Hinkson Creek Watershed Management Plan

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.

This plan is the result of a collaboration of the Hinkson Creek Watershed Restoration Project Steering Committee:

Mona Menezes, City of Columbia
Frank Gordon, Boone County
Bill Florea, Boone County
Scott Voney, Department of Conservation
Steve Pagan, landowner
Walter Lane, Natural Resource Conservation Service
Kevin Monckton, Boone County Soil & Water Conservation District
Bob Broz, University of Missouri Extension
Charles Laun, Show-Me Clean Streams

Scott Hamilton, Urban Conservationist with Show-Me Clean Streams, is the primary author of this document.

Introduction

Regulatory Framework

In 1998, the Missouri Department of Natural Resources (DNR) listed an 11 mile segment of Hinkson Creek as impaired by unspecified pollutants (that figure has been corrected to 14 miles). It has remained on the impaired 303(d) list since that time. The Hinkson is listed for the designated uses of Livestock and Wildlife Watering and 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 downstream of I-70. The perennially flowing (Class P) section of the Hinkson begins at Providence Rd and extends to the mouth six miles downstream. Eighteen miles of the Hinkson is considered Class C, or intermittent. One tributary, Grindstone Creek, is listed as impaired for high levels of fecal coliform bacteria.

A TMDL (Total Maximum Daily Load) document on the Hinkson is required of the DNR by EPA by the end of 2009. Despite DNR's monitoring efforts over the last several years, no specific pollutant source has been found. The DNR's strategy for reducing the "load" of the unknown pollutant is to use the urbanized flow as a surrogate for the range of likely chemical contaminants causing the impairment of Hinkson Creek.

Goals of this Plan

The goals of this plan are as follows:

- To improve the water quality of the Hinkson 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 streamflow elevations following storm events ("flashiness") of the Hinkson 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 "baseflow".

Future Projections for the Watershed

Content primarily taken from CATSO 2025 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 Columbia Area Transportation Study Organization 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 138,600 persons by 2025. This is an increase of 34,507 persons from the 2000 Metro estimated population of 104,093. It is projected that 88% of this increase, or 30,366 persons, will occur within the City of Columbia by 2025. For purposes of transportation planning, it is projected that 147,000 people will be living in the county in the year 2025.

It is projected that 17,253 new housing units will be constructed in the Metro area. This projection assumes a 10% vacancy rate, and an average of 2.2 persons per household. Of these, 10,142 will be single-family houses, with 3,643 duplex units and 3,468 multi-family units. For single family homes, two or three units per acre is the typical density. At 2.5 units per acre, the midpoint of the range, 4,057 acres would be required for the construction of the projected 10,142 new single family residences.

Duplexes are typically constructed at densities ranging from five to seven dwelling units per acre. At six units per acre, 607 acres would be required for the construction of the projected new duplexes. Multi-family units such as townhouses, condominiums, single and two-story apartments are built to the highest densities, and can range from 7 to 17 units per acre. At 11 units/acre, 315 acres would be necessary. The estimated total acreage needed to build the projected 15,336 new housing units to be added to the Columbia metro area by the year 2025, at the typical densities constructed, would be approximately 4,979 acres, or 7.8 square miles.

The anticipated growth rate for Boone County for the period from 2000 to 2025 is 1.3% annually. This results in an increase of 22,624 jobs to a total employment of 95,137 in 2025. The Columbia Metro Area's share of total employment in Boone County is assumed to be 90%, so employment in the Metro Area would increase by 20,361 persons. This is a total of 85,623 jobs, and a 31% increase from the 2000 total of 65,261.

Estimated acreage requirements for this employment will vary by the type of classification. Office uses are estimated to have on average 29 employees/acre, industrial uses an estimated 18 employees/acre, and commercial uses estimated with 20 employees/acre. To accommodate the projected additional 20,362 employees in the Metro Area by 2025, it is estimated that a total of approximately 837 acres will be needed. This includes; 85 acres for industrial, 406 acres for office, and 346 acres for commercial.

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 watershed include:

I-70 corridor widening
Extension of Stadium Blvd (over Grindstone)
Extension of Lemone Industrial (over Grindstone)
Extension of Business Loop 70 to Conley Road (over Hinkson)
Ballenger Lane Extension from Clark Lane to St. Charles Road (over Hominy)
Realignment of Mexico Gravel Road (over Hinkson)

Chapter 1 City History and Watershed Development

Early Development

The earliest known inhabitants of this area lived between 14,000 and 9,000 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 1830’s, 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, 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 the Hinkson drainage area in the 1950s. During this time, a “trickling filter” treatment plant was constructed along the Hinkson southeast of the Forum Shopping Center, downstream of the confluence of Flat Branch and the Hinkson. Because of funding issues in the mid-1950s, and an unexpected amount of bedrock, the city wound up constructing 26 sewer lines creek crossings above grade. This configuration caused debris to get caught on the pipes, and pipes would often break under the weight and dump raw sewage into the Hinkson. The treatment plants themselves were discharging 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 the Hinkson Creek discharges into the 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.

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 2007 was 94,645 people, compared with 69,101 people in 1990. On average, Columbia gains more than 1000 additional people each year. Columbia is the largest city within Boone County, which covers 685 square miles. The total county population is 135,454. The main 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. MU has a student population of 27,930 students, and typically increases over 100 students per year.

Approximately five per cent of the county has been developed, with the remainder made up of wooded areas, pastureland, 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 flood plains. Much of the area within the City limits has been developed. In 2004, 1379 building permits were issued in the city and 1822 in the county. In 2006, the number of residential building permits fell from 1,426 to 898 because of overbuilding within the Columbia area. Since the Hinkson was designated as impaired in 1998, the city alone has issued an additional 6357 building permits. 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.

Impervious Surface

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 had the lowest impervious cover at the time (8%), and Hominy Creek had 9%. These figures have all increased since the time of the study.

Chapter 2 Natural History

Climate

The climate of central Missouri varies widely with fluctuations in temperature, precipitation, and humidity. The average annual precipitation is just over 40 inches. Precipitation is generally evenly distributed throughout the year. 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". The growing season is approximately 208 days (Nigh, 2002).

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. The soil types within the lower segments of Hinkson Creek are characterized as being thin cherty clay and silty to sandy clay. 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.

The Hinkson is supplied with water from several large tributaries. Varnon and Nelson creeks enter the Hinkson 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, drains approximately 8000 acres. Some springs can be found in the Flat Branch watershed and in the Hinkson direct watershed as well.

Soils and Topography

Content provided by Kevin Monckton, BCSWCD

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 made up of Mexico-Leonard - Associations. These soils have a 1 to 6 percent slope and are mostly ridges. The runoff rate for Mexico and Leonard soils are both very high and both soils are poorly drained. Permeability of Leonard soils is slow and permeability of Mexico soils is very slow. Leonard and Mexico may be considered hydric or have hydric inclusions. These characteristics make the soils unsuitable for conventional on-site sewage lateral lines for waste water. Presently much of the areas that are undeveloped are in row crops. Much of this area will gradually be used for housing and industry as the city and suburban areas expand.

Keswick-Hatton-Winnegan Association make up the largest areas of the watershed. These soils have slopes of 2 to 35 percent and are mostly ridges and hills. These soils are generally found in the lower portion of the watershed than the Mexico-Leonard-Associations. Keswick, Hatton, and Winnegan soils all have very high runoff rates, permeability is slow or very slow, and soils are moderately well drained Many of the soils are used for hay and pasture. Much of the area where these soils are located are being developed in the Hinkson watershed. Due to the high erodibility of these soils, proper care needs to be taken to reduce the potential of soil erosion from the areas. The soil characteristics allow for slow permeability and high drainage which can cause high levels of stormwater runoff.

Along the creeks are small areas of Wilbur-Moniteau-Perche-Haymond Asociations with slopes of 0 to 3 percent. Runoff rates on Wilbur and Perche are low, Moniteau is medium and Haymond is negligible. Permeability is moderate on all soils of this association and these soils are moderate to moderately well drained. The Moniteau soils may be considered hydric or contain hydric inclusions Many of these undeveloped areas are cropped or grazed with some of the area left in riparian buffers to protect Hinkson Creek.

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.

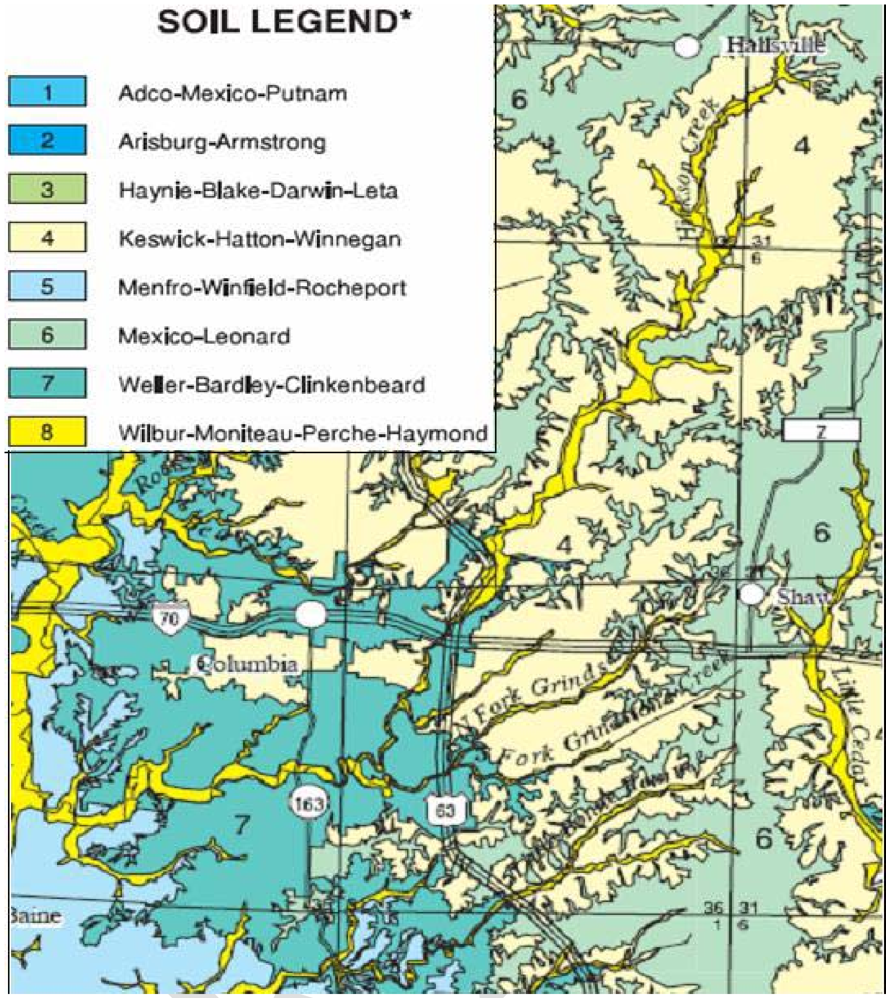

Figure 1. Soil map for Hinkson Creek Watershed. From *Soil Survey of Boone County, NRCS*

Agriculture

Content primarily taken from Boone County Soil and Water Conservation District SALT grant application

Of the 32,918 total acres in the upper watershed (upstream of Old 63), land use includes 5770.7 acres (17.6%) of cropland devoted mainly to corn, beans, and wheat. Grassland consists of 13820.1 acres (42.0%) that is primarily used for grazing and hay production, Forest and woodland include 6007.3 acres (18.3%) used for grazing, timber harvest, and recreation. Urban land, with the city of Columbia landfill included, constitutes 6616.5 acres (20.1%) of the watershed. These urban land uses are primarily residential with commercial expansion into the area. Other land uses make up the remaining 2% of the total area.

Primary crops grown in the watershed are corn, beans, and wheat. 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. The use of no-till in the area provides a fine demonstration of benefits, however the primary seedbed preparation is to disk once, field cultivate twice and plant. Residue, with the exception of cornstalks, is generally left undisturbed over the winter. Most of the land in row crop production is Mexico Silt Loam with 1 to 3 percent slopes on the northern and eastern sides of the watershed. The majority of the grassland is Keswick with slopes of 5 to 9 percent 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 4021 cattle, 585 horses/mules, 521 sheep, 222 pigs, and 50 llamas/emus reported in the upper Hinkson watershed. Horses are raised by many landowners on small, overgrazed 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 11. 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.

<u>Vegetation</u>:

Content primarily taken from The Flora of Columbia Missouri and Vicinity

"The vegetation of the region about Columbia is prevailingly mesophytic. It may be briefly characterized as an oak forest, in which many other trees, however, find place. As a deciduous forest, with the various oaks as dominant, the region has the aspect of an upland, or at least midland, rather than of a lowland, or alluvial, vegetation. The general physiographic features add to this impression, much of the ground is high and broken, the cliffs stand often close to the streams, and no extensive tracts of marshland occur. "

"Along the streams, willows, birches, cottonwoods, and sycamores form a noticeable fringe. In places alluvial flats are covered with elms, soft maples, basswoods and other bottoms' trees…There are also treeless marsh meadows, and ragweed flats,…and in the ponds, lakes and streams there is a strictly aquatic vegetation. In the other direction on the hills and cliffs, while the oaks are still in a measure dominant, the herbs and shrubs are quite different from those of the forest plain…. The forest plain is now poorly preserved. Its adaptability to agriculture has caused most of it to be cleared into fields and pastures. Between the cultivated field and the virgin forest (and none of the present forests are strictly virgin) lie all stages of primitiveness. There are pastured forests where the flora of the forest floor is ruined; there are underbrushed tracts, either lapsing back into forest, or becoming half-wild pastures…."

"Columbia lies on the boundary between two geological formations, that of the coal measures to the north, and that of the lower carboniferous limestone to the south. The flora of the coal measures is properly prairie, while that of the limestone is the deciduous forest of the Ozark plateau. The flora is then one of tension between forest and prairie. The prairie vegetation is that of Illinois and Iowa; the forest vegetation is that of the Ozark plateau of Missouri and northern Arkansas…"

From these excerpts, we can catch a glimpse of the Columbia environs before Columbia began to grow into the community that exists today. 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. Columbia's natural cover is mainly deciduous forest, with some small areas of prairie and marshland within the mix. The tallgrass 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, 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 landcover for the Hinkson 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.

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 580ft mean sea level at the confluence of Perche Creek to 900 ft msl in the headwaters (U.S.Army Corps of Engineers. 1971). Channel widths vary historically from 80ft at the southern end to 50ft at the north end. Channel slope averages 9ft of fall per mile. The gradient below Providence is 5 ft per mile, the gradient above I-70 is 12ft per mile. Floodplain widths vary from 1000ft at the north end to 1500ft in the south. Grindstone, the largest tributary, has a 15.4 sq mile watershed, with an average floodplain width of 500 ft, and an average channel width of 60ft.

A streamgage was established 400ft downstream of Providence Rd 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 sq miles of the Hinkson drainage area, and was zeroed at 583.5 ft msl. Flows ranged from zero flow to 19.8 ft above the channel bed. The highest discharge recorded during this interval was 10000 cfs. The most intense rainfall recorded was 6.6" in a 24hr period.

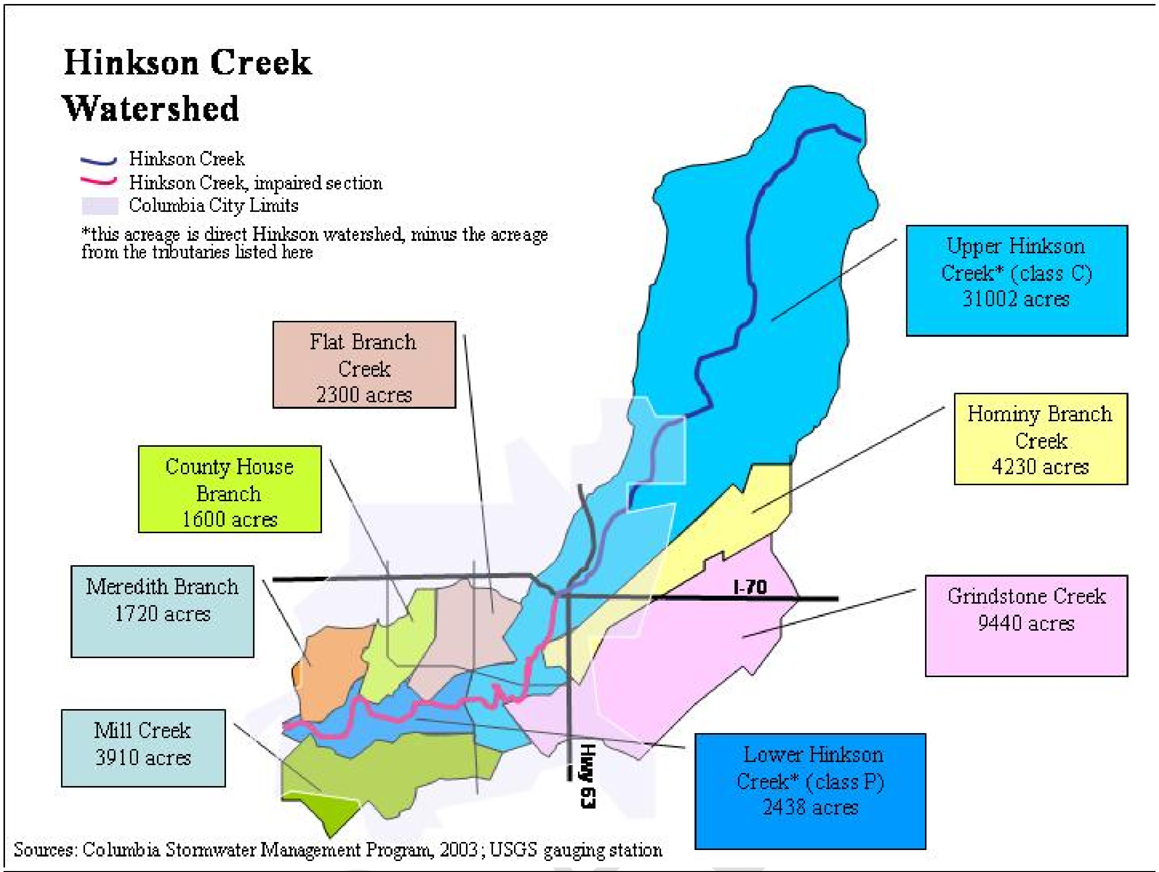

Figure 2. Subwatersheds within Hinkson Creek Watershed

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, where 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," and "whole body contact recreation – level 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," and "secondary contact recreation."

Grindstone Creek is the largest tributary of Hinkson Creek. The North Fork Grindstone Creek and South Fork Grindstone Creek flow together to form Grindstone Creek just east of Highway 63. Grindstone flows in a westerly direction approximately 1.5 miles before entering Hinkson Creek along the city of Columbia's Capen Park. Grindstone 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", and "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. 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," and "protection of warm water aquatic life and human health – fish consumption." 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.

Although significant flow exists in several other tributaries to Hinkson, 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.

<u>Fish Community</u>

Content provided by Doug Novinger, MDC

The fish community of the Hinkson Creek watershed can be described as slightly degraded based on historical fish collection data available in the MDC Fish Community Database, and similar to other central Missouri streams. There have been 17 samples of the fish community in the Hinkson Creek watershed between 1960 and 1999: 8 in Hinkson Creek mainstem, 6 in Grindstone Creek, 2 in Flat Branch, and 1 in Mill Creek. Of the 17 samples, 8 occurred during the 1960s, 2 during the 1970s, and 6 during the 1990s. Species richness ranged from 6-8 in Mill Creek and Flat Branch and 7-28 in Grindstone and Hinkson creeks (overall mean = 14). Shannon-Weaver diversity index, a measure of the distribution of numbers of individuals among the different species in each sample, ranged from 0.59-0.98 (mean = 0.81) and evenness, the observed diversity as a proportion of the maximum possible diversity in each sample, ranged from 0.58-0.94 (0.75). Overall, there was no clear indication that species richness or measures of diversity have decreased through time. Quantitative assessments of trends in the fish collection data are limited by potential differences between sampling dates/events in the methods that were used to collect fish and by the degree of effort (amount of habitat sampled and sample duration). 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. redhorse 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. For comparison, fish collection data from 12 sites in the upper half of the Moniteau Creek watershed (Cooper and Moniteau counties) included 5-18 species (mean = 11), with diversity index values ranging from 0.44-0.97 (0.73) and evenness ranging from 0.52-0.90 (0.74). The largest population of the Topeka shiner remaining in Missouri is found in this part of Moniteau Creek.

Table 1 Fish Kills Reported Within Hinkson Watershed Over Last 10 Years

(content taken entirely from Department of Conservation database

Cause	Source	Responsible party	Damage	Days
Floor Stripper + Floor Finish	Osco Drug Store	Osco Drug	Unknown	1 day
Latex paint.	Unknown.	Unknown	200 ft2	2 days
Dye suspected.	Unknown.	Unknown	1/3 mile	1 day.
Diesel fuel- 1100 gal	Spill @ Columbia Veterans Hosp	Harry S Truman Memorial Veterans Hospital	0.5 miles	1 day
Asphalt sealer	Illegal dumping	Unknown		
Turbidity	Erosion from broken water main	City of Columbia -- Water and Light Dept	0.75 miles	1 day
Waste oil and oil refuse	Disposal-stromdrn/domstc lndfl	Jiffy Lube, suspected	<1/2 mile	Months
Diesel Fuel	Suspected, Coca Cola Truck	Coca Cola, suspected	0.1 Mile	1 day
Fabric Shield/Detergents-5 gal	Fabric Cleaner Demonstration	Midwest Auto Steamers	<1/8 mile	1 day
Raw sewage	Broken sewer line	Columbia Public Works	1/8 mile	2 days
Municipal Water	Broken Water Main	City of Columbia	1/2 mile	1/2 day
Wastewater and detergents	Disposal direct from equipment	Midwest Carpet Cleaners	Unknown	47+ days
Instream gravel removal	Bridge maintenance work	City of Columbia c/o Charles Enochs	0.1 miles	68+ days
Low dissolved oxygen	Fire suppression runoff	None -- Columbia Fire Department (activity)	2.4 miles	2 days
Sediment, diesel fuel, grease.	Construction Site/Schnucks	Jose Lindner (developer)	1/2 mile	>1 week
Bentonite clay/water 60gal/min	Runoff from drilling operation	Ameren UE contact: Clay Taliaferro	150 feet	7+ days
Petroleum (gasoline suspected)	Spill	MFA Oil Co.	1/4 mile	1 day
Raw Sewage- 10 gal	Overflowing manhole / plugged line	Columbia Public Works	1/2 mile	1wk. -- ??
Likely natural, dead channel catfish	N/A	N/A	Unknown	Unknown
Human waste	Manhole overflow	Unknown	300 yards	1 day
Unleaded fuel- 350 gal	Overflow from underground tank	Warrenton Oil	0.5 mile	1 week+
Fly ash slurry	Coal power facility fire	University of Missouri Power Plant	250 feet	3 days

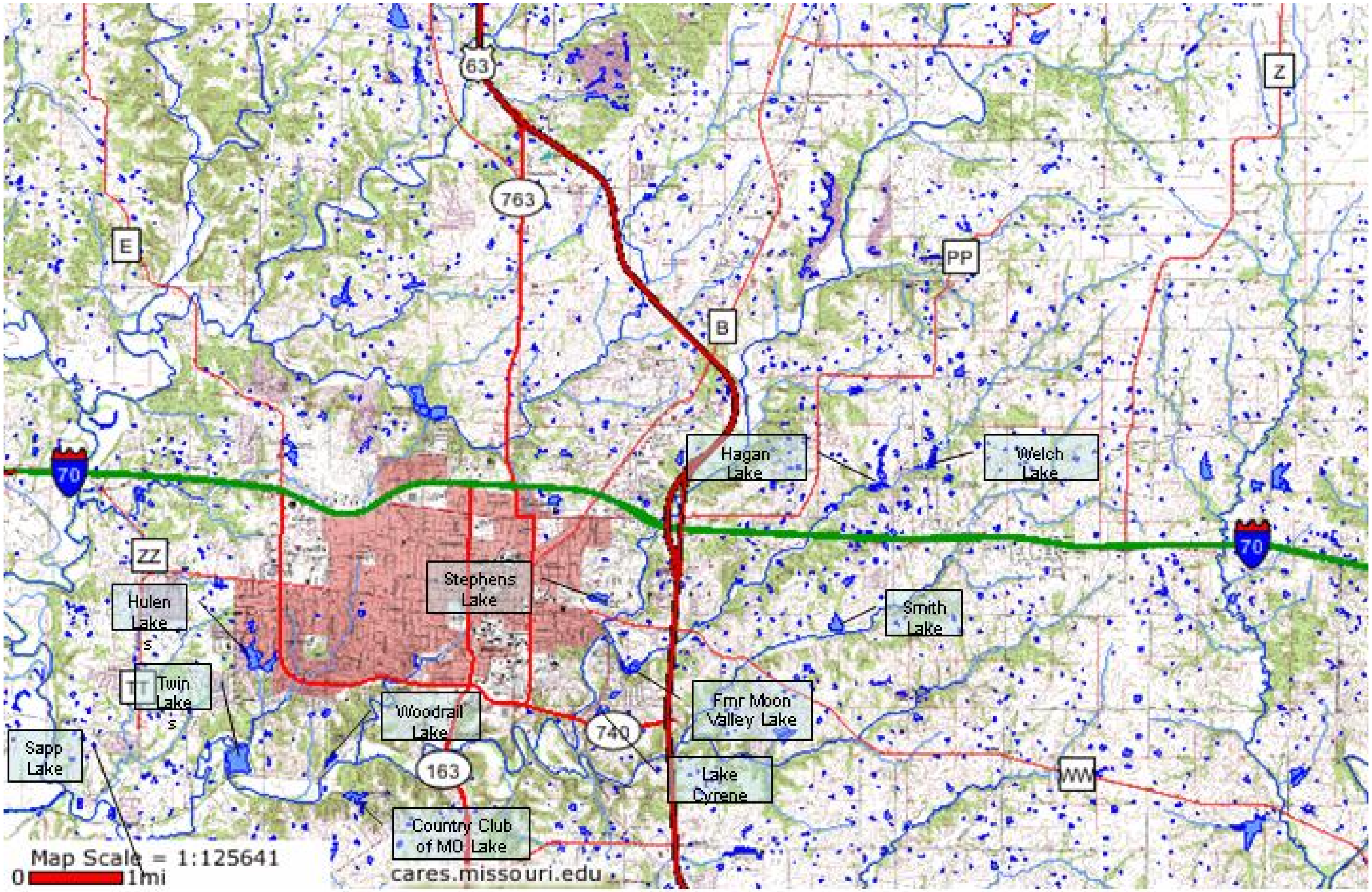

Figure 3. Major Lakes of the Hinkson Watershed from *Center for Applied Research and Environmental Systems (CARES)*

Lakes

Content taken from Department of Natural Resources 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 the Hinkson, 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 watershed, but none are known within the Hinkson watershed. Ponds and lakes found in the Hinkson watershed are manmade. The following is a brief list of the larger lakes within the watershed:

Table 2 Large Lakes within the Hinkson Watershed

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

Chapter 3 Stormwater Impacts on Water Quality

Many of our water pollution problems are due in large part to pollutants that are washed off the land by storms**.** *The National Water Quality Inventory: 2000 Report to Congress* identified urban runoff as one of the leading sources of water quality impairment in streams and lakes. Runoff from the urban environment and from construction activities can flush pollutants off the landscape and into surface waters. This runoff can include such pollutants as sediments, pathogens, fertilizers/nutrients, hydrocarbons, and metals. Pavement and compacted areas, roofs, and reduced tree canopy increase runoff volumes that rapidly flow into our waters. This increase in volume and velocity of runoff often causes stream bank erosion, channel incision and sediment deposition in stream channels. Runoff from these developed areas can increase stream temperatures that, along with the increase in flow rate and pollutant loads, negatively affect water quality and aquatic life (EPA, 2005).

Since the Hinkson pollutant source is officially unknown at this time, and the TMDL will target urbanized flow as a surrogate for multiple contaminants, it makes sense to address all the potential stressors to the Hinkson. Below are some categories of pollutants that typically impact urban streams and likely impact the water quality of the Hinkson:

Temperature

Air temperature above the stream surface is the greatest factor in increasing water temperature (Smith, 2006). Riparian vegetation near a stream can produce shading that reduces the transfer of solar heat to the surface of the water. Stormwater flows raise receiving water temperatures due to the transfer of heat that impervious surfaces (pavement, asphalt, and roofs) absorb from solar radiation. Stormwater retention/detention facilities, lakes, and ponds are affected by ambient air temperatures and solar heating, and can have significant impact when heated water is discharged to streams. Groundwater can have an important cooling effect on stream temperature. If there is less groundwater seepage occurring due to lack of recharge (typical in urban situations), stream temperatures will rise.

Water temperature is an important factor influencing the health and survival of all aquatic organisms, including native fish and amphibians. Temperature controls metabolic rates and reproductive activities and determines which species can survive. Warmer temperatures lower dissolved oxygen content by decreasing the solubility of oxygen in water, thereby decreasing the supply of oxygen available to aquatic organisms. Warm water can cause the fish's need for dissolved oxygen to increase. This effect disrupts its metabolism, and can affect adult migration and spawning. Temperature can influence embryonic development, reducing the survival rate of eggs and the growth of juveniles. Higher temperatures influence the activity of toxic chemicals, bacteria, and parasites in water, which in turn can cause stress, increasing the incidence of fungal infections and disease.

Turbidity

Content primarily taken from "Stream invertebrate community functional responses to deposited sediment" by Rabeni et al.

As far back as 1979, sediment was considered the greatest pollutant in volume entering the nation's waterways, with an estimated 4.5 billion tons of soil annually (Rabení 2005). In a summary of the top 15 categories of impairment identified on the 1998 303(d) lists of impaired waters, the EPA listed sediment as the number one source of impairment with the highest number of stream miles impaired. In Missouri, 943.8 miles of stream are 303(d) listed as impaired by sediment, and another 37 miles are listed as impaired by non-filterable residue (total suspended solids). Agricultural nonpoint sources are listed as the source of pollution in 94% of these streams.

A study of eight streams within watersheds of the Ozark Border of Missouri looked at the effects of percent forest, pasture and row crop on total suspended solids (TSS). The results showed that TSS was significantly negatively correlated with percent forest and positively correlated with percent pasture and row crop (Rabeni et al. 2005). A southern California study suggested that the source of almost two-thirds of the sediment yield in an urban creek came from stream channel erosion as a result of greater magnitude and frequency of peak flows due to increased impervious surface. In 1995, daily samples from Hinkson Creek found concentrations of turbidity and TSS increased with increasing discharge and exhibited distinct seasonal patterns. Both suspended solids and turbidity increased by 100– 400 fold during periods of high discharge when elevated erosion rates were accompanied by increased runoff. Barren land in Missouri has been reported to lose soil at a rate 123 times that of similar land that is covered in sod.

Turbidity and sedimentation impact water quality by increasing chemical oxygen demand and increasing water temperatures, which decrease oxygen in the water. Reduced light from high turbidity, as well as impacts from smothering and scouring, causes reduced primary production, as well as changes in plant species composition and abundance. Inorganic sedimentation and nutrient addition can operate synergistically, and eliminate a higher number of species than would exposure to one pollutant alone.

Substrate conditions are considered to be the most important factor regulating invertebrate distribution and abundance in streams. Alteration of the substrate by the deposition of fine particles eliminates the preferred habitat of the benthic invertebrates. Other effects include interference with organism respiration and feeding activities. Most studies of community changes induced by sediment show reductions in benthic invertebrate abundances and diversity, and an elimination of filter-feeding organisms. Community structure changes were generally described as taxonomic shifts from insect orders Ephemeroptera, Plecoptera, and Trichoptera (EPT) to Oligochaetes and burrowing Chironomidae.

For fish species, various levels of suspended sediment can cause changes in species distribution, reduced feeding and growth, respiratory impairment, increased stress, reduced tolerance to disease and toxicants, and mortality of both immatures and adults (Doisy and Rabeni, 2004). Besides a reduction in growth, many aspects of the reproductive cycle may be affected, including age at maturity, timing of gonad maturation, fecundity, and spawning success. High turbidities cause particles to settle on the gill filaments, resulting in decreased respiration and waste exchange. Symptoms of major physiological stress in fishes may include changes in the blood chemistry, changes in the gill tissues, or reduced feeding and growth rates.

Salt

Content primarily taken from "Environmental Impacts of Road Salt and Alternatives in the New York City Watershed" by Wegner and Yaggi

Chloride salts are composed of approximately 60% chloride and 40% positive ion. De-icing operations use calcium, potassium, and magnesium chlorides, but to a lesser degree than NaCl. These salts may be applied in liquid or crystalline form, either of which can be used in conjunction with abrasives. Sodium ferrocyanide is added to chloride salts to prevent clumping during storage and application. In water, sodium ferrocyanide can be photolyzed to release approximately 25% cyanide ions.

Runoff to surface waters and percolation to groundwater are the most common mechanisms for road salts to enter water supplies. These salts remain in solution in surface waters and are not subject to any significant natural removal mechanisms. Their accumulation and persistence in watersheds pose risks to aquatic ecosystems and to water quality. Salinity stresses the food organisms upon which benthic grazers forage, and inhibits microbial processing of leaf litter. Reduction of primary productivity causes repercussions at the top of the food chain in addition to the stress salinity imposes on the organisms themselves. The presence of salt in aquatic ecosystems also releases toxic metals from sediment into the water column and impairs distribution and cycling of oxygen and nutrients. Prolonged retention of salt in streambeds or lakebeds decreases dissolved oxygen and can increase nutrient loading, which in turn promotes eutrophication.

Toxicity responses of aquatic organisms to NaCl vary. Laboratory studies report that the LC_{50} for six freshwater fish and crustacean species exposed to NaCl for one day ranged from 2,724 to 14,100 mg/l with a mean of 7,115 mg/l.

Oils and Greases

Content primarily taken from "The Science of Stormwater"

Oils and greases are a common component of stormwater runoff pollutants, primarily because there are so many common sources: streets and highways, parking lots, food waste storage areas, heavy equipment and machinery storage areas, and areas where pesticides have been applied. Oils and greases can be petroleum-based or food-related (such as cooking oils). Oil and grease are known to be toxic to aquatic organisms at relatively low concentrations; they can coat fish gills, prevent oxygen from entering the water, and clog drainage facilities (leading to increased maintenance costs and potential flooding problems). Hydrocarbons can also persist in sediments for long periods of time and adversely impact benthic macroinvertebrates. The USGS (2005) stated that polyaromatic hydrocarbons (PAHs) were 65% higher in runoff from parking lots sealed with coal-tar based sealcoat than from other types of parking lot surfaces.

Metals

Content primarily taken from "The Science of Stormwater"

Many heavy metals, including lead, copper, zinc and cadmium, are commonly found in urban runoff. Metals can contaminate surface and ground waters and concentrate in bottom sediments, presenting health problems for fish and animals that eat from the bottom. Reproductive cycles of bottom-dwelling species can be severely reduced, and fish inhabiting such metal-contaminated locations often exhibit lesions and tumors. Metals can bioaccumulate in fish and shellfish. Metals can also contaminate drinking water supplies. Industrial areas, scrap yards, paints, pesticides, and fallout from automobile emissions are typical sources of heavy metals in runoff.

Toxic Organic Compounds

Content primarily taken from "The Science of Stormwater"

Pesticides and PCBs are toxic organic compounds that are particularly dangerous in the aquatic environment. Excessive application of insecticides, herbicides, fungicides, and rodenticides, or application of any of these shortly before a storm, can result in toxic pesticide chemicals being carried from agricultural lands, construction sites, parks, golf courses, and residential lawns to receiving waters. Many pesticide compounds are extremely toxic to aquatic organisms and can cause fish kills. PCBs are a similar class of toxic organic compounds. They can contaminate stormwater through leaking electrical transformers. PCBs can settle in sediments of receiving waters and, like pesticide compounds, present a serious toxic threat to aquatic organisms that come in contact with them. Many other toxic organic compounds can also affect receiving waters. These toxic compounds include phenols, glycol ethers, esters, nitrosamines, and other nitrogen compounds. Common sources of these compounds include wood preservatives, antifreeze, dry cleaning chemicals, cleansers, and a variety of other chemical products. Like pesticides and PCBs these other toxic organic compounds can be lethal to aquatic organisms.

Fecal Coliform Bacteria

Content primarily taken from "National Management Measures to Control Nonpoint Source Pollution from Urban Areas"

Fecal coliform bacteria in water may indicate the presence of pathogenic (disease-causing) bacteria and viruses. E. coli is another indicator of the presence of pathogens in streams. Pet and other animal wastes, failing septic systems, livestock waste in agricultural areas, and fertilizers can all contribute fecal coliform bacteria. This can be a problem for treatment of drinking water and can limit recreational use of a water body. Conditions affecting the upper respiratory tract, ear, eye, and skin, may result from contact with contaminated water. Wildlife can also contract diseases from contaminated water, as in the case of otters in California contracting Toxoplasmosis gondii from water contaminated by cat feces.

Hydrology

Content primarily taken from "Stream Corridor Restoration"

Research has shown that streams in urban watersheds have a character fundamentally different from that of streams in forested, rural, or even agricultural watersheds. The amount of impervious cover in the watershed can be used as an indicator to predict how severe these differences can be. In many regions of the country, as little as 10 percent watershed impervious cover has been linked to stream degradation, with the degradation becoming more severe as impervious cover increases. Impervious cover directly influences urban streams by dramatically increasing surface runoff during storm events. Depending on the degree of watershed impervious cover, the annual volume of storm water runoff can increase by 2 to 16 times its predevelopment rate, with proportional reductions in ground water recharge.

The peak discharge associated with the bankfull flow (i.e., the 1.5- to 2-year return storm) increases sharply in magnitude in urban streams. In addition, channels experience more bankfull flood events each year and are exposed to critical erosive velocities for longer intervals. Since impervious cover prevents rainfall from infiltrating into the soil, less flow is available to recharge groundwater. Consequently, during extended periods without rainfall, baseflow levels are often reduced in urban streams.

The hydrologic regime that had defined the geometry of the predevelopment stream channel irreversibly changes toward higher flow rates on a more frequent basis. The higher flow events of urban streams are capable of moving more sediment than they had done before. The customary response of urban streams is to increase their crosssectional area to accommodate the higher flows. This is done by streambed downcutting or streambank widening, or a combination of both. Urban stream channels often enlarge their cross-sectional areas by a factor of 2 to 5, depending on the degree of impervious cover in the upland watershed and the age of development. Stream channels react to urbanization not only by adjusting their widths and depths, but also by changing their gradients and meanders.

The prodigious rate of channel erosion in urban streams, coupled with sediment erosion from active construction sites, increases sediment discharge to urban streams. Researchers have documented that channel erosion constitutes as much as 75 percent the total sediment budget of urban streams. Urban streams also tend to have a higher sediment discharge than nonurban streams, at least during the initial period of active channel enlargement.

Urban streams are routinely scored as having poor instream habitat quality, regardless of the specific metric or method employed. Habitat degradation is often exemplified by loss of pool and riffle structure, embedding of streambed sediments, shallow depths of flow, eroding and unstable banks, and frequent streambed turnover. Large woody debris is an important structural component of many low-order streams systems, creating complex habitat structure and generally making the stream more retentive. In urban streams, the quantity of large woody debris is reduced due to the loss of riparian forest cover, storm washout, and channel maintenance practices.

Chapter 4 Water Quality Monitoring Data

Content entirely taken from Phase II and Phase III Hinkson Creek Stream Study

The Missouri Department of Natural Resources (MDNR) has conducted a study of the Hinkson to confirm the impairment of the aquatic community and attempt to determine the nature and source(s) of the impairment. The MDNR conducted a study consisting of a combination of biological and chemical monitoring combined with toxicity testing. Water and sediment samples were collected from main-stem Hinkson Creek and storm drainages.

Reason for study

An aquatic macroinvertebrate community study was conducted during the fall of 2001 and spring of 2002 by MDNR. Information obtained from the study showed impairment to the aquatic macroinvertebrate populations within the urbanized reach of the Hinkson. Biological metrics comparisons were made against similar size, high quality streams within the same geographical area. The study results indicated that Hinkson Creek downstream of the Interstate 70 bridge crossing was only “partially supporting” for aquatic life and confirmed stream impairment as summarized below.

Table 3. Aquatic Community Scores on 8 Sites within Hinkson Creek

Site	Fall 2001	Spring 2002	Fall 2003	Spring 2004
Rogers Rd.	12	18		
Hinkson Creek Rd.	12	18	18	18
Hwy 63 Connector				16
Walnut Street	12	12	16	14
Broadway St.			16	16
Capen Park	16	12		
Rock Quarry Rd.	18	14		
Forum Blvd.	18	14		
Twin Lakes	18	14		
Scott Rd.	16	14		

Note: Scores less than 16 indicate impairment of the invertebrate community.

Because of the aquatic macroinvertebrate findings, further work was required to determine the nature and cause of impairment. A comprehensive study of main-stem Hinkson Creek and major storm drainages located within the impaired segment of Hinkson Creek was initiated. The studies consist of water quality and sediment monitoring, toxicity testing, and additional biological sampling through the duration of the study.

The first phase of the study was conducted during the 2004 state fiscal year and concentrated on an approximately 2.0 mile segment of Hinkson Creek between the I-70 and Broadway bridge crossings. The second phase of the study began during July 2004

and continued until July 2005. The phase II portion of the study concentrated on an approximately 5-mile long segment of Hinkson Creek located between the Broadway bridge and Recreational Drive low-water bridge crossing (located just upstream of Providence Road).The third phase focused on an approximately 7.5-mile long segment from Recreational Drive to the mouth at Perche Creek and was completed in June 2006.
.

Methodology

The source and the type of pollutant(s) impacting the Hinkson are unknown. Therefore, a water quality triad was used to document impairments to the aquatic community and identify pollutants that are likely contributing to those impairments. This approach is an integrated assessment of information obtained from the aquatic organism assemblages, chemical analyses, and toxicity testing. Because the macroinvertebrate data indicated impairment to Hinkson, it was necessary to collect a series of water samples for testing. Before the samples were submitted for chemical analysis, aquatic toxicity was determined using a Microtox test system. If the water samples were found to be toxic, a Toxicity Identification Evaluation procedure was conducted to determine the possible pollutant type(s) (e.g.,organic, metals, etc). The water samples were then submitted for analysis based on the toxicity identification results.

Sampling Methods

The methods that were used during this study were consistent with MDNR's standard operating procedures, (American Public Health Association.Standard Methods), and widely accepted by the scientific community.

The toxicity of surface waters and stormwaters were determined using the Microtox bacterial bioluminescence test. Microtox has been shown to correlate well with other standard toxicity test organisms, including fathead minnows (*Pimephales promelas*) and daphnids (*Ceriodaphnia dubia*). Since Microtox organisms are marine bacteria, they are less sensitive to the presence of chlorides, especially sodium and calcium salts, whereas *C. dubia* are relatively sensitive to the presence of these salts. Therefore, it was decided to utilize both the Microtox and *C. dubia* tests. Microtox acute toxicity tests were used to screen water samples for further toxicity and/or chemical analyses. The purpose of screening toxic samples prior to additional testing was to attempt to determine broad classes of chemicals that might be causing or contributing to the toxicity. For example, if toxicity is reduced or eliminated following filtration, it might indicate that the toxic component was adhering to suspended particles. Toxicity that is reduced or eliminated in the presence of a strong chelating agent, such as EDTA, might indicate that metals are a toxic component.

Semi-permeable membrane devices (SPMD) were used to monitor for semi-volatile organic chemicals that can bioconcentrate in aquatic organisms. When exposed to air or water, any bioavailable organic compounds diffuse through the membrane and accumulate in the device's lipid in a manner that mimics contaminant uptake into the fatty tissues of living organisms.

The biological assessment monitoring was conducted according to the MDNR Semi-Quantitative Macroinvertebrate Stream Bioassessment Project Procedure. In summary, macroinvertebrates were collected using a multi-habitat sampling method. Macroinvertebrate identifications were made to the lowest possible taxonomic level (usually genus or species). Four metrics (Taxa Richness, Ephemeroptera/Plecoptera/Trichoptera Taxa, Biotic Index, and Shannon Diversity Index) were aggregated into a single value presented as the Stream Condition Index (SCI). The SCI is calculated for each season and year and is based upon data collected from reference streams within the same EDU as the study stream.

Results- Macroinvertebrate sampling

During Phase II sampling, the macroinvertebrate community from Station 7, representative of the largely rural upstream Hinkson Creek watershed, was compared with the community within this study's urbanized reach (Stations 3.5, 5.5, and 6) to observe whether the differences observed in previous biological assessments were still present. Numbers of EPT Taxa showed a general downward trend while progressing downstream. Stations 3.5 and 5.5 failed to achieve fully supporting status in fall 2005, Station 3.5 was the only site of the four to fail to be fully supporting in the spring. During Phase III sampling in 2006, one site (Twin Lakes Recreational area) of the three tested failed to have a fully supporting score.

Figure 4. DNR Macroinvertebrate Sampling Locations

Table 4 Hinkson Creek Metric Values and Scores, Fall 2005, Using Ozark/Moreau/Loutre Biocriteria Reference Database

Station #	TR	EPT Taxa	BI	SDI	SCI	Support
#7 Value	78	16	7.12	3.29		
#7 Score	5	5	3	5	18	**Full**
#6 Value	78	11	7.04	3.32		
#6 Score	5	3	5	5	18	**Full**
#5.5 Value	69	10	7.33	2.88		
#5.5 Score	5	3	3	3	14	Partial
#3.5 Value	72	9	7.45	2.91		
#3.5 Score	5	3	3	3	14	Partial

Table 5. Hinkson Creek and Bonne Femme Metric Values and Scores, Spring 2006, Using Ozark/Moreau/Loutre Biocriteria Reference Database

Hinkson #3 Value	73	10	7.15	3.00		
Hinkson #3 Score	5	3	3	5	16	Full
Hinkson #2 Value	69	6	7.30	3.22		
Hinkson #2 Score	3	3	3	5	14	Partial
Hinkson #1 Value	75	7	7.28	3.27		
Hinkson #1 Score	5	3	3	5	16	Full
B. Femme #1 Value	79	15	6.46	3.15		
B. Femme #1 Score	5	5	3	5	18	Full

EPT Taxa among all Hinkson Creek stations were considerably lower than the average for the reference streams. Hinkson Creek EPT Taxa averaged 11 percent (range 9-14), EPT Taxa at Bonne Femme Creek made up 19 percent of the total, and samples collected from Ozark/Moreau/Loutre EDU reference streams had an average of 22 percent EPT.

Despite two of the three lower Hinkson Creek stations increasing in status from partially to fully supporting, the biological community is largely unchanged compared to conditions observed in 2002. Only one station demonstrated a notable increase in Taxa Richness (which resulted mostly from an increase in tolerant taxa), whereas the remaining stations changed very little. Among the remaining biological metrics, there were no consistent trends that would indicate notable changes in the aquatic community since the 2002 study.

Results- Chemical Sampling

According to the MDNR 10 CSR 20-7.030 (MO CSR 2004) water quality standards, in-stream water quality limits were not exceeded at any time during the base flow monitoring portion of the study. Brief discussions of the findings are discussed below.

Specific Conductivity

The *in situ* conductivity field measurements were within expected ranges for streams in the Ozark/Moreau/Loutre EDU. When compared to the Phase I base flow results, the Phase II conductivity results tended to be slightly lower at Hinkson Creek Road, East Walnut, and Broadway bridge crossings. When compared to the reference and control streams, the conductivity readings were significantly higher (approximately 55 percent higher) in Hinkson Creek at all stations. Grindstone Creek was consistently higher throughout the Phase II study when compared to Hinkson Creek, Hominy Creek, and reference/control streams. The higher readings may be due to the contribution of point source discharges (e.g., small domestic wastewater treatment facilities) located within the Grindstone watershed. Eight NPDES permits have been issued for wastewater discharges from subdivisions, one for a mobile home park, one for a concentrated animal feeding operation, and three for domestic waste discharges from commercial businesses.

Specific conductivity of stormwater collected from the storm drains during Phase II sampling ranged from 106 to 1220 S/cm. Pure rainwater contains very little ions and, therefore, has very low conductivity. When elevated conductivity values are found in stormwater runoff, it is an indication that the rainwater runoff is picking up and transporting materials deposited on the ground and/or impervious surfaces.

Bacteriological Samples - Escherichia coli

"Whole body contact – level B" is a recently added beneficial use listed for Hinkson Creek Now, according to DNR Water Quality Standards, *E. coli* levels should not exceed a geometric mean of 548 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.

Stormwater samples collected from the four tributaries in Phase III (Flat Branch, County House, Meredith Branch, and Mill Creek) frequently exceeded the 2419 mpn/100mL level. *E. coli* values from the stormwater monitoring locations at Rock Hill Park, Boone Hospital, and around Eastgate Plaza were in excess of 2400 mpn/100 mL.

Although elevated levels of *E. coli* in the lower stream segments of Hinkson Creek cannot be directly attributed to any specific source, they might be correlated with the documented increase in the resident Giant Canada goose populations in recent years. In addition, the upper reaches of Hominy Creek receive domestic wastewater from three domestic wastewater systems, two mobile home parks and one subdivision. Pet waste from dog walking trails next to Grindstone and Hinkson Creeks (in Grindstone and Capen Parks) can contribute to bacteria as well. Lastly, periodic sewer line breaks and/or bypasses can contribute to elevated in-stream *E. coli* readings. .

Turbidity

Turbidity measures the clarity of the water caused by the presence of suspended material such as clay, silt, algae, and other microscopic organisms. Visual observations of Hinkson Creek during and for several days following a rainfall event showed that water flowing in Hinkson Creek tended to turn brown during rainfall events and remained discolored for several days afterward, suggesting increased turbidity. When compared to other stream systems within the same EDU, Hinkson Creek remained turbid for several days while other tributaries returned to normal conditions within 24-48 hours following rainfall events. A study conducted by Parris (2000) indicated that it took approximately three days for Hinkson Creek to return to base flow turbidity conditions. During the Phase I portion of the study, visual observations indicated that some sites remained turbid even during base flow conditions, which was thought to be related to land disturbance activities. Turbidity values collected from storm drains ranged from 2.85 to 374 NTU.

Turbidity monitoring was conducted by DNR to determine if longitudinal trends existed and/or to isolate the general area. During non-storm events the Hinkson Creek turbidity values ranged from 1.65 NTU to 49 NTU. The overall mean and median turbidity values tended to increase from upstream to downstream starting at the Highway 63 connector, and then decreased at downstream sites. 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 or colloidal sediments.

The turbidity in Hinkson Creek was often greatest during low flow regimes. Throughout the study area, there is evidence that during high flow events the stream is cutting away at the stream banks creating erosion along Hinkson Creek. Visual observations at a few of the drainages entering Hinkson Creek between the Mexico Gravel Road and Highway 63 connector bridge crossings indicate that sediments are being transported and deposited into Hinkson Creek. The highest turbidities collected from Hinkson Creek were during the summer and late fall months and correlated with the Parris (2000) findings.

Chloride

Chloride values tended to be slightly less on average in the DNR Phase II study in 2005 than in the Phase I study in 2004. In the Phase I study, four discharges were found to be toxic, all were located around the development along the 63 connector (see table below). Instream toxicity was documented in Hinkson Creek at the Broadway bridge during the snowmelt sampling. This observation is significant because it ties instream effects to a particular runoff event.

During Phase II sampling, chloride values for Hinkson Creek baseflow ranged from 19.6 to 64.7 mg/L. Chloride levels at Hinkson Creek sites during Phase III baseflow sampling were considerably higher. High values were also reported in Grindstone Creek, which may be influenced by the number of point source discharges located throughout the watershed. Flat Branch Creek had significantly higher chloride levels than those from the other tributaries. When compared to the reference/control streams, the Hinkson Creek chloride values on average were approximately 40% higher. The chloride values for the reference/control streams ranged from 8.67 mg/L to 17.1 mg/L.

Table 6. Chloride Tests Exceeding Acute Toxicity Standard

Site Name	# chloride tests	# acute tox.
Hinkson Cr. bl. Rogers Road	8	0
Hinkson Cr. ab. Hinkson Cr. Rd.	9	0
Tributary from I-70	3	1
Hinkson Cr. bl. I-70	1	0
Tributary from MoDot	3	1
Tributary from Walmart	2	1
Hinkson Creek ab. Walnut St.	7	0
Tributary from Golf Course	1	0
Tributary from Sams,Lowes	2	0
Tributary from Megamarket	2	1
Hinkson Cr. at Broadway Bridge	5	0

Chloride levels of stormwater ranged from 14.3 mg/L (Mill Creek) to 283 mg/L from Flat Branch. Chloride levels of Hinkson stormwater ranged from 5 to 148 mg/L during the Phase II study.

The major sources of chloride in surface water come from deicing salt, urban and agricultural runoff, and discharges from municipal wastewater and industrial plants. Elevated chloride and conductivity values during base flow periods may also be a result of long term use of de-icing agents used on roadways and parking lots in the form of sodium chloride (salt). The salt accumulates in the soils along roadways and migrates through the soil where, over time, it has the potential to leach into groundwater and surface waters

Nutrients
The nutrient data collected during the base flow portions of the Phase II and III studies were found to be within the expected ranges for a stream within the Ozark/Moreau/Loutre EDU. Slightly elevated NO2 + NO3 as N and total nitrogen readings occurred during the December 2004 sampling event and corresponded with the higher flow regimes.

Organics
Various organic chemicals were found in low levels within the Hinkson. Chloropyrifos and Oleic acid, were found in stream samples and are associated with pesticide products and/or pesticide breakdown products. Long-chain fatty acids were also found in the Hinkson and are associated with cooking oils and greases. Phthalates and hexanedioic acid were found in stream samples, and most likely came from plastic bottles and plastic grocery type bags located in and around drainage pipes and in main-stem Hinkson Creek at various locations. As plastics are exposed to ambient environmental conditions and UV light, they begin to degrade, allowing these plasticizing agents to leach into the environment. Low levels of pharmaceuticals and/or breakdown products (such as Fenretinide and Verapamil) were also found, similar to other urban stream studies.

Within stormwater, the occurrence of plasticizers (phthalates) can likewise be attributed to plastic debris within storm drains and the leaching from polyvinyl chloride (PVC) drainpipes and/or sampling equipment. The presence of polycyclic aromatic hydrocarbons (PAH), such as fluoranthene, is often associated with incomplete combustion of fossil fuels and is a derivative of coal tar/asphalt products. Carbaryl, a common lawn and garden insecticide, was present in stormwater in sufficient quantities (~64 µg/L) to cause or contribute to the observed toxicity in one sample. Carbaryl is listed as a general use carbamate pesticide that can be toxic to many aquatic macroinvertebrate at low (10-20 µg/L) concentrations.

Chemical analyses of the I-70 sediments found a variety of PAHs such as Benzo (a) anthracene, benzo (a) pyrene, chrysene, fluoranthene, and pyrene in concentrations higher than the Threshold Effects Concentration (TEC). The TEC is a concentration of a particular contaminant, below which toxicity generally does not occur. During the summer of 2003, a petroleum sheen was noted on the water surface upon disturbing the sediments, and PAHs and total petroleum hydrocarbons (#2 diesel) in sediment samples. The presence of these constituents in the sediment samples may be attributed to the drainage's proximity to the I-70/Highway 63 interchange, and the result of a gas station located higher in the drainage..

Metals
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 Cu, Ni, and Co at high levels, but no clear correlation between observed toxicity and contaminants found could be made. The presence of certain metals often is a reflection of the impervious surface types found within the localized area. Metals found in stormwater runoff may be associated with vehicle exhaust, worn tires, brake linings, and weathered paint and rust. The synergistic effect of the metals is likely to contribute to water quality impairments as opposed to a single metal.

Dissolved Oxygen and Temperature
Data loggers that recorded temperature and dissolved oxygen concentrations over an 8-week period showed that lower dissolved oxygen appeared to correlate better with pool stagnation at low flows during dry periods than with stormwater inputs resulting from precipitation events. Dissolved oxygen conditions generally improved following rainfall events.

Sediment
In general, the percent sediment coverage tended to increase while progressing downstream. Sediment coverage at the Hinkson Creek stations was considerably higher when compared to Bonne Femme Creek, indicating that even in the upstream, non-urbanized portion of Hinkson Creek, excessive sedimentation exists at least occasionally. The mean percent coverage for each grid (Hinkson Creek Road, 63 Connector, and Broadway) was 63.6%, 79%, and 96%, respectively. According to the DNR Phase I report, the amount of runoff from the storm drainages was "impressive" and showed the potential for severe soil erosion and gully erosion. This may contribute to the observed sediment deposition and prolonged turbid conditions.

Chapter 5 Information and Education Activities

The Hinkson 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 have a joint MS4 permit from DNR. Each of the three entities is considered to be a Regulated Small MS4, and must therefore develop and implement a Storm Water Management Program (SWMP) in compliance with the National Pollutant Discharge Elimination System Phase II requirements for Small Municipal Separate Storm Sewer Systems (NPDES Phase II, MS4). The joint permittees have been implementing their programs for nearly five-years and, have been conducting public education and outreach and public involvement activities for nearly eight-years. The City of Columbia has recently passed two ordinances, a stream buffer ordinance and stormwater treatment ordinance, which should vastly improve water quality in the future. Two grant projects are currently targeting the Hinkson watershed in their costshare and education projects, the current Hinkson Creek Watershed Restoration Project 319 grant and the Upper Hinkson SALT grant. A survey of public attitudes toward the Hinkson was conducted by a graduate student at the University of Missouri.

<u>Public Input Surveys</u>

Content entirely taken from Resident's Perceptions of Water Quality in Hinkson Creek

In 2006, an attitude and awareness study sponsored by the University of Missouri and the Department of Conservation surveyed randomly selected landowners and homeowners in the Hinkson watershed to explore opinions on issues within the watershed. The assessment began by conducting eight focus groups. A 12 page mail survey was then designed based on information gained from those focus groups and was randomly sent to 10,000 residents (4653 surveys were returned). The watershed was stratified into urban, suburban, exurban (large lots in the outskirts of town) and rural areas to assess the variation of awareness and attitudes among residents of each area within the watershed

Focus Group Knowledge of Issues

Most groups knew the definition of a watershed. All groups agreed that streams can have positive and negative affects on property value. People in all groups shared a concern for the large amount of development occurring in the area and how that development affects streams. Most group members had been in or near Hinkson Creek at some point in their lives and had strong opinions about the Creek. The suburban residents had seen or read about the Creek in the newspaper or on television but did not have direct contact. The urban groups were quite knowledgeable about Hinkson Creek and passionate about how they would or would not use the stream.

Focus Group Views on Sources

When asked what water quality meant to them, all groups immediately thought of drinking water, and rural residents added fishing and swimming as aspects of water quality. Rural groups believed the problems in the Hinkson were attributed to the lack of city sewer lines, and buffer strips, grass waterways, terraces and retention ponds could improve the water quality in Hinkson Creek. Exurban residents believe that development is the problem and water quality could improve by teaching people to recycle; developing an anti-litter campaign and educating others about water quality. The suburban group believes some of the problems include farming and animal runoff, and improvement will come from enforcing the laws. The urban people had the strongest opinions of water quality in Hinkson Creek, with this group having the most ideas for stream improvement and were the least likely to get into the stream without gloves and shoes.

Focus Group Management Strategies
The rural groups felt that laws are needed to force developers to protect water quality, but too many laws "bind up the process in regulation". They also felt education and incentive programs were also better than laws. The people in the suburban group felt that collaborations would be successful, such as having a "Partners in Conservation" for schools to "adopt a spot along the creek". The urban residents were interested in stiff fines for infractions, with the addition of local ordinances and incentives for developers to protect streams.

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. Only 2.3% of people didn't think the stream was polluted, while 69% thought it was somewhat or very polluted, and 29% did not know if Hinkson Creek was polluted. More people thought that water quality had worsened than improved in the last decade. Respondents get most of their information about Hinkson Creek from the newspaper, followed by television. The majority did not get their information regarding Hinkson Creek from the radio, internet, local government and environmental organizations.

Survey Views on Sources
A quarter of the residents of Hinkson Creek watershed believe that that runoff of insecticides or pesticides from lawn care contributes most to water pollution. Unfortunately, roughly that same amount didn't know what contributes to pollution of the creek. Agricultural runoff, construction sites, and automobile fluids were also listed as major contaminants. Overdevelopment was rated the most serious potential issue in the Hinkson Creek watershed, while agricultural pollution was rated the least serious potential issue in the watershed.

Survey Management Strategies
Residents generally agree 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. Media involvement and encouraging people to reduce lawn chemicals was the next most important management strategy, followed by enforcing laws. Improving laws and offering incentives for people to buy an existing home were ranked lowest.

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

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 the University of Missouri-Columbia developed a joint storm water management program to effectively minimize storm water pollutant runoff and meet DNR Phase II requirements. MU has been designated the coordinating authority to give DNR a single point of contact for issues arising out of this joint permit application. Note that designation as the coordinating authority does not give MU any regulatory control over the City or County. Each party fully intends to maintain these programs as outlined in the permit application, and as appropriate, will develop and add new programs for the various minimum control measures (MCM).

Public Education and Outreach

Through a series of one-year contracts with the University of Missouri, Columbia and Boone County have provided a public education and outreach program to its citizens and business and property owners. The focus of the education efforts are to educate the public on issues involving storm water discharges and their relative impacts on storm water quality, as well as informing the public of measures they can take to reduce pollutants in storm water runoff. The three entities have cooperated in developing storm water public education and outreach programs. A Storm Water Steering 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 storm water public education and outreach program.

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

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

Public Involvement and Participation

This MCM has the goal of transforming public education into action and involve the public in decision making regarding storm water management policies. The Columbia City Council and the Boone County Commission formed a Joint Storm Water Task Force, composed of citizen volunteers, whose mission is: *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 storm water flows and protect the quality of life for citizens of the City of Columbia and Boone County.* 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 storm water 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

Columbia, Boone County and MU will implement an effective program to detect and eliminate illicit discharges as defined in 10 CSR 20-6.200 into each entity's regulated MS4. Columbia has already enacted an illicit discharge ordinance. Boone County intends to prepare ordinances to improve their ability 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 Storm Water Runoff Control

The city of Columbia has a working construction site storm water runoff control program which has been in place since 1991. All construction sites greater than one acre are required to submit land disturbance plans to the city. Mechanisms for enforcement include stop work orders and prosecution through Municipal Court. Wastes required to be controlled include discarded building materials, concrete truck washouts, chemicals, litter, and sanitary waste. Boone County has similar requirements and practices, but plans to improve its capabilities in the future. 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.

Post-construction Storm Water Management in New Development and Redevelopment

The Columbia City Council and the Boone County Commission have appointed a Storm Water Task Force to provide community input into the development of the City and County storm water programs. The City council has recently approved a stream buffer ordinance and stormwater ordinance to address storm water runoff from new development and redevelopment projects. The county is expected to follow suit within a year.

An example of a 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

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 NPDES permit for discharges of storm water. 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.

<u>Overview of Hinkson Creek Watershed Restoration Project</u>

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 non-point source pollution prevention project for the Hinkson Creek watershed in 2004. The project addresses 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. A quarter-time grant administrator and a full-time urban conservationist have been employed to address these issues. The project focuses on public education, as well as watershed restoration activities. Education activities include a low-chemical yard maintenance program, raingarden workshops, field days for bmps in the watershed, conservation development workshops, and media workshops. Restoration activities include bank stabilization, riparian tree planting, raingarden construction, and LID structure costshare. The project has extensive inter-agency coordination between state, local and non-governmental organizations. Project partners include: Natural Resources Conservation Service, City of Columbia, Boone County Soil and Water Conservation District, Boone County, Missouri Department of Conservation, and Sierra Club.

Effectiveness of our Current Program

Some of the milestones have received tremendous response, while others have been 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 current Hinkson grant project on overall water quality. A more practical measure of program success is participation. The overall response to raingardens has been tremendous. Raingarden workshops have been given several times per year, sometimes with as many as 50 attendees. Over 50 homeowner raingarden consults have been conducted, and the milestone of 20 installed raingardens was achieved at the halfway mark of the grant. The Show Me Yards program has been similarly well-received, and over 100 attendees have shown up (at a time) for semi-annual workshops. Surveys mailed to 250 Show-Me Yard workshop attendees revealed that 91% of respondents have changed their behavior as a result of the program. Stream clean-ups morphed into an annual Hinkson Clean Sweep event that draws over 100 volunteers. The Conservation Development workshops drew an average of 90 attendees. The annual newsletter has been an effective means of transmitting water quality information (based on anecdotal responses), while the media workshops are effective only if there is a story to report.

Unfortunately, the bank stabilization costshare program has been difficult to implement. "Conservation Development" costshare projects were modified to "Low Impact Development" costshare 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 milestone was reduced from 20ac to 15ac (a trade for increased raingardens) mainly because it is difficult to find that much open land in an urban watershed.

Overview of Upper Hinkson SALT Grant

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

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

In order to improve and protect water quality in the watershed, the AgNPS 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 are 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 includes buffers and filter strips along corridors, livestock exclusion, and streambank stabilization.

Chapter 6 Implementation Measures

Assumptions

Because of the unknown nature of the contaminants contributing to impairment of the Hinkson, it is difficult to make detailed recommendations for restoration, and extremely difficult to quantify load reductions. This is not to say that we are wholly without knowledge of the contaminants within Hinkson Creek, we simply do not yet know the relative importance of these contaminants in the impairment. However, the problems associated with urban streams are not unique to this watershed, and therefore many of the solutions to these problems can be found in other urban stream settings. In making these recommendations, we are also making certain assumptions:

1) The source of impairment emanates from the urban setting. Data collected by DNR indicate that the impairment begins where the urbanized portions of the watershed begins. Macroinvertebrate samples from above I-70 indicates the Hinkson 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 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.

2) 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 dumpsites and litter within the creek. However, DNR 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.

3) Altered, or "urbanized", streamflow 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 baseflow, 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 streambanks 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 DNR will in fact target the urban flows in their Total Maximum Daily Load (TMDL) document.

TMDL Issues

At the time of this writing, the DNR has not yet completed the TMDL for the Hinkson. DNR has said in public meetings that they will not target a chemical pollutant in their TMDL document, but will instead target the urbanized flow or "flow duration curve" for their load reduction calculations. The initial TMDL will be a very general document because of the lack of flow data on Hinkson Creek. As more data from an array of monitoring stations comes in, this real data will replace the landuse modeling data used to estimate flow/run-off rates. Accordingly, this watershed plan has not targeted any particular contaminant or flow volume. As new information is made available, it will be integrated into this document (and assumedly into the next version of the Hinkson TMDL) 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 calculate the expected load reduction of some common urban contaminants from the reasonable implementation of the recommendations found elsewhere in this chapter.

Key Areas

Because the goal of this plan is to remove the Hinkson from the 303(d) list of impaired streams by improving water quality, restoration efforts should focus on those stream segments that have historically been classified as not fully supporting of aquatic life. Sampling events from DNR 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 are up to 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.

Retail complexes near Highway 63

The large commercial areas just north of the Hwy 63/Broadway interchange 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. The shear expanse of impervious surface, now approximately 85 acres, allows undetained flow directly into the Hinkson. (To be fair, the development upstream on Clark Lane is now approximately 40 acres, and most likely contributes to the water quality degradation as well.) These areas 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.

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 the Hinkson. Dissolved solids, metals, salt, and other contaminants have been detected in various sampling events conducted by DNR. The drainage area for this tributary includes the MODOT storage facility, a gas station, some hotels, and roads. At this time, MODOT is reportedly moving its facility, which will help tremendously, since they were the 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 run-off 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 area was supposed to be implemented in this area, but has been neglected. Planting trees around this tributary would stabilize its banks and provide better habitat.

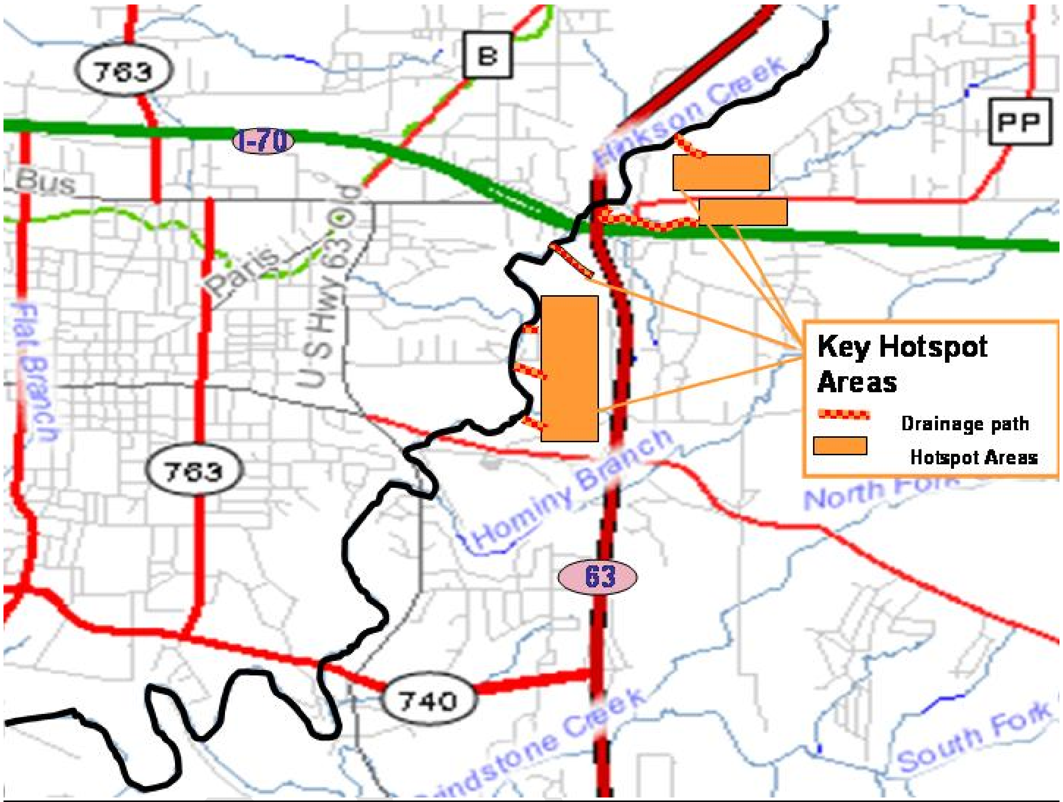

Figure 5 Hotspot locations within the Hinkson Watershed

Load Reductions

Content primarily taken from Center for Watershed Protection's Urban Stormwater Retrofit Practices

As stated earlier, no specific contaminant of concern has been identified, and no load reduction target has been established. The load reductions that follow are several common 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 drainage area is 100% impervious in all scenarios except the stream buffer. Three representative contaminants (sediment, metals, 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 in the table that directly follows.

Table 7. Stormwater Runoff Pollutant 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[1]	5,091	7,000	4,600	2,400	1,700	7,200
NO2 + NO3	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[2]	8.0	7.0	7.57	8.0	10.9	--
Total Cu[2]	16	12	17	20.8	34.7	10
Dissolved Zn[2]	52	31.5	59	112	51	--
Total Zn[2]	116	73	150	199	200	40

Source: Pitt *et al.*, 2004.
[1] MPN/100 mL, which represents the most probable number (MPN) of bacteria that would be found in 100 mL of water
[2] Cu and Zn values are shown in μg/l

Bioretention areas treating 10 acres of impervious parking lot would have 400 ac/in or 33.33 ac/ft or 1,451,000 cubic ft 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 49mg/L, 2,017,045 grams, or 2017 kg of suspended sediment would be present in the stormwater runoff, and 60%, or 1210kg, would be removed from the pollutant load to the Hinkson.

Table 8. Load Reduction of Suspended Sediment by Recommended BMPS

BMP	**Median Load Reduction %**	**Treated area**	**Load Reduction of Suspended Sediment**
Bioretention	60	10ac (commercial)	2017 kg
Swale	80	1ac (road)	326 kg
Stream buffer		10ac (residential)	453kg
Dry Extended Detention basins (raingarden)	50	1ac (residential)	161kg

Table 9. Load Reduction of Bacteria by Recommended BMPS			
BMP	**Median Load Reduction %**	**Treated area**	**Load Reduction of E. Coli (millions of bacteria)**
Bioretention	40	10ac (commercial)	757,421.132800
Swale	-25	1ac (road)	8747.390375 (load increase)
Stream buffer		10ac (residential)	
Dry Extended Detention basins (raingarden)	35	1ac (residential)	100,852.265500

Table 10. Load Reduction of Zinc by Recommended BMPS			
BMP	**Median Load Reduction %**	**Treated area**	**Load Reduction of Zinc (grams)**
Bioretention	80	10ac (commercial)	4939g
Swale	70	1ac (road)	576g
Stream buffer		10ac (residential)	
Dry Extended Detention basins (raingarden)	30	1ac (residential)	0.09g

Table 11. Runoff Reduction by BMPs	
BMP	**Runoff Reduction (%)**
Green Roof	*45 to 60*
Rooftop Disconnection	*25 to 50*
Raintanks 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*
ED Pond	*0 to 15*
Soil Amendments[4]	*50 to 75*
Sheetflow to Open Space	*50 to 75*
Filtering Practice	*0*
Constructed Wetland	*0*
Wet Pond	*0*

Tables 8, 9, and 10 are useful for estimating pollutant reductions that would occur by installing certain BMPs. As stated before, the targeted "pollutant" in this case is the run-off itself. Thus, runoff reduction rates of certain BMPs are just as important. Table 11 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.

Recommendations

The majority of the Hinkson watershed within the impaired section is already developed. This can be said of most of the area within city limits. Absent a significant economic downturn, the city is predicted to keep growing, and the remaining greenspaces are likely to shrink. This reduces the opportunities to "fix" water quality problems in areas that are not intensively used (e.g. fields, waste areas). The alternatives are to 1) improve conditions in the upper watershed, and thereby increasing the water quality to a point that the subsequent contamination from the urban areas may not reduce the quality below standards, or 2) retrofit the existing developed areas to treat stormwater where opportunities present themselves. 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 as they occur, and the retrofits can be tailored to the pollutants of concern at a specific area.

Retrofitting requires transforming existing landscapes into more environmentally benign situations. As stated before, the majority of the city is developed, so any retrofits accomplished must be done with the landowner's cooperation. This will require significant education on water quality in general, and some form of incentive to get landowners to make changes to their property. Education on water quality itself is valuable in changing behavior, and can be thought of as retrofitting the existing mindset within the watershed. Changing people's minds on issues such as littering, dumping chemicals into stormdrains, or lawn chemical use, can be a significant factor in restoring water quality, without necessitating structural changes.

At the time of this document, the City of Columbia has implemented a stream buffeer ordinance and stormwater ordinance, and the county is in the process of adopting a stream buffer ordinance. These ordinances are key in protecting water quality in the Hinkson watershed, and some suggestions for improvement are made below. Our recommendations for improving conditions in Hinkson Creek include retrofitting the physical landscape, education, and improvements in ordinance language.

Watershed Retrofitting

Content primarily taken from the Center For Watershed Protection

Retrofits are structural stormwater management measures for urban watersheds 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 12. 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 streambank 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 counter 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 their erosion. There are no current dams on the Hinkson to modify, but all of the tributaries have ponds within their watersheds. Both Hominy and County House have several large (>2ac) ponds that could potentially detain a significant amount of water that could be released over several days. For example, if the outfall structures on the 30 acre Hulen Lakes system were to be modified to store just 6" more water (by installing a notched weir in front of the outfall), 653, 400 cubic feet of water could be detained. If the "notch" on the weir allowed 1 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 6" more water, approximately 1 million cubic ft 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.

Existing ponds can also be reconfigured to incorporate wetland forebays 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 costshare project of the Hinkson project). By placing large stone and backfilling with soil, a serpentine pathway for parking lot runoff was created. Emergent wetland plants were placed in this area, with the intent that they would filter contaminants as water flowed past.

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 built-up watershed like the Hinkson. 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 headcut development that might be traveling upstream from downstream development.

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. 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.

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, useable compactable 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
As mentioned in the "Key Areas" section, some of the parking areas within this watershed have the capability of causing serious run-off problems. Large parking lots (5+ acres) are a good retrofit opportunity to treat runoff quality. Examples in the Hinkson watershed include lots serving the Home Depot Complex, the Lowe's complex, Grindstone Walmart and former south Wal-Mart area, grocery store lots, high schools, hospitals, and University lots. 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.

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 up1,200 ft^2 to treat runoff from 70 acres of mixed use land. Pollutant removal rates average 81 percent for oils and grease, 84 percent for petroleum hydrocarbons, 58 to 94 percent for solids and nutrients, and 68 to 93 percent 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.

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 Landcover 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." In order to reduce run-off and filter pollutants, feasible planting sites within public land, road rights-of-way, and utility easements should be reforested. Planting trees on private lands should also be pursued, and incentives for planting trees could be given by the City, similar to their existing shade-tree program through their Water & Light Division. 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 varied from $400-$700/acre, and does not factor in the maintenance/watering needed.

City Ordinances

Content primarily taken from the City of Columbia Code of Ordinances

As of January 2007, new developments and redevelopments within Columbia city limits will have to set aside land which borders streams having at least 50 ac watersheds. A city stormwater ordinance that affects the run-off rates and treatment of stormwater was also passed in March 2007, which took effect in September 2007.

Overview of Stream Buffer Ordinance

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, slope, and nature of development (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 13. Columbia City Ordinance Stream Buffer Widths

Streamside Zone				Outer Zone			
	Type I Stream	Type II Stream	Type III Stream		Type I Stream	Type II Stream	Type III Stream
Width	50	25	15	Width	50	25	15
Vegetation	Indigenous Vegetation			Vegetation	Type I – Indigenous Vegetation Type II – Managed Lawns Permissible Type III – Managed Lawns Permissible		
Uses	Flood control, footpaths, road crossings, utility corridors			Uses	Biking/hiking paths, flood control, detention/retention structures, utility corridors, storm water BMPs, residential yards, landscaped areas		
Function	Protect the physical and ecological integrity of the stream ecosystem			Function	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 (except by the City) are clearing of existing vegetation, grading and filling, or grazing of livestock.

Overview of Columbia Stormwater Management Ordinance.

The City of Columbia established a set of water quality and water quantity policies to provide reasonable guidance for the regulation of stormwater runoff for the purpose of protecting local water resources from degradation. The purpose of the ordinance is to establish minimum stormwater management requirements and controls to protect and safeguard the general health, safety and welfare of the public residing in watersheds within Columbia. The stormwater ordinance requires a "Level of Service" (LS) method of on-site treatment of run-off. First, the predevelopment run-off characteristics, or "curve number" is computed for a site based on the cover types (pavement, grass, etc), which are given a value rating. The post-development curve numbers are then computed. In order to make up for the difference between these two numbers, various BMPs (with much better value ratings) must be emplaced to intercept on-site run-off, and these structures are included in a stormwater management plan. The final stormwater management plan must be approved prior to approval of the final plat or plan

This ordinance applies to new plats and replats, site plans, development and redevelopment plans. The minimum requirements for stormwater management may be waived in whole or in part by the Board of Adjustment, given certain conditions. If the requirements for stormwater management are waived, the applicant must satisfy the minimum requirements by implementing one of several mitigation measures. Certificates of Occupancy are not issued for a structure on any property until construction of the required stormwater management facilities is completed.

Stormwater Ordinance Revision Recommendations

The City of Columbia's stream buffer ordinances 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 downtown area, the University of Missouri, or current developments.

No detention is required for the downtown area of Columbia known as “The District”, ostensibly because space is tight and redevelopment is encouraged in this area. 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 trucks capable of “scrubbing” and suctioning oily deposits. Another possibility would be increasing the number of trees and tree boxes to intercept more run-off and decrease impervious surface.

The University is not under the jurisdiction of municipal ordinances, though they are a regulated MS4 and have to address stormwater through their 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 municipal ordinance. They should also be invited to be members of the steering committee for the future Hinkson grant, since they are large landowners within the impaired section of the watershed.

The stream buffer ordinance should be amended to delete “manicured lawns” 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 halves the buffer area. Sewer lines and other utility lines that can interfere with mature woody vegetation should be barred from the streamside buffer zone entirely. 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.

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 storm-water 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 run-off. Revisions to the land disturbance permit process should be made to reduce the time that land sits relatively unprotected from run-off. Reductions in the amount of grading that can occur on a site, or reducing the amount of area that can have its topsoil removed, would also help with infiltration of stormwater run-off.

Incentives for Retroactive Stormwater Controls

Since the stormwater ordinances cannot be made retroactive, a funding mechanism should be pursued that will pay for an incentive fund for retrofitting stormwater controls in existing developments. Large incentives for redeveloping vacant areas, such as paying for all needed stormwater controls, should be provided by the City. Sprawling development can cost the city more because of the greater distance that city-financed infrastructure such as roads, sewers, and utilities, must reach. The potential savings in infrastructure could be used as incentive funds for redevelopment. Currently, the city's incentive for redevelopment is to waive stormwater requirements if the redevelopment cost does not exceed 50% of the value of the property. This obviously does not benefit water quality.

Future Grants

Content primarily taken from the Hinkson Creek Watershed Restoration Project Phase II and the Thomas Jefferson Agricultural Institute 319 grant proposasl Additional information can be found in Appendix C

At least three 319 grant-funded projects have been proposed for the Columbia area/Hinkson watershed for 2008. These projects have objectives of educating the public on stormwater issues and funding examples of stormwater treatment technology. The City has received grants for educational programs in the past, and will likely do so in the future.

Proposed Rainbarrel and Raingarden Projects

The Missouri River Communities Network has submitted a 319 minigrant proposal to cost-share installation of raingardens within the Columbia area. They have also proposed to construct and sell reduced-priced rainbarrels.

Proposed Future Hinkson Outreach Project

The Boone County Commission and current Hinkson Urban Conservationist have submitted a proposal for an "implementation" 319 grant to DNR. Funding this grant proposal is recommended because it provides the only incentive for retrofitting existing developments within the Hinkson watershed. It also contains many avenues for educating the public on stormwater issues.

A Project Steering Committee comprised of representatives from the Missouri Department of Conservation, Boone County Soil and Water Conservation District, City of Columbia, University of Missouri, and Boone County, will provide guidance for this proposed project. A website will provide information on grant cost-share programs, monitoring results, and efforts to improve water quality on the Hinkson and its tributaries. Public service announcement short films will be developed for broadcast by local TV. The main focus of the grant will be to costshare retrofitted stormwater BMPs within the Hinkson watershed area. The grant will also fund riparian corridor restoration and bank stabilization projects.

Proposed Future Jefferson Institute Project

This two year project will provide innovative solutions to reducing surface runoff from municipal and agricultural sources. The suite of best management practices being implemented for this project will take place at the new Jefferson Farm and Gardens facility. This new public educational farm is currently under development on 67 acres of the 1500 acre University of Missouri South Farm, on the southeast edge of Columbia. The Jefferson Farm will include a variety of agricultural, horticultural, and conservation components, with an emphasis on environmentally-sound land management. Indoor facilities will include an 11,000 square foot visitors' center, attached teaching greenhouse, and livestock barn. The visitors' center will house a large exhibit hall with an indoor display on water quality issues and steps that can be taken to protect water quality in rural and urban settings.

Water quality control measures to be implemented include use of riparian buffers, constructed wetland, bioswales and rain gardens, and permeable paving technologies. An extensive and thorough education and outreach program will educate thousands of landowners and school children about methods of protecting water quality. A variety of tours and workshops will be offered on land management for farmers and rural land owners At all age levels, water quality issues will be included in the curriculum, with a special emphasis on water quality and soil conservation as part of the fifth grade curriculum.

Table 14. Projected Schedule of Implementation

	Current	Short term: 2008-2009	Mid term: 2010-2012	Long term: 2013-2020
Upper Hinkson watershed		-County Stream Buffer ordinance passes -Hinkson Watershed Restoration Project Phase II and Jefferson Institute 319 projects begun	-County Stormwater ordinance passes -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	-Landcover 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 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 streetsweeping occurs -detention built into local road projects	-Landcover 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	-Landcover 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

Potential Funding Sources

Funding for many of the educational milestones will come mainly from 319 grants disseminated by the DNR. The Hinkson Phase II grant has a proposed budget of $550,000 total, $315,000 coming from 319 grants, and the remainder will come from local partners. The Jefferson Institute proposal has a budget of $348,000, $188,000 coming from DNR, the remainder coming from local 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 the Hinkson 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.

Chapter 7 Monitoring Criteria and Milestones

In order to determine whether the goals of this plan are being met, milestones, or interim targets, should be set to chart progress. Criteria for achievement must also then be formulated for these milestones, and an overall monitoring plan will outline the entire process.

<u>Measureable Milestones</u>
The goals of this plan are to improve the quality of the Hinkson to remove it from the impaired list, and to reduce the flashiness of the stream. These goals will be accomplished through education and implementing BMPs. The following milestones will gauge whether non-point source management practices are heading in the right direction.

Website- A website providing information on construction BMPs, Low Impact Development practices, cost-share programs, monitoring results, and other pertinent information should be created and maintained for the next 3 years. (This is a milestone of Hinkson Phase II)

Non-point source education workshops- LID, erosion control, Show-Me Yards, and raingarden workshops should be made available to the public and the development community over the next 3 years. (This is a milestone of Hinkson Phase II)

Public Service Announcements with stormwater pollution themes should be produced and broadcast on local tv over the next 3 years. (This is a milestone of Hinkson Phase II)

Water quality protection educational programs and demonstration sites featuring permeable pavement and treatment wetlands will be provided to the public for the next two years. (This is a milestone of the Jefferson Institute 319 grant)

Implementation
Twenty rain gardens should be established and cost-shared in multiple neighborhoods within the next 3 years. (This is a milestone of MNRC's raingarden minigrant)

Four bioretention structures and other LID structures should be retrofitted into existing commercial, residential, and publicly owned landscapes and integrated into new developments to detain and treat stormwater runoff from impervious areas within the next 3 years. (This is a milestone of Hinkson Phase II)

Rainbarrels should be promoted, and residents and business owners within the watershed will be partially reimbursed for purchasing 100 rainbarrels within the next 3 years. (This is a milestone of MNRC's raingarden minigrant)

10 acres of trees should be planted around streams and 500' of streambanks will be stabilized within the next 3 years. (This is a milestone of Hinkson Phase II)

Columbia's stream buffer and stormwater ordinances should remain in current form or be made more stringent. Boone county should adopt similar ordinances in the next year (2008). All new developments should incorporate stormwater treatment structures in accordance with the municipal stormwater ordinance.

Monitoring and Measures of Success

In order to determine whether elements of this plan are having a significant impact on the water quality of the Hinkson, monitoring of progress should occur.

Individual stormwater BMPs should be monitored for their effectiveness of pollutant removal. This management plan, as well as the Columbia city ordinance, make assumptions that stormwater treatment structures such as raingardens, sand filters, and wetlands are removing a significant amount of pollutant into are creeks. If they are not performing up to standards (such as the national BMP database), the recommended BMPs should be changed accordingly.

Stormwater complaints, and the location of the complaints, are tracked by Columbia public works staff. Flooding and erosion problems should be reduced as the stream buffer and stormwater ordinances take affect, and BMPs are retrofitted within the watershed. A reduction in per capita stormwater complaints should occur each successive year. Ideally, stormwater complaints should diminish in areas where stormwater BMPs have been implemented.

The mainstem Hinkson Creek should be monitored for macroinvertebrate health throughout its impaired length, using previously monitored areas for consistency. A score of 16 will indicate that the stream segment is fully sustaining in a given area. The Hinkson will be considered fully supporting of warm water aquatic life when all sites are fully supporting, which will of course be the first step in de-listing the stream from the 303(d) list. It is assumed that continued monitoring of the Hinkson will be performed by DNR.

The flow of Hinkson Creek should be monitored to determine if peak flows are being reduced, and low flows are being increased as a result of efforts (ordinances, education, costshared BMPs) to improve the water quality. A proposed project by a University of Missouri professor will use an established USGS monitoring station and set up four additional monitoring stations to investigate the water budget of the Hinkson system. Each station will be equipped with dataloggers, automated flow and sediment related sensors/samplers, and meteorological stations to measure precipitation. The outputs from the project will include hydrograph data, to determine water yield, flow regimes, peak flushing events and continuous sediment data.