteristic of sedges, rushes, and reeds are found within the stream bank at the water's edge.

Riparian vegetation performs important functions in the creation and maintenance of fish habitat as adapted from Ann Riley (1998):

- *Vegetative roots and other growth create a barrier on the bank of the stream to provide soil erosion resistance. High water velocities cause soil erosion along banks, producing deep undercut channels. However, exposed vegetative root systems hold the bank together. These undercut banks and associated vegetation provide cover for fish, thus, creating critical habitat.*
- *Overhanging vegetation along the stream moderates the water temperature, providing a livable habitat for aquatic species to thrive in, and produces woody debris that creates in-stream habitat through backwater pools and sediment storage for fish spawning.*
- *Riparian vegetation also supplies a basis for food chain systems by providing cover for fish and encouraging fish spawning.*
- *Riparian vegetation slows water flow velocities and stores sediment on the banks as opposed to allowing it to flow downstream. During storm events when there are high velocity flows vegetation protects the banks from erosion by lying flat against the surface.*
- *Riparian vegetation decreases the amount of stormwater runoff by intercepting rain water through its leaves and roots and then releasing it during dry seasons.*

The State of Idaho has set standards for riparian buffers requiring that each fish-bearing stream classification has a 75 foot buffer on each side (Belt & O'Laughlin, 1994, 43). However, the U.S. Environmental Protection Agency suggests buffer widths should be designed based upon the "slope, vegetation, soils, depth to impermeable layers, runoff sediment characteristics, type and amount of pollutants, and annual rainfall" (EPA, 2012). It is also suggested that as the bank slope increases, the buffer should increase in width and be intermixed with native vegetation.

Using native vegetation makes a tangible contribution to the identity of the site, and provides phytoremediation. Phytoremediation is the use of particular plant species to filter and remove contaminants from soil, water, and air. Bioswales and rain gardens are common filtration systems and phytoremediation to use in treating stormwater runoff.

Bio-swales and Rain Gardens as a Benefit

Impervious surfaces are a result of increasing urbanization through the construction of roads, vehicular parking, and buildings. Impervious surfaces alter "surface runoff in both quantity and quality because of the effects of surface retention storage, rainfall interception, and infiltration" (Xiao & Mcpherson, 2009, 4). Bioswales or rain gardens placed near impervious surfaces reduce nutrients, metals, and organic elements like, petroleum hydrocarbons—gas, diesel, and motor oil—from entering the stream. As shown in figure 2.4 and 2.5, bioswales and rain gardens absorb pollutants and reduce runoff through interception by not allowing the rain to reach the soil surface. They also reduce the heat island index, increase the air quality by the reduction of impervious surface area, increase the amount of shaded or moist surface areas, and reduce polluted surface runoff.

Wetlands, riparian vegetation, bioswales, pools, riffles, meanders, and floodplains begin to play an important role in projects for their restorative performance and their value as a public amenity.

HUMAN AMENITIES

Landscape Well-Being Benefits through Recreation

In recent years human well-being has been a central focus to researchers, policy-makers and designers. Literature such as, Last Child in the Woods and The Nature Principle, written by Richard Louv, include staggering results on the relationship between human development and nature. Studies have shown that outdoor spaces provide recreational and educational opportunities, spiritual enrichment, and aesthetic experiences (Corvalan et al., 2005). Regular contact with

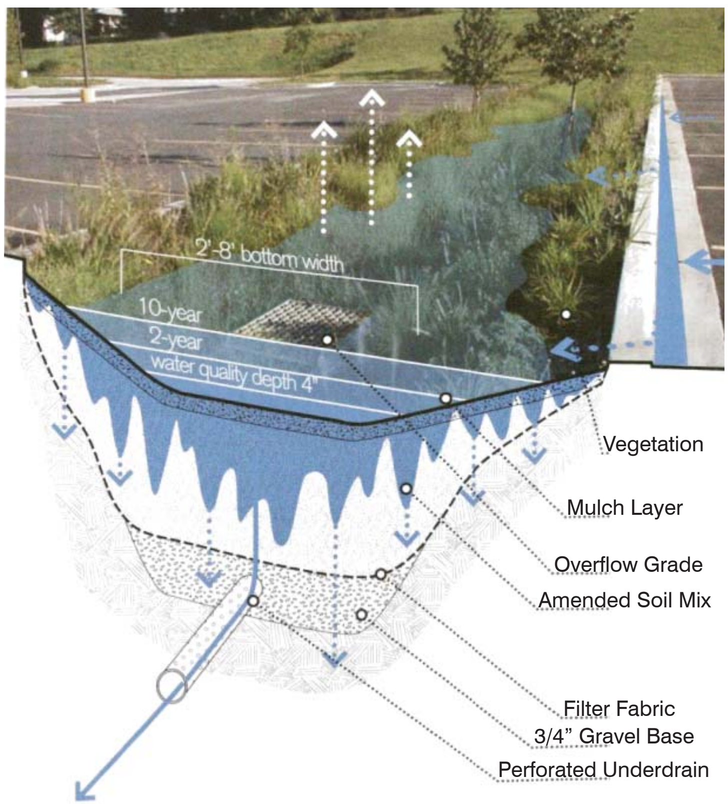


Figure 2.4 Constructed Bioswale. Adapted from UACDC (2010)

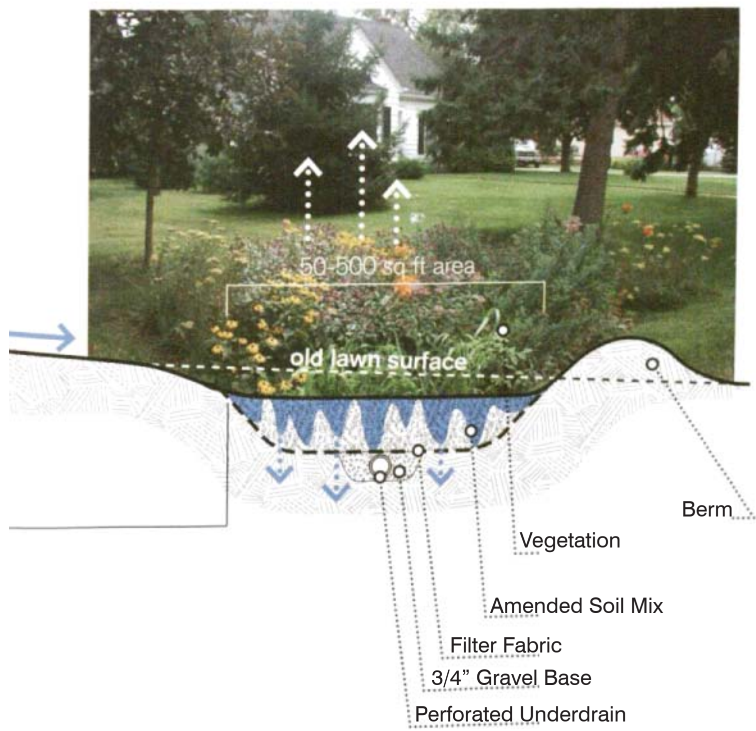


Figure 2.5 Constructed Rain Garden. Adapted from UACDC (2010)

elements of nature fosters stress relief and promotes higher-order cognitive functions (Miller, 2008).

Art and Aesthetics as a Human Amenity and Identity

Aesthetic appreciation and evaluation is an important concern for environmental planning and landscape architecture (Silva et al., 2004). Aestheticism has the potential to enhance a river corridor's natural beauty. Art can be interwoven along a creekside in the form of painted murals to incorporate the community's sense of identity.

URBAN STREAM AND WETLAND PRECEDENT STUDIES

Precedents were found and studied to review existing examples of green infrastructure, and stormwater BMP integration in urban settings.

Two-Stage Channels- Various Locations

A two-stage channel, as shown in figure 2.6, is a bank stabilization design that takes advantage of the floodplain. Two-stage channel or drainage ditches have been used throughout the United States, from north-central, Iowa, to Hillsdale County, Michigan. "At the first stage, a small channel allows for enough velocity to minimize sediment deposition during normal or lower flows. The second stage provides bank stability, an outlet for subsurface drains, and capacity to drain the flow from larger storm events" (Witter, D'Ambrosio & Ward, 2011). The two-stage channel design is considered a Best Management Practice and requires little maintenance. "When coupled with appropriate upland conservation practices, the two-stage design can be self-sustaining, reducing the need for expensive and destructive clean-outs" (Witter, D'Ambrosio & Ward, 2011). Compared to a trapezoidal channel the two-stage channel provides a larger cross-sectional area. "This lowers the water surface, which reduces flooding in adjacent upland areas and can lead to overall improved performance of the subsurface drainage system" (Witter, D'Ambrosio & Ward, 2011). An advantage of a two-stage channel is that during high flows sediment and nutrients that are suspended will be trapped in the bench vegetation instead of being transported downstream. Another advantage is the increase in fish habitat; the bench provides "forage for mammals and birds, cover for birds and amphibians, and a level corridor for animal movement between wooded habitats" (Witter, D'Ambrosio & Ward, 2011). The inclusion of vegetation also reduces the water temperature and increases oxygen availability.



Figure 2.6 Two Stage Channel

Buffalo Bayou Promenade, Houston, Texas

The 84 kilometer river meandering through Houston, Texas is a "principle drainage system for much of Houston, balancing built environment with a diverse urban ecosystem of native riparian plants, bottomland hardwood forests, and a range of flora and fauna and marine life" (SWA, 2011, 38). Due to rapid urbanization and increasing stormwater runoff Buffalo Bayou became severely degraded.

The Buffalo Bayou Promenade project, as shown in figure 2.7, converted "a neglected, trash-soaked eyesore, challenged by an entangled infrastructure of freeways and bridges, into a multifaceted urban park—adding 9.3 hectares of park land to Houston's inner city" (SWA, 2011, 38-39). The project completed in 2006, celebrates the urban corridor rather than hiding it. "Re-engineered sloping of the banks and a series of stairs and ramps reconnect Houstonians to their native bayou" (SWA, 2011, 39).

The ecological design of the project utilizes native and naturalized vegetation as a habitat creator and bank stabilizer. Bank slopes within the project site were re-engineered to a "33-percent slope to maintain hydrologic flows and strengthen opportunities for open-space recreation, access, and circulation", and then implemented with an underwater gabion system (SWA, 2011, 42). The gabion system includes a stepped design where water can "egress at any point while allowing floating storm debris to pass through" (SWA, 2011, 43). The design of the site includes 20 miles of recreational trails for pedestrians and bikers, and native habitat for migratory birds and wildlife, such as, loggerhead turtles, hawks, herons, and the Mexican free-tailed bat.

Cheonggyecheon Stream Restoration Project

Completed in 2005, the City of Seoul, South Korea restored the historic Cheonggyecheon stream by taking a costly and aging elevated freeway along a 3.6 mile corridor and implementing "ecological and recreational opportunities" in its stead for the city (Robinson & Myvonwynn, 2011). Designed by SeoAhn Total Landscape the project site's performance benefits include increased flood protection and biodiversity, reduction in the urban heat island index and air pollution, and an increase in sustainable transportation, property values, and business economics.

The stream, as shown in figure 2.8, provides protection up to the 200-year floodplain and sustains a regular flow rate. Biodiversity on the site has increased by 639%. By removing the expressway and implementing vegetation the stream temperature was reduced. The use of natural stones within the stream creates pedestrian walkways, and helps to slow water

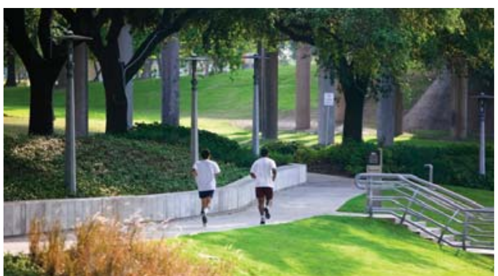


Figure 2.7 Buffalo Bayou Promenade

Figure 2.8 Cheonggyecheon Stream

velocity. Terraced walls help provide public art space for local artists to display their work.

The Cheonggyecheon restoration project provided a "green corridor for pedestrians, bicyclists, and wildlife," wetlands, and a transportation network of bridges, subway, bus, and waterway connections (Robinson & Myvonwynn, 2011). The project, however, was met with many challenges, such as the traffic congestion from removing the freeway. To encourage pedestrian walkability a series of bridges span the Cheonggyecheon stream and a governmental clause was implemented to discourage vehicular use.

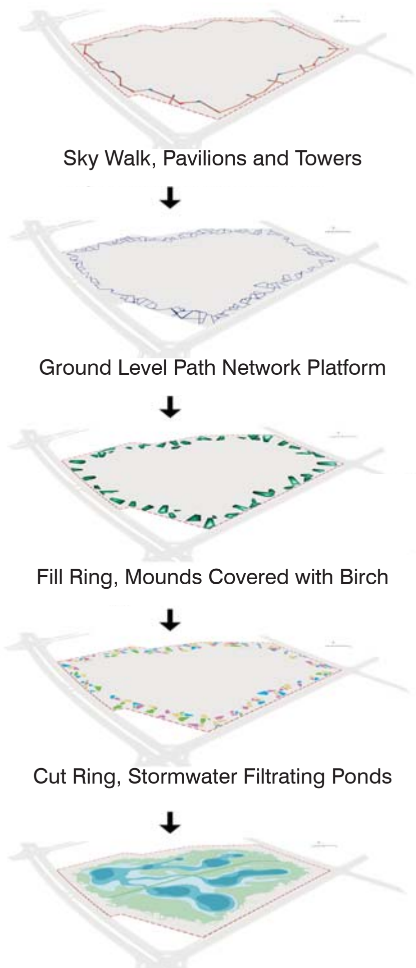
Qunli National Urban Wetland

The Qunli National Urban Wetland was developed by the landscape architectural firm Turenscape as a national ecological security pattern for Haerbin City, in Heilongjiang Province, China in 2009. Haerbin City was beset by frequent urban flooding due to the torrential rains that occur in the area, and the expansion of impervious surfaces (Yu, 2011, 73). The 85 acre park within the expected 2,733 acre planned project began in 2006 as a development for expectancy of 750,000 people. "The site was formerly a wetland but had been surrounded on four sides by roads and dense development. Water sources for the wetland were severely diminished, and the wetland was under threat of complete disappearance" (Yu, 2011, 74). Turenscape was hired to address the economic feasibility of transforming the site, filtering and cleansing of site water, and recreational and aesthetic services. Figures 2.9 shows pictures of the project.

Turenscape's design differs from conventional engineering solutions; the creation of cut and fill grading techniques "create a necklace of ponds-and-mounds surrounding the former wetland. While leaving a major core of the wetland untouched for natural evolution and transformation, the pond-and-mound ring surrounds the periphery of the wetland and creates a stormwater-filtering and-cleansing buffer zone for the core wetland" (Yu, 2011, 75). Figure 2.10 shows the cut and fill technique plan and diagrams used to create the necklace of ponds and mounts. Piped stormwater from the urban landscape into the circumference of the site allows for even distribution and infiltration to recharge the groundwater.

Fields of native flowers and grasses along pedestrian pathways provide an aesthetic quality. The "project demonstrates an ecosystem services - oriented approach to urban park design, and showcases a water-based approach to urbanism - one that is firmly grounded in the practice of landscape architecture" (Yu, 2011, 75). Ecosystem services include provisions such as renewable energy, minerals, biomass fuel, regulating water and erosion, nutrient cycling services, and educational services (Zhang et al., 2010). The

Figure 2.9 Qunli National Urban Wetland



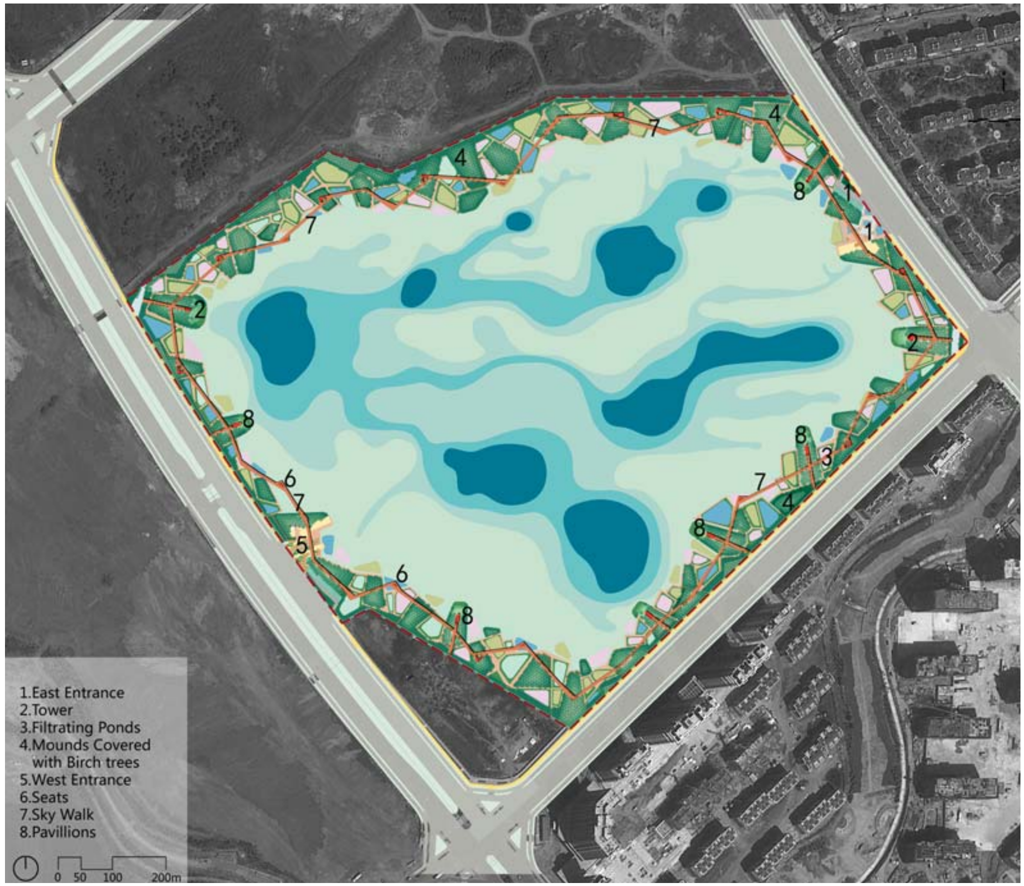


Figure 2.10 Qunli National Urban Wetland Plan.

Inclusion of ecosystem services and stormwater management is integral to the landscape, and provides habitat, wetland restoration, and cultural heritage.

Bishan Park

Located in Bishan, Singapore the Bishan Park, as designed by Atelier Drieseitl, is a transformed 153 acre park of concrete canal to naturalized river community space. As a part of the Active, Beautiful, Clean Water (ABC Waters) Program, a 1.5 mile section of Kallang River was transformed to eliminate the separation of residents that the concrete canal provided through the use of soil bioengineering (figure 2.11). Seven different soil bioengineering techniques were used including “fascines, rip-rap with cuttings, geotiextile wrapped soil-lifts, brush mattresses with fascines, reed rolls, planted gabions and geotextile with plantings” (Holmes, 2012). A fascine is a brushwood bundle that is used to strengthen the landscape.

When the river water level is low, users can get closer to water and enjoy recreational activities along the river banks. During heavy rain, the park land next to the river serves as a channel to carry water downstream” (CNA, 2012). The transformation in river quality has “brought birds, dragonflies, waterhens and little egrets closer to our doorsteps” (CNA, 2012). The park offers a variety of amenities including, recreation, restaurants, and art. “With the variety of amenities catering to the diverse needs of [the park users,] Bishan Park will draw visitors from all over, and bring Singapore closer to being a City in a Garden” (CNA, 2012).

Performance benefits of the project include increased water conveyance capacity, decreased velocity, and increased biodiversity. Through the reintegration of the natural riverbed, rocks, pools and riffles the water velocity and sedimentation has decreased (Holmes, 2012). Decreasing the velocity of the river provides better flood protection for the urban area. With an area that used to have limited biodiversity, the community has seen an increase of biodiversity by 30%.

Root River Restoration Project

Root River “is located within the Western Corn Belt Plains and Driftless Area Ecoregions of southeastern Minnesota and northeastern Iowa” (USDA & NRCS, 2008). Root River and its tributaries, as shown in figure 2.12, began to show signs of degradation due to human activities. “The problems of this watershed typify those found in areas experiencing changing land use patterns and water resource-related problems and have a direct effect on the property and general welfare of the residents of the watershed” (SEWRPC, 2012). A restoration plan for Root River, to be implemented over 2014 to 2018, will

Figure 2.11 Bishan Park

Figure 2.12 Root River

restore and improve water resources.

Problems within the river "restrict its potential uses and threaten its ecological integrity" (SEWRPC, 2012). Concentrations of dissolved oxygen are below the required levels for aquatic life, and high concentrations of bacteria present during the recreational season are harmful to humans. The terrestrial "habitat within the watershed is highly fragmented. Aquatic and terrestrial exotic invasive species are present at many locations and may be displacing native species and depredating habitat" (SEWRPC, 2012).

River problems threaten the ecological integrity and resource usage (SEWRPC, 2012). Of the focus issues, water quality deals with nutrients, sediment, and chloride, recreational use and access deals with bacteria, access points, and fishery quality, and habitat conditions deals with buffers, connectivity, passage barriers, and invasive species.

Regulatory recommendation requirements include the regulation of point sources, bans and restrictions on the transport of invasive species, fertilizer bans, and pet litter ordinances. Implementation recommendations include the construction and maintenance of sanitary sewer systems, construction practices that reduce soil losses in agricultural lands, the establishment of riparian buffers, and the restoration and enhancement of stream channels.

Swan River Restoration Project

Located in Summit County near Breckenridge, Colorado, the Swan River Restoration Project, as designed by Dave Rosgen, proposes to restore one mile of river. The stretch of the river "was heavily impacted by dredge boat mining in the early 1900's" and is devoid of resources (BRWG, 2009). A majority of the land surrounding the river is barren filled with "gravel and cobble left in stockpiles by the dredge boats after they extracted precious metals" (BRWG, 2009).

The proposed design for the Swan River Restoration Project, as shown in figure 2.13, is broken down into six categories: aquatic environment; riparian habitat; upland habitat; floodplain, channel grades and elevations; channel dimensions and construction; road alignments. "The proposed aquatic environment is the creation of a natural stable river channel meandering through a mosaic of wetland, riparian and upland habitats. The channel will look and function like a natural channel with a series of pools, riffles and runs whose substrate is established with native river cobble" (BRWG, 2009). The proposed river channel relates to its pre-development state, before mining occurred.

"The proposed condition for riparian habitat is to create a mosaic of native riparian communities interspersed with wetland habitats at lower elevations. The riparian communities would include native grasses and forbs with both aspen

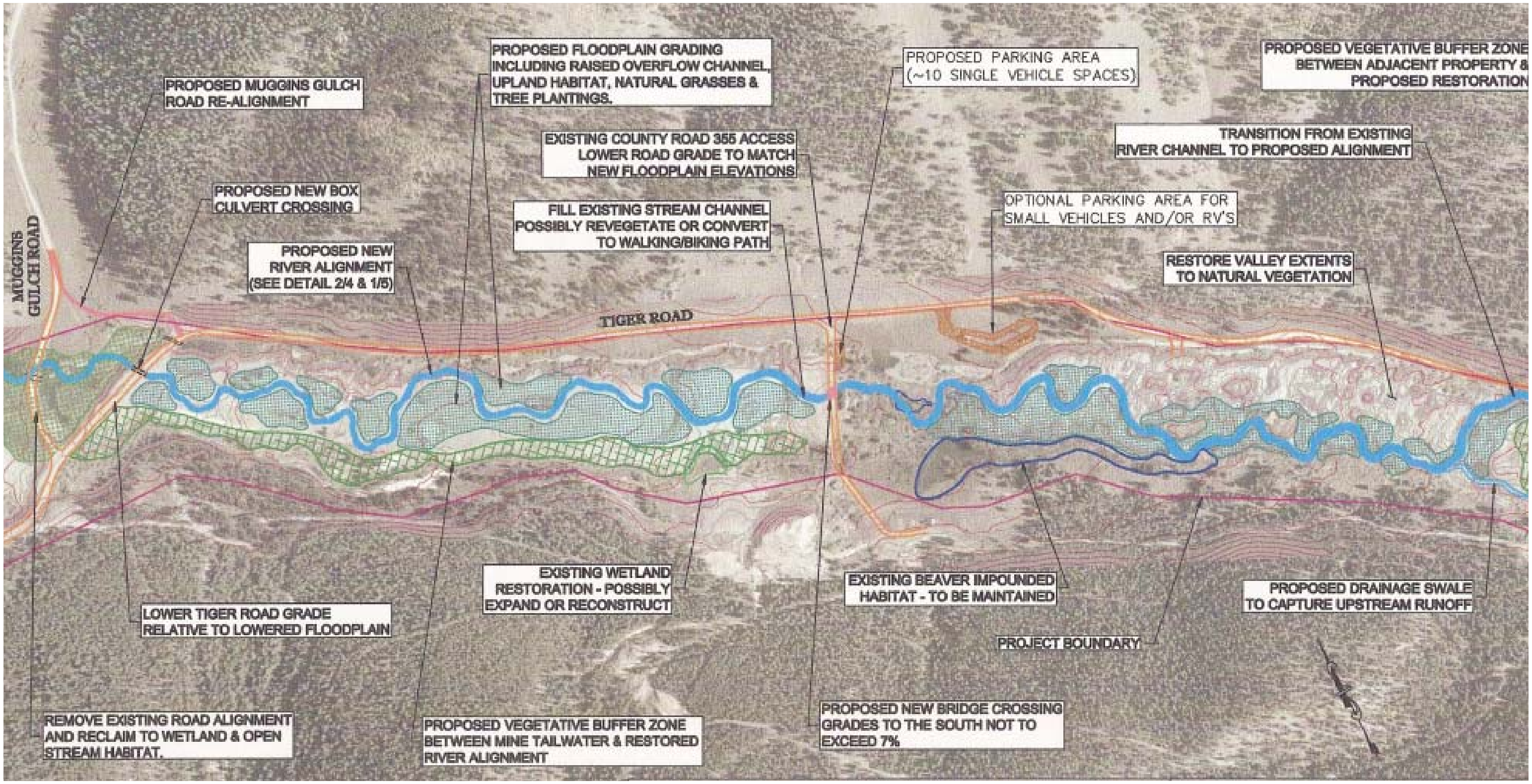


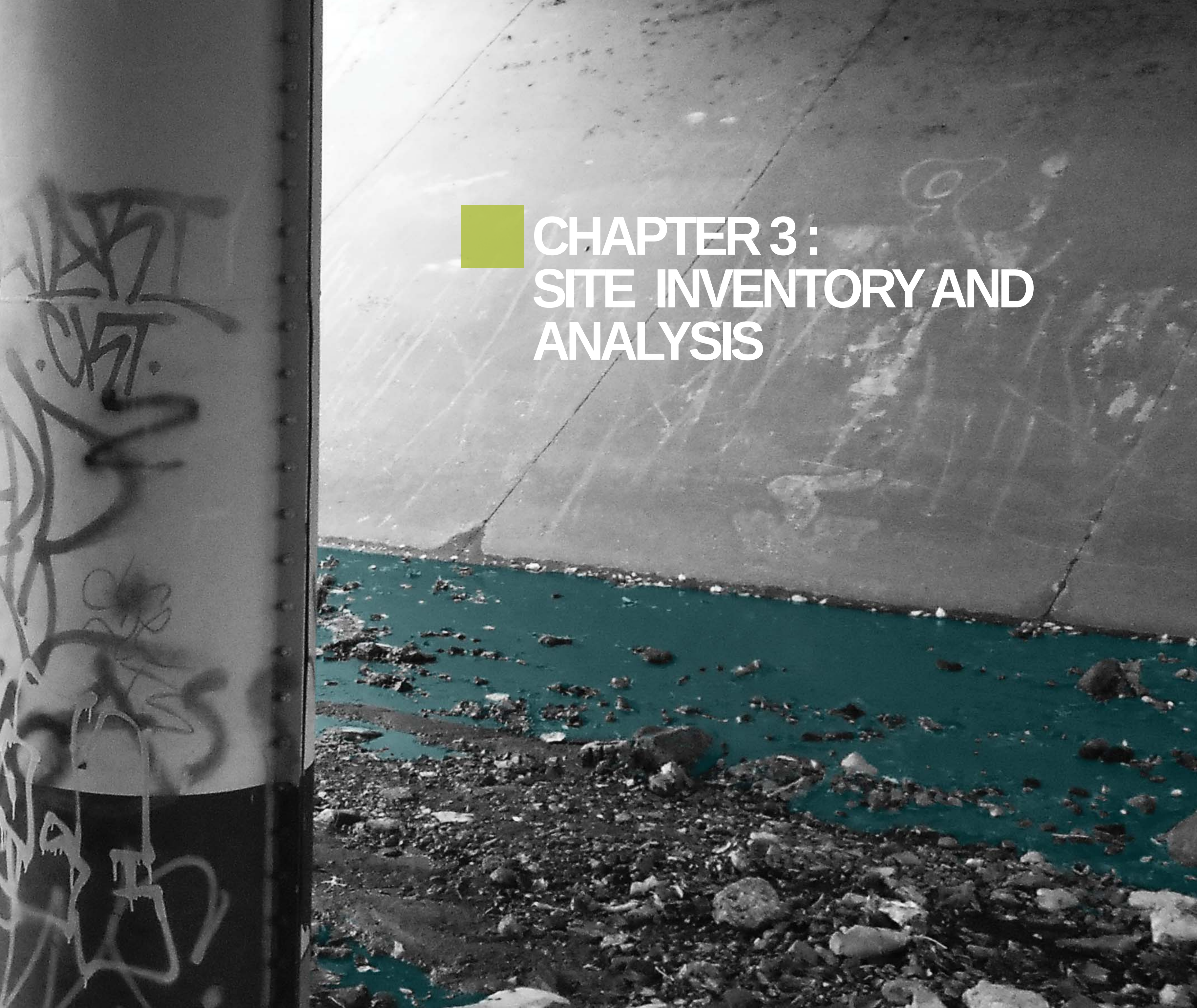
Figure 2.13 Swan River Proposed Conditions

(Populus tremuloides) and a shrub component consisting of serviceberry (Amelanchier alnifolia) and shrubby cinquefoil (Pentafloides floribunda)" (BRWG, 2009). The wetland habitats include "a mixture of sedge, rush and grass dominated systems on point bars and willow stream banks with possible willow and sedge systems on lower topographic positions within the floodplain" (BRWG, 2009).

The upland areas of the river will house a number of habitat types "from grassland, shrub-grassland, to forested habitats" (BRWG, 2009). The floodplain, channel grades and elevation changes will be excavated to elevations "within one to two feet of the existing groundwater elevations" and a new stream channel elevation will be placed below the "current groundwater levels" (BRWG, 2009). The channel dimensions will be "designed to accommodate fishery habitat at low seasonal flows as well as pass full-bank conditions during design flow events" (BRWG, 2009). The final proposal is to re-align "the channel and floodplain to the center of the valley with a new box-culvert crossing adequate in size to pass the design flood flows" (BRWG, 2009).

Deer Creek Bridge, Anne Denney (2012)

CHAPTER 3 : SITE INVENTORY AND ANALYSIS



SITE INVENTORY AND ANALYSIS

A methodology pertinent in developing a stormwater BMP suitability plan for the River des Peres watershed, and corresponding project site master plans was through a watershed inventory and analysis. There are many factors affecting the River des Peres watershed. These factors impact the design of Deer Creek, Gravois Creek, and River des Peres channels. The following inventory and analysis of the watershed includes:

- *Missouri and River des Peres Site History*
- *Site Selection*
- *Combined Sewer Outfalls*
- *Land Use*
- *Geologic Conditions*
- *Land Cover*
- *Hydrologic Conditions*
- *Floodplains and Riparian Vegetation*
- *Watershed Stormwater BMP Suitability*
- *Stormwater Runoff*
- *Project Site Locations*

The site inventory and analysis factors were developed through Geographic Information Systems (GIS) data gathered from St. Louis County, St. Louis University, River des Peres Watershed Coalition, Federal Emergency Management Agency (FEMA), Metropolitan St. Louis Sewer District, National GAP Analysis (GAP), United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Geospatial Data Gateway, Missouri Spatial Data Information Service (MSDIS), National Hydrography Dataset (NHD), National Wetlands Inventory (NWI), and USDA NRCS Soil Data Mart. GIS is a tool for capturing, analyzing, and displaying geographical data. Much of the data gathered from these government and community sources was a starting point for inventorying and analyzing watershed constraints and opportunities.

By inventorying these factors watershed stormwater BMPs and wet meadow potential opportunities were mapped, and the acreage calculated to find the reduction in peak flow volumes in Deer Creek, Gravois Creek, and the River des Peres. Land use, geologic conditions, land cover, hydrologic conditions, floodplains, riparian vegetation, and roads were all factors in the location of potential stormwater BMPs and wet meadows throughout the watershed. The concluding site inventory and analysis provides design solutions to the stated dilemma, and accomplishes the goals listed the thesis:

- *Lowering the flood frequency rate of the river through the inclusion of stormwater BMPs.*
- *Enhancement of wildlife habitat by the inclusion of native fauna and flora through the re-vegetation of the stream bank, stormwater BMPs, and wet meadows.*
- *Enhance the local identity of waterway by integrating public art into the inner and middle stream buffer.*
- *Fix the infrastructural performance problems of the site, including, stormwater and sanitary overflows.*
- *Encourage growth in areas damaged by previous engineering projects such as trapezoidal channel lining.*

MISSOURI AND RIVER DES PERES SITE HISTORY

To understand the impacts on the River des Peres watershed historical information was studied and categorized into 5 periods of time: prehistoric, exploration, frontier and pioneer, early agricultural, and agriculture and industrial. A complete listing of historic data is located in Appendix A. Reviewing historical information on the River des Peres answered the question on why the historic civil engineering landmark is such a wreck today.

As shown in figure 3.1, the main stem of the River des Peres is a constructed concrete trapezoidal channel that is heavily degraded. Figure 3.2 adapted from the Metropolitan St. Louis District, shows the open and piped underground areas of the River des Peres watershed. From Macklind Avenue through Forest Park to Skinker Boulevard the River des Peres flows underground in a concrete culvert.

SITE SELECTION

A walking tour in collaboration with the River des Peres Watershed Coalition occurred on November 24th to gather river information that factored into the development of site selections for stormwater BMPs, wet meadows, and river channel implementations. Each site that was investigated varied in scale, land use, and river channelization. As shown in figure 3.2, the first chosen location is in the headwaters of the River des Peres at Forest Park. The second location is along Wilson Avenue and Drexel Drive, where 26 homes were removed from the floodplain. The third location is at Deer Creek Shopping Center where the Missouri Department of Transportation (MODOT) would like to implement a South County Connector highway. The fourth location is near Grant's Trail where the trail will be extended to connect to the River des Peres Greenway. Lastly, the fifth location is along the main channel of the River des Peres at Willmore Park. Each site is impacted by combined sewer overflows.

COMBINED SEWER OUTFALLS

Encompassing the City of St. Louis and St. Louis County is approximately 75 square miles of combined sewers. The wastewater and stormwater collection system is owned and operated by the Metropolitan St. Louis Sewer District (MSD). MSD provides wastewater and stormwater services to 1.4 million people throughout the City of St. Louis and St. Louis County. MSD has prepared a Long-Term Control Plan (LTCP) as a part of the CSO Control Policy issued in 1994 to bring all CSOs into compliance with the Clean Water Act. In the report MSD provides descriptions of current CSO locations, the impacted waters, and solutions to fix the impairments. Located

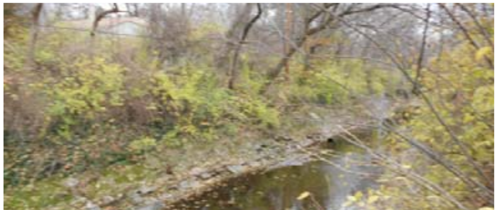
RIP-RAPPED
River des Peres Blvd. and Lansdowne Avenue

CONCRETE TRAP./ REC. CHANNEL
River des Peres Blvd. and Chippewa St.

UNDERGROUND
Macklind Avenue

Figure 3.1 River Channelization Types

1 Forest Park



2 Wilson Avenue and Drexel Drive

3 Deer Creek near Deer Creek Park

4 Grant's Trail Extension

5 Main Channel of the River des Peres

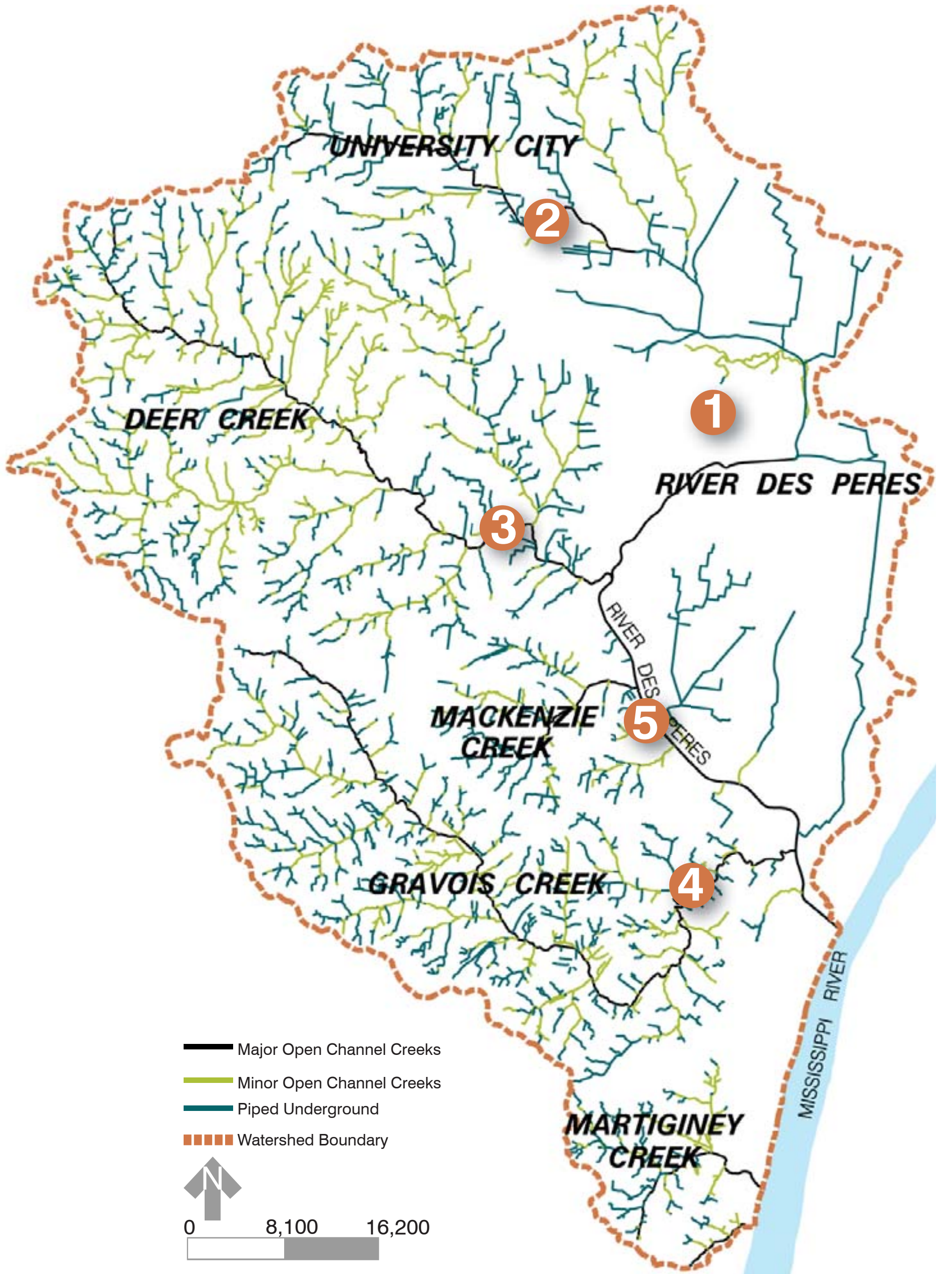


Figure 3.2 Open and Piped Locations. Adapted from Kastil, 2007.

throughout the River des Peres watershed there are 199 CSO outfalls. As shown in figure 3.3, the lower and middle River des Peres have 52 CSO locations, the upper River des Peres has 39 CSO locations, the tributaries of the River des Peres have 42 CSO locations, and Gravois Creek has 1 CSO location.

The Lower River des Peres "consists of a small base flow, and large volumes of intermittent storm drainage from runoff, storm sewers, and combined sewers. The Lower River des Peres is subject to backwater from the Mississippi River" (MSD, 2011). The upper four miles of the Middle River des Peres is "enclosed and is a combined sewer. The lower three mile reach, beginning near the Macklind Pump Station, is an open channel with a concrete base and concrete or riprap slopes" (MSD, 2011). The river's flow is intermittent and consists mainly of stormwater runoff from the upper portions of the river. Both the Lower and Middle River des Peres are impaired due to low levels of dissolved oxygen and high levels of chloride.

The Upper River des Peres consists of an intermittent flow from stormwater sewer runoff. The upper River des Peres is also impaired due to low levels of dissolved oxygen.

What MSD is Planning

To reduce the amount of CSO discharge MSD evaluated a "range of control technologies including source control technologies, collection system controls, storage technologies, and treatment technologies" (MSD, 2011). Control technologies are as listed (MSD, 2011):

- *Source Control technologies- technologies that affect the quantity or quality of runoff prior to entering the collection system.*
- *Collection System Technologies- technologies that affect CSO flows and loads once the runoff has entered the collection system.*
- *Storage Technologies- those technologies that provide for storage of flows from the collection system for subsequent treatment after the storm is over and conveyance and treatment capacity have been restored.*
- *Treatment Technologies- technologies that provide for either local (at the CSO) or centralized treatment of CSO flows to reduce the pollutant loading to receiving waters.*

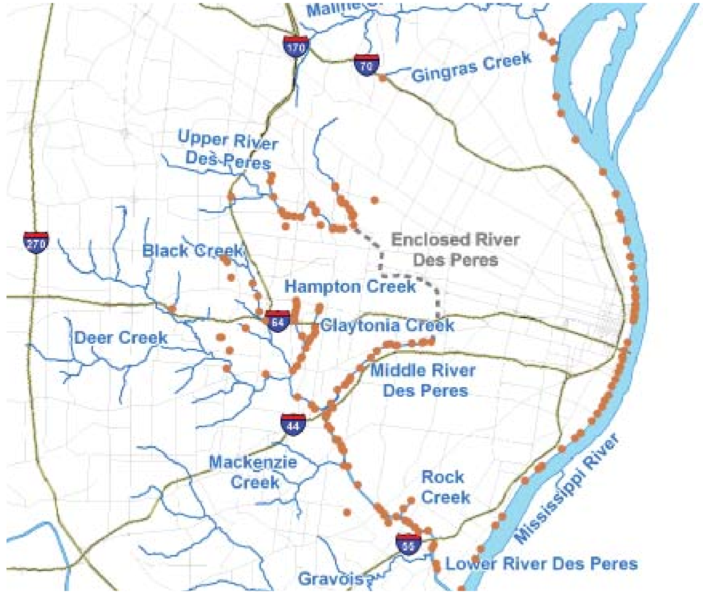


Figure 3.3 CSO Locations. Adapted from MSD, 2011.

By evaluating control technologies MSD then created a plan to improve the water quality. The plan "consists of controlling CSOs to MSD's urban streams to the point where further expenditures yield significantly diminished returns (the 'knee-of-the-curve'), coupled with an enhanced green infrastructure program in areas with CSOs that discharge directly to the Mississippi River" (MSD, 2011). As a part of the plan site specific components will be implemented, as depicted in figure 3.4, includes the following (MSD, 2011):

Upper River des Peres:

- *Skinker-McCausland Tunnel to express convey separate sewer system flows around the combined sewer system*

- *Storage tunnel to store flows from CSO outfalls to the Upper River des Peres*

River des Peres Tributaries

- *Sewer separation of 15 smaller CSOs*
- *Elimination of all CSO outfalls to tributaries, tunnel to store/convey flows to the River des Peres channel*

Lower and middle River des Peres:

- *Lemay Overflow Regulation System*
- *Full utilization of excess primary treatment capacity at Lemay Treatment Plant*
- *Sewer separation of 5 smaller CSOs*
  Repair of inflow to interceptor sewers under River des Peres
- *Upstream CSO control (Upper River des Peres)*
- *Flow storage in 29-ft horseshoe sewers under Forest Park and in new storage tunnel, 100 MGD treatment unit near Outfall 063, removal of secondary treatment bottlenecks at WWTP*

LAND USE CONDITIONS

Knowing the location of land use types is pertinent to understanding where potential toxins and pollutants originate. Figure 3.5 shows the potential point sources of toxins based upon land use, where industrial zones are high point sources of pollution, and figure 3.6 shows the land use data of the watershed. Currently the River des Peres watershed has approximately 35,850 acres of residential land, 6,000 acres of commercial land, 600 acres of land being redeveloped, 5,300 acres of institutional land, 2,800 acres of industrial and utility land, 250 acres of civic land, 5,150 acres of common area, park and recreational land, 170 acres of cemetery land, and 2,500 acres of vacant land.

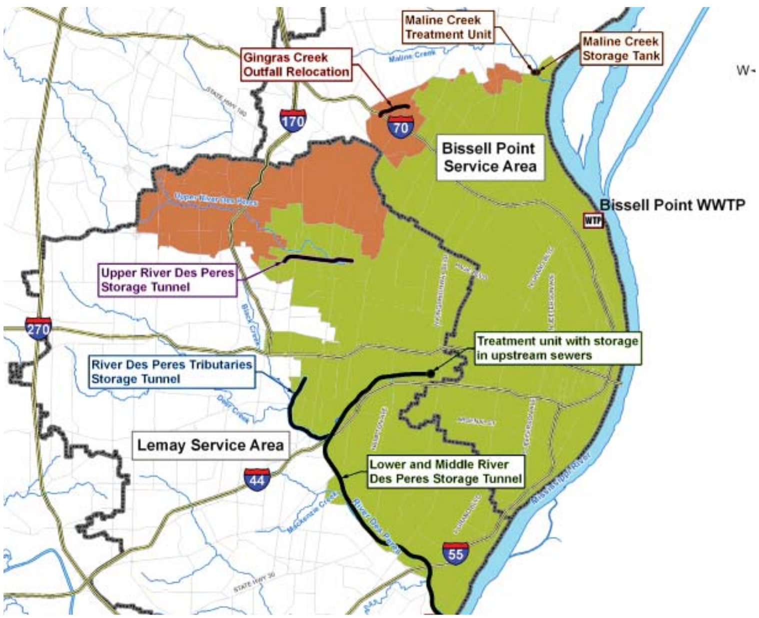


Figure 3.4 MSD CSO Solutions. Adapted from MSD, 2011.

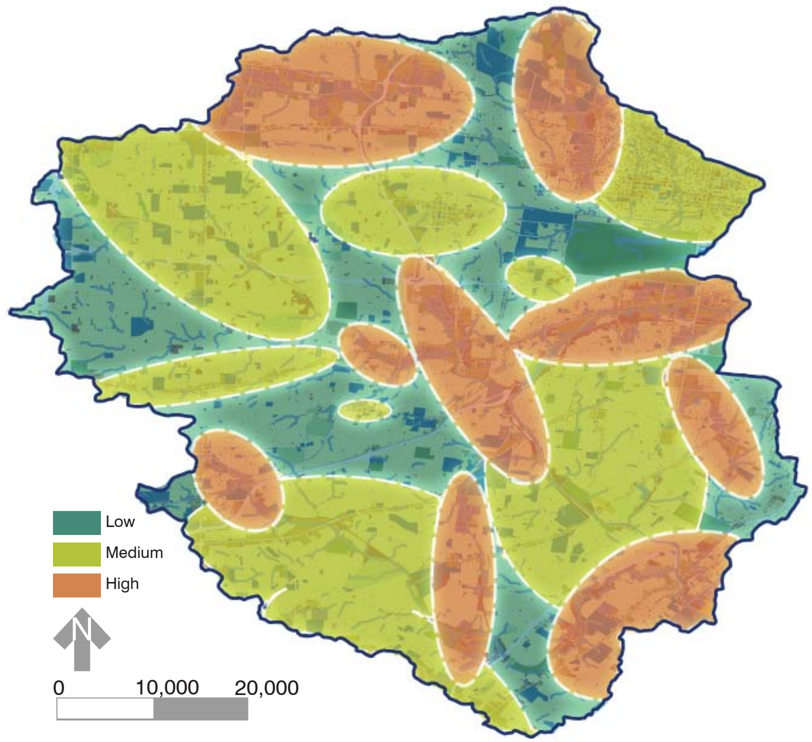


Figure 3.5 Potential Point Sources of Toxins

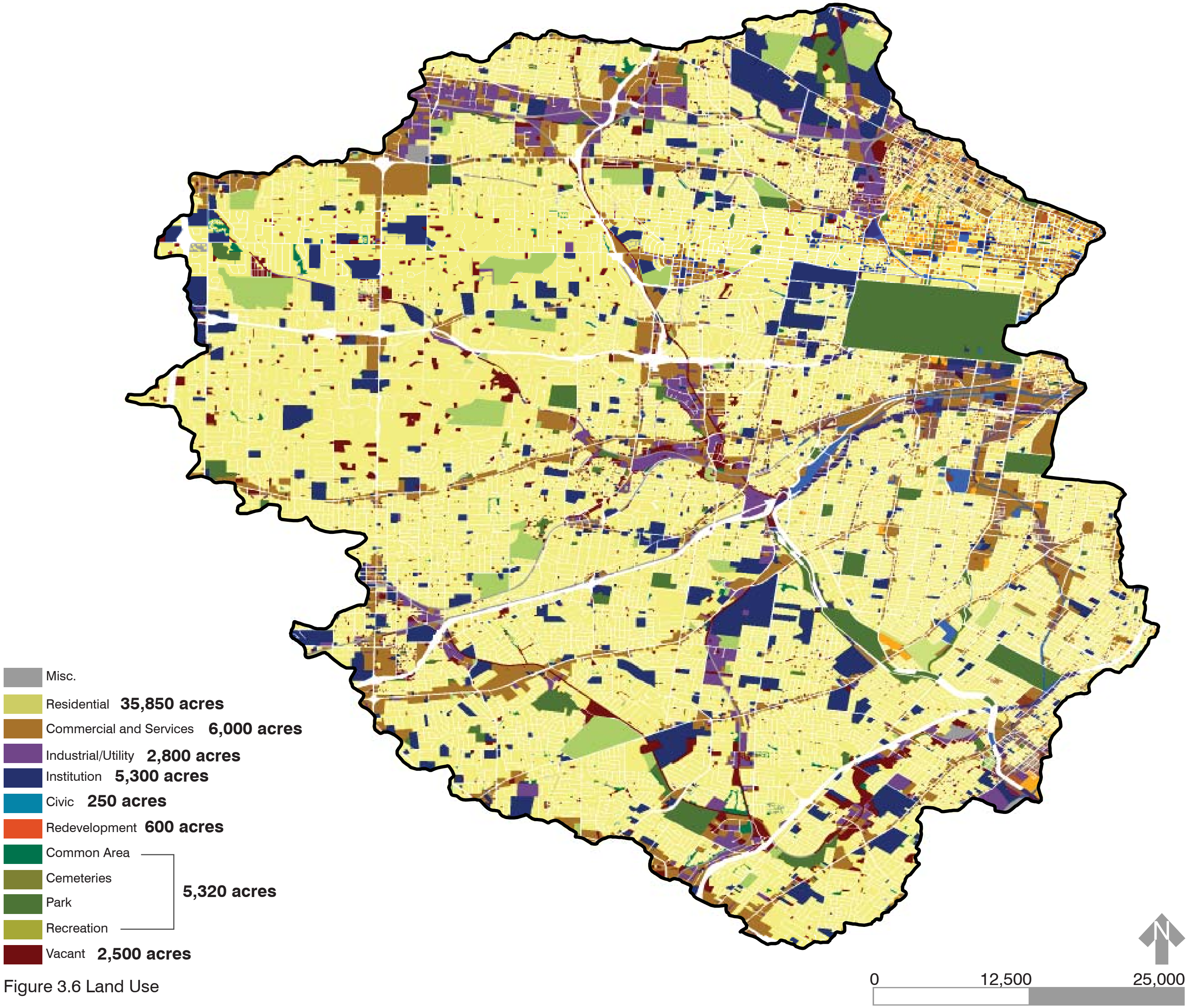


Figure 3.6 Land Use

GEOLOGIC CONDITIONS

Geology is a significant factor in determining water permeability and land development. The science of geology is important in locating resources, mineral deposits, erosion, and determining land development opportunities.

Soils

The existing soil data for the River des Peres watershed is incomplete due to many soil locations being in an urban area, and could have a range of soil types. The soil classification data that is complete is either a coarse-silty, fine-loam, or a fine-silty soil type. A coarse-textured soil is stable during dry and wet conditions, which makes it excellent for development potential. Coarse soils, however, are poor for plant material due to their drainage capability. Fine-textured soils have high expansion and contraction rates, lacking stability for development. However, fine-textured soils intermixed with loams provide high "inherent soil fertility which makes them desirable for establishing lawns and gardens" (Tompkins County, 2012). Organic soils provide a wide variety of nutrients for plant types but are easily compacted.

The soil permeability of a coarse-silty soil, as shown in figure 3.7, is moderately well-drained, the fine-loamy somewhat poorly drained, fine-silty well drained, and the urban soil mix is assumed to be poorly drained. Poorly drained soils hold water longer and are suitable for wetland usage. Corresponding percolations rates for each soil type is shown in table 3.1.

Topography and Slopes

Topography is the "measurement of elevation, and slope is the percent change in" elevation over a designated distance interval (Tompkins County, 2012). The consideration of slope and topography are important in construction projects to minimize environmental impacts from development. A slope of 0-5% is most favorable for development, whereas, a slope greater than 20% is not suited for development. Figure 3.8 shows the slopes of the watershed at 5% intervals. Along the

Table 3.1 Soil Texture Classes and Percolation Rates

General Texture Classes	*USDA Texture Classes*	*Estimated Percolation Rate Range (Minutes/Inch)*
Sand	Sand, loamy sand	Less than 10
Sandy Loam	Sandy Loam	3 to 30
Loam	Loam	10 to 45
Silt Loam	Silt Loam, silt	45 to 90
Clay Loam	Clay loam, sandy clay loam, silty clay loam	Greater than 45
Clay	Sandy clay, silty clay, clay	Greater than 60

Adapted from : Anderson and Halsey, 2010

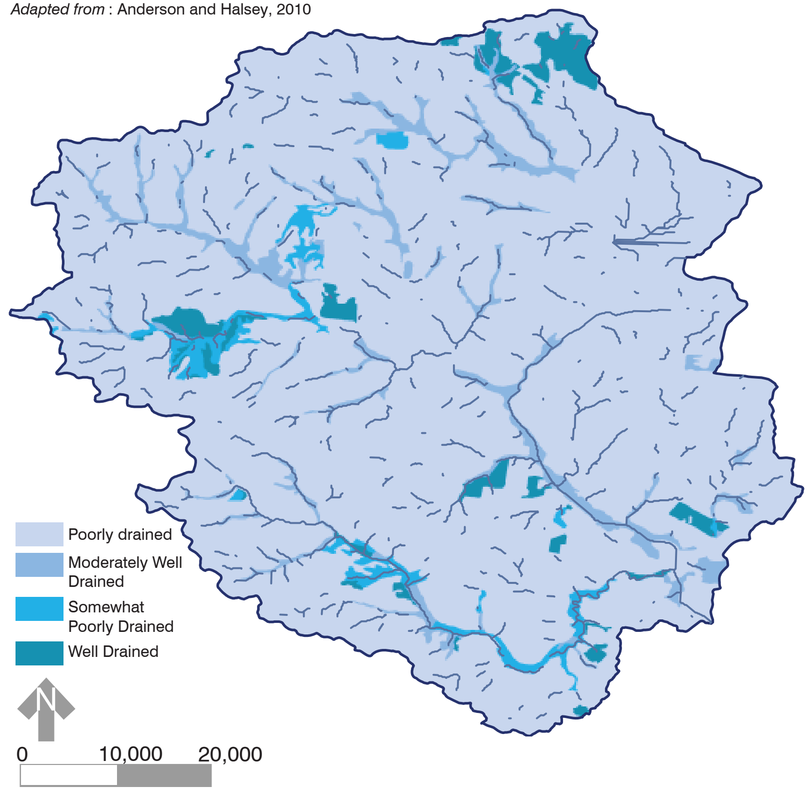


Figure 3.7 Soil Permeability

River des Peres steep slopes are mainly found in the upper portion of the main channel.

LAND COVER CONDITIONS

Land cover data is vital for identifying wildlife habitat. "Information about land cover is a key component of effective conservation planning and the management of biological diversity because it is used to build predictive models of wildlife distribution and biodiversity across large geographic areas" (USGS, 2012). Within the watershed (figure 3.9) there is a lack of forestland and grassland, which is linked to the low number of wildlife being found in the area. In addition, the lack of vegetation can be linked to the increased number of threatened and endangered species within Missouri.

HYDROLOGIC CONDITIONS

Without water, the hydrologic cycle could not be sustained. Human use is one of the many pathways water takes in the hydrologic cycle. For example, humans use water for irrigation, households, and industries. After we use water it

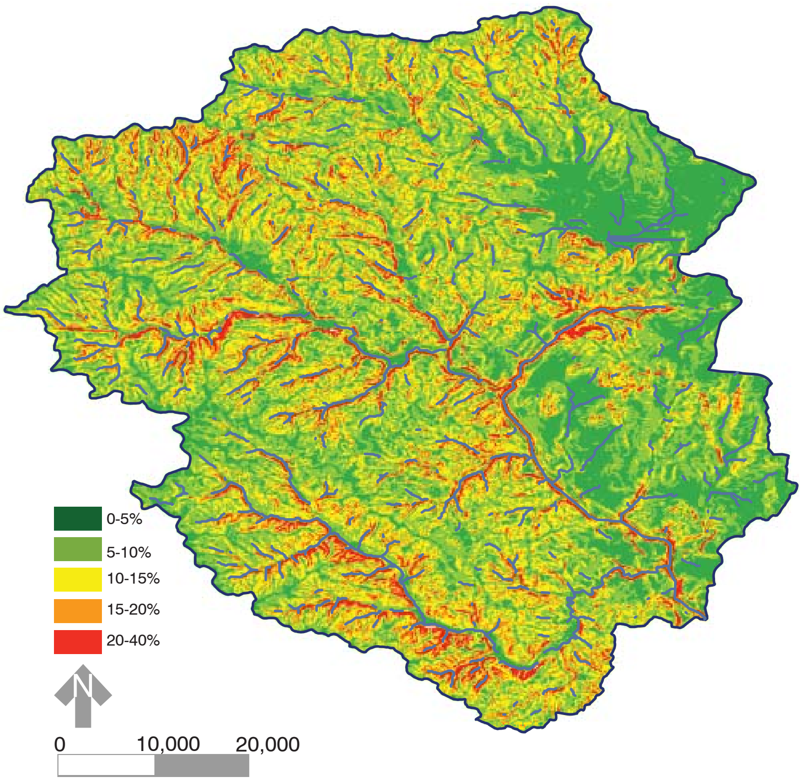


Figure 3.8 Slope

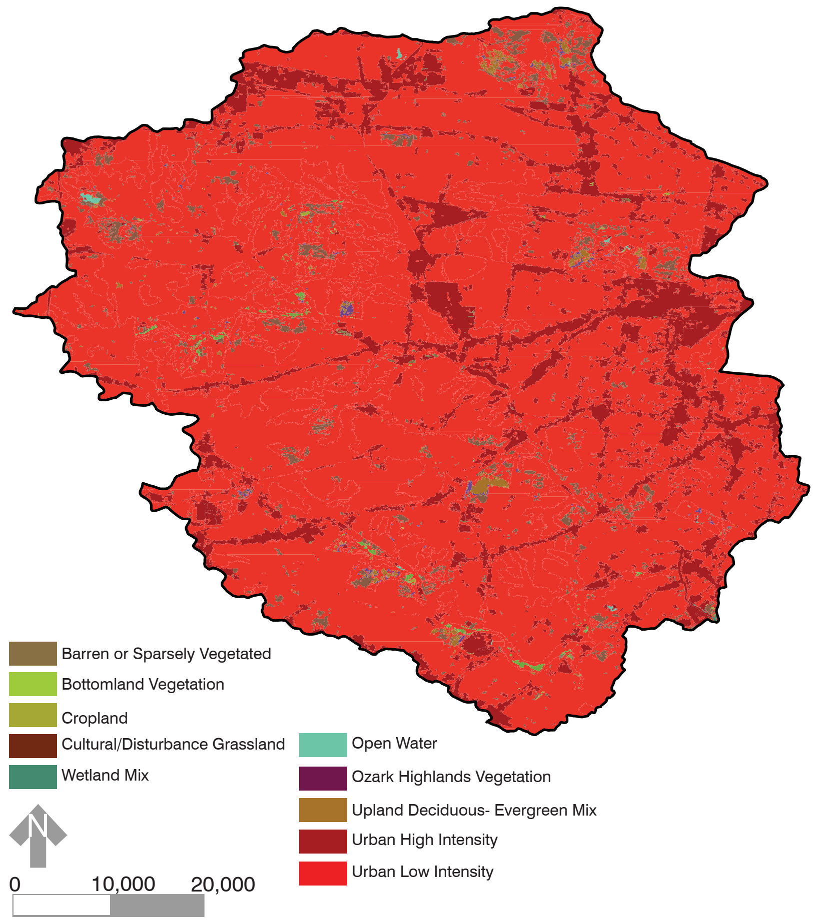


Figure 3.9 Land Cover

is returned usually via streams. However, because of treatment, used water is lower in quality, which poses problems for users downstream (Lane, 2012). Hydrologists and environmental scientists use stream gauges to monitor and test water levels and quality. Located in the River des Peres watershed there are four gauges.

River Inventory and Time Series Data

The stream gauge positioned in the River des Peres at St. Louis, MO is located 390.7 feet above NAVD88, which is close to the mouth of the River des Peres. The gauge captures river measurements from an 82.5 square mile drainage area. The peak stream flow table shown in Table 3.2 shows the flood frequency intervals for River des Peres at St. Louis. The 1.5 year return frequency flow is 9,200 cfs.

The stream gauge positioned in the River des Peres at University City, MO is located 491.97 feet above the NGVD29, close to Heman Park. The gauge captures river measurements from a 8.94 square mile area. The peak stream flow table shown in Table 3.3 shows the flood frequency intervals for River des Peres at University City. The 1.5 year return frequency flow is 3,000 cfs.

The stream gauge positioned in Deer Creek at Ladue, MO is located 457.76 feet above NAVD88, near Old Warson County Club. The gauge captures river measurements from a 21.4 square mile drainage area. The peak stream flow table shown in Table 3.4 shows the flood frequency intervals for Deer Creek. The 1.5 year return frequency flow is 4,690 cfs.

The stream gauge positioned in Gravois Creek is located 422.15 feet above NGVD29, close to St. Trinity Cemetery. The gauge captures river measurements from an 18.1 square mile drainage area. The peak stream flow table shown in Table 3.5 shows the flood frequency intervals for Gravois Creek. The

Table 3.2 Streamflow for River des Peres at St. Louis, MO

Water Year	*Date*	*Gage Height (feet)*	*Stream- flow (cfs)*
2002	Aug. 06, 2002	9.93	3,830
2003	Jun. 26, 2003	19.85	19,900
2004	Nov. 18, 2004	17.7	15,200
2005	Jan. 13, 2005	14.67	9,820
2006	Nov. 28, 2005	14.2	9,340
2007	May. 11, 2007	14.1	8,810
2008	Jun. 30, 2008	21.95	25,100
2009	Feb. 11, 2009	14.35	9,190
2010	Jun. 28, 2010	19.86	19,900
2011	Jun. 26, 2011	20.8	22,200

Adapted from : USGS, 2012

Table 3.3 Streamflow for Deer Creek at Ladue, MO

Water Year	*Date*	*Gage Height (feet)*	*Stream- flow (cfs)*
2001	Sep. 09, 2001	12.24	3190
2002	Jun. 12, 2002	16.3	5230
2003	Sep. 02, 2003	16.86	5530
2004	Jul. 05, 2004	17.9	6120
2005	Jan. 13, 2005	17.68	6000
2006	Nov. 28, 2005	12.5	3310
2007	Jul. 05, 2007	14.27	4170
2008	Sep. 14, 2008	23.07	10200
2009	Jun. 16, 2009	15.88	4690
2010	Oct. 30, 2009	16.27	4890
2011	Jun. 26, 2011	17.5	5550

Adapted from : USGS, 2012

Table 3.4 Streamflow for Gravois Creek near Mehlville, MO

Water Year	*Date*	*Gage Height (feet)*	*Stream- flow (cfs)*
2001	Sep. 09, 2001	12.24	3190
2002	Jun. 12, 2002	16.3	5230
2003	Sep. 02, 2003	16.86	5530
2004	Jul. 05, 2004	17.9	6120
2005	Jan. 13, 2005	17.68	6000
2006	Nov. 28, 2005	12.5	3310
2007	Jul. 05, 2007	14.27	4170
2008	Sep. 14, 2008	23.07	10200
2009	Jun. 16, 2009	15.88	4690
2010	Oct. 30, 2009	16.27	4890
2011	Jun. 26, 2011	17.5	5550

Adapted from : USGS, 2012

Table 3.5 Streamflow for River des Peres at University City, MO

Water Year	*Date*	*Gage Height (feet)*	*Stream- flow (cfs)*
1997	Sep. 17, 1997	8.02	889
1998	Jul. 22, 1998	13.87	3,180
1999	Jun. 12, 1999	15.74	4,130
2000	Jun. 24, 2000	14.24	3,360
2001	Sep. 08, 2001	11.98	2,320
2002	Jun. 11, 2002	13.51	3,010
2003	Jun. 26, 2003	16.31	4,430
2004	May. 27, 2004	15.56	4,030
2005	Jan. 12, 2005	14.2	3,340
2006	Nov. 28, 2007	12.01	2,330
2007	Jun. 01, 2007	11.95	2,310
2008	Sep. 14, 2008	17.4	5,050
2009	May. 27, 2009	15.82	4,170
2010	Oct. 30, 2009	13.36	2,940
2011	Jun. 26, 2011	16.04	4,290

Adapted from : USGS, 2012

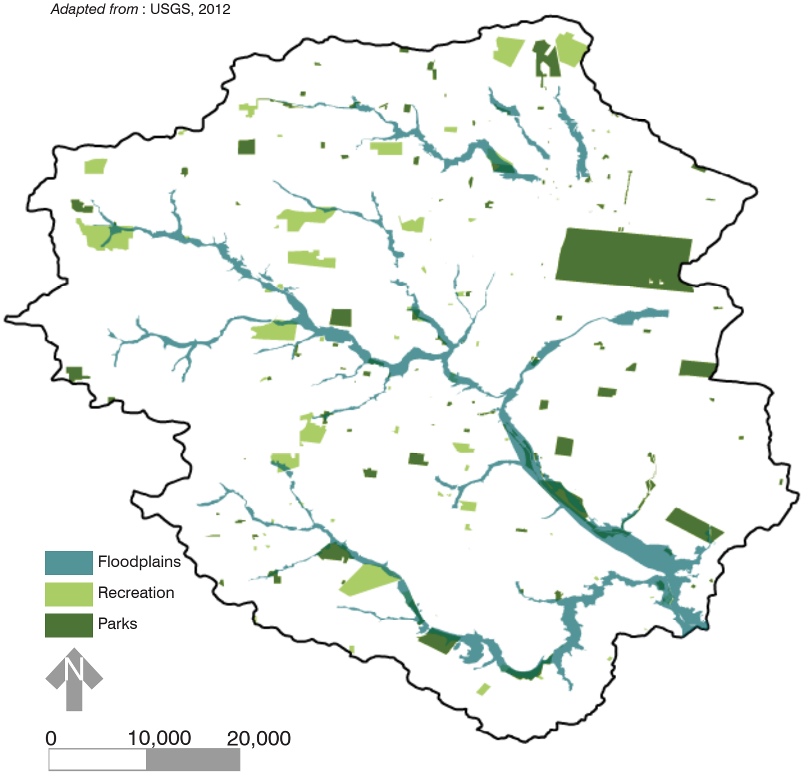


Figure 3.10 Floodplains and Recreational Areas

1.5 year return frequency flow is 3,200 cfs. Using the 1.5 year return frequency flow is important because it is the average recurrence interval at bankfull discharge. By using the 1.5 year return frequency flow a river channel can correctly be designed to contain the bankfull discharge.

FLOODPLAINS AND RIPARIAN VEGETATION

Re-introducing the floodplain back into the stream system is one way of increasing flood storage in urban areas during rain events. A floodplain is a flat area of land adjacent to a stream that periodically floods during rain events. A functioning floodplain will usually flood every 1.5 years. Figure 3.10 shows the parks and recreational lands in relation to the floodplains. Parks are useful in planning wet meadow and flood storage locations due to their open space and effectiveness as educational space.

Currently the River des Peres watershed has three types of wetlands: freshwater emergent, freshwater forested and shrub, and riverine. Less than two acres of emergent wetland and freshwater forested/ shrub, and 132 acres of riverine are present in the River des Peres Watershed. Emergent wetlands are characteristic of herbaceous species and are present during the spring. Freshwater forested and shrub wetlands are characteristic of broad-leaf deciduous vegetation.

STORMWATER BMP SUITABILITY

Green Streets

Increased impervious surfaces as a result of urbanization increase runoff from rain events. “Public streets and roads cover up to one-third of the land area in our urban landscapes. While streets are efficient conveyors of traffic, they are equally efficient at conveying high volumes of pollutants that are deposited directly into streams and other water bodies”

(Metropolitan Service District, 2002).

Using the excess land between the roadway and a developed parcel, the right-of-way or public throughway can be implemented with a stormwater BMP. Throughout the River des Peres watershed, as shown in figure 3.11, there are 2,381 acres of potential public throughways that could be implemented with stormwater BMPs.

A "green street", as shown in figure 3.12, is a street designed to treat and filter stormwater runoff from roadways and houses with an eight foot minimum. By redirecting stormwater flows through curb cuts into filtering and cleansing basins stormwater entering the rivers and streams directly is minimized. In addition, green streets provide an aesthetic appeal for the community.

Wet Meadows

Parks and institutions in urban areas are key locations for infiltration basins due to their expanse of open space and educational opportunities. Throughout the River des Peres watershed, as shown in figure 3.13, there are 10,385 acres of potential wet meadow location implementations. There are 3,035 acres of park space, 1,778 acres of recreation space, 261 acres of common area, and 5,311 acres of institutional land.

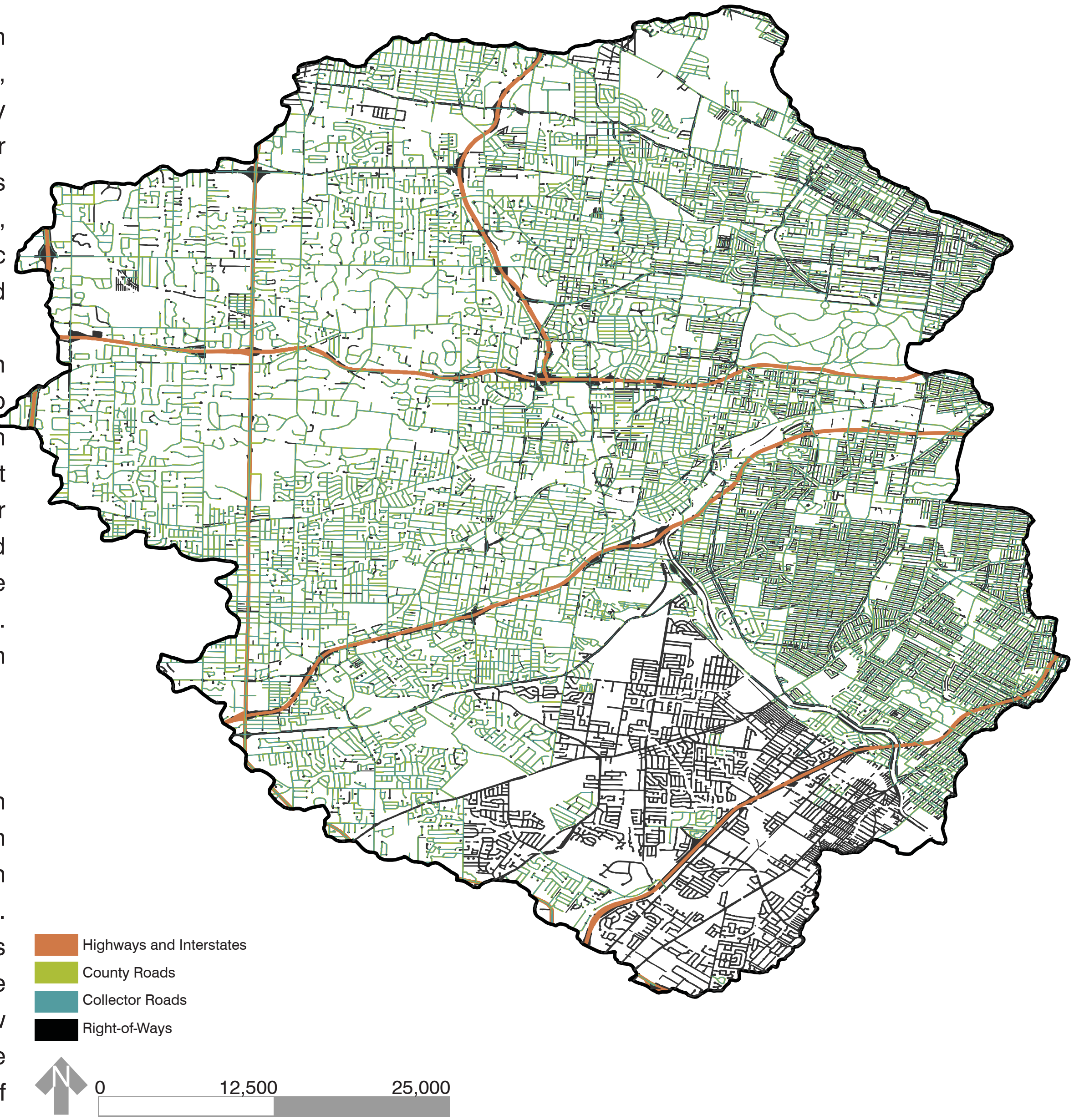
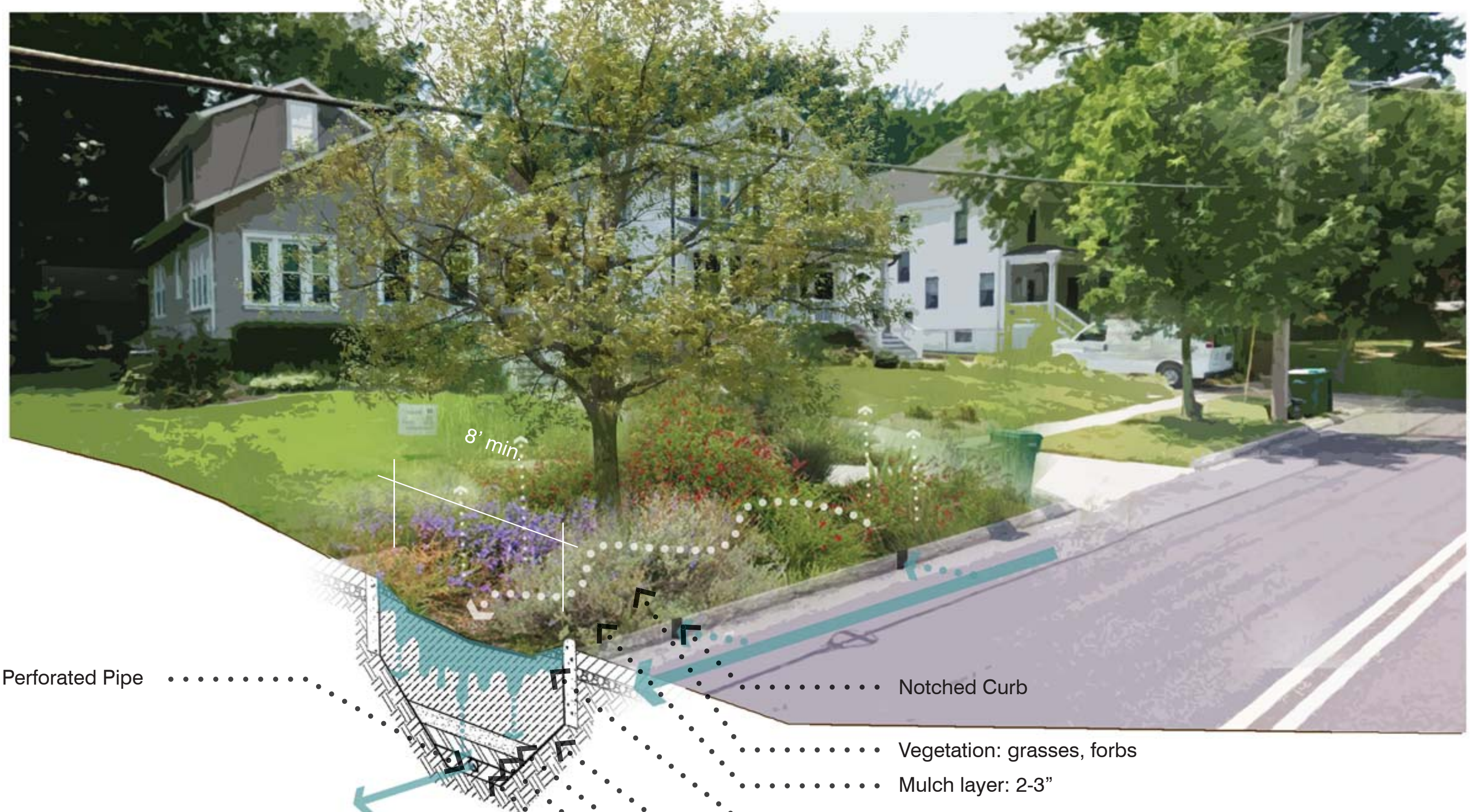


Figure 3.11 Green Street Suitability

"Infiltration basins, or wet meadows, are shallow impound areas with highly permeable soils designed to temporarily detain and infiltrate stormwater runoff. [Infiltration basins] do not retain a permanent pool of water" (UACDC, 2010).

As shown in figure 3.14, infiltration basins mitigate pollutants in stormwater runoff through phytoremediation. Infiltration basins differ from bioswales and green street stormwater BMPs because they can serve a larger developed land area, whereas, stormwater BMPs are commonly used in single applications.



References:
UACDC Low Impact Development: a design manual for urban areas (2010)
MSD Stormwater Best Management Practices (2012)

Figure 3.12 Green Street Stormwater BMP

The locations of stormwater BMPs and wet meadows helped in the creation of total runoff estimations to find reduced flow volumes for the 1.5 year bankfull discharge. These bankfull discharge calculations sought to restore the hydrograph to a pre-development return frequency flow to reduce impacts on ecological services. Using the 1.5 year return frequency flow is important because it is the average recurrence interval at bankfull discharge, and helps in correctly designing a river channel. In order to estimate the total amount of runoff the rational method was used.

The rational method is a calculation used to determine bankfull discharge for a watershed. The rational method equation is Q=ciA, where Q is total runoff, c is the rational method runoff coefficient, i is rainfall intensity (inch per hour), and A is the area in acres of the watershed. For rainfall intensity a 1 hour storm was used with no time of concentration inputted. To calculate total runoff throughout the watershed three sample sites were selected. These 200 acre sites of mainly park, residential, and industrial land uses were overlaid with land cover changes and then stormwater BMPs and wet meadows. These calculations were then inputted to a weighted overlay table and

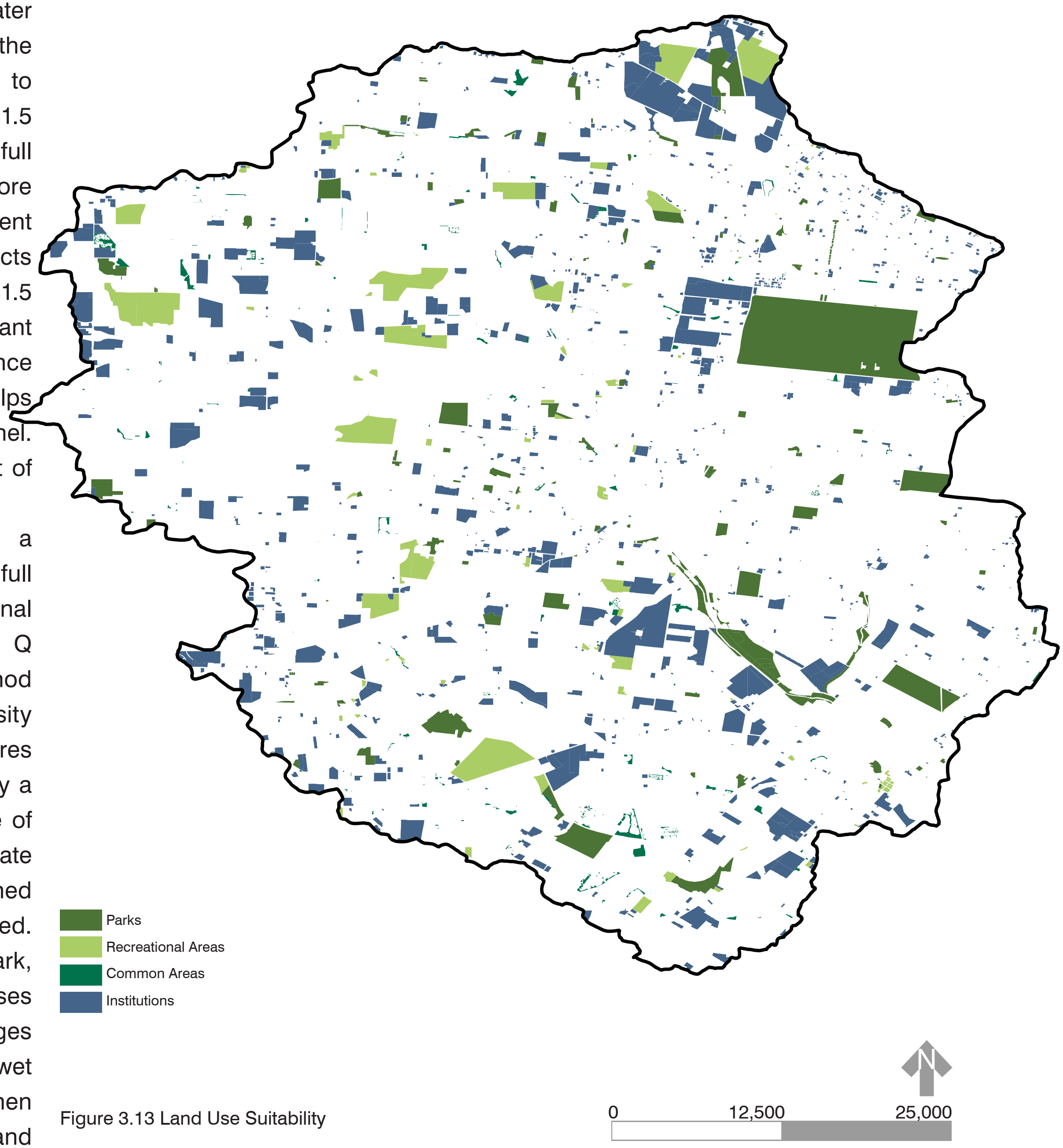


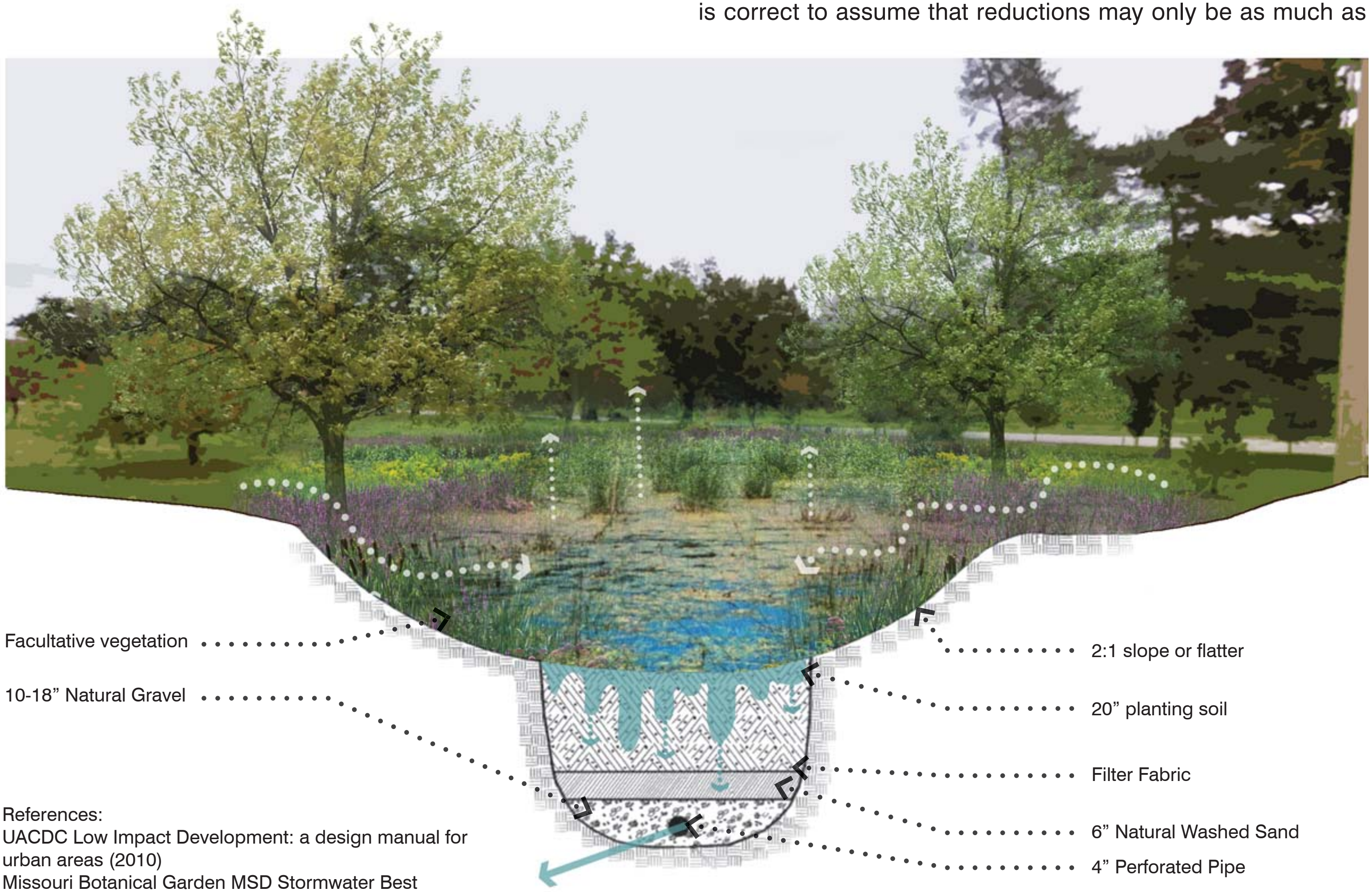
Figure 3.13 Land Use Suitability

extrapolated over the watershed to estimate the total amount of flow reduction in the River des Peres at University City and St. Louis City, Deer Creek, and Gravois Creek.

STORMWATER REDUCTION

Park

Stormwater reduction in a 200 acre park site, such as Forest Park, as shown in figure 3.15, can be reduced up to 90%. This site is optimistic, because most parks are not this scale. It is correct to assume that reductions may only be as much as



References:
UACDC Low Impact Development: a design manual for urban areas (2010)
Missouri Botanical Garden MSD Stormwater Best Management Practices (2012)

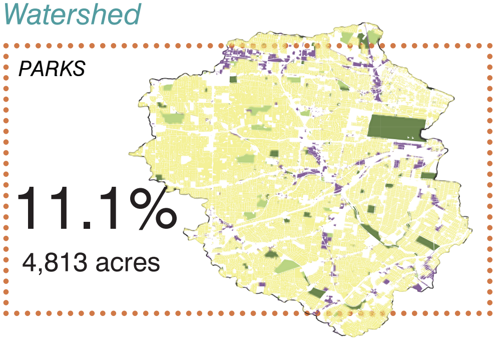
Figure 3.14 Land Use Stormwater BMP

70%. A change in landcover, including, soil, plant material, and impervious surface can reduce stormwater runoff as much as 9.6%. Through the implementation of a wet meadow, all the runoff on site is captured for both the two year and ten year storm, and up to 80% for the 100 year storm, as shown in table 3.6. Over the entire watershed there is approximately 4,813 acres of park space.

Residential

As shown in figure 3.16, stormwater reduction in a 200 acre residential site, such as the Newport Avenue Neighborhood, can be reduced up to 20%. A change in landcover, including, soil, plant material, and impervious surface can reduce stormwater runoff as much as 6.5%. Through the implementation of street stormwater BMPs and a wet meadow located in an open space stormwater runoff can be reduced up to 30% for

Watershed



Location:
Forest Park in St. Louis, MO

Wetland Area Calculations:
Q = Total Runoff
A = Acres
i = inch/hr Rainfall Intensity
c = Rational Method Coefficient
Q = Aic

Figure 3.15 Park Stormwater Reduction Potential

Table 3.6 Park Stormwater Reduction

	2 YEAR STORM	10 YEAR STORM	100 YEAR STORM
EXISTING AREA (0% REDUCTION)	A= 200 i = 1.5 in/hr c= .105 Q= 2.63 acre feet/hr	A= 200 i = 2.5 in/hr c= .105 Q= 4.38 acre feet/hr	A= 200 i = 3.2 in/hr c= .105 Q= 5.60 acre feet/hr
CHANGE IN LAND COVER (9.6%)	A= 200 i = 1.5 in/hr c= .095 Q= 2.38 acre feet/hr	A= 200 i = 2.5 in/hr c= .095 Q= 3.96 acre feet/hr	A= 200 i = 3.2 in/hr c= .095 Q= 5.06 acre feet/hr
IMPLEMENTATION OF STORMWATER BMPS (90% OVERALL)	A= 116,750 ft depth= 1.5 ft V=4.02 acre feet 100% Reduction	A= 116,750 ft depth= 1.5 ft V=4.02 acre feet 100% Reduction	A= 116,750 ft depth= 1.5 ft V=4.02 acre feet 80% Reduction

Location:
Newport Avenue Neighborhood located in Webster Groves, MO

Street BMP Calculations:
V = Volume
l = Length
d = Depth
w = Width
V = ldw

Wetland Area Calculations:
Q = Total Runoff
A = Acres
i = inch/hr Rainfall Intensity
c = Rational Method Coefficient
Q = Aic

Figure 3.16 Residential Stormwater Reduction Potential

Table 3.7 Residential Stormwater Reduction

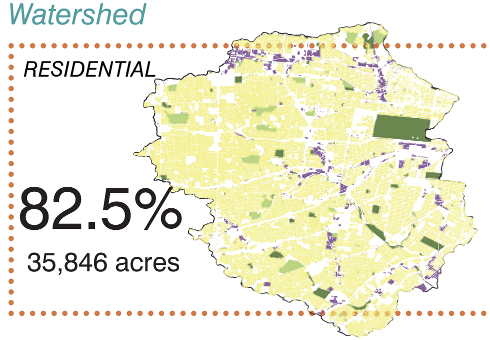
	2 YEAR STORM	10 YEAR STORM	100 YEAR STORM
EXISTING AREA — 0% REDUCTION	A= 200 i = 1.5 in/hr c= .105 Q= 4.88 acre feet/hr	A= 200 i = 2.5 in/hr c= .105 Q= 8.13 acre feet/hr	A= 200 i = 3.2 in/hr c= .105 Q= 10.4 acre feet/hr
CHANGE IN LAND COVER — 6.5%	A= 200 i = 1.5 in/hr c= .095 Q= 4.56 acre feet/hr	A= 200 i = 2.5 in/hr c= .095 Q= 7.60 acre feet/hr	A= 200 i = 3.2 in/hr c= .095 Q= 9.73 acre feet/hr
IMPLEMENTATION OF STORMWATER BMPS — 20% OVERALL	A= 19,000 ft -1.5 ft depth L= 5,200 ft - 1.5 ft depth - 4 ft width V=1.37 acre feet 30% Reduction	A= 19,000 ft -1.5 ft depth L= 5,200 ft - 1.5 ft depth - 4 ft width V=1.37 acre feet 18% Reduction	A= 19,000 ft -1.5 ft depth L= 5,200 ft - 1.5 ft depth - 4 ft width V=1.37 acre feet 14% Reduction

the two year storm, 18% for the ten year storm, and 14% for the 100 year storm, as shown in table 3.7. Over the entire watershed there is approximately 35,856 acres of residential land.

Industrial

As shown in figure 3.16, stormwater reduction in a 200 acre residential site, such as the Newport Avenue Neighborhood, can be reduced up to 20%. A change in landcover, including, soil, plant material, and impervious surface can reduce stormwater runoff as much as 6.5%. Through the implementation of street stormwater BMPs and a wet meadow located in an open space stormwater runoff can be reduced up to 30% for the two year storm, 18% for the ten year storm, and 14% for the 100 year storm, as shown in table 3.7. Over the entire watershed there is approximately 35,856 acres of residential land.

Watershed



Weighted Overlay

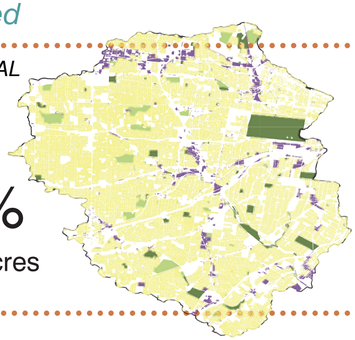
The weighted overlay table is broken down into 4 watersheds to correctly estimate the amount of runoff reduction that occurred within each Individual watershed drainage area through stormwater BMP and wet meadow implementation. Each drainage area has varying percentages of park, residential and industrial land use. In addition individual drainage area return frequency flows vary from the headwaters of Deer Creek to the mouth of the River des Peres.

As shown in table 3.9, with 4.3% park land, 40.2% residential, and 3.8% industrial land, the 1.5 year return frequency flow for the River des Peres at St. Louis can be reduced up to 59% through the implementation of stormwater BMPs and wet meadows. Therefore, the bankfull discharge is reduced from 9,200 cfs to 3,722 cfs.

With 21% park land, 29.4%

Watershed

INDUSTRIAL



6.4%

2,763 acres

Figure 3.17 Industrial Stormwater Reduction Potential

Location:
South Hanley Road Industrial Area near Strassner Drive located in Maplewood, MO

Street BMP Calculations:
V = Volume
l = Length
d = Depth
w = Width
V = ldw

Wetland Area Calculations:
Q = Total Runoff
A = Acres
i = inch/hr Rainfall Intensity
c = Rational Method Coefficient
Q = Aic

Table 3.8 Industrial Stormwater Reduction

EXISTING AREA — *REDUCTION* 0%

2 YEAR STORM	*10 YEAR STORM*	*100 YEAR STORM*
A= 200 i = 1.5 in/hr c= .105 Q= 8.63 acre feet/hr	A= 200 i = 2.5 in/hr c= .105 Q= 14.37 acre feet/hr	A= 200 i = 3.2 in/hr c= .105 Q= 18.4 acre feet/hr

CHANGE IN LAND COVER — 5.1%

2 YEAR STORM	*10 YEAR STORM*	*100 YEAR STORM*
A= 200 i = 1.5 in/hr c= .095 Q= 8.19 acre feet/hr	A= 200 i = 2.5 in/hr c= .095 Q= 13.65 acre feet/hr	A= 200 i = 3.2 in/hr c= .095 Q= 17.46 acre feet/hr

IMPLEMENTATION OF STORMWATER BMPS — 40% *OVERALL*

2 YEAR STORM	*10 YEAR STORM*	*100 YEAR STORM*
A= 150,400 ft -1.5 ft depth L= 8,600 ft - 1.5 ft depth - 4 ft width V=4.65 acre feet 57% Reduction	A= 150,400 ft -1.5 ft depth L= 8,600 ft - 1.5 ft depth - 4 ft width V=4.65 acre feet 34% Reduction	A= 150,400 ft -1.5 ft depth L= 8,600 ft - 1.5 ft depth - 4 ft width V=4.65 acre feet 27% Reduction

Table 3.9 Overall Weighted Stormwater Reduction

EXISTING PEAK STREAM FLOWS

LAND USE TYPES	RDP AT ST. LOUIS	RDP AT UNIVERSITY CITY	DEER CREEK AT LADUE	GRAVOIS CREEK
	Peak Flow- 9,200 cfs	Peak Flow- 3,000 cfs	Peak Flow- 4,690 cfs	Peak Flow- 3,200 cfs
PARK	2 year- 11.31 cfs 10 Year- 18.83 cfs 100 Year- 24.08 cfs	2 year- 55.06 cfs 10 Year- 91.70 cfs 100 Year- 117.24 cfs	2 year- 15.60 cfs 10 Year- 25.97 cfs 100 Year- 33.21 cfs	2 year- 9.42 cfs 10 Year- 15.68 cfs 100 Year- 20.05 cfs
RESIDENTIAL	2 year- 196.32 cfs 10 Year- 327.07 cfs 100 Year- 418.39 cfs	2 year- 143.35 cfs 10 Year- 238.82 cfs 100 Year- 305.50 cfs	2 year- 349.51 cfs 10 Year- 582.27 cfs 100 Year- 744.85 cfs	2 year- 185.46 cfs 10 Year- 308.98 cfs 100 Year- 395.25 cfs
INDUSTRIAL	2 year- 32.84 cfs 10 Year- 54.68 cfs 100 Year- 70.01 cfs	2 year- 46.08 cfs 10 Year- 76.74 cfs 100 Year- 98.26 cfs	2 year- 20.54 cfs 10 Year- 34.20 cfs 100 Year- 43.80 cfs	2 year- 19.76 cfs 10 Year- 32.91 cfs 100 Year- 42.14 cfs
	0% REDUCTION	0% REDUCTION	0% REDUCTION	0% REDUCTION

CHANGE IN LAND COVER

LAND USE TYPES	RDP AT ST. LOUIS	RDP AT UNIVERSITY CITY	DEER CREEK AT LADUE	GRAVOIS CREEK
PARK	2 year- 11.31 cfs 10 Year- 18.83 cfs 100 Year- 24.08 cfs	2 year- 49.84 cfs 10 Year- 82.92 cfs 100 Year- 105.96 cfs	2 year- 14.11 cfs 10 Year- 23.48 cfs 100 Year- 30.01 cfs	2 year- 8.52 cfs 10 Year- 14.18 cfs 100 Year- 18.11 cfs
RESIDENTIAL	2 year- 196.32 cfs 10 Year- 327.07 cfs 100 Year- 418.39 cfs	2 year- 133.95 cfs 10 Year- 223.25 cfs 100 Year- 285.82 cfs	2 year- 326.59 cfs 10 Year- 544.31 cfs 100 Year- 696.86 cfs	2 year- 173.3 cfs 10 Year- 288.84 cfs 100 Year- 369.79 cfs
INDUSTRIAL	2 year- 31.16 cfs 10 Year- 51.94 cfs 100 Year- 66.44 cfs	2 year- 43.73 cfs 10 Year- 72.89 cfs 100 Year- 93.24 cfs	2 year- 19.49 cfs 10 Year- 32.49 cfs 100 Year- 41.55 cfs	2 year- 18.76 cfs 10 Year- 31.26 cfs 100 Year- 39.98 cfs
	6.5% OVERALL	7.0% OVERALL	6.6% OVERALL	6.5% OVERALL

IMPLEMENTATION OF STORMWATER BMPS

LAND USE TYPES	RDP AT ST. LOUIS	RDP AT UNIVERSITY CITY	DEER CREEK AT LADUE	GRAVOIS CREEK
PARK	2 year- 0 cfs 10 Year- 0 cfs 100 Year- 4.47 cfs	2 year- 0 cfs 10 Year- 0 cfs 100 Year- 21.78 cfs	2 year- 0 cfs 10 Year- 0 cfs 100 Year- 6.17 cfs	2 year- 0 cfs 10 Year- 0 cfs 100 Year- 3.72 cfs
RESIDENTIAL	2 year- 128.33 cfs 10 Year- 250.63 cfs 100 Year- 336.32 cfs	2 year- 93.71 cfs 10 Year- 183.01 cfs 100 Year- 245.58 cfs	2 year- 228.47 cfs 10 Year- 446.19 cfs 100 Year- 598.74 cfs	2 year- 121.24 cfs 10 Year- 236.77 cfs 100 Year- 317.72 cfs
INDUSTRIAL	2 year- 13.47 cfs 10 Year- 34.25 cfs 100 Year- 48.74 cfs	2 year- 18.90 cfs 10 Year- 48.06 cfs 100 Year- 68.89 cfs	2 year- 8.43 cfs 10 Year- 21.42 cfs 100 Year- 30.49 cfs	2 year- 8.12 cfs 10 Year- 20.61 cfs 100 Year- 29.33 cfs
	59% OVERALL	46% OVERALL	61% OVERALL	60% OVERALL
	Reduced Flow- 3,772 cfs	Reduced Flow- 1,620 cfs	Reduced Flow- 1,829 cfs	Reduced Flow- 1,280 cfs

residential, and 5.3% industrial land, the 1.5 year return frequency flow for the River des Peres at University City can be reduced up to 46% through the implementation of stormwater BMPs and wet meadows. Therefore, the bankfull discharge is reduced from 3,000 cfs to 1,620 cfs.

With 6% park land, 71.6% residential, and 2.4% industrial land, the 1.5 year return frequency flow for the Deer Creek at Ladue can be reduced up to 61% through the implementation of stormwater BMPs and wet meadows. Therefore, the bankfull discharge is reduced from 4,690 cfs to 1,829 cfs.

With 3.6% park land, 38% residential, and 2.3% industrial land, the 1.5 year return frequency flow for the Gravois Creek near Mehlville can be reduced up to 60% through the implementation of stormwater BMPs and wet meadows. Therefore, the bankfull discharge is reduced from 3,200 cfs to 1,280 cfs.

The stormwater reductions for each creek and river were then applied to the river channel designs located in each of the project site locations. Along with the River des Peres Watershed Coalition these project sites were chosen due to the level of channel restoration required, surrounding land use, differences in scale, and stakeholders. Site data was accumulated from the River des Peres Watershed Coalition, the Federal Emergency Management Agency, the Metropolitan St. Louis Sewer District, the County of St. Louis, St. Louis University, the Great Rivers Greenway, DG//RE Studio, and the Missouri Department of Transportation (MODOT).

PROJECT SITE LOCATIONS

Forest Park

Forest Park, as shown in figure 3.18, is a public recreational area located to the west of the City of St. Louis, Missouri. "At 1,293 acres, it is approximately 500 acres larger than Central Park in New York" (City of St. Louis, 2012). The park is "home to the region's major cultural institutions—the Zoo, Art Museum, History Museum, Science Center and the Muny Opera as shown in figure 3.19 and 3.20. It also serves as a sports center for golf, tennis, baseball, bicycling, boating, fishing, handball, ice skating, roller blading, jogging, rugby and more" (City of St. Louis, 2012). As one of the largest cities in the United States, St. Louis's Forest Park became the site of the 1904 World's Fair. During the early 1900's the River des Peres flowed through the upper-middle portion of Forest Park, but was more an open sewer than a river. When the World's Fair location was selected plans were made to remove the sewer from Forest Park. "One remedy was the enclosure of a portion of the western end of the channel within a large wooden box. At the eastern end of the river, bends in the stream were cut off. The channel was also altered by subdivision developments and railroad/rail yard construction to the north and south of Forest Park" (Metropolitan St. Louis Sewer District, 1988, 3). Eventually the river was placed underground in concrete "tubes" or culverts from Skinker Boulevard to Macklind Avenue (figure 3.21).

Today a man-made waterscape, as shown in figure 3.22, exists where the River des Peres would have flowed due to a "plan to integrate the Park's natural and man-made systems into a cohesive and mutually beneficial ecosystem" (Forest Park Forever, 2012). The planners created "a 'flowing, riverlike water system' that [mimics] the original river's route, avoiding 'straight lines and unnatural or tight curves' and flowing down cascades, over spillways and through restored wetlands" (Batz, 2000). The reason the river still runs below and not as a part of the "natural" waterscape is because "water quality couldn't be guaranteed safe for 'whole body contact'" (Batz, 2000). Since Forest Park is located in the headwaters of

Figure 3.18 Forest Park Area of Opportunity

the River des Peres, day-lighting the water into the park helps to accomplish three goals mentioned in my thesis:

- *Lower the flood frequency rate of the river through the inclusion of stormwater BMPs.*
- *Enhancement of wildlife habitat by the inclusion of native fauna and flora through the re-vegetation of the stream bank, stormwater BMPs, and wet meadows.*
- *Fix the infrastructural performance problems of the site.*

Forest Park Site Inventory and Analysis

Based upon the suitability of stormwater BMPs throughout the watershed, there is a 59% reduction in overall peak flow volume. The current flow volume through the River des Peres at University City, MO is around 3,000 cfs. Through the inclusion of stormwater BMPs and wet meadows the peak flow volume is reduced to 1,620 cfs. Currently, the City of St. Louis's water department pumps 3.5 million gallons (5.4 cfs) of water into Forest Park daily. During rain events additional stormwater runoff from buildings and parking lots onsite enter the waterscape and combined with the city water is re-circulated through the system. Water is re-circulated and pumped through due to the elevations across the site.

By day-lighting the River des Peres into the existing waterscape, widening the channel, and increasing the water-holding capacity flooding can be reduced downstream. In addition, by increasing the water holding capacity within Forest Park water can be cleansed and filtered, while additional stormwater runoff can be stored from the surrounding residential neighborhoods.

Analysis of the land cover data collected from National Gap Analysis Program (GAP), a majority of wildlife (table 3.10) within St. Louis inhabit Forest Park. The parks current wetland and tall grass vegetation cater toward a variety of reptiles, amphibians, mammals, and birds.

Figure 3.19 Forest Park Attractions

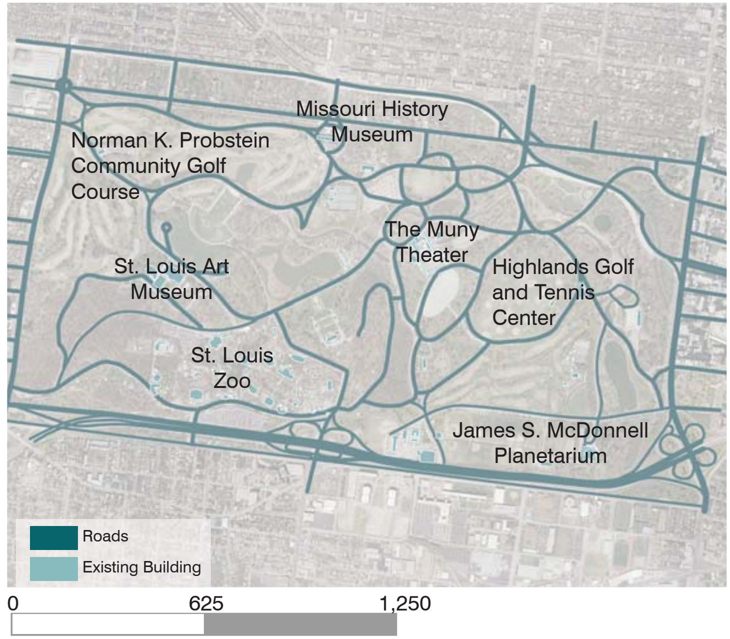


Figure 3.20 Forest Park Buildings, Parking Lots, and Roads

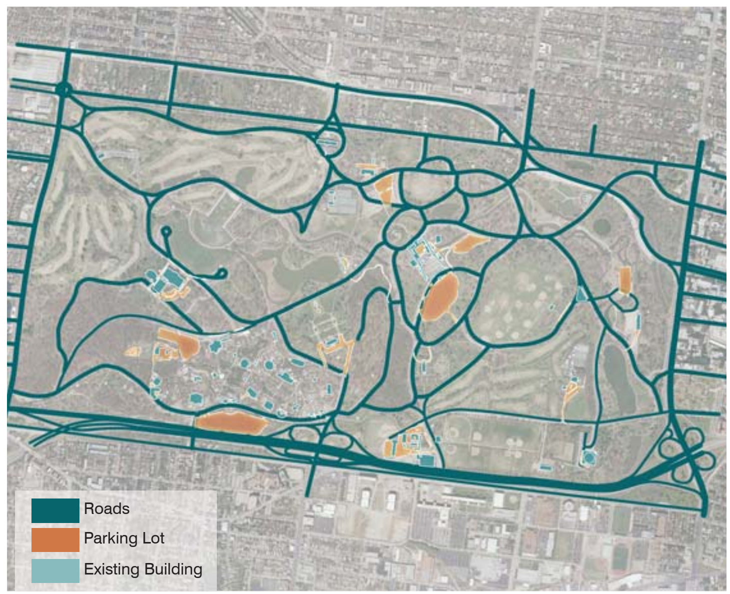


Figure 3.21 Forest Park Sewer Locations

Figure 3.22 Forest Park Waterscape

Table 3.10 Forest Park Wildlife *-Based Upon Landcover*

Reptiles:
Broadhead Skink
Brown Rat Snake
Bull Snake
Common Garter Snake
Eastern Hognose Snake
False Map Turtle
Graham's Crayfish Snake
Great Plains Rat Snake
Midland Brown Snake
Midland Water Snake
Northern Water Snake
Ornate Box Turtle
Prairie King Snake
Red-eared Slider Turtle
Red Milk Snake
Rough Green Snake
Slender Glass Lizard
Snapping Turtle
Three-toed Box Turtle
Western Earth Snake
Western Painted Turtle
Western Ribbon Turtle
Western Worm Snake

Amphibians:
Blanchard's Cricket Frog
Bull Frog
Bronze Frog
Central Newt
Dwarf American Toad
American Toad
Fowler's Toad
Graybell's Salamander
Green Frog
Gray Tree Grog
Marbled Salamander
Mudpuppy
Pickerel Frog
Southern Leopard Grog
Smallmouth Salamander
Tiger Salamander
Western Chorus Frog

Mammals:
Common Gray Fox
Eastern Cottontail
Gray Bat
Indiana Bat
Little Brown Bat
Least Shrew
Marsh Rice Rat
Meadow Jumping Mouse
Mink
Muskrat
Southern Bog Lemming
Townsend's Big-eared Bat

Birds:
American Bittern
American Coot
American Crow
American Goldfinch
Belted Kingfisher
Blue Jay
Blue-winged Teal
Brown Thrasher
Canada Goose
Chipping Sparrow
Common Grackle
Eastern Kingbird
Field Sparrow
Gray Catbird
Great Blue Heron
Great Horned Owl
House Sparrow
Killdeer
Least Bittern
Mallard
Northern Cardinal
Northern Parula
Orchard Oriole
Osprey
Pied-billed Grebe
Red-winged Black Bird
Summer Tanager
Tricolored Heron
Virginia Rail

Wilson Avenue and Drexel Drive

As shown in figure 3.23, the second location is along Wilson Avenue and Drexel Drive in University City, where the city bought 26 homes that were located in the headwater floodplains of the River des Peres.

"On September 14 2008, flash flooding of the River Des Peres severely damaged over 100 University City residences. A federal disaster was subsequently declared, providing the mechanism necessary for the City to apply for federal disaster relief funds. In August of 2010 the Federal Emergency Management Agency (FEMA) awarded a $3 million grant to University City to acquire twenty-six residents in the floodplain" (University City, 2012).

As of today the 26 homes acquired by the city have been removed and the land cleared. However, there are two houses still left on the northern portion of the site. The long linear site runs parallel to the River des Peres, and has the opportunity to reconnect the floodplain to the river, and increase flood storage capacity through open space use. The River des Peres along the site is slightly channelized and lined with concrete blocks on both sides. The river has the potential to become more naturalized through stream restoration.

Since Wilson Ave and Drexel Drive are located in the headwaters of the River des Peres, restoring the river and implementing stormwater BMPs will help to accomplish four goals mentioned in my thesis:

- *Lower the flood frequency rate of the river through the inclusion of stormwater BMPs.*
- *Enhancement of wildlife habitat by the inclusion of native fauna and flora through the re-vegetation of the stream bank, stormwater BMPs, and wet meadows.*
- *Fix the infrastructural performance problem of the site, including, stormwater and sanitary overflows.*
- *Encourage growth in areas damaged by previous engineering projects.*

Figure 3.23 Wilson Avenue and Drexel Drive Area of Opportunity

Wilson Avenue and Drexel Drive Site Inventory and Analysis

Due to development the elevations surrounding the river are higher, or built-up, as shown in figure 3.24, but are still within the 100-year floodplain. As shown in figure 3.25, roads and residential houses are built along both sides of the river, removing the floodplain function of the river. There is an opportunity to create flood storage in the southern portion of the site where there is large open space. In figure 3.26, the existing soil is a fine loam that is somewhat poorly drained intermixed with an urban soil mixture that is poorly drained. Stormwater sewers from housing and roadways, as shown in figure 3.27, are piped into the river increasing flood waters during rain events, by implementing a wetland, water can be slowed, filtered, and then cleansed before it reaches the river. The wetland can also store water during heavy rain events. The open lot transformed into a wetland has the potential to foster education, spiritual enrichment, and aesthetic experience.

The current flow volume through the River des Peres at University City, MO is around 3,000 cfs. Through the inclusion of stormwater BMPs the peak flow volume is reduced by 46%. By lowering the flow volume of the river, the river bank has the opportunity to become more naturalized through the removal of the concrete blocks, re-vegetation, and the re-establishment of the floodplain.

Analysis of the land cover data collected from National Gap Analysis Program (GAP) shows a low number of wildlife (table 3.11) within St. Louis City inhabit this area. Increasing vegetation and introducing native riparian species has the potential to increase wildlife habitat, thus, increasing wildlife numbers and human well-being.

Figure 3.24 Wilson Avenue and Drexel Drive Contours

Figure 3.25 Wilson Avenue and Drexel Drive Buildings, Parking Lots and Roads

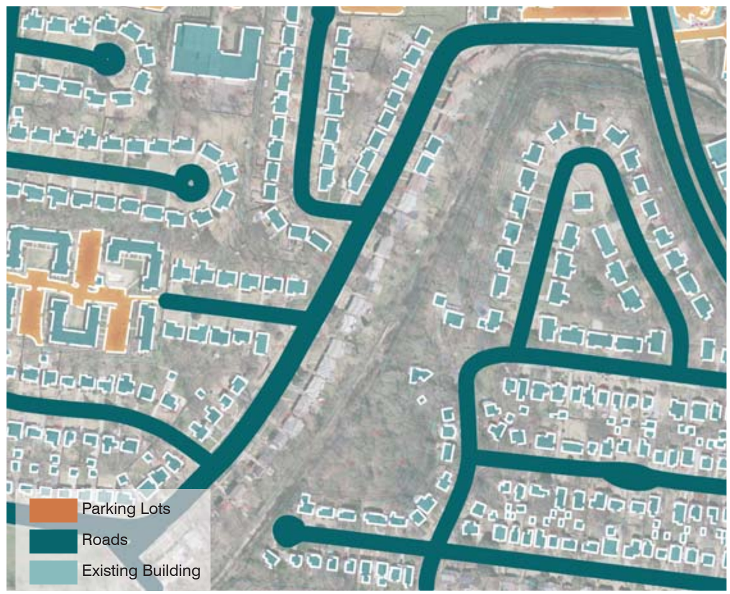


Figure 3.26 Wilson Avenue and Drexel Drive Soil and Drainage

Figure 3.27 Wilson Avenue and Drexel Drive Sewer Locations

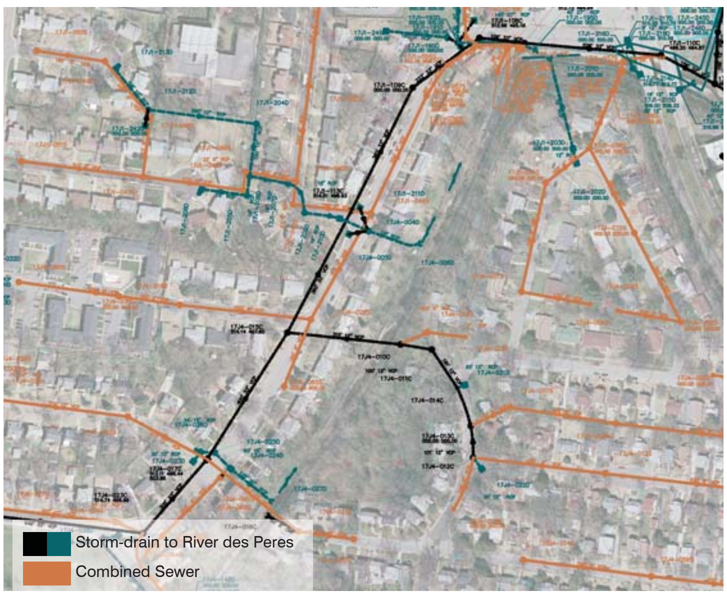


Table 3.11 Wilson Avenue and Drexel Drive Wildlife *-Based Upon Landcover*

Reptiles:
Broadhead Skink
Brown Rat Snake
Bull Snake
Common Garter Snake
Common Map Turtle
False Map Turtle
Graham's Crayfish Snake
Great Plains Rat Snake
Midland Brown Snake
Mississippi Map Turtle
Midland Water Snake
Northern Water Snake
Ornate Box Turtle
Prairie King Snake
Red Milk Snake
River Cooter Turtle
Slender Glass Lizard
Smooth Soft Shell Turtle
Snapping Turtle
Western Earth Snake
Western Painted Turtle
Western Ribbon Turtle
Western Worm Snake

Amphibians:
Blanchard's Cricket Frog
Bull Frog
Fowler's Toad
Green Frog
Green Tree Frog
Gray Tree Grog
Mudpuppy
Central Newt
Southern Leopard Grog
Smallmouth Salamander
Tiger Salamander
Western Chorus Frog

Mammals:
Eastern Cottontail
Common Gray Fox
Little Brown Bat
Mink

Birds:
American Crow
American Goldfinch
American Woodcock
Belted Kingfisher
Blue Jay
Brown Thrasher
Field Sparrow
Great Blue Heron
House Sparrow
Northern Cardinal
Orchard Oriole
Pileated Woodpecker
Red-headed Woodpecker
Summer Tanager
Tricolored Heron

Deer Creek Park and South County Connector

As shown in figure 3.28, the third location is at Deer Creek Shopping Center where the Missouri Department of Transportation (MODOT) would like to implement a South County Connector highway. The South County Connector is to provide better north-south access and connectivity through the St. Louis County suburbs. The connector is to also improve "access to Interstates 44, 64, 55, and 170" (Hicks, 2012).

"The project area is generally bounded by Manchester Road to the north, Hanley Road and Laclede Station Road to I-44 to the west, Murdoch Avenue and Watson Road to the South and Big Bend Boulevard and River Des Peres to the east. The study area includes Maplewood, Webster Groves, Shrewsbury, and southern/ southwestern portions of the City of St. Louis. The SCC could also impact travel to and from additional areas, including Brentwood, Richmond Heights, and Clayton" (Hicks, 2012).

A route that the South County Connector may take is "from Hanley and Manchester south through Maplewood staying north of Deer Creek, through Deer Creek Center across Big Bend through recycle plant, then through Maplewood and connect there at I-44" (Hicks, 2012). Due to the close proximity to Deer Creek, which is within the more "naturalized" portion of the River des Peres watershed there is an opportunity to implement stormwater BMPs. Strategic stormwater BMP and highway implementation can reduce the impact on the stream, which would otherwise cause changes in water flow velocity, stream bank erosion, and depositional patterns.

Since Deer Creek is located in the headwaters of the River des Peres, implementing stormwater BMPs will help to accomplish three goals mentioned in my thesis:

- *Lower the flood frequency rate of the River through the inclusion of stormwater BMPs.*
- *Enhancement of wildlife habitat by the inclusion of native fauna and flora through the re-vegetation of the stream bank, stormwater BMPs, and wet meadows.*
- *Fix the infrastructural performance problem of the site, including, stormwater and sanitary overflows*

Figure 3.28 Deer Creek and South County Connector Area of Opportunity

Deer Creek Park and South County Connector Site Inventory and Analysis

The newly renovated Deer Creek Shopping Center, as shown in figure 3.29, exists where the South County Connector will potentially be constructed. The shopping center is not frequented by the community, thus, vacancies are a continuing problem for the center. The site has a huge concrete parking lot running parallel to Deer Creek, as shown in figure 3.30. The large parking lot removes the floodplain from the river, increasing the amount of stormwater runoff during rain events. Increased stormwater entering the creek could be one of the many causes of bank erosion, as shown in figure 3.31, causing the creek to have steep banks along both sides. By accommodating runoff from a large impervious area, such as a highway, can minimize flooding, and reduce environmental impacts to river systems. The soil onsite is poorly drained (figure 3.32), and has the potential to be implemented with stormwater BMPs and wetlands.

The current flow volume through Deer Creek at Ladue, MO is 4,690 cfs. Through the inclusion of stormwater BMPs the peak flow volume is reduced by 61%. By lowering the peak flow volume of the river, the adjacent land to the river has the opportunity to become wildlife habitat. Stormwater sewers from housing and roadways, as shown in figure 3.33, are piped into the creek increasing flood waters during rain events, by implementing a bioswale, water can be slowed, filtered, and then cleansed before it reaches the creek.

Analysis of the land cover data collected from National Gap Analysis Program (GAP) shows a low number of wildlife, as shown in table 3.12 within St. Louis City that inhabit the area. Increasing vegetation and introducing wetland species has the potential to increase wildlife habitat, thus, encouraging wildlife to inhabit the area.

Figure 3.29 Deer Creek and South County Connector Businesses

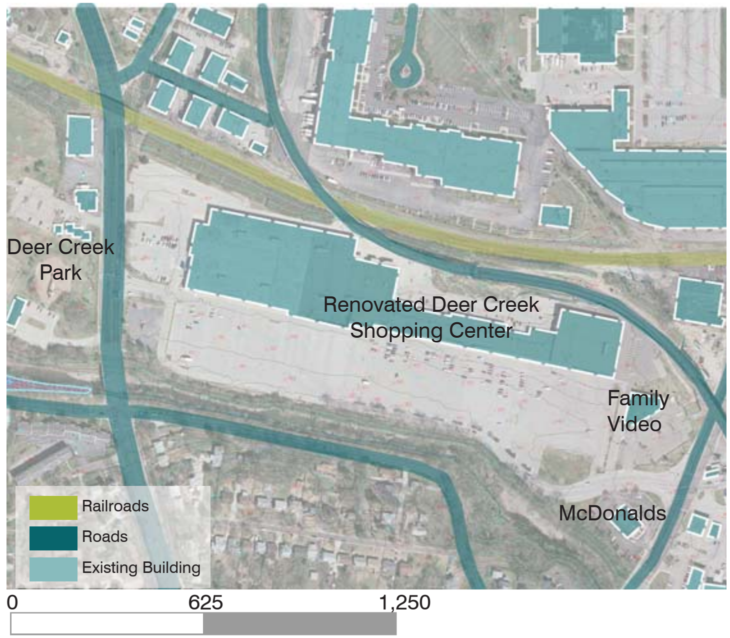


Figure 3.30 Deer Creek and South County Connector Roads and Parking

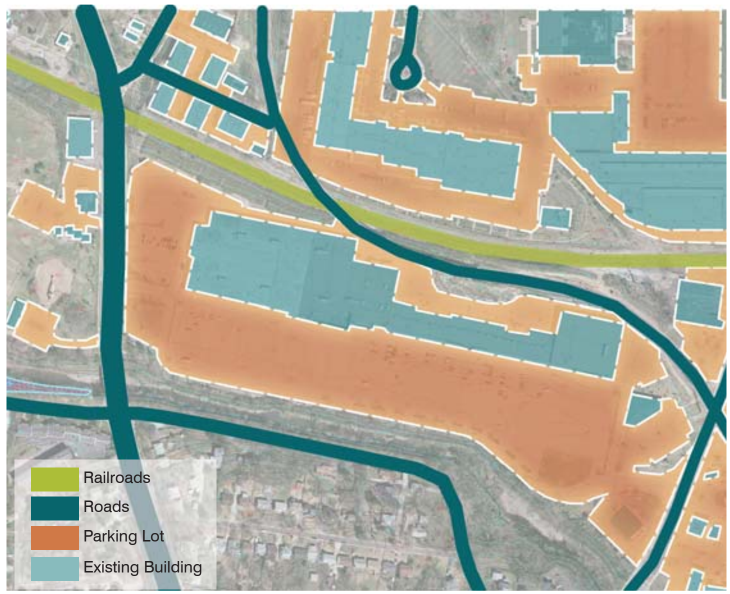


Figure 3.31 Deer Creek and South County Connector Contours

Figure 3.33 Deer Creek and South County Connector Sewer Locations

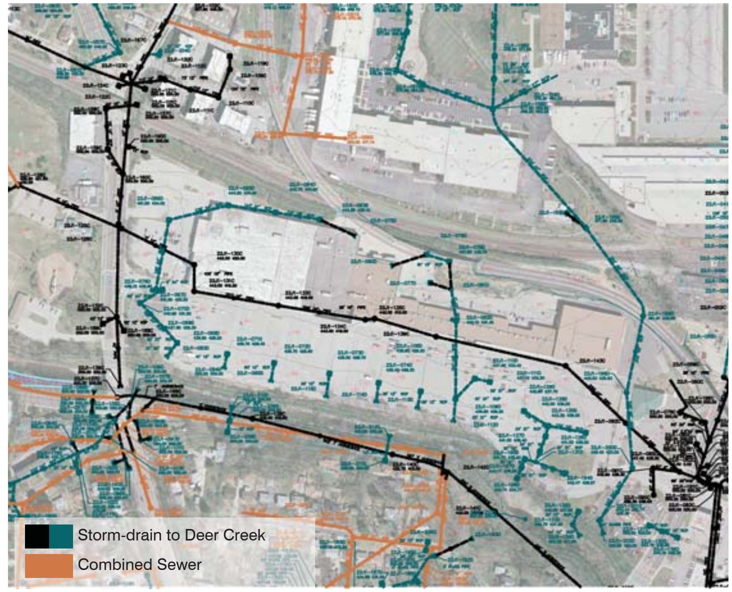


Figure 3.32 Deer Creek and South County Connector Soil and Drainage

Table 3.12 Deer Creek Wildlife *-Based Upon Landcover*

Reptiles:
Broadhead Skink
Brown Rat Snake
Bull Snake
Common Garter Snake
Common Map Turtle
False Map Turtle
Graham's Crayfish Snake
Great Plains Rat Snake
Midland Brown Snake
Mississippi Map Turtle
Midland Water Snake
Northern Water Snake
Ornate Box Turtle
Prairie King Snake
Red Milk Snake
River Cooter Turtle
Slender Glass Lizard
Smooth Soft Shell Turtle
Snapping Turtle
Western Earth Snake
Western Painted Turtle
Western Ribbon Turtle
Western Worm Snake

Amphibians:
Blanchard's Cricket Frog
Bull Frog
Fowler's Toad
Green Frog
Green Tree Frog
Gray Tree Grog
Mudpuppy
Central Newt
Southern Leopard Grog
Smallmouth Salamander
Tiger Salamander
Western Chorus Frog

Mammals:
Eastern Cottontail
Common Gray Fox
Little Brown Bat
Mink

Birds:
American Crow
American Goldfinch
American Woodcock
Belted Kingfisher
Blue Jay
Brown Thrasher
Field Sparrow
Great Blue Heron
House Sparrow
Northern Cardinal
Orchard Oriole
Pileated Woodpecker
Red-headed Woodpecker
Summer Tanager
Tricolored Heron

Grant's Trail Extension

As shown in figure 3.34, the fourth location is near Grant's Trail where the trail will be extended to connect to the River des Peres Greenway. The extension is a part of the Gravois Greenway, developed by the Great Rivers Greenway (GRG), an organization with a mission to "make St. Louis a better place to live while creating an enduring legacy for future generations" (GRG, 2012). GRG is partnering with the architectural firm DG//RE, and Reitz & Jens, a consulting engineering firm, to develop the project. The goal of the Gravois Greenway is to develop a significant connection to the River des Peres Greenway with four primary objectives including (provided by DG//RE):

- *Documenting current conditions*
- *Evaluating a safe connection between the existing trailhead to the proposed trailhead located in Lemay Park*
- *Development of the Greenway System*
- *Development of trail amenities and enhancing neighborhood connections*

Along the trail near Gravois Creek and current trailhead, an old driving range and illegal dump site provides an opportunity to develop a floodplain park. The floodplain park has the prospect to provide a new and safer trailhead, educational opportunities for children, wildlife habitat, and the capacity to store water.

It will also be a destination to the community, giving the surrounding residence something to take pride in. - DG//RE

Since Gravois Creek is located in the headwaters of the River des Peres, implementing a floodplain park will help to accomplish three goals mentioned in my thesis:

- *Lowering the flood frequency rate of the river through the inclusion of stormwater BMPs.*
- *Enhancement of wildlife habitat by the inclusion of native fauna and flora through the re-vegetation of the stream bank, stormwater BMPs, and wet meadows.*
- *Fix the infrastructural performance problems of the site, including, stormwater and sanitary overflows.*

Figure 3.34 Grants Trail Extension Area of Opportunity

Grant's Trail Extension Site Inventory and Analysis

The floodplain park is relatively low in elevation (figure 3.35), and is within the 100 year floodplain of Gravois Creek. Surrounding a majority of the creek are forested areas of Buttonbush, Black Willow, Water Locust, Sycamore, Hackberry, Cottonwood, Elm, and Ash (figure 3.36). The old driving range is a mixture of grasses from its previous use and is impacted by prevailing northwest winter winds. Roads, residential houses and businesses, as shown in figure 3.37, are built along both sides of the river, removing the floodplain function of the river. Existing onsite is an old driveway and foundation where the driving range office used to be. In addition, 30 telephone-sized posts are still in place along the border of the range. As shown in figure 3.38, the existing soil is a fine loam that is somewhat poorly drained intermixed with an urban soil mixture that is poorly drained.

Stormwater sewers from the roadway and surrounding buildings are piped into the river increasing flood waters during rain events (figure 3.39). By implementing bioswales, water can be slowed, filtered, and then cleansed before it enters Gravois Creek. The current flow volume through Gravois Creek near Mehlville, MO is around 3,200 cfs. Through the inclusion of stormwater BMPs the peak flow volume is reduced by 60%, lowering the discharge to 1,280 cfs. By lowering the river bankfull discharge volume, the river bank has the opportunity to become more naturalized through re-vegetation, and the floodplain can be re-established.

Analysis of the land cover data collected from National Gap Analysis Program (GAP) shows a high number of wildlife (table 3.13) within St. Louis City inhabit the area. Including educational signage throughout the park can raise awareness within the community on wildlife and river hydrology.

Figure 3.35 Grants Trail Extension Contours

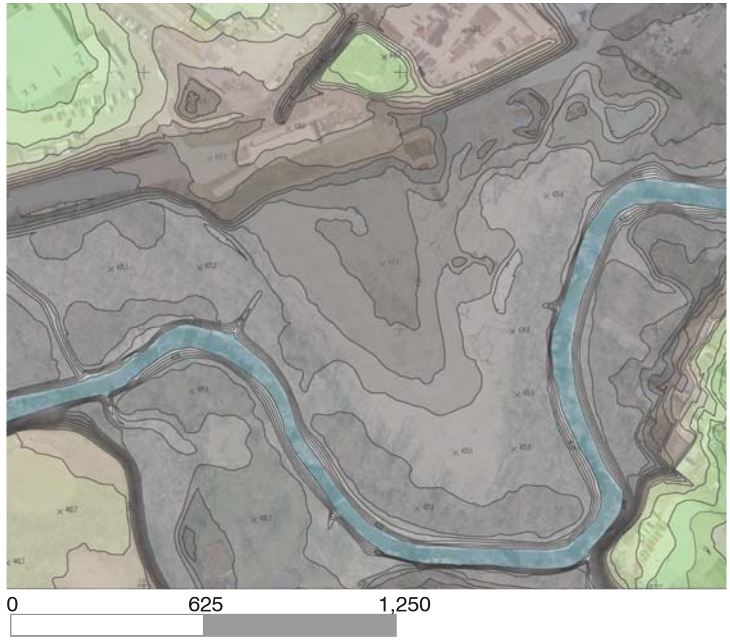


Figure 3.36 Grants Trail Prevailing Winds and Vegetation

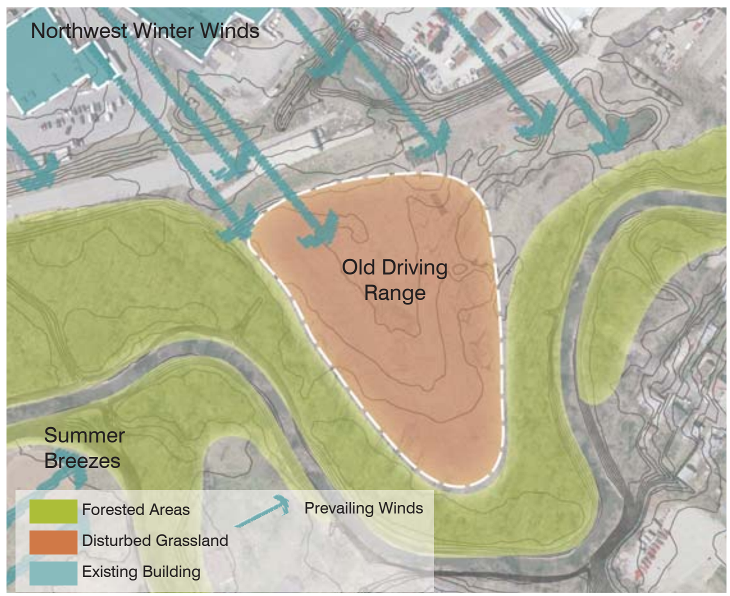


Figure 3.37 Grants Trail Fence Posts and Driveways

Figure 3.39 Grants Trail Sewer Locations

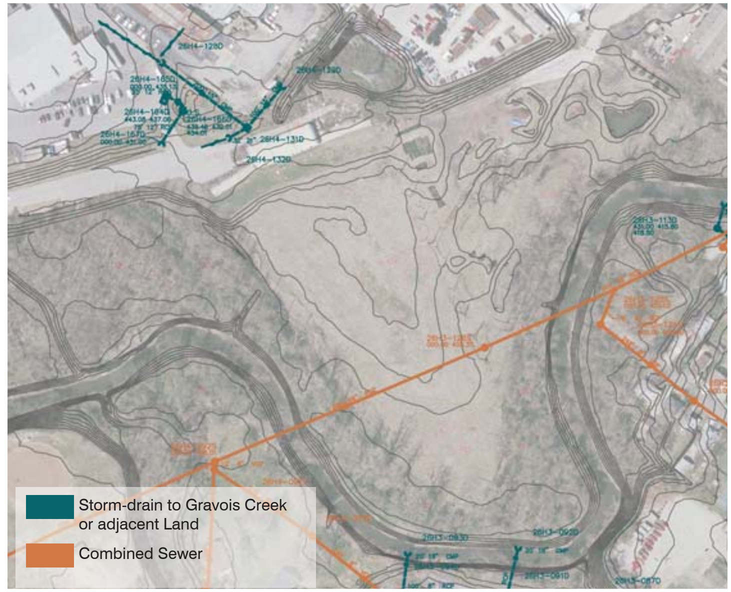


Figure 3.38 Grants Trail Soil and Drainage

Table 3.13 Grants Trail Wildlife *-Based Upon Landcover*

Reptiles:
Broad Banded Water Snake
Broadhead Skink
Brown Rat Snake
Bull Snake
Brown Water Snake
Common Garter Snake
Common Map Turtle
Common Musk Turtle
Eastern Hognose Snake
False Map Turtle
Graham's Crayfish Snake
Great Plains Rat Snake
Midland Brown Snake
Mississippi Map Turtle
Mississippi Mud Turtle
Midland Water Snake
Northern Water Snake
Ornate Box Turtle
Prairie King Snake
Red-eared Slider Turtle
Red Milk Snake
River Cooter Turtle
Rough Green Snake
Slender Glass Lizard
Smooth Soft Shell Turtle
Snapping Turtle
Spiny Softshell Turtle
Western Earth Snake
Western Painted Turtle
Western Ribbon Turtle
Western Worm Snake
Yellowbelly Water Snake

Amphibians:
Blanchard's Cricket Frog
Bull Frog
Bronze Frog
Dwarf American Toad
American Toad
Fowler's Toad
Green Frog
Green Tree Frog
Gray Tree Grog
Marbled Salamander
Mudpuppy
Central Newt
Pickerel Frog
Lesser Siren
Southern Leopard Grog
Smallmouth Salamander
Tiger Salamander
Upland Chorus Frog
Western Chorus Frog

Mammals:
Eastern Cottontail
Common Gray Fox
Little Brown Bat
Least Shrew
Mink
Muskrat

Birds:
American Crow
American Goldfinch
American Woodcock
Barred Owl
Belted Kingfisher
Blue Jay
Brown Thrasher
Carolina Chickadee
Carolina Wren
Common Grackle
Common Yellowthroat
Downy Woodpecker
Field Sparrow
Great Blue Heron
Great Horned Owl
House Sparrow
Killdeer
Mallard
Northern Cardinal
Northern Flicker
Northern Parula
Orchard Oriole
Pied-billed Grebe
Pileated Woodpecker
Red-bellied Woodpecker
Red-headed Woodpecker
Red-shouldered Hawk
Red-winged Black Bird
Summer Tanager
Tricolored Heron
Virginia Rail
Warbling Vireo
White-breasted Nut Hatch
Wood Duck
Wood Thrust
Yellow Warbler
Yellow-throated Warbler

Main Channel of the River des Peres

As shown in figure 3.40, the fifth location is the main channel of the River des Peres at Willmore Park. Willmore Park is a 70 acre strip along the eastern side of the river with roads located along the outer edge. On the opposite site of the park the River des Peres Greenway runs parallel to the river. The main channel of the River des Peres is a phasing project, and will occur after a major reduction in stormwater peak discharge occurs through the implementation of stormwater BMPs, wet meadows, and floodplain reconnection.

Since the main channel of River des Peres is located towards the mouth of the river, near the Mississippi River, the channel holds a high volume of water during rain events. By re-designing the stream channel five goals mentioned in my thesis can be accomplished:

- *Lowering the flood frequency rate of the river through the inclusion of stormwater BMPs.*
- *Enhancement of wildlife habitat by the inclusion of native fauna and flora through the re-vegetation of the stream bank, stormwater BMPs, and wet meadows.*
- *Enhance the local identity of waterway by integrating public art into the inner and middle stream buffer.*
- *Fix the infrastructural performance problems of the site, including, stormwater and sanitary overflows.*
- *Encourage growth in areas damaged by previous engineering projects such as trapezoidal channel lining.*

Main Channel of the River des Peres Site Inventory and Analysis

The river is highly channelized with steep concrete bank slopes, and the floodplain has been removed (figure 3.41). Willmore Park's existing open space includes ponds, picnic grounds, pavilions, playgrounds, and sports grounds, as shown in figure 3.42. Surrounding the park and along the opposite side of the river are housing developments (figure 3.43). The soil within the site, as shown in figure 3.44, is a fine loam that is somewhat poorly drained intermixed with an urban soil mixture that is poorly drained. Poorly drained soils produce an opportunity to implement wet meadows to store stormwater. In figure 3.45, stormwater sewers from the roadway and surrounding housing developments are piped into the river potentially increasing flood waters during rain events, by implementing bioswales and wet meadows along the roadways, water can be slowed, filtered, and then cleansed before it reaches the river. BMP implementation also has the potential to help filter backwater that occurs during heavy rain events from the Mississippi River. In addition, increasing natural vegetation along the river can slow water flows and provide flood storage capacity for the river during heavy rain events.

The current flow volume through the River des Peres at St. Louis, MO is around 9,200 cfs. Through the inclusion of stormwater BMPs the peak flow volume is lowered by 59%, lowering the discharge volume to 3,772 cfs. By lowering the

Figure 3.40 Main Channel Area of Opportunity

flow volume of the river, the river bank has the opportunity to become more naturalized through re-vegetation, and floodplain re-establishment. By re-designing the channel a pedestrian walkway can be implemented along with riparian vegetation and local artwork. According to Noel Fehr of Parsons HBA, "it's perfectly possible to terrace the sides of the channel with native species that can survive underwater. One of their scenarios suggests putting in low-water dams and create a flowing urban waterway, stabilized by living tree walls whose tenacious roots hold the soil in place" (Batz, 2000).

Analysis of the land cover data collected from National Gap Analysis Program (GAP) shows a low number of wildlife (table 3.14) within St. Louis City inhabit the area. Increasing vegetation and introducing native riparian vegetation species has the potential to increase wildlife habitat, thus, increasing wildlife numbers and human well-being.

Figure 3.41 Main Channel Contours

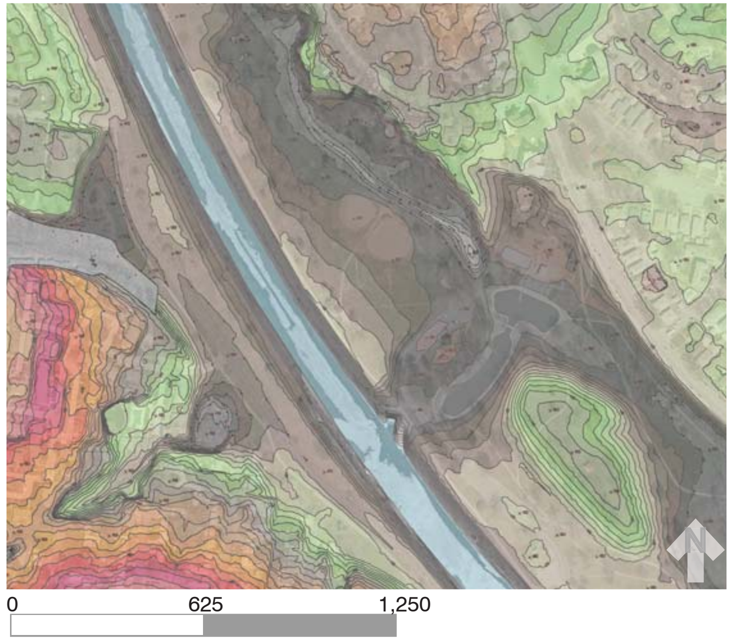


Figure 3.42 Main Channel Attractions

Figure 3.43 Main Channel Buildings, Parking Lots, and Roads

Figure 3.45 Main Channel Sewer Locations

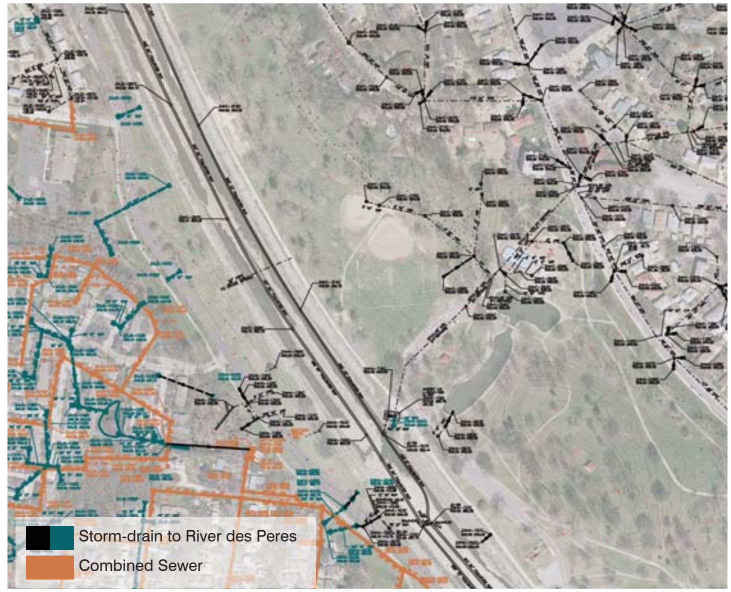


Figure 3.44 Main Channel Soil and Drainage

Table 3.14 Main Channel Wildlife *-Based Upon Landcover*

Reptiles:
Broadhead Skink
Brown Rat Snake
Bull Snake
Common Garter Snake
Common Map Turtle
Common Musk Turtle
Eastern Hognose Snake
False Map Turtle
Graham's Crayfish Snake
Great Plains Rat Snake
Midland Brown Snake
Mississippi Map Turtle
Midland Water Snake
Northern Water Snake
Ornate Box Turtle
Prairie King Snake
Red Milk Snake
River Cooter Turtle
Rough Green Snake
Slender Glass Lizard
Smooth Soft Shell Turtle
Snapping Turtle
Western Earth Snake
Western Painted Turtle
Western Ribbon Turtle
Western Worm Snake

Amphibians:
Blanchard's Cricket Frog
Bull Frog
Dwarf American Toad
American Toad
Fowler's Toad
Green Frog
Gray Tree Grog
Mudpuppy
Central Newt
Southern Leopard Grog
Smallmouth Salamander
Tiger Salamander
Western Chorus Frog

Mammals:
Eastern Cottontail
Common Gray Fox
Little Brown Bat
Mink

Birds:
American Crow
American Goldfinch
American Woodcock
Belted Kingfisher
Blue Jay
Brown Thrasher
Common Grackle
Field Sparrow
Great Blue Heron
House Sparrow
Killdeer
Mallard
Northern Cardinal
Orchard Oriole
Pileated Woodpecker
Red-headed Woodpecker
Red-winged Black Bird
Summer Tanager
Virginia Rail

Geko, Paul Sableman (2012)

CHAPTER 4: DESIGN DEVELOPMENT

CONCEPT DEVELOPMENT

The development of the individual sites involved bringing together the River des Peres watershed stormwater BMP plans, and the reduced peak flow calculations to design the individual river channels. In addition, stormwater, wildlife habitat and aesthetics played a strong role in the visualization of the individual sites and to meet the goals established in the thesis:

- *Lowering the flood frequency rate of the river through the inclusion of stormwater BMPs.*
- *Enhancement of wildlife habitat by the inclusion of native fauna and flora through the re-vegetation of the stream bank, stormwater BMPs, and wet meadows.*
- *Enhance the local identity of River des Peres by integrating public art into the river corridor.*
- *Fix the infrastructural performance problems of the site, including, stormwater and sanitary overflows.*
- *Encourage growth in areas damaged by previous engineering projects including trapezoidal channel lining.*

CONCEPT STATEMENT

The design of each individual site focuses on restoring the hydrograph to a pre-development bankfull discharge, restoring the floodplain function of the river, restoring the channel dimensions for stability, improving wildlife habitat, increasing river aesthetics, and fixing infrastructural performance problems. These designs produce performance benefits that increase the well-being of the community and reduce impacts on water quality.

FOREST PARK CONCEPTUAL PLAN

The existing river is day-lighted from the culvert near the Norman K. Probstein Community Golf Course and reenters the culvert by I-40, as shown in figure 4.1. The master plan and corresponding river channel design accomplishes three goals stated in the thesis. Day-lighting the river causes the peak flow discharge to reduce due to increased vegetation along the new river bank, the extended river length, and bed material. Infrastructural performance problems, including the millions of gallons of water needed to be pumped into the site daily are eliminated, thus, saving the city thousands of dollars each year.

The plan that MSD produced, which included the need for flow storage in the 29-ft horseshoe sewers underneath Forest Park, and in a new storage tunnel will no longer be necessary. The Skinker-McCausland tunnel can continue to convey stormwater and sewer systems flows, but will not be needed due to reduced flows.

On site, the existing fountain areas will remain the same except for the implementation of irrigation gates at the mouth of each fountain area. The irrigation gates will allow 5.40 cfs of water to flow into each of the fountain areas, enough to retain the existing water levels. The river channel is widened throughout the park and implemented with three planting

Figure 4.1 Forest Park Master Plan

zones: riparian, grassland and forestland. Each zone caters to a specific group of plant and wildlife species.

Riparian zones are implemented along the banks of the river and extend out into the park to serve as a buffer between the park's many activities and the river, and to intercept stormwater runoff from roadways and development. Riparian areas are implemented with grasses, sedges, forbs, shrubs, and trees. Grass and sedge species include Bur and Fox Sedge, River Oats, and Soft Rush. Forb species consist of Shining Bluestar, Marsh Milkweed, Cardinal Flower, and Sweet Coneflower. Shrub and tree species consist of Paw Paw, Green Hawthorne, Winterberry Holly, Black gum, and Willow. Native vegetation was compiled from St. Louis Missouri Botanical garden and inputted into a table by vegetative type and is located in Appendix C. The use of native vegetation cater to wildlife species that are native to the area such as, the Black-tailed Jackrabbit, Cotton Mouse, Plains Harvest and Pocket Mouse, Black-crowned Night Heron, Cerulean Warbler, and Cooper's Hawk.

Grassland zones are implemented in large open spaces and include tall and short grasses, forbs, shrubs, and trees. Grass species include Big Bluestem, Broomsedge, Switchgrass, and Little Bluestem. Forb species include Golden Aster, Slender Bush Cover, Old Field Goldenrod, and Yellow Wingstem. Shrubs and trees include Serviceberry, Scarlet Oak, and Short-leaf Pine.

Forestland zones are areas that can be increased with over-story and understory species. Such species include American Sweetgum, Ponderosa Pine, Douglas-fir, White Oak, Bur Oak, Chinquapin and Shumard Oak, American Linden, and Western Hemlock.

Figure 4.2 Forest Park River Channels


Bankfull
5% Slope
Native Vegetation


10'
Bankfull
33% Slope
Riparian Vegetation
0
20
40

River Channel Design

The existing river channel, as shown in figure 4.2, is shallow and only holds the re-circulated gallons of city and storm water. Currently, there is existing native vegetation buffers placed along the waterscape that cater to some of the existing wildlife in the area.

The proposed channel holds the 1.5 year bankfull discharge with a bankfull depth of 10 feet and a cross-sectional area of 950 feet. The river banks slope at 3:1 or 33% and are implemented with boulders to provide additional water resistance for water velocity reduction, to decrease bank erosion, and to increase dissolved oxygen within the water.

Increasing riparian vegetation along the river banks and into the existing park landscape increases wildlife habitat, and by implementing diverse plant species within this zone an increase in wildlife can occur.

Forest Park Vision

Towards the southeastern portion of Forest Park a bridge can be implemented on Clayton Ave to allow for the river to flow underneath to the next pool, such as shown in figure 4.3. By constructing a bridge and removing

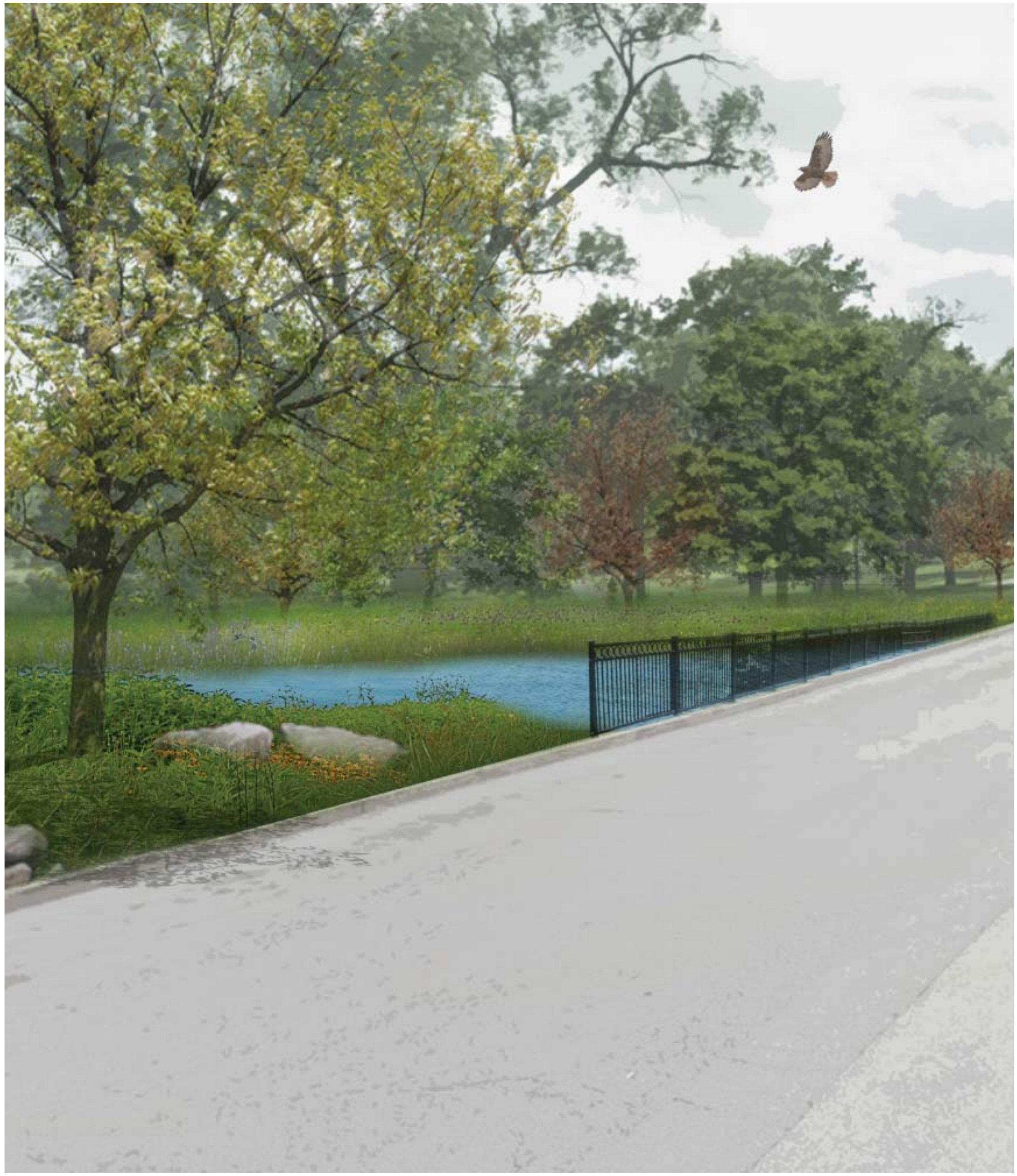


Figure 4.3 Forest Park Bridge Vision

Figure 4.4 - Grand Prairie Central Park
Grand Prairie Central Park, located in Grand Prairie, Texas, is a 180 acre project that "features a 36-acre lake system that serves to solve severe flooding problems while also cleaning the stormwater runoff from surrounding neighborhoods" (MESA, 2013).

excess soil, the river can flow through, allowing for even flow across the site, from where the river will be day-lighted to where it will enter back into the culvert. The river channel will be deepened in this region to allow for the pooling of water for times of low flow.

Grand Prairie Central Park, a precedent study, as shown in figure 4.4, was used in the visioning of Forest Park. Grand Prairie Central Park, as designed by MESA Design Group, is a 180 acre project that helps solve the flooding problems within the area. The waterscape is designed to help filter and clean the stormwater from the surrounding roadways and neighborhoods.

As shown in figure 4.5, the use of rocks and boulders onsite provide cover for wildlife and the mixture of grasses, forbs, shrubs, and trees provide a variety of food for wildlife species (table 4.1). Pedestrian and vehicular bridges throughout the park will be widened as to not create pinch points along the river. 'Pinching' causes the water to back up, creating flooding and increasing bank erosion. By lengthening the bridges bank stability can be provided. These bridges can then be implemented with bat boxes to provide nesting sites for threatened and endangered species such as, Gray Myotis, Eastern Small-footed Myotis, and

Figure 4.5 Forest Park River Vision

Table 4.1 Vegetation and Wildlife Species

FORESTLAND

Trees/Shrubs:

Liquidambar styraciflua
American Sweetgum

Pinus ponderosa
Ponderosa Pine

Pseudotsuga menziesii
Douglas-fir

Quercus alba
White Oak

Quercus macrocarpa
Bur Oak

Quercus muehlenbergii
Chinquapin Oak

Quercus shumardi
Shumard Oak

Tilia americana
American Linden

Tsuga heterophylla
Western Hemlock

RIPARIAN VEGETATION

Grasses/Sedges:

Carex grayi
Bur Sedge

Carex vulpinoidea
Fox Sedge

Chasmanthium latifolium
River Oats

Juncus effusus
Soft Rush

Forbs:

Amsonia illustris
Shining Bluestar

Asclepias incarnata
Marsh Milkweed

Lobelia cardinalis
Cardinal Flower

Rubeckia subtomentosa
Sweet Coneflower

Trees/Shrubs:

Asimina triloba
Paw Paw

Crataegus viridis
Green Hawthorne

Ilex verticillata
Winterberry Holly

Nyssa sylvatica
Black Gum

Salix sp.
Willow

GRASSLAND

Grasses/Sedges:

Andropogon gerardii
Big Bluestem

Andropogon virginica
Broomsedge

Panicum virgatum
Switchgrass

Schizachyrium scoparium
Little Bluestem

Forbs:

Chrysopsis camporum
Golden Aster

Lespedeza virginica
Slender Bush Cover

Solidago nemoralis
Old Field Goldenrod

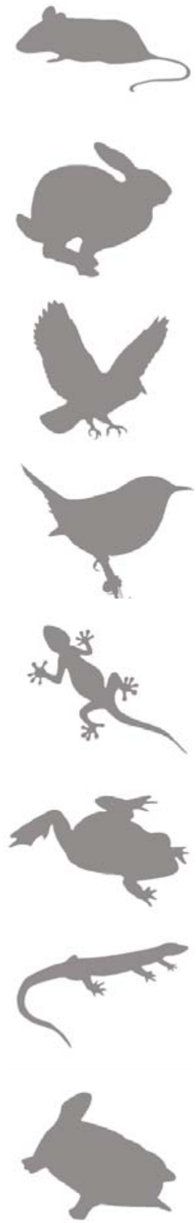
Verbesina helianhoides
Yellow Wingstem

Trees/Shrubs:

Amelanchier arborea
Serviceberry

Quercus coccinea
Scarlet Oak

Pinus echinata
Short-leaf Pine



MAMMALS

Lepus californicus
Black-tailed Jackrabbit

Myotis grisescens
Gray Myotis

Myotis leibii
Eastern Small-footed Myotis

Myotis sodalis
Indiana Myotis

Peromyscus gossypinus
Cotton Mouse

Reithrodontomys montanus
Plains Harvest Mouse

Perognathus flavescens
Plains Pocket Mouse

BIRDS

Nycticorax nycticorax
Black-crowned Night Heron

Setophaga cerulea
Cerulean Warbler

Accipiter cooperii
Cooper's Hawk

Gallinula chloropus
Common Moorhen

Ammodramus henslowii
Henslow's Sparrow

Lanius ludovicianus
Loggerhead Shrike

Circus cyaneus
Northern Harrier

Buteo lineatus
Red-shouldered Hawk

Bartramia longicauda
Upland Sandpiper

AMPHIBIANS

Hemidactylium scutatum
Four-toed Salamander

Hyla cinerea
Green Treefrog

Pseudacris streckeri illinoensis
Illinois Chorus Frog

Lithobates pipiens
Northern Leopard Frog

Plethodon angusticlavius
Ozark Zigzag Salamander

Ambystoma annulatum
Ringed Salamander

GRAY MYOTIS

The preferred habitat of the Gray Myotis is cave dwellings. "Nearby streams with adjacent woodlands provide critical foraging habitat. These basts seem to especially utilize woody stream corridors and even linear tree plantings" – KDWPT, 2011

REPTILES

Macrochelys temminckii
Alligator Snaping Turtle

Emydoidea blandingii
Blanding's Turtle

Eumeces obsoletus
Great Plains Skink

Deirochelys reticularia miaria
Western Chicken Turtle

Kinosternon flavescens
Yellow Mud Turtle

Indiana Myotis. These species help control insects such as mosquitoes, and provide the community with opportunities to view wildlife viewing at night.

Ecological Performance Benefits

Water Infiltration

The deep roots of native plant species "help develop pore space in the soil to promote infiltration of rainfall, which reduces stormwater runoff" (MBG, 2011). With 92 acres of improved land cover, as shown in figure 4.6, 23 acre feet per hour can be infiltrated. Pervious surface infiltration rates were found in the 1995 Stapleton Area Stormwater Outfall Systems Plan (LAF, 2013), which listed infiltration rates of .25 acre feet per hour. By implementing native vegetation and improving infiltration within Forest Park the air quality can be increased, and mowing can be reduced.

Reused Concrete

As referenced from the City of St. Louis, Missouri recycling versus land-filling costs, by reusing concrete saves $34.55 per ton or roughly $1,796,600 for 52,000 cubic feet of both vehicular and pedestrian concrete bridges (City of St. Louis, 2013). This concrete can be crushed to be used for pathway material and bioswale base within the landscape to increase permeability.

Reclaimed Soil

By reusing the 625,207 square feet of soil that will be excavated from the river channel and using it to fill in the main channel of the River des Peres reduces the need for landfill disposal. Reusing the soil in the main channel also reduces the need to cut soil from another location.

Increased Dissolved Oxygen

Through the creation of pools, small drop structures, rock dams, and rock riffles an increase in water turbulence can occur, thus, increasing the amount of dissolved oxygen in the water. By implementing boulders and rocks within the channel, water quality downstream can be improved. In addition, by day-lighting the river and increasing friction by rock and boulder implementation water velocity is reduced. With the River des Peres currently being impaired due to low levels of dissolved oxygen and chloride, improving the levels of dissolved oxygen within the water will increase water habitability.

Increased Carbon Sequestration

Referencing the Westerly Creek at Stapleton landscape performance benefits, a native vegetative cover was found to sequester 4.85 tons per acres (LAF, 2013). Therefore, up to 450 tons of carbon can be sequestered for the 92 acre park, which is 24 times more than using a bluegrass sod covering.

Figure 4.6 Forest Park Performance Benefits

WILSON AVENUE AND DREXEL DRIVE CONCEPTUAL PLAN

As shown in figure 4.7, all the houses along this quarter mile long site will be completely removed, allowing the proposed open space to become naturalized. This naturalized open space provides recreational and educational opportunities, and community spiritual and aesthetic enrichment. The master plan and corresponding river channel design accomplishes four goals stated in the thesis. The implementation of stormwater BMPs and wet meadows throughout the watershed lowers the peak return frequency flow of the River, accomplishing the goal of lowering the flood frequency.

The river channel is widened along the parallel section of the river and is implemented with three planting zones: riparian, grassland and bioswale. Each zone caters to a specific group of plant and wildlife species, accomplishing the goal of enhancing the wildlife habitat in the area.

Riparian zones are implemented along the banks of the river and extend out into the housing development along the east and into the open space to the west to serve as a buffer between the housing development and the river. With the soil being a fine-loamy mix, riparian vegetation will thrive in the area due to high soil fertility. Riparian zones are implemented with grasses, sedges, forbs, shrubs, and tree species. Grass and sedge species include Bur and Fox Sedge, River Oats, and Soft Rush. Forb species consist of Shining Bluestar, Marsh Milkweed, Cardinal Flower, and Sweet Coneflower. Shrub and tree species consist of Paw Paw, Green Hawthorne, Winterberry Holly, Black gum, and Willow. The use of native vegetation caters to threatened and endangered wildlife species that are native to the area such as, Black-tailed Jackrabbit, Cotton Mouse, Bachman's Sparrow, Black-crowned Night Heron, Bewick's Wren, Cerulean Warbler, and Cooper's Hawk.

Grassland zones are implemented along the large open space parallel to the river and include tall and short grasses, forbs, shrubs, and trees. Grass species include Big Bluestem, Broomsedge, Switchgrass, and Little Bluestem. Forb species include Golden Aster, Slender Bush Cover, Old Field Goldenrod, and Yellow Wingstem. Shrubs and trees include Serviceberry, Scarlet Oak, and Short-leaf Pine.

Two bioswale zones are implemented onsite, both are placed near the stormwater sewer outlets that collect water from the roadway and surrounding the housing developments. These bioswales are implemented to filter and store stormwater during rain events. Bioswale implementation helps accomplish the goal of fixing the infrastructural performance problems on the site by retaining stormwater during rain events. Grass species include Yellow Fruited and Bur Sedge, Soft Rush, Little Bluestem, and Prairie Dropseed. Forbs include Shining Bluestar, Purple Coneflower, Copper Iris, Cardinal Flower and

Figure 4.7 Wilson Avenue and Drexel Drive Master Plan

Zig-zag Goldenrod. Tree and shrub species include Red Buckeye, Redbud, Fringetree and Persimmon.

River Channel Design

The existing river channel, as shown in figure 4.8, is narrow with banks at a steep 53% slope. The floodplain of the river extends out into the nearby residential neighborhoods creating flooding problems for the residents during heavy rain events.

The proposed channel holds the 1.5 year bankfull discharge with a bankfull depth of 8 feet and a cross-sectional area of 400 feet, on average, throughout the site. The large open space to the east of the site will be lowered to a 3% slope to increase flood storage. The western river bank slopes at 3:1 or 33%, and is dotted with boulders to provide additional water resistance for water velocity reduction, decrease bank erosion, and to increase dissolved oxygen within the water. The proposed channel accomplishes the goal of encouraging growth in areas damaged by previous engineering projects. Removing invasive plant species including, Bush Honeysuckle, Wintercreeper Euonymus, and Garlic Mustard, and adding native riparian and grassland vegetation creates wildlife habitat that improves the community well-being in the area.

Wilson Avenue and Drexel Drive Vision

The riparian vegetation lining the river channel, as shown in figure 4.9, intercepts and

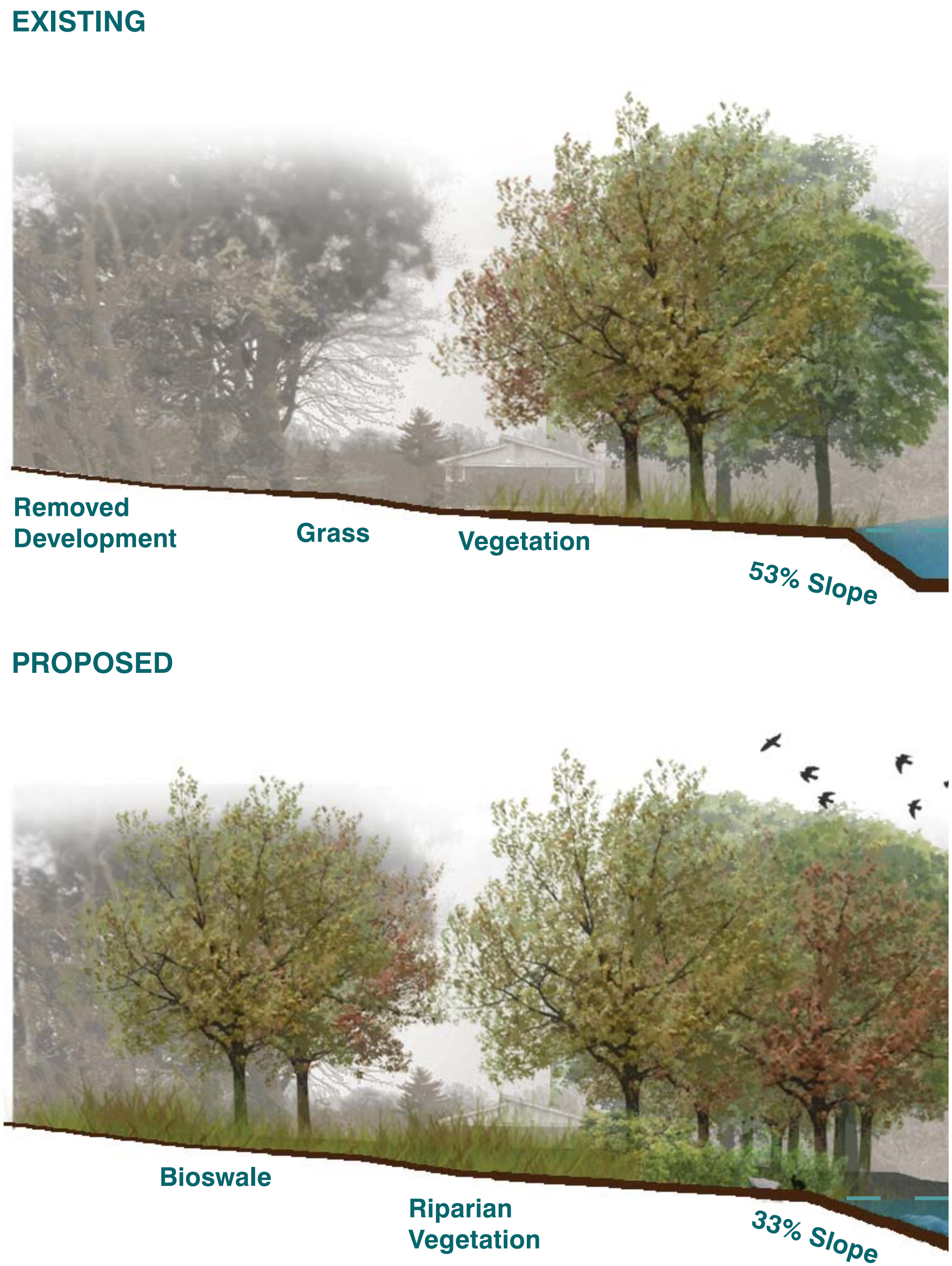
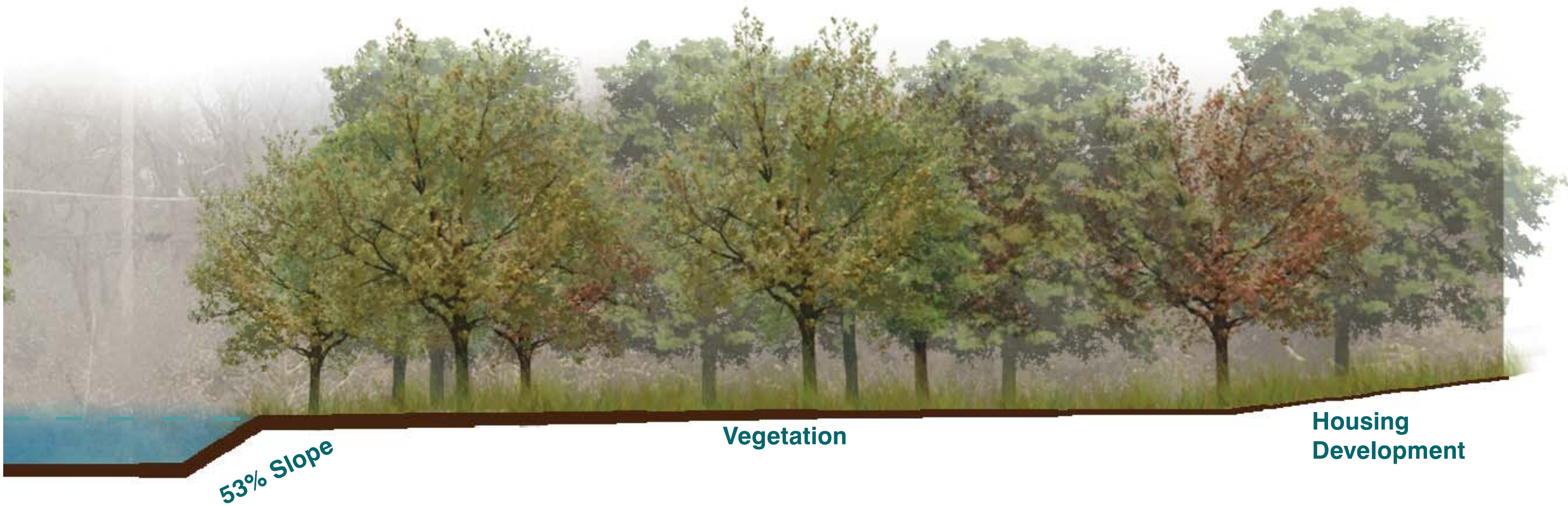
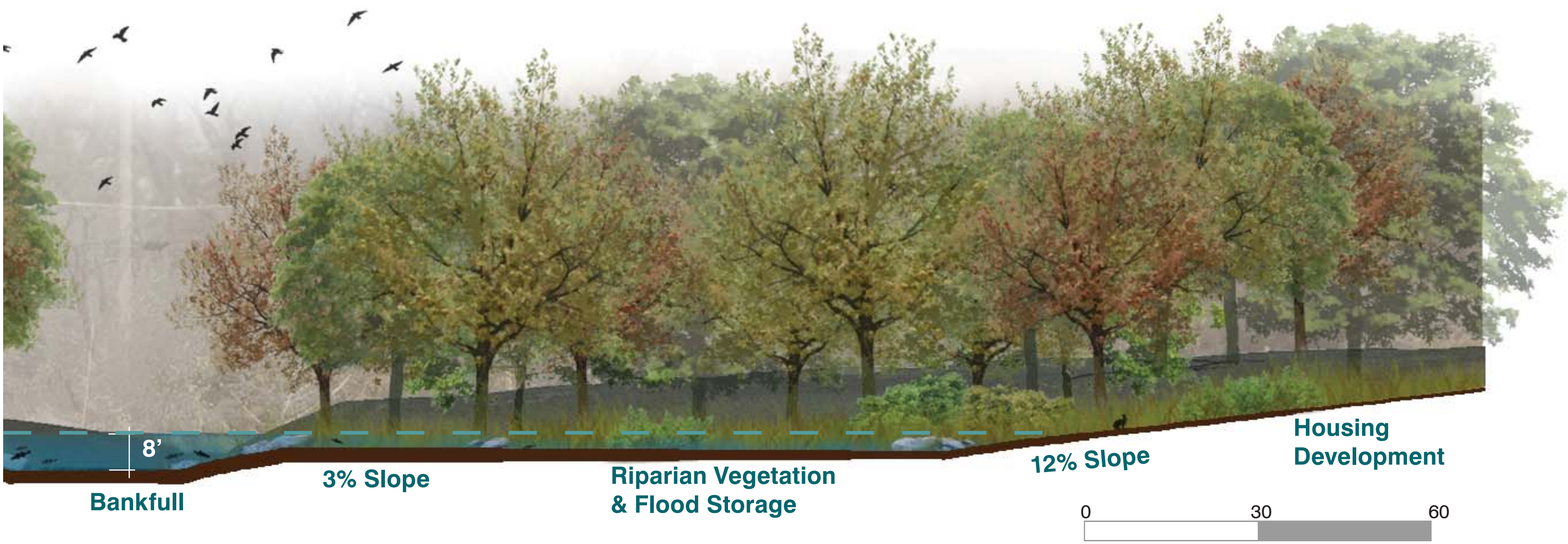


Figure 4.8 Wilson Avenue and Drexel Drive River Channel


53% Slope
Vegetation
Housing Development


8'
Bankfull
3% Slope
Riparian Vegetation & Flood Storage
12% Slope
Housing Development
0
30
60

holds stormwater runoff, and then releases it, slowly, back into the river, allowing for a consistent flow of water. The consistent flow of water and increased organic debris from the shrubs and trees increases food and cover for aquatic life in the river including, amphibians, reptiles, and fish.

Daybreak community and Elmer Avenue neighborhoods retrofit are precedent studies, as shown in figure 4.10 and 4.11 that were used in the visioning of the open space at Wilson Avenue and Drexel Drive. Daybreak Community, a 4,127 acre development located in South Jordan, Utah merges the natural landscape with the development to successfully retain 100% of the rain that falls on the site. The site promotes “species diversity with nearly 2.5 times the national average for comparable wetland bird populations present in man-made Oquirrh Lake and the surrounding wetlands” (LAF, 2013). Elmer Avenue neighborhoods retrofit is a 4 acre project in Los Angeles, California that aims to capture rainwater from a 40 acre development area. The retrofit project “transformed a typical residential street into a model ‘green street’ by incorporating stormwater best management practices (BMPs) that capture and filter runoff” (LAF, 2013). The site improves the quality of water by reducing suspended solids from street runoff.

As shown in figure 4.12, rocks and boulders onsite provide cover for wildlife, and the mixture of grasses, forbs, shrubs, and trees provide a variety of food for different wildlife species contributing to

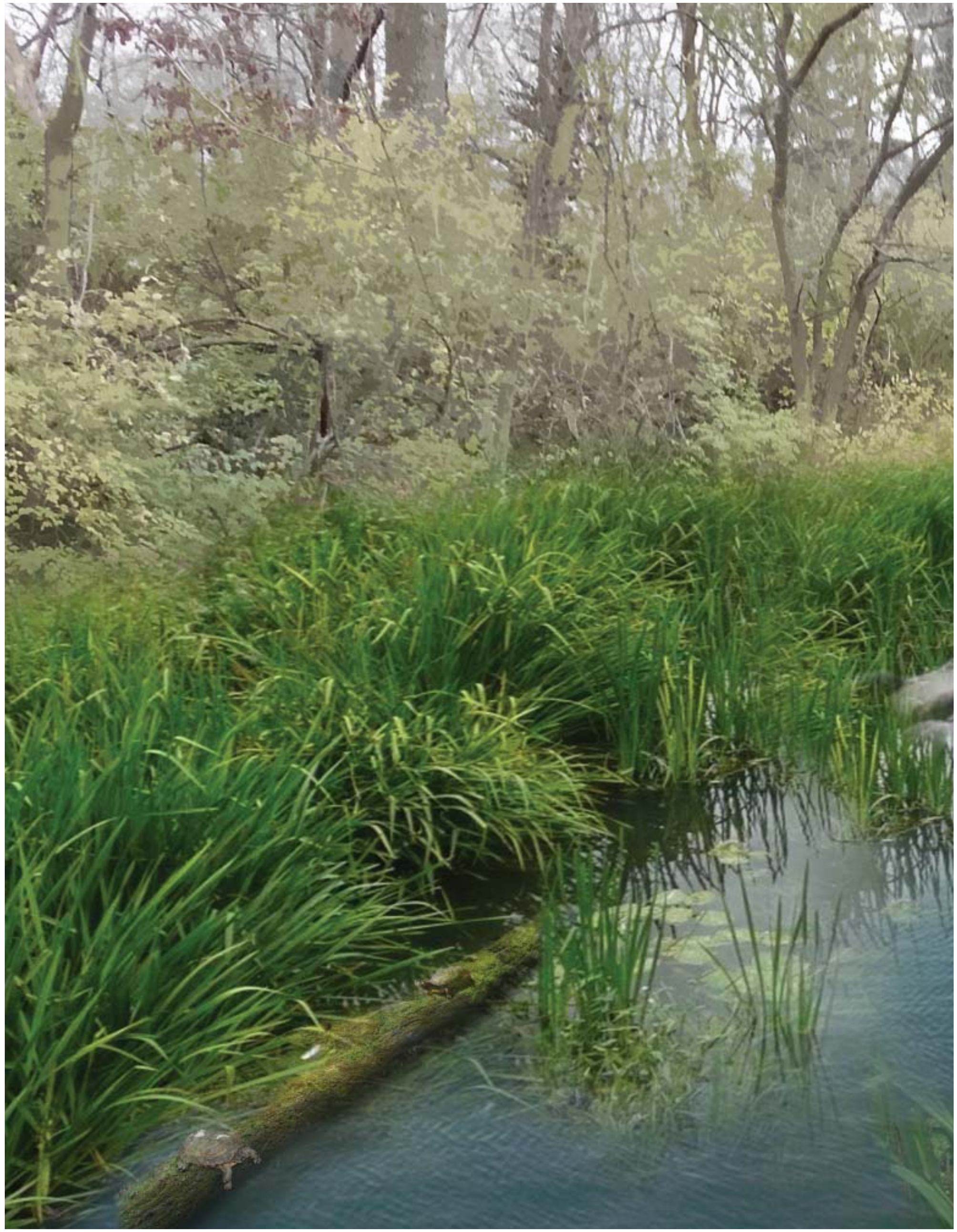


Figure 4.9 Wilson Avenue and Drexel Drive River Vision

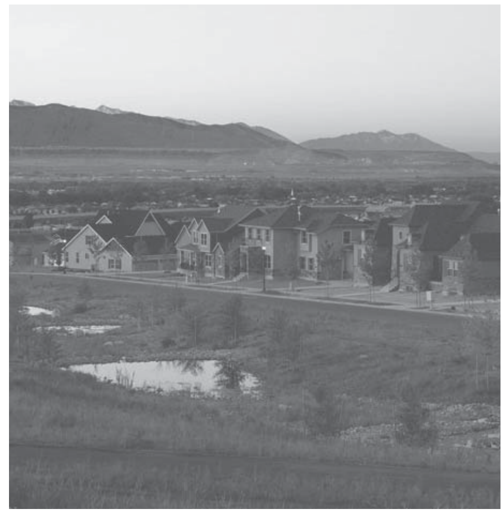


Figure 4.10 (Top)- Elmer Avenue Retrofit
The site improves the quality of water by reducing suspended solids from street runoff.

Figure 4.11 (Bottom)- Daybreak Community
Located in South Jordan, Utah the parks and open spaces of the 4,127 acre development merges with the natural landscape and retains 100% of the rain that falls on the site.

the aesthetics and biodiversity of the site (table 4.2).

Ecological Performance Benefits

Water Infiltration

As shown in figure 4.13, the deep roots of native plant species "help develop pore space in the soil to promote infiltration of rainfall, which reduces stormwater runoff" (MBG, 2011). With 6 acres of improved land cover, 1.5 acre feet per hour can be infiltrated. Pervious surface infiltration rates were found in the 1995 Stapleton Area Stormwater Outfall Systems Plan, which listed infiltration rates of .25 acre feet per hour (LAF, 2013). By implementing native vegetation and improving infiltration, Wilson Avenue's air quality can be increased.

Increased Flood Storage Capacity

Increased flood storage capacity occurs on the site by the addition of 200,000 cubic feet of storage. Increasing the flood storage encourages groundwater recharge by storing and infiltrating water volumes into the ground. Vegetation planted in the storage area traps sediments and takes up nutrients via root systems.

Figure 4.12 Wilson Avenue and Drexel Drive Bioswale Vision

Table 4.2 Vegetation and Wildlife Species

RIPARIAN VEGETATION

Grasses/Sedges:

Carex grayi
Bur Sedge

Carex vulpinoidea
Fox Sedge

Chasmanthium latifolium
River Oats

Juncus effusus
Soft Rush

Forbs:

Amsonia illustris
Shining Bluestar

Asclepias incarnata
Marsh Milkweed

Lobelia cardinalis
Cardinal Flower

Rubeckia subtomentosa
Sweet Coneflower

Trees/Shrubs:

Asimina triloba
Paw Paw

Crataegus viridis
Green Hawthorne

Ilex verticillata
Winterberry Holly

Nyssa sylvatica
Black Gum

Salix sp.
Willow

BIOSWALE

Grasses/Sedges:

Carex annectans
Yellow Fruited Sedge

Carex grayii
Bur Sedge

Juncus effusus
Soft Rush

Schizachyrium scoparium
Little Bluestem

Sporobolus heterolepis
Prairie Dropseed

Forbs:

Amsonia illustris
Shining Bluestar

Echinacea purpurea
Purple Coneflower

Iris fulva
Copper Iris

Lobelia cardinalis
Cardinal Flower

Solidago flexicaulis
Zig-zag Goldenrod

Trees/Shrubs:

Aesculus pavia
Red Buckeye

Cercis canadensis
Redbud

Chionanthus virginicus
Fringetree

Diospyos virginiana
Persimmon

GRASSLAND

Grasses/Sedges:

Andropogon gerardii
Big Bluestem

Andropogon virginica
Broomsedge

Panicum virgatum
Switchgrass

Schizachyrium scoparium
Little Bluestem

Forbs:

Chrysopsis camporum
Golden Aster

Lespedeza virginica
Slender Bush Cover

Solidago nemoralis
Old Field Goldenrod

Trees/Shrubs:

Amelanchier arborea
Serviceberry

Quercus coccinea
Scarlet Oak

Pinus echinata
Short-leaf Pine

MAMMALS

Lepus californicus
Black-tailed Jackrabbit

Myotis grisescens
Gray Myotis

Myotis leibii
Eastern Small-footed Myotis

Myotis sodalis
Indiana Myotis

Peromyscus gossypinus
Cotton Mouse

BIRDS

Peucaea aestivalis
Bachman's Sparrow

Nycticorax nycticorax
Black-crowned Night Heron

Thryomanes bewickii
Bewick's Wren

Setophaga cerulea
Cerulean Warbler

Accipiter cooperii
Cooper's Hawk

Gallinula chloropus
Common Moorhen

Ammodramus henslowii
Henslow's Sparrow

Lanius ludovicianus
Loggerhead Shrike

Circus cyaneus
Northern Harrier

Buteo lineatus
Red-shouldered Hawk

Bartramia longicauda
Upland Sandpiper

AMPHIBIANS

Hyla cinerea
Green Treefrog

Lithobates pipiens
Northern Leopard Frog

Plethodon angusticlavius
Ozark Zigzag Salamander

Ambystoma annulatum
Ringed Salamander

REPTILES

Macrochelys temminckii
Alligator Snaping Turtle

Emydoidea blandingii
Blanding's Turtle

Eumeces obsoletus
Great Plains Skink

Deirochelys reticularia miaria
Western Chicken Turtle

Kinosternon flavescens
Yellow Mud Turtle

BLANDING'S TURTLE

The preferred habitat of the Blanding's Turtle is wet meadows, streams, and rivers. The diet of the turtle includes insects, snails, frogs, and small fish.

Reused Concrete

The concrete excavated from the existing housing units and the concrete blocks currently lining the river channel can be crushed down into gravel. The gravel can then be used for pathway material and bioswale base within the landscape to increase permeability. By reusing the concrete on site hauling and landfill costs are reduced.

Reclaimed Soil

By balancing the cut and fill in the grading plan, hauling and landfill costs are eliminated. The soil excavated from the river channel and placed within the open space creates landform variety and provides moments of exploration for neighborhood children.

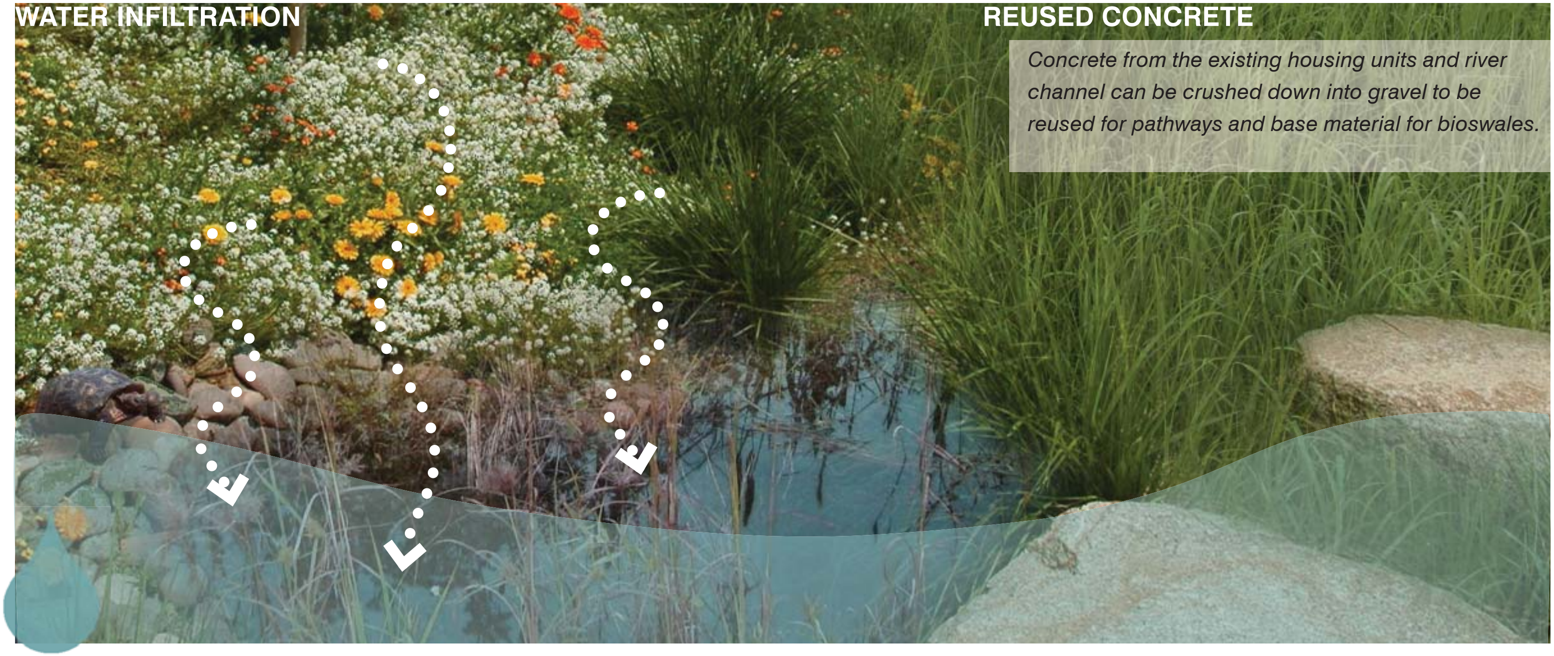
Increased Dissolved Oxygen

Through the creation of rock riffles an increase in water turbulence can occur, thus, increasing the amount of dissolved oxygen in the water. By implementing rocks and boulders within the river channel water quality downstream is improved. Rocks and boulders increase friction within the river, hence, reducing water velocity. With the River des Peres currently being impaired due to low levels of dissolved oxygen and chloride, improving the levels of dissolved oxygen within the water will increase water habitability for aquatic species.

Increased Carbon Sequestration

Referencing the Westerly Creek at Stapleton landscape performance benefits, a native vegetative cover was found to sequester 4.85 tons per acre (LAF, 2013). Therefore, up to 30 tons of carbon can be sequestered for the 6 acre site, which is 24 times more than using a bluegrass sod covering.

Figure 4.13 Wilson Avenue and Drexel Drive Performance Benefits


WATER INFILTRATION
REUSED CONCRETE
Concrete from the existing housing units and river channel can be crushed down into gravel to be reused for pathways and base material for bioswales.


RECLAIMED SOIL
A balance of cut and fill can occur on site through the creation of landforms in the open space.
CARBON SEQUESTRATION
The native vegetative cover sequesters more carbon than a bluegrass sod covering.
Oxygen
Oxygen
Carbon

DEER CREEK AND SOUTH COUNTY CONNECTOR CONCEPTUAL PLAN

As shown in figure 4.14, the new South County Connector begins at the entrance to the existing Deer Creek Shopping Center and then runs parallel to the Metro line, finally merging into interstate 44. Due to the placement of the new connector, Deer Creek Shopping Center and the industrial area to the east of South Big Bend Boulevard were removed. However, the placement of the road improves connectivity between South St. Louis County, City of St. Louis, and central St. Louis County by improving access to interstate 44.

By placing the new connector next to the metro social impacts are minimized, namely ecological and natural resource impacts on the River des Peres. The placement also allows for the concrete parking lot to be removed, the floodplain to be extended north, and an open park space to be implemented. By removing the existing development the proposed open space encourages recreational, educational, spiritual, and aesthetic enrichment opportunities. The master plan and corresponding stream channel design accomplish three goals stated in the thesis. The implementation of stormwater BMPs and wet meadows throughout the watershed lowers the peak return frequency flow of the creek, accomplishing the goal of lowering the flood frequency.

The creek channel is widened along the northern portion of the creek. The southern portion of the River des Peres is too constricted due to a major roadway and residential development. The northern portion of the creek is implemented with four planting zones: riparian, grassland, roadway tall grasses, and bioswale. Each zone caters to a specific group of plant and wildlife species.

Riparian zones are implemented along the banks of the creek and extend out into the housing development along the south and into the open space to the north. With the soil being a fine-loamy mix, riparian vegetation thrives in the area due to high soil fertility. With riparian vegetation acting as a buffer, stormwater from the roadway to the south and the surrounding development is intercepted. Riparian areas are implemented with different species of grasses, sedges, forbs, shrubs, and trees. Grass and sedge species include Bur and Fox Sedge, River Oats, and Soft Rush. Forb species consist of Shining Bluestar, Marsh Milkweed, Cardinal Flower, and Sweet Coneflower. Shrub and tree species consist of Paw Paw, Green Hawthorne, Winterberry Holly, Black gum, and Willow. Using native plant species increase phytoremediation by removing contaminants from the soil, water and air. The use of native vegetation also caters towards wildlife species that are native to the area such as, Black-tailed Jackrabbit, Cotton Mouse, Plains Harvest and Pocket Mouse, Bachman's Sparrow, Black-crowned Night Heron, Cerulean Warbler, and Cooper's Hawk.

Figure 4.14 Deer Creek and South County Connector Master Plan

Grassland and roadway tall grass zones are implemented along the large open spaces parallel to the creek and along the roadway slopes. These zones include tall and short grasses, forbs, shrubs, and trees. Grass species include Big Bluestem, Broomsedge, Switchgrass, and Little Bluestem. Forb species include Golden Aster, Slender Bush Cover, Old Field Goldenrod, and Yellow Wingstem. Shrubs and trees include Serviceberry, Scarlet Oak, and Short-leaf Pine.

Bioswale zones are placed along the new connector to collect stormwater runoff, enabling the filtration of toxic substances from the road surface before allowing the water to return to the creek. Bioswale implementation helps accomplish the goal of fixing the infrastructural performance problems on the site by retaining stormwater during rain events. Grass species include Yellow Fruited and Bur Sedge, Soft Rush, Little Bluestem, and Prairie Dropseed. Forbs include Shining Bluestar, Purple Coneflower, Copper Iris, Cardinal Flower and Zig-zag Goldenrod. Tree and shrub species include Red Buckeye, Redbud, Fringetree and Persimmon.

Creek Channel Design

The existing creek channel, as shown in figure 4.15, is wide with banks at a steep 47-66% slope. The floodplain of the creek is cut short due to the large Deer Creek Shopping

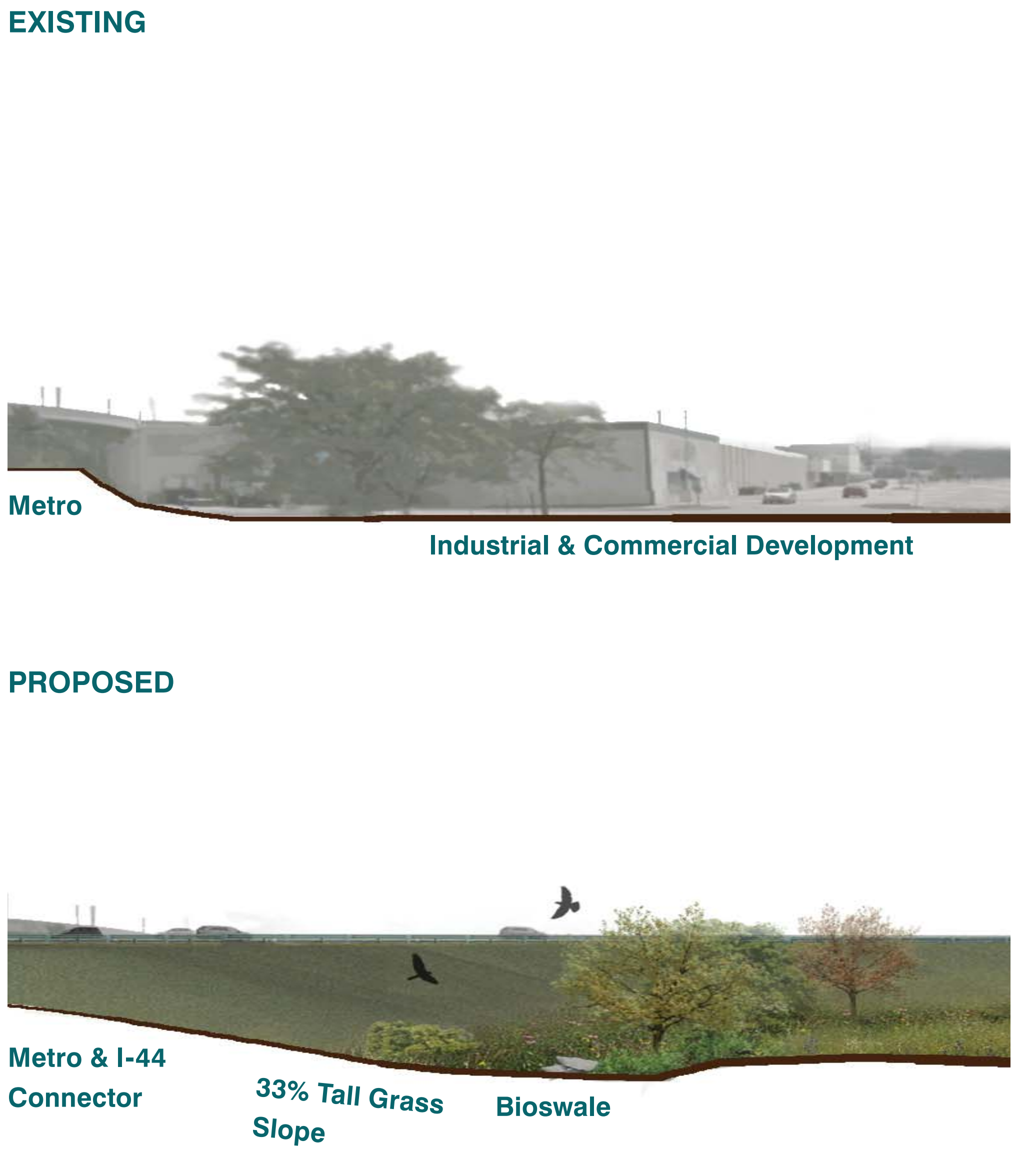
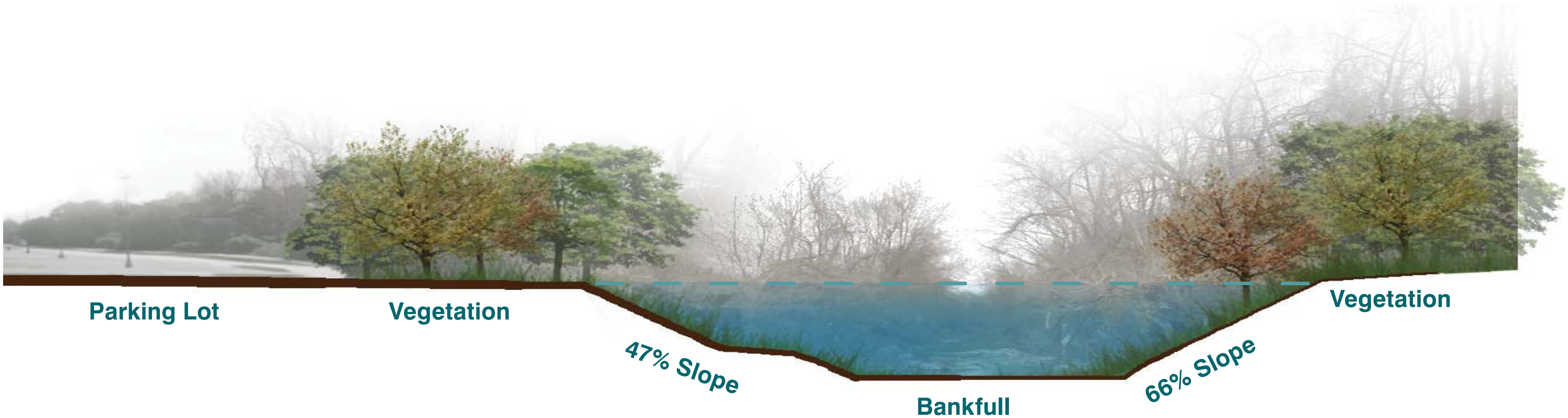
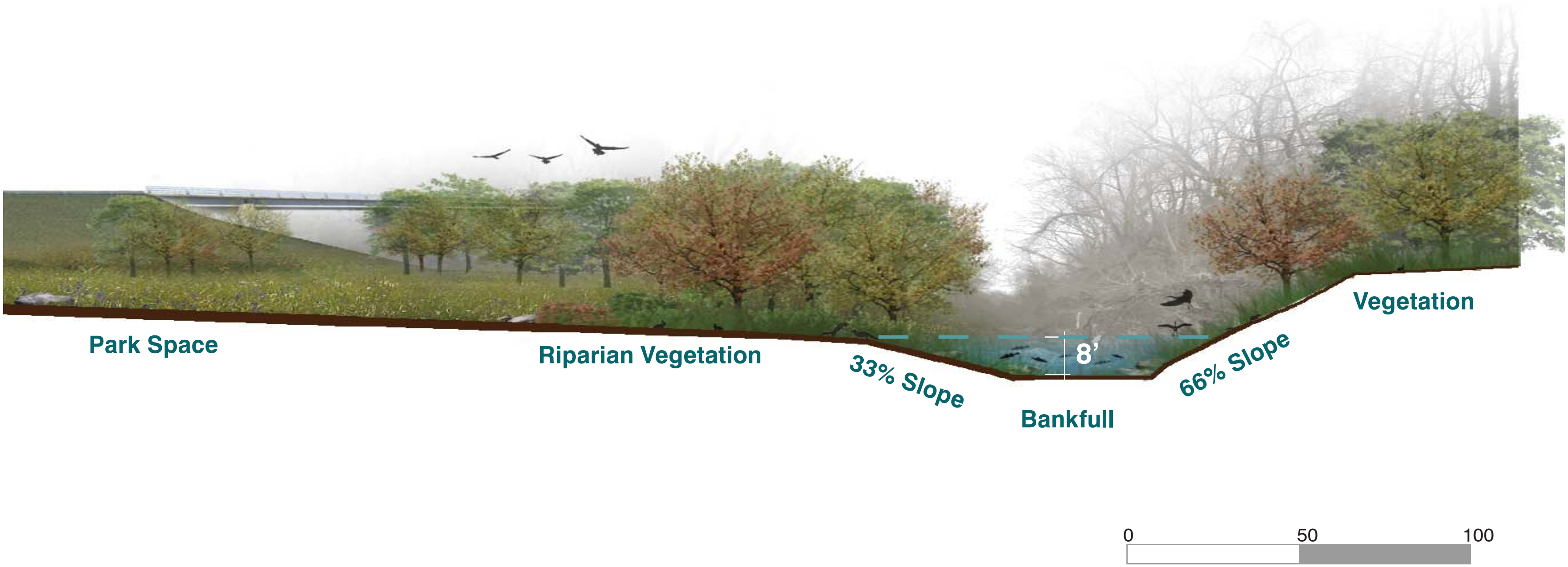


Figure 4.15 Deer Creek and South County Connector Creek Channel


Parking Lot
Vegetation
47% Slope
Bankfull
66% Slope
Vegetation


Park Space
Riparian Vegetation
33% Slope
8'
Bankfull
66% Slope
Vegetation
0
50
100

Center parking lot.

The proposed channel holds the 1.5 year bankfull discharge with a bankfull depth of 8 feet and a cross-sectional area of 460 feet. The northern creek bank is re-graded to a 3:1 or 33% slope and extends out at a 3% slope to the new South County Connector where the landscape gradually slopes down for bioswale implementation, and back up to match the height of the metro. The channel is implemented with rocks and boulders to provide additional water resistance for water velocity reduction, decrease bank erosion, and to increase dissolved oxygen within the water.

Removing invasive plant species including, Bush Honeysuckle, Wintercreeper Euonymus, and Garlic Mustard, and adding native riparian and grassland vegetation creates wildlife habitat that also improves the community well-being in the area.

Deer Creek Vision

Along S. Big Bend Blvd. a new bridge is implemented to allow commuters to travel on the new connector to interstate 44. A sidewalk is placed along the outer edge of the river bankfull allowing visitors to travel through Deer Creek Park and into the new open space (figure 4.16).

Manchaca Greenway, precedent study, as shown in figure 4.17, was used in the visioning of the Deer Creek South County Connector. Manchaca Greenway is a "3.6-mile controlled-access [that] is based upon the idea that a road can be an asset; a road can add value. It improves the ability to get from one place to another, but also improves quality of life while respecting the environment" (AECOM, 2013). The project restored wildlife habitat, protected natural resources, promoted environmental education, and managed water resources that

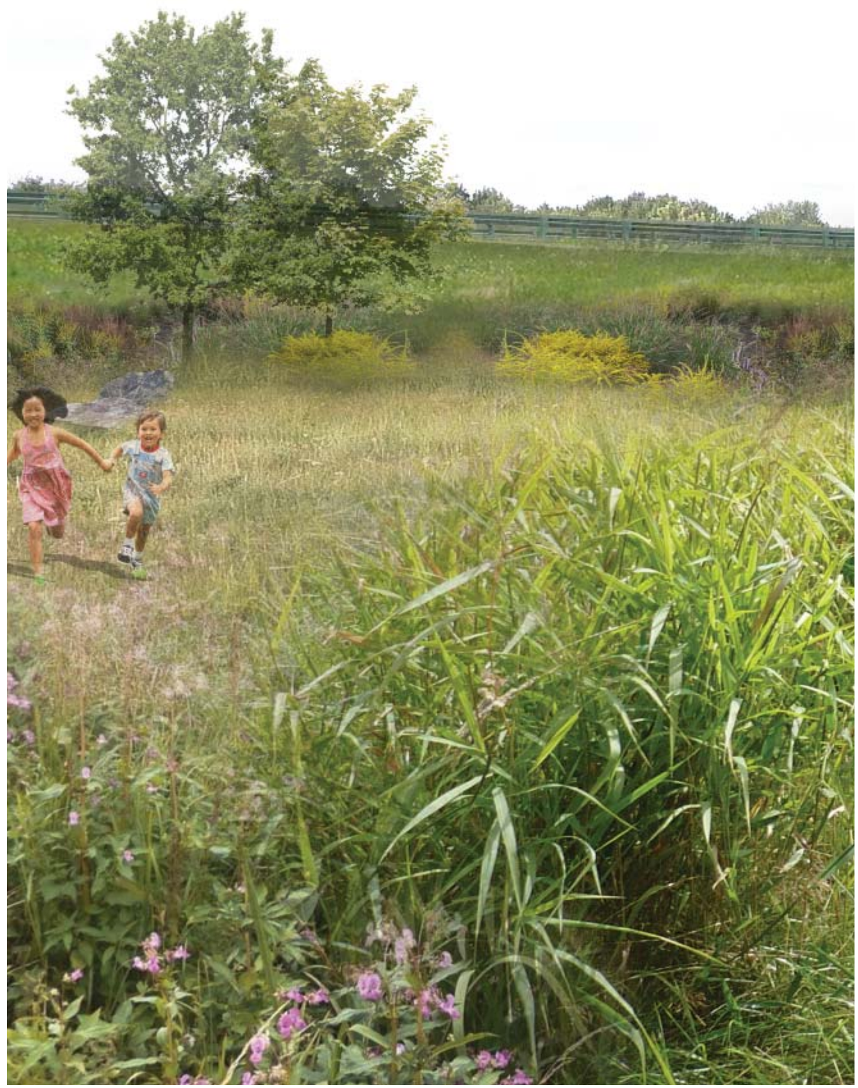
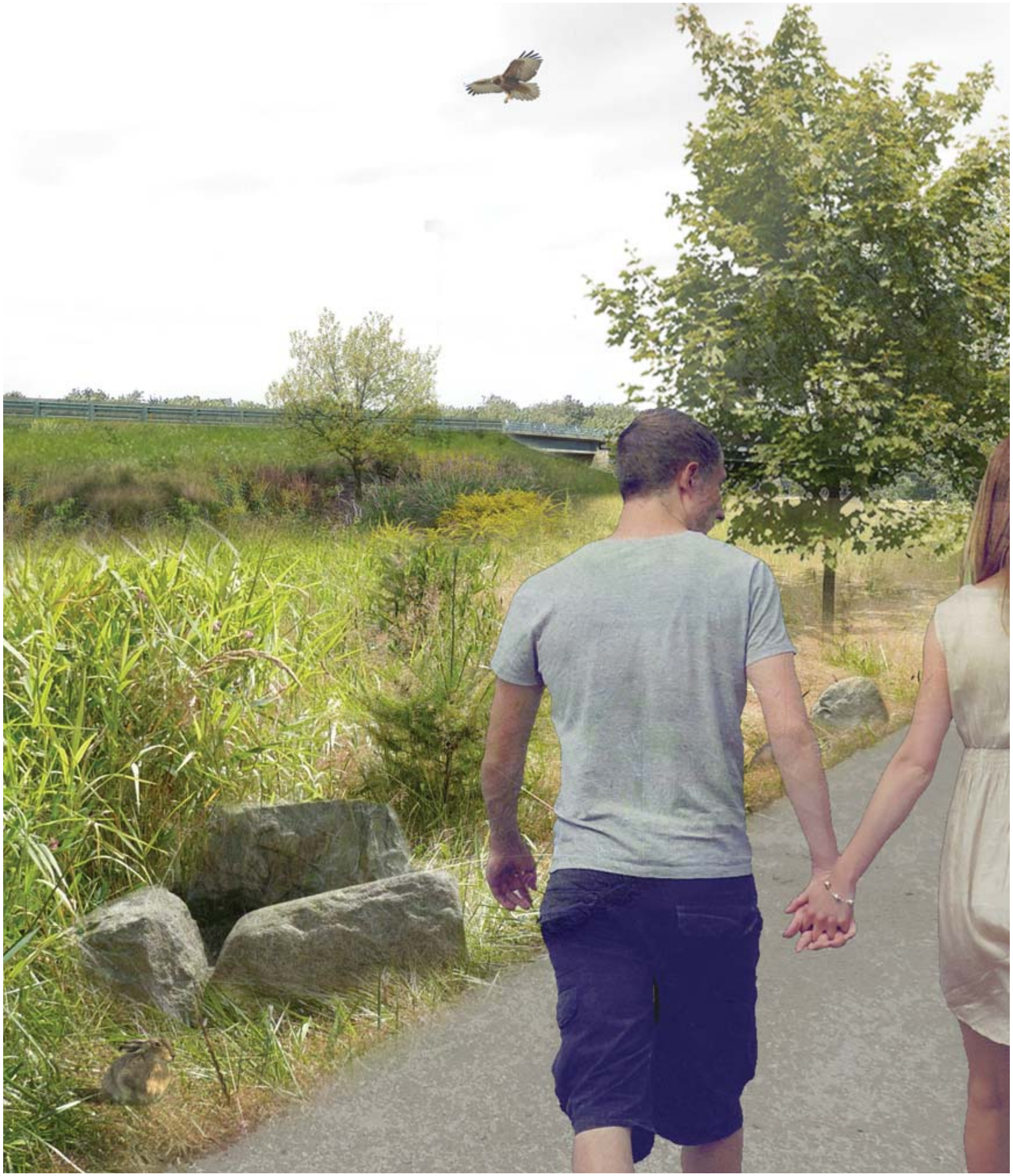


Figure 4.16 Deer Creek and South County Connector Open Space Vision



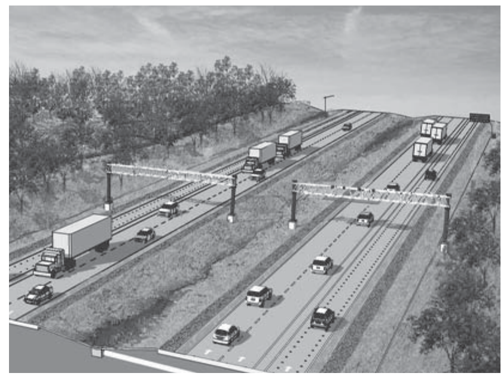


Figure 4.17- Manchaca Greenway
The project restored wildlife habitat, protected natural resources, promoted environmental education, and managed water resources that enhance the quality of life for the community (AECOM, 2013).

enhance the quality of life for the community (AECOM, 2013).

As shown in figure 4.18, the use of rocks and boulders onsite provide cover for wildlife, and the mixture of grasses, forbs, shrubs, and trees provide a variety of food for a diverse group of wildlife species contributing to the aesthetics and biodiversity of the site (table 4.3).

Ecological Performance Benefits

Water Infiltration

As shown in figure 4.19, the deep roots of native plant species help the “biological uptake of pollutants and nitrogen” and the increase soil pore space “to promote infiltration of rainfall” (MBG, 2011). With 34 acres of improved land cover 8.5 acre feet per hour can be infiltrated. Pervious surface infiltration rates were found in the 1995 Stapleton Area Stormwater Outfall Systems Plan, which listed infiltration rates of .25 acre feet per hour (LAF, 2013). By implementing native vegetation and improving infiltration the air quality at Deer Creek’s can be improved.

Increased Flood Storage Capacity

Increased stormwater storage occurs on the site by the addition of 300,000 cubic feet of bioswales. Increasing the storage capability can provide groundwater recharge by storing and infiltrating water volumes into the ground. Vegetation planted in the storage area trap sediments and take up nutrients into their roots.

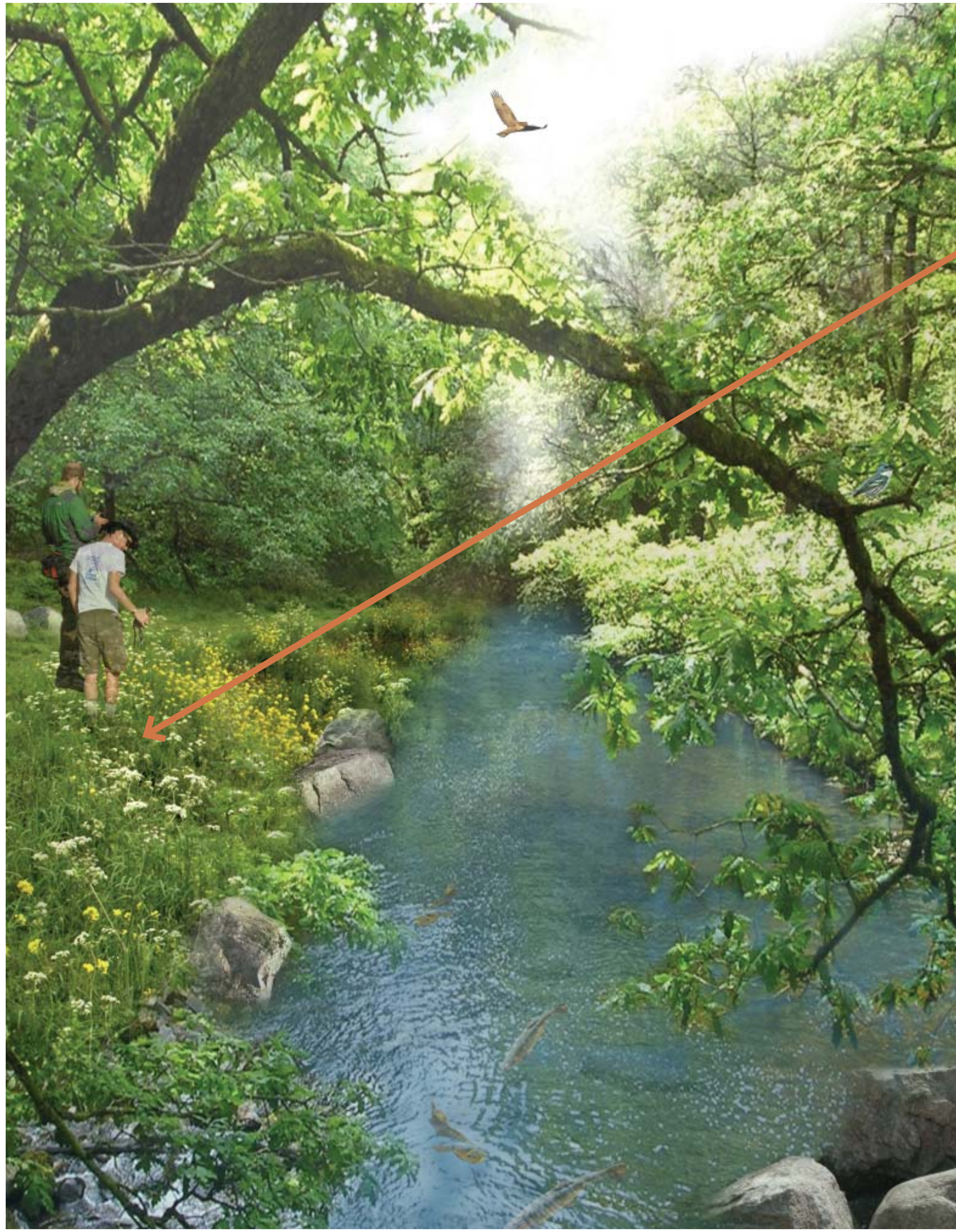


Figure 4.18 Deer Creek and South County Connector Creek Vision

Table 4.3 Vegetation and Wildlife Species

RIPARIAN VEGETATION

Grasses/Sedges:

Carex grayi
Bur Sedge

Carex vulpinoidea
Fox Sedge

Chasmanthium latifolium
River Oats

Juncus effusus
Soft Rush

Forbs:

Amsonia illustris
Shining Bluestar

Asclepias incarnata
Marsh Milkweed

Lobelia cardinalis
Cardinal Flower

Rubeckia subtomentosa
Sweet Coneflower

Trees/Shrubs:

Asimina triloba
Paw Paw

Crataegus viridis
Green Hawthorne

Ilex verticillata
Winterberry Holly

Nyssa sylvatica
Black Gum

Salix sp.
Willow

BIOSWALE

Grasses/Sedges:

Carex annectans
Yellow Fruited Sedge

Carex grayii
Bur Sedge

Juncus effusus
Soft Rush

Schizachyrium scoparium
Little Bluestem

Sporobolus heterolepis
Prairie Dropseed

Forbs:

Amsonia illustris
Shining Bluestar

Echinacea purpurea
Purple Coneflower

Iris fulva
Copper Iris

Lobelia cardinalis
Cardinal Flower

Solidago flexicaulis
Zig-zag Goldenrod

Trees/Shrubs:

Aesculus pavia
Red Buckeye

Cercis canadensis
Redbud

Chionanthus virginicus
Fringetree

Diospyos virginiana
Persimmon

GRASSLAND

Grasses/Sedges:

Andropogon gerardii
Big Bluestem

Andropogon virginica
Broomsedge

Panicum virgatum
Switchgrass

Schizachyrium scoparium
Little Bluestem

Forbs:

Chrysopsis camporum
Golden Aster

Lespedeza virginica
Slender Bush Cover

Verbesina helianhoides
Yellow Wingstem

Trees/Shrubs:

Amelanchier arborea
Serviceberry

Quercus coccinea
Scarlet Oak

Pinus echinata
Short-leaf Pine

MAMMALS

Lepus californicus
Black-tailed Jackrabbit

Peromyscus gossypinus
Cotton Mouse

Myotis grisescens
Gray Myotis

Myotis leibii
Eastern Small-footed Myotis

Myotis sodalis
Indiana Myotis

Reithrodontomys montanus
Plains Harvest Mouse

Perognathus flavescens
Plains Pocket Mouse

BIRDS

Peucaea aestivalis
Bachman's Sparrow

Nycticorax nycticorax
Black-crowned Night Heron

Setophaga cerulea
Cerulean Warbler

Accipiter cooperii
Cooper's Hawk

Gallinula chloropus
Common Moorhen

Ammodramus henslowii
Henslow's Sparrow

Lanius ludovicianus
Loggerhead Shrike

Circus cyaneus
Northern Harrier

Buteo lineatus
Red-shouldered Hawk

Bartramia longicauda
Upland Sandpiper

AMPHIBIANS

Hemidactylium scutatum
Four-toed Salamander

Hyla cinerea
Green Treefrog

Pseudacris streckeri illinoensis
Illinois Chorus Frog

GREEN TREEFROG

The preferred habitat of the Green Treefrog is forested and shrubby areas near water. Their diet includes small insects such as crickets, moths and flies.

Lithobates pipiens
Northern Leopard Frog

Plethodon angusticlavius
Ozark Zigzag Salamander

Ambystoma annulatum
Ringed Salamander

REPTILES

Macrochelys temminckii
Alligator Snaping Turtle

Emydoidea blandingii
Blanding's Turtle

Eumeces obsoletus
Great Plains Skink

Deirochelys reticularia miaria
Western Chicken Turtle

Kinosternon flavescens
Yellow Mud Turtle

Reused Concrete

The concrete excavated from the existing parking lot on site can be crushed down into gravel. The gravel can then be used for pathway material and bioswale base within the landscape to increase permeability. By reusing the concrete on site hauling and landfill costs are reduced.

Reclaimed Soil

By balancing the cut and fill in the grading plan hauling and landfill costs are eliminated. The soil excavated from the river channel and the soil used as fill for the new connector provides an open area for community recreation.

Increased Dissolved Oxygen

Through the creation of pools, rock dams, and rock riffles an increase in water turbulence can occur, thus, increasing the amount of dissolved oxygen in the water. By implementing rocks and boulders within the creek channel water quality downstream is improved. Rocks and boulders increase friction within the creek, hence, reducing water velocity. With the River des Peres currently being impaired due to low levels of dissolved oxygen and chloride, improving the levels of dissolved oxygen within the water will increase water habitability for aquatic species.

Increased Carbon Sequestration

Referencing the Westerly Creek at Stapleton landscape performance benefits, a native vegetative cover was found to sequester 4.85 tons per acre (LAF, 2013). Therefore, up to 165 tons of carbon can be sequestered for the 34 acre site, which is 24 times more than using a bluegrass sod covering.

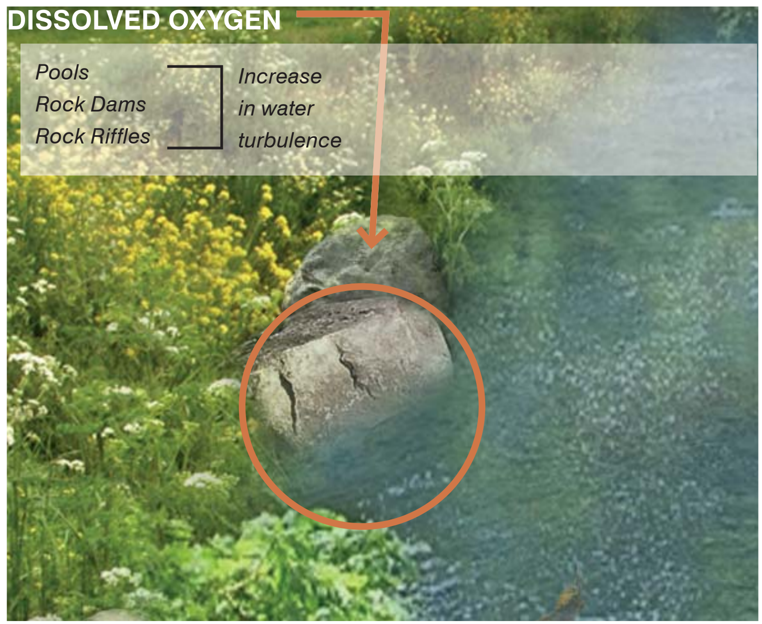
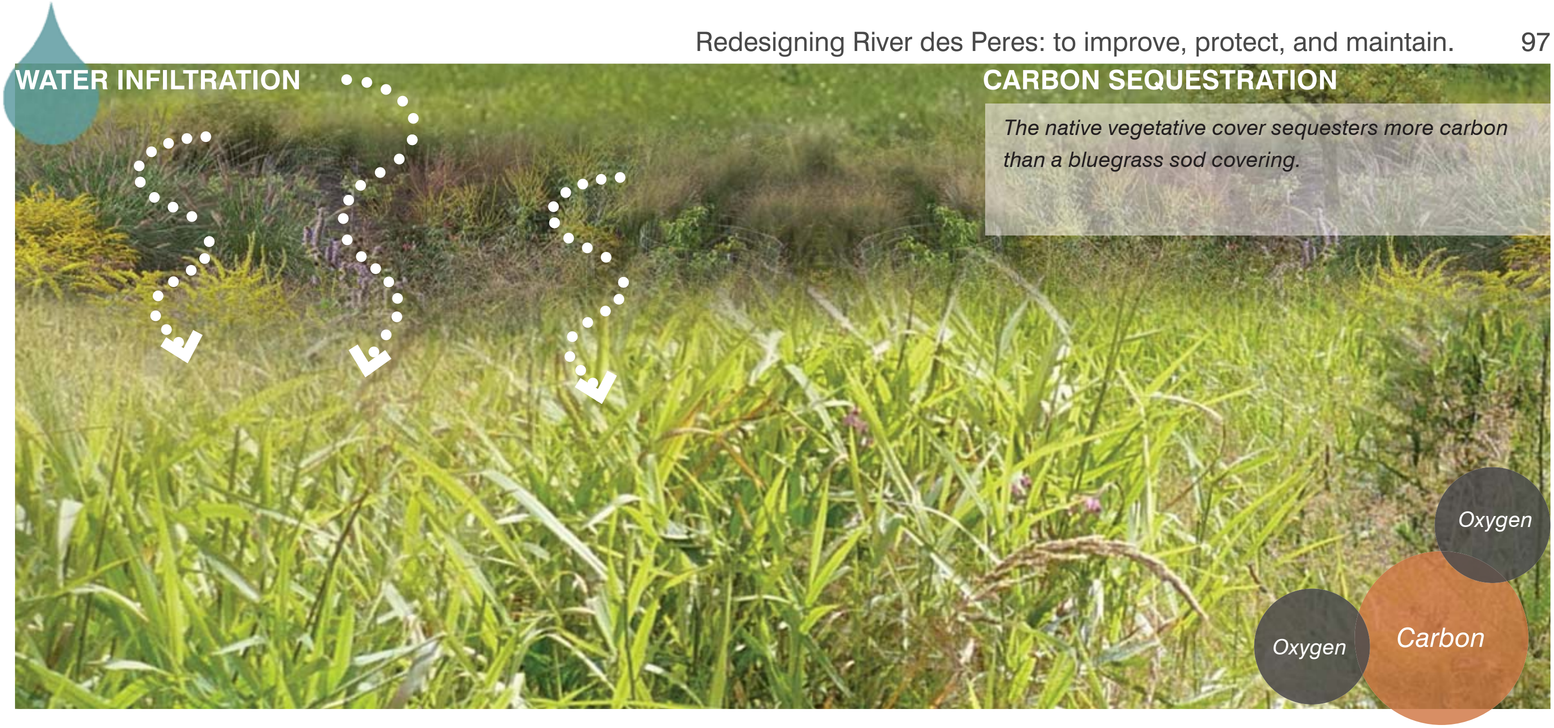


Figure 4.19 Deer Creek and South County Connector Performance Benefits

WATER INFILTRATION

CARBON SEQUESTRATION

The native vegetative cover sequesters more carbon than a bluegrass sod covering.

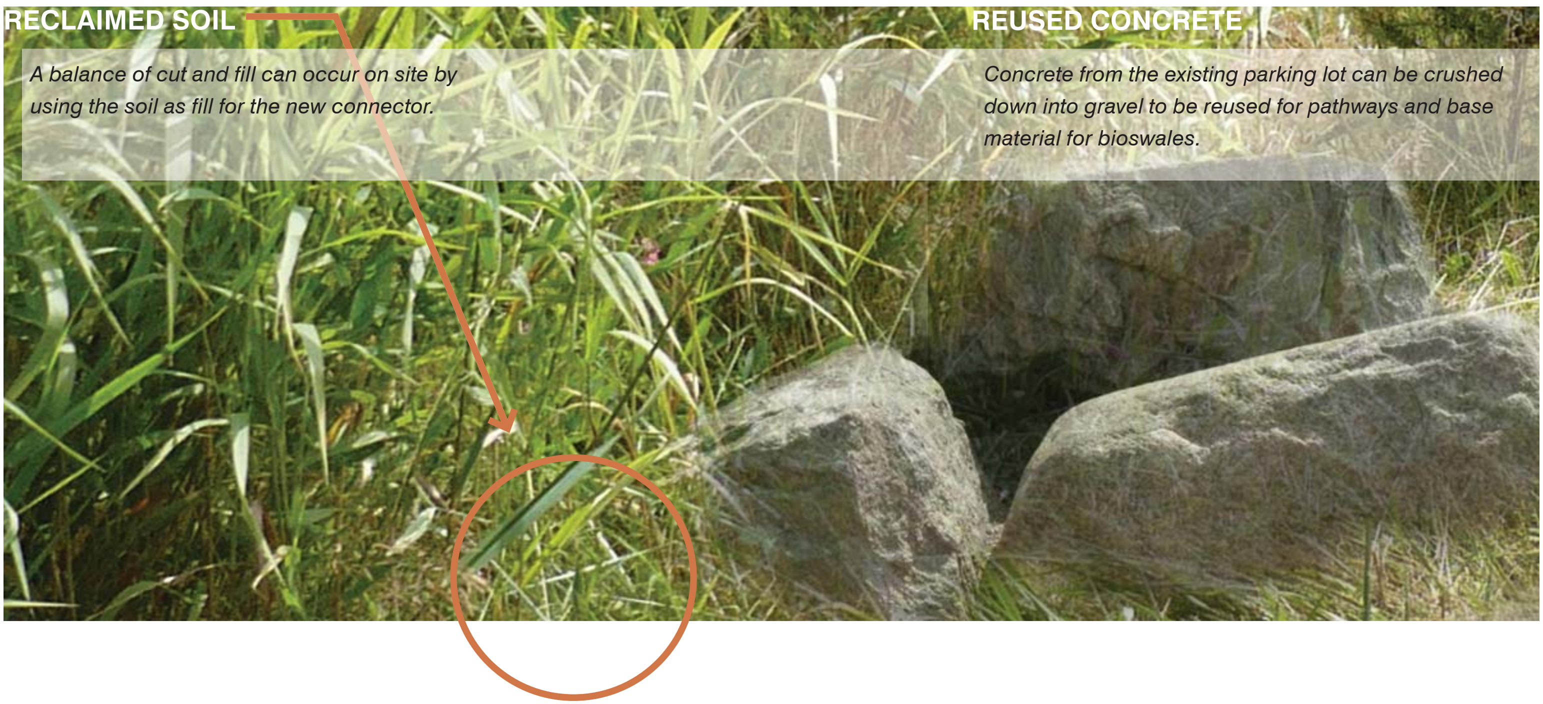


RECLAIMED SOIL

A balance of cut and fill can occur on site by using the soil as fill for the new connector.

REUSED CONCRETE

Concrete from the existing parking lot can be crushed down into gravel to be reused for pathways and base material for bioswales.



GRANTS TRAIL EXTENSION CONCEPTUAL PLAN

As shown in figure 4.20, the floodplain park is north of Gravois Creek and just south of the proposed Grants Trail Extension. Walls implemented in front of housing developments provide bank stabilization by reducing steep bank slopes and erosion. Parking lot removal allows for recreational and educational opportunities through the implementation of riparian vegetation.

Concrete notches placed on the entrance and exit of the flood storage area allow for water accumulation and lessens the erosive force of stormwater on the meander of Gravois Creek. The banks to the northwest are re-sloped to balance the cut and fill on site, and to reduce steep banks and erosion. The master plan and corresponding creek channel design accomplish three goals stated in the thesis. The implementation of stormwater BMPs and wet meadows throughout the watershed lowers the peak return frequency flow of the creek, accomplishing the goal of lowering the return flood frequency.

Along the half mile portion of the creek there are three planting zones: riparian, grassland, and bioswale. Each zone caters to a specific group of plant and wildlife species, and accomplishes the goal of enhancing the wildlife habitat.

Riparian zones are implemented along the banks of the creek and extend out into the housing development along the south and into the open space to the north, to serve as a buffer between development and the creek. Riparian areas are implemented with a variety of grasses, sedges, forbs, shrubs, and tree species. Grass and sedge species include Bur and Fox Sedge, River Oats, and Soft Rush. Forb species consist of Shining Bluestar, Marsh Milkweed, Cardinal Flower, and Sweet Coneflower. Shrub and tree species consist of Paw Paw, Green Hawthorne, Winterberry Holly, Black gum, and Willow. The use of native vegetation caters to wildlife species that are native to the area including, Black-tailed Jackrabbit, Cotton Mouse, Plains Harvest and Pocket Mouse, Bachman's Sparrow, Black-crowned Night Heron, Cerulean Warbler, and Cooper's Hawk.

Grassland zones are implemented along the large open spaces parallel to the river and along the roadways. The soil onsite will need to be mixed with a fine-loam to provide soil fertility and plant longevity. The grassland zone includes grasses, sedges, forbs, shrubs, and trees. Grass species include Big Bluestem, Broomsedge, Switchgrass, and Little Bluestem. Forb species include Golden Aster, Slender Bush Cover, Old Field Goldenrod, and Yellow Wingstem. Shrubs and trees include Serviceberry, Scarlet Oak, and Short-leaf Pine.

A bioswale placed near the new trail extension collects and filters stormwater runoff from the nearby businesses and parking area. Bioswale implementation helps accomplish the goal of fixing the infrastructural performance problems

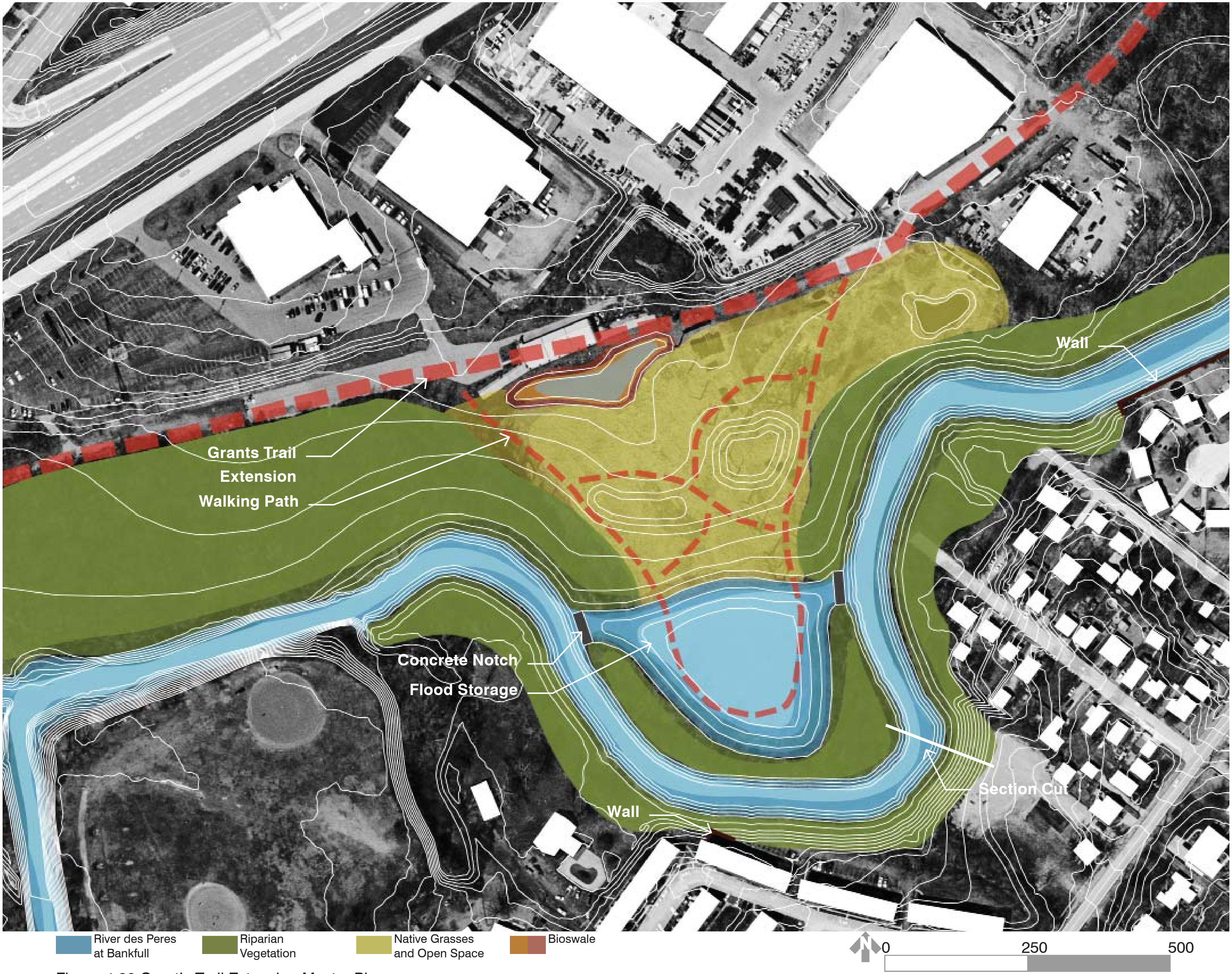


Figure 4.20 Grant's Trail Extension Master Plan

on the site by retaining stormwater during rain events. Grass species include Yellow Fruited and Bur Sedge, Soft Rush, Little Bluestem, and Prairie Dropseed. Forbs include Shining Bluestar, Purple Coneflower, Copper Iris, Cardinal Flower and Zig-zag Goldenrod. Tree and shrub species include Red Buckeye, Redbud, Fringetree and Persimmon.

Creek Channel Design

As shown in figure 4.21, the existing creek channel is deep with banks at a steep 42% slope on the south side and a 28% on the north. The floodplain of the creek extends out into the park space on the north. The steep slope to the south is due to the construction of the concrete parking lot.

The proposed channel holds the 1.5 year bankfull discharge with a bankfull depth of 8 feet and a cross-sectional area of 320 feet throughout the site. The creek banks are re-graded to a 22% slope, and the removal of the parking lot created the opportunity for an open recreational space. The channel is implemented with rocks and boulders to provide additional water resistance for water velocity reduction, decrease bank erosion, and to increase dissolved oxygen within the water.

Removing invasive plant species including, Bush Honeysuckle, Wintercreeper Euonymus, and Garlic Mustard, and adding native riparian and grassland vegetation creates wildlife habitat that also improves the community well-being.

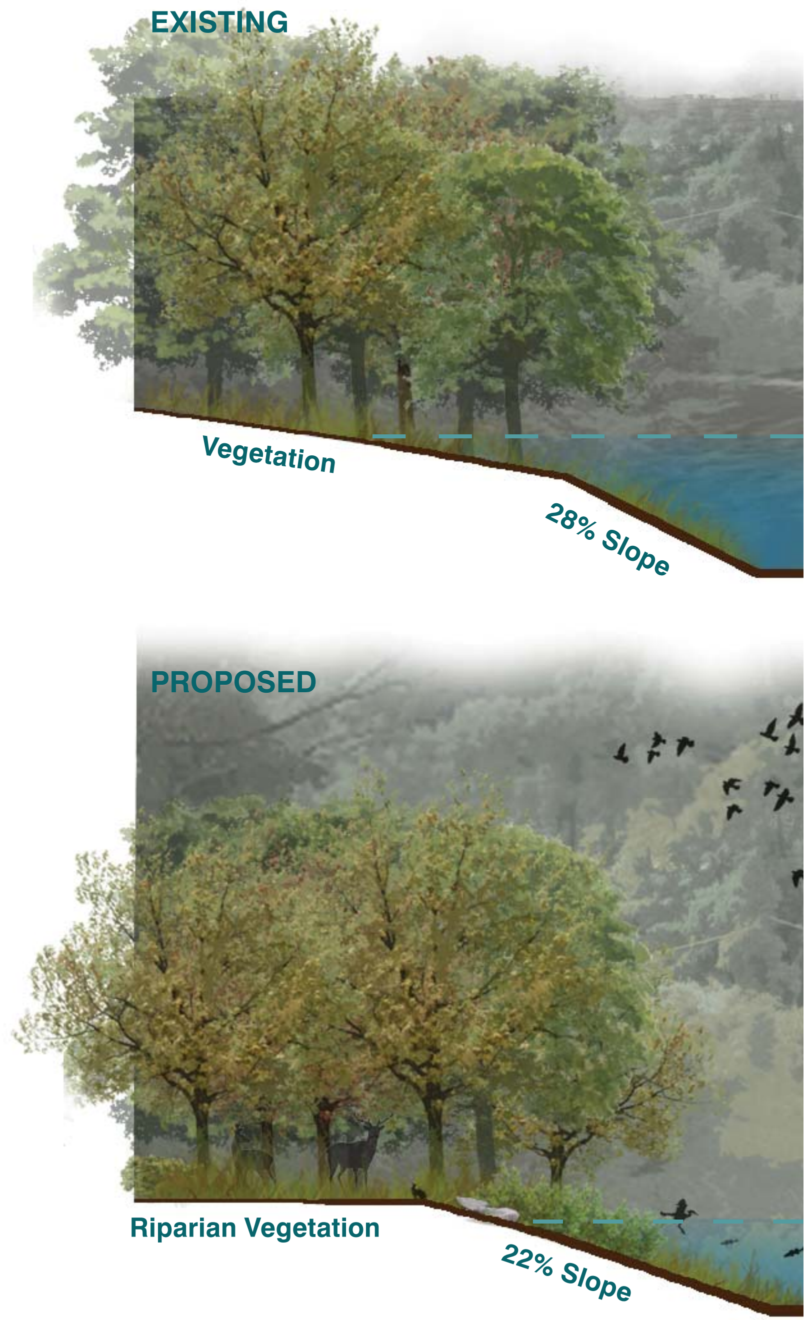
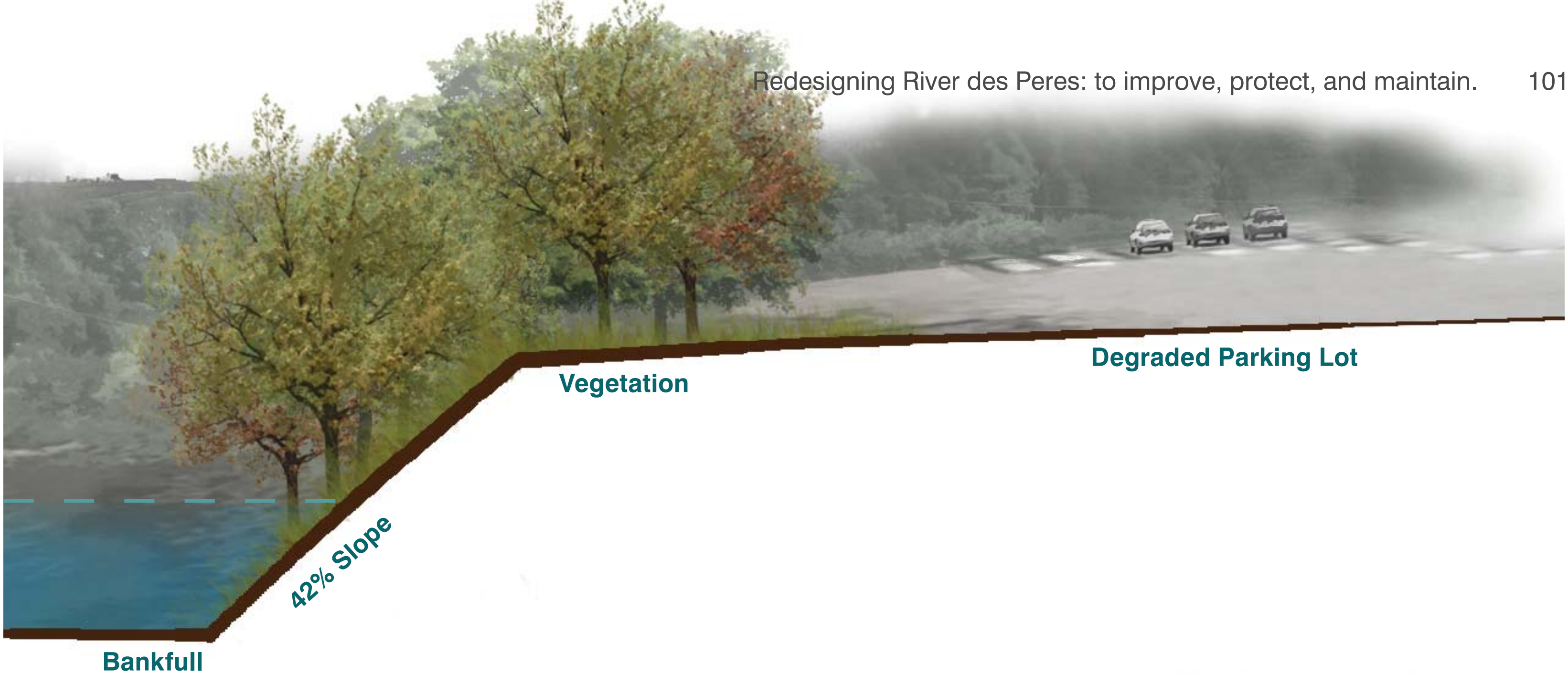


Figure 4.21 Grant's Trail Extension Creek Channel


Degraded Parking Lot
Vegetation
42% Slope
Bankfull


Open Space
Riparian Vegetation
8'
22% Slope
Bankfull
0
30
60

Floodplain Park Vision

As shown in figure 4.22, Grant's Trail floodplain park provides recreational and educational opportunities, spiritual enrichment, and aesthetic experiences. The natural playscapes provide contact with outdoor elements that can foster stress relief and promote higher-order cognitive functions in children.

Jester Park Natural Playscape, a precedent study, as shown in figure 4.23, was used in the visioning Grant's Trail Floodplain Park. Jester Park Natural Playscape, located in Granger, Iowa, "utilizes native materials in place of prefabricated play equipment to create a play experience for users that is unique in the Des Moines Metro Area" (RDG, 2013). Through public and client "discussions it was decided that no prefabricated play structures would be a part of this play space and that materials that might be naturally occurring in the area would be used to create a series of play elements that would allow play space users to '...go over, under, around and through them'" (RDG, 2013).

As shown in figure 4.24, the use of rocks and boulders onsite provide cover for wildlife,

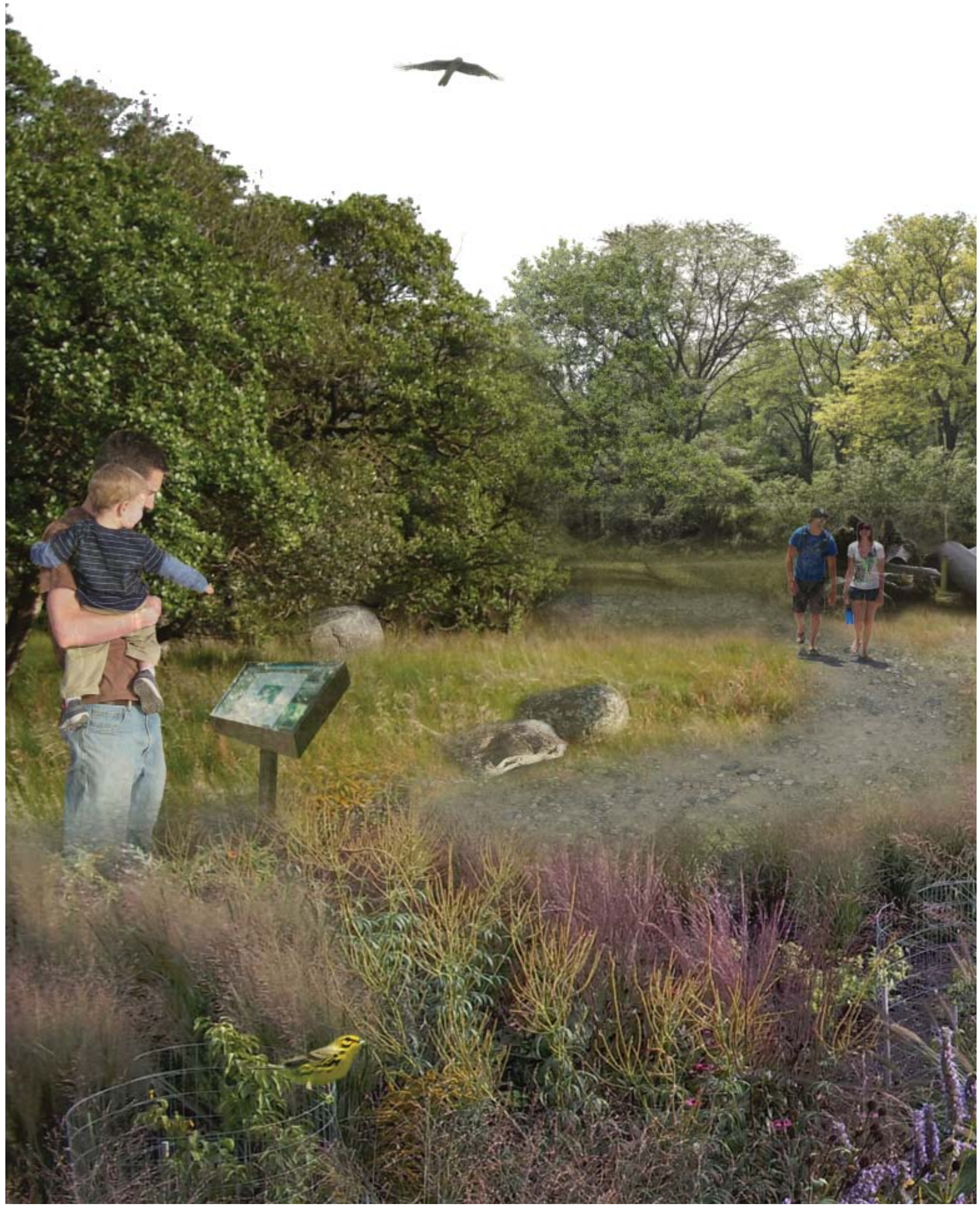


Figure 4.22 Grant's Trail Extension Open Space Vision

Figure 4.23- Jester Park Natural Playscape
Located in Granger, Iowa, Jester Park “utilizes native materials in place of prefabricated play equipment to create a play experience for users that is unique in the Des Moines Metro Area” (RDG, 2013).

and the mixture of grasses, forbs, shrubs, and trees provide a variety of food for different wildlife species contributing to the aesthetics and biodiversity of the site (table 4.4).

Ecological Performance Benefits

Water Infiltration

As shown in figure 4.25, the deep roots of native plant species help the "biological uptake of pollutants and nitrogen" and the increase soil pore space "to promote infiltration of rainfall" (MBG, 2011). With 24 acres of improved land cover 6 acre feet per hour can be infiltrated. Pervious surface infiltration rates were found in the 1995 Stapleton Area Stormwater Outfall Systems Plan, which listed infiltration rates of .25 acre feet per hour (LAF, 2013). By implementing native vegetation and improving infiltration Grant's Trail open space's air quality can be improved.

Increased Flood Storage Capacity

Increased stormwater storage occurs on the site by the addition of 285,000 cubic feet of bioswale and flood storage space. Increasing the storage capability provides groundwater recharge by storing and infiltrating water volumes into the ground. Vegetation planted in the storage area trap sediments and take up nutrients into their roots.

Reused Concrete

The concrete excavated from the existing parking lot on site can be crushed down into

Figure 4.24 Grant's Trail Extension Flood Storage Vision

Table 4.4 Vegetation and Wildlife Species

RIPARIAN VEGETATION

Grasses/Sedges:

Carex grayi
Bur Sedge

Carex vulpinoidea
Fox Sedge

Chasmanthium latifolium
River Oats

Juncus effusus
Soft Rush

Forbs:

Amsonia illustris
Shining Bluestar

Asclepias incarnata
Marsh Milkweed

Lobelia cardinalis
Cardinal Flower

Rubeckia subtomentosa
Sweet Coneflower

Trees/Shrubs:

Asimina triloba
Paw Paw

Crataegus viridis
Green Hawthorne

Ilex verticillata
Winterberry Holly

Nyssa sylvatica
Black Gum

Salix sp.
Willow

BIOSWALE

Grasses/Sedges:

Carex annectans
Yellow Fruited Sedge

Carex grayii
Bur Sedge

Juncus effusus
Soft Rush

Schizachyrium scoparium
Little Bluestem

Sporobolus heterolepis
Prairie Dropseed

Forbs:

Amsonia illustris
Shining Bluestar

Echinacea purpurea
Purple Coneflower

Iris fulva
Copper Iris

Lobelia cardinalis
Cardinal Flower

Solidago flexicaulis
Zig-zag Goldenrod

Trees/Shrubs:

Aesculus pavia
Red Buckeye

Cercis canadensis
Redbud

Chionanthus virginicus
Fringetree

Diospyos virginiana
Persimmon

GRASSLAND

Grasses/Sedges:

Andropogon gerardii
Big Bluestem

Andropogon virginica
Broomsedge

Panicum virgatum
Switchgrass

Schizachyrium scoparium
Little Bluestem

Forbs:

Chrysopsis camporum
Golden Aster

Solidago nemoralis
Old Field Goldenrod

Verbesina helianhoides
Yellow Wingstem

Trees/Shrubs:

Amelanchier arborea
Serviceberry

Quercus coccinea
Scarlet Oak

Pinus echinata
Short-leaf Pine

MAMMALS

Lepus californicus
Black-tailed Jackrabbit

Peromyscus gossypinus
Cotton Mouse

Reithrodontomys montanus
Plains Harvest Mouse

Perognathus flavescens
Plains Pocket Mouse

BIRDS

Thryomanes bewickii
Bewick's Wren

Nycticorax nycticorax
Black-crowned Night Heron

Setophaga cerulea
Cerulean Warbler

Accipiter cooperii
Cooper's Hawk

Gallinula chloropus
Common Moorhen

Ammodramus henslowii
Henslow's Sparrow

Lanius ludovicianus
Loggerhead Shrike

Circus cyaneus
Northern Harrier

Buteo lineatus
Red-shouldered Hawk

Bartramia longicauda
Upland Sandpiper

AMPHIBIANS

Hemidactylium scutatum
Four-toed Salamander

Hyla cinerea
Green Treefrog

Pseudacris streckeri illinoensis
Illinois Chorus Frog

Lithobates pipiens
Northern Leopard Frog

Plethodon angustíclavius
Ozark Zigzag Salamander

Ambystoma annulatum
Ringed Salamander

REPTILES

Macrochelys temminckii
Alligator Snaping Turtle

Emydoidea blandingii
Blanding's Turtle

Eumeces obsoletus
Great Plains Skink

Deirochelys reticularia miaria
Western Chicken Turtle

Kinosternon flavescens
Yellow Mud Turtle

BEWICK'S WREN

The preferred habitat of the Bewick's Wren is open areas covers in shrubs and thickets. "Depending on where you live, you may find them in chaparral-covered hillsides, oak woodlands, mixed evergreen forests, desert scrub, stands of prickly pear and other cacti, mesquite and century plant, willows and tamarisk, hedgerows, or suburban plantings" – Cornell University, 2012

gravel. The gravel can then be used for pathway material and bioswale base within the landscape to increase permeability. By reusing the concrete on site hauling and landfill costs are reduced.

Reclaimed Soil

By balancing the cut and fill in the grading plan, hauling and landfill costs are eliminated. The soil excavated from the river channel and the soil used as fill for landform creation provides an open area for community recreation.

Increased Dissolved Oxygen

Through the creation of pools, rock dams, and rock riffles an increase in water turbulence can occur, thus, increasing the amount of dissolved oxygen in the water. By implementing rocks and boulders within the creek channel water quality downstream is improved. Rocks and boulders increase friction within the creek, hence, reducing water velocity. With the River des Peres currently being impaired due to low levels of dissolved oxygen and chloride, improving the levels of dissolved oxygen within the water will increase water habitability for aquatic species.

Increased Carbon Sequestration

Referencing the Westerly Creek at Stapleton landscape performance benefits, a native vegetative cover was found to sequester 4.85 tons per acre (LAF, 2013). Therefore, up to 116 tons of carbon can be sequestered for the 24 acre site, which is 24 times more than using a bluegrass sod covering.

Figure 4.25 Grant’s Trail Extension Performance Benefits

WATER INFILTRATION

CARBON SEQUESTRATION

The native vegetative cover sequesters more carbon than a bluegrass sod covering.

REUSED CONCRETE

Concrete from the existing parking lot and foundation can be crushed down into gravel to be reused for pathways and base material for bioswales.

RECLAIMED SOIL

A balance of cut and fill can occur on site through the creation of landforms in the open space.

MAIN CHANNEL OF THE RIVER DES PERES CONCEPTUAL PLAN

Figure 4.26 shows a half mile section of the main channel of the River des Peres next to Willmore Park. By removing the existing concrete channel and implementing a two-stage channel system, bank stabilization and floodplain reconnection is provided. By naturalizing the river banks, sediment during high flows can be trapped in the vegetation instead of being transported downstream. Advantages of the two-stage channel are the increase in aquatic habitat and the potential for sidewalks along the river bankfull. Concrete wall systems placed along the eastern side of the river reduce steep river banks. The master plan and corresponding stream channel design accomplish five goals stated in the thesis. The implementation of stormwater BMPs and wet meadows throughout the watershed lowers the flood frequency of the River, accomplishing the goal of lowering the flood frequency of the river.

Along this section of the river there are four planting zones: riparian, grassland, and bioswale. Each zone caters to a specific group of plant and wildlife species, and accomplishes the goal of enhancing the wildlife habitat in the area.

Riparian zones are implemented along the banks of the river and extend out into Willmore Park to the east and into the open space to the west. With the soil being a fine-loamy mix, riparian vegetation thrives in the area due to high soil fertility. The riparian zone serves as a buffer between roadways, housing developments, and the river. Riparian buffers intercept stormwater from the roadway and housing developments that run parallel to the river. Riparian zones are implemented with a variety of grasses, sedges, forbs, shrubs, and tree species. Grass and sedge species include Bur and Fox Sedge, River Oats, and Soft Rush. Forb species consist of Shining Bluestar, Marsh Milkweed, Cardinal Flower, and Sweet Coneflower. Shrub and tree species consist of Paw Paw, Green Hawthorne, Winterberry Holly, Black gum, and Willow. The use of native vegetation caters to wildlife species that are native to the area including, Black-tailed Jackrabbit, Cotton Mouse, Plains Harvest and Pocket Mouse, Bachman's Sparrow, Black-crowned Night Heron, Cerulean Warbler, and Cooper's Hawk.

Grassland and roadway tall grass zones are implemented along the large open spaces parallel to the river and along the roadways. These zones include tall and short grasses, forbs, shrubs, and trees. Grass species include Big Bluestem, Broomsedge, Switchgrass, and Little Bluestem. Forb species include Golden Aster, Slender Bush Cover, Old Field Goldenrod, and Yellow Wingstem. Shrubs and trees include Serviceberry, Scarlet Oak, and Short-leaf Pine.

Two bioswale zones near the roadway and housing development to the east collect stormwater runoff, filtering

Figure 4.26 Main Channel River des Peres Master Plan

the toxic substances that are found on roadways before returning the water to the river. Bioswale implementation helps accomplish the goal of fixing the infrastructural performance problems on the site by retaining stormwater during rain events. Grass species include Yellow Fruited and Bur Sedge, Soft Rush, Little Bluestem, and Prairie Dropseed. Forbs include Shining Bluestar, Purple Coneflower, Copper Iris, Cardinal Flower and Zig-zag Goldenrod. Tree and shrub species include Red Buckeye, Redbud, Fringetree and Persimmon.

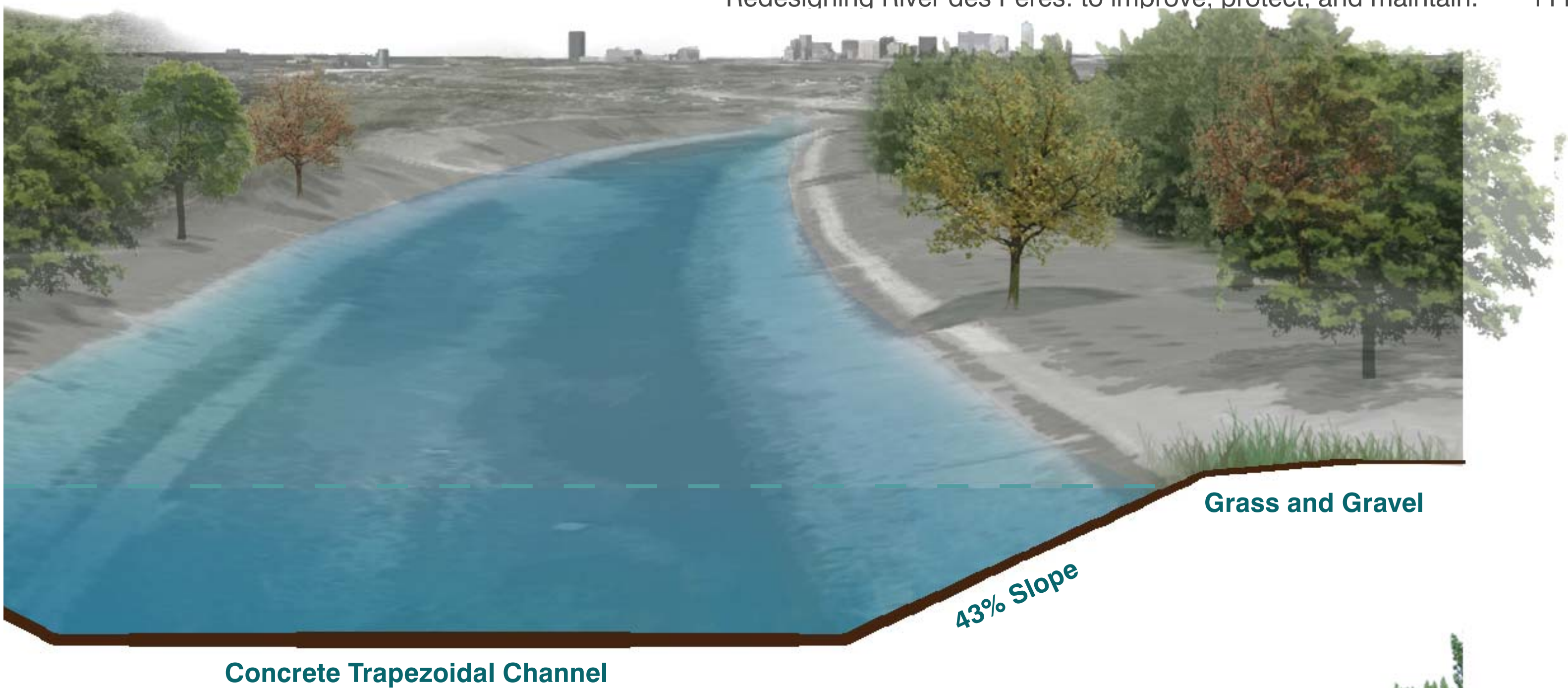
River Channel Design

The existing river channel, as shown in figure 4.27, is wide with banks at a steep 43%. The floodplain of the river is removed from the river and no flood storage is found onsite. Overall, there is a lack of riparian vegetation and trees along the main channel.

The proposed channel holds the 1.5 year bankfull discharge with a bankfull depth of 8 feet and a cross-sectional area of 950 feet. The river banks are regraded to bankfull at a 3:1 or 33% slope and extend out on both sides to include sidewalks for pedestrian recreation. On the north side two reused concrete wall systems rise 4-6 feet to keep the contours from extending into the channel. The channel is implemented with rocks and boulders to provide additional water resistance for water velocity reduction, decrease bank erosion, and to increase dissolved oxygen within the water.

Increasing the native riparian vegetation along the river helps moderate water temperatures providing livable habitat for aquatic species to thrive in, and produces woody debris that creates in-stream habitat through backwater pools and sediment storage for fish spawning (Riley, 1998).

Figure 4.27 Main Channel River des Peres River Channel


Grass and Gravel
43% Slope
Concrete Trapezoidal Channel


Sidewalk
33% Slope
8'
Concrete Bottom
33% Slope
Sidewalk
6' Rise
Concrete Slab
Wall
4' Rise
Concrete Slab
Wall
0
30
60

Main Channel Vision

As shown in figure 4.28, the river looks more naturalized surrounded by extensive native riparian vegetation and grassland. The community can explore the main channel along the sidewalks lining the river. These sidewalks provide additional recreational opportunities outside the River des Peres Greenway. Local art is placed onto the concrete wall systems and in the surrounding landscape in the form of sculpture and paintings to incorporate the community's sense of identity. The placement of artwork accomplishes the goal of enhancing the local identity of the waterway.

Cheonggyecheon restoration project, a precedent study, as shown in figure 4.29, was used in the visioning of the main channel of the River des Peres. Located in South Korea the historic Cheonggyecheon stream was restored by taking a costly and aging elevated freeway and providing "ecological and recreational opportunities along a 3.6-mile corridor" for the city (Robinson & Myvonwynn, 2011). Designed by SeoAhn Total Landscape, the project provides performance benefits including: increased flood protection and biodiversity, a reduction of urban heat island index and air pollution, and an increase in sustainable transportation, property values, and business economics. The restoration of Cheonggyecheon contains a 3.6 mile "green corridor for pedestrians, bicyclists, and wildlife," wetlands, and a transportation network of bridges, subway, bus, and waterway connections

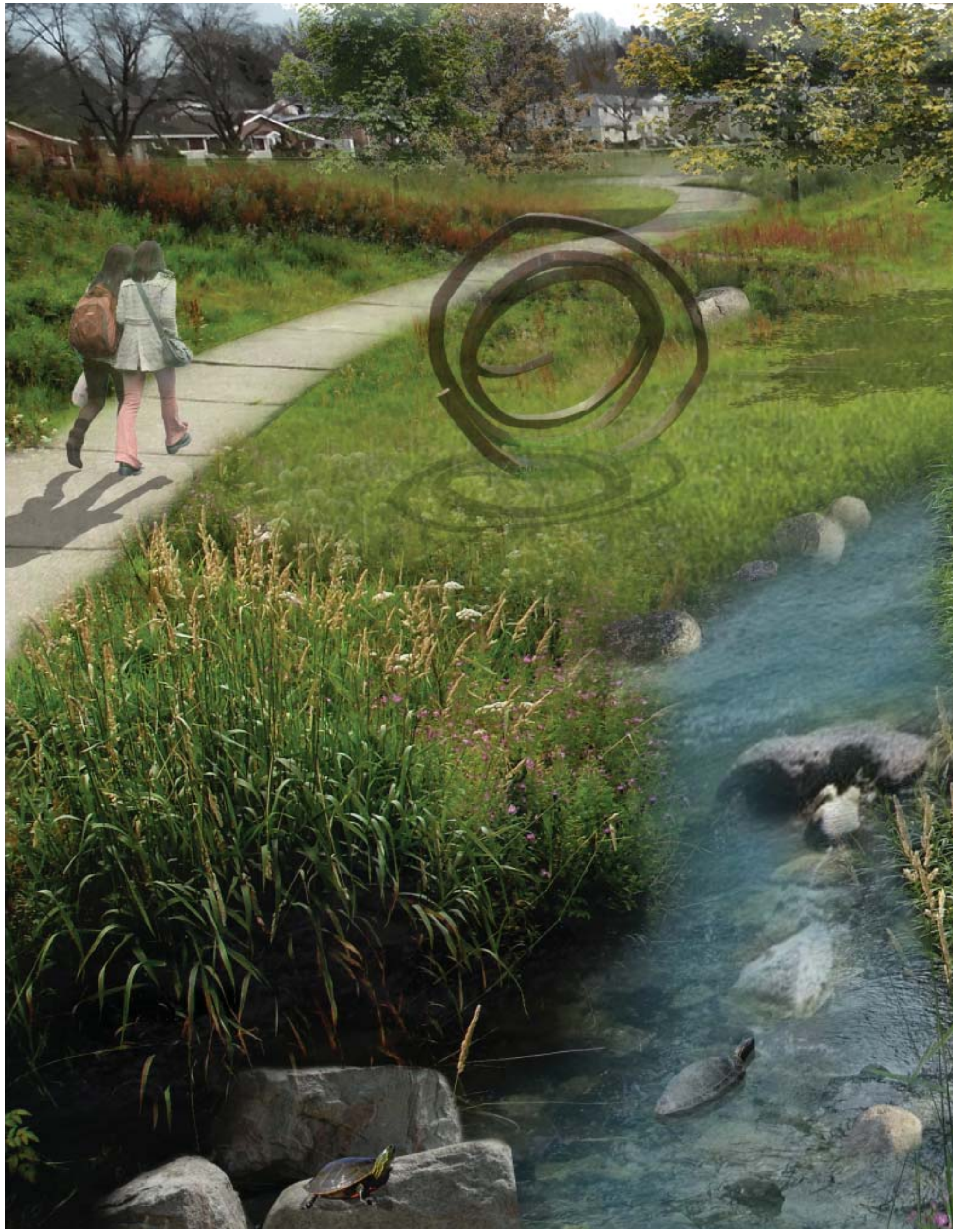


Figure 4.28 Main Channel River des Peres River Vision

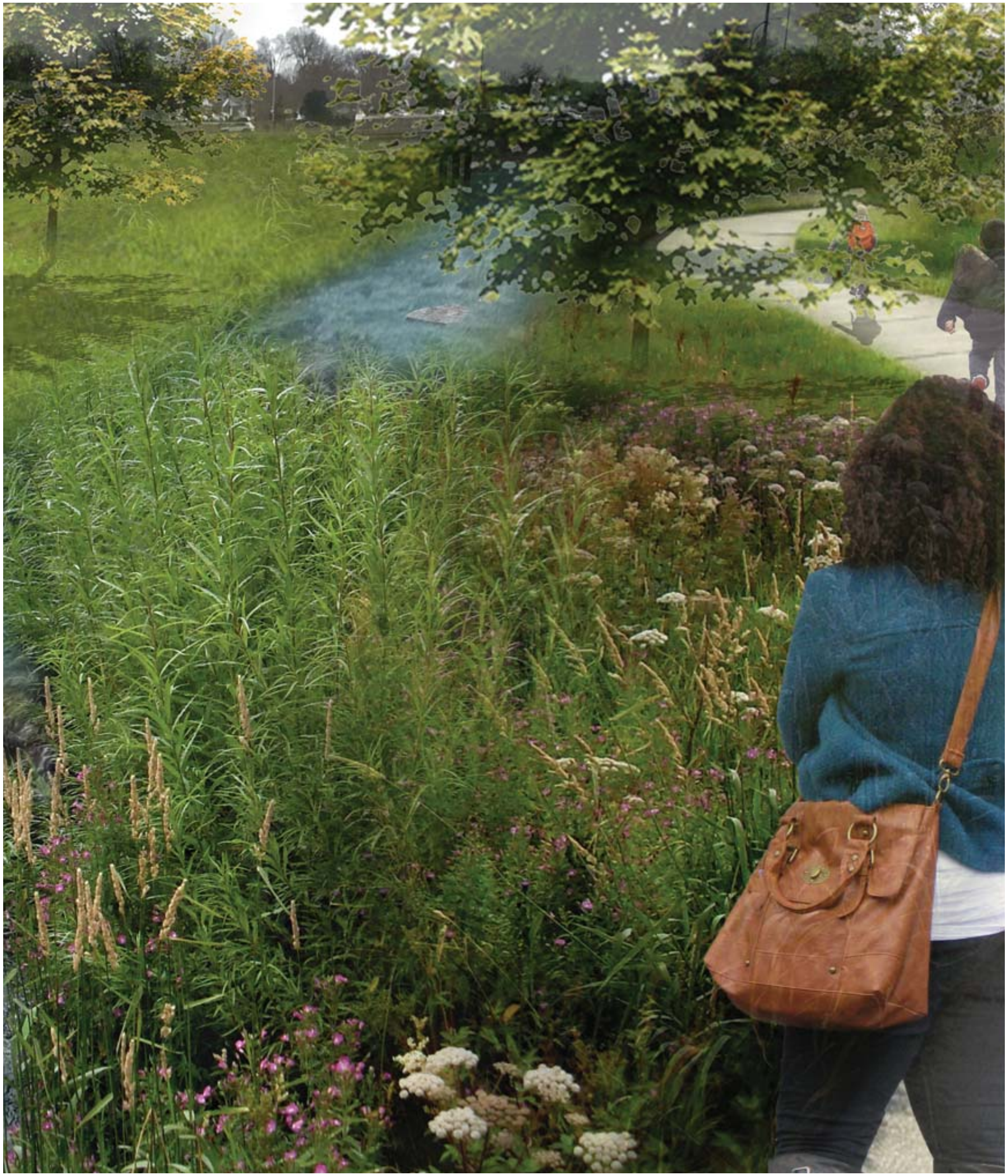


Figure 4.29- Cheonggyecheon Stream
Located in South Korea the Cheonggyecheon stream was restored by taking a costly and aging elevated freeway and providing “ecological and recreational opportunities along a 3.6-mile corridor” for the city (Robinson & Myvonwynn, 2011).

(Robinson & Myvonwynn, 2011).

As shown in figure 4.30, the use of rocks and boulders onsite provide cover for wildlife, and the mixture of grasses, forbs, shrubs, and trees provide a variety of food for a diverse group of wildlife species, contributing to the aesthetics and biodiversity of the site (table 4.5).

Ecological Performance Benefits

Water Infiltration

As shown in figure 4.31, the deep roots of native plant species help the "biological uptake of pollutants and nitrogen" and the increase soil pore space "to promote infiltration of rainfall" (MBG, 2011). With 33 acres of improved land cover 8.25 acre feet per hour can be infiltrated. Pervious surface infiltration rates were found in the 1995 Stapleton Area Stormwater Outfall Systems Plan, which listed infiltration rates of .25 acre feet per hour (LAF, 2013). By implementing native vegetation and improving infiltration the main channel of the River des Peres' air quality can be improved.

Increased Flood Storage Capacity

Increased stormwater storage occurs on the site by the addition of 320,000 cubic feet of storage within bioswale areas. Increasing the flood storage capability enables groundwater recharge by storing and infiltrating water volumes into the ground. Vegetation planted in the storage area trap sediments and take up nutrients into their roots.

Figure 4.30 Main Channel River des Peres Bioswale and River Vision

Table 4.5 Vegetation and Wildlife Species

RIPARIAN VEGETATION

Grasses/Sedges:

Carex grayi
Bur Sedge

Carex vulpinoidea
Fox Sedge

Chasmanthium latifolium
River Oats

Juncus effusus
Soft Rush

Forbs:

Amsonia illustris
Shining Bluestar

Asclepias incarnata
Marsh Milkweed

Lobelia cardinalis
Cardinal Flower

Rubeckia subtomentosa
Sweet Coneflower

Trees/Shrubs:

Asimina triloba
Paw Paw

Crataegus viridis
Green Hawthorne

Ilex verticillata
Winterberry Holly

Nyssa sylvatica
Black Gum

Salix sp.
Willow

BIOSWALE

Grasses/Sedges:

Carex annectans
Yellow Fruited Sedge

Carex grayii
Bur Sedge

Juncus effusus
Soft Rush

Schizachyrium scoparium
Little Bluestem

Sporobolus heterolepis
Prairie Dropseed

Forbs:

Amsonia illustris
Shining Bluestar

Echinacea purpurea
Purple Coneflower

Iris fulva
Copper Iris

Lobelia cardinalis
Cardinal Flower

Solidago flexicaulis
Zig-zag Goldenrod

Trees/Shrubs:

Aesculus pavia
Red Buckeye

Cercis canadensis
Redbud

Chionanthus virginicus
Fringetree

Diospyos virginiana
Persimmon

GRASSLAND

Grasses/Sedges:

Andropogon gerardii
Big Bluestem

Andropogon virginica
Broomsedge

Panicum virgatum
Switchgrass

Schizachyrium scoparium
Little Bluestem

Forbs:

Lespedeza virginica
Slender Bush Cover

Solidago nemoralis
Old Field Goldenrod

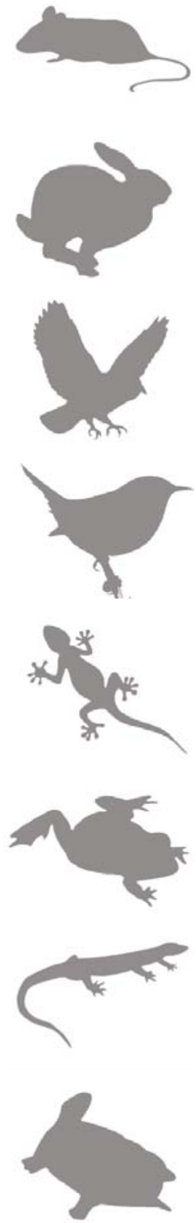
Verbesina helianhoides
Yellow Wingstem

Trees/Shrubs:

Amelanchier arborea
Serviceberry

Quercus coccinea
Scarlet Oak

Pinus echinata
Short-leaf Pine



MAMMALS

Lepus californicus
Black-tailed Jackrabbit

Peromyscus gossypinus
Cotton Mouse

Reithrodontomys montanus
Plains Harvest Mouse

Perognathus flavescens
Plains Pocket Mouse

BIRDS

Nycticorax nycticorax
Black-crowned Night Heron

Setophaga cerulea
Cerulean Warbler

Accipiter cooperii
Cooper's Hawk

Gallinula chloropus
Common Moorhen

Ammodramus henslowii
Henslow's Sparrow

Lanius ludovicianus
Loggerhead Shrike

Circus cyaneus
Northern Harrier

Buteo lineatus
Red-shouldered Hawk

Bartramia longicauda
Upland Sandpiper

AMPHIBIANS

Hemidactylium scutatum
Four-toed Salamander

Hyla cinerea
Green Treefrog

Pseudacris streckeri illinoensis
Illinois Chorus Frog

Lithobates pipiens
Northern Leopard Frog

Plethodon angusticlavius
Ozark Zigzag Salamander

Ambystoma annulatum
Ringed Salamander

REPTILES

Macrochelys temminckii
Alligator Snaping Turtle

Emydoidea blandingii
Blanding's Turtle

Eumeces obsoletus
Great Plains Skink

Deirochelys reticularia miaria
Western Chicken Turtle

Kinosternon flavescens
Yellow Mud Turtle

COOPER'S HAWK

The preferred habitat of the Cooper's Hawk is forested areas, and is commonly found in suburban neighborhoods and parks. The diet of the hawk includes: starlings, doves, pigeons "along with American Robins, several kinds of jays, Northern Flicker, and quail, pheasants, grouse, and chickens" –Cornell University, 2012

Reused Concrete

The concrete excavated from the existing concrete trapezoidal channel can be cut into slabs and used as a concrete wall. With deadman anchoring the concrete slabs can be used as retaining walls. By reusing the concrete on site hauling and landfill costs are reduced.

Reclaimed Soil

By reusing the soil excavated from Forest Park and using it to fill in the channel to desired specifications reduces the need for soil cutting and landfill costs.

Increased Dissolved Oxygen

Through the creation of pools, rock dams, and rock riffles an increase in water turbulence can occur, thus, increasing the amount of dissolved oxygen in the water. By implementing rocks and boulders within the creek channel water quality downstream is improved. Rocks and boulders increase friction within the creek, hence, reducing water velocity. With the River des Peres currently being impaired due to low levels of dissolved oxygen and chloride, improving the levels of dissolved oxygen within the water will increase water habitability for aquatic species.

Increased Carbon Sequestration

Referencing the Westerly Creek at Stapleton landscape performance benefits, a native vegetative cover was found to sequester 4.85 tons per acre (LAF, 2013). Therefore, up to 160 tons of carbon can be sequestered for the 33 acre site, which is 24 times more than using a bluegrass sod covering.

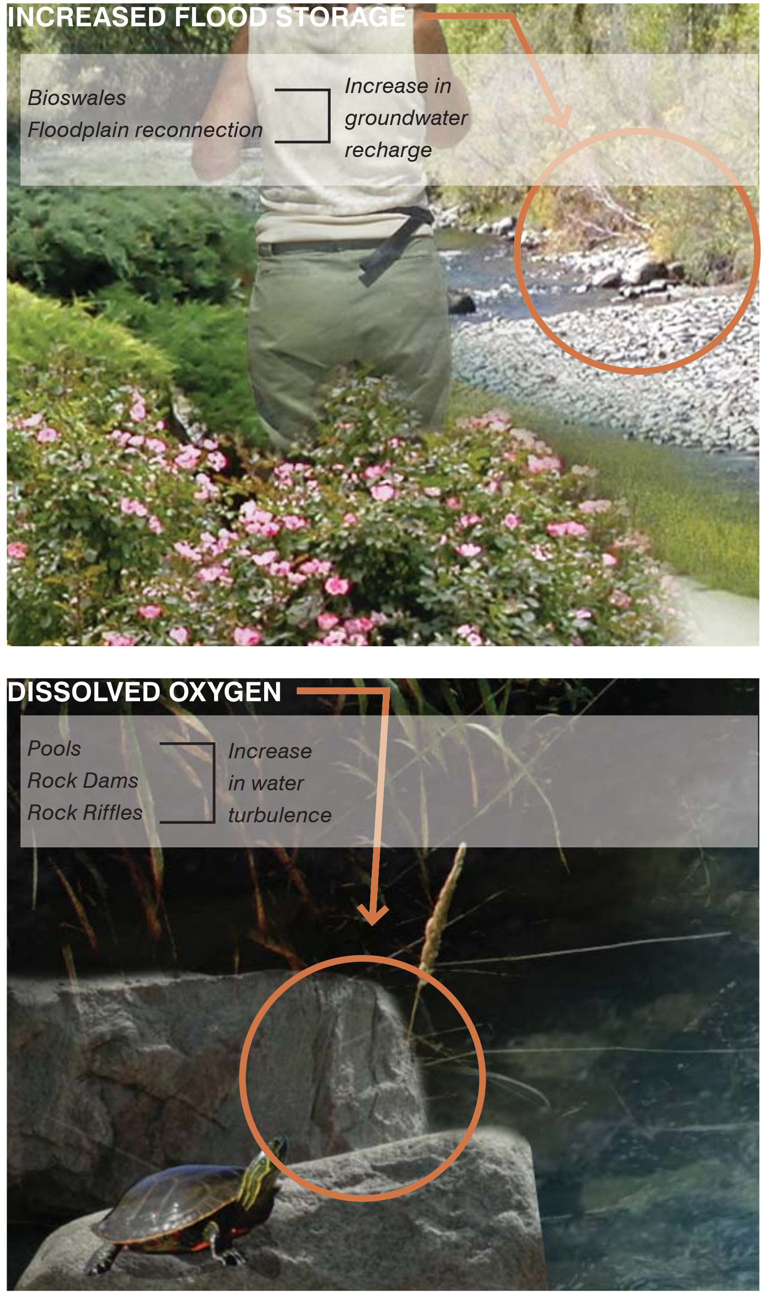
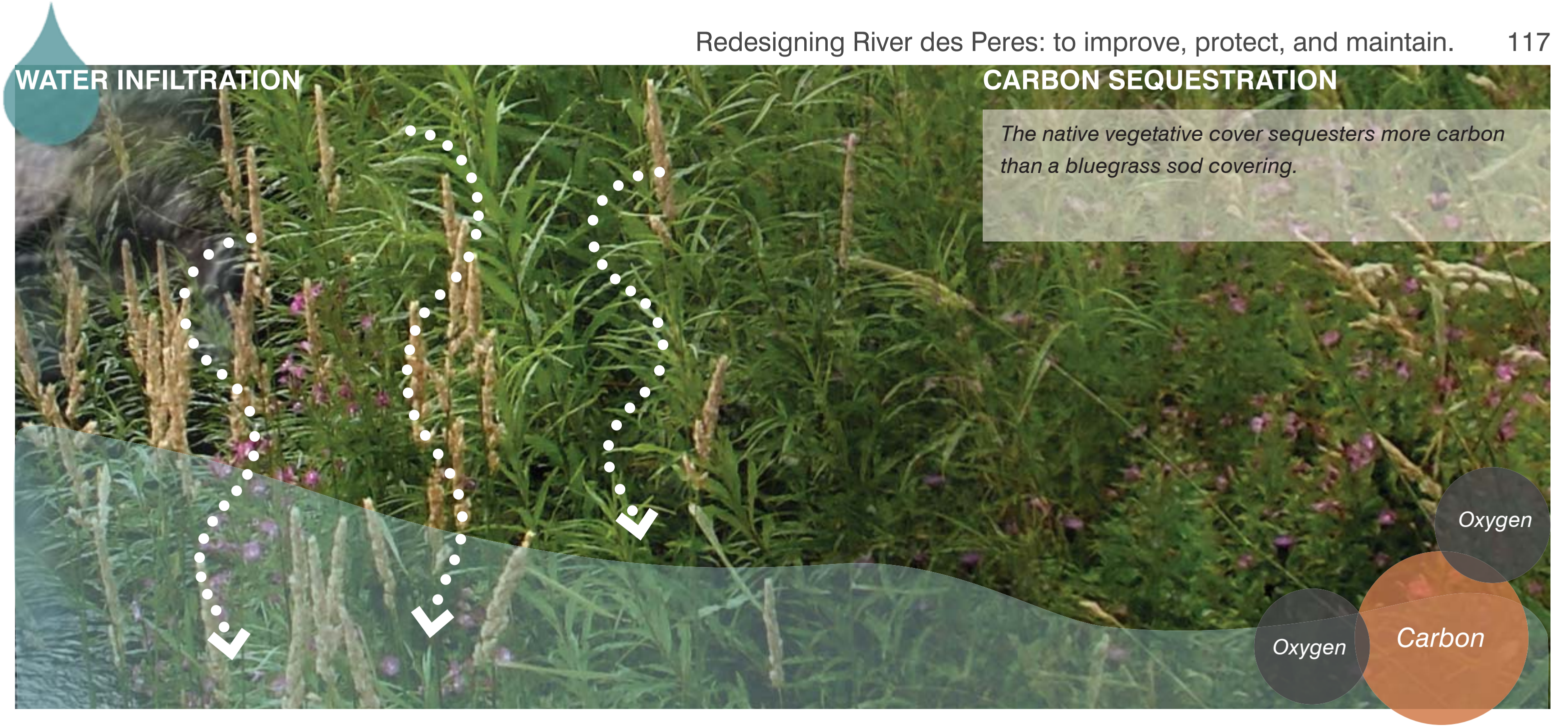


Figure 4.31 Main Channel River des Peres Performance Benefits


WATER INFILTRATION
CARBON SEQUESTRATION
The native vegetative cover sequesters more carbon than a bluegrass sod covering.
Oxygen
Oxygen
Carbon


RECLAIMED SOIL
Soil can be reclaimed from Forest Park and used to grade the two stage channel to desired specifications.
REUSED CONCRETE
Concrete from the existing trapezoidal channel can be cut into slabs and implemented into the landscape as a retaining wall.

River Des Peres, Paul Sableman (2012)

CHAPTER 5: PROJECT CONCLUSIONS

CONCLUSIONS

By incorporating the components of urban ecology and green infrastructure, urban waterways can contain the 1.5 year bankfull discharge, provide wildlife habitat, and become a recreational and educational opportunity for the community. There are many urban waterway design solutions that seek to revive and improve ecological processes. By incorporating stormwater best management practices and wet meadows, river water quality is improved, flooding decreased, wildlife habitat increased, and the aesthetic quality of the river corridor improved. Through watershed site inventory and analysis it was found that through stormwater BMP and wet meadow implementations an averaged 56% peak flow reduction across the watershed during rain events is possible for the River des Peres, thus, restoring the hydrograph. By restoring the floodplain and channel dimensions of Forest Park, Wilson Creek and Drexel Avenue, Deer Creek and South County Connector, Grant's Trail Extension, and the main channel of the River des Peres the goals as mentioned in the thesis were achieved.

In Forest Park by day-lighting the river into the waterscape water infiltration, dissolved oxygen, carbon sequestration are increased, and soil and concrete are able to be reclaimed and reused. Along the open space near Wilson Avenue and Drexel Drive, Deer Creek Park and where the new South County Connector, the floodplain park at Grant's Trail extension, and the main channel of the River des Peres are all seeing increased in water infiltration, flood storage, dissolved oxygen, and carbon sequestration, and soil and concrete are able to be reused. Maintenance for these areas in theory should be less due to the effective channel design being self-sustaining. The rivers will still need to be monitored to make sure no woody vegetation is obstructing water flow.

The River des Peres is similar in channelization quality to the Los Angeles River, which consumes 52 miles of concrete. The restoration methods of the River des Peres can be replicated throughout other watershed systems in the United States. Implementing stormwater BMPs and wet meadows are a great alternative to concrete engineered projects such has trapezoidal channels and culverts. By restoring the hydrographs through BMPs, restoring the floodplains to bankfull elevation, and redesigning river channels to hold bankfull discharge within other watershed systems in the mid-west has the potential to reduce flooding along the Missouri and Mississippi rivers.

STAKEHOLDER INVOLVEMENT

Agencies involved in the process of developing this Master's project include the River des Peres Watershed Coalition, the Federal Emergency Management Agency, the Metropolitan St. Louis Sewer District, the County of St. Louis, St. Louis University, the Great Rivers Greenway, DG//RE Studio, Missouri Department of Transportation (MODOT), and the College of Architecture, Planning and Design at Kansas State University. Utilizing agencies, such as the River des Peres Watershed Coalition allowed for community involvement in the planning and inventory process. In addition, the River des Peres Watershed Coalition was utilized in a walking tour to receive community and historical information, and a better perspective of the River des Peres. Agencies, such as the Metropolitan St. Louis Sewer District, the County of St. Louis, and the St. Louis University were necessary in collecting and gathering data on stormwater/sewer, floodplains, and parcels.

Future stakeholders include the Army Corps of Engineers, American Society of Landscape Architects (ASLA), and the Council of Educators in Landscape Architecture (CELA). Taking the completed project to an agency, such as the Army Corps of Engineers has the potential to raise awareness that could lead to congressional representation where the "representative has great influence over whether a project in her/his district should receive federal assistance" (Riley, 1998, 25). By entering the work accomplished in this project to ASLA, and CELA, it has the potential to further the future practice of landscape architecture specifically in the fields of hydrology, ecology and urban planning. As a future landscape architect, research and projects that improve the landscape around us gives me hope that generations to come can enjoy the outdoors as much as I did as a child.

Bridge at Wellington, Anne Denney (2012)

APPENDICES

GLOSSARY

GLOSSARY OF TERMS

Armoring- Formation of a layer of rocks on the surface of a streambed that resists erosion by water flows. The rocks can be naturally occurring, caused by the scour of smaller particles from high discharges, or placed by humans to stop channel erosion.

Bankfull Channel- The stream channel that is formed by the dominant discharge, also referred to as the active channel, which meanders across the floodplain as it forms pools, riffles, and point bars.

Base Flow- The flow that a perennially flowing stream reduces to during the dry season. It is supported by ground-water seepage into the channel.

Best Management Practice (BMP)- Engineered areas that serve to slow, filter, and treat stormwater runoff.

Biodiversity- Concept of multiple species living together in an environment.

Buffer- A vegetated transitional area surrounding a stream to protect the water body from polluted stormwater runoff.

Channelization- The straightening of river meanders to control flooding and/or to provide bank stabilization.

Combined Sewer Overflow (CSO)- During dry weather and small rain events CSOs can adequately transport wastewater and stormwater to the control plant. However, during heavy rain events CSOs exceed capacity resulting in polluted waters entering nearby river and stream systems.

Day-lighting- The process of taking a buried river and bringing it back up to the surface.

Degrade- The lowering of a stream-channel bed with time due to the erosion and transport of bed materials or the blockage of sediment sources.

Discharge- The volume of water passing through a channel during a given time, usually measured in cubic feet per second.

Emergent Vegetation- Typically tall marsh-like plants that rise above the water surface, such as cattails.

Erosion- Widening, deepening, and cutting of the stream channel due to flow events.

Evapotranspiration- Loss of water to the atmosphere through evaporation and transpiration in plants.

Floodplain- The land adjacent to a channel at the elevation of the bankfull discharge, which is inundated on the average of about 2 out of 3 years. The floor of stream valleys, which can be inundated by small to very large floods. The one-in-100-year floodplain has a probability of .01 chance per year of being covered with water.

Greenway- Linear public corridors along waterways or multi-modal streets that connect parks, retail, and historical sites together.

Groundwater Recharge- Infiltration of surface runoff through permeable soil layers into subsurface water reservoirs. Groundwater reservoirs serve as a supply source for streams.

Hydrograph- The measurement of a stream flow over a period of time.

Hydrologic Cycle- Flow, distribution, and various routes that water takes from the atmosphere to the land surface and back.

Hydrology- The science of water circulation across a landscape, through permeable layers into the ground, and in the atmosphere.

Impermeable Material- A material that has properties preventing movement of water through it. Nonporous.

Infiltration- The portion of rainfall or surface runoff that moves downward into the subsurface rock and soil.

Interception- Precipitation that falls on foliage surface such as, trees, shrubs, and grass.

Outfall- Where discharge from a pipe or drain enters a water body.

Peak Discharge- The maximum volume of flow occurring during a rainfall event.

Phytoremediation- The process of using plant material to remove soil contaminants.

Public Right-of-way- Areas that provide access to private and public property for people and services.

Riparian- Referring to the riverside or riverine environment next to the stream channel, e.g., riparian, or streamside, vegetation.

Rip-rap- Heavy stones used to protect soil from the action of fast-moving water.

Runoff- Water that flows across a surface derived from a rainfall event.

Sediment- Soil particles that have been transported from their natural location by wind or water erosion.

Stormwater- Water derived from a rainfall event.

Stream Bank- The side slopes of an active channel between which the stream flow is normally confined.

Stream Bank Erosion- Removal of soil particles from a bank slope primarily due to water action. Climatic conditions, ice and debris, chemical reactions, and changes in land and stream use may also lead to bank erosion.

Surface Runoff- The portion of rainfall that moves over the ground toward a lower elevation and does not infiltrate the soil.

Urban Heat Island Index- Heat storing material including concrete and asphalt are high heat sources, raising temperatures approximately five to ten degrees higher.

Water Velocity- The distance that water can travel in a given direction during a period of time. Usually expressed in feet per second.

Watershed- An area confined by topographic divides that drains a given stream or river.

Definition References:
Ann Riley, 1998
Robert France, 2003
Metropolitan Service District, 2002

APPENDIX A

RIVER DES PERES HISTORY

Prehistoric period: ? BC - 1500 AD and Protohistoric period: 1500 AD -1673

During the prehistoric period, aboriginals, descendents of the Kwapas, Ponkas, Osage, and Kansas tribes inhabited what are now the states of Missouri, Ohio, and Indiana. However, due to encroaching "Algonquian tribes, these bands were gradually forced down the Ohio via the Wabash to the outfall into the Mississippi River. A portion of the group continued south down the Mississippi while the remainder moved north up the valley" (Nixon, 1982, 12). Leading into the protohistoric period tribes, such as, the Mahas, Umahas, and Omahas traveled north.

Exploration period: 1674 - 1764

The exploration period experienced many expeditions, particularly by LaSalle, Tonti, Joliet, and Father Marquette. In 1681 explorers LaSalle and Tonti encountered "scattered villages along the Mississippi which were occupied by descendents of" the Mahas, Umahas, and Omahas (Nixon, 1982, 13). Illini Indians inhabited portions of the Illinois Valley in the late 1600s. "One such Tamaroa Village was located on the eastern bank of the Mississippi River across from the future location of St. Louis. It is likely that this was the village encountered by Marquette on his voyage down the Mississippi in 1673" (Nixon, 1982, 13). In the early 1700s the Osage and the Missouris relocating to the Osage and Meramec River locations, while the Fox and Saukee were reported in the northwest portion of the Mississippi and Missouri confluence. "The territory between these four groups is the area west of the Mississippi, south of the Missouri and north of the Meramec. This area may have been a buffer zone between the groups and utilized sporadically by all four for hunting activities" (Nixon, 1982, 13). By the turn of the 18th century French and Spanish missions were interspersed among the Indian villages.

Frontier/Pioneer period: 1765 – 1803 and Early Agricultural period: 1804 – 1830

A "number of communities sprang up along the east bank of the Mississippi River" with the intention of trapping and trading with Indian villages (Nixon, 1982, 14). After the treaty of Fontainebleau, the French developed a number of communities along the westerns shores. In 1735 the earliest documented settlement along the western bank of the Mississippi and below the Missouri River is where the city of St. Genevieve, Missouri is located today. The development of this community sparked others, including Laclede and chouteau's trading post in St. Louis in 1764, to develop similar trading posts. Within a few months of the trading post development DeTreget was awarded land on the River des Peres, where the community of Carondelet grew. In 1771 plots of land became fields of cropland. These plots were organized in the traditional French plan, with tight village centers and outlying agricultural fields.

The development of Carondelet sparked the establishment of three villages: San Ferdinand in 1767, St. Charles in 1769, and Marais de Liars in 1794 (Nixon, 1982, 14). Due to the lure of trading goods, bordering Indian tribes entered into the area. “By the time of the Louisiana Purchase, St. Louis and Carondelet were well established. After the epic journey of Lewis and Clark in (1803- 1806), there was a mass migration to the western territory” (Nixon, 1982, 15). As Americans settled in the area, the traditional French planning was no longer used; homesteads developed outside the village center and agricultural lands were developed. These homesteads were usually built close to roadways or rivers where ferries were present. These rivers were characterized by mills, which contributed to early industry in the Frontier period. Leading into the agriculture period a series of new roads and developments were built.

Agricultural/Industrial period: 1831 – present

Due to the arrival of the steamboat prior to the 1850s, the St. Louis area entered the industrial period earlier than most developments. “Industry such as mining, brick making, breweries, and many others began to develop in St. Louis in the 1830s” (Nixon, 1982, 15). The steamboat allowed for easy importation and exportation of material goods. From the 1840s to 1850s the St. Louis area as a port city grew in population size. “As a result of immigration from Germany and Ireland, the work force was greatly enlarged. Industry and mining progressed rapidly under these conditions” (Nixon, 1982, 15). The discovery of sources of clay, lead, coal, and limestone contributed to expansion within the mining industry. Along the River des Peres, Gratiot League Square, and Oak Hill localities, became major mining areas. Even with the growth of industry in St. Louis, agriculture still had a major presence along outlying areas of development. From 1830 through 1900 two major farming communities developed along the River des Peres to utilize its valuable water resource.

In 1887 “the city forefathers realized the river would require management and set about the task of preparing a general plan for the drainage of Mill Creek and the River des Peres. The objectives of this plan were to collect sewage flows in the upper River des Peres watershed and carry them eastwardly to the Mississippi River via the Mill Creek sanitary sewer, thereby preventing the discharge of sewage into the River des Peres” (Metropolitan St. Louis Sewer District, 1988, 4). However, this plan was never carried out, instead the River des Peres turned into a sewer system, flowing sanitary and stormwater discharges out to the Mississippi River.

With the construction of railways across the United States and especially through the central Midwest a new market was introduced to the St. Louis area. St. Louis became an important processing center through the establishment of mills, ports, mining, and railway construction. Late in the 1800s plots of land began to be issued out including adjacent land to River des Peres, and Carondelet. By the turn of the century, St. Louis "was counted as the fourth largest city in the United States" (Nixon, 1982, 15). As one of the largest cities in the United States, St. Louis became the site of the 1904 World's Fair utilizing Forest Park. However, River des Peres flowed through the Forest Park area and something had to be done about the open sewer. "One remedy was the enclosure of a portion of the western end of the channel within a large wooden box. At the eastern end of the river, bends in the stream were cut off. The channel was also altered by subdivision developments and railroad/rail yard construction to the north and south of Forest Park" (Metropolitan St. Louis Sewer District, 1988, 3). After flooding occurred in 19010, Mayor Frederick Kreismann announced plans for enclosing the river. At $4 million the plans were too costly, and instead a sanitary sewer was constructed in 1910 from Landsdowne Avenue to the Mississippi river. However, development of plans and a sewer did not account for the devastating flood of 1915 in which 10.6 inches of rain was recorded in a one day period within St. Louis.

In 1910 Mayor Henry Kiel of St. Louis called for the drafting of plans to fix the drainage problem of River des Peres. In 1923 the project plans were passed and the River des Peres project began with a cost estimation of $11 million. Yet, if this project were "to be built today, it would cost nearly $257 million to construct" (Metropolitan St. Louis Sewer District, 1988, 7). The construction project was developed in 9 phases, and construction statistics estimate that 5 million cubic yards of earth and 400,000 cubic yards of rock and shale had been excavated when the project finished in 1933. The newly constructed channel of River des Peres could now carry flows up to 40,000 cubic feet per second, which is greater than the low flows of the Mississippi River (Metropolitan St. Louis Sewer District, 1988, 15).

Additions and Improvements to River des Peres

Additions and improvements to the River des Peres began in December 1933, just a few months after the project was completed. From December to June the city "employed 1,014 men to construct over 1,000 feet of the Lindell sewer and 2,000 feet of the Wydown sewer" to join the sewer located in Forest Park (Metropolitan St. Louis Sewer District, 1988, 15). These two construction projects would excavate even more soil from the River des Peres watershed. The following December another project commenced to include concrete slab covers placed over the River des Peres sewer system.

With the creation of the Work Projects Administration (WPA) three more projects began in 1935 and were completed in 1940. These projects included placement of rock, quarried riprap, and access ramps along 6 miles of the lower River des Peres channel. River bed and bank slopes were also undertaken along 3 miles of the upper channel through the use of concrete to stabilize the river. Maintenance of these fixed channels later included drain tiles to carry off water seepage that had begun to heave the concrete (Metropolitan St. Louis Sewer District, 1988, 15).

In May of 1939 additional sewer plans were drawn from University City to River des Peres. Funded by a 1938 bond issue and the Public Works Administration, the project cost totaled

$764,813.37 (Metropolitan St. Louis Sewer District, 1988, 17). In 1940 a grit chamber was placed in the river channel near Macklind Avenue in an attempt to control heavy sediment and debris flowing in the channel before they could enter the sanitary sewer system. In the 1940's after these projects were completed, "it became evident that the River des Peres channel required significant and continuous maintenance expenditures" (Metropolitan St. Louis Sewer District, 1988, 17). From 1944 to the late 1940's, the City of St. Louis began appropriating funds to perform construction repairs on the concrete river channel. It also became evident that overflow accumulation was growing and additional sewer and sanitary lines would be needed.

In 1954 after sanitary sewer plans were drawn, construction of two pumping stations and enlarged sanitary sewer lines were completed. The Metropolitan St. Louis Sewer District (MSD), formed in the 1950s and was given charge of the River des Peres channel in 1956. "As one of its first tasks, MSD initiated a pollution abatement study which was conducted during 1959-1961. Out of this study came the Pollution Abatement Program, which called for the construction of the Lemay Pump Station Number 1, in the River des Peres area" (Metropolitan St. Louis Sewer District, 1988, 17). In addition to the Pollution Abatement Program, the study also showed that it would be necessary to construct a sanitary sewer lines to relieve flows in the lower part of River des Peres. A sanitary line constructed from Lemay Pump Station Number 1 to the Linewood sewer system was completed in 1970.

During the spring flood of 1973 a number of civilians "and contractors volunteered their labor and materials to construct earthen levees along Germania and Carondelet Drives. These levees, constructed without the aid of formal plans, are still in place today" (Metropolitan St. Louis Sewer District, 1988, 18). These levees were later armored and landscaped.

Even though Saint Louis does not face the same drainage problems it did in the 1900's there are still many stream channel functional problems. "It still requires labor-intensive maintenance to repair the heaving of pavement and the bank slides and curtail the growth of vegetation. Currently, around $100,000 is allotted annually to maintain the River des Peres" (Metropolitan St. Louis Sewer District, 1988, 18). The Army Corps of Engineers have drawn a few plans to make repairs along portions of the river channel; however, federal grants are directed at sewage treatment instead.

In May of 1988,"the American Society of Civil Engineers designated the River des Peres Sewerage and Drainage Works as a National Historic Civil Engineering Landmark" (Metropolitan St. Louis Sewer District, 1988, 18). Located above a sewer line, a monument commemorating this honor was placed in front of the Jefferson Memorial as a tribute to the innovative stream channel design.

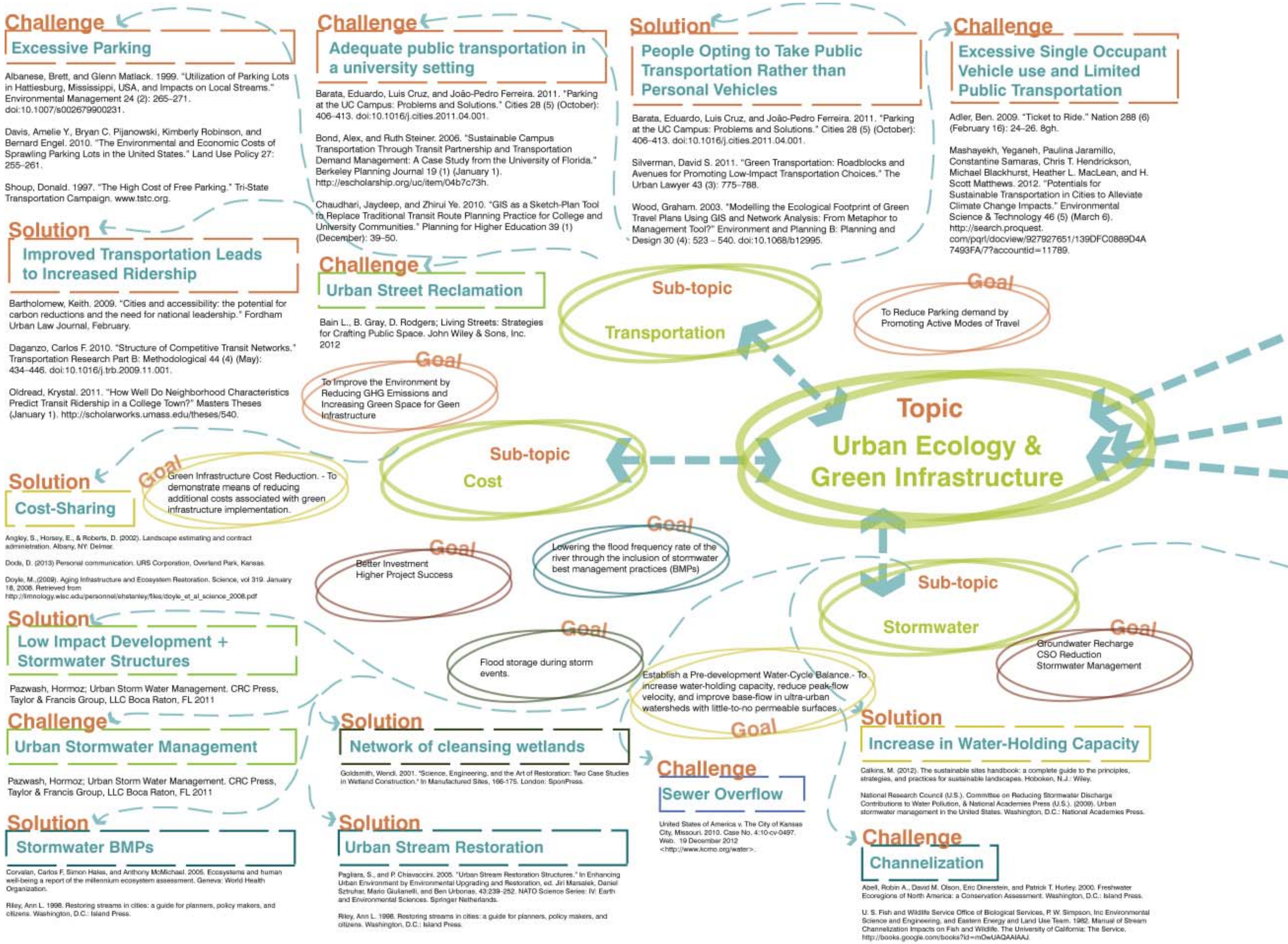
APPENDIX B

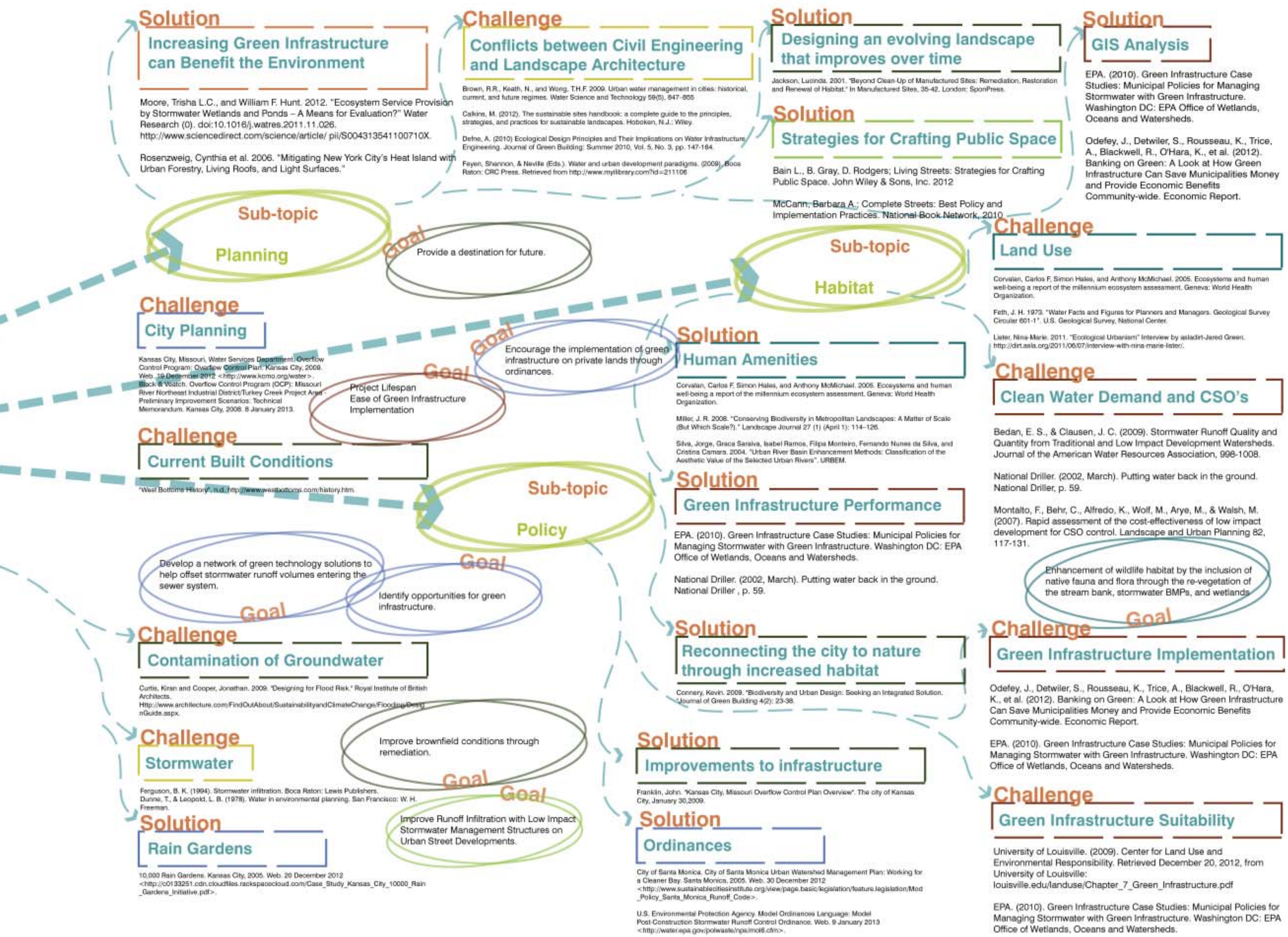
GROUP PRECEDENT MATRIX:

	Precedent Name	Location	Policy	Habitat	Planning	Transportation	Cost	Stormwater	Methodology	Source
Jena	University of Florida	Gainesville, FL				■				Bond and Steiner, 2006
	Auburn University	Auburn, AL				■			■	Chaudhari and Ye, 2010
	University of Western Australia	Perth, Australia				■				Shannon et al, 2006
	University of Coimbra	Coimbra, Portugal				■			■	Barata et al, 2011
	Tippecanoe County	Indiana			■	■	■	■	■	Davis et al, 2010
	Green Travel Plan	Newbury, England			■	■			■	Wood, 2003
Jessie	Revival Fields	Blue Mountain, Pennsylvania			■				■	Comis, 1995
	Creek Water Quality Channel	Seattle, Washington			■			■		LAF, 2012
	Bishan-Ang Mo Kio Park	Singapore		■	■			■	■	Dreiseitl, 2012
	Shanghai Houtan Park	China		■	■			■		LAF, 2012
	Federal Medical Center	Massachusetts		■	■			■		Goldsmith, 2012
	Teardrop Park	New York City		■	■					LAF, 2012
	Lurie Garden	Chicago		■	■					LAF, 2012
	Kresge Foundation Headquarters	Michigan		■	■					LAF, 2012
	Magnuson Park Wetlands and Active	Seattle, Washington		■	■			■		LAF, 2012
	Qunli Stormwater Park	China		■	■			■		LAF, 2012
	Menomonee Valley Redevelopment	Milwaukee		■	■			■	■	LAF, 2012
	Sydney Olympic Millennium Parklands	Australia		■	■			■		LAF, 2012
	Milwaukee Oil Spill Landscape	Milwaukee			■					Carman, 2001
	Landscape Park Duisburg Nord	Germany			■			■	■	Latz, 2001

Anne	Buffalo Bayou Promenade	Houston, TX		■	■			■		SWA, 2011
	Cheonggyecheon Stream Restoration Project	Seoul, South Korea	■	■	■	■		■		Robinson & Myvonwynn, 2011
	Qunli National Urban Wetland	Haerbin, China		■	■			■		Yu, 2011; Zhang et al. 2010
	Bishan Park	Bishan, Sinapore		■	■			■		CNA, 2012; Holmes, 2012
	Root River	Rochester, MN	■	■	■			■		SEWRPC, 2012
	Swan River	Breckenridge, CO		■	■			■	■	BRWG, 2009
Patrick	City of Santa Monica Urban Watershed Management Program	Santa Monica, CA	■		■			■		City of Santa Monica, 2005
	Adding Green to Urban Design	Chicago, IL	■		■			■		City of Chicago, 2008
	10,000 Rain Gardens				■			■		Bishop, 2005
Aaron	Alachua County	Florida	■		■			■		
	Chicago	Illinois	■		■	■		■		
	Emeryville	Claifornia	■	■						
	Lenexa	Kansas	■	■	■	■		■		
	Olympus	Washington		■				■		
	Philedelphia	Pennsylvania	■		■			■		
	Portland	Oregon	■	■	■	■	■	■		
	San Jose	California	■		■		■	■		
	Santa Monica	California	■	■		■	■	■		
	Seattle	Washington	■		■		■	■		
	Stafford County	Virginia	■		■			■		
	Wilsonville	Oregon	■	■	■					
Dan	PWD CSO Project	Philadelphia, PA	■		■		■	■		
	Horizon Bay Congregate Living Facility	Tampa, FL	■		■	■		■	■	
	Disston Ave., Drainage Improvement	Orlando, FL	■		■	■	■	■	■	
	Portland CSO Abatment Program	Portland, OR	■	■	■		■	■		
	NJ Transit Park & Ride Facility	Wayne, NJ	■		■	■	■	■	■	
	Methuen Readiness Center	Methun, Massachusetts	■		■	■	■	■	■	

GROUP LITERATURE MAP:




Solution
Increasing Green Infrastructure can Benefit the Environment
Moore, Trisha L.C., and William F. Hunt. 2012. "Ecosystem Service Provision by Stormwater Wetlands and Ponds – A Means for Evaluation?" Water Research (0). doi:10.1016/j.watres.2011.11.026. http://www.sciencedirect.com/science/article/ pii/S004313541100710X.
Rosenzweig, Cynthia et al. 2006. "Mitigating New York City's Heat Island with Urban Forestry, Living Roofs, and Light Surfaces."
Challenge
Conflicts between Civil Engineering and Landscape Architecture
Brown, R.R., Keath, N., and Wong, T.H.F. 2009. Urban water management in cities: historical, current, and future regimes. Water Science and Technology 59(5), 847-855
Calkins, M. (2012). The sustainable sites handbook: a complete guide to the principles, strategies, and practices for sustainable landscapes. Hoboken, N.J.: Wiley.
Defne, A. (2010) Ecological Design Principles and Their Implications on Water Infrastructure Engineering. Journal of Green Building: Summer 2010, Vol. 5, No. 3, pp. 147-164.
Feyen, Shannon, & Neville (Eds.). Water and urban development paradigms. (2009). Boca Raton: CRC Press. Retrieved from http://www.mylibrary.com?id=211106
Solution
Designing an evolving landscape that improves over time
Jackson, Lucinda. 2001. "Beyond Clean-Up of Manufactured Sites: Remediation, Restoration and Renewal of Habitat." In Manufactured Sites, 35-42. London: SponPress.
Solution
Strategies for Crafting Public Space
Bain L., B. Gray, D. Rodgers; Living Streets: Strategies for Crafting Public Space. John Wiley & Sons, Inc. 2012
McCann, Barbara A.; Complete Streets: Best Policy and Implementation Practices. National Book Network, 2010
Solution
GIS Analysis
EPA. (2010). Green Infrastructure Case Studies: Municipal Policies for Managing Stormwater with Green Infrastructure. Washington DC: EPA Office of Wetlands, Oceans and Watersheds.
Odefey, J., Detwiler, S., Rousseau, K., Trice, A., Blackwell, R., O'Hara, K., et al. (2012). Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-wide. Economic Report.
Sub-topic
Planning
Goal
Provide a destination for future.
Sub-topic
Habitat
Challenge
Land Use
Corvalan, Carlos F, Simon Hales, and Anthony McMichael. 2005. Ecosystems and human well-being a report of the millennium ecosystem assessment. Geneva: World Health Organization.
Feth, J. H. 1973. "Water Facts and Figures for Planners and Managers. Geological Survey Circular 601-1". U.S. Geological Survey, National Center.
Lister, Nina-Marie. 2011. "Ecological Urbanism" Interview by aslaidr-Jared Green. http://dirt.asla.org/2011/06/07/interview-with-nina-marie-lister/.
Challenge
City Planning
Kansas City, Missouri, Water Services Department. Overflow Control Program: Overflow Control Plan. Kansas City, 2009. Web. 19 December 2012 <http://www.kcmo.org/water>.
Black & Veatch. Overflow Control Program (OCP): Missouri River Northeast Industrial District/Turkey Creek Project Area - Preliminary Improvement Scenarios: Technical Memorandum. Kansas City, 2008. 8 January 2013.
Goal
Encourage the implementation of green infrastructure on private lands through ordinances.
Goal
Project Lifespan
Ease of Green Infrastructure Implementation
Solution
Human Amenities
Corvalan, Carlos F, Simon Hales, and Anthony McMichael. 2005. Ecosystems and human well-being a report of the millennium ecosystem assessment. Geneva: World Health Organization.
Miller, J. R. 2008. "Conserving Biodiversity in Metropolitan Landscapes: A Matter of Scale (But Which Scale?)." Landscape Journal 27 (1) (April 1): 114–126.
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Challenge
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Bedan, E. S., & Clausen, J. C. (2009). Stormwater Runoff Quality and Quantity from Traditional and Low Impact Development Watersheds. Journal of the American Water Resources Association, 998-1008.
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Challenge
Current Built Conditions
"West Bottoms History". n.d. http://www.westbottoms.com/history.htm.
Sub-topic
Policy
Solution
Green Infrastructure Performance
EPA. (2010). Green Infrastructure Case Studies: Municipal Policies for Managing Stormwater with Green Infrastructure. Washington DC: EPA Office of Wetlands, Oceans and Watersheds.
National Driller. (2002, March). Putting water back in the ground. National Driller , p. 59.
Goal
Develop a network of green technology solutions to help offset stormwater runoff volumes entering the sewer system.
Goal
Identify opportunities for green infrastructure.
Goal
Enhancement of wildlife habitat by the inclusion of native fauna and flora through the re-vegetation of the stream bank, stormwater BMPs, and wetlands
Challenge
Contamination of Groundwater
Curtis, Kiran and Cooper, Jonathan. 2009. "Designing for Flood Risk." Royal Institute of British Architects. Http://www.architecture.com/FindOutAbout/SustainabilityandClimateChange/FloodingDesignGuide.aspx.
Solution
Reconnecting the city to nature through increased habitat
Connery, Kevin. 2009. "Biodiversity and Urban Design: Seeking an Integrated Solution.'Journal of Green Building 4(2): 23-38.
Challenge
Green Infrastructure Implementation
Odefey, J., Detwiler, S., Rousseau, K., Trice, A., Blackwell, R., O'Hara, K., et al. (2012). Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-wide. Economic Report.
EPA. (2010). Green Infrastructure Case Studies: Municipal Policies for Managing Stormwater with Green Infrastructure. Washington DC: EPA Office of Wetlands, Oceans and Watersheds.
Challenge
Stormwater
Ferguson, B. K. (1994). Stormwater infiltration. Boca Raton: Lewis Publishers.
Dunne, T., & Leopold, L. B. (1978). Water in environmental planning. San Francisco: W. H. Freeman.
Goal
Improve brownfield conditions through remediation.
Goal
Improve Runoff Infiltration with Low Impact Stormwater Management Structures on Urban Street Developments.
Solution
Improvements to infrastructure
Franklin, John. "Kansas City, Missouri Overflow Control Plan Overview". The city of Kansas City, January 30,2009.
Solution
Rain Gardens
10,000 Rain Gardens. Kansas City, 2005. Web. 20 December 2012 <http://c0133251.cdn.cloudfiles.rackspacecloud.com/Case_Study_Kansas_City_10000_Rain_Gardens_Initiative.pdf>.
Solution
Ordinances
City of Santa Monica. City of Santa Monica Urban Watershed Management Plan: Working for a Cleaner Bay. Santa Monica, 2005. Web. 30 December 2012 <http://www.sustainablecitiesinstitute.org/view/page.basic/legislation/feature.legislation/Mod_Policy_Santa_Monica_Runoff_Code>.
U.S. Environmental Protection Agency. Model Ordinances Language: Model Post-Construction Stormwater Runoff Control Ordinance. Web. 9 January 2013 <http://water.epa.gov/polwaste/nps/mol8.cfm>.
Challenge
Green Infrastructure Suitability
University of Louisville. (2009). Center for Land Use and Environmental Responsibility. Retrieved December 20, 2012, from University of Louisville: louisville.edu/landuse/Chapter_7_Green_Infrastructure.pdf
EPA. (2010). Green Infrastructure Case Studies: Municipal Policies for Managing Stormwater with Green Infrastructure. Washington DC: EPA Office of Wetlands, Oceans and Watersheds.

APPENDIX C

Latin Name	Common Name	Submerged & Emergent (water depth in Ft)	Pond Edge & Permanent Water	Over Sand	Lower Slopes & Bioretention Base	Upper Slopes	Height (Ft)	Spacing (Ft)	Color	Seasonal Interest - Jan.	Feb.	Mar.	Apr.	May
Grasses/Sedges														
Andropogon gerardii	Big Bluestem			X		X	4-6 ft	2-5 ft	Plum	X	X			
Andropogon ternarius	Splitbear Bluestem			X		X	1-2 ft	1.5 ft	Silver	X	X			
Andropogon virginicus	Broomsedge			X		X	1-2 ft	1.5 ft	Orange					
Bouteloua curtipendula	Sideoats Grama			X		X	1-2 ft	1 ft	Tan					
Carex albicans	Oak Sedge				X	X	10 in	1 ft	Evergreen	X		X	X	
Carex annectans	Yellow Fruited Sedge		X		X		2-3 ft	1.5 ft	Tan				X	X
Carex eburnea	Bristle-leaf Sedge					X			Evergreen	X		X	X	
Carex crinita	Fringed Sedge		X		X		2-3 ft	1.5 ft	Brown					X
Carex grayi	Bur Sedge		X		X		1-2 ft	1.5 ft	Tan				X	X
Carex muskingumensis	Palm Sedge		X	X	X		2-3 ft	1.5 ft	Tan				X	X
Carex Praegracilis	Tollway Sedge		X		X	X	1-2 ft	2 ft	Tan				X	X
Carex shortiana	Short's Sedge		X		X	X	2 ft	1.5 ft	Blush				X	X
Carex vulpinidea	Fox Sedge		X		X		2-3 ft	1.5 ft	Tan					X
Carex hirsutella	Fuzzy Wuzzy Sedge			X	X		1 ft	1 ft	Green/Tan				X	X
Chasmanthium latifolium	River Oats			X	X	X	2-5 ft	1.5 ft	Green					
Juncus biflorus	Bog Rush			X	X		2 ft	1 ft	Green/Orange					
Juncus effusus	Soft Rush	0-1 ft	X				2-3 ft	1.5 ft	Green					
Panicum virgatum	Switchgrass			X	X	X	3-6 ft	2.5 ft	Pink	X	X			
Schizachyrium scoparium	Little Bluestem			X		X	2-4 ft	1.5 ft	Bronze					
Scirpus atrovirens	Great Green Bullrush		X	X	X		2-3 ft	1.5 ft	Green				X	X
scirpus cyperinus	Wool Grass		X				3-4 ft	1.5 ft	Orange					X
Spartina pectinata	Prairie Cordgrass		X		X		4-5 ft	2.5 ft	Green					
Sporobolus heterolepis	Prairie Dropseed				X	X	2-3 ft	1.5 ft	Tan					

*Adapted from MBG, 2012

Color and Months

June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Sun	Pt Sun	St Shade	Shade	Dry	Medium	Wet	Birds	Butterflies	Fall Color	Winter Interest	Flood Frequency Tolerance	Flood Height Tolerance	Flood Duration Tolerance (Days)	Salt Tolerance	Aggressiveness	Silt Tolerance
			X	X	X	X	X				X	X				X	X	M	12	2		M	
			X	X	X	X	X				X			X		X	X	L				L	L
		X	X	X	X	X	X				X			X		X	X	L		1		M	L
	X	X	X	X	X		X				X	X		X			X	L		1		L	L
				X	X	X	X	X	X	X	X	X					X	M	12	1		L	
X							X	X	X			X	X	X			X	H	12	3		L	
				X	X	X			X	X	X	X					X	L				L	
X							X	X	X			X	X	X				H	12	3	U	L	
X								X	X	X		X	X	X				M	12	2		L	M
X	X	X					X	X	X	X		X	X	X			X	H	24	3		M	M
X							X	X			X	X	X	X				H	12	2	H	H	H
X							X	X	X		X	X	X	X			X	M	24	3		L	
X	X						X	X	X			X	X				X	H	24	3	L	L	
X	X	X	X				X	X			X	X		X				L				L	
X	X	X	X	X	X			X	X	X	X	X		X		X	X	M	12	1		H	
X	X	X	X	X	X		X	X				X	X	X		X	X	M	6	2		L	
			X	X	X	X	X	X				X	X	X			X	H	24	4	L	M	M
	X	X	X	X	X	X	X	X	X			X	X	X		X		M	12	2	M	M	M
		X	X	X	X	X	X				X	X		X		X	X	L	12	1	M	L	L
X							X	X				X	X	X			X	M	12	3		L	
X	X	X	X	X	X	X	X	X					X	X		X	X	H	24	3		M	
			X	X	X		X	X				X	X	X		X	X	H	36	5		H	H
		X	X	X	X	X	X				X	X		X			X	L				L	

Latin Name	Common Name	Submerged & Emergent (water depth in Ft)	Pond Edge & Permanent Water	Over Sand	Lower Slopes & Bioretention Base	Upper Slopes	Height (Ft)	Spacing (Ft)	Color	Seasonal Interest - Jan.	Feb.	Mar.	Apr.	May
Forbs														
Amsonia illustris	Shining bluestar		X	X	X		2-3 ft	2.5 ft	Lt. Blue				X	X
Asclepias incamala	Marsh Milkweed		X	X	X		2-4 ft	2 ft	Pink					
Asclepias tuberosa	Butterfly Milkweed			X		X	1-2 ft	1.5 ft	Orange					
Aster novae-agliae	New England Aster		X		X		3-4 ft	2 ft	Violet					
Aster oblongifolius	Aromatic Aster					X	2 ft	1.5 ft	Lav./Blue					
Baptisia australis	Blue Wild Indigo					X	3-4 ft	3-4 ft	Blue					
Baptisia sphaerocarpa	Yellow Wild Indigo					X	2 ft	2 ft	Yellow				X	X
Blephilia cilata	Ohio Horsemint					X	3-4 ft	2 ft	Yellow					
Chelone obliqua	Rose Turtlehead		X		X		3-4 ft	2 ft	Rose/Purple					
Chrysopsis camporum	Golden Aster			X		X	2-3 ft	1-5 ft	Yellow					
Coreopsis lanceolata	Lanceleaf Coreopsis			X		X	1-2 ft	1.5 ft	Yellow				X	X
Coreopsis palmata	Finger Coreopsis			X		X	2 ft	1 ft	Yellow					X
Coreopsis triptris	Tall Coreopsis			X			2-8 ft	2 ft	Yellow					
Echinacea pallida	Pale Purple Coneflower					X	2-3 ft	1.5 ft	Violet					
Echinacea purpurea	Purple Coneflower					X	2-3 ft	1.5 ft	Lt. Purple					
Equisetum hyemale	Horsetail		X	X	X		2-4 ft	2.5 ft	Green				X	X
Eryngium yuccifolium	Rattlesnake Master				X	X	4-5 ft	1.5 ft	Green					
Eupatorium coelestinum	Wild Ageratum		X	X	X		1-2 ft	1.5 ft	Lavender					
Helenium autumnale	Sneezeweed		X		X		3-4 ft	2 ft	Yellow					
Heuchera americana	American Alumroot					X	1 ft	1.5 ft	Cream					X
Heuchera parviflora	Late-Flowering Alumroot					X	1 ft	1.5 ft	White					
Heuchera richardsonii	Prairie Alumroot				X	X	1 ft	1.5 ft	Cream				X	X
Heuchera villosa	Maple-leaf Alumroot					X	1 ft	1.5 ft	White					
Hibiscus lasiocarpos	Rose Mallow		X	X	X		3-7 ft	2.5 ft	White/Pink					
Iris cristata	Dwarf Crested Iris					X	1 ft	1 ft	Violet			X	X	
Iris fulva	Copper Iris		X	X	X		2-3 ft	1.5 ft	Copper					X
Iris virginica	Southern Blueflag Iris		X		X		2-3 ft	2 ft	Blue					
Lespedeza virginica	Slender Bush Clover			X	X	X	1-2 ft	1-5 ft	Pink					
Liatris spicata	Dense Blazingstar			X	X	X	2-3 ft	1.5 ft	Lavender					
Lobelia cardinalis	Cardinal Flower		X	X	X		2-3 ft	1.5 ft	Red					
Lobelia siphilitica	Blue Lobelia		X		X	X	1-2 ft	1.5 ft	Blue					

*Adapted from MBG, 2012

Color and Months																							
June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Sun	Pt Sun	St Shade	Shade	Dry	Medium	Wet	Birds	Butterflies	Fall Color	Winter Interest	Flood Frequency Tolerance	Flood Height Tolerance	Flood Duration Tolerance (Days)	Salt Tolerance	Aggressiveness	Silt Tolerance
							X	X	X		X	X	X		X	X		H	36	5		L	H
	X	X	X	X			X	X				X	X		X			M	18	3	M	M	
X	X	X					X				X	X			X			L			V	M	
		X	X				X	X				X	X		X	X		M	24	3	L	H	
			X	X			X	X			X	X		X		X		L				M	L
X	X						X	X	X		X	X			X			L				M	
							X	X			X	X					X	L				L	
X	X	X	X				X	X				X	X		X		X	H	12	2		M	
		X	X	X			X	X	X	X		X	X					M	12	1		M	
	X	X	X	X			X	X			X				X			M	12	1		M	
X							X	X			X	X			X			L		1		L	
X							X	X			X	X			X			L				L	
	X	X	X				X				X	X			X							M	
X	X						X	X			X	X		X				L				L	
X	X	X						X	X	X	X	X		X	X			L				L	
				X	X		X	X	X			X	X			X	X	H	36	5		H	H
X	X	X	X				X				X	X			X		X	M	12	2	M	L	
	X	X	X	X			X	X				X	X		X			H	12	3		M	H
	X	X	X	X			X	X	X			X	X	X	X			M	18	3	M	M	
X							X	X	X		X	X			X			L				L	
			X	X				X	X	X	X	X			X			L				L	
							X	X	X	X	X	X	X		X			M	12	1		L	
			X	X				X	X	X	X	X			X			L				L	
	X	X	X	X			X	X	X			X	X		X	X		H	36	5		M	M
								X	X	X	X				X			L				L	
X							X	X				X	X	X				M	12	1		M	
	X	X					X	X					X	X			X	H	36	4		M	M
		X	X				X	X			X	X		X				L				L	
X	X						X	X			X	X	X	X	X			M	12	1		L	
	X	X	X				X	X	X	X		X	X	X	X			H	18	5	L	M	U
		X	X				X	X			X	X	X		X			H	24	3		L	H

Latin Name	Common Name	Submerged & Emergent (water depth in Ft)	Pond Edge & Permanent Water	Over Sand	Lower Slopes & Bioretention Base	Upper Slopes	Height (Ft)	Spacing (Ft)		Seasonal Interest -				
Forbs									Color	Jan.	Feb.	Mar.	Apr.	May
Mimulus ringans	Allegehny Monkey Flower		X	X	X		1-2 ft	1.5 ft	Lavender					
Monard Fistulosa	Wild Bergamont			X	X	X	3-4 ft	2 ft	Pink					
Nymphaea odorata	Fragrant Water Lily	1-5 ft					1 ft	10 ft	White					
Parthenium hispidim	American Feverfew					X	1-2 ft	1.5 ft	White				X	X
Parthenium Integrifolium	Wild Quinine			X	X	X	2-3 ft	1.5 ft	White					
Penstemon digitalis	Smooth Beard-Tongue			X	X		2-3 ft	1.5 ft	White				X	X
Phlox paniculata	Meadow Phlox				X		3-4 ft	1.5 ft	Purple/Pink					
Pontedaria cordata	Pickeral Weed	0-1 ft	X				1-2 ft	2.5 ft	Blue					
Pycnanthemum tenuifolium	Slender Mountain Mint			X	X	X	2-3 ft	1.5 ft	White					
Tatibida pinnata	Yellow/Grey Coneflower			X	X	X	3-5 ft	1.5 ft	Yellow					
Rudbeckia fulgida	Orange Coneflower				X		2 ft	2 ft	Yellow					
Rudbeckia hirta	Black-Eyed Susan						2-3 ft	1.5 ft	Yellow					
Rudbeckia subtomentosa	Sweet Coneflower				X	X	3-4 ft	2 ft	Yellow					
Sagittaria latifolia	Arrowleaf	0-1 ft	X				1-4 ft	2.5 ft	White					
Saururs cernuus	Lizard Tail	0-1 ft	X				1-2 ft	2.5 ft	White					
Scutellaria incana	Hoary Skullcap				X		2-3 ft	2 ft	Blue					
Sedum ternatum	Woodland Stonecrop					X	6 in	1 ft	White/Evergreen	X			X	X
Solidage nemoralis	Old Field Goldenrod			X		X	4-6 ft	1.5 ft	Yellow					
Solidago flexicaulis	Zig-zag Goldenrod				X	X	2 ft	1.5 ft	Yellow					
Solidago rigida	Stiff Goldenrod				X	X	3-5 ft	1.5 ft	Yellow					
Solidago rugosa	Rough-Leaved Goldenrod				X	X	2-3 ft	1.5 ft	Yellow					
Solidago speciosa	Showy Goldenrod					X	2-3 ft	1.5 ft	Yellow					
Spigelia marylandica	Indian Pink				X	X	1-2 ft	1.5 ft	Yellow					X
Tephrosia virginiana	Goatsbeard			X		X	1-2 ft	1.5 ft	Pink/White					X
Thalia dealbata	Wild Canna	0-2 ft	X				4-7 ft	5 ft	Purple					
Verbesina helianthoides	Yellow Wingstem						2-3 ft	1.5 ft	Yellow					
Ziza aurea	Golden Alexander					X	1-3 ft	1.5 ft	Yellow					

*Adapted from MBG, 2012

Color and Months							Sun	Pt Sun	St Shade	Shade	Dry	Medium	Wet	Birds	Butterflies	Fall Color	Winter Interest	Flood Frequency Tolerance	Flood Height Tolerance	Flood Duration Tolerance (Days)	Salt Tolerance	Aggressiveness	Silt Tolerance
June	July	Aug.	Sept.	Oct.	Nov.	Dec.																	
	X	X	X				X	X				X	X					M	24	1		M	
	X	X	X				X	X	X		X	X		X	X			L	12	1	M	M	M
	X	X	X				X						X					H	36			H	
X							X	X			X	X			X			L				M	
X	X	X	X				X	X			X	X						L				M	L
							X	X			X	X		X				M	12	1		M	M
	X	X	X				X	X	X	X		X	X	X	X			L	12	1		M	
X	X	X	X	X			X	X	X				X					M	12	4	L	L	U
	X	X	X				X	X	X		X	X						L		1		M	
X	X	X					X	X			X	X		X	X			M	12	1	M	H	L
X	X	X	X				X	X			X	X			X		X	L				M	
X	X	X	X				X				X	X			X			L				M	
X	X	X	X				X	X				X	X		X		X	H	12	2		M	
	X	X	X				X						X	X				M	18	3	M	M	L
X	X	X	X				X	X	X	X			X					H	24			H	
X	X	X							X	X	X	X			X			L					L
				X	X	X			X	X	X	X					X	L				L	
	X	X	X				X	X			X	X		X				L				L	L
			X	X				X	X	X	X	X			X			L				L	
		X	X				X					X					X	L	12	2	M	H	L
		X	X				X	X	X	X	X	X			X		X	L			M	H	L
		X	X				X	X	X		X	X			X		X	L			M	H	L
X	X								X	X	X	X		X				L				L	
X	X	X					X	X	X	X	X	X						L				L	
	X	X	X				X						X					H	24			M	H
	X						X	X	X		X	X		X	X			L				M	
X	X						X	X	X			X			X			H	12	1	M	H	U

Latin Name	Common Name	Submerged & Emergent (water depth in Ft)	Pond Edge & Permanent Water	Over Sand	Lower Slopes & Bioretention Base	Upper Slopes	Height (Ft)	Spacing (Ft)		Seasonal Interest -				
Tree/Shrubs									Color	Jan.	Feb.	Mar.	Apr.	May
Aesculus pavia	Red Buckeye		X		X		10-20 ft	15 ft	Red				X	X
Amelanchier arborea	Serviceberry			X	X	X	10-15 ft	10 ft	White			X	X	
Aronia melanocarpa	Black Chokeberry				X	X	5-7 ft	5 ft	White					X
Asimina triloba	Paw Paw		X		X		15-25 ft	15 ft	Purple			X	X	
Betula nigra	River Birch		X		X	X	30-40 ft	15-20 ft	Cream			X	X	
Calicarpa americana	Beautyberry					X	3-5 ft	4-6 ft	Pink/Purple					X
Carpinus caroliniana	Musclewood				X	X	15-20 ft	20 ft	Yellow	X	X	X		
Cephalanthus occidentalis	Buttonbush	X	X		X		5-10 ft	7.5 ft	White					
Cercis canadensis	Redbud			X	X	X	10-20 ft	15 ft	Pink			X	X	
Chioanthus virginicus	Fringetree					X	10-15 ft	10 ft	White				X	X
Cornus alternifolia	Pagoda Dogwood					X	10-15 ft	10 ft	White				X	X
Corun florida	Flowering Dogwood			X	X	X	10-20 ft	15 ft	White			X	X	
Crataegus virdis	Green Hawthorne		X		X		15-20 ft	15 ft	White					X
Diospyos virginiana	Persimmon			X	X	X	30-40 ft	20 ft	Orange				X	X
Dirca palustrus	Leatherwood					X	5-7 ft	5 ft	Lt Yellow			X	X	
Hamamelus virginiana	Eastern Witchazel		X		X	X	10-15 ft	15 ft	Yellow					
Hydrangea arborescens	Wild Hydrangea				X	X	5-7 ft	5 ft	White					X
Ilex verticallata	Winterberry Holly		X	X	X		5-10 ft	10 ft	Red					
Neviusia albamense	Alabama Snowreath				X	X	8-10 ft	7 ft	White				X	X
Nyssa sylvatica	Black Gum			X	X		40-50 ft	25 ft	Red					
Ostrya virginiana	Hopohornbeam				X	X	20-30 ft	20 ft	Green					
Pinus echinata	Short-leaf pine			X	X	X	40-50 ft	20 ft	Green					
Quercus alba	Whita Oak				X	X	40-60 ft	30 ft	Green			X	X	
Quercus bicolor	Swamp White Oak			X	X	X	10-15 ft	10 ft	Red					
Quercus coccinea	Scarlet Oak			X	X	X	30-40 ft	30 ft	Red					
Quercus macrocarpa	Bur Oak		X		X	X	40-60 ft	35 ft	Green					
Quercus muhlenbergii	Chinquapin Oak				X	X	40-50 ft	35 ft	Green					
Quercus phellos	Willow Oak		X		X	X	40-50 ft	25 ft	White				X	X
Quercus shumardi	Shumard Oak						40-50 ft	25 ft	White				X	X
Ribers odoratum	Golden Current					X	5-7 ft	5 ft	Yellow			X	X	X
Taxodium disticum	Bald Cypress	X	X	X	X		40-60 ft	20 ft	Orange					
Tilia americana	American Linden		X		X	X	50-60 ft	30 ft	Cream				X	X

*Adapted from MBG, 2012

Color and Months

June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Sun	Pt Sun	St Shade	Shade	Dry	Medium	Wet	Birds	Butterflies	Fall Color	Winter Interest	Flood Frequency Tolerance	Flood Height Tolerance	Flood Duration Tolerance (Days)	Salt Tolerance	Aggressiveness	Silt Tolerance
							X	X	X			X	X	X				H	18	2		L	M
				X				X	X	X	X	X		X		X		L				L	
X			X	X				X	X	X	X	X	X	X		X	X	M	12	2		L	
			X					X	X			X	X	X	X	X		H	36	5	L	M	H
							X	X	X		X	X	X	X			X	H	36	5		H	H
X			X	X	X	X		X	X	X	X	X				X		L				L	
				X	X	X	X	X	X		X	X				X	X	M	6	1		L	
X	X	X					X	X	X			X	X		X			H	36	7		M	H
							X	X	X		X	X						L			L	M	L
			X	X			X	X			X	X		X		X		L				L	
			X	X			X	X	X	X	X	X		X		X	X	L				L	
			X	X	X	X		X	X	X	X	X		X		X	X	L			L	L	L
X			X	X			X	X	X			X	X	X		X	X	M	12	1	H	L	
			X	X	X		X	X	X		X	X		X		X	X	M	12	1		M	M
								X	X	X	X	X	X			X	X	L				L	
				X	X	X		X	X	X	X	X	X			X	X	L			L	L	
X	X	X	X	X			X	X	X	X	X	X	X		X	X	X	L			L	L	L
			X	X	X	X	X	X	X			X	X	X		X	X	H	12	3		L	M
								X	X			X	X				X	M				M	
				X	X	X	X	X	X		X	X		X		X	X	L			H	L	
			X	X				X	X	X	X	X						L				L	L
			X	X	X	X	X	X	X	X	X	X		X		X		L			L	L	
				X	X		X	X	X	X	X	X		X	X	X	X	L			H	L	
				X	X		X	X	X		X	X				X		L	6	1	H	L	
				X	X		X	X	X		X	X				X		L	6	1	H	L	
				X	X		X	X	X			X	X				X	H	36	5	H	L	H
			X	X				X	X	X	X	X					X	L			H	L	L
							X	X	X			X	X	X	X		X	M	24	3		L	
							X	X	X		X	X		X			X	L				L	
							X	X	X		X	X		X				L				L	
				X	X		X	X	X			X	X			X	X	H	36	7		L	H
							X	X	X	X		X	X	X	X		X	H	36	7		M	H

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Figure 1.1-

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Denney, Anne. 2012. Forest Park. Photograph.

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Denney, Anne. 2012. Deer Creek near Deer Creek Park. Photograph.

Denney, Anne. 2012. Grant's Trail Extension. Photograph.

Denney, Anne. 2012. Main Channel of the River des Peres. Photograph.

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Denney, Anne. 2012. Potential Point Sources of Toxins. Illustrator on top of GIS data. Source data: St. Louis University, St. Louis County GIS Service Center. "parcelpublic," "Des_Peres_WaterShed_Parcels."

Figure 3.6-

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Figure 3.7-

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Figure 3.13-

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Figure 3.14-

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Figure 3.15-

Denney, Anne. 2013. Green Street Stormwater BMP. Photoshop on top of image. Source image: Google Street View. Forest Park, St. Louis, MO. Accessed January 2013.

Figure 3.16-

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Figure 3.17-

Denney, Anne. 2013. Residential Stormwater Reduction Potential. Illustrator on top of aerial image. Source Map: Google Earth. Newport Avenue, Webster Groves, MO. Accessed January, 2013.

Figure 3.18-

Denney, Anne. 2013. Industrial Stormwater Reduction Potential. Illustrator on top of aerial image. Source Map: Google Earth. South Hanley Road, Maplewood, MO. Accessed January, 2013.

Figure 3.19-

Denney, Anne. 2013. Forest Park Area of Opportunity. Illustrator on top of aerial image. Source Aerial: River des Peres Watershed Coalition. "19G," "19H," 20G," 20H."

Figure 3.20-

Denney, Anne. 2012. Forest Park Attractions. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "19G," "19H," 20G," 20H."

Figure 3.21-

Denney, Anne. 2012. Forest Park Buildings, Parking Lots, and Roads. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "19G," "19H," 20G," 20H."

Figure 3.22-

Denney, Anne. 2012. Forest Park Sewer Locations. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "19G," "19H," 20G," 20H."

Figure 3.23-

Denney, Anne. 2012. Forest Park Waterscape. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "19G," "19H," 20G," 20H."

Figure 3.24-

Denney, Anne. 2012. Wilson Avenue and Drexel Drive Area of Opportunity. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "17J."

Figure 3.25-

Denney, Anne. 2012. Wilson Avenue and Drexel Drive Contours. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "17J."

Figure 3.26-

Denney, Anne. 2012. Wilson Avenue and Drexel Drive Buildings, Parking Lots and Roads. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "17J."

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Denney, Anne. 2013. Wilson Avenue and Drexel Drive Soil and Drainage. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "17J."

Figure 3.28-

Denney, Anne. 2013. Wilson Avenue and Drexel Drive Sewer Locations. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "17J."

Figure 3.29-

Denney, Anne. 2013. Deer Creek and South County Connector Area of Opportunity. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "22J."

Figure 3.30-

Denney, Anne. 2013. Deer Creek and South County Connector Businesses. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "22J."

Figure 3.31-

Denney, Anne. 2013. Deer Creek and South County Connector Roads and Parking. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "22J."

Figure 3.32-

Denney, Anne. 2013. Deer Creek and South County Connector Contours. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "22J."

Figure 3.33-

Denney, Anne. 2013. Deer Creek and South County Connector Soil and Drainage. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "22J."

Figure 3.34-

Denney, Anne. 2013. Deer Creek and South County Sewer Locations. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "22J."

Figure 3.35-

Denney, Anne. 2013. Grant's Trail Extension Area of Opportunity. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "26H."

Figure 3.36-

Denney, Anne. 2013. Grant's Trail Contours. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "26H."

Figure 3.37-

Denney, Anne. 2013. Grant's Prevailing Winds and Vegetation. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "26H."

Figure 3.38-

Denney, Anne. 2013. Grant's Trail Fence Posts and Driveways. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "26H."

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Figure 3.40-

Denney, Anne. 2013. Grant's Trail Sewer Locations. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "26H."

Figure 3.41-

Denney, Anne. 2013. Main Channel Area of Opportunity. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "24H," "24J."

Figure 3.42-

Denney, Anne. 2013. Main Channel Contours. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "24H," "24J."

Figure 3.43-

Denney, Anne. 2013. Main Channel Attractions. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "24H," "24J."

Figure 3.44-

Denney, Anne. 2013. Main Channel Buildings, Parking Lots, and Roads. Illustrator on top of aerial image. Source Map: River des Peres Watershed Coalition. "24H," "24J."

Figure 3.45-

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Figure 3.46-

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Figure 4.1-

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Figure 4.2-

Denney, Anne. 2013. Forest Park River Channel. Photoshop.

Figure 4.3-

Denney, Anne. 2013. Forest Park Bridge Vision. Photoshop.

Figure 4.4-

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Table 4.1-

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Figure 4.7-

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Figure 4.8-

Denney, Anne. 2013. Wilson Avenue and Drexel Drive River Channel. Photoshop.

Figure 4.9-

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Figure 4.14-

Denney, Anne. 2013. Deer Creek and South County Connector Master Plan. Illustrator on aerial image. Source Map: River des Peres Watershed Coalition. "22J."

Figure 4.15-

Denney, Anne. 2013. Deer Creek and South County Connector Creek Channel. Photoshop.

Figure 4.16-

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Figure 4.20-

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Figure 4.26-

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Figure 4.27-

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Figure 4.28-

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