Missouri Department of Natural Resources
Water Protection Program

Total Maximum Daily Loads (TMDLs)

for

Mound Branch
Bates County, Missouri

Completed: March 17, 2010
Approved: May 26, 2010

Total Maximum Daily Load (TMDL)
for Mound Branch
Pollutant: Low Dissolved Oxygen

Name: Mound Branch

Location: Bates County near Butler, MO

Hydrologic Unit Code (HUC): 10290102-120005

Water Body Identification (WBID): 1300

Missouri Stream Class: C[1]

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

Use that is impaired: Protection of Warm Water Aquatic Life

Location of Impaired Segment: Mouth to Section 13, T40N, R31W

Length of Impaired Segment: 10.0 miles

Location of Impairment within Segment: From N ½ Section 5, T39N, R31W (downstream) to Center of Section 34, T40N, R31W (upstream).

Length of Impairment within Segment: 1.0 mile

Pollutant: Low Dissolved Oxygen

TMDL Priority Ranking: High

[1] Class C streams may cease to flow in dry periods but maintain permanent pools which support aquatic life. See the Missouri water quality standards at 10 Code of State Regulations (CSR) 20-7.031(1)(F). The standards can be found at the following uniform resource locator (URL): http://www.sos.mo.gov/adrules/csr/current/10csr/10c20-7.pdf

Table of Contents

Figures

Tables

1 Introduction

This Mound Branch Total Maximum Daily Load, or TMDL, is being established in accordance with Section 303(d) of the Clean Water Act. This water quality limited segment near Butler in Bates County, MO, is included on the U.S. Environmental Protection Agency, or EPA, approved Missouri 2008 303(d) List.

The purpose of a TMDL is to determine the maximum amount of a pollutant that a water body can assimilate without exceeding the water quality standards for that pollutant. Water quality standards are benchmarks used to assess the quality of rivers and lakes. The TMDL also establishes the pollutant load allocation necessary to meet the standards established for each water body based on the relationship between pollutant sources and instream water quality conditions. The TMDL consists of a wasteload allocation, a load allocation and a margin of safety. The wasteload allocation is the portion of the allowable load that is allocated to point sources. The load allocation is the portion of the total pollutant load that is allocated to nonpoint sources. The margin of safety accounts for the uncertainty associated with the model assumptions and data inadequacies.

2 Background and Water Quality Problems

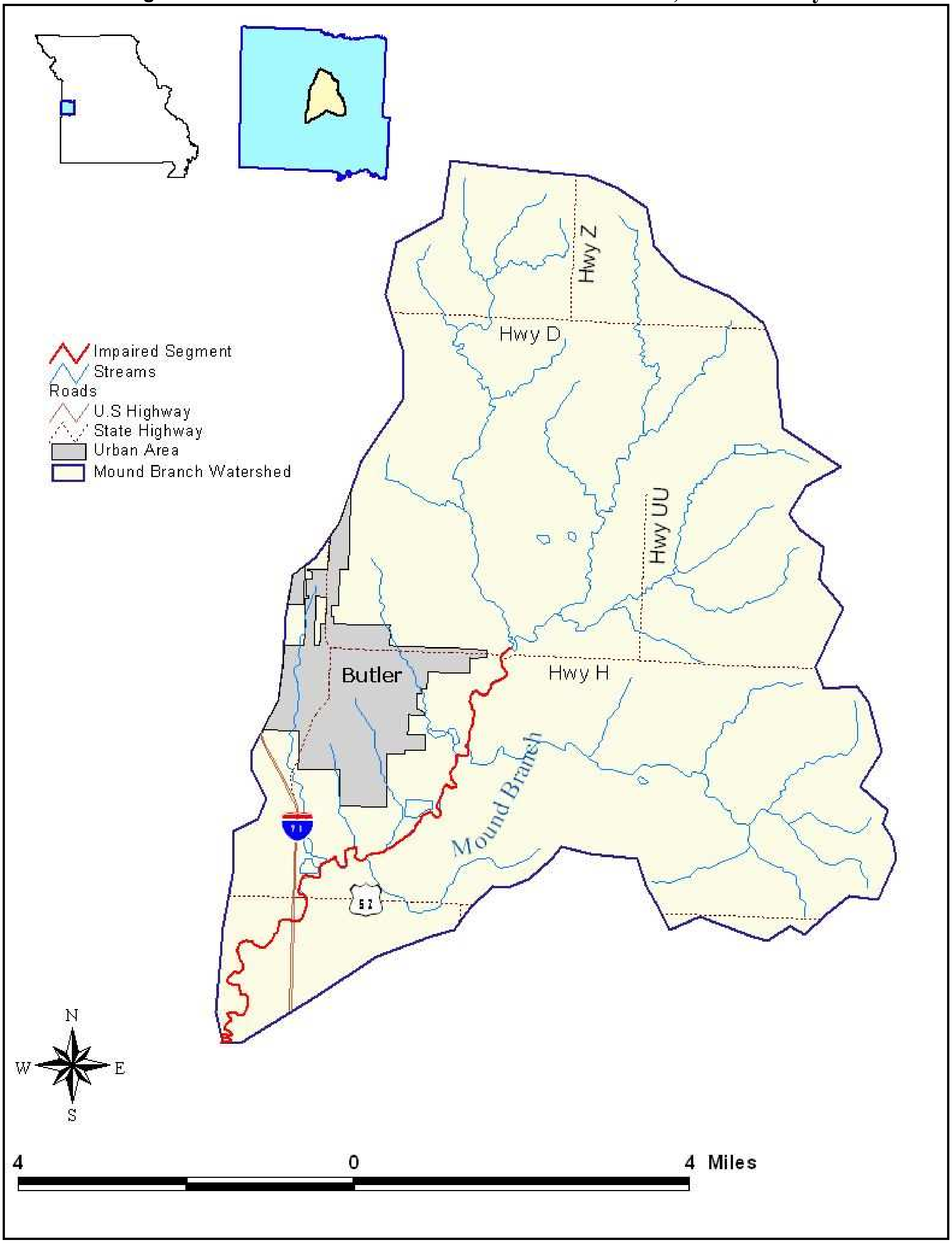
This section of the report provides background information on Mound Branch and its watershed.

2.1 The Setting

Mound Branch is a small stream that originates northeast of Butler in Bates County, MO, and flows southwest to join Miami Creek, which then flows into the Marais des Cygnes River. Mound Branch is 14.2 miles long (10 miles are classified) with a watershed of 49 square miles. The unglaciated basin is Pennsylvanian rock overlain with up to six feet of loess in the uplands. This Pennsylvanian strata of shale, coal and clay hinders the movement of water into the subsurface. Limited water movement results in very few springs; therefore, stream flow is primarily sustained by surface precipitation and runoff. Even though the average annual precipitation for Bates County is about 42 inches, baseflow of the creeks is not well sustained during dry periods.

Streams, lakes and rivers in Missouri that are called “classified” have been assigned designated beneficial uses and contain at least some water year-round. Streams and rivers can be either Class P (streams that maintain permanent flow during drought conditions), Class P1 (standing water reaches of Class P streams), or Class C (streams that may cease flow during dry periods but maintain permanent pools that support aquatic life). Unclassified streams only carry water when there is enough rainfall to cause runoff. Mound Branch is classified as a Class C stream.

Figure 1. **Location of the Mound Branch Watershed, Bates County**



Section 303(d) of the federal Clean Water Act requires that each state identify waters that are not meeting water quality standards. Mound Branch was listed in Missouri's Section 303(d) List of impaired waters for biochemical oxygen demand, which is the measure of oxygen used by microorganisms to decompose organic matter, and ammonia in 1998.

The Missouri Department of Natural Resources (the Department) changed the pollutants causing the impairment from biochemical oxygen demand (listed as BOD) to dissolved oxygen (listed as low DO) on the 2004/2006 303(d) List to provide a more understandable list to the general public. Ammonia was removed as a pollutant on that list since the data no longer indicated an impairment. Also, EPA chose to list the entire classified segment, which is 10 miles long rather than just the impairment within that segment, which is 1.0 mile. Mound Branch remains on the EPA approved 2008 303(d) List of impaired waters for low dissolved oxygen from unknown sources.

The classified segment of Mound Branch corresponds to that portion of the stream defined in Missouri's water quality standards (See Section 5 of this document for more details); the impairment within the segment corresponds to that portion of the stream determined as not meeting water quality standards.

2.2 Population

The population of the Mound Branch watershed is not directly available; however, the Census reports that the 2007 population for the city of Butler is 4,269 (Census Bureau, 2008). Additionally, the rural population of the watershed can be roughly estimated based on the proportion of the watershed that is located in Bates County. Bates County covers an area of 851 square miles and has a population of 17,034. It incorporates 11 towns (Adrian, Amoret, Amsterdam, Butler, Drexel, Foster, Hume, Merwin, Passaic, Rich Hill and Rockville) with a total urban population of 9,844. Since the rural population in Bates County is 7,190 (total county population minus urban population) and the rural area of the Mound Branch watershed is approximately 48 square miles, the rural population of the watershed is estimated to be 406 (48 square miles divided by 851 square miles multiplied by 7,190 persons).

2.3 Land Use

Historically, the Mound Branch watershed was dominated by tall grass prairies and oak and hickory forests in uplands and along stream corridors. Recent land use/land cover data for the Mound Branch watershed indicates that 55 percent of the watershed is classified as grassland (which can include pastures), 28 percent is classified as cropland, and only about 7 percent is classified as urban areas; Table 1 and Figure 2 (MoRAP, 2005).

Figure 2. Land Use/Land Cover in Mound Branch Watershed (MoRAP, 2005)

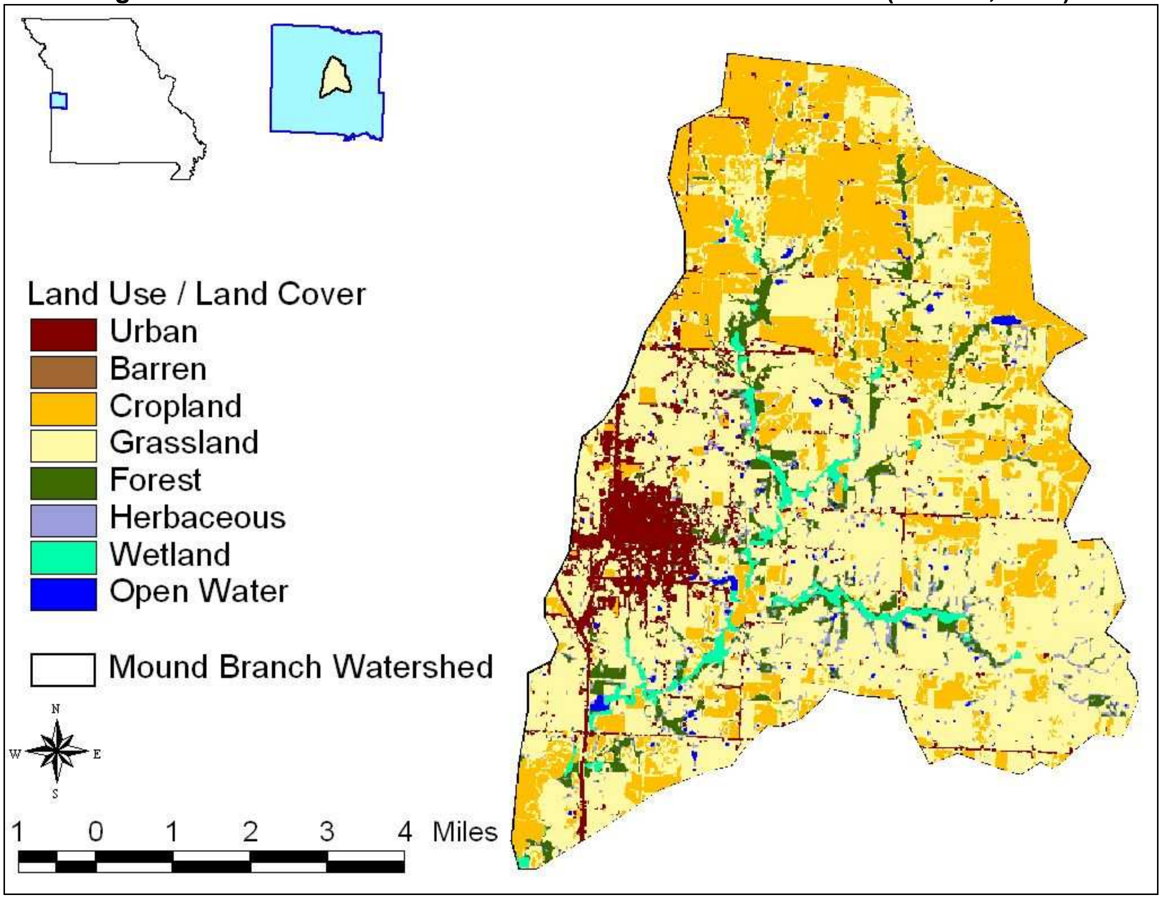


Table 1. Land Use/Land Cover in Mound Branch Watershed (MoRAP, 2005)

Land Use/Land Cover	Watershed Area		Percent
	Acres	Square Miles	
Barren	20.46	0.03	0.06
Cropland	9,024.39	14.10	27.56
Forest	1,630.22	2.55	4.98
Grassland	18,016.32	28.15	55.03
Herbaceous	810.66	1.27	2.48
Open water	267.03	0.42	0.82
Urban	2,282.74	3.57	6.97
Wetlands	687.16	1.07	2.10
Total	32,738.98	51.15	100.00

2.4 Defining the Problem

Low dissolved oxygen is a condition present in many headwater and low flowing streams in Missouri, particularly in locations where the natural reaeration capability of the stream is limited. Streams that have no flowing water at base flow conditions along with a fine sediment substrate, limited riparian cover, and morphology that lacks riffles and slopes that enhance reaeration, have a likelihood to exhibit lower dissolved oxygen concentrations during warm weather months. Many of these low dissolved oxygen streams receive no discharges of pollutants from permitted point source discharges and also exhibit no apparent impact from nonpoint source pollution. Some of these low dissolved streams are, in fact, identified as biocriteria reference streams. This means they have been identified as streams that are fully attaining the aquatic life use even though dissolved oxygen concentrations drop below Missouri's water quality criteria of an instantaneous minimum of 5.0 mg/L. The Department is actively pursuing development of dissolved oxygen criteria that recognizes the natural conditions of these water bodies and the needs of the aquatic organisms that live in these waters.

In the case of Mound Branch, a TMDL is needed because it is not meeting Missouri's dissolved oxygen criterion of 5.0 milligrams per liter, or mg/L. Low dissolved oxygen is generally a problem in streams because aquatic animals need oxygen to survive and thrive. This includes not only fish, but also all of the macroinvertebrates (e.g., insect larvae and crayfish) that make up the entire aquatic community.

Water from Mound Branch was sampled and analyzed by the Department to produce water quality data in July 1996, August 1997, August 2003, and August 2004. The dissolved oxygen results for the four Department surveys are summarized in Table 2 and indicate that a minimum of 42 percent of the dissolved oxygen samples from each survey were less than 5 mg/L. Also, an increase in stream dissolved oxygen can be noted following the city of Butler's wastewater treatment plant upgrade in 2003. All of the data from the 2003 and 2004 surveys are presented in Appendix A (A.1). Also, instream monitoring data collected by Butler's treatment plant may be found in Appendix A.3.

Table 2. Summary Dissolved Oxygen Data for Mound Branch

Survey	Number of DO Samples	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Percentage of Samples < 5 mg/L
July 1996	4	1.4	2.7	4.2	100%
August 1997	24	1.6	2.6	3.9	100%
August 2003	12	1.8	3.8	8.7	83%
August 2004	12	3.8	5.2	7.1	42%

The low dissolved oxygen problem in Mound Branch could be due to the discharge from the city of Butler's wastewater treatment plant and/or one or more of the following:

- Excessive loads of decaying matter, as measured by CBOD.

- Too much algae in the stream as a result of excessive phosphorus or nitrogen loading.
- High consumption of oxygen from decaying matter on the streambed.
- Physical factors such as naturally low flows due to a lack of ground water inputs or a lack of riffles, which help to increase dissolved oxygen through aeration.

At this time, the exact contribution of each of the above sources to the low dissolved oxygen conditions in Mound Branch has not been specifically determined.

3 Source Inventory

This section summarizes the available information on significant sources of nutrients and oxygen-consuming substances in the Mound Branch watershed. Point (or regulated) sources are presented first, followed by nonpoint (or unregulated) sources.

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. Point sources are typically those regulated through the Missouri State Operating Permit program[2]. By law, point source also includes concentrated animal feeding operations (facilities where animals are confined and fed) and storm water runoff from Municipal Separate Storm Sewer Systems. There are none of these types of permits within the Mound Branch Watershed.

The permitted facilities in the Mound Branch watershed are listed in Table 3 and are displayed in Figure 3. There is one facility with a general permit, three with storm water permits and one with a site-specific permit. 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. The general permit listed below does not discharge to the stream, but does have storm water runoff during rain events. Storm water permits are issued to activities that discharge only in response to precipitation events. In general, these permits are not considered to contribute to the impairment because low dissolved oxygen is a problem at low flow. Specifically, the Lumber and Wood Primary (MO-R22A) and Agrichemical Facilities (MO-R240) storm water permits may contribute nutrients at high flow, but these permits are not considered to contribute to the low dissolved oxygen impairment during low flow conditions.

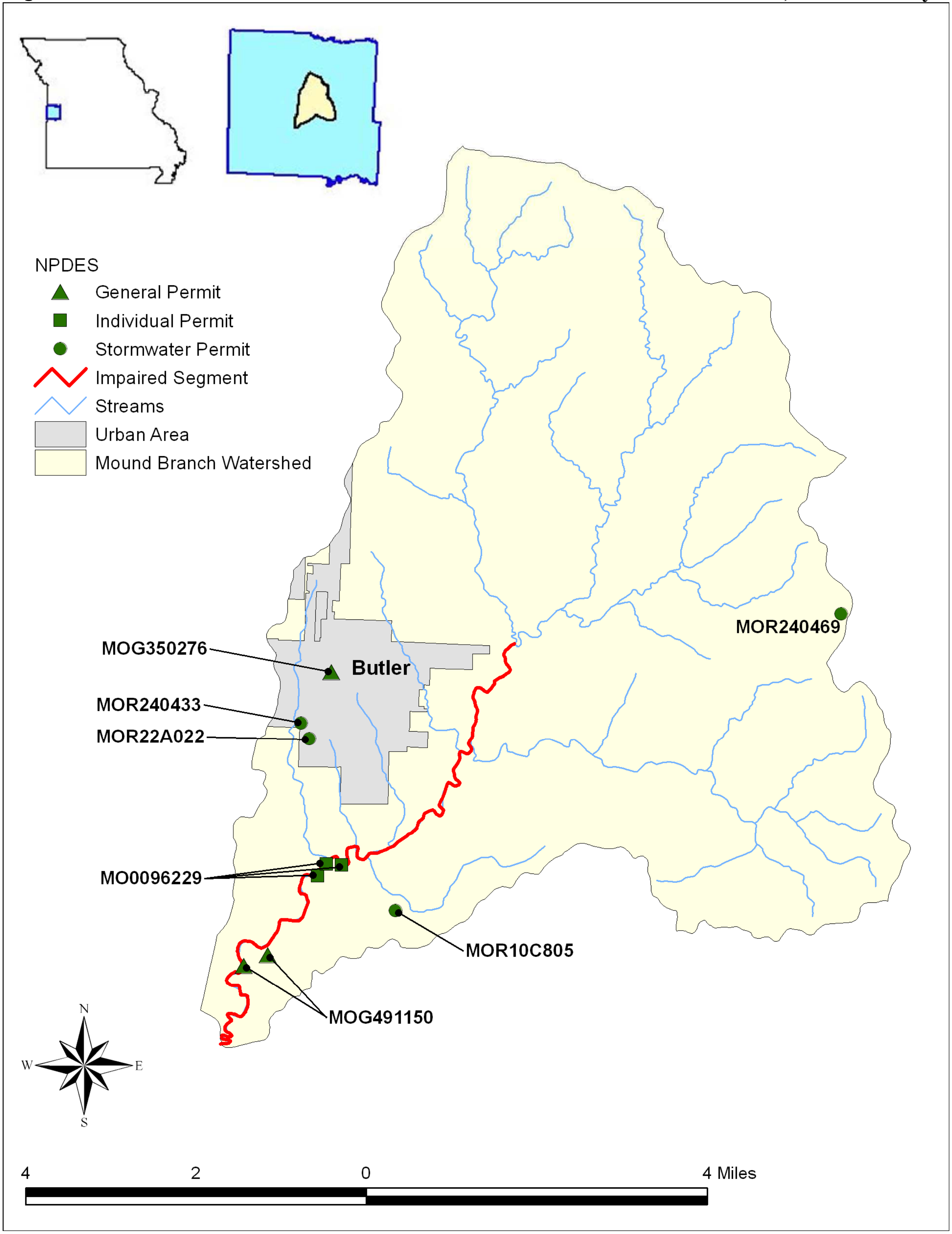
[2] The Missouri State Operating Permitting program is Missouri's program for administering the federal National Pollutant Discharge Elimination System (NPDES) program

Table 3. Permitted Facilities in the Mound Branch Watershed

Facility ID	Facility Name	Receiving Stream	Design Flow (MGD)	Permit Expiration Date
MO0096229	City of Butler Wastewater Treatment Plant	Tributary To Mound Branch	Site-Specific Permit 1.5	2009
MOG350276	MFA Oil Bulk Plant – Butler Bulk Plant	Tributary To Mound Branch	General Permit	2012
MOG491150	Hilty Quarries, Inc., Lone Oak Quarry	Tributary To (001) Mound Branch and Mound Branch (002)	General Permit	2011
MOR10C805	Hilty Quarries, Inc.	Tributary To Mound Branch	Land Disturbance	2012
MOR22A022	South Side Lumber Company	Tributary To Mound Branch	Storm Water Permit	2009
MOR240433	MFA West Central Agriservices, LLC	Tributary To Mound Branch	Storm Water Permit	2008
MOR240469	Heiman Agri Services Inc	Tributary To Mound Branch	Storm Water Permit	2008

MGD = million gallons per day

Figure 3. Location of Permitted Facilities in the Mound Branch Watershed, Bates County.



The only site-specific permit in the watershed is for the city of Butler's Wastewater Treatment Plant. It consists of two oxidation ditches, two final clarifiers and aerobic sludge digestion with the sludge being land applied. The sludge is currently land applied on three local farms with one additional farm to be added in the near future. Two of the farms at which land application occurs are within the Mound Branch watershed. One has a total land application area of 15 acres and the other has several pastures that encompass a total of 115 acres. In 2008, a total of 43 tons of sludge were land applied to these farms, which is well below the permitted limit of two tons per acre (Terry Smalley, City of Butler's treatment plant office, personal communication, March 13, 2009).

The city of Butler's Wastewater Treatment Plant underwent an upgrade that was completed in March 2003 and has a design flow of 1.5 million gallons per day, or 2.3 cubic feet per second, or cfs. Like all wastewater treatment plants in Missouri, the city of Butler facility must meet the requirements of a discharge permit issued by the Department. This permit contains discharge limits that the treatment plant must meet to be protective of instream water quality standards.

The city of Butler facility is a source of nutrients, organic material, and oxygen demanding substances to the downstream sampling locations. The fact that dissolved oxygen problems were also observed upstream of the treatment plant indicates that the organic material (and possibly nutrients) is also originating from nonpoint sources. The four other facilities in the watershed are not considered to be contributors to the low dissolved oxygen problem. They are all located upstream of the treatment plant, but have no runoff during critical low flow conditions (See Figure 3).

Another potential source of nutrients and organic material to the stream is through infiltration and inflow associated with the sanitary sewer collection system. A sanitary sewer collection system is the network of pipes and pumps that convey sewage to a wastewater treatment facility. Infiltration and inflow allow excess storm water to enter the sewage collection system, which leads to sanitary sewer overflows and wet weather treatment issues at wastewater treatment facilities. Collection systems all across the country are aging and countless communities are struggling to address the needed maintenance. Maintenance of sanitary sewer collection systems is often addressed through the wastewater treatment facility's Missouri State Operating Permit.

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

3.2 Nonpoint Sources

Nonpoint sources include all other categories not classified as point sources. Nonpoint sources potentially contributing to the low dissolved oxygen problem in the Mound Branch watershed include runoff from agricultural areas, runoff from urban areas, onsite wastewater treatment systems and various sources associated with riparian habitat conditions. Each of these is discussed further in the following sections.

3.2.1 Runoff from Agricultural Areas

Lands used for agricultural purposes can be a source of nutrients and oxygen-consuming substances. Accumulation of nitrogen and phosphorus on cropland occurs from decomposition of residual crop material, fertilization with chemical and manure fertilizers, atmospheric deposition, wildlife excreta and irrigation water. There are 9,024 cropland acres in the watershed, which account for approximately 28 percent of the watershed's area (MoRAP, 2005). An even higher proportion of the riparian corridor along Mound Branch (41 percent) is classified as cropland (MoRAP, 2005).

Countywide data from the National Agricultural Statistics Service (USDA, 2002) were combined with the size of the Mound Branch watershed to estimate there are almost 4,729 cattle in the watershed[3]. The cattle are most likely located on the approximately 18,016 acres of grassland in the watershed and runoff from these areas can be potential sources of nutrients and other oxygen consuming substances. For example, 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 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. Based on previous TMDL projects by Tetra Tech and others, the density of cattle in the Mound Branch Watershed (93 cattle per square mile) suggests they are a potentially significant source of pollutants (OEPA, 2007; Tetra Tech, 2009). The National Agricultural Statistics Service also reports there are 11,090 hogs and pigs, 1,217 sheep and lambs and 330 poultry broilers in Bates County. Data was not available to estimate the number of these animals that might be located within the Mound Branch Watershed.

A citizen watershed group in the Mound Branch watershed is the recipient of a 319 grant called the Mound Branch Watershed and Restoration Project. The 319 grant application stated that livestock production consists mainly of beef cattle and cow-calf operations; however, increasing numbers of sheep, goats and horses are recent additions to the watershed. Continuous livestock grazing operations are most prevalent with concentrations of manure occurring in heavy use areas such as shaded stream banks, winter feeding areas, and watering points. Current practices allow for livestock to roam freely and access ponds, streams, rivers and their tributaries. This practice allows a direct contribution of nutrients, pathogens, and organic matter that can impair surface water quality. Winter feeding areas generally are located close to stream banks where riparian vegetation provides shelter, thus these are a major source of concentrated animal manure that can enter surface water. Riparian areas and buffer zones tend to have concentrated and uncontrolled livestock grazing and loafing, resulting in major erosion concerns (sediment) and associated pollutants delivered to the stream network. Pastures and hayland are typically treated with commercial fertilizers applied in the spring of the year. These nutrients are subject to the intense seasonal rains of spring, like row crops, creating huge rainfall runoff events into the stream system. Between commerical and animal generated fertilizers, the nutrient input into Mound Branch from livestock and grazing operations could be sizable.

---

[3] According to the National Agricultural Statistic Service, there are approximately 81,000 head of cattle in Bates County (www.nass.usda.gov/). According to the 2005 Missouri Resource Assessment Program there are 482 square miles of grasslands in Bates County. These two values result in a cattle density of approximately 168 cattle per square mile of grasslands. This density was then multiplied by the number of square miles of grassland in the Mound Branch watershed to estimate the number of cattle in the watershed.

3.2.2 Runoff from Urban Areas

Storm water runoff from urban areas can also be a significant source of nutrients and other oxygen-consuming substances. Lawn fertilization can lead to high nutrient loads and pet wastes can contribute both nutrients and other oxygen-consuming substances. For example, phosphorus loads from residential areas can be comparable to, or higher than, loading rates from agricultural areas (Reckhow et al., 1980; Athayde et al., 1983).

Storm water runoff from impervious surfaces such as parking lots and roofs is typically warmer than runoff from grassy and woodland areas. As this runoff is delivered to adjacent streams, it can lead to higher stream temperatures that lower the dissolved oxygen saturation capacity of the stream. Excessive discharge of suspended solids from urban areas (especially construction sites) can lead to streambed siltation problems and can convey nutrients and oxygen consuming substances to nearby streams. Leaking or illicitly connected sewers can also be a significant source of pollutant loads within urban areas.

Examples of other urban nonpoint sources in Butler that have the potential to add nutrients to the stream include:

- Cattle operations within the city limits (in Dec. 2005, animals with access to the stream were observed near the Main St. bridge at site 3),
- City golf course (fertilizer runoff),
- City composting site (leachate, or rainwater that percolates through the compost)
- City/county livestock show-grounds.

Approximately seven percent of the Mound Branch watershed is classified as urban, and this area is located adjacent to the impaired segment; therefore, urban storm water runoff is considered a potentially significant contributor to the dissolved oxygen problem in Mound Branch.

3.2.3 Onsite Wastewater Treatment Systems

Onsite wastewater treatment systems (e.g., individual home 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 (surface breakouts) or hydrogeologically (inadequate soil filtration), there can be adverse effects to surface waters (Horsely and Witten, 1996). Failing septic systems are sources of nutrients that can reach nearby streams through both surface runoff and ground water flows. The exact number of onsite wastewater systems in the Mound Branch Watershed is unknown. However, as discussed in Section 2.2 of this document, the estimated rural population of the Mound Branch watershed is approximately 406 persons. Based on this population and an average density of 2.5 persons per household, there may be approximately 162 systems in the watershed. There is no available information on the percent of systems failing within the Mound Branch Watershed. The only information available is from complaints that are received by the Bates County Health Department, which has regulatory authority over onsite systems. This Department receives about 10 complaints per year for the whole county (Steve Durnell, Bates

County Public Health Department, personal communication, March 16, 2009). However, EPA reports that the statewide failure rate of onsite wastewater systems in Missouri is 30 to 50 percent (USEPA, 2002).

3.2.4 Riparian Habitat Conditions

Riparian[4] habitat conditions can also have a strong influence on instream dissolved oxygen. Wooded riparian buffers are a vital functional component of stream ecosystems and are instrumental in the detention, removal and assimilation of excess nutrients, soil and other pollutants before they reach the stream. Therefore, a stream with good riparian habitat is better able to prevent erosion and moderate the impacts of high nutrient loads than is a stream with poor habitat. Wooded riparian buffers can also provide shading that reduces stream temperatures, which can increase the dissolved oxygen saturation capacity of the stream.

On the other hand, riparian areas can be sources of natural background material that contribute to the low dissolved oxygen problem. Leaf fall from vegetation near the water's edge, aquatic plants, and drainage from organically rich areas like wetlands are all natural sources of material to the stream that consume oxygen.

As indicated in Table 4, almost 22 percent of the land in the Mound Branch mainstem riparian corridor is classified as grassland, which might include pasture areas (MoRAP, 2005). Grassland provides limited riparian habitat compared to wooded areas, very little shading, and can also be associated with livestock activity. Another 41 percent of the riparian corridor is classified as cropland, which also provides limited habitat and shading and can be associated with high nutrient loads and erosion related to runoff from agricultural areas. Therefore, a lack of good riparian habitat conditions should be considered as one possible component of water quality problems in Mound Branch.

Table 4. Land Use/Land Cover Percentages within a 30-meter Riparian Buffer of Mound Branch

Land Use/Land Cover	Mound Branch
Cropland	40.60
Forest	7.43
Grassland	21.81
Herbaceous	3.71
Open Water	1.16
Urban	2.32
Wetland	22.97

4 Applicable Water Quality Standards and Numeric Water Quality Targets

The purpose of developing a TMDL is to identify the maximum amount of a pollutant that a water body can receive and still achieve water quality standards. Water quality standards are

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

therefore central to the TMDL development process. Under the Clean Water Act, every state must adopt water quality standards to protect, maintain and improve the quality of the nation's surface waters (U.S. Code Title 33, Chapter 26, Subchapter III (U.S. Code, 2009)). Water quality standards consist of three components: designated beneficial uses, numeric and narrative criteria and an antidegradation policy.

4.1 Designated Beneficial Uses

The designated beneficial uses of Mound Branch, WBID 1300, are:

- Livestock and wildlife watering
- Protection of warm water aquatic life
- Protection of human health (fish consumption)
- Whole body contact recreation – Category B

The use that is impaired is the protection of warm water aquatic life. The designated beneficial uses and stream classifications for Missouri may be found in the water quality standards at 10 CSR 20-7.031(1)(C), (1)(F) and Table H (Missouri Secretary of State, 2008).

4.2 Numeric Criteria

As mentioned in Section 2.4, dissolved oxygen is one of the most critical characteristics of our surface waters because fish, mussels, macroinvertebrates and all other aquatic life utilize dissolved oxygen to breathe; without dissolved oxygen, little aquatic life would survive. The water quality criteria for all Missouri streams, except cold water fisheries, require a daily minimum dissolved oxygen of 5 mg/L [10 CSR 20-7.031 Table A (Missouri Secretary of State, 2008)

4.3 Antidegradation Policy

Missouri's water quality standards include EPA's "three-tiered" approach to antidegradation, which may be found at 10 CSR 20-7.031(2):

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

Tier 2 – Protects and maintains the existing level of water quality where it is better than applicable water quality criteria. Before water quality in Tier 2 waters can be lowered, there must be an antidegradation review consisting of: (1) a finding that it is necessary to accommodate important economical and social development in the area where the waters are located; (2) full satisfaction of all intergovernmental coordination and public participation provisions; and (3) assurance that the highest statutory and regulatory requirements for point sources and best management practices (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 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 Water Quality Targets

There are several water quality targets for this TMDL. To attain the protection of warm water aquatic life designated use, the minimum water quality criterion of 5 mg/L for dissolved oxygen must be met through reductions in 5-day carbonaceous biochemical oxygen demand, or $CBOD_5$. A QUAL2K model was used to determine the $CBOD_5$wasteload allocation protective of the criteria. To meet the water quality minimum criterion of 5 mg/L dissolved oxygen, total suspended solids, total nitrogen and total phosphorus will also be targeted as pollutants that affect dissolved oxygen levels in the stream system. Total suspended solids as organic particles (e.g. algae or sludge) consume oxygen during decomposition. Both types of solids on the stream bottom can contribute to sediment oxygen demand which can further reduce dissolved oxygen concentrations. The TMDL also sets targets to reduce nutrient concentrations (total nitrogen and total phosphorous) to a level that will decrease algal productivity, thereby reducing the algal biomass available for decay and decomposition. The reduction of available algae will lead to a reduction in oxygen demanding substances in the water column ($CBOD_5$) and on the stream bottom as sediment oxygen demand (SOD). The targets for total suspended solids, total nitrogen, and total phosphorous will be based on load duration curves, which determine the TMDL for each of these parameters at every flow probability (Section 7).

5 Calculation of Load Capacity

Load capacity is defined as the greatest amount of loading of a pollutant that a water body can receive without violating water quality standards. This load is then divided among the point source (wasteload allocation, or WLA) and nonpoint source (load allocation or LA) contributions to the stream, with an allowance for an explicit margin of safety, or MOS. If the margin of safety is implicit, no numeric allowance is necessary. This is expressed in the following manner:

$$\text{Load capacity} = \sum WLA + \sum LA + MOS$$

The wasteload allocation and load allocation are calculated by multiplying the appropriate flow in cubic feet per second, or cfs, by the appropriate pollutant concentration in mg/L. A conversion factor of 5.395 is used to convert the units (cfs and mg/L) to pounds per day (lbs/day).

(stream flow in cfs)(maximum allowable pollutant concentration in mg/L)(5.395)= pounds/day

Critical conditions must be considered when the load capacity is calculated. Dissolved oxygen levels that threaten the integrity of aquatic communities generally occur during low flow periods, so these periods are considered the critical conditions.

6 Waste Load Allocation (Point Source Loads)

The wasteload allocation is the portion of the load capacity that is allocated to existing or future point sources of pollution. The wasteload reduction is allocated entirely to the city of Butler

Wastewater Treatment Plant. The other permitted facilities in the watershed are general or storm water permits with no design flow (discharge). Therefore, these facilities discharge an insignificant volume of effluent compared to the city of Butler facility and are also unlikely to discharge during critical low flow periods. The two general permits within the watershed have effluent limits that are protective of in-stream water quality from their respective operations. One of the general permits, a petroleum storage facility, does not discharge pollutants (hydrocarbons) that cause or contribute to the in-stream impairment impairment. The quarry general permit contains total suspended solids limits of 70 mg/L for both the daily maximum and monthly average. The wasteload allocations for each of these facilities remains equal to existing permit limits. New wasteload allocations for the Butler's wastewater treatment plant were calculated through the modeling processes and are shown in Tables 5 through 8.

7 Load Allocation (Nonpoint Source Load)

The load allocation includes all existing and future nonpoint sources and natural background contributions (40 CFR § 130.2(g)). The load allocations for the Mound Branch TMDL are for all nonpoint sources of 5-day carbonaceous biochemical oxygen demand, total suspended solids, total phosphorus, and total nitrogen, and include loads from agricultural lands, runoff from urban areas, livestock, and failing onsite wastewater treatment systems. The load allocations provided in Table 5 were calculated based on the total of all headwater and lateral inflow loads used in the QUAL2K model for the allocation scenario model run. The load allocations are intended to allow the dissolved oxygen target to be met at all locations within the stream. The nutrient load allocations in Tables 7 and 8 are based on the load duration curves in Figures 6 and 7. During critical conditions when flow is at its lowest, and there is effectively no flow from non point sources, the load allocation for all targeted pollutants is zero pounds per day.

8 TMDL Modeling[5]

Two different models were used in the development of the Mound Branch TMDL. The QUAL2K model was used to calculate the allowable carbonaceous biochemical oxygen demand load to Mound Branch and load duration curves were used to generate secondary target loads for total suspended solids and nutrients.

8.1 Modeling Approach for Dissolved Oxygen (QUAL2K)

An essential component of developing a TMDL is establishing a relationship between the source loadings and the resulting water quality. For this TMDL, the relationship between the source loadings of biochemical oxygen demand and nutrients on dissolved oxygen is generated by the water quality model QUAL2K (Chapra et al., 2007).

QUAL2K is supported by EPA and it and its predecessor (QUAL2E) have been used extensively for TMDL development and point source permitting issues across the country, especially for dissolved oxygen. QUAL2K is well accepted within the scientific community because of its proven ability to simulate the processes important to dissolved oxygen conditions within streams. The QUAL2K model is suitable for simulating the hydraulics and water quality conditions of a small river. It is a one-dimensional model with the assumption of a completely mixed system for

[5] EPA Region 7 performed the modeling for this TMDL

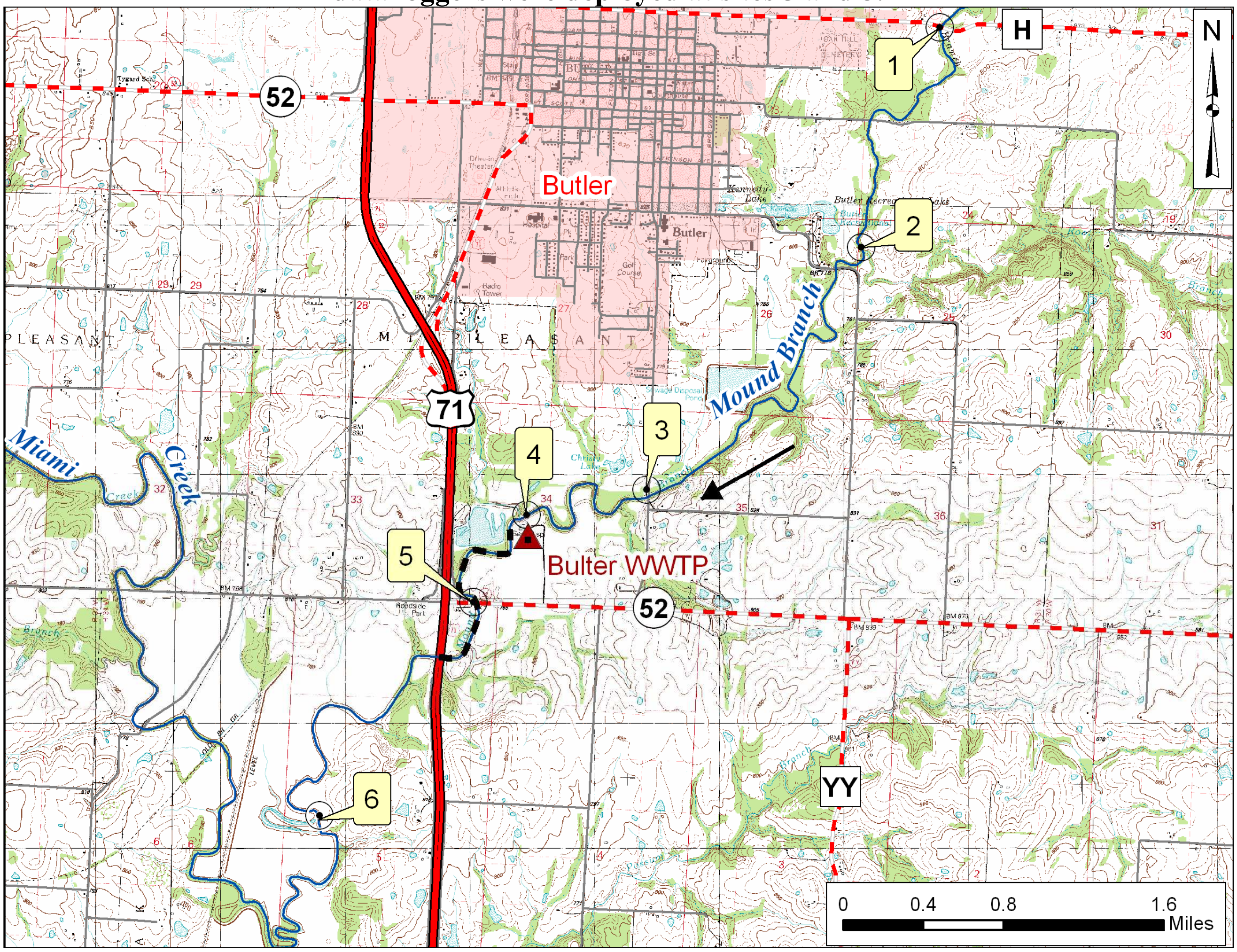
each computational cell. QUAL2K assumes that the major pollutant transport mechanisms, advection and dispersion, are significant only along the longitudinal direction of flow. The model allows for multiple waste discharges, water withdrawals, tributary flows, and incremental inflows and outflows. The processes employed in QUAL2K address nutrient cycles, algal growth, and dissolved oxygen dynamics. Once the QUAL2K model was setup and calibrated for Mound Branch, a series of scenarios were run to evaluate the pollutant load reductions needed to achieve the dissolved oxygen criterion. A detailed discussion of the QUAL2K model is included in Appendix B.

The QUAL2K model was setup and calibrated to the August 2003 sampling data (ESP 2003). See Appendix A.1.for the data and Figure 4 below for a map of the sampling sites. Table 5 shows the results of the QUAL2K model. The load allocation is based on the low flow condition corresponding to the August 2003 sampling event.

Table 5. Allocations for 5-Day Carbonaceous Biochemical Oxygen Demand in Mound Branch

	Flow Regime	Concentration Limits	Allocation
Butler treatment plant (WLA)	at Design Flow Q = 2.325 cfs (1.5 MGD)	1.5 mg/l	18.8 lbs/day
Nonpoint Source (LA)	7Q10 = 0.6 cfs	1.0 mg/l	3.2 lbs/day

Figure 4. Location of Sampling Sites in the Mound Branch Watershed. Dissolved oxygen data loggers were deployed at sites 3 and 5.



8.2 Modeling for Total Suspended Solids and Nutrients (LDCs)

Dissolved oxygen concentrations in streams are determined by factors such as photosynthetic productivity, respiration (autotrophic and heterotrophic), reaeration and temperature. These factors are influenced by natural and anthropogenic conditions within a watershed. Generally, reaeration is based on the physical properties of the stream and on the capacity of water to hold dissolved oxygen. This capacity is mainly determined by water temperature, with colder water having a higher saturation concentration for dissolved oxygen. In a review of variables and their importance in dissolved oxygen modeling, Nijboer and Verdonschot (2004) categorized the impact of a number of variables on oxygen depletion. For this TMDL, the effects of temperature and the physical aspects of the stream itself were discounted. Even though the hydrological regime of historic prairie streams was modified by changes in land cover and channelization, manipulation of these parameters does not address a pollutant and so is not the goal of a TMDL. Pollutants which result in oxygen concentrations below saturation are:

- fine particle size of bottom sediment
- high nutrient levels (phosphorus and nitrogen)
- suspended particles of organic matter

Because these three pollutants vary to a large extent based on anthropogenic influences, they are appropriate targets for a TMDL written to address an impairment of low dissolved oxygen.

8.2.1 Total Suspended Solids

Since fine particle sized sediment and suspended particles of organic matter are derived from similar loading conditions of terrestrial and stream bank erosion, this TMDL will have total suspended solids (sediment) as one of its allocations. This target was derived based on a reference approach by targeting the 25th percentile (44 mg/L) of total suspended solids measurements[6] in the geographic region in which Mound Branch is located (see Appendix C.2. for a list of sites and data)[7]. For a full description of the development of suspended solids targets using reference load duration curves refer to Appendix C.1.

The load capacity for total suspended solids has been defined as a curve over the range of flows for Mound Branch. Figure 5 contains the total suspended solids, or TSS, TMDL for Mound Branch (the upper, red curve) as well as individual water quality measurements for this pollutant, shown as black points.

[6] From U.S.Geological Survey non-filterable residue data, 25th percentile of the data equals 44 mg/L.
[7] The EPA ecoregion for Mound Branch is Level III 40, the Central Irregular Plains.

Figure 5. TMDL Sediment Curve for Mound Branch

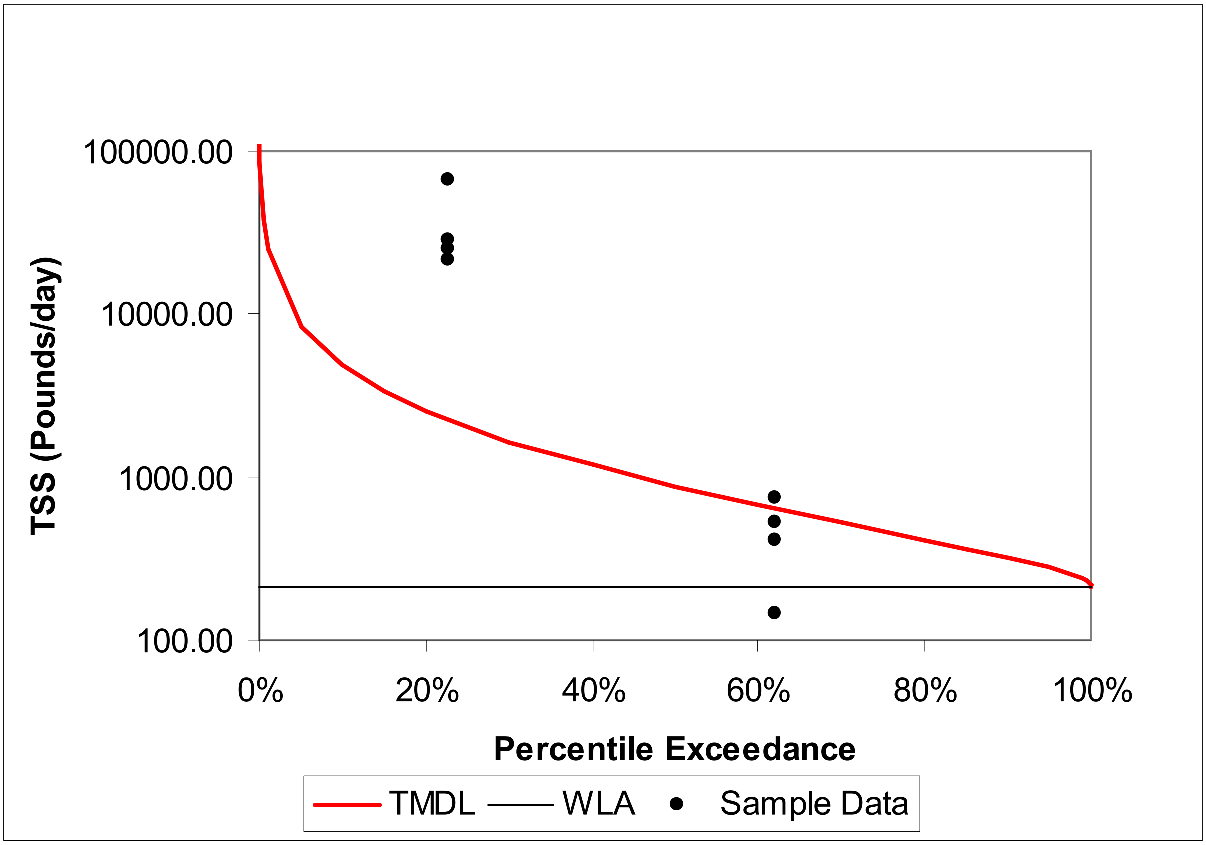


Table 6. Total Suspended Solids Allocations

Percent exceedance	Flow cfs	LC(TMDL) lbs/day	WLA Butler WWTP lbs/day	WLA (other permits) lbs/day	LA lbs/day
100	2.33	210.10	210.10	0.00	0.00
80	4.58	414.05	210.10	0.00	203.95
60	7.47	675.09	210.10	0.00	464.99
40	13.03	1177.63	210.10	0.00	967.53
20	28.2	2548.08	210.10	0.00	2337.98

8.2.2 Nutrients

To address nutrient levels in Mound Branch, the TMDL targeted EPA nutrient ecoregion reference concentrations for the Central Irregular Plains (Level III 40,). These concentrations are 0.855 mg/L total nitrogen[8] and 0.092 mg/L total phosphorus (USEPA 2001a and USEPA 2001b.).

[8]Total Nitrogen equals Total Kjeldahl nitrogen and nitrate plus nitrite as nitrogen.

To develop load duration curves for total nitrogen and total phosphorus, a method similar to that used for total suspended sediment was employed. First, total nitrogen and total phosphorus measurements were collected from U.S.Geological Survey, or USGS, sites in the vicinity of the impaired stream. These data were adjusted such that the median of the measured data was equal to the ecoregion reference concentration. This was accomplished by subtracting the difference of the data median and the reference concentration. Where the result was a negative concentration, the data point in question was replaced with the minimum concentration seen in the measured data. This resulted in a modeled data set which retained much of the original variability seen in the measured data. These modeled data were then regressed as instantaneous load versus flow. The resultant regression equation was used to create the load duration curves in Figures 6 and 7.

Figure 6. Load Duration Curve for Total Nitrogen – Mound Branch

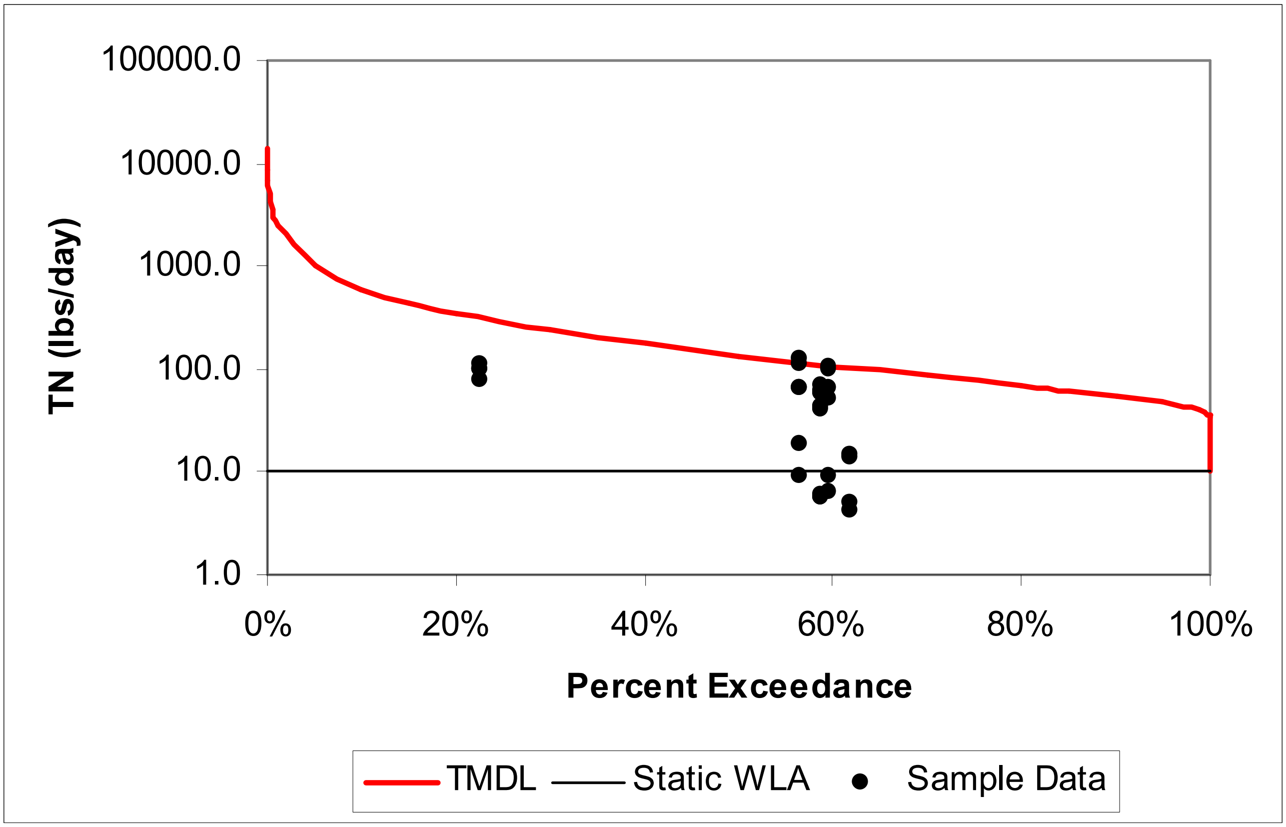


Table 7. Allocations for Total Nitrogen

Percent exceedance	Flow cfs	LC lbs/day	WLA Butler WWTP lbs/day	WLA (other permits) lbs/day	LA lbs/day
100	2.33	10.10	10.10	0.00	0.00
80	4.58	68.50	10.10	0.00	58.4
60	7.47	106.73	10.10	0.00	96.63
40	13.03	175.77	10.10	0.00	165.67
20	28.2	347.86	10.10	0.00	337.76

Figure 7. **Load Duration Curve for Phosphorus – Mound Branch**

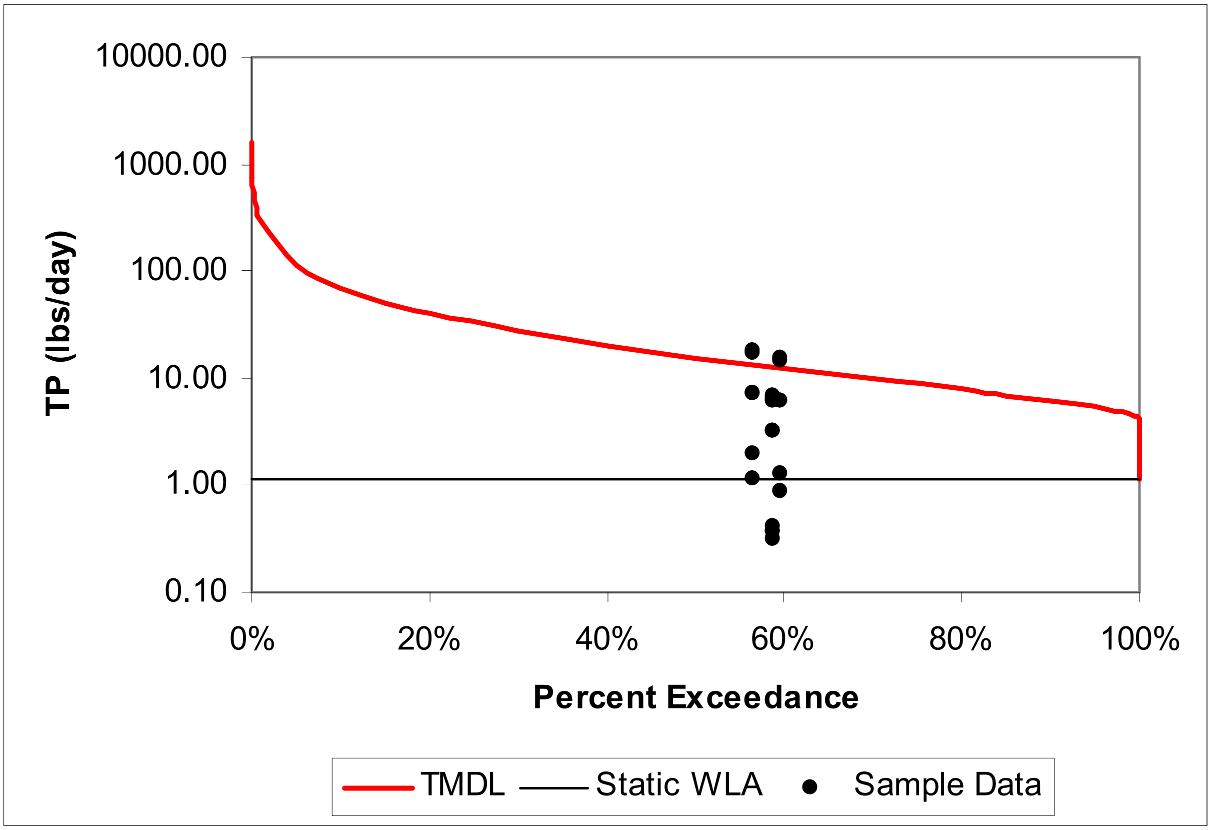


Table 8. **Allocations for Total Phosphorus**

Percent exceedance	Flow cfs	LC lbs/day	WLA Butler WWTP lbs/day	WLA (other permits) lbs/day	LA lbs/day
100	2.33	1.15	1.15	0.00	0.00
80	4.58	7.78	1.15	0.00	6.63
60	7.47	12.13	1.15	0.00	10.98
40	13.03	19.97	1.15	0.00	18.82
20	28.2	39.53	1.15	0.00	38.38

9 Margin of Safety

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

(1) Explicit - Reserve a portion of the load capacity as a separate term in the TMDL.

(2) Implicit - Incorporate the margin of safety as part of the critical conditions for the wasteload allocation and the load allocation calculations by making conservative assumptions in the analysis.

The margin of safety for the Mound Branch TMDL is implicit and based on the conservative assumptions incorporated into the QUAL2K model and used in developing and applying the TMDL load duration curves. Among the conservative approaches used, the TMDL calculates wasteload allocations by targeting the 25th percentile of total suspended solids concentrations in the geographic region in which Mound Branch is located. The TMDL also establishes wasteload allocations for the Butler Wastewater treatment Plant under critical low flow conditions when discharge from this facility will dominate in-stream pollutant loading.

10 Seasonal Variation

Federal regulations at 40 CFR §130.7(c)(1) require that TMDLs take into consideration seasonal variation in applicable standards. The Mound Branch TMDL addresses seasonal variation in two ways. One is by identifying a loading capacity that is protective of the critical low flow period sampled in August 2003. QUAL2K TMDL development for low dissolved oxygen during critical low-flow conditions are expected to be protective year round.

The second way in which the Mound Branch TMDL takes seasonal variation into account is through the use of load duration curves. Load duration curves represent the allowable pollutant load under different flow conditions and across all seasons. The results obtained using the load duration curve method are more robust and reliable over all flows and seasons when compared with those obtained under critical low-flow conditions.

11 Monitoring Plan for TMDLs Developed under Phased Approach

Post-TMDL monitoring will be scheduled and carried out by the Department approximately three years after the TMDL is approved, or in a reasonable period of time following any TMDL compliance schedule outlined in the permit and the application of any new effluent limits.

Additionally, the Department will routinely examine physical habitat, water quality, invertebrate community, and fish community data collected by other state and federal agencies in order to assess the effectiveness of TMDL implementation. One example is the Resource Assessment and Monitoring Program administered by the Missouri Department of Conservation. This program randomly samples streams across Missouri on a five to six year rotating schedule.

For nonpoint sources, follow-up monitoring would be scheduled for three years after BMPs are installed and effective. Also, monitoring is required in the Marais des Cygnes, Marmaton and Little Osage Rivers Watershed Management Action Plan, as a measure of success (See Section 12.2).

12 Implementation Plans

Since low dissolved oxygen is an issue upstream of the wastewater treatment plant as well as downstream, addressing the sources of impairment in Mound Branch will require developing nonpoint source, as well as point source, controls in the watershed. However, due to issues regarding low dissolved oxygen in prairie streams, the Department intends to develop revised dissolved oxygen criteria for Mound Branch and similar streams during future triennial reviews of the water quality standards. Revised dissolved oxygen criteria may better reflect natural stream reaeration conditions to assure that treatment plant effluent limits are based on meeting dissolved oxygen criteria that are naturally occurring. The Department acknowledges that, should revised criteria be developed, a revised Mound Branch TMDL may be necessary. It also acknowledges that the revised criteria may result in no impact for Mound Branch and that new loading calculations may not differ or offer relief from what is currently contained in the Mound Branch TMDL.

12.1 Point Sources

The permit for the City of Butler's waste water treatment plant was renewed on February 11, 2010 and retained effluent limits for biochemical oxygen demand of 10 mg/L weekly average and 10 mg/L monthly average. The Department intends the implementation of TMDL wasteload allocations for carbonaceous biochemical oxygen demand, total suspended solids, total nitrogen and total phosphorus occur using a phased approach.

The Department anticipates numeric and narrative water quality criteria will be met after the new effluent limits for $CBOD_5$ and TSS have been applied to the Butler Wastewater Treatment Plant. Implementation of these effluent limits will require continued proper operation and maintenance of the facility, and may include upgrades and improvements to address reductions in $CBOD_5$ and TSS. Effluent monitoring for nutrient species and instream monitoring for dissolved oxygen, temperature, pH, ammonia and chlorophyll *a* will also be required in the Butler Wastewater Treatment Plant operating permit. Additional monitoring and analysis may be conducted by either the Department or the city to determine whether the dissolved oxygen minimum criterion of 5 mg/L found in 10 CSR 20-7.031, Table A is appropriate or if a site-specific dissolved oxygen criterion is required. Any such evaluation would likely coincide with the Department's triennial review of the Water Quality Standards, when a new dissolved oxygen criterion may be promulgated.

If post-TMDL monitoring indicates that point source reductions are not achieving the desired improvements in water quality, the Department will reevaluate the TMDL for further appropriate actions. These actions may include additional permit conditions on the Butler Wastewater Treatment Plant (including effluent limits for total nitrogen and total phosphorus) and further control of nonpoint sources through a nonpoint source management plan.

The Missouri State Operating Permit for the city of Butler's wastewater treatment plant requires instream monitoring downstream of the wastewater treatment plant to provide additional data with which to assess the impact of the permit limits on Mound Branch. Instream data currently collected monthly in Mound Branch includes flow (a 24-hour estimate), dissolved oxygen, pH, ammonia, nitrate plus nitrite as nitrogen and temperature. These data will be used for screening purposes, to compare the stream's current condition with future, post-TMDL conditions. The wastewater treatment plant instream monitoring data are included in Appendix A.

Because general and storm water permits within the watershed are not significantly contributing to the water quality impairments, individual facilities covered by general and storm water permits within the watershed are set at current permit limits and conditions. Should future inspection, assessment, or monitoring data indicate these permits contribute pollutants of concern to the impaired water body, they will be reopened to include requirements sufficient to characterize and reduce impacts from these discharges.

12.2 Nonpoint Sources

In November 2005, a watershed committee was formed through the efforts of the Osage Valley Resource Conservation and Development Council. The aim of this committee was to facilitate a cooperative effort between all residents within the Marais des Cygnes River watershed to develop a comprehensive watershed management plan. The Marais des Cygnes River originates in east-central Kansas and the downstream one-third of the watershed lies in Missouri. As stated in Section 1, Mound Branch is a tributary to Miami Creek which flows into the Marais des Cygnes River. The Citizens Watershed Committee is composed of county commissioners and Soil and Water Conservation District boards in Barton, Bates, Cass and Vernon counties plus interested watershed residents. Natural resource agencies and watershed residents from Kansas and Missouri were invited to provide technical expertise. Four public meetings were held during the planning and writing process of the watershed management plan to obtain public input. Through this process, the following 10 issues and concerns were identified, prioritized and compiled into the plan:

1. Erosion/soil loss
2. Solid waste management
3. Water quality and quantity
4. Public information
5. Mines and quarries
6. Farmland conversion to residential land use
7. Habitat loss- aquatic and upland
8. Agricultural systems-CAFO/AFO[9]; Grazing/cropping systems
9. Private/Public Interaction
10. Residential/Urban

In August 2006, the Bates and Vernon County Commissioners, the Bates and Vernon County Soil and Water Conservation Districts and the Osage Valley Resource Conservation and Development Council signed the Marais des Cygnes, Marmaton and Little Osage Rivers Watershed Management Action Plan.

A Clean Water Act Section 319 Nonpoint Source Implementation Grant has been awarded to the Osage Valley Resource Conservation and Development Council to implement the watershed management plan relating to Mound Branch. The watershed encompasses 32,748 acres located entirely within east-central Bates County. The project start date was July 1, 2009, and will terminate on June 30, 2013, with a total project cost of $1,928,338. The project seeks to improve water quality in Mound Branch by increasing the average dissolved oxygen level and reducing the average ammonia levels and sediment loading. Management practices to be implemented include conservation tillage, field borders, agricultural and urban riparian buffers, filter strips, planned grazing systems, stream bank erosion rehabilitation, residue management, integrated crop and nutrient management, urban lawn nutrient and pest management, urban lawn clippings

[9] CAFO – Confined Animal Feeding Operation; AFO - Animal Feeding Operation

composting and modifying onsite wastewater treatment systems. A Quality Assurance Project Plan will be developed jointly between partnering agencies for water quality monitoring at numerous sites on Mound Branch. Monitoring parameters will include dissolved oxygen, ammonia, total suspended solids, sediment, total nitrogen, total phosphorus, pH, temperature, specific conductivity, optical brighteners and flow. In addition to collection of grab samples, automated samplers will be strategically positioned throughout the watershed in cooperation with Missouri Department of Conservation-Fisheries and other partners. The Osage Valley Resource Conservation and Development Council has hired a project specialist to coordinate and manage the project.

13 Reasonable Assurances

The Department has the authority to issue and enforce State Operating Permits. Inclusion of effluent limits determined from the wasteload allocations established by the TMDL modeling into a state permit, and monitoring of the effluent and receiving stream reported to the Department, should provide reasonable assurance that instream water quality standards will be met. In most cases, "Reasonable Assurance" in reference to TMDLs relates only to point sources. As a result, any assurances that nonpoint source contributors of low dissolved oxygen will implement measures to reduce their contribution in the future will not be found in this section. Instead, discussion of reduction efforts relating to nonpoint source can be found in the "Implementation" section of this TMDL.

14 Public Participation

This water quality limited segment of Mound Branch is included on the approved 2004/2006 303(d) List for Missouri. The public notice period for the draft Mound Branch TMDL was Oct. 30, 2009 to Dec. 14, 2009. Groups that received the public notice announcement included the Missouri Clean Water Commission, the Water Quality Coordinating Committee, the City of Butler, Bates County Commissioners, Bates County Soil and Water Conservation District, the Marais des Cygnes Watershed Group, 18 Stream Team volunteers in the county and the three state legislators representing Bates County. Also, the public notice, the Mound Branch TMDL Information Sheet and this document were posted on the Department Web site, making them available to anyone with access to the Internet. Seven comments were received and incorporated into the TMDL where appropriate. These comments have been posted to the Department’s website and have been placed in the Mound Branch docket [file] along with the Department’s responses and any other documentation.

15 Administrative Record and Supporting Documentation

An administrative record on the Mound Branch TMDL has been assembled and is being kept on file with the Department. It includes the following:

- City of Butler’s Wastewater Treatment Plant State Operating Permit #MO-0096229
- Survey Sampling Report; City of Butler’s treatment plant - Mound Branch and Miami Creek; Butler Missouri; Bates County; August 4-6, 2003; Environmental Services Program

- Survey Sampling Report; City of Butler's treatment plant - Mound Branch and Miami Creek; Butler Missouri; Bates County; August 16-18, 2004; Environmental Services Program
- Marais des Cygnes, Marmaton and Little Osage Rivers Watershed Management Action Plan – August 2006
- 319 "Application for Nonpoint Source Implementation Grants Form"-Fillable Form., Oct 1, 2007. MO-780-1896.doc.
- 319 Mound Branch Watershed Evaluation and Restoration Project-Bates County 2009-2012
- QUAL2K input and output files
- Mound Branch TMDL Information Sheet
- Public notice announcement

References

Athayde, D., P. Shelley, E. Driscoll, D. Gaboury and G. Boyd. 1983. Results of the Nationwide Urban Runoff Program, Volume I, Final Report. U.S. Environmental Protection Agency, 186 p.

Census Bureau. 2008. 2007 Population Estimates. [Online WWW]. Available URL: www.census.gov/ [Accessed Nov. 6, 2008].

Chapra, S.C., G.J. Pelletier, and H. Tao. 2007. QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality, Version 2.07: Documentation and Users Manual. Civil and Environmental Engineering Dept., Tufts University, Medford, MA.,

Durnell, Steve. Bates County Public Health Department. Personal communication on March 16, 2009.

ESP (Department of Natural Resources' Environmental Services Program). 2003. Survey Sampling Report; City of Butler's WWTP- Mound Branch and Miami Creek; Butler Missouri; Bates County; August 4-6, 2003.

__________ 2004. Survey Sampling Report; City of Butler's WWTP- Mound Branch and Miami Creek; Butler Missouri; Bates County; August 16-18, 2004.

Horsley and Witten, Inc. 1996. Identification and evaluation of nutrient and bacterial loadings to Maquoit Bay, New Brunswick and Freeport, Maine. Final Report.

Missouri Secretary of State. 2008. Code of State regulation-Title 10 Department of Natural Resources. Water Quality Standard 10 CSR 20-7.031. [Online WWW]. Available URL: www.sos.mo.gov/adrules/csr/current/10csr/10csr.asp#10-20 [Accessed Feb. 19, 2009].

MoRAP (Missouri Resource Assessment Program). 2005. Land Use/Land Cover Data. [Online WWW]. Available URL: www.msdis.missouri.edu [Accessed April 26, 2007].

Nijboer, R.C. and P.F.M. Verdonschot. 2004. Variable selection for modelling effects of eutrophication on stream and river ecosystems. Ecol. Model. 177,17-39.

OEPA (Ohio Environmental Protection Agency). 2007. *Total Maximum Daily Loads for the Beaver Creek and Grand Lake St. Marys Watershed.* Final Report. August 29, 2007.

Reckhow, K. H., M. N. Beaulac, and J. R. Simpson. 1980. Modeling Phosphorous Loading and Lake Response under Uncertainty: A Manual and Compilation of Export Coefficients. EPA-440/5-8-011, U.S. Environmental Protection Agency, Washington, D.C.

Tetra Tech, Inc. 2009. *Total Maximum Daily Load Report for the Kankakee/Iroquois Watershed. Public Review Draft.* Prepared for the U.S. Environmental Protection Agency Region 5, Illinois Environmental Protection Agency, and the Indiana Department of Environmental Management. February 24, 2009.

U.S. Code. 2009. Title 33 of the U.S. Code. [Online WWW]. Available URL: www.gpoaccess.gov/uscode/ [Accessed Feb. 19, 2009].

USDA (U.S. Department of Agriculture). 2002. National Agriculture Statistics Service. [Online WWW]. Available URL: www.nass.usda.gov/ [Accessed Feb. 19, 2009].

USEPA (U.S. Environmental Protection Agency). 2001a. Ambient Water Quality Criteria Recommendations: Rivers and Streams in Nutrient Ecoregion IX. U.S. Environmental Protection Agency, Washington DC. EPA 822-B-001-019.

__________ 2001b. Ambient Water Quality Criteria Recommendations: Rivers and Streams in Nutrient Ecoregion X. U.S. Environmental Protection Agency, Washington DC. EPA 822-B-001-016.

__________ 2002. Onsite Wastewater Treatment System Manual. EPA/625/R-00/008. U.S. Environmental Protection Agency, Office of Water, Washington, DC, and Office of Research and Development, Cincinnati, OH. February 2002

Appendix A
Mound Branch Water Quality Data

Appendix A.1 –Data Collected by the Department of Natural Resources 2003-2007
(After the Butler WWTP facility upgrade in 2003)

Site ID	Site #	Site Name	Year	Mo	Day	Time	C	DO	DOS	pH	SC	TKN	NH3N	NO3N	TP	CBOD
1300/6.38	1	Mound Br. At Hwy H	2005	12	28		4.5	7.8		7.15	685					
1300/6.91	2	Mound Br. 3.3 mi.ab. Butler WWTP	2007	8	8	1007	26.1	2.1		7.2			0.23			0.99
1300/6.91	2	Mound Br. 3.3 mi.ab. Butler WWTP	2007	9	27	1005	17.6	2.5		6.9			0.13			0.99
1300/4.8	3	Mound Br. 1.2 mi.ab. Butler WWTP	2003	8	5	640	24	1.8	22	7.5	564	1.53	0.16	0.00499	0.2	
1300/4.8	3	Mound Br. 1.2 mi.ab. Butler WWTP	2003	8	5	1245	26.5	2.5	31	7.7	549	3.15	0.04	0.00499	0.34	26.7
1300/4.8	3	Mound Br. 1.2 mi.ab. Butler WWTP	2003	8	6	640	24.5	2	24	7.7	546	1.29	0.16	0.00499	0.17	3.51
1300/4.8	3	Mound Br. 1.2 mi.ab. Butler WWTP	2003	8	6	1240	28	3.5	44	7.8	559	1.78	0.18	0.00499	0.26	6.03
1300/4.8	3	Mound Br. 1.2 mi.ab. Butler WWTP	2004	8	17	630	19	3.8	41	7.8	623	0.71	0.04	0.35	0.07	0.99
1300/4.8	3	Mound Br. 1.2 mi.ab. Butler WWTP	2004	8	17	1255	20.9	4.5	45	7.8	623	0.76	0.015	0.34	0.07	0.99
1300/4.8	3	Mound Br. 1.2 mi.ab. Butler WWTP	2004	8	18	630	20.9	4.2	47	7.9	637	0.8	0.025	0.32	0.08	0.99
1300/4.8	3	Mound Br. 1.2 mi.ab. Butler WWTP	2004	8	18	1230	22.9	4.7	55	8	637	0.77	0.015	0.33	0.06	0.99
1300/4.8	3	Mound Br. 1.2 mi.ab. Butler WWTP	2005	12	28		5.5	5.6		6.8	710					
Mean: Mound Br. Upstream of WWTP								3.8		7.5	592	1.349	0.0794	0.17	0.156	5.74
1300/3.6	4	Butler WWTP outfall	2003	8	5	615	24.5	4.9	59	7.1	876					
1300/3.6	4	Butler WWTP outfall	2003	8	5	1200	26	7.6	94	7.4	870	0.025	0.015	24.2	3.98	0.99
1300/3.6	4	Butler WWTP outfall	2003	8	6	530	24.5	7.3	88	7.6	870					
1300/3.6	4	Butler WWTP outfall	2003	8	6	1205	26.5	7.4	92	7.4	859	0.94	0.015	24.5	4	0.99
1300/3.6	4	Butler WWTP outfall	2004	8	17	607	21.7	7.4	84	8	800					
1300/3.6	4	Butler WWTP outfall	2004	8	17	1020						0.18	0.62	17.6	2.24	4.2
1300/3.6	4	Butler WWTP outfall	2004	8	17	1230	23.7	7.4	87	8	790					
1300/3.6	4	Butler WWTP outfall	2004	8	18	545	22.4	6.2	72	8	801					
1300/3.6	4	Butler WWTP outfall	2004	8	18	1045	23.4	6.8	80	8.1	793	0.62	0.1	15.8	2.48	3.6
Mean: Butler WWTP effluent								6.9		7.7	832	0.441	0.1875	20.525	3.175	2.445

Site		Site Name	Year	Mo	Day	Time	C	DO	DOS	pH	SC	TKN	NH3N	NO3N	TP	CBOD
1300/3.0	5	Mound Br. 0.6 mi.bl. Butler WWTP	2003	8	5	700	24	2.8	34	7.3	875	0.025	0.15	19.3	3.03	
1300/3.0	5	Mound Br. 0.6 mi.bl. Butler WWTP	2003	8	5	1315	25	4.6	56	7.2	866	0.025	0.13	19.9	2.97	0.99
1300/3.0	5	Mound Br. 0.6 mi.bl. Butler WWTP	2003	8	6	615	24.5	2.7	32	7.3	859	0.51	0.13	20.4	3.07	0.99
1300/3.0	5	Mound Br. 0.6 mi.bl. Butler WWTP	2003	8	6	1300	25.5	4.2	52	7.4	856	0.025	0.11	20.2	2.98	0.99
1300/3.0	5	Mound Br. 0.6 mi.bl. Butler WWTP	2004	8	17	650	19.4	5.1	56	7.9	707	0.025	0.015	11.1	1.21	0.99
1300/3.0	5	Mound Br. 0.6 mi.bl. Butler WWTP	2004	8	17	1315	22.3	5.8	67	7.9	692	0.48	0.04	10.8	1.17	0.99
1300/3.0	5	Mound Br. 0.6 mi.bl. Butler WWTP	2004	8	18	645	21.6	4.3	52	7.8	721	1.83	0.33	11.6	1.32	0.99
1300/3.0	5	Mound Br. 0.6 mi.bl. Butler WWTP	2004	8	18	1310	24.2	5	60	7.7	702	0.75	0.24	10.8	1.2	0.99
Mean: Mound Br. 0.6 mi. downstream of WWTP								4.3		7.6	785	0.459	0.1431	15.5125	2.119	0.99
1300/1.1	6	Mound Br. 2.5 mi.bl. Butler WWTP	2003	8	5	645	24	3	36	7.3	875	0.48	0.09	10.4	1.25	0.99
1300/1.1	6	Mound Br. 2.5 mi.bl. Butler WWTP	2003	8	5	1315	27	8.7	109	7.8	868	1	0.06	10.4	1.22	0.99
1300/1.1	6	Mound Br. 2.5 mi.bl. Butler WWTP	2003	8	6	730	24	2.9	35	7.3	856	1.34	0.09	10.1	1.22	0.99
1300/1.1	6	Mound Br. 2.5 mi.bl. Butler WWTP	2003	8	6	1415	27	7	88	7.6	858	0.25	0.06	10.3	1.21	0.99
1300/1.1	6	Mound Br. 2.5 mi.bl. Butler WWTP	2004	8	17	645	19	5.5	60	7.5	661	0.9	0.015	6.73	0.62	0.99
1300/1.1	6	Mound Br. 2.5 mi.bl. Butler WWTP	2004	8	17	1245	21.1	6.5	73	7.5	658	0.68	0.015	6.9	0.62	0.99
1300/1.1	6	Mound Br. 2.5 mi.bl. Butler WWTP	2004	8	18	720	21.1	5.3	59	7.8	663	1.09	0.015	7.15	0.63	0.99
1300/1.1	6	Mound Br. 2.5 mi.bl. Butler WWTP	2004	8	18	1400	23.4	7.1	84	7.8	657	0.84	0.015	7.42	0.65	0.99
Mean: Mound Br. 2.5 mi. downstream of WWTP								5.8		7.6	762	0.823	0.045	8.675	0.928	0.99

See notes and definitions of abbreviations on next page.

A.1.a. Flow data associated with the 2003 and 2004 studies

Date	Site	Flow (cfs)		Date	Site	Flow (cfs)
8/4/03	3	0.06		8/16/04	3	0.42
	5	1.05			5	0.83
	6	0.59			6	0.93

Additional information regarding the available Mound Branch water quality data:

Sampling Entity	**Type of Data**	**Used for Modeling?**
MoDNR	QA	Yes
Butler treatment plant	Screening	No

Notes:

- QA or Quality Assurance = These data are of sufficient quality to evaluate compliance with water quality standards and to support TMDL development because they were collected in accordance with required quality assurance procedures and MODNR sampling protocols.
- Screening = These data can only be used for screening purposes (i.e., not to evaluate compliance with water quality standards or to support TMDL development).
- All measurements are in milligrams per liter (mg/L) unless otherwise noted
- Empty cell means no data available.
- Detection limits and non-detects were expressed as "less-than" numbers and show up in this list as those data ending in 99. Examples: <2 appears as 0.99; <5 appears as 2.499

Abbreviations:

ab.= above
bl.= below
Br. = Branch
C = temperature in degrees Celsius
CBOD = Carbonaceous Biochemical Oxygen Demand (5 days)
DO = Dissolved Oxygen
DOS = Dissolved Oxygen Saturation
Flow is in cubic feet per second (cfs or ft^3/s)
mi = mile
MoDNR = Missouri Department of Natural Resources
NH3N = Ammonia as Nitrogen
NO3N or NO2+NO3 = Nitrite + Nitrate as Nitrogen
SC = Specific Conductivity (micro mhos per centimeter or µmhos/cm)
TKN = Total Kjeldahl Nitrogen
TP = Total Phosphorus

Appendix A.2.

During the stream survey of Mound Branch in August, 2003, dataloggers were deployed at sites B1 and B3 (identified as sites 3 and 5 in Appendix A.1. above). They were set to record temperature and dissolved oxygen concentrations every 15 minutes during the length of the study (48 hours). Graphs of the results are in Figures X and Y.

Figure X. Temperature and dissolved oxygen data, Mound Branch Survey, Site B1/3 (upstream of Butler WWTP), Aug 4-6, 2003

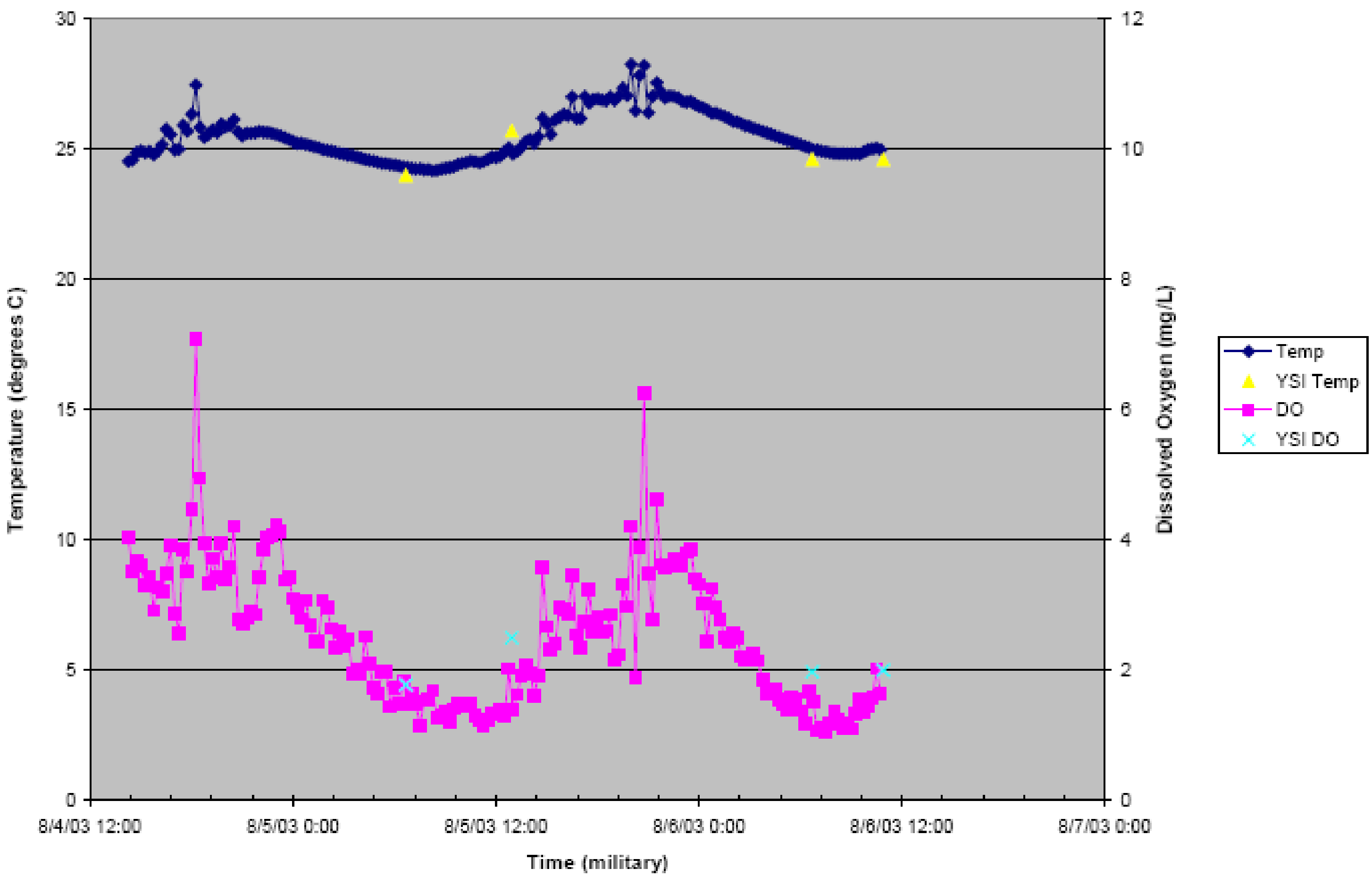
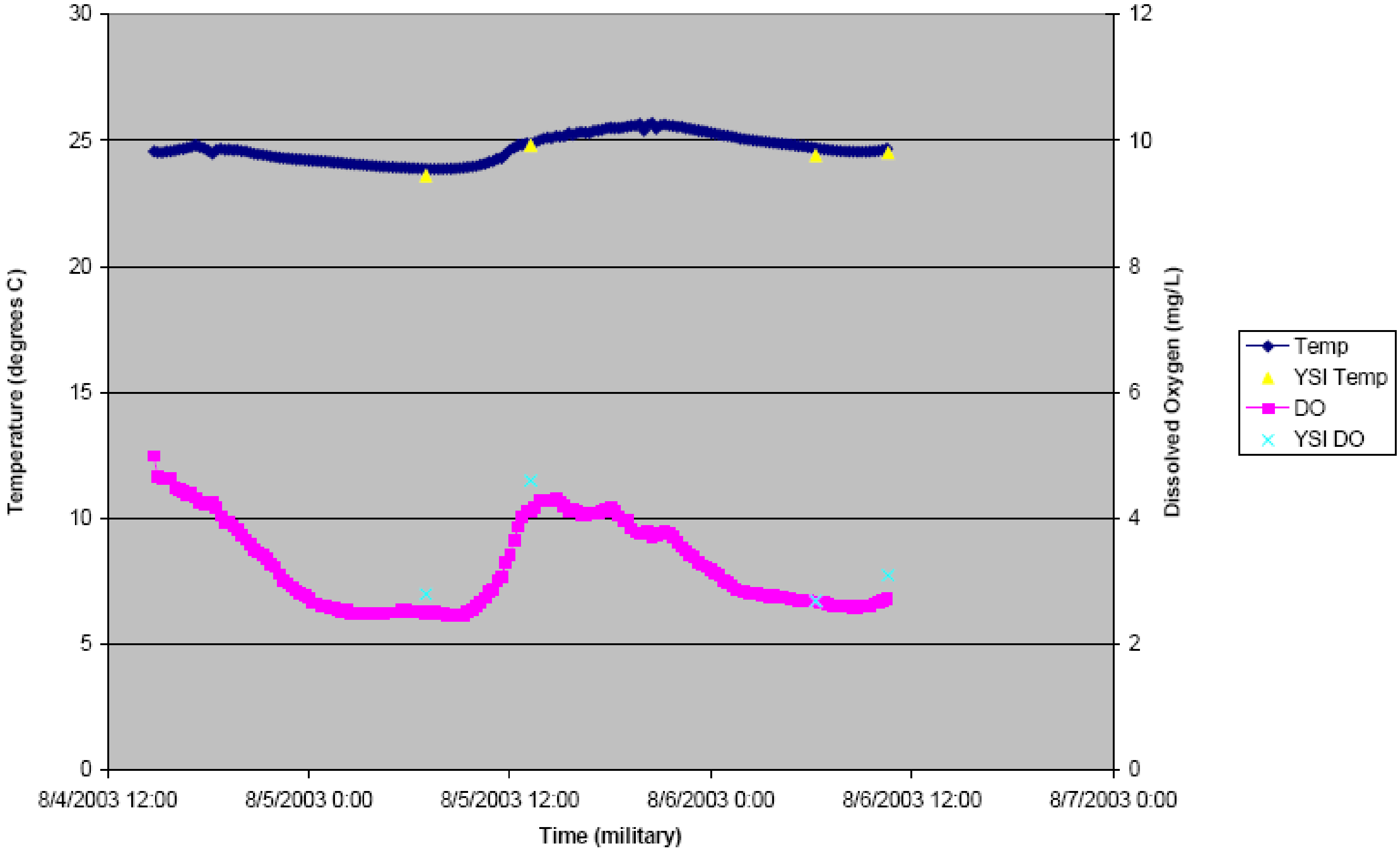


Figure Y. Temperature and dissolved oxygen data, Mound Branch Survey, Site B3/5 (downstream of Butler WWTP), Aug 4-6, 2003



Appendix A.3

Instream data collected by the Butler Wastewater Treatment Plant (Permit #MO-0096229) from 9/30/2004 to 4/30/2009

Note: Site 5 = Upstream of the plant on Mound Branch
Site 6 = Downstream, ¼ mile below the WWTP outfall on Mound Branch

Date	Site	Flow (cfs)	Temp	DO (Min)	pH	NH3N	NO2+NO3
9/30/2004	5	0.224	21	3.2	7.7	0.0637	0.234
	6	0.894	22	4.5	7.7	0	8.37
10/31/2004	5	0.289	13	6.9	8		
	6	0.867	13	6.7	8		
11/30/2004	5	0.301	13	8.1	9.1	0	0.612
	6	0.964	13	8.9	8.1	0	1.21
4/30/2005	5	0.314	19	6.02	7.5	0.0465	0.0576
	6	0.941	18	5.9	7.6	0.0605	2.37
5/31/2005	5	0.241	20	4.4	7.4	0.177	1.16
	6	0.722	21	4.4	7.4	0.121	5.65
6/30/2005	5	0.864	22	6.4	7.5	0	0.76
	6	2.592	22	6.4	7.5	0	0.988
7/31/2005	5	0.207	24	3.3	7.4	0	0
	6	0.621	24	4.1	7.3	0	13.6
8/31/2005	5	1.632	21	6.9	7.8	0	0.694
	6	4.895	22	6.9	7.8	0	1.19
9/30/2005	5	0.215	23	3.8	7.6	0	0.164
	6	0.645	23	4.8	7.6	0	13.9
10/31/2005	5	0.213	14	5.6	7.7	0	0
	6	0.639	15	6.5	7.7	0	0
11/30/2005	5	0.664	7.5	3.6	7.8	0	0
	6	1.991	8.4	3.9	8	0.33	9.5
4/30/2006	5	307	16	6.6	7.6	0	0
	6	941	15	5.4	7.5	0	2.7
5/31/2006	5		21	1.7	7.3		0.82
	6		20	1.8	7.3		1.3
6/30/2006	5	0.271	21	2.6	7.5	0.35	0.23
	6	0.312	21	3	7.5	0.15	6.2
7/31/2006	5				7.1		
	6				7.5		
8/31/2006	5				7.1		
	6				7.1		
9/30/2006	5		23	1.7	7.3	0.19	0.16
	6		23	1.8	7.3		11
10/31/2006	5	0.5	17	1.7	7.3		
	6	0.5	15	1.9	7.3	0.4	29
11/30/2006	5	0.415	17	1.9	7.5		
	6	0.415	17	2	7.5		16.7

4/30/2007	5	0.273	9	9.2	8.2		
	6	0.818	10	9.2	8.1		4
5/31/2007	5	2.784	19	6.8	7.9		1.4
	6	8.351	19	6.4	7.8		1.4
6/30/2007	5	0.491	22	1.6	7.6		0.41
	6	1.472	22	1.8	7.6		2.2
7/31/2007	5	0.185	24	6.1	7.3	0.11	0.44
	6	0.554	24	8.8	7.4		0.66
8/31/2007	5	0.234	27	3.5	7		
	6	0.698	26	3.9	7		11.5
9/30/2007	5	0.206	22	2.8	7.4	0.17	0.1
	6	0.618	22	3.3	7.3		5.5
10/31/2007	5	0.228	19	2.3	7	0.15	
	6	0.687	19	3.1	7	1.3	16.6
11/30/2007	5	0.171	10.9	2.8	7.4		
	6	0.512	12	3.2	7.3		16.6
4/30/2008	5	5.77	13	6.9	7.6		0.24
	6	2.908	14	7.3	7.8		0.48
5/31/2008	5	0.548	11		7.8		1.3
	6	1.644	17	6	7.8		1.8
6/30/2008	5	2.487	20		7.6	0.13	1.1
	6	9.748	20	5.8	7.6	0.13	1.1
7/31/2008	5	0.235	25		7.6		0.41
	6	0.938	26	3.7	7.4		5
8/31/2008	5	0.225	24	2.5	7.5	0.22	0.13
	6	0.876	24	5	7.4		14.1
9/30/2008	5	0.947	17		7.3		0.39
	6	3.786	16	7.6	6.8		0.46
10/31/2008	5	0.235	17		7.2		0.12
	6	0.894	16		7		4.4
11/30/2008	5	0.349	5		7		0.44
	6	1.39	6.4		7.2		1.4
4/30/2009	5	0.515	8.1	10.2	7.4	0.11	2.5
	6	1.6	8.5	10	7.3		2.4

Appendix B
Mound Branch QUAL2K Modeling

I. Modeling Approach

Missouri Department of Natural Resources data from the 2003 stream survey (ESP 2003) sampling at Mound Branch were used in developing the QUAL2K model described below. The sampling data obtained in 2008 were not used because of poor quality of stream section/flow and continuous dissolved oxygen measurements, timing of stream section and chemistry samples, and sampling time not representative of critical condition.

The Department's QUAL2K model for the 2003-04 dataset served as starting point for developing the model described below. The hydraulics and segmentation of the Department's QUAL2K model were revised.

1.1 Hydraulics/Hydrology

a. **Stream Segmentation and Power Relations**

At-a-site hydraulic geometry relations were developed from the August 5, 2003 flow measurements at three stream sections of Mound Branch creek (MB1, MB3 and MB4 in Figure B1). The relationship between mean flow depth (***d***), width (***w***) and velocity (***u***) as a function of discharge (***q***) were estimated from the water level measurements at each site. Manning's equation ($u \sim r^{2/3}$) was used to derive the functions $d = aq^b$, $u=cq^d$, and $w=eq^f$, where $bdf=1.0$. These power relations were used in the QUAL2K calibration model.

b. **Boundary Conditions**

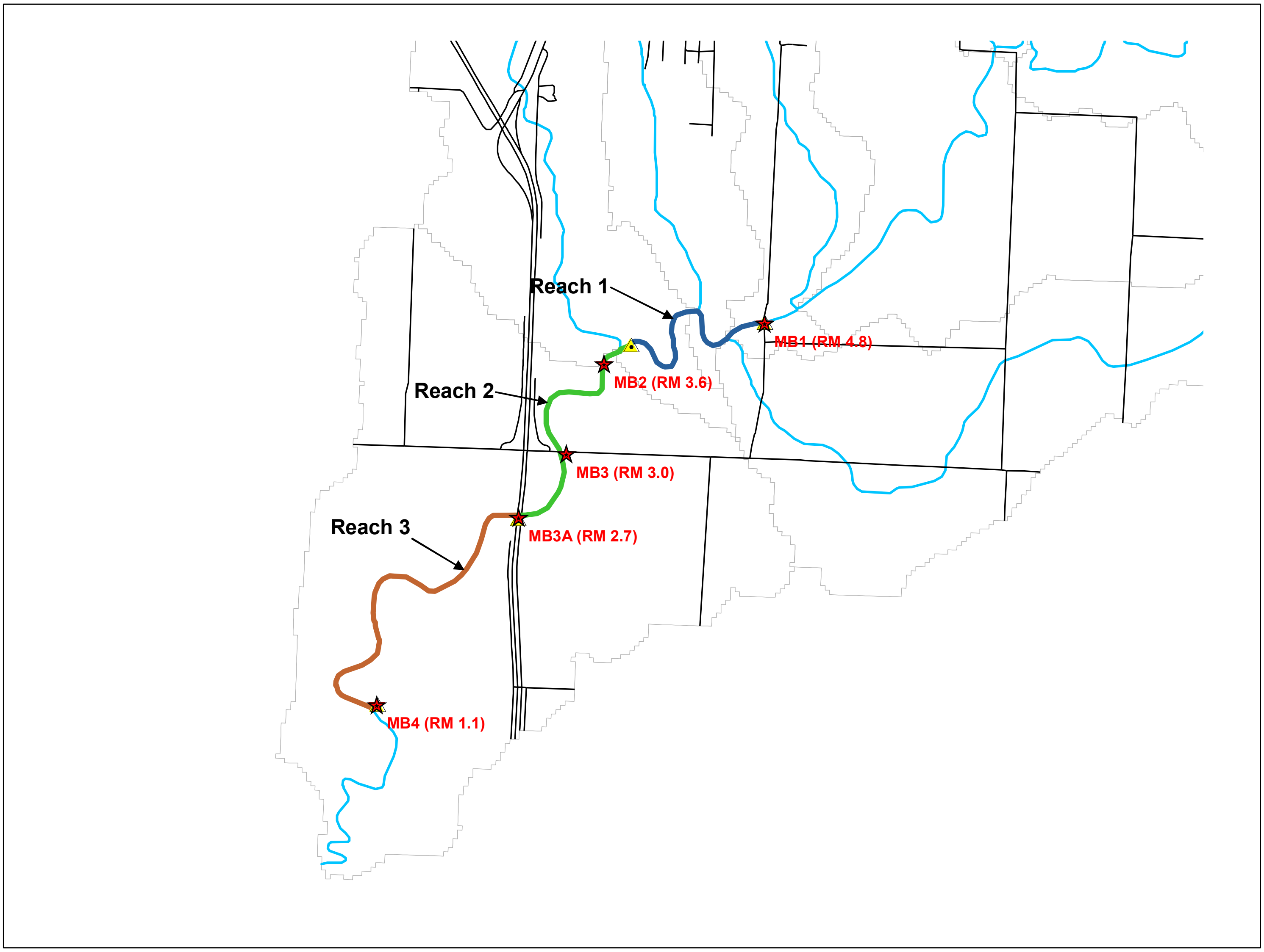
The hydraulics/hydrology of the system was modeled using MB1 and MB4 as the upstream and downstream boundaries, respectively (Figure B1). The modeled reach is about 3.7 miles. The calibration model assumes no intervening lateral inflows into the modeled reach of Mound Branch. The stream survey sampling report (ESP 2003) indicated no visual evidence of storm water runoff into Mound Branch at the time of sampling. The hydraulics model was calibrated using the upstream boundary flow of 0.06 cfs, or cubic feet per second, (at MB1) and a point source discharge of 0.605 cfs from Butler WWTP (MB2).

1.2 Water Quality

a. **Data Source and weather conditions**

The water quality model was setup and calibrated using the water chemistry data from MB1, MB2, MB3, and MB4 (early morning and mid-afternoon grab samples on August 5-6, 2003) and the continuous diurnal dissolved oxygen and water temperature measurements at MB1 and MB3 (August 4-6, 2003). Water chemistry data from MB1 was used as the upstream boundary condition. Weather conditions during the sampling period were very hot and humid with temperatures ranging from the middle 70s (^oF) in the morning to the upper 90s in the afternoon (ESP, 2003).

Figure B1. Map of Schematic QUAL2K Model Domain



b. **Calibration**

The model was calibrated by matching the observed diurnal dissolved oxygen data at MB3 which is about 0.6 mi downstream of Butler treatment plant. The calibration process involved adjusting the kinetic rates such that the measured water chemistry parameters and the diurnal dissolved oxygen were reasonably simulated. Greater emphasis was placed on matching the CBOD decay downstream of the treatment plant discharge. The kinetic rates from the Department's QUAL2K model were used as an initial set for calibration.

c. **Scenarios Tested**

Using the calibrated model, several scenarios were simulated to determine the waste load (WLA) and load allocation (LA) for Mound Branch. Simulations were performed to determine the reduction in CBOD necessary to meet the dissolved oxygen standard (5.0 mg/l) upstream and downstream of the Butler treatment plant. The scenarios were:

c.1. **Model A** – WWTP design discharge; current condition (calibration model) upstream boundary flow and WWTP and nonpoint source total nitrogen , TP, $CBOD_5$ and Chlorophyll-A.

c.2. **Model B** - WWTP design discharge; 7Q10 boundary flow and current condition (calibration model) WWTP and nonpoint source total nitrogen , TP, $CBOD_5$ and Chlorophyll-A.

c.3. **Model C**- WWTP design discharge; 7Q10 boundary flow and current condition (calibration model) WWTP total nitrogen , TP, $CBOD_5$ and Chlorophyll-A; nonpoint source total nitrogen =0.855 mg/l, TP=0.092 mg/l, Chlorophyll-A=5 ppb, and $CBOD_5$=1.0 mg/l.

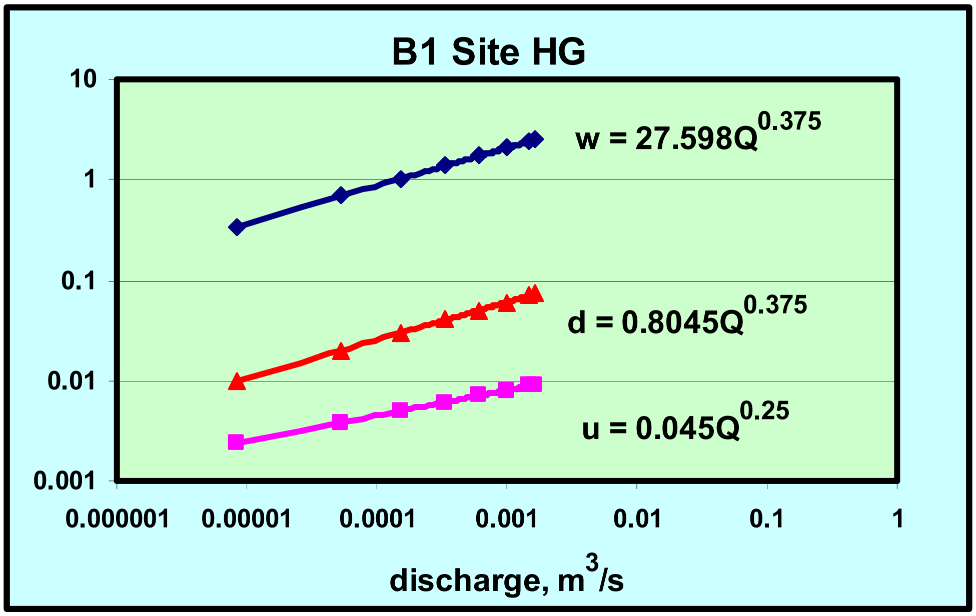
c.4. **Model D** - WWTP design discharge; 7Q10 boundary flow; WWTP total nitrogen =0.855 mg/l, TP=0.092 mg/l, $CBOD_5$=1.5 mg/l; nonpoint source total nitrogen =0.855 mg/l, TP=0.092 mg/l, Chlorophyll-A=5 ppb, and $CBOD_5$=1.0 mg/l (Allocation run)

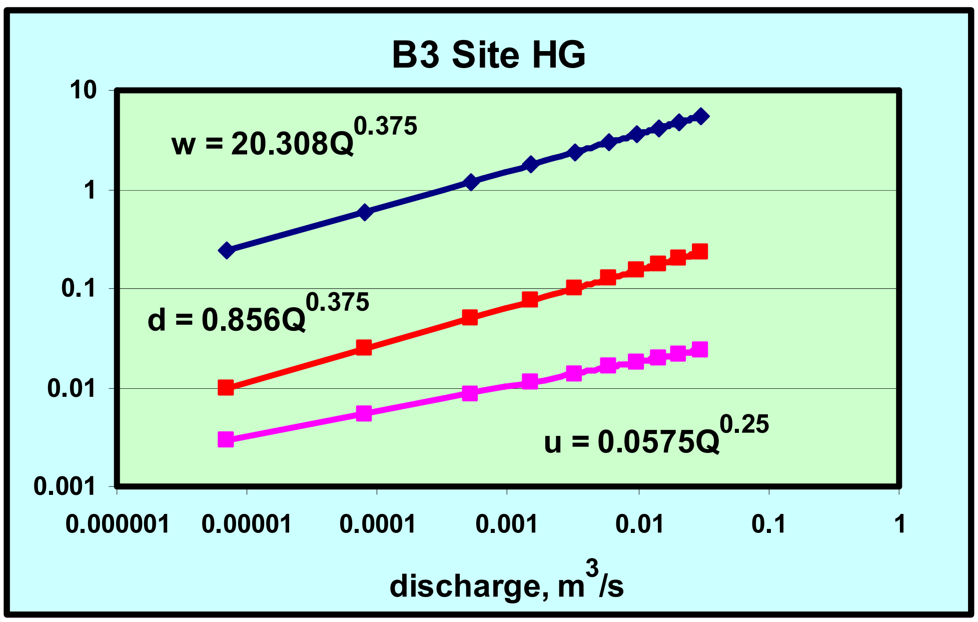
II. Model Results

2.1 Model Results - Hydraulics/Hydrology

a. Hydraulic Geometry Functions

Figure B2 (three charts) shows the hydraulic geometry functions for the flow measurements on August 5, 2003 at MB1, MB3 and MB4.


B1 Site HG
w = 27.598Q^0.375
d = 0.8045Q^0.375
u = 0.045Q^0.25
10
1
0.1
0.01
0.001
0.000001
0.00001
0.0001
0.001
0.01
0.1
1
discharge, m^3/s


B3 Site HG
w = 20.308Q^0.375
d = 0.856Q^0.375
u = 0.0575Q^0.25
10
1
0.1
0.01
0.001
0.000001
0.00001
0.0001
0.001
0.01
0.1
1
discharge, m^3/s

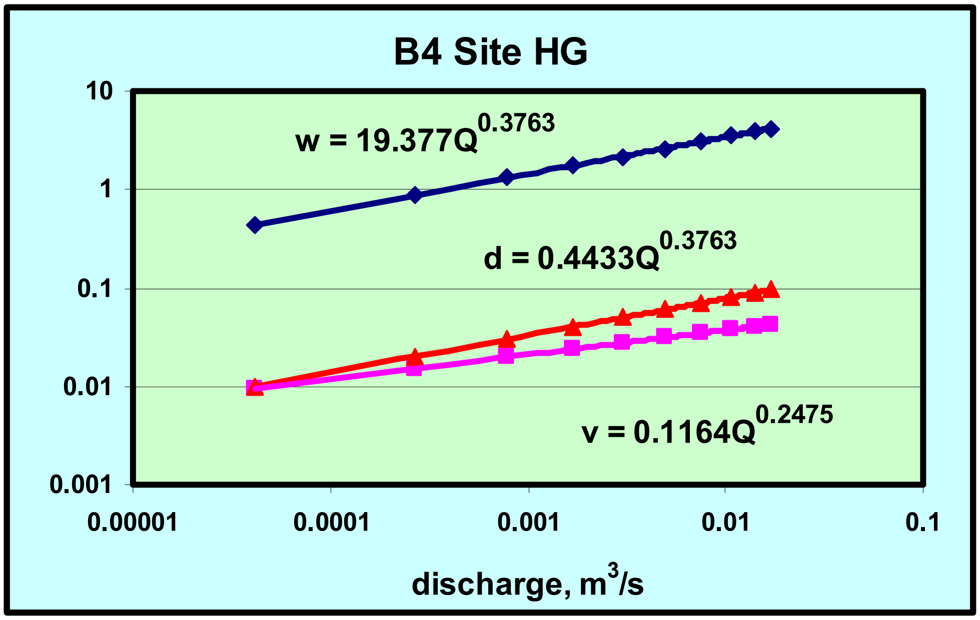
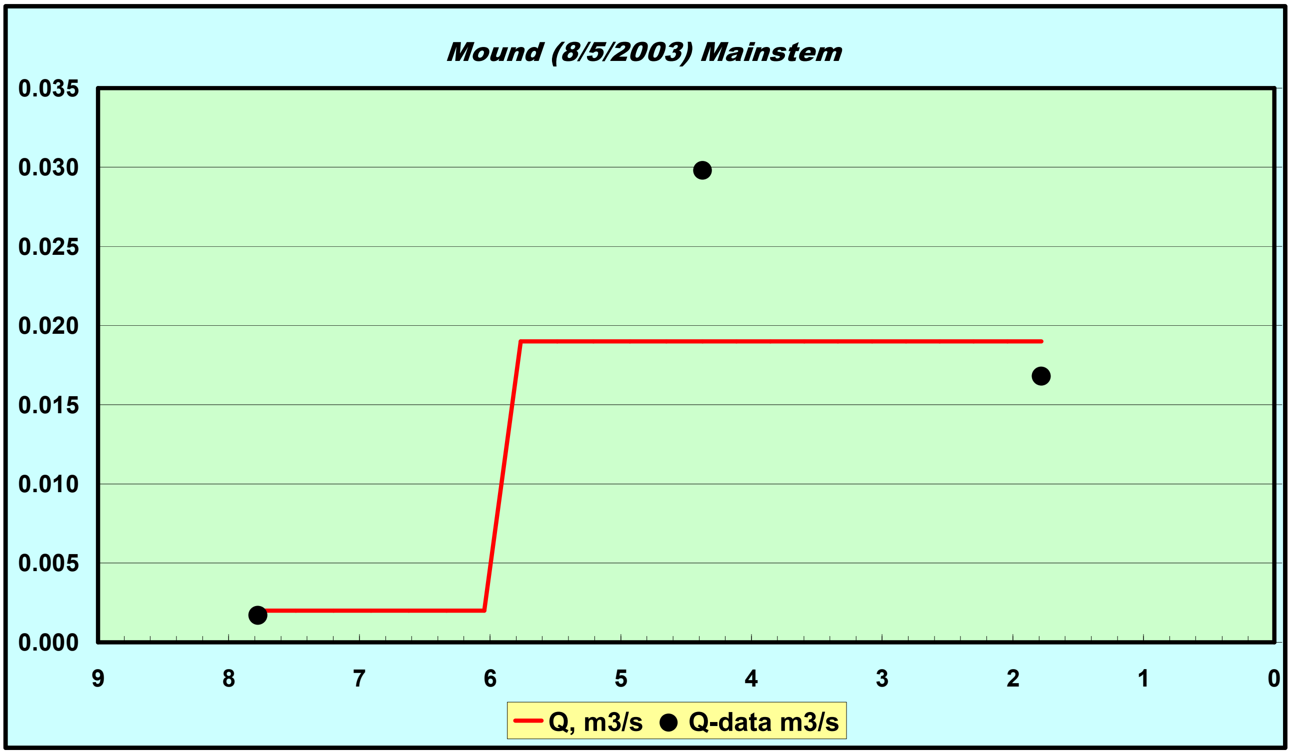
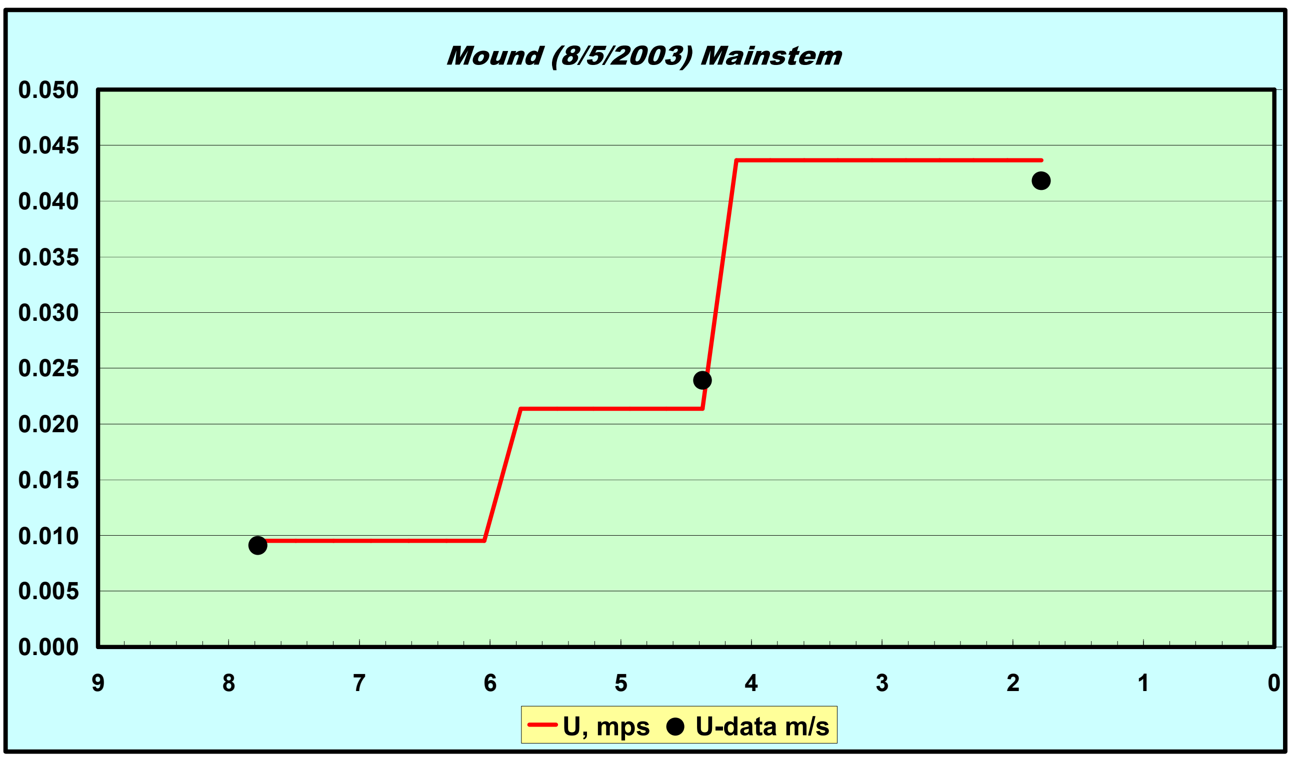


Figure B2. Hydraulic geometry functions for Mound Branch, August 5, 2003.

b. Results of the flow, depth and velocity calibration

Figure B3 (three charts below) shows the results of the flow, depth and velocity calibration using the stream survey data on August 5, 2003. Mean flow depth and velocity at MB1 (7.8 kilometers, or km), MB3 (4.9 km) and MB4 (1.8 km) were reasonably simulated. It should be noted that the stream measurements were instantaneous values (in time and space) and may not necessarily reflect steady state conditions as predicted by the model. QUAL2k assumes a steady state condition and predictions of hydraulic variables are reach averages. QUAL2k calculates flow by mass balance. With an upstream boundary flow of 0.0017 cms (cubic meters per second) and a point source discharge of 0.017 cms, a mass balance would indicate a flow of 0.0177 cms for the model segment from the point source (5.8 km) to the downstream boundary.


Mound (8/5/2003) Mainstem
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
9
8
7
6
5
4
3
2
1
0
Q, m3/s
Q-data m3/s


Mound (8/5/2003) Mainstem
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
9
8
7
6
5
4
3
2
1
0
U, mps
U-data m/s

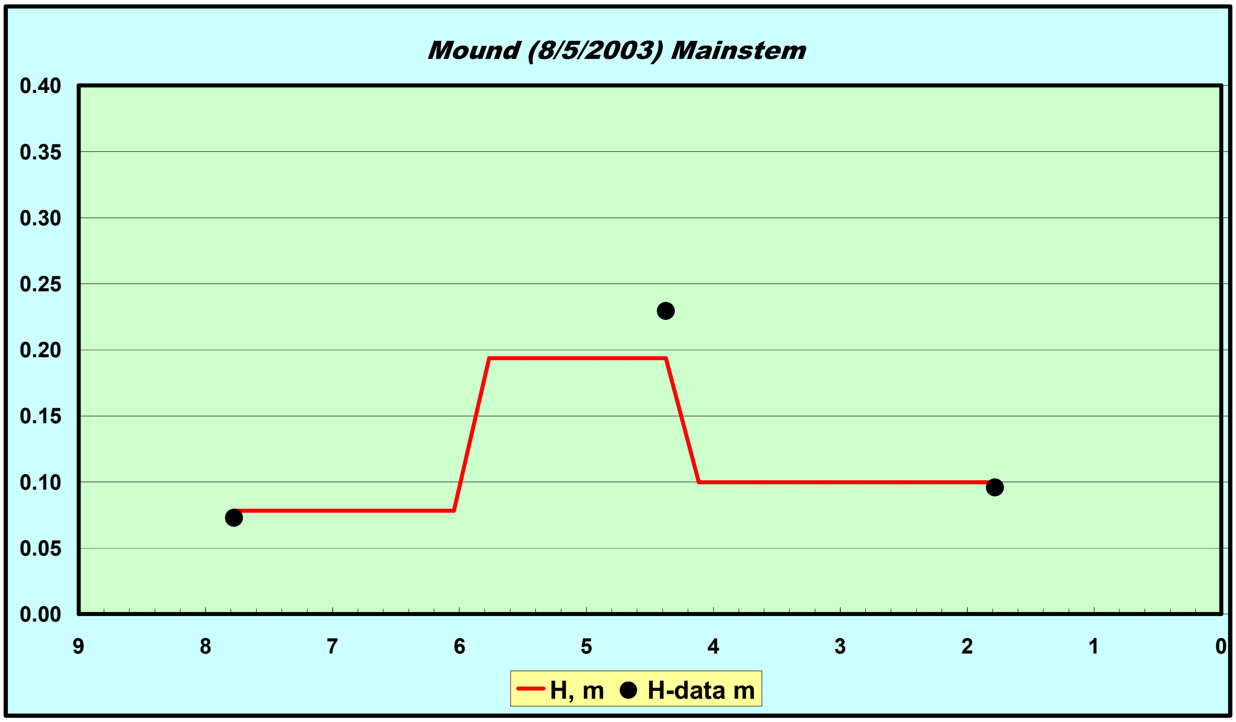


Figure B3. Observed and simulated flow (Q), velocity (U) and depth (H).

2.2 Model Results - Water Quality

a. **Diurnal Oxygen**

The comparison of observed and predicted diurnal dissolved oxygen at MB3 (0.6 mile downstream of Butler treatment plant) is shown in Figure B4. The model adequately predicts the diurnal variation of dissolved oxygen.

b. **Predicted Oxygen**

The predicted longitudinal profile of dissolved oxygen is shown in Figure B5. Also plotted are the minimum, maximum and mean dissolved oxygen at MB1 and MB3 from the diurnal measurements and the dissolved oxygen from grab samples at MB4. The large dissolved oxygen sag from upstream boundary to about 6.5 km is a result of the large $CBOD_5$ and chlorophyll-A loads and the low dissolved oxygen of the boundary flow at MB1. The $CBOD_5$ and Chlorophyll-A measured at MB1 at 12:45 pm are 27 and 358 mg/l, respectively. The diurnal measurements at MB1 indicate a dissolved oxygen range of 1.25 to 4.2 mg/l.

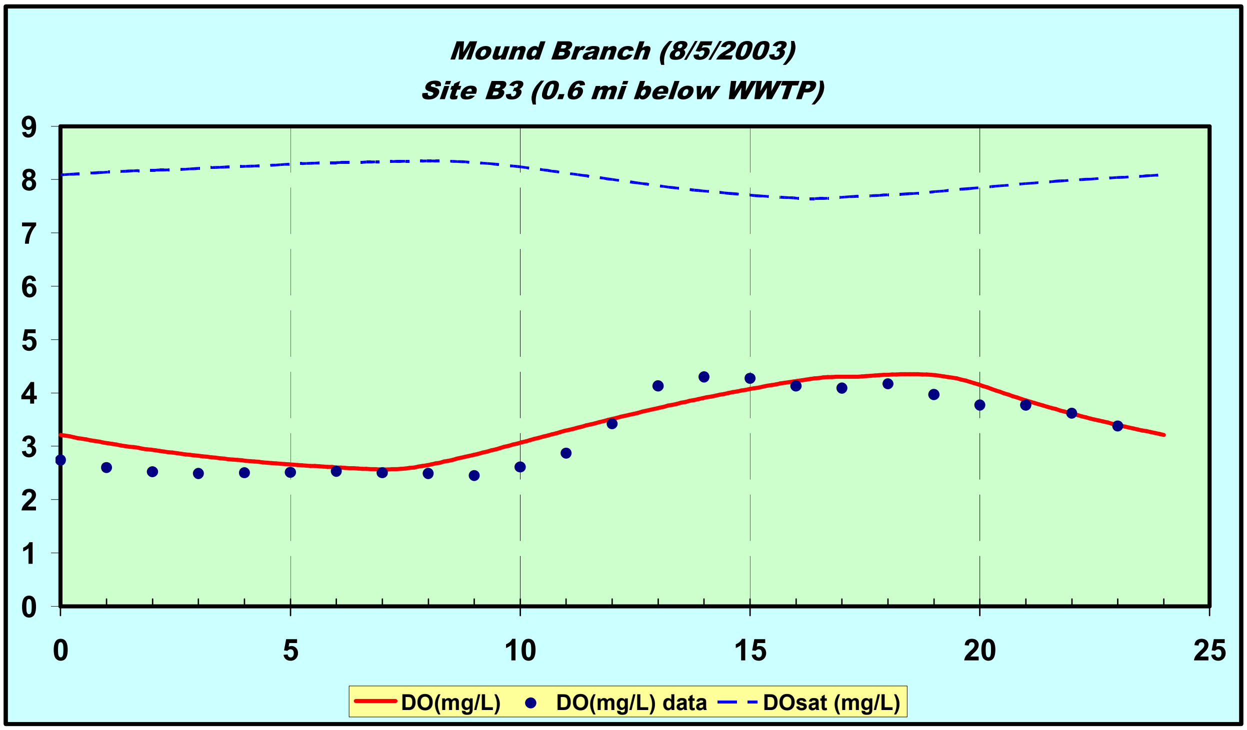


Figure B4. Observed and predicted diurnal dissolved oxygen at site B3.

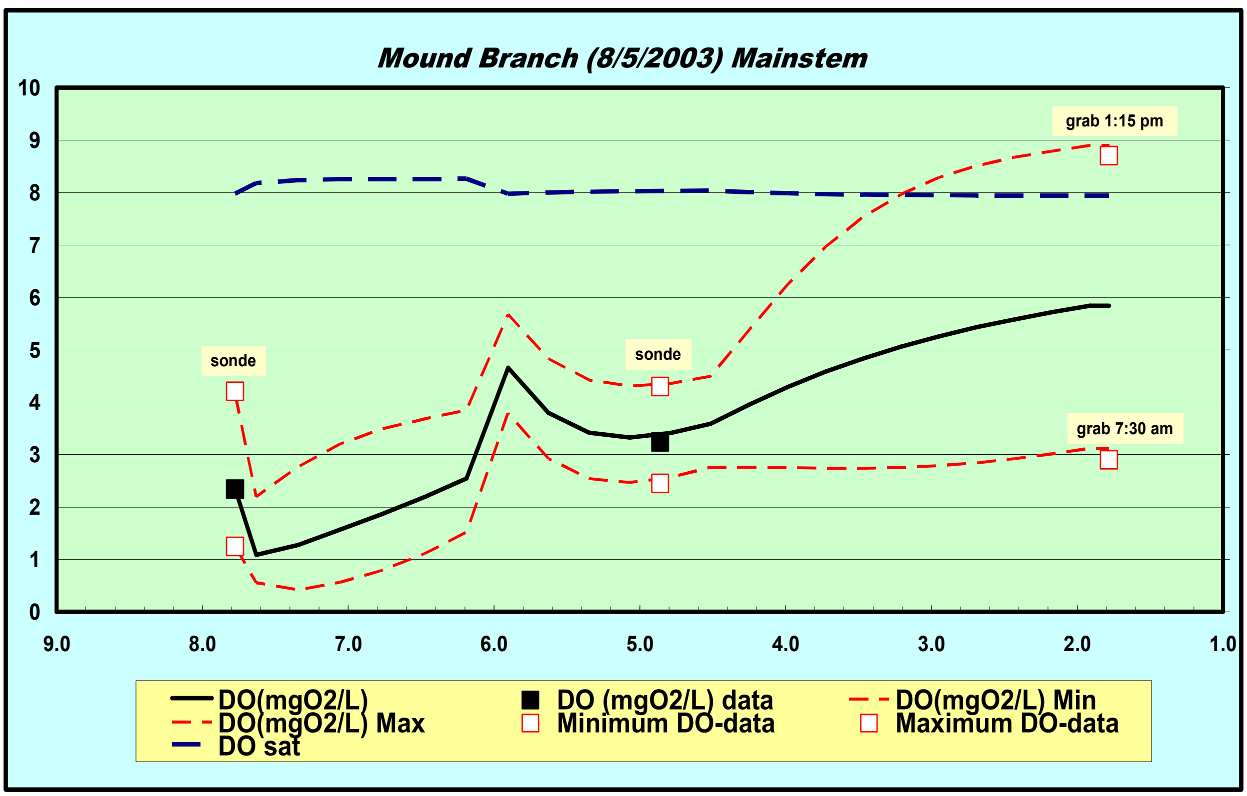


Figure B5. Predicted longitudinal profile of minimum, maximum and mean DO.

c. **Comparison of Scenarios**

Figure B6 shows the predicted longitudinal profile of minimum dissolved oxygen corresponding to the various scenarios described in Section 1.2.c. As shown in the predicted profile from model D, under critical condition the dissolved oxygen criterion is met downstream of the treatment plant when the point source $CBOD_5$ is limited to 1.5 mg/l and with the ecoregion, or EDU, reference concentrations for total nitrogen and phosphorous for both point and nonpoint sources. Upstream of the plant, the dissolved oxygen criterion is met with ecoregion reference concentrations for total nitrogen and phosphorous, 1.0 mg/l $CBOD_5$ and 5 *u*g/l Chlorophyll-A.

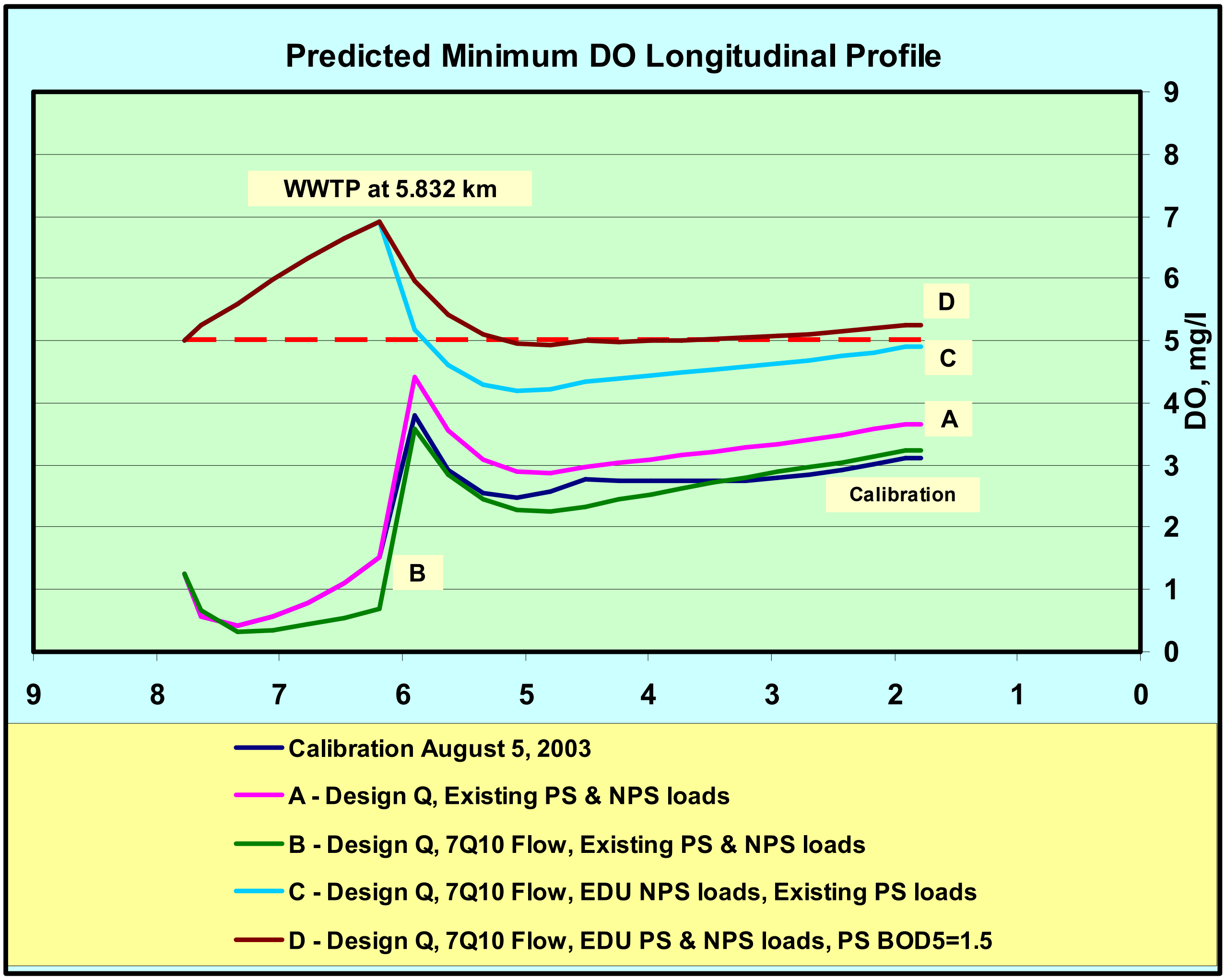


Figure B6. Predicted longitudinal profile of minimum dissolved oxygen for various simulation scenarios.

III. Wasteload and Load Allocation

Simulation results from model D were used to calculate the wasteload and load allocations for Mound Branch. These are summarized in Tables B.1.

Table B1. Allocations for 5-day Carbonaceous Biochemical Oxygen Demand in Mound Branch

	Flow Regime	**Concentration Limits**	**Allocation**
Butler treatment plant (WLA)	at Design Flow Q = 2.325 cfs (1.5 MGD)	1.5 mg/l	18.8 lbs/day
Nonpoint Source (LA)	7Q10 = 0.6 cfs	1.0 mg/l	3.2 lbs/day

Appendix C

C.1. Development of Suspended Sediment Targets using Reference Load Duration Curves

Overview

This procedure is used when a lotic[10] system is placed on the 303(d) List for a pollutant and the designated use being addressed is aquatic life. In cases where pollutant data for the impaired stream is not available a reference approach is used. The target for pollutant loading is the 25th percentile calculated from all data available within the ecological drainage unit (EDU) in which the water body is located. Additionally, it is also unlikely that a flow record for the impaired stream is available. If this is the case, a synthetic flow record is needed. In order to develop a synthetic flow record calculate an average of the log discharge per square mile of USGS gaged rivers for which the drainage area is entirely contained within the EDU. From this synthetic record develop a flow duration from which to build a load duration curve for the pollutant within the EDU.

From this population of load durations follow the reference method used in setting nutrient targets in lakes and reservoirs. In this methodology the average concentration of either the 75th percentile of reference lakes or the 25th percentile of all lakes in the region is targeted in the TMDL. For most cases available pollutant data for reference streams is also not likely to be available. Therefore follow the alternative method and target the 25th percentile of load duration of the available data within the EDU as the TMDL load duration curve. During periods of low flow the actual pollutant concentration may be more important than load. To account for this during periods of low flow the load duration curve uses the 25th percentile of EDU concentration at flows where surface runoff is less than 1 percent of the stream flow. This result in an inflection point in the curve below which the TMDL is calculated using load calculated with this reference concentration.

Methodology

The first step in this procedure is to locate available pollutant data within the EDU of interest. These data along with the instantaneous flow measurement taken at the time of sample collection for the specific date are recorded to create the population from which to develop the load duration. Both the date and pollutant concentration are needed in order to match the measured data to the synthetic EDU flow record.

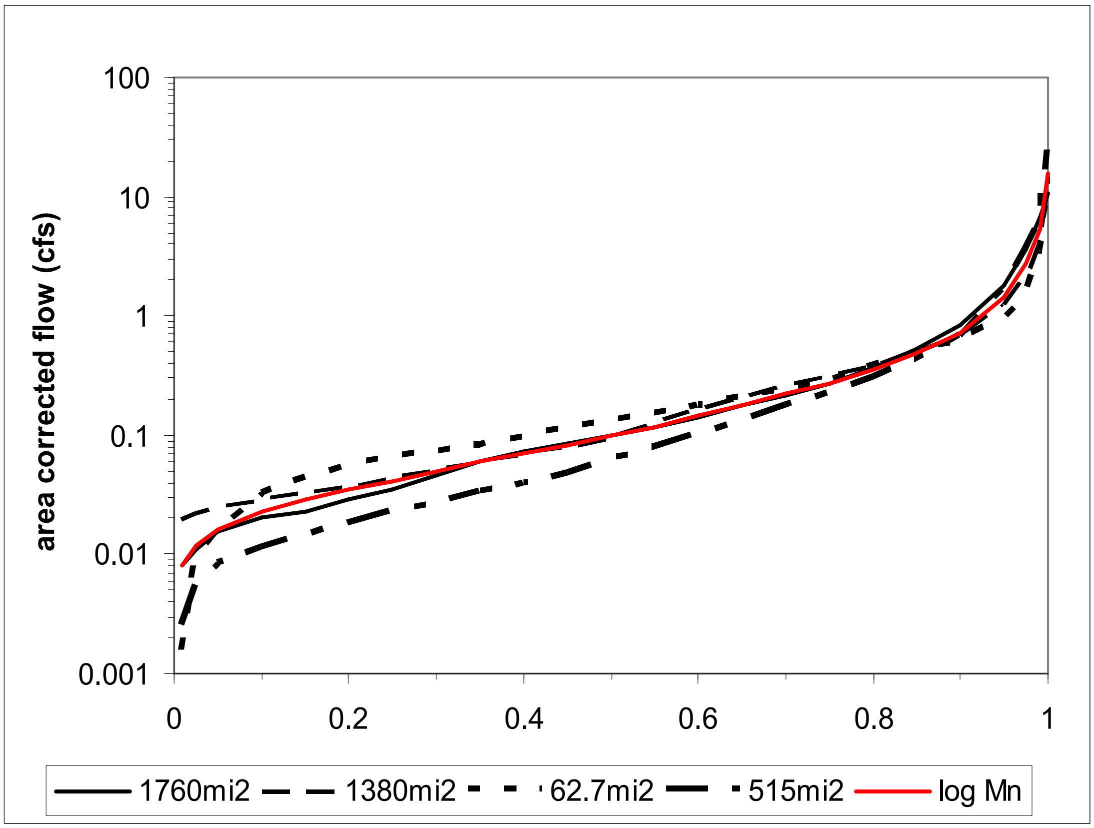
Secondly, collect average daily flow data for gages with a variety of drainage areas for a period of time to cover the pollutant record. From these flow records normalize the flow to a per square mile basis. Average the log transformations of the average daily discharge for each day in the period of record. For each gage record used to build this synthetic flow record calculate the Nash-Sutcliffe statistic to determine if the relationship is valid for each record. This relationship must be valid in order to use this methodology. This new synthetic record of flow per square mile is

[10] Lotic = pertaining to moving water

used to develop the load duration for the EDU. The flow record should be of sufficient length to be able to calculate percentiles of flow.

The following examples show the application of the approach to one Missouri EDU.

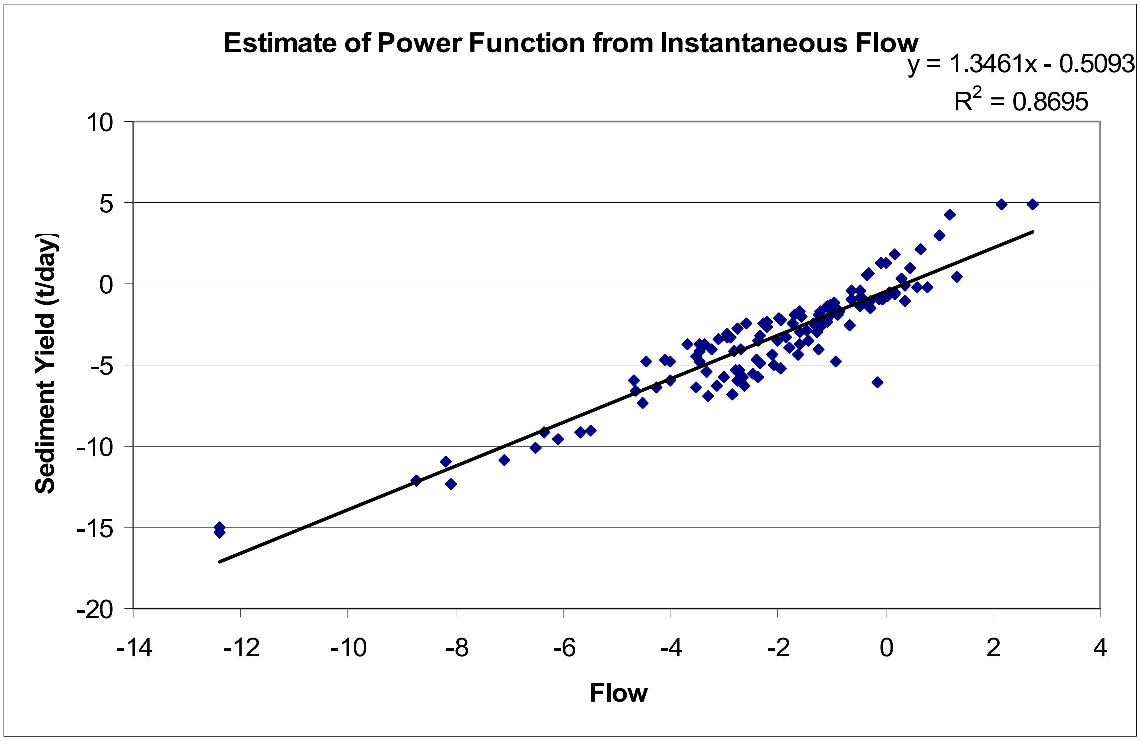
The watershed-size normalized data for the individual gages in the EDU were calculated and compared to a pooled data set including all of the gages. The results of this analysis are displayed in the following figure and table:



Gage	gage	area (mi^2)	normal Nash-Sutcliffe	lognormal Nash-Sutcliffe
Platte River	06820500	1760	80%	99%
Nodaway River	06817700	1380	90%	96%
Squaw Creek	06815575	62.7	86%	95%
102 River	06819500	515	99%	96%

This demonstrates the pooled data set can confidently be used as a surrogate for the EDU analyses.

The next step is to calculate pollutant-discharge relationships for the EDU, these are log transformed data for the yield (tons/mi^2/day) and the instantaneous flow (cfs/mi^2.) The following graph shows the EDU relationship:



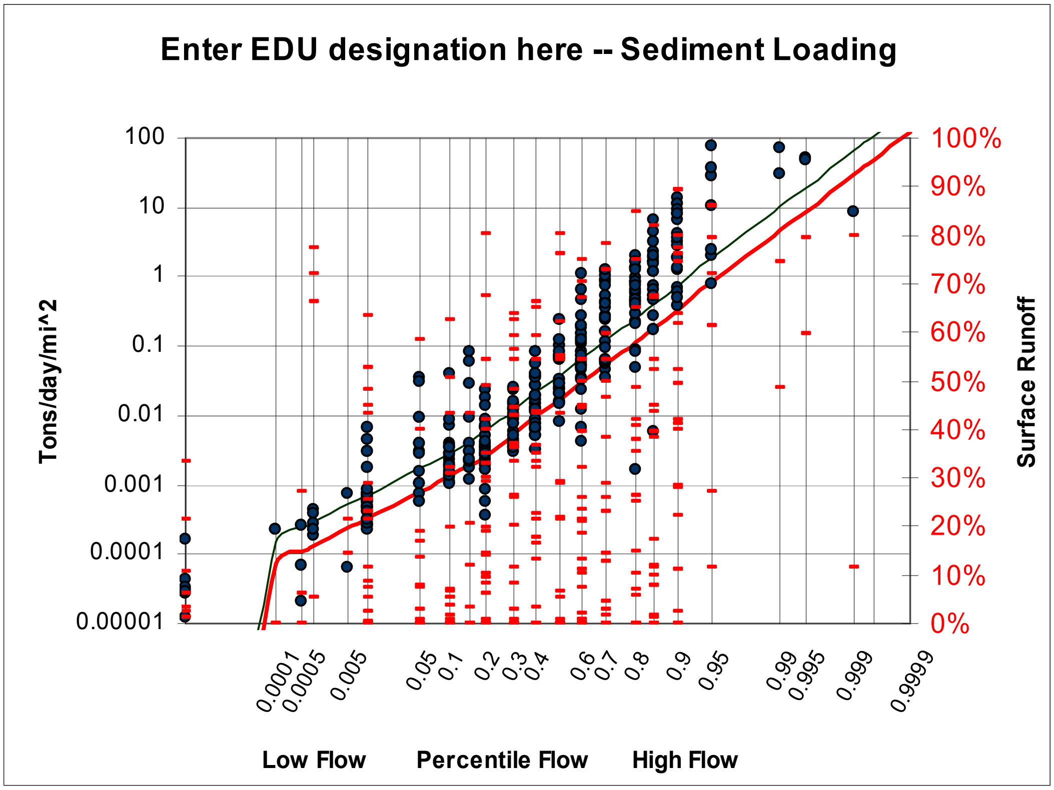
Further statistical analyses on this relationship are included in the following Table:

m	1.34608498	b	-0.509320019
Standard Error (m)	0.04721684	Standard Error (b)	0.152201589
r^2	0.86948229	Standard Error (y)	1.269553159
F	812.739077	DF	122
SSreg	1309.94458	SSres	196.6353573

The standard error of y was used to estimate the 25 percentile level for the TMDL line. This was done by adjusting the intercept (b) by subtracting the product of the one-sided Z_{75} statistic times the standard error of (y). The resulting TMDL Equation is the following:

*Sediment yield (t/day/mi^2) = exp (1.34608498 * ln (flow) - 1.36627)*

A resulting pooled TMDL of all data in the watershed is shown in the following graph:



To apply this process to a specific watershed would entail using the individual watershed data compared to the above TMDL curve that has been multiplied by the watershed area. Data from the impaired segment is then plotted as a load (tons/day) for the y-axis and as the percentile of flow for the EDU on the day the sample was taken for the x-axis.

For more information contact:
Environmental Protection Agency, Region 7
Water, Wetlands, and Pesticides Division
Total Maximum Daily Load Program
901 North 5th Street
Kansas City, Kansas 66101
Website: http://www.epa.gov/region07/water/tmdl.htm

Appendix C.2.
Suspended solids [sediment] and instantaneous discharge data for reference targeting Ecoregion 40c, the Wooded Osage Plains
(Source: USGS data provided by EPA)

Date	Flow (cfs)	TSS (mg/L)	TN (mg/L)	TP (mg/L)
USGS 06918070 Osage River above Schell City, MO				
11/8/1989	1400		1.2	0.16
1/11/1990	802			0.08
3/8/1990	8470		3	0.14
5/8/1990	5360		1.4	0.15
7/12/1990	1080		1	0.09
9/6/1990	1.4		1	0.1
5/8/1991	1210		2	0.22
7/18/1991	540		0.39	0.17
9/5/1991	500		2.3	0.16
11/5/1991	200		0.66	0.07
1/9/1992	720		2.3	0.1
3/3/1992	380		1.4	0.1
5/6/1992	500		1.4	0.07
7/9/1992	16000		1.3	0.5
9/2/1992	300			0.07
11/19/1992	13700		1.5	0.34
1/12/1993	4160		1.3	0.07
3/10/1993	6440		1.5	0.13
5/5/1993	7740		1.6	0.14
7/27/1993	45300		1.2	0.26
9/28/1993	48200		0.78	0.15
11/29/1994	13900	270	1.7	0.28
3/7/1995	1430		1.1	0.11
4/13/1995	1860		1.2	0.17
5/16/1995	13900		1.4	0.13
6/27/1995	45400	140	1.6	0.14
8/22/1995	822	82	1.5	0.15
11/7/1995	228	30		0.1
4/1/1996	226		1.1	0.12
5/7/1996	15500		7.5	1.4
6/19/1996	5960	480	2.8	0.46
8/6/1996	493		1.4	0.16
11/5/1996	2110	50	0.82	0.08
3/4/1997	15400		1.9	0.19
4/15/1997	27800		2.7	0.36
5/13/1997	1100		1.3	0.14
6/24/1997	2480	190	1.8	0.18
8/13/1997	80		1.1	0.08
11/6/1997	401	31		
6/8/1998	545	150		
3/9/1999	13300		3.1	0.7

Date	Flow (cfs)	TSS (mg/L)	TN (mg/L)	TP (mg/L)
4/6/1999	1150			0.1
5/17/1999	18600		1	0.07
6/7/1999	7920	195	1.6	0.25
8/25/1999	148			0.14
11/1/1999	253	21		0.12
3/20/2000	8830		2.6	0.39
4/11/2000	662			0.1
5/22/2000	300	61	0.91	0.13
6/5/2000	385		1.5	0.17
7/24/2000	3560		2.3	0.67
11/27/2000	177	11	0.86	0.07
3/21/2001	9090		3.1	0.28
4/18/2001	2720		1.8	0.19
5/21/2001	5450		4	0.64
6/13/2001	5080		1.4	0.22
11/28/2001	185	24		0.09
3/11/2002	621	50	0.82	0.09
4/15/2002	949	183	1.1	0.26
5/22/2002	6400	49	1.5	0.16
6/17/2002	5600	252	1.8	0.35
7/24/2002	229	E 90[1]	1.2	0.17
11/6/2002	93	13		0.05
3/17/2003	538	75	1.3	0.13
4/15/2003	211	78		0.15
5/13/2003	2700	426	2.6	0.47
6/17/2003	1220	188	2	0.3
7/9/2003	524	120	1.3	0.2
11/4/2003	113	32		0.08
3/9/2004	44000	164	2.5	0.56
4/19/2004	860	49		0.1
5/11/2004	783	62	0.97	0.12
6/7/2004	567	83	1.2	0.17
7/21/2004	2310	130	1.2	0.22
11/15/2004	5000	109	1.5	0.31
3/28/2005	1950	35	1.3	0.08
4/12/2005	3780	432	1.4	0.38
5/24/2005	3130	256	2.4	0.33
6/28/2005	7400	120	1.5	0.29
7/25/2005	1600	178	1.4	0.27
11/28/2005	159	23		0.07
3/22/2006	792	36	0.99	0.11
4/19/2006	330	76	0.85	0.15
5/22/2006	2590	172	1.6	0.29
6/20/2006	259	68	1.2	0.16
11/13/2006	37	18	0.8	0.06
2/26/2007	6430	264	3.1	0.58
3/6/2007	1880	156	2.4	0.41

Date	Flow (cfs)	TSS (mg/L)	TN (mg/L)	TP (mg/L)
4/16/2007	21700	560	3	0.67
5/7/2007	20500	370	2.7	0.59
6/26/2007	2420	156	1.6	0.25
7/24/2007	8320	448	2	0.6
11/5/2007	179	58	1.2	0.17
3/17/2008	3400	111	1.2	0.13
4/22/2008	4330	108	1.4	0.17
5/28/2008	19900	532	2.8	0.74
6/3/2008	15700	456	2.6	0.63
7/21/2008	785	50	1.2	0.13
10/14/2008	587	55	0.67	0.14
3/17/2009	4140	152	1.3	0.2
4/7/2009	7560	96	1.6	0.17
5/19/2009	14400	176	1.6	0.31
6/2/2009	2440	140	1.3	0.21
USGS 06919500 Cedar Creek near Pleasant View, MO				
10/14/2008	8.8	< 15[2]	E 0.33[1]	E 0.03[1]
11/3/2008	13	< 15[2]		E 0.03[1]
12/1/2008	16	< 15[2]	E 0.32[1]	E 0.04[1]
1/26/2009	34	< 15[2]	0.35	E 0.03[1]
2/3/2009	37	< 15[2]	0.24	E 0.03[1]
3/17/2009	66	< 15[2]		E 0.03[1]
4/7/2009	235	< 15[2]	0.73	0.04
5/19/2009	430	< 30[2]	1.2	0.1
6/2/2009	106	< 15[2]	1	0.06
10/14/2008	8.8	< 15[2]	E 0.33[1]	E 0.03[1]
11/3/2008	13	< 15[2]		E 0.03[1]
12/1/2008	16	< 15[2]	E 0.32[1]	E 0.04[1]
1/26/2009	34	< 15[2]	0.35	E 0.03[1]
2/3/2009	37	< 15[2]	0.24	E 0.03[1]
3/17/2009	66	< 15[2]		E 0.03[1]
4/7/2009	235	< 15[2]	0.73	0.04
5/19/2009	430	< 30[2]	1.2	0.1
6/2/2009	106	< 15[2]	1	0.06
USGS 06919925 Brush Creek above Collins, MO				
5/25/1994	13			< 0.01[1]
9/21/1994	0.39			0.02
5/23/1995	62			0.01
USGS 06921590 South Grand River at Archie, MO				
6/14/2007	49	22	1.8	0.13
7/13/2007	59	30	1.7	0.13
9/13/2007	5.2	12	2.1	0.16
11/30/2007	4.1	< 10[2]	3.2	0.45
1/17/2008	61	15	1.8	0.16
3/20/2008	579	128	2.4	0.22
5/14/2008	280	180	1.8	0.3
7/23/2008	14	17	1	0.09

Date	Flow (cfs)	TSS (mg/L)	TN (mg/L)	TP (mg/L)
9/11/2008	11	27	0.92	0.17
10/9/2008	13	< 15[2]	0.71	0.09
1/6/2009	121	< 15[2]	1.3	0.06
3/27/2009	200	130	1.3	0.17
5/19/2009	118	40	1.4	0.14
USGS 06921720 Big Creek near Blairstown, MO				
10/9/2008	11	78		0.21
11/4/2008	62		0.85	0.17
3/24/2009	198	324	1.2	0.34
5/19/2009	218	76	1.8	0.2
USGS 06922190 West Fork Tebo Creek near Lewis, MO				
10/13/1989	1			0.07
11/9/1989	1			0.03
12/7/1989	1			0.04
1/11/1990	1			0.02
2/8/1990	2.7			0.03
3/8/1990	9.3		0.6	0.03
4/4/1990	9.6			0.03
5/7/1990	9.6		1	0.04
6/7/1990	9.5		0.7	0.03
7/12/1990	9.6		1.8	0.07
8/10/1990	9			0.04
9/6/1990	1		0.8	0.06
10/16/1990	1			< 0.01[2]
11/7/1990	1			0.02
12/5/1990	1			0.02
1/9/1991	1			0.02
3/6/1991	1			0.02
4/17/1991	1			0.03
5/7/1991	8		1.4	0.08
6/4/1991	1		1.5	0.03
7/18/1991	0.1			0.07
8/12/1991	0			0.13
9/6/1991	0			0.14
USGS 3844410942043 South Trib. Muddy Creek nr Harrisonville, MO				
4/29/1992	0.19	20		0.02
5/20/1992	0.03	32	1.1	0.05
6/17/1992	0	132		0.24
8/27/1992	0.03		1.7	0.12
9/29/1992	0.05			0.07
11/4/1992	0.1		1.2	0.08
12/8/1992	0.13		0.9	0.13
1/27/1993	1.6		1.1	0.24
2/24/1993	0.2		0.7	0.08
3/24/1993	0.5		1.1	0.05
USGS 3845250942233 Muddy Creek nr Harrisonville, MO				
4/30/1992	0.14	31		0.01

Date	Flow (cfs)	TSS (mg/L)	TN (mg/L)	TP (mg/L)
5/20/1992	0.24	40	2.3	0.04
8/27/1992	0.01		2.5	0.47
12/8/1992	0.11		1.8	0.06
1/27/1993	1.7		2.7	0.22
2/24/1993	0.12		1.4	0.02
3/24/1993	0.13		1	0.03
USGS 3846130942231 North Trib. Muddy Creek nr Harrisonville, MO				
4/29/1992	0.48	9		0.03
5/20/1992	0.15	6	1.1	0.02
6/17/1992	0.03	9	0.88	0.03
8/27/1992	0.03		0.6	0.06
11/4/1992	0.27		2.6	0.8
12/8/1992	0.77		3.1	0.1
1/27/1993	3.5		2.6	0.25
2/24/1993	0.52		3.3	0.16
3/24/1993	0.56		2.8	0.08
USGS 06921582 South Grand River below Freeman, MO				
1/14/1998	95	10		
6/1/1998	112	1		
8/20/1998	3.6	23		
11/18/1998	76	14	1.1	0.07
12/3/1998	150		0.81	0.19
1/26/1999	56	12	1.3	0.07
2/24/1999	84		0.97	E 0.05[1]
3/24/1999	56		0.46	E 0.04[1]
4/14/1999	60		E 0.33[1]	< 0.05[2]
5/17/1999	995		3	0.7
6/16/1999	27	92	2	0.2
7/28/1999	4.4			0.1
8/11/1999	4.2	22	0.69	0.1
9/15/1999	6.3		0.58	0.07
10/21/1999	4			0.09
11/8/1999	3.5	12		0.18
12/8/1999	34		1.2	0.17
1/5/2000	11	3	1.2	0.09
2/16/2000	5.8		0.94	0.08
3/14/2000	12		0.6	0.09
4/11/2000	11		0.5	0.07
5/23/2000	16	75	1	0.14
6/13/2000	15		0.99	0.17
7/18/2000	4.2	37		0.14
8/17/2000	0.89			0.12
9/13/2000	0.53			0.14
10/19/2000	2.1		2.7	0.36
11/20/2000	2.4	< 10[2]	0.83	0.13
12/12/2000	1.7		1.4	0.15
1/16/2001	10	22	4.1	0.54

Date	Flow (cfs)	TSS (mg/L)	TN (mg/L)	TP (mg/L)
3/1/2001	94		3.9	0.12
3/21/2001	84		3	0.12
4/11/2001	648		3.4	0.81
5/9/2001	32	73	1.4	0.18
6/21/2001	952		3.6	1.12
7/18/2001	8.3	56	0.94	0.13
8/14/2001	1.8		0.69	0.12
9/6/2001	1.1		1.4	0.17
10/17/2001	46	61	1.3	0.23
11/13/2001	3.7	16	E 0.62[1]	0.15
12/18/2001	4.9	20	1.2	0.11
1/23/2002	3.8	12	2.3	0.21
2/20/2002	125	82	1.4	0.19
3/4/2002	22	< 10[2]	0.94	0.08
4/23/2002	120	160	2	0.24
5/15/2002	239	108	1.7	0.2
6/11/2002	19	40	0.98	0.1
7/10/2002	1.6	40		0.11
8/13/2002	8.2	41	0.9	0.16
9/25/2002	0.62	23	1.1	0.09
10/21/2002	1.3	10	E 0.47[1]	0.07
11/14/2002	0.95	< 10[2]	E 0.58[1]	0.12
12/13/2002	1.4	< 10[2]		0.08
1/7/2003	1.5	22		0.13
2/11/2003	1.5	28	2	0.41
3/5/2003	1.9	24	4.5	0.6
3/7/2003	1.5			
3/7/2003	1.5			
4/10/2003	2.8	28	E 1.1[1]	0.15
5/30/2003	2.8	36		0.15
6/19/2003	3.8	43	1.1	0.17
7/23/2003	0.35	17		0.17
8/22/2003	0.12	12		0.18
9/23/2003	1.2	12	1	0.13
11/10/2003	2.9	11		0.09
1/13/2004	8.3	< 10[2]	1.9	0.13
2/23/2004	23			
3/10/2004	107	44	2.5	0.13
5/7/2004	24	30		0.11
7/20/2004	17	44	1.2	0.17
9/22/2004	18	60	1.5	0.23
11/3/2004	105	38	1.2	0.21
1/11/2005	412	56	1.6	0.16
3/22/2005	39	13		0.1
5/6/2005	16	16	E 0.51[1]	0.07
7/22/2005	12	44	0.69	0.11
9/30/2005	8	25	1.4	0.16

Date	Flow (cfs)	TSS (mg/L)	TN (mg/L)	TP (mg/L)
11/15/2005	3.8	15		0.24
1/13/2006	3.6	< 10[2]	1.8	0.19
2/27/2006	3			
3/17/2006	14	37	0.79	0.18
5/17/2006	15	29	0.94	0.1
7/14/2006	28	92	1.6	0.29
9/11/2006	2.1	39	1	0.17
11/27/2006	1.5	17	0.6	0.18
1/12/2007	12	11	1.7	0.16
2/9/2007	31	14	2.9	0.29
3/28/2007	33	42	1	0.15
4/17/2007	194	90	1.8	0.15
5/4/2007	1380	600	3.1	0.75
USGS 06920580 Weaubleau Creek near Collins, MO				
5/8/2007	111	13	0.53	E 0.03[1]

[1] Estimated value modifier - estimate was used in calculations.
[2] Less than value modifier - one half of less than value was used in calculations.

Appendix C.3.

USGS gaging sites used for synthetic flow development

	Gage		Period of Record
USGS	06917000	Little Osage River	10/01/1989 - 06/30/2009
USGS	06918070	Osage River	10/01/1989 - 06/30/2009
USGS	06918460	Turnback Creek	10/01/1989 - 06/30/2009
USGS	06921760	South Grand River	10/01/1989 - 06/30/2008
USGS	06919500	Cedar Creek	10/01/1989 - 06/30/2009
USGS	06915000	Big Bull Creek	10/01/1989 - 06/30/2009