Missouri Department of Natural Resources
Water Protection Program

Total Maximum Daily Loads (TMDLs)

for

Gravois Creek
St. Louis County and
St. Louis City, Missouri

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Total Maximum Daily Load (TMDL) for Gravois Creek
Pollutant: Bacteria

Name:
Gravois Creek


State Map Showing Location of Watershed

Location:
St. Louis County and St. Louis City

12-digit Hydrologic Unit Code (HUC):
071401010505 – Gravois Creek

Water Body Identification Number (WBID) and Missouri Stream Classification:[1]
WBID 1712 – Class P
WBID 1713 – Class C

Designated beneficial uses:[2]
Livestock and wildlife watering
Protection of warm water aquatic life
Protection of human health (fish consumption)
Metropolitan no-discharge stream
Whole body contact recreation – Category B

Use that is Impaired:
Whole body contact recreation – Category B

Length and locations of impaired segments:[3]
WBID 1712 2.3 miles, from mouth to Section 24, T44N, R6E
(Latitude, Longitude: 38.5481, -90.2719 to 38.5408, -90.2990)
WBID 1713 6 miles, from Section 24, T44N, R6E to Section 16, T44N, R6E
(Latitude, Longitude: 38.5408, -90.2990 to 38.5472, -90.3482)

Pollutant on 2010 303(d) List:
Bacteria (*Escherichia coli, or E. coli*)

[1] For stream classifications see 10 CSR 20-7.031(1)(F). Class P streams maintain flow during drought conditions. Class C streams may cease flow during dry periods, but maintain permanent pools that support aquatic life.
[2] For designated beneficial uses see 10 CSR 20-7.031(1)(C) and 10 CSR 20-7.031 Table H.
[3] Length of water body segments are revised in 10 CSR 20-7.031 Table H, effective October 2009. These lengths differ from what is presented on the 2010 303(d) list of impaired waters. These revisions reflect more accurate measurements of length. The locations and starting and ending points of these segments have not changed. Revisions to 10 CSR 20-7.031 were approved by the U.S. Environmental Protection Agency on August 12, 2011.

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1. Introduction

The Missouri Department of Natural Resources in accordance with Section 303(d) of the federal Clean Water Act is establishing this Gravois Creek Total Maximum Daily Load, or TMDL. These water quality-limited segments in St. Louis County and city are included on Missouri's 2010 303(d) List of impaired waters, which was approved by the U.S. Environmental Protection Agency on Oct. 6, 2011. Gravois Creek is listed as impaired due to bacteria. Previous 303(d) listings cited urban nonpoint sources as the cause of the impairment. This report addresses the Gravois Creek bacteria impairment by establishing TMDLs for *Escherichia coli*, or *E. coli*. Data analyses conducted to support these listings and TMDL development indicate that *E. coli* bacteria are present at concentrations that result in exceedances of Missouri's water quality criteria for the whole body contact recreation category B designated beneficial use.

Section 303(d) of the federal Clean Water Act and Chapter 40 of the Code of Federal Regulations (CFR) Part 130 requires states to develop TMDLs for waters not meeting designated beneficial uses. The TMDL process quantitatively assesses the impairment factors so that states can establish water quality-based controls to reduce pollution and restore and protect the quality of their water resources. The purpose of a TMDL is to determine the pollutant loading a water body can assimilate without exceeding state water quality standards. Missouri's water quality standards consist of three components: designated beneficial uses, water quality criteria to protect those uses and an antidegradation policy. The TMDL establishes the pollutant loading capacity necessary to meet the water quality standards established for each water body based on the relationship between pollutant sources and instream water quality conditions. A TMDL consists of a wasteload allocation, a load allocation, and a margin of safety. The wasteload allocation is the fraction of the total pollutant load apportioned to point sources. The load allocation is the fraction of the total pollutant load apportioned to nonpoint sources. The margin of safety is a percentage of the TMDL that accounts for any uncertainty associated with the model assumptions as well as any data inadequacies.

Gravois Creek was first listed as impaired by bacteria in 2006 due to data showing elevated *E. coli* concentrations. The state's current listing methodology determines a water to be impaired by bacteria if the geometric mean in a given recreational season exceeds the water quality criteria in any of the last three years for which there are available data. This listing methodology also states that at least five samples are needed during the recreational season in order to determine impairment. Data for Gravois Creek do not meet these requirements; however, the listing methodology in 2006 did not have this requirement. Due to the lack of any additional data showing good cause for delisting, Gravois Creek remained listed as impaired on the 2008 and 2010 303(d) lists.

In addition to bacteria, Gravois Creek is also on the 2010 303(d) List as impaired by chloride and low dissolved oxygen. Separate TMDLs will be developed to address these pollutants and are currently scheduled for completion in 2014 for chloride and 2016 for low dissolved oxygen.

2. Background

Gravois Creek is an urban stream located in eastern Missouri in St. Louis County, and includes two classified water body segments. Water body identification number, or WBID, 1712 is the downstream segment, and WBID 1713 is the upstream segment (Figure 1). Gravois Creek is located in the Apple/Joachim Ecological Drainage Unit[4], or EDU, in the Ozark aquatic subregion[5] (MoRAP 2005a). Gravois Creek originates in eastern Kirkwood, Mo. and flows generally west to east for approximately 13 miles before entering the River des Peres in St. Louis at about 1.5 miles upstream of where it enters the Mississippi River. The Gravois Creek watershed drains approximately 22.5 square miles.

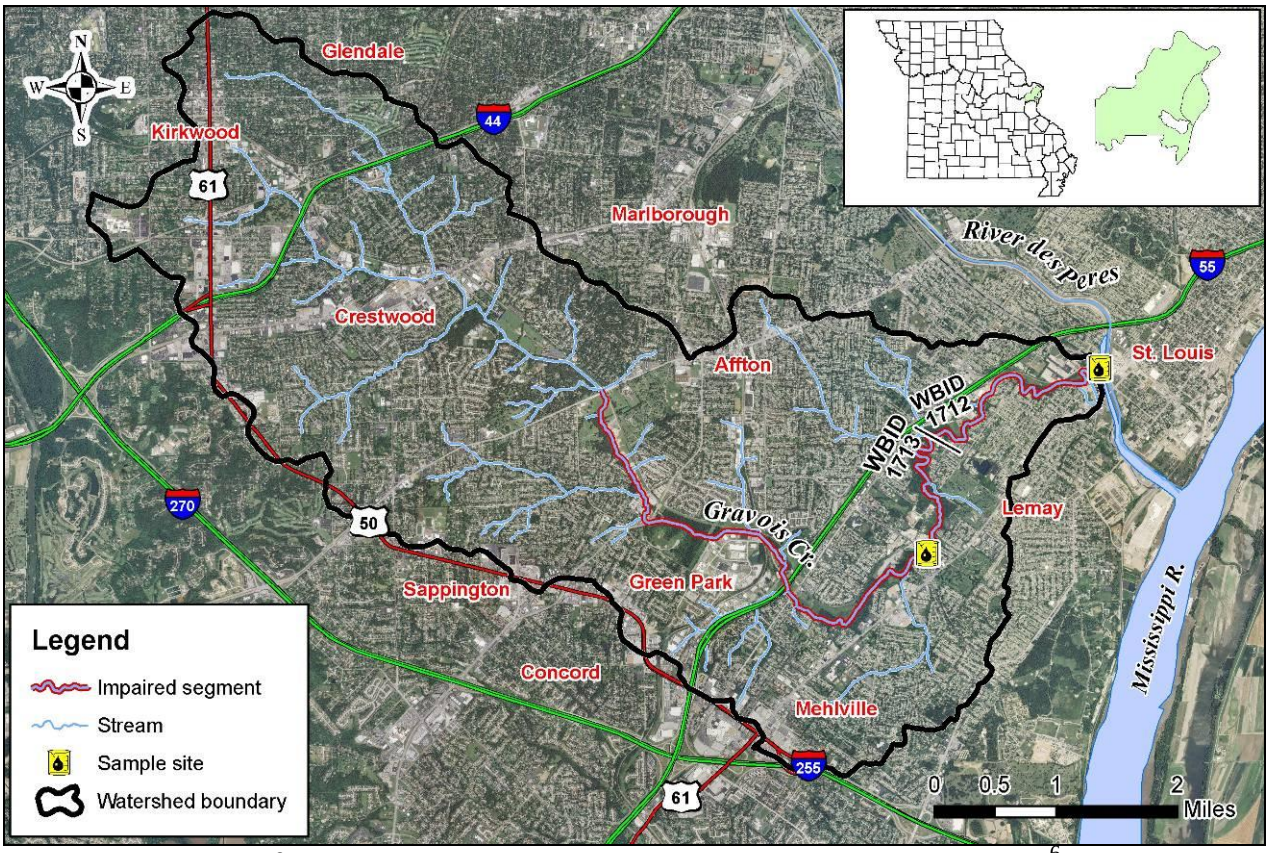

Figure 1. Location of the Gravois Creek watershed in St. Louis County, Missouri[6]

[4] Ecological Drainage Units are groups of watersheds having generally similar biota, geography, and climatic characteristics (USGS 2009).
[5] Missouri's three aquatic subregions are the Central Plains, the Mississippi Alluvial Basin, and the Ozark (MoRAP 2005a).
[6] Sampling sites from downstream to upstream (east to west): 1) Gravois Creek near mouth at Webber Ave and Tennessee St. and 2) Gravois Creek at Green Park Rd, Mehlville, Mo.

2.1 Geology, Physiography and Soils

Gravois Creek is located within the Cahokia-Joachim subbasin, identified by the 8-digit hydrologic unit code,[7] or HUC, 07140101. This subbasin lies within both Illinois and Missouri. Within Missouri, this subbasin contains portions of the River Hills, Middle Mississippi Alluvial Plain, and Eastern Ozark Border level IV ecoregions.[8] The Gravois Creek watershed is contained almost entirely within the River Hills ecoregion. This area is a transition zone between the Central Irregular Plains and the Ozark Highlands. Key characteristic features of the River Hills are loess-covered hills and numerous karst features (Chapman et al. 2002). Karst features in the Gravois Creek watershed include 149 sinkholes (CARES 2010).

Water body segment 1712 of Gravois Creek has a stream length of 2.3 miles. The topographic relief along this segment is generally 23 feet along the stream valley up to 108 feet in the adjoining uplands. The elevation of WBID 1712 ranges from approximately 413 feet above sea level (upstream) to 390 feet (downstream). Water body segment 1713 of Gravois Creek has a stream length of 6 miles. The topographic relief along this segment is generally 62 feet along the stream valley up to 197 feet in the adjoining uplands. The elevation of WBID 1713 ranges from 475 feet (upstream) to 413 feet (downstream). The elevation of the entire Gravois Creek watershed ranges from approximately 669 feet (upstream) to 390 feet (downstream) (CARES 2005).

Soils in the Gravois Creek watersheds are varied, but can be grouped based on similar characteristics. Table 1 provides a summary of hydrologic soil groups in the Gravois Creek watershed. Hydrologic soil groups categorize soils by their runoff potential. A soil's hydrologic soil group relates to the rate at which water enters the soil profile, which in turn affects the potential amount of water entering the stream as runoff. Group A represents soils with the highest rate of infiltration and group D represents the group with the lowest rate of infiltration. The dominant soil group in the Gravois Creek watershed is Group D, which covers approximately 59 percent of the watershed. This hydrologic soil group has the highest runoff potential. In general, soils within this group have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. Soils within the second most represented group, Group C, cover about 25 percent of the watershed. Group C includes sandy clay loam soils that have a moderately fine to fine structure. These soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water. Group B soils, which include silt loam and loam that have moderate infiltration rates account for the remaining 6 percent of rated soils in the watershed. These soils consist of well-drained soils with moderately fine to moderately coarse textures (NRCS 2007). The remaining area of the watershed was not rated. Areas not rated are typically areas of open water, quarries or landfills. In the Gravois Creek watershed, most areas not rated in a hydrologic soil group are classified as being of the soil type Urban land, upland, 0 to 5 percent slopes. This soil type is classified as being 90 percent urban land and has no specific associated soil data given (NRCS 2010). Figure 2 shows the location and distribution of these hydrologic soil groups throughout the watershed.

[7] Watersheds are delineated by the U.S. Geological Survey using a nationwide system based on surface hydrologic features. This system divides the country into 2,270 8-digit hydrologic units (USGS and NRCS 2011).

[8] Ecoregions are areas with similar ecosystems and environmental resources. A level I ecoregion is a coarse, broad category, while a level IV is a more defined grouping.

Table 1. Hydrologic soil groups in the Gravois Creek watershed (NRCS 2009)

Hydrologic Soil Group	***Group A***	***Group B***	***Group C***	***Group D***	***Not Rated***
Square Miles	0	1.44	5.58	13.34	2.21
Percentage	0%	6.4%	24.7%	59.1%	9.8%

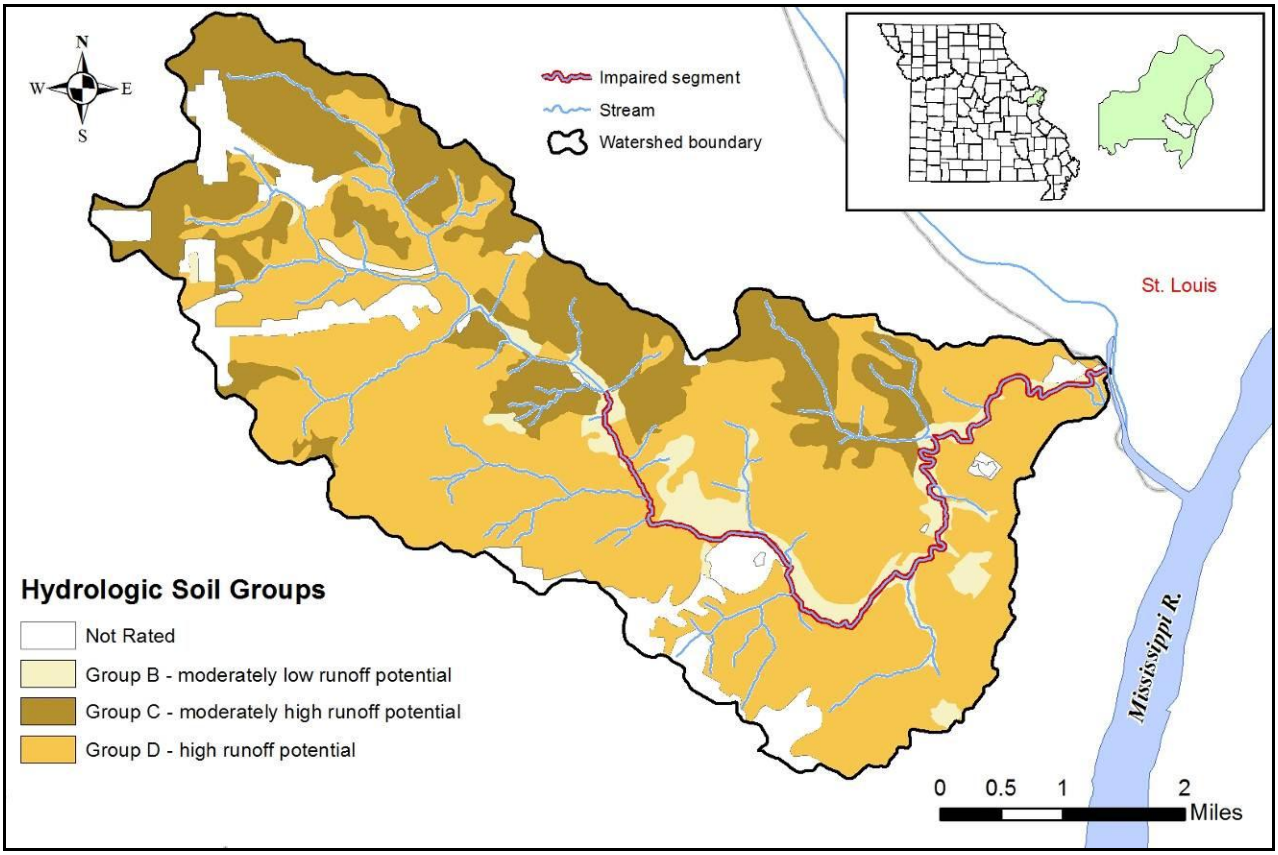

Figure 2. Hydrologic soil groups in the Gravois Creek watershed (NRCS 2009)

The hydrologic soil groupings within the Gravois Creek watershed are comprised of 24 individual soil types. The five most abundant soil types found in the Gravois Creek watershed are defined as being primarily urban land with an accompanying soil type, and cover approximately 69 percent of the watershed (Table 2). These five abundant soil types are derived from loess parent materials and are silt loams with a silt clay loam component. The most abundant is the Urban land-Harvester complex, karst, with 2 to 9 percent slopes. This soil type is defined as being 60 percent urban land and karst, and 30 percent Harvester or similar soils. This soil type is found along hill slopes, sinkholes and interfluves. It is moderately well drained and is not prone to frequent flooding. Urban land-Harvester complex, 9 to 20 percent slopes, is the second most abundant soil type in the Gravois Creek watershed. It is defined as being composed of 55 percent urban land and 25 percent

Harvester and similar soils. This soil type is found primarily on hill slopes and is also moderately well drained and not prone to frequent flooding. The third most abundant soil type in the watershed is Urban land-Harvester complex, 2 to 9 percent slopes. This soil type is defined as being 50 percent urban land and 40 percent Harvester and similar soils. This soil is found along interfluves and hill slopes, is moderately well drained and not prone to frequent flooding. The fourth most abundant soil type is classified as Urban land, upland, 0 to 5 percent slopes. As previously noted, no specific soil data are available for this soil type as it is defined as 90 percent urban. The fifth most abundant soil type is Winfield-Urban land complex, 5 to 9 percent slopes, which is comprised of 55 percent Winfield soils and 35 percent urban land. This soil type is found on hill slopes and ridges, is moderately well drained, and is not prone to frequent flooding (NRCS 2010).

Table 2. Abundant soil types in the Gravois Creek watershed (CARES 2010)

Soil Type	***Acres***	***Percent***
Urban land – Harvester complex, karst, 2 to 9 percent slopes	3,919	27.15 %
Urban land – Harvester complex, 9 to 20 percent slopes	2,003	13.87 %
Urban land – Harvester complex, 2 to 9 percent slopes	1,665	11.53 %
Urban land, upland, 0 to 5 percent slopes	1,238	8.57 %
Winfield-Urban land complex, 5 to 9 percent slopes	1,199	8.30 %

2.2 Rainfall and Climate

Weather stations provide useful information for developing a general understanding of climatic conditions in the watershed. The St. Louis Science Center and the St. Louis International Airport weather stations are the closest sources to the Gravois Creek watershed with recent and available weather and climate data. Both of these stations are expected to provide climate data that are representative of the impaired watershed. The St. Louis International Airport weather station is located in St. Louis County about 11 miles north of the Gravois Creek watershed between the municipalities of Bridgeton and Berkeley. The St. Louis Science Center weather station is located in St. Louis City about 6 miles northeast of the Gravois Creek watershed. Both stations record daily precipitation, maximum and minimum temperatures, snowfall and snow depth data. The locations of these weather stations in relation to the Gravis Creek watershed are shown in Figure 3.

Precipitation is an important factor related to stream flow and stormwater runoff events that can influence certain pollutant sources. The average annual precipitation and annual average minimum and maximum temperatures over the 30-year period from 1981 through 2010 are 40.92 inches and 47.8/66.1 degrees Fahrenheit (°F) for the St. Louis International Airport station and 41.29 inches and 48/66.3 °F for the St. Louis Science Center weather station (NOAA 2011). The 30-year climate data from these stations are summarized in Figure 4.

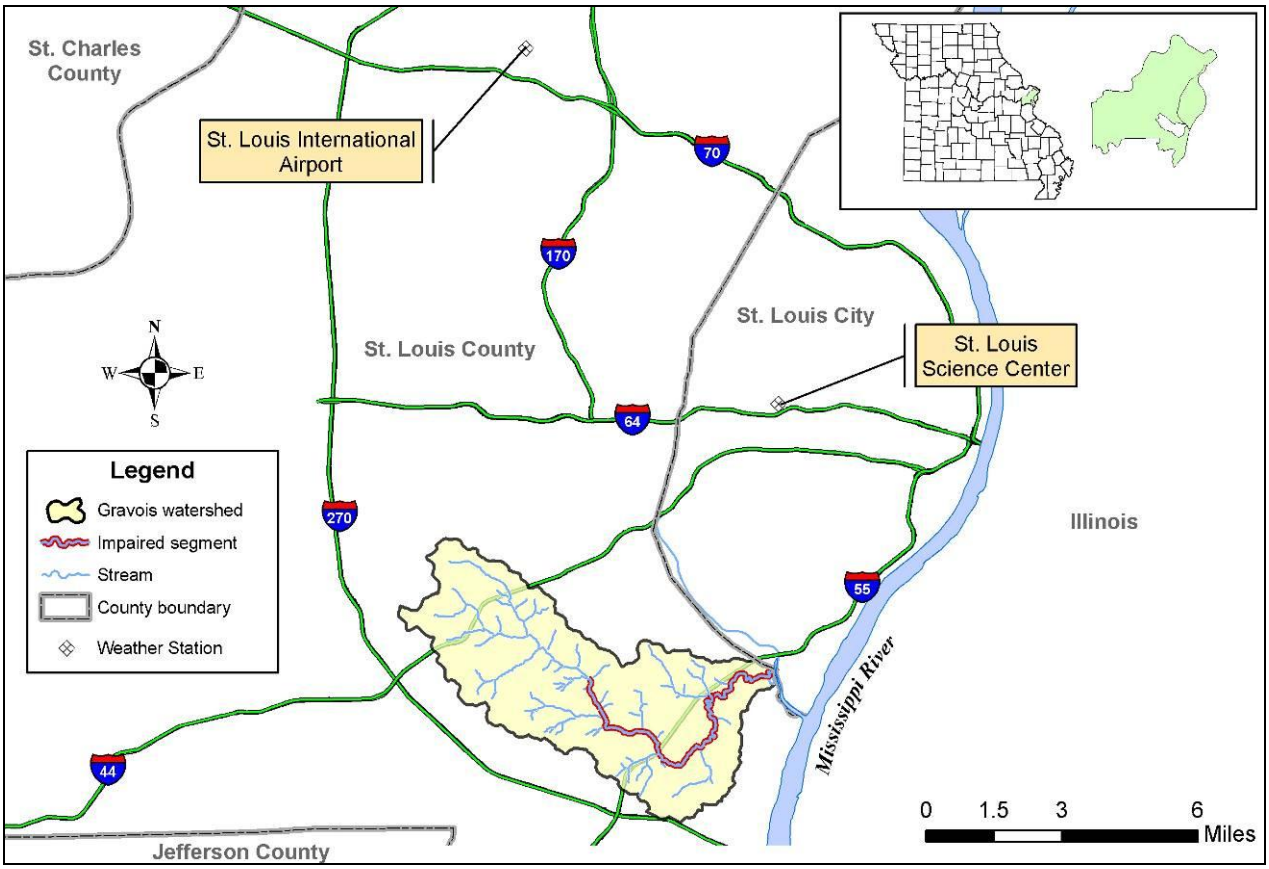

Figure 3. Location of weather stations near the Gravois Creek watershed

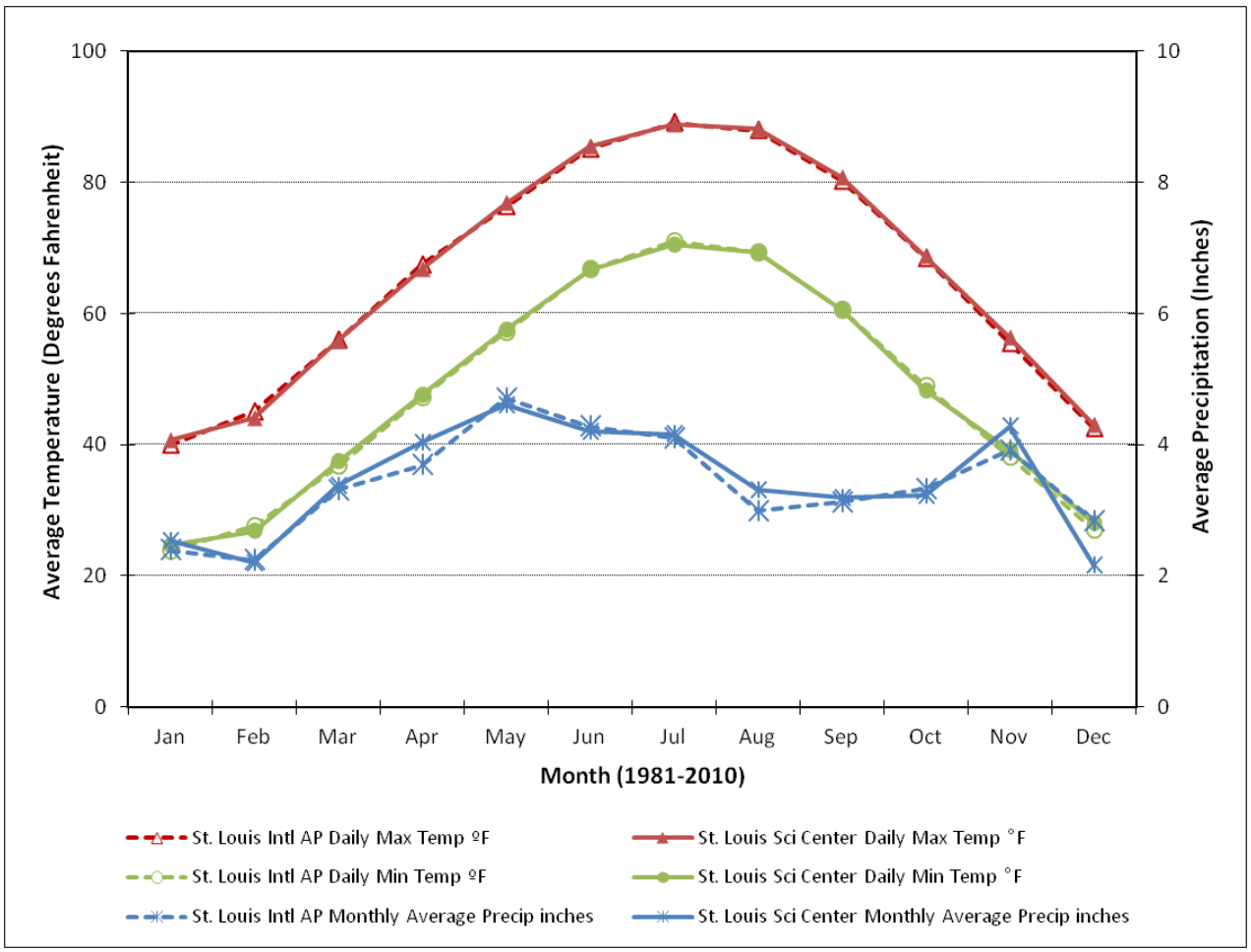

Figure 4. Thirty-year monthly temperature and precipitation averages for the St. Louis International Airport and Science Center weather stations.

2.3 Population

St. Louis County covers an area of 523 square miles and, according to 2010 census data, has a population of 999,021 people (U.S. Census Bureau 2010). The population of the Gravois Creek watershed is not directly available; however, using U.S. Census Bureau census block data from 2010, the population of the Gravois Creek watershed is estimated to be approximately 78,969. The entire watershed area is considered by the U.S. Census Bureau to be urban (EPA 2002).

This population estimation was completed by using GIS software and superimposing the watershed boundary over a map of census blocks. Whenever the centroid of a census block fell within the watershed boundary, its total population was included in the total. If the centroid of the census block was outside the watershed boundary, then the population was excluded.

EPA completed a similar analysis using 2000 census data and 12-digit hydrologic unit code watershed boundaries and determined that the Gravois Creek watershed is an Environmental

Justice watershed.[9] EPA based this determination on the area of the 12-digit watershed and the percentages of racial minority and low-income populations (Steve Schaff, EPA, e-mail communication, June 30, 2011). Environmental Justice communities may qualify for financial and strategic assistance for addressing environmental and public health issues (EPA 2011).

2.4 Land Use and Land Cover

Land use calculations are based on data from 2000 to 2004 at 30-meter resolution obtained from Thematic Mapper imagery (MoRAP 2005b). These calculations are presented in Table 3. Figure 5 graphically presents the available land use data for the Gravois Creek watershed. Because WBID 1712 is the downstream segment of Gravois Creek, the land use data for this segment comprises the entire watershed including the drainage area of WBID 1713.

Table 3. Land use in the Gravois Creek watershed (MoRAP 2005b)

Land Use Type	***WBID 1712***			***WBID 1713***		
	Acres	***Sq. Miles***	***Percentage***	***Acres***	***Sq. Miles***	***Percentage***
Impervious	1,343	2.10	9.30 %	1,221	1.91	9.14 %
High-Intensity Urban	118	0.18	0.82 %	112	0.18	0.84 %
Low-Intensity Urban	10,250	16.02	70.98 %	9,453	14.77	70.76 %
Row and Close-grown Crops	54	0.09	0.38 %	51	0.08	0.38 %
Grassland	1,494	2.33	10.34 %	1,402	2.19	10.49 %
Forest & Woodland	1,003	1.57	6.94 %	966	1.51	7.23 %
Herbaceous	5	0.01	0.04 %	4	0.01	0.03 %
Wetland	64	0.10	0.44 %	52	0.08	0.39 %
Open Water	44	0.07	0.30 %	31	0.05	0.23 %
Barren	66	0.10	0.46 %	66	0.10	0.49 %
Total:	14,441	22.57	100.00 %	13,358	20.87	100.00 %

The Gravois Creek watershed is predominantly an urban environment. For the entire Gravois Creek watershed, low-intensity urban accounts for the majority of the land use comprising about 71 percent of the total area. Areas categorized as low-intensity urban are defined as vegetated urban environments with a low density of buildings. In the Gravois Creek watershed, these are primarily residential areas. The second most abundant land use type is grassland, which accounts for about 10 percent of the watershed area. Because this is an urban watershed, areas classified as grassland include golf courses, cemeteries, parks, school playgrounds and other open spaces not typically thought of as grassland or pasture. Areas classified as impervious comprise about 9 percent of the watershed area. Impervious areas are non-vegetated areas dominated by streets, parking lots, and buildings. These areas have little, if any, vegetation. Forested areas account for about 7 percent of the watershed area followed by high-intensity urban areas, which comprise 0.8 percent of the total watershed area. High-intensity urban areas are defined as vegetated urban environments with a high density of buildings. Together, open water and wetlands account for 0.7

[9] EPA defines Environmental Justice as the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations and policies.

percent of the watershed. Area classified as cropland accounts for only about 0.4 percent of the watershed, but is likely much less and probably nonexistent. A comparison of the available land use data with 2009 National Agriculture Imagery Program aerial imagery shows areas in the Gravois Creek watershed categorized by this analysis as cropland to include rooftops, parking lots, and baseball diamonds (USDA 2009). Recent crop-specific satellite data from the U.S. Department of Agriculture's National Agricultural Statistics Service also do not indicate that there is any row or close-grown crops in the Gravois Creek watershed (NASS 2009). The remainder of the land use area as well as calculations specific to the drainage area of water body 1713 can be found in Table 3.

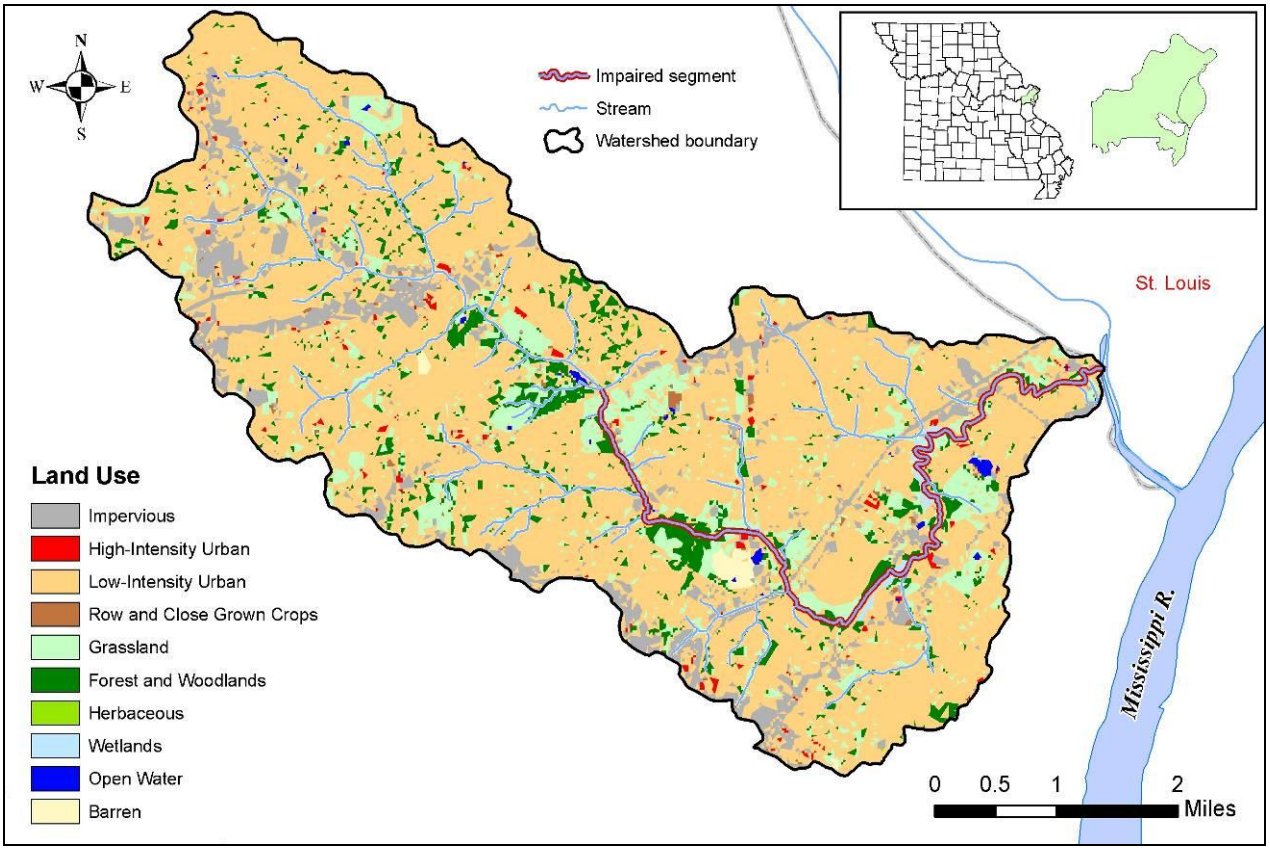

Figure 5. Land use in the Gravois Creek watershed

2.5 Defining the Problem

A TMDL is needed for Gravois Creek, because the Department has determined that this stream is not meeting the state bacteria water quality criteria for whole body contact recreation (See Section 4). Data collected by the U.S. Geological Survey, or USGS, on water body 1713 of Gravois Creek show exceedances of the state's whole body contact recreation category B criterion of 206 *E. coli* counts per 100 milliliters of water (206/100mL). This assessment is based on the geometric mean of samples collected during the state's recreational season (April 1 through October 31). For water body 1712, data were collected by the Metropolitan St. Louis Sewer District. These data also show exceedances of the whole body contact recreation category B criterion. The recreational season bacteria data collected from Gravois Creek are summarized in Table 4 and Figure 6. For water

body 1713, *E. coli* data were collected from 1996 through 2004. *E. coli* data for water body 1712 was collected from 2004 through 2010. A summary of all *E. coli* data by month for both water bodies can be found in Figures 7 and 8 respectively. All available *E. coli* data for Gravois Creek, including samples collected outside the recreational season, can be found in Appendix A. The state's current listing methodology states that at least five samples are needed during the recreational season in order to determine impairment. Data for Gravois Creek do not meet these requirements; however, the listing methodology in 2006, when these streams were fist assessed as impaired, did not have this requirement. Due to the lack of any additional data showing good cause for delisting, Gravois Creek has remained listed as impaired on the 2008 and 2010 303(d) lists.

High counts of *E. coli* are an indication of fecal contamination and an increased risk of pathogen-induced illness to humans. *E. coli* are bacteria found in the intestines of humans and warm-blooded animals and are used as indicators of the risk of waterborne disease from pathogenic bacteria or viruses (EPA 1997). Infections due to pathogen-contaminated waters include gastrointestinal, respiratory, eye, ear, nose, throat, and skin diseases. To address these health risks, this TMDL targets instream bacteria levels using *E. coli* as the primary measurement parameter.

Table 4. Recreational season *E. coli* data for Gravois Creek*

Water Body ID	***Year***	***Sampling Events***	***Geometric Mean***	***Minimum***	***Maximum***	***WBC Category†***	***Criterion***
1713	1996	2	24,083	10,000	58,000	B	206
	1997	1	5,000	5,000	5,000	B	206
	1998	2	19,799	5,600	70,000	B	206
	1999	3	1,689	80	8,600	B	206
	2000	3	4,179	2,200	7,900	B	206
	2001	3	526	30	11,000	B	206
	2002	3	1,119	67	11,000	B	206
	2003	4	1,522	88	47,000	B	206
	2004	2	201	150	270	B	206
1712	2004	1	49.9	49.9	49.9	B	206
	2005	2	2,100	2,100	2,100	B	206
	2006	1	49.9‡	49.9	49.9	B	206
	2007	3	2,530	2,000	3,000	B	206
	2009	4	275	161	585	B	206
	2010	1	2,755	2,755	2,755	B	206

* The units for all *E. coli* values are counts/100 mL of water. For calculation purposes, *E. coli* measurements recorded as greater than (>) values were doubled and measurements recorded as less than (<) values were halved.
† WBC = whole body contact recreation

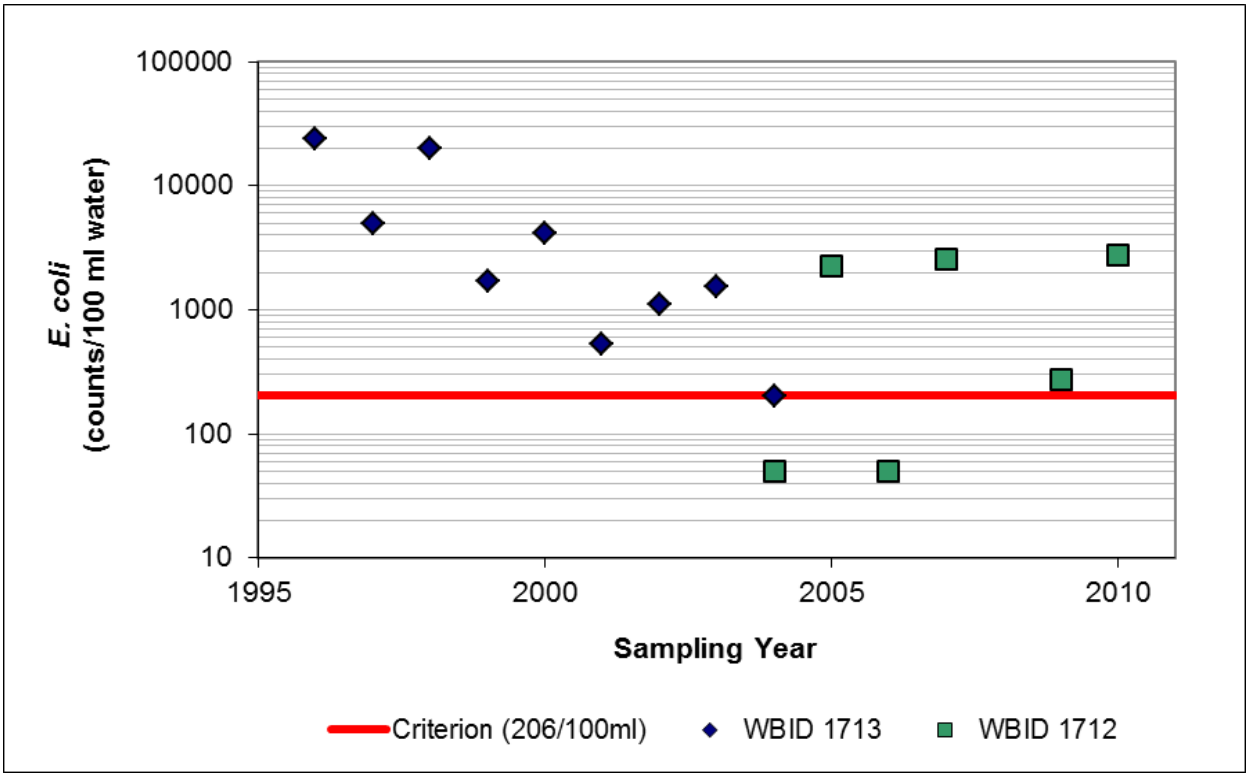

Figure 6. 1996 - 2010 recreational season geometric mean *E. coli* data for Gravois Creek

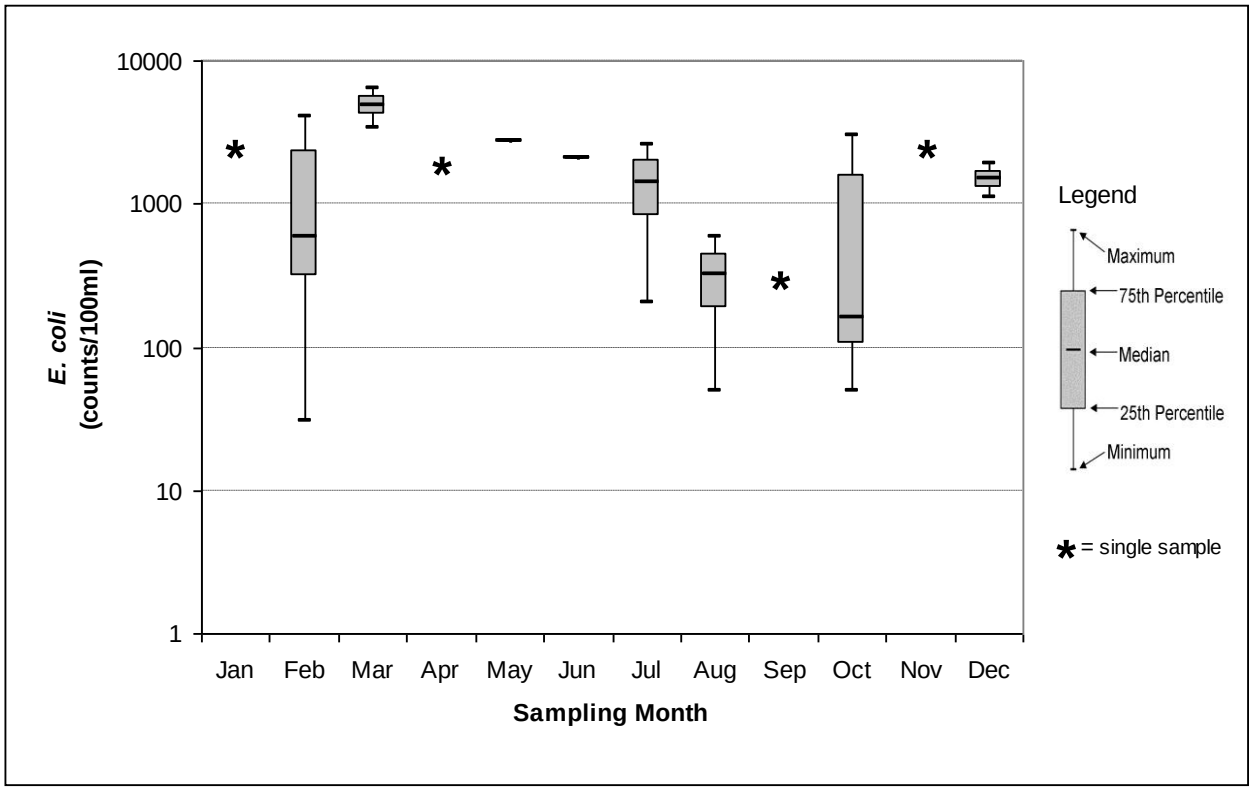

Figure 7. Monthly *E. coli* data for WBID 1712 from 2004 - 2010

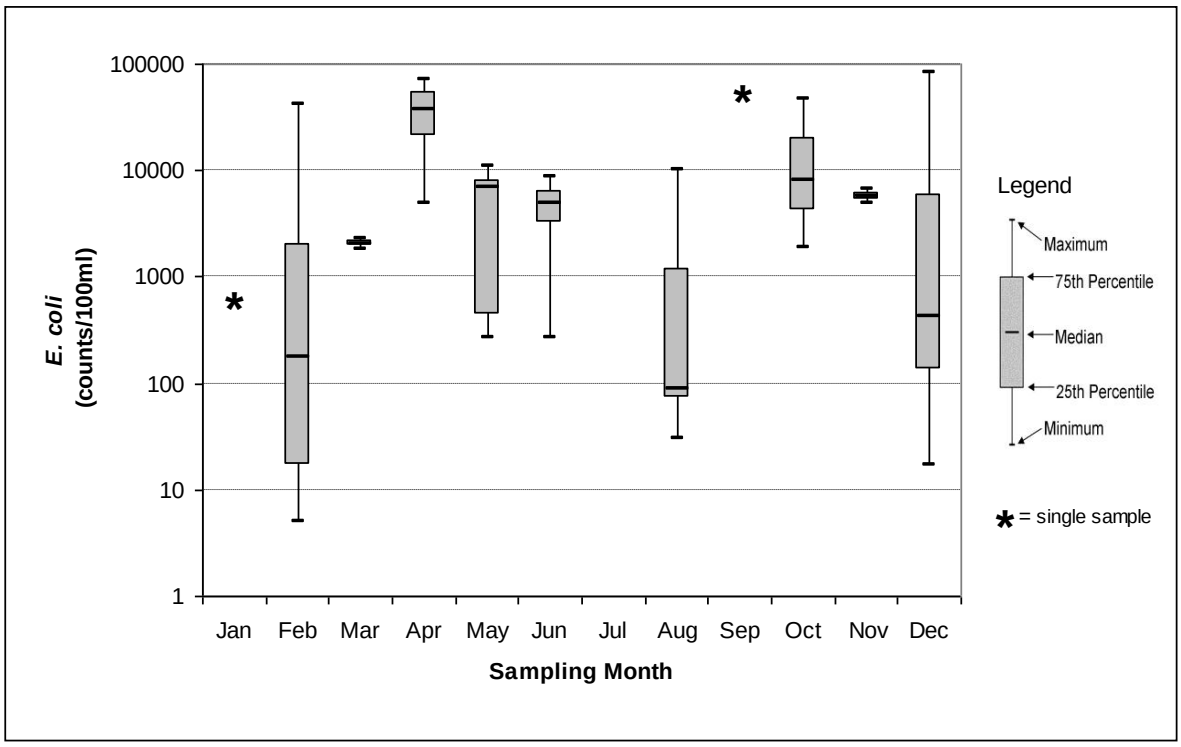

Figure 8. Monthly *E. coli* data for WBID 1713 from 1996 - 2004

3. Source Inventory and Assessment

Source inventory and assessment characterizes known, suspected and potential sources of pollutant loading to the impaired water body. Pollutant sources identified within the watershed are categorized and quantified to the extent that information is available. Sources of pollutants may be point (regulated) or nonpoint (unregulated) in nature.

3.1 Point Sources

Point sources are defined under Section 502(14) of the federal Clean Water Act and are typically regulated through the Missouri State Operating Permit program[10] and include any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel or conduit, by which pollutants are transported to a water body. Under this definition, point sources include domestic and municipal wastewater treatment facilities, concentrated animal feeding operations, or CAFOs, stormwater discharges from municipal seperate storm sewer systems, illicit straight pipe discharges, and stormwater runoff from construction and industrial sites. Designated as a Metropolitan No-Discharge Stream, no water contaminant except uncontaminated cooling water, permitted stormwater discharges in compliance with permit conditions and excess wet-weather bypass discharges not interfering with beneficial uses may be discharged into the Gravois Creek watershed per 10 CSR 20-7.031(6).

[10] The Missouri State Operating system is Missouri's program for administering the federal National Pollutant Discharge Elimination System (NPDES) program

At the time this document was written, the Gravois Creek watershed contained 47 permitted facilities. Two of these facilities have general permits and the remaining 45 have stormwater permits. There are no facilities with site-specific permits in the Gravois Creek watershed, nor are there any permitted CAFOs. Figure 9 shows the location of the permitted outfalls within the watershed.

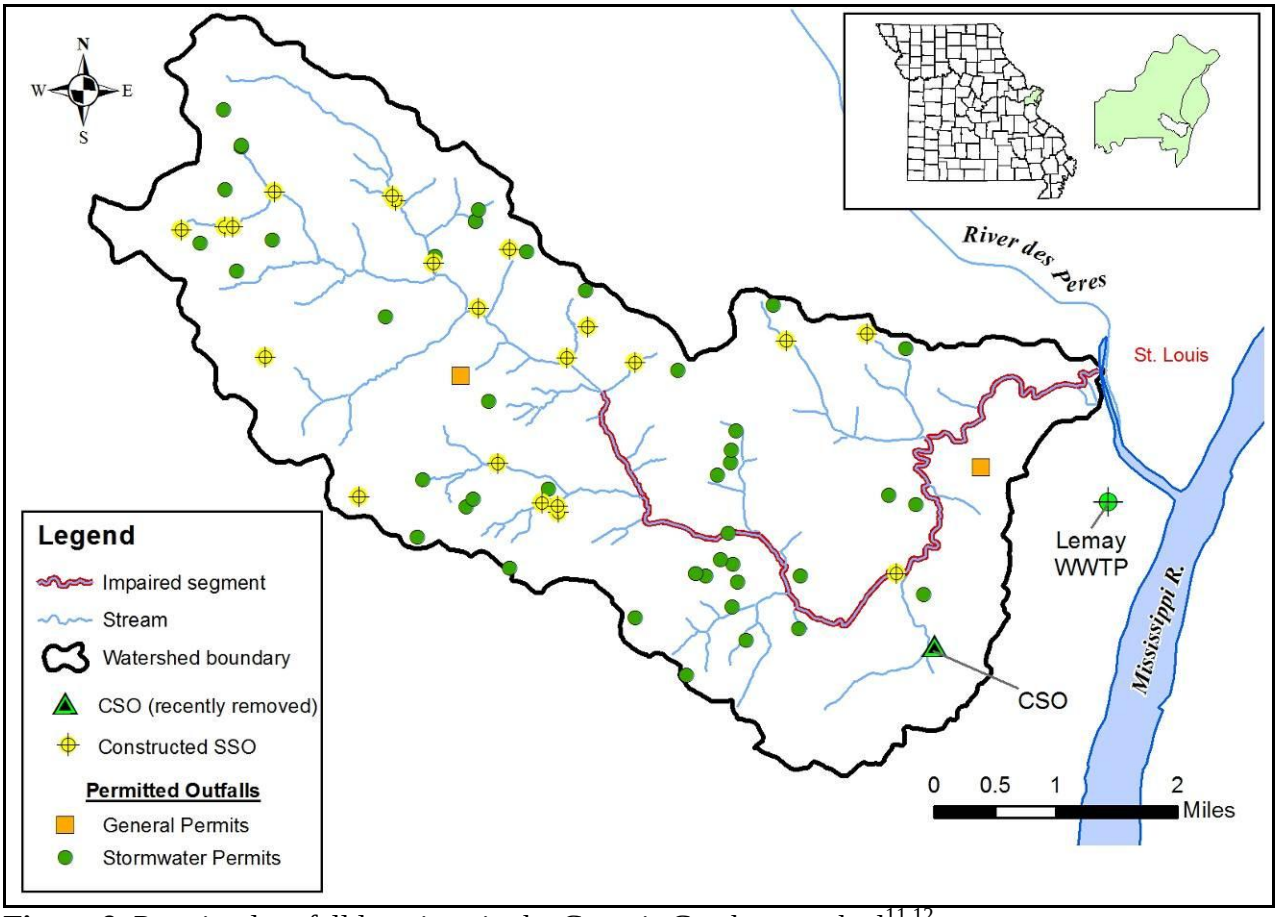

Figure 9. Permitted outfall locations in the Gravois Creek watershed[11,12]

3.1.1 Municipal and Domestic Wastewater Permits

There are no municipal or domestic wastewater permitted facilities or outfalls in the Gravois Creek watershed. However, the urban area within the watershed is serviced by a sanitary sewer system maintained by the Metropolitan St. Louis Sewer District. A sanitary sewer system is designed to carry household waste, which includes both greywater and sewage, to a wastewater treatment facility, in this case the Lemay wastewater treatment facility located outside the watershed (Figure 9). Although the treatment facility is located outside the watershed, the presence of the sewerage system infrastructure within the Gravois Creek watershed is a potential source of bacteria due to possible malfunctions, vandalism, mismanagement, or excessive storm

[11] CSO = combined sewer overflow (separated and removed); WWTP = wastewater treatment plant
[12] An MS4 permit regulates the entire watershed area, permit no. MO-R040005.

flows that can cause sewage to discharge into Gravois Creek. Such discharges, known as sanitary sewer overflows, are unpermitted and are not authorized by the federal Clean Water Act. Occurrences of sanitary sewer overflows can result in elevated bacteria concentrations. Constructed sanitary sewer overflows are present in the Gravois Creek watershed and were installed to relieve the sanitary sewers during high rain events (Paul Morris, Missouri Department of Natural Resources St. Louis Regional Office, e-mail communication, Feb. 7, 2011). Data from the Metropolitan St. Louis Sewer District show there to be 21 constructed sanitary sewer overflows in the Gravois Creek watershed (Bruce Litzsinger, Metropolitan St. Louis Sewer District, e-mail communication, March 14, 2012). Dry weather sanitary sewer overflows also can occur. In 2010, four dry weather sanitary sewer overflows occurring in the Gravois Creek watershed were reported to the Department (Paul Morris, Missouri Department of Natural Resources St. Louis Regional Office, e-mail communication, March 30, 2011).

In addition to sanitary sewer overflows, combined sewer overflows are also common within areas serviced by the Metropolitan St. Louis Sewer District. A combined sewer system collects both stormwater runoff and wastewater, including domestic sewage. These systems are designed to not only transport wastewater to treatment facilities, but to also discharge directly to a water body if its capacity is exceeded due to the stormwater inputs. Combined sewer systems were an early sewer design and are found in many older cities. As with sanitary sewer overflows, combined sewer overflows can result in periods of elevated bacteria concentrations in a water body due in large part to the discharge of domestic sewage as well as the runoff component from roofs, parking lots and residential yards and driveways. As noted in Figure 9, one combined sewer outfall was present in the Gravois Creek watershed, but was separated and removed in 2009 (MSD 2011). This outfall was identified as Outfall 157 and discharged into an unnamed tributary of Gravois Creek in Mehlville, Mo.

A study of the sources of *E. coli* in metropolitan St. Louis streams was conducted by the USGS from 2004 through 2007. This study showed that about one-third of the *E. coli* found in metropolitan St. Louis streams did originate from humans and that there was a strong correlation between *E. coli* densities and the number of upstream combined sewer and sanitary sewer overflows (USGS 2010). For these reasons, sanitary sewer and combined sewer overflows are considered significant potential contributors of *E. coli* to Gravois Creek. Due to the recent removal of the combined sewer outfall, discharges from combined sewer overflows are no longer expected to be contributing to the impairment.

3.1.2 Industrial and Non-Domestic Wastewater Permits

There are no industrial or non-domestic wastewater facilities in the Gravois Creek watershed. Industrial and non-domestic facilities discharge wastewater resulting from non-sewage generating activities. For these reasons, industrial and non-domestic facilities are not expected to cause or contribute to the bacteria impairment of Gravois Creek.

3.1.3 General and Stormwater Permits

General and stormwater permits are issued based on the type of activity occurring and are meant to be flexible enough to allow for ease and speed of issuance, while providing the required protection of water quality. General and stormwater permits are issued to activities similar enough to be

covered by a single set of requirements, and are designated with permit numbers beginning with "MO-G" or "MO-R" respectively. A summary of the general and stormwater permits in the Gravois Creek watershed can be found in Table 5.

Table 5. General (MO-G) and stormwater (MO-R) permits in the Gravois Creek watershed

Permit No.	***Facility Name***	***Design Flow***	***Receiving Stream***	***Permit Expires***
MO-G490038	Ruprecht Quarry	stormwater	Gravois Cr.	10/5/2011
MO-G760050	City of Crestwood Municipal Pool	n/a	Trib. to Gravois Cr.	4/9/2014
MO-R040005	MSD Small MS4 Co-Permit	stormwater	--	6/12/2013
MO-R106664	Villas Of Grantwood	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R107897	Wilson Manufacturing Company	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R108227	The Timbers At Creekside	stormwater	Gravois Cr	2/7/2012
MO-R108346	Crestview Senior Living	stormwater	Gravois Creek	2/7/2012
MO-R108596	Albury Estates	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R108782	Sappington Square	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R109CY6	Grants Farm Manor	stormwater	Trib. to Gravois Cr.	3/7/2012
MO-R109FK6	Alexian Brothers Sherbrooke Village	stormwater	Trib. to Gravois Cr.	3/7/2012
MO-R109FL5	Nolan Commercial Site	stormwater	Trib. to Gravois Cr.	3/7/2012
MO-R10A175	Pardee Spur Estates	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R10A183	Salama Office Building	stormwater	Gravois Cr.	2/7/2012
MO-R10A248	Magic House, Inc.	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R10A347	Nomax, Inc.	stormwater	Gravois Ck	2/7/2012
MO-R10A644	Copia Medical Office Building	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R10A750	Sappington Elementary School	stormwater	Gravois Cr.	2/7/2012
MO-R10A788	Lot 16d Green Park Commerce Center	stormwater	Gravois Cr.	2/7/2012
MO-R10A789	Lot 16c Green Park Commerce Center	stormwater	Gravois Cr.	2/7/2012
MO-R10A832	Lot 16b Green Park Commerce Center	stormwater	Gravois Cr.	2/7/2012
MO-R10A938	Trailer Storage	stormwater	Gravois Cr.	2/7/2012
MO-R10B052	Shell/Convenient Food Mart	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R10B234	Metropolitan Place	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R10B309	Bexley Station	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R10B496	Lot 22 Green Park Commerce Center	stormwater	Gravois Ck	2/7/2012
MO-R10B616	Lutheran High School South	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R10B727	Grant's Farm Manor Welcome	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R10C037	Pepper Mill	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R10C124	Lion's Choice Restaurant	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R10C348	54th Street Grill And Bar	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R10C364	Flexibile Cutting Systems	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R10C579	Golden Corral Buffet And Grill	stormwater	Trib. to Gravois Cr.	2/7/2012

MO-R10C840	St. Johns Church Activity	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R10C903	Heimos Tract	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R10D013	Early Childhood And Track R	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R10D029	St. Mark School	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R10D468	Cor Jesu Academy	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R10D473	Bitrode Corporation	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R10D585	Village At Mackenzie Place	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R10D598	Walmart #2694-04, Expansion	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R10D712	Parkway South High School	stormwater	Trib. to Gravois Cr.	2/7/2012
MO-R12A064	Haas Baking Company	stormwater	Gravois Cr	7/26/2006
MO-R203054	Charles S Lewis and Co, Inc.	stormwater	Trib. to Gravois Cr.	6/14/2014
MO-R23A005	Missouri Electrochem, Inc.	stormwater	Trib. to Gravois Cr.	3/11/2015
MO-R80C319	First Student, Inc #1172	stormwater	Trib. to Gravois Cr.	10/4/2012
MO-R80C347	Laidlaw Education Service	stormwater	Trib. to Gravois Cr.	10/4/2012

Note: MGD = million gallons per day

As noted in Table 5, there is a small municipal separate storm sewer system permit, or MS4 permit, in the Gravois Creek watershed. This type of permit addresses pollutant contributions from urban runoff. Urban runoff has been found to carry high levels of bacteria and can be expected to exceed water quality criteria for bacteria during and immediately after storm events in most streams throughout the country (EPA 1983). Therefore, urban runoff is a significant potential contributor of bacteria to Gravois Creek. Bacterial inputs to streams from urban runoff can be caused by sanitary sewer overflows as discussed in Section 3.1.1, but also commonly results from residential and green space runoff carrying domestic and wild animal wastes. Common sources of *E. coli* contamination in urban stormwater have been documented as being from birds, dogs, cats, and rodents (Burton and Pitt 2002). A USGS study specific to the sources of *E. coli* in metropolitan St. Louis streams concluded that in addition to one third of the bacteria originating from human sources, approximately 10 percent of the *E. coli* found in streams in this area originates from dogs and 20 percent from geese (USGS 2010). *E. coli* from such sources can enter streams as contaminated runoff and can come from both heavily paved areas and from open areas where soil erosion is common (Burton and Pitt 2002).

In the case of Gravois Creek, the MS4 permit regulates urban stormwater discharges for the entire watershed area. For this reason, urban stormwater runoff is considered a point source for this TMDL. Although stormwater discharges are untreated, small MS4 permit holders must develop, implement, and enforce stormwater management plans to prevent the input of harmful pollutants. These plans must include measurable goals, must be reported on annually, and must meet six minimum control measures. These six minimum control measures are public education and outreach, public participation and involvement, illicit discharge detection and elimination, construction site runoff control, post-construction runoff control, and pollution prevention. Entities within the Gravois Creek watershed that are regulated as co-permittees under the MS4 permit noted in Table 5 include the Metropolitan St. Louis Sewer District, St. Louis County and the municipalities of Crestwood, Glendale, Green Park, Kirkwood, Lakeshire, Oakland, St. George, Sunset Hills, and Webster Groves.

Regarding the remaining general and stormwater permits in Table 5, the Department assumes activities in the watershed will be conducted in compliance with all permit conditions, including monitoring and discharge limitations. It is expected that compliance with these permits will result in bacterial loadings at or below applicable targets. For these reasons, these facilities are not expected to cause or contribute to the bacterial impairment of Gravois Creek.

3.1.4 Illicit Straight Pipe Discharges

Illicit straight pipe discharges of household waste are also potential point sources of bacteria. These sources are illegal and unpermitted discharges straight into streams or land areas and are different from illicitly connected sewers. However, there are no specific data on the number or presence of illicit straight pipe discharges of household waste in the Gravois Creek watershed. Due to the presence of a sewerage system throughout the watershed, illicit straight pipe discharges are not expected to be a significant contributor of *E. coli* to Gravois Creek. Illicit discharge detection and elimination is one of the six minimum control measures required by an MS4 permit.

3.2 Nonpoint Sources

Nonpoint source pollution refers to pollution coming from diffuse, non-permitted sources that typically cannot be identified as entering a water body at a single location. They include all other categories of pollution not classified as being from a point source, and are exempt from Department permit regulations as per state rules at 10 CSR 20-6.010(1)(B)1. These sources involve stormwater runoff from non-regulated areas and are minor or negligible under low-flow conditions. Typical nonpoint sources of pollution that have the potential to influence water quality include various sources associated with runoff from agricultural and non-MS4 permitted urban areas, onsite wastewater treatment systems, and riparian corridor conditions.

3.2.1 Agricultural Runoff

Stormwater runoff from lands used for agricultural purposes are often sources of bacterial loading to water bodies. Activities associated with agricultural land uses that may contribute bacteria to a water body include manure fertilization of croplands or pastures, and livestock grazing. However, as noted in Section 2.4, agricultural land in the Gravois Creek watershed is virtually nonexistent. Although over 10 percent of the watershed was classified as grassland, when compared to the most recent aerial imagery, these areas were found to most commonly be cemeteries, parks, or schoolyards and not pastureland where livestock animals are likely to be grazing. Similarly, areas within the watershed classified as cropland were commonly found to be comprised of rooftops, parking lots, and baseball diamonds. For these reasons, typical agricultural practices associated with these land use types are not expected to contribute to the impairment of Gravois Creek.

Although not a typical agricultural operation, the public attraction Grant's Farm lies within the Gravois Creek watershed and is adjacent to a portion of the unclassified segment of Gravois Creek. Located in Grantwood Village, this attraction serves as a wildlife preserve and as a zoo. The property that comprises Grant's Farm is approximately 273 acres and houses approximately 423 animals owned by the Anheuser-Busch company, including 292 mammals and 84 birds. In a portion of this property, various grazing animals are allowed to roam freely (NPS 2010). In addition to these animals, the Anheuser-Busch company also houses approximately 25 Clydesdale horses in pastures and stables on the east side of Gravois Creek (Grant's Farm 2011). Although well vegetated, it is feasible that animal wastes from pasture areas may reach Gravois Creek via

runoff during rain events. Aerial imagery shows the streamside conditions near this attraction to be mostly forested, which may alleviate some of the pollutant impacts associated with runoff by providing a buffer for pollutant detention, removal and assimilation. Direct input of animal waste to Gravois Creek is not likely to occur, because the animals are excluded from the stream. Though animal densities here are low, they are potential contributors of *E. coli* to Gravois Creek. As previously mentioned, stormwater runoff within the watershed, including from Grant's Farm, is regulated through the MS4 permit noted in Table 5.

3.2.2 Urban Runoff (non-MS4 permitted areas)

Stormwater runoff from urban areas not having MS4 permits is considered a nonpoint source. Although urban nonpoint sources were cited as the cause of impairment on Missouri's 2008 303(d) list of impaired waters, the entire Gravois Creek watershed falls within the jurisdiction of an MS4 permit, for which the Metropolitan St. Lewis Sewer District, St. Louis County, and several municipalities are co-permittees. Therefore, for purposes of this TMDL, urban runoff within the Gravois Creek watershed is considered a potential point source contributor of *E. coli* to Gravois Creek. For this reason, there are no nonpoint urban runoff sources likely to be contributing to the bacteria impairment of Gravois Creek. See Section 3.1.3 for discussion pertaining to the MS4 permit.

3.2.3 Onsite Wastewater Treatment Systems

When properly designed and maintained, onsite wastewater treatment systems (e.g., home septic systems) should not serve as a source of contamination to surface waters; however, onsite wastewater treatment systems do fail for a variety of reasons. When these systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration), there can be adverse effects to surface water quality (Horsley and Witten 1996). Failing onsite wastewater treatment systems are known to be sources of bacteria, which can reach nearby streams through both surface runoff and groundwater flows, thereby contributing bacteria loads under either wet or dry weather conditions.

The exact number of onsite wastewater treatment systems in the Gravois Creek watershed is unknown, however such systems are known to exist, especially in older developed areas of the watershed, such as in the municipality of Lemay, that were developed prior to the sewerage systems serviced by the Metropolitan St. Lewis Sewer District (Jack Fischer, St. Louis County Public Works, personal communication, Jan. 31, 2011). Although septic system installations and repairs within St. Louis County require a permit, the county database cannot distinguish between work pertaining to onsite wastewater treatment systems and work pertaining to sanitary sewers because they are classified the same (Jack Fischer, St. Louis County Public Works, personal communication, Jan. 31, 2011). A 1963 water quality study by the Metropolitan St. Louis Sewer District indicates that before the completion of a trunk sewer in that same year, septic systems were common throughout the watershed and were contributing to the degradation of Gravois Creek (MSD 1963). The construction of the sewer is credited with the removal of many failing septic systems from the watershed and the recovery of Gravois Creek from its previous condition (MSD 1980). Further septic system eliminations likely occurred as a result of a St. Louis County ordinance, which requires that a sewer connection to a building be made when a sanitary sewer line is within 200 feet of the property (O. No. 13701, 1-29-88). Although the specific number of onsite wastewater treatment systems are unknown, due to the availability of sanitary sewer lines

and the overall urban nature of the watershed, actual numbers are expected to be low. Further septic system reductions are likely to occur as a result of the consent decree established as part of the *United States of America and the State of Missouri, and Missouri Coalition for the Environment Foundation v. Metropolitan St. Louis Sewer District*, No. 4:07-CV-1120, which was lodged with the U.S. District Court for the Eastern District of Missouri on Aug. 4, 2011. This consent decree requires the implementation of a supplemental environmental project to decommission septic tanks to residences within the Metropolitan St. Louis Sewer District's service area.

EPA's Spreadsheet Tool for Estimating Pollutant Load website estimates the failure rate of onsite wastewater treatment systems in St. Louis County as being 39 percent (EPA 2010a). However, a more recent study conducted by the Electric Power Research Institute suggests that up to 50 percent of onsite wastewater treatment systems in Missouri may be failing (EPA 2010b; EPRI 2000). Due to these high failure rates, onsite wastewater treatment systems present in the watershed are likely contributing bacteria loads to Gravois Creek. However, because the number of septic systems in the watershed is expected to be low, onsite wastewater treatment systems are not expected to be a significant contributor to the bacteria impairment of Gravois Creek.

3.2.4 Riparian Corridor Conditions

Riparian (streamside) corridor conditions can have a strong influence on instream water quality. Wooded riparian buffers are a vital functional component of stream ecosystems and are instrumental in the detention, removal and assimilation of pollutants from runoff. Therefore, a stream with good riparian cover is better able to moderate the impacts of high pollutant loads than a stream with poor or no riparian cover.

Table 6 presents land use data for the riparian corridors within the watersheds of both classified water bodies. This analysis used the land use data calculated in Section 2.4 and defined the riparian corridor as including a 30-meter area on each side of all streams included in the National Hydrography Dataset 1 to 24,000-scale flowline.[13] Similar to the land use discussion in Section 2.4, the riparian corridor for WBID 1712 accounts for all riparian areas within the entire Gravois Creek watershed including areas within the drainage area of WBID 1713. As can be seen in Table 6, the riparian corridor of Gravois Creek is predominantly urban. Land classified as low-intensity urban comprises over 65 percent of the riparian corridor. Runoff from low-intensity urban areas, such as residential areas, can contribute bacteria loading to a water body from pet or wild animal wastes. For this reason, the riparian corridor conditions in the watershed are likely to contribute to bacteria impairment of Gravois Creek. Vegetated areas categorized as grassland and forest and woodland account for over 27 percent of the Gravois Creek riparian corridor. In rural areas, grassland areas may provide higher bacterial loading than forest and woodland areas due to the presence of livestock. However, due to the highly urbanized environment of the Gravois Creek watershed, livestock inputs are not likely to be contributing bacteria to Gravois Creek. However, bacterial inputs from these areas may still occur from pets and wildlife since, as previously noted in Section 2.4, areas categorized as grassland in the Gravois Creek watershed are, in most cases, parks, cemeteries, and playgrounds. Areas within the riparian corridor of Gravois Creek fall under

[13] The National Hydrography Dataset is digital surface water data for geographic information systems (GIS) for use in general mapping and in the analysis of surface-water systems. Available URL: http://nhd.usgs.gov

the regulations of the shared MS4 permit therefore making stormwater runoff from these areas a regulated point source (see Section 3.1.2).

Table 6. Land use/land cover data for the Gravois Creek riparian buffer, 30-meter

Land Use Type	*WBID 1712*			*WBID 1713*		
	Acres	*Square Miles*	*Percent*	*Acres*	*Square Miles*	*Percent*
Impervious	45.4	0.07	4.2 %	38.5	0.06	3.9 %
High-Intensity Urban	5.1	0.01	0.5 %	5.1	0.01	0.5 %
Low-Intensity urban	712.5	1.11	65.3 %	635.8	0.99	64.6 %
Row and close-grown crops	4.5	0.01	0.4 %	4.2	0.01	0.4 %
Grassland	116.9	0.18	10.7 %	106.3	0.17	10.8 %
Forest and woodland	184.4	0.29	16.9 %	178.4	0.28	18.1 %
Open water	3.8	0.01	0.4 %	2.7	0.00	0.3 %
Barren	0.2	0.00	0.0 %	0.2	0.00	0.2 %
Herbaceous	1.6	0.00	0.1 %	0.9	0.00	0.0 %
Wetlands	16.7	0.03	1.5 %	12.2	0.02	1.2 %
Total:	1,091.1	1.71	100.0 %	984.3	1.54	100.0 %

Source: MoRAP 2005b

4. Applicable Water Quality Standards and Numeric Target

The purpose of developing a TMDL is to identify the pollutant loading that a water body can assimilate and still achieve water quality standards. Water quality standards are therefore central to the TMDL development process. Under the federal Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters (U.S. Code Title 33, Chapter 26, Subchapter III). Water quality standards consist of three components: designated beneficial uses, water quality criteria, and an antidegradation policy.

4.1 Designated Beneficial Uses

Designated beneficial uses are the uses for a water body identified in the state water quality standards that must be maintained in accordance with the federal Clean Water Act. The following designated beneficial uses have been assigned to Gravois Creek:

- Livestock and wildlife watering
- Protection of warm water aquatic life
- Protection of human health (fish consumption)
- Metropolitan no-discharge stream
- Whole body contact recreation – Category B

The use impaired by bacteria in this stream is the protection of whole body contact recreation category B. Whole body contact recreation includes activities in which there is direct human contact with surface water that results in complete body submergence, thereby allowing accidental ingestion of the water as well as direct contact to sensitive body organs, such as the eyes, ears and

nose. Category A waters include water bodies that have been designated as public swimming areas and waters with existing whole body contact recreational uses. Category B applies to waters designated for whole body contact recreation, but are not contained within category A.

4.2 Water Quality Criteria

Water quality criteria are limits on particular chemicals or conditions in a water body to protect particular designated beneficial uses. Water quality criteria can be expressed as specific numeric criteria or as general narrative statements.

In Missouri's water quality standards at 10 CSR 20-7.031(4)(C), specific numeric criteria are given for the protection of the whole body contact recreation use. For category B waters, *E. coli* counts, measured as a geometric mean, shall not exceed 206 counts/100 mL of water. Missouri's whole body contact recreation criteria are applicable only during the state's recreational season, which is defined as being from April 1 to October 31.

4.3 Antidegradation Policy

Missouri's Water Quality Standards include the EPA "three-tiered" approach to antidegradation, and may be found at 10 CSR 20-7.031(2).

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

Tier 2 – Protects and maintains the existing level of water quality where it is better than applicable water quality criteria. Before water quality in Tier 2 waters can be lowered, there must be an antidegradation review consisting of: (1) a finding that it is necessary to accommodate important economic and social development in the area where the waters are located; (2) full satisfaction of all intergovernmental coordination and public participation provisions; and (3) assurance that the highest statutory and regulatory requirements for point sources and best management practices for nonpoint sources are achieved. Furthermore, water quality may not be lowered to less than the level necessary to fully protect the "fishable/swimmable" uses and other existing uses.

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

Waters in which a pollutant is at, near or exceeds the water quality criteria are considered in Tier 1 status for that pollutant. Therefore, the antidegradation goals for Gravois Creek are to restore the streams' water quality to levels that meet water quality standards.

4.4 Numeric Target for TMDL Development

As noted in Section 4.2, Missouri's water quality standards include a specific numeric *E. coli* water quality criterion of 206 *E. coli* counts per 100 mL of water, measured as a geometric mean during the recreational season for waters designated with the whole body contact recreation

category B use. The concentration value of 206 counts/100 mL will serve as the numeric target for TMDL development. This targeted concentration will be expressed as a daily load that varies by flow using a load duration curve. Achieving this targeted load will also result in achieving the state's whole body contact B water quality criterion.

5. Modeling Approach

For Gravois Creek, the load duration approach was used. When stream flow gage information is available, a load duration curve is useful in identifying and differentiating between storm-driven and steady-input sources. The load duration approach may be used to provide a visual representation of stream flow conditions under which bacteria criteria exceedances have occurred, to assess critical conditions and to quantify the level of reduction necessary to meet the surface water quality targets for bacteria in the stream (Cleland 2002; Cleland 2003).

A load duration curve also identifies the maximum allowable daily pollutant load for any given day as a function of the flow occurring that day, which is consistent with the Anacostia Ruling (*Friends of the Earth, Inc., et al v. EPA*, No 05-5010, April 25, 2006) and EPA guidance in response to this ruling (EPA 2006; EPA 2007a). EPA guidance recommends that all TMDLs and associated pollutant allocations be expressed in terms of daily time increments, and suggests that there is flexibility in how these daily increments may be expressed. This guidance indicates that where pollutant loads or water body flows are highly dynamic, it may be appropriate to use a load duration curve approach, provided that such an approach "identifies the allowable daily pollutant load for any given day as a function of the flow occurring on that day." In addition, for targets that are expressed as a concentration of a pollutant, it may be appropriate to use a table or graph to express individual daily loads over a range of flows as a product of a water quality criterion multiplied by stream flow and a conversion factor (EPA 2006).

Average daily flow data for Gravois Creek was directly available from July 23, 1996 to Nov. 30, 2010, from the USGS gaging station USGS 07010180 Gravois Creek near Mehlville, Mo (Figure 10). Flow data from this gage were adjusted to the impaired watersheds based on the ratio of the impaired watershed areas to the gage drainage area of 18.1 square miles. A detailed discussion of the methods used to develop the bacteria load duration curves is presented in Appendix B.

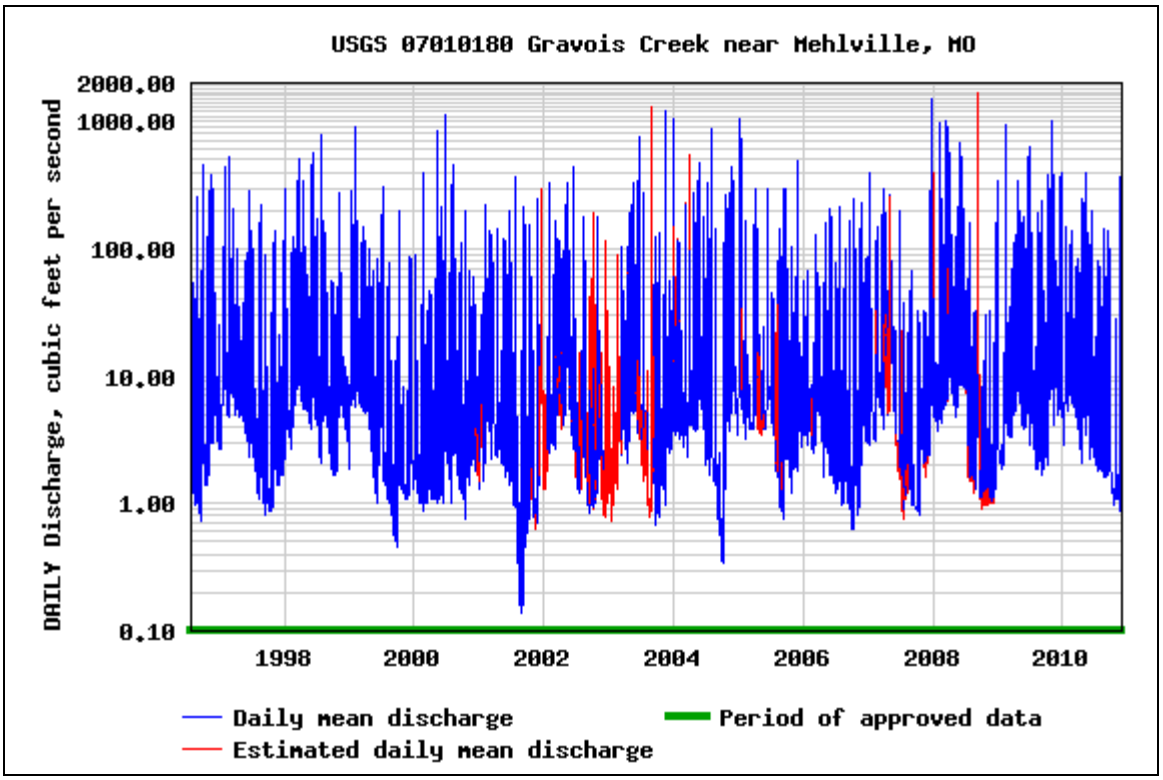

Figure 10. 1996 – 2010 flow data from Gravois Creek (USGS 2011)

6. Calculating Loading Capacity

Loading capacity is the maximum pollutant load that a water body can assimilate and still attain water quality standards. It is equal to the sum of the wasteload allocation, load allocation and the margin of safety, and can be expressed as the equation:

$$LC = \sum WLA + \sum LA + MOS$$

where LC is the loading capacity, ∑WLA is the sum of the wasteload allocations, ∑LA is the sum of the load allocations, and MOS is the margin of safety.

According to 40 §CFR 130.2(i), TMDLs can be expressed in terms of mass per time, toxicity or other appropriate measures. For Gravois Creek, bacteria TMDLs are expressed as *E. coli* counts per day using a load duration curve. To develop a load duration curve, the TMDL target concentration is multiplied by the flow and a conversion factor to generate the maximum allowable load at different flows. The load duration curves presented in Figures 11 and 12 represent the loading capacity as a solid curve over the range of flows. Bacteria measurements observed during the recreational season (Apr. – Oct.) are plotted as blue points and geomeans of observed bacteria data within a specific flow condition (i.e., high flows) are plotted as green triangles. Flow condition ranges presented in Figures 11 and 12 illustrate general base-flow and surface-runoff conditions consistent with EPA guidance on using load duration curves for TMDL development (EPA 2007b). Tables 7 and 8 present the TMDL loading capacity and the TMDL allocations for Gravois Creek over a range of flows.

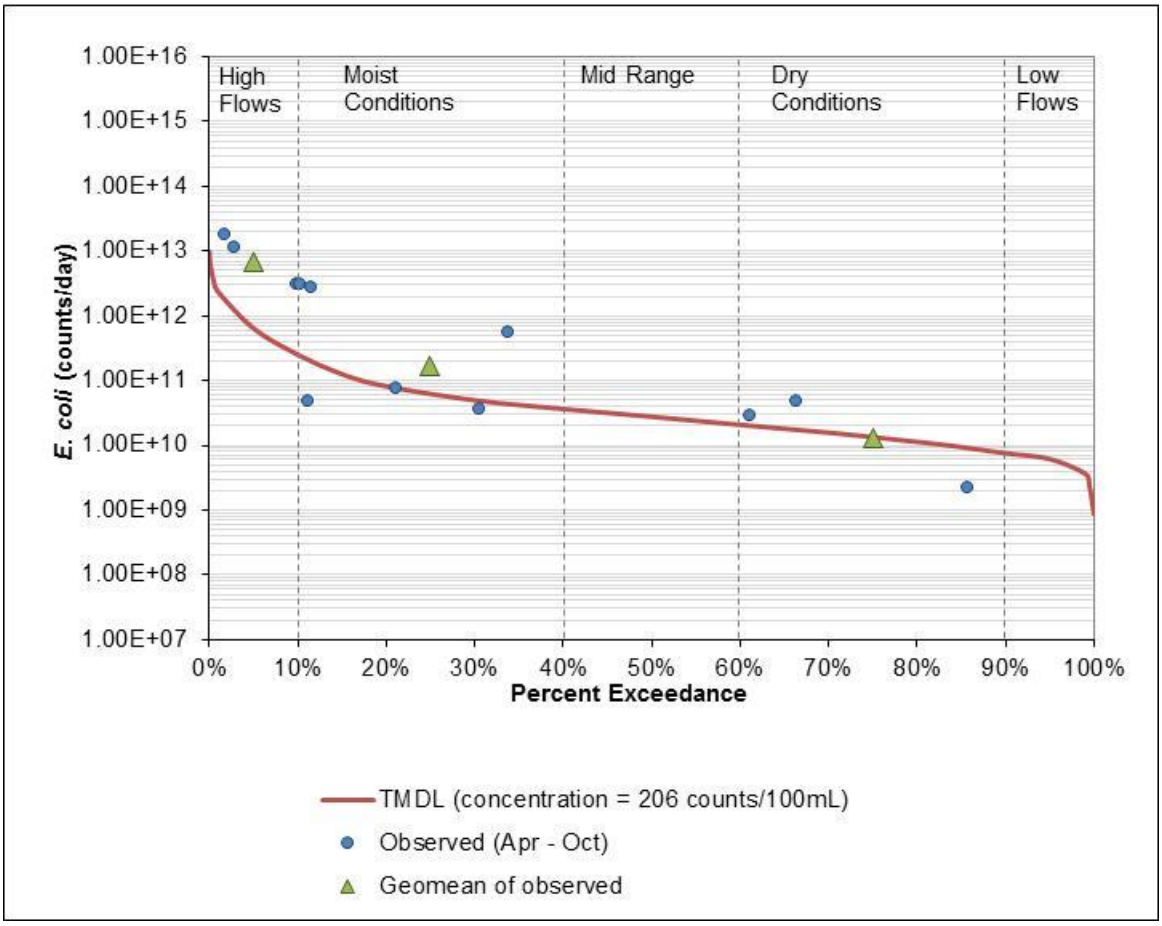

Figure 11. WBID 1712 load duration curve

Table 7. *E. coli* TMDL for WBID 1712 over a range of flow conditions

Percentile Flow Exceedance	***Flow (cfs)***	***Targets Based on concentration of 206/100mL***			
		TMDL (counts/day)	***MS4 WLA (counts/day)***	***LA (counts/day)***	***MOS (counts/day)***
95	1.2	6.17E+09	5.55E+09	0	6.17E+08
90	1.5	7.55E+09	6.80E+09	0	7.55E+08
70	3.1	1.57E+10	1.42E+10	0	1.57E+09
50	5.5	2.77E+10	2.49E+10	0	2.77E+09
30	9.9	4.97E+10	4.47E+10	0	4.97E+09
10	49.9	2.52E+11	2.27E+11	0	2.52E+10
5	127.2	6.41E+11	5.77E+11	0	6.41E+10

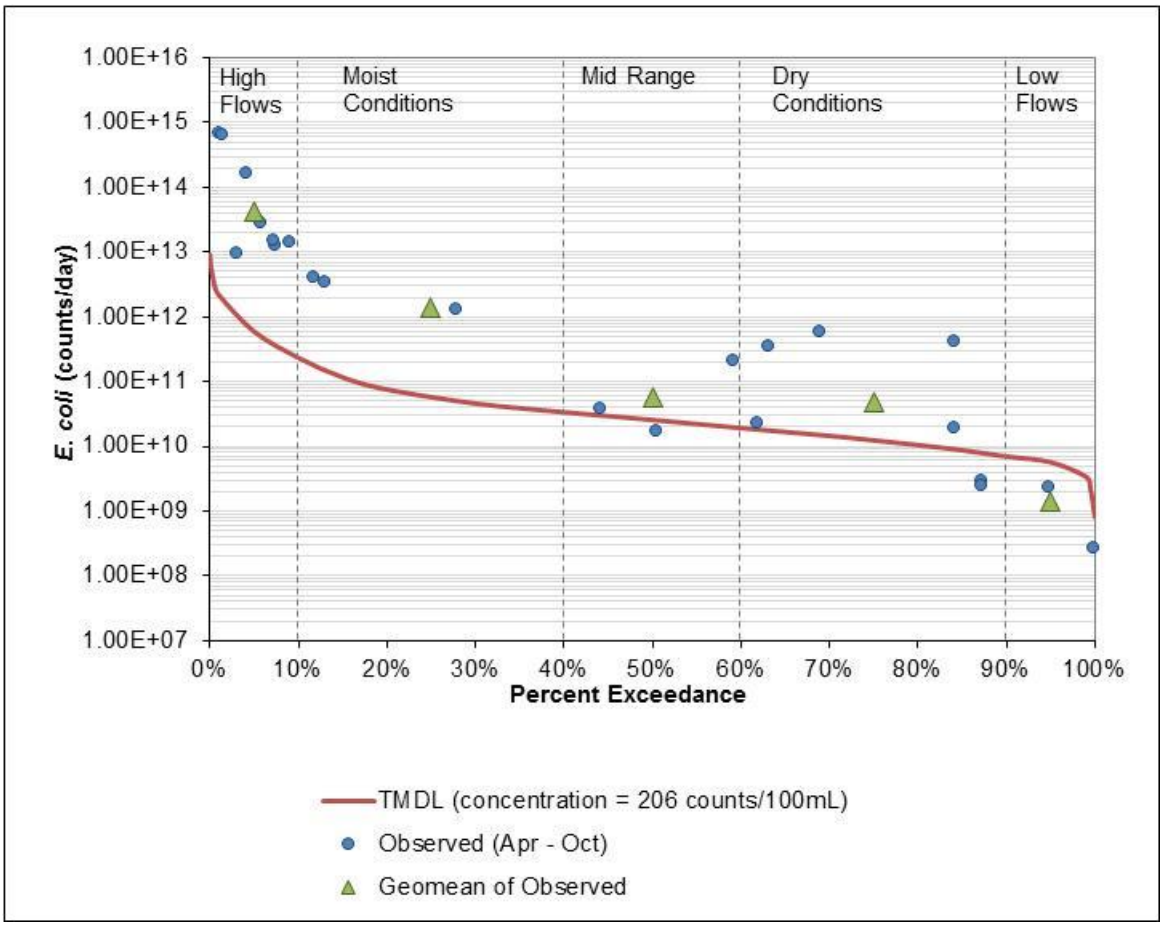

Figure 12. WBID 1713 load duration curve

Table 8. *E. coli* TMDL for WBID 1713 over a range of flow conditions

Percentile Flow Exceedance	***Flow (cfs)***	***Targets Based on concentration of 206/100mL***			
		TMDL (counts/day)	***MS4 WLA (counts/day)***	***LA (counts/day)***	***MOS (counts/day)***
95	1.1	5.70E+09	5.13E+09	0	5.70E+08
90	1.4	6.98E+09	6.29E+09	0	6.98E+08
70	2.9	1.46E+10	1.31E+10	0	1.46E+09
50	5.1	2.56E+10	2.30E+10	0	2.56E+09
30	9.1	4.60E+10	4.14E+10	0	4.60E+09
10	46.2	2.33E+11	2.10E+11	0	2.33E+10
5	117.6	5.93E+11	5.34E+11	0	5.93E+10

7. Wasteload Allocation (Point Source Load)

The wasteload allocation is the allowable amount of the pollutant that can be allocated to existing or future point sources. Typically, point sources are permitted with limits for a given pollutant that are the most stringent of either technology-based effluent limits or water quality-based effluent limits. Technology-based effluent limits are based upon the expected capability of a treatment

method to reduce the pollutant to a certain concentration. Water quality-based effluent limits represent the most stringent concentration of a pollutant that a receiving stream can assimilate without violating applicable water quality standards at a specific location. Wasteload allocations over a range of flows for Gravois Creek are presented in Tables 7 and 8.

As noted in Section 3.1.1 and 3.1.2, there are no site-specific permitted point sources in the Gravois Creek watershed that may contribute to *E. coli* loading. A sewerage system is present in the watershed; however, this system discharges from a facility located outside of the watershed. Even so, sanitary sewer overflows still occur and are likely significant contributors of bacteria to Gravois Creek. However, these discharges are unpermitted and not authorized under the Clean Water Act. For this reason, the elimination of sanitary sewer overflows to the greatest extent possible is essential for improving water quality in the Gravois Creek watershed. Therefore, constructed sanitary sewer overflows in the Gravois Creek watershed are given a wasteload allocation of zero. However, while the constructed sanitary sewer overflows are being included in the wasteload allocation, this does not reflect an authorization to discharge from these unpermitted point sources.

Urban stormwater runoff is another likely significant contributor of bacteria loading to Gravois Creek. Bacterial contributions from MS4 permitted entities are precipitation dependent and vary with flow. The data available are inadequate to provide specific wasteload allocations for each MS4 co-permittee in the watershed. However, a total wasteload allocation for the MS4 permit can be determined. Since there are no other permitted facilities likely to contribute to the impairment, the entire wasteload allocation is allocated to the MS4 permit. Table 5 lists other facilities with general or stormwater permits; however, the Department assumes activities in the watershed will be conducted in compliance with all permit conditions, including monitoring and discharge limitations. It is expected that compliance with these permits will result in bacterial loading at or below applicable targets. For these reasons, these facilities are not expected to cause or contribute to the bacterial impairment of Gravois Creek. The wasteload allocation for these general and stormwater permitted dischargers is zero.

The wasteload allocations listed in this TMDL do not preclude the establishment of future point sources of bacterial loading in the watershed. Any future point sources should be evaluated against the TMDL and the range of flows, which any additional bacterial loading will affect.

8. Load Allocation (Nonpoint Source Load)

The load allocation is the allowable amount of the pollutant load that can be assigned to nonpoint sources and includes all existing and future nonpoint sources, as well as natural background contributions (40 CFR §130.2(g)). No nonpoint sources were identified that are likely to significantly cause or contribute to the impairment of Gravois Creek. Runoff within the watershed is regulated by an MS4 permit, which for purposes of this TMDL is considered a point source. For these reasons, the load allocation is set to zero at all flows and no nonpoint source reductions are required.

9. Margin of Safety

A margin of safety is required in the TMDL calculation to account for uncertainties in scientific and technical understanding of water quality in natural systems. The margin of safety is intended to account for such uncertainties in a conservative manner. Based on EPA guidance, the margin of safety can be achieved through two approaches:

- Explicit - Reserve a portion of the loading capacity as a separate term in the TMDL.
- Implicit - Incorporate the margin of safety as part of the critical conditions for the wasteload allocation and the load allocation calculations by making conservative assumptions in the analysis.

The margin of safety for these TMDLs is an explicit 10 percent as shown in Tables 7 and 8. Furthermore, bacterial decay or die off was not accounted for in the establishment of these TMDLs. This conservative assumption provides an additional implicit margin of safety.

10. Seasonal Variation

Missouri's water quality criteria for the protection of whole body contact recreation are applicable during the recreational season defined as being from April 1 to October 31. However, the TMDL load duration curves in Figures 11 and 12 represent stream flow under all conditions. For this reason, the *E. coli* targets and allocations established in this TMDL will be protective throughout all seasons and conditions. The advantage of a load duration curve approach is that all flow conditions are considered and the constraints associated with using a single-flow critical condition are avoided.

11. Monitoring Plans

The Department has not yet scheduled post-TMDL monitoring for Gravois Creek. Post-TMDL monitoring is usually scheduled and carried out by the Department approximately three years after the approval of the TMDL or in a reasonable time period following completion of permit compliance schedules and the application of new effluent limits, or following significant implementation actions, such as the removal of constructed sanitary sewer overflows. The Department will routinely examine water quality data collected by other local, state and federal entities in order to assess the effectiveness of TMDL implementation. Such entities include the USGS, EPA, neighboring state agencies, the Missouri Department of Health and Senior Services, the Missouri Department of Conservation and county health departments. In addition, certain quality-assured data collected by universities, municipalities, private companies and volunteer groups may potentially be considered for monitoring water quality following TMDL implementation.

12. Implementation Plan

States are not required under Section 303(d) of the Clean Water Act to develop TMDL implementation plans and EPA does not approve or disapprove them. However, the Department will develop and make available for public comment an implementation plan in conjunction with

the development of this TMDL. The implementation plan will provide additional information regarding how point and nonpoint sources can or should be controlled to ensure implementation efforts achieve the loading reductions identified in this TMDL. This TMDL establishes the allowable bacteria loadings that Gravois Creek can receive without violating water quality standards. Therefore, the TMDL provides a basis for establishing appropriate pollutant controls (EPA 2001). Any management practices already in place or being developed in the watershed to eliminate the impairment will be included in the TMDL implementation plan. Table 9 presents the needed reductions to successfully implement this TMDL and meet water quality standards.

Table 9. Needed load reductions to achieve water quality standards in Gravois Creek*

WBID	*Percentile Flow Exceedance*	*Flow (cfs)*	*Observed Load (counts/day)*	*TMDL (counts/day)*	*Load Reduction (counts/day)*	*Percent Reduction (%)*
1712	95	1.2	--	6.17E+09	--	--
	75	2.6	1.32E+10	1.32E+10	-6.57E+07	0 %
	50	5.5	--	2.77E+10	--	--
	25	12.0	1.69E+11	6.04E+10	1.09E+11	64.3 %
	5	127.2	6.90E+12	6.41E+11	6.26E+12	90.7 %
1713	95	1.1	1.42E+09	5.70E+09	-4.28E+09	0 %
	75	2.4	4.81E+10	1.22E+10	3.59E+10	74.6 %
	50	5.1	5.55E+10	2.56E+10	2.99E+10	53.9 %
	25	11.1	1.39E+12	5.59E+10	1.33E+12	96.0 %
	5	117.6	4.29E+13	5.93E+11	4.23E+13	98.6%

*Based on geomeans of observed bacteria data within a specific flow condition (i.e., high flows)

In general, point source reductions are typically implemented through discharge permits administered through the Missouri State Operating Permit program to meet the requirements of Missouri's water quality standards and the National Pollutant Discharge Elimination System (NPDES). In the case of constructed sanitary sewer overflows discussed in this TMDL, implementation should be completed in accordance to the consent decree established as part of the *United States of America and the State of Missouri, and Missouri Coalition for the Environment Foundation v. Metropolitan St. Louis Sewer District*, No. 4:07-CV-1120, which was lodged with the U.S. District Court for the Eastern District of Missouri on Aug. 4, 2011 and approved on April 27, 2012. Because the Department does not regulate nonpoint sources, nonpoint source loading is typically reduced through the use of best management practices, or BMPs, that may be implemented to address and improve land use practices that may contribute bacteria to the impaired water bodies. Grant money from the Department's Section 319 Nonpoint Source Implementation Program may also be available for implementing nonpoint source controls in the watershed. Nonpoint sources for Section 319 purposes may vary from what is presented in this TMDL. For example, urban runoff regulated by an MS4 permit are point sources for TMDL purposes, but in some instances can be considered nonpoint sources for Section 319 purposes. Although this TMDL determined that no reductions of nonpoint sources are necessary, projects within the watershed could still be eligible for incremental 319 funding.

13. Reasonable Assurance

Section 303(d)(1)(C) of the federal Clean Water Act requires that TMDLs be established at a level necessary to implement applicable water quality standards. As part of the TMDL process, consideration must be given to the assurances that point and nonpoint source allocations will be achieved and water quality standards attained. Where TMDLs are developed for waters impaired by point sources only, reasonable assurance is derived from the National Pollutant Discharge Elimination System permitting program through discharge permits issued with effluent limits as stringent as necessary to meet water quality standards [CWA Section 301(b)(1)(C)]. For impaired waters, these discharge permits must be issued so that effluent limits are consistent with the assumptions and requirements of approved TMDL wasteload allocations [40 CFR 122.44(d)(1)(vii)(B)]. The Department has the authority to issue and enforce Missouri State Operating Permits for point source discharges. Inclusion of effluent limits in a state operating permit and requiring that effluent and instream monitoring be reported to the Department should provide reasonable assurance that instream water quality standards will be met.

Where a TMDL is developed for waters impaired by both point and nonpoint sources, point source wasteload allocations must be stringent enough so that in conjunction with the water body's other loadings (i.e., nonpoint sources) water quality standards are met. This generally occurs when the TMDL's combined nonpoint source load allocations and point source wasteload allocations do not exceed the water quality standards-based loading capacity and there is reasonable assurance that the TMDL's allocations can be achieved. Reasonable assurance that nonpoint sources will meet their allocated amount in the TMDL is dependent upon the availability and implementation of nonpoint source pollutant reduction plans, controls or BMPs within the watershed. If BMPs or other nonpoint source pollution controls make more stringent load allocations practicable, then wasteload allocations can be made less stringent. Thus, the TMDL process provides for nonpoint source control tradeoffs [40 CFR 130.2(i)]. When a demonstration of nonpoint source reasonable assurance is developed and approved for an impaired water body, additional pollutant allocations for point sources may be allowed provided water quality standards are still attained. When a demonstration of nonpoint source reasonable assurance does not exist, or it is determined that nonpoint source pollutant reduction plans, controls or BMPs are not feasible, durable, or will not result in the required load reductions, allocation of greater pollutant loading to point sources cannot occur.

A variety of grants and loans may be available to assist watershed stakeholders with developing and implementing watershed plans, controls and practices to meet the required wasteload and load allocations in the TMDL and demonstrate reasonable assurance. Any discussion of reduction efforts relating to point or nonpoint sources will be found in the supplemental implementation plan to be developed by the Department following the recommendations found in Section 12 of this document.

Reasonable assurances of nonpoint source reductions are not required within this TMDL, because no nonpoint source reductions are required in order to meet TMDL goals.

14. Public Participation

EPA regulations require that TMDLs be subject to public review (40 CFR 130.7). These water quality-limited segments of Gravois Creek in St. Louis County and city are included on Missouri's EPA-approved 2010 303(d) List of impaired waters. The 45-day public notice and comment period for this TMDL is from June 15 to July 30, 2012. Groups that received the public notice announcement include the Missouri Clean Water Commission, the Missouri Water Quality Coordinating Committee, the Missouri Department of Conservation, the St. Louis County Soil and Water Conservation District, St. Louis County Department of Heath, St. Louis County Public Works, the St. Louis County council, the University of Missouri Extension, the River des Peres Watershed Coalition, the Metropolitan St. Louis Sewer District, the Missouri Coalition for the Environment, 91 Stream Team volunteers in the watershed, any affected permitted entities, and the eight state legislators representing areas within the watershed. In addition, the Department posted the notice, the water body TMDL information sheets and this TMDL document on the Department website, making them available to anyone with access to the Internet. Announcement of the public notice period for this TMDL was also issued as a press release. Any comments received and the Department's responses to those comments will be maintained on file with the Department and on the Gravois Creek TMDL record webpage at dnr.mo.gov/env/wpp/tmdl/1712-1713-gravois-ck-record.htm

15. Administrative Record and Supporting Documentation

An administrative record on the Gravois Creek TMDL has been assembled and is being kept on file with the Missouri Department of Natural Resources. It includes any studies, data and calculations on which the TMDL is based. This information is available upon request to the Department at dnr.mo.gov/sunshine-form.htm. Any request for information on this TMDL will be processed in accordance with Missouri's Sunshine Law (Chapter 610, RSMO) and the Department's administrative policies and procedures governing Sunshine Law requests. For more information on open record/Sunshine requests, please consult the Department's website at dnr.mo.gov/sunshinerequests.htm.

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Appendix A

Gravois Creek *E. coli* data

Sampling Organization[14]	Site Description[15]	WBID	Easting	Northing	Sampling Date	*E. coli* [16] (#/100mL)	Flow[17] (cfs)
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	8/1/1996	10,000	2.32
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	9/23/1996	58,000	2800.0
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	10/13/1997	5,000	19.0
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	12/16/1997	83,000	2.0
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	2/23/1998	1,500	6.4
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	4/15/1998	70,000	679.0
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	6/22/1998	5600	7.9
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	11/30/1998	6,600	32.0
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	2/7/1999	41,000	3300.0
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	2/10/1999	150	11.0
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	5/12/1999	7,000	460.0
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	6/16/1999	8,600	2.5
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	8/3/1999	80	1.2
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	12/9/1999	7,800	117.0
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	1/5/2000	500	2.4
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	2/28/2000	2,000	2.1
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	5/26/2000	7,900	151.0
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	6/19/2000	4,200	2.4
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	8/23/2000	2,200	3.8
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	11/6/2000	4,800	100.0
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	12/18/2000	260	3.4
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	2/24/2001	2,800	153.0
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	2/27/2001	176	18.0
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	5/29/2001	440	1.6

[14] USGS = U.S. Geological Survey; MSD = Metropolitan St. Louis Sewer District
[15] See Figure 1 in Section 2 for sample site locations.
[16] For TMDL calculation purposes, less-than (<) values were halved and greater-than (>) values were doubled. This methodology is consistent with the Department's water quality assessment protocols.
[17] cfs = cubic feet per second.

Sampling Organization[14]	Site Description[15]	WBID	Easting	Northing	Sampling Date	*E. coli* [16] (#/100mL)	Flow[17] (cfs)
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	8/27/2001	30	0.3
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	10/15/2001	11,000	115.0
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	12/10/2001	92	1.5
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	2/4/2002	5	7.4
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	3/9/2002	1,800	297.0
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	5/28/2002	11,000	7.4
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	8/5/2002	67	1.1
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	10/3/2002	1,900	191.0
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	12/17/2002	17	1.5
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	2/3/2003	8	2.3
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	4/4/2003	4,800	133.0
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	6/24/2003	270	3.2
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	8/11/2003	88	1.0
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	10/9/2003	47,000	278.0
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	12/4/2003	580	8.5
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	2/18/2004	17	4.1
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	3/3/2004	2,300	85.0
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	5/17/2004	270	5.4
USGS	Gravois Cr.@Green Park Rd, Mehlville	1713	735416	4267710	8/2/2004	150	4.4
MSD	Gravois Cr.nr mouth	1712	737703	4270158	8/17/2004	<100	
MSD	Gravois Cr.nr mouth	1712	737703	4270158	12/7/2004	1,900	
MSD	Gravois Cr.nr mouth	1712	737703	4270158	1/4/2005	2,400	
MSD	Gravois Cr.nr mouth	1712	737703	4270158	6/9/2005	2,100	
MSD	Gravois Cr.nr mouth	1712	737703	4270158	6/9/2005	2,100	294.0
MSD	Gravois Cr.nr mouth	1712	737703	4270158	7/12/2005	2,600	41.0
MSD	Gravois Cr.nr mouth	1712	737703	4270158	11/15/2005	2,400	60.0
MSD	Gravois Cr.nr mouth	1712	737703	4270158	10/17/2006	<100	34.0
MSD	Gravois Cr.nr mouth	1712	737703	4270158	4/11/2007	2,000	192.0
MSD	Gravois Cr.nr mouth	1712	737703	4270158	5/2/2007	2,700	40.0
MSD	Gravois Cr.nr mouth	1712	737703	4270158	10/3/2007	3,000	32.0
MSD	Gravois Cr.nr mouth	1712	737703	4270158	12/10/2007	1,100	9.3
MSD	Gravois Cr.nr mouth	1712	737703	4270158	2/5/2008	590	974.0
MSD	Gravois Cr.nr mouth	1712	737703	4270158	3/3/2008	6,400	109.0

Sampling Organization[14]	Site Description[15]	WBID	Easting	Northing	Sampling Date	*E. coli* [16] (#/100mL)	Flow[17] (cfs)
MSD	Gravois Cr.nr mouth	1712	737703	4270158	2/11/2009	4,100	946.0
MSD	Gravois Cr.nr mouth	1712	737703	4270158	2/28/2009	30	2.3
MSD	Gravois Cr.nr mouth	1712	737703	4270158	3/25/2009	3,400	15.0
MSD	Gravois Cr.nr mouth	1712	737703	4270158	7/28/2009	206	13.0
MSD	Gravois Cr.nr mouth	1712	737703	4270158	8/12/2009	585	2.8
MSD	Gravois Cr.nr mouth	1712	737703	4270158	9/8/2009	295	3.3
MSD	Gravois Cr.nr mouth	1712	737703	4270158	10/21/2009	161	7.8
MSD	Gravois Cr.nr mouth	1712	737703	4270158	5/11/2010	2,755	7.0

Appendix B

Development of bacteria load duration curves

B. 1 Overview

the load duration curve approach was used to develop TMDLs for the drainage areas of WBID 1712 and WBID 1713 of Gravois Creek. The flow duration curve for these streams were developed using area corrected flow from flow gage data from Gravois Creek. The load duration curve method allows for characterizing water quality concentrations (or water quality data) at different flow regimes and estimating load allocations and wasteload allocations for an impaired segment. The method also provides a visual display of the relationship between stream flow and loading capacity. Using the duration curve framework, allowable loadings are easily presented.

B. 2 Methodology

Using a load duration curve method requires a long time series of flow data, numeric water quality targets, and bacteria data from the impaired streams. Bacteria data, along with the flow measurements for the same date, are plotted along with the load duration curve to assess when the water quality target is exceeded.

A long record of average daily flow data from a gage or multiple gages that are representative of the impaired reach are used to develop the load duration curve. Therefore, the flow record should be of sufficient length to be able to calculate percentiles of flow (typically 20 years or more). If a flow record for an impaired stream is not available, then a synthetic flow record is needed. For this TMDL, flow gage data from Gravois Creek were used, USGS 07010180 Gravois Creek near Mehlville, Mo. This gage had an approved daily flow record from July 23, 1996 to Nov. 30, 2010. Data from this gage were corrected for the drainage areas of the impaired segments (Table B.1). From these flow records, flow duration curves were developed (Figure B.1 and B.2).

Table B.1. Drainage areas of gage and impaired watersheds and correction factors

Location:	USGS 07010180	WBID 1712	WBID 1713
Drainage Area:	18.1 sq. miles	22.6 sq. miles	20.9 sq. miles
Correction Factor:	--	1.2486	1.1547

The selected watershed targets are multiplied by the flow and a conversion factor to generate the allowable load at different flows. With this load duration curve, the targeted concentration is constant at all flow percentiles. The target concentration used for this load duration curve was the recreation season geometric mean criterion of 206 *E. coli* counts / 100 mL of water, which was applied as a daily target.

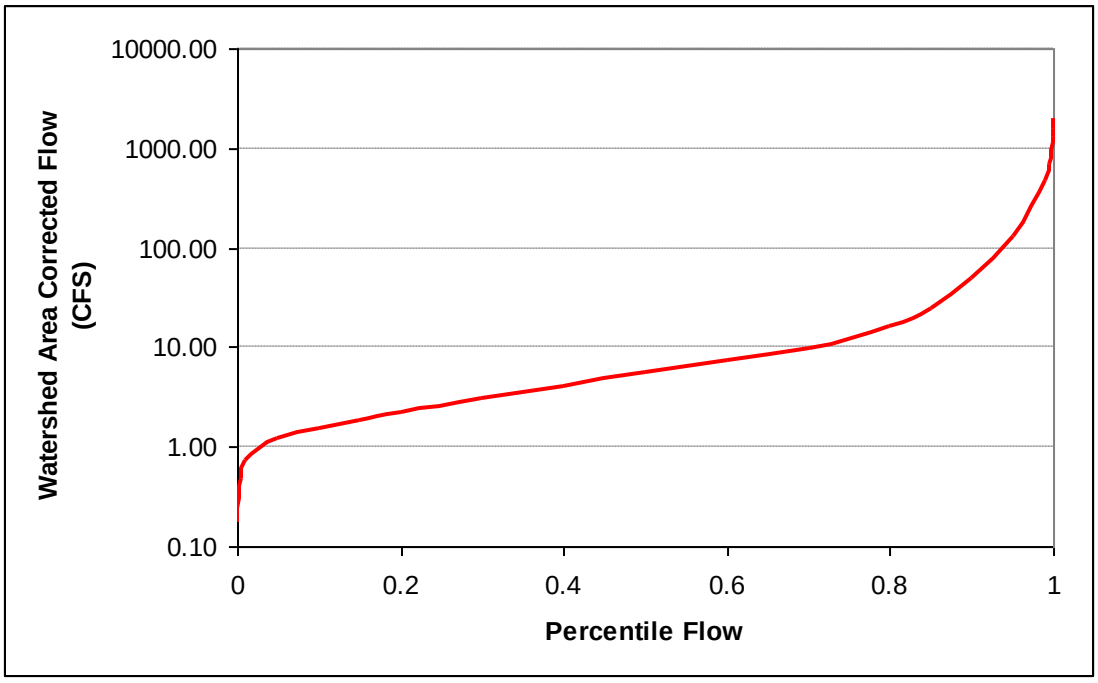

Figure B.1 Flow duration curve for WBID 1712 of Gravois Creek

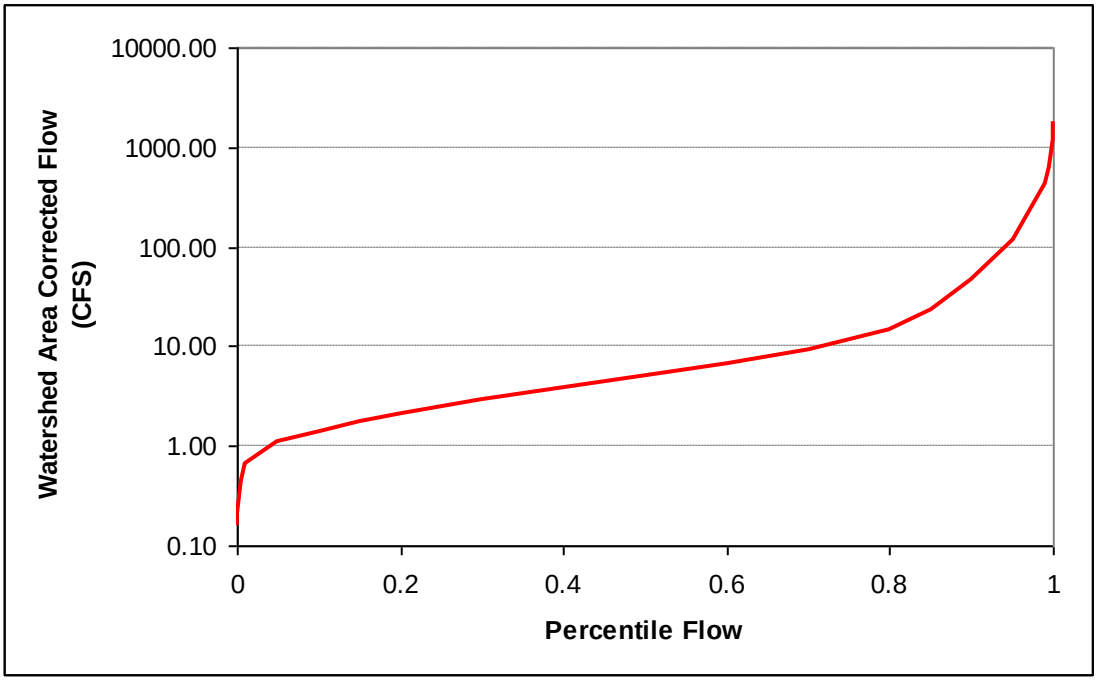

Figure B.2 Flow duration curve for WBID 1713 of Gravois Creek