U.S. Environmental Protection Agency Region 7

Monegaw Creek
St. Clair County, Missouri

Total Maximum Daily Load

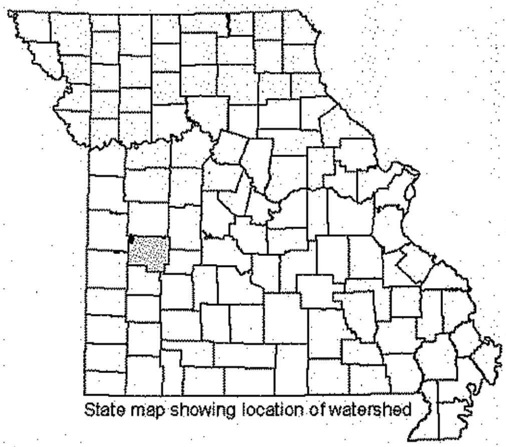
August, 2006

Approved by:

for William A. Spratlin
Director
Water, Wetlands, and Pesticides Division

08/17/06
Date

Total Maximum Daily Load (TMDL)
For Monegaw Creek
Pollutant: Sulfate


State map showing location of watershed

Name: Monegaw Creek

Location: St.Clair County near Appleton City, Missouri

Hydrologic Unit Code (HUC): 10290105-040001

Water Body Identifications (WBID): 1234

Missouri Stream Classification: Class C[1]

Beneficial Uses[2]:
- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Protection of Human Health associated with Fish Consumption
- Whole Body Contact Recreation (Swimming)

Use that is impaired: Protection of Warm Water Aquatic Life

Size of Impaired Segment: 3.0 miles

Location of Impaired Segment: From (upstream end) NE ¼, Section 8, T39N, R28W to (downstream end) SW ¼, Section 21, T39N, R28W

Pollutant Source: Montee Abandoned coal mining areas in St. Clair County

Pollutant: Sulfate

TMDL Priority Ranking: Medium

1. Introduction

This Monegaw Creek Total Maximum Daily Load (TMDL) for Sulfate is being established in accordance with Section 303(d) of the Clean Water Act, because the State of Missouri determined on the 1998 and 2002 303(d) lists of impaired waters that the water quality standards (WQS) for Monegaw Creek were exceeded due to sulfate. The Missouri Department of Natural Resources' (MDNR) Water Protection Program developed and public noticed

[1]Class C streams may cease to flow in dry periods but maintain permanent pools that support aquatic life. See Missouri WQS 10 Code of State Regulations 20-7.031(1) (F).
[2] For Beneficial uses see 10 CSR 20-7.031(1) (C) and Table (H).

documentation that Monegaw Creek is meeting WQS from data collected from 2000-2003, this TMDL utilizes additional data and analysis. To meet the milestones of the 2001 Consent Decree, *American Canoe Association, et al. v. EPA*, No. 98-1195-CV-W in consolidation with No. 98-4282-CV-W, February 27, 2001, EPA is establishing this TMDL. EPA will be responding to comments on this draft TMDL after public notice ends on July 31, 2006.

The purpose of a TMDL is to determine the pollutant loading a waterbody can assimilate without exceeding the WQS for that pollutant. The TMDL also establishes the pollutant load allocation necessary to meet the WQS established for each water body based on the relationship between pollutant sources and in-stream water quality conditions. The TMDL consists of a wasteload allocation (WLA), a load allocation (LA), and a margin of safety (MOS). The WLA is the fraction of the total pollutant load apportioned to point sources. The LA is the fraction of the total pollutant load apportioned to nonpoint sources. The MOS is a percentage of the TMDL that accounts for the uncertainty associated with the model assumption and data inadequacies.

2. Background and Water Quality Problems

2.1 Physical Characteristics of Basin

St. Clair County was organized January 29, 1841, from a section of Rives County (which became Henry County); the county seat is Osceola. According to the U.S. Census Bureau, the county has a total area of 702 square miles which is divided between 677 square miles of land and 25 square miles of water. The northwest one-fourth of the county is undulating prairie.

St. Clair County is situated on the west side of southern Missouri. It is fifty miles east of Kansas and seventy miles south of the Missouri River at Lexington. The Monegaw Creek is in St. Clair, southeastern Bates, northeastern Vernon and extreme southwestern Henry counties primarily within the Osage Plains. Monegaw Creek arises in extreme southwestern Henry County and flows southeast to the Osage River. Areas along the creek were strip-mined for coal in the 1950s. Sulfide minerals, commonly found in coal and the surrounding rock, oxidize in the presence of water and oxygen to form highly acidic (low pH), iron and sulfate rich drainage, subsequently infiltrating to groundwater. Both low pH and high levels of sulfate are harmful to aquatic life. There are many types of sulfide minerals, with pyrite and marcasite being the iron sulfides most common in coal regions. In many old coal mining areas, the weathering process results in large amounts of sulfate dissolved in ground waters and in surface waters. Fresh water aquatic life cannot tolerate large amounts of dissolved substances (like salts) in the water.

2.2 Land Use Information in Basin

The West Osage Basin encompasses 6,841 square miles in Kansas and Missouri (41% lies in Missouri). There is 65% of the watershed lies in the Osage Plains and 35% lies in the Springfield and Salem plateaus. The basin is divided into six subbasins, including the Monegaw Sub-basin which is 209 square miles and completely within Missouri. Monegaw Creek originates in the northwest quarter of St. Clair County. Monegaw Creek flows southeasterly into the Osage River. The total watershed for Monegaw Creek is about 13.6 square miles.

Historically, the West Osage Basin was dominated by tall grass prairies and oak and hickory forests in uplands and along stream corridors. The West Osage Basin is rural, averaging only 21 inhabitants/ square miles, compared to the Missouri statewide average of 65 inhabitants/ square miles. Land use in Missouri is primarily agriculture (78%), forest (20%) and mine areas (0.7 %). Row crops, pasture and hay production, beef, swine and dairy cattle dominate the agricultural activities. The basin is 98% privately owned. Forest acreage in the basin increased 71% between 1959 and 1989. There are 45 public use areas totaling almost 37,000 acres and 40 miles of stream frontage in public ownership.

All waters of the state, as per Missouri WQS, must provide suitable conditions for aquatic life. The conditions include both the physical habitat and the quality of the water. TMDLs are not written to address habitat, but are written to correct water quality conditions.

Monegaw Creek was listed on the 1998 and 2002 303(d) list for sulfate impairment from the Montee Abandoned Mine Land (AML) area. Monegaw Creek was not acidified, but was mineralized by sulfate leaching from spoils or coal waste areas (MDNR 1992a). Mineralized groundwater moving through the spoils produced high levels of sulfate in Monegaw Creek all the way to its confluence with main stem of Osage River. Monegaw Creek was placed on the 303(d) list due to water quality measurements near Appleton City that showed high levels of conductivity, which is a measure of the amount of dissolved substances. Conductivity strongly correlates with the amount of sulfate plus chloride in solution. The Missouri WQS for dissolved substances is 1,000 milligrams per liter (mg/L) of sulfate plus chloride. Levels of chloride in Missouri streams are typically much less than 100 mg/L so most dissolved substances problems are related to high levels of sulfate. The Montee AML around Monegaw Creek was identified as the source of the sulfate and monitoring of the stream for sulfate and chloride began in 2000.

In 1977, the Abandoned Mine Reclamation fund had been established as a means to provide funding to recover abandoned coal mine lands in the United States. Using this authority, the MDNR reclaimed two areas along Monegaw Creek. These included the Montee project on 78 acres, completed in 1987 at a cost of $647,295 and the Appleton City project on seven acres, completed in 1992 at a cost of $69,675. These were accomplished mainly by re-contouring the surface of the land, eliminating acid ponds, burying acid-forming spoils and establishing permanent vegetation. Data collected from 2000-2003, show that sulfate levels are much improved since the reclamations were completed. In fact, Monegaw Creek did not exceed WQS in that time frame (Data, Appendix B). The table of recent water quality data (Appendix B) shows that on Monegaw Creek there are three miles of highly mineralized water that still exceeds the state standard for sulfate. Remaining sulfate problems presently result from the movement of shallow groundwater through spoils and buried coal wastes and the emergence of these ground waters into the Monegaw Creek. Maps of the areas and graphs summarizing the existing data are contained in the appendices at the end of this document.

3. Description of the Applicable Water Quality Standards and Numeric Water Quality Targets

Beneficial Uses

The designated uses of Monegaw Creek, WBID 1234, are

- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Protection of Human Health associated with Fish Consumption
- Whole Body Contact Recreation (Swimming)

The stream classifications and designated uses may be found at 10 CSR20-7.031(1) (C) and (F) and Table H.

Use that is impaired:

Protection of Warm Water Aquatic Life

Anti-degradation Policy

Missouri's WQS include the U.S. Environmental Protection Agency's (EPA) "three-tiered" approach to anti-degradation, and may be found at 10 CSR 20-7.031(2).

Tier 1 – defines baseline conditions for all waters and it requires that existing beneficial uses be protected. TMDLs would normally be based on this tier when waters are impacted by pollutants originating before the enactment of the Clean Water Law, assuring that numeric criteria (such as dissolved oxygen and ammonia) are met to protect us.

Tier 2 – Protects the level of water quality necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water in waters that are currently of higher quality than required to support these uses. 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 or social development in the area where the waters are located; (2) full satisfaction of all intergovernmental coordination and public participation provisions; and (3) assurance that the highest statutory and regulatory requirements for point sources and best management practices for nonpoint sources are achieved. Furthermore, water quality may not be lowered to less than the level necessary to fully protect the "fishable/swimmable" uses and other existing uses.

Tier 3 – (the most stringent) applies to waters designated in the WQS as outstanding state and national resource waters; Tier 3 requires that no degradation under any conditions occurs. Management may prohibit discharge or certain polluting activities. TMDLs would need to assure no measurable increase in pollutant loading.

This TMDL will result in the protection of existing beneficial uses, which conforms to Missouri's Tier 1 anti-degradation policy.

Specific Criteria and Numeric Water Quality Target

The most severe episodes of high levels of sulfate occur during low flow conditions when there is little or no upstream flow to dilute the drainage from these abandoned mine lands. For this reason the critical flow condition for this TMDL is 7Q10 low flow.

Numeric Water Quality Target for Sulfate: Sulfate and Chloride criteria for the protection of aquatic life are linked in Missouri's WQS. Because tributaries to Monegaw creek each have a 7Q10 low flow of less than one (1) cubic foot per second, the in-stream concentration of chloride plus sulfate in Monegaw creek shall not exceed one thousand milligrams per liter (1,000 mg/L) at the 7Q10 flow per 10 CSR 20-7.031 (4) (L) 1.[3]

4. Loading Capacity – Linkage Water Quality and Pollutant Sources

The Load capacity (LC) is defined as the maximum pollutant load that a stream can assimilate and still attain WQS. It is equal to the sum of the Load Allocation (LA), the Waste Load Allocation (WLA) and the Margin of Safety (MOS) and can be expressed as an equation:

$$LC = LA + WLA + MOS$$

Dry weather design flow from the Monegaw Creek AML can not be accurately determined because surface flow and seepage rates from this area are variable. Monegaw Creek is a Class C stream, which ceases to flow in dry periods but maintains permanent pools that support aquatic life. Dry weather design flow is therefore 0.1 cubic feet per second (cfs) or less. Since there can be minimal upstream dilution during dry weather conditions, the flow of water coming from the Monegaw Creek AML area will have to meet in-stream WQS for sulfate plus chloride.

Sulfate

For sulfate, load capacity is the combined sulfate plus chloride WQS of 1,000 mg/L. Using the numeric water quality target and a margin of safety, an in-stream sulfate plus chloride target of 900 mg/L should ensure that WQS are met and maintained in Monegaw Creek. A margin of safety of 100 mg/L or ten percent (10%) would ensure combined sulfate and chloride totals on Monegaw Creek would remain below 1,000 mg/L.

$$900 \text{ mg/L} + 100 \text{ mg/L (MOS)} = 1{,}000 \text{ mg/L}$$

The paucity of specific in-stream data does not allow for the generation of a site specific TMDL curve and a generalized ecological drainage unit evaluation was therefore used, as shown in the Figure 1 below.

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[3] 7Q10 is the lowest average flow for seven consecutive days with a recurrence interval of ten years.

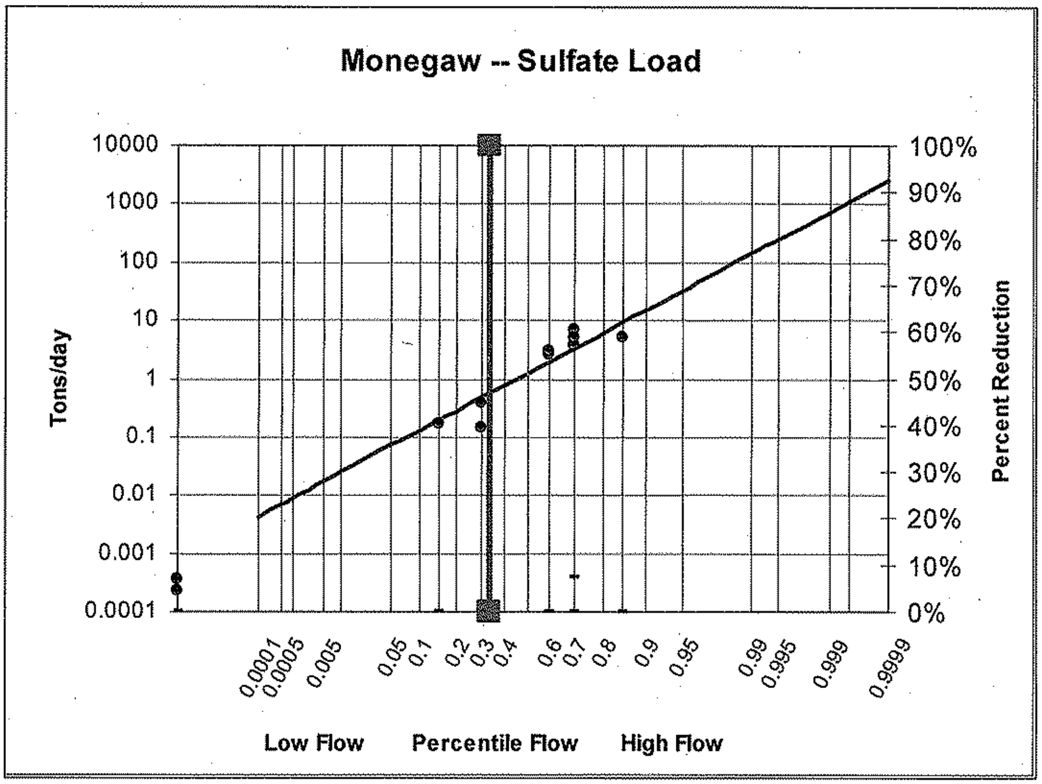


Figure 1—TMDL curve over the range of flows.

For a full description of the development of a small drainage area flow, refer to Appendix D.

5. Load Allocation (Nonpoint Source Loads)

Load Allocation is the maximum allowable amount of the pollutant that can be assigned to nonpoint sources. Using the numeric water quality target and a margin of safety, an in-stream sulfate plus chloride target of 900 mg/L should ensure that WQS are met and maintained in Monegaw Creek. The load allocation is set at 90% of the TMDL curve shown in Figure 1. For example, at the flow probability of 0.7, the TMDL is about 5 tons/day of sulfate and the LA would therefore be 4.5 tons/day of sulfate.

6. Waste Load Allocation (Point Source Loads)

This WLA is based on the fact that streams are particularly susceptible to the influence of point source discharge during low flow conditions. The town of Appleton City has one municipal wastewater treatment facility (WWTF- MO-0021105) that discharges treated effluent to a tributary of Monegaw Creek. The permit does not include monitoring or effluent limits for sulfate plus chloride. The WLA for this NPDES permitted facility water quality criteria is derived by considering the "end-of-pipe" criterion. The WLA is set at 900 mg/L of sulfate which corresponds to 2.93 tons/day of sulfate at design flow of 0.78 mg/day. The actual flow in the permit is 0.14 mg/day corresponding to 0.57 tons/day. Any future discharges would be required by the Missouri State Operating Permit (per the EPA NPDES permit) to meet the in-stream chloride plus sulfate criterion of 1,000 mg/L.

7. Margin of Safety (MOS)

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

(1) Explicit – Reserve a numeric portion of the loading capacity as a separate term in the TMDL.

(2) Implicit – Incorporate the MOS as part of the critical conditions for the waste load allocation and the load allocation calculations by making conservative assumptions in the analysis.

Because the modeling of Monegaw Creek TMDL consists solely of data trend analysis, no assumptions were made regarding pollutant fate and/or transport. An explicit margin of safety will be utilized. The MOS includes an in-stream allocation for the chloride portion of the combined sulfate plus chloride standard.

No other significant sulfate plus chloride sources exist within the watershed, therefore a MOS equal to a ten percent reduction (10%) or 100 mg/L ($SO4 + Cl$) of the loading capacity has been selected. If future in-stream monitoring indicates applicable WQS are exceeded, the TMDL will be reopened.

8. Seasonal Variation

The water quality data collected to this date represents all seasons. The TMDL curve represents flow under all seasonal conditions. While critical condition is during periods of low flow, the LA and TMDL (expressed as concentrations) are applicable at all flow conditions, hence all seasons. Missouri's WQS do not distinguish seasonal differences when determining applicable sulfate plus chloride water quality criteria. The TMDL for sulfate plus chloride should ensure compliance with the WQS year-round.

9. Monitoring Plans for Monegaw Creek

As listed in the public noticed document (January 13- February 12, 2006), MDNR has a quality assurance project plan that calls for five sites along Monegaw Creek to be monitored six times a year on a regular basis. The MDNR's Southwest Regional Office conducts the monitoring. Parameters to be monitored are temperature, pH, sulfate, chloride, conductivity, alkalinity, acidity, flow, and dissolved oxygen. To ensure that water quality is being maintained and protected in Monegaw Creek, water quality monitoring will continue.

10. Public Participation

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

This water quality limited segment of Monegaw Creek of St. Clair County, Missouri, is included on the approved 1998 and 2002 303(d) lists for Missouri. This TMDL is being produced by EPA to meet the requirements of the 2001 Consent Decree, *American Canoe Association, et. v.* EPA, No. 98-1195-CV-W in consolidation with No. 98-4282-CV-W, February 27, 2001. EPA is developing this TMDL in cooperation with the State of Missouri, and EPA is establishing this TMDL at this time to fulfill the *American Canoe* consent decree obligations. Missouri may submit and EPA may approve another TMDL for this water at a later time.

When MDNR public noticed this waterbody as meeting WQS, the public notice period was from January 13, 2006, to February 12, 2006. As part of the public notice process, MDNR maintained a distribution list of interested persons to provide notification of issues relating to Monegaw Creek TMDL. Groups that received the public notice announcement included the Missouri Clean Water Commission, the Water Quality Coordinating Committee, Stream Team volunteers in the county and the legislators representing St. Clair. No comments were received. The same groups will receive notice of this TMDL and are invited to provide comment. EPA will be responding to comments on this draft TMDL after public notice ends on July 31, 2006, and will post the response to comments on the EPA website: http://www.epa.gov/region07/water/apprtmdl.htm#Missouri.

12. Appendices:

Appendix A - Topographic map of Monegaw Creek, impaired segment and sampling site
Appendix B - Data for Monegaw Creek
Appendix C - Total Maximum Daily Load Information Sheet for Monegaw Creek
Appendix D - Load Duration Methodology

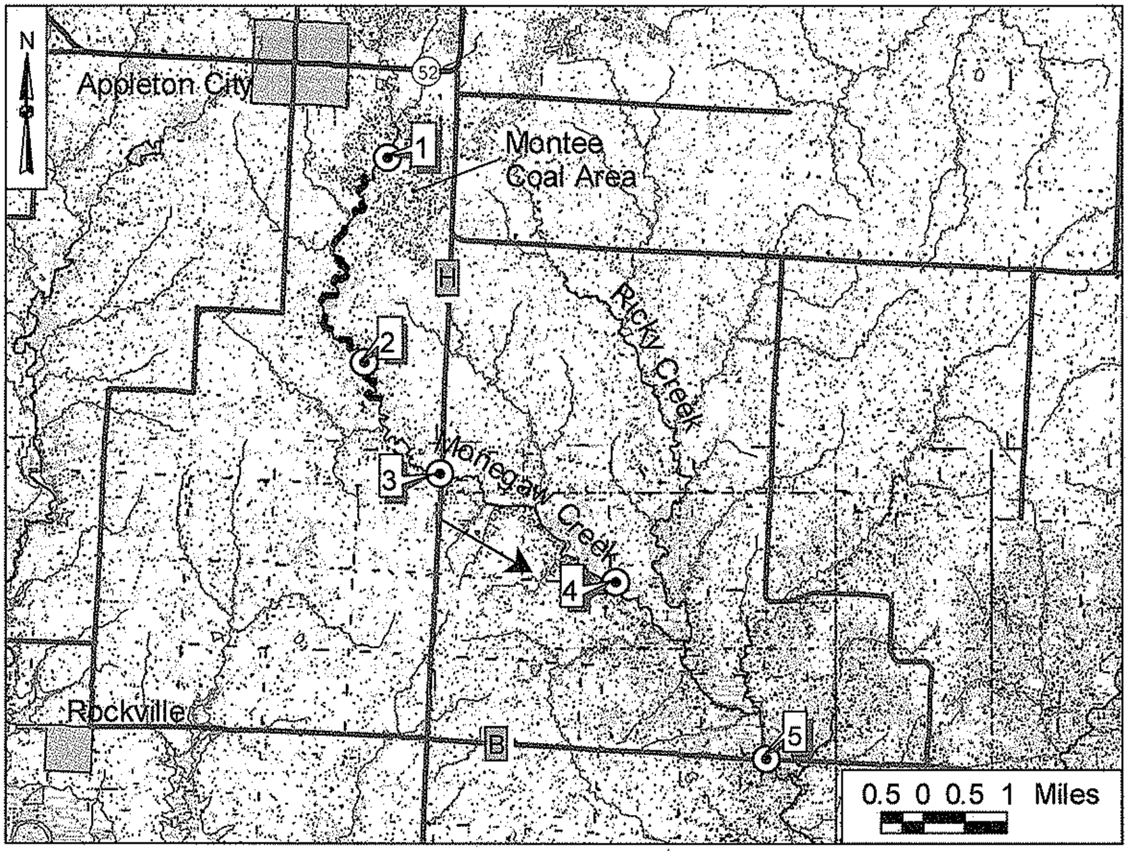
Basin Water Quality Studies:

- Evaluation of the Recovery of Fish and Invertebrate Communities Following Reclamation of a Watershed Impacted by an Abandoned Coal Surface Mine. By James F. Fairchild, Barry C. Poulton, Thomas W. May, and Stuart M. Miller, http://toxics.usgs.gov/pubs/wri99-4018/Volume1/sectionD/1501_Fairchild/pdf/1501_Fairchild.pdf

- Office of Surface Mining Annual Evaluation Summary Report for the Regulatory and Abandoned Mined Land Programs Administered by the Land Reclamation Program of Missouri for Evaluation Year 1998 (October 1, 1997 to September 30, 1998) November 1998 http://www.osmre.gov/missouri98.htm.

Appendix A

Monegaw Creek in St. Clair County, Missouri, with Sampling Sites



- - - - - Impaired Segment ——→ Direction of Flow

Site Index

1 – Monegaw Creek 1 mile below Appleton City
2 – Monegaw Creek 4.7 miles below Appleton City
3 – Monegaw Creek 7 miles below Appleton City at Highway H
4 – Monegaw Creek 10 miles below Appleton City
5 – Monegaw Creek 13.5 miles below Appleton City at Highway B

Appendix B
Water Quality Data from Monegaw Creek

Site Name	Year	Mo	Day	pH	Sulfate	Chloride	S04+Cl
Monegaw Cr. 1 mi.bl. Appleton City	2000	2	8	7.2	692	22	714
Monegaw Cr. 1 mi.bl. Appleton City	2000	3	23	7.8	559	23	582
Monegaw Cr. 1 mi.bl. Appleton City	2002	9	26	7.4	315	56	371
Monegaw Cr. 1 mi.bl. Appleton City	2003	5	29	7.6	545	26	571
Monegaw Cr. 1 mi.bl. Appleton City	2003	10	21	7.6	371	42	413
Monegaw Cr. 1 mi.bl. Appleton City	2003	10	29	7.62	521	37	558
Monegaw Cr. 4.7 mi.bl. Appleton City	2000	2	8	8	910	26	936
Monegaw Cr. 4.7 mi.bl. Appleton City	2000	3	23	7.8	506	16	522
Monegaw Cr. 4.7 mi.bl. Appleton City	2001	10	3	7	669	29	698
Monegaw Cr. 4.7 mi.bl. Appleton City	2003	3	16		946	16	952
Monegaw Cr. 4.7 mi.bl. Appleton City	2003	5	29	7.3	716	21	737
Monegaw Cr. 4.7 mi.bl. Appleton City	2003	10	21	7.5	630	25	655
Monegaw Cr. 4.7 mi.bl. Appleton City	2003	10	29	7.36	582	30	612
Monegaw Cr. 4.7 mi.bl. Appleton City	**2006**	**2**	**2**		**1060**	**23**	**1083**
Monegaw Cr. 7 mi.bl. Appleton City	2000	2	8	8.1	753	35	788
Monegaw Cr. 7 mi.bl. Appleton City	2000	3	23	7.7	376	14	390
Monegaw Cr. 7 mi.bl. Appleton City	2001	10	3	7.1	547	24	571
Monegaw Cr. 7 mi.bl. Appleton City	2002	9	26	7.4	238	9	247
Monegaw Cr. 7 mi.bl. Appleton City	2003	5	29	7.3	556	20	576
Monegaw Cr. 7 mi.bl. Appleton City	2003	10	21	7.4	637	22	659
Monegaw Cr. 7 mi.bl. Appleton City	2003	10	29	7.32	604	24	628
M Monegaw Cr. 7 mi.bl. Appleton City	2005	3	16		808	17	825
M Monegaw Cr. 7 mi.bl. Appleton City	2005	8	12		837	21	858
M Monegaw Cr. 7 mi.bl. Appleton City	2006	2	2		937	24	961
Monegaw Cr.10 mi.bl. Appleton City	2000	2	8	8.1	899	22	921
Monegaw Cr.10 mi.bl. Appleton City	2000	3	23	7.6	235	13	248
Monegaw Cr.10 mi.bl. Appleton City	2001	10	3	7	487	20	507
Monegaw Cr.10 mi.bl. Appleton City	2002	9	26	7.4	163	8	171
Monegaw Cr.10 mi.bl. Appleton City	2003	5	29	7.3	374	18	392
Monegaw Cr.10 mi.bl. Appleton City	2003	10	21	7.5	374	18	392
Monegaw Cr.10 mi.bl. Appleton City	2003	10	29	7.27	443	20	463
Monegaw Cr.10 mi.bl. Appleton City	2005	3	16		359	17	376
Monegaw Cr.10 mi.bl. Appleton City	2005	8	12		738	20	758
Monegaw Cr.10 mi.bl. Appleton City	2006	2	2		956	20	976
Monegaw Cr. 13.5 mi.bl. Appleton City	2000	2	8	7.9	694	19	713
Monegaw Cr. 13.5 mi.bl. Appleton City	2000	3	23	7.6	144	12	156
Monegaw Cr. 13.5 mi.bl. Appleton City	2001	10	3	7.2	421	15	436
Monegaw Cr. 13.5 mi.bl. Appleton City	2002	9	26	7.4	77	11	88
Monegaw Cr. 13.5 mi.bl. Appleton City	2003	5	29	7.6	665	16	681
Monegaw Cr. 13.5 mi.bl. Appleton City	2003	10	21	7.7	201	14	215
Monegaw Cr. 13.5 mi.bl. Appleton City	2003	10	29	7.31	243	14	257

Monegaw Cr. 13.5 mi.bl. Appleton City	2005	3	16		361	16	377
Monegaw Cr. 13.5 mi.bl. Appleton City	2005	8	12		502	19	521
Monegaw Cr. 13.5 mi.bl. Appleton City	2006	2	2		767	17	784
Mean:					554.95	21.16	575.89

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Appendix C
Total Maximum Daily Load Information Sheet for Monegaw Creek

This document is provided as link in electronic copies and will be included as a hard copy appendix in hard copy distributions of this TMDL.

http://www.dnr.mo.gov/env/wpp/tmdl/info/monegaw-ck-info.pdf

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Appendix D

Development of Pollutant Targets using Load Duration Curves for Drainage Areas Less Than 100 square Miles

Overview

This procedure is used when a lotic system is placed on the 303(d) impaired waterbody list for a pollutant with a numeric standard and the designated use being addressed is aquatic life. With small drainage areas it is unlikely a flow record for the impaired stream is available, in this case a synthetic flow record is needed. To develop a synthetic flow record, calculate the average of the log discharge per square mile of USGS gaged rivers for which the drainage area is entirely contained within the aquatic sub region. From this synthetic record develop a flow duration from which to build a load duration curve for the pollutant within the sub region. Using a relationship between drainage area and the percentile at which flow is 0.01 cubic feet per second (cfs), the load duration curve is modified to fit the conditions of the specific impaired stream.

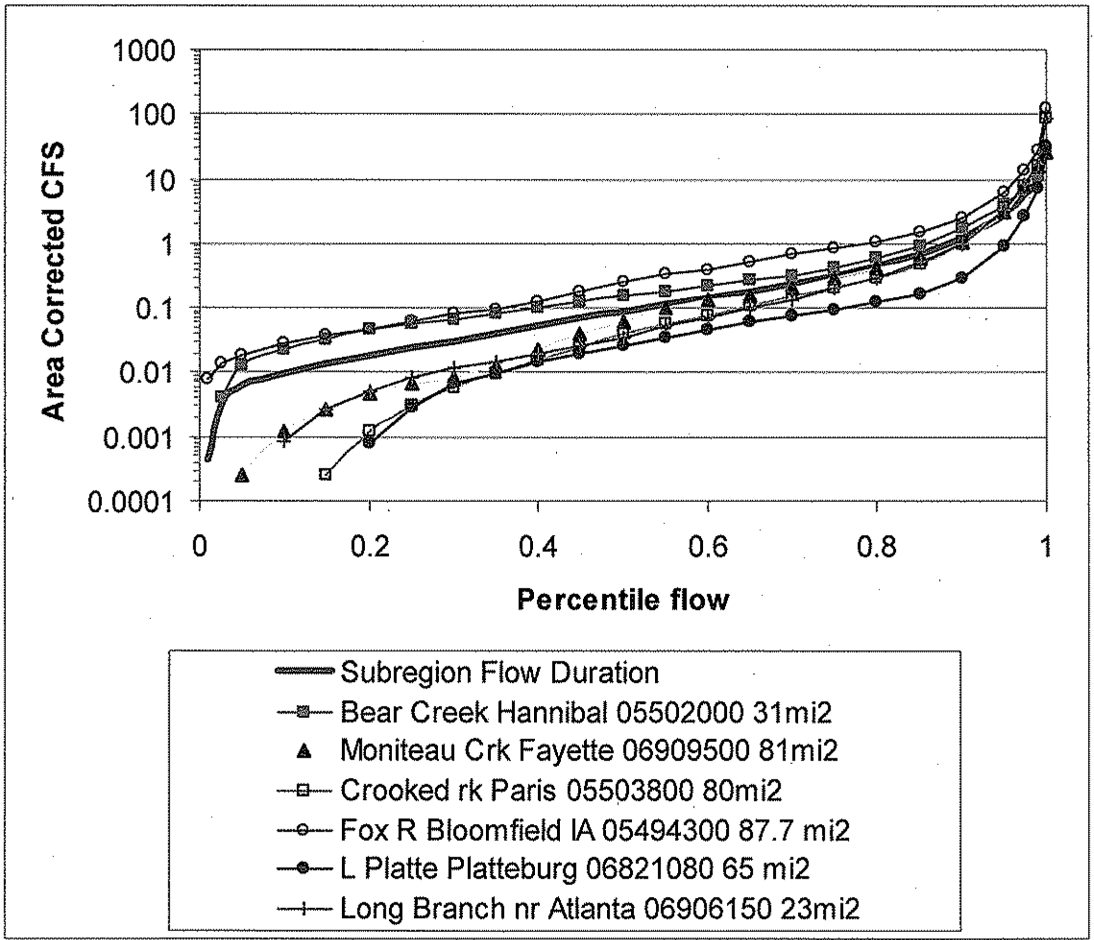
Methodology

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 sub region flow record.

Collect average daily flow data for gages with a variety of drainage areas of less than 90 square miles 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 used to develop the load duration for the aquatic sub region. The flow record should be of sufficient length to calculate percentiles of flow.

The following examples show the application of the approach to one Missouri aquatic sub region.

The watershed-size normalized data for the individual gages in the sub region 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:

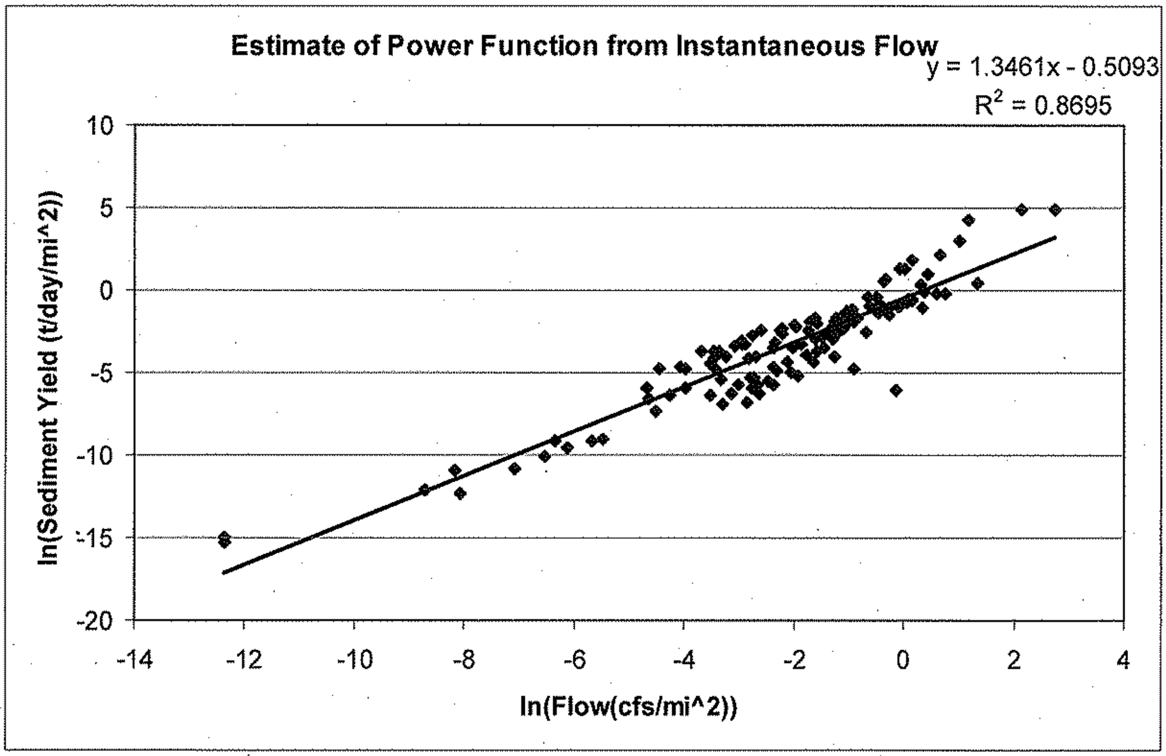


Gage	gage	area (mi^2)	lognormal Nash-Sutcliffe
Bear Creek	05502000	31	90%
Moniteau Creek	06909500	81	85%
Crooked Creek	05503800	80	62%
Fox River	05494300	87.7	46%
L Platte R	06821080	65	98%
Long Branch	06906150	23	62%

As demonstrated, the pooled data set can confidently be used as a surrogate for the sub region analyses.

The next step is to calculate pollutant-discharge relationships for the sub region; these are log transformed data for the yield (tons/mi^2/day) and the instantaneous flow (cfs/mi^2). The load duration cure (TMDL) is derived using the flow at each percentile and the numeric water quality standard. The measured data points are plotted on this graphical relationship to develop the model.

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:



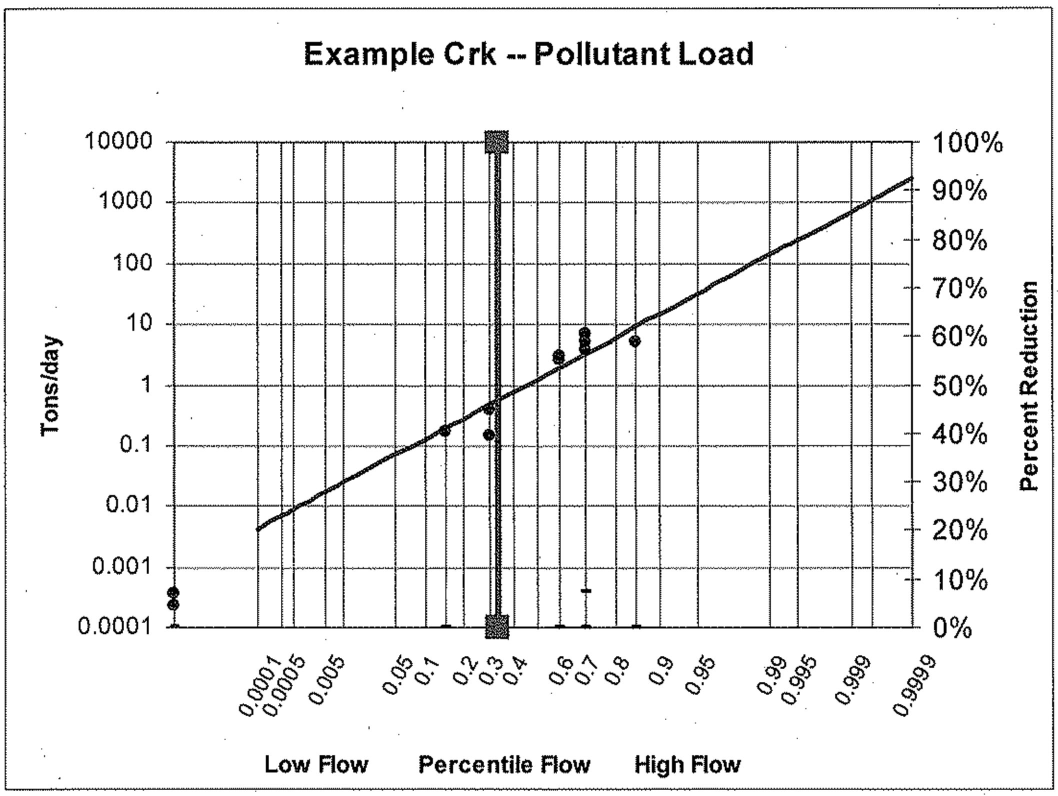
Further statistical analyses on this relationship are included in the following Table:

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%ile 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)*

The resulting TMDL of all data in the watershed is shown in the following graph. In this example a vertical red line marks the point at which the stream flow for the specific stream goes below 0.01 cfs. This point is calculated by the general relationship of percentile and drainage area. At percentiles below the red line, there is no load because the stream has no flow. Data points in this range indicate concentrations in isolated pools in the stream.



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. In the above example the impaired stream has flow of 0.01 cfs or less 30% of the time.

For more information contact:
Environmental Protection Agency, Region 7
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