United States Environmental Protection Agency

Region 7

Total Maximum Daily Load

Wilson and Jordan Creeks (MO_2375 and 3374)

Christian and Greene Counties, Missouri

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

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Date

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

Name: Wilson Creek and Jordan Creek

Location: Wilson[2] Creek: Near the city of Springfield in Christian County and Greene County, Missouri
Jordan Creek: Joins Fassnight Creek to form Wilson Creek

Hydrologic Unit Code (HUC): 110100020301, 110100020302, and 110100020303

Water Body Identification (WBID): 2375 (Wilson Creek), 3374 (Jordan Creek)

Missouri Stream Class: P[3]

Designated Beneficial Uses:
- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Whole Body Contact Recreation (Category B)
- Protection of Human Health (Fish Consumption) (CSR, 2009)

Size of Classified Segment: WBID 2375: 18 miles; WBID 3374: 3.8 miles

Location of Classified Segments: WBID 2375: Mouth to Section 16, T29N, R22W
WBID 3374: From mouth at C Section 29, T29N, R22W to Section 13, T29N, R22W

Location of Impaired Segment: From the confluence with James River upstream approximately 18 miles and including 3.8 miles of Jordan Creek from its confluence with Wilson Creek (CSR, 2008).

Size of Impaired Segment: WBID 2375: 18 miles[4], WBID 3374: 3.8 miles[3]

Pollutant: WBID 2375: Unknown
WBID 3374: Unknown

Identified Source on 303(d) List: WBID 2375: Multiple point sources and urban nonpoint sources
WBID 3374: Urban nonpoint sources

TMDL Priority Ranking: Medium

[1] The term "runoff" is used to describe overland flow from all types of land uses, for both point and nonpoint sources of storm water.
[2] Wilson Creek is also referred to as Wilsons Creek on USGS topographic maps. The Missouri Department of Natural Resources (MDNR) is revising WQS to make the naming conventions consistent.
[3] Class P streams maintain flow even during drought conditions. See Missouri Water Quality Standards (WQS) 10 [CSR] 20-7.031(1)(F). The WQS can be found at: www.sos.mo.gov/adrules/csr/current/10csr/10c20-7.pdf
[4] The mileage listed corresponds with the length of the impaired reach in the 2008 303(d) List and WQS Table H. Due to the increased accuracy of Geographic Information System (GIS) data layers over previous methods of stream length measurements, the stream length used in the TMDL analysis may not correspond exactly to Table H. The descriptive start and end point of each segment remains the same, and this TMDL addresses the impaired segment in its entirety.

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List of Acronyms

AVG	Average
BMP	Best Management Practice
CAFO	Concentrated Animal Feeding Operation
cfs	Cubic Feet per Second
CSR	Code of State Regulations
CFR	Code of Federal Regulations
CWA	Clean Water Act
CWP	Center for Watershed Protection
Deg	Degrees
DO	Dissolved Oxygen
DRO	Diesel Range Organics
EDU	Ecological Drainage Unit
e.g.	For Example
EPA	Environmental Protection Agency
FDC	Flow Duration Curve
GIS	Geographical Information System
GPM	Gallons Per Minute
GRO	Gasoline Range Organics
HUC	Hydrologic Unit Code
LA	Load Allocation
LC	Loading Capacity
MDC	Missouri Department of Conservation
MDNR	Missouri Department of Natural Resources
mg	Milligrams
MGD	Million Gallons per Day
MO	Missouri
MoRAP	Missouri Resource Assessment Partnership
MOS	Margin of Safety
MRBCA	Missouri Risk Based Corrective Action
MS4	Municipal Separate Storm Sewer Systems
MSOPS	Missouri State Operating Permit System
MSDIS	Missouri Spatial Data Information Service
NA	Not Applicable
NASS	National Agricultural Statistics Service
NESC	National Environmental Service Center
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NTU	Nephelometric Turbidity Units
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
O&G	Oil and Grease
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl

List of Acronyms

PCS	Permit Compliance System
RTI	RTI International Corporation
SPMD	Semi Permeable Membrane Device
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
µg	Microgram
URS	URS Corporation
U.S.	United States
VOC	Volatile Organic Compound
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WBID	Water Body Identification
WERF	Water Environment Research Federation
WLA	Wasteload Allocation
WQS	Water Quality Standards
WWTP	Wastewater Treatment Plant

WILSON CREEK and JORDAN CREEK TMDLs PHASED and ADAPTIVE MANAGEMENT PLAN

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

In this instance, the United States Environmental Protection Agency (EPA) is establishing the Wilson Creek TMDL in order to comply with the 2001 Consent Decree, *American Canoe Association, et al. v. EPA*, Consolidated Case No. 98-1195-CV-W-SOW, consolidated with 98-4282-CV-W-SOW. However, EPA recognizes that it may be appropriate to revise these TMDLs based on analyses performed after additional data and information has been collected. Considering such possible revisions, it is appropriate to characterize these TMDLs as phased TMDLs. In this first phase of the Wilson Creek and Jordan Creek TMDLs, EPA recommends that monitoring be conducted to assess the effect of implementation of the TMDL on the water quality of the watersheds.

In a phased TMDL, EPA uses the best information available at the time to establish the TMDL to meet applicable water quality standards (WQS) and to allocate loads to the pollutant sources. However, the phased TMDL approach recognizes that additional data and information may be necessary to further validate the assumptions of the TMDL and to provide greater certainty that the TMDL will achieve the WQS. EPA anticipates that additional data and information will be collected to reassess the Wilson Creek and Jordan Creek biocommunities and other water quality parameters, and additionally studies will be conducted to further evaluate a potential source of the impairment, known as "Brewery Springs" located on the Union Pacific property. This new data and information can then be used to determine if the TMDLs should be revised. Revision may include adjustments to the overall TMDL approach, or the specific wasteload allocations (WLA) and load allocations (LA).

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

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[5] Additional information on green infrastructure can be viewed at http://cfpub.epa.gov/npdes/greeninfrastructure/information.cfm#greenpolicy and www.epa.gov/nps/lid/.

1 INTRODUCTION

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

Section 303(d) of the CWA and Chapter 40 of the Code of Federal Regulations (CFR) Part 130 requires states to develop TMDLs for waters not meeting 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 maximum amount of a pollutant (the load) that a water body can assimilate without exceeding the WQS for that pollutant. WQS are benchmarks used to assess the water quality of rivers and lakes. The TMDL also establishes the pollutant loading capacity (LC) necessary to meet the Missouri WQS established for each water body based on the relationship between pollutant sources and instream water quality conditions. The TMDL consists of a WLA, a LA and a margin of safety (MOS). The WLA is the portion of the allowable load that is allocated to point sources. The LA is the portion of the allowable load that is allocated to nonpoint sources. The MOS accounts for the uncertainty associated with pollutant loads and the receiving water body's response. This is often associated with the assumptions and data limitations of the analysis methods used to assess the water body.

The goal of the TMDL program is to restore designated beneficial uses to water bodies. In addition to establishing TMDLs for Wilson and Jordan Creeks, this report provides a summary of information, results and recommendations related to the impairment based on a broad analysis of watershed information and detailed analysis of flow data and comparison to unimpaired biological reference streams.

Section 2 of this report provides background information on the Wilson and Jordan Creek watersheds and defines the water quality problems. Section 3 describes potential sources of concern. Section 4 presents the applicable WQS and TMDL targets. Sections 5 to 8 present the required TMDL elements (LC, WLA, LA, MOS, seasonal variation) and Sections 9 to 12 summarize the follow-up monitoring plan, reasonable assurances, public participation and a summary of the administrative record.

2 BACKGROUND

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

2.1 THE SETTING

Wilson Creek drains a 102-square mile watershed. The northern and eastern portions of the watershed are heavily urbanized. The southwest end of the watershed is comprised of scattered agricultural, grassland and forested areas. Agricultural activities include row cropping, dairy farming and pasturing beef cattle. Wilson Creek is one of the largest tributary streams in the James River system and it drains much of the city of Springfield, Missouri. It flows south along the west side of the city, passes through the Wilson Creek National Battlefield, and joins the James River about eight miles south of the city. Jordan Creek drains a 13.5 square mile watershed that is entirely within the city of Springfield. It flows approximately 2 miles in a southerly direction until it joins with Fassnight Creek. This segment flows in a westerly direction approximately 1.5 miles until it joins Wilson Creek. Approximately 3.5 miles downstream of Jordan Creek, South Creek joins Wilson Creek. Segments of Wilson Creek and many of its tributaries below Jordan Creek to the confluence with the James River are classified as losing streams by the Missouri Department of Natural Resources (MDNR) (MDNR, 2007a). The Springfield Southwest Wastewater Treatment Plant (WWTP) discharges 39 million gallons per day (MGD), (60 cubic feet per second (cfs)), of treated municipal wastewater below the confluence of South Creek and Wilson Creek. The addition of flow from the WWTP changes the hydrologic and hydraulic character of the stream.

As an urban stream, Jordan Creek has a long history of anthropogenic impacts. Once a source of water for early settlers' livestock, the creek became a flood-prone liability in the early 1900s, serving as a conduit for all kinds of trash and pollutants produced in Springfield's original industrial area. The creek was considered such a liability that by the late 1920s, city leaders had it confined to concrete channels and tunnels as it flowed through downtown. Now, it's at the heart of an effort to redevelop the Jordan Creek valley with parks and rehabilitated buildings.

The two impaired sections include portions of Wilson Creek and all of Jordan Creek. The Wilson Creek impaired segment spans approximately 18 miles[6], beginning south of Springfield and ending at the confluence with the James River. Jordan Creek is also impaired and is part of this study. Jordan Creek is listed as impaired from its confluence with Wilson Creek upstream 3.8 miles.

[6] The stream length listed is consistent with EPA approved 2008 303(d) List and Missouri WQS Table H. Due to the increased accuracy of GIS data layers for analysis over previous methods of stream length measurements, the stream length used in the TMDL analysis may not correspond exactly to Table H; however, the descriptive start and end point of each segment remains the same, and this TMDL addresses the impaired segment in its entirety.

Wilson Creek is listed as impaired due to low diversity of fish and aquatic invertebrate species. The reduction in the natural community of aquatic invertebrates is an exceedance of Missouri's General WQS for protection of aquatic life and natural biological aquatic communities. Water quality monitoring has identified heavy metals, pesticides and other organic chemicals in Wilson Creek and its tributaries. Toxicity is likely caused by many different contaminants that enter the stream during storm water events, which is supported by a United States Geological Survey (USGS, 2003) study and EPA study (2009a) that identified the presence of low levels of pesticides, metals, polycyclic aromatic hydrocarbon (PAH) and volatile organic compounds (VOCs) in water and Semi Permeable Membrane Device (SPMD) samples. The water quality limited segments are included on the 2008 Missouri 303(d) List and are identified as impaired due to multiple point/urban nonpoint sources (Wilson Creek) and urban nonpoint sources (Jordan Creek).

Evidence of toxicity includes very low diversity of fish and aquatic invertebrate animals based upon sampling by biologists at City Utilities of Springfield and Missouri Department of Conservations' Resource Assessment and Monitoring database.[7] Wilson Creek has been the subject of several studies over the past two decades. These studies include the following:

- Biological Assessment Report for Springfield Urban Streams Clear Creek, Jordan Creek, Wilson Creek and Galloway Creek (MDNR, 2007b)
- The deterioration of the macroinvertebrate fauna of lower Pearson Creek along the eastern edge of Springfield, Missouri, with comparison to other local sampling points under varying influence from the city of Springfield. City Utilities of Springfield, Missouri (Youngsteadt, N.W. 1994)
- Selected Chemical Characteristics and Toxicity of Base Flow and Urban Storm Water in the Pearson Creek and Wilson Creek Basins, Greene County, Missouri, August 1999 to August 2000, USGS 02-4124. (USGS, 2003)
- Water quality in the upper James River in 1984-85 with comparisons to 1964-65 (Youngsteadt and Gumucio 1986)
- James River nutrient TMDL, (MDNR, 2001)

While each of these studies focused on different spatial scales, locations and parameters of concern, they indicate the health and stability of the resident biological community has been a concern for some time.

2.2 PHYSIOGRAPHIC LOCATION, GEOLOGY AND SOILS

The area is part of the Springfield Plateau physiographic province. The Springfield Plateau consists of undulating to rolling plains. Elevation ranges from about 900 to 1,500 feet above sea level. The climate is hot in summer and moderately cool in winter. Rainfall averages about 43 inches per year and is well distributed throughout the year. Mean monthly temperatures range from an average of 35 degrees Fahrenheit in winter (December, January and February) and 76 degrees Fahrenheit in summer (June, July and August).

[7] MDC RAM Database (e-mail communication with Mike McKee, MDC per MDNR).

Bottomland soils in the Wilson Creek drainage area (including Jordan Creek) are of the Goss-Wilderness-Peridge association and comprise approximately one-third of the watershed. This soil association is characterized by narrow to relatively wide upland ridges, flood plains and terraces. This soil association exhibits strongly sloping to steep, stony or rocky areas next to flood plains and stream terraces. It was formed from rocks weathered from cherty limestone or dolomite. Typically, the soil's surface layer is a dark grayish brown cherty silt loam to brown silt loam from two to nine inches thick. Karst topography is common, with many sinkholes, caves and losing streams. The area around Springfield is within Missouri's primary karst area. Sinkholes are common and are known to convey storm water to streams. Slope ranges from 2 to 20 percent. Upland soils consist primarily of the Wilderness-Viraton association and comprise approximately two-thirds of the watershed. This association consists of broad upland ridges, narrow flood plains, and terraces. Sinkholes range from few to many. Slope of the major soils ranges from 2 to 9 percent. These soils are formed from cherty limestone, and the surface layer is from two to seven inches thick. This association has a fragipan or hardpan layer that restricts root growth in the subsoil. These soils are mostly used for grasses and legumes with some areas suitable for growing small grain crops.

Table 1 and Figure 1 provide a summary of soil types in the Wilson Creek (including Jordan Creek) watershed. Soil with hydrologic soil group C covers approximately 67 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. Approximately 26 percent of the soils in the impaired watershed are categorized as Group B. Group B soils are silt or loam and have moderate infiltration rate when thoroughly wetted. No soil types of Group D or A soils are found in the watershed (Purdue Research Foundation, 2009). The soil's hydrologic group relates to the rate at which rainfall enters the soil profile, which in turn affects the amount of water that enters the stream as direct runoff. Soil characteristics are an important factor in the watershed hydrology and influence the amount of precipitation that is partitioned into storm flow via surface and shallow subsurface flows. This, in turn, influences the frequency, magnitude and duration of stream flows.

Table 1. Wilson Creek Watershed Soils Breakdown (NRCS, 2009)

Soil Type	Hydrologic Soil Group	Area (Acres)	Percent
Bona gravelly silt loam	B	1,190.54	1.8
Cedargap silt loam	B	1,353.94	2.1
Cedargap-Razort complex	B	654.16	1.0
Creldon silt loam	B	8,394.63	12.8
Dapue silt loam	B	701.51	1.1
Newtonia silt loam	B	2,037.08	3.1
Peridge silt loam	B	2,616.58	4.0
Subtotal	**B**	**16,948.44**	**25.9**
Captina-Needleye complex	C	762.75	1.2
Goss gravelly silt loam	C	10,120.73	15.5
Goss-Gasconade complex	C	1,217.48	1.9
Goss-Wilderness complex	C	1,996.08	3.1
Hepler silt loam	C	1,132.68	1.7
Keeno gravelly silt loam	C	696.37	1.1
Keeno-Bona complex	C	5,268.73	8.1
Tonti silt loam	C	2,942.93	4.5
Viraton silt loam	C	3,579.34	5.5
Wanda silt loam	C	8,023.69	12.3
Wilderness gravelly silt loam	C	8,224.28	12.6
Subtotal	**C**	**43,965.05**	**67.5**
Other[8]	B/C	4,485.03	6.9

[8] Other soil types that make up less than one percent of the total watershed area include: Barco fine sandy loam, Basehor fine sandy loam, Bolivar fine sandy loam, Bolivar stony fine sandy loam, Cedergap gravelly silt loam, Clarksville very gravelly silt loam, Collinsville-Rock outcrop complex, Gasconade-Gatewood-Rock outcrop complex, Gerald silt loam, Hoberg silt loam, Humansville silt loam, Needleye silt loam, Osage sitly clay loam, Pits-Dumps complex, Sacville silty clay loam, Scholten gravelly silt loam, Secesh-Cadargap complex, Sowcoon silt loam, Splitlimb silt loam, Udorthents, Waben-Cedergap, and Water.

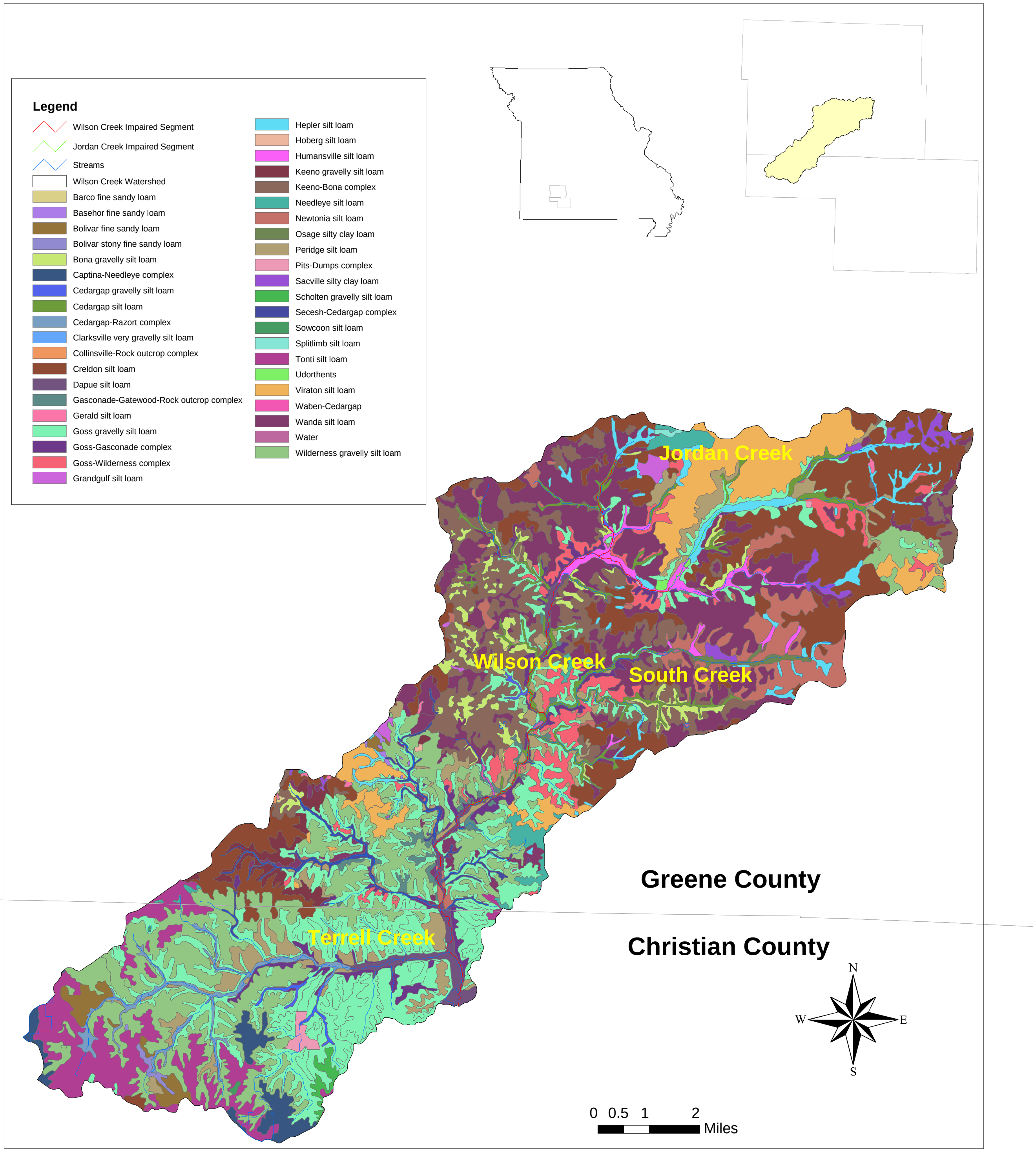

Figure 1. Wilson Creek Soils Map

2.3 SPRINGS AND SINKHOLES

The Wilson Creek watershed is underlain with Burlington-Keokuk Limestone which contains many fractures and solution channels. Consequently, the area is dominated by karst features, which include springs, as well as losing streams, caves and sinkholes. Figure 2 includes springs in the watershed and indicates which sections are losing and gaining streams. This hydrology involves a high level of interaction between surface water and ground water. There are 61 known springs in the watershed and spring output (Table 2 and Figure 2) provides flow to Wilson and Jordan Creeks. Karst features and springs have been known to contribute pollutants to Wilson Creek in some locations, while facilitates the loss of water in other areas. Past studies (USGS, 2003) have reported that sinkholes have been used, and may function, as storm water conduits. The recharge areas for many of these springs include past and present industrial sites with the potential to contaminate streams.

The National Park Service Study (Pulley et al., 1998) reports that Radar Springs has a drainage area that extends far from its outlet and includes several sinkholes much closer to Springfield. This further indicates that recharge from springs is a known source of storm water and may contribute pollutants to Wilson or Jordan Creeks from locations far from the stream.

Table 2. Springs in the Wilson Creek Watershed (MDNR, 2006)

Spring	Flow	Water Body
Sherrod Spring	100 gpm - 1 cfs	South Creek
Rader Spring	10-100 cfs	Wilson Creek
Unnamed Spring	10-100 cfs	Unknown
Campground Spring	10-100 gpm	Shuyler Creek
Pruitt Spring	10-100 gpm	Shuyler Creek
Roundtree Spring	10-100 gpm	Wilson Creek
Double Spring (2)	1-10 gpm	Unknown
Rolland Spring	1-10 gpm	Mcelhaney
Lindsey Spring	1-10 gpm	Mcelhaney
Unnamed Spring	No Flow Data	Unknown
Terrell Spring	No Flow Data	Unknown
Unnamed Spring	No Flow Data	Unknown
Unnamed Spring	No Flow Data	Unknown
Unnamed Spring	No Flow Data	Unknown
Unnamed Spring	No Flow Data	Unknown
Skeggs Branch	No Flow Data	Wilson Creek
Unnamed Spring	No Flow Data	Shuyler Creek
Pipeline Spring	No Flow Data	Wilson Creek
Ragsdale Spring	No Flow Data	Shuyler Creek
Mcclure Spring #3	No Flow Data	Shuyler Creek
Mcclure Spring #2	No Flow Data	Shuyler Creek
Mcclure Spring #1	No Flow Data	Shuyler Creek
Harold Don Spring	No Flow Data	Shuyler Creek

Spring	Flow	Water Body
Sanders Spring	No Flow Data	Shuyler Creek
Robertson Spring	No Flow Data	Shuyler Creek
Jones Spring	No Flow Data	Unknown
Rey Spring	No Flow Data	Wilson Creek
Prestley Spring	No Flow Data	Shuyler Creek
Homer's Spring	No Flow Data	Shuyler Creek
Mccorkle Spring	No Flow Data	Shuyler Creek
Sylvania Spring #2	No Flow Data	Shuyler Creek
Sylvania Spring #1	No Flow Data	Shuyler Creek
Sylvania Spring #3	No Flow Data	Shuyler Creek
Lily Spring	No Flow Data	Shuyler Creek
Keith Spring	No Flow Data	Shuyler Creek
Short Spring	No Flow Data	Mcelhaney Creek
Taylor Springs	No Flow Data	Wilson Creek
Poplar Spring	No Flow Data	Mcelhaney
Rader Estevella	No Flow Data	Wilson Creek
Unnamed Spring	No Flow Data	Del Prado
Boehm Spring	No Flow Data	Del Prado
Boehm Spring #2	No Flow Data	Del Prado
Rader Upper Estavelle	No Flow Data	Wilson Creek
Jackson Spring	No Flow Data	Unknown
Sunset Street Spring	No Flow Data	South Creek
Jefferson Spring	No Flow Data	South Creek
Durst Park Seeps	No Flow Data	South Creek
Falling Branch Cave Spring	No Flow Data	Wilson Creek
Elfindale Spring	No Flow Data	Unknown
Syntex Spring	No Flow Data	Unknown
Phelps Grove Spring	No Flow Data	Fassnight
Fassnight Park Spring	No Flow Data	Fassnight
Dingledein Spring	No Flow Data	Jordan Creek
Jordan Creek Spring	No Flow Data	Jordan Creek
Lyman Spring	No Flow Data	Jordan Creek
Unnamed Spring	No Flow Data	Unknown
Jones Spring	No Flow Data	Jordan Creek
Grant Beach Park Spring	No Flow Data	Jordan Creek
Silver Spring	No Flow Data	Jordan Creek
Brewery Spring	400,000 – 800,000 gpd	Jordan Creek

Flow abbreviations: gpm = gallons per minute; gpd = gallons per day; cfs = cubic feet per second (1 cfs equals 448.83 gpm)

In June 2009, a citizen reported that a spring discharging to Jordan Creek about 300 feet upstream of Fort Street, had a diesel smell. MDNR sampled the spring in June 2009, and determined there were gasoline range organic (GRO) compounds indicative of gasoline products, and benzene and naphthalene at levels higher than the state groundwater criteria. While the spring smelled strongly of diesel, diesel range organic (DRO) compounds were not detected in the analysis (Table 3). Discharge from the spring was estimated to be between 400,000 to 800,000 gallons per day. During the summer months, however, the spring can run dry and have no noticeable discharge.

Table 3. Sampling Data Summary for Brewery Spring (All Units µg/L)

Parameter	June 2009	Drinking Water MCL/ MRBCA Domestic Use	Missouri WQS Protection of Aquatic Life	Missouri WQS Groundwater	Missouri WQS Human Health/ Fish Consumption
GRO	1,590	18,100	*	**	*
DRO	<500 (ND)	34,300	*	**	*
Benzene	***54.7***	5	*	5	71
Toluene	39.2	1000	*	1000	200,000
Ethylbenzene	13.5	1000	*	**	*
Xylenes	348	10,000	*	10,000	*
Naphthalene	***40.2***	20	*	20	*

Italics indicate the value exceeds one or more of the standards listed to the right.
µg/L = micrograms per liter, ND = non detect, MCL = Maximum Contaminant Levels, MRBCA = Missouri Risk-Based Corrective Action
* - No surface water quality criteria exist in Missouri's WQS for these parameters
** - No groundwater criteria exist in Missouri's WQS for these parameters

For the 2009 sampling event, benzene and naphthalene concentrations from the spring exceeded the Missouri WQS for groundwater, drinking water Maximum Contaminant Levels (MCL) and the Domestic Use targets of the Missouri Risk-Based Corrective Action (MRBCA) program. The MRBCA targets are designed to be protective of human health risk from ingestion of contaminated groundwater. No surface water (rivers and streams) criteria exist in Missouri's WQS for the Protection of Warm Water Aquatic Life for these particular contaminants. This does not mean, however, that there is no effect on aquatic life due to the contaminated spring discharge.

The spring is on property now owned by Union Pacific Railroad, which leases railroad track to the Missouri and Northern Arkansas Railroad. It is being referred to as "Brewery Spring" since it is near the old Dingledein Brewery; however, the correct name for the spring is uncertain. The spring itself could be relatively new in origin as older springs may have been obliterated by the filling of the area for the Burlington Northern Santa Fe rail yard to the north of Jordan Creek (now Jordan Valley Park - West Meadows) and the water may now be emerging in a new spot.

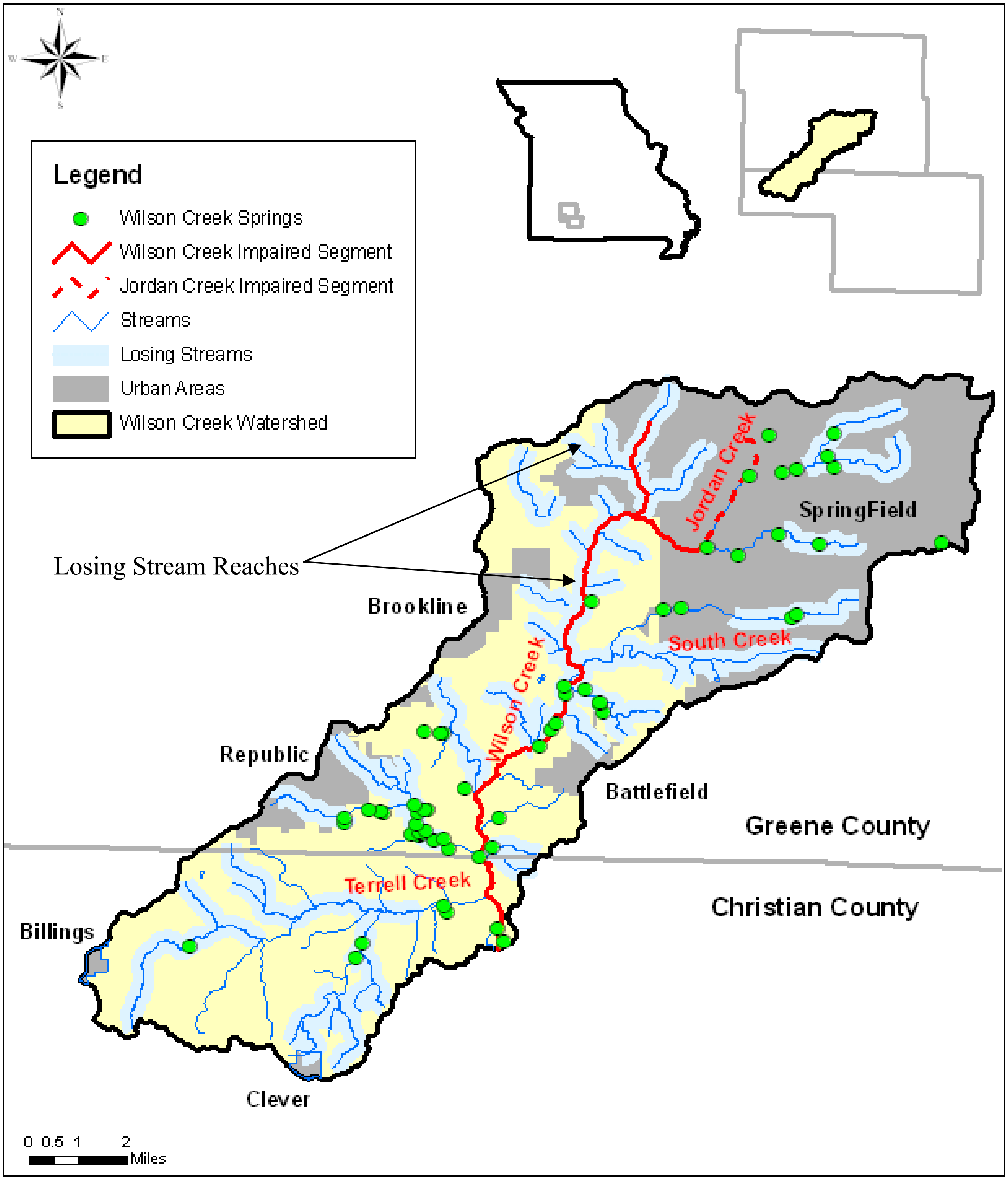

Figure 2. Wilson Creek Springs and Losing Streams[9]

[9] A stream that is losing water to (or recharging) the groundwater system as identified by MDNR (MDNR, 2007a).

2.4 RAINFALL AND CLIMATE

Two active weather stations are located near Wilson and Jordan Creeks in Greene County. The Springfield Weather Station and the Springfield Regional Airport Weather Station are west of Springfield and approximately 10 miles from Wilson Creek (Figure 4). Both stations record daily precipitation, maximum and minimum temperature, snowfall and snow depth. Figure 3 provides a summary of rainfall and climate data for Station 72440 (Springfield, MO Regional Airport) based on 30 year totals (1971 – 2000) (NOAA, 2009). The annual average precipitation and temperature over the 30 year period is 44.97 inches and 56.2 degrees Fahrenheit, respectively. These two weather stations provide useful information for understanding when critical conditions occur and establishing a general understanding of the hydrology of the watershed.

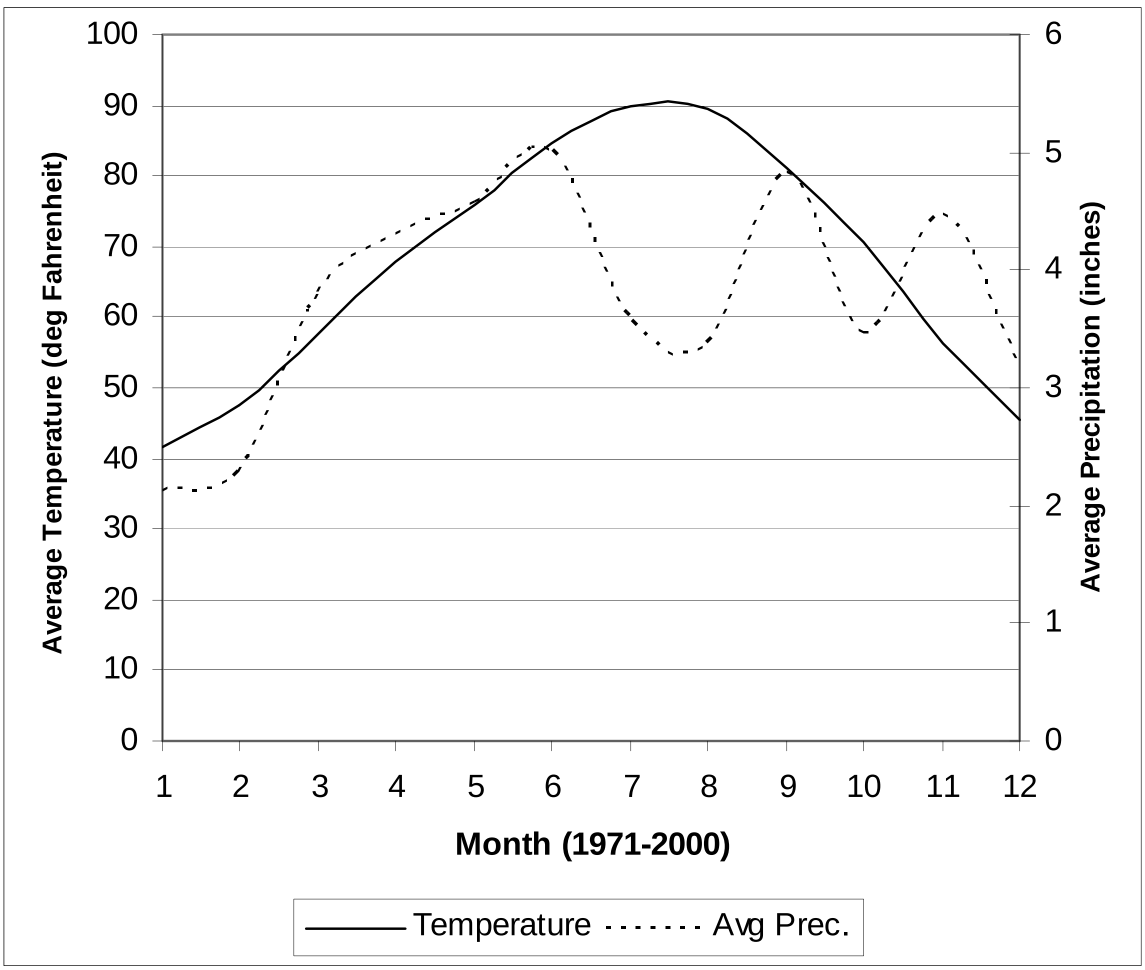

Figure 3. 30-Year Temperature and Precipitation Monthly Averages for Station 72440 (Springfield, MO Regional Airport)

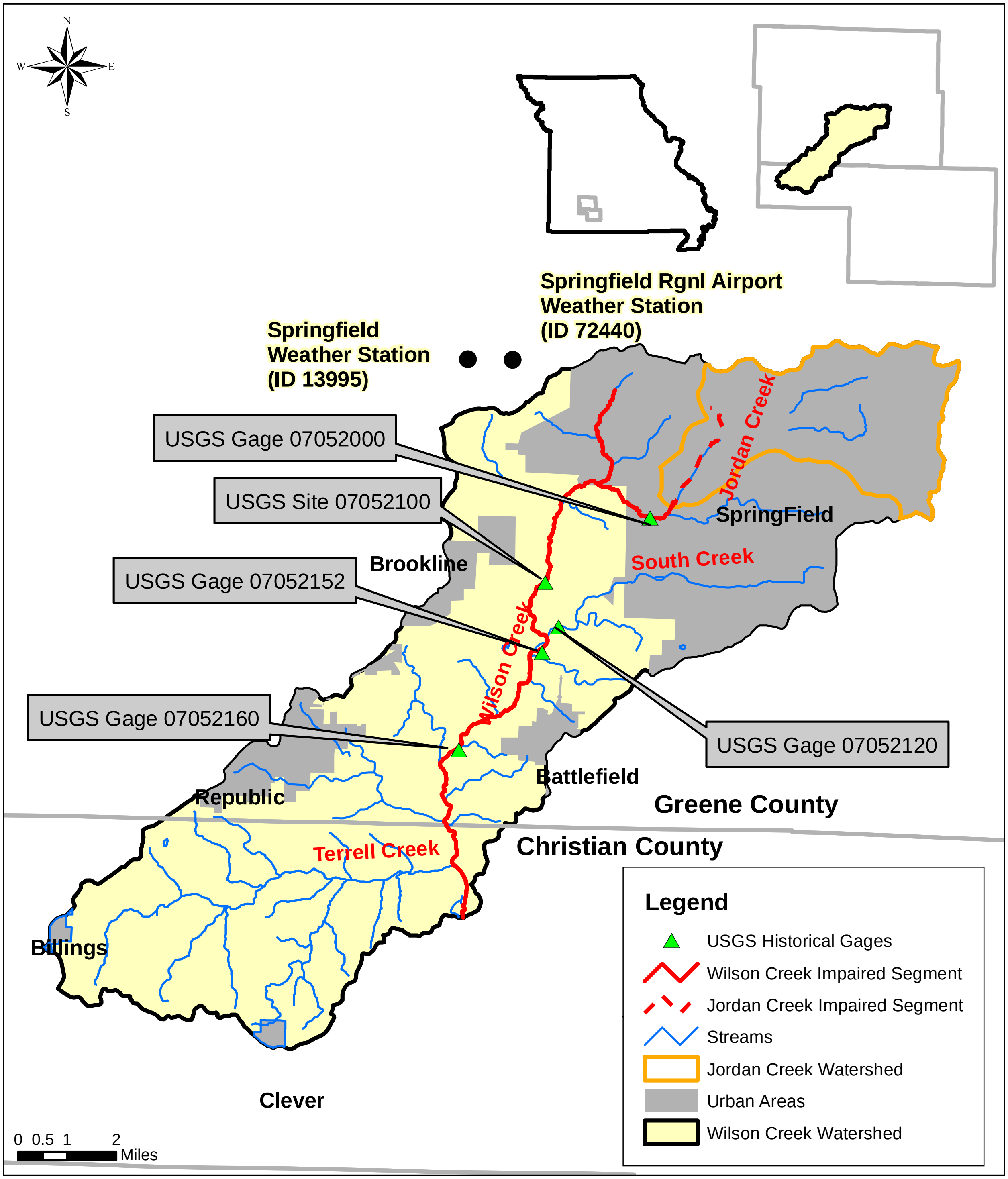

Figure 4. Location of Wilson Creek Watershed with Weather Stations and USGS Gages

2.5 POPULATION

The population of the Wilson Creek watershed is not directly available. However, the Census reports that the 2000 population in Greene County and Christian County for all urban areas was 107,930 and 26,039, respectively (U.S. Census Bureau, 2000). The urban population of the watershed can be roughly estimated by multiplying the percent of urban area (Springfield, Republic, Battlefield, Brookline, Billings and Clever) that are within the watershed by the individual population of each urban area. The urban population of the Wilson Creek watershed is approximately 80,024.

The rural population of the watershed can be estimated based on the proportion of the watershed compared to Greene and Christian Counties. Greene County covers an area of 677.32 square miles and has a population of 240,391. Christian County covers an area of 563.30 square miles and has a population of 54,285.

The rural population in Greene County is approximately 69,461 people (total county population minus the sum of Springfield, Strafford, Republic, Battlefield, Brookline, Ash Grove, Walnut Grove, Fair Grove and Willard) and the rural county area is 579.27 square miles (total county area minus county urban area). The portion of the Wilson Creek watershed rural population located in Greene County was estimated to be 3,931 persons; calculated by dividing the rural watershed area in Greene County (32.78 square miles) by the Greene County rural area (579.27 square miles), and multiplying the product by the Greene County rural population (69,461 persons).

The rural population in Christian County is approximately 28,246 people (total county population minus the sum of Billings, Clever, Spokane, Highlandville, Sparta, Nixa and Ozark) and the rural county area is 540.62 square miles (total county area minus county urban area). The portion of the Wilson Creek watershed rural population located in Christian County was estimated to be 1,420 persons; calculated by dividing the rural watershed area in Christian County (27.18 square miles) by the Christian County rural area (540.62 square miles), and multiplying the product by the Greene County rural population (28,246 persons).

The total estimated rural population of the Wilson Creek watershed is approximately 5,351, and the total estimated population (rural and urban) of the Wilson Creek watershed is 85,375. An overall population density for the Wilson Creek watershed was calculated to be (85,375 persons divided by 102 square miles) 837 persons per square mile.

Population in the Wilson Creek watershed has likely increased during the past several decades along with Springfield, MO. Springfield is the third largest city in the state of Missouri and the largest city within and near the Wilson Creek watershed. Springfield's estimated population is 156,000. The Springfield metropolitan area's population was approximately 426,000 in 2009, and is ranked 114th in the United States. It includes the counties of Christian, Dallas, Greene, Polk and Webster. The Springfield metropolitan area has experienced significant growth since the 1960s (Table 4), averaging 21 percent growth per decade.

Table 4. Population Growth in the Springfield Metropolitan Area Between 1960 and 2000

	1960	1970	1980	1990	2000
Total	152,388	183,615	228,118	264,346	325,721
Change		31,227	44,503	36,228	61,375
Percent Change		20.5	24.2	15.9	23.2

2.6 LAND USE AND LAND COVER

The land use and land cover of the Wilson Creek watershed is shown in Figure 5 and summarized in Table 5 (MoRAP, 2005). The primary land uses/land covers are grassland (48.92 percent) and urbanized areas (impervious areas 13.3 percent; low intensity urban 18.9 percent; and high intensity urban 1.3 percent). Forest and cropland cover 9.8 percent and 3.5 percent, respectively. The remaining land area in the watershed is covered by herbaceous areas, barren areas, wetlands and open water. These categories comprise less than 5 percent of the watershed area.

Land use and land cover has been linked to water quality and aquatic life degradation. The Center for Watershed Protection (CWP) (CWP, 2003) identified 10 percent imperviousness as a threshold level. Watersheds with impervious or nearly impervious areas of 10 percent or greater typically had degraded aquatic communities. Watersheds with less than 10 percent impervious areas had healthier aquatic communities. If reasonable assumptions are made regarding the percent impervious area included in high intensity urban and low intensity urban, it is likely that the Wilson Creek watershed has approximately 20 percent impervious area. However, the impervious area may be greater than 30 percent because all the pervious portions of high and low intensity urban areas might have been impervious due to compaction of the soil (EPA, 2005).

Table 5. Land Use/Land Cover in the Wilson Creek Impaired Watershed

Land Use/Land Cover	Estimated Percent Impervious	Watershed Area		Percent of Watershed
		Acres	Square Miles	
Impervious[10]	100	9,939.3	15.5	13.3
High Intensity Urban[11]	45	939.2	1.5	1.3
Low Intensity Urban[12]	30	14,109.2	22.1	18.9
Barren or Sparsely Vegetated	2	481.0	0.8	0.7
Cropland	2	2,207.9	3.5	3.5
Grassland	2	29,405.1	46.0	48.9
Forest	2	5,989.1	9.4	9.8
Herbaceous	2	1,968.0	3.1	3.1
Wetland	0	126.5	0.20	0.2
Open Water	0	194.6	0.30	0.3
Total		**65,360**	**102**	**100**

A portion of the Greene County Municipal Separate Storm Sewer System (MS4) that covers the Springfield Urban area is within the Wilson Creek watershed. The MS4 comprises most of the urbanized area in the watershed. The land use of the MS4 area is included in Table 6. MS4s are required to be included in the WLA of a TMDL and have specific numeric targets. The land use in Table 6 is used to develop the TMDL targets for the Greene County MS4.

[10] Impervious land use includes non-vegetated, impervious surfaces dominated by streets, parking lots and buildings (MoRAP, 2005).
[11] High Intensity Urban land use includes vegetated urban environments with a high density of buildings (MoRAP, 2005).
[12] Low Intensity Urban land use includes vegetated urban environments with a low density of buildings (MoRAP, 2005).

Table 6. Land Use/ Land Cover in the Portion of the Greene County MS4 Contained within the Impaired Wilson Creek Watershed

Land Use/Land Cover	Estimated Percent Impervious	Watershed Area		Percent
		Acres	Square Miles	
Impervious	100	8,187.8	12.8	29.3
High Intensity Urban	45	831.3	1.3	3.0
Low Intensity Urban	30	12,422.6	19.4	44.4
Barren or Sparsely Vegetated	2	51.4	0.08	0.2
Cropland	2	131.9	0.21	0.5
Grassland	2	4,417.5	6.9	15.8
Forest	2	1,146.9	1.8	4.1
Herbaceous	2	725.0	1.1	2.5
Wetland	0	27.1	0.04	0.1
Open Water	0	35.4	0.06	0.1
Total		**27,977**	**43.7**	**100**

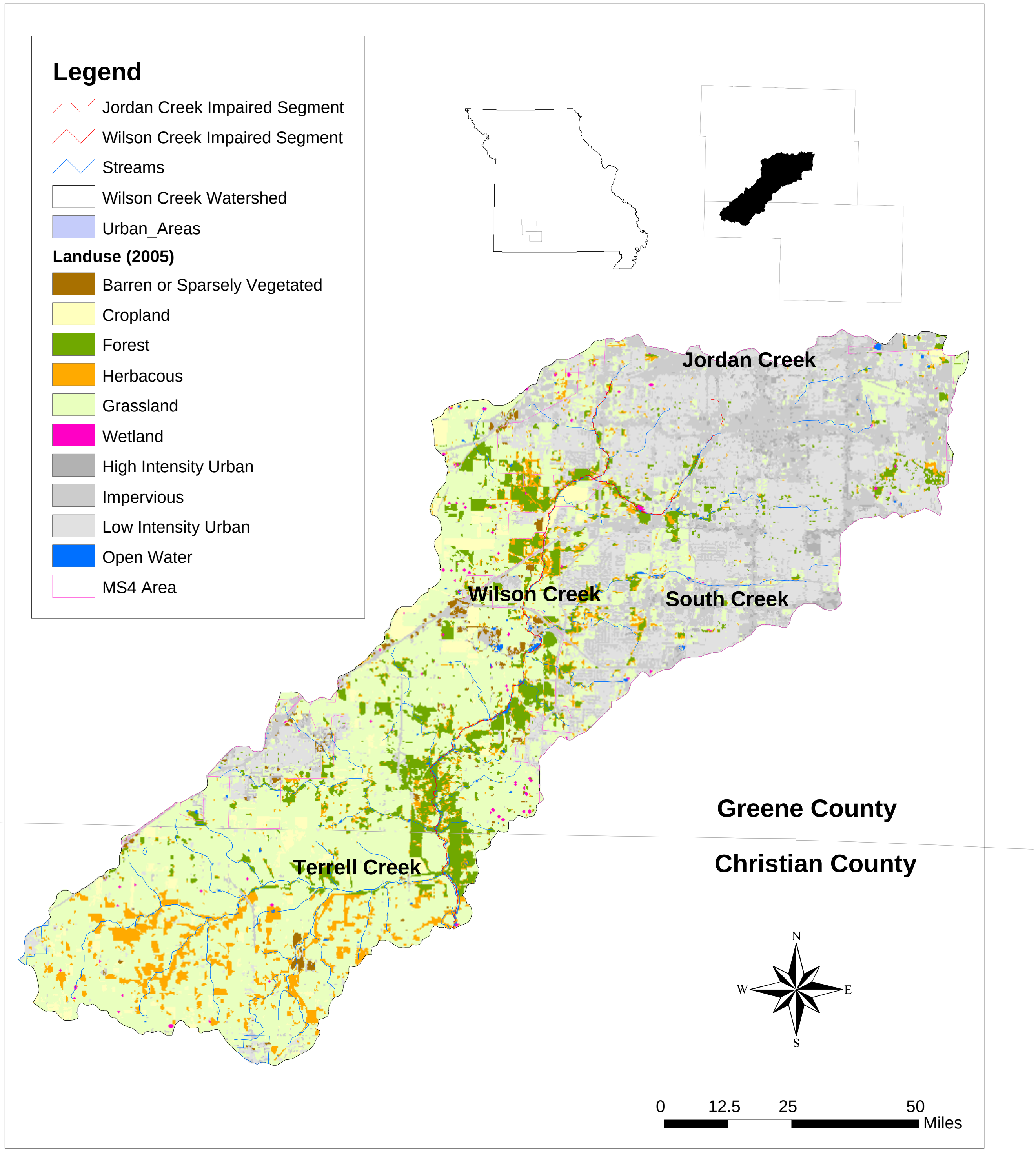

Figure 5. Land Use/Land Cover in the Wilson Creek Watershed

3 SOURCE INVENTORY

A source assessment is used to identify and characterize the known and suspected sources contributing to the impairment in Wilson and Jordan Creeks. For the purpose of this report, sources have been divided into two broad categories: point sources and nonpoint sources. Point sources can be defined as sources, either constant or time transient, which occur at a fixed location in a watershed. Nonpoint sources are generally accepted to be diffuse sources not entering a water body at a specific location. Substances from both point and nonpoint sources may be contributing to the decline in aquatic invertebrate populations, as well as impacts from changing flow dynamics and channel characteristics common to urbanized streams.

3.1 POINT SOURCES

The term "point source" refers to any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel or conduit, by which pollutants are transported to a water body. For the purposes of TMDL development, point sources are defined as sources regulated through the National Pollutant Discharge Elimination System (NPDES) program. Missouri has its own program for administering the NPDES program, referred to as the Missouri State Operating Permit System (MSOPS). The NPDES and MSOPS programs are the same and for the purposes of this document the term "NPDES" will be used. The following regulated entities are included in this source category:

- Municipal and industrial wastewater treatment plants (WWTPs),
- Concentrated animal feeding operations (CAFOs),
- Storm water runoff from MS4s and
- General permitted facilities (e.g., including storm water runoff from construction and industrial sites).

General permits (as opposed to site specific permits) are issued to activities that are similar enough to be covered by a single set of requirements. Storm water permits are issued to activities that discharge only in response to precipitation events. Point sources in the Wilson and Jordan Creek watersheds were identified by consulting EPA's Permit Compliance System (PCS) website[13] and MDNR's Geographic Information Systems (GIS) inventory[14] of NPDES-permitted facilities covered under storm water or general permits.

There are 176 point sources currently permitted in Wilson Creek watershed. NPDES permits include 17 general permits, 13 individual permits and 146 storm water permits. These are listed in Appendix A and shown in Figure 6. A breakdown of the general and storm water permits is also shown in Table 7. Of the permits listed, only the site specific permittees are required to monitor and report effluent concentrations.

The city of Springfield was the first city in the state to obtain its MS4 storm water permit which was issued by MDNR on July 26, 2002. As of October 2009 the city was working with

[13] www.epa.gov/enviro/html/pcs/index.html
[14] http://msdis.missouri.edu/datasearch/ThemeList.jsp; GIS layers updated May 2009 and June 2009 (MSDIS, 2009)

MDNR on reissuance of the permit for the next five years. The permit requires the city to administer a storm water management program that addresses storm water discharges from the MS4 that may impact the designated beneficial uses and water quality of area streams. The city accomplishes this by reducing both pollutants in storm water runoff and the dumping of pollutants directly into the MS4. The permit contains specific required activities and programs that must be implemented to comply with the permit, such as stream and runoff monitoring, public education and industry inspections.

The city of Springfield has conducted several studies that are intended to improve water quality of the urban streams within its borders. These or similar studies and projects have the potential to provide additional scientific understanding of the problems identified in Wilson and Jordan Creeks and to mitigate the impacts of urban storm water runoff. Projects and studies conducted include: biological assessments, water quality monitoring, daylighting and restoration of streams, watershed management plans and storm water management guidance.

Runoff from the city of Springfield MS4 has increased the frequency, duration and magnitude of storm runoff and carries pollutants from the urban land surface into the local streams. Increased runoff from urbanized areas may include increased loads of suspended sediment, metals, nutrients, organic chemicals, oil and grease (O&G) and toxic compounds. The runoff may also lead to increased channel scour, change in substrate, sediment deposition, low dissolved oxygen (DO) and toxic conditions within the stream. Several studies have demonstrated that urban storm water negatively impact the aquatic life of Wilson and Jordan Creeks. For example, a USGS study (2003) examined the chemistry and toxicity of baseflow and storm water in and near the city of Springfield and concluded that urban derived contaminants significantly degraded the water quality and aquatic biota of Wilson Creek. A biological assessment conducted by MDNR (2007b) also indicated that Jordan and Wilson Creeks above the Springfield WWTP were classified as non-supporting of aquatic life, with macroinvertebrate stream condition index (MSCI) value being 6 and 8, respectively. A stream with the MSCI of 16-20 is considered fully sustaining, 10-14 partially sustaining, and 4-8 as non-sustaining of aquatic life.

The Springfield Southwest WWTP is located at the confluence of Wilson Creek and South Creek and has operated at this location since 1959. Discharge volumes and the treatment processes used have upgraded since the plant's expansion and improvements in 1993. Currently, the plant is permitted to discharge 42.5 MGD but on average its discharge is slightly less (39 MGD). The WWTP employs advanced treatment systems that result in high quality effluent. Typical effluent characteristics are reported in Table 8 and the plants effluent passes whole effluent toxicity testing. In addition, the WWTP's discharge affects the streams hydrology in fundamental ways. Upstream of the plant, stream flows are storm event driven and little to no baseflow is present. Below the WWTP, there is a steady baseflow of approximately 60 cfs. The WWTP flows provide all of the baseflow during dry periods of the year. According to the 1997 invertebrate monitoring, MDNR indicated that both of the two study sites (3 and 5 miles) below the WWTP was considered partially sustaining, with MSCI values of 10.

Table 7. Individual, General and Storm Water Permits by Description in the Wilson and Jordan Creek Watersheds (MDNR, 2009 and EPA, 2009b)

Permit #[15]	Description	Total By Category
MOxxxxxxx	Individual Permits	13
MOG140xxx	Gasoline Service Stations	1
MOG350xxx	Petroleum Bulk Stations and Terminals	3
MOG490xxx	Crushed and Broken Limestone	11
MOG760xxx	Amusement and Recreation Services	1
MOG822xxx	Meat Packing Plants	1
MOR040xxx	Small MS4	4
MOR103xxx	Heavy Construction	1
MOR104xxx	Heavy Construction	1
MOR109xxx	Heavy Construction	76
MOR12A0xx	Ice Cream and Frozen Desserts	3
MOR12A129	Fluid Milk	1
MOR14A004	Corrugated and Solid Fiber Boxes	1
MOR14A033	Paper and Allied Products	1
MOR203083	Industrial Trucks, Tractors, Trailers, and Stackers	1
MOR203093	Fabricated Structural Metal	1
MOR203099	Refined Petroleum Pipelines	1
MOR203187	Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment	1
MOR203195	Food Products Machinery	1
MOR203206	Fabricated Plate Work	1
MOR203235	Electroplating, Plating, Polishing, Anodizing, and Coloring	1
MOR203314	Scrap and Waste Materials	1
MOR203329	Refined Petroleum Pipelines	1
MOR2033xx	Railroad Equipment	5
MOR203407	Fabricated Metal Products	1
MOR23Axxx	Medicinal Chemicals and Botanical Products	6
MOR23Dxxx	Plastics Products	1
MOR240xxx	Farm Supplies	2
MOR60Axxx	Motor Vehicle, Parts Used	11
MOR80Cxxx	Terminal and Joint Terminal Maintenance Facilities for Motor Freight Transportation	19
MOR80H031	Refuse Systems	2
MOR80H084	Heavy Construction	2
Total	**-**	**176**

[15] All permits are within the Wilson Creek (WBID: 2375) and Jordan Creek (WBID: 3374) watersheds.

Table 8. Average Springfield Southwest WWTP Effluent Characteristics (Springfield, 2009)

Parameter	Typical Concentration
BOD	< 2 mg/L
TSS	< 2 mg/L
NH4	<0.1 mg/L
DO	> 20 mg/L
Fecal Coliform	< 10 cfu/ 100 ml
Copper	15 µg/L
Chromium	< 10 µg/L
Zinc	40 µg/L
Cadmium	<5 µg/L
Lead	<20 µg/L
Nickel	< 10 µg/L
Mercury	<0.2 µg/L
Silver	<5 µg/L
Arsenic	<20 µg/L
Cyanide	< 10 µg/L
Total Toxic Organics	Below detection limit

mg/L = milligrams per liter, cfu = colony forming units, ml = milliliters, µg/L = micrograms per liter

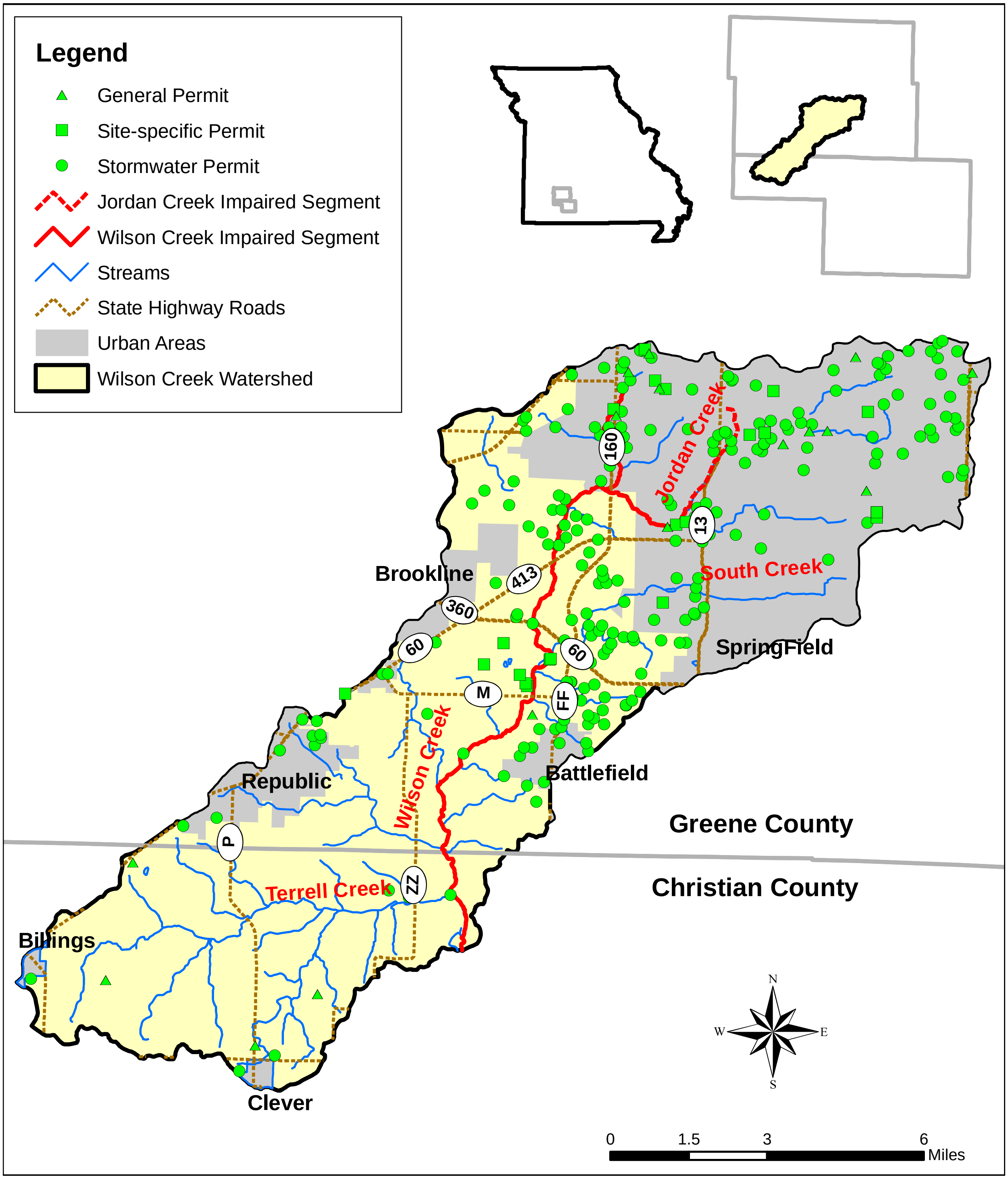

Figure 6. Location of Permitted Facilities in the Wilson Creek Watershed

3.1.1 RUNOFF FROM MUNICIPAL SEPARATE STORM SEWER SYSTEMS (MS4) URBAN AREAS

The city of Springfield is required to have and comply with a NPDES permit for its storm water drainage system, known as an MS4. The MS4 area consists of the urban area around Springfield, Missouri, and is regulated under Phase I of the program. The MS4 permit requires the city to administer a storm water management program to address the potential for discharges from the MS4 to negatively impact area waterways by reducing both pollutants in storm water runoff and dumping of pollutants directly into the MS4. The permit contains specific required activities and programs that must be implemented to comply with the permit, such as stream and runoff monitoring, public education, industry inspections and more. Springfield was the first city in the state to obtain its MS4 permit, which was issued by MDNR on July 26, 2002. The permit must be renewed every five years. The city's permit reapplication was submitted as required in the 2005-2006 annual report. They are currently working with MDNR on reissuance of the permit for the next five years.

Storm water from urban areas is known to contribute numerous pollutants (e.g., sediments, nutrients, organic solids, organic chemicals and toxic compounds) and increased magnitude, duration and frequency of storm runoff (EPA, 1983). These pollutants and the modified stream hydrology, as indicated in the earlier sections, can result in: 1) physical changes of the stream channel such as scouring, channelization and incision; 2) alterations of stream substrates; and 3) degradation of water quality. Because increased impervious areas have changed the natural hydrograph of Wilson Creek by increased peak flows and reduced baseflow, the mitigation of storm water runoff can be achieved by implementing BMPs to control storm water runoff and increase infiltration to increase water reaching the stream via interflow and groundwater.

3.2 NONPOINT SOURCES

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

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

3.2.1 RUNOFF FROM NON-MS4 URBAN AREAS

Storm water runoff from urban areas is a significant source of pollutants. Various organic chemicals, nutrients, sediment and oxygen consuming substances are found in storm water runoff from urban areas. This runoff can include such pollutants as sediments, pathogens, fertilizers/nutrients, hydrocarbons, and metals. Pavement and compacted areas, roofs, reduced tree canopy and open space increase storm water runoff that rapidly flows into stream channels. This increase in flow and velocity of runoff often causes stream bank erosion, channel incision and sediment deposition in stream channels. In addition, runoff from developed areas can increase stream temperatures that, along with increases in flow rate and pollutant loads negatively affect water quality and aquatic life.

Other common sources of urban pollution include improperly sited, designed and maintained onsite waste water treatment (i.e., septic) systems, pet wastes, lawn and garden fertilizers and pesticides, household chemicals that are improperly disposed of, automobile fluids, road deicing/anti-icing chemicals and vehicle emissions.

Since approximately 33 percent of the Wilson Creek watershed is classified as urban (i.e., impervious, low intensity urban or high intensity urban), and a significant portion of that area is adjacent to the impaired segment, urban storm water runoff is considered a primary cause of the impairment for unknown.

3.2.2 RUNOFF FROM AGRICULTURAL AREAS

Lands used for agricultural purposes can be a source of sediment, nutrients, pesticides and oxygen consuming substances. Accumulation of nutrients and pesticides on cropland occurs from decomposition of residual crop material, fertilization with chemical and manure fertilizers, atmospheric deposition, wildlife excreta and irrigation water. The 2005 land use/land cover data indicates there are 2,207 cropland acres in the watershed, which comprises 3.5 percent of the entire watershed and 48.9 percent of the watershed is grassland which may include pasture areas (Table 5).

County-wide livestock data from the National Agricultural Statistics Service (NASS) (USDA, 2007), combined with the land cover data for the Wilson Creek watershed, indicated that there were approximately 16,320 cattle in the watershed[16]. The cattle are most likely located on the approximately 46.0 square miles of grassland/pastureland in the watershed and runoff from these areas can be potential sources of nutrients and oxygen consuming substances. Animals grazing in pasture areas deposit manure directly upon the land surface and, even though a pasture may be relatively large and animal densities low, the manure will often be concentrated

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[16] According to the National Agricultural Statistics Service there are approximately 64,241 head of cattle in Greene County and 51,162 head of cattle in Christian County (USDA, 2007). According to the 2005 MORAP there are 131 square miles of grasslands in Greene County and 263 square miles of grasslands in Christian County (MORAP, 2005). These values result in a cattle density of approximately 490 cattle per square mile of grasslands in Greene County and 195 cattle per square mile of grassland in Christian County. These densities were multiplied by the number of grassland square miles in each respective county in the Wilson Creek watershed to estimate the number of cattle in the watershed.

near the feeding and watering areas in the field. These areas can quickly become barren of plant cover, increasing the possibility of erosion and contaminated runoff during a storm event. In addition, when pasture land is not fenced off from the stream, cattle or other livestock may contribute nutrients to the stream while walking in or adjacent to the water body. The NASS also reports there were 525 hogs and pigs, 858 sheep and lambs, 3,879 horses and ponies, 1,692 chickens (layers), 318 broilers, and 29 turkeys in Greene County in 2007 and 101,008 turkeys, 2,888 horses and ponies, 1,161 goats, and 1,102 chickens (layers) in Christian County in 2007. Therefore, agricultural areas that are identified as cropland or grasslands are potential sources of pollutants.

Permitted CAFOs identified in this TMDL are part of the assigned WLA. Animal Feeding Operations (AFOs) and unpermitted CAFOs are considered under the LA because currently there is not enough detailed information to know whether these facilities are required to obtain NPDES permits. This TMDL does not reflect a determination by EPA that such facility does not meet the definition of a CAFO nor that the facility does not need to obtain a permit. To the contrary, a CAFO that discharges or proposes to discharge has a duty to obtain a permit. If it is determined that any such operation is an AFO or CAFO that discharges, any future WLA assigned to the facility must not result in an exceedance of the sum of the WLAs in this TMDL as approved.

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

3.2.3 ONSITE WASTEWATER TREATMENT SYSTEMS

Onsite wastewater treatment systems (e.g., septic systems) that are properly designed and maintained should not serve as a source of contamination to surface waters. However, onsite systems do fail for a variety of reasons. When these septic systems fail hydraulically (i.e., surface breakouts) or hydrogeologically (i.e., inadequate soil filtration) there can be adverse effects to surface waters. Failing septic systems are sources of nutrients and pathogens that can reach nearby streams through both runoff and groundwater flows. Since the Wilson Creek watershed is underlain by karst geology there is an increased possibility that pollutants from failing septic systems reach a water body.

The exact number of onsite wastewater systems in the Wilson Creek watershed is unknown. However, the National Environmental Service Center (NESC) reports via the EPA STEPL program that in 1998 there were 21,528 septic systems with an average population per septic system of 2.20 and a septic failure rate of 0.39 percent in the James River Watershed (HUC 11010002). As discussed in Section 2.3, the estimated rural population of the Wilson Creek watershed is approximately 5,351 persons. Based on this population and an average density of 2.20 persons per septic system we can estimate that there are approximately 2,432 systems in the watershed. Based on a failure rate of 0.39 percent (EPA, 2009c) there are 10 failing septic systems within the Wilson Creek watershed. EPA reports that the statewide failure rate of onsite wastewater systems in Missouri is 30 to 50 percent (EPA, 2002b). This would imply that there are approximately 700 to 1,200 failing onsite treatment systems in the watershed. At higher rates of failure, onsite wastewater treatment systems could be a potentially significant source of nutrients and pathogens. No information was identified that would suggest failing onsite wastewater systems were a significant problem at the watershed scale. In addition, these estimates are based on the assumption that septic systems are more prevalent in rural areas and that the majority of households in urban areas are served by centralized wastewater treatment. Thus, these estimates may underestimate septic system numbers as some septic systems may be present in urban areas.

3.2.4 RIPARIAN CORRIDOR CONDITIONS

Riparian corridor[17] conditions can also have a strong influence on controlling nonpoint sources of pollutants and DO concentrations in streams. Well-vegetated riparian areas are a vital functional component of stream ecosystems and are instrumental in the detention, removal and assimilation of sediment, excess nutrients and other pollutants before they reach a stream. In essence, they act as buffers. Therefore, a stream with a well-vegetated riparian corridor is better protected from the impacts of storm water runoff laden with sediment, nutrients and pesticides than is a stream with a poorly vegetated corridor. Trees also provide a root system that helps stabilize streambanks and resist bank erosion more effectively than roots of grasses, row crops or shrubbery. Wooded riparian corridors can also provide shade that reduces stream temperatures, which can increase the DO saturation capacity of the stream.

As indicated in Table 9, approximately 10 percent of the land in the Wilson and Jordan Creek riparian corridor (defined as a 30 meter wide strip along both sides of the stream) is classified as low intensity urban or impervious, 28.2 percent is classified as forest, 36.4 percent is classified as grassland and 12.7 percent as herbaceous (MoRAP, 2005). Urban and Grassland area provides limited riparian benefits compared to wooded areas. Urban areas provide very little shading and in developed areas such as Springfield, Missouri, can often be associated with parks and other manicured lawn areas that provide pollutants to the stream.

Table 9. Percentage Land Use/ Land Cover within Riparian 30 meter Buffer[18]

Land Use/Land Cover	Percent (%)
Cropland	4.1
Forest	28.2
Herbaceous	12.7
Grassland	36.4
Impervious	2.9
Low Intensity Urban	7.6
Open Water	7.7
Wetland	0.1
Barren or Sparsely Vegetated	0.2

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

4 APPLICABLE WQS AND NUMERIC WATER QUALITY TARGETS

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

Designated beneficial uses for Missouri streams are found in the WQS at 10 Code of State Regulations (CSR) 20-7.031(1)(C), (1)(F) and Table H (CSR, 2009). Criteria for designated beneficial uses are found at 10 CSR 20-7.031, Tables A and B (CSR, 2009). Missouri's antidegradation policy is outlined at 10 CSR 20-7.031(2) (CSR, 2009).

4.1 DESIGNATED BENEFICIAL USES

The impaired reaches include 18 miles of Wilson Creek (WBID 2373) and 3.8 miles of Jordan Creek (WBID 3374). Both streams have the following designated beneficial uses:

- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Whole Body Contact Recreation (Category B)
- Protection of Human Health (Fish Consumption) (CSR, 2009)

The protection of warm water aquatic life is the impaired designated beneficial use.

4.2 CRITERIA

In the 2008 Missouri 303(d) List, Wilson and Jordan Creeks were listed as impaired due to unknown pollutants. Water quality monitoring has not revealed exceedance of a specific numeric water quality criterion. However, all water bodies in Missouri are protected by the general criteria (standards) contained in Missouri's WQS at 10 CSR 20-7.031(3). These criteria are also called narrative criteria, since they do not contain specific numeric limits. For Wilson and Jordan Creeks, criteria (3) (D) and (G) apply:

- Waters shall be free from substances or conditions in sufficient amounts to result in toxicity to human, animal or aquatic life and;
- Waters shall be free from physical, chemical or hydrologic changes that would impair the natural biological community.

Brewery Spring (previously discussed in Section 2.3) is causing or contributing to water quality contamination of Jordan Creek from unknown sources. Therefore, in addition to the general criteria listed above, criteria (3) (B) and (C) also apply:

- Waters shall be free from oil, scum and floating debris in sufficient amounts to be unsightly or prevent full maintenance of beneficial uses and;
- Waters shall be free from substances in sufficient amounts to cause unsightly color or turbidity, offensive odor or prevent full maintenance of beneficial uses.

Specific numeric water quality criteria were not used as TMDL targets because no specific pollutant was identified as the cause of impairment. Instead, surrogate targets related to storm water runoff was used to develop the TMDL for Jordan Creek and Wilson Creek, in particular for its upper stream portion above the Springfield WWTP, where the water quality and biological communities are significantly impaired by urban storm water.

4.3 ANTIDEGRADATION POLICY

Missouri's WQS include EPA's "three-tiered" approach to antidegradation, which may be found at 10 CSR 20-7.031(2) (CSR, 2009).

> 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 November 28, 1975, the date of EPA's first WQS Regulation.
>
> Tier 2 – Protects and maintains the existing level of water quality where it is better than applicable water quality criteria. Before water quality in Tier 2 waters can be lowered, there must be an anti-degradation 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 BMPs for nonpoint sources are achieved. Furthermore, water quality may not be lowered to less than the level necessary to fully protect the "fishable/swimmable" uses and other existing or designated beneficial uses.
>
> Tier 3 – Protects the quality of outstanding national and state resource waters, such as waters of national and state parks, wildlife refuges, and exceptional recreational or ecological significance. There may be no new or increased discharges to these waters and no new or increased discharges to tributaries of these waters that would result in lower water quality.

4.4 IMPAIRMENTS AND STRESSORS OF CONCERN

4.4.1 DETECTION AND DESCRIPTION OF IMPAIRMENTS

MDNR's (2007b) aquatic life assessment found that the sites assessed on Wilson and Jordan Creeks were impaired. The report states,

> "…the impairment is most likely due to the usual urban influences …road salt, automobile fluid, lawn fertilizers and pesticides." And further states that, "urban

stream quality problems are also typically compounded by increased areas of impervious surfaces in their watersheds that cause runoff to flow at a faster rate into the streams and carry more pollutants."

This statement is supported by USGS and EPA studies finding low levels of pesticides, metals, PAHs and VOCs in water and SPMD samples (USGS, 2003; EPA, 2009a). Thus, while the biological assessment did not pinpoint a specific pollutant, this is not surprising in light of the recent research related to the impacts of storm water. It is well documented that storm water can contribute to biological impairments from a toxic mix of chemical constituents, hydraulic changes and impacts to physical habitat.

Hydraulic changes to the stream attributed to increased development include more frequent occurrence of higher flows and velocities that create greater shear stresses that make it difficult for aquatic life to live in the stream. Decreased infiltration due to the increased impervious area results in reduced baseflow that limits available habitat during low flow periods. The greater and more frequent flows permanently change the physical characteristics of the stream by increasing incision, stream bank erosion and changes to substrate.

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

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

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

4.4.2 STRESSORS OF CONCERN AND PROBABLE SOURCES

The benthic invertebrate and fish communities of Wilson and Jordan Creeks near Springfield, MO, have been shown to be degraded (EPA, 2009a; MDNR, no date; USGS 2003). Several studies were conducted to evaluate the cause of the decreased aquatic life. The USGS (2003) collected water quality data and identified the presence of numerous toxic pollutants. MDNR also collected water quality data at several locations on Wilson and Jordan Creeks. These data showed that elevated levels of water quality parameters had a negative impact on aquatic life. These parameters included metals, nutrients, organic compounds, water temperature, decreased levels of DO, suspended sediment, turbidity, polychlorinated biphenyls

(PCBs) and PAHs. Table 10 provides the water quality data collected and demonstrates that a wide variety of chemical constituents that can cause toxicity are present in the stream. The table summarizes the number of samples taken since 1998 on Wilson Creek and the maximum, minimum, median and average of select chemical constituents. While these studies did not identify a single pollutant causing the decline of aquatic life, they do provide evidence that toxic pollutants are present in low levels and are harmful to aquatic life either alone or in combination (USGS, 2003).

Table 10. Historical Water Quality Summary

Parameter	Units	Count	Max	Min	Ave	Median
Ammonia-Nitrogen	mg/L	649	16.40	<IDL, 0.01	0.44	0.05
Total Nitrogen	mg/L	815	97.5	0.36	9.65	8.10
Total Phosphorus	mg/L	863	9.1	<IDL, 0.005	1.28	0.44
Total Suspended Solids	mg/L	177	773	<IDL, 0.50	26.6	5.0
Turbidity	NTU	687	82.4	0	4.0	2.0
Total Dissolved Solids	µg/L	91	880	< IDL, 5.0	475.2	503.0
Chlorides	µg/L	670	1116.53	<IDL, 0.015	111.13	110.00
Dissolved Iron	µg/L	59	130	< IDL, 5.0	30.97	30.00
Dissolved Manganese	µg/L	59	131	2.0	21.71	15.80
Total Cyanide	µg/L	36	<IDL, 2.5	<IDL, 2.5	NA	NA
Total Aluminum	µg/L	59	6260	15.0	769.97	118.00
Dissolved Aluminum	µg/L	59	74	6.0	23.27	15.90
Total Arsenic	µg/L	29	< IDL, 10.0	< IDL, 10.0	NA	NA
Dissolved Arsenic	µg/L	46	9.99	0.099	4.17	2.07
Total Cadmium	µg/L	88	2.6	0	1.03	0.50
Dissolved Cadmium	µg/L	74	3.99	0	1.75	1.44
Total Chromium	µg/L	29	< IDL, 5.0	< IDL, 5.0	NA	NA
Dissolved Chromium	µg/L	15	< IDL, 5.0	< IDL, 5.0	NA	NA
Total Copper	µg/L	23	58.7	<IDL, 2.5	13.61	8.33
Dissolved Copper	µg/L	63	11	1.1	4.12	3.60
Total Nickel	µg/L	29	< IDL, 5.0	< IDL, 5.0	NA	NA
Dissolved Nickel	µg/L	15	< IDL, 5.0	< IDL, 5.0	NA	NA
Total Lead	µg/L	87	110	0.37	10.14	4.00
Dissolved Lead	µg/L	74	50.0	0.14	13.98	1.54
Total Thallium	µg/L	9	< IDL, 25.0	< IDL, 25.0	NA	NA
Dissolved Thallium	µg/L	11	< IDL, 25.0	< IDL, 25.0	NA	NA
Total Zinc	µg/L	87	354	<IDL, 2.5	50.80	36.00
Dissolved Zinc	µg/L	66	162	<IDL, 2.5	31.93	26.00
Oil and Grease (O&G)	mg/L	24	< IDL, 5	< IDL, 5	NA	NA

mg/ L = milligrams per liter; NTU = Nephelometric Turbidity Units; µg/L = micrograms per liter; IDL = instrument detection limit

In addition to the historic sampling conducted by MDNR (summarized in Table 10), EPA conducted sampling during 2009 (EPA, 2009a). The sampling program conducted in 2009 investigated water quality (chlorides, Total Suspended Solids [TSS], semi volatile organic compounds [SVOCs], VOCs and organic analysis of SVOCs) via grab samples at seven locations, SPMDs at two locations and macroinvertebrate sampling at six locations. The results of the sampling program are detailed in the Wilson Creek Sampling Report (EPA, 2009a). Findings of particular interest to the TMDL study are briefly described below.

The surface water grab sampling detected several potentially toxic constituents. Chlorides were detected in all samples. They displayed no seasonal trend but did have geographical trend. The most downstream sampling locations, sites 2 and 7 (Figure 7), had consistently higher chloride concentrations than the more upstream sites. Elevated TSS concentrations were detected at sample sites 3 and 4 during a March 2009 high flow event, and at sampling site 1 during a May 2009 high flow event. These results indicate that TSS may be more related to the greater urbanization in the upper portions of the watershed and that chlorides are related to a more downstream source, such as the Springfield WWTP. The analysis of VOCs and SVOCs found low levels of numerous pollutants known to be toxic.

A SPMD was used to test for pesticides, PCBs and PAHs. Of the fifteen pesticides that were reported for the deployed SPMD samplers, all were detected during at least one of the SPMD events on Wilson Creek. Five pesticides (heptachlor epoxide, gamma-chlordane, alpha-chlordane, diedrin and 4,4’-DDD) were detected above their associated laboratory reporting limit during each event at both SPMD locations. Sampling between May 27 to July 1, 2009, showed generally higher values for each of the two SPMD locations. Lindane was the pesticide with the highest detected concentration (at SPMD location 1 during the May 27 to July 1, 2009 sampling period). Of the twelve PCB congeners that were reported, three (PCB 81, PCB 118 and PCB 169) were detected at both locations during each of the sampling events. PCB congener concentrations were generally consistent throughout the events. Elevated concentrations of PCB 81, PCB 118 and PCB 169 were detected at sample SPMD location 2 during the May 27 to July 1, 2009 sampling period. Five of the sixteen PAHs that were analyzed for in the SPMD samplers were detected above the associated method detection limits. These five PAHs included: phenanthrene, fluoranthene, pyrene, chrysene and benzo(b)fluoranthene. The highest concentrations were detected at sample location 2 during the May 27 to July 1, 2009 sampling period.

Macroinvertebrates were collected at six locations in the Wilson Creek watershed. Due to their sensitivity to habitat and water quality conditions they are a reflection of the streams condition. Of the six stream reaches sampled, stream reach 7 (the second most downstream location on Wilson Creek) has the greatest overall community/stream health (i.e., community health, water quality, few pollution tolerant species, community richness and evenness). For the pool habitat, stream reach 5 on Jordan Creek has the greatest community/stream heath. For the riffle habitat and stream reaches, 2 (most downstream location on Wilson Creek) and 5 (Jordan Creek) have the greatest community/stream health for the rootmat habitat. According to the habitat assessments conducted by EPA (EPA, 2009a), stream reach 7 had the highest habitat score (143) and stream reach five had the lowest habitat score (98). The fact that stream reach 7 had the highest habitat score and some of the highest metric values for macroinvertebrates for the pool habitat may indicate that the overall integrity for this type of habitat may be high in this reach. Stream reach 5 had the lowest habitat score and field personnel were only able to collect a limited number of organisms from this reach (54 percent of targeted organisms for riffle habitat and 80 percent of targeted organisms for rootmat habitat). However, stream reach 5 had some of the highest rated riffle and rootmat habitat. This presence of highly rated habitat, but limited numbers of organisms may be an indication of poor water quality.

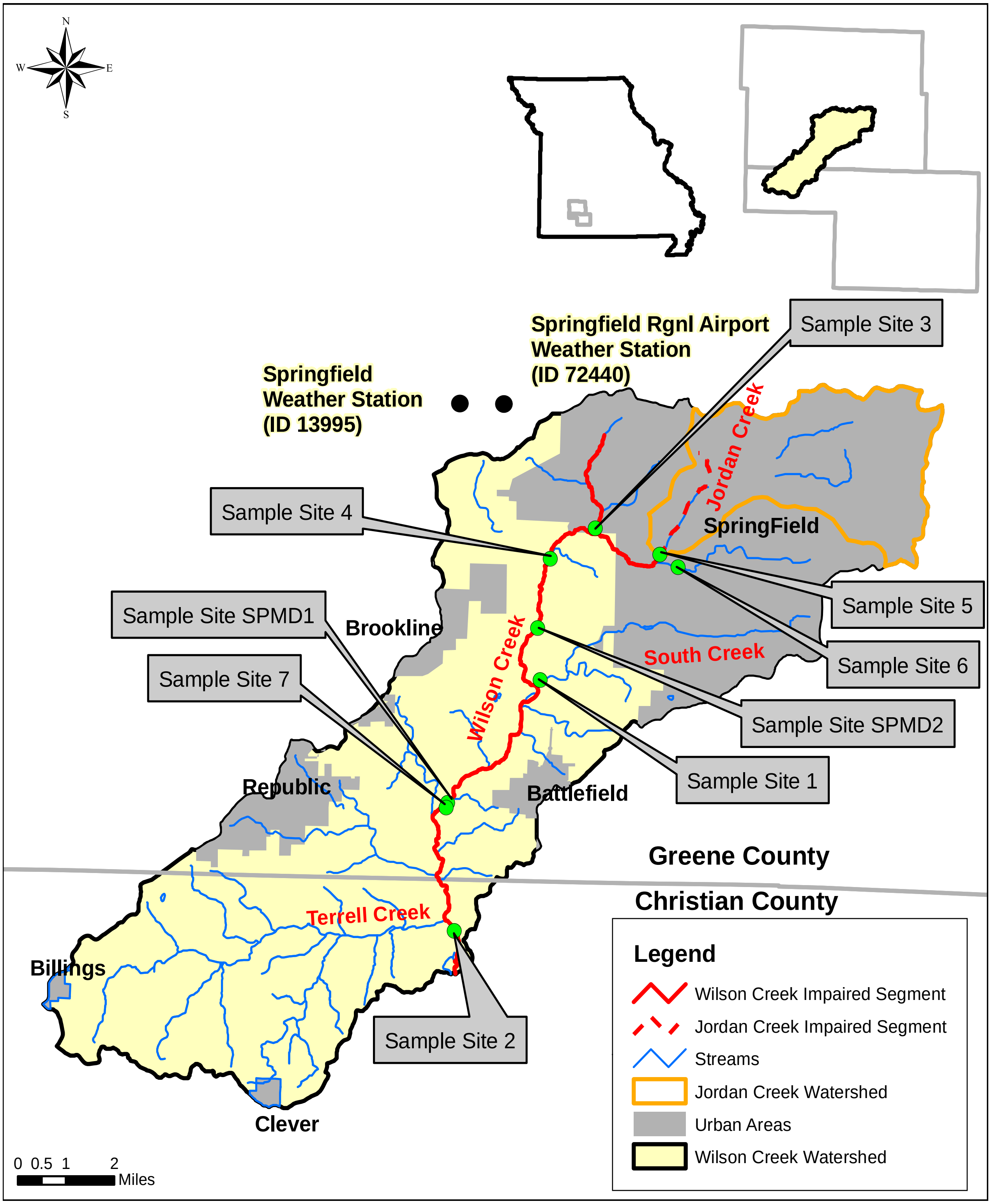

Figure 7. Location of 2009 Sampling Stations

MDNR's historic sampling identified the presence of several metals, TSS, turbidity and nutrients that can all lead to aquatic life impacts and the EPA sampling during 2009 identified several compounds with known toxicity to aquatic life. Sources of these contaminants are associated with urban areas and will be mitigated if storm water is controlled.

4.4.3 STRESSORS OF CONCERN AND URBAN STORM WATER RUNOFF

Storm water runoff from urban areas has been broadly linked to degradation of aquatic life in urban areas (CWP, 2003; Water Environment Research Federation (WERF), 2003). The scientific literature suggests that increases in runoff from urbanized areas negatively impact aquatic life in streams in four principal ways.

1. Runoff carries a mix of pollutants that may be toxic to aquatic life.
2. More frequent occurrence of higher flows and velocities create greater shear stresses that make it difficult for aquatic life to live in the stream and decreased infiltration depresses baseflow, reducing available habitat during low flow periods.
3. The greater and more frequent flows permanently change the physical characteristics of the stream by increasing incision, increasing stream bank erosion and reducing stream substrates.
4. Aquatic habitats are significantly degraded due to stream enclosure, channelization, armoring (using rip rap and concrete to reduce erosion) and loss of riparian vegetation.

These characteristics of urban storm water runoff can lead to decreased aquatic life at relatively low levels of development. The CWP (2003) reviewed hundreds of research studies. The combined review and synthesis of information in these studies lead CWP to conclude that impervious cover as low as 10 percent can be related to aquatic life impairments and worsens as more areas within the watershed are developed (CWP, 2003). The Wilson Creek watershed has approximately 20 percent impervious cover; therefore, it would be expected to have many of the negative water quality related problems associated with urban development.

Table 11 identifies stressors and their sources in the Wilson Creek watershed, based on the field investigation (2010 URS sampling report) and the USGS water quality study (2003) and the MDNR biological assessment report (2007b). Sources representing natural conditions are *italicized* and those that are related to impervious surfaces are highlighted.

Table 11. Identified Stressors and their Sources in the Wilson Creek Watershed

Stressor	Importance	Sources	
		Likely	Possible
High peak flows	High	High percentage of impervious surfaces	Increased storm water runoff
Presence of toxic contaminants	High	Commercial and industrial practices	Sewage system leaks
		Runoff from roads and parking lots	Atmospheric deposition
		Dumping of municipal solids and wastes	*Natural sources*
		Winter road sand and salts	
Impaired instream habitat	High	Channelization	Increased urban runoff
		Riparian land cover alteration	Lawn and landscape runoff
		Low stream gradient	Animal waste from livestock and wildlife and sewer leaks
Increased sedimentation	High	*Naturally sandy and silty substrate and soils*	Erosion from land use activities
		Natural channel processes	High percentage of impervious surfaces
		Reduced riparian vegetation	Winter road sand
Low baseflow	Medium	High percentage of impervious surfaces	Increased consumptive uses

The negative effects on water quality from urbanization within a watershed include loss of habitat, increased temperatures, sedimentation and loss of fish populations (EPA, 2005). These effects can be explained in large part by the increase in the magnitude, frequency and duration of storm water runoff in urban watersheds, relative to flows in watersheds with less impervious area, and the chemical pollutants that are carried by storm water. Figures 8 and 9 show the flow duration curve (FDC) for Wilson and Jordan Creek watersheds and a synthetic flow record developed from three biological reference streams. The synthetic FDC represents flow from unimpaired watersheds. The differences between the Wilson and Jordan Creek FDC and the synthetic flow FDC demonstrate the impact from increased urbanization: larger and more frequent high flows and reduced baseflow. Specific data collected in Wilson Creek demonstrate that storm water impacts described in the literature are present. The chemical and physical data linking storm water impacts to decreased aquatic life are described below.

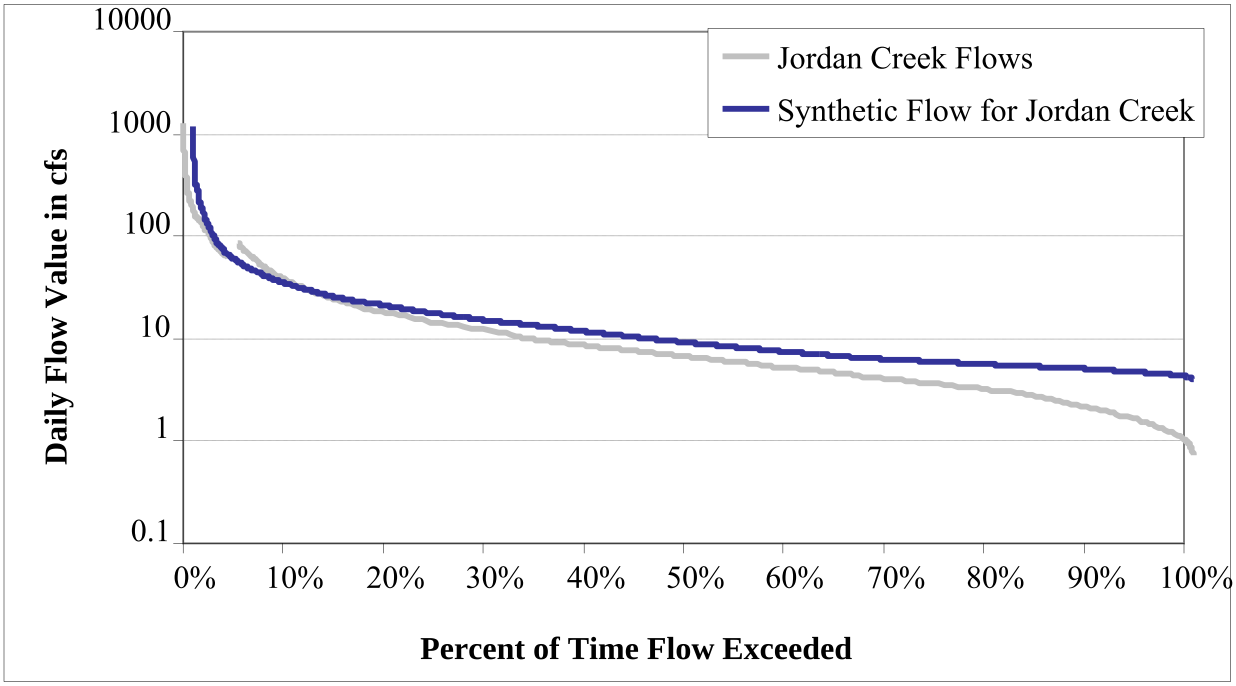

Figure 8. Jordan Creek and Reference Stream Synthetic Flow Comparison Demonstrating the Increased Frequency and Magnitude of High Flows

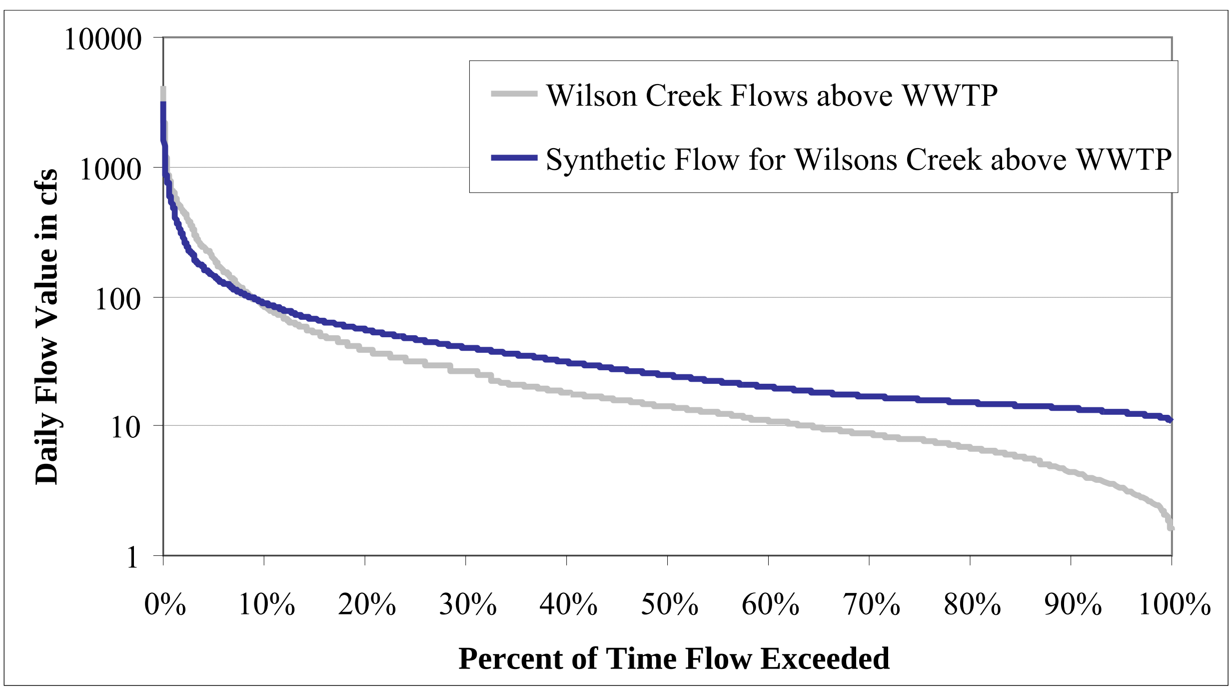

Figure 9. Wilson Creek and Reference Stream Synthetic Flow Comparison Demonstrating the Increased Frequency and Magnitude of High Flows

The increased magnitude, frequency and duration of higher flows created by storm water runoff have an adverse impact on stream physical habitats. Figure 10, taken from Physical Effects of Wet Weather Flows on Aquatic Habitats: Present Knowledge and Research Needs (WERF 2003), shows the complex relationships between changes in flow, geomorphology and physical habitat. The physical changes to the stream include impacts that permanently change the stream, such as changes to substrate and riparian conditions (bank features, vegetation and floodplain connectivity). While reducing the magnitude and frequency of high flows and increasing baseflow will limit further degradation, stream restoration is needed to repair changes that have already occurred. For this TMDL, the focus is placed on the impacts associated with the changes in flow regime (e.g., modifications of hydraulic conditions and loss of refugia) and improved water quality by reducing the frequency and magnitude of high flows.

Relationships between urban storm water hydrology and degraded aquatic life are well documented in the scientific literature. Biological studies conducted by the city of Springfield (2008) follow the pattern and conclusions of studies conducted in other parts of the county. The city conducted a biological assessment of Wilson, Jordan and Galloway Creeks in 2008 as part of its storm water sampling program (city of Springfield, 2008). The report identified several habitat deficiencies that can be related to changes in hydrology:

- Jordan Creek had an absence of riffles;
- Wilson and Jordan Creeks had an absence of pools, and;
- Wilson Creek had little brush or woody debris suitable for macroinvertabrate habitat or fish cover.

Changes to the riffle pool relationship are a possible result of changes to watershed hydrology from increased impervious areas and the lack of woody debris can be the result of higher peak flows and reduced woody material in the riparian area.

Additionally, reduced baseflow can lead to lower "low flows" that are critical in supporting fish and other aquatic organisms during prolonged dry periods. Storm water management that encourages infiltration will reduce peak flows in the stream and increase low flows through increased interflow and ground water flowing into Wilson and Jordan Creeks.

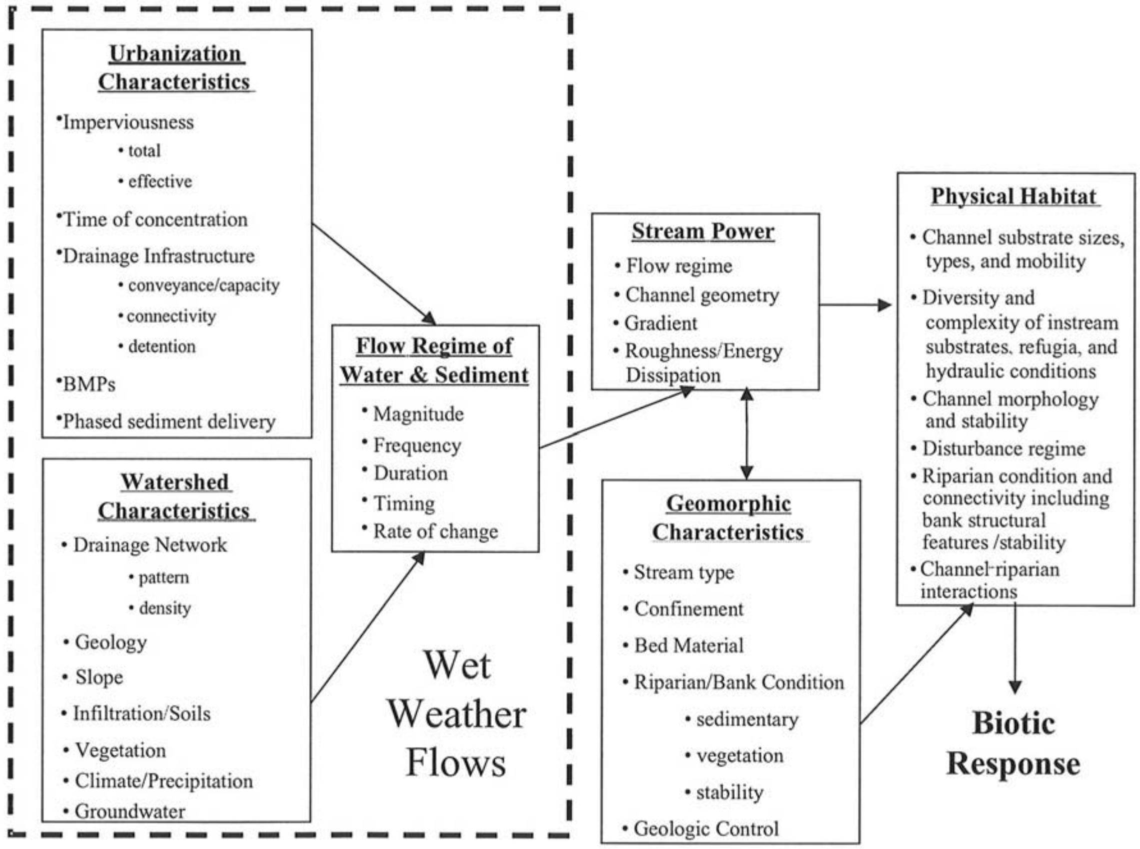

Figure 10. Interrelationship of Hydrologic and Geomorphic Variables and Processes that Define Wet Weather Impacts on Physical Habitat (Source WERF, 2003; Figure ES-1)

Past studies of Wilson Creek are consistent with the scientific literature on the impacts of increased storm water contributions from urban areas. The stream's 303(d) listing for impaired aquatic life uses due to unknown sources and causes reflects the combined effects from multiple stressors. Therefore, storm water runoff targets are used as a surrogate for the pollutants that together may lead to chronic toxicity and directly reflects the changes to habitat that result from changes to the magnitude, frequency and duration of instream flows, such as, scour and loss of the riffle / run / pool habitat structure.

Some studies have discussed the possibility that changes to stream hydrology from urbanization may result in decreased baseflow. Decreased baseflow may reduce available habitat during low flows; with less water in the stream, habitat areas shrink and become less hospitable to aquatic life. Due to the presence of the Springfield WWTP, baseflow below the plant is very consistent. Thus, baseflow quantity is not an issue below the plant; however, it is an issue above the WWTP where Wilson Creek is a losing stream. The combination of the stream losing water due to the natural karst geology and reduced baseflow from changes to watershed hydrology (due to increased impervious areas) likely adds additional stress to the biological community.

The targets selected for storm water runoff that reflect an acceptable aquatic life use have been described throughout Section 4.4 Impairments and Stressors of Concern. The method used to assess storm water runoff compares Wilson and Jordan Creeks' flows to synthetic flows developed from reference streams.

4.5 SETTING THE WATER QUALITY TARGETS

A TMDL requires that a water quality target be developed for the impaired segment. The TMDL load is the greatest amount of a pollutant that a water body can receive without exceeding the WQS. For this TMDL storm water runoff is a surrogate for the mixture of toxic pollutants and physical stressors causing aquatic life beneficial use impairments. The instream water quality target for the TMDL is the high flow category of the FDC developed from the biological reference streams (as described in the sections below).

The linkage between pollutants, aquatic life impairment and storm water runoff was established using instream flow conditions from reference streams in the Ozark/White Ecological Drainage Unit (EDU), which is the same EDU that Wilson and Jordan Creeks are located. Reference streams from the same EDU as the impaired stream were used to insure that the reference locations were similar to the impaired stream. An EDU is a collection of watersheds that share a common zoogeographic history (i.e., similar distributions of animals), physiographic and climatic characteristics, and therefore likely have a distinct set of freshwater assemblages and habitats (TNC, 2005). In addition, since the EDU has similar climatic characteristics, precipitation over time should be similar for the reference and impaired streams.

4.5.1 TECHNICAL APPROACH FOR DEVELOPING REFERENCE STREAM FLOWS

Synthetic flow data were developed by averaging flows from the individual watersheds used as biological reference streams. These synthetic stream flows are used as the TMDL target. Therefore, the synthetic flows are representative of streams attaining healthy biological conditions (e.g., macroinvertebrate stream condition index $\geq$16, see MDNR Biological Assessment Report, 2007b). The necessary percent reduction in storm water runoff needed to match the synthetic flow record are statistically determined by comparing the highest 10 percent of flows measured in Wilson and Jordan Creeks to the highest 10 percent of the synthetic flow record developed from the biological reference streams. Controlling the highest flows will limit pollutant loads from urban runoff therefore decreasing potentially toxic water quality conditions, and increase baseflow through increased infiltration of storm water runoff.

Flows in Wilson and Jordan Creeks are compared to the synthetic flow record developed from the biological reference stream flows by calculating discharge per square mile for each watershed. The area normalized flows allow direct comparison of stream flows in the impacted and reference watersheds. FDC analysis allows for the comparison of stream reaches' frequency and magnitude of flows. Using the biological reference streams from the same EDU as Wilson and Jordan Creeks minimizes differences in the rainfall variation. Development of the synthetic FDC for the biological reference streams is described in Appendix B.

4.5.2 SELECTION OF REFERENCE STREAM

The reference streams chosen are similar to Wilson Creek watershed with respect to soils and physiography. One difference is that sections of Wilson Creek are classified as a losing stream (MDNR, 2007a). This difference between the streams results in lower flows occurring more often in Wilson Creek than in the reference streams. Reference streams are used by MDNR to set biological criteria, therefore using reference sites to develop targets for the TMDL surrogate is appropriate for this TMDL. According to MDNR (MDNR, 2002) biological reference streams,

> "Describe characteristics of water bodies least impaired by anthropogenic activities and are used to define attainable habitat and biological conditions. Reference conditions are the standard by which impairment is judged."

Furthermore, reference streams must have habitat and stream characteristics similar to other streams in the ecoregion and exhibit a healthy biological community. The intended use of a reference stream approach according to MDNR is consistent with this TMDL application. Stream flows observed in the biological reference stream are supportive of a healthy biological community. The water bodies selected as reference streams for this TMDL meet MDNR's reference stream criteria and applicable WQS.

The FDC target for this TMDL was developed from reference streams in the Ozark / White EDU. This EDU also includes the impaired streams, Wilson and Jordan Creeks. Four reference streams are present in the EDU and all four were used; however, since both North Fork and Spring Creek are upstream of the same USGS gage only three USGS gages were used to develop the synthetic flow record. All reference sites and associated USGS gages had similar soil types, similar physiography and do not show any water quality impairments. Table 12 reports the reference streams in the Ozark / White EDU and identifies the reference stream location, rationale for selection and associated USGS gage. Appendix B contains a description of how synthetic flows were calculated, and figures showing the reference stream locations, land uses and soil types.

To demonstrate the extent to which land use changes have altered stream hydrology, contributions of flow from each land use type in the Wilson and Jordan Creeks' watershed were quantified using runoff coefficients based on the percentage of imperviousness. Since the reference streams have a healthy biological assemblage and limited urbanized areas, their flow regime is the target for this TMDL. Reductions to flow in Wilson and Jordan Creeks are based on a comparison with the synthetic flow record developed from the reference stream flows. Appendix C includes the calculation method and results for the required changes to FDC analysis was also used to assess and compare the frequency of daily flows.

Table 12. Reference Streams Used to Develop TMDL Target

Reference Stream	Location	Rationale for Selection	USGS Gage
Bryant Creek (Drainage Area is 217 square miles)	Latitude 36°37'38.0", Longitude 92°18'21.8"	16 years (1994-2009) of flow data available; similar soils; USGS gage watershed had similar land use as reference stream watershed (less than 0.6 percent impervious and urban lands).	Bryant Creek near Tecumseh USGS Gage at 07058000. Drainage Area is 570 square miles
Bull Creek (Drainage Area is 115 square miles)	Latitude 36°43'03.9", Longitude 93°12'24.5"	16 years (1994-2009) of flow data available. Soils may have less infiltration than Wilson Creek. Bull Creek has the highest level of urbanization (2 percent) of the reference streams.	Bull Creek near Walnut Shade USGS Gage 07053810. Drainage Area is 191 square miles
North Fork (Drainage Area is 121 square miles)	Latitude 36°37'22.9", Longitude 92°14'53.3"	Long historical record of flow data available (1944-2009); similar soils; USGS gage watershed had similar land use as reference stream watershed (less than 0.6 percent impervious and urban lands).	North Fork near Tecumseh USGS Gage 07057500. Drainage Area is 561 square miles
Spring Creek (Drainage Area is 131 square miles)	Latitude 36°37'22.9", Longitude 92°14'53.3"	Drains to the same gage as North Fork reference stream.	North Fork near Tecumseh USGS Gage 07057500. Drainage Area is 561 square miles

One of the clearest and most straightforward indicators of stream health is the biological community. The insects and other small aquatic animals that form the basis of the food chain in a stream are an indicator of the overall health of the water body. A healthy aquatic community reflects the overall condition of the stream and cannot be present without the underlying problems in the stream and its watershed being addressed. Therefore, an indicator for determining whether Wilson and Jordan Creeks are attaining WQS is for the water body to receive a fully supporting biological rating for all sites surveyed. MDNR believes a target of 100 percent of all sites surveyed receiving a fully supporting rating can be accomplished through actions and BMPs used to reduce storm water runoff and stream restoration.

5 CALCULATION OF LOADING CAPACITY

A TMDL quantifies the amount of a pollutant a water body can assimilate without violating a state's WQS and allocates that LC to known point and nonpoint sources in the form of WLA, LA, a MOS and natural background conditions. The MOS accounts for uncertainty in the relationship between pollutant loads and the quality of the receiving water body. Conceptually, this definition is represented by the equation:

$$TMDL = \Sigma WLAs + \Sigma LAs + MOS \qquad \textbf{Equation 1}$$

Where:

TMDL = Total Maximum Daily Load (may be seasonal, for critical conditions, or have other constraints)

WLA =	Wasteload Allocations (point source)
LA =	Load Allocations (nonpoint source)
MOS =	Margin of Safety (may be implicit and factored into a conservative WLA or LA, or explicit)

Wilson and Jordan Creeks do not currently meet aquatic life beneficial uses. For streams in urbanized areas, additional stressors affecting aquatic life exist in the form of non-pollutant impacts such as alterations in channel morphology and the flow regime or elimination of the riparian buffer. In this TMDL, storm water runoff is used as a surrogate for the complex suite of pollutants and physical stressors causing the aquatic life impairment and attributable to storm water runoff from developed areas. The FDC method is used to assess and compare the high flows in Wilson and Jordan Creeks to high flows from a synthetic flow record developed from biological reference streams. The FDC describes important hydrologic characteristics of a watershed and is used to quantify the differences between Wilson and Jordan Creeks and the synthetic flow data for this TMDL. The FDC is a useful analytical tool because it is capable of incorporating:

- A long period of time;
- Seasonal variability;
- Frequency of high flows; and
- Critical conditions.

The high flow category of the FDC provides an appropriate flow target and an approach to estimating how much flows in Wilson and Jordan Creeks need to be reduced or baseflow increased (see Tables 18 and 19).

5.1 DEVELOPMENT OF TARGETS

The results of the FDC analysis for the synthetic flows and Wilson Creek (above and below the WWTP) and Jordan Creek flows are included in Figure 11, Figure 12 and Figure 13. FDC analysis was used to assess and compare the frequency of daily flows. FDCs were calculated by creating a synthetic flow record by averaging area normalized flows for the biological reference streams for a ten year period (August 3 – February 9, 2009). Since the FDC comparison uses daily flows for a ten year period (August 3 – February 9, 2009), it reflects seasonal variations that occur in the reference watersheds. Wilson Creek and Jordan Creek flows were analyzed in the same manner as the reference streams; thus, a direct comparison between Wilson and Jordan Creek's flows and reference stream flows can be conducted using the synthetic flow record. The comparison of flows focused on the high flow category. Appendix B describes the method used to develop the synthetic FDC and Appendix C describes the approach used to develop the FDC for Wilson Creek (above and below the WWTP) and Jordan Creek.

The FDC analysis for Wilson and Jordan Creeks shows that flows in Jordan Creek and Wilson Creek above the WWTP have a greater frequency of higher flows which are generally of greater magnitude than the synthetic flow derived from the biological reference streams. In addition, the low flows in Wilson and Jordan Creeks are generally less than those derived from the reference streams and occur more often. This is consistent with impacts of urbanization. The FDC analysis of Wilson Creek below the WWTP results in slightly different conclusions. High flows on Wilson Creek below the WWTP are of a greater magnitude and occur more frequently than the flows derived from the biological reference streams. However, because of the impact of the WWTP flows mid-range to low flow periods in Wilson have greater flow than the reference stream flows.

Table 13, Table 14 and Table 15 report the median flow in each flow category and the percent difference between them and flows for Jordan Creek, Wilson Creek above the WWTP and Wilson Creek below the WWTP. For Wilson Creek, flow values are only provided for the high flow category. Since Wilson Creek is a losing stream comparing the lower flow categories to the synthetic reference FDC is not an applicable comparison. The result of the FDC analyses shows the following:

- The greatest 10 percent of flows were higher in Wilson and Jordan Creeks (above and below the WWTP) than in the biological reference streams. The median Jordan Creek flow in the "high flow" category is 45 percent greater that the biological reference streams. The Wilson Creek flow above the WWTP in the "high flow" category of the FDC is 37 percent greater than the biological reference stream flows and Wilson Creek below the WWTP is 27 percent greater.

- Jordan Creek and Wilson Creek both above and below the WWTP have lower flows than the biological reference streams for all other flow categories. This is due to the impacts of urbanization and because Wilson Creek is a losing stream for much of its length.

- Above the WWTP Wilson Creek has decreased baseflow; however, below the WWTP there is not a low baseflow problem due to the contribution of treated effluent from the WWTP.

In the broadest sense, the primary function of a TMDL is to determine and allocate among sources the maximum pollutant loading a water body can receive to maintain compliance with the appropriate WQS. For the Wilson and Jordan Creeks' TMDL, it's the storm water runoff that is being limited overall and allocated among sources. This approach works well within the TMDL framework for the high flow target whereby an overall reduction of storm water runoff is required. However, this approach does not fit particularly well for the low flow target where an increase in non-storm water instream flow is necessary and loading of storm water runoff is not directly being allocated. The restoration of low flows in Wilson and Jordan Creeks is actually a secondary result of controlling storm water runoff and increasing groundwater recharge. As storm water runoff is controlled and high flows reduced, the water that eventually reaches the stream and increases low flow is no longer considered storm water runoff because it is generally routed through the groundwater and does not reach the stream for a significant amount of time following the precipitation event.

Also, the benefit of decreased pollutant loading due to reduced storm water runoff at high flows provides a good fit for the TMDL framework, although indirectly. The same cannot be said of the low flow targets. The low flow targets represent conditions where pollutants are already substantially removed from water the stream receives from groundwater and thus there are no problematic "pollutants" to allocate.

For these reasons, EPA does not consider the low flow targets applicable to an allocation scenario and therefore they are not presented as official TMDL allocations. Rather, they are presented as complimentary targets for the overall remediation of the watershed.

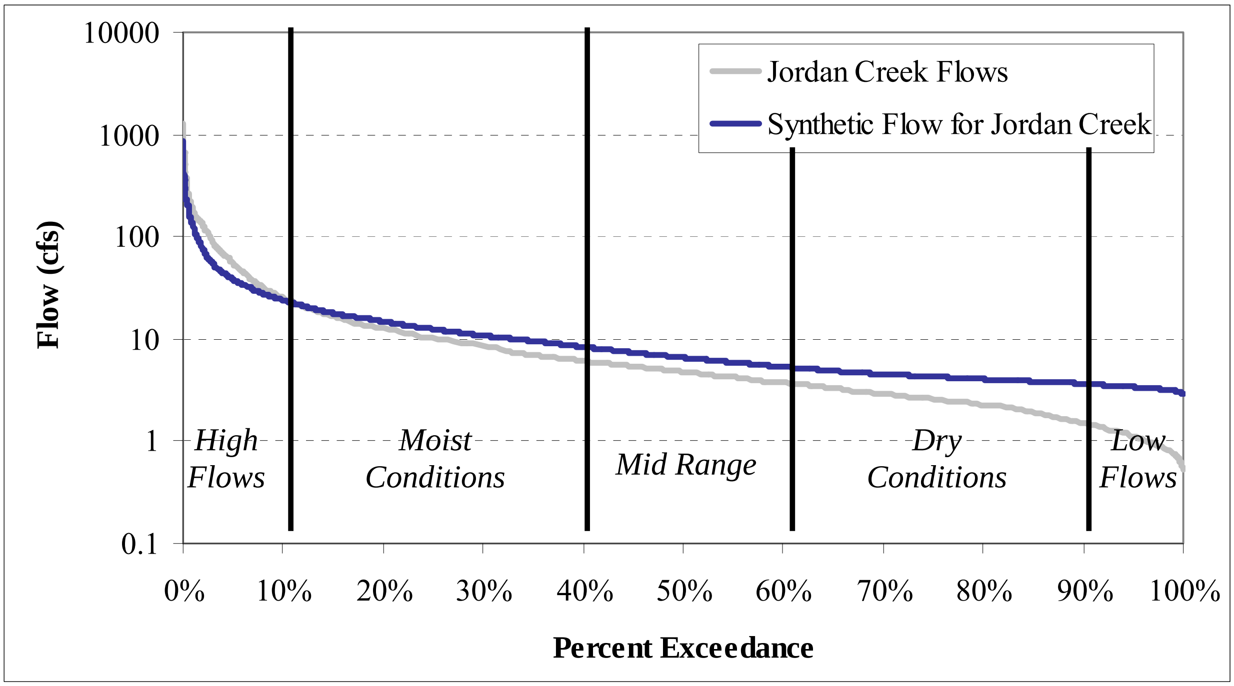

Figure 11. FDC Curve for Jordan Creek at the Confluence with Wilson Creek. Drainage area is 13.45 square miles

Table 13. Comparison of Synthetic Flow Targets and Jordan Creek Flows at the Confluence with the Wilson Creek (drainage area = 13.45 sq miles)

Flow Condition	Reference Site Flow (cfs)	Jordan Creek Flow at Confluence with Wilson Creek (cfs)	Percent Difference
High (5%)	38.2	55.9	46
Moist Conditions (25%)	12.5	10.6	-15
Mid Range (50%)	6.6	4.8	-27
Dry (75%)	4.3	2.6	-38
Low (95%)	3.4	1.1	-67

Reference flows were calculated based on the average of unit flows of reference streams, multiplied by the target drainage area (13.45 sq miles).

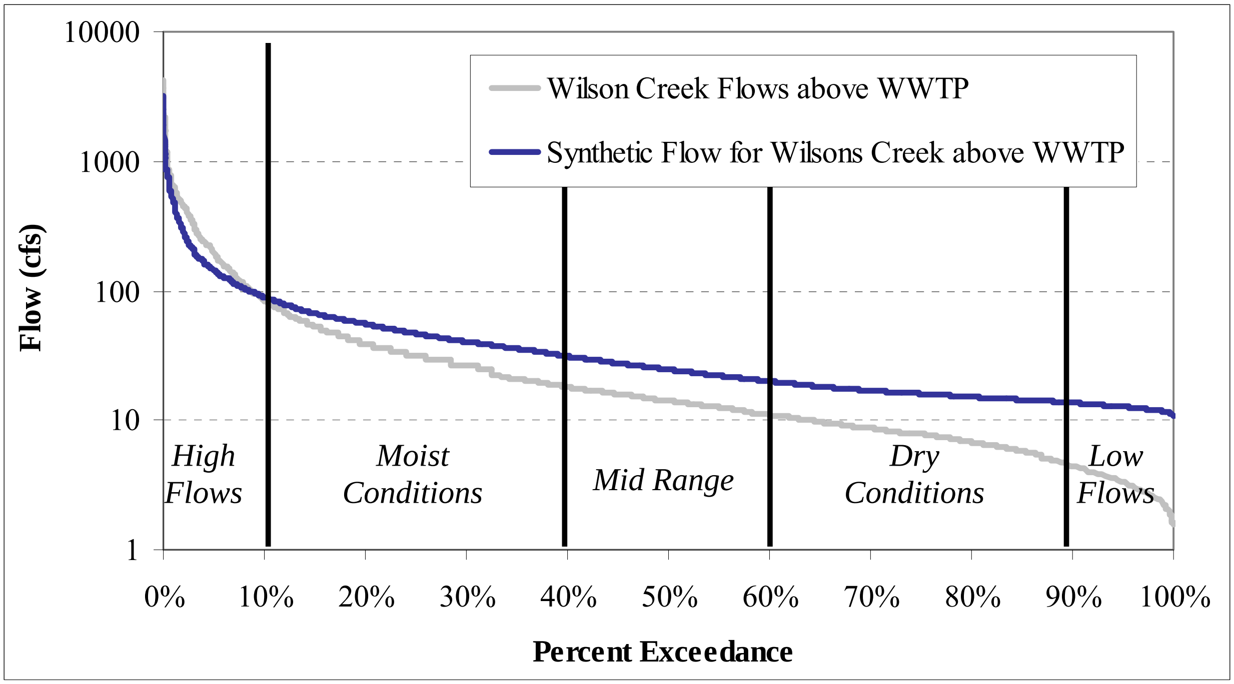

Figure 12. FDC for Wilson Creek Watershed above the Springfield WWTP at the Confluence with South Creek. Drainage area is 50.3 square miles

Table 14. Comparison of Synthetic Flow Targets and Wilson Creek Flows above the WWTP near the confluence with South Creek (drainage area = 50.5 sq miles)

Flow Condition	Reference Site Flow (cfs)	Wilson Creek Flow above WWTP (cfs)	Percent Difference
High (5%)	142.8	197.6	38
Moist Conditions (25%)	46.7	31.2	-33
Mid Range (50%)	24.5	14.0	-43
Dry (75%)	16.1	7.8	-51
Low (95%)	12.7	3.3	-74

Reference flows were calculated based on the average of unit flows of reference streams, multiplied by the target drainage area (50.5 sq miles).

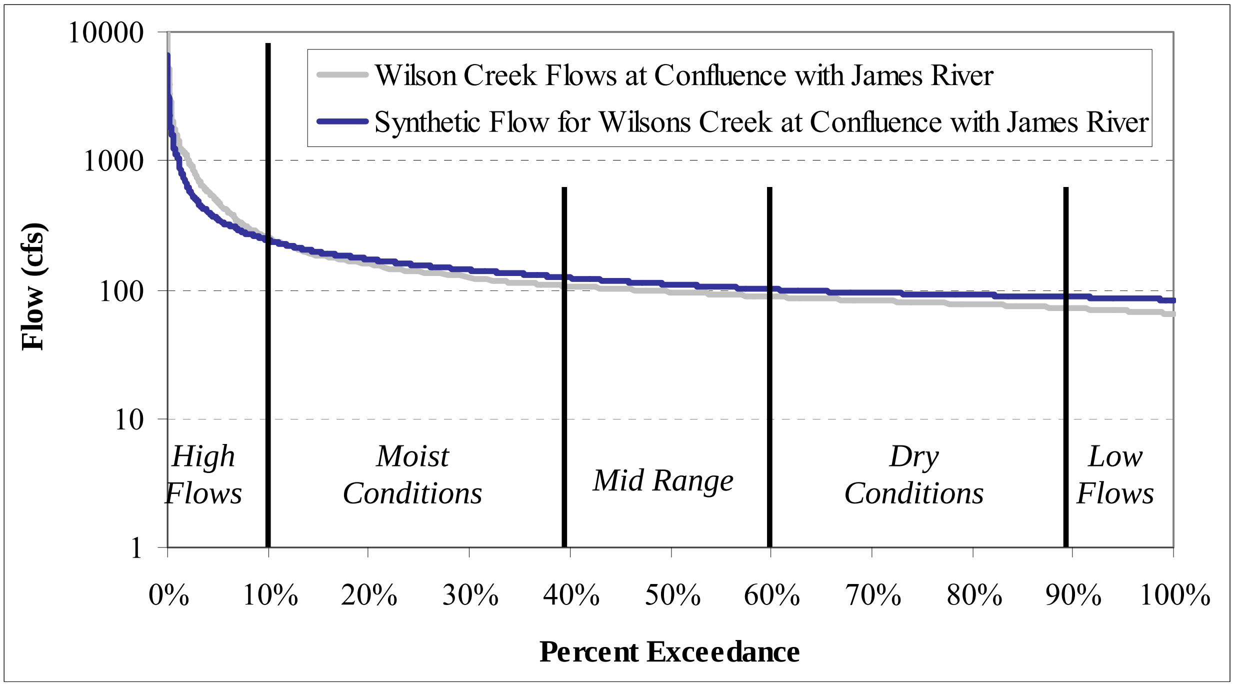

Figure 13. FDC for Wilson Creek Watershed below the Springfield WWTP at Confluence with James River. Drainage area is about 102 square miles.

Table 15. Comparison of Synthetic Flow Targets and Wilson Creek Flows at the Confluence with the James River (drainage area is about 102 sq miles)

Flow Condition	Reference Site Flow (cfs)	Wilson Creek Flow below WWTP (cfs)	Percent Difference
High	349.8	484.9	28
Moist Conditions	154.9	140.4	-10
Mid Range	109.8	96.2	-14
Dry	92.6	80.1	-16
Low	85.8	68.6	-25

Reference flows were calculated based on the average of unit flows of reference streams, multiplied by the target drainage area (102 sq miles), and plus the average discharge (60 cfs) of Springfield WWTP.

The FDC for Wilson Creek below the WWTP (Figure 9) demonstrates the influence of the Springfield WWTP on the Wilson Creek's hydrology. The Springfield WWTP continuously discharges an average of 60 cfs of treated effluent. This significantly adds to the base flow of Wilson Creek. Comparison of the stream flow gage USGS-07052100 (Wilson Creek near Springfield) and USGS-07052152 (Wilson Creek near Brookline) in Figure 14 shows periods of lower flow at the upstream gage and more consistent baseflow at the station below the WWTP. Thus, the WWTP provides continuous levels of baseflow for Wilson Creek. Because the Springfield WWTP's discharge makes up the majority of Wilson Creek flow during dry conditions, it impacts the FDC analysis. The WWTP elevates the daily average flows that occur at all flow ranges. However, the instantaneous peak flows in Wilson Creek at the confluence with the James River are very large in comparison to the daily average flows and WWTP flows (Table 16). This indicates that Wilson Creek below the WWTP is impacted by very "flashy" storm water runoff that have high instantaneous flows and much lower daily average flows; therefore, TMDL flow targets related to high storm water runoff are appropriate. The low flow impacts of increased urbanization are not an issue below the WWTP as the constant discharge provides adequate flow during dry periods.

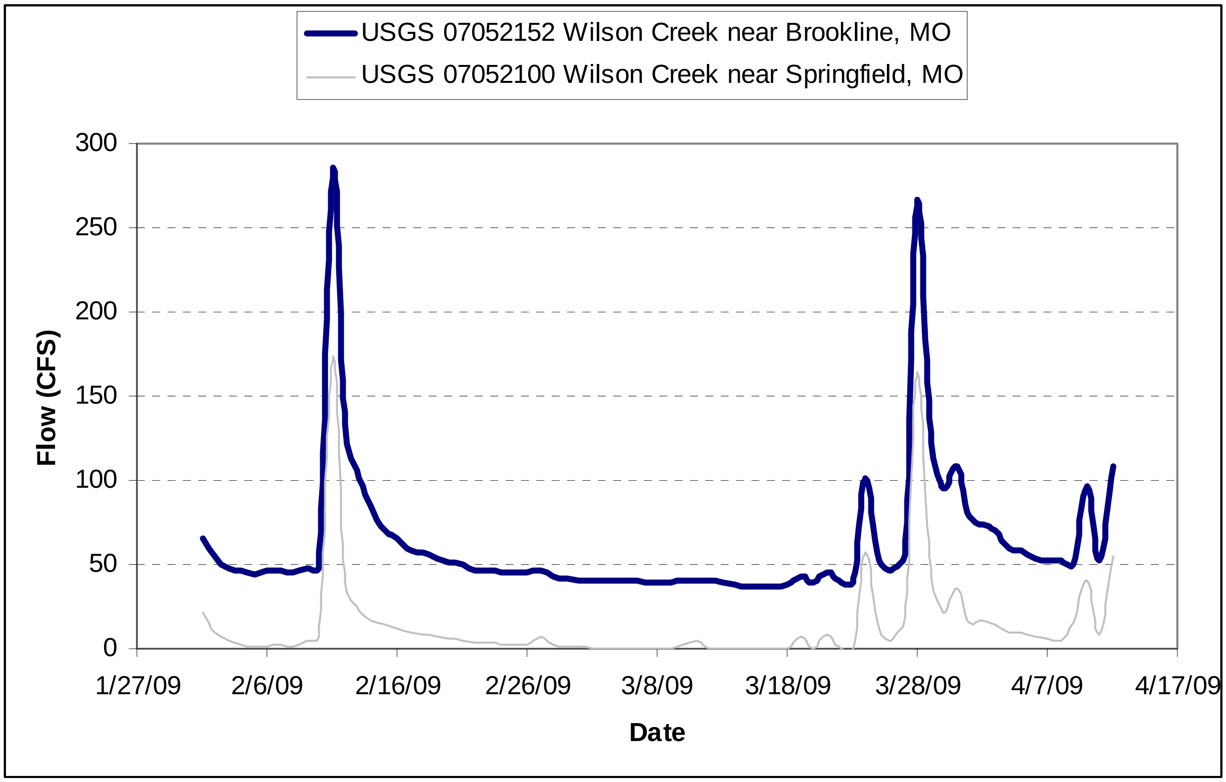

Figure 14. Comparison of USGS Gaged Flows at Stations Above and Below the Springfield WWTP

Table 16. Comparison of Peak and Daily Average Stream Flows at USGS 07052160 Wilson Creek Near Battlefield, Missouri

Water Year	Date	Peak Stream flow (cfs)	Daily Average Stream Flow (cfs)
2000	July 12, 2000	6,160	1,980
2001	February 24, 2001	2,130	1,420
2002	May 8, 2002	4,620	2,730
2003	June 30, 2003	1,810	304
2004	March 5, 2004	1,500	669

6 CALCULATION OF LOAD ALLOCATION AND WASTELOAD ALLOCATION

In addition to the overall watershed targets described in Section 6.2, TMDLs must provide allocation between regulated point sources (e.g. the WLA) and non regulated diffuse sources (e.g. LA). It may be reasonable to express allocations for NPDES-regulated storm water discharges from multiple point sources as a single categorical WLA when data and information are insufficient to assign each source or outfall individual WLAs (see 40 C.F.R. § 130.2(i)). In cases where WLAs are developed for categories of discharges, these categories should be defined as narrowly as available information allows.[19] To facilitate the allocation of assimilative capacity between MS4s WLA, non MS4 WLA sources and LA, EPA allows using land use analysis. The following two sections (Sections 6.1 and 6.2) provide WLA and LA of storm water runoff based on a land use analysis.

Appendix D estimates the percent change in runoff from the WLA and LA areas based on assumptions related to land use characteristics. The assumptions are that more developed areas convey greater amounts of storm water as surface runoff during precipitation events and less baseflow during dry periods due to the effects of increased impervious areas. Conversely, less developed areas convey less storm water runoff and greater amounts of baseflow. The details of this approach are described in Appendix D.

To develop the WLA and LA for this TMDL the watershed land use was aggregated into three functional categories which are described below.

- MS4 WLA includes all of the area within the boundary of the Springfield Urban area (U.S. Census Bureau, 2009). Runoff targets are provided for the MS4 area draining to Wilson Creek and Jordan Creek.
- Non MS4 WLA consists of regulated storm water from high intensity urban areas. This land use type was assumed to consist of areas likely to require a storm water permit. Runoff from this land use type that are outside of the Springfield urban area are included in the WLA for this TMDL.
- The LA component includes diffuse runoff from areas not within an MS4 or otherwise covered under an NPDES permit.
- Natural areas are land uses which are assumed to maintain their natural hydrology and thus do not contribute to deviations in stream flow, such as storm water peaks or reduced baseflow, are included in the LA for this TMDL provided they are not within the boundary of an MS4.

[19] Hanlon, James A.and Wayland, Robert H., 2002. Memorandum: Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs (EPA, 2002b).

6.1 WASTELOAD ALLOCATION (POINT SOURCE LOADS)

EPA's regulation at 40 CFR 130.2 requires that allocations for NPDES-regulated discharges of storm water be included in the WLA portion of the TMDL (EPA, 2002a). In instances where there are insufficient data to calculate loads on an outfall by outfall basis, the storm water WLA may be expressed as an aggregate or combined allocation. Additionally, EPA acknowledges that in cases where it is difficult to discern regulated from non regulated storm water discharges, it is acceptable to include both regulated storm water discharges and non regulated discharges (which would typically be included in the LA portion of the TMDL) in the aggregated WLA.

Because of data limitations and the wide variability of storm water discharges, a land use analysis was used to separate the storm water discharges that are subject to the permitting program (e.g., MS4 and storm water from industrial and construction activities) from storm water discharges that are not subject to permitting (e.g., storm water discharges in urbanized and agricultural areas not regulated by storm water permits). Therefore, all land area within an urban area boundary (as defined by the U.S. Census bureau (Census, 2009)) is assumed to be regulated by the Greene County small MS4s located in the watershed and Battlefield's MS4s. All high intensity urban areas outside of the MS4 areas are assumed to be individually regulated storm water sources. Other land use types that may contribute diffuse runoff and are outside of an MS4 area, such as impervious, low intensity urban land, grassland and cropland are included in the LA portion of the Wilson Creek TMDL.

To summarize, the following WLAs were calculated for Wilson and Jordan Creeks:

- MS4 draining to Jordan Creek
- MS4 draining to Wilson Creek
- Other permitted sources assumed to be represented by high intensity urban areas that are outside of the Greene County MS4 and Battlefield MS4.

Figure15 reports the daily flows that are the WLA curve for the Springfield MS4 area that drains into Jordan Creek. Figure 16 reports the daily flows that are the WLA for the MS4 areas (Battlefield - MOR040042 and Greene County small MS4s - MOR040014 as well as a Christian County small MS4 (MOR040010) that drain to Wilson Creek. The area of the Christian County MS4 only accounts for approximately 0.02 percent of the total MS4 area. Figure 17 reports the WLA for other storm water and point sources, and Table 17 reports the numeric daily flow WLA targets at the five and ten percent exceedance values where the current Wilson Creek flows are greater than the reference/synthetic flow. The MS4 Storm Water WLA represents the daily FDC for the cumulative MS4 area (which includes the drainage area for Wilson and Jordan Creek), Jordan Creek MS4 WLA and the WLA for other point sources within Wilson Creek watershed, but outside the boundary of the MS4. Jordan Creek watershed is entirely within the Greene County MS4; thus the TMDL for Jordan Creek does not have any other WLA or LA components.

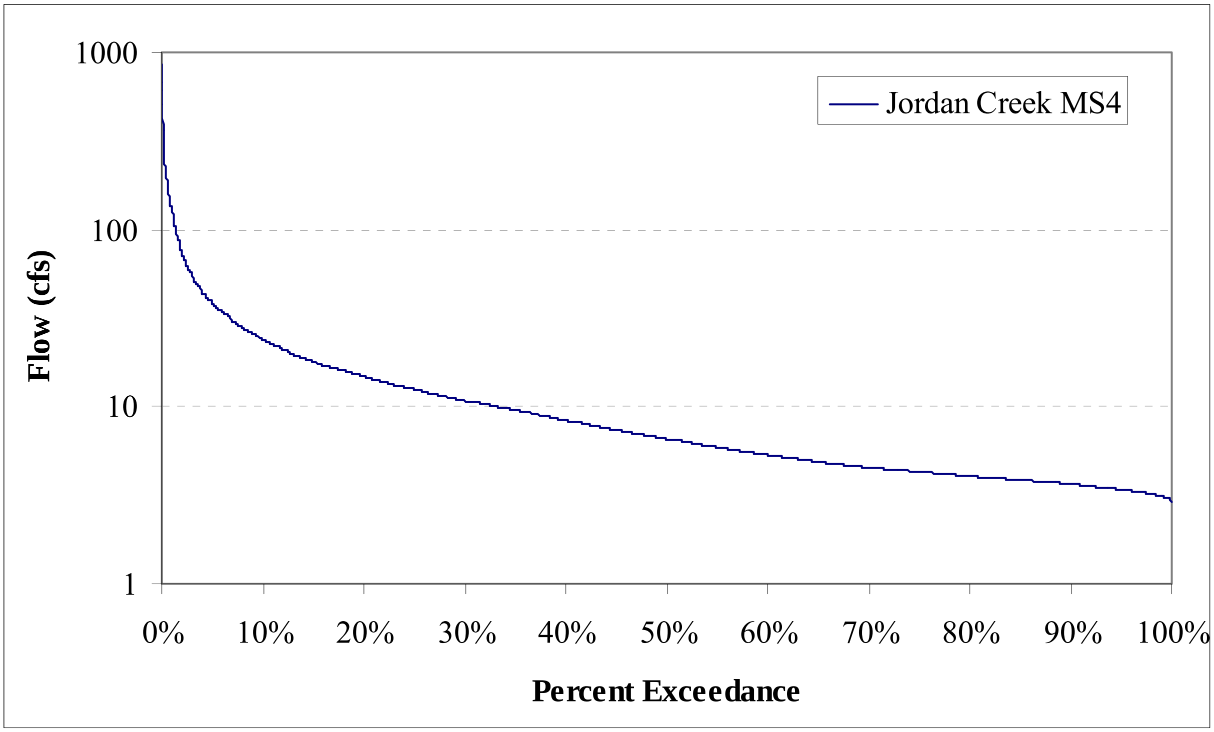

Figure 15. WLA for Springfield MS4 that Drains to Jordan Creek. Drainage area of Jordan Creek in MS4 is 13.5 square miles

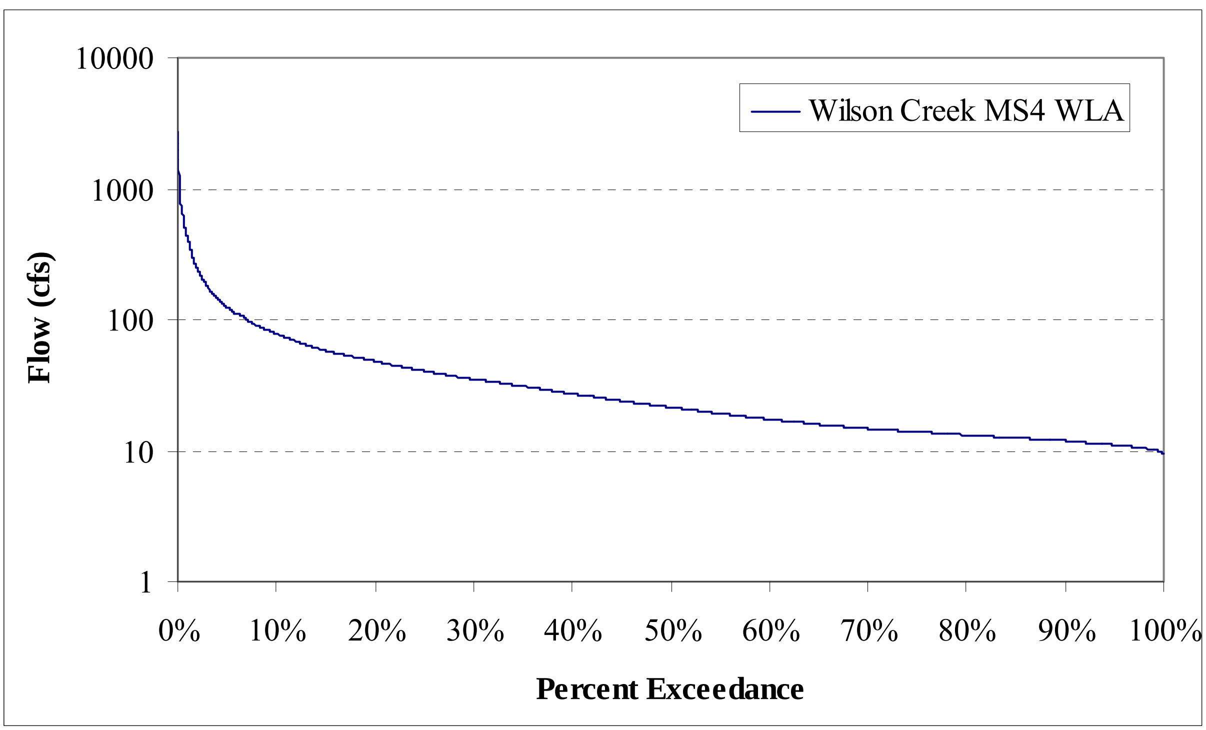

Figure16. WLA for Christian and Greene County MS4 (MOR040010, MOR040042, and MOR040014) that drains to Wilson Creek (includes Jordan Creek). Area of MS4 that Drains to Wilson Creek is 43.7 square miles

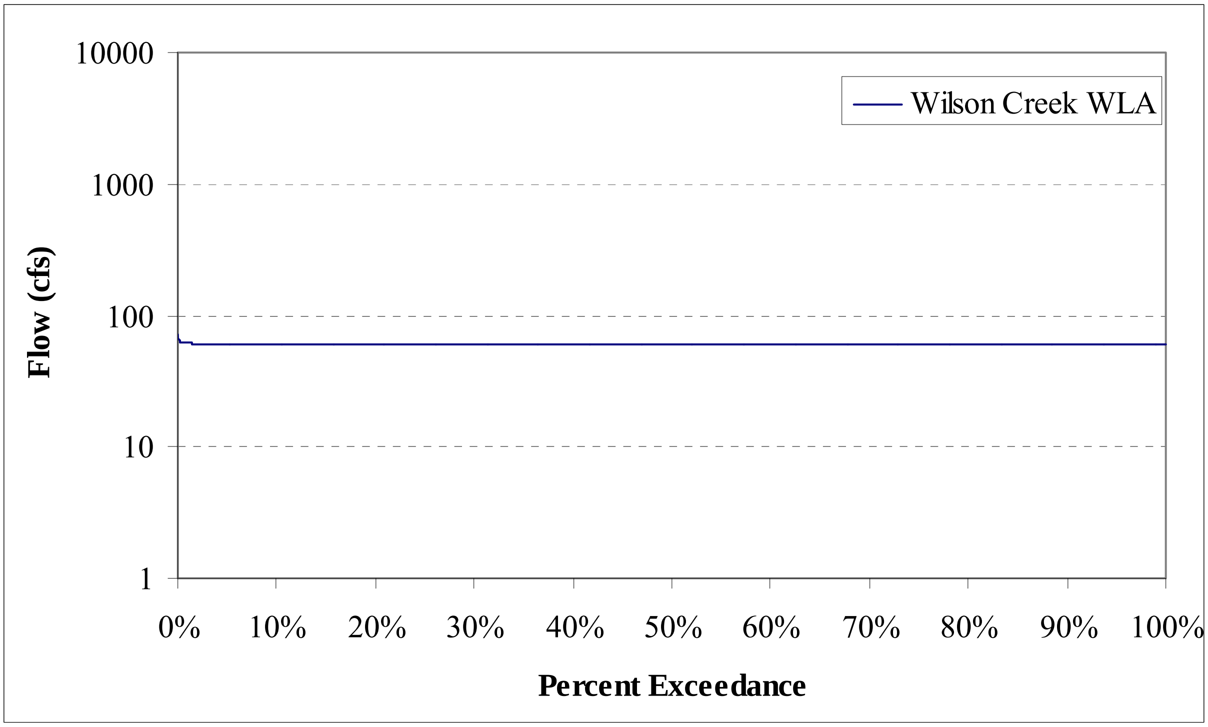

Figure 17. WLA for other point sources within Wilson Creek Watershed and Outside of the cities of Springfield and Battlefield as well as Christian and Greene County MS4 Jurisdiction

Table 17. WLA for point sources in Wilson and Jordan Creek Watersheds

	Percent Flow Exceedance	
	5	10
MS4 WLA – Jordan Creek (cfs)	38.2	23.8
MS4 WLA – Wilson Creek (cfs)	124.0	77.4
Other Sources WLA (cfs)	60.5	60.3

6.2 LOAD ALLOCATION (NONPOINT SOURCE LOADS)

Figure 18 reports the LA curve for Wilson Creek and Table 18 reports the numeric LA targets at the five and ten percent exceedance values. The LA represents the daily FDC for the storm water runoff from non regulated areas within the Wilson Creek watershed. These values are the runoff targets that should be met through voluntary, non regulated activities. It is anticipated the LA runoff reduction goals will be met through implementation of BMPs that will reduce storm water runoff, increase baseflow via infiltration and improve storm water runoff water quality. Should areas within the agricultural and open areas of the watershed be developed and urbanized, the land use area statistics found in the TMDL derivation must be recalculated to ensure no increased storm water runoff from newly developed or urbanized areas. Since Jordan Creek watershed is entirely within the Greene County MS4 coverage area, its LA is zero.

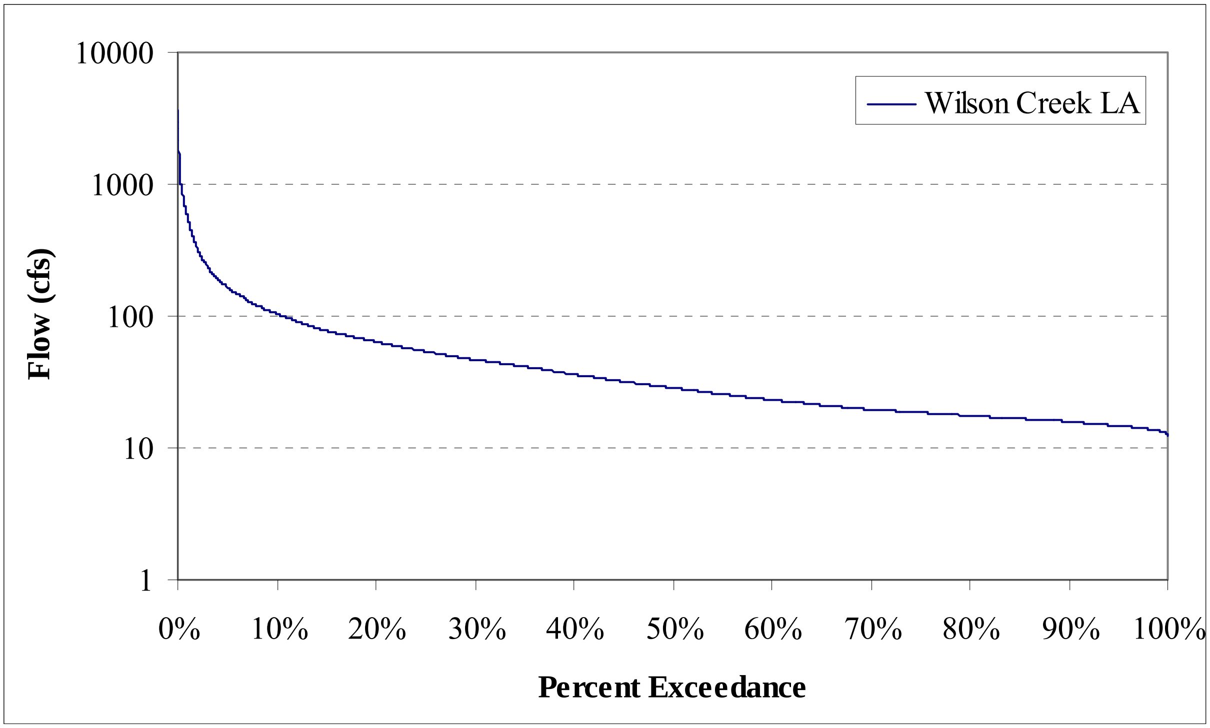

Figure 18. LA for Wilson Creek Watershed

Table 18. LA for Non Regulated Storm Water in Wilson and Jordan Creeks

	Percent Flow Exceedance	
	5	10
LA Wilson Creek (cfs)	165.3	103.2
LA Jordan Creek (cfs)	0	0

6.3 TMDL SUMMARY

This section summarizes the calculated TMDLs for Wilson and Jordan Creeks. Figure 19 and Table 19 report daily maximum flows at the five and ten percent exceedance values of each TMDL component for the Jordan Creek watershed. Figure 20 and Table 20 show the TMDL, LA and WLAs associated with the Wilson Creek watershed that includes the Jordan Creek watershed.

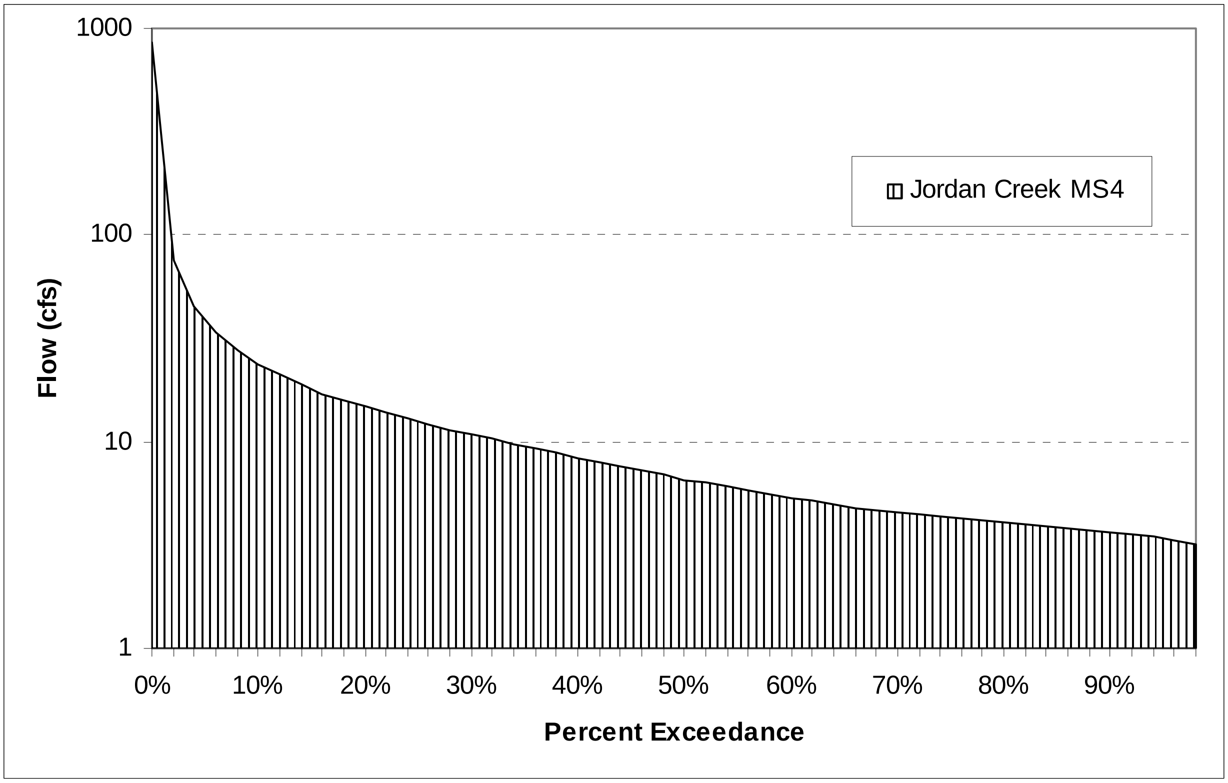

Figure 19. Jordan Creek TMDL FDC

Table 19. TMDL Summary for Jordan Creek

	Percent Exceedance from Jordan Creek FDC	
	5	10
TMDL (cfs)	38.2	23.8
MS4 WLA (cfs)	38.2	23.8
Other WLA (cfs)	0	0
LA (cfs)	0	0
MOS	Implicit	

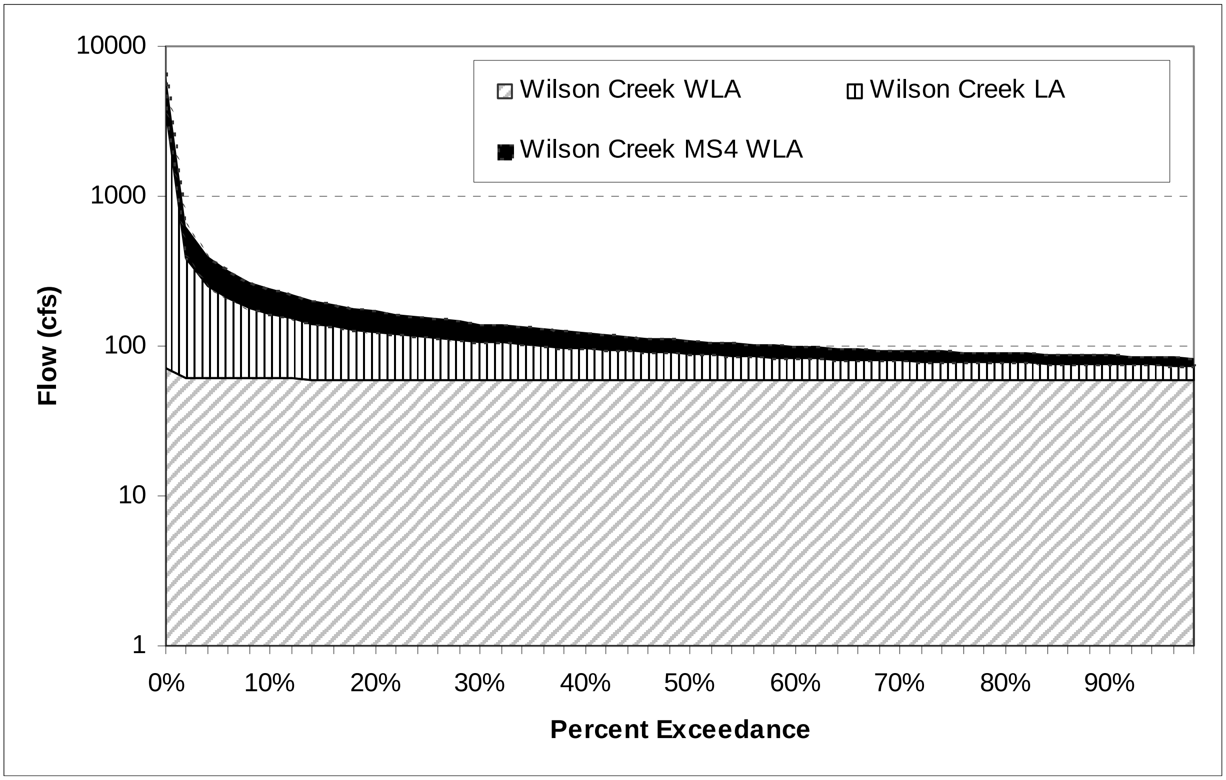

Figure 20. Wilson Creek TMDL, WLA and LA

Table 20. TMDL Summary for Wilson Creek

	Percent Exceedance from Wilson Creek FDC	
	5	10
TMDL (cfs)	349.8	240.9
MS4 WLA (cfs)	124.0	77.4
Other WLA (cfs)	60.5	60.3
LA (cfs)	165.3	103.2
MOS	Implicit	

7 MARGIN OF SAFETY

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

1) Explicit - Reserve a numeric portion of the LC as a separate term in the TMDL.
2) Implicit - Incorporate the MOS as part of the critical conditions for the WLA and LA calculations by making conservative assumptions in the analysis.

An implicit MOS was incorporated by using conservative assumptions during the development of the target FDC derived from the biological reference streams. The reference streams selected are unimpaired and reflective of high quality streams in the EDU. Thus, they are not near or at the threshold of attainment, but rather are representative of the best streams in the EDU; therefore, the TMDL target is a conservative representation of compliance. By meeting the conservative high and low flow targets defined in this TMDL, the physical impact of stream flow will be mitigated by reducing high flows and augmenting low flows. Water quality improvements are expected due to the increased BMPs that will be required to meet the runoff targets.

8 CRITICAL CONDITIONS AND SEASONAL VARIATION

The FDC methodology employed for this TMDL includes consideration of seasonal variation as required by the Federal CWA. The FDCs developed for this TMDL include the full range of daily average flows. These data include seasonal high flows measured during a nine year period (1999 – 2009). Thus, it includes seasonal variations.

9 MONITORING PLANS

MDNR has not made post-TMDL monitoring plans for Wilson and Jordan Creeks. However, USGS maintains a monitoring station on Wilson Creek near Brookline that collects annual ambient water quality data. The Upper White River Basin Foundation is conducting an on-going water quality project that includes data from this USGS station. The Upper White River Basin Foundation has been publishing the results of this project in annual report format. In addition, MDNR will routinely examine physical habitat, water quality, invertebrate community and fish community data collected by MDC under its Resource Assessment and Monitoring, or RAM, Program. This program randomly samples streams across Missouri on a five to six year rotating schedule.

10 REASONABLE ASSURANCES

MDNR has the authority to issue and enforce state operating permits. Inclusion of effluent limits into a state operating permit and requiring that effluent and instream monitoring be reported to MDNR should provide reasonable assurance that instream WQS will be met. Section 301(b)(1)(C) requires that point source permits have effluent limits as stringent as necessary to meet WQS. However, for WLAs to serve that purpose, they must themselves be stringent enough so that (in conjunction with the water body’s other loadings) they meet WQS. This generally occurs when the TMDL’s combined nonpoint source LAs and point source WLAs do not exceed the WQS-based LC and there is reasonable assurance that the TMDL's allocations can be achieved. Discussion of reduction efforts relating to nonpoint sources can be found in the implementation section of the TMDL. EPA believes that point source permitting authority and nonpoint source measures discussed in the supplemental implementation plan (see Appendix E) provides reasonable assurances that the TMDL allocations can be achieved.

11 PUBLIC PARTICIPATION

EPA regulations require that TMDLs be subject to public review (40 CFR Section 130.7). EPA is providing public notice of this draft TMDL for Wilson and Jordan Creeks on the EPA, Region 7, TMDL Website at http://www.epa.gov/region07/water/tmdl_public_notice.htm. The response to comments and the final TMDL will be available at: http://www.epa.gov/region07/water/apprtmdl.htm#Missouri.

These water quality limited segments of Wilson and Jordan Creeks in Christian and Greene Counties, Missouri, are included on the EPA approved 2008 303(d) List for Missouri. These TMDLs are being established by EPA to meet the requirements of the 2001 Consent Decree, *American Canoe Association, et al. v. EPA*, No. 98-1195-CV-W in consolidation with No. 98-4282-CV-W, February 27, 2001. EPA is developing this TMDL in cooperation with the state of Missouri, and EPA is establishing this TMDL at this time to meet the *American Canoe* consent decree milestones. Missouri may submit and EPA may approve another TMDL for this water at a later time.

Before finalizing EPA established TMDLs (such as this TMDL), the public is notified that a comment period is open on the EPA Region 7 website for at least 30 days. EPA's public notices to comment on draft TMDLs are also distributed via mail and electronic mail to major stakeholders in the watershed or other potentially impacted parties. After the comment period closes, EPA reviews all comments, edits the TMDL as is appropriate, writes a Summary of Response to Comments and establishes the TMDL. For Missouri TMDLs, groups receiving the public notice announcement include a distribution list provided by MDNR, the Missouri Clean Water Commission, the Missouri Water Quality Coordinating Committee, Stream Team Volunteers, state legislators, County Commissioners, the County Soil and Water Conservation District and potentially impacted cities, towns and facilities. EPA followed this public notice process for this TMDL. Links to active public notices for draft TMDLs, final (approved and established) TMDLs and Summary of Response to Comments are posted on the EPA website: http://www.epa.gov/region07/water/tmdl.htm.

The availability of the TMDLs in draft form was published on the EPA Region 7 Website for at least 30 days. The public notice period of the draft Wilson and Jordan Creeks TMDL document was from August 30 to September 30, 2010. EPA's public notice inviting comments on the draft TMDLs was also distributed via mail and electronic mail to major stakeholders in the watershed and other potentially impacted parties. Five public comments were received overall and the TMDL document has been adjusted where appropriate.

12 ADMINISTRATIVE RECORD AND SUPPORTING DOCUMENTS

An administrative record on the Wilson and Jordan Creek TMDL development has been assembled and is being kept on file with EPA.

13 APPENDICES

Appendix A – Wilson Creek Watershed Permitted Facilities
Appendix B – Approach to Calculating Synthetic Flow Record from Reference Streams
Appendix C – Approach to Calculating Wilson Creek Flow Duration Curve and the TMDL
Appendix D – Approach to Calculating Percent Flow Change by Land Use
Appendix E – Supplemental Implementation Plan
Appendix F – Location of Wilson Creek 2009 Water Quality Monitoring Stations
Appendix G – Location of Wilson Creek Historic USGS Water Quality Monitoring Stations

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Appendix A - Wilson Creek Watershed Permitted Facilities

Facility ID	Facility Name	Receiving Stream	Classification/ Description	Water Quality Sampling Requirements	Design Flow (MGD)	Permit Expiration Date
MO0001864	Carlisle Power Transformation Products	Trib. to South Creek	Operators Of Nonresidential Buildings	Temp, COD, pH, Flow, O&G, Rainfall, TSS, BOD, TOC	1.602	2012
MO0001945	Kraft Foods Global, Inc.	Trib. to Fassnight Creek	Natural, Processed, And Imitation Cheese	Nitrogen Ammonia, Temperature, COD, pH, Flow, O&G, Phosphorus, TSS, BOD, Solids, Rainfall	0.206	2009
MO0001970	Archimica Inc. Waste Water Treatment Facility (WWTF)	Jordan Creek	Medicinal Chemicals And Botanical Products	Temperature, COD, pH, Nitrogen Ammonia, O&G, Phosphorus, TSS	0.04	2014
MO0001988	Sweetheart Cup Co.	Trib. to Jordan Creek	Sanitary Food Containers, Except Folding	Temperature, pH, Flow, Surfactants, O&G	0.05	2007
MO0002127	Dairy Farmers Of America	Jordan Creek	Fluid Milk	Temperature, Flow, O&G, pH	0.18	2009

Facility ID	Facility Name	Receiving Stream	Classification/ Description	Water Quality Sampling Requirements	Design Flow (MGD)	Permit Expiration Date
MO0049522	Springfield Southwest WWTP	Wilson Creek	Sewerage Systems	Temperature, pH, Nitrogen Ammonia Total Kjeldahl Nitrogen, Nitrite Plus Nitrate Total, Phosphorus, Cyanide, Arsenic, Nickel, Zinc, Cadmium, Lead, Chromium, Copper, Mercury, Flow, DO	42.5	2007
MO0089940	Springfield Southwest Power Plant	Wilson Creek	Power Plant	Toxicity testing, Copper Total Recoverable, Flow, Chlorine, Sulfate, Temperature, Phosphorus, pH, TSS, Rainfall, O&G	45.6	2009
MO0097454	Gen Council Assembly God	Trib. Jordan Creek	Religious Organizations	Temperature, BOD, pH, TSS, Flow, Nitrite Plus Nitrate, Total Manganese, Nitrogen Ammonia, O&G	0.1	2013
MO0116823	BNSF Springfield Yard	Trib. Wilson Creek	Railroads, Line-Haul Operating	Oxygen Demand, pH, Flow, Oil Petroleum, Total Settleable Solids	0.00	2011

Facility ID	Facility Name	Receiving Stream	Classification/ Description	Water Quality Sampling Requirements	Design Flow (MGD)	Permit Expiration Date
MO0117331	Kerr-Mcgee Chemical, LLC	Trib. Wilson Creek	Wood Preserving	Oxygen Demand, Flow, O&G, Acenaphthylene, Anthracene, Benzo(K)Fluoranthene, Benzo(A)Pyrene, Chrysene, Fluoranthene, Indeno (1,2,3-Cd) Pyrene, Benzo(A)Anthracene, Dibenzo (A,H) Anthracene, Phenol, Single Compound, Naphthalene, pH	0.00	2007
MO0131440	Land O'lakes Purina Feed	Unnamed Trib. to Wilson Creek	Prepared Feeds And Feed Ingredients For Animals And Fowls, Except Dogs And Cats	Temp, BOD, TSS, pH, O&G, Nitrogen Ammonia, Total Phosphorus, Total Manganese, Rainfall, Flow, Nitrite plus Nitrate	0.00	2010
MO0132446	Willow Brook Foods	Unnamed Trib. Jordan Creek	Broiler, Fryer, And Roaster Chickens	NA	0.023	2011
MO0137333	Durakast Concrete Product	Trib. to Wilson Creek	NA	NA	0.00	2012
MOG140049	The Victor L. Phillips Co.	Mcelhaney Br	Gasoline Service Stations	NA	General Permit	2013
MOG350163	MFA Bulk Plant-Clever	Trib. to Terrell Creek	Petroleum Bulk Stations And Terminals	NA	General Permit	2007
MOG350168	Safety Kleen Systems, Inc.	Trib. to Wilson Creek	Petroleum Bulk Stations And Terminals	NA	General Permit	2012
MOG350171	Morris Oil Products	Trib. to Jordan Creek	Petroleum Bulk Stations And Terminals	NA	General Permit	2012

Facility ID	Facility Name	Receiving Stream	Classification/ Description	Water Quality Sampling Requirements	Design Flow (MGD)	Permit Expiration Date
MOG490011	Springfield Underground	Trib. To Wilson Creek	Crushed And Broken Limestone	NA	General Permit	2011
MOG490033	Leo Journagan Battlefield	Trib. to Terrell Branch	Crushed And Broken Limestone	NA	General Permit	2011
MOG490234	Quickrete Products	Trib. to Jordon Creek	Crushed And Broken Limestone	NA	General Permit	2011
MOG490348	Springfield Ready Mix Co.	Trib. to Wilson Creek	Crushed And Broken Limestone	NA	General Permit	2011
MOG490499	Midwest Block & Brick	Trib. to Fassnight Creek	Crushed And Broken Limestone	NA	General Permit	2011
MOG490502	Nattinger Materials Co.	Trib. to Jordan Creek	Crushed And Broken Limestone	NA	General Permit	2011
MOG490557	Prestressed Casting Co.	Trib. to Fassnight Creek	Crushed And Broken Limestone	NA	General Permit	2011
MOG490607	Apac - Missouri, Inc.	Wilson Creek	Crushed And Broken Limestone	NA	General Permit	2011
MOG490622	Kay Concrete-Republic	Trib. to Sink Hole	Crushed And Broken Limestone	NA	General Permit	2011
MOG490642	Concrete Company Of Springfield	Jordan Creek	Crushed And Broken Limestone	NA	General Permit	2011
MOG490985	Regional Ready Mix, Inc.	Unnamed Trib. to Wilson Creek	Crushed And Broken Limestone	NA	General Permit	2011
MOG760097	Ozarks Regional YMCA	Trib. to Jordan Creek	Amusement And Recreation Services, Not Elsewhere Classified	NA	General Permit	2014
MOG822095	Darling International, Inc.	Trib. to Terrell Creek	Meat Packing Plants	NA	General Permit	2011

Facility ID	Facility Name	Receiving Stream	Classification/ Description	Water Quality Sampling Requirements	Design Flow (MGD)	Permit Expiration Date
MOR040010	Christian County Small MS4	Wilson Creek and Spring Creek	Air And Water Resource And Solid Waste Management	NA	Storm water Permit	2013
MOR040014	Greene County Small MS4	Trib. to Wilson, South, Jordan Creek	Air And Water Resource And Solid Waste Management	NA	Storm water Permit	2013
MOR040042	Battlefield Small MS4	Trib. to Wilson Creek	Air And Water Resource And Solid Waste Management	NA	Storm water Permit	2013
MOR040066	U.S. Medical Center For Fed	South Creek and Trib. To Fassnight Creek	Air And Water Resource And Solid Waste Management	NA	Storm water Permit	2013
MOR103524	Barrington Park Subdivision	South Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR104748	Battlefield Crossing Co.	Trib. to Wilson Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109895	Bent Tree Subdivision	Trib. to Wilson Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109992	Golden Pond	Trib. to Wilson Creek	Data Not Found On PCS	NA	Storm water Permit	2012
MOR109A72	Creekside Subdivision	Trib. to South Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109AA5	Central Dodge Truck Sales	Trib. to Fassnight Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012

Facility ID	Facility Name	Receiving Stream	Classification/ Description	Water Quality Sampling Requirements	Design Flow (MGD)	Permit Expiration Date
MOR109AP1	New Republic High School	Trib. to Mcelhaney Branch	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109AT5	William H. Darr Agriculture	Trib. to South Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109AW4	Strasbourg Estates Phase 2	Trib. to Wilson Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109AX7	Westbury Gardens Subdivision	Trib. to Terrell Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109AX9	Weaver School	Trib. to Jordan Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109AY7	Springfield Plaza	Trib. to Wilson Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109B18	Bass Pro Shops Outdoor World	Trib. to Fassnight Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109BB5	Parkview High School	Trib. to Fassnight Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109BC5	The Beer Company Expansion	Trib. to South Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109BG5	Roberts Industrial Park	Trib. to Wilson Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012

Facility ID	Facility Name	Receiving Stream	Classification/ Description	Water Quality Sampling Requirements	Design Flow (MGD)	Permit Expiration Date
MOR109BH3	Rental Service Corp.	Trib. to Mcelhaney Brook	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109BI3	Six 23 Condominiums	Trib. to Jordan Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109BL1	Plaza Corp. Retail Center	Trib. to Wilson Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109BL8	Kansas Plaza - Battlefield	Trib. to South Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109BP3	Casey's General Store	Trib. to Workman Branch	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109BQ2	Metropolitan National Bank	Sink Hole	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109BQ3	Rhomar Industries New War	Wilson Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109BR5	Scenic Station Lot 6	Trib. to Jordan Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109BS5	Barrington Park Subdivsion	Trib. to South Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109BU2	Westwood Hills 3rd Additional	Wilson Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012

Facility ID	Facility Name	Receiving Stream	Classification/ Description	Water Quality Sampling Requirements	Design Flow (MGD)	Permit Expiration Date
MOR109BV0	JLA Construction Storage	Mcelhany Branch	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109BV1	Scenic Ave. Force Main	Trib. to South Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109BV4	Star Wholesale Supply Co	South Br. Of Jordan Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109C18	St. John's Regional Medic	Trib. to Fassnight Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109CA4	Vintage Hills Estates	Trib. to Wilson Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109CB5	Republic Commons	Trib. to Shuyler Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109CE3	Carroll's Warehouse Paint	Trib. to Jordan Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109CK2	Whispering Heights Subdivision	Trib. to Terrell Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109CK3	Southwest Ground Storage	Springfield Storm Water System	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109CM0	Dullin Property	Trib. to Wilson Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012

Facility ID	Facility Name	Receiving Stream	Classification/ Description	Water Quality Sampling Requirements	Design Flow (MGD)	Permit Expiration Date
MOR109CO1	Willard Elementary School	Trib. to Wilson Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109CO2	3M Company	Trib. to Jordan Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109CO6	Oak Court Place	Trib. to Shuyler Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109CP0	Westview Fields Phase 1	Trib. to Terrell Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109CP9	Eko Park	Trib. to Jordan Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109CR7	Kum & Go Springfield #489	Wilson Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109CS9	O'Reilly Family Event Center	Trib. to Jordan Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109CT9	Brick City South Parking	Jordan Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109CU4	Murfin's Market	Trib. to Terrell Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109CW5	Atomic Fireworks Midwest	Trib. to Wilson Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012

Facility ID	Facility Name	Receiving Stream	Classification/ Description	Water Quality Sampling Requirements	Design Flow (MGD)	Permit Expiration Date
MOR109CW7	BKD Office Building	Trib. to Fassnight Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109CX1	Cherry Street Townhomes	Trib. to Jones Spring	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109CY2	Killian Sports Complex	Trib. to Jordan Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109D02	Old Stone Development	Trib. to Mcelhaney Branch	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109DA3	Westgate Subdivision	Trib. to Wilson Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109DB5	Frisco Square Phase III	Trib. to Terrell Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109DD5	Lazer Perfect Striping	Trib. to Wilson Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109DE5	Jordan Valley Community	Trib. to Jordan Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109DE8	C & B Transfer & Storage	Trib. to Jordan Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109DG3	New Vista	Trib. to Shuyler Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012

Facility ID	Facility Name	Receiving Stream	Classification/ Description	Water Quality Sampling Requirements	Design Flow (MGD)	Permit Expiration Date
MOR109DG4	Silver Brook	Trib. to Wilson Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109DL9	Price Cutter Supermarket	Trib. to Wilson Creek	Data Not Found On PCS	NA	Storm water Permit	2012
MOR109G54	Frisco Trails Subdivision	Trib. to Wilson Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109L74	Terrell Creek Subdivision	Trib. to Terrell Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109M66	Park Place At 2025 - Lots	Unnamed Trib. to Fassnight Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109N08	Elite Storage Center-North	Unnamed Trib. To Jordan Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109N42	Dogwood Place Subdivision	Unnamed Trib. to Wilson Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109N87	Butler Rosenbury & Partners	Trib. to Jordan Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109Q04	Cherry Street Business Park	Trib. to Jones Branch	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109Q38	Oakwood Heights	Unnamed Trib. to Shuyler Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012

Facility ID	Facility Name	Receiving Stream	Classification/ Description	Water Quality Sampling Requirements	Design Flow (MGD)	Permit Expiration Date
MOR109Q92	Dickerson Heights Subdivision	North Branch Wilson Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109R69	Prairie View Heights 12th	Unnamed Trib. to Wilson Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109S25	Terrell Creek Phase 1	Trib. to Terrell Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109T46	ADM Alliance Nutrition, I	Unnamed Trib. to Jordan Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109V25	Chestnut At Duke	Trib. to Wilson Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109V44	The Wooten Company	Trib. to Wilson Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109W14	Pinegar Parking Lot	Trib. to Shuyler Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109W73	JQH Arena	Trib. To Fassnight Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109X18	Haseltine Mini Storage	Trib. to Wilson Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109X46	College Station Theater/R	Jordan Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012

Facility ID	Facility Name	Receiving Stream	Classification/ Description	Water Quality Sampling Requirements	Design Flow (MGD)	Permit Expiration Date
MOR109X48	Hicks Enterprises	Trib. To Fassnight Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR109X50	Cody's Convenience Store	Jordan Creek	Heavy Construction, Not Elsewhere Classified	NA	Storm water Permit	2012
MOR12A012	ADM Alliance Nutrition	Trib. to Jordan Creek	Ice Cream And Frozen Desserts	NA	Storm water Permit	2011
MOR12A050	ADM Alliance Nutrition	Trib. to Jordan Creek	Ice Cream And Frozen Desserts	NA	Storm water Permit	2011
MOR12A096	Butternut Bakery	Jordan Creek	Ice Cream And Frozen Desserts	NA	Storm water Permit	2011
MOR12A129	Dairy Farmers Of America	Trib. to Jordan Creek	Fluid Milk	Temperature, Flow, O&G, pH	Storm water Permit	2011
MOR14A004	Smurfit Stone Containers	Jordan Creek	Corrugated And Solid Fiber Boxes	NA	Storm water Permit	2009
MOR14A033	Smurfit Stone Container E	Trib. to South Creek	Paper and Allied Products	NA	Storm water Permit	2009
MOR203083	ACRO Trailer Company	Trib. to Jordan Creek	Industrial Trucks, Tractors, Trailers, And Stackers	NA	Storm water Permit	2014

Facility ID	Facility Name	Receiving Stream	Classification/ Description	Water Quality Sampling Requirements	Design Flow (MGD)	Permit Expiration Date
MOR203093	Doing Steel	Trib. to Spring Br.	Fabricated Structural Metal	Color, pH, TSS, O&G, Flow, Iron Total Recoverable, Zinc Total Recoverable, Copper Total Recoverable, Priority Pollutants Total Effluent, Hardness	Storm water Permit	2014
MOR203099	Paul Mueller Company	Trib. to Wilson Creek	Refined Petroleum Pipelines	pH, TSS, Flow, Priority Pollutants Total Effluent, O&G	Storm water Permit	2014
MOR203187	Loren Cook Company	Trib. to Jordan Creek	Air-Conditioning And Warm Air Heating Equipment And Commercial And Industrial Refrigeration Equipment	Color, pH, TSS, O&G, Flow, Iron Total Recoverable, Zinc Total Recoverable, Copper Total Recoverable, Priority Pollutants Total Effluent, Hardness	Storm water Permit	2014
MOR203195	Custom Metalcraft, Inc.	Trib. to Jordan Creek	Food Products Machinery	NA	Storm water Permit	2014
MOR203206	Acme Structural, Inc.	Trib. to Jordan Creek	Fabricated Plate Work	NA	Storm water Permit	2014
MOR203235	Pure-Flo Precision	Trib. to Jordan Creek	Electroplating, Plating, Polishing, Anodizing, And Coloring	NA	Storm water Permit	2014

Facility ID	Facility Name	Receiving Stream	Classification/ Description	Water Quality Sampling Requirements	Design Flow (MGD)	Permit Expiration Date
MOR203314	Engines Plus, Inc.	Trib. to South Creek	Scrap And Waste Materials	NA	Storm water Permit	2014
MOR203329	Paul Mueller Company	Trib. to Jordan Creek	Refined Petroleum Pipelines	pH, TSS, Flow, Priority Pollutants Total Effluent, O&G	Storm water Permit	2014
MOR203354	Custom Metalcraft, Inc.	Trib. to Wilson Creek	Railroad Equipment	NA	Storm water Permit	2014
MOR203355	Custom Metalcraft, Inc.	Trib. to Jordan Creek	Railroad Equipment	NA	Storm water Permit	2014
MOR203371	Rose Metal Products, Inc.	Trib. to Jordan Creek	Railroad Equipment	NA	Storm water Permit	2014
MOR203379	Springfield Remanufacturing	Unnamed Trib. Wilson Creek	Railroad Equipment	NA	Storm water Permit	2014
MOR203381	Southwest Stainless, Inc.	Unnamed Trib. Wilson Creek	Railroad Equipment	NA	Storm water Permit	2014
MOR203407	Turblex Inc.	Trib. to Jordan Creek	Fabricated Metal Products, Not Elsewhere Classified	NA	Storm water Permit	2014
MOR23A015	Ko Manufacturing Inc.	Trib. to Jordan Creek	Medicinal Chemicals And Botanical Products	COD, O&G, TSS, pH	Storm water Permit	2010
MOR23A036	Earl Scheib Auto Paint Finishing	Unnamed Trib. to Jordan Creek	Medicinal Chemicals And Botanical Products	Color, COD, Flow, TSS, O&G, pH	Storm water Permit	2010

Facility ID	Facility Name	Receiving Stream	Classification/ Description	Water Quality Sampling Requirements	Design Flow (MGD)	Permit Expiration Date
MOR23A080	Chem. Supply Co., Inc.	Trib. to Jordan Creek	Medicinal Chemicals And Botanical Products	Color, COD, Flow, TSS, O&G, pH	Storm water Permit	2010
MOR23A087	Brenntag Mid-South	Trib. to South Creek	Medicinal Chemicals And Botanical Products	Color, COD, Flow, TSS, O&G, pH	Storm water Permit	2010
MOR23A089	Dennis Oil Company	Trib. to Jordan Creek	Medicinal Chemicals And Botanical Products	Color, COD, Flow, TSS, O&G, pH	Storm water Permit	2010
MOR23A098	3m Company - Springfield	Trib. to Jordan Creek	Medicinal Chemicals And Botanical Products	Color, COD, Flow, TSS, O&G, pH	Storm water Permit	2010
MOR23D002	Viatech Publishing Solution	Trib. to South Br. Of Jordan	Plastics Products, Not Elsewhere Classified	NA	Storm water Permit	2010
MOR240134	MFA Agri Service – Springfield	Trib. to Jordan Creek	Farm Supplies	NA	Storm water Permit	2014
MOR240219	Midwest Plant Food/Supply	Trib. to Wilson Creek	Farm Supplies	NA	Storm water Permit	2014
MOR60A129	B And W Auto Salvage	Trib. to Jordan Creek	Motor Vehicle Parts, Used	NA	Storm water Permit	2013
MOR60A152	Westport Auto Salvage	Trib. to Wilson Creek	Motor Vehicle Parts, Used	NA	Storm water Permit	2013
MOR60A155	Bobs Scrap Metal Processing	Fassnight Creek	Motor Vehicle Parts, Used	NA	Storm water Permit	2013

Facility ID	Facility Name	Receiving Stream	Classification/ Description	Water Quality Sampling Requirements	Design Flow (MGD)	Permit Expiration Date
MOR60A156	Commercial Metals Company	Trib. to Jordan Creek	Motor Vehicle Parts, Used	NA	Storm water Permit	2013
MOR60A162	Howards Auto Salvage	Trib. to Jordan Creek	Motor Vehicle Parts, Used	NA	Storm water Permit	2013
MOR60A163	Mccoy's Iron & Metal Inc.	Trib. to Jordon Creek	Motor Vehicle Parts, Used	NA	Storm water Permit	2013
MOR60A192	G & S Auto Service	Trib. to Jordan Creek	Motor Vehicle Parts, Used	NA	Storm water Permit	2008
MOR60A207	C & S Auto Salvage	Trib. to Wilson Creek	Motor Vehicle Parts, Used	NA	Storm water Permit	2008
MOR60A209	All Metal Recycling, Inc.	Trib. to Wilson Creek	Motor Vehicle Parts, Used	NA	Storm water Permit	2008
MOR60A211	H & W Auto Parts	Trib. to Jordan Creek	Motor Vehicle Parts, Used	NA	Storm water Permit	2013
MOR60A281	Springfield Iron & Metal	Trib. to Jordan Creek	Motor Vehicle Parts, Used	NA	Storm water Permit	2013
MOR80C039	Trux Trailer Sales/Repair	Trib. to Wilson Creek	Terminal And Joint Terminal Maintenance Facilities For Motor Freight Transportation	NA	Storm water Permit	2012
MOR80C075	Wilcox Truck Line, Inc.	Trib. to Jordan Creek	Terminal And Joint Terminal Maintenance Facilities For Motor Freight Transportation	pH, Flow, O&G, TSS	Storm water Permit	2012

Facility ID	Facility Name	Receiving Stream	Classification/ Description	Water Quality Sampling Requirements	Design Flow (MGD)	Permit Expiration Date
MOR80C173	UPS, Springfield Metro	Trib. to Jordan Creek	Terminal And Joint Terminal Maintenance Facilities For Motor Freight Transportation	pH, Flow, O&G, TSS	Storm water Permit	2012
MOR80C186	Erickson Transport Corp.	Trib. to Jordan Creek	Terminal And Joint Terminal Maintenance Facilities For Motor Freight Transportation	pH, Flow, O&G, TSS	Storm water Permit	2012
MOR80C267	U.S. Postal Service, Springfield Ext.	Trib. to Jordan Creek	Terminal And Joint Terminal Maintenance Facilities For Motor Freight Transportation	pH, Flow, O&G, TSS	Storm water Permit	2012
MOR80C300	U.S. Postal Service John Griesemer Station	Trib. to Fassnight Creek	Terminal And Joint Terminal Maintenance Facilities For Motor Freight Transportation	NA	Storm water Permit	2012
MOR80C302	U.S. Postal Service Glenstone Station	Trib. to Fassnight Creek	U.S. Postal Service	NA	Storm water Permit	2007
MOR80C358	Fedex Express Corp.	Trib. to Wilson Creek	Terminal And Joint Terminal Maintenance Facilities For Motor Freight Transportation	NA	Storm water Permit	2007
MOR80C434	Trailiner Corporation	Trib. to Jordan Creek	Terminal And Joint Terminal Maintenance Facilities For Motor Freight Transportation	NA	Storm water Permit	2007
MOR80C438	Associated Wholesale Grocery	Trib. to Jordan Creek	Terminal And Joint Terminal Maintenance Facilities For Motor Freight Transportation	NA	Storm water Permit	2012

Facility ID	Facility Name	Receiving Stream	Classification/ Description	Water Quality Sampling Requirements	Design Flow (MGD)	Permit Expiration Date
MOR80C448	Milky-Way Transport Co.	Trib. to Jordan Creek	Terminal And Joint Terminal Maintenance Facilities For Motor Freight Transportation	NA	Storm water Permit	2012
MOR80C449	Baldwin Transportation	Trib. to Wilson Creek	Terminal And Joint Terminal Maintenance Facilities For Motor Freight Transportation	NA	Storm water Permit	2007
MOR80C450	Willie Jean Logistics LLC	Trib. to Fassnight Creek	Terminal And Joint Terminal Maintenance Facilities For Motor Freight Transportation	NA	Storm water Permit	2012
MOR80C451	Ozark Motor Lines, Inc.	Trib. to Jordan Cr	Terminal And Joint Terminal Maintenance Facilities For Motor Freight Transportation	NA	Storm water Permit	2012
MOR80C452	Springfield Multi-Bin Garage	Trib. to Wilson Creek	Terminal And Joint Terminal Maintenance Facilities For Motor Freight Transportation	NA	Storm water Permit	2012
MOR80C453	Steelman Transportation	Trib. to Jordan Creek	Terminal And Joint Terminal Maintenance Facilities For Motor Freight Transportation	NA	Storm water Permit	2007
MOR80C454	Central Trucking, Inc.	Trib. to Wilson Creek	Terminal And Joint Terminal Maintenance Facilities For Motor Freight Transportation	NA	Storm water Permit	2012
MOR80C461	Ozarks Coca-Cola/Dr. Pepper	Unnamed Trib. Jordan Creek	Terminal And Joint Terminal Maintenance Facilities For Motor Freight Transportation	NA	Storm water Permit	2007

Facility ID	Facility Name	Receiving Stream	Classification/ Description	Water Quality Sampling Requirements	Design Flow (MGD)	Permit Expiration Date
MOR80C465	Pepsi-Cola General Bottle	Unnamed Trib. to Jordan Creek	Terminal And Joint Terminal Maintenance Facilities For Motor Freight Transportation	NA	Storm water Permit	2012
MOR80H030	Springfield Relay System	Trib. to Jordan Creek	Refuse Systems	BOD, COD, Flow, TSS, O&G, pH, Rainfall	Storm water Permit	2009
MOR80H031	New American Recycling	Jordan Creek	NA	NA	Storm water Permit	2004
MOR80H046	Springfield Transfer Station	Trib. to Fassnight Creek	Refuse Systems	BOD, COD, Flow, TSS, O&G, pH, Rainfall	Storm water Permit	2009
MOR80H084	Stericycle, Inc.	Trib. to Jordan Creek	Heavy Construction, Not Elsewhere Classified	BOD, COD, Flow, TSS, O&G, pH, Rainfall	Storm water Permit	2009

Where BOD = Biochemical Oxygen Demand, COD = Chemical Oxygen Demand, TSS = Total Suspended Solids, and O&G = Oil and Grease
NA = Not Applicable. Permits identified as NA are typically storm water or general permits.
Trib. = Tributary; Br. = Branch; Cr = Creek

Appendix B – Approach to Calculating Synthetic Flow Record From Reference Streams

A synthetic flow record was developed from reference streams to provide target flow conditions representative of unimpaired streams. Biological reference streams are selected by MDNR to reflect streams that are meeting water quality criteria and are representative of good aquatic habitat. They are used as the basis for determining whether other streams in the EDU are meeting biological criteria. Therefore, the average flow pattern experienced within a reference stream should be protective of designated aquatic life beneficial uses and are a suitable TMDL target and surrogate measurement for impairments related to aquatic life impairments.

The synthetic flow record for the Ozark / White EDU was created from flows measured at three USGS gages downstream from four MDNR selected reference streams. Figure B.1 shows the location of each reference stream watershed, USGS gage and Wilson Creek watershed. The synthetic flow record is the average of area normalized flow measured at each gage.

The gages were selected for use because they were downstream of the reference streams in the same EDU as Wilson Creek. In addition the gages had the following characteristics:

- There was little to no development in the gaged watersheds. Table B.1 through Table B.3 reports the land use in each reference stream and USGS gage watershed.
- There were no impairments in the gaged watersheds.
- Each gage had a recent and overlapping period of record 2000 - 2009.
- The gaged watersheds had similar soil types. Table B.4 through Table B.6 reports the soil type in each reference stream and USGS gage watershed.

The above characteristics were considered because the soil type and land use in a watershed affects its hydrologic response. By ensuring that soil types were similar and land use changes due to urbanization were minimal it is possible to compare FDCs from Wilson Creek and Jordan Creek to the synthetic flow developed from the reference streams. The differences between the two FDCs are attributable to the development in the Wilson Creek and Jordan Creek watersheds. Using recent and overlapping gaged data minimized the impact of different precipitation patterns and long term climate changes, and allowed a direct comparison of the area normalized flow between Wilson Creek, Jordan Creek and the reference streams. The development and use of the synthetic flow record included the following steps:

- Estimated flow per square mile for each reference streams watershed.
- Averaged individual reference stream flows to create synthetic flow.
- Used synthetic flow record to calculate a stream FDC.

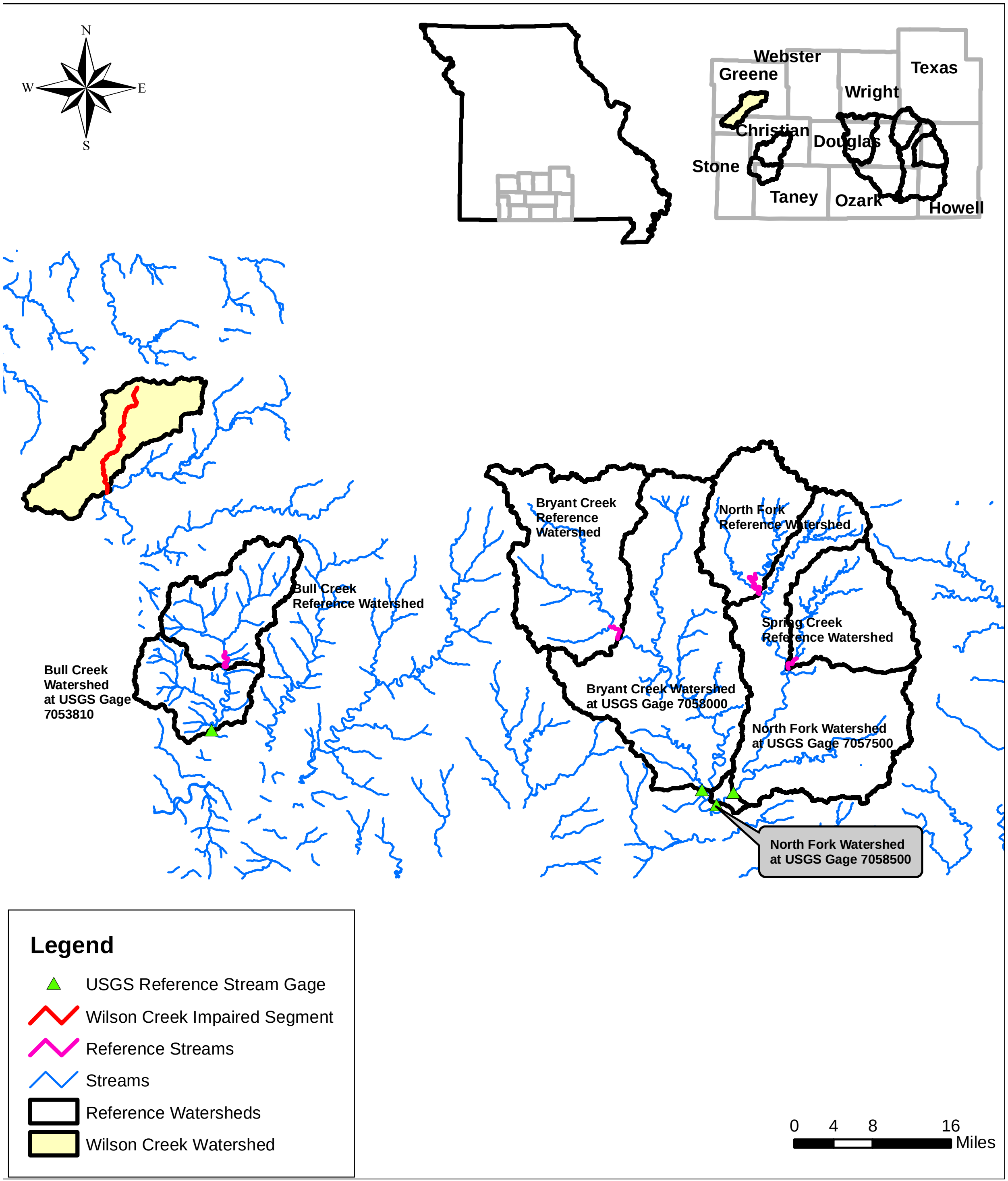

Figure B.1. Location of Reference Streams and USGS Gages Used to Develop the Synthetic Flow Record

Land Use

Tables B.1 through Table B.3 summarize land use from Missouri's 2005 land use data set (MoRAP, 2005) and an older dataset from 1993. The 1993 land use dataset was used because the 2005 data was not available for the entire area. The land use data of the reference streams and the stream gages located downstream from these streams suggest that the land use patterns above the stream gages are similar to the land use of the reference streams. In addition, all of the reference streams and gages watersheds have minimal urbanization. The reference stream watersheds have less than 2 percent developed land and more than 60 percent forest cover.

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Table B.1. Land Use for Bull Creek Reference Stream and Gage

	Bull Creek at Reference Stream		Bull Creek at USGS Gage 07053810	
Land use (2005)	**Area (Acres)**	**Percent (%)**	**Area (Acres)**	**Percent (%)**
Impervious	789	1.1	1,944	1.6
High Intensity Urban	19	0.0	38	0.0
Low Intensity Urban	292	0.4	427	0.3
Barren or Sparsely Vegetated	552	0.7	1,371	1.1
Cropland	291	0.4	297	0.2
Grassland	19,437	26.3	29,858	24.0
Deciduous Forest	47,162	63.9	79,938	64.1
Evergreen Forest	2,155	2.9	4,252	3.4
Mixed Forest	0	0.0	3	0.0
Deciduous Woody/Herbaceous	2,679	3.6	6,279	5.0
Evergreen Woody/Herbaceous	40	0.1	189	0.2
Woody-Dominated Wetland	1	0.0	3	0.0
Herbaceous-Dominated Wetland	41	0.1	42	0.0
Open Water	352	0.5	689	0.6
Total	73,810		125,328	

Table B.2. Land Use for Bryant Creek Reference Stream and Gage

	Bryant Creek at Reference Stream		Bryant Creek at USGS 07058000	
Land use (2005)	**Area (Acres)**	**Percent (%)**	**Area (Acres)**	**Percent (%)**
Impervious	146.1	0.1	560.9	0.2
Low Intensity Urban	136.3	0.1	274.7	0.1
Barren or Sparsely Vegetated	142.1	0.1	929.2	0.3
Cropland	410.5	0.3	1,214.7	0.3
Grassland	7,488.7	5.4	45,842.7	12.6
Deciduous Forest	12,911.1	9.3	70,878.8	19.5
Evergreen Forest	122.5	0.1	3,890.8	1.1
Deciduous Woody/Herbaceous	1,682.4	1.2	6,894.7	1.9
Evergreen Woody/Herbaceous	0.0	0.0	109.4	0.0
Woody-Dominated Wetland	0.0	0.0	5.1	0.0
Herbaceous-Dominated Wetland	8.7	0.0	32.5	0.0
Open Water	17.6	0.0	937.4	0.3
2005 Subtotal	23,066.1	16.6	131,570.8	36.2
Land use (1993)				
Urban Impervious	1.6	0.0	1.6	0.0
Urban Vegetated	17.3	0.0	17.3	0.0
Barren or Sparsely Vegetated	0.0	0.0	25.1	0.0
Row and Close Grown Crops	248.0	0.2	907.8	0.2
Cool Season Grassland	40,006.2	28.8	81,519.3	22.4
Warm Season Grassland	1,988.0	1.4	3,226.9	0.9
Glade Complex	2,208.2	1.6	3,426.9	0.9
Eastern Redcedar and Redcedar - Deciduous Forest and Woodland	5,970.9	4.3	7,012.3	1.9
Deciduous Woodland	1,903.9	1.4	3,614.4	1.0
Deciduous Forest	56,261.7	40.6	119,010.4	32.7
Shortleaf Pine - Oak Forest and Woodland	7,023.0	5.1	13,455.8	3.7
Shortleaf Pine Forest and Woodland	0.9	0.0	128.1	0.0
Open Water	2.0	0.0	28.9	0.0
1993 Subtotal	115,631.5	83.4	232,374.8	63.8
Total	138,697.7	100.0	363,945.6	100.0

Table B.3. Land Use for North Fork and Spring Creek Reference Streams and Gage

	North Fork River at Reference Stream		Spring Creek at Reference Stream		North Fork River at USGS Gage 07057500	
Land use (2005)	**Area (Acres)**	**Percent (%)**	**Area (Acres)**	**Percent (%)**	**Area (Acres)**	**Percent (%)**
Impervious	91.0	0.1	304.2	0.4	1,306.1	0.4
High Intensity Urban	0.0	0.0	0.0	0.0	11.1	0.0
Low Intensity Urban	79.0	0.1	180.4	0.2	635.2	0.2
Barren or Sparsely Vegetated	182.8	0.2	169.5	0.2	1,228.1	0.3
Cropland	93.4	0.1	235.7	0.3	1,089.3	0.3
Grassland	9,988.2	12.9	17,869.2	21.3	85,051.8	23.6
Deciduous Forest	12,268.2	15.9	41,033.4	48.9	132,991.2	37.0
Evergreen Forest	199.9	0.3	4,951.8	5.9	9,764.9	2.7
Deciduous Woody/Herbaceous	1,720.7	2.2	2,268.0	2.7	11,028.8	3.1
Evergreen Woody/Herbaceous	0.0	0.0	0.0	0.0	22.9	0.0
Woody-Dominated Wetland	0.0	0.0	15.8	0.0	42.0	0.0
Herbaceous-Dominated Wetland	7.1	0.0	19.1	0.0	174.6	0.0
Open Water	48.9	0.1	198.2	0.2	1,060.8	0.3
2005 Subtotal	24,679.2	32.0	67,245.3	80.2	244,406.8	67.9
Land use (1993)	**Area (Acres)**	**Percent (%)**	**Area (Acres)**	**Percent (%)**	**Area (Acres)**	**Percent (%)**
Barren or Sparsely Vegetated	36.3	0.0	0.0	0.0	39.1	0.0
Row and Close Grown Crops	179.0	0.2	36.0	0.0	241.7	0.1
Cool Season Grassland	23,559.8	30.5	3,210.5	3.8	37,954.8	10.5
Warm Season Grassland	396.8	0.5	31.6	0.0	627.4	0.2
Glade Complex	653.0	0.8	112.1	0.1	958.5	0.3
Eastern Redcedar and Redcedar - Deciduous Forest and Woodland	0.0	0.0	52.9	0.1	206.4	0.1
Deciduous Woodland	743.2	1.0	219.9	0.3	1,395.1	0.4
Deciduous Forest	20,744.8	26.9	9,517.2	11.3	56,353.1	15.7
Shortleaf Pine - Oak Forest and Woodland	5,918.1	7.7	3,363.7	4.0	17,020.3	4.7
Shortleaf Pine Forest and Woodland	163.5	0.2	58.0	0.1	392.7	0.1
Open Water	73.2	0.1	45.8	0.1	197.5	0.1
1993 Subtotal	52,467.6	68.0	16,647.8	19.8	115,386.7	32.1
Total	77,146.8	100	83,893.1	100.0	359,793.5	100

Soil Type

Table B.4 through Table B.6 report hydrologic soil groups of the reference streams and the downstream gage watersheds. As indicated in the tables, all of these watersheds are dominated by the hydrologic groups B and C with Bull Creek watershed having more soil group

D than the others. These hydrologic soil distributions of the reference stream watersheds were similar to that of the Wilson Creek and Jordan Creek watersheds.

Table B.4. Soil Types for Bull Creek Reference Stream and Gage (NRCS, 2009)

Hydro Group	**Bull Creek Gage Near Walnut Shade**	**Bull Creek at Reference Stream**
A	4.1%	0.0%
B	38.6%	45.8%
C	36.7%	46.4%
C/D	0	0.0%
D	20.6%	7.8%
(blank)	0.0%	0.0%
Total	100.0%	100.0%

Table B.5. Soil Types for Bryant Creek Reference Stream and Gage (NRCS, 2009)

Hydro Group	**Bryant Creek Gage Near Tecumseh**	**Bryant Creek at Reference Stream**
A	3.5%	3.3%
B	28.4%	30.8%
C	63.0%	62.8%
C/D	0.0%	0.0%
D	5.0%	3.1%
(blank)	0.2%	0.0%
Total	100.0%	100.0%

Table B.6. Soil Types for North Fork and Spring Creek Reference Streams and Gage (NRCS, 2009)

Hydro Group	**North Fork Gage at Tecumseh**	**North Fork at Reference Stream**	**Spring Creek at Reference Site**
A	2.4%	2.9%	2.0%
B	35.0%	22.1%	45.7%
C	59.6%	64.2%	52.1%
C/D	0.0%	0.0%	0.0%
D	2.8%	10.7%	0.1%
(blank)	0.1%	0.0%	0.0%
Total	100.0%	100.0%	100.0%

Reference Stream Flows

The watershed-size normalized data for the individual reference stream gages in the ecological drainage unit (EDU) were calculated and compared to the synthetic flow record (flow averages of the three reference stream gages). The result of this analysis is shown in Figure B.2. The statistics reported in Table B.7 demonstrates the synthetic flow record can confidently be used as a surrogate for the analyses. The reported Nash-Sutcliffe and Coefficient of Determination values indicate that all of the reference streams are well represented by the synthetic flow record, in particular at higher flows. At lower flows Bryant and North Fork match the synthetic flow record well, while Bull Creek has lower flows than the other streams.

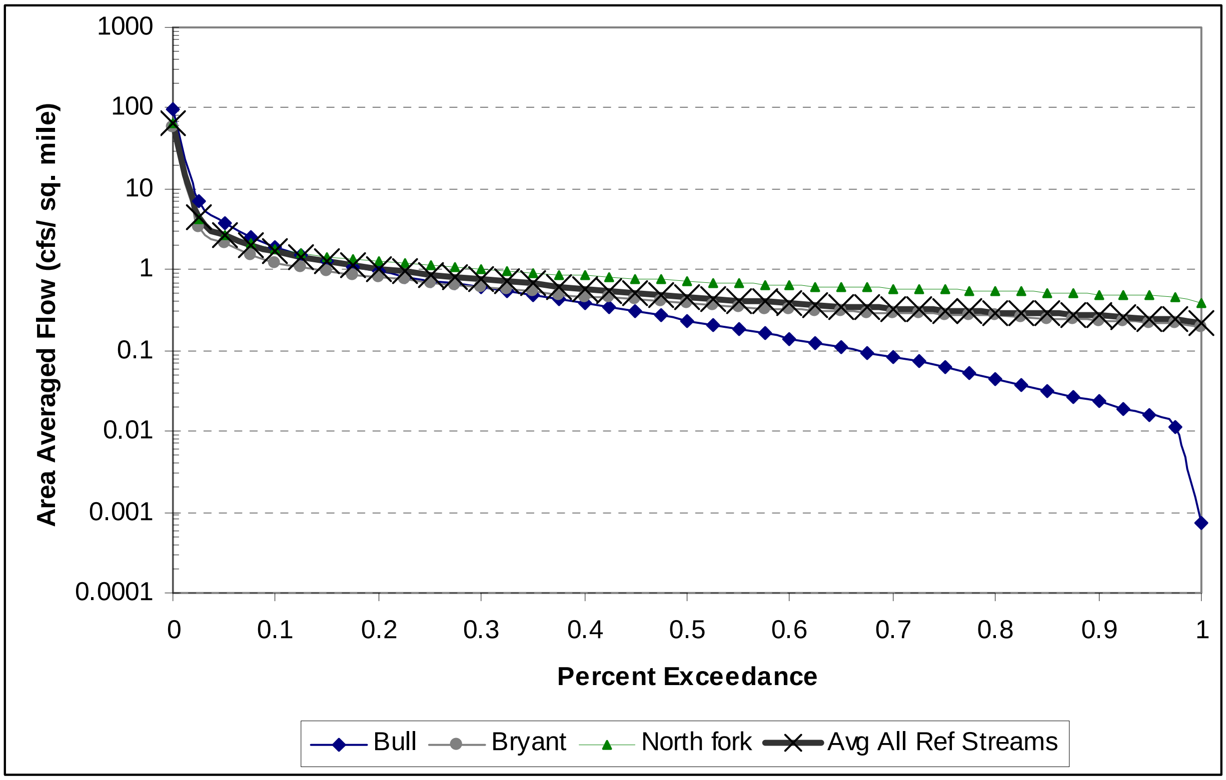

Figure B.2. FDCs for individual reference streams and average of all reference streams

Table B.7. Nash-Sutcliffe and Coefficient of Determination Statistics for each individual gage and the average of all gages

Reference Stream Gage Name	Gage Number	Area (mi^2)	Nash-Sutcliffe	Coefficient of Determination
Bull Creek near Walnut Shade	07053810	191	0.75	0.84
Bryant Creek near Tecumseh	07058000	570	0.68	0.85
North Fork near Tecumseh	07057500	561	0.71	0.81

Appendix C - Approach to Calculating Wilson Creek Flow Duration Curve and the TMDL

This appendix provides a detailed description of how Wilson Creek flows were analyzed and used to develop the Total Maximum Daily Load (TMDL). It includes the stream gage used for Wilson Creek, the process for developing the Flow Duration Curves (FDCs), the method used to compare Wilson Creek and the synthetic reference stream FDCs and the method for calculating the TMDL and its associated wasteload allocation (WLA) and load allocation (LA).

The Wilson Creek flow values were normalized by calculating the unit daily average flow values per square mile (cubic feet per second (cfs)/square mile). The Wilson Creek watershed has four active and one historic flow gage stations. These gages were used to develop a continuous stream flow record that overlaps with the reference stream gages. The flow data used for the TMDL is from 8/3/1999 through 2/9/2010. The use of each of the individual U.S. Geological Survey (USGS) flow gages is described as follows:

- USGS 07052000 Wilson Creek at Springfield, Missouri. This gage has data for the entire period used for TMDL development. Flows from this gage were used to estimate flows from the Jordan Creek and Wilson Creek watersheds.

- USGS 07052100 Wilson Creek near Springfield, Missouri. This gage has data for the entire period used for TMDL development. Because this gage includes segments that are classified as a losing stream, it was not used to represent storm water runoff.

- USGS 07052120 South Creek near Springfield, Missouri. This gage has data for the entire period used for TMDL development. Flows from this gage were used to estimate flows from South Creek watershed, a portion of the Wilson Creek watershed above the Springfield wastewater treatment plant (WWTP).

- USGS 07052160 Wilson Creek near Battlefield, Missouri. This gage has flows from 1999 through 2004. It was not used to estimate flows in Wilson Creek below the Springfield WWTP for this period because this gage includes stream segments that are classified as a losing stream.

- USGS 07052152 Wilson Creek near Brookline, Missouri. This gage has flow from 2001 through 2010. It was not used to estimate flow in Wilson Creek below the Springfield WWTP because this gage includes stream segments that are classified as a losing stream.

The stream gages that reflect the impact of losing stream reaches were carefully evaluated and ultimately not used to assess stream flows and storm water runoff in Wilson Creek watershed. The gages located at the lower end of the watershed recorded less flow per square mile than those at the upper portions of the watershed. One consequence of this is that the peak flows at the downstream gages are significantly reduced because the lower Wilson Creek segments are the losing reaches. Therefore, the Wilson Creek gage at Springfield was used to estimate runoff from the Wilson Creek watershed. This gage reflects runoff from the watershed, but it minimizes the impact of losing stream reaches.

Using the gages as described above, the Wilson Creek flow record was converted into a FDC by sorting and ranking the data. It was then compared to the synthetic reference stream FDC to calculate percent reduction in high flows or increases in low flows for the entire watershed. The flow regime was divided into five categories (high [0% - 10%], moist [10% - 40%], mid range [40% - 60%], dry [60%-90%] and low flow [90% - 100%]). Median values of the Wilson Creek FDC and synthetic reference stream FDC were compared to estimate percent reductions required for each flow category. This process was completed for Jordan Creek, Wilson Creek above the WWTP and Wilson Creek below the WWTP at the confluence with the James River. Numeric targets were provided for high flows. Low flows will be assumed to meet TMDL requirements due to greater infiltration of high flows. Thus, if high flow targets are met, low flow targets are assumed to be met.

The synthetic FDC was used to develop the TMDL, WLA and LA for Jordan and Wilson Creeks. The synthetic FDC represents the target flow and was used to calculate the TMDL, WLA and LA as follows:

- The Jordan Creek TMDL and municipal separate storm sewer system (MS4) WLA are the same since the entire Jordan Creek watershed is within the Greene County MS4. The TMDL/ MS4 WLA were calculated by multiplying the Jordan Creek watershed area (13.5 square miles) with the flow per area synthetic reference stream FDC. Figure 19 shows the resulting TMDL/WLA derived for Jordan Creek.

- The Wilson Creek TMDL was calculated by multiplying the Wilson Creek watershed area (102 square miles) with the flow per area synthetic reference stream FDC and adding 60 cfs to account for the WWTP flows. Figure 20 shows the TMDL derived for Wilson Creek.

- The Wilson Creek MS4 WLA was calculated by multiplying the MS4 area (43.7 square miles) of Wilson Creek with the flow per area synthetic reference stream FDC. The MS4 area was defined by U.S. Census urban area boundary (Census, 2009). Table 19 and Figure 20 report the WLA for Wilson Creek derived using this method.

- The non MS4 WLA for the Wilson Creek watershed was calculated by multiplying the land use type “high intensity urban” (0.17 square miles) by the flow per area synthetic reference stream FDC to get the Wilson Creek non MS4 storm water WLA and adding 60 cfs to include the Springfield WWTP flows. The other WLA area is defined as the non MS4 WLA within the Wilson Creek watershed. Figure 17 shows the WLA for non MS4 sources derived using this method.

- The LA area (58.2 square miles) of Wilson Creek watershed was calculated by multiplying the remaining area (i.e. the watershed area minus the MS4 area and all “high intensity urban” land use areas) by the flow per area synthetic reference stream FDC. Figure 18 shows the LA derived using this method.

This approach provides target flows for the watershed, MS4 areas, other regulated storm water sources and non regulated diffuse runoff sources. By comparing the target flows with the measured flows in Wilson Creek, estimates of overall flow reductions can be made; however, flow reductions for specific land uses cannot be calculated. Therefore, the method described in Appendix D was used to estimate changes in peak flows and baseflow required to achieve the TMDL by land use types.

Appendix D - Approach to Calculating Percent Flow Change by Land use

To facilitate the implementation and allocation of assimilative capacity between MS4s WLA, non MS4 (other) WLA sources and LA EPA allows using land use analysis. This appendix provides a method to estimate the reductions needed for the WLA and LA components of the TMDL. The method is based on the assumption that more developed areas, with greater impervious area, generate greater flows during precipitation events and lower baseflow during dry periods than less developed areas.

To develop the percent reductions for the WLA and LA for this TMDL, the watershed land use was aggregated into three functional categories:

- MS4 WLA includes all of the area within the boundary of the Springfield Urban area GIS coverage (Census, 2009). Flows from the MS4 area are included in the MS4 WLA. Non MS4 (other) WLA consists of regulated storm water from high intensity urban areas. This land use type was assumed to consist of areas likely to require a storm water permit. Flows from these land uses are also included in the WLA for this TMDL.

- Unregulated storm water includes runoff from agricultural areas. Flows from these land areas are included in the LA for this TMDL.

- Natural areas are land uses which are assumed to maintain their natural hydrology and thus do not contribute to deviations in stream flow, such as storm water peaks or reduced baseflow. These land uses are assumed to be hydrologically unchanged and do not require a change in flow and thus are not included in this analysis.

Table D.1 reports the land use characteristics used to estimate flow reductions for the WLA and LA areas.

Table D.1. Land Use Types and Assigned Classifications

Land Use	Description of Impervious Cover	Percent Imperviousness	Classification	Rv
Impervious	None provided	100	WLA/ LA	0.95
High Intensity Urban	80% - 100%	45	WLA	0.455
Low Intensity Urban	30% – 80%	30	WLA/ LA	0.32
Cropland	minimal impervious cover	2	WLA/ LA	0.068
Grassland	minimal impervious cover	2	WLA/ LA	0.068

Rv is Storm Runoff Coefficient (Schueler, 1987).

The overall percent changes to flow will be distributed to the MS4 WLA, other non MS4 WLA and LA using the land use types in the watershed. The focus of this approach is to provide an estimate of percent reductions needed from the MS4 WLA, other non MS4 WLA sources and LA. Since changes in hydrology are related to anthropogenic changes to the land use, a simple method of assessing changes to hydrology is used. To allocate flows to the MS4 WLA, other non MS4 WLA sources and LA, each land use is assigned a runoff coefficient using the following equation (Schueler, 1987):

$$R_v = 0.05+0.9(I_a)$$

Where; I_a = fraction of land area that is impervious

Percent imperviousness for each land use was estimated from literature values (USGS, 2006). However, the values were lowered because impervious areas were mapped as a separate land use category. The land use type "impervious" was assumed to be 100 percent impervious as the name implies. Because impervious area was mapped as a separate land use the literature values for percent impervious for the other land uses were lowered to account for the explicit measurement of impervious areas. For example, the literature values for percent impervious for high and low density urban land uses includes the presence of roads, parking lots and other impervious areas. Since some of these land surfaces would have been captured in the "impervious" land use category, the literature values for percent impervious were lowered. Table D.1 shows the land use types, their associated runoff coefficients and classification of the loadings. The MS4 area is separated from other WLA sources so its hydrologic changes can be quantified.

This approach provides a simple method of assessing how each land use type influences excess storm water runoff. It directly provides a method of estimating runoff changes based on percent impervious. The method assumes that land uses such as forest and wetland are not contributing to the impairment. Thus, they are excluded from the analysis.

The WLA and LA are estimated by weighting the runoff coefficient based on land area designated as a source of regulated and unregulated storm water runoff. Table D.2 and Table D.3 summarize the results of these calculations. Weighted Rv values are calculated for MS4 WLA, WLA and LA land use areas. Weighted Rv values are calculated by:

$$WeightedRv = \frac{\Sigma(Rv \times Area)}{\Sigma Area}$$

Weighted Rv are lumped runoff coefficients for the entire area (e.g., MS4 WLA, WLA and LA areas). The MS4 WLA, WLA and LA influence on excess runoff is calculated by:

$$PercentRunoff = \frac{(WeightedRv \times Area)}{\Sigma(WeightedRv \times Area)}$$

Table D.2. Weighted Runoff Coefficients by Land Use

Land Use	Area (acres)	Classification	Rv	Rv x Area	Weighted Rv
MS4 Area					
Impervious	8187.8	WLA	0.95	7778.4	0.48
High Intensity Urban	831.3	WLA	0.455	378.2	
Low Intenstiy Urban	12422.6	WLA	0.32	3975.2	
Cropland	131.9	WLA	0.068	9.0	
Grassland	4417.5	WLA	0.068	300.4	
Other WLA	107.9	WLA	0.455	49.1	0.46
LA					
Impervious	1751.5	LA	0.95	1663.9	0.13
High Intensity Urban	0.0	LA	0.455	0.0	
Low Intensity Urban	1686.5	LA	0.32	539.7	
Cropland	2076.1	LA	0.068	141.2	
Grassland	24987.6	LA	0.068	1699.6	

Table D.3. Weighted Runoff Coefficients and Excess Runoff Attributed to Each Land Use Category

Category	Weighted Rv	Developed Area (acres)	Percent of Excess Runoff Attributed to Each Category	Developed Area of Watershed
MS4 WLA	0.48	25991.0	75.3	45.9
Other WLA	0.46	107.9	0.3	0.19
LA	0.13	30501.7	24.5	53.9

This analysis may be interpreted to indicate that the MS4 area contributes 75.3 percent, other urbanized areas contribute 0.3 percent and nonpoint sources contribute 24.5 percent of the excess runoff flow or diminished baseflow. These areas comprise 45.9 percent, 0.19 percent and 53.9 percent of the developed land area in the watershed. The remaining land in the watershed consists of land uses that are assumed to be hydrologically unchanged, such as, forested and wetland areas. Therefore, it is clear that the land areas covered by the WLA contribute greater flow on a per area basis than the area covered by the LA. This is not surprising since the WLA area is much more urbanized than the LA area.

To calculate the portion of the excess flow attributable to each TMDL component (MS4 WLA, WLA and LA) the "percent excess runoff attributed to each category" value was multiplied by the difference between Wilson Creek FDC and the synthetic reference stream FDC. This calculation divides the excess flow between the MS4 WLA, WLA and LA. This step assumes that the excess flow (Wilson FDC – synthetic FDC) can be disaggregated based on the percent runoff values calculated.

Percent reductions by MS4 WLA, WLA and LA were calculated using the following process. The excess flow attributable to the MS4 WLA, WLA or LA was divided by the total flow of Wilson Creek to calculate the percent of the total flow attributable to the MS4 WLA, WLA or LA. This is the "extra" flow provided by the developed areas that must be reduced to meet the synthetic reference stream FDC. To get a percent reduction by each land use category (e.g. MS4 WLA, WLA or LA) the unit "extra" flow of each category was divided by the sum of the unit synthetic flow from the reference streams and the unit extra flow of each category. The result is the percent reduction needed.

The watershed estimates of storm water reductions or baseflow increases for the 5 percent, 10 percent, 30 percent, 50 percent, 70 percent, 90 percent and 95 percent flow exceedance values are found in Table D.4. The percent reductions provided are for the developed land use area included in the MS4 WLA, other sources WLA and LA. Specific controls for storm water discharge required for individual parcels and national pollutant discharge elimination system (NPDES) permits is site specific and highly dependent on site design features. Implicit in this analysis is that regulated and non regulated storm water runoff should mimic predevelopment flow rates in order to meet the storm water TMDL FDC and provide treatment to improve the water quality of the storm water runoff. It is assumed that the mitigation of high flows via infiltration and detention will result in increases in baseflow sufficient to meet the TMDL targets during mid range, dry conditions and low flow periods.

Table D.4. Estimates of TMDL Reduction Goals Derived from Weighted Land Use Runoff Coefficients

Percent Flow Exceedance	**5**	**10**	**30**	**50**	**70**	**90**	**95**
Reference Site Flow (cfs)	349.8	240.9	141.8	109.8	94.4	87.8	85.8
Wilson Creek Flow (cfs)	484.9	255.2	128.9	96.2	82.4	71.5	68.6
Difference in Flow (cfs)	135.1	14.3	-12.9	-13.6	-12.0	-16.3	-17.2
Percent increase / decrease in Flows	-28	-6	10	14	15	23	25
Portion Attributable to MS4 WLA, 75% (cfs)	101.6	10.8	-9.7	-10.3	-9.0	-12.3	-12.9
Portion Attributable to Other WLA Sources, 0.3% (cfs)	0.40	0.04	-0.04	-0.04	-0.04	-0.05	-0.05
Portion Attributable to LA, 24.5% (cfs)	33.03	3.50	-3.15	-3.34	-2.93	-4.00	-4.21
MS4 WLA % Reduction	40	9	An increase in moderate to low flows will occur if high flow targets are met.				
Other WLA % Reduction	41	10					
LA % Reduction	14	2					

Appendix E - Supplemental Implementation Plan

States are not required under Section 303(d) of the CWA to develop TMDL implementation plans and EPA does not approve or disapprove them. However, MDNR included an implementation plan in this TMDL to provide information regarding how point and nonpoint sources can or should be controlled to ensure implementation efforts achieve the loading reductions identified in this TMDL. EPA recognizes that technical guidance and support are critical to determining the feasibility of and achieving the goals outlined in this TMDL. Therefore, this informational plan is included to be used by local professionals, watershed managers and citizens for decision-making support and planning purposes. It should not be considered to be a part of the established Wilson and Jordan Creeks TMDL document.

The approach of using runoff as a surrogate to develop the Wilson Creek TMDL is based on the work by the CWP (2003), the Water Environment Research Federation (WERF) (Pomeroy, et al., 2008). The former study related biologic integrity scores to urbanization using percent imperviousness for estimating cumulative effect of urbanization. The latter study investigated the relationship between urbanization and biologic integrity and indicated that impervious area played an important role in the degradation of urban streams. Both studies suggest that to improve the biological condition and water quality of an urban stream, impervious surface and runoff velocities need to be reduced and the restoration of habitat, substrate and channel features may be needed to maintain water quality criteria.

The city of Springfield, Missouri, has a comprehensive storm water management manual and design guidance that outlines appropriate steps required to mitigate peak flow discharge volume and meet the goals of this TMDL. The storm water design guidance / manual includes discussion of storm water design related to water quality and encourages post development peak flows to match predevelopment flows. In addition, the city has a Capital Improvement plan that focuses on improving the water quality and habitat of the urban streams within its boundaries.

Because “Brewery Spring” has a potential of affecting the quality of surface water and groundwater in the study area, Missouri Department of Natural Resources’ (MDNR’s) Division of Geology and Land Survey may undertake the task of locating the recharge area of the spring and identify possible sources of the contamination. Because the timeline for such a study is uncertain, immediate steps to mitigate pollution at the spring may be an option to improve water quality in Jordan Creek should all parties agree the data require it. In addition, EPA intends to perform the second phase of a Brownfield Targeted Assessment on the Union Pacific property on behalf of the city of Springfield. This assessment is being conducted in preparation for the potential acquisition of the property for Jordan Valley Park and could answer the question of whether the property itself is a source. Given the volume of water discharging from the spring, it is unlikely the majority of the water originates on the Union Pacific property. The results of the targeted assessment will give the city of Springfield reassurance in regard to the condition of the site and whether known responsible parties still exist that could assist with remediation of the property.

Reducing and eliminating the organic compounds and offensive odor being discharged from Brewery Spring will aid in the restoration of beneficial uses of Jordan Creek which, in turn, should improve the beneficial uses of Wilson Creek further downstream.

Implementation Plans:

Storm water runoff was selected as a surrogate for pollutants causing these water bodies to be impaired. Accordingly, the WLA, which apply to regulated storm water discharges (Section 7.1), will be implemented primarily through MS4 permits. Jordan Creek originates in Springfield and is part of the headwaters of Wilson Creek. As it lies totally within the limits of the city of Springfield, it is covered by the city's MS4 permit. The city's MS4 permit also covers that portion of Wilson Creek which flows within the city of Springfield MS4 coverage area. After Wilson Creek leaves the city limits, it comes under the jurisdiction of Greene County, the city of Battlefield and then Christian County, each of which has its own MS4 permit.

The LA (Section 7.2) portion of the TMDL addresses runoff reductions related to nonpoint sources and unregulated storm water runoff. These reductions will be implemented through watershed groups and individual citizens in the Springfield, Green County, Battlefield and Christian County area using voluntary, non-regulated activities such as best management practices (BMPs).

Springfield's MS4:

The Phase I MS4 permit for the city of Springfield was first issued in 2002 under the state and federal NPDES storm water management program. The city became regulated as a Phase I based on their population exceeding 100,000 in the 1990 census. Their MS4 permit requires them to implement a fairly rigorous Storm Water Management Program plan (SWMP). Through their SWMP, the city is required to characterize storm water runoff quality through system-wide outfall mapping and monitoring for urban pollutants. They must also eliminate existing illicit discharges and regulate industrial runoff. In addition, the city must regulate land disturbance and post-construction runoff quality through local ordinance, inspection and enforcement. The city must also implement a municipal storm water quality program and, where applicable, obtain industrial storm water permits for municipal operations, obtain no-exposure certifications or otherwise include the municipal operation in their MS4 storm water quality program. The MS4 permit requires adequate public involvement, accountability and annual reporting to MDNR. For details on what the city is doing under the SWMP plan, visit their web site at: http://www.springfieldmo.gov/egov/publicworks/storm_water/permit.html.

The Jordan Creek Feasibility Study:

The United States Army Corp of Engineers (USACE) began the Jordan Creek Feasibility Study in 2004 to identify cost-effective alternatives to mitigate long-standing flooding concerns and advance environmental restoration along Jordan Creek. The city assisted the USACE through a 50/50 cost share agreement with local matching funds and in-kind tasks. The cost of the study was $3 million. Currently, a Review Plan was approved by Southwestern Division of the USACE on April 27, 2010. The Review Plan presents the process for agency technical review and independent external peer review for the study. These review processes are essential to improving the quality of the plan.

Other MS4s in Wilson Creek Watershed:

Other municipalities in the Wilson Creek watershed are implementing storm water management programs under Phase II storm water regulations. Christian County, Greene County, Battlefield and Nixa are subject to regulations based on their 10,000+ populations or their locations within the defined U.S. Census Bureau's urbanized area (see the following link for more information: http://www.epa.gov/npdes/pubs/ua_mo_springfield.pdf). Through their MS4 SWMPs, these communities are implementing the six minimum requirements outlined in regulation as follows:

1) Public Education and Outreach,
2) Public Involvement and Participation,
3) Illicit Discharge Detection and Elimination,
4) Construction Site Runoff Control,
5) Post-Construction Runoff Control, and
6) Pollution Prevention and General Housekeeping for Municipal Operations.

Like the city of Springfield, these Phase II MS4 communities must demonstrate accountability and submit annual reports to MDNR. Because Wilson Creek is a tributary to the James River; Christian County, Greene County, Battlefield, Republic, Springfield, Nixa and Ozark are all currently participating in a cooperative effort to monitor water quality as part of the James River TMDL implementation requirements. The city of Republic is participating voluntarily, but will become subject to MS4 regulations following publication of the 2010 census, based on a population greater than 10,000. The city of Republic (estimated population of 13,715 in 2008) lies within the Wilson Creek watershed.

Watershed Groups and BMPs:

The city of Springfield has two very active and successful watershed groups that work in close cooperation with each other. For years, these groups have been educating the Springfield area public about water quality, touting many actions and practices that individuals and organizations can take to protect and improve water quality in the local streams and rivers. Most of Springfield and the Greene, Christian and Stone counties are part of the James River watershed, which drains into Table Rock Lake, a very popular recreational attraction that was once exceptionally clear. Implementation of the James River TMDL through watershed groups and BMPs is having a positive impact on water quality in the lake.

The Watershed Committee of the Ozarks (WCO):

The WCO web page carries this banner: "Preserving and improving Springfield and Greene County water supplies since 1984." The express purpose of this watershed organization is to protect the city of Springfield's drinking water sources. This is a very important goal since ground water in the area is quite susceptible to contamination due to the local karst topography containing an abundance of losing streams, sinkholes and springs. This group takes public education very seriously and to that end is building the Watershed Center at Valley Water Mill. This is a state-of-the-art learning center with demonstrations of proper care of our water resources built in to the site. It will have conference rooms, outdoor classrooms and training space for septic and wastewater issues. The site has a lake, a stream, a spring, sinkholes and wetlands to showcase and demonstrate sustainable practices for maintaining good water quality.

The James River Basin Partnership:

On the James River Basin Partnership web page, the banner reads: "Our vision is clean water for you, your children and your grandchildren. Our mission is working to protect and improve the water quality in our springs, streams, rivers and lakes." This group conducts and promotes many activities and projects to enhance water quality in the James River watershed including:

- Organizing an annual James River clean-up, the River Rescue,
- Promoting rain barrels,
- Building/installing rain gardens,
- Pumping septic tanks,
- Creating and distributing all sorts of educational materials,
- Sponsoring water festivals, and
- Testing yard soil to help people apply fertilizer properly.

The Upper White River Basin Foundation:

Though not based in Springfield, the Upper White River Basin Foundation is another group that could help restore Wilson Creek. It was organized in 2001 and has 501(3)(C) not-for-profit status. From its web page[20], the Foundation describes itself as: "A consortium of business and environmental interests working together to clean up the Upper White River Basin in northwest Arkansas and Southwest Missouri. The group acts as an advocate for the water in the watershed, a catalyst for public policy change and an educator of community leaders." The focus of the Foundation is on the four major impoundments on the upper White River: Beaver Lake, Table Rock Lake, Lake Taneycomo, Bull Shoals Lake and the rivers and streams which drain into these impoundments. The Foundation works with federal, state and local governmental agencies and interested citizen groups as an advocate for clean water projects, as a catalyst to create and implement projects to improve water quality and as a community educator on the causes and impact of reduced water quality. It is currently conducting a water quality study on 16 sites throughout the focus area and producing an annual Status of the Watershed report[21].

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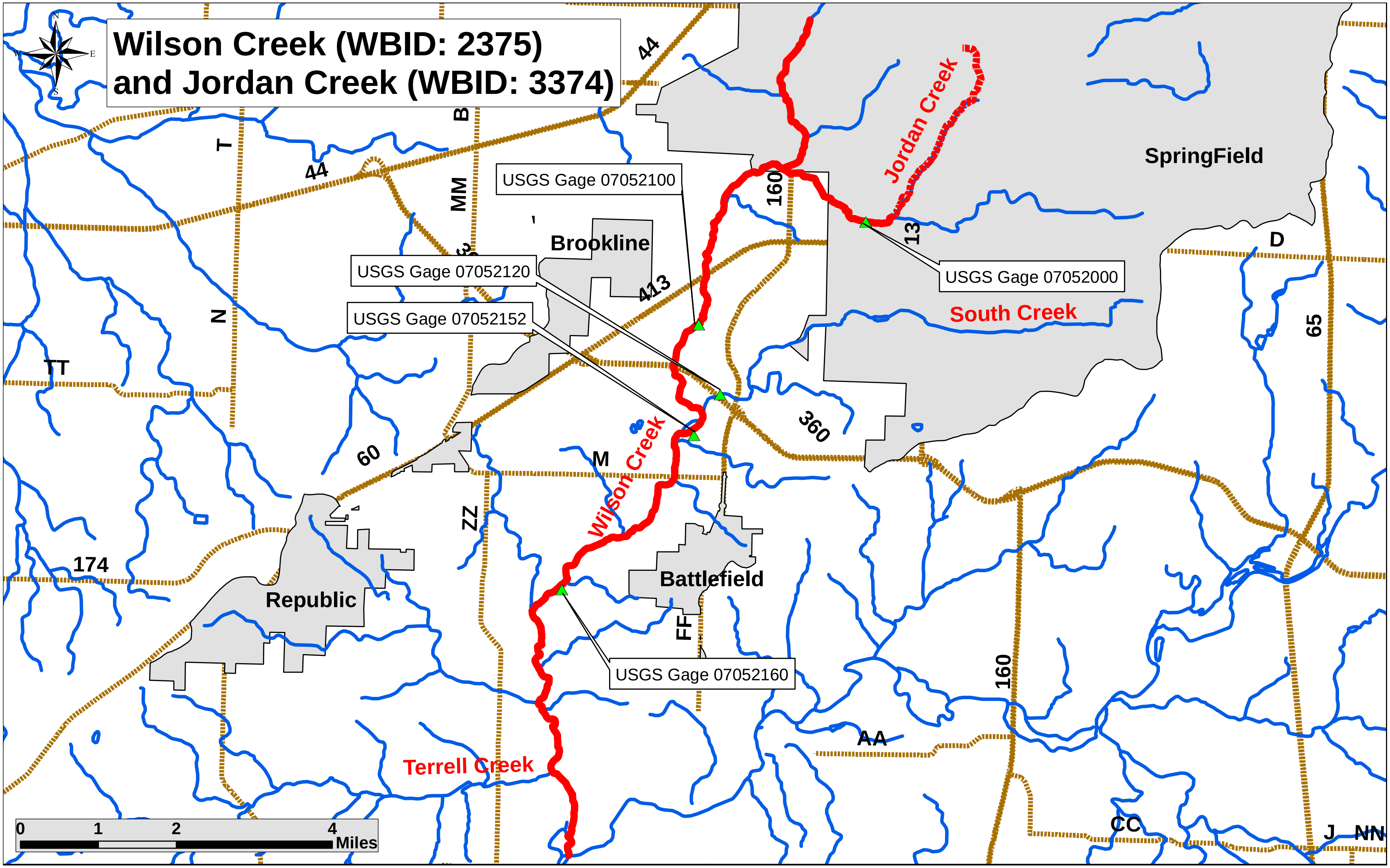
[20] http://www.envirolink.org/resource.html?itemid=200302171656340.706963&catid=5

[21] http://www.envirolink.org/external.html?www=http%3A//www.whiteriverbasin.org&itemid=200302171656340.706963

Appendix F - Location of Wilson Creek 2009 Water Quality Monitoring Stations



Appendix G – Location of Wilson Creek Historic USGS Water Quality Monitoring Stations