Hinkson Creek Watershed Management Plan

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Notes on this Plan

This watershed management plan is composed of material from many different sources. The documents used as references are cited within text. When a chapter is mostly composed of a single source, the document is cited at the beginning of the chapter. Most documents were edited for brevity/pertinent content.

The original plan, developed in 2008, is the result of a collaboration of the Hinkson Creek Watershed Restoration Project Phase I Steering Committee:

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Table of Contents

Executive Summary **1**

Introduction **6**
I.a Regulatory Framework 6
I.b The Stakeholders Vision 8
I.c Future Projections for the Watershed 8

Chapter 1. City History and Watershed Development **11**
1.a Early Development 11
1.b Recent Development 12
1.c Impervious Surface 13

Chapter 2. Watershed Characteristics **14**
2.a Climate 14
2.b Geology and Ecological Drainage Units 14
2.c Soils and Topography 15
2.d Agriculture 15
2.e Vegetation 16
2.f Stream Characteristics 17
2.g Stream Classifications 17
2.h Fish Community 18
2.i Lakes 20
2.j Land Cover 21

Chapter 3. Water Quality and Projected Load Reduction **23**
3.a Stream Contaminants 24
3.b Sediment Contaminants 24
3.c Bacteria Samples - Escherichia coli 25
3.d Total Maximum Daily Load (TMDL) 25
3.e Load Reductions 26

Chapter 4. Information and Education Activities **31**
4.a Public Input Surveys 31
4.b City-County-University of Missouri MS4 Permit Activities 32
4.c Educational Activities Through a 4-Year Hinkson Creek Subgrant Project 34
4.d Overview of the Upper Hinkson Creek SALT Program 35

Chapter 5. Recommendations **37**
5.a Summary of Hinkson Creek Impairment 37
5.b Vision Summary 38
5.c Recommendations: A Three-Dimensional Approach 38
5.d Restoration 39
5.e Feasibility Analysis for Retrofitting Stormwater Treatment Structures or Best Management Practices 46
5.f Protection 46
5.g Information Needs and Public Education 49
5.h Adaptive Management 50
5.i Funding 50

Appendix A Schedule of Milestones
Appendix B Feasibility Study
Appendix C Hinkson Creek TMDL

List of Figures

Figure 1.1 Downtown Columbia, MO August 5, 1939....11
Figure 1.2 Downtown Columbia, MO January 26, 2010....11
Figure 2.1 Soil Map for Hinkson Creek Watershed....14
Figure 2.2 Major Lakes within the Hinkson Creek Watershed....20
Figure 2.3 Land Cover Map from Columbia, MO NRI....21
Figure 2.4 Land Cover Map from Boone County Resource Management....22
Figure 3.1 Macroinvertebrate Sample Locations....24
Figure 5.1 Hotspot Locations within the Hinkson Creek Watershed....41
Figure 5.2 Pond Retrofit - Before....43
Figure 5.3 Pond Retrofit - After....43
Figure 5.4 Flow Splitter....44
Figure 5.5 Dry Pond Treatment Area....44
Figure 5.6 Reforestation Retrofit....45
Figure 5.7 Conveyance Retrofit....45
Figure 5.8 Stream Extravaganza....50

List of Tables

I.1 Boone County and City of Columbia Census Figures and Census Forecast....9
I.2 Projected 2030 Employment Growth....9
I.3 Projected Housing Growth....10
2.1 Fish Kills Reported within the Hinkson Creek Watershed 1996 - 2006....19
2.2 Large Lakes within the Hinkson Creek Watershed....20
2.3 Land Cover Data from Columbia, MO NRI....21
2.4 Land Cover Data from Boone County Resource Management....22
3.1 Stream Classification Index Scores within the Hinkson Creek Watershed....23
3.2 Median Stormwater Runoff Pollution Concentrations....27
3.3 Load Reductions of Suspended Sediment by Recommended BMPs....28
3.4 Load Reductions of Bacteria by Recommended BMPs....29
3.5 Load Reductions of Zinc by Recommended BMPs....29
3.6 Runoff Reductions by BMPs....329
5.1 Six Most Common Storage Retrofit Locations in Subwatersheds....42
5.2 City of Columbia and Boone County Stream Buffer Widths....47
5.3 Projected Schedule Implementation....52

Executive Summary

The Hinkson Creek Watershed Plan was originally written during Phase I of the Hinkson Creek Watershed Restoration Project (HCWRP). HCWRP Phase I began in 2005 and concluded in 2008. The original draft of this plan consisted of material from many different sources and one primary author.

While the original draft of this plan provided excellent background material it lacked community input. Therefore, a stakeholder committee was appointed to review and revise the plan. The purpose of the stakeholders review was to ensure that the recommendations contained within the plan were in line with the social, political and economic values of the community.

Chapter 1. City History and Watershed Development

A brief description of human occupation and physical development of the watershed is contained in Chapter 1. European-American settlement began in Boone County around 1812. The native inhabitants of the area had been forced out by 1815. By the early 1830's Columbia had a population of about 700 people and an economy supported primarily by agriculture.

Columbia built its first wastewater treatment plant in 1900. That system primarily treated the Flat Branch Creek watershed. In 1950 the system was expanded to include portions of the Hinkson Creek watershed. Due to the lack of available funding and large amount of bedrock, the 1950's expansion included 26 above grade creek crossings. In the 1990's several sewage treatment wetlands were added as additional treatment.

Although agriculture is still a dominant feature of the landscape, its economic value, while significant, has been eclipsed by higher education, medical services and insurance as the primary employers.

Chapter 2. Watershed Characteristics

This chapter includes basic information on the characteristics of the watershed including climate, geology, soils and topography, agriculture, vegetation and stream characteristics.

The average annual precipitation is 40-inches, with the heaviest rainfall occurring in April through August. Temperatures vary widely over the course of the year with average highs ranging from 37 to 89 degrees Fahrenheit. Lows range from 18-66 degrees Fahrenheit.

Hinkson Creek is a Missouri Ozark border stream. It is located in a transitional zone between the glaciated plains and the Ozarks. The watershed is approximately 90 square miles. Land surface elevation ranges from 580 to 900 feet above mean sea level. Channel slope averages nine feet of fall per mile. Beneficial uses of the creek include livestock and wildlife watering, protection of warm water aquatic life and human health associated with fish consumption, whole body contact recreation and secondary contact recreation.

Soils in the upper watershed are poorly drained with low permeability and are highly erodible. Soils in the lower, developed portion of the watershed have been altered by construction activities. These soils are generally high in clay content and have low permeability.

Agricultural activity is primarily confined to the upper watershed. Crops include corn, soybeans, and wheat. Grassland is used for grazing and hay production. Cattle, horses, and sheep are the primary livestock.

Chapter 3. Water Quality and Projected Load Reduction

Missouri Department of Natural Resources (MDNR) conducted a three part aquatic macroinvertebrate community study to confirm the impairment of Hinkson Creek. Four measurements of macroinvertebrate diversity were combined into a single value, the Stream Condition Index (SCI). An SCI score of 16 or more indicates a fully supporting condition. A total of 33 sampling events were conducted. SCI scores range from 12 to 18.

Hinkson Creek exhibits water quality problems typically associated with streams in urban areas. Those problems include:

- Larger and more frequent floods and lower base flow. This can be caused by the amount of impervious surface in the watershed.
- Increase soil erosion from construction sites and subsequent deposition of silt in the stream
- Contamination from urban stormwater flows
- Degradation of habitat for aquatic organisms due to the concerns listed above
- Degradation of aquatic habitat due to the physical alteration of stream channels and riparian areas such as: enclosing the stream in a large pipe, channelizing, paving the stream bed and/or banks with concrete or rip rap and removing trees and other permanent vegetation from riparian areas.

Although a specific pollutant was not identified as the cause of aquatic life impairment in Hinkson Creek, the general findings of the Phase I-III MDNR studies match the concerns of the stakeholders and the community. Therefore, future load reductions strategies will target the following runoff problems:

- Specific conductivity, specifically chloride from road salt
- Sediment from construction and agricultural activities
- Bacteria from livestock, lagoons and septic systems
- Low dissolved oxygen from decomposition or chemical demands
- High stream temperature from streets and parking lot runoff

Due to the lack of site-specific data and inability to identify a single pollutant of concern, both the state and community are unable to set a pollutant load reduction target. The Total Maximum Daily Load (TMDL) issued by the United States Environmental Protection Agency (EPA) assigns stormwater runoff volume as a surrogate in place of a traditional specified pollutant of concern. The preamble to the TMDL describes it as a phased and adaptive plan to restore water quality conditions in the Hinkson Creek Watershed. The phased TMDL recognizes the limitations of the existing data. As new data become available it can be used to determine if the TMDL should be revised. Accordingly, this watershed plan has not targeted any particular contaminant or flow volume. As new information is made available, it should be integrated into this document and recommendations will be tailored accordingly.

Chapter 4. Information and Education Activities

The County of Boone, City of Columbia and University of Missouri (MU) have a joint Municipal Separate Storm Sewer System (MS4) permit issued by the MDNR. Each of the three entities is considered to be a regulated small MS4 and must therefore develop and implement a Stormwater Management Program (SWMP) in compliance with the National Pollutant Discharge Elimination System (NPDES) Phase II requirements for small MS4s.

The joint permittees have been implementing their programs since 2001 and have been conducting public education and outreach since 1999. Columbia and Boone County have each adopted stream buffer, stormwater and elicit discharge regulations.

In 2006 an attitude and awareness study sponsored by MU and Missouri Department of Conservation (MDC) surveyed randomly selected landowners in the Hinkson Creek Watershed to explore opinions on issues within the watershed. The 12 page survey was mailed to 10,000 residents of which 4,653 were returned. Of the surveyed respondents, only 17% had heard of the term “nonpoint source pollution” and knew what it meant. While 2.3% stated they didn’t think the creek was polluted, 69% thought it was somewhat or very polluted. Residents generally agreed with the statement that small changes in people’s daily habits and activities will have an effect on improving water quality.

The joint MS4 program includes six elements, two of which are Public Education and Outreach and Public Involvement and Education. The focus of the education efforts continues to be to educate the public on issues involving stormwater discharges and their relative impacts on stormwater quality, as well as informing the public of measures they can take to reduce pollutants in stormwater runoff. The three entities have cooperated in developing public education and involvement efforts.

Chapter 5. Recommendations

From the flow and water quality studies performed in Hinkson Creek, we have concluded that the stream is impaired because of elevated pathogen counts and high flows during storm events. The source of the impairment emanates from the urban setting. Data collected by MDNR indicate that the impairment begins where the urban portion of the watershed begins.
Over the course of several meetings the stakeholder committee developed a vision for the watershed. This statement of intent is intended to provide guidance to policy makers in decisions affecting the watershed. The stakeholder vision for the watershed is:

Physical Characteristics

- Clean water
- Stable hydrology
- Healthy biological community

Social/Cultural Elements

- View of the stream as a cultural and ecological asset
- Watershed education addressing all age groups and professions
- Develop a sense of stewardship towards the watershed

Economics

- Thriving community
- Sustainable development and sustainable economic activity

The stakeholders proposed recommendations in three separate categories: practices that restore water quality, practices that protect water quality, and information needs/public education. Restoration practices address contaminants that emanate from existing impervious surfaces and inadequate sewage treatment. Protective practices look forward in time to address water quality issues as new development occurs.

Restoration requires land owners and managers to alter their developed property in a manner that reduce impacts to water quality. The burden, in this case, is on local government to retrofit properties or provide incentives for landowners to make stormwater related improvement to their property. Two alternatives exist: to retrofit the existing developed area in order to treat stormwater, or improve conditions in the upper watershed, thereby increasing the water quality to a point that the subsequent contamination from the urban areas may no reduce the quality below standards.

It is necessary to identify areas of the watershed that contribute more pollutants than others in order for restoration practices to be most effective. Two of those areas are identified in the plan: the large commercial area near the I-70 – U.S 63 interchange and a small tributary south of I-70 and east of Hinkson Creek.

Retrofits are structural stormwater management measures designed to help minimize accelerated channel erosion, reduce pollutant loads, promote conditions for improved aquatic habitat, and correct past mistakes. These Best Management Practices (BMPs) are inserted in an urban landscape where little or no prior stormwater controls existed. Examples of such BMPs are identified in the plan such as:

- Modification to existing impoundments
- Utilization of grade control structures within small channels and ditches
- Parking lot treatment opportunities
- Conversion of land cover to trees and deep rooted plants

In November 2009 a *Feasibility Study for Retrofitting Stormwater Treatment Structures or Best Management Practices* was completed by a local engineering firm, A Civil Group. The study was undertaken in an effort to determine the feasibility of retrofitting properties within the identified focus areas. BMP and site selection criteria outlined within the proposal include site identification and ownership, installation cost, 15-year maintenance cost, amount of imperious area treated, and the level of treatment provided. The Feasibility Study is incorporated into this document as Appendix B.

Protective measures are primarily in the form of local government regulations. Both Columbia and Boone County have adopted comprehensive stormwater management and stream buffer regulations. MU has enacted a comprehensive stormwater program. These regulations will help ensure water quality is not further degraded.

There is a need for continuous water quality monitoring to be carried out in order to refine and enhance data regarding the health the watershed for the long term duration. Due to the presence of MU, the opportunity for a long term study is excellent. The data obtained through such studies can be used by the MS4 and others to define and refine water quality practices in the Hinkson Creek Watershed.

Continuing public education programs are vital to developing a view of the watershed as a cultural and ecologic asset, and develop a sense of stewardship toward the watershed. A two faceted approach should be used to target the general public and elementary and secondary school students.

The program to educate the general public should include public service announcements, festivals and workshops on various topics. Schools should be encouraged to form Stream Teams. Other activities such as bird watching, fishing, hunting, science projects dealing with water quality issues, plant identifications and care, and art classes could be held in the watershed by schools utilizing the riparian corridor.

Adaptive management for natural resources has traditionally been used to manage game species populations to set hunting limits. However, applications for ecosystem management are now being examined. As information and knowledge about the ecosystem and the related stressors evolves, management strategies are adapted to address the new understanding. Once new management techniques are put into place, the next step is to study the impact of these implementation measures. This iterative process continuously refines a long term management strategy for the creek. Adaptive management is a promising and innovative process that could be used in the Hinkson Creek Watershed.

Introduction

I.a Regulatory Framework

Hinkson Creek is a dynamic stream system, with a drainage area of 90 square miles. This creek runs southwest through agriculture and pasture land, previous mining land, and urban land. The converted Katy Trail system and Flat Branch Park are recreational areas adjacent to the stream. These areas bring citizens in close contact with the resource, and provide our residents with a connection to the creek system. Rainfall amounts during 2008 and 2009 have exceeded the average by over ten inches. This has focused the community's attention on the flooding problems, and stream degradation issues in the watershed.

In 1998, the Missouri Department of Natural Resources (MDNR) listed a 14 mile segment of Hinkson Creek as impaired by an unspecified pollutant from urban nonpoint lagoon runoff on the 303 (d) list of Impaired Waters. The perennially flowing (Class P) section of Hinkson Creek begins at Providence Road and extends to the mouth 7.6 miles downstream. 18.8 miles of Hinkson Creek extending from I-70 northward is considered Class C, or intermittent, and 6.3 miles of this segment are impaired. In 2006, the entire 18.8 mile segment was listed impaired for bacteria. Hinkson Creek is listed for the designated uses of Livestock and Wildlife Watering, Protection of Warm Water Aquatic Life, and Human Health-Fish Consumption throughout its length. It has most recently been designated for Whole Body Contact Recreation for the stream segments up and downstream of I-70, and has been found to be impaired for that use.

In October 2009, the MDNR drafted a Total Maximum Daily Load (TMDL) that identified the source of the impairment as urban runoff, and calculated a reduction in stormwater runoff volume as a surrogate for any pollutants of concern. Bacteria was added as a pollutant to the upper reach of Hinkson Creek by EPA in January 2009. This reach is 18 miles long and extends roughly from Providence Road upstream to Mount Zion Church Road. Contributing to the problem are many small wastewater treatment plants on the north and south forks of Grindstone Creek, the largest tributary to Hinkson Creek. Grindstone Creek was also added to the new 303(d) list for bacteria.

MDNR plans to create a load duration curve (LDC) to address the bacteria listing. An LDC shows what bacteria load the stream can assimilate at any given flow and still be able to meet water quality standards. Though bacteria levels were found to be above standards many times, fixing the bacteria problem will not bring Hinkson Creek back to full health. It is part of the problem and needs to be addressed, but it is not the whole problem. Despite MDNR's monitoring efforts over the last several years, no other specific pollutant source has been found. The MDNR's strategy for reducing the "load" of the unknown pollutant is to use urbanized stormwater flow as a surrogate for the range of likely conditions and chemical pollutants causing the impairment of Hinkson Creek.

(Content primarily taken from *EPA Total Maximum Daily Load for Hinkson Creek* January 2011)

The pollutant(s) causing the impairment in Hinkson Creek are unknown. However, there are generally applicable water quality standards published in 10 CSR 20-7.031 (3). The specific standards that apply to Hinkson Creek are:

(A) Waters shall be free from substances in sufficient amount to cause the formation of putrescent, unsightly or harmful bottom deposits or prevent full maintenance of beneficial uses;

(C) Waters shall be free from substances in sufficient amounts to cause unsightly color or turbidity, offensive odor or prevent full maintenance of beneficial uses;

(D) Waters shall be free from substances or conditions in sufficient amounts to result in toxicity to human, animal or aquatic life;

(G) Waters shall be free from physical, chemical or hydrologic changes that would impair the natural biological community.

Hinkson Creek exhibits water quality problems typically associated with streams in urban areas that include:

1. Larger and more frequent floods and lower base flow. This is caused by the amount of impervious surface in the watershed and other hydrologic modifications.
2. Increased soil erosion from construction sites and subsequent deposition of silt in the stream.
3. Contamination from urban stormwater flows.
4. Degradation of habitat for aquatic organisms due to the concerns listed above.
5. Degradation of aquatic habitat due to the physical alteration of stream channels and riparian areas such as: enclosing the stream in a large pipe, channelizing, paving the stream bed and or banks with concrete or rip-rap, and removing trees and other permanent vegetation from riparian areas.

Bio-assessment studies have verified that the aquatic community in a portion of Hinkson Creek, downstream of Interstate – 70 is impaired. Hinkson Creek was compared to Bonne Femme Creek and other reference stream sites. The comparisons confirmed the impairment of Hinkson Creek but did not determine the pollutants or pollutant sources. To address the impairments and become eligible for various federal assistance grants, an EPA style nine element watershed plan was undertaken. Those elements a-i are listed below:

a. **Impairment -** An identification of the causes and sources of pollution (point and nonpoint), and pollutant(s) that will need to be controlled to fix the water body (lake, river, stream) impairment, and to achieve any other watershed goals.

b. **Load Reductions -** An estimate of the pollutant load reduction(s) expected for a water body. Modeling can be simple or quite complex depending upon the application. Spreadsheets and land cover mapping are typically employed in these models to estimate load reductions.

c. **Management Measures -** A description of the nonpoint best management practices necessary to achieve the pollutant load reductions identified in element **b.**

d. **Technical & Financial Assistance -** An estimate of the amounts of technical and financial assistance that is needed and/or the sources and authorities that will be relied on to implement the best management practices identified in element **c**.

e. **Public Information & Education -** An information/education component designed to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing nonpoint source best management practices that will be implemented.

f. **Schedule -** A detailed schedule for implementing best management practices identified in element **c**.

g. **Milestones -** A description of interim, measurable milestones for determining whether nonpoint source best management practices or other controls are being implemented.

h. **Performance -** Criteria to determine whether loading reductions are achieved over time, and if progress is being made towards attaining water quality standards and, if the criterion used to determine if this plan, or a related total maximum daily load, needs to be revised.

i. **Monitoring -** A monitoring component to evaluate the effectiveness of the implementation efforts over time.

I.b The Stakeholders Vision

During the initial stages of developing a set of policy recommendations to include in the plan a feeling began to develop, within the group, that they lacked a common vision for the watershed. The stakeholders decided that they would like to spend some additional time developing plan goals.

In response staff suggested that the committee engage in a guided visioning process. The committee was divided into two groups. Each group was asked to develop a list of issues based on the following themes: (1) What can we learn from the past? (2) What needs immediate attention in the watershed? (3) What do you want the watershed to look like in 2030? After each session, the two groups met as a whole and reported their findings. During subsequent sessions, the group was able to condense the vision to the following goals:

- To improve the water quality of Hinkson Creek so that all of its designated uses are fully supported, and it is removed from the 303(d) list of impaired waters.
- To reduce the rapid increase and decrease in stream flow elevations following storm events ("flashiness") of Hinkson Creek and its tributaries, and thereby reduce the resultant flooding and erosion problems during high flow, and increase the volume of water during low flow, or "base flow".

I.c Future Projections for the Watershed

Content primarily taken from CATSO 2030 Transportation Plan

The Columbia Area Transportation Study Organization (CATSO) was created in 1974, and designated as a Metropolitan Planning Organization (MPO) by the Governor of Missouri. As the designated MPO, the CATSO is responsible for ensuring a coordinated transportation planning process with the Metropolitan Area. The information below was taken from the online version of the plan available through the city website.
The population of the Metro Area is expected to increase to 156,836 people by 2030. This is 80% of the total Boone County population. This projection assumes an average effective annual growth rate of 1.5%, which is based on a percentage of population growth that is in the mid-range of the 1980s (1.15%) and 1990s (2.05%).

Table I.1 Boone County and City of Columbia Census Figures and Census Forecast			
Growth category	**2005**	**2030**	**Net change**
Boone County population	146,048	196,045	+49,997
Metro Area Population	113,698	156,836	+34,507 (+30.3%)
Employment - Total	68,464	101,890	+33,426
Commercial: Retail	16,959	22,530	+5,571
Commercial: Non-Retail	13,406	23,016	+9,610
Office	13,600	23,448	+9,848
Industrial/Mfg	3,407	6,068	+2,661
Warehouse/Storage	1,325	2,124	+799
Hospital/Medical	11,570	14,867	+3,297
University of Missouri/Colleges	8,197	9,837	+1,640

Since the Columbia Metro Area is the principal job generator of the county, it is projected that employment growth in the Metro Area will occur at a faster rate than in the rest of Boone County. The CATSO plan suggests 101,890 as the projected employment figure for 2030. With this assumption, employment in the Metro Area would increase by 33,426 persons, requiring 2.3 additional miles of development. Estimated acreage requirements for this employment will vary by the type of classification.

Table I.2 Projected 2030 Employment Growth			
Employment type	**Employees**	**Employees/acre**	**Area (ac) for new Employment**
Office	14,785	29	510
Industrial	3,460	18	192
Commercial	15,181	20	759
Total	**33,426**		**1,461**

It is projected that 21,049 new housing units will be constructed in the Metro Area, which would require approximately 7.6 square miles of new development. This projection assumes a 10% vacancy rate, and an average of 2.2 persons per household.

Table I.3 Projected Housing Growth			
Housing type	**Units**	**Units/acre**	**Area (ac) for new development**
Single-family	8,218	2.5	3,287
Duplexes	5,774	6	962
Multi-family	7,057	11	642
Total	**2,1049**		**4,891**

Future road projects envisioned for Columbia aim to relieve future congestion caused by an increase in both population and employment within the area. Additional lanes and roads will increase the impermeability of the watershed, and introduce more road-related pollutants into the area streams. Certain road extensions will directly impact streams by passing over them, either by bridge or fill and culvert pipes. Major road improvement projects expected to affect the Hinkson Creek Watershed include:

- I-70 corridor widening
- Extension of Stadium Boulevard (over Grindstone Creek)
- Extension of Lemone Industrial (over Grindstone Creek)
- Extension of Business Loop 70 to Conley Road (over Hinkson Creek)
- Ballenger Lane Extension from Clark Lane to St. Charles Road (over Hominy Branch)
- Realignment of Mexico Gravel Road and Vandiver (over Hinkson Creek)
- Expansion of Scott Boulevard (near Meredith Branch)

Chapter 1. City History and Watershed Development

1.a Early Development

Figure 1.1 Downtown Columbia, MO
August 5, 1939

Figure 1.2 Downtown Columbia, MO
January 26, 2010

The earliest known inhabitants of this area lived between 9,000 and 14,000 years ago (Young et al., 1998). At the time just before European-American expansion into the area, it was occupied by the Osage and Missouri tribes. The first known European-American settlement in Boone County was established in 1812; by 1815, all Native Americans had been forced from the area. Originally, the new town of Smithton was intended to function as the Boone County seat. Smithton was a 2,720 acre tract of land that was situated about a half mile to the west of what is now downtown Columbia. The location, however, turned out to be poor because of a lack of access to an adequate water supply. The town of Columbia was then established next to the Flat Branch of Hinkson Creek and became the county seat in 1821. Columbia grew as pioneers passed through the town as they traveled the "Boone's Lick" trail, a route that eventually connected the eastern United States to the Santa Fe Trail.

By the early 1830s, Columbia had a population of about 700 and a diverse agricultural base was the driving force of the economy. Commonly grown crops included corn, tobacco, hemp, and flax. The years immediately following the Civil War were marked by an expanding population and economy. A feeder line from Centralia connected Columbia to the Northern Missouri Railroad. This allowed industries such as timber mills, flour mills, and carriage factories to establish.

In 1900, Columbia built a wastewater treatment system at the current Martin Luther King memorial area along Flat Branch Creek, and ran the sewer lines upstream along Flat Branch into the city (Beck, 2007). Prior to this time, outhouses and septic tanks were used. Some septic systems/outhouses were still in use within the city up until the 1960s.

As the city grew, more sewer trunk lines were added, expanding into Hinkson Creek's drainage area in the 1950s. During this time, a "trickling filter" treatment plant was constructed along Hinkson Creek southeast of the Forum Shopping Center, downstream of the confluence of Flat Branch and Hinkson Creek.

Because of funding issues in the mid-1950s, and an unexpected amount of bedrock, the city constructed 26 sewer lines that crossed creeks above grade. This configuration caused debris to get caught on the pipes which would often break under the weight and dump raw sewage into Hinkson Creek. The treatment plants discharged poorly treated water into the creeks, often turning them black. These plants were decommissioned and replaced with a regional wastewater treatment facility in 1983. The facility is located in the southwestern part of Columbia where Hinkson Creek discharges into Perche Creek.

In the early 1990's, the City upgraded the Columbia Regional Wastewater Treatment Facility by constructing three wetland treatment units, in order to meet the needs of a growing community and to continue the City's efforts to protect streams and groundwater. A fourth wetland treatment unit was added in 2001. The constructed wetland treatment units are located in the McBaine Bottoms and receive wastewater after it is treated at the original treatment plant. After it flows through the constructed wetlands, the wastewater is discharged to the Missouri Department of Conservation's Eagle Bluffs Conservation Area near the Missouri River.

1.b Recent Development

Columbia is an expanding urban area, and agriculture, though still a dominant feature on the landscape, now plays a secondary role in the economy. Higher education, insurance centers, and medical centers are the major sources of commerce. According to the Columbia demographics statistics (City of Columbia, 2007), Columbia now covers 60 square miles. The population in 2009 was approximately 94,000 people, compared with 69,101 people in 1990. On average, Columbia gains more than 1,000 additional people each year. Columbia is the largest city within Boone County, which covers 685 square miles. The total county population is 146,048. The flagship campus of the University of Missouri-Columbia (MU) is located within the Columbia city limits, and is the largest of three colleges within the city. The MU campus is adjacent to the center of Columbia and extends southward roughly to Hinkson Creek. In fall 2008, MU had a student population of 32,200 students, and typically increases over 100 students per year.

Approximately 5% of the County has been developed, with the remainder made up of wooded areas, pasture land, and a small amount of crop land (University of Missouri, 2005). Most of the development taking place is either in the form of single-family residences on large lots or single-family residences built in isolated subdivisions. There has been little building in most of the floodplains. Much of the area within the City limits has been developed. In 2008, 404 building permits were issued for new structures in the city and 319 in the county.. This contrasts with 2006, when 1,651 building permits were issued for new structures in Columbia and 564 in the county, when the housing market was much stronger (City of Columbia, 2009; County of Boone, 2006-8). The increasing population translates into a significant demand for housing, as well as goods and services, causing further spread into relatively sparsely populated portions of the watersheds.

1.c Impervious Surface

With increasing development in the Hinkson Creek Watershed, the percentage of land covered with impervious cover is increasing. Literature suggests that when connected impervious cover increases to 8-12%, stream macroinvertebrate communities become degraded (EPA, 2005). In an unpublished study by Davis et al. at the University of Missouri, satellite data from 2000 was used to estimate the impervious cover of watersheds within the City of Columbia. The Flat Branch watershed showed the highest impervious cover (39%), primarily attributable to the densely developed downtown area. County House Branch watershed showed an intermediate level of impervious cover (20%), as did Mill Creek (24%), and Meredith Branch (18%) watersheds. Grindstone Creek watershed had the lowest impervious cover at the time (8%), and Hominy Creek watershed had 9%. These figures have likely increased since the time of the study.

Chapter 2. Watershed Characteristics

2.a Climate

The climate of central Missouri varies widely with fluctuations in temperature, precipitation, and humidity. The average annual precipitation is just over 40 inches. Heaviest rainfall typically arrives in the late spring and early summer with 70% of the total precipitation falling in the period from April through August. The driest period is from November through March. Annual snowfall is around 20 inches. The growing season is approximately 208 days (Nigh, 2002).

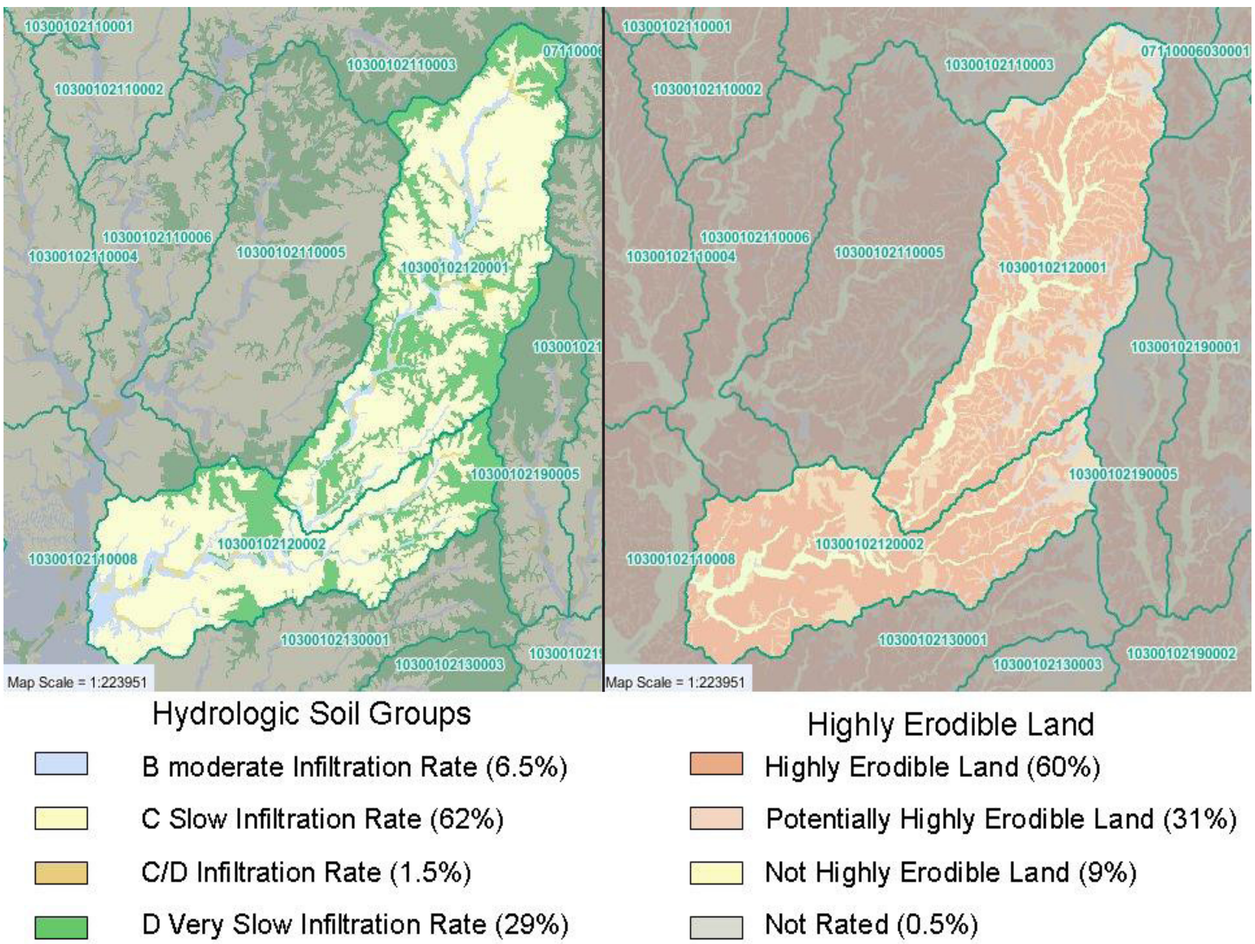

Figure 2.1. Soil Map for Hinkson Creek Watershed. From the University of Missouri's *Center for Applied Research and Environmental Studies (CARES) 2009*

2.b Geology and Ecological Drainage Unit

Content primarily taken from MDNR's Phase II Hinkson Creek Stream Study

Hinkson Creek is a Missouri Ozark border stream. It is located in a unique area that is characterized as a transitional zone between the Glaciated Plains and Ozarks. Streams within this region generally originate on level uplands underlain by shale and descend into rolling to hilly terrain underlain by limestone. The soil type within the Hinkson Creek Watershed drains soils located geographically in the Central Clay Pan and Central Mississippi Valley Wooded Slopes regions. Pennsylvanian sandstone, limestone, and shale also characterize this region.

Mississippian and Pennsylvanian limestone, sandstone, and shale with considerable bedrock exposure characterize this region. The state of Missouri is divided into 17 aquatic ecological drainage unit (EDU) systems, Hinkson Creek is located within the Ozark/Moreau/Loutre EDU.

Hinkson Creek is supplied with water from several large tributaries. Varnon and Nelson creeks enter Hinkson Creek above the impaired section, while Hominy, Grindstone, Flat Branch, County House, Meredith, and Mill Creeks enter within the impaired section (in descending order). The largest tributary, Grindstone Creek, drains approximately 8,000 acres. Some springs can be found in the Flat Branch Watershed and in Hinkson Creek direct watershed as well.

2.c Soils and Topography

Content provided by Kevin Monckton, Boone County Soil and Water Conservation District (BCSWD)

Boone County is extremely hilly and rocky with much of the rock located close to the surface. Soils in the area are generally fine-grained with moderately pervious surface soils and less pervious sub-soils. They are classified according to the unified classification system primarily as silt loams and silty clay loams. Soils are generally classified as hydrological Groups C and D with small areas of Group B, according to the Soil Conservation Service System. Group C soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water. Group D soils have the highest runoff potential, and have very low infiltration rates when thoroughly wetted. They consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, or soils with clay layer at or near the surface. The area is best characterized by rolling hills with steep slopes along the larger streams.

The soils of the upper elevations of the watershed are poorly drained. Permeability is slow, as a result, the soils are unsuitable for conventional on-site sewage treatment. Presently, much of the areas that are undeveloped are in row crops. The largest areas of the watershed have slopes of 2 - 35% and are mostly ridges and hills in the lower portion of the watershed. These soils all have very high runoff rates, permeability is slow, and are highly erodible. Along the creeks are small areas of soils with slopes of 0 - 3%. Runoff rates on these areas are low, permeability is moderate, and the soils are moderately well drained.

Within the urbanized areas of the Hinkson Creek Watershed, much of the soil structure has been altered throughout the construction phase of development. These soils are generally high in clay and have low permeability. This causes a potential for high stormwater runoff and a higher need for management to prevent nutrient and pesticide runoff.

2.d Agriculture

Content primarily taken from Boone County Soil and Water Conservation District Agricultural Nonpoint Source Special Area Land Treatment Project (AgNPS SALT) grant application

Of the 32,918 total acres in the upper watershed (upstream of Old Highway 63), land use includes cropland devoted mainly to corn, beans, and wheat; grassland used for grazing and hay production; forest and woodlands used for grazing, timber harvest, and recreation. Urban land uses are primarily residential with some commercial expansion into the area, and the landfill. The lower watershed has only 6.6% cropland, and 32% grassland (CARES 2009).

Most producers practice a soybean and corn crop rotation. Management systems vary from no-till to conventional tillage with their associated sheet and rill soil losses. Residue, with the exception of cornstalks, is generally left undisturbed over the winter. Most of the land in row crop production is on the northern and eastern sides of the watershed. The majority of the grassland is distributed throughout the watershed north of the city of Columbia. Primary vegetative cover includes fescue and orchard grass mixed with clover and lespedeza. There are also smaller acreages of timothy, alfalfa, and warm season grasses.

Cattle, horses, and sheep are the primary livestock raised in the upper Hinkson Creek Watershed. According to figures received from the Boone County Assessor's office, there are approximately 4,021 head of cattle, 585 horses/mules, 521 sheep, 222 pigs, and 50 llamas/emus reported in the upper Hinkson Creek Watershed. Horses are raised by many landowners on small, lots and pastures, cattle are raised on open and wooded pastures. There are no confined livestock operations in the watershed that can be classified as Class I or Class II. While some of the feeding operations utilize the accumulated animal wastes by using a manure spreader to top-dress pastures, most simply create a stockpile area or make no effort to clean out the dry lot area.

2.e Vegetation

Content primarily taken from The Flora of Columbia Missouri and Vicinity

The Flora of Columbia Missouri and Vicinity, written in 1907, describes the early vegetation of Columbia as "one of tension between forest and prairie ." However, even in 1907, things were not "pristine", as agriculture had presumably been occurring within the watershed since the precursor town of Smithton sprang up in the 1820s. According to the document, Columbia's natural cover is mainly deciduous forest, with some small areas of prairie and marshland within the mix. The tall grass prairie that existed in Boone County (according to this and other documents) was mainly found on the ridges of the Cedar Creek Watershed in north Boone County. The streamside areas contained riparian buffers mainly composed of common softwood species such as willows, birches, cottonwoods, and sycamores, perhaps reflecting the disturbance to the slower-growing hardwoods by agriculture in the floodplain.

Within the channel itself, vegetation such as American water willow and scouring rush "often completely choked up" the stream. At the same time, this document mentions the absence of aquatic plants within the streams, citing the turbidity and scouring nature of the streams as the cause. One can assume the "aquatic plants" referred to as absent were submerged or at least growing in mainly inundated conditions, since water willow and scouring rush grow up to and sometimes within the shoreline.

The natural land cover for the Hinkson Creek Watershed was deciduous forest, with pockets of marsh and prairie. Riparian zones were forested, and streamside zones were vegetated with highly stoloniferous and rhizomatous species that have high resistance to stream erosion.

2.f Stream Characteristics

Hinkson Creek originates northeast of Hallsville, in Boone County, and flows approximately 26 miles in a southwesterly direction to its mouth at Perche Creek (MDNR, 2006). The Hinkson

Creek Watershed is approximately 88.5 square miles. The basin land surface elevations vary from 580 feet mean sea level at the confluence of Perche Creek to 900 feet mean sea level in the headwaters (U.S. Army Corps of Engineers, 1971). Channel widths vary historically from 80 feet at the southern end to 50 feet at the north end. Channel slope averages nine feet of fall per mile. The gradient below Providence Road is five feet per mile; the gradient above I-70 is 12 feet per mile. Floodplain widths vary from 1,000 feet at the north end to 1,500 feet in the south. Grindstone Creek, the largest tributary, has a 15.4 square mile watershed, with an average floodplain width of 500 feet, and an average channel width of 60 feet.

A stream gage was established 400 feet downstream of Providence Road in November 1966, (U.S. Army Corps of Engineers, 1971) and was in operation until 1991. It was then decommissioned until spring of 2007. The gage measures flow from 69.8 square miles of the Hinkson Creek drainage area, and was zeroed at 583.5 feet mean sea level. Flows ranged from zero flow to 19.8 feet above the channel bed. The highest discharge recorded during this interval was 10,000 cubic feet per second (cfs) on April 11, 1977. The most intense rainfall recorded was 6.6 inches in a 24 hour period, which is considered an event that happens once in fifty years.

2.g Stream Classification

Content primarily taken from MDNR's Phase II Hinkson Creek Stream Study

The upper reaches of Hinkson Creek (from Mount Zion Church Road to approximately Providence Road) are classified as a Class C stream, whereby the stream may cease flowing in dry periods but maintains permanent pools that support life. The beneficial uses in this reach consist of:

- livestock and wildlife watering
- protection of warm water aquatic life and human health associated with fish consumption
- whole body contact recreation – category B

The lower reaches of Hinkson Creek (from approximately Providence Road to Perche Creek) are classified as a Class P stream, where the stream is capable of maintaining permanent flow even in drought periods. The beneficial uses in this reach consist of :

- livestock and wildlife watering
- protection of warm water aquatic life and human health - fish consumption
- whole body contact recreation – category B
- secondary contact recreation

Grindstone Creek is the largest tributary of Hinkson Creek. The North Fork of Grindstone Creek and South Fork of Grindstone Creek flow together to form Grindstone Creek just east of U.S. Highway 63. Grindstone Creek flows in a westerly direction approximately 1.5 miles before entering Hinkson Creek along the City of Columbia's Capen Park. Grindstone Creek is a class C stream with beneficial use designations of:

- livestock and wildlife watering
- protection of warm water aquatic life and human health – fish consumption
- whole body contact recreation – category A

Hominy Creek is the second largest tributary of Hinkson Creek, and originates in east central Boone County just north of I-70 and flows in a southwesterly direction. Approximately 0.45 miles of Hominy Creek was impounded to form a small lake located just before its confluence with Hinkson Creek. The dam broke in March 2008, and was removed in early 2009. The confluence of Hominy Creek and Hinkson Creek is located just south of the Broadway bridge crossing. From Highway 63 to its mouth at Hinkson Creek, Hominy Creek is classified as a class C stream with beneficial use designations of:

- livestock and wildlife watering
- protection of warm water aquatic life and human health – fish consumption
- whole body contact and secondary contact recreation

Although significant flow exists in several other tributaries to Hinkson Creek, only the tributaries noted above have designated uses assigned to them by the State of Missouri. Note that unclassified streams are still considered "waters of the state", and are afforded protection from degradation under state and federal law.

2.h Fish Community

Content provided by Doug Novinger, MDC

The fish community of the Hinkson Creek Watershed can be described as similar to other central Missouri streams, and slightly degraded based on historical fish collection data available in the Missouri Department of Conservation's (MDC) Fish Community Database. Overall, there was no clear indication that species richness or measures of diversity have decreased through time. However, some key species have apparently been lost from the watershed, such as the endangered Topeka shiner that was found in Grindstone, Hinkson, and Mill Creeks during the 1960s. Trout-perch and plains minnow, Missouri species of conservation concern, also were collected in Hinkson Creek during the 1960s, but not since this time. Other species including several bottom-oriented species such as suckers (e.g., red horse species, white sucker, quillback) show indications of decline by their absence in several 1990s samples. This may reflect a reduction in the suitability of benthic habitat.

Table 2.1 Fish Kills Reported Within Hinkson Watershed, 1996-2006
(Content taken entirely from Department of Conservation database)

Cause	Source	Date	Damage	Days
Floor Stripper + Floor Finish	Retail Store	4 / 7 / 1996	Unknown	1 day
Latex paint.	Unknown.	5 / 13 / 1996	200 ft2	2 days
Dye suspected.	Unknown.	6 / 5 / 1996	1/3 mile	1 day
Diesel fuel- 1100 gal	Hospital	8 / 1 / 1996	0.5 miles	1 day
Asphalt sealer	Illegal dumping	8 / 21 / 1996		
Turbidity	Erosion from broken water main	12 / 17 / 1996	0.75 miles	1 day
Waste oil and oil refuse	Oil changing station	2 / 27 / 1997	<1/2 mile	Months
Diesel Fuel	Truck spill	4 / 11 / 1997	0.1 Mile	1 day
Fabric Shield/Detergents-5 gal	Fabric Cleaner Demonstration	6 / 17 / 1997	<1/8 mile	1 day
Raw sewage	Broken sewer line	6 / 20 / 1997	1/8 mile	2 days
Municipal Water	Broken water main	7 / 31 / 1997	1/2 mile	1/2 day
Wastewater and detergents	Carpet cleaners	8 / 2 / 1997	Unknown	47+ days
Instream gravel removal	Bridge maintenance work	8 / 24 / 1997	0.1 miles	68+ days
Low dissolved oxygen	Fire suppression runoff	9 / 10 / 1997	2.4 miles	2 days
Sediment, diesel fuel, grease.	Construction site	8 / 27 / 1998	1/2 mile	>1 week
Bentonite clay/water 60 gal/min	Runoff from drilling operation	12 / 9 / 1998	150 feet	7+ days
Petroleum (gasoline suspected)	Transfer station	12 / 14 / 1998.	1/4 mile	1 day
Raw Sewage- 10 gal	Overflowing manhole	4 / 30 / 2000	1/2 mile	1 week -- ??
Likely natural	N/A	9 / 13 / 2000	Unknown	Unknown
Raw Sewage	Overflowing manhole	8 / 25 / 2001	300 yards	1 day
Unleaded fuel- 350 gal	Underground tank overflow	12 / 16 / 2002	0.5 mile	1 week+
Fly ash slurry	Coal power facility fire	10 / 5 / 2005	250 feet	3 days
High pH wastewater	Lift station failure	12 / 5 / 2006	Unknown	1 day

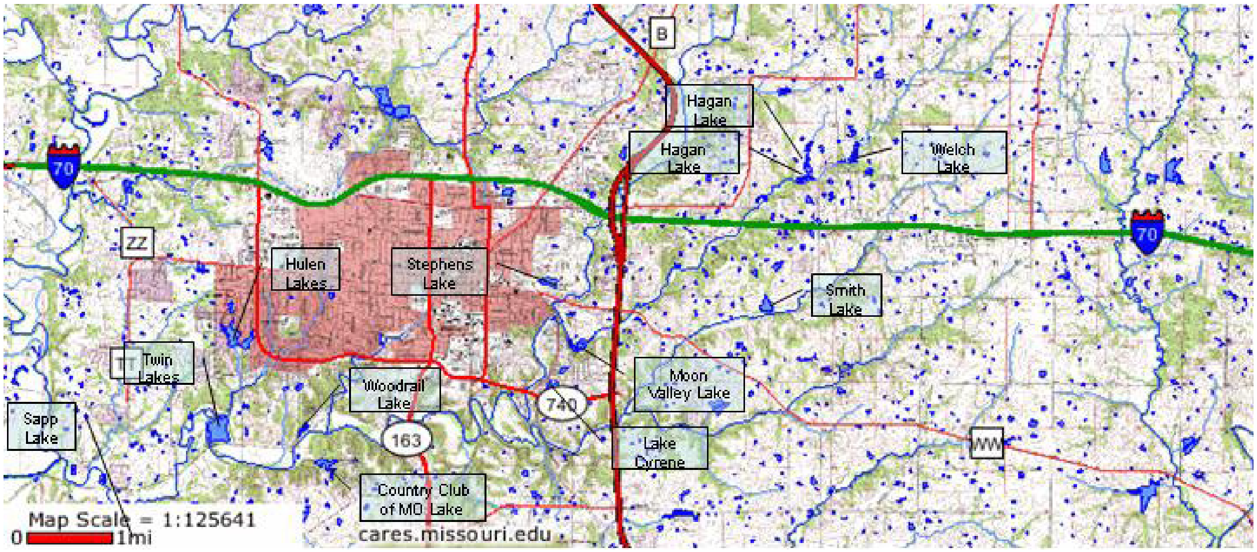

Figure 2.3. Major Lakes within the Hinkson Creek Watershed. From *Center for Applied Research and Environmental Studies (CARES) 2009.*

2.i Lakes

Content taken from MDNR data and findlakes.com. Note that some errors have been found on the findlakes.com website, the capacities below should be verified with their owners before being relied upon.

Over 100 small ponds ranging from less than an acre to 34 acres (Twin Lakes) have been constructed throughout the Hinkson Watershed. Some lakes are dammed tributaries to Hinkson Creek, others are old farm ponds or newer ponds developed for stormwater control. Although the area has at least one sizable oxbow lake, Brushwood Lake, it does not occur in the watershed. Numerous sinkhole ponds can be found in the Bonne Femme Creek Watershed, but none are known within the Hinkson Creek Watershed. Ponds and lakes found in the Hinkson Creek Watershed are man-made. The following is a brief list of the larger lakes within the watershed:

Table 2.2 Large Lakes Within the Hinkson Creek Watershed

Water body	Size	Watershed
Country Club Of MO Lake	8 acres	Mill Creek
Hagan Lake	7 acres	Hominy Branch
Hulen Lake East	7 acres	County House Branch
Hulen Lake West	18 acres	County House Branch
Lake Cyrene	7 acres	Hinkson Creek
Moon Valley Lake	17 acres (formerly)	Hominy Branch
Sapp Lake	6 acres	Mill Creek
Smith Lake	9 acres	North Fork Grindstone Creek
Stephens Lake	11 acres	Hinkson Creek
Twin Lakes	34 acres	County House Branch
Waters Edge Estates Lake	17 acres	Hominy Branch
Welch Lake	9 acres	Hominy Branch
Woodrail Lake	12 acres	Hinkson Creek

2.j Land Cover

The term land cover is often used synonymously with land use, but they are distinctly different. Land use refers to the manner in which humans utilize the land for socioeconomic activity. Land cover refers to the physical material that covers the surface of the earth.

Land cover has a distinct impact on the quantity and quality of stormwater. That impact is dependant upon the type of land cover. For instance, forested land provides several positive ecological functions such as infiltration, evapotranspiration, and removal of some of the pollutants that can be carried by overland flow. Conversely, urban impervious surfaces provide mostly negative effects such as increased runoff and pollutant loading.

Land cover data for most of the Hinkson Watershed was obtained from the City of Columbia Natural Resources Inventory (NRI). The NRI identified six land cover types:

- Tree Canopy: All tree cover, deciduous and evergreen
- Cropland: Tilled land areas that are typically planted with row crops
- Urban/Impervious: All manmade surfaces such as roofs, roads, parking lots and driveway that do not allow rainwater to penetrate to the soil.
- Water: Surface water features such as ponds, lakes and perennial streams
- Disturbed/Barren: Natural sparsely vegetated areas and with exposed soil
- Grass: Warm and cool season grass whether cultivated or naturally occurring

Table 2.3 Data from Columbia, MO Natural Resources Inventory

Land Cover Type	Acreage	Percent Total Map Area
Forest	17,989	41
Cropland	3,105.28	7
Impervious Cover	5,558	13
Water	732.26	2
Barren/Disturbed	1,336.80	3
Grass	15,306	35

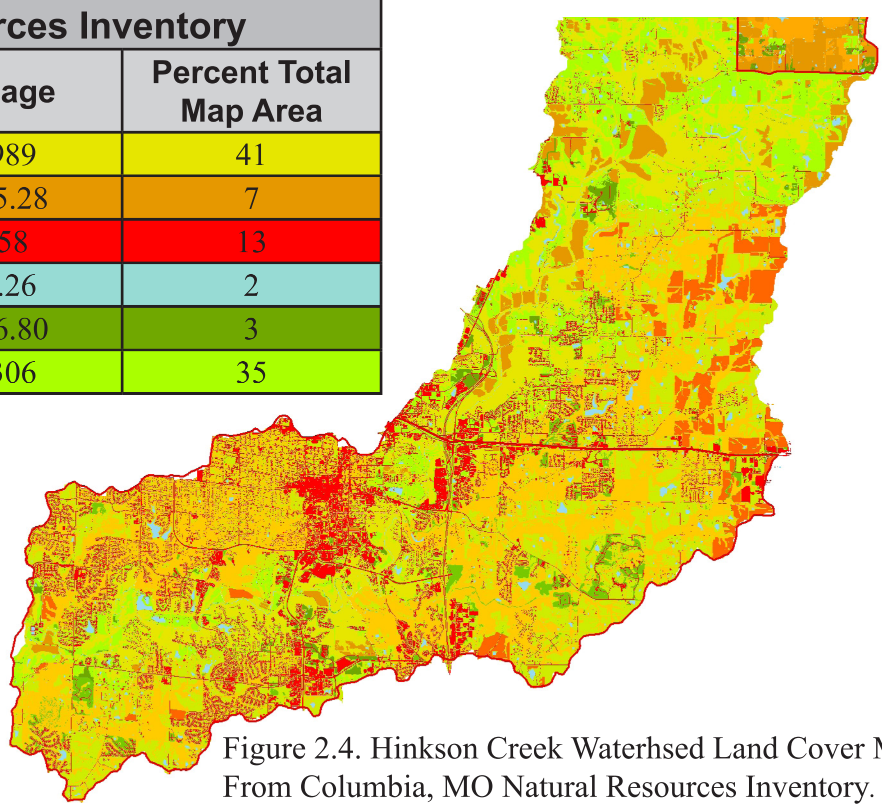

Figure 2.4. Hinkson Creek Waterhsed Land Cover Map. From Columbia, MO Natural Resources Inventory.

The portion of the watershed that was not included in the NRI was classified by the Boone County GIS Department and the Boone County Planning Division. The County used the same land cover categories that were used as for the NRI. Both sets of data were obtained from analysis of remotely sensed imagery although the methods of analysis were different.

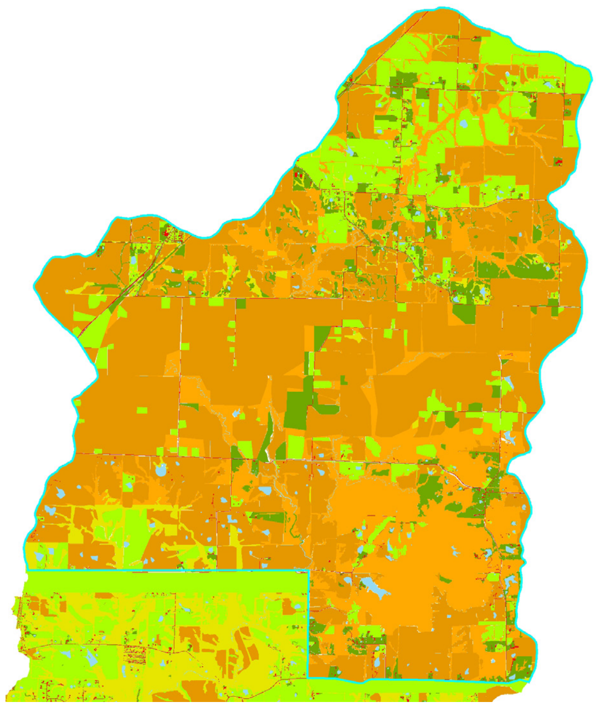

Figure 2.5. Upper Hinkson Creek Watershed Land Cover Map. From Boone County Resource Management.

Table 2.4 Data from Map Generated by Boone County Resource Management		
Land Cover Type	**Acreage**	**Percent Total Map Area**
Forest	4,854	34
Cropland	6,275.12	44
Impervious Cover	243	2
Water	305	2
Barren/Disturbed	967.01	7
Grass	1,724.99	12

Chapter 3. Water Quality and Projected Load Reduction

Content entirely taken from Phases I-III of the MDNR Hinkson Creek Stream Study

In 2001-2002, The Missouri Department of Natural Resources (MDNR) conducted an aquatic macroinvertebrate community study which showed impairment to the urban portion of Hinkson Creek. Four measurements of macroinvertebrate diversity were combined into a single value, the Stream Condition Index (SCI), which was used to determine the impairment of the stream. MDNR then followed up with a three-part study of Hinkson Creek to confirm the impairment of the aquatic community and attempt to determine the nature and source(s) of the impairment. At the end of their study, MDNR noted that the biological community was largely unchanged compared to conditions observed in 2002. Water and sediment samples were collected from Hinkson Creek and storm drainages, monitored for various chemicals, and tested for toxicity.

Table 3.1. Stream Condition Index Scores within Hinkson Creek
A score of 14 or less indicates impairment of the aquatic community.

Site (Location #)	Fall 2001	Spring 2002	Fall 2003	Spring 2004	Fall 2005	Spring 2006
Rogers Road	12	18				
Hinkson Creek Road (7)	12	18	18	18	18	
Hwy 63 Connector				16		
Walnut Street (6)	12	12	16	14	18	
Broadway Street (5.5)			16	16	14	
Capen Park	16	12				
Rock Quarry	18	14				
Recreation Drive (3.5)					14	
Forum Boulevard (3)	18	14				16
Twin Lakes (2)	18	14				14
Scott Boulevard (1)	16	14				16
Bonne Femme #1			16	18		18

* Note that conditions in the watershed have changed since the time of sampling; see text for details.

3.a Stream Contaminants

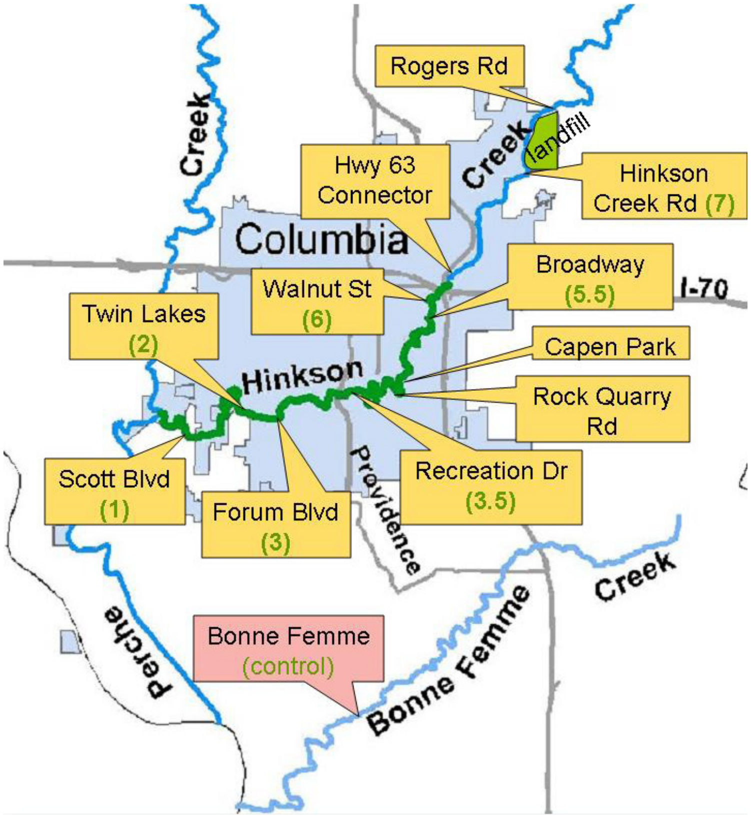

Figure 3.1. Macroinvertebrate Sample Locations

The specific conductivity of Hinkson Creek, a measurement of dissolved substances, was within the expected range, though elevated conductivity values were found in stormwater runoff. Nutrient levels in the stream were found to be within the expected ranges. Low dissolved oxygen concentrations correlated with pool stagnation during dry periods, and oxygen levels rose following rain events.

When compared to other streams, Hinkson Creek remained turbid for several days while other tributaries returned to normal conditions within one to two days following rainfall. Some sites remained turbid even during base flow conditions, which were thought to be related to land disturbance activities. The cause of turbidity was not due to organic matter (e.g., suspended algae), indicating that turbid conditions in Hinkson Creek were the result of suspended sediments.

Various organic chemicals were found in low levels within Hinkson Creek. Pesticide products, oils and greases, residue from plastics, and pharmaceuticals were found in low levels. Carbaryl, a common lawn and garden insecticide, was present in stormwater in sufficient quantities to cause toxicity in one sample (the storage practices have now been corrected). During the MDNR study, four discharges to Hinkson Creek around the Highway 63 connector, and one sample in Hinkson Creek, were found to be toxic. The Missouri Department of Transportation's (MODOT) salt storage facility, the source of the salt toxicity, was remediated and has now been moved to a different location. When compared to the reference/control streams, the Hinkson Creek chloride values on average were approximately 40% higher.

3.b Sediment Contaminants

In general, the percent sediment coverage tended to increase while progressing downstream, causing loss of habitat for macroinvertebrate and fish species. Sediment samples collected at the I-70 drainage and at the MODOT drainage were found to exhibit toxicity. Analysis of a sediment sample collected at the MODOT drainage showed the presence of Copper (Cu), Nickel (Ni), and Cobalt (Co) at high levels, but no clear correlation between observed toxicity and contaminants found could be made.

Chemical analyses of the I-70 sediments found #2 Diesel and a variety of Poly Aromatic Hydrocarbons (PAHs) in concentrations high enough to be toxic. The presence of these constituents may be attributed to the drainage's proximity to the I-70/Highway 63 or the gas station located higher in the drainage.

3.c Bacteriological Samples - Escherichia coli

"Whole body contact – category B" is a recently (2006) added beneficial use listed for Hinkson Creek. According to Federal standards, *E. coli* levels should not exceed a geometric mean of 206 colony forming units (cfu) per 100 milliliters (mL) of water during the recreational season (from April 1 to October 31). *E. coli* is associated with fecal contamination. Historical studies have indicated high levels of fecal bacteria present at various times. Elevated *E. coli* levels were found on four occasions at three different locations on Hinkson Creek during Phase III base flow sampling. High levels of bacteria found during MDNR's study were responsible for adding bacteria to the impairment of Hinkson Creek.

Elevated levels of *E. coli* in the lower stream segments of Hinkson Creek have not been directly attributed to any specific source. The increased levels of bacteria might be correlated with the increase in the resident Giant Canada Goose populations. Pet waste from dog walking trails next to Grindstone and Hinkson Creeks (in Grindstone and Capen Parks) can contribute to bacteria as well. Periodic sewer line breaks and/or bypasses have been seen along Hinkson Creek, and can contribute to elevated in-stream *E. coli* readings.

3.d Total Maximum Daily Load (TMDL)

At the time of this writing, a draft TMDL had been written for Hinkson Creek. In January 2011, the United States Environmental Protection Agency (USEPA) wrote and approved a TMDL for Hinkson Creek. The TMDL assigns stormwater runoff volume as a surrogate in place of a traditional pollutant of concern. It should be noted that the January 2011 TMDL was written and approved after the stakeholders had completed their work on this plan.

The TMDL is a very general document because of the lack of flow data on Hinkson Creek. The preamble to the TMDL describes it as a phased and adaptive plan to restore water quality conditions in the Hinkson Creek Watershed. The phased TMDL recognizes the limitations of the existing data. As new data becomes available it can be used to determine if the TMDL should be revised. Accordingly, this watershed plan has not targeted any particular contaminant or flow volume. As new information is made available, it should be integrated into this document and recommendations will be tailored accordingly.

Since Hinkson Creek is impaired because of unknown pollutants, and monitoring has indicated there are no numeric water quality standards violations, there are no quantifiable water quality targets from which to calculate the needed load reduction. This document will instead discuss the expected load reduction of some common urban contaminants from the reasonable implementation of the recommendations found elsewhere in this plan.
The pollutant(s) causing the impairment in Hinkson Creek are unknown. However, there are generally applicable water quality standards published in 10 CSR 20-7.031 (3). The specific

standards that apply to Hinkson Creek are:

(A) Waters shall be free from substances in sufficient amount to cause the formation of putrescent, unsightly or harmful bottom deposits or prevent full maintenance of beneficial uses;

(C) Waters shall be free from substances in sufficient amounts to cause unsightly color or turbidity, offensive odor or prevent full maintenance of beneficial uses;

(D) Waters shall be free from substances or conditions in sufficient amounts to result in toxicity to human, animal or aquatic life;

(G) Waters shall be free from physical, chemical or hydrologic changes that would impair the natural biological community.

Hinkson Creek exhibits water quality problems typically associated with streams in urban areas that include:

1. Larger and more frequent floods and lower base flow. This is caused by the amount of impervious surface in the watershed.
2. Increased soil erosion from construction sites and subsequent deposition of silt in the stream.
3. Contamination from urban stormwater flows.
4. Degradation of habitat for aquatic organisms due to the concerns listed above.
5. Degradation of aquatic habitat due to the physical alteration of stream channels and riparian areas such as: enclosing the stream in a large pipe, channelizing, paving the stream bed and or banks with concrete or rip rap, and removing trees and other permanent vegetation from riparian areas.

Bio-assessment studies have verified that the aquatic community in a portion of Hinkson Creek, downstream of Interstate–70 is impaired. Hinkson Creek was compared to Bonne Femme Creek and other reference stream sites. The comparisons confirmed the impairment of Hinkson Creek but did not determine the pollutants or pollutant sources.

3.e Load Reductions

Hinkson Creek watershed has been urbanizing since the 1830s though the conversion of open forest and prairie to fields, pastures, roads and now high density urban settlement. Human modification of the natural stream system has disrupted the biota through changed hydrology, chemical alteration and habitat damage. After more than 180 years of system changes, the stream bares little resemblance to the pre-settlement waterway.

Hinkson Creek has been on the 303(d) list of Impaired Waters since 1998, first for unspecified pollutants from urban nonpoint lagoon runoff, and then amended to Urban Runoff. In October 2009, the Department of Natural Resources drafted a TMDL that identified the source of the impairment as urban runoff, and calculated a reduction in stormwater runoff volume as a surrogate for any pollutants of concern.

By restoring a more natural flow regime, reducing the chemical pollutants, and re-establishing the geomorphology of the stream system, a new steady state may be achieved. Although the stream will never return to pre-settlement conditions, a healthy biological community is a goal the community can achieve.

Hydrology and Flow Regime

The stakeholders support the goal to restore the Hinkson Creek to a more natural hydrology and reduce the volume of stormwater reaching the creek. The major transport mechanisms used to remove volume are infiltration, evaporation, transpiration. However, little quantifiable data is available for stormwater managers, and engineers when evaluating site designs options. Monitoring and research is needed to understand these pathways in an urban Midwest setting.

Table 3.2 Median Stormwater Runoff Concentrations

	All Data	Residential	Commercial	Industrial	Freeways	Open Space
# of Storms Sampled	3,765	1,042	527	566	185	49
Median Event Mean Concentrations (mg/L or ppm, except where noted)						
TDS	80	72	72	86	77.5	125
TSS	59	49	43	81	99	48.5
BOD_5	8.6	9.0	11.0	9.0	8.0	5.4
COD	53	54.5	58	58.6	100	42.1
Fecal Coliform	5.091	7.000	4.600	2.400	1.700	7.200
$NO_2 + NO_3$	0.60	0.60	0.6	0.69	0.28	0.59
TKN	1.4	1.5	1.5	1.4	2.0	0.74
Total N	2.0	2.1	2.1	2.09	2.28	1.33
Dissolved P	0.13	0.18	0.11	0.10	0.20	0.13
Total P	0.27	0.31	0.22	0.25	0.25	0.31
Dissolved CU	8.0	7.0	7.57	8.0	10.9	--
Total CU	16	12	17	20.8	34.7	10
Dissolved Zn	52	31.5	59	112	51	--
Total Zn	116	73	150	199	200	40

The Green-Ampt Infiltration Model estimates an infiltration rate on clay soils between 0.01- 0.06 inches per hour, as compared to an infiltration rate of 0.86 inches per hour for a sandy loam. These models are not validated for the Midwest. Therefore, it is difficult for engineers to calculate the infiltration rates for BMPs such as bioretention or rain gardens, bioswales, and even pervious pavement.

Evapotranspiration (ET) is the evaporation from soils, plant surfaces and open water. ET rates determine the proportion of rainfall that will reach the stream. ET can be as much as 70% of the total precipitation in dry climates, but much less in humid areas. The amount of water that trees can transpire annually depends on a multitude of factors. These include soil water, tree species and canopy size, solar radiation, humidity, etc. ET is greatly affected by human activities that alter soil-plant ecosystems and the amount of vegetation in the watershed. The ET rates for the Midwest are largely unknown. By quantifying this data, managers and foresters will be able to calculate the benefits of trees, especially in an urban setting.

Chemical and Physical Pollutants

Although a specific pollutant was not identified as the cause of aquatic life impairment in Hinkson Creek, the general findings of the Phase I – III MDNR studies match the concerns of the stakeholders and the community. Therefore, future load reduction strategies will target the following urban runoff problems:

1. Specific Conductivity, specifically chloride from road salt
2. Sediment from construction and agricultural activities
3. Bacteria from livestock, lagoons and septic systems
4. Low dissolved oxygen from decomposition or chemical demands
5. High stream temperature from streets and parking lot runoff

Due to the lack of site-specific data and inability to identify a single pollutant of concern, both the state and community are unable to set a pollutant load reduction target. Therefore, the load reductions in Tables 3.3 - 3.6 are several common best management practices (BMPs) in their appropriate settings that have been recommended because they treat a wide variety of contaminants. In the calculations below, the "simple" method is used, and assumes the contributing drainage area for each specific BMP is 100% impervious in all scenarios except the stream buffer. Three representative contaminants (sediment, metals, and bacteria) are used to show the varying treatment efficiencies and load reductions of the BMPs. These reductions (except stream buffer scenario) were based on median values of contaminants taken from stormwater composition compiled by the Center for Watershed Protection (Table 3.2).

Bioretention areas treating ten acres of impervious parking lot would have 400 acres/inch or 33.33 acre/feet or 1,451,000 cubic feet of water draining from them each year in Columbia, which receives roughly 40 inches of rain per year. This equals 10,889,998 gallons or 41,164,192 L. So, at 49 mg/L, 2,017,045 grams, or 2017 kg of suspended sediment would be present in the stormwater runoff, and 60%, or 1210 kg, would be removed from the pollutant load to Hinkson Creek.

Table 3.3 Load Reduction of Suspended Sediment by Recommended BMPs

BMP	Median Load Reduction %	Treated area	Load Reduction of Suspended Sediment
Bioretention	60	10 ac (commercial)	2017 kg
Swale	80	1 ac (road)	326 kg
Stream Buffer	--	10 ac (residential)	453 kg
Dry Extended Detention Basins (rain garden)	50	1 ac (residential)	161 kg

Table 3.4 Load Reduction of Bacteria by Recommended BMPs

BMP	Median Load Reduction %	Treated area	Load Reduction of E. Coli (millions of bacteria)
Bioretention	40	10 ac (commercial)	757,421.132800
Swale	-25	1 ac (road)	8747.390375 (load increase)
Stream Buffer		10 ac (residential)	
Dry Extended Detention Basins (rain garden)	35	1 ac (residential)	100,852.265500

Table 3.5 Load Reduction of Zinc by Recommended BMPs

BMP	Median Load Reduction %	Treated area	Load Reduction of Zinc (grams)
Bioretention	80	10 ac (commercial)	4939 g
Swale	70	1 ac (road)	576 g
Stream Buffer		10 ac (residential)	
Dry Extended Detention Basins (rain garden)	30	1 ac (residential)	0.09 g

Table 3.6 Runoff Reduction by BMPs

BMP	Runoff Reduction (%)
Green Roof	*45 to 60*
Rooftop Disconnection	*25 to 50*
Rain tanks and Cisterns	*40*
Permeable Pavement	*45 to 75*
Grass Channel	*10 to 20*
Bioretention	*40 to 80*
Dry Swale	*40 to 60*
Wet Swale	*0*
Infiltration	*50 to 90*
Extended Detention Pond	*0 to 15*
Soil Amendments	*50 to 75*
Sheet flow to Open Space	*50 to 75*
Filtering Practice	*0*
Constructed Wetland	*0*
Wet Pond	*0*

Tables 3.3, 3.4, and 3.5 are useful for estimating pollutant reductions that would occur by installing certain BMPs. Table 3.6 is generated from the Center for Watershed Protection's Runoff Reduction Method Technical Memo. The percent reductions listed here are conservative estimates based on the total annual runoff volume reduced. See Appendix B for specifically identified BMPs and corresponding load reductions.

Habitat Restoration

Watershed geomorphology is the arrangement and interactions of landforms throughout the stream-channel network. Tributary streams converge with larger streams, taking water and pollutants downstream, sometimes miles from the source. The sinuosity and slope of the network is partially influenced by the underlying bedrock and bed material. The distribution and connection of the floodplain and the riparian corridor to the stream network provides energy dissipation and aquatic refuge during high flow events.

Modifications to channel morphology are evident throughout the Hinkson Creek watershed. Previous channelization and deforestation has caused the channel to deepen and widen. Once the stream banks are incised, high flow events that would have generated minor overflow in the floodplain are now unable to escape the channel. The increased volume and velocities creates additional stream bed and bank scour, exacerbating the problem in a perpetual cycle.

The morphology, chemical constituents and hydrology of Hinkson Creek are intricately connected. Therefore, to adequately improve the water quality and aquatic community health of Hinkson Creek, each of these processes must be considered.

Chapter 4. Information and Education Activities

The Hinkson Creek Watershed and the community that surrounds it are far from static entities. A variety of activities are taking place that benefit water quality or benefit our knowledge of water quality. The County of Boone, City of Columbia, and University of Missouri (MU) have a joint Municipal Separate Storm Sewer System (MS4) permit from the Missouri Department of Natural Resources (MDNR). Each of the three entities is considered to be a regulated small MS4, and must therefore develop and implement a Stormwater Management Program (SWMP) in compliance with the National Pollutant Discharge Elimination System Phase II (NPDES) requirements for small MS4s.

The joint permittees have been implementing their programs since 2001, and have been conducting public education and outreach and public involvement activities since 1999. The City of Columbia has passed three ordinances: a stream buffer ordinance (2007), stormwater management ordinance (2007), and the illicit discharge ordinance (2006) which should improve water quality in the future. Boone County has passed two ordinances: a stream buffer ordinance (2009) and a stormwater ordinance (2010). A survey of public attitudes toward Hinkson Creek was conducted by a graduate student at MU. Two grant projects have targeted the Hinkson Creek Watershed in their cost-share and education projects: the Hinkson Creek Watershed Restoration Phase II Project 319 grant and the Upper Hinkson SALT grant.

4.a Public Input Surveys

Baumer, Michele, "Attitudes, Awareness and Actions of the Residents of the Hinkson Creek Watershed Regarding Water Quality and Environmentalism," A Thesis presented to the Faculty of the University of Missouri, Columbia, 2007

In 2006, an attitude and awareness study sponsored by MU and the Missouri Department of Conservation (MDC) surveyed randomly selected landowners and homeowners in the Hinkson Creek Watershed to explore opinions on issues within the watershed. The assessment began by conducting eight focus groups. A 12 page mail survey (see appendix) was then designed based on information gained from those focus groups and was randomly sent to 10,000 residents (4,653 surveys were returned).

Survey Knowledge of Issues

Of the surveyed respondents, only 17.8% had heard of the term "nonpoint source pollution" and knew what it meant, while 66% had heard the term "watershed" and said they knew what it meant. While 2.3% of people didn't think the stream was polluted, 69% thought it was somewhat or very polluted, and 29% did not know if Hinkson Creek was polluted. More people thought water quality had worsened, rather than improved in the last decade. Respondents got most of their information about Hinkson Creek from the newspaper, followed by television. A quarter of the residents in the Hinkson Creek Watershed believed that runoff of insecticides or pesticides from lawn care contributed most to water pollution. Roughly that same amount didn't know what contributes to pollution of the creek. When asked about the major contributors of pollution in Hinkson Creek, the responses were often contradictory.

Residents generally agreed with the statement that "small changes in people's daily habits and activities will have an effect on improving water quality". Respondents felt that public or homeowner education was the most important strategy to improving water quality in Hinkson Creek.

According to the survey, the respondents tended to have strong ecological views. Demographically, they were much older, predominantly male, had higher income, and were better educated than the average resident of Boone County.

4.b City-County-University MS4 Permit Activities

Content primarily taken from the Columbia, Boone County and University of Missouri Columbia joint MS4 Program, Permit MO-R040045

The City of Columbia, Boone County, and MU developed a joint stormwater management program, Show-me Stormwater Management, to effectively minimize stormwater pollutant runoff and meet NPDES Phase II requirements. MU has been designated the coordinating authority to give MDNR a single point of contact for issues arising out of this joint permit application. While each permitted entity can rely on partnering to achieve regulatory compliance in the most cost efficient manner, each entity is ultimately responsible individually for regulatory compliance. The co-permittees will maintain these programs as outlined in the Stormwater Management Plan, and as appropriate, will develop and add new programs for the six minimum control measures (MCMs).

Public Education and Outreach (MCM 1)

A series of one-year contracts with MU, Columbia and Boone County originally provided a public education and outreach program to its citizens, business and property owners. While the funding mechanism has evolved, the focus of the education efforts continues to be to educate the public on issues involving stormwater discharges and their relative impacts on stormwater quality, as well as informing the public of measures they can take to reduce pollutants in stormwater runoff. The three entities have cooperated in developing stormwater public education and outreach programs. A Stormwater Coordination Committee meets on a monthly basis to discuss educational issues. The Directors of Public Works for Columbia and Boone County, and the Director of Environmental Health and Safety for MU are responsible for the management and implementation of the joint stormwater public education and outreach program.

The primary or target pollutant sources having a major impact on stormwater quality have been identified through a literature search, personal experiences, and EPA guidance documents:

- Stream bank erosion
- Connected impervious areas
- Improper disposal of waste oil
- Vehicle maintenance areas
- Application of lawn chemicals
- Gas stations
- Illicit dumping into storm drains
- Improper disposal of lawn wastes
- Snow removal and ice control
- Pet waste
- Failing septic systems
- Foundation drains connected to storm drains
- Infiltration from cracked sanitary sewers
- Sewer service connected to storm drain system
- Downspouts connected to storm drainage system
- Improper disposal of paint, hazardous chemicals
- Trash, debris and illegal dumping
- Spills from roadway accidents or fires
- Detergents washed into drains
- Sanitary sewer overflows

Public Involvement and Participation (MCM 2)

This MCM has the goal of transforming public education into action and involving the public in the development of stormwater management policies. The Columbia City Council and the Boone County Commission formed a Joint Stormwater Task Force, composed of citizen volunteers, whose mission was "To advise the City of Columbia and the County of Boone as to components and content of regulations, practices and policies in order to improve stormwater quality, reduce damage to streams, minimize damage to public and private property due to increased stormwater flows and protect the quality of life for citizens of the City of Columbia and Boone County." This group functioned during the first permit cycle, from 2002 to 2008. The Directors of Public Works for Columbia and Boone County, and the Director of Environmental Health and Safety for MU are responsible for the management and implementation of the joint stormwater public information and participation program. Activities such as storm drain stenciling help to connect the public with urban stream issues. The target audiences are: citizens, students, business leaders, trade associations, watershed partnership groups, local government officials, environmental groups, and media.

Illicit Discharge Detection and Elimination (MCM 3)

Columbia, Boone County and MU are required to implement a program to detect and eliminate illicit discharges (as defined in state regulation) into each entity's regulated MS4. Columbia has already enacted an illicit discharge ordinance. Boone County passed its stormwater ordinance in 2010, which addresses illicit discharge detection and elimination. The county is currently implementing their plan to regulate pollutants discharged to the MS4 by any user; to prohibit illicit connections and discharges to the MS4; and to establish the legal authority to carry out all inspections, surveillance, testing and monitoring necessary to insure compliance with this ordinance. MU exercises enforcement through campus policy and administrative actions. Methods used for detection may include on-site visual inspections, smoke and dye testing, closed circuit television inspections as well as public watch and reporting programs with established hotlines.

Construction Site Stormwater Runoff Control (MCM 4)

All disturbed sites greater than one acre must get a land disturbance permit from MDNR. All construction sites greater than 3,000 square feet are required to obtain a land disturbance permit and submit land disturbance plans to the city. Boone County requires that a land disturbance permit be acquired from the county and state if disturbing one or more acres of land, or 3,000 square feet or more in an environmentally sensitive area. Land disturbance plans and the stormwater pollution prevention plan (SWPPP) must be submitted for review and approval as well. All construction sites on University property are under the control of MU, regardless of size. At MU, project managers have the authority to withhold pay or issue stop work orders if performance is inadequate. Project managers are required to monitor construction sites on at least a weekly basis and after each significant rain event.

Wastes required to be controlled include discarded building materials, concrete truck washouts, chemicals, litter, and sanitary waste. Mechanisms for enforcement include stop work orders and prosecution through Municipal Court.

Post-construction Stormwater Management in New Development and Redevelopment (MCM 5)

The Columbia City Council and the Boone County Commission appointed a Stormwater Task Force to provide community input into the development of the City and County stormwater programs. The City Council approved a stream buffer ordinance and stormwater ordinance in 2007, to address stormwater runoff from new development and redevelopment projects. The county passed a stream buffer ordinance in 2009 and a comprehensive stormwater ordinance in 2010.

An example of a best management practice (BMP) already adopted is the revision of the city parking ordinance in 2002, which reduced parking requirements thus reducing impervious surfaces. Two wet cell extended detention basins with forebays have been constructed in the city and are in operation at this time. At MU, a detention basin has been constructed for the University Landfill and two detention basins were installed at Ellis Fischel Cancer Center.

Pollution Prevention/Good Housekeeping for Municipal Operations (MCM 6)

The three entities have developed an operation and maintenance program which will include training components with the ultimate goal of preventing and/or reducing pollutant runoff from municipal operations. Training will be primarily in the areas of hazardous material handling, pesticide application, vehicle maintenance and street maintenance including snow removal operations.

Boone County operates one industrial facility which is subject to an individual National Pollutant Discharge Elimination System (NPDES) permit for discharges of stormwater. The campus has the power plant and deep wells subject to EPA's multi-sector general permit, and also has a general permit for fuel spills. Columbia operates industrial facilities, (airport, landfill, power plant) which are subject to individual NPDES permits.

4.c Educational Activities Through a 4-Year Hinkson Creek Subgrant Project

Content primarily taken from the Show-Me Clean Streams' Hinkson Creek Watershed Restoration Project 319 grant application, more details in Appendix B.

Show-Me Clean Streams, a 501(c)(3) non-profit, began a watershed-wide nonpoint source pollution prevention project for the Hinkson Creek Watershed in 2004-2008. The project addressed multiple problems including development-related erosion and sedimentation, the effect of impervious surface on water quality, degradation of stream banks and riparian areas, and the role of watershed residents in creating and maintaining healthy watersheds. The project focused on public education, as well as watershed restoration activities. Education activities included a low-chemical yard maintenance program, rain garden workshops, field days for BMPs in the watershed, conservation development workshops, and media workshops. Restoration activities include bank stabilization, riparian tree planting, rain garden construction, and Low Impact Development (LID) structure cost-share. The project has extensive inter-agency coordination between state, local and non-governmental organizations. Project partners included: Natural Resources Conservation Service, City of Columbia, Boone County Soil and Water Conservation District, Boone County, Missouri Department of Conservation, and Sierra Club.

Some of the milestones received tremendous response, while others were difficult to implement. The effect of these programs on water quality is difficult to ascertain in a watershed that has 90,000+ inhabitants and so many other activities taking place at any given time.

The effect of the climate and other regional occurrences on water quality makes it very difficult to single out the impact of the grant project on overall water quality. A more practical measure of program success is participation. The overall response to rain gardens was tremendous. Rain garden workshops were held several times per year, sometimes with as many as 50 attendees. Over 50 homeowner rain garden consultations were conducted, and the milestone of 20 installed rain gardens was achieved at the halfway mark of the grant.

The Show Me Yards & Neighborhoods (SMY&N) program was similarly well-received, and had over 100 attendees for semi-annual workshops. Surveys mailed to 250 SMY&N workshop attendees revealed that 91% of respondents have changed their behavior as a result of the program. Stream clean-ups morphed into annual Hinkson Clean Sweep events that drew over 100 volunteers. The Conservation Development workshops drew an average of 90 attendees. The annual newsletter was an effective means of transmitting water quality information (based on anecdotal responses), while the media workshops were effective only if there is a story to report.

Unfortunately, the bank stabilization cost-share program was difficult to implement. “Conservation Development” cost-share projects were modified to “Low Impact Development” cost-share projects because there was not enough incentive to change the development plans of an entire project, but there was enough (monetary) incentive to install stormwater treatment structures that would improve water quality. The riparian restoration program has been successful, though the initial milestone was reduced from 20 acres to 15 acres (a trade for increased rain gardens) mainly because it was difficult to find that much open land in the watershed.

The second phase of the Hinkson Creek grant project began in the fall of 2008. The emphasis of this grant is on the implementation of components of the watershed management plan to improve water quality. Retrofitting stormwater BMPs in the area of interest around I-70 and Highway 63 is the focus of the grant activities. Educational activities such as LID workshops, debates, and the production of public service announcements are also milestones of the grant, which will end in the spring of 2011.

4.d Overview of Upper Hinkson SALT Grant

Content primarily taken from the Upper Hinkson Creek AgNPS SALT program, more details in Appendix B

The Special Area Land Treatment (SALT) grant started in 2001 and lasted until 2008. The area targeted by this grant is the upper Hinkson Creek Watershed, which encompasses the headwaters of Hinkson Creek down to the outlet point at the Old Highway 63 bridge.

In order to improve and protect water quality in the watershed, the SALT project provided technical assistance, cost-share, and incentives to install BMPs. Treatment for row cropland includes residue management, crop rotation, no-till, pest and nutrient management, filter strips, conversion to grass or trees, and installation of terraces and waterways. Treatment for grazing land includes rotational grazing pasture enhancement, managed intensive grazing, livestock exclusion from woodlands and riparian areas, nutrient management, prescribed burning, and providing alternative water sources for livestock. The landowners using small acreages for grazing were encouraged to use proper stocking rates, maintain adequate grass cover, and use good management practices to ensure animal waste will not become a problem. The treatment of riparian areas included buffers and filter strips along corridors, livestock exclusion, and stream bank stabilization.

Chapter 5. Recommendations

5.a Summary of Hinkson Creek Impairment

From the flow and water quality studies performed in Hinkson Creek, we have concluded that the stream is impaired because of: 1) elevated pathogen counts and 2) high flows during storm events. In addition, the stream may be further impaired by pollutants associated with urban land use. Pathogens make it unwise to wade in and float on the stream; high flow causes scouring and stream bank degradation, which themselves contribute to stream instability. Urban runoff brings many toxic pollutants in the stream, which impair aquatic life.

The source of impairment emanates from the urban setting**.** Data collected by Missouri Department of Natural Resources (MDNR) indicate that the impairment begins where the urbanized portions of the watershed begin. Macroinvertebrate samples from above I-70 indicate Hinkson Creek supports an adequate diversity of stream fauna. The possibility exists that contaminants from the upper watershed are acting synergistically with inputs from the urban watershed to produce the impairment. Focusing on the urban setting will still ameliorate this situation, and some of the recommendations that follow are also appropriate in an agricultural setting.

A) *E. coli* is associated with fecal contamination. "Whole body contact – category B" is a recently (2006) added beneficial use listed for Hinkson Creek. According to Federal standards, *E. coli* levels should not exceed a geometric mean of 206 colony forming units (cfu) per 100 milliliters (mL) of water during the recreational season (from April 1 to October 31). Historical studies have indicated high levels of fecal bacteria present at various times. Elevated *E. coli* levels were found on two occasions (one of which was outside of the recreational season) at three different locations on Hinkson Creek during Phase III base flow sampling.

Elevated levels of *E. coli* in the lower stream segments of Hinkson Creek have not been directly attributed to any specific source. From the mouth of Hinkson Creek to Highway 163, 7.6 miles of water is listed as category B and Secondary Contact; 18.8 miles of the creek from Highway 163 to 36-50N-12W is listed as category B. However, raw wastewater bypasses from municipal sewer system manholes have reportedly entered Hinkson Creek. The increased levels of bacteria might also be correlated with an increase in the resident Giant Canada goose population or pet waste from dog walking trails next to Grindstone and Hinkson Creeks (in Grindstone and Capen Parks).

B) Altered, or "urbanized", stream flow is a significant contributor to the impairment of the Hinkson. Literature suggests that the amount of impervious surface within an urban watershed affects stream quality due to the alteration of urban hydrology. Reduced base flow, greater deposition of fines within the substrate, scouring of habitat, and increased turbidity are all manifestations of urban hydrology. Literature also suggests that the source of turbidity/sediment in urban streams is often from the erosion of stream banks due to sustained and/or more frequent high flows. Furthermore, many contaminants attach to soil particles and contribute to stream toxicity in this manner. It is our understanding that MDNR will in fact target the urban flows in its Total Maximum Daily Load (TMDL) document.

C) Pollution enters Hinkson Creek primarily through stormwater. There are some hazardous waste sites and other properties that can potentially contaminate groundwater, and there are numerous dump sites and litter within the creek. However, MDNR data collected from outfall pipes found many instances of toxicity, and information from EPA and many other sources overwhelmingly point to stormwater as a major culprit in urban stream pollution.

5.b Vision Summary

Over the course of several meetings the stakeholders developed a vision for the watershed. This is a statement of intent that is intended to provide guidance to policy makers in decisions affecting the watershed. The elements of the vision statement, discussed in the Introduction, Section I.b, also form the foundation for the recommendations in this section. The stakeholder vision for the watershed is:

Physical Characteristics and Basic Ecology of the Watershed

- Clean water
- Stable hydrology
- Healthy biological community

Social/Cultural Element

- View of the stream as a cultural and ecologic asset
- Watershed education addressing all age groups and professions
- Develop a sense of stewardship towards the watershed

Economics

- Thriving community
- Sustainable development and sustainable economic activity

5.c Recommendations: a Three Dimensioned Approach

The recommendations are proposed in three separate categories: practices that restore water quality, practices that protect water quality, and information needs and public education. Restoration practices address contaminants that emanate from existing impervious surfaces and inadequate sewage treatment. Protective practices look forward in time to address water quality issues as new development occurs. Information needs and public education addresses scientific informational needs/monitoring and education to the general public regarding watershed issues. The stakeholders felt it was necessary to differentiate between protection and restoration practices due to the different methods of implementation.

Restoration requires land owners or managers to alter their developed property in a manner that reduces impacts to water quality. Since development regulations cannot be applied retroactively, there is no regulatory mechanism to ensure that restoration occurs. The burden then, is on local government to install the retrofits or to create programs that provide incentives for landowners to make stormwater related improvement to their property.

Most of the Hinkson Watershed within the city limits of Columbia, which includes the impaired section of the creek, is already developed. It is expected that, over time, development of the watershed will continue. The existing green spaces are likely to be reduced in size. This reduces the opportunities to remediate water quality problems in areas that are not intensively used (e.g., fields, waste areas). The alternatives are to 1) retrofit the existing developed areas to treat stormwater where opportunities present themselves or 2) improve conditions in the upper watershed, thereby increasing the water quality to a point that the subsequent contamination from the urban areas may not reduce the quality below standards. While improving conditions in the upper watershed may work for some contaminants (such as reducing salt input, for instance), this is not likely to be an effective strategy for temperature, sediment, or other pollutants. Retrofitting areas therefore makes logical sense in that it is correcting problems where they occur, and the retrofits can be tailored to the pollutants of concern at a specific area.

In order for restoration practices to be most effective it is necessary to identify areas of the watershed that contribute more pollutants than others. Several of those areas have been identified below. However, it should be noted that it is the stakeholder's intent that these areas should be kinetic rather than fixed. As the watershed changes, the location of the key areas should change as needed.

Implementation of protective practices will be primarily driven by development regulations and administrative practices. As development or redevelopment occurs, the regulations adopted by Columbia and Boone County and the University's administrative practices will guide construction in a manner that will help to maintain and enhance water quality.

Data regarding the water quality problems associated with Hinkson Creek is far from exhaustive. Studies are currently being conducted but there is a need for additional work in this area. The resulting information can be used to further refine this plan and help to identify solutions. This plan strongly encourages continued scientific inquiry of Hinkson Creek.

The Stakeholder vision states a desire to shape community opinion of Hinkson Creek as a social and cultural asset. Accordingly, a strong public education program is recommended. The program should highlight the creek as an asset and encourage its use as an outdoor classroom. Raising awareness of the issues surrounding Hinkson Creek will help to facilitate public discussion about the creek's management.

5.d Restoration

Key Areas

Restoration efforts should focus on those stream segments that have historically been classified as not fully supporting of aquatic life because the goal of this plan is to enable Hinkson Creek to meet and maintain water quality standards. Sampling events from MDNR over the last several years indicate that the areas just downstream from I-70 have diminished water quality. Areas upstream of I-70 have water quality that is up to standards. Areas downstream of Twin Lakes meet the standards as well.

Though the water quality of the impaired section varies, and certainly there are a variety of potential areas for improvement, a few areas stand out as hotspots that could significantly affect the quality of water downstream. It is recognized that the location of hotspots may change as the watershed continues to develop and due to installation of new stormwater BMPs. Therefore, it should also be recognized that the hotspots identified in this plan are temporal and the location of hotspots should be reassessed over time.

a. **Impervious Areas near the I-70 U.S. Highway 63 Interchange**
This large commercial area is an obvious hotspot for stream impact. Sampling has shown several of the outfalls from this area to be acutely toxic (due to chloride), and it is in this area that impairment begins.

This area should be targeted for retrofitting, with the goal of detaining and treating stormwater runoff. Since most of the surface is paved, the existing tree islands and green space should be modified to treat stormwater. Increased street sweeping and inlet filters may be appropriate since they take little space. Cisterns/water tanks could be situated to receive and detain roof runoff (which accounts for approximately 16 acres) that could be released gradually into the existing stormwater system.

A significant portion of this area now flows to Hinkson Creek through two large extended detention wetlands that were required by the City of Columbia's stormwater regulations. The impact that these basins have on water quality has not been quantified.

b. **I-70 Tributary**
The headwater stream that is just south of I-70 on the east side of the stream is a hotspot for contaminants that flow into Hinkson Creek. Dissolved solids, metals, salt, and other contaminants have been detected in various sampling events conducted by MDNR. The drainage area for this tributary includes the former Missouri Department of Transportation (MODOT) storage facility, a gas station, some hotels, and roads. MODOT has moved its facility, which eliminates a source of salt contamination.

Sewer lines/manholes have overflowed here as well. Inlet filters could be retrofitted on some of the commercial property. MODOT ditches could be reconfigured to detain runoff from roads, supporting small wetland cells that could treat the water. There are already wetland plants growing in small depressions in this area, and fish have been observed in pools within the tributary.

A MODOT mitigation plan has been carried out on the north side of I-70. Maintenance of the mitigation area has been neglected. MODOT should be encouraged to sustain maintenance of this area. Planting additional trees around this tributary would stabilize its banks and provide better habitat.

Retrofitting Developed Areas

Retrofitting requires transforming existing landscapes into more environmentally beneficial situations. All retrofits accomplished must be done with the landowner's cooperation. A significant effort toward public education on water quality in general, and some form of incentive program will be necessary to convince landowners to make changes to their property. Water quality education is valuable in changing behavior and can be thought of as retrofitting the existing mind set within the watershed. Changing people's minds on issues such as littering, dumping chemicals into storm drains, or lawn chemical use, can be a significant factor in restoring water quality, without necessitating structural changes.

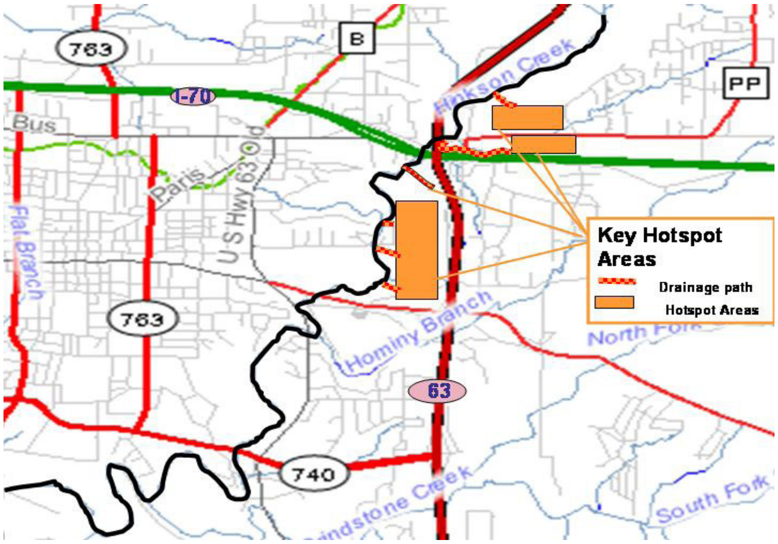

Figure 5.1 Hotspot Locations within the Hinkson Creek Watershed

Many engineers and developers are unwilling to experiment with retrofit techniques designed to increase infiltration, when those techniques have not been tested on Midwest soils. Therefore most engineers design detention basins to address most stormwater problems. While detention basins can reduce peak flows, they are expensive, often have a large footprint, and do not reduce pollutants in the runoff. Demonstration projects that provide costs estimates, water quality reduction and infiltration data are needed throughout the community. This will enable engineers and developers to explore other stormwater treatment options.

Retrofits are structural stormwater management measures designed to help minimize accelerated channel erosion, reduce pollutant loads, promote conditions for improved aquatic habitat, and correct past mistakes. Simply put, these BMPs are inserted in an urban landscape where little or no prior stormwater controls existed. Stormwater retrofits should be applied along with other available watershed restoration strategies for reducing pollutants, restoring habitat and stabilizing stream morphology as part of a holistic watershed restoration program. The best retrofit sites fit easily into the existing landscape, are located at or near major drainage or stormwater control facilities, and are easily accessible. Table 5.1 describes six of the most common retrofit practices.

Table 5.1 The Six Most Common Storage Retrofit Locations in a Subwatershed (From Center for Watershed Protection, 2007)	
Add Storage to Existing Ponds	Add water quality treatment storage to an existing pond that lacks it by excavating new storage on the pond bottom, raising the height of the embankment, modifying riser elevations/dimensions, converting unneeded quantity control storage into water quality treatment storage and/or installing internal design features to improve performance.
Storage Above Roadway Culverts	Provide water quality storage immediately upstream of an existing road culvert that crosses a low gradient, non-perennial stream without wetlands. Free storage is created by adding wetland and/or extended detention treatment behind a new embankment just upstream of the existing roadway embankment.
New Storage Below Outfalls	Flows are split from an existing storm drain or ditch and are diverted to a stormwater treatment area on public land in the stream corridor. Works best for storm drain outfalls in the 12- to 36- inch diameter range that are located near large open spaces, such as parks, golf courses and floodplains.
Storage in Conveyance System	Investigate the upper portions of the existing stormwater conveyance system to look for opportunities to improve the performance of existing swales, ditches and non-perennial streams. This can be done either by creating in-line storage cells that filter runoff through swales and wetlands or by splitting flows to off-line treatment areas in the stream corridor.
Storage in Road Right-of-Ways	Direct runoff to a depression or excavated stormwater treatment area within the right of way of a road, highway, transport or power line corridor. Prominent examples include highway cloverleaf, median and wide right-of-way areas.
Storage Near Large Parking Lots	Provide stormwater treatment in open spaces near the downgradient outfall of large parking lots (5 acres plus).

The following examples of retrofit structures may contribute to increased water quality and stormwater detention. These are only a few examples of structures that may help slow stream bank erosion and flooding problems. This is not an exhaustive list.

Modification of Existing Impoundments

Retrofitting existing impoundments and lakes to detain more water by restricting or raising the outlet in conjunction with allowing a small amount of water to flow for longer periods will help to mitigate the flashiness of certain streams. Consideration will have to be made to ensure they do not extend the time that receiving streams receive bankfull flows, which would increase stream bank erosion.

There are no current dams on Hinkson Creek to modify, but all of the tributaries have ponds within their watersheds. Both Hominy Creek and County House Branch have several large (greater than two acres) ponds that could potentially detain a significant amount of water that could be released over several days. For example, the outfall structures on the 30 acre Hulen Lakes system could be modified to store just six inches more water by installing a notched weir in front of the outfall. If this was done, 653,400 cubic feet of water could be detained. If the “notch” on the weir allowed one cubic feet per second (cfs) to flow through the outfall structure, it would take 7.5 days to discharge. Similarly, if the 49 acres of stored waters in impoundments near the beginning of the impaired area (Stephens Lake and Hominy confluence) were retrofitted to store six inches more water, approximately one million cubic feet of water could be detained.

Many of the existing lakes in Columbia are old and the earthen dams haven’t been inspected recently. A strategy for retrofitting greater capacity in these lakes would be to pay for an inspection of the lake/dam structure for those willing to modify their outfalls.

Figures 5.2 and 5.3 Pond Retrofit - Before and After

Existing ponds can also be reconfigured to incorporate wetland fore bays or other areas that may act as biological filters for the stormwater entering these systems. “Wing dikes” or small peninsulas that stick out into ponds can direct inflow into ponds so that water residence time is increased, and contact with wetland vegetation is maximized. A good example of this is the retrofitting of the pond at The Crossing, a church off Grindstone Parkway (a cost-share project of Hinkson Creek Watershed Restoration Project Phase I). A serpentine pathway for parking lot runoff was created by placing large stone and backfilling with soil. Emergent wetland plants were placed in this area, with the intent that they would filter contaminants as water flowed past.

The cost of modifying existing ponds can cost from $ 3,600 to $37,000 per acre of treated impervious surface, with a median cost of $11,150 (2006 figures from the east coast). Factors decreasing costs include neutral earthwork balance, only simple adjustment to low flow pipe in riser, the existing pond is dry, no utility conflicts, and wide setback from pond to structures. Factors increasing costs include the need to move soil, dewatering needed to excavate bottom, embankment reinforcement needed, or new access ramps must be installed.

Grade Control Structures within Small Channels and Ditches

Since increased high flow intensity is significantly responsible for channel erosion, it makes sense to detain water and release it at every practicable opportunity, especially in a developed watershed like Hinkson’s. By installing notched weir structures in first order streams that are ephemeral in nature (and therefore have no fish populations to present fish passage issues), water can be stored behind small structures and released slowly downstream, in a “dry detention” type of configuration. Appropriate rock will have to be placed with these structures to avoid streambed scouring. This configuration may also have the effect of arresting any head cuts that might be occurring upstream.

The Center for Watershed Protection recommends retrofitting intermittent swales and ditches that have a gradient ranging between 0.5% and 2.0%, have a drainage area of 15 to 30 acres, have been altered to promote efficient drainage, and have less than three feet of elevation difference between the top of bank and the channel bottom. Many roadside ditches may lend themselves to modification.

Figure 5.4 Flow Splitter

Retrofits do not necessarily have to occur "inline", as described above. Flow-splitting structures can be installed that can divert the first flush of water into treatment wetlands or other stormwater treatment structures. As EPA mentions in *National Management Measures to Control Nonpoint Source Pollution from Urban Areas,* regular maintenance may be needed to remove trapped sediments behind these structures.

The cost of retrofitting small channels with grade control structures ranges from $9,000 to $32,000 per acre of treated impervious surface, with a median cost of $19,400 (2006 figures from the east coast). Factors that decrease construction cost include: treatment area contains no trees or wetlands, staging areas available adjacent to floodplain, no access roads are needed to get to site, usable compactible fill available close by, and existing roadway embankment doesn't need to be modified. Factors increasing costs include replacing culverts, sewer or utility relocation, and the need for materials to be hauled off-site.

Parking Lot Treatment Opportunities

Figure 5.5 Dry Pond Treatment Area

As mentioned in the "Key Areas" section, some of the parking areas within this watershed have the capability of causing serious runoff related problems. Large parking lots (5+ acres) are a good retrofit opportunity to treat runoff quality. Examples in the upper portion of the impaired section include lots serving the Home Depot Complex, the Lowe's complex, Center State Mall, Regional Hospital area. Examples in the lower portion of the impaired section include MU Campus, Boone Hospital, Nifong/Grindstone area, grocery store lots and high schools.

Larger parking lots are normally served by extensive storm drain systems and contain numerous inlets, underground pipes and outfalls. Common stormwater treatment options include extended detention, ponds, constructed wetlands or large bioretention areas that can be situated in landscaped areas used as setbacks for screening or parking islands. Increased parking lot sweeping, inlet filters, and litter screens/collection are methods for improving the water quality of runoff, but do not take up additional space. Runoff reduction techniques could be considered during redevelopment projects by replacing parking lot areas with trees or other deep rooted vegetation or with pervious pavement.

Another option for space-efficient treatment is organic media filters. Organic media filters have been used to improve water quality on parking lots through a combination of sedimentation, filtration, and adsorption processes (Stewart, 1992). An example used in Oregon uses trenches that are backfilled with leaf compost. These compost filters take up 1,200 square feet to treat runoff from 70 acres of mixed use land. Pollutant removal rates average 81% for oils and grease, 84% for petroleum hydrocarbons, 58 to 94% for solids and nutrients, and 68 to 93% for metals. The cost of surface facilities using organic media filters is comparable to the cost of filtration facilities that use sand medium. A price of $3,400 to $16,000 per impervious acre served can be used to estimate the construction cost of a proposed facility, excluding real estate, design, and contingency costs.

The cost of parking lot treatment with bioretention or other BMPs range from $9,000 to $32,000 per acre of treated impervious surface with a median cost of $19,400 (2006 figures from the east coast). Factors that decrease construction cost include: public land or cooperative landowner, storage via embankment rather than excavation, existing storm drains discharge near surface, or extended wetland detention is used. Factors increasing costs include off-site hauling of soil, pavement repair due to construction equipment, reworking the storm drain system under the parking lot, or land acquisition.

Conversion of Land Cover to Trees and Native Plants

According to the Center for Watershed Protection's Urban Watershed Forestry Manual, "Forest cover is the highest and best use of land in a watershed, and is superior to turf grass as a vegetative cover in terms of water storage, groundwater recharge, runoff reduction, pollutant reduction, and habitat." Other deep rooted plants such as native prairie grasses and forbs are also effective in runoff reduction and promotion of stormwater infiltration.

Figure 5.6 Reforestation Retrofit

In order to reduce runoff and filter pollutants, feasible planting sites on public land, road rights-of-way, and utility easements should be converted to forest or deep rooted plants. Plantings on private lands should also be pursued, and incentives could be provided, similar to Columbia Water and Light's existing shade-tree program. Reducing forest clearing during construction, either by ordinance or incentive, is another avenue for increasing tree cover in the watershed.

The cost of conversion of an area to native vegetation varies greatly with the type of plant material used, availability of volunteers, weather, and the degree of maintenance/aesthetics needed. The cost of installing trees funded by the Hinkson Creek Watershed Restoration Project Phase I varied from $400-$700/acre, and does not factor in the maintenance/watering needed.

Runoff Reduction

Figure 5.7 Conveyance Retrofit

The MS4 is encouraged to investigate the feasibility of reducing runoff by using techniques such as streamside infiltration trenches. Such techniques could also help to maintain base flow in streams. The trenches would be located on each side of a stream, filled with sand and gravel (or other appropriate filtering media), parallel to the stream. Stormwater could be channeled in a manner that it will be well distributed in the trench system. The size of the trenches should be large enough (depth, width, and length) to hold the first one-half inch of rainfall that drains to the stream. In areas where there is not enough linear creek side to meet the volume needs, a detention basin with a very porous bottom and appropriate drainage bed might suffice although maintenance of base flow in the stream probably would be difficult to achieve.

The cost to install a streamside infiltration trench is approximately $200 per linear foot. Additional costs will include engineering 20% of installation cost, right of way acquisition 25% of installation cost and 15% contingency. Therefore a 1,000 foot trench would cost approximately $333,500.

5.e Feasibility Analysis for Retrofitting Stormwater Treatment Structures or Best Management Practices

In November 2009, the Hinkson Creek Watershed Restoration Project Phase II funded a retrofit feasibility study that was completed by a local engineering firm, A Civil Group. The study was undertaken in an effort to determine the feasibility of retrofitting properties, within the "hot spot" area with stormwater treatment and detention structures or practices. BMP and site selection criteria outlined within the proposal include site identification and ownership, installation cost, 15 year maintenance cost, the amount of impervious area treated and the level of treatment provided. The Feasibility Study is incorporated into this document as Appendix B. The recommendations within the study stand by themselves as proposed BMPs. The study also includes methodology that can be used within or outside of the watershed for purposes of retrofit BMP site selection.

5.f Protection

Protective measures are primarily in the form of local government regulations. Both Columbia and Boone County have adopted comprehensive stormwater management regulations. Those regulations address land disturbance, post development stormwater management and illicit discharge of pollutants into waterways within their jurisdiction. The University of Missouri also has enacted a comprehensive stormwater program. Unlike the City and County, MU does not have the authority or need to adopt ordinances. Instead, the University relies on administrative policy to enact stormwater controls.

MU intends to develop a Stormwater Management Plan. The plan will consist of two major components. The first is a master plan for stormwater management detailing BMPs that can serve large portions of the MU campus. The second component will be new design standards that will be incorporated into the University's "Green Book" which specifies design standards to be used on new construction on campus

New developments and redevelopments within Columbia or Boone County will have to set aside land which borders streams having at least a 50 ac watershed. A city stormwater ordinance that affects the runoff rates and treatment of stormwater was also passed in March 2007, which took effect in September 2007. Boone County adopted a stormwater management ordinance which was effective April 15, 2010.

Stream Buffer Regulations

An adequate buffer for a stream system shall consist of a predominantly undisturbed strip of land extending along both sides of a stream and its adjacent wetlands, floodplains or slopes. The buffer is measured from the ordinary high water mark of the channel, and extends a certain width outward on both sides of the stream. This buffer width is determined by the size of stream and steepness of adjacent slopes (see table below).

The buffer is divided into two sections, the streamside zone and outer zone. The function of the streamside zone is to protect the physical, biological and ecological integrity of the stream ecosystem. The function of the outer zone is to prevent encroachment into the streamside zone and to filter runoff from residential and commercial development.

Table 5.2 City of Columbia and Boone County Stream Buffers

	Streamside Zone			Outer Zone		
Stream Types	Type I	Type II	Type III	Type I	Type II	Type III
Width	50	25	15	50	25	25
Vegetation	Native Vegetation			Type I - Native Vegetation Type II - Managed Lawns Permissible Type III - Managed Lawns Permissible		
Uses	Flood control, foot and bicycle paths, road crossings, utility crossings, stream or stream bank restoration and restoration of native vegetation			All used allowed in the Streamside Zone, hard-surfaced biking/hiking paths, detention/retention structures, utility corridors, stormwater BMPs, residential yards, landscaped areas		
Function	Protect the physical and ecological integrity of the stream ecosystem			Protect key components of the stream and filter and slow velocity of water runoff		

Some structures and activities are permitted in the streamside zone, such as roads and bridges, utilities, and recreation trails. Practices that are prohibited within the streamside zone of the stream buffer are clearing of existing vegetation, grading and filling, or grazing of livestock.

Overview of the City of Columbia's Stormwater Management Ordinance

The purpose of the City of Columbia's Stormwater Ordinance is to establish minimum stormwater management requirements and controls to protect and safeguard the general health, safety and welfare of the public. This ordinance is intended to meet that purpose through the following objectives:

(1) Minimize increases in stormwater runoff from any development in order to reduce flooding, siltation and stream bank erosion and stream channel degradation;

(2) Minimize increases in nonpoint source pollution caused by stormwater runoff from development which would otherwise degrade local water quality;

(3) Minimize the total annual volume of surface water runoff which flows from any specific site during and following development to not exceed the predevelopment hydrologic regime to the maximum extent practicable; and

(4) Reduce stormwater runoff rates and volumes, soil erosion and nonpoint source pollution, wherever possible, through stormwater management controls and to ensure that these management controls are properly maintained and pose no threat to public safety.

Overview of Boone County's Stormwater Management Ordinance

The purpose of Boone County's Stormwater Ordinance is to establish minimum stormwater management requirements and controls to protect and safeguard the general health, safety and welfare of the public. This ordinance is intended to meet that purpose through the following objectives:

(1) Minimize increases in stormwater runoff from any development in order to reduce flooding, siltation and stream bank erosion and stream channel degradation;

(2) Minimize increases in nonpoint source pollution caused by stormwater runoff from development which would otherwise degrade local water quality;

(3) Minimize the total annual volume of surface water runoff which flows from any specific site during and following development to not exceed the predevelopment hydrologic regime to the maximum extent practicable; and

(4) Reduce stormwater runoff rates and volumes, soil erosion and nonpoint source pollution, wherever possible, through stormwater management controls and to ensure that these management controls are properly maintained and pose no threat to public safety.

Stormwater Ordinance Revision Recommendations

The City of Columbia's stream buffer and stormwater ordinances are a step in the right direction. However, they can be improved to benefit water quality. The stormwater ordinance does not apply to the University of Missouri, or existing developed land unless the owner redevelops the property.

Stormwater controls are particularly subject to waiver in the downtown area of Columbia because space is so tight. An amendment could be made to the stormwater ordinance so that new developments in the downtown area can pay into a fund that implements downtown stormwater improvements, or mitigation projects elsewhere in the watershed, rather than implementing stormwater treatment on individual parcels. One example of District-wide stormwater programs would be night-time street-sweeping of downtown problem areas with regenerative air vacuum trucks which do a better job of picking up pollutants, including oily deposits. Another possibility would be increasing the number of trees and tree boxes to intercept more runoff and decrease impervious surface. This mechanism would help with variance requests in other parts of town as well.

The University is a regulated MS4 and must address stormwater through its stormwater management plan. The University should be encouraged to develop internal policies that direct construction projects to detain and treat their stormwater runoff in a manner similar to the Columbia or Boone County ordinances.

The stream buffer ordinance should be amended to delete manicured lawns in the outer buffer of Type II and Type III buffers from the list of acceptable land uses within a stream buffer. The inclusion of lawns negates any water quality benefit from these areas, and effectively reduces the buffer area by half. Sewer lines and other utility lines that can interfere with mature woody vegetation should only be allowed within the streamside zone where no other practical alternative exists. The installation of utility lines initially destroys a riparian corridor, the maintenance of those lines disturbs the corridor, and the natural migration of streams threatens to undercut utility structures in these areas.

When utilities must be installed in the stream buffer, the buffer should be mitigated in place with native vegetation restored or installed and maintained and monitored for 10 years to ensure the plantings succeed. Access paths for maintenance should be kept as narrow and short as possible and the vegetation in the paths should be native or at least noninvasive.

In the City some mechanism should be provided whereby official stream buffers can be established on previously developed (and thus exempt) land. A program of this nature would be most effective if some type of incentive is provided to the landowner.

Land Disturbance Ordinance Revision Recommendations

Currently, Columbia and Boone County have little control over the grading practices of developers. To fulfill the requirements for a land disturbance permit, a developer must submit a detailed site development plan that includes tree preservation, landscaping, soil-erosion controls and stormwater management. Unfortunately, land can be cleared and graded in anticipation of development, and sit in a state that makes it susceptible to erosion and increases the rate of runoff. Revisions to the land disturbance permit process should be made to reduce the time that land sits relatively unprotected from runoff. Reductions in the amount of grading that can occur on a site and/or reducing the amount of area that can have its topsoil removed, would also help with infiltration of stormwater runoff. Boone County has adopted regulations that address the amount of time that soil can be left unstabilized and Columbia is in the process of developing regulations to address this problem.

5.g Information Needs and Public Education

Information Needs

There should be ongoing water quality monitoring projects carried out in order to refine and enhance data regarding the health of the watershed for long term duration. Few studies in the field of natural resources happen over the long term since they almost always require more funding and cooperation. Due to the presence of the University of Missouri, in the watershed, the opportunity for a long term study is excellent. The data obtained through study can be used by the MS4 to define and refine water quality practices in the Hinkson Watershed. The entities conducting such studies should utilize available grant money to the maximum extent possible.

Monitoring should occur on a least two scales: the BMP specific scale, and the watershed scale. BMP monitoring should be used to determine the efficacy of installed BMPs. Specific monitoring plans should be developed and implemented as practices are installed and therefore should follow the Schedule of Milestones in Appendix A.

Watershed monitoring should be used to determine the overall health of Hinkson Creek. At present, five bridges throughout Boone County have been equipped with climate stations, solar panels, stream gauges, and sediment samplers. This is part of a comprehensive monitoring project on Hinkson Creek hosted by the University of Missouri. This three-year project will help researchers understand how Hinkson Creek responds to precipitation events. The climate stations will track the amount of precipitation, wind and even the amount of solar radiation. The gauges monitor stream rise and fall. The continuous sediment samplers are tracking the concentration and size of the silt and clay, as it moves through the stream system. in the summer of 2009, the research team started collecting nutrients such as phosphorus and nitrogen. The information may help show where stormwater problems are occurring in the watershed.

Public Education and Outreach

Figure 5.8 Stream Extravaganza

Continuing public education programs are vital to developing a view of the watershed as a cultural and ecological asset and develop a sense of stewardship toward the watershed. A two faceted approach should be used to target the general public and elementary and secondary school students. The program to educate the general public should include public service announcements, festivals and workshops on various topics. Volunteerism with groups such as Stream Teams and Tree Keepers should be encouraged. Students should be taught at an early age (5th or 6th grade) what watersheds are and how they themselves impact water quality anywhere they may live in life. Schools should be encouraged to form Stream Teams. Other activities such as bird watching, fishing, hunting (with bows), science projects dealing with water quality issues, plant identification and care and art classes could be held in the watershed by schools utilizing the riparian corridor.

In residential subdivisions, homeowners need additional information and strategies about ways they can increase infiltration and reduce runoff from their property. Low Impact Development (LID) techniques are still a difficult sell in the Midwest. Public demonstration areas are needed to showcase LID techniques such as structural soils, pervious pavement, and underground detention to slow and filter stormwater. Additionally, contractors need opportunities for hands-on demonstrations and construction so that the structures are being correctly built and maintained.

5.h Adaptive Management

Adaptive management for natural resources has traditionally been used to manage game species populations and to set hunting limits. However, applications for ecosystem management are now being examined. The key components of adaptive management are to establish what is known and unknown about the system. Each unknown is then prioritized and investigated until it is fully understood.

As information and knowledge about the ecosystem and the related stressors evolves, then management strategies are adapted to address the new understanding. Once new management techniques are put into place, the next step is to study the impact of these implementation measures. Are the expected outcomes achieved? For example, by monitoring the effects that practices have on the creek it is possible to determine whether those practices are leading toward achievement of the WMP's goals. If not, the types of practices should be altered. This iterative process continuously refines a long term management strategy for the creek. Furthermore, stakeholders are empowered as they gain knowledge about the effects of various practices and apply that knowledge.

5.i Funding

Since the stormwater ordinances cannot be made retroactive, a funding mechanism should be pursued that will pay for a fund for retrofitting stormwater controls in existing developments. This fund could be used to provide a cost share program to private property owners who retrofit their property with stormwater controls or for capital improvements to the City or County stormwater infrastructure. The potential savings in infrastructure could be used as incentive funds for redevelopment.

The City, County and University should retrofit stormwater treatment that, at the very least, treats the rights-of-way and other properties owned by the entities. This can make the replacement of worn out storm pipes downstream less expensive in addition to providing water quality benefits.

Potential Funding Sources

According to the City of Columbia Finance Department, the Storm Water Utility fund budget for FY 2006 was a little over $2.5 million. Funding sources for the Storm Water Utility include development charges on new construction and charges on existing improved properties. The Storm Water Utility was established to provide funding for the implementation of storm water management projects, maintenance of existing storm water drainage facilities, modeling of developing drainage basins and implementing regional detention facilities. Stormwater retrofits, as well as funds for stormwater education, would be drawn from this fund.

Funding for stormwater controls on new developments and certain redevelopments within the city will be paid by the developers of that property, according to city ordinance.

The Stream Stewardship Trust Fund is a potential funding source for stream restoration projects on Hinkson Creek or its tributaries. The fund is managed by the Missouri Conservation Heritage Foundation, and applications for potential projects must be submitted by Conservation Department employees. The budget for projects is derived from mitigation costs for stream-damaging activities such as channelization. The overall budget for projects is several million dollars.

Funding for many of the educational milestones will come mainly from 319 grants disseminated by the MDNR The Hinkson Phase II grant has a total budget of $669,340 of which $401,904 is from federal funds and $267,736 is from local sources.

The Boone County Soil and Water Conservation District's Landowner Assistance Program has many practices designed for improved water quality that are offered in addition to the traditional practices used to combat soil erosion. The cost share program is available to qualifying land owners. Funding is limited: some areas of funding have waiting lists for cost-share. This funding source is directed toward rural land owners and would primarily benefit the upper portion of the watershed.

Table 5.3 Projected Schedule of Implementation

	Current	Short Term 2008-2009	Mid Term 2010-2012	Long Term 2013-2020
Upper Hinkson Creek Watershed	-County Stream Buffer ordinance passed -Hinkson Watershed Restoration Project Phase II and Jefferson Institute 319 projects begun	-County Stormwater ordinance passed	-Hinkson Watershed Restoration Project Phase II and Jefferson Institute 319 projects end -Dr. Hubbart's monitoring study reveals water budget -Detention built into local road projects	-Land cover change from "idle areas" to woodland occurs -Sewers replace most lagoons, septic systems -Upper Hinkson impacted by I-70 widening -Detention built into MODOT road projects
Lower Hinkson Creek Watershed (impaired section)	-City of Columbia Stormwater ordinance passed -City of Columbia Stream Buffer ordinance passed	-Hinkson Watershed Restoration Project Phase II and Jefferson Institute 319 projects begun -City of Columbia Stream Buffer ordinance revised -Hinkson TMDL written with flow recommendations	-Hinkson Watershed Restoration Project Phase II and Jefferson Institute 319 projects end Dr. Hubbart's monitoring study reveals water budget -Parking lot BMP retrofits implemented -Lake retrofits implemented -"District" area increased street sweeping occurs -Detention built into local road projects	-Land cover change from "idle areas" to woodland occurs -Greater percentage of developments have BMPs as result of redevelopment clause of stormwater ordinance -Detention built into MODOT road projects
Tributary Streams	-City of Columbia Stormwater ordinance passed -City of Columbia Stream Buffer ordinance passed	-Hinkson Watershed Restoration Project Phase II and Jefferson Institute 319 projects begun -City of Columbia Stream Buffer ordinance revised	-Hinkson Watershed Restoration Project Phase II and Jefferson Institute 319 projects end -Dr. Hubbart's monitoring study reveals water budget -Grindstone impacted by Stadium Rd. extension, other roads -Parking lot BMP retrofits implemented -Lake retrofits implemented -Detention built into local road projects	-Land cover change from "idle areas" to woodland occurs -Sewers replace most lagoons, septic systems -Hominy, Grindstone impacted by I-70 widening -Detention built into MODOT road projects

Appendix A

Schedule of Milestones

Schedule of Milestones				
Category	**Action**	**Actor(s)**	**Desired Completion Date**	**Possible Funding Source**
Restoration	Add storage to existing ponds/lakes	Public Land Managers	1 per year 2011-2015	Governmental Agencies, Public and Private Grants
Restoration	Add storage to existing ponds/lakes	Private Land Owners	1 per year 2011-2015	Private funds leveraged with public grant money
Restoration	Add storage in right of way	Columbia, Boone County, MODOT	1 per year 2011-2015	Public funds. Public funds leveraged with grant money
Restoration	Implement measures from Feasibility Analysis	MS4, MODOT, Private Owners	1 per year 2011-2015	Public, private, public private partnerships, grants
Restoration	Add storage to existing parking lots	Private Owners	1 per year	Private possibly leveraged with grants
Restoration	Stream clean-ups	MS4, Sierra Club	Annual	MS4, Sierra Club
Protection	Review and Update Stormwater regulations	Boone County/ Columbia	Annual	Public funds
Protection	Develop and Implement Stormwater Management Plan	University of Missouri	2012	University of Missouri
Information Needs	Continuous Monitoring	Stream Teams	Quarterly	Volunteer, Missouri Department of Conservation
Information Needs	Update Invertebrate Studies	MS4	2013	MS4, Department of Natural Resources
Information Needs	Water Quality Monitoring	University of Missouri, Missouri Department of Conservation, MS4	Continuous	University of Missouri, MDC, Public and Private Grant Money, MS4
Information Needs	Continuing Stormwater Public Education Program	MS4	Annual: 30 points of public contact per year	MS4

Appendix B

Feasibility Study

HINKSON CREEK WATERSHED RESTORATION PROGRAM

BOONE COUNTY, MISSOURI

FEASIBILITY ANALYSIS FOR RETROFITTING STORMWATER TREATMENT STRUCTURES OR BEST MANAGEMENT PRACTICES

PREPARED FOR:

BOONE COUNTY PLANNING AND BUILDING DEPARTMENT

PREPARED BY:

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NOVEMBER, 2009

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Table of Contents

PROJECT BACKGROUND 6

SCOPE OF FEASIBILITY STUDY AND COST BENEFIT ANALYSIS 7

SITE AND BMP SELECTION METHODOLOGY 8

PREVIOUS DEVELOPMENTS INFLUENCE ON STORMWATER INFRASTRUCTURE AND STORMWATER QUANTITY 8

PREVIOUS DEVELOPMENTS INFLUENCE ON STORMWATER QUALITY 11

PHYSICAL PROPERTIES OF SOILS IN THE AREA OF INTEREST 13

REGIONAL APPROACH Vs. SMALL AREA BMPs, THE BENEFIT OF REGIONAL TREATMENT 16

PROPERTY OWNER COOPERATION AND BMP MAINTENANCE 18

BMP PROXIMITY TO HINKSON CREEK 18

STORMWATER CONVEYANCE STABILIZATION AND REVEGETATION 19

SELECTED BMP INFORMATION 20

EXTENDED WET DETENTION BASINS 20

EXTENDED DRY DETENTION BASINS 22

Table of Contents

NATIVE VEGETATION SWALE	23
BIOSWALE	25
TURF SWALE	26
SITE SPECIFIC INFORMATION	27
AREA OF INTEREST	27
SITE #1	28
SITE #2	31
SITE #3	32
SITE #4	34
SITE #5	36
SITE #6	38
SITE #7	41
SITE #8	44
SITE #9	47
SITE #10	48

Table of Contents

SITE #11 52

SITE #12 55

SITE #13 58

SITE #14 60

SITE #15 63

SITE #16 64

SITE #17 66

SITE #18 69

SITE #19 72

SUMMARY OF OVERALL EFFECTS ON HOTSPOT AREA 75

SUMMARY OF DETENTION EFFECTS 75

SUMMARY OF CHANNEL STABILIZATION EFFECTS 75

SUMMARY DATA TABLE 76

DEFINITIONS 77

SITE SELECTION QUESTIONNAIRE AND BMP SCORING MATRIX 83

Table of Contents

SITE SELECTION PROCESS 83

BMP SELECTION PROCESS 85

BMP SCORING MATRIX 87

REFERENCES 88

PROJECT BACKGROUND (From RFP#: 67-30DEC08)

Since 1998, the Missouri Department of Natural Resources (MDNR) has listed Hinkson Creek on the 303(d) list of impaired waters. Neither the source of pollution nor the specific pollutants responsible for the impairment have been identified, despite a recent three year study by MDNR. In 2004, the Hinkson Creek Watershed Restoration Project (HCWRP) was funded by a four year grant from the Environmental Protection Agency (EPA) through the MDNR. In addition to education activities directed at the development community and residents, the grant project developed a watershed management plan. This plan and the (MDNR) authors of the ongoing Hinkson Creek Total Maximum Daily Load (TMDL) have indicated a focus on stormwater runoff as the key to restoring the health of Hinkson Creek. An "area of interest" has been identified in the plan as a place to concentrate efforts to provide cost-share funding to landowners who agree to install stormwater best management practices (BMPs).

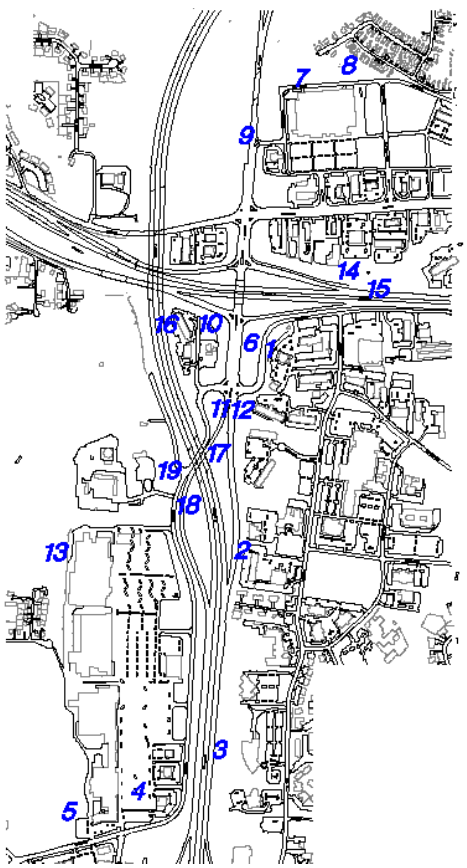
The area of interest is comprised of the commercial lots located in the general area of the I-70 and Hwy-63 intersection. The lots in question lie east of Hwy-63 and both north and south of I-70. The area has been identified because the beginning of the impaired section of Hinkson Creek is adjacent to this area, nearby stormwater outfalls have had elevated levels of contaminants, and the area has a high concentration of impervious surface cover.

A stormwater ordinance and a stream buffer ordinance were both recently passed by the City of Columbia in 2007. Neither ordinance is retroactive: only new development and redevelopment are affected. The stream buffer ordinance requires a setback of varying width, dependent upon the size of the stream. The stormwater ordinance requires a level of service approach be taken on applicable developments: run-off from areas converted to impervious surface is ameliorated by various BMPs that must be installed to detain and treat the stormwater. These ordinances are intended to prevent further degradation of Columbia streams. The focus of this grant is to improve the health of Hinkson Creek by retrofitting BMPs on parcels not affected by these ordinances, or to fund improved BMPs on parcels that are affected by these ordinances.

SCOPE OF FEASIBILITY STUDY AND COST BENEFIT ANALYSIS

This study was completed in an effort to determine the feasibility of retro-fitting properties within the area of interest with stormwater treatment and detention structures or practices. BMP and site selection criteria outlined within the proposal request include installation cost, 15-year maintenance cost, the amount of impervious area treated, and the level of treatment provided. This report outlines additional site and BMP selection criteria used to evaluate site and BMP combinations resulting in a list of recommended sites and their corresponding BMPs. In addition to the selection criteria detailed within this report, a Site and BMP Selection Questionnaire and a BMP Scoring Matrix have been developed to assist in selection of BMP sites and applicable BMPs.

The following Figure shows selected BMP sites within the area of interest.



SITE AND BMP SELECTION METHODOLOGY:

Upon receipt of GIS information from both the City of Columbia and Boone County, a base map of the entire area of interest was compiled. The base map was then overlaid with aerial photography, topographic maps, and utility maps. The topographic maps and the storm water utility maps were utilized to delineate watersheds and sub-watersheds within the area of interest. From this point, potential BMP sites were selected for further investigation subject to the following criteria and ideology.

Previous Developments Influence on Stormwater Infrastructure and Stormwater Quantity:

Waterways and receiving waters near urban and suburban areas are often adversely affected by urban stormwater runoff. The degree and type of impact varies from location to location, but it is often significant relative to other sources of pollution and environmental degradation. Urban stormwater runoff affects water quality, water quantity, habitat and biological resources, public health, and the aesthetic appearance of urban waterways. As reported in the National Water Quality Inventory 1996 Report to Congress (US EPA, 1998d), urban runoff was the leading source of pollutants causing water quality impairment related to human activities in ocean shoreline waters and the second leading cause in estuaries across the nation. Urban runoff was also a significant source of impairment in rivers and lakes. The percent of total impairment attributed to urban runoff is substantial. This impairment constitutes approximately 5,000 square miles of estuaries, 1.4 million acres of lakes, and 30,000 miles of rivers. Seven states also reported in the inventory that urban runoff contributes to wetland degradation. (US EPA Preliminary Data Summary of Urban Stormwater Best Management Practices, EPA-821-R-99-012, August 1999).

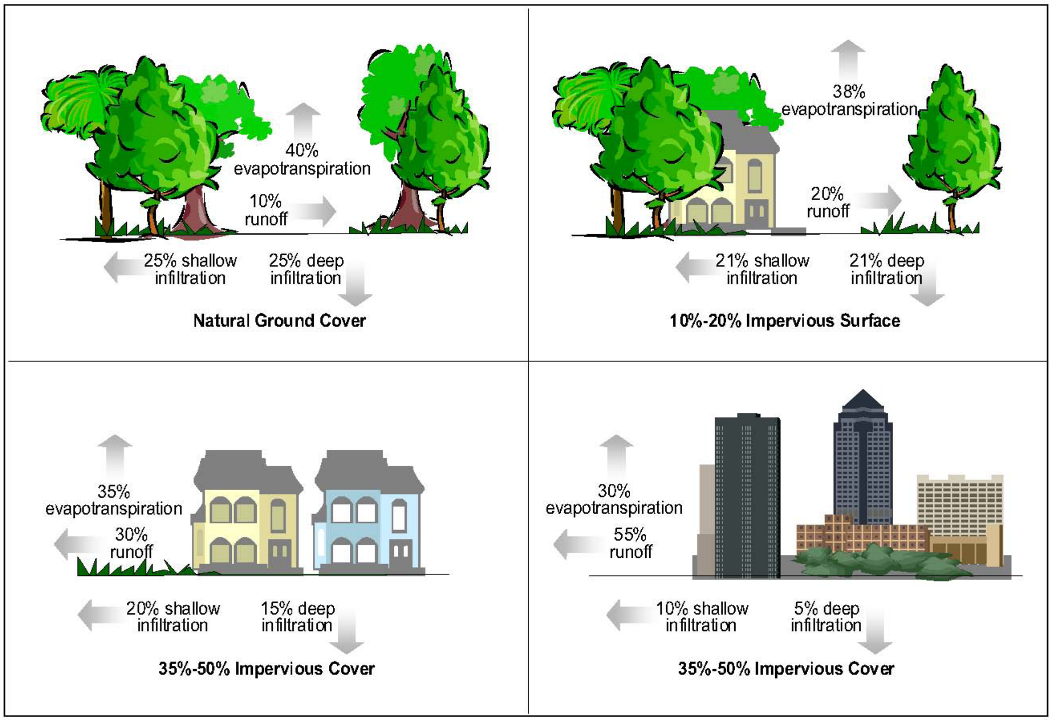
Leading sources[b] of water quality impairment related to human activities for rivers, lakes, and estuaries (USEPA, 2002b).

Rivers and Streams	Lakes, Ponds, and Reservoirs	Estuaries
Agriculture (48%) [a]	Agriculture (41%) [a]	Municipal point sources (37%)[a]
Hydrologic modifications (20%)	Hydrologic modifications (18%)	Urban runoff/storm sewers (32%)
Habitat modifications (14%)	Urban runoff/storm sewers (18%)	Industrial discharges (26%)
Urban runoff/storm sewers (13%)	Misc. nonpoint source pollution (14%)	Atmospheric deposition (24%)

[a]Values in parentheses represent the percentage of assessed river miles, lake acres, or estuary square miles that are classified as impaired. States assessed 19% of stream miles, 43% of lakes, ponds, and reservoirs, and 36% of square mileage of estuaries.
[b] Excluding unknown, natural, and "other" sources.

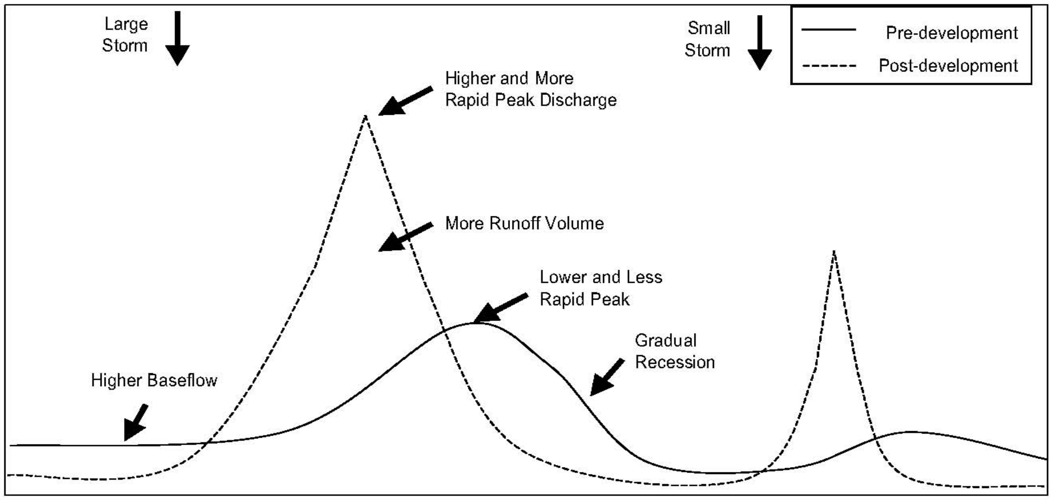
While water quality impacts are often unobserved by the general public, other stormwater impacts are more visible. Stream channel erosion and channel bank scour provide direct evidence of water quantity impacts caused by urban stormwater. Urban runoff increases directly with imperviousness and the degree of watershed development. As urban areas grow, urban streams are forced to accommodate larger volumes of stormwater runoff that recur on a more frequent basis. This leads to stream channel instability. The change in watershed hydrology associated with urban development also causes channel widening and scour, and the introduction of larger amounts of sediment to urban streams. Visible impacts include eroded and exposed stream banks, fallen trees, sedimentation, and recognizably turbid conditions. The increased frequency of flooding in urban areas also poses a threat to public safety and property. (US EPA Preliminary Data Summary of Urban Stormwater Best Management Practices, EPA-821-R-99-012, August 1999).

Historically, as urbanization occurred and storm drainage infrastructure systems were developed in this country, the primary concern was to limit nuisance and potentially damaging flooding due to the large volumes of storm water runoff that are generated. Little, if any, thought was given to the environmental impacts of such practices. As a result, streams that receive stormwater runoff frequently cannot convey the large volumes of water generated during runoff events without significant degradation of the receiving stream.



Impacts of urbanization on the water cycle (Adapted from FIRSWG, 1998).

In addition to the problems associated with excess water volume, the levels of toxic or otherwise harmful pollutants in stormwater runoff and combined sewer overflows can cause significant water quality problems in receiving streams (US EPA Preliminary Data Summary of Urban Stormwater Best Management Practices, EPA-821-R-99-012, August 1999).



Changes in stream flow hydrograph as a result of urbanization (Schueler, 1987).

Previous Developments Influence on Stormwater Quality:
During the development process, both the existing landscape and hydrology are altered. As development occurs, soil porosity decreases due to removal of vegetation and compaction of topsoil by construction equipment. Impervious surfaces increase with the addition of rooftops and paving. Artificial conveyances such as pipes and lined channels are constructed to rapidly convey stormwater. Existing slope angles become less acute, vegetative cover decreases and surface roughness decreases. (EPA-841-B-05-004)

Everyday activities that occur after development may cause the discharge of pollutants in runoff that can have harmful effects on waters and habitat. Pollutants related to vehicle petroleum and coolant leaks and overflows, tire and brake wear, pet waste, pesticides, and fertilizers can be carried into estuaries, streams, rivers, and lakes through runoff. Soils and sediment can constitute a significant fraction of the solids on urban surfaces. Weather related erosion and transport of eroded soil increases solids in urban areas. Other sources of solids on urban surfaces are wear of automotive parts, combustion products from diesel and gasoline fueled engines, fireplaces, construction sites, and industrial facilities. (EPA-841-B-05-004)

Typical pollutant concentrations found in urban storm water (adapted from MDE, 1999, and Terrene Institute, 1994).

Typical Pollutants Found in Storm Water Runoff	Units	Residential[a]	Mixed[a]	Commercial[a]	General Urban[b]
Total suspended solids	mg/L	101	67	69	80[c]
Total phosphorus	mg/L	383	263	201	0.30[c]
Total nitrogen	mg/L	–	–	–	2.0[c]
Total Kjeldahl nitrogen	mg/L	1.9	1.3	1.2	–
Nitrate + Nitrite	µg/L	736	558	572	–
Total organic carbon	mg/L	–	–	–	12.7[c]
Biological oxygen demand	mg/L	10	7.8	9.3	–
Chemical oxygen demand	mg/L	73	65	57	–
Fecal coliform bacteria	MPN/100 mL	–	–	–	3,600[c]
E. coli bacteria	MPN/100 mL	–	–	–	1,450[c]
Petroleum hydrocarbons	mg/L	–	–	–	3.5[c]
Oil and grease	mg/L	–	–	–	2 to 10[d]
Cadmium	µg/L	–	–	–	2[c]
Copper	µg/L	33	27	29	10[c]
Lead	µg/L	144	114	104	18[c]
Zinc	µg/L	135	154	226	140[c]
Chlorides (winter only)	mg/L	–	–	–	230[c]
Insecticides	µg/L	–	–	–	0.1 to 2.0[c]
Herbicides	µg/L	–	–	–	1 to 5.0[c]

[a] Source: USEPA, 1983.
[b] These concentrations represent mean or median storm concentrations measured at typical sites and may be greater during individual storms. Also note that mean or median runoff concentrations from storm water "hotspots" are 2 to 10 times higher than those shown here. Units: mg/L = milligrams/liter, µg/L = micrograms/l, MPN = most probable number.
[c] Source: MDE, 1999.
[d] Source: Terrene Institute, 1994.

Many pollutants bind to and are entrained in sediment or particulate loadings. Particulates include suspended, settleable, and bedload solids. Metals, phosphorus, nitrogen, hydrocarbons and pesticides are commonly found in urban sediments.

Total suspended solids (TSS) is a measure of the concentrations of sediment and other solid particles suspended in the water column of a stream, lake, or other water resource. TSS is an important parameter because it quantifies the amount of sediment entrained in runoff. This information can be used to link sources of sediments to the resulting sedimentation in a stream, lake, wetland, or other water resources. TSS is also an indirect measure of other pollutants carried by runoff, because nutrients (phosphorus, metals, and organic compounds) are typically attached to sediment particles. (EPA-841-B-05-004)

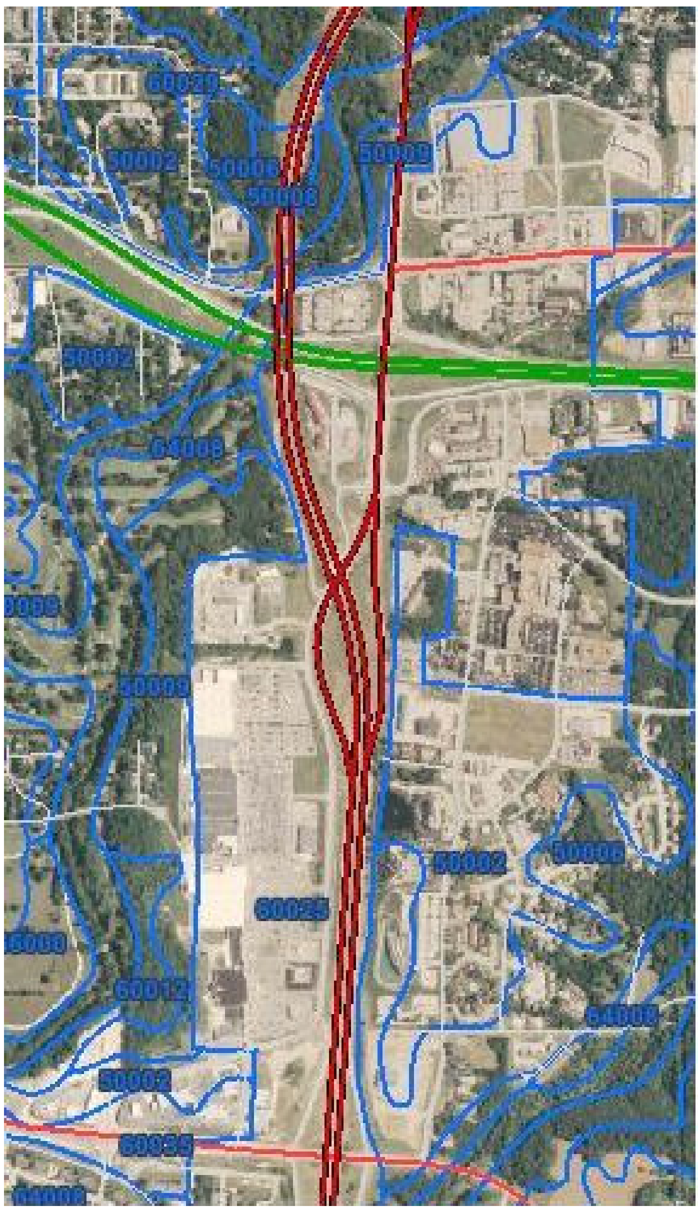
Physical Properties of Soils in the Area of Interest:

The efficacy of infiltration BMPs, such as infiltration basins and infiltration trenches, varies greatly with the rate at which the surrounding soil can accept the excess stormwater. Because infiltration BMPs are meant to treat stormwater through infiltration into the surrounding soil, guidelines have been established that set minimum values for the infiltration rate of the soil within which the BMP is constructed. These minimum infiltration rate values were set in an effort to ensure that ponding within an infiltration BMP does not reach a duration which might cause loss of vegetation or a habitat for mosquito breeding. Infiltration rate guidelines have also been set to promote the infiltration of excess stormwater within a reasonable time frame to ensure that the BMP is capable of receiving stormwater from subsequent rainfall events. The City of Columbia Stormwater Management and Water Quality Manual states that the minimum infiltration rate for soils surrounding an infiltration trench is 0.5 inches per hour. It also states that the minimum infiltration rate for soils surrounding an infiltration basin is 0.33 inches per hour, based on a maximum ponding depth of 24 inches and a maximum ponded duration of 72 hours. Because of these minimum infiltration rate guidelines, the opportunity to place infiltration BMPs has been significantly reduced within the City of Columbia (based on prior design projects completed by A Civil Group). Some of the soils within the area of interest do exhibit infiltration rates greater than the 0.5 inch per hour minimum, however, to construct the basin or trench, the upper soil horizons must often be removed, either exposing the lower horizon or substantially decreasing the distance to the lower horizon which often has a much lower hydraulic conductivity.

Utilizing data taken from the Boone County Soil Survey (http://soildatamart.nrcs.usda.gov/Manuscripts/MO019/0/boone_MO.pdf)
in conjunction with soil mapping offered through the CARES website (http://www.cares.missouri.edu/) the predominant soils within the area of interest were determined and their corresponding saturated hydraulic conductivities were noted.

The area of interest is comprised of six soils from four different soil series. The soil series include the Keswick Series, Vanmeter Series, Bardley Series, and the Harvester Series. The soil classification map (follows) shows outlines of the soil types and their corresponding classification number in and around the area of interest.

Soil Map within the Area of Interest: SSURGO Soil Outlines (2008 Update), USDA – NRCS, June 9, 2008, http://cares.missouri.edu/



The following data, taken from the Boone County Soil Survey, lists the soils present within the area of interest, their typical slopes, parent material and saturated hydraulic conductivity.

50002 – Keswick-Urban Land Complex

Typical Slope: 5% - 9%

Parent Material: Loess over clayey till

Saturated Hydraulic Conductivity:

0" – 7" Depth: 0.5"/hr – 2.0"/hr

7" – 20" Depth: 0.06"/hr – 0.2" / hr

50006 – Vanmeter Clay Loam

Typical Slope: 5% - 14%

Parent Material: Residuum derived from clayey shale

Saturated Hydraulic Conductivity:

0" – 5" Depth: 0.2"/hr – 0.6"/hr

5" – 12" Depth: 0.2"/hr – 0.6" / hr

12" – 23" Depth: 0.001"/hr – 0.06"/hr

50008 – Keswick Silt Loam

Typical Slope: 5% - 9%

Parent Material: Loess over clayey till

Saturated Hydraulic Conductivity:

0" – 7" Depth: 0.5"/hr – 2.0"/hr

7" – 20" Depth: 0.06"/hr – 0.2" / hr

50009 – Keswick Silt Loam

Typical Slope: 9% - 14%

Parent Material: Loess over clayey till

Saturated Hydraulic Conductivity:

0" – 4" Depth: 0.5"/hr – 2.0"/hr

4" – 53" Depth: 0.06"/hr – 0.2" / hr

60012 – Bardley-Clinkenbeard Complex

Typical Slope: 20% - 45%

Parent Material: Colluvium over clayey residuum derived from cherty limestone

Saturated Hydraulic Conductivity:

0” – 3” Depth: 0.5”/hr – 2.0”/hr

3” – 9” Depth: 0.5”/hr – 2.0” / hr

9” – 36” Depth: 0.5”/hr – 2.0”/hr

60025 – Urban Land-Harvester Complex

Typical Slope: 2% - 9%

Parent Material: Fine silty loess

Saturated Hydraulic Conductivity:

0” – 6” Depth: 0.2”/hr – 0.6”/hr

6” – 30” Depth: 0.2”/hr – 0.6” / hr

Regional Approach vs. Small Area BMPs & the Benefits of Regional Treatment:

With the exception of steep terrain, poorly drained or low lying areas, MODOT right-of-way, and small pockets of green space, the vast majority of the area of interest is fully developed. Throughout the development of this area, storm water was dealt with on a site-by-site basis along with the stormwater infrastructure established by MODOT. As such; the existing storm water infrastructure rapidly combines flows from contributing areas into concentrated flow paths at a considerable distance from Hinkson Creek, relative to the extent of the area of interest.

Because of the development density, the abundance of impervious area, and the existing stormwater infrastructure, the area of interest has few locations suitable for placement of small area BMPs capable of effectively detaining and treating their impervious contributing areas while surviving the heavier rainfall events.

Because the existing infrastructure concentrates the flows high in the area of interest watershed, the only applicability for small area BMPs is at the very top of said watershed or offline from the concentrated flows, leaving the remainder of the watershed more applicable to regional treatment options. Regional treatment options such as dry extended detention basins and wet extended detention basins have been shown to remove an average of 61% and 80%, respectively, of total suspended solids. (EPA-841-B-05-004)

Small area BMPs such as rain gardens, infiltration basins, filter strips, and bio-retention basins have been shown very effective at increasing water quality and ground water recharge, however, they require placement in close proximity to their contributing area and often require sheet flow and a pre-filtering BMP. (See City of Columbia, Missouri Stormwater Management and Water Quality Manual, EPA-821-R-99-012)

Effectiveness of management practices for runoff control (adapted from Caraco and Winer, 2000).

Runoff Treatment or Control Practice Category or Type	Median Pollutant Removal (Percent)							
	No. of studies	TSS	TP	OP	TN	NOx	Cu	Zn
Quality Control Pond	3	3	19	N/A	5	9	10	5
Dry Extended Detention Pond	6	61	20	N/A	31	-2	29	29
Dry Ponds	9	47	19	N/A	25	3.5	26	26
Wet Extended Detention Pond	14	80	55	69	35	63	44	69
Multiple-Pond System	1	91	76	N/A	N/A	87	N/A	N/A
Wet Pond	28	79	49	39	32	36	58	65
Wet Ponds	43	80	51	65	33	43	57	66
Shallow Marsh	20	83	43	66	26	73	33	42
Extended Detention Wetland	4	69	39	59	56	35	N/A	-74
Pond/Wetland System	10	71	56	37	19	40	58	56
Submerged Gravel Wetland	2	83	64	14	19	81	21	55
Wetlands	36	76	49	48	30	67	40	44
Organic Filter	7	88	61	30	41	-15	66	89
Perimeter Sand Filter	3	79	41	68	47	-53	25	69
Surface Sand Filter	7	87	59	N/A	31.5	-13	49	80
Vertical Sand Filter	2	58	45	21	15	-87	32	56
Bioretention	1	N/A	65	N/A	49	16	97	95
Filtering Practices[a]	18	86	59	*57*	38	-14	49	88
Infiltration Trench	3	100	42	100	42	82	N/A	N/A
Porous Pavement	3	95	65	10	83	N/A	N/A	99
Ditches[b]	9	31	-16	N/A	-9	24	14	0
Grass Channel	3	68	29	32	N/A	-25	42	45
Dry Swale	4	93	83	70	92	90	70	86
Wet Swale	2	74	28	-31	40	31	11	33
Open Channel Practices	9	81	34	*1.0*	*84*	31	51	71
Oil-Grit Separator	1	-8	-41	40	N/A	47	-11	17

Shaded rows show data for groups of practices (i.e., dry ponds include quality control ponds and dry extended detention ponds).
Numbers in italics are based on fewer than five data points.
[a] Excludes vertical sand filters
[b] Refers to open channel practices not designed for water quality.
TSS=total suspended solids, TP=total phosphorus, OP=ortho-phosphorus, TN=total nitrogen, NOx=nitrate and nitrite nitrogen, Cu=copper, Zn=zinc.

Due to their limited capacity, small area BMPs are suitable for small contributing areas only, and they offer little to no benefit during significant rainfall events. Were it possible to place BMPs such as these at every development within the area of interest, the use of regional facilities might not be necessary, however; because not all sites can be retrofitted with these BMPs, a regional treatment approach offers water quality treatment and more significant detention to a much greater percentage of the area of interest, than would the placement of small area BMPs at the top of the watershed.

Property Owner Cooperation and BMP Maintenance:
The use of small area BMPs to attain similar water quality and detention levels of service that can be provided by the larger regional facilities would require the placement of small area BMPs at the majority of the 155 (approximate) developed sites. For this to occur, the majority of the owners of those sites must cooperate with the County in these efforts. Were cooperation of the majority of the owners to occur, and the small area BMPs were to be constructed, there would then be a large number of small area BMPs subject to the voluntary inspection and maintenance by the owners. The placement of larger regional facilities on much fewer sites would still require inspection and maintenance, however; because there are substantially fewer sites, any oversight or even periodic inspection by the applicable governing authority or a third party would be more feasible. In addition, the proper functioning of the larger regional facilities (wet ponds, dry ponds, etc) is more visually apparent than that of the small area BMPs, and if properly established; the larger facilities require less frequent maintenance (excluding mowing). The larger regional facilities are also less susceptible to the negative impact of sediment and small debris (common roadside trash) than are the small area BMPs.

BMP Proximity to Hinkson Creek:
With the underlying goal of this study being to determine what locations and their corresponding BMPs will have the maximum positive impact on the health of Hinkson Creek, it should be considered that treated stormwater can once again

become polluted en route to Hinkson Creek. Placement of detention and water quality BMPs at the point of concentrated flow outfalls to Hinkson Creek is the only way to ensure that all of the stormwater from that concentrated flow's contributing area is treated and detained.

Stormwater Conveyance Stabilization and Revegetation:
Within the area of interest the stormwater is conveyed towards Hinkson Creek through a combination of culverts, flumes, reinforced channels, and earthen channels. Throughout a field investigation conducted by A Civil Group, it was noted that substantial lengths of earthen channel, which comprise the majority of the conveyance length, are highly eroded and completely devoid of any vegetation. While the flumes and culverts do not offer any detention, infiltration, or opportunity for settlement of particulates, they do not worsen the quality of the storm water. The highly eroded channels, however; do little to slow the storm water as well as contributing additional sediment through continued scouring of the already worn thalweg and channel side slopes. Because these channels are so highly eroded and because they convey the majority of the stormwater from within the area of interest, they currently serve as a potential detriment to the quality of the stormwater, however; they have the opportunity to serve as a BMP. Within the area of interest, the restabilization of 8,920 linear feet of highly eroded channel has been proposed.

Native grass swales are inexpensive to construct and maintain in comparison with other stormwater BMPs. The native grass swales improve water quality through infiltration, sedimentation and biological uptake, reduce the total volume of water at the outfall, offer detention by slowing the flow velocity, and offer an aesthetic benefit. (EPA-841-B-05-004) The use of turf reinforcement mats beneath the channels offers protection against the heavier rainfall events and the channels could be outfitted with intermittent check dams to further promote detention, infiltration, and sediment deposition.

Selected BMP Information

Extended Wet Detention: Extended wet detention basins (EWDBs) are designed to collect stormwater runoff in a permanent pool and a temporary water quality pool during storm events (Urban Drainage and Flood Control District, 2005). The primary removal mechanism is settling as stormwater runoff resides in this pool, but pollutant uptake, particularly of nutrients, also occurs to some degree through biological and chemical activity in the pond (California Stormwater Quality Association, 2003). In addition, a temporary detention volume is provided above this permanent pool to capture the water quality volume and enhance sedimentation (Urban Drainage and Flood Control District, 2005).

EWDBs are similar to extended dry detention basins (EDDBs) because they are designed to capture runoff from frequently occurring storms. However, EWDBs differ from EDDBs because the influent water mixes with the permanent pool water as it rises above the permanent pool level. The surcharge captured volume above the permanent pool is then released over 40 hours (Urban Drainage and Flood Control District, 2005). EWDBs are also similar in function to constructed wetlands, and differ primarily in having a greater average depth (California Stormwater Quality Association, 2003)

EWDBs can be very effective in removing pollutants, and, under the proper conditions, can satisfy multiple objectives, including water quality improvement, flooding and erosion protection, creation of wildlife and aquatic habitats, and recreational and aesthetic provision (Urban Drainage and Flood Control District, 2005) EWDBs can be used to improve stormwater runoff quality and reduce peak stormwater runoff rates and peak stages. An EWDB can be used to improve the quality of urban runoff from roads, parking lots, residential neighborhoods, commercial areas, and industrial sites, and is generally used to treat larger tributary areas than other best management practices or as follow-up treatment downstream of other BMPs. It can be used as an onsite BMP if the tributary area is sufficient to sustain a permanent pool. An EWDB works well in conjunction with other BMPs, such as upstream onsite source controls and downstream filter basins or wetland channels (Urban Drainage and Flood Control District, 2005).

Extended Wet Detention Basin Advantages:

- Because of the presence of the permanent wet pool, properly designed and maintained EWDBs can provide significant water quality improvement across a relatively broad spectrum of target constituents, including dissolved nutrients and many urban pollutants (California Stormwater Quality Association, 2003) (Urban Drainage and Flood Control District, 2005).
- Widespread application of EWDBs with sufficient capture volume and a 40-hour water quality pool drawdown can provide significant control of channel erosion and enlargement caused by changes to flow frequency relationships resulting from the increase of impervious cover in a watershed (California Stormwater Quality Association, 2003).
- If properly designed, constructed, and maintained, EWDBs can provide substantial aesthetic / recreational value and wildlife and wetlands habitat (California Stormwater Quality Association, 2003).
- EWDBs can easily be designed to incorporate flood control volumes.
- EWDBs can be used for larger tributary areas.

Extended Wet Detention Basin Disadvantages:

- The public can sometimes view EWDBs as a safety concern (California Stormwater Quality Association, 2003).
- Maintenance and sediment removal can be more difficult for EWDBs than it is for EDDBs because of the presence of the permanent pool. Possible additional maintenance concerns with an EWDB include floating litter, scum and algal blooms, nuisance odors, and aquatic plants blocking outlet works (Urban Drainage and Flood Control District, 2005).
- EWDBs require a permanent pool to function properly (California Stormwater Quality Association, 2003). These facilities may not be feasible in some location because of insufficient tributary area to maintain

the permanent pool.

- If not properly designed and maintained, the permanent pool may attract large numbers of geese, which can add to the nutrient and fecal coliform loads entering and leaving the facility (Urban Drainage and Flood Control District, 2005).
- In general, EWDBs can be more expensive and take more land than other BMPs (Besides EDDBs).

Extended Dry Detention: Extended dry detention basins (EDDBs) are designed to detain the stormwater water quality volume for 40 hours to allow particles and associated pollutants to settle (Urban Drainage and Flood Control District, Denver, Colorado, 2005). Unlike extended wet detention basins, these facilities do not maintain a permanent pool between storm events (California Stormwater Quality Association, 2003). However, EDDBs may develop wetland vegetation and sometimes shallow pools in the bottom portions of the facilities that can enhance the basin's soluble pollutant removal efficiency through maintenance removal and biological uptake (Urban Drainage and Flood Control District, Denver, Colorado, 2005).
EDDBs can be used to improve stormwater runoff quality and reduce peak stormwater runoff rates and peak stages. If these basins are constructed early in the development cycle, they can also be used to trap sediment from construction activities within the tributary drainage area. The accumulated sediment, however, will need to be removed after upstream land disturbances cease and before the basin is placed into final long-term use.

EDDBs can be used to improve the quality of urban runoff coming from roads, parking lots, residential neighborhoods, commercial areas, and industrial sites, and are generally used for site or regional treatment (Urban Drainage and Flood Control District, Denver, Colorado, 2005). They can be used as an onsite BMP that works well with other BMPs, such as upstream onsite source controls and downstream infiltration/filtration basins or wetland channels. If desired, additional volume can be provided in an EDDB for flood control benefits (Urban Drainage and Flood Control District, Denver, Colorado, 2005).

Extended Dry Detention Basin Advantages:

- Because of the design, extended detention basins are relatively easy and inexpensive to construct and operate (California Stormwater Quality Association, 2003).
- EDDBs can provide substantial capture of sediment and the pollutants adsorbed onto the surfaces of the particles (California Stormwater Quality Association, 2003).
- Widespread application of EDDBs with sufficient capture volume can provide significant control of channel erosion and enlargement caused by changes to flow frequency relationships resulting from the increase of impervious cover in a watershed (California Stormwater Quality Association, 2003).
- EDDBs can be designed to provide other benefits, such as recreation and open space opportunities, in addition to reducing peak runoff rates and improving water quality (Urban Drainage and Flood Control District, Denver, Colorado, 2005) (Metropolitan Nashville – Davidson County, 2000).

Extended Dry Detention Basin Disadvantages:

- EDDBs have only moderate pollutant removal when compared to some other structural stormwater practices, and they are relatively ineffective at removing soluble pollutants (California Stormwater Quality Association, 2003).
- Dry ponds can potentially detract from the value of a home because of the adverse aesthetics of dry, bare areas and inlet and outlet structures; however, wet ponds can increase property values (California Stormwater Quality Association, 2003)

Native Vegetation Swale: (Information taken from the City of Columbia Stormwater Management and Water Quality Manual) Native grass swales are broad, shallow, natural or constructed channels with a dense native grass stand covering the side slopes and channel bottom. They slowly convey stormwater runoff and, in the process promote infiltration, reduce flow velocities, and pretreat stormwater. Native grass swales can have either parabolic or trapezoidal cross sections and are intended to be used as a substitute for traditional pipe systems to convey roadway, parking lot and other site drainage.

Native grass swales can serve as part of a stormwater drainage system and can replace curb and gutter storm sewer systems. Native grass swales promote infiltration and also help settle many particulate contaminants by slowing flow velocities. Native grass swales are intended to treat an area of approximately five acres or less to maintain their effectiveness. Larger drainage areas produce too much water for the swale to be effective. (City of Columbia Stormwater Management and Water Quality Manual)

Native Vegetation Swale Advantages:

- Constructed less expensively and maintained more easily than underground pipe stormwater conveyance systems.
- Improve water quality by infiltration, sedimentation and biological uptake.
- Reduce total volume of runoff to surrounding streams and rivers.
- Minimize erosion by slowing the conveyance of stormwater.

Native Vegetation Swale Disadvantages:

- May require irrigation to establish proper vegetative cover for controlling erosion and reducing pollution in the channel.
- May require the use of erosion control or turf reinforcement mats on slopes prior to full establishment of vegetation.
- May not be feasible to implement after development has occurred.
- Area requirements can be excessive for highly developed sites.
- Require relatively large areas, proper sloping, and connection with other conveyance components.
- The reduced velocity of stormwater conveyance through a native vegetation swale may increase the risk of flooding.

Bioswale: (Information taken from the City of Columbia Stormwater Management and Water Quality Manual) Bioswales are broad, shallow, natural, or constructed channels with a dense stand of vegetation covering the side slopes and channel bottom. They slowly convey stormwater runoff, and in the process promote infiltration, reduce flow velocities, and pretreat stormwater. Bioswales can have either parabolic or trapezoidal cross-sections. Bioswales include an engineered soil matrix and an under-drain system.

Bioswale Advantages:

- Constructed less expensively and maintained more easily than underground pipe stormwater conveyance systems.
- Underdrain system allows swale to remain dry most of the time.
- Bioswales improve water quality primarily by filtration through an engineered media. Pollutants are also removed through biological uptake.
- Bioswales can reduce the total volume of excess urban runoff to surrounding streams and rivers.
- Bioswales minimize stream erosion by slowing the conveyance of water.
- Bioswales enhance biological diversity and create beneficial habitat between upland and surface waters.

Bioswale Disadvantages:

- Bioswales may not be feasible to implement after development has occurred.
- Area requirements can be excessive for high-density development sites.
- The reduced velocity of stormwater conveyance through a bioswale may increase the risk of flooding.

Turf Swales: (Information taken from the City of Columbia Stormwater Management and Water Quality Manual) Turf grass swales are broad, shallow, natural, or constructed channels with a dense stand turf grass covering the side slopes and channel bottom. They slowly convey stormwater runoff, and in the process promote infiltration, reduce flow velocities, and pretreat stormwater. Turf grass swales are intended to be used as a substitute for traditional pipe systems to treat and convey roadway drainage.

Turf Swale Advantages:

- Constructed less expensively and maintained more easily than underground pipes.
- Improve water quality by infiltration, sedimentation and biological uptake.
- Reduce total volume of runoff to surrounding streams and rivers.
- Minimize erosion by slowing the conveyance of water

Turf Swale Disadvantages:

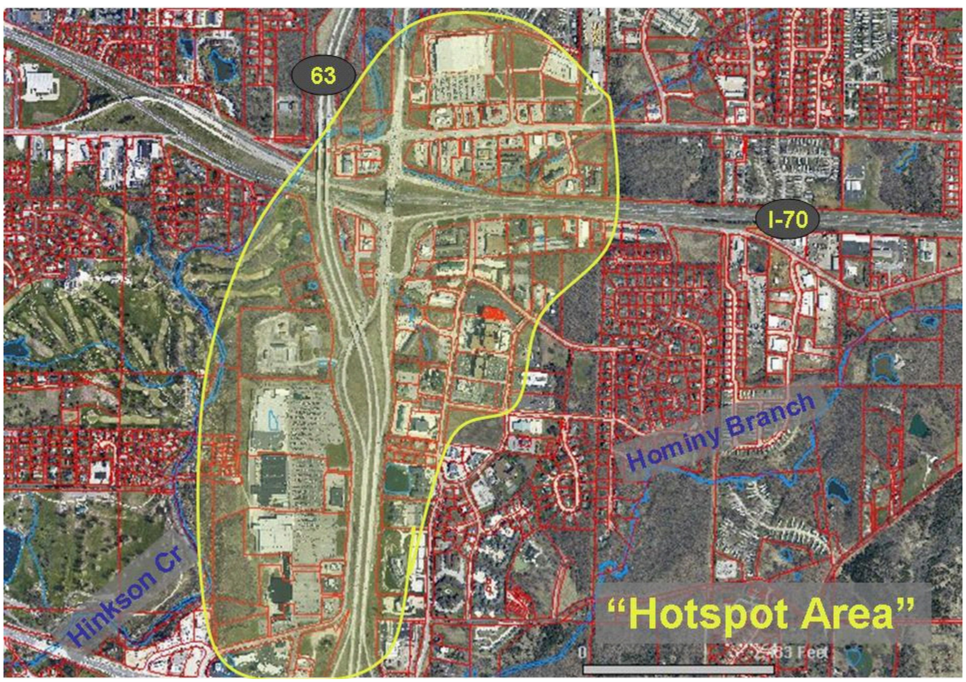
- May require irrigation to maintain proper vegetative cover for controlling erosion and reducing pollution in the channel.
- May not be feasible to implement after development as occurred.
- Require relatively large areas, proper sloping, and connection with other conveyance components.
- The reduced velocity of stormwater conveyance through a bioswale may increase the risk of flooding.

<u>SITE SPECIFIC INFORMATION:</u>

Area of Interest: The area of interest was chosen by the Missouri Department of Natural Resources as part of the Watershed Management Plan. The Watershed Management Plan was created through a grant for Hinkson Creek Watershed Restoration Project, funded by the Environmental Protection Agency.

Location: The area of interest (hotspot area) is comprised of the residential and commercial lots located in the general area of the I-70 and US Hwy-63 intersection. This area was chosen because it is adjacent to the beginning of the impaired section of Hinkson Creek.

Description: The area is fully developed and includes residential and commercial uses. The commercial uses include, but are not limited to: hotels, office, restaurants, convenience stores, medical buildings, big box retail, strip-mall retail, all associated paved parking area, and street, highway, and interstate pavement and infrastructure.



Composite Curve Number: The composite curve number for the 354.53-acre area was calculated to be 92.52 with 79.89 % impervious cover.

Water Quality Volume: The water quality volume for the entire area is 1,355,842 cubic feet.

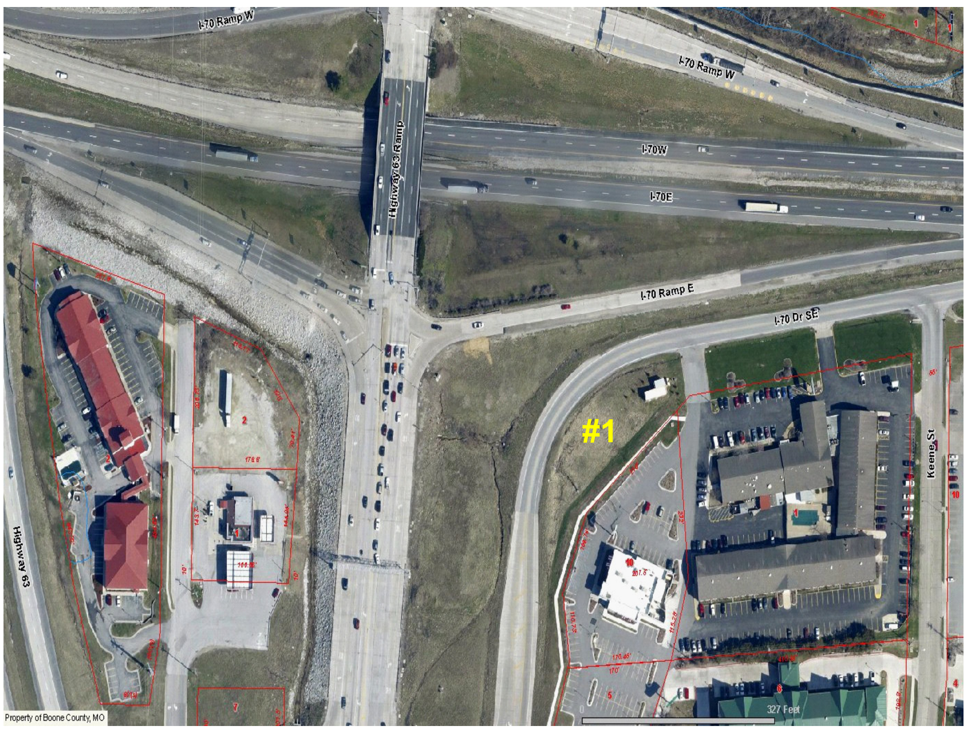
1-year, 2-year, 10-year, 100-year Flow Rates: 1150 cfs, 1380 cfs, 2155 cfs, 3100 cfs.

Site #1

Location: BMP site #1 is located on MODOT right-of-way, southeast of I-70 Drive SE, northeast of and adjacent to the TGI Friday's restaurant.

Description: This BMP site consists of a fairly flat, open, turf-grass area. The proposed BMP would reside between the outfall of a stormwater culvert from the southeast and the invert of a stormwater culvert to the west. The BMP site is bordered by electrical utilities on the east side and a sanitary sewer line on the south. Site #1 discharges to sites #6 and #10.

Property Owner: Missouri Department of Transportation



Contributing Area Details: The site specific contributing area to site #1 is 11.0 acres and contains seven buildings with uses including hotel, office and restaurant. The site also receives stormwater runoff from the I-70 eastbound onramp, and I-70 Drive SE.

Total Area Treated by Site: 11.0 acres (3.1 % of total hotspot area)

Composite Curve Number: 94 (85 % impervious cover)

Water Quality Volume: 44,566 cubic feet (3.29 % of hotspot area total)

1-year, 2-year, 10-year, 100-year Flow Rates: 36 cfs, 44 cfs, 68 cfs, 98 cfs

Flow Distance / Conveyance Network to Hinkson Creek: 1,640 linear feet of earthen channel, reinforced channel, and culverts.

Area Available and Proposed BMP: Approximately 7,000 square feet with 3 feet of elevation drop across the site. The proposed BMP for this site is a vegetated extended wet detention basin. Should a permanent pool of water be undesirable at this location, a vegetated extended dry basin may be substituted with a minor loss in water quality benefits.

Constructability: Access to site one is easily attained from either I-70 Drive SE or from the business lots immediately to the east. Site one has ample room for delivery and staging of construction equipment. This site should only require minimal traffic control during construction. I-70 Drive SE is a MODOT road, as such, work on site one will require a MODOT right-of-way permit. MODOT could potentially require the installation of a guardrail at this site as well.

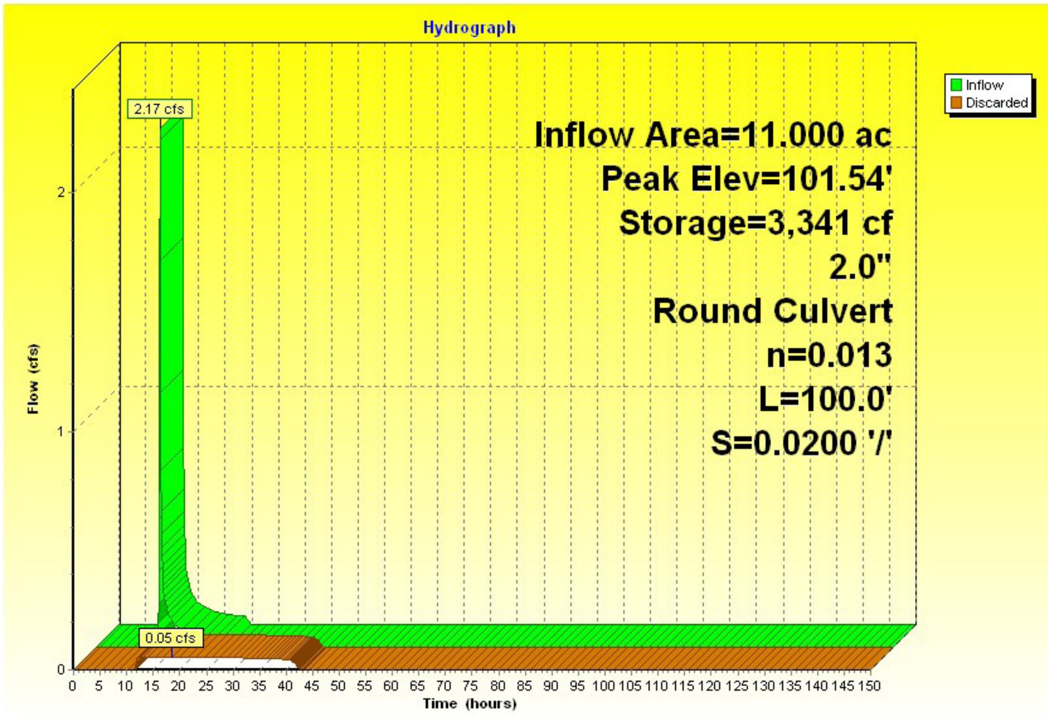
BMP Benefits: Detention, infiltration, pollutant uptake. Based on a preliminary design this extended wet detention basin can offer a 99.2 % reduction in the 1" 24-hour storm peak flow rate and a 97.7% reduction in the ½" 24-hour storm peak flow rate (see hydrographs).

Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 1.41%

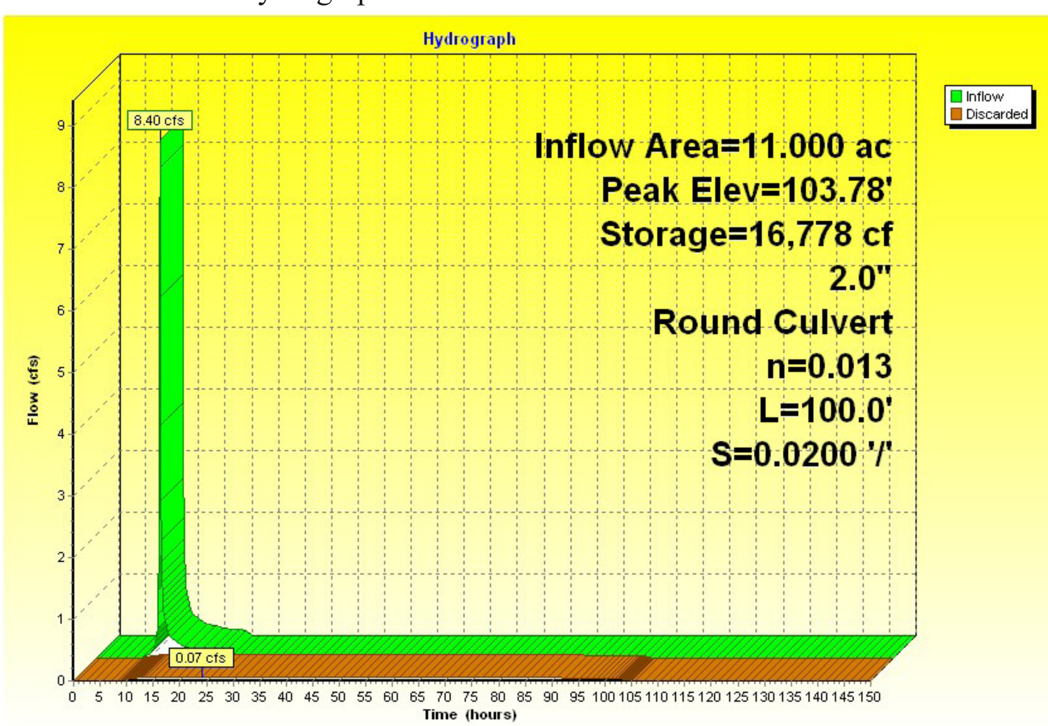
BMP Construction Cost: Estimated construction cost is $ 15,437

15-year Maintenance Cost: Estimated 15-year maintenance cost is $9,473

Site #1 Detention Hydrograph – ½” 24-Hour Storm Event



Site #1 Detention Hydrograph – 1” 24-Hour Storm Event

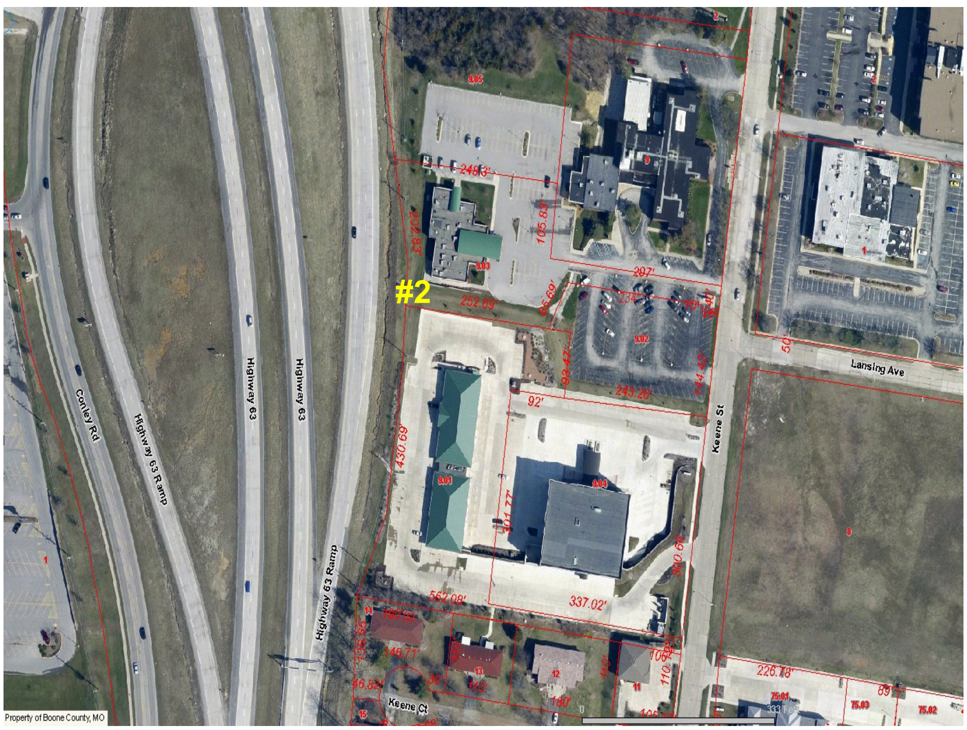


<u>Site #2</u>

Location: Site #2 is located within the MODOT right-of-way on the east side of the US Hwy-63 north bound offramp, in alignment with the western terminus of Lansing Avenue.

Description: Site #2 consists of an existing earthen channel, approximately 1,830 feet in length. The channel runs north / south parallel to the adjacent offramp and is sharply cut and highly eroded. The channel runs adjacent to an electric utility line. Site #2 discharges to site #10.

Property Owner: Missouri Department of Transportation



Contributing Area Details: The earthen channel in site #2 receives stormwater from approximately 1.0 acre consisting of drainage from US Hwy-63 and the rear yards of adjacent office sites.

Total Area Treated by Site: 1.05 acres (0.3 % of total hotspot area)

Composite Curve Number: 89 (70% impervious area)

Water Quality Volume: 3,544 cubic feet (0.26 % of hotspot area total)

1-year, 2-year, 10-year, 100-year Flow Rates: 3 cfs, 3.7 cfs, 6 cfs, 8.9 cfs.

Flow Distance / Conveyance Network to Hinkson Creek: 3,760 linear feet of earthen channel, reinforced channel, and culverts.

Area Available and Proposed BMP: The existing condition of the 1,830 linear feet of earthen channel is a detriment to the quality of the stormwater conveyed through it. The channel should be re-graded to a 6'-wide flat bottom trapezoidal channel, reinforced with turf reinforcement mat, and vegetated with native vegetation. Should native vegetation be undesirable the channel should be regraded, armored with turf reinforcement mat and vegetated with turf grass.
Constructability: Site two is most easily accessed via the shoulder of the US-63 northbound offramp. The shoulder should offer reasonable space for loading and unloading of equipment. Equipment could be stored on the commercial lots to the east. This site will require substantial traffic control due to it's proximity to US-63. Work on site two will require a MODOT right-of-way permit. MODOT could potentially require the installation of a guardrail at this site as well.
BMP Benefits: The reinforced native vegetation swale will slow the flow velocity promoting infiltration and offering detention, as well as settling of particulates. The vegetation will decrease the total quantity of stormwater and offer pollutant uptake. Restabilization of this channel has been calculated to decrease flow velocities by 55.2 %.
BMP Construction Cost: Estimated construction cost is $36,149
15-year Maintenance Cost: Estimated 15-year maintenance cost is $8,134

Site #3
Location: Site #3 is located adjacent to northbound US Hwy-63, immediately adjacent to the Missouri Employer's Mutual property.
Description: Site #3 consists of 1,380 linear feet of earthen channel. The channel runs north / south parallel to Hwy-63. The channel is moderately eroded with very sparse vegetation. Site #3 discharges to site #5.
Property Owner: Missouri Department of Transportation / Missouri Employers Mutual

Contributing Area Details: The earthen channel on site #3 receives stormwater from 17.01 acres. The 17.01 acres contains 7 buildings with office, residential care, and single family detached housing uses. The site also receives the discharge from a large pond located adjacent to the Missouri Employer's Mutual building.

Total Area Treated by Site: 17.01 acres (4.8 % of total hotspot area)

Composite Curve Number: 92 (82% impervious cover)

Water Quality Volume: 66,651 cubic feet (4.92 % of hotspot area total)

1-year, 2-year, 10-year, 100-year Flow Rates: 53.8 cfs, 65 cfs, 102.6 cfs, 148.5 cfs

Flow Distance / Conveyance Network to Hinkson Creek: 3,900 linear feet consisting of earthen channel and culverts.

Area Available and Proposed BMP: The 1,380 linear feet of channel is proposed for restabilization and revegetation. The channel should be graded to a 6'-wide flat bottom trapezoidal channel, reinforced with turf reinforcement mat and vegetated with native vegetation. Should native vegetation be undesirable at this location, turf grass may substitute with losses in water quality benefits.

Constructability: Site three can be accessed from either the shoulder of US-63 or the commercial lots to the east. Site three offers substantial room for equipment and material storage. Should site three be accessed from the shoulder of US-63, traffic control devices will be necessary. Work on site three will require a MODOT right-of-way permit. MODOT could potentially require the installation of a guardrail at this site as well.

BMP Benefits: The reinforced native vegetation swale will slow the flow velocity promoting infiltration and offering detention, as well as settling of particulates. The vegetation will decrease the total quantity of stormwater and offer pollutant uptake. Restabilization of this channel has been calculated to decrease flow velocities by 42.7 %.

Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 3.90%

BMP Construction Cost: Estimated construction cost is $34,327.

15-year Maintenance Cost: Estimated maintenance cost is $13,724.

<u>Site #4</u>

Location: Site #4 consists of the vegetated parking lot islands within the Conley Road shopping complex.

Description: Site #4 consists of approximately 3.40 acres of paved parking area and drive aisle with intermittent vegetated parking lot islands.

Property Owner: Broadway Crossings II

Contributing Area Details: Site #4 receives flow generally from the adjacent parking and drive aisle areas as well as portions of the developed lots to the east. The site decreases in elevation from east to west.

Composite Curve Number: 98

Total Area Treated by Site: 3.40

1-year, 2-year, 10-year, 100-year Flow Rates: 12.51 cfs, 14.65 cfs, 21.90 cfs, 30.82 cfs

Flow Distance / Conveyance Network to Hinkson Creek: Approximately 1100 linear feet of surface flow over pavement followed by culverts to the outlet at Hinkson Creek.

Water Quality Volume: 14,842 cubic feet (1.09% of hotspot total)

Area Available and Proposed BMP: The 3.4 acres of site #4 contains several parking lot islands that are currently mulched and vegetated with shrubs and small trees. The vegetated parking lot islands currently serve as a BMP in the sense that they treat and detain or infiltrate the rainfall that lands directly on them, however; because they are curbed islands they do not receive drainage from any additional contributing area. The grading of the parking area as it currently exists conveys the greater concentration of stormwater down the center of the drive aisles, away from the curbed islands. Even with the use of structural soils, the curbs would have to be removed and the majority of the parking lot pavement removed, regraded, and repaved to promote the flow of stormwater to these islands. Because this area is already fully developed and the parking lot and islands constructed, this proposal is considered infeasible due to extreme cost and coordination with property owners.

Constructability: Site four resides completely on private property and is not in close proximity to a high-speed roadway. As such, the entire site is available for equipment loading and unloading as well as equipment and material storage. These operations as well as closure of the parking area would have to be coordinated with the property owner.

BMP Benefits: The rain gardens proposed for this site would offer stormwater retention and infiltration, as well as nutrient uptake by the vegetation within these islands.

BMP Construction Cost: Approx. $463,288

15-year Maintenance Cost: $7,500

Site #5

Location: Site #5 is located north of Trimble Road, west and adjacent to the Conley Road shopping complex. Site #5 resides in very close proximity to Hinkson Creek.

Description: Site #5 consists of several undeveloped lots that have been recently graded to a very minor slope from east to west. The site receives only minor surface flow from the paved areas to the south and east and the site discharges to a swale along its western edge. The swale currently conveys stormwater to a newly constructed detention facility at the north end of the site.

Property Owner: Broadway Crossings II

Contributing Area Details: The area draining to site #5 consists of overland flow from the commercial development to the east and south, as well as the discharge of two large culverts from the same development.

Composite Curve Number: 94

Total Area Treated by Site: 27.48 acres

1-year, 2-year, 10-year, 100-year Flow Rates: 92.55 cfs, 110.43 cfs, 170.58 cfs, 244.0 cfs

Flow Distance / Conveyance Network to Hinkson Creek: 1,520 lf of earthen channel to a detention basin, followed by discharge through an outlet structure to Hinkson Creek.

Water Quality Volume: 111,374 cubic feet (8.21% of hotspot total)
Area Available and Proposed BMP: Site #5 currently consists of a large, fairly flat turf grass field, all of which drains to a newly constructed detention basin via an earthen swale. Any structural stormwater BMP placed in this area is likely to be altered or removed entirely during continued development of this area, and new development of this area should be subject to the City of Columbia Storm Water Ordinance, requiring treatment and detention. Because the earthen swale is located near the rear (west side) of these lots, the proposal to regrade the earthen swale and convert it to a bioswale is likely the only option for construction of a BMP that will not require alteration or removal as the site continues to develop. Should the construction of a bioswale within the channel be undesirable, the channel should still be regraded, reinforced with turf reinforcement mat, vegetated, and intermittent rock checks should be place along its length to decrease flow velocity and promote sedimentation and infiltration.
Constructability: Site five is very easily accessible from either Trimble Road or from the paved area immediately east of site five and west of the adjacent commercial buildings. Site five is not in close proximity to any high-speed roadways and will not require any traffic control during equipment transport or construction. Site five also has ample space for equipment and material storage.
BMP Benefits: The bioswale offers improved water quality primarily through filtration through an engineered media. Pollutants are also removed through biological uptake. The bioswale will also offer a net reduction in stormwater discharged to Hinkson Creek (City of Columbia Stormwater Management and Water Quality Manual). Regrading of the swale and establishment of the bioswale vegetation should offer a 30% reduction in channel velocity.
BMP Construction Cost: Approx. $73,804
15-year Maintenance Cost: $16,606

Site #6

Location: Site #6 is located north and west of I-70 Drive SE, east of the US Hwy-63 connector, and south of the I-70 eastbound onramp.

Description: Site #6 consists of a large turf grassed area with sharply cut and highly eroded channels approaching from the south and from the east. The BMP site is proposed to reside between the outfall of a culvert from the east and the invert of a culvert to the west, as well as the channels to the east and south. The BMP area is bordered by a sanitary sewer line in the south-central area as well as a water line on the southern end. Site #6 receives flow from site #1 and discharges to site #10.

Property Owner: Missouri Department of Transportation

Contributing Area Details: The site and earthen channels receive stormwater from portions of I-70 Drive SE as well as the right-of-way upon which the site resides. This site also receives all of the discharge from site #1. The site specific contributing area for site #6 is 1.41 acres.

Total Area Treated by Site: 15.99 acres (4.51 % of total hotspot area)

Composite Curve Number: 94 (85% impervious)

Water Quality Volume: 64,819 cubic feet (4.78 of hotspot total)

1-year, 2-year, 10-year, 100-year Flow Rates: 52.0 cfs, 64.3 cfs, 99.3 cfs, 142.0 cfs.

Flow Distance / Conveyance Network to Hinkson Creek: 1,500 linear feet of culvert, earthen channel, and reinforced channel.

Area Available and Proposed BMP: There is approximately 33,000 square feet available for a detention structure capable of receiving stormwater from the earthen channels from the east and south as well as receiving stormwater from the eastern culvert. The area is suitable for placement of an extended wet detention basin at the outfall of the eastern culvert. Should a permanent pool of water be undesirable at this location, a vegetated extended dry basin may be substituted with a loss in water quality benefits. Along with the detention basin, there is approximately 1,070 linear feet of highly eroded, sharply cut channel on the site that should be regraded to a 6'-wide flat bottom trapezoidal channel, reinforced with turf reinforcement mat, and vegetated with native plants and grasses. Should native vegetation be undesirable, turf grass may substitute with decreases in water quality benefit.

Constructability: Site six will be most easily accessed from the north and west shoulders of I-70 Drive SE. Traffic control will be required during equipment transport, but once on site, no traffic control should be necessary. The site offers substantial room for material and equipment storage within the project area. Work on site six will require a MODOT right-of-way permit. The possibility does exist that MODOT would require the installation of a guardrail at this site.

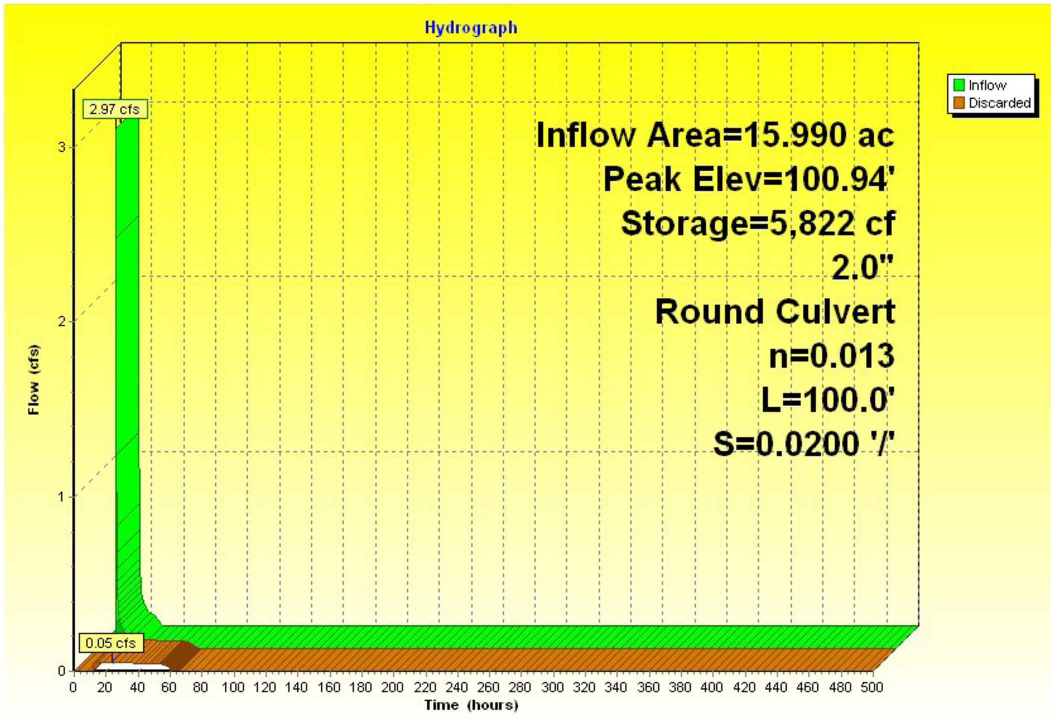
BMP Benefits: The extended wet detention basin will offer detention, infiltration, and pollutant uptake. Based on a preliminary design this extended wet detention basin can offer a 99.5 % reduction in the 1" 24-hour storm peak flow rate and a 98.3% reduction in the ½" 24-hour storm peak flow rate (see hydrographs). The reinforced native vegetation swale will slow the flow velocity promoting infiltration and offering detention, as well as settling of particulates. The vegetation will decrease the total quantity of stormwater and offer pollutant uptake. Restabilization of this channel has been calculated to decrease flow velocities by 42.9 %.

Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 4.09%

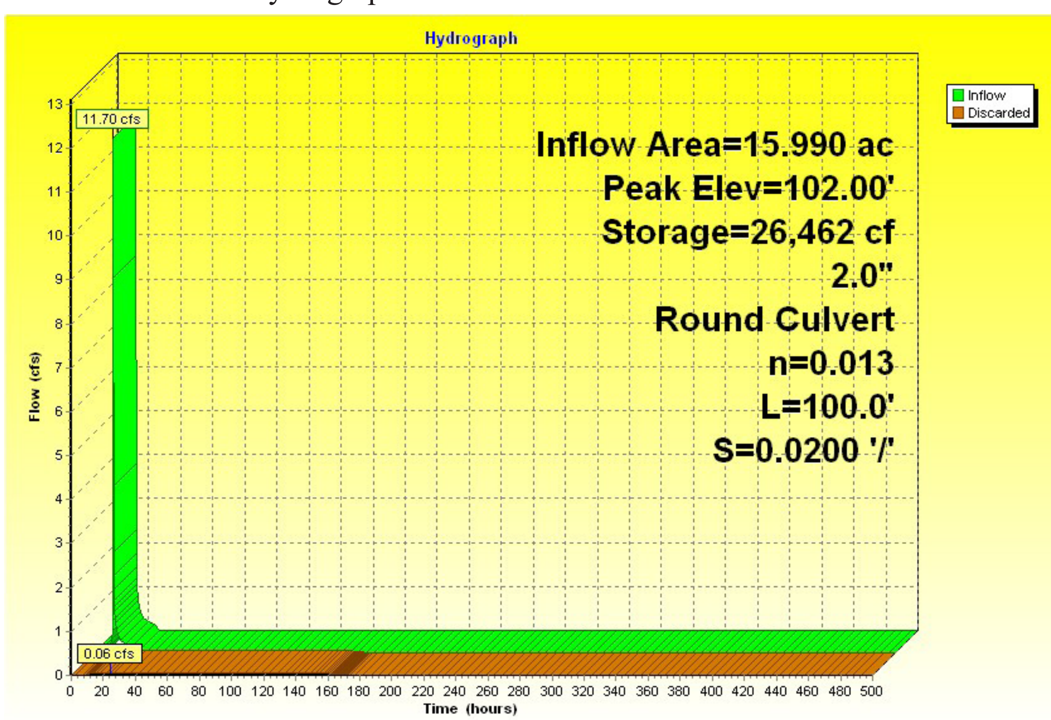
BMP Construction Cost: The estimated construction cost is $82,334

15-year Maintenance Cost: The estimated maintenance cost is $24,525

Site #6 Detention Hydrograph – ½” 24-Hour Storm Event



\Site #6 Detention Hydrograph – 1” 24-Hour Storm Event



Site #7

Location: Site #7 is located east of the US Hwy-63 northbound onramp and north-northwest of and adjacent to Home Depot.

Description: The site consists of a large turf-grass open area fairly flat on the east half, then dropping rather quickly towards the northwest corner. The northwest corner contains the outfall of two large culverts and a very broken and semi-vegetated concrete flume. This BMP area is bordered by a sanitary sewer line to the west and a water line to the east. Site #7 does not receive water from or discharge to any other BMP sites.

Property Owner: Home Depot USA, Inc. / Robert J. Tull et al, Trustee

Contributing Area Details: The contributing area to site #7 includes 18 buildings with single family detached residential, big box retail, mixed retail, restaurant, and bank uses. The site specific contributing area for site #7 is 45.70 acres.

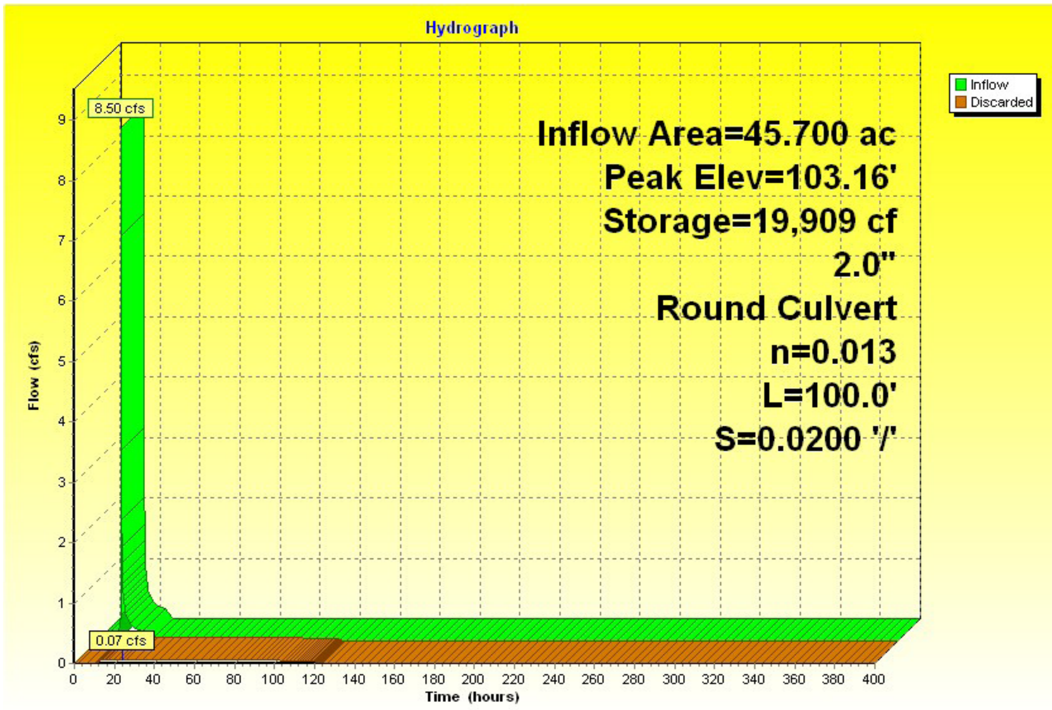
Total Area Treated by Site: 45.70 acres (12.89 % of total hotspot area)

Composite Curve Number: 94 (85 % impervious area)

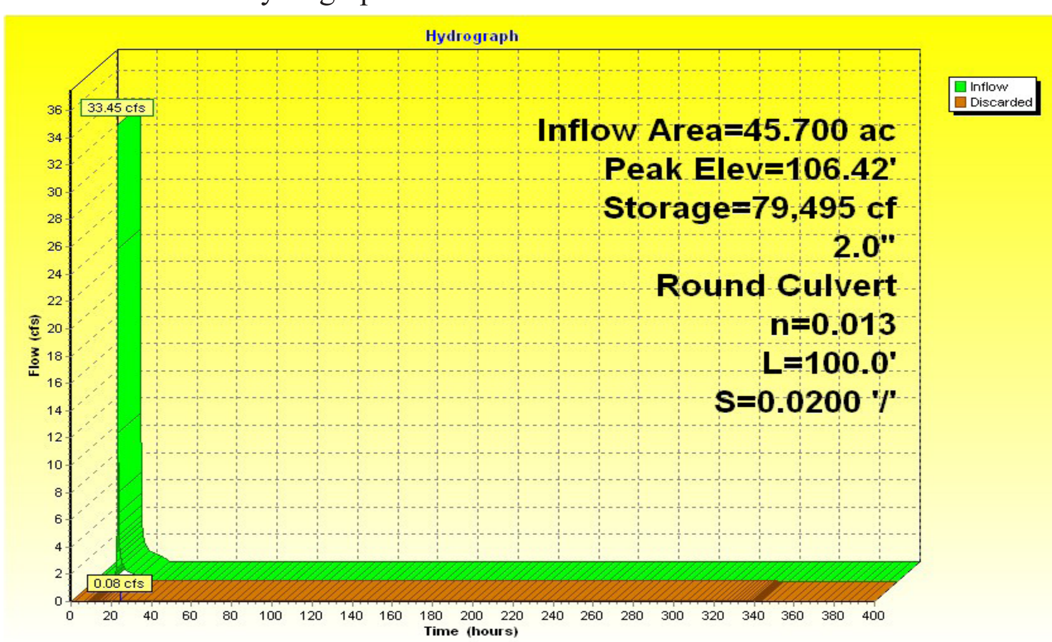
Water Quality Volume: 185,227 cubic feet (13.66 % of hotspot total)

1-year, 2-year, 10-year, 100-year Flow Rates: 147.7 cfs, 183.6 cfs, 283.7 cfs, 405.8 cfs.
Flow Distance / Conveyance Network to Hinkson Creek: 240 linear feet of earthen channel.
Area Available and Proposed BMP: An extended wet detention basin should be constructed on 25,000 square feet of the BMP site. The basin should intercept the flows from the two large culverts that discharge at the northwest corner of the site and the outfall of the proposed basin should reside just downstream from the location of the current outfall of the existing culverts. Should a permanent pool of water be undesirable at this location, a vegetated extended dry basin may be substituted with a loss in water quality benefits.
Constructability: Site seven will be most easily accessed from Penn Terrace, immediately south of the project site. Because Penn Terrace receives so little traffic, only minimal traffic control will be necessary, if at all. Site seven offers plenty of space for material and equipment storage and handling.
BMP Benefits: The extended wet detention basin will offer detention, infiltration, and pollutant uptake. Based on a preliminary design this extended wet detention basin can offer a 99.8 % reduction in the 1" 24-hour storm peak flow rate and a 99.2% reduction in the ½" 24-hour storm peak flow rate (see hydrographs).
Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 10.01%
BMP Construction Cost: Estimated construction cost is $73,854.
15-year Maintenance Cost: Estimated maintenance cost is $22,617

Site #7 Detention Hydrograph – ½" 24-Hour Storm Event



Site #7 Detention Hydrograph – 1" 24-Hour Storm Event



Site #8

Location: Site #8 is located east of site #7, between Penn Terrace and the residential neighborhood to the northeast.

Description: Site #8 consists of a low lying turf-grass open area. The site breaks from the south and from the north creating a large swale formation that ultimately drains to the northwest. The site is bordered by sanitary lines, electrical lines, and water lines to the northeast and north west, and is bordered by electric lines to the southwest. Site #8 does not receive water from or discharge to any other BMP sites.

Property Owner: Home Depot USA, Inc. / Tull Group, LLC.

Contributing Area Details: Site #8 receives stormwater from 18 single family detached residences, as well as the open area to the southwest. The site specific contributing area for site #8 is 3.63 acres.

Total Area Treated by Site: 3.63 acres (1.02 % of total hotspot area)

Composite Curve Number: 83 (38 % impervious cover)

Water Quality Volume: 7,081 cubic feet (0.52 % of hotspot total)

1-year, 2-year, 10-year, 100-year Flow Rates: 7.62 cfs, 10.21 cfs, 18.17 cfs, 28.17 cfs.

Flow Distance / Conveyance Network to Hinkson Creek: 430 linear feet of earthen channel.

Area Available and Proposed BMP: Site #8 is suitable for placement of a 5,000 square foot extended wet detention basin. The basin will drain to the northwest, following existing drainage patterns established within this area.

Constructability: Situated adjacent to site seven, site eight will be most easily accessed from Penn Terrace, immediately south of the project site. Because Penn Terrace receives so little traffic, only minimal traffic control will be necessary, if at all. Site eight offers plenty of space for material and equipment storage and handling.

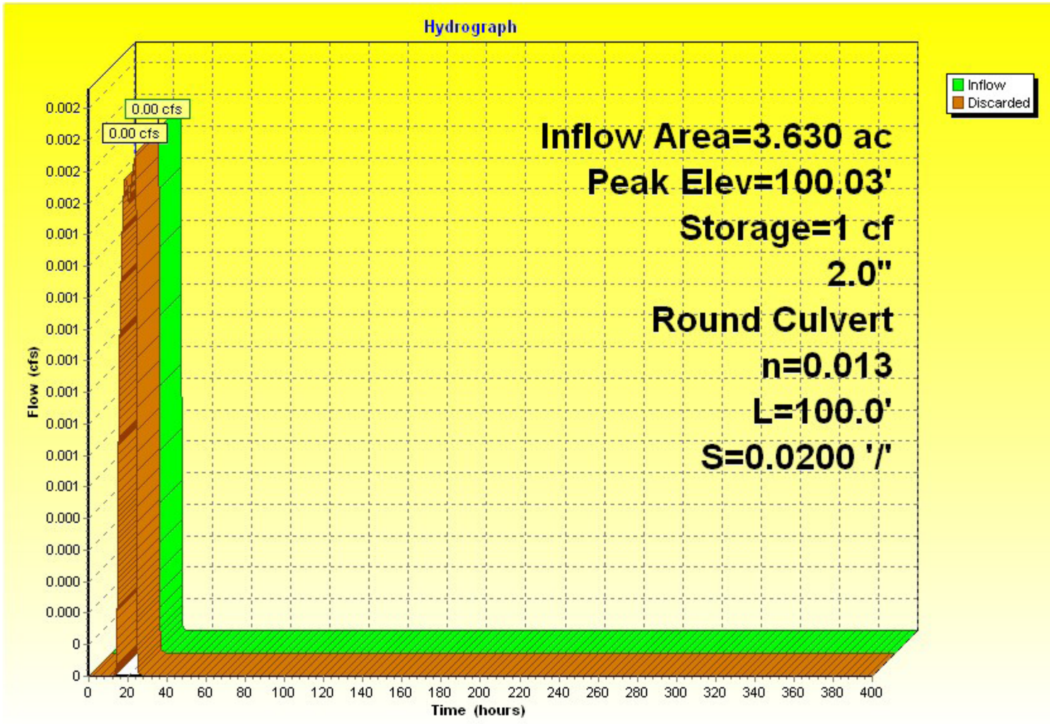
BMP Benefits: The extended wet detention basin will offer detention, infiltration, and pollutant uptake. Based on a preliminary design this extended wet detention basin can offer a 90.6 % reduction in the 1" 24-hour storm peak flow rate and due to the low curve number of the contributing area and the fact that the ½" storm modeled occurs over a 24-hour period, less than 0.01 cfs was seen entering the basin from the ½" event (see hydrographs). Should a permanent pool of water be undesirable at this location, a vegetated extended dry basin may be substituted with a loss in water quality benefits.

Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 0.57%

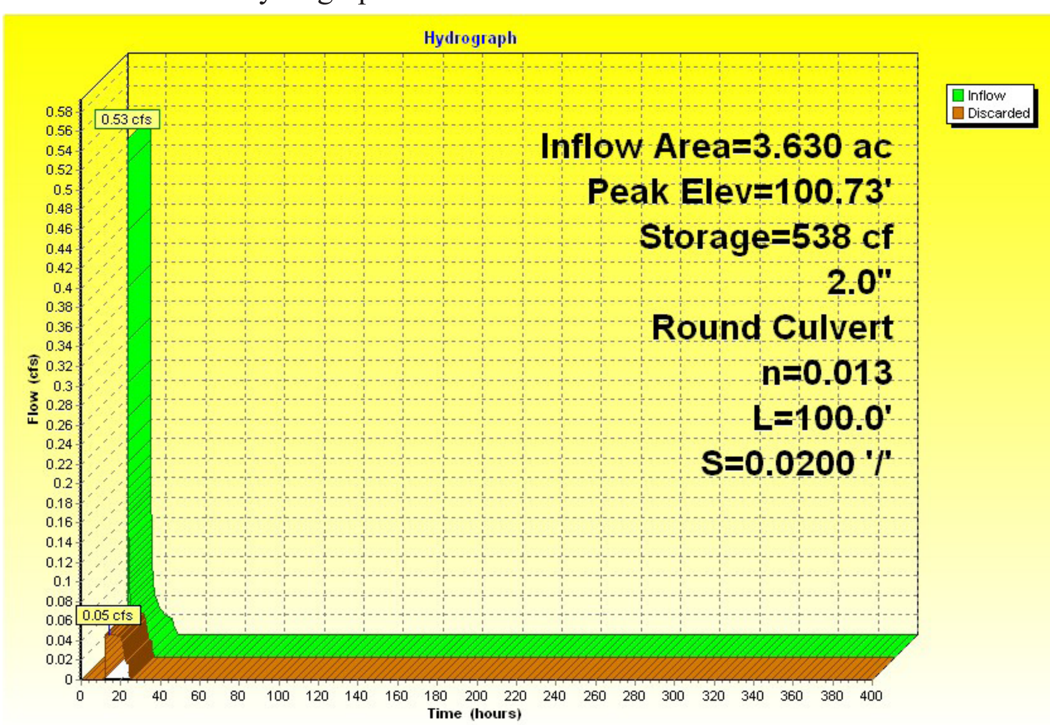
BMP Construction Cost: Estimated construction cost is $11,241

15-year Maintenance Cost: Estimated maintenance cost is $8,529

Site #8 Detention Hydrograph – ½" 24-Hour Storm Event



Site #8 Detention Hydrograph – 1" 24-Hour Storm Event



<u>Site #9</u>

Location: Site #9 is located adjacent to and west of the US Hwy-63 connector and extends from approximately 300 feet south of Clark Lane north to an existing concrete flume, along an existing earthen channel approximately 800 feet in length.

Description: Site #9 consists of the 800 foot length of earthen channel adjacent to the US Hwy-63 connector. The channel is moderately eroded, sparsely vegetated, and outfalls to a concrete flume on the north end, which conveys the stormwater north to Hinkson Creek. Site #9 does not receive water from or discharge to any other BMP sites.

Property Owner: City of Columbia / Missouri Department of Transportation

Contributing Area Details: Site #9 receives stormwater from the adjacent length of the US Hwy-63 connector. The site specific contributing area for site #9 is 1.87 acres.

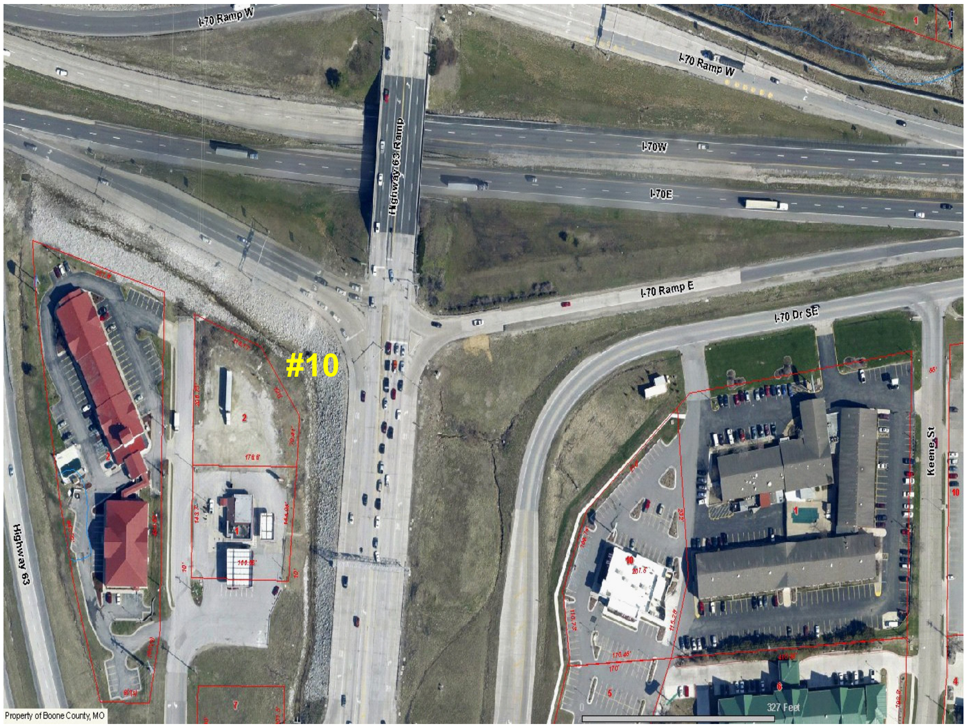
Total Area Treated by Site: 1.87 acres (0.53 % of total hotspot area)

Composite Curve Number: 85 (50% impervious cover)

Water Quality Volume: 4,638 cubic feet (0.34 % of hotspot total)

1-year, 2-year, 10-year, 100-year Flow Rates: 5.5 cfs, 6.7 cfs, 10.9 cfs, 16.0 cfs.
Flow Distance / Conveyance Network to Hinkson Creek: 170 linear feet of concrete flume.
Area Available and Proposed BMP: The 800 linear feet of earthen channel is proposed for restabilization and revegetation. The channel is to be graded into a 6'-wide flat bottom trapezoidal channel, lined with turf reinforcement mat and vegetated with native plants. Should native vegetation be undesirable at this location, turf grass may substitute with a loss in water quality benefit.
Constructability: Site nine will be most easily accessed from the east shoulder of the US-63 connector. Material and equipment loading and unloading as well as the construction process will require traffic control due to the immediate proximity of the adjacent high-speed roadway. Work on site nine will require a MODOT right-of-way permit and could require installation of a guardrail along the adjacent section of roadway.
BMP Benefits: The reinforced native vegetation swale will slow the flow velocity promoting infiltration and offering detention, as well as settling of particulates. The vegetation will decrease the total quantity of stormwater and offer pollutant uptake. Restabilization of this channel has been calculated to decrease flow velocities by 51.9 %.
BMP Construction Cost: Estimated construction cost is $15,724.
15-year Maintenance Cost: Estimated maintenance cost is $9,538.

<u>**Site #10**</u>
Location: Site #10 is located west of and adjacent to the US Hwy-63 connector and south of the I-70 eastbound offramp.
Description: Site #10 consists of approximately 1,000 linear feet of riprap reinforced channel. The channel has substantial depth (12' – 30') and rises sharply to the adjacent roadways on the west and north, as well as to the commercial sites to the west and south. The channel receives substantial amounts of stormwater from the culverts to the south and east. Site #10 receives the second greatest volume of stormwater in comparison with the other 18 examined BMP sites, surpassed only by site #15. Site #10 receives water from sites #1, #2, #6, #11, #12, #17, #18, and #19.
Property Owner: Missouri Department of Transportation



Contributing Area Details: The site specific contributing area for site #10 is 6.97 acres, consisting of 2 buildings with retail and convenience store uses. Site #10 also receives the discharge from sites 1, 2, 6, 11, 12, 17, 18, and 19.

Total Area Treated by Site: 100.53 acres (28.4 % of total hotspot area)

Composite Curve Number: 92 (80% impervious cover)

Water Quality Volume: 384,948 cubic feet (28.39% of hotspot total)

1-year, 2-year, 10-year, 100-year Flow Rates: 306.7 cfs, 384.1 cfs, 606.6 cfs, 877.9 cfs.

Flow Distance / Conveyance Network to Hinkson Creek: 1600 linear feet of reinforced channel.

Area Available and Proposed BMP: Because of the substantial volume of stormwater received by site #10, the channel should remain armored with riprap as it currently exists. The placement of multiple rock checks with very shallow grades on the heel and toe of each check will offer multiple storage volumes for detention. The channel could also be vegetated with woody vegetation, capable of withstanding the heavy flows. Should any portion of the channel downstream of site ten, as it approaches Hinkson Creek, reside in an unarmored and eroded state, that portion of channel should be examined and armoring considered. However; if that portion of unarmored channel appears to be fairly stable then the detention and velocity dissipation offered from the proposed work at site ten will decrease the likelihood of erosion in the downstream section and should offer the opportunity for increased vegetation establishment within the channel.

Constructability: Site ten will be most easily accessed from the commercial lots to the south and west, as well as the dead-end street that runs north-south and terminates on the south side of the west end of site ten. Although site ten resides many feet below the elevation of the adjacent eastbound I-70 offramp, traffic control will most likely be required because of the volume of traffic utilizing the offramp on a daily basis. Although difficult, tracked equipment should be capable of entering the site and working their way down the steep slopes to the channel thalweg. Should this not be an option, the use of a wheeled excavator, as opposed to tracked, could place material and perform the required grading from the top of the slope. Work within site ten will require a MODOT right-of-way permit. Most of the roadway adjacent to site ten already has a guardrail, however; MODOT could require all adjacent roadways to receive guardrail.

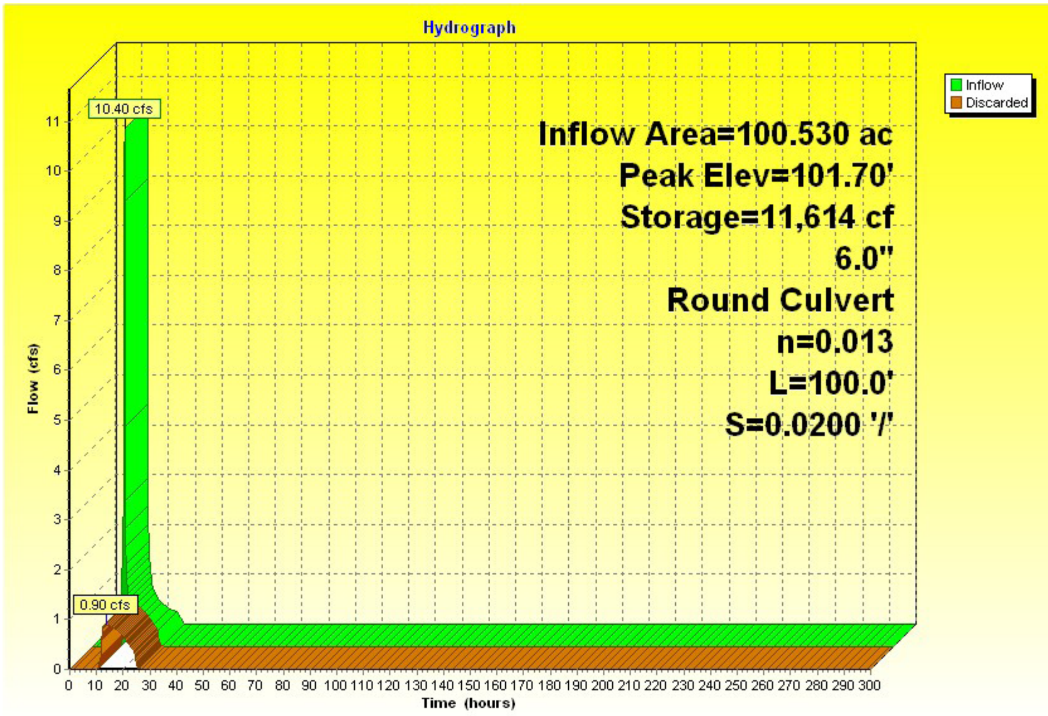
BMP Benefits: The intermittent rock checks will provide detention and promote infiltration as well as slowing the velocity within the channel. The woody vegetation will aid in slowing the velocity as well as pollutant uptake and shading to help minimize the temperature of the stormwater prior to discharge to Hinkson Creek. Detention provided by the intermittent rock checks along with the establishment of woody vegetation will offer a 97.7% reduction in the 1” 24-hour storm peak flow and a reduction of 91.3% of the ½” 24-hour storm peak flow (see hydrograph), as well as a 41% reduction in the peak velocity of the 1-year storm flow.

Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 9.99%

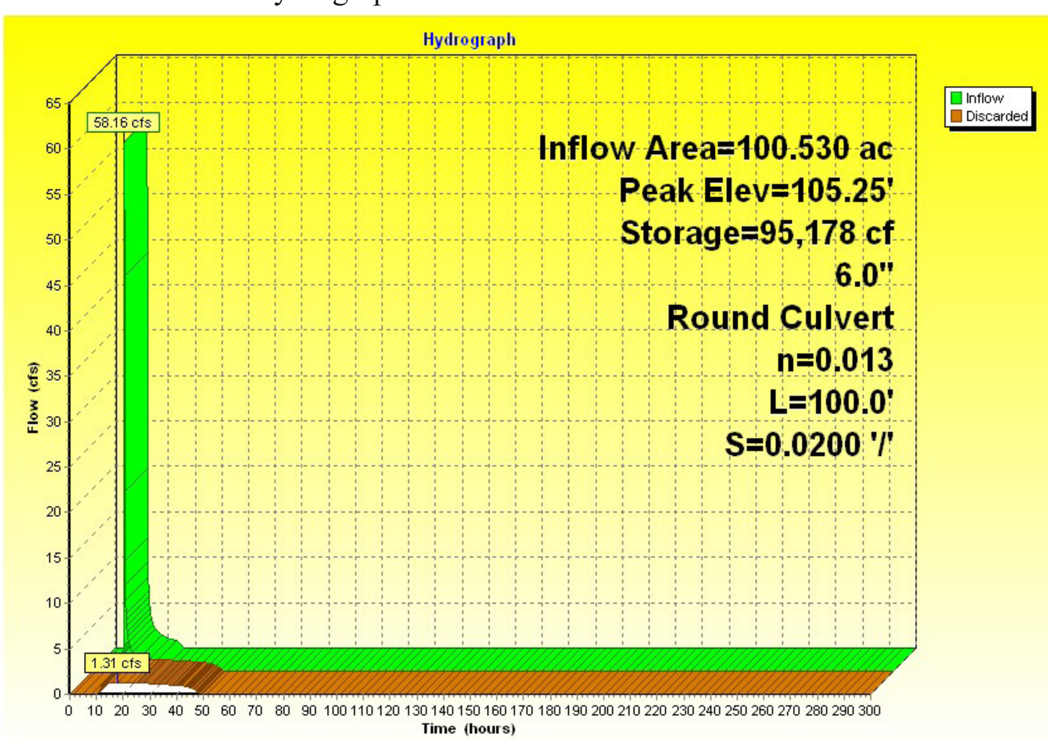
BMP Construction Cost: Estimated construction cost is $25,583.

15-year Maintenance Cost: Estimated maintenance cost is $11,756.

Site #10 Detention Hydrograph – ½" 24-Hour Storm Event



Site #10 Detention Hydrograph – 1" 24-Hour Storm Event

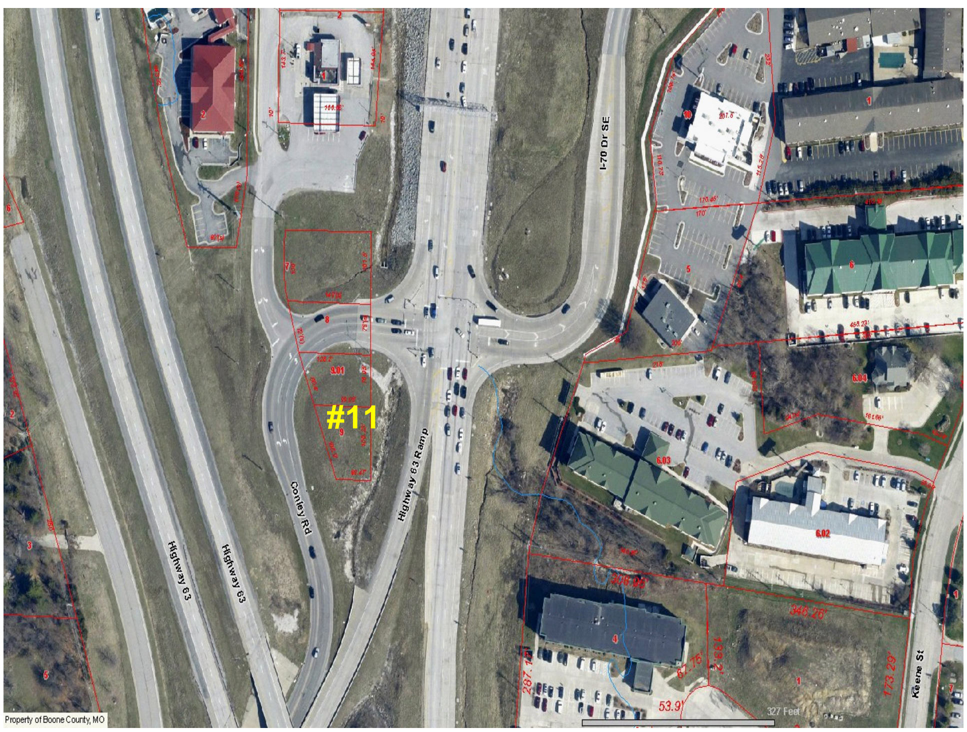


<u>Site #11</u>

Location: Site #11 is located west of and adjacent to the US Hwy-63 southbound onramp, and south and east of, and adjacent to Conley Road.

Description: Site #11 consists of a large open turf-grass area surrounded on all sides by roadways. The site receives flow from the south and west via four culverts and outfalls to the north via a culvert to site #10. Site #11 conveys stormwater from the discharging culverts to the outfall culvert through a series of highly eroded and sparsely vegetated earthen channels. The site is bordered on the south by electric and water utilities, and is bordered on the west by two sanitary sewer lines. Site #11 receives drainage from sites #17, #18 and #19 and discharges to site #10.

Property Owner: Missouri Department of Transportation / Missouri Highways & Transportation Commission



Contributing Area Details: Site #11 receives flow from Conley Road, the US Hwy-63 southbound onramp, the US Hwy-63 connector and US Hwy-63 northbound and southbound. The site specific contributing area to site #11 is 5.53 acres.

Total Area Treated by Site: 28.77 acres (8.12 % of total hotspot area)

Composite Curve Number: 91 (78 % impervious cover)

Water Quality Volume: 107,595 cubic feet (7.94% of hotspot total)

1-year, 2-year, 10-year, 100-year Flow Rates: 84.8 cfs, 106.9 cfs, 170.8 cfs, 248.8 cfs.

Flow Distance / Conveyance Network to Hinkson Creek: 1,880 linear feet of channel and culverts.

Area Available and Proposed BMP: Site #11 offers 4,375 square feet for placement of an extended wet detention basin along with 260 linear feet of channel for restabilization and revegetation. The extended wet detention basin should be located on the northeast corner of the site at the outfall of the culvert discharging from the west. The basin should be situated to discharge immediately to the existing outfall culvert on the north end of the site. Should a permanent pool of water be undesirable at this location, a vegetated extended dry basin may be substituted with a loss in water quality benefits. The 260 feet of channel should be regraded to a 6'-wide flat bottom trapezoidal channel, armored with turf reinforcement mat, and vegetated with native plants.

Constructability: Site eleven is bordered to the east and south by the US-63 southbound onramp and to the west and north by Conley Road. Because Conley Road is a low-speed roadway, in comparison to the highway onramp, a temporary construction entrance should be constructed off of Conley Road for access to the site. The site will likely require traffic control for both Conley Road and the US-63 onramp. Once on the site, sufficient room exists for material and equipment storage and operation. Work within site 11 will require a MODOT right-of-way permit and could require the installation of a guardrail along all adjacent roadway.

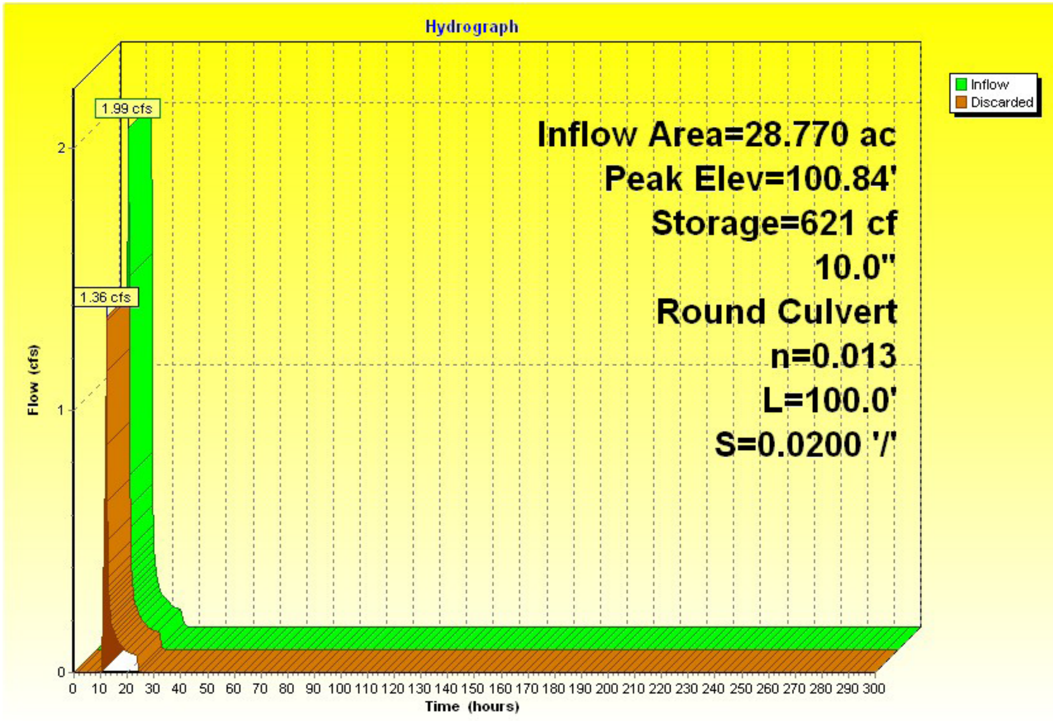
BMP Benefits: The extended wet detention basin will offer detention, infiltration, and pollutant uptake. Based on a preliminary design this extended wet detention basin can offer a 74.2 % reduction in the 1" 24-hour storm peak flow rate and a 31.7% reduction in the ½" 24-hour storm peak flow rate (see hydrographs). The reinforced native vegetation swale will slow the flow velocity promoting infiltration and offering detention, as well as settling of particulates. The vegetation will decrease the total quantity of stormwater and offer pollutant uptake. Restabilization of this channel has been calculated to decrease the flow velocity of the 1-year storm by 41.9 %

Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 0.77%

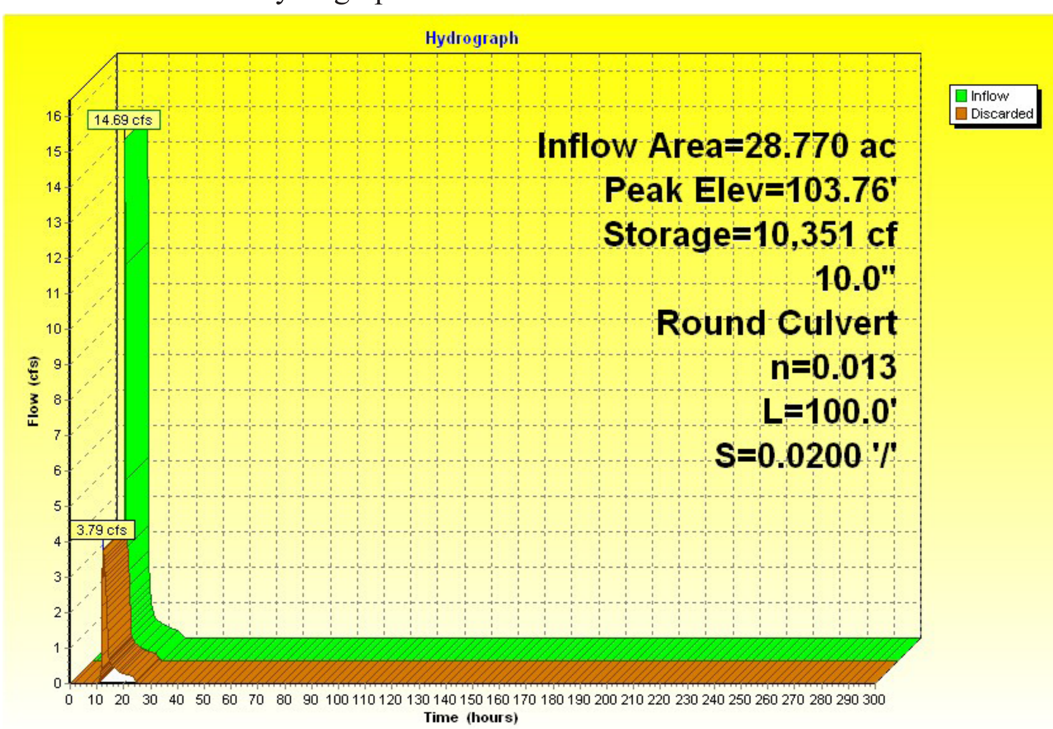
BMP Construction Cost: Estimated construction cost is $20,443.

15-year Maintenance Cost: Estimated maintenance cost is $10,600.

Site #11 Detention Hydrograph – ½” 24-Hour Storm Event



Site #11 Detention Hydrograph – 1” 24-Hour Storm Event

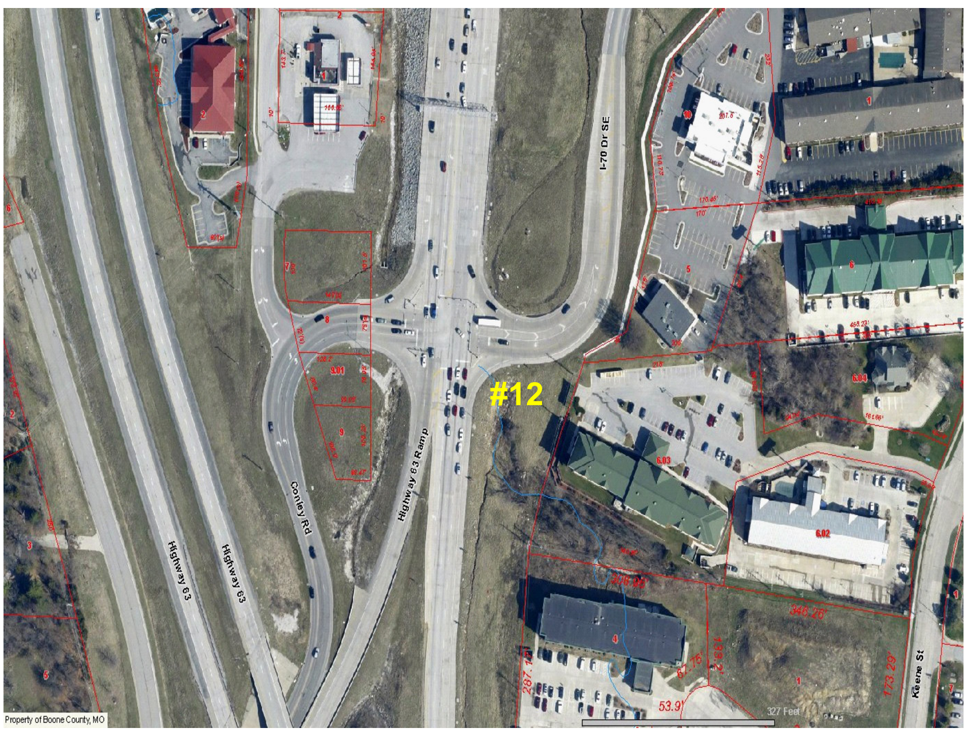


<u>Site #12</u>

Location: Site #12 is located south of and adjacent to I-70 Drive SE, and is east of and adjacent to the US Hwy-63 northbound offramp / US Hwy-63 connector.

Description: Site #12 consists of both a moderately sized open turf-grass area as well as 1,830 feet of channel running adjacent to the US Hwy-63 northbound offramp. The existing earthen channel is highly eroded sharply cut and devoid of vegetation. The channel and site drain to the north, to a culvert that ultimately discharges to site #10. The site is bordered by water and electric lines to the east and is crossed by water, electric and sewer lines approximately 200 feet from its northern end. Site #12 does not receive discharge from any other sites.

Property Owner: Missouri Department of Transportation



Contributing Area Details: Site #12 receives stormwater from the US Hwy-63 northbound offramp, as well as from 17 buildings with office, medical, and residential uses. The site specific contributing area to site #12 is 47.75 acres.

Total Area Treated by Site: 47.75 acres (13.5% of total hotspot area)

Composite Curve Number: 90 (76% impervious cover)

Water Quality Volume: 174,298 cubic feet (12.9% of hotspot total)

1-year, 2-year, 10-year, 100-year Flow Rates: 138.5 cfs, 172.2 cfs, 278.6 cfs, 408.6 cfs.

Flow Distance / Conveyance Network to Hinkson Creek: 1,900 feet of channel and culverts.

Area Available and Proposed BMP: Site #12 offers approximately 13,000 square feet for placement of an extended wet detention basin. The basin will be located at the northern end of the site and will discharge to the outfall culvert in the northwest corner. Should a permanent pool of water be undesirable at this location, a vegetated extended dry basin may be substituted with a loss in water quality benefits. The 1,830 feet of channel running adjacent to the US Hwy-63 northbound offramp should be regraded to a 6'-wide flat bottom trapezoidal channel, lined with turf reinforcement mat, and vegetated with native plants. Should native vegetation be undesirable at this location, turf grass may substitute.

Constructability: Site twelve could be most easily accessed from the south shoulder of I-70 Drive SE. Site twelve is adjacent to a hotel parking area to the east, however; the parking area resides at an elevation substantially higher than that of the site and access could require the inadvisable traversing of a retaining wall. Site twelve will likely require traffic control on both I-70 Drive SE and the northbound US-63 connector. This site should offer room for storage of materials and equipment at a reasonably safe distance from the US-63 connector. Work within site 12 will require a MODOT right-of-way permit and could require the installation of a guardrail along adjacent portions of roadway.

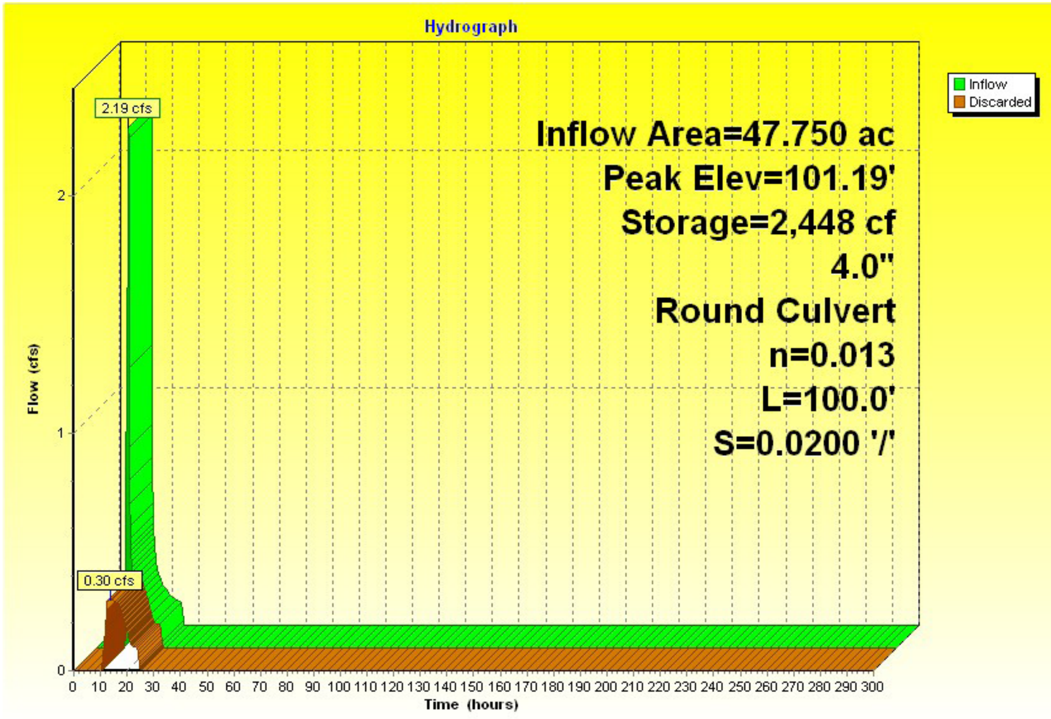
BMP Benefits: The extended wet detention basin will offer detention, infiltration, and pollutant uptake. Based on a preliminary design this extended wet detention basin can offer a 97.8 % reduction in the 1" 24-hour storm peak flow rate and a 86.3% reduction in the ½" 24-hour storm peak flow rate (see hydrographs). The reinforced native vegetation swale will slow the flow velocity promoting infiltration and offering detention, as well as settling of particulates. The vegetation will decrease the total quantity of stormwater and offer pollutant uptake. Restabilization of this channel has been calculated to decrease flow velocities by 41.5 %.

Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 4.91%

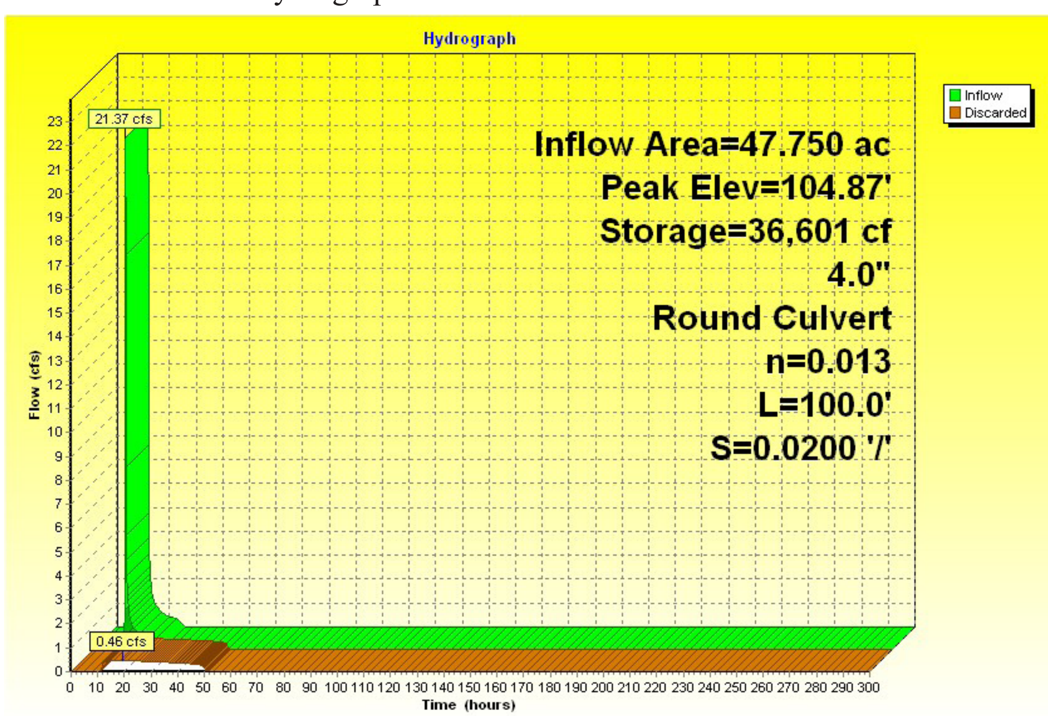
BMP Construction Cost: Estimated construction cost is $71,469.

15-year Maintenance Cost: Estimated maintenance cost is $22,081.

Site #12 Detention Hydrograph – ½” 24-Hour Storm Event



Site #12 Detention Hydrograph – 1” 24-Hour Storm Event



Site #13

Location: Site #13 resides west of and adjacent to the Wal-Mart Supercenter, near the buildings northwest corner.

Description: Site #13 consists of the turf grass area northwest of the existing Wal-Mart Supercenter. The area contains steep slopes that break to the west-southwest towards a newly constructed detention facility.

Property Owner: Conley Road Transportation Development District, RHL Columbia Development, LP

Contributing Area Details: Site #13 receives drainage from the fully developed retail area to the east. The vast majority of drainage to site #13 is via culverts, with only a very minor amount of surface flow.

Composite Curve Number: 95

Total Area Treated by Site: 24.16 acres

1-year, 2-year, 10-year, 100-year Flow Rates: 83.49 cfs, 99.07 cfs, 151.52 cfs, 215.63 cfs

Flow Distance / Conveyance Network to Hinkson Creek: The existing detention facility at site #13 discharges through a culvert, approximately 75 lf to Hinkson Creek

Water Quality Volume: 103,139 cubic feet (7.61% of hotspot total)

Area Available and Proposed BMP: Since the beginning of the Hinkson Creek Watershed Restoration Program, a private developer has constructed a large detention basin at site #13. Site #13 receives very little overland flow from the adjacent parking lot or roof tops and the area is in the process of becoming fully stabilized and vegetated. Any stormwater that does reach the northwest corner of the parking lot is picked up by a nearby curb inlet and discharged to the culvert that outfalls into the basin. All surface flow is conveyed along a vegetated swale, at a steep, yet unavoidable slope, towards the basin. Because of the volume of water received by the existing detention basin and the constructed volume of the basin, it is unlikely that the outlet structure could be altered to further detain any stormwater, except for only the smallest of flows. The BMP proposed for this site is the establishment of native vegetation within the basin and the placement of turf reinforcement mat and native vegetation within the swale leading down to the basin.

Constructability: Site 13 would be most easily accessed from the northern terminus of Willow Way, south of the site. The small residential street is very narrow, so coordination with adjacent property owners would be necessary for transport of equipment and materials. Once on site, there is substantial room for equipment and material storage. Because this site has been very recently graded and vegetated, light weight tracked vehicles are recommended for use on site. Site 13 resides at a very low elevation and in close proximity to Hinkson Creek, as such; it is possible that a no-rise certification be required for work within the floodway.

BMP Benefits: Establishment of native vegetation within the detention basin should provide additional opportunity for nutrient uptake from the deposited sediment as well as decreasing the total volume of water through evapotranspiration. Placement of native vegetation within the swale will offer similar benefits as well as decreasing the velocity of flow.

BMP Construction Cost: Estimated construction cost is $24,400.

15-year Maintenance Cost: Estimated maintenance cost is $5,490.

Site #14

Location: Site #14 is located south of and adjacent to the Cracker Barrel restaurant parking lot, on the south side of the building.

Description: The site consists of the existing failing detention structure that appears to have been cut-off from its incoming flows. The detention structure is an earthen basin with a concrete weir outlet structure that discharges to the south. Site #14 discharges to site #15 and does not receive stormwater from any other BMP sites.

Property Owner: Cracker Barrel Old Country Store, Inc.

Contributing Area Details: The 2.64 acres site specific contributing area includes 3 buildings of the restaurant, and hotel uses, along with their associated parking.

Total Area Treated by Site: 2.64 acres (0.74% of the total hotspot area)

Composite Curve Number: 94 (85% impervious cover)

Water Quality Volume: 7,858 cubic feet (0.58% of the hotspot total)

1-year, 2-year, 10-year, 100-year Flow Rates: 8.6 cfs, 10.3 cfs, 15.9 cfs, 22.7 cfs

Flow Distance / Conveyance Network to Hinkson Creek: 1,580 linear feet of channel and culverts.

Area Available and Proposed BMP: The existing detention basin and the surrounding area offer approximately 8,500 square feet for renovation of the existing basin. The basin should be cleaned of all foreign debris, the floor of the basin should be regraded and leveled to an elevation below the lowest outlet invert, the earthen side slopes should be regraded to a mowable 3:1 slope and the outlet structure should be renovated or replaced to maximize the detention capability of the basin. The basin should then be revegetated with native plants. The culverts that were meant to discharge into the basin should be located and either repaired or cleaned to direct the stormwater from the adjacent contributing area back into the basin. Another option for this existing basin is reconstruction as outlined above, but with the inclusion of a bioretention basin within the detention basin. The bioretention basin consists of engineered filtration media and an underdrain system. Based on existing topographical maps, there appears to be sufficient fall from the floor of the basin to the adjacent lowland to allow for discharge of an underdrain system.

Constructability: Site 14 would be most easily accessed from the commercial parking lot to the north. The site does lie adjacent to westbound I-70, however; the highway is at a safe distance from site 14 and the highway resides at an elevation much greater than that of the site. No traffic control should be required for work on site 14. The open area adjacent to site 14, site 15, provides ample room for storage of material and equipment.

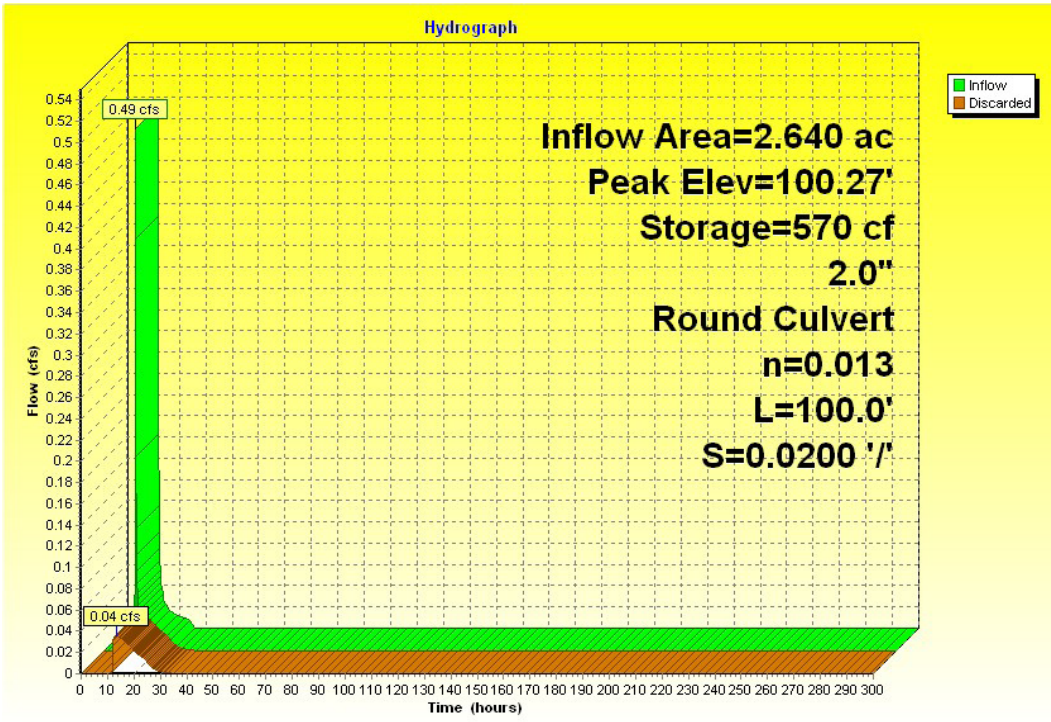
BMP Benefits: The extended wet detention basin will offer detention, infiltration, and pollutant uptake. Based on a preliminary design this extended wet detention basin can offer a 97.4 % reduction in the 1” 24-hour storm peak flow rate and a 91.8% reduction in the ½” 24-hour storm peak flow rate (see hydrographs).

Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 0.73%

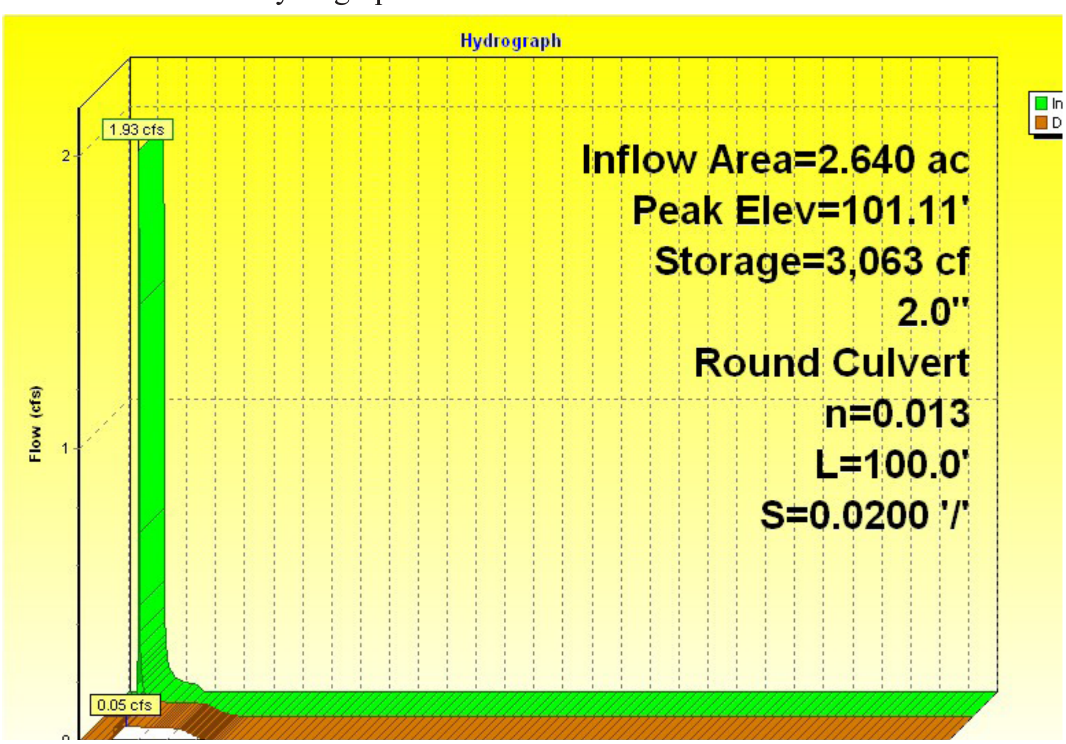
BMP Construction Cost: Estimated construction cost is $14,897.

15-year Maintenance Cost: Estimated maintenance cost is $9,352.

Site #14 Detention Hydrograph – ½” 24-Hour Storm Event



Site #14 Detention Hydrograph – 1” 24-Hour Storm Event



<u>Site #15</u>

Location: Site #15 resides south of and adjacent to the south Cracker Barrel parking lot and north of and adjacent to westbound I-70 and the westbound I-70 offramp. Site #15 encompasses the south and east sides of site #14

Description: Site #15 consists of a large low-lying open space between the highway to the south and the parking lot to the north. Site #15 contains the convergence of two channels, one entering from the east and one entering from the northeast. The site contains multiple billboards and their associated electrical connections as well as a sanitary sewer utility along the northern and eastern edges. Site #15 receives stormwater from site #14 and does not discharge to any other BMP sites.

Property Owner: Missouri Department of Transportation / Hazel E. Cannon 1991 Trust

Contributing Area Details: This site receives stormwater from a site specific contributing area of 143.4 acres including 50 buildings with office, retail, storage, and residential uses. This site receives stormwater from both the north and south sides of I-70.

Total Area Treated by Site: 143.4 acres (40.4 % of total hotspot area)

Composite Curve Number: 94 (85% impervious cover)
Water Quality Volume: 581,049 cubic feet (42.86 % of hotspot total)
1-year, 2-year, 10-year, 100-year Flow Rates: 482.8 cfs, 576.1 cfs, 889.9 cfs, 1,272.9 cfs.
Flow Distance / Conveyance Network to Hinkson Creek: 1,580 feet of channel and culvert.
Area Available and Proposed BMP: Because site #15 has very little elevation across its length, the construction of a detention facility is infeasible. The channels within site #15 are fairly stabile given their enormous flow rates during heavy rainfall events. Site #15 does offer a substantial area (60,000 square feet) for establishment of a more suitable riparian buffer including the establishment of woody vegetation to help slow and control water during heavy flows.
Constructability: Like site 14, site 15 resides adjacent to I-70, but at a much lower elevation. Traffic control should not be required for work on site 14. The most convenient point of access to site 15 is via the commercial parking lots to the north and northeast. Site 15 has ample room for storage of material and equipment during the construction process. Site 15 could require a MODOT right-of-way permit.
BMP Benefits: The establishment of wetland woody vegetation will anchor the soil against erosion, shade the existing channel, offer pollutant and water uptake, and slow the flow velocity during heavier rainfall events.
BMP Construction Cost: Estimated construction cost is $66,000.
15-year Maintenance Cost: Estimated maintenance cost is $14,850.

<u>Site #16</u>
Location: Site #16 resides east of, adjacent to, and parallel with northbound US Hwy-63 and south of and adjacent to eastbound I-70.
Description: Site #16 consists of 750 feet of eroded and sparsely vegetated earthen channel running parallel from south to north along northbound US Hwy-63. The channel outfalls at its northern end to the western terminus of site #10 and is then conveyed to Hinkson Creek. Site #16 does not receive stormwater from any other BMP sites.
Property Owner: Missouri Department of Transportation

Contributing Area Details: Site #16 receives stormwater from northbound US Hwy-63 as well as from the rear yard of the adjacent hotel to the east. The site specific contributing area for site #16 is 1.81 acres.

Total Area Treated by Site: 1.81 acres (0.51% of the total hotspot area)

Composite Curve Number: 80 (40 % impervious cover)

Water Quality Volume: 3,687 cubic feet (0.27 % of hotspot total)

1-year, 2-year, 10-year, 100-year Flow Rates: 3.4 cfs, 4.5 cfs, 8.4 cfs, 13.3 cfs.

Flow Distance / Conveyance Network to Hinkson Creek: 770 linear feet of channel.

Area Available and Proposed BMP: The 750 feet of highly eroded channel should be graded to a 6'-wide flat bottom trapezoidal channel, lined with turf reinforcement mat and vegetated with native plants. Turf grass may be substituted for the native vegetation, should native vegetation be undesirable at this location.

Constructability: Site 16 would be most easily accessed from the rear parking lot of the hotel immediately to the east. Site 16 is very narrow and lies adjacent to and in close proximity of northbound US-63. Traffic control along US-63 will most certainly be required and portions of the adjacent parking lot will likely be needed for material and equipment storage. Work on site 16 will require a MODOT right-of-way permit and will most likely require the installation of a guardrail along US-63.

BMP Benefits: The reinforced native vegetation swale will slow the flow velocity promoting infiltration and offering detention, as well as settling of particulates. The vegetation will decrease the total quantity of stormwater and offer pollutant uptake. Restabilization of this channel has been calculated to decrease flow velocities by 54.7 %.

BMP Construction Cost: Estimated construction cost is $14,742.

15-year Maintenance Cost: Estimated maintenance cost is $3,317.

<u>**Site #17**</u>

Location: Site #17 resides east of and adjacent to both northbound US Hwy-63 and the southbound US Hwy-63 onramp and west of and adjacent to the northbound US Hwy-63 offramp.

Description: Site #17 consists of a large turf-grass area along with the convergence of two roadside channels from the southeast and southwest. The site breaks to the north and outfalls to a culvert which conveys the stormwater to site #11. Site #17 is bordered by a water line and a sewer line at the extreme northern end of the site. Site #17 receives flow from site #18 and discharges to sites #11 and #10.

Property Owner: Missouri Department of Transportation

Contributing Area Details: Site #17 receives drainage from US Hwy-63 and from the US Hwy-63 northbound offramp. The site specific contributing area to site #17 is 8.40 acres.

Total Area Treated by Site: 12.89 acres (3.64% of total hotspot area)

Composite Curve Number: 84 (40% impervious cover)

Water Quality Volume: 26,277 cubic feet (1.94% of hotspot total)

1-year, 2-year, 10-year, 100-year Flow Rates: 27.9 cfs, 37.7 cfs, 66.2 cfs, 101.7 cfs.

Flow Distance / Conveyance Network to Hinkson Creek: 2,246 feet of culvert and channel.

Area Available and Proposed BMP: Site #17 offers approximately 15,150 square feet for placement of an extended wet detention basin at the convergence of the two incoming channels. The basin should be placed to outfall to the culvert leaving the site to the northwest. Should a permanent pool of water be undesirable at this location, a vegetated extended dry basin may be substituted with a loss in water quality benefits.

Constructability: Site 17 will be most easily accessed from the southbound US-63 onramp. Delivery of materials and equipment might be required to occur in the early morning hours to minimize the volume of traffic during delivery. Traffic control will likely be required for the US-63 southbound onramp, the northbound US-63 connector and for northbound US-63. A MODOT right-of-way permit will be required for work on site 17 and the possibility exists that MODOT will require guardrail installation along all adjacent roadway.

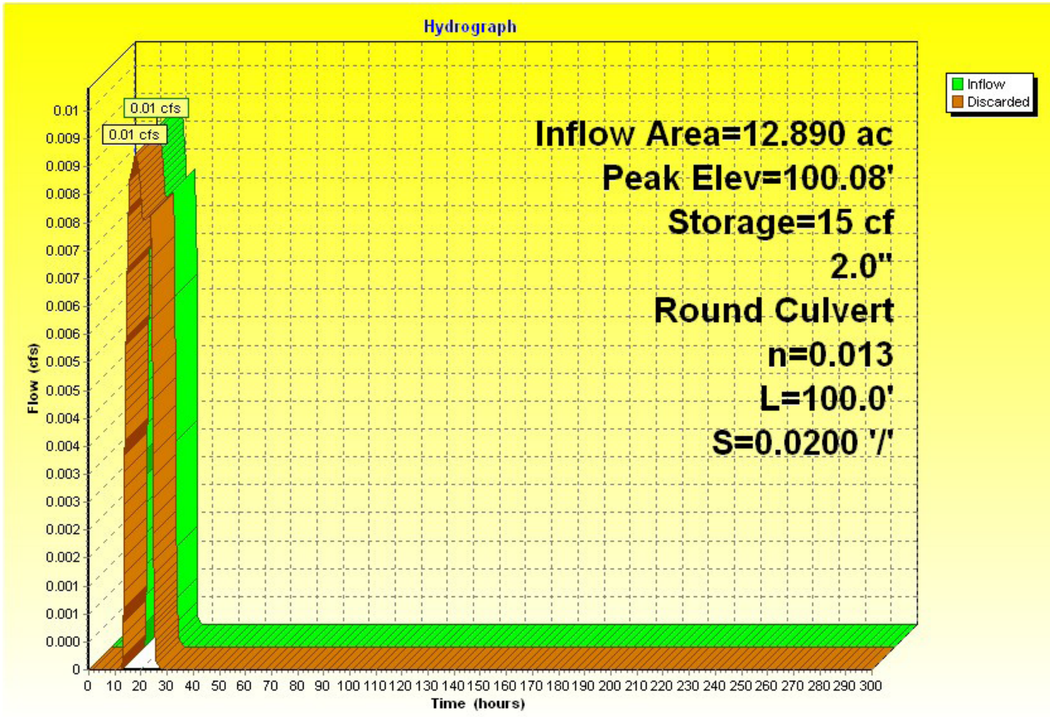
BMP Benefits: The extended wet detention basin will offer detention, infiltration, and pollutant uptake. Based on a preliminary design this extended wet detention basin can offer a 97.6 % reduction in the 1" 24-hour storm peak flow rate and due to the low curve number of the contributing area and the fact that the ½" storm modeled occurs over a 24-hour period, less than 0.01 cfs was seen entering the basin from the ½" event (see hydrographs).

Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 1.15%

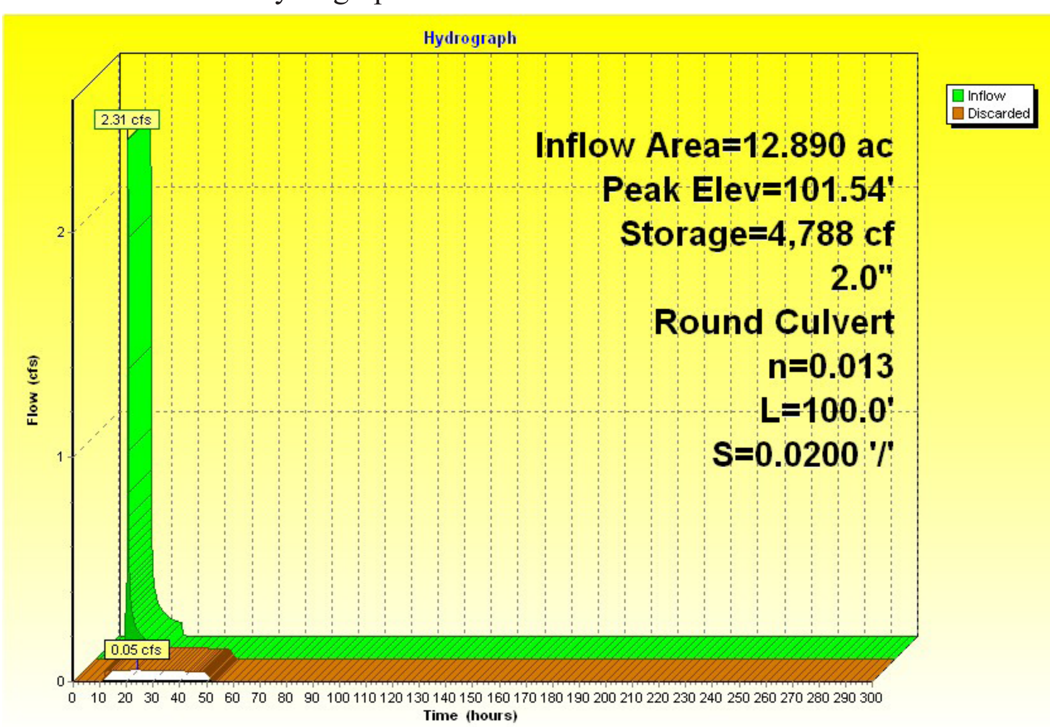
BMP Construction Cost: Estimated cost is $23,166.

15-year Maintenance Cost: Estimated maintenance cost is $11,212.

Site #17 Detention Hydrograph – ½" 24-Hour Storm Event



Site #17 Detention Hydrograph – 1" 24-Hour Storm Event

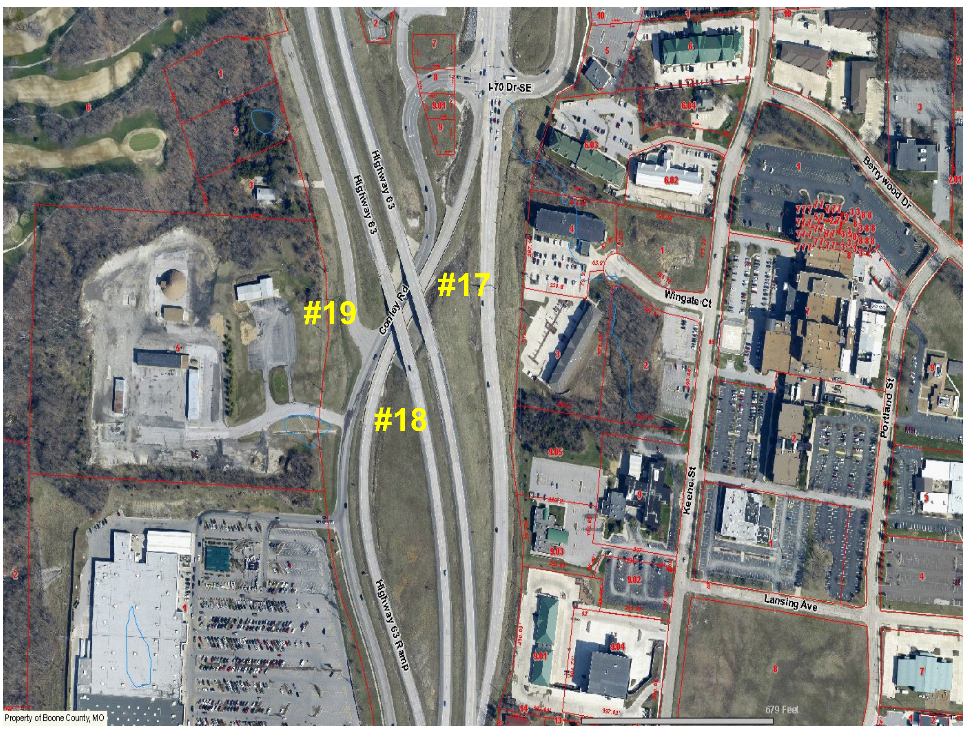


Site #18

Location: Site #18 is located east of and adjacent to the southbound US Hwy-63 onramp and west of and adjacent to southbound US Hwy-63.

Description: Site #18 consists of a large open area bordered on all sides by roadways. The site breaks consistently from southeast to northwest and contains the roadside drainage ditch adjacent to and parallel with the southbound US Hwy-63 onramp. The site does not appear to contain any utilities other than the concrete stormwater flume that the site discharges to on the north end. Site #18 discharges to sites #17, #11, and #10.

Property Owner: Missouri Department of Transportation



Contributing Area Details: Site #18 receives drainage from the southbound US Hwy-63 onramp as well as from southbound US Hwy-63. The total site specific contributing area for site #18 is 4.49 acres.

Total Area Treated by Site: 4.49 acres (1.27 % of total hotspot area)

Composite Curve Number: 78 (15% impervious cover)

Water Quality Volume: 4,133 cubic feet (0.30% of hotspot total)

1-year, 2-year, 10-year, 100-year Flow Rates: 7.2 cfs, 10.2 cfs, 19.6 cfs, 31.8 cfs.

Flow Distance / Conveyance Network to Hinkson Creek: 2,816 feet of channel, culverts, and concrete flume.

Area Available and Proposed BMP: Site #18 offers approximately 5,000 square feet for placement of an extended wet detention basin. The basin will reside along the west side of the site, adjacent to the southbound US Hwy-63 onramp. The space available for the basin is far greater than 5,000 square feet, however; because the ground slopes fairly rapidly and consistently up to the east, the additional surface area at suitable depth would require substantial grading, and without placement of a retaining structure, the remaining grade up to southbound US Hwy-63 could be unstable or un-mowable. The basin should reside such that it discharges immediately to the concrete flume on the northern end of the site. Should a permanent pool of water be undesirable at this location, a vegetated extended dry basin may be substituted with a loss in water quality benefits.

Constructability: Site 18 will be most easily accessed from the shoulder of the southbound US-63 onramp. Like site 17, equipment and material delivery might be required to occur during the early morning hours to minimize the volume of adjacent traffic. Once on site, site 18 offers substantial room for material and equipment storage and operation. A MODOT right-of-way permit will be required for work on site 18 and MODOT could require the installation of a guardrail along all adjacent roadways.

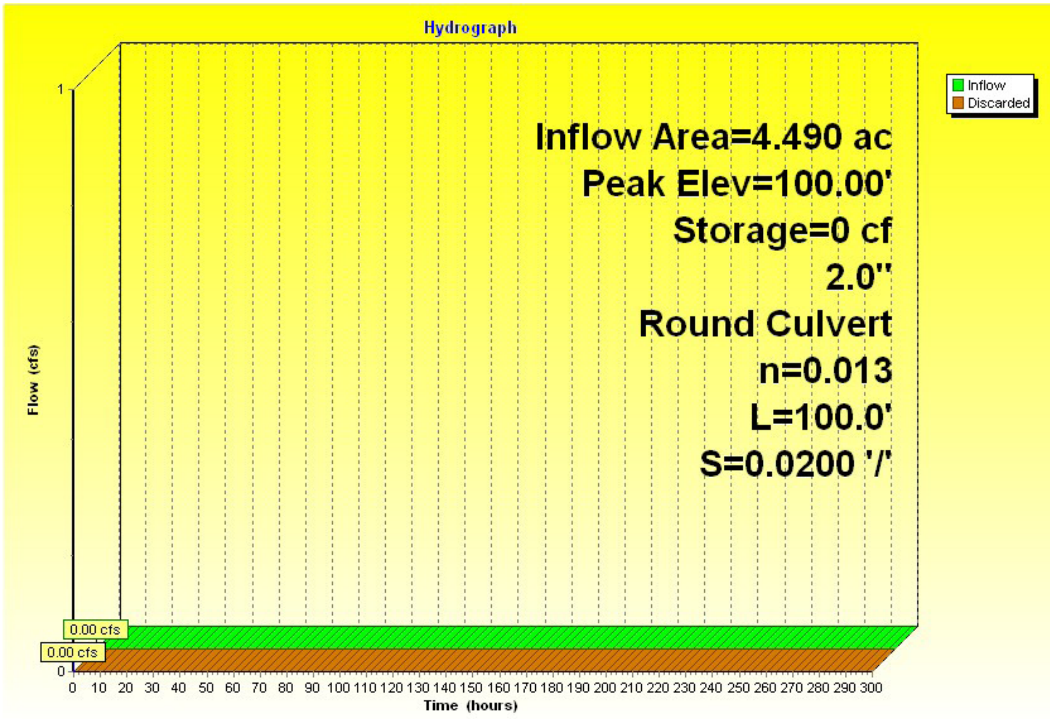
BMP Benefits: The extended wet detention basin will offer detention, infiltration, and pollutant uptake. Based on a preliminary design this extended wet detention basin can offer a 60% reduction in the 1" 24-hour storm peak flow rate and due to the low curve number of the contributing area and the fact that the ½" storm modeled occurs over a 24-hour period, no runoff was seen entering the basin from the ½" event (see hydrographs).

Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 0.30%

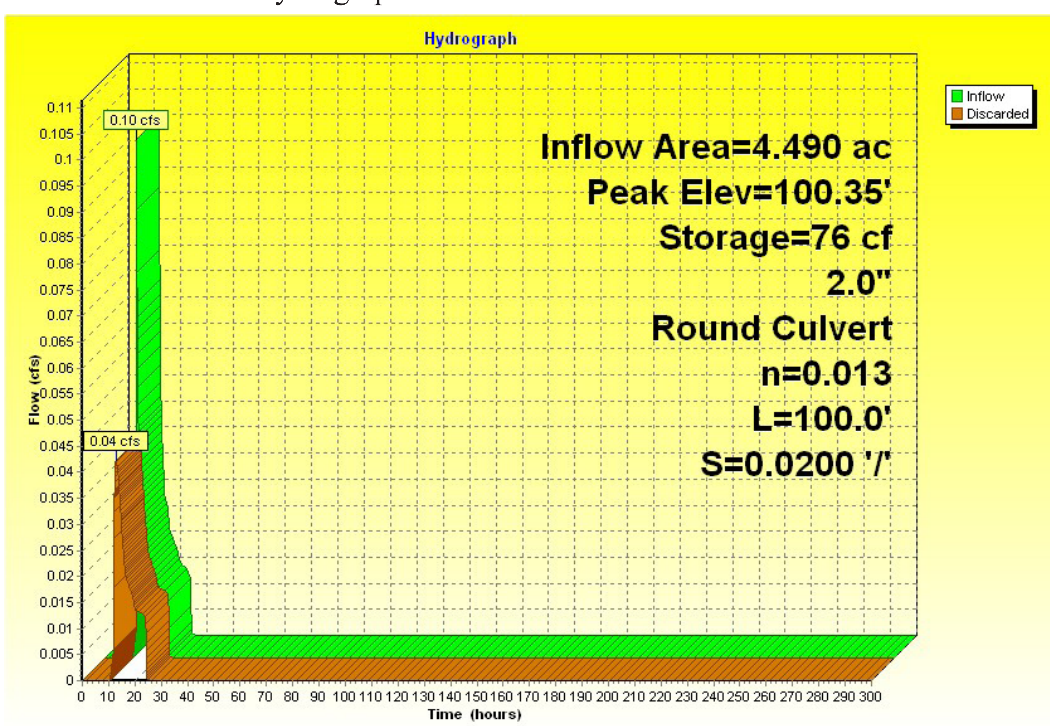
BMP Construction Cost: Estimated construction cost $8,509.

15-year Maintenance Cost: Estimated maintenance cost is $7,914.

Site #18 Detention Hydrograph – ½” 24-Hour Storm Event



Site #18 Detention Hydrograph – 1” 24-Hour Storm Event

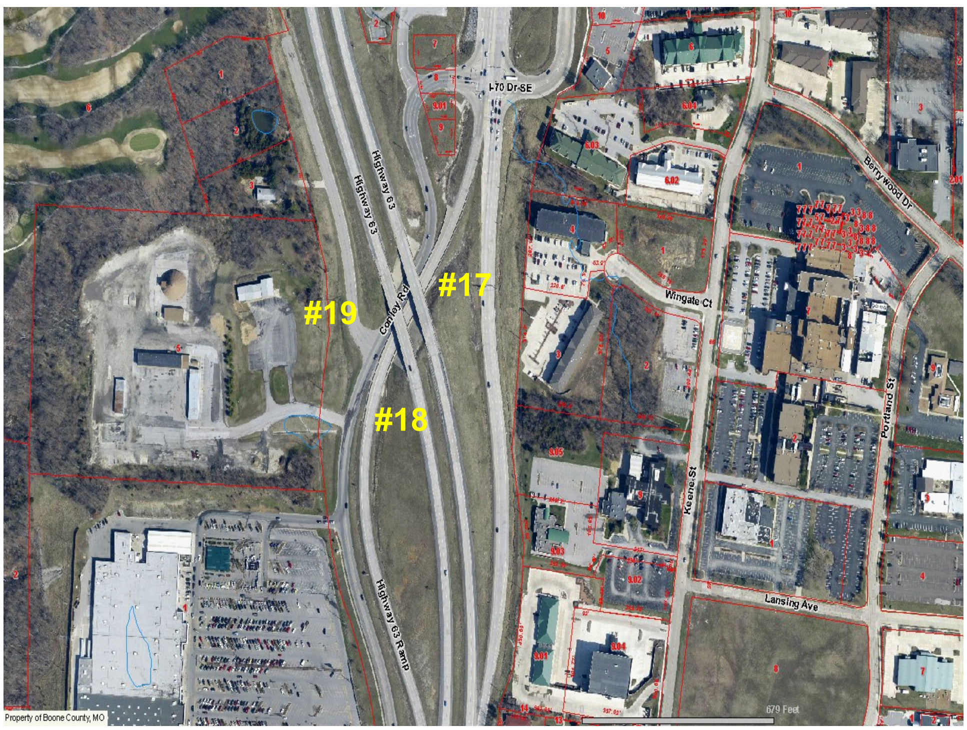


Site #19

Location: Site #19 is located west of and adjacent to Conley Road and east of and adjacent to the old MODOT facility off of Conley Road.

Description: Site #19 consists of a large open turf grass area bordered on the east and south by roadways and bordered on the west by the MODOT facility. The site breaks primarily to the north to a culvert that discharges to site #11. The site resides in a large swale formed between the slope up to Conley Road on the east and the slope up to the MODOT facility on the west. The site is crossed by both water lines and electrical lines. Site #19 discharges to sites #11, and #10.

Property Owner: Missouri Department of Transportation / TKG Conley Rd. Investments, LLC.



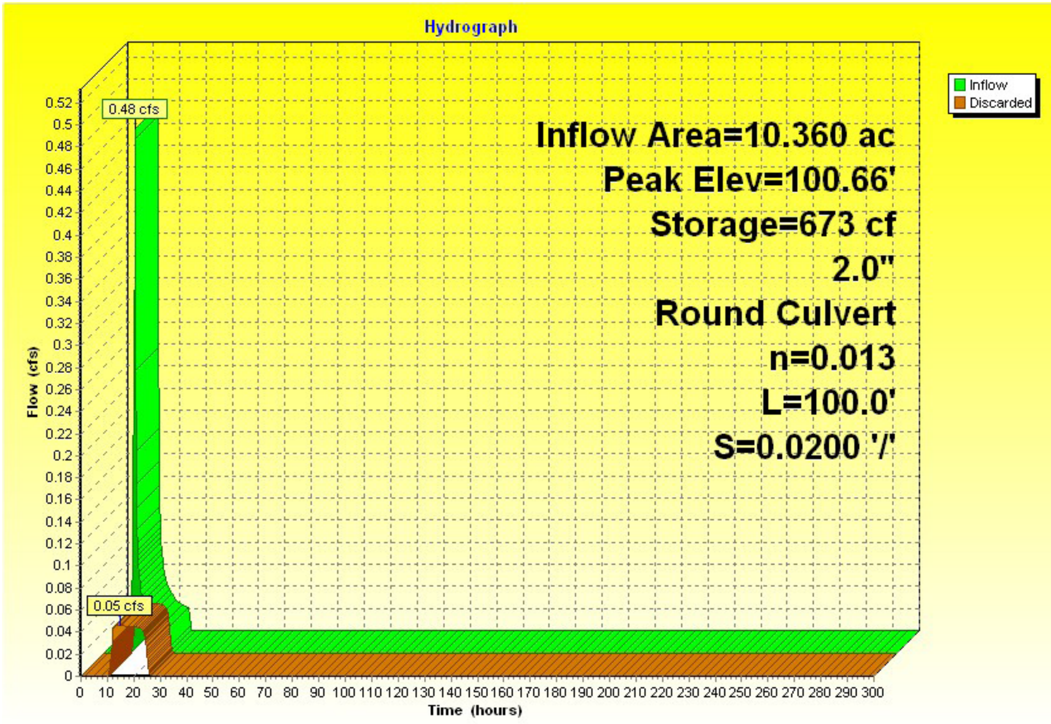
Contributing Area Details: Site #19 receives stormwater from the MODOT facility as well as from two culverts that receive stormwater from the east and west sides of Conley Road. The site specific contributing area to site #19 is 10.36 acres.

Total Area Treated by Site: 10.36 acres (2.92% of total hotspot area)

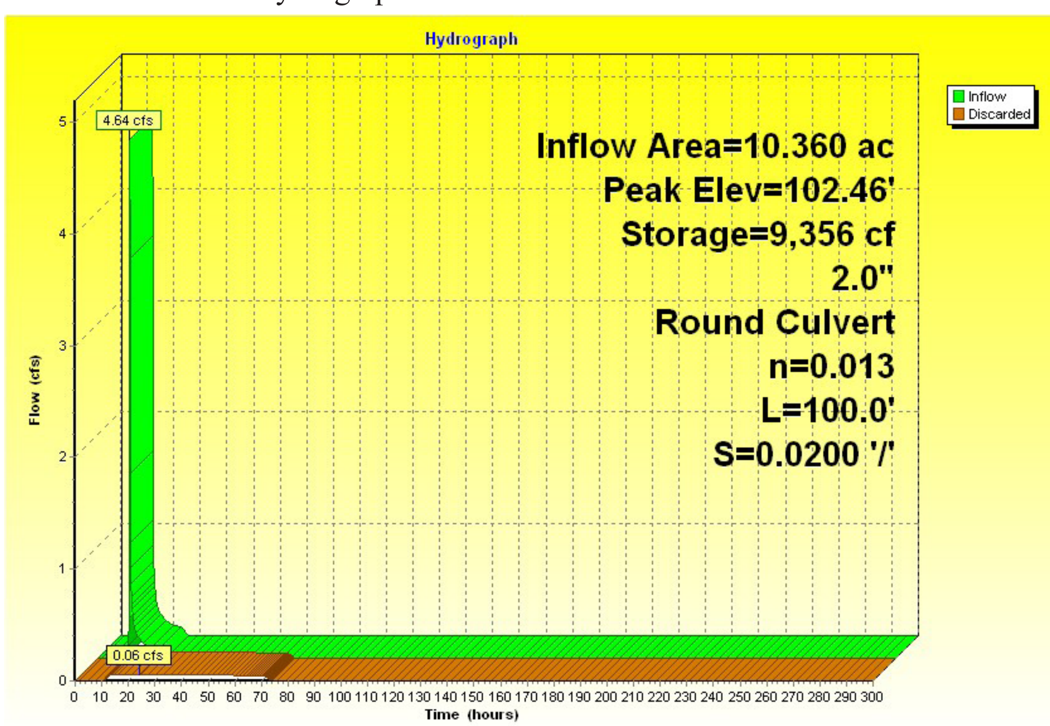
Composite Curve Number: 90 (50% impervious cover)

Water Quality Volume: 25,755 cubic feet (1.90% of hotspot total)
1-year, 2-year, 10-year, 100-year Flow Rates: 29.5 cfs, 37.4 cfs, 60.4 cfs, 88.6 cfs.
Flow Distance / Conveyance Network to Hinkson Creek: 2,533 linear feet of culvert and channel.
Area Available and Proposed BMP: Because of the close proximity of the electric and water utilities, grading within this area should be kept to a minimum. With minimal grading, the site can offer 11,640 square feet of fairly shallow depth for establishment of an extended dry detention basin. The dry detention basin is recommended in this location because of the shallow water depths. The basin should be constructed to discharge to the outfall at the northern end of the site. The basin surface and volume detailed in this report are as the ground currently resides and will only require the construction of a dam and outlet structure.
Constructability: Site 19 will be most easily accessed from the unnamed road stemming off of Conley Road and proceeding to the north. The road sees very little traffic as it is a dead end, however, traffic control should still be provided on adjacent portions of Conley Road. The adjacent property to the west was previously occupied by MODOT, but now lies vacant and offers substantial room for material and equipment storage. A MODOT right-of-way permit will be required for work on site 19 and it is possible that MODOT will require guardrail installation along adjacent sections of roadway.
BMP Benefits: The extended dry detention basin will offer detention, infiltration, and pollutant uptake. Based on a preliminary design this extended wet detention basin can offer a 98.7 % reduction in the 1" 24-hour storm peak flow rate and a 89.6% reduction in the ½" 24-hour storm peak flow rate (see hydrographs).
Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 2.06%
BMP Construction Cost: Estimated construction cost is $23,885.
15-year Maintenance Cost: Estimated maintenance cost is $11,374.

Site #19 Detention Hydrograph – ½" 24-Hour Storm Event



Site #19 Detention Hydrograph – 1" 24-Hour Storm Event



Summary of Overall Effects on Hotspot Area

(Summary Table listed in Appendices)

The following values are a total net effect on the hotspot area as a whole if all 19 subject sites were to be renovated with the BMPs proposed within this report.

Detention: There are a total of 11 detention structures proposed with a collective total of 442,969 cubic feet of storage, which is approximately 33% of the total hotspot water quality volume (WQ_v). Collectively, the detention structures will decrease the 1-year peak flow from the entire hotspot area by 42.54%. Because of their placement along existing concentrated flow paths, many of the detention basins have the opportunity to work in succession with other basins, further increasing detention and offering water quality treatment train benefits.

Channel Stabilization: There is a total of 8,920 linear feet of channel proposed for restabilization on eight of the BMP sites. The total water quality volume conveyed through these channels is 459,924 cubic feet, which is 34% of the total hotspot water quality volume. The average decrease in channel velocity among the restabilized channels is 46.48%, approximately doubling the residence time within the channels.

SUMMARY DATA

SUMMARY OF BMP PERFORMANCE AND COST

SITE	TOTAL AREA TREATED BY SITE (ACRES)	TOTAL AREA TREATED BY SITE AS A PERCENT OF TOTAL AREA (%)	PERCENT REDUCTION IN 1''-EVENT Q PER SITE (%)	PERCENT REDUCTION IN 0.5''-EVENT Q PER SITE (%)	PERCENT REDUCTION IN CHANNEL VELOCITY (%)	PROPOSED BMP	PROPERTY OWNER	ESTIMATED CONST. COST	ESTIMATED 15 YR MAINT. COST	TOTAL COST PER ACRE TREATED ($/ACRE)
1	11.0	3.10	99.20	97.70	NA	DETENTION	MODOT	$15,437	$9,473	$2,265
2	1.0	0.30	N/A	N/A	55.17	VEGETATED CHANNEL	MODOT	$36,149	$8,134	$42,259
3	17.0	4.80	N/A	N/A	42.73	VEGETATED CHANNEL	MODOT, MISSOURI EMPLOYERS MUTUAL	$34,327	$13,724	$2,825
4	3.4	0.96	N/A	N/A	N/A	PARKING ISLAND RAIN GARDENS	BROADWAY CROSSINGS II	$463,288	$7,500	$138,504
5	27.5	7.75	N/A	N/A	30.40	BIOSWALE	BROADWAY CROSSINGS II	$73,804	$16,606	$3,290
6	16.0	4.51	99.50	98.30	42.91	DETENTION, VEGETATED CHANNEL	MODOT	$82,334	$24,525	$6,682
7	45.7	12.89	99.80	99.20	NA	DETENTION	HOME DEPOT, TULL et al	$73,854	$22,617	$2,111
8	3.6	1.02	90.60	MIN.	NA	DETENTION	HOME DEPOT, TULL GROUP	$11,241	$8,529	$5,443
9	1.9	0.53	N/A	N/A	51.94	VEGETATED CHANNEL	CITY OF COLUMBIA, MODOT	$15,724	$9,538	$13,543
10	100.5	28.36	97.70	91.30	40.96	DETENTION, WOODY VEGETATION	MODOT	$25,583	$11,756	$371
11	28.8	8.12	74.20	31.70	41.88	DETENTION, VEGETATED CHANNEL	MODOT	$20,443	$10,600	$1,079
12	47.7	13.47	97.80	86.30	41.49	DETENTION, VEGETATED CHANNEL	MODOT	$71,469	$22,081	$1,959
13	24.1	6.80	N/A	N/A	N/A	NATIVE VEGETATION	CONLEY TDD, RHL COLUMBIA	$24,400	$5,490	$1,239
14	2.6	0.74	97.40	91.80	NA	DETENTION	CRACKER BARREL	$14,897	$9,352	$9,185
15	143.4	40.44	N/A	N/A	NA	WOODY VEGETATION	MODOT, CANNON TRUST	$66,000	$14,850	$564
16	1.8	0.51	N/A	N/A	54.68	VEGETATED CHANNEL	MODOT	$14,742	$3,317	$9,987
17	12.9	3.64	97.60	MIN.	NA	DETENTION	MODOT	$23,166	$11,212	$2,668
18	4.5	1.27	60.00	MIN.	NA	DETENTION	MODOT	$8,509	$7,914	$3,656
19	10.4	2.92	98.70	89.60	NA	DETENTION	MODOT	$23,885	$11,374	$3,404

DETENTION BMP PERFORMANCE

BMP SITE	OUTLET STRUCTURE DIAMETER (INCHES)	0.5 INCH INFLOW (CFS)	0.5 INCH ROUTED FLOW (CFS)	0.5 INCH TIME TO DRAIN (HRS)	0.5 INCH CM TO CM DETENTION (MINS)	1.0 INCH INFLOW (CFS)	1.0 INCH ROUTED FLOW (CFS)	1.0 INCH TIME TO DRAIN (HRS)	1.0 INCH CM TO CM DETENTION (MINS)
1	2.00	2.17	0.05	42.50	708.00	8.40	0.07	104.20	2,405.00
6	2.00	2.97	0.05	62.50	1,241.00	11.70	0.06	170.00	4,293.00
7	2.00	8.50	0.07	122.40	2,937.00	33.45	0.08	342.40	8,922.00
8	2.00	< 0.01	< 0.01	24.00	0.00	0.53	0.05	24.40	119.00
10	6.00	10.40	0.90	26.40	150.00	58.16	1.31	50.00	831.00
11	10.00	1.99	1.36	24.40	5.00	14.69	3.79	24.40	21.00
12	4.00	2.19	0.30	25.00	82.00	21.37	0.46	51.20	911.00
14	2.00	0.49	0.04	27.40	225.00	1.93	0.05	44.40	695.00
17	2.00	< 0.01	< 0.01	24.40	29.00	2.08	0.05	52.20	950.00
18	2.00	< 0.01	< 0.01	24.00	0.00	0.10	0.04	24.25	17.00
19	2.00	0.48	0.05	25.60	170.00	4.64	0.06	73.20	1,576.00

DETAILED COST ESTIMATE BREAKDOWN

sites	excavation (ft^3)	excavation cost ($)	riprap (tons)	riprap cost ($)	outlet structure / culverts costs ($)	vegetation area (ft^2)	vegetation cost ($)	turf reinforcement mat area (ft^2)	turf reinforcement mat cost ($)	New Pavement Cost	total construction cost ($)	15-year maintenance cost ($)
1	16185	2847	12	300	4590	7000	7700	0	0	0	**$15,437**	**$9,473**
2	12000	2111	0	0	0	10980	12078	10980	21960	0	**$36,149**	**$8,134**
3	49221	8659	0	0	0	8280	9108	8280	16560	0	**$34,327**	**$13,724**
4	11520	2027	0	0	0	0	0	0	0	461261	**$463,288**	****$7500**
5	91200	16044	0	0	0	30400	33440	12160	24320	0	**$73,804**	**$16,606**
6	68378	12029	47	1163	12940	39420	43362	6420	12840	0	**$82,334**	**$24,525**
7	125059	22001	94	2344	22009	25000	27500	0	0	0	**$73,854**	**$22,617**
8	7118	1252	54	1350	3139	5000	5500	0	0	0	**$11,241**	**$8,529**
9	4800	844	0	0	0	4800	5280	4800	9600	0	**$15,724**	**$9,538**
10	117000	20583	200	5000	0	0	0	0	0	0	**$25,583**	**$11,756**
11	9004	1584	7	169	3441	7500	8250	3500	7000	0	**$20,443**	**$10,600**
12	50700	8919	38	938	10112	25000	27500	12000	24000	0	**$71,469**	**$22,081**
13	0	0	0	0	0	20000	22000	1200	2400	0	**$24,400**	**$5,490**
14	10000	1759	8	188	3600	8500	9350	0	0	0	**$14,897**	**$9,352**
15	0	0	0	0	0	60000	66000	0	0	0	**$66,000**	**$14,850**
16	4500	792	0	0	0	4500	4950	4500	9000	0	**$14,742**	**$3,317**
17	12728	2239	9	225	4036	15150	16665	0	0	0	**$23,166**	**$11,212**
18	2846	501	2	53	2455	5000	5500	0	0	0	**$8,509**	**$7,914**
19	25637	4510	19	469	6102	11640	12804	0	0	0	**$23,885**	**$11,374**

** 3% biennial charge is not applied to pavement

DEFINITIONS:

Water Quality Volume:

The water quality volume (WQ_v) is defined as the storage volume needed to capture and treat 90 percent of the average annual stormwater runoff volume. The water quality volume is based on the water quality storm, a site specific volumetric runoff coefficient, and the area of the site. (Per City of Columbia Stormwater Management and Water Quality Manual)

Water Quality Storm:

The water quality storm is defined as the storm event that produces less than or equal to 90 percent (by volume) of all 24-hour storms on an annual basis. The depth of the water quality storm for Columbia is 1.37 inches. (Per City of Columbia Stormwater Management and Water Quality Manual)

1-Year Storm Event:

The 1-year storm event has a statistical recurrence interval of one year and has a 100 percent statistical likelihood of occurrence on any given year. The 24-hour rainfall depth for the 1-year storm event in Columbia is 3.0 inches. (Per City of Columbia Stormwater Management and Water Quality Manual)

2-Year Storm Event:

The 2-year storm event has a statistical recurrence interval of two years and has a 50 percent statistical likelihood of occurrence on any given year. The 24-hour rainfall depth for the 2-year storm event in Columbia is 3.5 inches. (Per City of Columbia Stormwater Management and Water Quality Manual)

10-Year Storm Event:

The 10-year storm event has a statistical recurrence interval of ten years and has a 10 percent statistical likelihood of occurrence on any given year. The 24-hour rainfall depth for the 10-year storm event in Columbia is 5.2 inches. (Per City of Columbia Stormwater Management and Water Quality Manual)

100-Year Storm Event:

The 100-year storm event has a statistical recurrence interval of one hundred years and has a 1 percent statistical likelihood of occurrence on any given year. The 24-hour rainfall depth for the 100-year storm event in Columbia is 7.3 inches. (Per City of Columbia Stormwater Management and Water Quality Manual)

Composite Curve Number:

The composite curve number is a curve number assigned to a specific sub-watershed and is based upon the sum of the products of the area (as a decimal percent of total area) for each individual surface cover type and its corresponding curve number. The composite curve number for a given watershed offers a more accurate representation of runoff rates than does the use of a general curve number often assigned to an area based solely on land use classification.

Specific curve numbers were attained from the City of Columbia Stormwater Management and Water Quality Manual.

Composite Curve Number Calculation:

Composite CN = SUM $\{(A_1 / A_T)*CN_1 + (A_2 / A_T)*CN_2 + \ldots(A_N / A_T)*CN_N\}$

Where: A = Area

CN = Curve Number

Typical Composite Curve Numbers listed by cover type and land use are as follows (Per City of Columbia Stormwater Management and Water Quality Manual). Each item has four curve numbers listed which correspond to hydrologic soil groups A, B, C, and D, and are listed in that order:

		A B C D
Open Space / Lawn / Parks:	Poor	68, 79, 86, 89
Open Space / Lawn / Parks:	Fair	49, 69, 79, 84
Open Space / Lawn / Parks:	Good	30, 61, 74, 80
Pavement / Roofs		98, 98, 98, 98
Urban District - Commercial & Business		89, 92, 94, 95
Urban District - Industrial		81, 88, 91, 93
Residential – 1/8th acre lots		77, 85, 90, 92
Residential - 1/4th acre lots		61, 75, 83, 87
Residential – ½ acre lots		54, 79, 80, 85
Residential – 1 acre lots		51, 68, 79, 84
Completely Pervious – 100% Denuded		77, 86, 91, 94
Continuous Graze Pastureland:	Poor	68, 79, 86, 89
Continuous Graze Pastureland:	Fair	49, 69, 79, 84
Continuous Graze Pastureland:	Good	39, 61, 74, 80
Woods & Grass Combination	Poor	57, 73, 82, 86
Woods & Grass Combination	Fair	43, 65, 76, 82
Woods & Grass Combination	Good	32, 58, 72, 79
Woods Only	Poor	45, 66, 77, 83
Woods Only	Fair	36, 60, 73, 79
Woods Only	Good	30, 55, 70, 77

Treatment Train:

The treatment train refers to a series of BMPs used in succession to improve water quality (as opposed to the use of a single BMP).

Site Specific Contributing Area:

The term “site specific contributing area” is used to classify the contributing area that drains to one BMP site only. This contributing area value does not include the contribution of stormwater that has been previously intercepted by an upstream BMP site. It is necessary to determine for both calculation of total watershed area (as the sum of the individual site specific contributing areas) and the analysis of “treatment train” water quality levels of service. It should be noted that although the site specific contributing areas are listed for each site, the proposed BMP for each site is designed to treat the entire contributing area for each site which includes the site specific contributing area and the site specific contributing areas for any upstream sites, the sum of which is the total area treated by a site.

Total Area Treated By a Site:

The total area treated by a site is defined as the sum of the site specific contributing area and the site specific contributing areas of any upstream BMP sites which then contribute to the site in question. The total area treated by a site can also be defined by the common definitions of “contributing area” or “drainage area”.

Conveyance Network:

The conveyance network for outfall waters from a BMP site is defined by the underlying surface upon which water flows to reach a point of lower elevation. Conveyance networks include culverts, flumes, vegetated channels, reinforced channels, etc. or a combination thereof.

Flow Distance to Hinkson:

The flow distance to Hinkson Creek from each BMP site is defined as the distance of travel required for the outfall water from a BMP site to reach Hinkson Creek. The flow distance includes all applicable conveyance methods.

Area Available for BMP Placement:

The area available for BMP placement is defined as the amount of surface area at a proposed BMP site available for construction / maintenance of a BMP structure. Topographic and utility maps were reviewed for determination of this area and each area listed is based upon availability without the relocation of any utilities.

Elevation Available for BMP Placement:

Topographic maps and field research were utilized to determine the approximate elevation available for BMP placement at each site. The available elevation is primarily dictated by the difference between the flow line elevation into a BMP site and the flow line elevation out of a BMP site. The elevation available is necessary to determine the volume of storage that can be attained with various BMP structures within the area available for BMP placement, as well as to ensure that upon treatment or detention, an area will drain.

Estimated Construction Cost:

The estimated construction cost for the BMPs includes the cost of excavation, assuming no material is removed from or delivered to the site, as well as the material and placement cost for riprap, outlet structures, culverts, vegetation and turf reinforcement mat. Excavation cost is based on $4.75 per cubic yard excavated. Riprap cost is based on $25 per ton delivered and placed. Outlet structures, culverts, and vegetation are based on actual cost from previously completed projects. Turf reinforcement mat is based on $2 per square foot.

Estimated construction cost does not include temporary erosion control, permitting, easement acquisition and associated legal fees or traffic control.

Estimated 15-year Maintenance Cost:

The 15-year maintenance cost includes the cost of removing sediment and debris, re-vegetating, reinforcing, etc. on a biennial basis. This is a roughly estimated value and is subject to seasonal conditions, proper initial construction and unforeseen events. All BMPs receive an initial maintenance cost of 3% of initial construction cost on a biennial basis. Maintenance for BMPs likely to receive sediment also includes one full day of sediment removal on a biennial basis.

Maintenance cost does not include general grounds keeping such as mowing, etc.

Center-of-mass Detention:

Center of mass detention (noted as CM detention in accompanying tables) refers to the time-span between the center-of-mass of an inflow hydrograph and the center of mass of it's corresponding outflow hydrograph for a given stormwater detention structure.

SITE AND BMP SELECTION QUESTIONNAIRE
AND
BMP SCORING MATRIX

SITE SELECTION PROCESS:

The following questions regarding BMP site selection are meant to serve as reminders of some of the most fundamental factors that should be considered during the site selection process. Should the site in question fail to receive preference within this questionnaire, that site should not necessarily be dismissed, however; additional caution should be used during consideration of that site. Upon completion of the site selection process, proceed to the BMP selection portion of this questionnaire.

SITE SELECTION CONSIDERATIONS:

1. **Is the BMP site in question located such that any treated stormwater can be subject to re-contamination on its path to the outfall from the subject property?**

   Preference should be given to sites that will allow the treated stormwater to either discharge directly to the receiving stream, or to follow a path that will not subject the treated stormwater to any polluted or unstable surface prior to outfall from the property.

2. **What type of existing ground cover will be removed or disturbed for placement of a BMP at the site in question?**

   Preference should be given to sites that will not require the removal or disturbance of existing healthy vegetation including dense turf grass, trees or other native vegetation. Preference should also be given to BMP sites that will not require the disturbance or removal of an existing stable and healthy natural stormwater conveyance system, such as a stream.

3. **Does the BMP site display any topographical or geological characteristics that might cause excessive difficulty in BMP construction and maintenance, or that will substantially decrease the efficacy of a BMP, such as extreme slopes or exposed or shallow bedrock?**

   Preference should be given to sites that will not require the excavation and removal of large bedrock structures, due to excessive cost. Preference should also be given to sites that are not located on or immediately adjacent to extreme slopes due to the difficulty in stabilizing the adjacent slopes as well as the likelihood of slope failure due to the concentration of stormwater in the adjacent BMP.

4. **Is the BMP site located in close proximity to a direct conduit to groundwater, such as a sinkhole, losing stream, or cave system?**

   Preference should be given to sites that are not in close proximity to a direct conduit to ground water. BMP sites, during the course of treating stormwater, often concentrate pollutants until those pollutants can be assimilated. Excessive storm events can cause these pollutants to be removed from the BMP site and enter into these environmentally sensitive features.

5. **Does the BMP site in question offer reasonable access for routine maintenance?**

   Preference should be given to sites that are easily accessible during most weather conditions. Access to the site during varying weather conditions should be feasible to allow for inspection and maintenance. Any site that is likely to receive a BMP that promotes deposition of sediment should be accessible to equipment suitable for removal of sediment on an annual or biennial basis with minimum disturbance to the surrounding.

6. **Is the BMP site in question located such that construction, maintenance, or the existence of the BMP will place construction and maintenance personnel or the general public at excessive risk or subject the property owner to excessive liability?**

   Preference should be given to sites that are not located such that construction or maintenance personnel or the general public will be continuously subjected to excessive risk of injury during construction or maintenance on the BMP site.

   BMPs that will incorporate either permanent or long lasting pools of water should not be located in close proximity to areas of heavy pedestrian traffic, unless those sites can be fenced or offer some other deterrent.

7. **Is the BMP site in question within immediate proximity to a foundation, retaining wall, roadway or other structure that could be adversely affected by the frequent inundation of stormwater at the BMP site or repeated or constant elevated soil moisture levels?**

   Preference should be given to sites that will not pose a threat to the physical integrity of adjacent structures. Sites that lie adjacent to and upslope from these structures should be considered with a great deal of caution.

BMP SELECTION PROCESS:

The following portion of this questionnaire is meant to serve as guidance during the BMP selection process for a given site. The majority of BMPs can be altered or redesigned to work with sites outside of their normal or recommended scenarios, as such; dismissal of a BMP as a result of this questionnaire does not mean that the BMP can not be modified for use in the specific application. In addition, supplemental thought should be given to the BMP selected as a result of this questionnaire. The criteria for this BMP questionnaire and the associated BMP Scoring Matrix are based on common recommended practices.

The BMP scoring matrix should be present during completion of the following portion of this questionnaire.

1. Approximate the area available for placement of the BMP within the selected site.

   Area Available: ________________

2. Approximate the size of the area draining to the proposed BMP site.

   Drainage Area: ________________

3. Determine the size of the area available for BMP placement as a percent of the total drainage area.

   Percent of Drainage Area = (Area Available / Drainage Area) x 100

   Percent of Drainage Area: ________________

4. Does the BMP site in question reside in close proximity to a structure as defined in item #7 of the BMP Site Selection Process? Consider close proximity as 10-feet or less from the downhill side or 100-feet or less from the uphill side.

   Distance to Structure (if applicable):________________

5. Will the proposed BMP site receive stormwater in the form of sheet flow or concentrated flow?

   Sheet Flow or Concentrated Flow: ________________

6. Will a permanent or long term pool of water be acceptable at this BMP site?

   Pool Acceptable / Unacceptable: ________________

7. Are the underlying soils of the proposed BMP site well drained soils or poorly drained soils? (high or low saturated hydraulic conductivity)

Well Drained / Poorly Drained Soils: _______________

8. Is the ENTIRE area draining to the BMP site comprised of pervious surface, impervious surface, or both?

Pervious / Impervious / Both: _______________

9. The BMP Scoring Matrix has rows labeled 1-8 that correspond to the answers from questions 1-8 of the BMP Selection Process, above. Proceeding with row #1, review each cell within that row and strike through any cell that does not concur with your answer from question #1.

   Complete this same task for rows 2-8, corresponding to answers 2-8, above.

10. Strike through any column (1-19) that contains a cell that is struck through as a result of non-concurrence with answers 1-8, above.

11. The columns that remain are BMP options available for this particular site.

    Each column lists the type of BMP as well as a ranking for various environmental, cost, and infrastructure criteria. The numeric rankings contain a number, one through five (1-5), five being the most desirable, and one being the least.

    Example:

    A BMP with a ranking of 5 in the row labeled "Detention" offers greater capability for stormwater detention than does a BMP with a ranking of 1 in the row labeled "Detention"

BMP SCORING MATRIX

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		NATIVE VEGETATION PRESERVED OR ESTABLISHED	RAIN GARDEN	INFILTRATION BASIN	INFILTRATION TRENCH	BIO-RETENTION BASIN	PERVIOUS PAVEMENT	EXTENDED DETENTION WETLAND	WETLAND SWALE	BIO-SWALE	SURFACE SAND FILTER	UNDERGROUND SAND FILTER	POCKET SAND FILTER	PERIMETER SAND FILTER	EXTENDED WET DETENTION BASIN	EXTENDED DRY DETENTION BASIN	NATIVE VEGETATION SWALE	TURF GRASS SWALE	HYDRODYNAMIC SEPARATOR	CATCH BASIN INSERT
1	AREA REQUIRED FOR BMP (MIN.)	NO MIN.	NO MIN.	NO MIN.	NO MIN.	25' X 40' MIN.	NO MIN.	NO MIN.	2' WIDTH MIN.	2' WIDTH MIN.	NO MIN.	NO MIN.	NO MIN.	NO MIN.	NO MIN.	NO MIN.	100' LENGTH MIN., 2' WIDTH MIN.	2' WIDTH MIN.	PER MANUFACTURER	PER MANUFACTURER
2	DRAINAGE AREA LIMITATIONS	NONE	4 ACRE MAX	2 ACRE MAX	2 ACRE MAX	4 ACRE MAX	3 X BMP AREA	NONE	5 ACRE MAX	NONE	5 ACRE MAX	1 ACRE MAX	5 ACRE MAX	1 ACRE MAX	2 ACRE MIN.	NONE	5 ACRE MAX	5 ACRE MAX	PER MANUFACTURER	PER MANUFACTURER
3	BMP AREA AS PERCENT OF DRAINAGE AREA (MIN.)	N/A	30% MIN.	12% MIN.	24% MIN	UP TO 15%	33% MIN	8% MIN	12% MIN.	12% MIN.	3% MIN.	3% MIN.	3% MIN.	3% MIN.	VARIES W/ DEPTH	VARIES W/ DEPTH	VARIES W/ SLOPE & WIDTH	VARIES W/ SLOPE & WIDTH	VARIES	VARIES
4	PROXIMITY TO STRUCTURES	ANY	10' MIN.	10' DOWNHILL,100' UPHILL	10' DOWNHILL,100' UPHILL	10' MIN.	10' DOWNHILL,100' UPHILL	10' DOWNHILL,100' UPHILL	10' DOWNHILL,100' UPHILL	10' DOWNHILL,100' UPHILL	10' MIN	ANY	10' MIN	ANY	10' DOWNHILL,1 00' UPHILL	10' DOWNHILL, 100' UPHILL	10' MIN	ANY	ANY	ANY
5	PREFERENCE FOR SHEET OR CONCENTRATED FLOW	SHEET	SHEET (UNLESS ENERGY DISSIPATOR)	EITHER	EITHER	EITHER	SHEET	EITHER	EITHER	SHEET (UNLESS ENERGY DISSIPATOR)	EITHER	CONCENTRATED	EITHER	SHEET	EITHER	EITHER	EITHER	SHEET (UNLESS ENERGY DISSIPATOR)	CONCENTRATED	CONCENTRATED
6	PERMANENT OR LONG TERM POOL	NONE	SHORT TERM, SHALLOW	NONE	NONE	SHORT TERM, SHALLOW	NONE	LONG TERM	LONG TERM	SHORT TERM, SHALLOW	NONE	NONE	NONE	NONE	PERMANENT	LONG TERM	SHORT TERM	NONE	NONE	NONE
7	WELL DRAINED OR POORLY DRAINED SOILS	ANY	WELL DRAINED	ANY (UNDERDRAIN)	WELL DRAINED	ANY (UNDERDRAIN)	ANY (UNDERDRAIN)	ANY (OUTLET)	ANY (OUTLET)	ANY (UNDERDRAIN)	ANY (UNDERDRAIN)	ANY (UNDERDRAIN)	ANY (UNDERDRAIN)	ANY (UNDERDRAIN)	ANY (MAY NEED LINER)	ANY	ANY	ANY	ANY	ANY
8	DRAINAGE AREA: PERVIOUS, IMPERVIOUS OR BOTH	EITHER	EITHER	EITHER	EITHER	EITHER	IMPERVIOUS	EITHER	EITHER	EITHER	EITHER	IMPERVIOUS	EITHER	IMPERVIOUS	EITHER	EITHER	EITHER	EITHER	IMPERVIOUS	IMPERVIOUS
	DETENTION	3	2	3	2	2	3	5	3	3	2	2	2	2	5	5	2	1	1	1
	VOLUME REDUCTION	3	4	3	5	3	2	3	3	2	2	2	2	2	3	2	2	1	1	1
	THERMAL REDUCTION	3	5	5	5	5	3	4	4	3	3	2	3	2	3	2	3	2	1	1
	TSS REMOVAL	3	5	4	4	4	5	5	4	4	5	5	5	5	5	3	4	4	3	4
	COMPATIBLE WITH EXISTING STORMWATER INFRASTRUCTURE	5	5	4	5	4	4	4	4	4	4	2	4	2	3	3	4	4	2	5
	AESTHETICS	5	5	4	3	4	1	4	4	4	4	1	4	1	4	2	4	3	1	1
	CONSTRUCTION COST	M	L	M	L	M	H	H	M	M	M	H	M	H	H	M	L	L	H	M
	MAINTENANCE COST	L	L	L	M	M	L	L	L	L	L	M	L	M	L	M	L	M	M	M
	COST PER AREA TREATED	H	M	M	H	L	M	L	L	L	L	H	L	H	L	L	L	L	H	H

RANKING 1-5 WHERE 5 IS MOST DESIRABLE, 1 IS LEAST DESIRABLE
H = HIGH, M = MODERATE, L = LOW

VALUES FOR THIS TABLE WERE ADAPTED FROM THE CITY OF COLUMBIA, MISSOURI, STORMWATER MANAGEMENT AND WATER QUALITY MANUAL AS WELL AS INFORMATION FROM THE UNITED STATES EPA NATIONAL MANAGEMENT MEASURES TO CONTROL NONPOINT SOURCE POLLUTION FROM URBAN AREAS, EPA-841-B-05-004

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Appendix C

Hinkson Creek Total Maximum Daily Load (TMDL)

United States Environmental Protection Agency
Region 7
Total Maximum Daily Load

Hinkson Creek (MO_1007 and _1008)
Boone County, Missouri

Karen A. Flournoy
Karen A. Flournoy
Acting Director
Water, Wetlands and Pesticides Division

Jan. 28, 2011
Date

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Total Maximum Daily Load (TMDL)
for Hinkson Creek
Pollutant: Storm water runoff[1] as a surrogate for
multiple pollutants and stressors associated with urban storm water

State map showing location of watershed

Name: Hinkson Creek

Location: Columbia in Boone County, Missouri

Hydrologic Unit Code (HUC): 10300102-120

Water Body Identification Numbers (WBIDs): 1007, 1008

Missouri Stream Class[2]: WBID 1007 – Class P
WBID 1008 – Class C

Designated Beneficial Uses (WBID 1007 and 1008):
- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Protection of Human Health (Fish Consumption)
- Whole Body Contact Recreation – Category B
- Secondary Contact Recreation (WBID 1007 only)

Location of Impaired Segments: WBID 1007 – From mouth to Hwy 163
WBID 1008 – From Hwy 163 to Section 36, T50N, R12W

Length of Impaired Segments: WBID 1007 – 6 miles
WBID 1008 – 18 miles

Location of Impairment within Segments: WBID 1007 – From mouth to Hwy 163
WBID 1008 – From Hwy 163 to Interstate 70

Length of Impairment within Segments: WBID 1007 – 6 miles
WBID 1008 – 6.3 miles

Impaired Use: Protection of Warm Water Aquatic Life

Pollutant on the 303(d) List: Unknown

Pollutant Source: Urban Runoff (WBID 1007) and Urban Nonpoint Source (WBID 1008)

TMDL Priority Ranking: Medium

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[1] The term "runoff" is used to describe overland flow from all types of land uses, for both point and nonpoint sources of storm water.
[2] For stream classifications see 10 Code of State Regulations (CSR) 20-7.031(1)(F). Class P streams maintain permanent flow even during drought conditions. Class C streams may cease flow in dry periods but maintain permanent pools which support aquatic life.

TABLE OF CONTENTS

1.	**Introduction**		1
2.	**Background and Water Quality Problems**		2
	2.1	Geography	2
	2.2	Land Use	2
	2.3	Soils	5
	2.4	Defining the Problem	7
3.	**Source Inventory**		8
	3.1	Point Sources	8
		3.1.1 Domestic Wastewater Permits	9
		3.1.2 Non-Domestic Wastewater Permits	9
		3.1.3 General and Storm Water Permits	10
		3.1.4 Other "Point" Source Concerns	11
	3.2	Nonpoint Sources	12
		3.2.1 Runoff from Agricultural Acres	13
		3.2.2 Onsite Wastewater Treatment Systems	14
		3.2.3 Riparian Habitat Conditions	15
4.	**Description of Applicable Water Quality Standards and Numeric Water Quality Targets**		15
	4.1	Designated Beneficial Uses	16
	4.2	Impaired Use	16
	4.3	Antidegradation Policy	16
	4.4	Criteria	17
	4.5	Impairments and Stressors of Concern	18
		4.5.1 Detection and Description of Impairments	18
		4.5.2 Stressors of Concern and Probable Sources	18
		4.5.2.1 Biological Assessment Report, Hinkson Creek, Boone County (Missouri), December 18, 2002	21
		4.5.2.2 Stream Survey Sampling Report, Hinkson Creek Stream Study, Columbia, Missouri, Boone County, November 22, 2004	22
		4.5.2.3 Stream Survey Sampling Report, Phase II, Hinkson Creek Stream Study, Columbia, Missouri, Boone County, June 2004-June 2005	23
		4.5.2.4 Stream Survey Sampling Report, Phase III, Hinkson Creek Stream Study, Columbia, Missouri, Boone County, July 2005-June 2006	24
		4.5.3 Stressors of Concern and Urban Storm Water Runoff	25
	4.6	Setting the Water Quality Targets	30
		4.6.1 Technical Approach for Developing Reference Stream Flows	30
		4.6.2 Selection of Reference Streams	30
5.	**Calculation of Loading Capacity**		35
	5.1	Development of Targets	36
	5.2	Land-Use Based TMDL Allocations	37
6.	**Wasteload Allocation (Point Source Load)**		39

7. **Load Allocation (Nonpoint Source Load)**………………………………………….. 40
8. **Margin of Safety**……………………………………………………………….. 40
9. **Seasonal Variation**.. 41
10. **Monitoring Plans**……………………………………………………………… 41
11. **Reasonable Assurances**…………………………………………………….……….. 41
12. **Public Participation**…………………………………………………………………. 42
13. **Administrative Record and Supporting Documentation**……………………… 43

References

Appendix A - Location Maps from the Four Studies Showing Sample Sites………… 47
Appendix B - General and Storm Water Permits in Hinkson Creek Watershed..….. 52
Appendix C - Land-Use Maps for Reference Streams Percentage Tables Included Land-Use Coverage Data from 2002-2005……………………………… 57
Appendix D - Additional Activities in the Hinkson Creek Watershed……………….. 61
Appendix E - Supplemental Implementation Plan………………………………….… 67

LIST OF TABLES

Table 1. Hinkson Creek Watershed Land Use Percentages – 1993…………………………………5
Table 2. Hinkson Creek Watershed Land Use Percentages – 2005…………………………………5
Table 3. Site Specific Permits in the Hinkson Creek Watershed………………………………..10
Table 4. Storm Water (MOR) and General (MOG) Permits………………………………………11
Table 5. Hinkson Creek Watershed Land Use Percentages – 2005………………………………..15
Table 6. Noted Stressors and their Sources…………………………………………………...19
Table 7. Noted Pollutants or Conditions and their Sources……………………………………...20
Table 8. Stream Condition Index Scores for Hinkson Creek…………………………………….22
Table 9. Comparison of Precipitation and Flow for April 1 – July 31…………………………….26
Table 10. Summary of Hydrologic Conditions During the Period from 1967 to 2010……………...28
Table 11. Hinkson Creek and Reference Streams Used in TMDL Reduction Analysis…………....31
Table 12. Yearly Precipitation at Hinkson Creek and Reference Streams During Flow Analysis Periods……………………………………………………………………………….…32
Table 13. Flows for Hinkson Creek and Reference Streams with Target Changes at the USGS USGS Hinkson Gauging Station……………………………………………………….34
Table 14. Estimated Runoff Coefficients based on the Percent of Imperviousness…………………37
Table 15. Storm Water TMDL and Its Allocation at the Outlet of Hinkson Creek Watershed……..39

LIST OF FIGURES

Figure 1. Land Use Map of Hinkson Creek Watershed – 1993 3
Figure 2. Land Use Map of Hinkson Creek Watershed – 2005 4
Figure 3. Hinkson Creek Watershed Showing Location of Permits 12
Figure 4. Flow Duration Curves for April – July, 1967 and 2007 27
Figure 5. Annualized Flow Duration Curves for the 3 and 22-Year Flow Records. 29
Figure 6. The Determination of Bankful Discharge for Hinkson Creek 29

Figure 7. Location of Reference Streams in Relation to Hinkson Creek.. 32
Figure 8. Hydrologic Comparison of the Synthetic Flow and Reference Streams…………………......33
Figure 9. Annualized Flow Duration Curves for Hinkson Creek and Reference Streams at the USGS Hinkson Gauging Station 34

List of Acronyms

AFOs	Animal Feeding Operations
AgNPS	Agriculture Nonpoint Source
SALT	Special Area Land Treatment
AMS	American Meterological Society
BCRSD	Boone County Regional Sewer District
BMPs	Best Management Practices
CAFOs	Concentrated Animal Feeding Operations
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
cfs/mi^2	Cubic Feet per Second per Square Mile
CL	Confidence Limit
CSR	Code of State Regulations
CWA	Clean Water Act
CWP	Center for Watershed Protection
DO	Dissolved Oxygen
e.g.	For Example
E. coli	Escherichia coli
EPA	U.S. Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera and Trichoptera
FDC	Flow Duration Curve
ft	Feet
ft^3	Cubic Feet
ft^3/sec	Cubic Feet per Second
HUC	Hydrologic Unit Code
Hwy	Highway
i.e.	that is
in	Inches
LA	Load Allocation
LC	Loading Capacity
MDC	Missouri Department of Conservation
MDNR	Missouri Department of Natural Resources
mi^2	Square Miles

ACRONYMS (CONTINUED)

mg	Milligrams
mg/L	Milligrams per Liter
MGD	Million Gallons per Day
MO	Missouri
MoDOT	Missouri Department of Transportation
MoRAP	Missouri Resource Assessment Partnership
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System
MSCI	Missouri Stream Condition Index
MSOP	Missouri State Operating Permit
NASS	National Agricultural Statistics Service
No.	Number
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRC	National Research Council
NRCS	Natural Resources Conservation Service
P	Precipitation
PAH	Polycyclic Aromatic Hydrocarbon
Rv	Runoff Coefficient
SCI	Stream Condition Index
SPMD	Semi Permeable Membrane Device
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
U.S.	United States
UMC	University of Missouri Columbia
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WBID	Water Body Identification
WERF	Water Environment Research Federation
WLA	Wasteload Allocation
WQS	Water Quality Standards
WWTF	Wastewater Treatment Facility
WWTP	Wastewater Treatment Plant

HINKSON CREEK TMDLs
PHASED and ADAPTIVE MANAGEMENT PLAN

The Hinkson Creek Total Maximum Daily Loads (TMDLs) are a phased and adaptive plan to restore water quality conditions in the Hinkson Creek watershed.

In this instance, the United States Environmental Protection Agency (EPA) is establishing this TMDL in order to comply with the 2001 Consent Decree, *American Canoe Association, et al. v. EPA*, Consolidated Case No. 98-1195-CV-W-SOW, consolidated with 98-4282-CV-W-SOW. However, EPA recognizes that it may be appropriate to revise these TMDLs based on analyses performed after additional data and information has been collected. Additional data and information collection may be warranted to further assess the sources of the impairment and to assess the affect of water quality improvement measures put in place since data was collected by the Missouri Department of Natural Resources (MDNR) in 2006.[3] Considering such possible revisions, it is appropriate to characterize these TMDLs as phased TMDLs.

In a phased TMDL, EPA uses the best information available at the time to establish the TMDL to meet applicable water quality standards (WQS) and to allocate loads to the pollutant sources. However, the phased TMDL approach recognizes that additional data and information may be necessary to further validate the assumptions of the TMDL and to provide greater certainty that the TMDL will achieve the WQS. EPA anticipates that additional data and information will be collected to reassess the Hinkson Creek biocommunity and other water quality parameters. This new data and information can then be used to determine if the TMDL should be revised. Revision may include adjustments to the overall TMDL approach, or the specific wasteload allocations (WLA) and load allocations (LA).

EPA anticipates that much of this data and information will be collected by Boone County, the city of Columbia and the University of Missouri-Columbia (UMC) collective MS4 permittees. In this first phase of the Hinkson Creek TMDLs, EPA recommends that an assessment of the biocommunity be conducted in accordance with MDNR protocols and an EPA- and MDNR-approved Sampling and Analysis Plan and Quality Assurance Project Plan.[4] EPA believes that this assessment could be used to determine whether Hinkson Creek is attaining the state's general biological criteria.

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[3] See Appendix D, *Additional Activities in Hinkson Creek Watershed*, for a list compiled by Boone County, the city of Columbia, Missouri and the UMC.

[4] In order to effectively assess the biocommunity of Hinkson Creek, EPA recommends that a number of specifics to be considered. EPA recommends that it be given the opportunity to review the list of reference streams that will be used to compare the biological data to Hinkson Creek biological data in the Missouri Stream Condition Index (MSCI). EPA recommends submission of the associated raw macroinvertebrate data (i.e., bench sheets) and the MSCI scores for the reference streams. EPA recommends the addition of the Jaccard Similarity Index to the reference and test streams to assess any detrimental change in the aquatic community. EPA also recommends an additional biotic index (i.e., Fish diversity).

Additionally, EPA recognizes that implementation of these TMDLs will be adaptive and iterative, using new data or information to adjust the implementation activities. EPA recommends that implementation of the TMDLs begin with the immediate collection of additional data and information. EPA also recommends that concurrently, initial actions to improve water quality be taken including, but not limited to: 1) addressing excursions to some of the State's narrative water quality criteria by taking measures to eliminate harmful bottom deposits, 2) rigorous implementation of protective city and county ordinances and 3) improving the use of best management practices (BMPs) within the Hinkson Creek watershed. EPA anticipates that more long-term actions will be implemented in the future including, but not limited to, consideration of incorporating green infrastructure in existing and future developments, continuation of on-going watershed restoration projects and water quality projects, continued efforts of existing watershed protection groups and the formation of additional watershed protection groups.[5] If this approach reveals that the TMDLs' loading capacity (LC) needs to be changed, the TMDLs may be revised by MDNR with EPA approval.

[5] Appendix E for additional information on green infrastructure.

1. Introduction

The Hinkson Creek TMDLs are being established in accordance with Section 303(d) of the Clean Water Act (CWA). The water quality limited segments are included on the EPA approved 2008 Missouri 303(d) List. The pollutants of concern for the impaired segments are identified on the list as "unknown" and the source of the impairments is listed as "urban runoff" and "urban nonpoint source." The pollutant causing the impairments is listed as unknown on the 303(d) List; however, toxicity from multiple pollutants and changes in hydrology from increased impervious surfaces are the suspected cause of the impairment. Hinkson Creek was first listed on the 1996 Missouri 303(d) List for unknown pollutants due to urban nonpoint sources. Hinkson Creek continued being listed on the 1998, 2002 and 2006 Missouri 303(d) Lists for unknown toxicity due to urban runoff. By establishing this TMDL, EPA will meet milestones of the 2001 Consent Decree, *American Canoe Association, et al. v. EPA*, No. 98-1195-CV-W-SOW, consolidated with 98-4282-CV-W-SOW, February 27, 2001.

Section 303(d) of the CWA and Chapter 40 of the Code of Federal Regulations (CFR) Part 130 requires states to develop TMDLs for waters not meeting applicable WQS, including designated beneficial uses. The TMDL process quantitatively assesses the impairment factors so that states can establish water-quality based controls to reduce pollutants and restore and protect the quality of their water resources.

The purpose of a TMDL is to determine the pollutant loading a water body can assimilate without exceeding the applicable WQS. The TMDL also establishes the pollutant load necessary to meet the WQS established for each water body based on the relationship between pollutant sources and instream water quality conditions. The TMDL consists of a WLA, a LA and a margin of safety (MOS). The WLA is the portion of the allowable pollutant load that is allocated to point sources. The LA is the portion of the allowable pollutant load that is allocated to nonpoint sources. The MOS accounts for the uncertainty associated with the model assumptions and data inadequacies. The pollutants of concern impairing Hinkson Creek were listed as unknown on the 303(d) List, but this TMDL calculates a reduction in storm water runoff as a surrogate for multiple pollutants and stressors associated with urban storm water. This approach has been used and approved by EPA in other states and is supported at 40 CFR 130.2(i) for TMDL development as an "other appropriate measure."

The goal of the TMDL program is to restore impaired designated beneficial uses to water bodies. In addition to establishing a TMDL for Hinkson Creek, this report provides a summary of information, results and recommendations related to the impairment based on a broad analysis of watershed information and detailed analysis of flow data and comparison to unimpaired reference streams. As discussed earlier, this TMDL is a phased and adaptive management TMDL that anticipates the additional collection of data and information. New data and information can then be used to determine if the TMDL should be revised.

Section 2 of this report provides background information on the Hinkson Creek watershed and defines the water quality problems. Section 3 describes potential sources of pollutants of concern. Section 4 presents the applicable WQS, TMDL targets and describes the technical approach used to develop the TMDL. Sections 5 to 9 present the required TMDL elements (LC,WLA, LA, MOS, seasonal variation) and Sections 10 to 13 summarize the follow-up monitoring plan, reasonable assurances, public participation and the administrative record.

2. Background and Water Quality Problems

This section of the report provides information on Hinkson Creek and its watershed. Included in this section is a description of the watershed location, geology, soils, population, land use and land cover. In addition, water quality problems present in the watershed are described.

2.1 Geography

Hinkson Creek originates in northeastern Boone County and flows southwest through the city of Columbia before joining Perche Creek, which then flows south into the Missouri River. The Hinkson Creek watershed covers approximately 90 square miles (mi^2) and drains roughly 60 percent of the land area within the city of Columbia. The water body is considered a Missouri Ozark border stream and is located in a unique physiographic area characterized as a transitional zone between the Glaciated Plains and the Ozark Natural Divisions (Thom and Wilson 1980). The impaired portion of Hinkson Creek begins at Interstate 70 and flows through the city of Columbia to the stream's confluence with Perche Creek.

2.2 Land Use

Land use within the Hinkson Creek watershed has changed substantially within the past decade. This section compares and contrasts land use maps and data from the Hinkson Creek watershed for two different time periods. Land use data and information for both time periods are an amalgam of Landsat Thematic mapper data collected just prior to development of the final land use data layer. The 1993 land use data presented in this section are an amalgam of images from 1991 to 1993. The 2005 land use data presented are based on images circa 2000 to 2005. These data and information are considered representative of land use types and percentages within the watershed for the dates given.

Figure 1 and Table 1 present 1993 land use data for the Hinkson Creek watershed. Land use within the watershed at this time was 7.9 percent urban, 13.1 percent row crops, 48.6 percent grasslands and 29.7 percent forest (MoRAP 1999). By comparison, land use within the Hinkson Creek watershed in 2005 was 20.7 percent urban, 11.5 percent row crops, 38.2 percent grasslands and 26.9 percent forest (MoRAP 2005). Land use data for 2005 are presented in Figure 2 and Table 2.

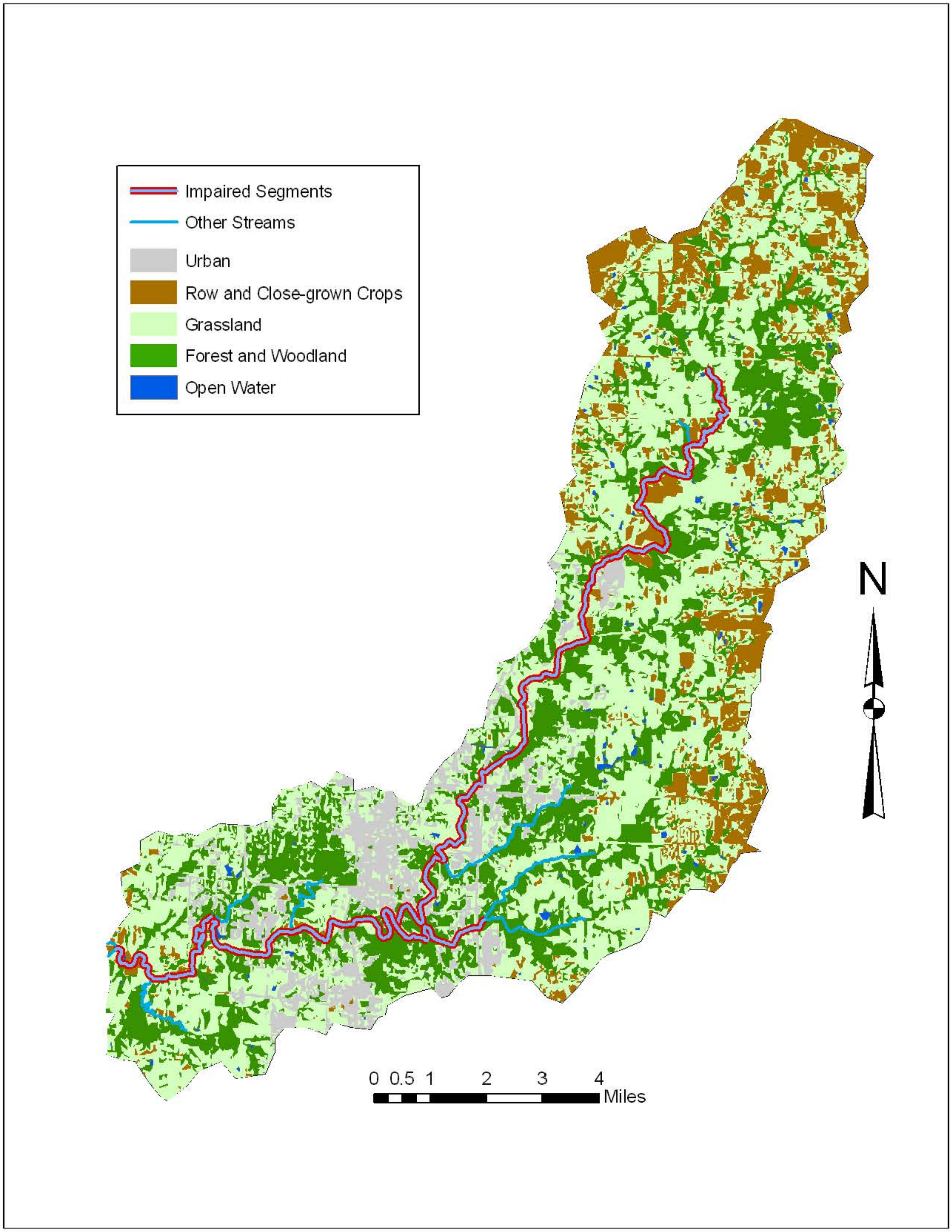

Figure 1. Land Use Map of Hinkson Creek Watershed – 1993

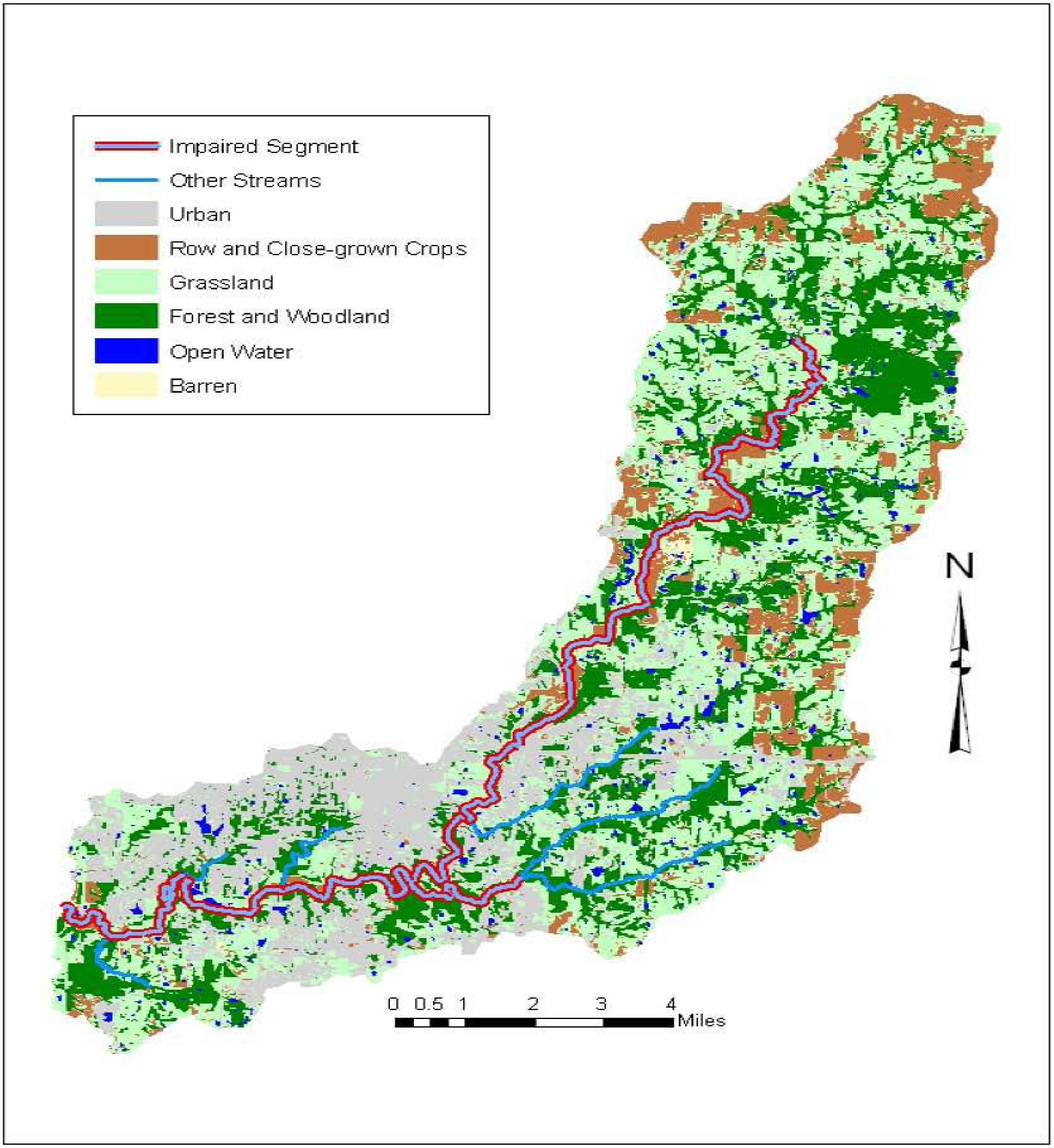

Figure 2. Land Use Map of Hinkson Creek Watershed - 2005

Table 1. Hinkson Creek Watershed Land Use Percentages – 1993

Land Use	Acres	Square Miles	Percentage
Urban	4,527	7.07	7.9
Row and Close-grown Crops	7,533	11.77	13.1
Grassland	27,987	43.73	48.6
Forest & Woodland	17,113	26.74	29.7
Open Water	422	0.66	0.7
Total	**57,582**	**89.97**	**100.0**

Table 2. Hinkson Creek Watershed Land Use Percentages - 2005

Land Use	Acres	Square Miles	Percentage
Urban	11,890	18.58	20.7
Row and Close-grown Crops	6,625	10.35	11.5
Grassland	21,962	34.32	38.2
Forest & Woodland	15,443	24.13	26.9
Open Water	1,439	2.25	2.5
Barren	79	0.12	0.1
Total	**57,438**	**89.75**	**100.0**

In both the 1993 and 2005 land use data, land use in the upper portion of the watershed is predominantly rural grassland and wooded areas, while the lower portion contains the urbanized area of the city of Columbia. The percentage of urban land use in the Hinkson Creek watershed increased approximately 160 percent between 1991 and 2005, with the majority of urban growth occurring as retail and residential development. To substantiate this point, the following was retrieved from the Housing Market Analysis on the city's website[6]:

> According to census data, the number of housing units in Columbia increased by 8,412 units between 1990 and 2000 (from 27,551 to 35,963). This is a 30.5 percent increase. Also, according to building permit data, 1,173 new housing units (on average) were built each year between 2000 and 2003. This compares to 836 units built per year between 1990 and 2000. The number of housing units increased 9.1 percent between 2000 and 2003.

This represents additional loss of forest and grassland areas with conversion to urban land use, increasing the amount of impervious cover. Increases in impervious cover within the watershed directly influence the quantity and quality of storm water runoff into Hinkson Creek.

2.3 Soils

The type and distribution of soils within the Hinkson Creek watershed is an important factor in determining whether storm water is absorbed into the subsurface or runs off into nearby streams. Although absorption of rainwater in natural settings can be highly variable, soils with

[6] http://gocolumbiamo.com/Planning/Documents/chapter_2.pdf

slower permeability generally exhibit less infiltration and higher runoff rates than soils with higher permeability. Soils at the top of the Hinkson Creek watershed have low permeability. Soil permeability increases as one goes lower in the watershed. However, the lower portion of the watershed contains most of the impervious surface area which tends to counteract the greater soil permeability. The next few paragraphs go into more detail about the specific soils within the Hinkson Creek watershed.[7]

The upland ridge land that surrounds and extends into the upper and central portions of the Hinkson Creek watershed is in the Mexico-Leonard soil association. These soils are formed from fine and fine-silty loess over pedisediment and glacial till. They are poorly to somewhat poorly drained and permeability is slow to very slow. Slopes range from 1 to 6 percent. Most of the row crop agriculture in the area occurs on these soils. This area constitutes about 20 percent of the watershed.

The hills and ridges within the upper and central portions of the watershed are predominantly characterized by the Keswick-Hatton-Winnegan soil association. These soils cover the most extensive area within the watershed, nearly 50 percent. These soils are formed from loess over clayey till and fine-silty pedisediment. They are moderately well drained but with slow to very slow permeability. Slopes range from 2 to 35 percent. Outside of the urban area, land cover is principally a mixture of pasture and woodland.

In the central lower portion of the watershed, the uplands are mostly characterized by the Weller-Bardley-Clinkenbeard association. The geographic extent of this soil association within the watershed is predominantly within the Columbia city limits. The Weller silt loam, formed in deep loess, is situated on summits, shoulders and benches within this area. It is moderately well drained with low permeability. At least 40 percent of the Weller soil area within the watershed is in urbanized land use. Slopes range from 2 to 9 percent. The backslopes downhill from Weller soil areas are constituted principally of the Bardley-Clinkenbeard complex. This is very stony ground on slopes that range from 20 to 45 percent. It is well drained and has moderate permeability.

The upland portion of the Hinkson Creek watershed closest to the confluence with Perche Creek, is characterized by the Menfro-Winfield association. Within the watershed, this is a relatively small area, about 5 percent. These soils are formed in deep, fine-silty loess and are very common in uplands across the Midwest that are relatively close to large rivers such as the Missouri River. They are well drained to moderately well drained with moderate permeability. Some of the lower slopes in this area are made up of the Rocheport-Bonnefemme complex, which is moderately well drained, with moderately slow permeability.

The Hinkson Creek bottomlands are relatively narrow, generally half a mile or less in width. In this area, the soil has been formed principally from alluvial processes. There are a wide variety of soil types, with a range of textural characteristics. For example, Perche loam is characterized by stratified layers with a high sand content. The Cedargap-Dameron complex, located mainly in tributary bottomland areas of Flat Branch and County House Branch, is very stony and well drained with moderate permeability. Elsewhere, mainly on the flood plain

[7] Source: USDA – NRCS, 2003. Soil Survey of Boone County, Missouri

terraces, soils such as Aux Vasse and Tanglenook tend to be finer textured with slower permeability. Upstream from the city, much of the bottomland area is used for row crop agriculture. Within the city, development in the bottomland has been minimal and much of it is in city parks.

2.4 Defining the Problem

While Hinkson Creek appears on the EPA-approved 2008 Missouri 303(d) List of impaired waters with the pollutant listed as unknown and the source as urban runoff and urban nonpoint source, it was originally placed on the 1998 Missouri 303(d) List for unspecified pollutants due to urban nonpoint runoff.[8] According to EPA (1994), nonpoint source pollution[9] is the number one cause of water quality impairment in the United States and accounts for the pollution of approximately 40 percent of all waters surveyed. As found in numerous studies, there is typically not one pollutant or condition that is the sole cause of nonpoint source impairment to streams that flow through urbanized areas. The stressors, conditions and pollutants are collectively causing the impairment of Hinkson Creek. What is known, is that water quality problems typically associated with streams in urban areas include the following:

1. Larger and more frequent floods, as well as lower base flows, due to the increase in impervious surfaces (e.g., rooftops, paved roads and parking lots) in the watershed.

2. Increased soil erosion in construction and development areas and instream erosion with subsequent deposition of the soil in streams.

3. Water contamination from urban storm water flows that carry pollutants from sources within the watershed.

4. Degradation of habitat for aquatic organisms due to the causes listed above.

5. Degradation of aquatic habitat due to the physical alteration of stream channels and adjacent streamside (riparian) corridors. Such practices include:
   - enclosing the stream in a large pipe,
   - straightening (channelizing) the stream,
   - paving the stream bottom and/or banks with concrete or rip rap (large rocks) and
   - removing trees and other permanent vegetation near streams.

MDNR has received citizen reports regarding all five of the water quality problems mentioned above as being issues with the stream. These reports were the basis for the original 303(d) listing.

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[8] Some of urban storm water (during the 1998 assessment) might well have been point source discharge that is now or could be permitted one day.

[9] Nonpoint source means the general runoff from the land, not a specific pipe as from industry or a wastewater treatment facility (WWTF). Nonpoint source impairments are a reflection of what is occurring in the watershed or the land that drains into a particular stream.

No particular pollutant, or suite of pollutants, has been identified as the main cause of the impairment observed in Hinkson Creek. Sediment has been established as the primary source of impairment in numerous TMDLs throughout the country. However, since sediment was not studied with respect to the impairment in Hinkson Creek, sediment cannot act as the basis for a surrogate TMDL as it has elsewhere. MDNR water quality studies did reveal, however, that a large percentage of the problems, including increased sediment and low dissolved oxygen (DO) at low flows, can be attributed to urban runoff conditions which result in excessive storm water runoff and lower than normal base flow conditions.

EPA regulations state that TMDLs can be expressed in several ways, including in terms of toxicity which is a characteristic of one or more pollutants, or by some "other appropriate measure" [40 CFR 130.2(i)]. Federal regulation also states that TMDLs may be established using a biomonitoring approach as an alternative to the pollutant-by-pollutant approach [40 CFR 130.7(c)(1)]. This flexibility in the expression of TMDLs supports reliance on a surrogate where, as in this case, there is a reasonable rationale for the choice of that surrogate and the TMDL is designed to ensure attainment with WQS.

When impairment cannot be tied to an exceedance of a single specific numeric criterion, or when a specific numeric criterion target is not discernable, using a surrogate parameter may be the most appropriate approach to developing a TMDL and restoring the water body (EPA 2011). In this case, the surrogate chosen to measure the needed reduction in stressors and toxic pollutants in Hinkson Creek is the stream's storm events. The TMDL will identify reductions in storm water flow as a surrogate for limits on specific pollutants of concern causing the aquatic life impairment in the stream. Specifically, this TMDL is aimed at restoring the stream's natural flow dynamics. Creating more natural stream flows will restore habitat and reduce the release of toxic pollutants into Hinkson Creek.

3. Source Inventory

This section summarizes the available information on possible sources of the pollutants affecting Hinkson Creek. In general, sources are divided into point sources and nonpoint sources. The term point source refers to any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel or conduit, by which pollutants are transported to a water body. Examples of point sources of pollutants are those sources regulated through the Missouri State Operating Permit (MSOP) system.[10] Nonpoint sources of pollutants include general runoff from the watershed and all other categories not classified as point sources.

3.1 Point Sources

For the purposes of this TMDL, point sources are defined as sources regulated through the National Pollutant Discharge Elimination System (NPDES) program. Missouri has its own program for administering the NPDES program, referred to as the MSOP system. The NPDES and MSOP programs are the same and for the purposes of this document the term "NPDES" will

[10] The MSOP system is the state of Missouri's program for administering the federal NPDES program.

be used. By law, point sources also include: concentrated animal feeding operations (CAFOs), which are places where animals are confined and fed; storm water runoff from Municipal Separate Storm Sewer Systems (MS4s); and storm water runoff from construction and industrial sites. These facilities must have a discharge permit issued by MDNR that contain discharge limits and other requirements the facility must meet to protect instream WQS.

There are 25 site specific permits located in the Hinkson Creek watershed. Of these permits, 21 are for domestic facilities and 4 are for non-domestic facilities. There are 6 general permits within the Hinkson Creek watershed and 126 storm water permits. Details on site specific, general and storm water permits within the Hinkson Creek watershed can be found in the following sections.

3.1.1 Domestic Wastewater Permits

Domestic WWTFs are designed to treat household waste, both grey water and sewage. These treatment facilities can be potential sources of pollutants to the stream due to malfunctions, mismanagement and/or excessive storm flows that cause or allow contaminants to discharge into the receiving water body. Domestic wastewater permits may have water quality-based or technology-based effluent discharge limits for pollutants of concern such as bacteria, nutrients, toxics and oxygen demanding substances. Properly treated domestic wastewater discharged in accordance with the facility operating permit should not cause or contribute to an exceedance of WQS in the receiving water body. There are 21 site specific domestic wastewater permits within the Hinkson Creek watershed. These permits are listed in Table 3 and shown in Figure 3.

3.1.2 Non-Domestic Wastewater Permits

Non-domestic WWTFs are designed to treat wastewater generated from predominantly industrial or non-sewage generating activities. There are four site specific non-domestic wastewater permits within the Hinkson Creek watershed. These permits are listed in Table 4 and shown in Figure 3. In terms of the volume of flow discharged (i.e., design flow), the largest site specific permit in the Hinkson Creek watershed is the Columbia Sanitary Landfill which is non-domestic. The landfill is located north of Interstate 70 on Peabody Road and directly adjacent to Hinkson Creek (see map in Appendix A.1). The design flow listed in Table 3 is the combined design flow from the six facility outfalls. The actual flow for all facility outfalls depends on precipitation. In the Phase I water quality study, high conductivity was recorded below the landfill during low flow conditions and is presumed to be caused by leachate from the landfill.

Table 3. Site Specific Permits in the Hinkson Creek Watershed

Permit #	Name	Design Flow	Classified Waterbody	Permit Expires
Domestic				
MO0049913	BCSD, Sun Valley Estates	0.030	Trib Hinkson Creek	2013
MO0050989	BCSD, El Chaparral Subdivision		S Fork Grindstone Ck	terminated
MO0053376	BCSD, Highfield Acres	0.029	Trib N Fork Grindstone	2011
MO0081922	Manchester Heights Subdivision	0.013	Trib Hominy Creek	2011
MO0082066	Woodstock Mobile Home Park	0.031	Trib Grindstone Creek	2013
MO0085952	BCSD, Sharidan Hills Subdivision	0.030	Trib Hinkson Creek	2013
MO0088668	BCSD, Hillview Acres Subdivision	0.023	Trib Hinkson Creek	2011
MO0090816	BCSD, Sunrise Estates NE	0.013	Trib N Fork Grindstone	2012
MO0090824	BCSD, Sunrise Estates NW	0.009	Trib N Fork Grindstone	2012
MO0091766	BCSD, El Rey Heights	0.014	Trib Nelson Creek	2013
MO0096415	BCSD, Cedar Gate Subdivision	0.011	Trib Varnon Creek	2012
MO0096539	BCSD, Concorde Estates Subdivision		S Fork Grindstone Ck	terminated
MO0096954	BCSD, Sunrise Estates, SE		S Fork Grindstone Ck	terminated
MO0104302	Slumberland Furniture	0.001	Trib S Fork Grindstone	2012
MO0105520	El Rey Mobile Home Park	0.008	Trib Hominy Branch	2012
MO0109631	Lake of the Woods Mobile Home Park	0.005	Hominy Branch	1999
MO0114782	BCSD, Lake Capri Subdivision	0.021	Trib Hinkson Creek	2011
MO0117781	BCSD-OTSCON		S Fork Grindstone Ck	terminated
MO0118672	BCSD, Shaw WWTF	0.050	N Fork Grindstone Ck	2011
MO0123072	BCSD, Fall Creek Subdivision	0.003	Trib Hinkson Creek	2011
MO0124605	Sallee Post Service Sanctuary	0.003	Trib Hinkson Creek	2011
Non-domestic				
MO0104337	Kraft Foods Global / Columbia Foods Co.	0.408	Trib Hinkson Creek	2012
MO0104591	Analytical Bio-Chem Laboratories, Inc.	0.034	N Fork Grindstone Ck	2013
MO0107735	UMC Power Plant	0.488	Flat Branch	2009
MO0112640	Columbia Sanitary Landfill & Yard Waste Compost	12.214	Trib Hinkson Creek	2008

Note: Design flow in million gallons per day (MGD); BCSD = Boone County [Regional] Sewer District; WWTP(F) = Wastewater Treatment Plant (Facility); UMC = University of Missouri at Columbia

3.1.3 General and Storm Water Permits

General and storm water permits are issued based on the type of activity occurring and are meant to be flexible enough to allow for ease and speed of issuance, while providing the required protection of water quality. General permits are issued to activities similar enough to be covered by a single set of requirements and have permit numbers starting with MOG. Six facilities within the Hinkson Creek watershed hold general permits. There are also storm water permits for 13 industrial sites and 112 land disturbance/construction sites within the watershed. The general and storm water permits within the Hinkson Creek watershed are listed in Appendix B and compiled and shown in Table 4 and Figure 3, respectively.

Also, Boone County, the city of Columbia and the UMC are jointly responsible for a NPDES permit for the storm water drainage system, known as a MS4. The MS4 permit is designed to reduce storm water runoff and pollution within the permittee's jurisdiction. Appendix D contains detailed information regarding the MS4 co-permit.

Two additional permits not listed in the table below are held by the Missouri Department of Transportation (MoDOT), which was issued state-wide permits that apply to the Hinkson Creek watershed. These permits are an MS4 permit, MOR040063, and a land disturbance permit, MOR100007; they cover MoDOT construction projects and activities statewide. The effluent limitations and requirements found in these statewide permits do not differ from the versions held by other permittees that apply only to a specific site.

Table 4. Storm Water (MOR) and General (MOG) Permits

Permit #	**Description**	
MOR040xxx	Storm sewer – municipal MS4	**1**
MOR10xxxx	Storm water/Land Disturbance	**112**
MOR12Axxx	Food Processing	**1**
MOR203xxx	Metal scrap and resale	**2**
MOR23Dxxx	Plastic manufacture	**1**
MOR23Dxxx	Rubber Products	**1**
MOR240xxx	Agriculture/Chemical plant	**1**
MOR60Axxx	Vehicle salvage yards	**3**
MOR80Cxxx	Truck maintenance facility	**4**
MOG35xxxx	Petroleum storage	**2**
MOG49xxxx	Limestone quarry	**1**
MOG76xxxx	Swimming pool discharge	**2**
MOG94xxxx	Fuel spill cleanup	**1**
	Total	**132**

3.1.4 Other Point Source Concerns

Another source of pollutants to the stream is through infiltration and inflow associated with the sanitary sewer collection system. A sanitary sewer collection system is the network of pipes and pumps that convey sewage to a WWTF. Infiltration and inflow allow excess storm water to enter the sewage collection system, which leads to sanitary sewer overflows and wet weather treatment issues at WWTFs. Collection systems across the country are aging and countless communities are struggling to address the needed maintenance. Maintenance of sanitary sewer collection systems is often addressed through the WWTF's NPDES permit.

Other potential point sources of pollutants are illicit (i.e., illegal) straight pipe discharges of household wastewater in rural as well as urban areas. These pipes discharge human waste directly into streams or land areas and are different than illicit sewer connections into a city sewer system. Untreated straight pipe discharges can pose significant localized impacts on water quality while being extremely difficult to detect and regulate.

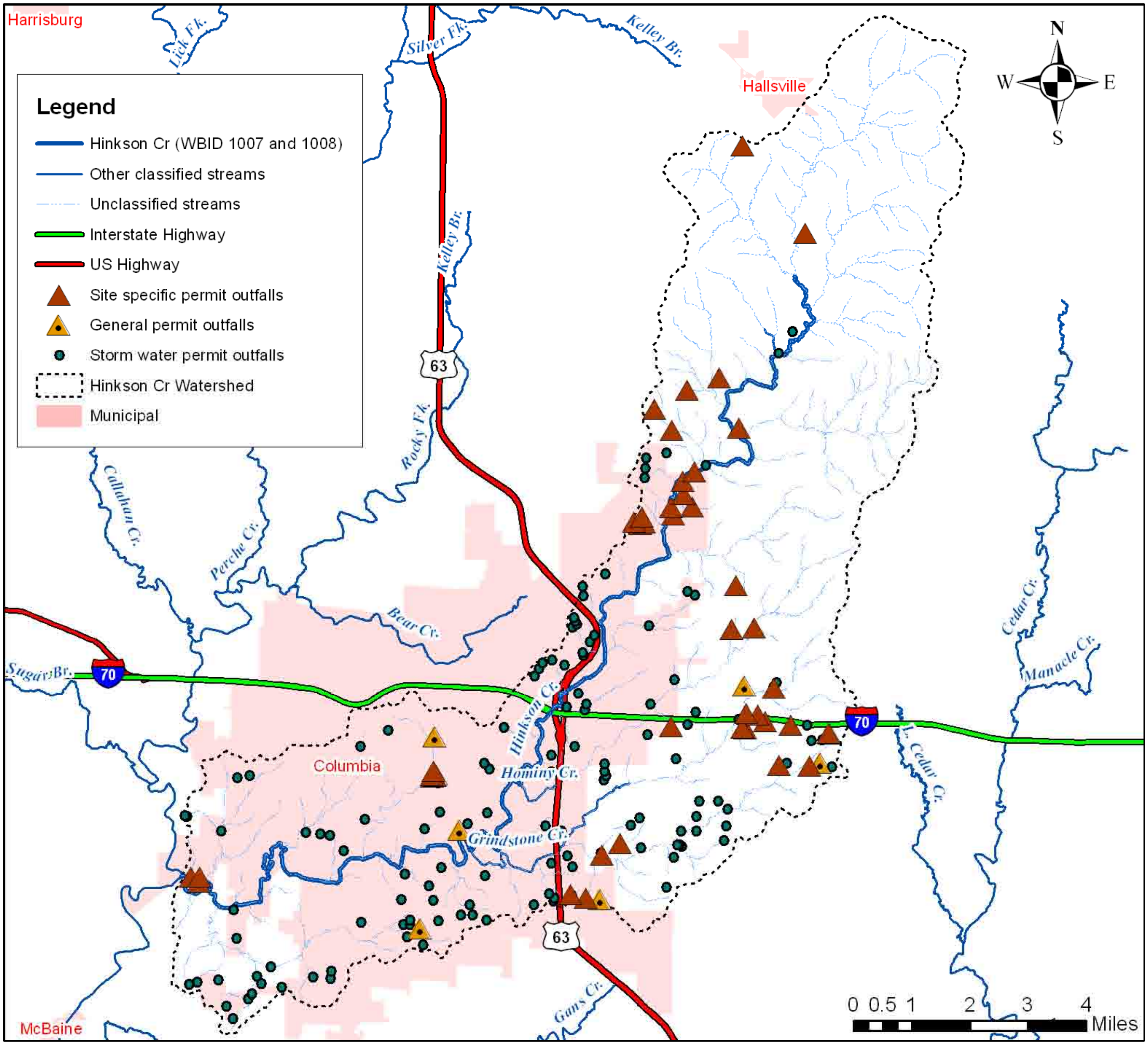

Figure 3. Hinkson Creek Watershed Showing Location of Permits

3.2 Nonpoint Sources

Nonpoint sources include all other categories not classified as point sources. Potential nonpoint sources contributing to toxicity problems in the Hinkson Creek watershed include runoff from urban areas outside of MS4s (via overland flow), agricultural runoff, onsite wastewater treatment systems and various sources associated with riparian habitat conditions. Each of these is discussed further in the following sections.

In the absence of an NPDES permit, the discharges associated with nonpoint sources discussed in this Section 3.2, were applied to the LA, as opposed to the WLA, for purposes of this TMDL. The decision to allocate these sources to the LA does not reflect any determination by EPA as to whether these discharges are, in fact, unpermitted point source discharges within this watershed. In addition, by establishing these TMDLs with some sources treated as LAs, EPA is not determining that these discharges are exempt from NPDES permitting requirements. If sources of the allocated pollutant in this TMDL are found to be, or become, NPDES-regulated discharges, for permitting purposes their loads must be considered as part of the calculated sum of the WLAs in this TMDL. WLA in addition to that allocated here is not available.

3.2.1. Runoff from Agricultural Areas

Lands used for agricultural purposes can be a source of pesticides, sediment, nutrients and organic material. Accumulation of nutrients and pesticides on cropland occurs from decomposition of residual crop material, fertilization with chemical and manure fertilizers, atmospheric deposition, wildlife excreta and irrigation water. The 2005 land use/land cover data indicates there are 6,625 cropland acres in the watershed, which comprises about 12 percent of the entire watershed (see Table 2). Pollutants related to agricultural areas can contribute to sediment deposition, low DO and nutrient enrichment. In addition, agricultural practices can contribute to streambank erosion and poor riparian cover if cattle are not kept from accessing streams.

Based on county-wide data from the National Agricultural Statistics Service (NASS) (USDA 2007) and the watershed land cover data, there are approximately 3,740 cattle in the Hinkson Creek watershed.[11] Because the cattle are most likely located on the approximately 34.32 square miles of grassland/pastureland in the watershed, runoff from these areas is an important source of nutrients and oxygen consuming substances transported to streams. For example, animals grazing in pasture areas deposit manure directly on the land surface and their feces are readily washed to streams during rainfall events. Though a pasture may be relatively large and have low livestock densities, the manure will often be concentrated near the feeding and watering areas in the field. These areas can become barren of plant cover and increase soil erosion and pollutant loads. In addition, when pasture land is not fenced off from streams, cattle or other livestock may contribute nutrients to a stream while walking in or adjacent to the water body. The density of cattle in the Hinkson Creek watershed (109 cattle per square mile or 3,740 cattle in the entire watershed) suggests livestock are a significant source of pollutants. The NASS (USDA 2007) also reports there were 1,278 hogs and pigs, 409 horses and ponies and 365 broilers in Boone County in 2007.

Permitted CAFOs identified in this TMDL are part of the assigned WLA. Animal Feeding Operations (AFOs) and unpermitted CAFOs are considered under the LA because there is insufficient information at this time to determine whether these facilities are required to obtain

[11] According to the NASS there are approximately 31,547 head of cattle in Boone County (USDA 2007). According to the 2005 MoRAP there are 291 square miles of grasslands in Boone County (MoRAP 2005). These two values result in a cattle density of approximately 109 cattle per square mile of grasslands. This density was multiplied by the number of grassland square miles in the Hinkson Creek watershed to estimate the number of cattle in the watershed.

NPDES permits. This TMDL does not reflect a determination by EPA that such facility does not meet the definition of a CAFO nor that the facility does not need to obtain a permit. To the contrary, a CAFO that discharges or proposes to discharge has a duty to obtain a permit. If it is determined that any such operation is an AFO or CAFO that discharges, any future WLA assigned to the facility must not result in an exceedance of the sum of the WLAs in this TMDL as approved.

Any CAFO that does not obtain an NPDES permit must operate as a no discharge operation. Any discharge from an unpermitted CAFO is a violation of CWA Section 301. It is EPA's position that all CAFOs should obtain an NPDES permit because it provides clarity of compliance requirements, authorization to discharge when the discharges are the result of large precipitation events (i.e., in excess of 25-year and 24-hour frequency/duration) or are from a man-made conveyance.

3.2.2. Onsite Wastewater Treatment Systems

Onsite wastewater treatment systems (e.g., septic systems) that are properly designed and maintained should not serve as a source of contamination to surface waters. However, onsite systems do fail for a variety of reasons. When these septic systems fail hydraulically (i.e., surface breakouts) or hydrogeologically (i.e., inadequate soil filtration) there can be adverse effects to surface waters. Failing septic systems are sources of nutrients and pathogens that can reach nearby streams through both runoff and groundwater flows.

The exact number of onsite wastewater systems in the Hinkson Creek watershed is unknown. However, the estimated rural population of the Hinkson Creek watershed is approximately 3,926 persons, based on the 2000 U.S. census block data from the Missouri Spatial Data Information Service. Based on this population and an average density of 2.38 persons per septic system, there would be approximately 1,650 systems in the watershed. Based on a failure rate of 0.39 percent, there would potentially be seven failing septic systems within the Hinkson Creek watershed. EPA reports that the statewide failure rate of onsite wastewater systems in Missouri is 30 to 50 percent (EPA 2002a). At this failure rate there would be approximately 495 to 825 failing septic tanks. The large difference in failure rates between the studies is likely related to difficulties in identifying failing onsite wastewater systems and different definitions of what constitutes failure. At higher rates of failure onsite wastewater treatment systems could be a potentially significant source of nutrients and pathogens. Because very little information was identified that would suggest failing onsite wastewater systems were a significant problem in this watershed, the contribution of failed septic systems is thus considered minor.

3.2.3. Riparian Habitat Conditions

Riparian[12] (streamside) habitat conditions can have a strong influence on the habitat and water quality of a stream. Wooded riparian buffers are a vital functional component of stream ecosystems and are instrumental in the detention, removal and assimilation of pollutants entering

[12] A riparian corridor (or zone or area) is the linear strip of land running adjacent to a stream bank.

the water column. Therefore, a stream with good riparian habitat is better able to moderate the impacts of high pollutant loads than a stream without buffer. Wooded riparian buffers can also provide shading that reduces stream temperatures, increases the DO saturation capacity of the stream and provides valuable habitat.

As indicated in Table 5, almost 28 percent of the land in the Hinkson Creek's 30-meter riparian corridor is classified as urban. Approximately 47 percent is classified as forest and woodland areas and 16 percent is classified as grassland (MoRAP 2005). Low intensity urban and grassland area provide limited riparian benefits compared to forest or wooded areas. Low intensity urban areas provide very little shading. In developed areas such as Columbia, Missouri, pollutants to the stream can often be associated with grassland in parks, manicured lawn areas and pasture.

Table 5. Hinkson Creek Watershed Land Use Percentages for the 30-meter Riparian Corridor - 2005

Land Use	Acres	Square Miles	Percentage
Urban	510	0.80	27.8
Row and Close-grown Crops	43	0.07	2.3
Grassland	301	0.47	16.4
Forest & Woodland	857	1.34	46.6
Open Water	121	0.19	6.6
Barren	5	0.01	0.3
Total	**1,837**	**2.88**	**100.0**

4. Description of Applicable Water Quality Standards and Numeric Water Quality Targets

Section 303(d) of the CWA and Chapter 40 of the CFR Part 130 require states to develop TMDLs for waters not meeting applicable WQS, including designated uses. The TMDL process quantitatively assesses the impairment factors so that states can establish water quality-based controls to reduce pollutants from both point and nonpoint sources and to restore and protect the quality of their water resources.

The purpose of developing a TMDL is to identify the maximum amount of a pollutant (i.e., the load) that a water body can receive and still achieve WQS. WQS are therefore central to the TMDL development process. Under the CWA, every state must adopt WQS to protect, maintain and improve the quality of the nation's surface waters (U.S. Code Title 33, Chapter 26, Subchapter III (U.S. Code 2009)). These standards represent a level of water quality that will support the CWA goal of "fishable / swimmable" waters. Missouri's WQS at (10 CSR 20-7.031) consist of three main components: designated beneficial uses, criteria that apply to those uses (both numeric and narrative) and antidegradation requirements. These three components collectively ensure the quality of Missouri's waters are protected and maintained.

4.1 Designated Beneficial Uses

The Class P segment of Hinkson Creek (WBID 1007) extends from its mouth at Perche Creek to Highway 163. The Class C segment (WBID 1008) extends 18 miles upstream of Highway 163 to Mount Zion Church Road in rural Boone County. Upstream of the Class C segment, Hinkson Creek is currently unclassified. The designated beneficial uses for each classified segment are as follows:

WBID 1007:

- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Protection of Human Health (Fish Consumption)
- Whole Body Contact Recreation – Category B[13]
- Secondary Contact Recreation

WBID 1008:

- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Protection of Human Health (Fish Consumption)
- Whole Body Contact Recreation – Category B

Additional information regarding stream classifications and designated beneficial uses may be found at 10 CSR 20-7.031(1)(C) and Table H.

4.2 Impaired Use

Both segments of Hinkson Creek (WBID 1007 and 1008) are listed as impaired for the Protection of Warm Water Aquatic Life designated use.

4.3 Antidegradation Policy

Missouri's WQS include the EPA "three-tiered" approach to antidegradation, which can be found at 10 CSR 20-7.031(2):

Tier 1 – Protects existing uses and a level of water quality necessary to maintain and protect those uses. Tier I provides the absolute floor of water quality for all waters of the United States. Existing instream water uses are those uses that were attained on or after November 28, 1975, the date of EPA's first WQS Regulation.

Tier 2 – Protects and maintains the existing level of water quality where it is better than applicable water quality criteria. Before water quality in Tier 2 waters can be lowered, there must be an antidegradation review consisting of: 1) a finding that it is necessary to accommodate important economic and social development in the area where the waters

[13] Category B means (paraphrased) that swimming occurs, but there are no publically owned and maintained swimming areas or beaches.

are located; 2) full satisfaction of all intergovernmental coordination and public participation provisions; and 3) assurance that the highest statutory and regulatory requirements for point sources and BMPs for nonpoint sources are achieved. Furthermore, water quality may not be lowered to less than the level necessary to fully protect the "fishable/swimmable" uses and other existing uses.

Tier 3 – Protects the quality of outstanding national and state resource waters, such as waters of national and state parks, wildlife refuges and waters of exceptional recreational or ecological significance. There may be no new or increased discharges to these waters and no new or increased discharges to tributaries of these waters that would result in lower water quality.

4.4 Criteria

Hinkson Creek has been listed as impaired for unknown pollutants on the EPA-approved 2008 Missouri 303(d) List. Water quality monitoring has not revealed exceedances of a specific numeric water quality criterion. However, all Missouri streams are protected by the general criteria contained in Missouri's WQS at 10 CSR 20-7.031(3). These criteria are also called narrative criteria, since they do not contain specific numeric limits. The particular general criteria that apply to Hinkson Creek state:

(A) Waters shall be free from substances in sufficient amounts to cause the formation of putrescent, unsightly or harmful bottom deposits or prevent full maintenance of beneficial uses.

(C) Waters shall be free from substances in sufficient amounts to cause unsightly color or turbidity, offensive odor or prevent full maintenance of beneficial uses.

(D) Waters shall be free from substances or conditions in sufficient amounts to result in toxicity to human, animal or aquatic life.

(G) Waters shall be free from physical, chemical or hydrologic changes that would impair the natural biological community.

4.5 Impairments and Stressors of Concern

4.5.1 Detection and Description of Impairments

After a thorough review of the water quality studies detailed in Section 4.5.2, no one contaminant was discerned to be the primary pollutant of concern. Rather, the stressors, conditions and pollutants documented in Tables 6 and 7 are collectively causing the impairment of Hinkson Creek in response to increased storm water flows in the stream. The use of storm water as a surrogate for pollutants causing aquatic life beneficial use impairments is supported by scientific literature and site specific studies as identified by this TMDL. Therefore, storm water runoff was used as a surrogate to represent the suite of stressors, conditions and pollutants of concern.

Hydraulic changes to the stream, attributed to increased development, include more frequent occurrence of higher flows and velocities that create greater shear stresses making it difficult for aquatic life to live in the stream. Decreased infiltration due to the increased impervious area results in reduced baseflow that limits available habitat during low flow periods. The greater and more frequent flows permanently change the physical characteristics of the stream by increasing incision, stream bank erosion and changes to substrate. With the growing amount of impervious surface within the Hinkson Creek watershed, hydrologic changes have and will continue to occur in Hinkson Creek. Stream studies on other urban streams have documented strong correlations between the imperviousness[14] of a drainage basin and the health of its receiving streams (Arnold and Gibbons 1996, EPA 1993, Stankowski 1972, Schueler 1994). As the percentage of land area covered by impervious surfaces increases, a consistent degradation of water quality can be detected. Degradation can occur at relatively low levels of imperviousness (10-20 percent) and worsens as more areas within the watershed are covered. The negative effects on water quality from urbanization within a watershed include loss of habitat, increased temperatures, sedimentation and loss of fish populations (EPA 1993).

Reducing storm water runoff to Hinkson Creek will address the vast majority of the issues associated with the impairment and restore the aquatic life designated use by achieving the following:

- Reduce physical impacts of storm water on the stream channel (e.g., erosion, scour and deposition) and the habitat impairment or toxicity that may result from sedimentation.
- Increase available habitat during low flow periods by increasing baseflow.
- Reduce pollutant loads of sediment, toxics, metals and nutrients when storm water flows are reduced.

In the report for Urban Storm water Management in the United States*,* the National Research Council suggests: "A more straightforward way to regulate storm water contributions to water body impairment would be to use flow or a surrogate, like impervious cover, as a measure of storm water loading . . . Efforts to reduce storm water flow will automatically achieve reductions in pollutant loading. Moreover, flow is itself responsible for additional erosion and sedimentation that adversely impacts surface water quality" (NRC, 2009).

4.5.2 Stressors of Concern and Probable Sources

EPA has identified pollutants in storm water runoff associated with rainwater or melting snow that washes off impervious surfaces (e.g., roads, bridges, parking lots, rooftops, etc.) (EPA 1995). Storm water runoff picks up and transports dirt and dust, rubber and metal deposits from tire wear, antifreeze, engine oil and other automotive fluids, road salt, herbicides, pesticides, fertilizers, animal feces, heat and trash directly into lakes, rivers, streams and oceans. Because the pollutants and sources impairing Hinkson Creek are listed as unknown, a plan was needed to determine what stressors and sources are causing the impairment. To accomplish this task, MDNR devised and conducted a series of studies which are listed below, along with a brief

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[14] An impervious surface is a hard surface, like pavement or rooftops, which does not allow water to soak into the soil and replenish the groundwater. Instead this water runs off into the nearest stream and flows downstream.

summary of findings and conclusions. To view the Executive Summaries from these studies, or the studies, in their entirety, go to www.dnr.mo.gov/env/esp/esp-wqm.htm.

Based on data collected during the Hinkson Creek water quality studies, Tables 6 and 7 were constructed to list stressors and conditions found in the Hinkson Creek main stem and selected storm water outfalls. Additionally, Tables 6 and 7 include likely and/or possible sources of pollutants for each stressor and condition.

Table 6. Noted Stressors[15] and Their Sources.

Stressor	**Effect**	**Sources**	
		Likely	**Possible**
Toxic contaminants (See Table 7 for examples)	Toxic to life, both plant and animal	Runoff from local roads and parking lots	Illegal/illicit discharges
		Landfill	
		Winter road salt	
		Local industry	
Scour of stream channel	Impaired instream habitat	Peak storm flows	
Narrow or non-existent riparian zone		Development/Land clearing	
Construction runoff		Unprotected disturbed areas	
Increased sedimentation	Impaired habitat/ Property damage	Construction site erosion	
		Scour from high storm flows	
		Lack of bank stabilization	
		Winter road sand	
Increased storm flow	Floods/Scour	High percentage of impervious surfaces	
Low base flow	Creek dries up or leaves stagnant pools/ Higher water temperatures/ Low DO	High percentage of impervious surfaces	Increased consumptive use of water
		Reduced infiltration to groundwater	
Warmer water temperature	Harmful to aquatic life/ Warmer water contains less oxygen	Heat from hard or paved surfaces in first flush of storm water	
		Lack of riparian tree cover (i.e., no shade)	
		Channel widened by erosion	
		Increased suspended silt	

[15] A stressor is any physical, chemical or biological entity or phenomenon that can induce an adverse effect either directly or as one step in a chain of causation (EPA 2009).

Table 7. Noted Pollutants or Conditions and Their Sources.

Pollutant/condition	Effect	Sources: Likely	Sources: Possible
Presence of toxic contaminants (*some specific examples)		Runoff from local roads, parking lots and store lots	Illegal/illicit discharges
		Road de-icing materials	Golf course
		Columbia Sanitary Landfill & Yard Waste Compost	
		Local industry	
*Polycyclic Aromatic Hydrocarbons (PAHs)	Toxic	Incomplete combustion of fossil fuels	Automobile maintenance activities
		Coal tar and asphalt	
*Insecticides and herbicides	Toxic	Improper storage /disposal	
		Over or poorly timed application (especially to lawns, parks and golf courses)	
*Plasticizers	Toxic	Plastic debris	
		Leaching from PVC	
*Caffeine		Discarding caffeinated drinks on parking lots or directly into storm drain	
*Petroleum waste oil		Leaking vehicles	
		Improper disposal (in driveways or storm drains)	
		Vehicle maintenance locations	
Chloride[16]		Road de-icing materials	
Occasional *E.coli* bacteria spikes		Sewer breaks, leaks and overflows	Other illegal/illicit discharges
		Sanitary sewer overflows (manhole)	
		Pet and other animal waste	Leaking or failing on-site septic systems
		Lack of sanitary facilities at homeless individuals camps along the creek	
Metals	Synergistic effect	Vehicle exhaust, worn tires and brake linings	Weathered paint and rust

[16] Volunteer water quality monitors have been monitoring Hinkson Creek since 2007. Overall, Hinkson Creek has had higher chloride levels than reference streams. Most recently, the late winter 2008 and early spring 2009 data contains readings higher than the water quality criterion for chronic toxicity which is 230 mg/L.

Elevated conductivity		Runoff (of salts) from ground or impervious surface	
Low DO		Stagnant pools	Low/no base flow
Increased sedimentation		Construction runoff	Inadequate riparian (buffer) zone
		Scour from high storm flows	
		Lack of bank stabilization	
Severe soil and gully erosion		Storm flow (outfalls)	
		Unprotected banks	
Warmer water temperature		Heat from parking lots in first flush of storm water	
		Lack of riparian tree cover	
		Channel widened by erosion	
		Increased suspended silt (i.e., turbidity)	

(*some specific examples)

4.5.2.1. Biological Assessment Report, Hinkson Creek, Boone County [Missouri] December 18, 2002.

Biological monitoring is extremely useful in determining stream health in that it directly measures the health of the aquatic community. Biological monitoring also reflects the environmental conditions that occur in a stream over an extended period of time (e.g., months or years), including the effects of intermittent discharges such as storm water. Therefore, the first step in analyzing Hinkson Creek was to conduct a bioassessment to determine if, indeed, the aquatic invertebrate communities[17] were actually impaired.

MDNR completed a one-year bioassessment study in 2002 and verified the biological community downstream of Interstate 70 was impaired and that water quality was not protective of the aquatic life designated use (MDNR 2002). The impairment was determined by comparing Hinkson Creek to a similar sized portion of nearby Bonne Femme Creek, which is relatively unaffected by human activity. Hinkson Creek was also compared to biological reference streams within the Central Irregular Plains, in particular, and Interior River Valley and Hills ecoregions, of which it is a part. The stream condition index (SCI) scores[18] for Hinkson Creek are in Table 8 with results for this first study in the Fall of 2001 and Spring 2002 columns. According to MDNR bioassessment procedures, a score of 16 or higher is considered fully supporting (protective) of the aquatic life beneficial use.

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[17] Invertebrate means a creature with no backbone. An aquatic invertebrate community is made up of insect larvae and other small animals like crayfish, worms and scuds that live in the water and are an integral part of the food chain in a healthy stream.

[18] SCI = Stream Condition Index. It is the sum of four metrics: Taxa (different types of invertebrates) Richness, Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) or EPT, Taxa (pollution intolerant species), Biotic Index (a measure of the degree of tolerance to pollution) and Shannon Diversity Index.

Table 8. Stream Condition Index Scores for Hinkson Creek (MDNR 2002)

Site No.	Site	Fall 2001	Spring 2002	Fall 2003	Spring 2004	Spring 2005	Fall 2005	Spring 2006
8	Rogers Rd.	12	16					
7	Hinkson Creek Rd.	12	18	18	18	18	18	
6.5	Hwy 63 Connector				*17**			
6	Walnut Street	12	12	16	14	18	16	
5.5	Broadway St.			16	16	16	*12*	
5	Capen Park	16	12					
4	Rock Quarry Rd.	*17**	14					
3.5	Recreation Dr.					14	14	
3	Forum Blvd.	18	14					16
2	Twin Lakes	16	14					*12*
1	Scott Rd.	*14*	14					16

* represents the mean of two duplicate samples

Note: Some SCI scores in this table (italics) may vary from what is reported in the four surveys. This is due to the data being rescored based on more recent sampling of reference streams in the ecoregion.

4.5.2.2 Stream Survey Sampling Report, Hinkson Creek Stream Study, Columbia, Missouri, Boone County, November 22, 2004.

Biological monitoring is limited in its ability to identify the various causes of pollutants and the extent to which they contribute to an impairment. Therefore, MDNR initiated a second study in 2003 to identify potential pollutants and pollutant sources impacting Hinkson Creek. The study focused on storm water runoff along an approximately 1.5 mile long segment of Hinkson Creek between Interstate 70 and Broadway Street. A map showing site locations can be found in Appendix A.1. MDNR used screening methods to narrow the field of potential pollutants and to focus on possible pollutant sources.[19] The following problems were found in this section of Hinkson Creek:

- Thirty-three percent of the storm water discharges exhibited toxicity,
- An 8-foot deep erosion gully from the storm water pipe draining a road salt storage and handling facility,
- A 6-to-8-foot erosion gully in a drainage below a shopping center,
- Organic hydrocarbons, including petroleum products and some pesticides, from some of the storm water discharges coming off of the shopping center parking lot,

[19] A water quality triad was used to document impairments to the aquatic community and identify pollutants that are likely contributing to those impairments. The triad is a non-numeric, weight-of-evidence approach that uses an integrated assessment of information obtained from the aquatic organism assemblages, chemical analysis and toxicity testing.

- Salts from a road salt storage and handling facility and the Interstate 70 and Route 63 interchange area (in February during a large snow melt),
- Sediment accumulation as water moves downstream and
- Occasional spikes of Escherichia coli (*E. coli)* bacteria.

Also, additional macroinvertebrate data were collected under this phase of the study, in the fall of 2003 and spring of 2004. MDNR released preliminary results from this study in spring 2004. Soon after, businesses, developers and other sources began taking actions to remedy the problems identified and to prevent future ones from occurring.

4.5.2.3 Stream Survey Sampling Report, Phase II, Hinkson Creek Stream Study, Columbia, Missouri, Boone County, June 2004 – June 2005.

A third study, similar to the Phase I study described in Section 4.5.2.2, was conducted in 2004-2005 on the approximately five-mile-long segment of Hinkson Creek between Broadway Street and Providence Road. The Hinkson Creek Phase II study included storm water and macroinvertebrate monitoring and the findings are summarized below. A map showing site locations is in Appendix A.2 and A.3.

- *In situ* conductivity values were higher in Hinkson Creek during base flow conditions when compared to reference/control streams within the same ecoregion.
- Turbidity levels were highest at the Highway 63 connector and old Highway 63 sites during base flow conditions. High turbidity levels during periods of low or base flow is indicative of instream activity, such as that which occurs during land disturbance activities.
- Chloride values in Hinkson Creek were approximately 40 percent higher when compared to reference/control streams within the same ecoregion base flow events.
- Toxicity tended to be sporadic and none of the sampled drainages were found to be consistently toxic. Of the storm water samples collected, eight samples were toxic to the Microtox organisms. Metals (e.g., arsenic, chromium, copper, lead, nickel, zinc), organic pollutants (e.g., PAHs) and plasticizers were the main constituents found.
- Semi-Permeable Membrane Device (SPMD) analyses indicated the presence of several low-level, semi-volatile organic chemicals (e.g., pesticides and/or breakdown products, phthalates and pharmaceutical drugs) that have the potential to bioaccumulate in aquatic organisms.
- Macroinvertebrate sampling was conducted in the spring and fall of 2005.[20] Biological metrics describing the macroinvertebrate community at Station 6 showed improvement

[20] Note: The fall data was reported in Phase III, as it had not been analyzed in time for the Phase II report.

when compared to spring samples collected in 2002 and 2004. Also, for the first time among three sampling seasons, biological metrics were sufficient to merit a fully supporting SCI score (see footnote 14). Compared to 2002, taxa richness increased by 14 taxa and EPT (pollution intolerant) taxa nearly doubled, increasing by seven.

- The improvement in metric scores and increasing similarity of indices between Station 6 and Station 7 could be interpreted as a demonstration that Station 6 is developing better potential to support a diverse macroinvertebrate community. This increased potential may be the result of a decrease in the quantity and frequency of perturbations that were observed and/or suspected in previous years (e.g., sewer bypasses, petroleum products, insecticides, road salt and sediment).

- Although Station 6 appears to have improved compared to previous years, the macroinvertebrate community within the urbanized reach nevertheless showed some important differences compared to the upstream reference reach. Most notably, Station 3.5 had a fraction of the number of mayflies and stoneflies compared to each of the other stations. In addition, each of the urbanized reaches had much higher numbers of tubificid worms than Station 7. Tubificid worms tend to be tolerant of sediment and organic pollutants. Tubificids were nearly twice as abundant at Station 3.5 as at the next nearest site. This distribution and abundance may reflect the effects of previously documented inputs of sediment and organic loading (i.e., bypasses) to the stream.

4.5.2.4 Stream Survey Sampling Report, Phase III, Hinkson Creek Stream Study, Columbia, Missouri, Boone County, July 2005 – June 2006.

In 2005-2006, MDNR studied the remaining segment of Hinkson Creek not covered under previous studies. The segment extends from Providence Road to the confluence with Perche Creek and includes tributaries entering this segment as well as selected upstream sites that were sampled during Phases I and II. Methods used were similar to those from the earlier phases of the study and a map showing site locations can be found in Appendix A.4. Water quality samples were collected during base flow conditions and storm events and analyzed for toxicity, nutrients, metals, organic chemicals and *E. coli* bacteria. In addition, field measurements of pH, temperature, specific conductivity, DO and discharge (i.e., flow) were collected.

- Macroinvertebrate sampling was conducted at four sites in fall 2005 and spring 2006. Final results of the fall 2005 sampling indicated two sites in the urbanized portion of Hinkson Creek (sites 3.5 and 5.5) continue to be partially supporting of the aquatic life use when compared to the most upstream site (site 7). Final results of the spring 2006 sampling indicated just one site (site 2, located near the Twin Lakes Recreation Area) was partially supporting of the aquatic life use when compared to the control site on Bonne Femme Creek. The Bonne Femme Creek site was used as the control during this phase of the study due to it being more comparable in size to Hinkson Creek in this lower section.

- Results of Phase III water quality analyses did not indicate toxicity or measure organic chemical constituents above laboratory detection levels. This may have been due to the lack of clearly defined storm water inputs to mainstem Hinkson Creek as compared to the previously studied segments.

- Chloride concentrations during base flow conditions were considerably higher in the lower portion of Hinkson Creek than in the upper sites sampled during Phases I and II. Although base flow chloride concentrations were not higher in the tributaries sampled during Phase III, storm water samples collected from Flat Branch Creek were high, reaching 283 milligrams per liter (mg/L) on December 14, 2005. Overall, Hinkson Creek has higher chloride concentrations than the reference streams.

- Data loggers that recorded temperature and DO concentrations over an eight-week period showed that lower DO appeared to correlate better with pool stagnation at low flows that result from extended dry periods than with storm water inputs resulting from precipitation events. DO readings fell below the water quality criterion of 5 mg/L 10-15 percent of the time at the Highway 63 connector after an extended dry period and 44-62 percent of the time at the Broadway Street stream crossing. DO conditions improved following rainfall events.

4.5.3 Stressors of Concern and Urban Storm Water Runoff

Storm water runoff from urban areas has been broadly linked to degradation of aquatic life in urban areas (CWP 2003; WERF 2003). The scientific literature suggests that increases in runoff from urbanized areas negatively impact aquatic life in streams in four principal ways.

1. Runoff carries a mix of pollutants that may be toxic to aquatic life.
2. More frequent occurrence of higher flows and velocities create greater shear stresses that make it difficult for aquatic life to live in the stream. Decreased infiltration depresses baseflow, reducing available habitat during low flow periods.
3. The greater and more frequent flows permanently change the physical characteristics of the stream by increasing incision, increasing stream bank erosion and reducing stream substrates.
4. Aquatic habitats are significantly degraded due to stream enclosure, channelization, armoring (i.e., using rip rap and concrete to reduce erosion) and loss of riparian vegetation.

These characteristics of urban storm water runoff can lead to decreased aquatic life at relatively low levels of development. The Center for Watershed Protection (CWP 2003) reviewed hundreds of research studies. The combined review and synthesis of information in these studies lead CWP to conclude that impervious cover as low as 10 percent can be related to aquatic life impairments and worsens as more areas within the watershed are developed (CWP 2003).

The negative effects on water quality from urbanization within a watershed include loss of habitat, increased temperatures, sedimentation and loss of fish populations (EPA 2005). These effects can be explained in large part by the increase in the magnitude, frequency and duration of storm flows in urban watersheds relative to flows in watersheds with less impervious area and the chemical pollutants that are carried by storm water (EPA 2005).

In researching modeling approaches for the Hinkson Creek TMDL, flow duration curves (FDCs) were determined to provide the best surrogate for defining hydrologic targets. FDCs are useful at describing the hydrologic condition of a stream because they incorporate the full spectrum of flow conditions from very low to very high that occur in the stream system over a long period of time. FDCs also incorporate any flow variability that may be due to seasonal variations. A comparison between the FDC of an impaired stream and an appropriate reference stream can reveal obvious patterns. For example, a FDC for a storm water impaired water body will typically show significantly higher flow rates per unit area for high flow events and significantly lower flow rates per unit area for low-base flow conditions than the FDC for a reference watershed. The increased predominance of high flow events in the impaired watershed creates the potential for increased watershed storm water pollutant loadings, increased scouring and stream bank erosion events and the possible displacement of biota from within the system. Also, the reduction in stream base flow can create a potential loss of habitat during low flow conditions.

Flow response to precipitation in Hinkson Creek has increased markedly over time. A comparison of flow response to precipitation between 1967 and 2007 shows that, despite a smaller amount of rainfall in the latter year, average daily flow was more than 80 percent higher (Table 9).

Table 9. Comparison of Precipitation and Flow for April 1 – July 31. Data were Based on the Sanborn Field (UMC) Weather Station and USGS Gage (06910230).

	1967 (n = 122)	2007 (n = 122)
Maximum daily precipitation (in)	2.54	1.93
Total precipitation (in)	15.46	13.08
Average daily flow (cfs)	38.62	69.94
Standard Deviation for daily flow (cfs)	82.8	154.8
Maximum daily flow (cfs)	528	938

in = inches   cfs = cubic feet per second

Base flow is that part of stream discharge that is not attributable to direct runoff from precipitation or snow melt; it is usually sustained by groundwater (AMS 2009). In addition to higher flows in the stream from storm water, increased impermeable surface area within the watershed results in reduced base flows. This is illustrated in the FDCs for these same two time periods in Figure 4. The right half of the graph gives an indication that base flow in 2007 is consistently lower than in 1967 and the left half indicates the opposite effect for higher flows.

To establish the LC for storm water runoff, trends in storm water runoff must be calculated from a continuous period of record for the water body of interest. The United States

Geological Survey (USGS) gaging station on Hinkson Creek at Providence Road in Columbia (USGS-06910230, drainage area 69.8 mi^2) was chosen for the TMDL analyses due to its location on the impaired segment and extensive period of record (i.e., 1966-1981, 1987-1991 and 2007-2010). Table 10 shows a summary of hydrologic conditions for the gaging station. As indicated, the last three water years (October 1 to September 30) from 2008-2010 had the highest peak flow values. Over 22 years of flow record, the average flow value is 0.63 cfs, while the peak flow values range from 5.95 cfs in 1980 to 111.89 cfs in 2008, with an average value of 37.74 cfs (see Table 10). The impairment occurs in the last decade. Because only the recent three years of flow data are available and the flow in these years was considered high flow, this TMDL focuses on or targets the high flow conditions that contribute to the impairment observed in Hinkson Creek.

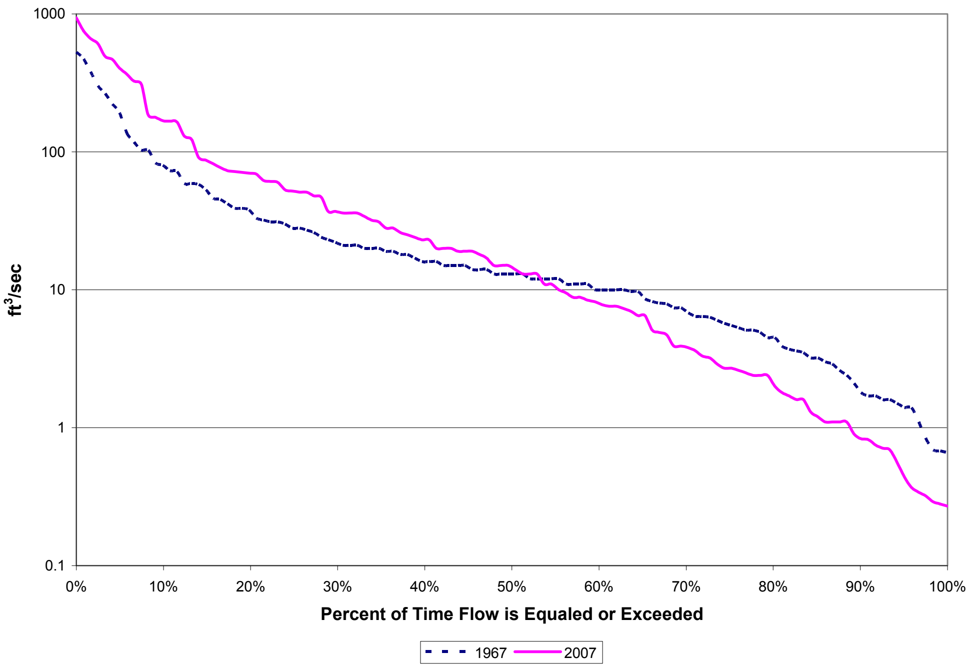

Figure 4. Flow Duration Curves for April – July, 1967 and 2007

Table 10. Summary of Hydrologic Conditions During the Period from 1967 to 2010

Water Year (October - September)	Peak Flow (cfs/sq mile)	Average Flow (cfs/sq mile)	Median Flow (cfs/sq mile)
1967	7.56	0.23	0.03
1968	35.10	0.64	0.11
1969	37.97	1.58	0.36
1970	66.05	1.29	0.17
1971	19.34	0.47	0.10
1972	17.77	0.36	0.04
1973	26.36	1.59	0.34
1974	41.69	1.41	0.42
1975	22.49	0.67	0.13
1976	30.09	0.40	0.07
1977	12.84	0.24	0.04
1978	26.22	0.63	0.09
1979	45.56	0.48	0.04
1980	5.95	0.19	0.02
1981	54.30	0.98	0.03
1987	36.96	0.60	0.14
1988	11.25	0.43	0.06
1989	18.34	0.47	0.07
1990	57.88	1.26	0.10
1991	18.77	0.48	0.10
2008	111.89	2.29	0.34
2009	89.97	1.33	0.19
2010	73.78	2.28	0.44

cfs = cubic feet per second, sq mile = square mile

Figure 5 shows an annualized FDC developed for the water year periods (October to September) of 2008, 2009 and 2010 with an annualized FDC for the entire 22 years of flow record. From 2008 to 2010, the median flow is 0.30 cfs/sq mile, 10 percent exceedance flow is 3.15 cfs/sq mile and 95 percent exceedance flow is approximately 0.02 cfs/sq mile. High flow, determined by bankfull discharge (approximately 1.3-year recurrence interval flow, $Q_{1.3}$), reflects the flood discharging capacity of river channels. Impairment beyond this discharge value may not be technically and/or economically feasible for a general watershed management approach on protecting beneficial uses of the stream since BMPs do not typically address flood control floodplain management. The bankfull discharge of 14.45 cfs/sq mile was calculated using the intersection (i.e., 1008 cfs at stage height of 8 ft) of the regression lines derived from field flow-stage measurements and peak flow-stage data (Figure 6). The corresponding flow exceedance is approximately 3 percent for the FDC for the 2008-2010 flow data (see Figure 5).

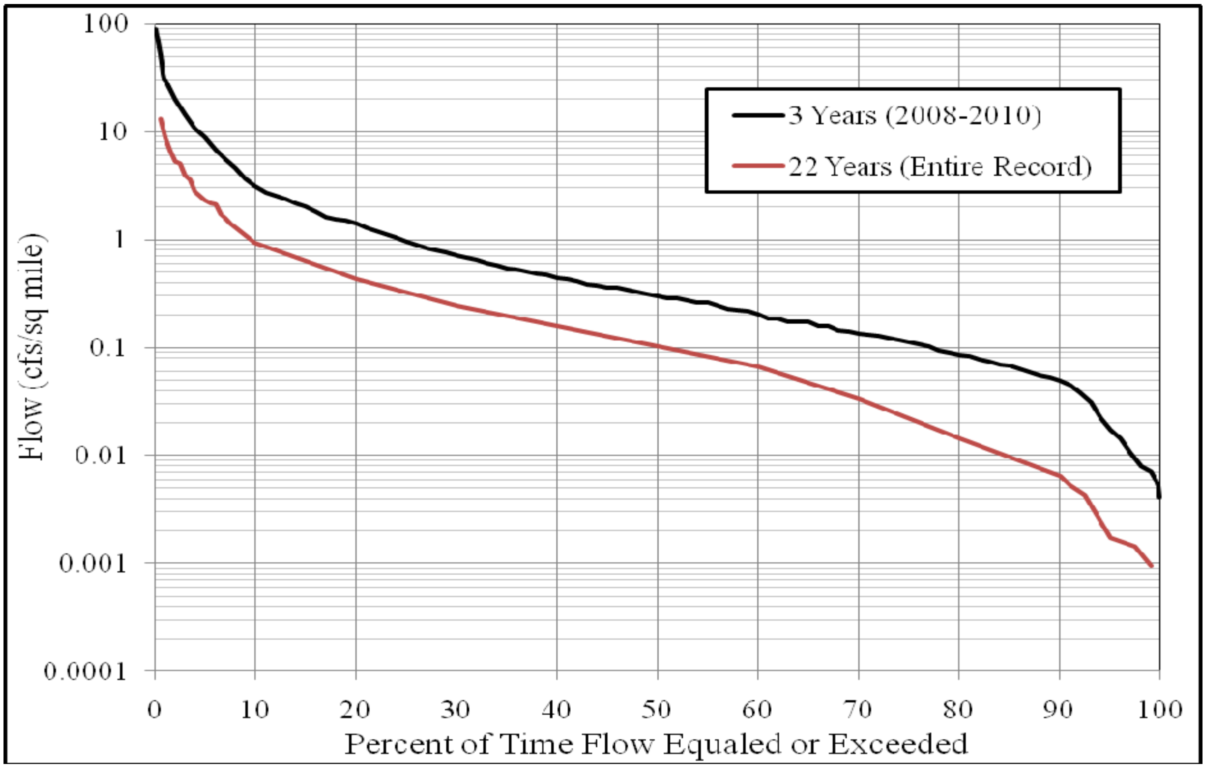

Figure 5. Annualized Flow Duration Curves for the 3 and 22-Year Flow Records for Hinkson Creek (USGS Gage 06910230)

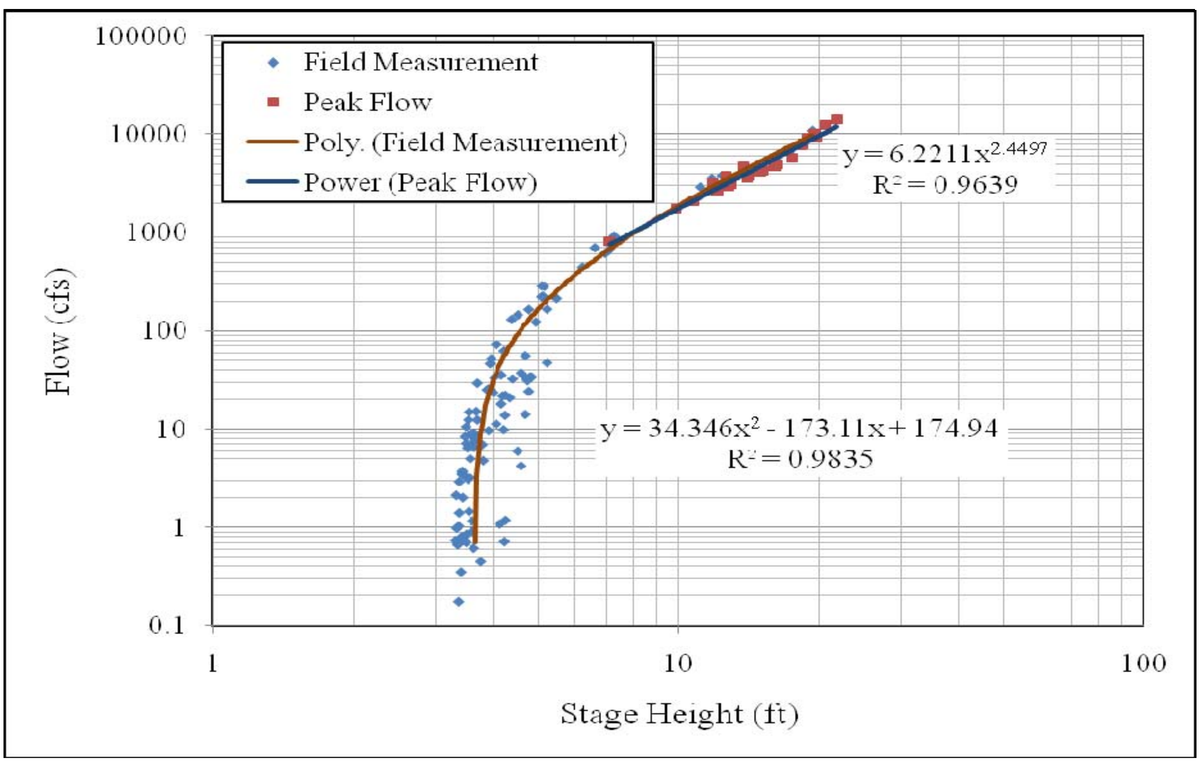

Figure 6. Determination of Bankfull Discharge for Hinkson Creek

4.6 Setting the Water Quality Targets

A TMDL requires that a water quality target be developed for the impaired segment. The TMDL load is the greatest amount of a pollutant that a water body can receive without violating the WQS. For this TMDL storm water flows are a surrogate for the mixture of toxic pollutants and physical stressors causing aquatic life beneficial use impairments. The instream water quality target for the TMDL is the high flow category of the FDC developed from the biological reference streams (as described in the section below).

The linkage between pollutants, aquatic life impairment and storm water was primarily established using instream flow conditions from reference streams in the Central Irregular Plains ecoregion, which is the same ecoregion in which Hinkson Creek is located. Reference streams from the same ecoregion as the impaired stream were used to insure that the reference locations were similar to the impaired stream. An ecoregion is a collection of watersheds that share a common zoogeographic history (i.e. similar distributions of animals), physiographic and climatic characteristics, and therefore likely have a distinct set of freshwater assemblages and habitats (Omernik, 1987). In addition, since the ecoregion has similar climatic characteristics, precipitation over time should be similar for the reference and impaired streams.

4.6.1 Technical Approach for Developing Reference Stream Flows

Synthetic flow data were developed by averaging flows from the individual watersheds used as biological reference streams. These synthetic stream flows are used as the TMDL target. Therefore, the synthetic flows are representative of streams attaining healthy biological conditions (e.g., macroinvertebrate stream condition index $\geq$16, (MDNR 2002). The necessary percent reductions in storm water flows needed to match the synthetic flow record are statistically determined by comparing the highest 10 percent of flows measured in Hinkson Creek to the highest 10 percent of the synthetic flow record developed from biological reference streams. Controlling the highest flows will limit pollutant loads from urban runoff therefore decreasing potentially toxic water quality conditions and increasing baseflow through increased infiltration of storm water runoff.

Flows in Hinkson Creek are compared to a synthetic flow record developed from biological reference stream flows by calculating discharge per square mile for each watershed. The area normalized flows allow direct comparison of stream flows in the impacted and reference watersheds. FDC analysis allows for the direct comparison of stream reaches' frequency and magnitude of flows. Using the biological reference streams from the same ecoregion as Hinkson Creek minimizes differences in the rainfall variation.

4.6.2 Selection of Reference Streams

The reference streams chosen are similar to Hinkson Creek with respect to soils and physiography as well as land use characteristics (Appendix C). Since reference streams are used by MDNR to set biological criteria, using biological reference streams to develop targets for the

TMDL surrogate is appropriate for this TMDL. According to MDNR (MDNR 2002) biological reference streams,

> "Describe characteristics of water bodies least impaired by anthropogenic activities and are used to define attainable habitat and biological conditions. Reference conditions are the standard by which impairment is judged."

Furthermore, reference streams must have habitat and stream characteristics similar to other streams in the ecoregion and exhibit a healthy biological community. The intended use of a reference stream approach according to MDNR is consistent with this TMDL application. Stream flows observed in the biological reference stream support a healthy biological community. The water bodies selected as reference streams for this TMDL meet MDNR's reference stream criteria and applicable WQS.

Because storm water runoff is being used as a surrogate for contaminant loading in this stream, the target shall be determined as a percent reduction in runoff during storm events. Four streams that are in attainment of biological criteria were selected to develop a robust analysis and to determine the required target goals for Hinkson Creek. All streams selected are located within the same ecological regions as Hinkson Creek. These are the Interior River Valleys and Hills and, in particular, the Central Irregular Plains ecoregions (Omernik, 2007). The reference streams are located in watersheds that are three to seven times greater in size than the size of the Hinkson Creek watershed. These reference streams are listed in Table 11 and shown in Figure 7.

Table 11. Hinkson Creek and Reference Streams Used in TMDL Reduction Analysis

Stream	Watershed Size* (mi^2)	USGS Gauging Station No.	Flow Analysis Period
Hinkson Creek	69.8	06910230	Oct 2007 – Sept 2010
Big Creek	414	06921720	Oct 1965 – Sept 2010
Middle Fork Salt River	313	05506350	Oct 1999 – Sept 2010
North River	354	05501000	Oct 1960 – Sept 2010
S Fabius River	620	05500000	Oct 1960 – Sept 2010

*Area of watershed upstream from USGS gaging station

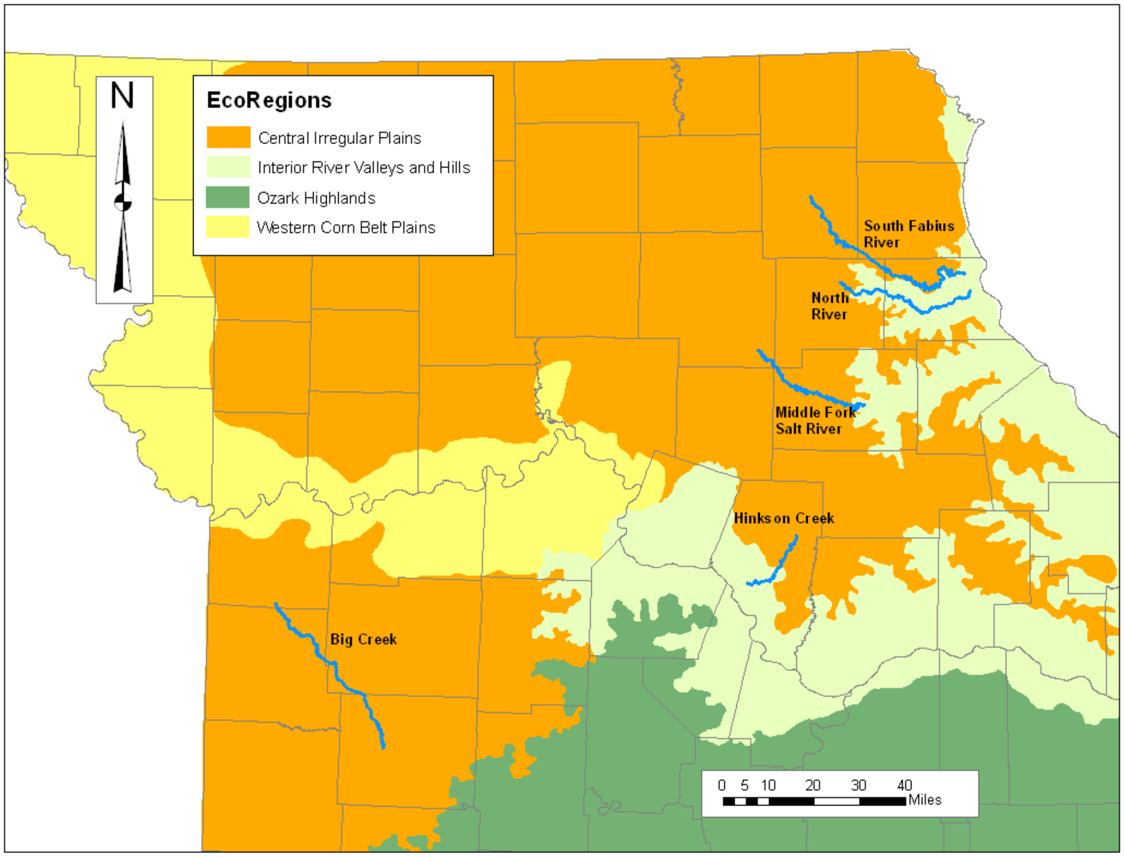

Figure 7. Location of Reference Streams in Relation to Hinkson Creek

To generate representative flows for the four selected streams, synthetic flow was calculated by averaging the log transformation of the daily streamflow values. Table 12 shows annual precipitation data associated with each of these individual streams, and Figure 8 summarizes a comparison of the synthetic flow and the four selected streams during the hydrologic period from 1961-2010. As indicated in Figure 8, the estimated synthetic flow describes the hydrologic conditions of the four reference streams.

Table 12. Yearly Precipitation at Hinkson Creek and Reference Streams During Flow Analysis Periods (Source: NOAA and USGS)

Stream	Precipitation (in)	NOAA Weather Station	Latitude	Longitude
Hinkson Creek	52.78	Sanborn Field (UMC)	38° 57" N	92° 19" W
Big Creek	45.04	Kingsville	38° 45" N	94° 04" W
		Pleasant Hill	38° 48" N	94° 17" W
Middle Fork Salt River	45.73	Long Branch	39° 45" N	92° 30" W
		Paris	39° 29" N	92° 00" W
North River	36.78	Palmyra	39° 48" N	91° 30" W
S Fabius River	42.26	Steffenville	39° 58" N	91° 53" W

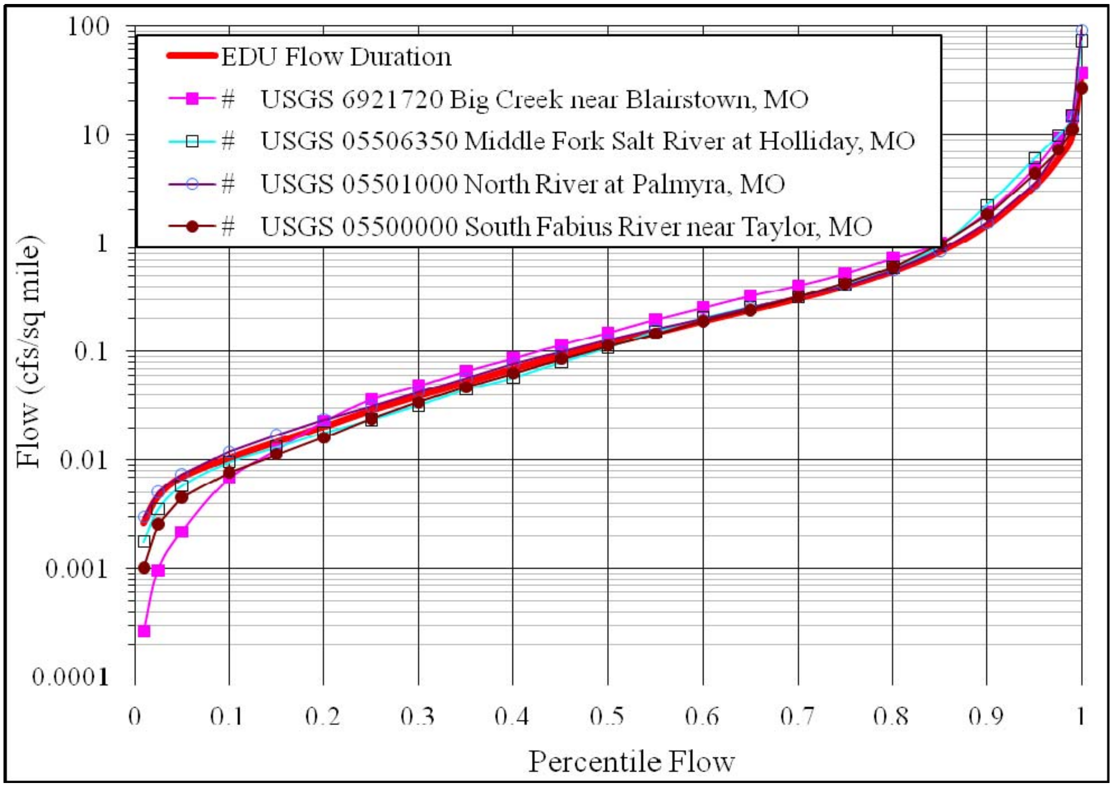

Figure 8. Hydrologic Comparison of the Synthetic Flow and Reference Stream Flows

As mentioned previously, the mean daily flow data used to develop this TMDL was based on the flow conditions in the period of October 2007-September 2010 (see Table 10 and Figure 5). Since these flows fall within the upper 5th percentile of the entire flow values, the 95 percent upper confidence level (CL) of the synthetic flow was used to calculate TMDL load and its related components. The upper 95 percent CL is the data distribution associated with 1.96 times the standard deviation around the mean value of a flow population between 1961 and 2010. In order to calculate the 95 percent CL, the fifty yearly FDCs from 1961 to 2010 were constructed and then averaged. Figure 9 shows average and the 95 percent upper CL of the synthetic FDCs and the high FDC for Hinkson Creek. The TMDL flows were therefore determined as the difference between the present flows seen in Hinkson Creek during 2008-2010 and the 95 percent upper CL of the synthetic flows for the reference streams. Table 13 lists the TMDL target flows for various hydrologic conditions.

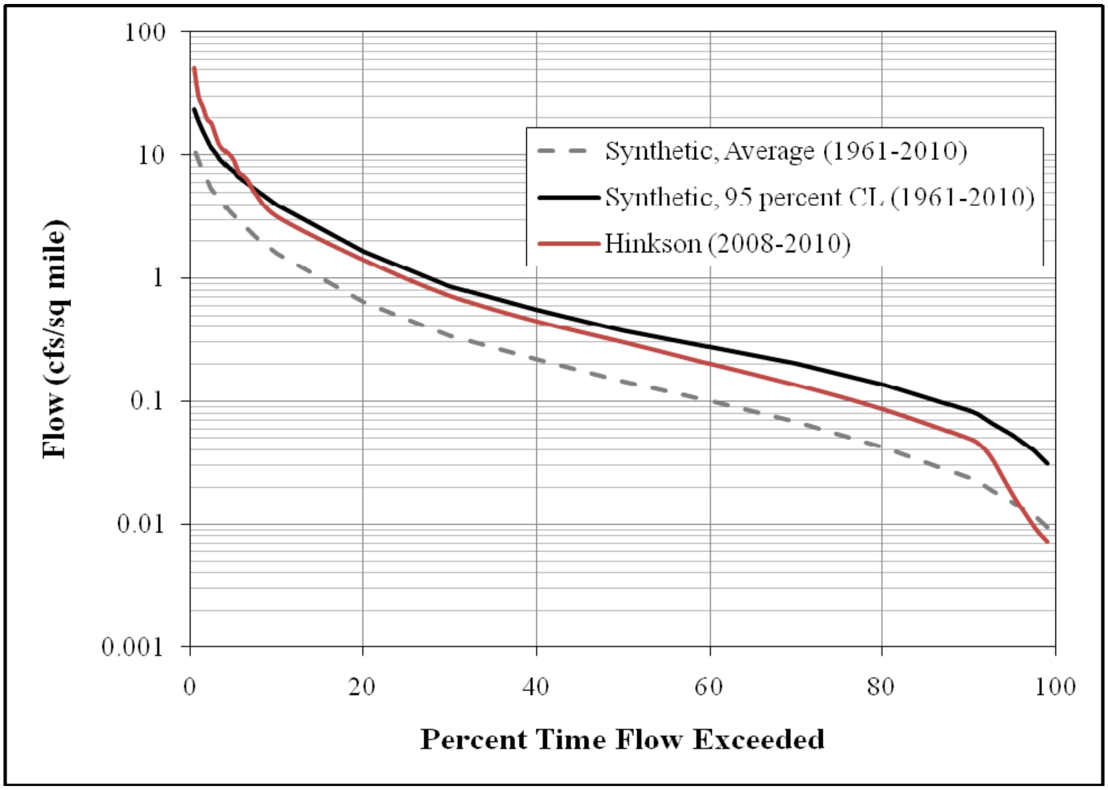

Figure 9. Annualized Flow Duration Curves based on water year data for Hinkson Creek and Reference Streams at the USGS Hinkson Gaging Station.

Table 13. Flows for Hinkson Creek and Reference Streams with Target Changes at the USGS Hinkson Creek Gaging Station

Flow Duration (percent)	Current (Hinkson) (cfs/sq mile)	TMDL (Synthetic Flow, 95th percent CL, cfs/sq mile)	Difference (percent)
1	29.95	18.83	37.1
3	14.45	10.31	28.7
5	8.93	7.31	18.1
7	5.56	5.56	0
10	3.15	3.96	-
30	0.72	0.86	-
50	0.30	0.38	-
70	0.20	0.13	-
90	0.05	0.08	-

As indicated in Figure 9 and Table 13, the flow in Hinkson Creek is equal to the synthetic flow at seven percent of their FDCs. Based on peak flow analysis, the bankfull discharge occurs at three percent of the Hinkson Creek's FDC (14.45 cfs/sq mile or 1,008 cfs) where general watershed management is not technically warranted to control storm water at flows greater than three percent of Hinkson Creek's FDC. Thus, the TMDL targets for Hinkson Creek should be between three and seven percent of the FDC derived from flow data collected from October 2007 to September 2010. To mitigate the impairment that appears in Hinkson Creek, a 29 percent flow reduction is needed at the three percent flow exceedance of the FDC, while an 18 percent flow reduction is needed at the five percent flow exceedance of the FDC at the gaging station (USGS-06910230). Reductions from current levels are not needed at the 70 percent flow duration interval since this interval is more closely related to sustaining base flow conditions in the water body.

In the broadest sense, the primary function of a TMDL is to determine and allocate among sources the maximum pollutant loading a water body can receive to maintain compliance with the appropriate WQS. For the Hinkson Creek TMDL, it's the storm water runoff that is being limited overall and allocated among sources. This approach works well within the TMDL framework for the high flow target whereby an overall reduction of storm water runoff is required. However, this approach does not fit particularly well for the low flow target where an increase in non-storm water instream flow is necessary and loading of storm water runoff is not directly being allocated. The restoration of low flows in Hinkson Creek is actually a secondary result of controlling storm water runoff and increasing groundwater recharge. As storm water runoff is controlled and high flows reduced, the water that eventually reaches the stream and increases low flow is no longer considered storm water runoff because it is generally routed through the groundwater and does not reach the stream for a significant amount of time following the precipitation event.

Also, the benefit of decreased pollutant loading due to reduced storm water runoff at high flows provides a good fit for the TMDL framework, although indirectly. The same cannot be said of the low flow targets. The low flow targets represent conditions where pollutants are already substantially removed from water the stream receives from groundwater and thus there are no problematic "pollutants" to allocate.

For these reasons, EPA does not consider the low flow targets applicable to an allocation scenario and therefore they are not presented as official TMDL allocations. Rather, they are presented as complimentary targets for the overall remediation of the watershed.

5. Calculation of Loading Capacity

A TMDL quantifies the amount of a pollutant a water body can assimilate without violating a state's WQS and allocates that LC to known point and nonpoint sources in the form of WLA, LA, a MOS and natural background conditions. The MOS accounts for uncertainty in the relationship between pollutant loads and the quality of the receiving water body. Conceptually, this definition is represented by the equation:

$$TMDL = \Sigma\, WLAs + \Sigma\, LAs + MOS$$

Where:

TMDL = Total Maximum Daily Load (may be seasonal, for critical conditions or have other constraints)

WLA = Wasteload Allocations (point source)

LA = Load Allocations (nonpoint source)

MOS = Margin of Safety (may be implicit and factored into a conservative WLA or LA, or explicit)

In the Hinkson Creek TMDL, because the pollutant of concern is represented by the surrogate measure of storm water runoff , the LC is the greatest volume of storm water runoff Hinkson Creek can receive and still maintain a fully supporting warm water aquatic life designated use. The FDC method is used to assess and compare the flows in Hinkson Creek to flows from a synthetic flow record developed from biological reference streams. The FDC describes important hydrologic characteristics of a watershed and is used to quantify the differences between Hinkson Creek and the synthetic flow data for this TMDL. The FDC is a useful analytical tool because it is capable of incorporating,

- A long period of time,
- Seasonal variability,
- Frequency of high flows and
- Critical conditions.

Hinkson Creek does not currently meet aquatic life beneficial uses. For streams in urbanized areas, additional stressors affecting warm water aquatic life exist in the form of non-pollutant impacts such as alterations in channel morphology and the flow regime or elimination of the riparian buffer. In this TMDL, the complex suite of pollutants and physical stressors causing the aquatic life impairment are attributable to storm water flows from developed areas. The high flow category of the FDC provides an appropriate flow target and an approach to estimating how much flow in Hinkson Creek needs to be reduced or baseflow increased.

The linkage between unknown pollutants, aquatic life impairment and storm water was accomplished using streams that are physiographically similar to Hinkson Creek and where the biological community is attaining the aquatic life designated use. The necessary percent reduction in storm water flow needed to restore the aquatic community in Hinkson Creek was statistically determined using stream discharge records collected during periods of aquatic life use attainment in the physiographically similar streams.

A secondary target for the Hinkson Creek TMDL relates to attainment of biological criteria within the stream. One of the clearest and most straightforward indicators of stream health is the biological community. That is, the insects and other small aquatic animals that form the basis of the food chain in a stream are an indicator of the overall health of the water body. A healthy aquatic community reflects the overall condition of the stream and cannot be present without the underlying problems in the stream and its watershed being addressed. Therefore, a secondary target for determining whether Hinkson Creek is attaining water WQS is for the water body to receive a fully supporting biological rating for all sites surveyed. Table 8 indicates that across all four of the water quality studies downstream of Interstate 70 (site 6.5 through site 1), 13 of 26 sampling events or 50 percent, were rated as fully supporting the aquatic life designated use. In contrast, 93 percent of all invertebrate samples collected in the reference streams for Hinkson Creek's ecoregion show normal, fully supporting invertebrate communities. The secondary target of 100 percent of all sites surveyed receiving a fully supporting rating can be accomplished through actions and BMPs used to reduce storm water runoff.

5.1 Development of Targets

Having determined the percent reduction of storm water runoff needed to restore the aquatic life protection designated use in Hinkson Creek, the TMDL must also provide an allocation of the required reduction between point and nonpoint sources. Rather than assigning individual allocations for every discrete storm water source within the watershed, EPA guidance allows for a gross allocation between point and nonpoint sources of storm water (EPA 2002b). This approach has been successfully used in the State of Vermont where, like Missouri, data are unavailable to allow for finer allocation among the many storm water sources within the watershed (VTDEC 2006).

EPA guidance allows for use of a land use analysis based on the extent of imperviousness to determine the amount of allocation that will be allocated to point versus nonpoint sources (EPA 2002). The underlying assumption in the approach is that urban, more developed areas typically convey more storm water due to less infiltration while rural, less developed or agricultural areas generate less runoff because of fewer impervious surface areas. With appropriate classification of land use within the watershed, developed/urbanized areas can be included in the WLA portion of the TMDL and lesser developed areas can be included in the LA portion. This approach is reasonable as urban areas tend to be dominated by point source conveyances of storm water, while rural areas are predominantly drained by surface flows. Therefore, the TMDL allocation process for Hinkson Creek will be simplified through the use of a land-use based allocation approach to distribute the overall percent reduction targets for the watershed.

5.2 Land Use Based TMDL Allocations

To develop the percent reductions for the WLA and LA for this TMDL, the watershed land use was aggregated into two functional categories:

- WLA is calculated based on the city boundary of Columbia in the watershed. Flows from the MS4 area are included in the WLA for this TMDL. Table 2 (2005 land use data) was used to estimate impervious cover for both rural and urban.

- Unregulated storm water includes agricultural areas (i.e., cropland and grassland) and these areas contribute unregulated storm water. Flows from these land areas will be included in the LA for this TMDL.

Natural areas are land uses (e.g., forest, woodland, open water and barren areas) which are assumed to maintain their natural hydrology and thus do not contribute to deviations in stream flow, such as storm water peaks or reduced baseflow. These land uses are assumed to be hydrologically unchanged and do not require a change in flow and thus are not included in this analysis. Table 14 shows the land use characteristics used to estimate runoff coefficients for the WLA and LA areas. A runoff coefficient (Rv) is estimated using the following equation (Schueler 1987):

$$R_v = 0.05+0.9(I_a)$$

Where; I_a = fraction of land area that is impervious

Table 14. Estimated Runoff Coefficients Based on the Percent of Imperviousness

Land Use (2005 Data)	Area (sq miles)	Percent Imperviousness	Rv	Rv*Area	Weighted Rv	Percent Runoff
WLA (Columbia)	*33.12*				0.31	64
Impervious	3.11	100	0.95	2.95		
High Intensity Urban	1.85	45	0.46	0.85		
Low Intensity Urban	10.01	30	0.32	3.20		
Cropland	1.48	2	0.07	0.10		
Grassland	8.57	2	0.07	0.60		
Sub-Total	25.02			7.68		
Rest of Watershed/LA	*56.63*				0.11	36
Impervious	1.15	100	0.95	1.09		
High Intensity Urban	0.10	45	0.46	0.05		
Low Intensity Urban	2.38	30	0.32	0.76		
Cropland	8.76	2	0.07	0.61		
Grassland	25.97	2	0.07	1.82		
Sub-Total	38.35			4.26		
Total Watershed	*89.75*					

The WLA and LA can be estimated by weighting the runoff coefficient based on land area designated as a source of regulated and unregulated storm water flows. Weighted Rv values are calculated for WLA and LA land use areas. Weighted Rv values are calculated by:

$$WeightedRv = \frac{\Sigma(Rv \times Area)}{\Sigma Area}$$

Weighted Rv are lumped runoff coefficients for the entire area (e.g., WLA and LA areas). The WLA and LA influence on excess runoff calculated by:

$$PercentRunoff = \frac{(WeightedRv \times Area)}{\Sigma(WeightedRv \times Area)}$$

As indicated in Table 14, the point sources area (WLA area or city limit of Columbia) contributes 64 percent of total storm water flow while nonpoint sources (or rest of watershed) contribute 36 percent of the storm water. The MS4 area comprises 19.4 percent, 5.6 percent and 30.2 percent of the impervious, high intensity urban and low intensity areas, while the remaining watershed consists of 2.0 percent, 0.2 percent and 4.2 percent of the impervious, high intensity urban and low intensity areas, respectively. The agricultural area (i.e., cropland and grassland) in the WLA area and the remainder of the watershed occupies 30.3 percent and 61.3 percent of their associated watershed areas, respectively.

To calculate the portion of excess flow (or storm water) attributable to each TMDL component, the percent excess runoff attributed to each subwatershed [i.e., WLA (point sources, including MS4) and LA (nonpoint sources)] was multiplied by the difference between Hinkson Creek FDC and the synthetic reference stream FDC. This calculation divides the excess flow between the WLA and LA. This step assumes that the portion of excess flow (i.e., Hinkson FDC – synthetic FDC) can be disaggregated based on the percent runoff values estimated (see Table 14).

Percent reductions by the WLA and the LA were then calculated using the following procedures. Excess flow attributable to the WLA or LA was divided by total flow in Hinkson Creek to calculate the percent of total flow attributable to the WLA or LA. This is the "extra" flow generated by the developed/urban areas that must be reduced to meet the synthetic reference stream FDC. To get a percent reduction by each subwatershed (e.g., WLA and LA), the excess flow of each subwatershed was divided by the sum of the synthetic flow from the reference streams and the excess flow of the each subwatershed. The result is the percent reduction needed. The estimated storm water reductions at the watershed outlet for the three percent and five percent flow exceedance values are shown in Table 15, where the Hinkson flow values are greater than the synthetic flow values. As shown in Table 15, a larger reduction is required as flow increases. Storm water runoff, transport the large amounts of pollutants being washed off from both rural and urban areas. By targeting and reducing storm water runoff at the upper 3 to 5 percentiles of flow exceedance, Hinkson Creek may be restored to its historic conditions to bring the water body into attainment of WQS.

Table 15. Storm Water TMDL and Its Allocation at the Outlet of Hinkson Creek Watershed

Percent Flow Exceedance	3	5	10	30	50	70	90
Synthetic Flow/TMDL (cfs)	925.3	656.1	355.4	77.2	34.1	18.0	7.2
Hinkson Creek Flow (cfs)	1296.9	801.5	282.7	64.6	26.9	11.7	4.5
Difference in Flow (cfs)	371.6	145.4	-72.7	-12.6	-7.2	-6.3	-2.7
Target Percent Increase (+)/Decrease(-)	28.7	18.1	-25.7	-19.4	-26.7	-53.8	-60.0
Portion Attributable to WLA (Columbia) (cfs)	239.1	93.5	-	-	-	-	-
Portion Attributable to LA (cfs)	132.5	51.8	-	-	-	-	-
WLA Percent Reduction	39.6	26.5	-	-	-	-	-
LA Percent Reduction	19.1	11.5	-	-	-	-	-

6. Wasteload Allocation (Point Source Load)

EPA interprets federal regulation at 40 CFR 130.2 to require that allocations for NPDES-regulated discharges of storm water be included in the WLA portion of the TMDL (EPA 2002b). EPA also states that in instances where there are insufficient data to calculate loads on an outfall by outfall basis, the storm water WLA can be expressed as an aggregate or combined allocation. Additionally, EPA acknowledges that in cases where it is difficult to discern regulated from non-regulated storm water discharges, it is acceptable to include both regulated storm water discharges and non-regulated discharges (which would typically be included in the LA portion of the TMDL) in the aggregated WLA.

Because of data limitations and the wide variability of storm water discharges, it is not possible to separate the storm water discharges that are subject to the permitting program (e.g., MS4 and storm water from construction activities) from storm water discharges that are not subject to permitting (e.g., storm water discharges from impervious areas not regulated by the MS4 co-permit). Therefore, all storm water discharges from the city boundary of Columbia where most of the area (45.2%) is developed are included in the WLA portion of the Hinkson Creek TMDL. This includes the regulated storm water discharges as well as other sources of storm water runoff not regulated as permitted discharges.

The WLA target runoff for various flow conditions can be found in Table 15. These values represent the weighted proportion of storm water runoff that must be reduced primarily from the urban and developed areas of the watershed (i.e., the area of the city boundary of Columbia to the entire watershed, 37 percent) through regulated activities. It does not mean, however, that storm water discharges outside of the scope of the permit program within the city limit of Columbia will be required to obtain a storm water permit. Rather, these discharges will be encouraged to comply with design and BMPs outlined by the Hinkson Creek Watershed Management Plan.

7. Load Allocation (Nonpoint Source Load)

Table 15 also reports the numeric LA targets at several percent exceedance conditions. The LA represents the daily FDC for the storm water runoff from non regulated areas within Hinkson Creek watershed. These values represent the flow targets that need to be met primarily through voluntary, non regulated activities which are outside of the MS4 area. It is anticipated the LA storm water flow reduction goals will be met through implementation of BMPs that will reduce storm water runoff flows, increase baseflow via infiltration and improve storm water runoff water quality. Should areas within the agricultural and open areas of the watershed be developed and urbanized, the land use area statistics found in the TMDL may need to be recalculated to ensure no increased storm water runoff from these.

8. Margin of Safety

A MOS is required in TMDL calculations to account for uncertainties in scientific and technical understanding of water quality in natural systems. The MOS is intended to account for such uncertainties in a conservative manner. Based on EPA guidance, the MOS can be achieved through one of two approaches:

1) Explicit – Reserve a numeric portion of the LC as a separate term in the TMDL.

2) Implicit – Incorporate the MOS as part of the critical conditions for the WLA and the LA calculations by making conservative assumptions in the analyses.

The MOS for this TMDL is implicit based on conservative assumptions applied while modeling. The TMDL flow values were determined as the percentage difference between the Hinkson Creek flow rate and the 95 percent CL of flow values for the reference streams to target the high flow conditions between 2008 and 2010.

According to the reference stream approach, the flows for the reference streams represent flows under which the biologic criteria are being met. This can be thought of as a range of flows in streams similar to Hinkson Creek that are capable of sustaining appropriate aquatic life standards. Because of limited of flow data measured at Hinkson Creek, the flow data recorded in the wet years from 2008 to 2010 was used to determine the TMDL target goals. The average flow of these values approximately occur at the upper five percentile of all the entire 22-year flow data record, which prompted EPA to use the 95 percent CL to set statistically conservative targets. This TMDL does not include channel forming flow conditions (i.e., above bankfull flow conditions) and as a result at high flows of these wet years, this represents a range of flows from the upper 3 to 7 percentiles of flow exceedances (see Tables 13 and 15). Since the current TMDL focuses on the wet years, it is likely that the flows represented by the reference streams are typically not at the "threshold" of attainment. That is, the modeled flows in the streams currently meeting WQS likely represent flows somewhat below that at which impairment would occur, thus adding an additional level of safety.

9. Seasonal Variation

The CWA and implementing regulations require that a TMDL be established with consideration of seasonal variation. FDCs have been demonstrated to be the best surrogate for defining hydrologic targets because they represent all flow conditions, across all seasons. The FDCs developed for this TMDL are useful for describing the hydrologic condition of Hinkson Creek and its watershed over a long period of time. The curves incorporate the full spectrum of stream flow conditions from very low to very high and any flow variability due to seasonal variations.

Because the FDC represents flow under all possible stream conditions, it has the advantage of avoiding the constraints associated with using a single-flow critical condition approach during the development of the TMDL. Because the TMDL is applicable under all flow conditions, it is also applicable for all seasons. Seasonal variation is therefore implicitly taken into account within the TMDL calculations.

10. Monitoring Plans

There are several monitoring efforts planned in the Hinkson Creek watershed for TMDL implementation and assessment purposes. One of the milestones of the Hinkson Creek Watershed Restoration Plan is to monitor the performance of storm water treatment structures and verify their effectiveness. The Storm Water Management Plan for the MS4 permit in the watershed will also require monitoring and other actions necessary to implement the requirements of the TMDL once the TMDL is effective. Additionally, a grant to monitor the hydrology of Hinkson Creek was recently initiated (See Appendix E).

In the first phase of implementation of the TMDL, EPA recommends assessment of the biocommunity to be conducted. In addition, MDNR intends to conduct a follow-up bioassessment of Hinkson Creek, including collection of water quality data, once substantial implementation of the TMDL has occurred, typically three to five years. Chloride data will also continue to be collected by volunteer water quality monitors to determine trends in chloride concentrations in Hinkson Creek.

11. Reasonable Assurances

EPA believes that point source permitting authority and nonpoint source measures discussed in the supplemental implementation plan (see Appendix E of the TMDL) provides reasonable assurances that the TMDL allocations can be achieved.

MDNR has the authority to issue and enforce MSOPs. Inclusion of effluent limits into a state operating permit and requiring effluent and instream monitoring be reported to MDNR should provide reasonable assurance that instream WQS will be met. CWA Section 301(b)(1)(C) requires that point source permits have effluent limits as stringent as necessary to meet WQS. However, for WLAs to serve that purpose, they must themselves be stringent enough so that in conjunction with the water body's other loadings they meet WQS. This generally occurs when the TMDL's combined nonpoint source LAs and point source WLAs do not exceed the WQS-based LC and there is reasonable assurance that the TMDL's allocations can be achieved. Any discussion of reduction efforts relating to nonpoint sources would be found in the supplemental implementation plan of the TMDL (see Appendix E).

12. Public Participation

EPA regulations require that TMDLs be subject to public review (40 CFR 130.7). EPA is providing public notice of this draft TMDL for Hinkson Creek on the EPA, Region 7, TMDL Website: http://www.epa.gov/region07/water/tmdl_public_notice.htm. The response to comments and final TMDL will be available at:
http://www.epa.gov/region07/water/apprtmdl.htm#Missouri.

This water quality limited segment of Hinkson Creek in Boone County, Missouri, is included on the EPA-approved 2008 Missouri 303(d) List. This TMDL is being established by

EPA to meet the requirements of the 2001 Consent Decree, *American Canoe Association, et al. v. EPA*, No. 98-1195-CV-W in consolidation with No. 98-4282-CV-W, February 27, 2001. EPA is developing this TMDL in cooperation with the state of Missouri and EPA is establishing this TMDL at this time to meet the *American Canoe Association, et al.* consent decree milestones. Missouri may submit and EPA may approve a revised or modified TMDL for this water at any time.

Before finalizing EPA established TMDLs, the public is notified that a comment period is open on the EPA Region 7 website for at least 30 days. EPA's public notices to comment on draft TMDLs are also distributed via mail and electronic mail to major stakeholders in the watershed and other potentially impacted parties. After the comment period closes, EPA reviews all comments, edits the TMDL as is appropriate, writes a Summary of Response to Comments and establishes the TMDL. For Missouri TMDLs, groups receiving the public notice announcement include a distribution list provided by MDNR, the Missouri Clean Water Commission, the Missouri Water Quality Coordinating Committee, stream team volunteers, state legislators, County Commissioners, the County Soil and Water Conservation District and potentially impacted cities, towns and facilities. EPA followed this public notice process for this TMDL. Links to active public notices for draft TMDLs, final (approved and established) TMDLs and Summary of Response to Comments are posted on the EPA Website: http://www.epa.gov/region07/water/tmdl.htm.

A draft Hinkson Creek TMDL was originally public noticed by the state of Missouri from March 8 to April 22, 2010. Groups receiving the public notice announcement include the Missouri Clean Water Commission, the Water Quality Coordinating Committee, the mailing list for Hinkson Creek Restoration Project, Boone County, the city of Columbia, UMC, 187 stream team volunteers in the county and the six legislators representing Boone County. Also, the public notice, the Hinkson Creek Information Sheet and the TMDL document were posted on MDNR's website making them available to anyone with access to the Internet. All comments received were placed in the Hinkson Creek docket along with MDNR's response to comments and any other documentation.

13. Administrative Record and Supporting Documentation

An administrative record on the Hinkson Creek TMDL has been assembled and is being kept on file with EPA. An administrative record on the draft Hinkson Creek TMDL public noticed by MDNR was also assembled and kept on file with MDNR during the state public notice periods. It includes the following:

- Biological Assessment Report, Hinkson Creek, Boone County [Missouri] December 18, 2002, Environmental Services Program
- Stream Survey Sampling Report, Hinkson Creek Stream Study, Columbia, Missouri, Boone County, November 22, 2004, Environmental Services Program

- Stream Survey Sampling Report, Phase II, Hinkson Creek Stream Study, Columbia, Missouri, Boone County, June 2004 – June 2005, Environmental Services Program

- Stream Survey Sampling Report, Phase III, Hinkson Creek Stream Study, Columbia, Missouri, Boone County, July 2005 – June 2006, Environmental Services Program

- Hinkson Creek Watershed Restoration 319 Project - Phase I, Final Report

- Hinkson Creek Watershed Restoration 319 Project – Phase II, Project Plan

- Monitoring the Hydrology on Hinkson Creek – 319 grant, Project Plan

- Upper Hinkson Creek AgNPS SALT Water Quality Project, Final Report

- Co-permittees' Phase II Storm Water Permit and Storm Water Management Plan

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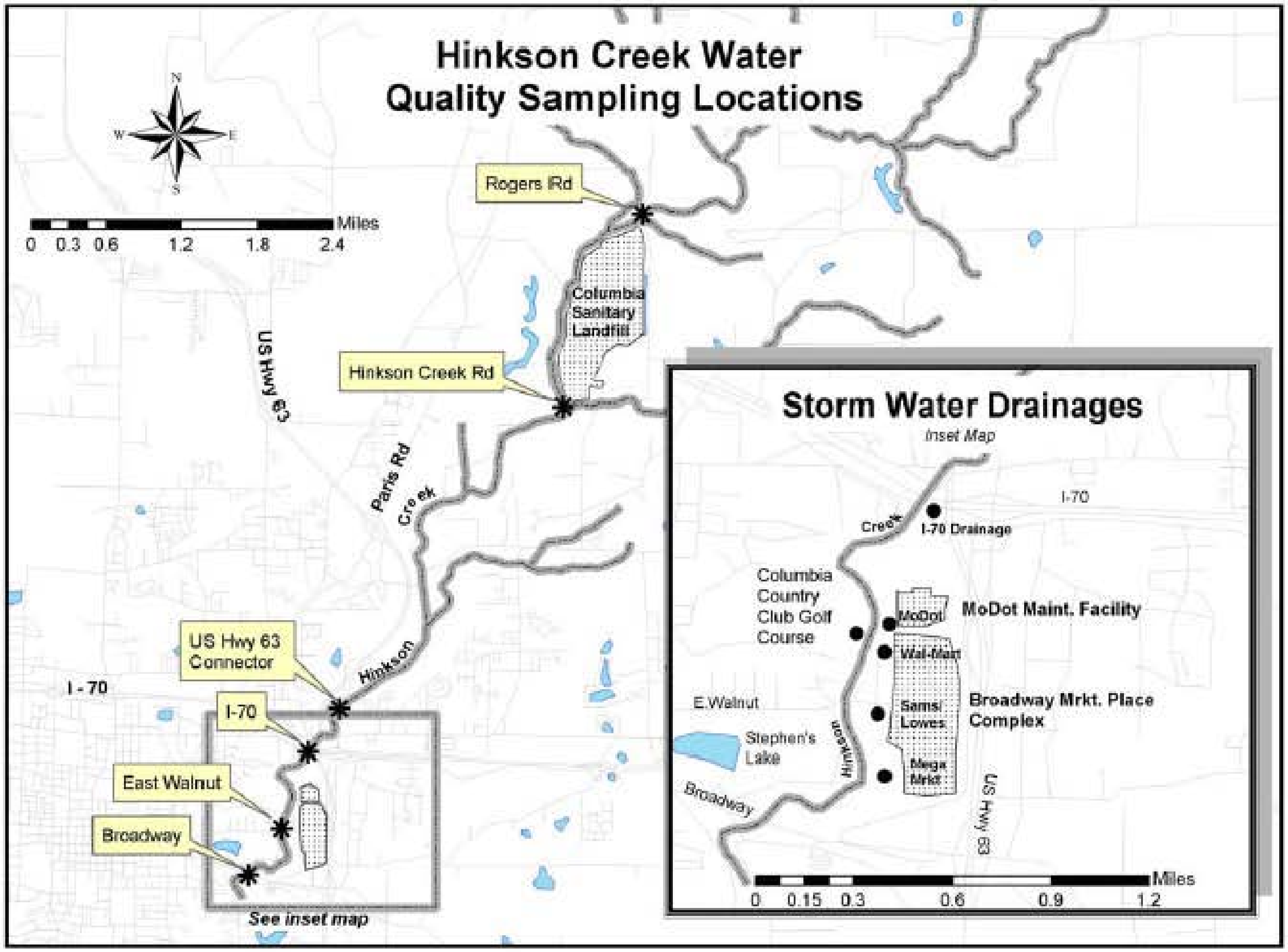
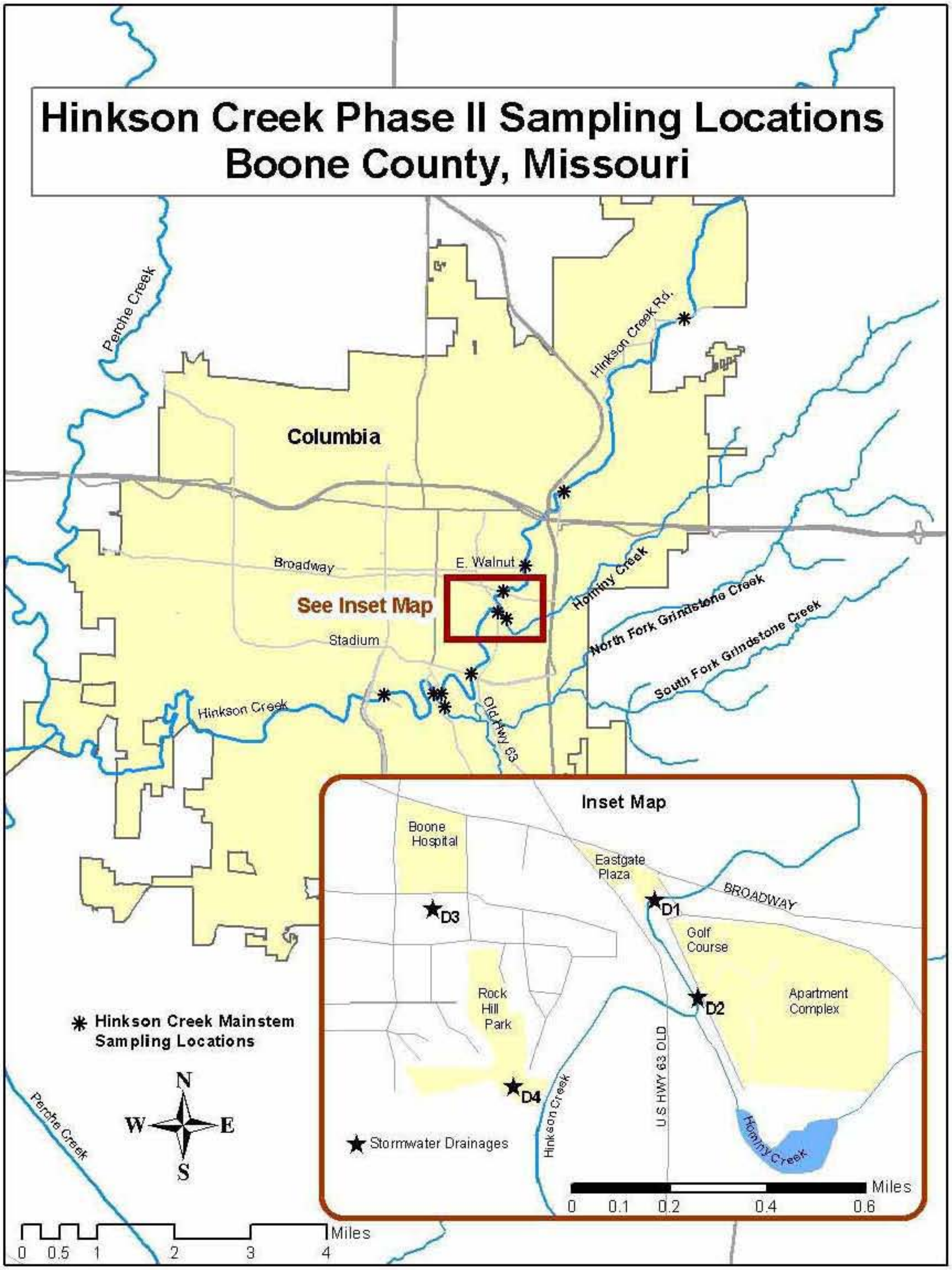
Appendix A - Location Maps from the Four Studies Showing Sample Sites

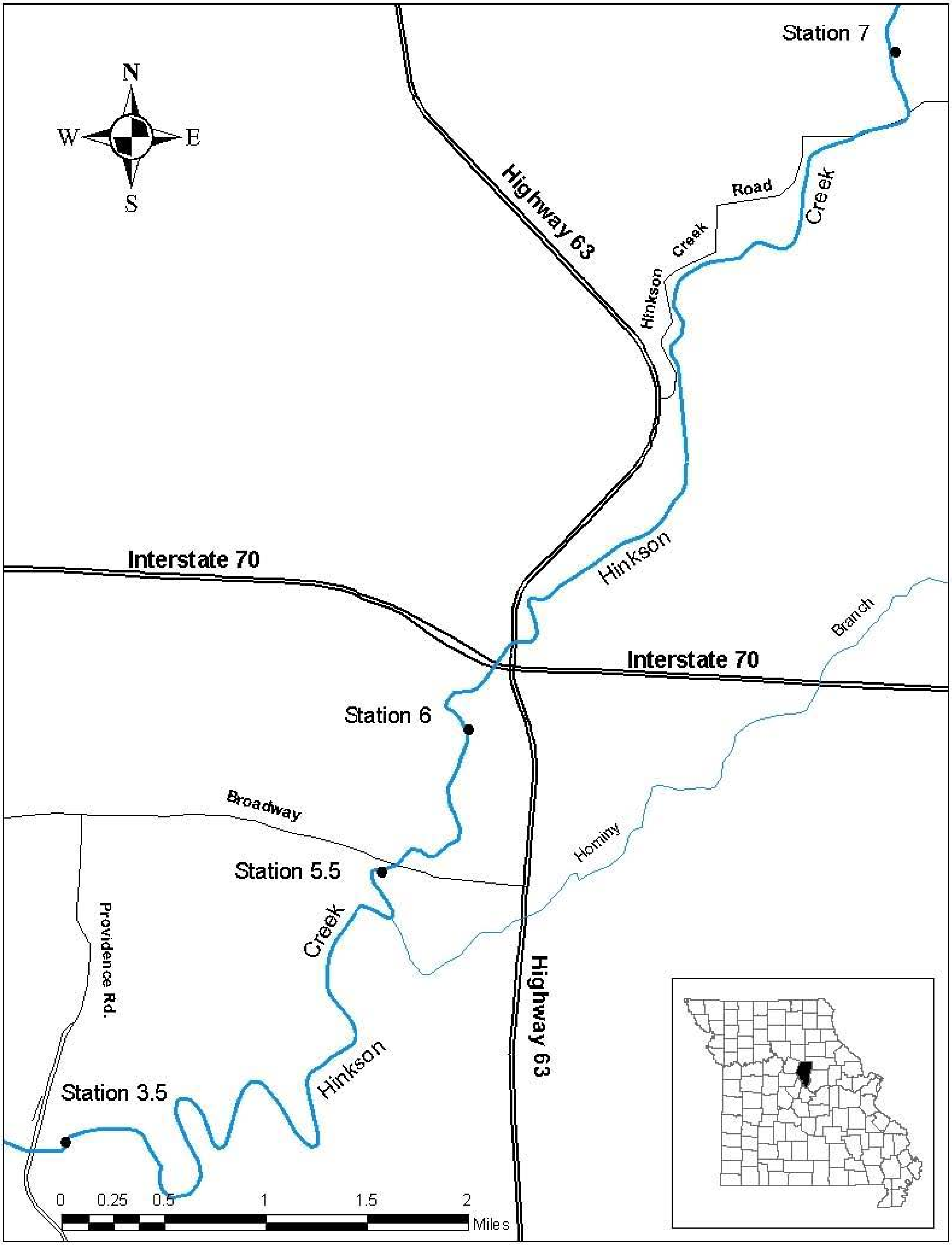
A.1. Water Quality Monitoring Sites – Phase I



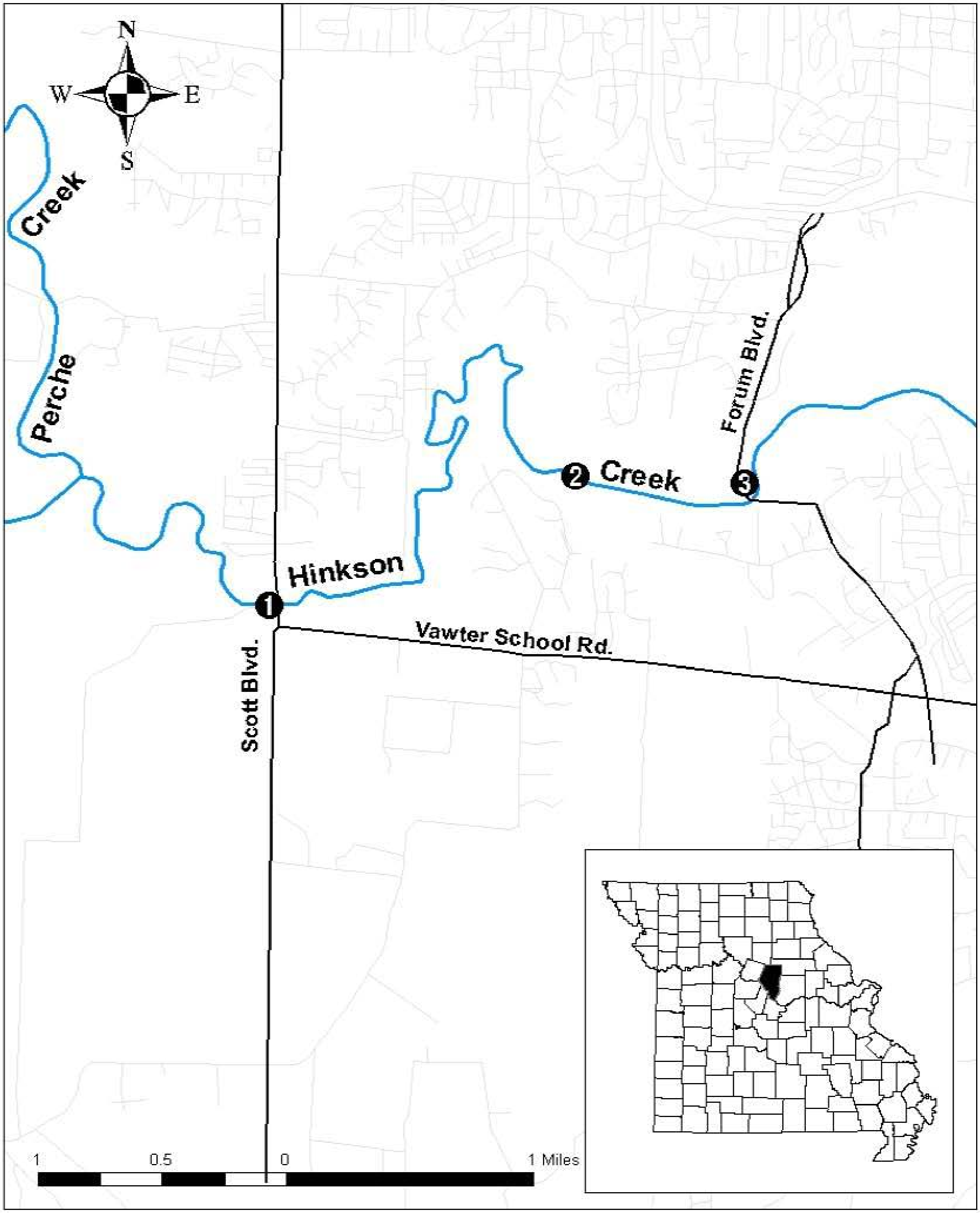
A.2. Hinkson Creek Water Quality Monitoring Sites – Phase II



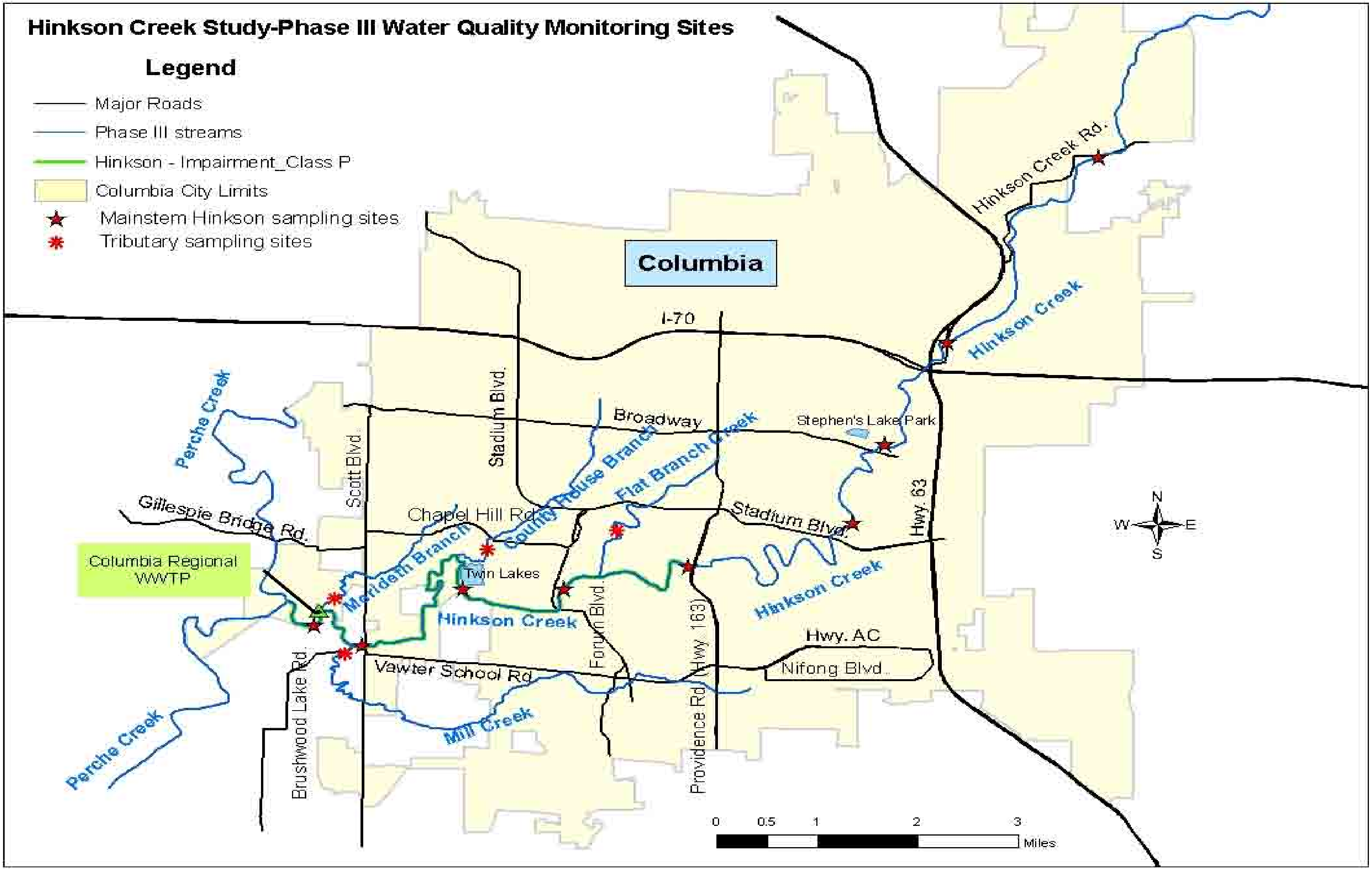
A.3. Hinkson Creek Macroinvertebrate Monitoring Locations- Phase II



A.4. Spring 2006 Macroinvertebrate Monitoring Locations Phase III



A.5. Hinkson Creek Phase III Water Quality Monitoring Sites



Appendix B - General (MOG) and Storm Water (MOR) Permits in Hinkson Creek Watershed

(Numeric order by permit number)

Facility ID	Facility Name	Type/ Design Flow (MGD)	Receiving Stream	Permit Exp. Date
MOG350183	UMC UNIVERSITY GARAGE	0.000	HINKSON CREEK	2012
MOG350238	UMC POWER PLANT	0.000	TRIB FLAT BRANCH	2012
MOG490953	PRECISION PRECAST	0.000	S FORK GRINDSTONE CK	2011
MOG760099	DOUGLAS FAMILY AQUATIC CENTER	0.000	TRIB FLAT BRACH CREEK	2012
MOG760100	LAKE OF THE WOODS POOL	0.000	TRIB N FORK GRINDSTONE	2012
MOG940206	BREAK TIME #3028	0.000	TRIB MILL CREEK	2010
MOR010007	MISSOURI DEPARTMENT of TRANSPORTATION	SLAND	JURISDICTION WIDE	2012
MOR040045	BOONE CO/COLUMBIA/UMC	MS4	TRIB GANS CREEK	2013
MOR040063	MISSOURI DEPARTMENT of TRANSPORTATION	MS4	JURISDICTION WIDE	2013
MOR100039	UMC CAMPUS	SLAND	FLAT BRANCH	2012
MOR107196	GOLFVIEW GARDENS	SLAND	TRIB N FK GRINDSTONE CK	2012
MOR109656	DANIEL BOONE LITTLE LEAGUE	SLAND	TRIB GOODING BRANCH	2012
MOR109695	TRIMBLE ROAD PROPERTY	SLAND	TRIB HOMINY CREEK	2012
MOR109AE9	WHITE OAK CONDOMINIUMS	SLAND	TRIB HINKSON CREEK	2012
MOR109BQ7	SPRING CREEK - CAR WASH	SLAND	HINKSON CREEK	2012
MOR109T03	OLD HAWTHORNE TRACT 3-D	SLAND	TRIB S FK GRINDSTONE CK	2012
MOR109Y98	HAMPTON INN & SUITES	SLAND	TRIB HINKSON CREEK	2012
MOR109Z08	RGM PROPERTIES LLC	SLAND	TRIB HINKSON CREEK	2012
MOR109Z24	MID-MO INDUSTRIAL PARK	SLAND	TRIB HINKSON CREEK	2012
MOR109Z25	GREENBRIAR VILLAGE PLAT 1	SLAND	TRIB HINKSON CREEK	2012
MOR109Z27	NORCO SUBDIVISION	SLAND	TRIB HINKSON CREEK	2012
MOR109Z58	COPPERSTONE	SLAND	MILL CREEK	2012
MOR109Z70	BROADWAY MARKETPLACE	SLAND	TRIB HINKSON CREEK	2012
MOR109Z83	CAMPUS VIEW CONDOMINIUMS	SLAND	TRIB HINKSON CREEK	2012
MOR10A249	OLD HAWTHORNE PLAT 4	SLAND	TRIB S FK GRINDSTONE CK	2012
MOR10A452	COLUMBIA AREA CAREER CENTER	SLAND	TRIB MILL CREEK	2012
MOR10A454	GRINDSTONE PLAZA PHASE 2	SLAND	TRIB HINKSON CREEK	2012
MOR10A455	GRINDSTONE PLAZA-OUTLOTS	SLAND	TRIB HINKSON CREEK	2012
MOR10A457	THE VINEYARDS PLATS 1 & 3	SLAND	S FK GRINDSTONE CREEK	2012
MOR10A458	THE VINEYARDS PLAT 2	SLAND	S FK OF GRINDSTONE CK	2012
MOR10A461	MILL CREEK MANOR PLAT 1	SLAND	TRIB MILL CREEK	2012

Facility ID	Facility Name	Type/ Design Flow (MGD)	Receiving Stream	Permit Exp. Date
MOR10A463	GOLD STAR FARMS PLAT 2	SLAND	TRIB NELSON CREEK	2012
MOR10A464	HERITAGE ESTATES PLAT 1	SLAND	TRIB MILL CREEK	2012
MOR10A465	HERITAGE ESTATES PLAT #2	SLAND	TRIB MILL CREEK	2012
MOR10A466	MILL CREEK MANOR PLAT 2	SLAND	TRIB MILL CREEK	2012
MOR10A468	RED OAK COMMERCIAL DEVELOPMENT	SLAND	TRIB HINKSON CREEK	2012
MOR10A469	DAKOTA RIDGE PLAT 2	SLAND	TRIB HINKSON CREEK	2012
MOR10A474	TRADE WIND PARK	SLAND	TRIB S FK GRINDSTONE	2012
MOR10A476	HERITAGE WOODS PLAT 1	SLAND	TRIB MILL CREEK	2012
MOR10A480	FAST LANE AT CENTERSTATE	SLAND	TRIB HINKSON CREEK	2012
MOR10A483	LOT 402 EWING INDUSTRIAL	SLAND	TRIB HINKSON CREEK	2012
MOR10A493	TRAIL RIDGE PLAT 3	SLAND	TRIB HINKSON CREEK	2012
MOR10A496	WW-63 SUBDIVISION LOTS 1&	SLAND	TRIB HOMINY CREEK	2012
MOR10A498	PARIS ROAD PLAZA	SLAND	TRIB HINKSON CREEK	2012
MOR10A499	STRATFORD CHASE	SLAND	TRIB GRINDSTONE CREEK	2012
MOR10A501	OLD HAWTHORNE	SLAND	TRIB S FK GRINDSTONE CK	2012
MOR10A504	MILL CREEK MANOR PLAT 3	SLAND	TRIB MILL CREEK	2012
MOR10A511	BUSENBARK CARPET OUTLET	SLAND	TRIB N FK GRINDSTONE CK	2012
MOR10A512	THE LINKS OF COLUMBIA	SLAND	TRIB HOMINY CREEK	2012
MOR10A515	THE VISTAS AT OLD HAWTHORNE	SLAND	TRIB S FK GRINDSTONE CK	2012
MOR10A516	LAKE OF THE WOODS CENTER	SLAND	TRIB N FK GRINDSTONE CK	2012
MOR10A519	THORNBROOK PLAT 12	SLAND	TRIB MILL CREEK	2012
MOR10A520	THORNBROOK PLAT 13	SLAND	TRIB MILL CREEK	2012
MOR10A521	THORNBROOK PLAT 14	SLAND	TRIB MILL CREEK	2012
MOR10A522	CREEKWOOD CENTER	SLAND	N FK GRINDSTONE CREEK	2012
MOR10A531	OLD HAWTHORNE	SLAND	S FK GRINDSTONE CREEK	2012
MOR10A532	OLD HAWTHORNE PLAT 2	SLAND	S FK GRINSTONE CREEK	2012
MOR10A534	BEARFIELD PLAZA	SLAND	TRIB GRINDSTONE CREEK	2012
MOR10A558	WESTCLIFF SUBDIVISION PL2	SLAND	TRIB PERCHE CREEK	2012
MOR10A562	WEST LAWN PHASE II	SLAND	TRIB SCOTTS BRANCH	2012
MOR10A563	WEST LAWN PLAT 2	SLAND	TRIB GOODIN BRANCH	2012
MOR10A565	TIGER PLACE PHASE 2	SLAND	TRIB GRINDSTONE CREEK	2012
MOR10A566	TIGER PLACE PHASE III	SLAND	TRIB GRINDSTONE CREEK	2012
MOR10A574	LAKE BROADWAY C-P DEVELOPMENT	SLAND	COUNTRY HOUSE BRANCH	2012
MOR10A591	RIVER BIRCH APARTMENTS WEST	SLAND	TRIB HINKSON CREEK	2012

Facility ID	Facility Name	Type/ Design Flow (MGD)	Receiving Stream	Permit Exp. Date
MOR10A603	BLUFF RIDGE PLAT 1-F	SLAND	TRIB GRINDSTONE CREEK	2012
MOR10A605	THE GATES AT OLD HAWTHORNE	SLAND	TRIB S FK GRINDSTONE CK	2012
MOR10A609	EASTLAND HILLS ESTATES	SLAND	HOMINY BRANCH	2012
MOR10A724	HONEYWELL REOCHEM	SLAND	TRIB BEAR CREEK	2012
MOR10A799	MADISON PARK PLAT 1	SLAND	TRIB COUNTY HOUSE BR	2012
MOR10A816	DEER RIDGE PLAT 3	SLAND	TRIB NELSON CREEK	2012
MOR10A822	BAY HILLS PLAT 2	SLAND	TRIB N FK GRINDSTONE CK	2012
MOR10A826	EWING INDUSTRIAL PARK PLAT 3	SLAND	TRIB HINKSON CREEK	2012
MOR10A861	WYNDHAM RIDGE PLAT 1	SLAND	TRIB MILL CREEK	2012
MOR10A901	HOLIDAY INN EASTPORT	SLAND	TRIB N FK GRINDSTONE CK	2012
MOR10A944	MAGNOLIA FALLS	SLAND	MILL CREEK	2012
MOR10B042	MILL CREEK MANOR PLAT 4	SLAND	TRIB MILL CREEK	2012
MOR10B056	LIBERTY TOWER	SLAND	TRIB HINKSON CREEK	2012
MOR10B089	RIDGEWAY PLACE PLAT 1	SLAND	TRIB FLAT BRANCH	2012
MOR10B170	BOONE COUNTY NATIONAL BAN	SLAND	TRIB HOMINY CREEK	2012
MOR10B176	OLD HAWTHORNE PLAZA	SLAND	TRIB S FK GRINDSTONE	2012
MOR10B189	BLUFF CREEK O-1	SLAND	TRIB GRINDSTONE CREEK	2012
MOR10B205	WILLIAM STREET GARAGE	SLAND	TRIB HINKSON CREEK	2012
MOR10B228	BERLEKAMP LOT 202	SLAND	TRIB HINKSON CREEK	2012
MOR10B252	BETHEL RIDGE ESTATES	SLAND	TRIB MILL CREEK	2012
MOR10B294	ROCK BRIDGE SUBD BLOCK VII LOTS1&2	SLAND	TRIB MILL CREEK	2012
MOR10B299	ROCK VALLEY PLAT 4	SLAND	COUNTY HOUSE BRANCH	2012
MOR10B357	JENNE HILL TOWNHOMES LLC	SLAND	TRIB BEAR CREEK	2012
MOR10B440	WOODLAND SPRINGS LOT 103B	SLAND	TRIB HINKSON CREEK	2012
MOR10B462	WYNDHAM RIDGE PLAT #2	SLAND	TRIB MILL CREEK	2012
MOR10B469	THE VILLAGE AT WYNDHAM #1	SLAND	TRIB MILL CREEK	2012
MOR10B485	BCSD S FK OF GRINDSTONE CK	SLAND	TRIB S FK GRINDSTONE CK	2012
MOR10B526	RETINA ASSOCIATES	SLAND	TRIB HINKSON CREEK	2012
MOR10B537	OLD DOMINION FREIGHT TERMINAL	SLAND	TRIB S FK GRINDSTONE	2012
MOR10B576	GI DOCTOR OFFICE	SLAND	HOMINY CREEK	2012
MOR10B593	THESSALIA PLAT #7	SLAND	TRIB HOMINY CREEK	2012
MOR10B650	VILLAGE SQUARE LOT 105B	SLAND	TRIB MILL CREEK	2012
MOR10B674	WELLINGTON MANOR PLAT 3	SLAND	TRIB HOMINY CREEK	2012
MOR10B725	WELLINGTON MANOR PUD	SLAND	TRIB HOMINY CREEK	2012

Facility ID	Facility Name	Type/ Design Flow (MGD)	Receiving Stream	Permit Exp. Date
MOR10B738	WENDY'S OLD FASHIONED HAMBURGER	SLAND	TRIB HINKSON CREEK	2012
MOR10B739	HY-VEE COLUMBIA #2	SLAND	TRIB HINKSON CREEK	2012
MOR10B772	ROCK QUARRY PUD PHASE II	SLAND	TRIB HINKSON CREEK	2012
MOR10B813	SOUTHFORK OF THE GRINDSTONE SUBD	SLAND	TRIB S FK GRINDSTONE CK	2012
MOR10B814	JEFFERSON FARM & GARDENS	SLAND	TRIB S FK GRINDSTONE CK	2012
MOR10B827	CHAPEL MILLS ESTATES	SLAND	TRIB HINKSON CREEK	2012
MOR10B853	FASTLANE AT CENTERSTATE	SLAND	TRIB HINKSON CREEK	2012
MOR10B854	LOT 1222B THE COLONIES PLAT 4D	SLAND	TRIB HINKSON CREEK	2012
MOR10B856	WOODLANDS PLAT 5	SLAND	TRIB S FK GRINDSTONE CK	2012
MOR10B986	LANDMARK HOSPITAL	SLAND	TRIB HINKSON CREEK	2012
MOR10B998	RSC RENTAL	SLAND	TRIB HINKSON CREEK	2012
MOR10C046	BCSD EL CHAPARREL LAGOON	SLAND	S FK GRINDSTONE CREEK	2012
MOR10C101	THE CROSSINGS CHURCH	SLAND	TRIB HINKSON CREEK	2012
MOR10C230	AMERENUE COLUMBIA OPERATIONS AND TRAINING CENTER	SLAND	TRIB GRINDSTONE CREEK	2012
MOR10C294	NEW COLUMBIA HIGH SCHOOL	SLAND	N FK GRINDSTONE CREEK	2012
MOR10C295	DISCOVERY CHURCH	SLAND	TRIB HINKSON CREEK	2012
MOR10C336	PATIENT TOWER	SLAND	TRIB HINKSON CREEK	2012
MOR10C350	LINKSIDE AT OLD HAWTHORNE	SLAND	TRIB S FK GRINDSTONE CK	2012
MOR10C432	ROCK BRIDGE CENTER TRANSPORTATION IMPROVEMENTS	SLAND	TRIB HINKSON CREEK	2012
MOR10C489	BETHEL RIDGE ESTATES PHASE II	SLAND	TRIB MILL CREEK	2012
MOR10C504	CENTERSTATE CROSSING NORTH	SLAND	TRIB HINKSON CREEK	2012
MOR10C510	100 ACRE EMPLOYMENT AND ECONOMIC DEVELOPMENT CENTER	SLAND	TRIB HINKSON CREEK	2012
MOR12A131	QUAKER MANUFACTURING LLC	FOOD	TRIB BEAR CREEK	2011
MOR203041	DANA LIGHT AXLE PRODUCTS	METAL	TRIB GRINDSTONE CREEK	2009
MOR203369	3M COLUMBIA	METAL	TRIB BEAR CREEK	2009
MOR23D060	AAF - MCQUAY INC	PLAST	HINKSON CREEK	2005
MOR23D107	GATES CORP	RUBER	GRINDSTONE CREEK	2010
MOR240637	MFA AGRI SERVICE - COLUMBIA	AGCEM	TRIB HINKSON CREEK	2014
MOR60A115	A-1 AUTO RECYCLERS	SALV	TRIB N FK GRINDSTONE CK	2013
MOR60A245	DAVENPORT TOWING & SALVAGE	SALV	TRIB HINKSON CREEK	2013
MOR60A267	MD TRANSMISSION	SALV	HINKSON CREEK	2013

Facility ID	Facility Name	Type/ Design Flow (MGD)	Receiving Stream	Permit Exp. Date
MOR80C147	UNITED PARCEL SER-COLUMBIA	TRU M	TRIB HINKSON CREEK	2012
MOR80C192	UPS GROUND FREIGHT-COLUMBIA	TRU M	TRIB HINKSON CREEK	2012
MOR80C327	FIRST STUDENT INC #11396	TRU M	TRIB HINKSON CREEK	2012
MOR80C489	VEOLIA ES COLUMBIA HAULING	TRU M	TRIB S FK GRINDSTONE CK	2012

Note: MS4 = Municipal Separate Storm Sewer System; SLAND = Storm water/Land disturbance; FOOD = Food Processing; METAL = Metal scrap and resale; PLAST = Plastic manufacture; RUBER = Rubber products; AGCHEM = Agriculture/Chemical plant; SALV = Vehicle salvage yards; TRU M = Truck maintenance facility

Appendix C - Land Use Maps for Reference Streams Percentage Tables Included Land Use Coverage Data from 2002-2005

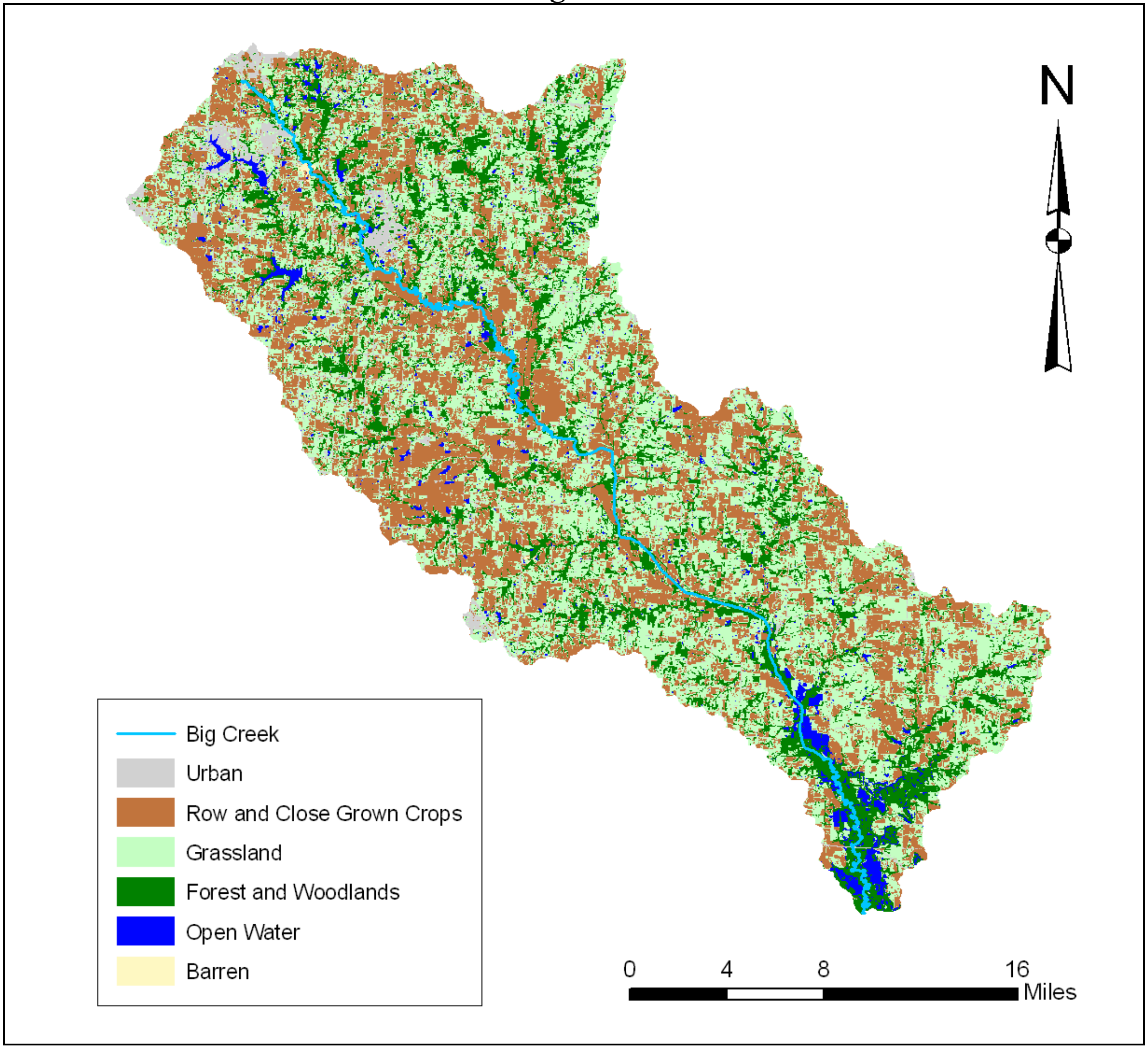


Figure C.1. Land Use Map for Big Creek in Cass, Johnson and Henry Counties

Table C.1. Big Creek Watershed Land Use Percentages

Land Use Type	Acres	Square Miles	Percentage
Urban	17,446	27.26	5.1
Row and Close-grown Crops	111,946	174.92	32.6
Grassland	140,507	219.55	40.9
Forest & Woodland	64,545	100.85	18.8
Open Water	8,936	13.96	2.6
Barren	221	0.35	0.1
	343,601	**536.89**	**100.0**

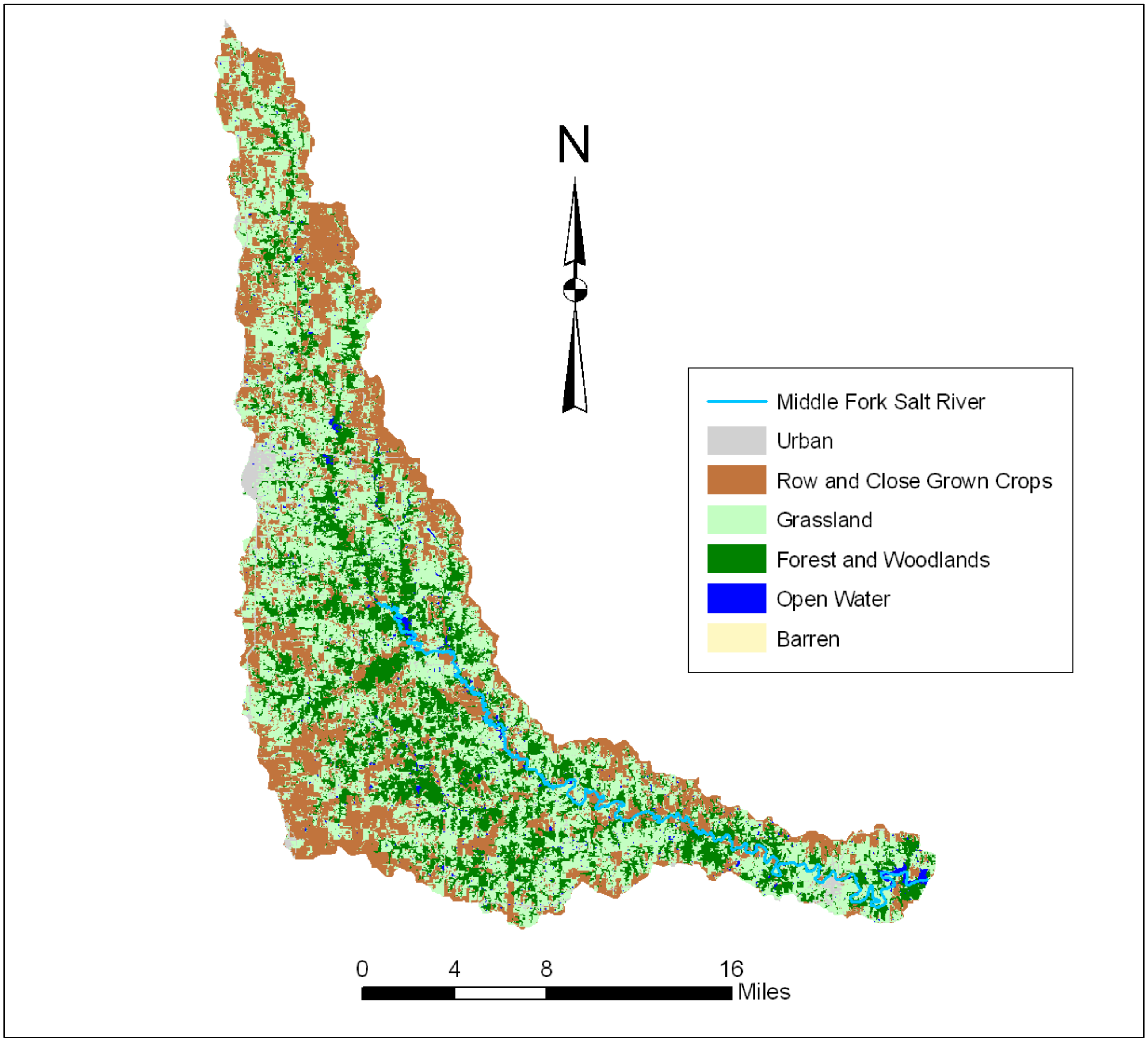


Figure C.2. Land Use Map for Middle Fork Salt River in Macon to Monroe Counties

Table C.2. Middle Fork Salt River Watershed Land Use Percentages

Land Use Type	Acres	Square Miles	Percentage
Urban	6,916	10.81	3.1
Row and Close-grown Crops	64,539	100.84	28.8
Grassland	94,902	148.29	42.4
Forest & Woodland	54,232	84.74	24.2
Open Water	3,365	5.26	1.5
Barren	15	0.02	0.0
Total	**223,969**	**349.96**	**100.0**

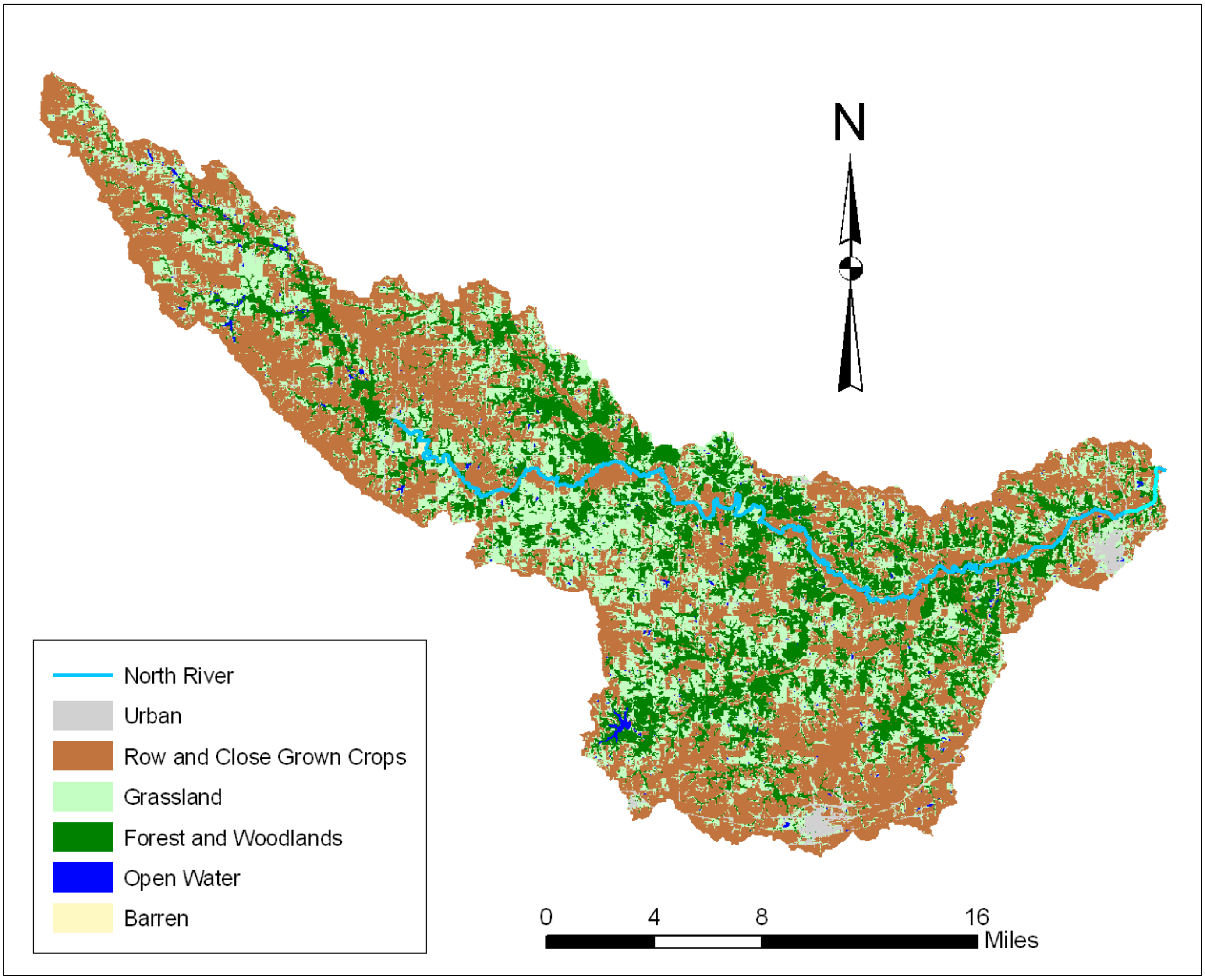


Figure C.3. Land Use Map for North River in Shelby and Marian Counties

Table C.3. North River Watershed Land Use Percentages

Land Use Type	Acres	Square Miles	Percentage
Urban	5,893	9.21	2.5
Row and Close-grown Crops	105,279	164.50	44.6
Grassland	65,462	102.29	27.8
Forest & Woodland	57,296	89.53	24.3
Open Water	1,807	2.82	0.8
Barren	107	0.17	0.0
Totals	**235,844**	**368.52**	**100.0**

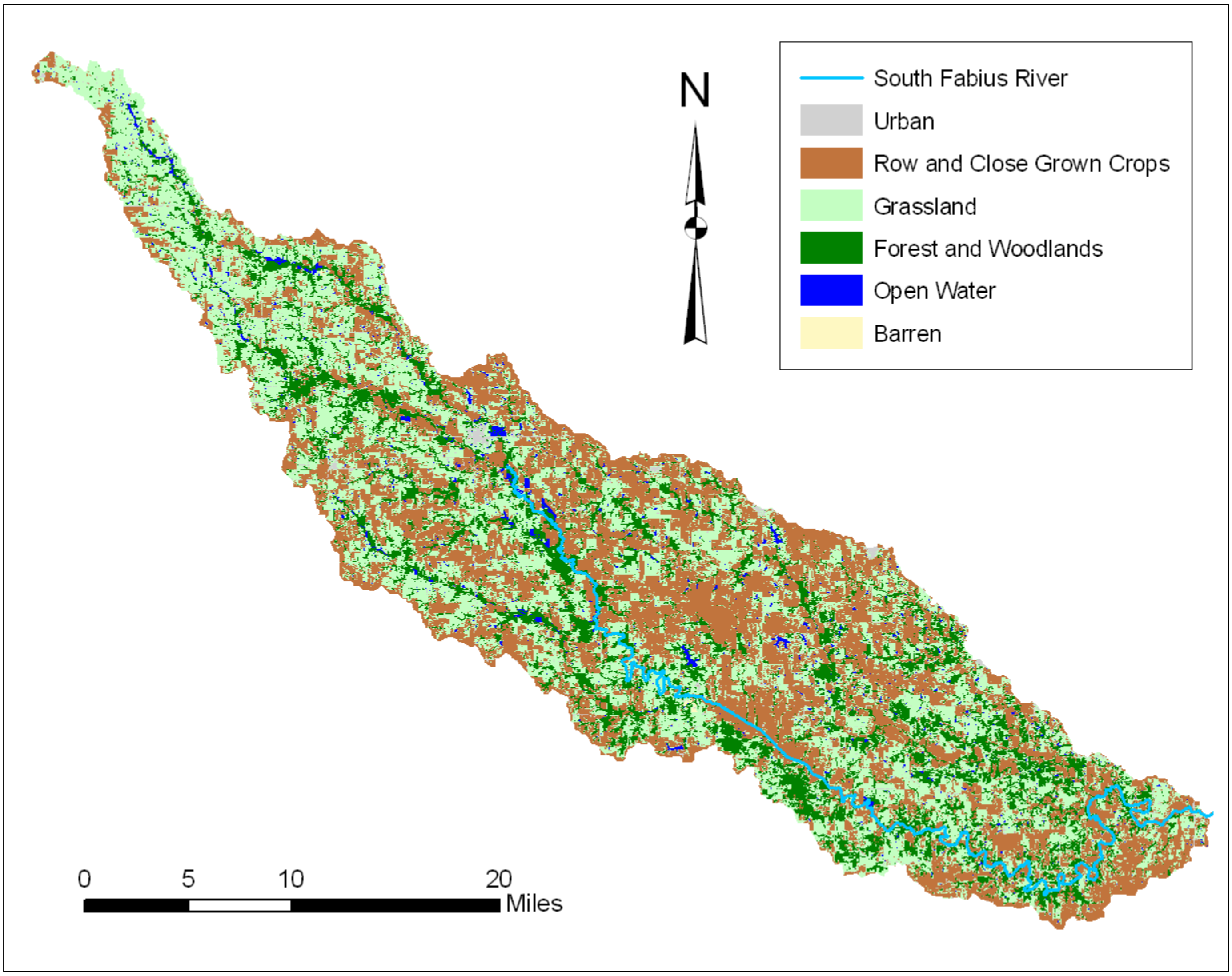


Figure C.4. Land Use Map for South Fabius River in Knox to Marian Counties

Table C.4. South Fabius River Watershed Land Use Percentages

Land Use Type	**Acres**	**Square Miles**	**Percentage**
Urban	6,828	10.67	1.7
Row and Close-grown Crops	149,917	234.25	37.9
Grassland	157,160	245.57	39.7
Forest & Woodland	75,207	117.51	19.0
Open Water	6,512	10.18	1.6
Barren	118	0.18	0.0
Total	**395,742**	**618.36**	**100.0**

Appendix D - Additional Activities in the Hinkson Creek Watershed

Contributed by Boone County, the city of Columbia and the University of Missouri-Columbia

EXHIBIT A. Boone County Regional Sewer District Actions To Enhance Hinkson Creek Watershed Post 303(d) Listing

1. Closed the Fairway Meadows West Lagoon by installing a pump station and pumping flows to the city of Columbia. The Fairway Meadows West Lagoon discharged into a tributary of the North Fork of the Grindstone, which is a tributary to Hinkson Creek.

2. Closed the Fairway Meadows East Lagoon by installing a pump station and pumping flows to the city of Columbia. The Fairway Meadows East Lagoon discharged into the North Fork of the Grindstone, which is a tributary to Hinkson Creek.

3. Closed the Lake of the Woods WWTP by installing a gravity sewer that connected to the city of Columbia's wastewater collection system. The Lake of the Woods WWTP discharged into the North Fork of the Grindstone, which is a tributary to Hinkson Creek.

4. Closed the El Chaparral Lagoon by installing a gravity sewer that connected to the city of Columbia's wastewater collection system. The El Chaparral Lagoon was the largest remaining WWTP in the Hinkson Creek watershed controlled by the public. It discharged into the South Fork of the Grindstone, which is a tributary to Hinkson Creek.

5. Closed the Sunrise Estates WWTP by installing a gravity sewer that connected to the city of Columbia's wastewater collection system. The Sunrise Estates WWTP discharged into the South Fork of the Grindstone, which is a tributary to Hinkson Creek.

6. Closed the OTSCON WWTP by installing a gravity sewer that connected to the city of Columbia's wastewater collection system. The OTSCON WWTP discharged into the South Fork of the Grindstone, which is a tributary to Hinkson Creek.

7. Boone County voters approved a $21 million revenue bond issue in April 2008, to further improvements to Hinkson Creek. These will close additional discharges to the Hinkson Creek watershed and/or improve wastewater treatment at the existing Boone County Regional Sewer District facilities. These include the closure of the Sun Valley Lagoon, the Hillview Acres Lagoon, the Lake Capri Lagoon, the Fall Creek Recirculating Sand Filter and the Sheraton Hills WWTP in 2011. All these facilities are in the Hinkson Creek watershed and are located along State Highway HH. The closure of these facilities will be accomplished by the construction of about five pump stations and forced mains along Highway HH with connection to the city of Columbia's wastewater collection system.

8. In 2010, the budget calls for closure of the Shaw WWTP by installing a gravity sewer that connects to the city of Columbia's wastewater collection system. This is a joint project with the city of Columbia. The Shaw WWTP discharges into the North Fork of the Grindstone, which is a tributary to Hinkson Creek.

These improvements will result in the removal of over 700,000 gallons per day design capacity from discharging into the Hinkson Creek watershed, removing various pollutant loads and bacteria from the watershed, reducing impact.

The District has also increased its sewer system maintenance activities to reduce risk to sewer integrity, which might result in discharges to the environment during peak events and enhancing the integrity of the system.

EXHIBIT B. City Of Columbia Actions To Enhance Hinkson Creek Watershed Post 303(d) Listing

1. A significant sewer line has been repaired, which had a direct impact on Hinkson Creek.

2. New storm water, illicit discharge and stream buffer ordinances were passed from late 2004 to early 2007. A new Storm Water and Water Quality Manual was released in early 2007 and was revised in early 2009.

3. New ordinances requiring scoring for water quality treatment, which are established up front for development or redevelopment projects. The developer is required to add water quality treatments to the plan until the required score is achieved for the site. These include storm water BMPs that address volume reduction and hydrology modification.

4. All projects, both redevelopment and new development, are impacted by the new ordinance. These include modifications to impervious surfaces, BMPs, volume reductions and hydrological modifications. Improvements such as rain gardens and bio-retention cells are included in the alternatives to provide scoring.

5. New rules encourage the use of edge buffer outfalls, which work together with the stream buffer ordinance. Water is dispersed through the buffer before reaching the stream so that more water is absorbed and stored in the buffer soil.

6. The point system provided in the rules encourages the preservation of existing soil strata and vegetation through point reductions.

7. The new rules allow for the use of channel protection detention rather than traditional detention in order to modify the hydrograph. The new rules and ordinances have resulted in significant extended detention wetlands being installed behind businesses

on Conley Road (just west of Highway 63 and south of Interstate 70) that were identified as hot spots in the original 303(d) list. These basins treat a significant amount of impervious area and can be expected to have significant beneficial effects on the Hinkson Creek watershed.

8. A number of other private businesses have been required to retrofit storm water treatment practices in the Hinkson Creek watershed as a result of the manual. Some examples include:
   a. Rain gardens and a wetland have been added and the stream buffer enhanced at Stevens Lake Park along the main reach of Hinkson Creek.
   b. Pervious pavement and underground detention are being installed at the Columbia City Hall development and redevelopment along the Flat Branch, which is a tributary to the Hinkson Creek.
   c. Pervious pavement and a large bio-retention cell was installed with the help of grants at the city's new Fire Station No. 7, which discharges to Mill Creek in the Hinkson Creek watershed.
   d. Rain gardens were installed on the Harvard Drive Rehabilitation project, which discharges to County House Branch, a tributary to the Hinkson Creek.
   e. Missouri's Katy Trail (MKT) Trail Head Park redeveloped a former industrial area in downtown Columbia, removing contaminated soil and stabilizing stream banks with large rocks and planting. A rain guard was installed in the most recent phase. These all impacted the Flat Branch, which is a tributary to the Hinkson Creek.

EXHIBIT C. City Sanitary Sewer Changes In The Hinkson Creek Watershed

1. The City has implemented sanitary sewer changes that have benefitted Hinkson Creek, which include the construction of interceptors that eliminate small treatment facilities and performed pipe and manhole rehabilitation projects. They include:
   a. The South Grindstone Interceptor and the Lake of the Woods Mobile Home Park Lagoon Interceptor removed several small treatment plants from the watershed and connected them to the city's sewer system. These were in cooperation with the Boone County Regional Sewer District.
   b. The city has implemented a program involving cured-in-place linings of old pipes and manholes. These projects stopped sewage from leaving old systems as well as preventing overflows by preventing storm water from entering the system.
   c. The city has undertaken an effort to eliminate "private sewer systems" that were prone to bad repair and overflow problems. An example is the Sewer District 154 Project in the Flat Branch watershed, which eliminated 20+ acres of failing sewers. The city has methodically taken over and rehabilitated private sewers that impacted the Hinkson Creek system.

2. The city has a history of eliminating WWTPs and direct discharges to Hinkson Creek. These include both city plants and county plants in an effort to improve the watershed. This began in the early 1970s and more of these projects are programmed

for the near future. This will reduce pollutant levels of nutrients and bacteria. This should also reduce many pollutants which are difficult to test for and may have episodic effects on stream life. Examples are: cosmetics, medicines and other household pollutants, which are often flushed down the drain but poorly removed by small treatment systems.

EXHIBIT D. University Of Missouri Actions To Enhance Hinkson Creek Watershed Post 303(d) Listing

1. BMPs at the University Power Plant in conjunction with its NPDES permit have resulted in extremely low Total Suspended Solids (TSS) in spite of the Power Plant sitting directly on the Flat Branch, which is a tributary to the Hinkson Creek. A comprehensive street sweeping program at the Power Plant takes place every day coal is delivered, and there are numerous controls that have been established at storm sewer inlets in the area near the Plant.

2. Each of the University's large aboveground fuel storage units has individual NPDES permits, which require strict controls on discharge of storm water that accumulates in secondary containment. The University has three Spill Prevention Containment and Control Plans covering parts of the watershed. These plans provide formal procedures to prevent release to waters of the state of any oil products, which include both inorganic and organic oils and fats.

3. All construction on the University Campus is coordinated by a designated land disturbance permitting authority on campus. The campus has dedicated employees that provide weekly and post-rain event inspections on all University construction for compliance. Additional inspections are provided by University Environmental Health and Safety, and audits are conducted of all open land disturbance events.

4. The University's Master Plan for the entire campus, which is reviewed and revised annually, incorporates storm water concerns. All campus storm and sanitary sewers are mapped and are in the process of being inspected via in-line cameras.

EXHIBIT E. County of Boone Actions to Enhance Hinkson Creek Watershed Post-303(d) Listing

Boone County has taken significant administrative steps to pass ordinances, including stream buffer protection, which directly impacts the quality of Hinkson Creek.

1. The county has passed a stream buffer ordinance. This ordinance has a setback requirement depending on stream size. Streams are categorized by USGS topographic maps. Blue line streams are categorized as Type 1 streams. They are required to have a setback of 100 feet from the ordinary high water mark. Type 2 streams (USGS-blue lines) and Type 3 streams (unmarked tributaries with drainage areas greater than 50

acres) have 50-foot and 30-foot setbacks respectively. Each of those setbacks is divided into two zones. The stream-side zone or "no-mow" zone is for undisturbed native vegetation. The outer zone can have managed landscape areas but no new structures. The ordinance went into effect in the county in 2009. The ordinance is not retroactive, but will prevent new structures from being built adjacent to the creek and increase stream bank vegetation and stabilization.

2. The county is in the final stages of a public review of a storm water ordinance that addresses the consequences and impacts of urban runoff and protects waterways from storm water-related pollutant load.

3. The county ordinance is based on the Center for Watershed Protection's model ordinance. The county uses a nested approach to storm water management to treat different runoff volumes. The details of the county ordinance, which is currently going through appropriate public participation, can be found on the county's website.

EXHIBIT F. Activities By Private Or Quasi-Public Agencies To Enhance Hinkson Creek Watershed Post 303(d) Listing

1. The county has partnered with the city of Columbia and the UMC on a 319 project in the Hinkson Creek watershed. The restoration project is updating the watershed management plan so that all of EPA's nine key elements are included. The project has developed a feasibility study to examine and provide cost estimates for retrofitting areas in the impaired section of the stream. The next step in the 319 grant is to approach landowners to cost share the placement of retrofits that will reduce peak flows to the stream in the impaired section. See also Appendix E.

2. The city, county and University have worked cooperatively on stream clean-up activities which have continued and expanded in the past four years. The beneficial effects of these cleanups is expected to continue to grow in the coming years as more and more trash and sources of pollution are removed, like decaying, partially-filled motor oil bottles. The last event was held on October 17, 2009. Over 400 local citizens volunteered at least two hours of time to clean up Hinkson Creek and remove debris.

3. A University hydrology study of the stream was initiated in 2008. The researcher has collected data for about one year. That data will be extremely helpful in the triage process, enhancement of the TMDL strategy, and validating the changes in the watershed due to the storm water ordinances and stream buffer regulations. The hydrology study data will assist in providing baseline information. See also Appendix E.

4. The MoDOT has relocated salt domes and distribution facilities. The facilities were formerly located off Conley Road on the banks of Hinkson Creek. They have been relocated with state-of-the-art storm water control structures. Chlorides have long been a suspect of concern, and they have had a major source removed.

5. Columbia Country Club has provided greater buffer zones along its golf course adjacent to Hinkson Creek.

6. The Conley Road Transportation Development District has constructed significant detention, treatment and control facilities in an area suspected of impacts to Hinkson Creek. The area has significant parking lots with large impervious square footage and substantial roof structures.

Appendix E – Supplemental Implementation Plan

States are not required under Section 303(d) of the CWA to develop TMDL implementation plans and EPA does not approve or disapprove them. However, MDNR included an implementation plan in this TMDL to provide information regarding how point and nonpoint sources can or should be controlled to ensure implementation efforts achieve the loading reductions identified in this TMDL. EPA recognizes that technical guidance and support are critical to determining the feasibility of and achieving the goals outlined in this TMDL. Therefore, this informational plan is included to be used by local professionals, watershed managers and citizens for decision-making support and planning purposes. It should not be considered to be a part of the established Hinkson Creek TMDL.

A reduction in storm water runoff can be accomplished by storm water retention and enhanced infiltration and evapotranspiration. Reductions in storm water runoff will result in an improvement in Hinkson Creek water quality by accomplishing the following:

- Reduction in the erosive power of the stream. This will decrease stream turbidity and result in less sediment in the stream, less scouring and allow for better habitat for the biological community.

- Retention and/or treatment of storm water before entering the stream. This will address the many and varied pollutants such as heat, automotive fluids, pet manure, salts, trash, lawn fertilizers and more that are transported from impervious surfaces into the water body.

- Enhanced infiltration of precipitation to groundwater. This should address the instream low DO problem by raising base flow and allowing for greater continuous periods of flow throughout the summer. Higher instream base flow may reduce or even eliminate stagnant pools within the water body that are naturally low in DO.

One of the hallmarks of the TMDL process is adaptive management or implementation. Adaptive implementation is an iterative process that makes progress toward achieving water quality goals while using any new data and information to reduce uncertainty and adjust implementation activities. The National Research Council 2001 report suggests that adaptive implementation include "immediate actions, an array of possible long-term actions, success monitoring and experimentation for model refinement" (NRC 2001). By using the adaptive implementation approach, one can utilize the new information available from monitoring, following initial TMDL implementation efforts, to appropriately target the next suite of implementation activities.

Considerable implementation efforts have been made by the city, county and university since the last bioassessment. These include storm water ordinances for both the city and county. The ordinances require undisturbed buffers or set-backs along stream banks, with the width of the buffer increasing with stream size. MoDOT has moved its local maintenance operations facility, which had been just south of Interstate 70 on the east side of Hinkson Creek. This effectively removes a significant source of chlorides from the stream. For a detailed list of all of the beneficial actions taken by the city, county and university, see Appendix D, Exhibits A-F.

To judge the effectiveness of these improvements, before the reductions called for in this TMDL are put into effect, the MS4 permittees have agreed to reassess the Hinkson Creek biocommunity. This includes collecting sediment data and other water quality parameters to be agreed upon by the permittees and MDNR. All sampling activities will follow applicable MDNR protocols and a Sampling and Analysis Plan and Quality Assurance Project Plan must be submitted to and approved by MDNR prior to sampling. If new data collected by the permittees or MDNR indicate that WQS are not being met, TMDL reductions shall then be implemented in the following way:

> Over a five-year period, a one percent reduction in the volume of runoff from the one-year average annual storm (called a Water Quality Storm), as measured at the USGS stream gage near Providence Road, will be applied to the WLA. A four percent reduction in the volume of runoff from the one-year average annual storm will be applied to the LA. This runoff reduction will help the stream by encouraging the retrofitting of volume reduction practices, such as bioretention and level spreaders. These measures provide benefit by intercepting and treating runoff from the Water Quality Storm (treating 90 percent of the rainfall events in this area), reducing the most damaging runoff to the stream, increasing the time of concentration and extending the hydrograph for a broad range of runoff events.

Implementation for the Hinkson Creek TMDL will be accomplished primarily through the Hinkson Creek Watershed Restoration Project and the MS4 co-permit held by Boone County, the city of Columbia and the UMC. Progressive and innovative land management and land use practices (such as green, sustainably designed infrastructure) are needed to halt and reverse degradation of Hinkson Creek and establish long-term protection of the resource. Both the Hinkson Creek Watershed Restoration Project and MS4 co-permit programs contain several opportunities for improvement and protection, including best site designs for development, retrofit considerations, onsite BMPs and overall strategies that address storm water runoff quantity and quality.

As mentioned in Section 2.4, a strong correlation can be made between the imperviousness of a drainage basin and the health of its receiving streams. As the percentage of land area covered by impervious surfaces increases, a consistent degradation of water quality can be detected. Degradation can occur at relatively low levels of imperviousness (10-20 percent) and worsens as more areas within the watershed are covered. The negative effects on water quality from urbanization within a watershed include loss of habitat, increased temperatures, sedimentation and loss of fish populations (EPA 1993). Precipitation events between 0.5 and 1.5 inches (12 and 38 mm) are responsible for about 75 percent of runoff pollutant discharges and are key events when addressing mass pollutant discharges into urban streams (Pitt 1999). The types and concentrations of pollutants in urban runoff are affected by many factors including rainfall amount, rainfall intensity, land use, geology, season, period between rainfall events, pollutant mobility and site hydrology. Pollution controls such as green infrastructure and low impact development can be designed to consider these factors and mitigate pollution in the short term and protect the watershed in the long-term. Both green infrastructure and low impact development are recommended to help mitigate the detrimental effects of urbanization on streams.

Green Infrastructure

Green infrastructure, also referred to as low impact development, is an approach to wet weather or storm water management that is cost-effective, sustainable and environmentally friendly. Green infrastructure management approaches and technologies infiltrate, evapotranspire, capture and reuse storm water to maintain or restore the natural hydrology of a watershed. These approaches are often referred to as green infrastructure because soil and vegetation are used instead of, or in addition to, pipes, pumps, storage tunnels and other hard infrastructure traditionally used to store and/or discharge storm water. Specifically, green infrastructure is the interconnected network of open spaces and natural areas, such as greenways, wetlands, parks, urban forests and native plant vegetation, that naturally manage storm water, reduce flooding risk, and improve air and water quality. Green infrastructure typically costs less to install and maintain when compared to conventional forms of infrastructure and also enhances livability, increases energy efficiency and counteracts the urban heat island effect. Green infrastructure projects can also foster community cohesiveness by engaging all stakeholders in the planning, planting and maintenance of green infrastructure sites.

At the largest scale, preservation and restoration of natural landscape features (such as forests, floodplains and wetlands) is critical to a holistic and comprehensive green infrastructure approach. By protecting these ecologically sensitive areas, communities can improve water quality while providing wildlife habitat, opportunities for outdoor recreation and aesthetics that aid in stress reduction and community well-being. On a smaller scale, green infrastructure practices include rain gardens, porous pavements, green roofs, infiltration planters, trees, tree boxes, bioswales, parking lot sand filters and rainwater harvesting for non-potable uses such as toilet flushing and landscape irrigation.

The EPA and other organizations have produced a number of policies, memorandums and resolutions explaining the benefits of using green infrastructure and low impact development to mitigate overflows from combined and separate sewers and to reduce storm water pollution. The publications encourage implementation of green infrastructure and low impact development in cities and municipal storm water programs. These policies, memorandums and resolutions can be found at the following links: http://cfpub.epa.gov/npdes/greeninfrastructure/information.cfm#greenpolicy and www.epa.gov/nps/lid/. Additional information on green infrastructure and low impact development can also be found on state, local and nonprofit organization websites.

Point Sources

As stated in Section 3, the term point source refers to any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel or conduit, by which pollutants are transported to a water body. Strategies to address known point sources in the Hinkson Creek watershed are discussed in this section.

Domestic Wastewater Permits

In general, domestic wastewater permits are not anticipated to cause or contribute to the impairment of Hinkson Creek for unknown pollutants. Domestic wastewater is well-characterized and permit terms and conditions should be protective of instream water quality. During implementation of the Hinkson Creek TMDL, an analysis of facility compliance history, sampling results, permit effluent limitations and monitoring requirements will be conducted during reissuance of site specific domestic wastewater permits. If MDNR determines a domestic wastewater permit may be causing or contributing to the impairment of Hinkson Creek, additional monitoring requirements (e.g., effluent, whole effluent toxicity or instream) will be included in the reissued permit. Should MDNR determine more protective effluent limitations or permit conditions are necessary, these requirements will be included in the facility permit as soon as practicable.

As of July 2009, there were five small domestic WWTFs in operation in the Grindstone Creek watershed, a tributary to Hinkson Creek. All five facilities are owned and operated by the Boone County Regional Sewer District (BCRSD). It is anticipated the city of Columbia will have completed trunk sewer lines in the Grindstone watershed by the end of 2011. The city and BCRSD have agreements in place for four of the five WWTFs to regionalize and connect those facilities to the Columbia Regional WWTP. The city and BCRSD are currently working on an agreement for the fifth WWTF. The matter of who actually connects these WWTFs to the city's sewer system is handled on a case by case basis, but usually BCRSD makes the connection. Size is typically not a factor in removing these facilities and it is the city's goal to eliminate them all. The factors in prioritizing the connection are proximity to city sewer and the cost to connect (Tom Wellman, city of Columbia Public Works, e-mail communication, July 6, 2009). The benefit of regionalizing the BCRSD facilities will be to remove potential sources of bacteria, nutrients, toxics and oxygen demanding substances from the watershed. Removing these pollutants from the watershed should alleviate some of the stressors exerting impacts on the aquatic communities in Hinkson Creek. Additional improvements and upgrades to sanitary sewers within the city and county can be found in Appendix D, Exhibit C.

Non-Domestic Wastewater Permits

In general, non-domestic wastewater permits are not anticipated to cause or contribute to the impairment of Hinkson Creek for unknown pollutants. Non-domestic wastewater is well-characterized by the type of industrial operation and permit terms and conditions should be protective of instream water quality. During implementation of the Hinkson Creek TMDL, an analysis of facility compliance history, sampling results, permit effluent limitations and monitoring requirements will be conducted during reissuance of site specific non-domestic wastewater permits. If MDNR determines a non-domestic wastewater permit may be causing or contributing to the impairment of Hinkson Creek, additional monitoring requirements (e.g., effluent, whole effluent toxicity or instream) will be included in the reissued permit. Should MDNR determine more protective effluent limitations or permit conditions are necessary, these requirements will be included in the facility permit as soon as practicable.

General and Storm Water Permits

General and storm water permits contain effluent limitations, monitoring requirements and permit conditions protective of water quality under most circumstances. However, facility inspections during TMDL implementation may reveal that a general or storm water permit may not be protective of water quality for a specific discharger. Provisions are contained in each general and storm water permit that allow MDNR to revoke the general permit and issue a site specific permit in its place should more protective permit conditions be required to correct an impairment caused by the facility. In the case of storm water permits, where a site specific permit may not be appropriate or applicable, the more protective land disturbance in designated areas permit (i.e., MOR109) shall be issued. Recommendations may also be given for implementing and maintaining BMPs that are protective of the impaired segments. The general and storm water permits within the Hinkson Creek watershed are listed in Appendix B and compiled and shown in Table 4 and Figure 3, respectively. Two of those permits are held by the MoDOT, which was issued state-wide permits that apply to the Hinkson Creek watershed. These permits are an MS4 permit, MOR040063, and a land disturbance permit, MOR100007; they cover MoDOT construction projects and activities statewide. The effluent limitations and requirements found in these statewide permits do not differ from the versions held by other permittees that apply only to a specific site.

Also, Boone County, the city of Columbia and the UMC are jointly responsible for a NPDES permit for the storm water drainage system, known as a MS4. The MS4 permit is designed to reduce storm water runoff and pollution within the permittee's jurisdiction. Appendix D contains detailed information regarding the MS4 co-permit. The joint MS4 permit is described in more detail below.

Municipal Separate Storm Sewer System Co-Permit

MDNR is in the process of renewing the Municipal Separate Storm Sewer System (MS4) Phase II co-permit for Boone County, the city of Columbia and the UMC. The three co-permittees became subject to storm water permit requirements on March 10, 2003. These communities, along with approximately 150 others in Missouri, are regulated because of at least one of the following three criteria:

1) They have at least 1,000 residents within an urbanized area as defined by the United States Census Bureau.

2) They have a population of at least 10,000 people, with a density of 1,000 people per square mile.

3) They are specially designated by MDNR.

The MS4 permit requires implementation of a comprehensive storm water management program to minimize negative impacts to water quality and the aquatic ecosystem, to monitor and eliminate illicit discharges and to provide long-term water quality protection. As required by the MS4 permit, the county, city and university have co-written a Storm Water Management Program plan to address the six basic requirements of the MS4 permit, called minimum control measures. They are:

1) Public Education and Outreach,

2) Public Involvement and Participation,

3) Illicit Discharge Detection and Elimination,

4) Construction Site Runoff Control,

5) Post-Construction Runoff Control and

6) Pollution Prevention and General Housekeeping for Municipal Operations.

The MS4 permit requires new development projects to be designed and built to reasonably mimic pre-construction runoff conditions. The permit also requires redevelopment projects to be designed and built to provide incremental water quality improvement. Additionally, the MS4 permit requires proactive detection, source determination and correction of illicit discharges. In some cases, this may require retrofitting existing storm water management features. While the MS4 permit provides for program implementation to the maximum extent practicable, the TMDL provisions of Section 3.1 of the permit provide for a more prescriptive approach to implementing green infrastructure and low impact development in order to reach TMDL targets.

Additional information on MS4 permit requirements can be found in Missouri's Storm Water Clearinghouse at www.dnr.mo.gov/env/wpp/stormwater/sw-local-gov-programs.htm.

Other "Point" Sources

Other point sources of pollutants that must be addressed during TMDL implementation include infiltration and inflow and illegal and illicit discharges. The MS4 Storm Water Management Program plan will address these sources by requiring the co-permittees to inspect the storm water collection system for damage and illegal and illicit discharges. It is anticipated these actions, together with regionalization of wastewater treatment, will eliminate the impact of untreated storm and wastewater on Hinkson Creek.

Nonpoint Sources

Nonpoint sources of pollutants include general runoff from the watershed and all other categories not classified as point sources. This section provides information and details on past and current grants affecting restoration of the Hinkson Creek Watershed, primarily addressing nonpoint source issues. It should be noted that since 2004, the city and county have passed a number of ordinances that address nonpoint sources. These ordinances cover storm water, illicit discharge and stream buffers (See Appendix D, Exhibits B and E).

Hinkson Creek Restoration 319 Project – Phase I

To begin to address the urban pressures on Hinkson Creek, MDNR approved a CWA Section 319 grant in 2004 for a restoration project within the watershed. The grant ran through May 31, 2008, and has been extended through 2011. Phase I of the project, called the Hinkson Creek Restoration Project, formed a steering committee, produced an annual newsletter, stenciled storm drains, staged workshops and conducted water quality monitoring, among other activities. The objectives for the original grant included:

- Develop a Watershed Management Plan and use it to implement project milestones.
- Fund various low impact development components in local development projects.
- Plant 20 acres of trees in riparian areas of Hinkson Creek watershed.
- Stabilize 1,500 feet of stream bank along Hinkson Creek and its tributaries.
- Recruit 40 homeowners to participate in the Show-Me Yards & Neighborhoods Program.
- Establish 20 rain gardens on public and/or private sites.
- Improve knowledge of watershed issues and facts among the development community (e.g., builders, developers, real estate professionals) by at least 25 percent.
- Improve knowledge of watershed issues and facts among the media community (e.g., reporters, editors, broadcasters) by at least 25 percent.

All of the above grant objectives were realized, with some going above and beyond the original goals and expectations.

The second objective listed above, low impact development, incorporates development practices that decrease and slow storm water discharges while simultaneously creating attractive green space. Grassy and/or vegetative swales allow water to percolate through the soil and recharge groundwater, rather than rushing off-site and downstream. Further implementation of low impact development within the watershed will help to reduce storm water runoff and increase base flows in Hinkson Creek.

Educating the public about watersheds and storm water issues is of the utmost importance. Each citizen must be made aware of how their personal actions affect the health of the water bodies that drain the land. Educational efforts focusing on the importance of storm water management practices are widely used throughout the nation. Many of the objectives for this grant contained educational components. Furthering these education and outreach activities will enable the successful implementation of the reductions and goals found in this TMDL.

Hinkson Creek Restoration 319 Project – Phase II

The Hinkson Creek Restoration Project - Phase II is a continuation of the original Hinkson Creek Restoration Project that started in spring 2008 and is under the sponsorship of Boone County. The specific milestones of this phase are:

- Forming a stakeholder group to review and update the draft watershed management plan developed in Phase I.
- Retain a consultant to propose possible locations to retrofit storm water treatment structures within a hotspot area near the Interstate 70/Highway 63 connector.
- Provide 60 percent cost share to landowners wishing to retrofit storm water treatment structures on their property (with emphasis on the hotspot area).
- Produce public service announcements concerning water pollution and stream quality that are humorous and engaging.
- Conduct several educational events, such as low impact development and water quality sensitive residential yard management workshops.
- Monitor the performance of storm water treatment structures to verify their effectiveness.
- Conduct stream clean-ups and monitor the water quality of local streams.

The first objective in Phase I, develop the Hinkson Creek Watershed Management Plan, was accomplished in as far as the plan was drafted. The watershed management plan presents the Hinkson Creek watershed history, development and natural history in depth. The plan also provides a thorough review of the bioassessment and water quality studies conducted by MDNR.

The watershed management plan then goes into detail about current activities within the watershed, covering such topics as city ordinances, the co-permittee MS4 permit and watershed restoration project grants. The plan also presents recommendations for more improvements to the watershed. While the watershed management plan depends on local people to become involved in restoring Hinkson Creek, the scope of Phase I did not include public review of the plan. Therefore, one of the first activities under Phase II was to form a Stakeholder Committee to ensure the recommendations of the watershed management plan reflect the social and economic values of the local community. The watershed management plan should then be usable by Boone County, the city of Columbia, the UMC, developers, industry and local citizens and home/land owners as a blueprint for improving and protecting water quality in Hinkson Creek.

Everyone who owns or uses land in the Hinkson Creek watershed has an impact on the health of the stream. The challenge is to adjust land use and management to make that impact a positive one. Additional information on activities to restore the Hinkson Creek watershed can be found at www.helpthehinkson.org/ or by contacting Boone County government. See also Appendix D, Exhibit F.

Monitoring Hydrology of Hinkson Creek – 319 grant[21]

The purpose of this three year project is to improve the understanding of the hydrologic cycle, peak flow events and sediment transport in Hinkson Creek. It involved installing four additional stream gaging stations along Hinkson Creek, three upstream and one downstream of the existing station at Providence Road.

As discussed in Section 3, pollutants in an urbanized watershed come from a variety of point and nonpoint sources. Quite often, those pollutants are transported to streams by precipitation events of various intensities. A correlation exists between rainfall volume, watershed land use, infiltration and permeability of soils and pollutant loadings from a watershed (Novotny and Olem 1994). Urbanization and other hydrologic modifications of a watershed can increase or decrease the pollutant load transported to receiving streams. Therefore, before communities can control the generation and transport of point and nonpoint source pollution within urbanized areas, the hydrologic processes governing the fate and transport of pollutants must be monitored and the pathways from source areas to receiving water bodies considered.

To improve upon the current understanding of sediment and nutrient transport mechanisms in Hinkson Creek, the UMC initiated a comprehensive long-term monitoring project during the winter of 2008-2009. By examining water yield, peak flow and suspended sediment, this 319 project will help determine the areas within the watershed contributing to storm water and identify point and nonpoint sources of pollutants. Five permanent monitoring sites associated with major bridges have been equipped with dataloggers, automated sediment sensors and fully equipped hydroclimate stations. These stations will help researchers understand how

[21] As with all 319 grants, the U.S. Environmental Protection Agency, Region 7 through the MDNR, has provided partial funding for this project under Section 319 of the Clean Water Act. Additionally, the Missouri Department of Conservation has added funding contributions for nutrient analysis.

Hinkson Creek, and the watershed at large, responds to precipitation events under various land-use types.

The Hinkson Creek urban watershed project is facilitating collaboration between local, state and federal agencies, not-for profit awareness groups, private landowners and others in the watershed. The data collected will benefit watershed stakeholders by providing information generated from continuous flow records from multiple locations. This information will supply details pertaining to peak flow events and sediment transport. The first two years of monitoring will begin to close the water budget and help researchers better understand the urban hydrograph in terms of peak flow and flushing events. The third year of the project will help to validate the Hinkson Creek TMDL and advance understanding of the efficacy of BMPs in the Hinkson Creek watershed.

Upper Hinkson Creek AgNPS SALT Water Quality Project: 2001 – 2008

An Agricultural Nonpoint Source Special Area Land Treatment (AgNPS SALT) grant targeted 32,918 acres of the upper Hinkson Creek watershed from 2001-2008. The project area encompassed the headwaters and mainstem of Hinkson Creek down to the Old Highway 63 bridge, including major tributaries Hominey Creek, Nelson Creek and Varnon Branch. The overall goals of the project were to:

- Restore riparian area along stream banks and small wetlands.
- Reduce sedimentation in streams, ponds and wetlands.
- Reduce coliform, nitrate and pesticide contamination of streams, ponds and wetlands.

The specific objectives of the project were to:

- Encourage the use of buffers on 20 acres using riparian forest buffers, filter strips and field borders.
- Reduce sedimentation in streams, ponds and wetlands by implementing terrace systems, terrace/underground outlets and diversions on 40 acres.
- Improve crop management on 1,710 acres through nutrient and pest management.
- Protect 500 feet of stream bank and 10 acres of woodland.
- Implement pasture management on 1,710 acres using pasture enhancement, planned grazing systems, grazing systems/pond and alternative watering.
- Hold 104 information and education activities including annual meetings, steering committee meetings, field days, watershed festival, poster contest, grazing school, burn workshop, crop scouting/pest management workshop, community presentations, Upper Hinkson Creek Watershed newsletters and district newsletters.

- Decommission eight wells to protect ground water quality.

In the seven-year life of the AgNPS SALT grant, 90 percent of the objectives were achieved. All areas of the project did well with the exception of the pest and nutrient management practices. The rest of the goals were close to being met or were exceeded. The project was successful in building good working relationships with landowners and other stakeholders in the watershed. Several of the landowners are also applying practices from other cost-share sources and have plans to continue implementing practices in the future to protect water quality. Projects such as this help ensure the water coming from upper Hinkson Creek is of good quality.