U.S. Environmental Protection Agency Region 7

Mussel Fork Creek Adair, Linn, Macon, and Sullivan Counties, Missouri

Total Maximum Daily Load

September, 2006

Approved by:

/s/ 09/25/2006

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

Total Maximum Daily Load (TMDL)
For Mussel Fork Creek
Pollutant: Sediment

Name: Mussel Fork Creek

Location: In northeast Linn County, northwest Macon County, southeast Adair County, and southwest Sullivan County, Missouri

Hydrologic Unit Code (HUC): 10280202

Water Body Identifications (WBID): 674

Missouri Stream Classification: Class C[1]

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

Impairment: Sediment

Size of Impaired Segment: 29 miles

Location of Impaired Segment: From (upstream) Section 18, T58N, R17W in Sullivan County to (downstream) Section 2, T62N, R18W in Macon County.

Pollutant Source: Agricultural Nonpoint Sources

Pollutant: Sediment

TMDL Priority Ranking: High

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[1] Class C streams may cease to flow in dry periods but maintain permanent pools that support aquatic life. See Missouri Water Quality Standards (WQS) 10 Code of State Regulations 20-7.031(1)(F). The WQS can be found at the following uniform resource locator (URL): http://www.dnr.mo.gov/env/wpp/rules/index.html#Chap7

[2] Beneficial uses see 10 CSR 20-7.031(1)(C) and Table (H)

1. Introduction

This Mussel Fork Creek Total Maximum Daily Load (TMDL) for sediment is being established in accordance with Section 303(d) of the Clean Water Act. The State of Missouri placed Mussel Fork Creek on the 1998 and 2002 303(d) lists of impaired waters because water quality standards (WQS), were exceeded due to sediment. 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.

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 waterbody 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 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 can be expressed as percentage of the TMDL that accounts for the uncertainty associated with the model assumption and data inadequacies.

2. Background and Water Quality Problems

Background

Mussel Fork Creek is a small northeastern Missouri tributary of the Chariton River. The stream begins at the confluence of Little Mussel Fork in Adair County, to Section 2, Township 62 North, Range 18 West, in Sullivan County. A biological assessment and habitat study was done on Mussel Fork Creek. The study was split at the county line between Sullivan-Adair Counties (upper) and Macon-Linn Counties (lower). The 15 miles of upper Mussel Fork are listed as Class C waters, and constitute approximately the upper half of the listed segment. The 14 miles of lower Mussel Fork from Section 31, township 61 North, Range 17 West in Adair County (at the confluence of Little Mussel Creek) to Section 18, Township 58 North, Range 17 West in Macon County are also listed as Class C waters, and constitute approximately the lower half of the listed segment. It then flows south for approximately 60-70 miles through Adair, Macon, Linn, and Chariton counties to its confluence with the Chariton River approximately 2 miles south of Keytesville and approximately 6 miles north of the confluence of the Chariton River with the Missouri River. The drainage of the impaired segment of Mussel Fork Creek is approximately 350 square miles. The drainage basin is long and narrow in shape stretching almost 60 miles north to south and being approximately 8 miles wide at its widest point.

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. Because the water body addressed by this TMDL was assessed as to its biological function, many factors may have contributed to the impairment. The state of Missouri continues to do field evaluation and in the future, may define the role sediment is playing in the potential biological impairment of this waterbody. However, the water quality condition for which

Mussel Fork Creek is currently listed is sedimentation; therefore, this TMDL addresses sediment. The state of Missouri may submit and EPA may approve another TMDL or a modified 303(d) listing for this water at a later time to address new information on the impairment.

Water Quality

Northern Missouri landforms are the result of glaciation and consist of plains and low rolling hills. Agriculture is a major industry in northern Missouri including row crops and confined animal feeding operations. In many cases row crops are planted up to the banks of streams, thereby decreasing the quality of the riparian zone and leading to unstable banks and a loss of woody debris input to the stream, which in turn results in a loss of habitat. Many of the larger streams and rivers in northern Missouri have been channelized to provide more area in the river bottoms for cropland. Channelization causes a loss of channel structure, which would normally promote the formation of good quality habitat.

The quality and quantity of habitat for aquatic life have been affected generally in Missouri. A combination of natural geology and land use in the prairie portions of the State (where Mussel Fork Creek is located) is believed to have incurred these habitat alterations. In the Chariton River basin, the most serious nonpoint problem is degradation of aquatic habitat. A total of 400 miles (94 percent) of classified streams in the basin are considered to have degraded aquatic habitat.[3] The lack of infiltration of rainfall, when combined with local soil tillage and other land uses, leads to a large amount of surface runoff during wet weather. This contributes to soil erosion and high levels of sediment deposition in streams. The quality of aquatic habitat is further impaired by removal of wooded riparian vegetation elevating water temperatures in the summer, and by the channelization, or straightening, of streams. Channelization has occurred in 128 miles (30 percent) of streams in the basin. Excessive rates of sediment deposition due to stream bank erosion and sheet erosion from agricultural lands as well as changes in basin hydrology increasing flood flows and prolonged low flow conditions all are impacting the habitat. The most compelling evidence of loss or impairment of aquatic habitat has been demonstrated by the historical change in distribution of fishes in Missouri. Many species of fish no longer appear in portions of the State where they once lived. However, as mentioned above, habitat loss is not an appropriate TMDL target to correct the water quality conditions. Other water quality measures must be assessed (See Table 1 and Figure 1).

Mussel Fork Creek was placed on the 1998 and 2002 Missouri 303(d) lists for sedimentation. This was primarily based on best professional judgment because little sediment data exists to directly document sediment impacts to the stream. General fisheries data and the effect of sediment on fish were the initial data used to consider Mussel Fork Creek for 303(d) listing. For this TMDL, sediment targets were derived using generalized information from the ecological drainage unit (EDU).

Figure 1 – Mussel Fork Creek Map

[3] Chariton River Basin – 10280201, 10280202, Department of Natural Resources, Water Protection Program, Water Quality Monitoring and Assessment Section, Watershed Information Sheet. http://www.dnr.mo.gov/env/wpp/watersheds/info/10280201-2.pdf

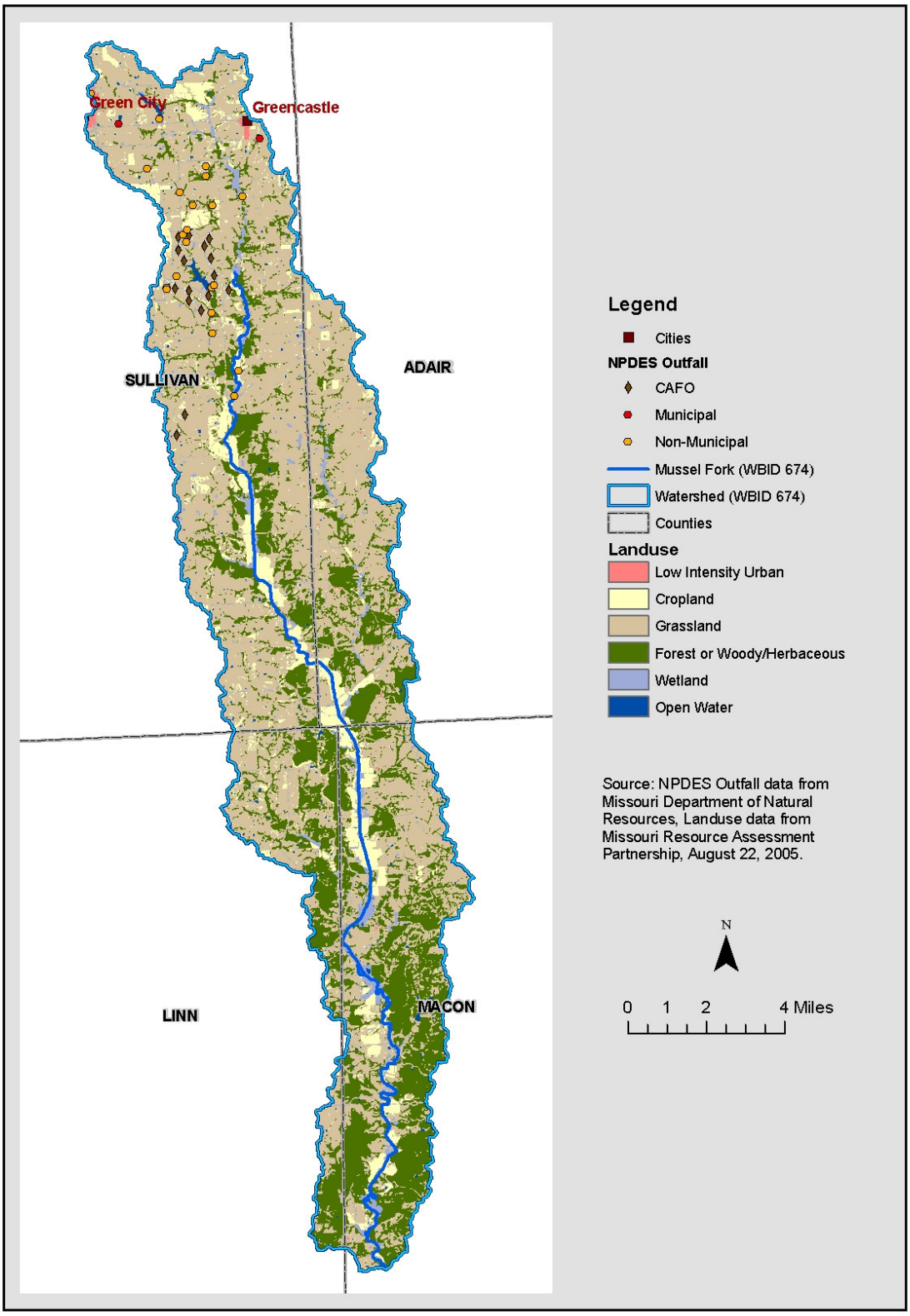

Table 1 – Mussel Fork Landuse

%	Class
60.0	Grassland
26.0	Deciduous forest/woody/herbaceous
8.2	Cropland
3.0	Wetland
1.5	Impervious
0.7	open water
0.3	low intensity urban
0.1	Barren

Since the 303(d) listing, Missouri Department of Natural Resources (MDNR) has developed a sediment protocol to determine if sediment is actually the pollutant in the streams listed and to arrive at a standard way to measure sediment. The first step of that protocol is a biological assessment to see if the biological community is actually impaired. In the case of Mussel Fork Creek, the studies measured habitat quality, water quality, and macroinvertebrate (like larval mayflies and crayfish) communities. It found that those three measures are similar among Mussel Fork Creek stream segments and are similar between Mussel Fork Creek and biocriteria reference (high quality) streams within the same Ecological Drainage Unit (see maps in Appendices A and B). For more details, refer to the study itself (Appendices E[4] and F[5]).

3. Description of Sources

Point Sources

Four NPDES permitted facilities are located within the watershed (Table 2). Green City and Green Castle Wastewater Treatment Plants (WWTP) are both three-cell lagoons. The design flows are 0.1 MGD and 0.027 MGD, respectively.

Livestock in the watershed include many horses, cattle, and hogs held in pastures, feedlots, and Combined Animal Feeding Operations (CAFO). Three operations are registered, certified or permitted within the watershed (Figure 1). CAFOs are animal feeding operations in which animals are confined to areas that are totally roofed. CAFOs typically utilize earthen or concrete structures to contain and store manure prior to land application.

All permitted livestock facilities have waste management systems designed to minimize runoff entering their operations or detaining runoff emanating from their areas. Such systems are designed for the 25 year, 24 hour rainfall/runoff event. NPDES permits, also non-discharging, are issued for facilities with more than 1,000 animal units. Total potential animal units (AU) for all facilities are approximately 56,000 AU. The actual number of animal units on site is variable, but typically less than potential numbers.

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[4] Biological Assessment and Habitat Study, Upper Mussel Fork Creek, Sullivan and Adair Counties, 2002-2003. Department of Natural Resources, Environmental Services Program

[5] Biological Assessment and Habitat Study, Lower Mussel Fork Creek, Adair and Macon Counties, 2004-2005. Department of Natural Resources, Environmental Services Program

Table – 2 Permitted Facilities

Facility - CAFOs	Permit number	County	Design Flow
PSF, Valley View Finishing Site	MO-0118478	Sullivan	Non discharging
Lawrence Vasey	MO-G010425	Sullivan	Non discharging
Joe Jones	MO-G010170	Sullivan	Non discharging
Facility - Construction			
Larry & Diane Carmack	MO-R109Q11	Sullivan	Land disturbance in designated areas
PSF, Valley View Facility	MO-R104851	Sullivan	Land disturbance in greater than 1 acre
Facility – Other			
City of Green City	MO-G640136	Sullivan	filter backwash
City of Green City	MO-0112135	Sullivan	0.1 MGD
MFA Oil Company	MO-G350095	Sullivan	Storm water, dewatering
City of Green Castle	MO-0103322	Sullivan	0.027 MGD

Non-Point Sources

Most of the watershed is grassland (60%), woodland (26%), or cropland (8.2%). The cropland in the watershed appears to be concentrated near the main stem. Cropland that is adjacent to and drains into Mussel Fork Creek, could contribute to the sediment impairment. There are three NPDES-permitted CAFOs in the watershed (Table 2), as well as other livestock (Table 3). Overland runoff can easily carry sediment into the stream. Soil, from exposed land, runs into the creek, increasing the turbidity and concentration of total suspended solids (TSS) and decreasing the transparency. Background levels of TSS come from geological sources. Sediment becomes suspended during high flow events as soil along the banks is eroded and bed sediment is resuspended. Sediment loading comes predominantly from nonpoint source pollution. Sediment from urban land may get transported into the watershed, but less than one percent of the watershed is urban (Figure 1).

Table 3 – Livestock Estimates per County[6]

	Sullivan	Macon	Adair	Linn
Cattle				
Beef	29,203	26,893	17,907	26,818
Milk	276	279	187	1,383
Cow/Calf	63,254	49,552	32,065	55,231
Hogs/Pigs	(D)	20,652	2,662	6,299
Sheep/Lambs	660	2,231	1,060	667
Poultry				

[6] USDA- NASS Quick Stats (Livestock) 2002 Census of Agriculture, Volume 1 Chapter 2: Missouri County Level Data http://www.nass.usda.gov/census/census02/volume1/mo/st29_2_001_001.pdf

Layers	527	1,126	666	829
Broilers	(D)	354	225	3,018

(D) Withheld to avoid disclosing data for individual farms.

4. Description of the Applicable WQS and Numeric Water Quality Targets

Beneficial Uses:

The designated uses of Mussel Fork Creek, WBID 674:

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

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 EPA "three-tiered" approach to anti-degradation, and may be found at 10 CSR 20-7.031(2).

Tier 1 – Protects existing uses and 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 29, 1975, the date of EPA's first WQS Regulation, or uses for which existing water quality is suitable unless prevented by physical problems such as substrate or flow.

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 (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 uses.

Tier 3 – Protects the quality of outstanding national resources, such as waters of national and state parks, wildlife refuges and waters of exceptional recreational or ecological significance. There may be no new or increased discharges to these waters and no new or increased discharges to tributaries of these waters that would result in lower water quality (with the exception of some limited activities that result in temporary and short-term changes in water quality).

Specific Criteria:

The impairment of this waterbody is based on exceedence of the general, or narrative, criteria contained in Missouri's WQS, 10 CSR 20-7.031(3)(A), (C) and (G).

(A) Waters shall be free from substances in sufficient amounts to cause the formation of putrescent, unsightly or harmful bottom deposits or prevent full maintenance of beneficial uses.
(C) Waters shall be free from substances in sufficient amounts to cause unsightly color or turbidity, offensive odor or prevent full maintenance of beneficial uses.
(G) Waters shall be free from physical, chemical or hydrologic changes that would impair the natural biological community.

When the WQS is expressed as a narrative value, a measurable indicator of the pollutant may be selected to express the narrative as a numeric value. There are many quantitative indicators of sediment, such as, TSS, turbidity, and bedload sediment, which are appropriate to describe sediment in rivers and streams.[7] TSS was selected as the numeric target for this TMDL because it enables the use of the highest quality data available, including permit conditions and monitoring data.

5. Calculation of Load Capacity

Load capacity (LC) is defined as the maximum pollutant load that a waterbody can assimilate and still attain WQS. This total load is then divided among a WLA for point sources, a LA for nonpoint sources and a MOS. The LC for this TMDL has been defined as a curve over the range of flows for Mussel Fork Creek; see Figure 2, where the solid (red) curve is the TMDL. The TMDL targets up to a 39% reduction in sediment load over the range of flows as seen in Figure 2. Measurements are shown in Figure 2, where round (black) points are loads calculated from TSS concentrations in Mussel Fork Creek and any corresponding horizontal bars (red) are the percent reduction required to meet the TMDL. Turbidity measurements taken during the biological assessment were used to estimate TSS concentrations using relationships developed by Doisey and Rabeni (2004). These estimates along with measured TSS data are shown in Figure 2.

Modeling Approaches

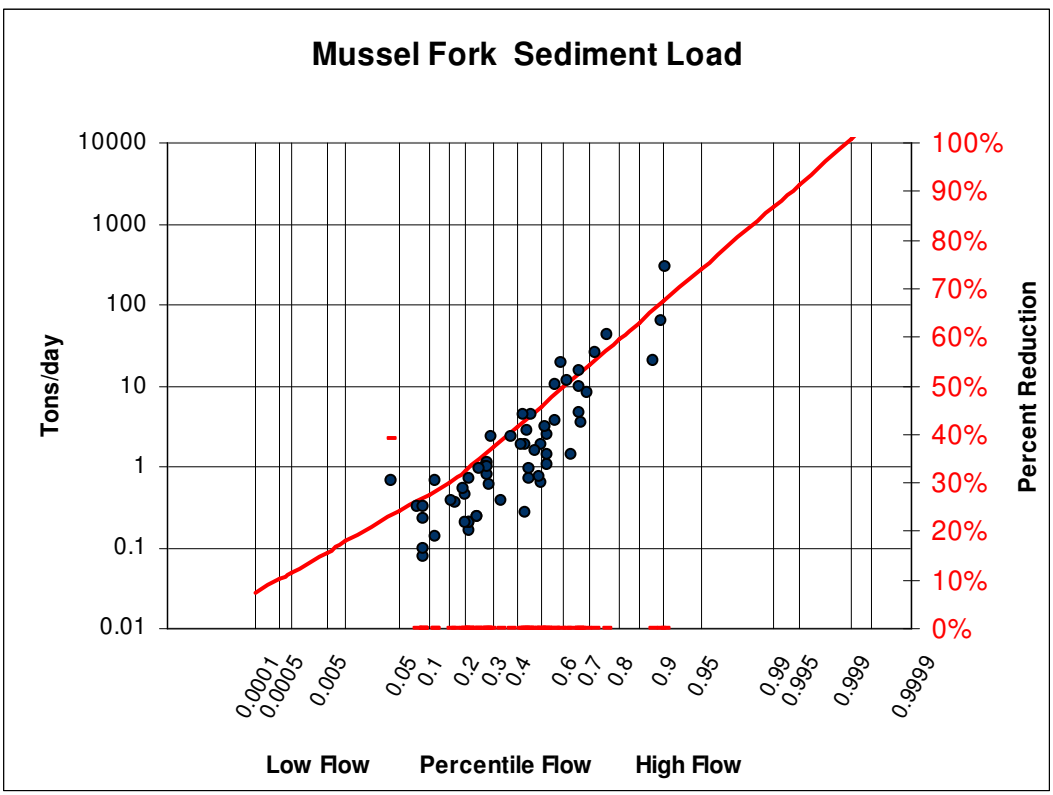
[7] Framework for Developing Suspended and Bedded Sediments (SABS) Water Quality Criteria, U.S. Environmental Protection Agency, EPA-822-R-06-001, May 2006.

In the case of Mussel Fork Creek where narrative standards are targeted for the impaired stream, a reference approach is used. In this approach, the target for pollutant loading is the 25th percentile of the current EDU condition calculated from all data available within the EDU in which the waterbody is located. Therefore, the 25th percentile is targeted as the TMDL load duration curve (LDC). For a full description of the development of suspended sediment targets using reference LDC refer to Appendix D. Specific data sources for this TMDL's flow and EDU-wide TSS data are listed in Appendix E. Table 4 shows estimates of discharge at flow percentiles. The biological assessment showed that lower Mussel Fork Creek is supporting the aquatic life use and upper Mussel Fork Creek is partially supporting the aquatic life use.

Table 4 – Estimated flow for range of percentiles at the impaired segment outlet

	Percent of Flow	Discharge (cubic feet per second)
Flow estimate for Mussel Fork based on drainage area and synthetic ecological drainage unit flow.	10	9.6
	30	28.1
	50	60.6
	70	134
	90	444

Figure 2 -- TMDL curve over the range of flows



6. Load Allocation (Nonpoint Source Loads)

LA is the allowable amount of the pollutant that can be assigned to non-point sources. The LA is set to 90% of the TMDL (Figure 2). Based on measured data from the creek, the percentage of reduction in sediment load ranges to 39% over the range of flows.

7. Waste Load Allocation (Point Source Loads)

WLA is the allowable amount of the pollutant that can be assigned to point sources. The WLA is set to the lesser of current permit limits or technology based effluent limits (TBELs). TBELs are defined in a permit based on facility type. Mechanical WWTFs' permit limits are a weekly average TSS concentration of 45 mg/L and a monthly average TSS concentration of 30 mg/L. Secondary equivalent WWTFs' permit limits are a weekly average TSS concentration of 60 mg/L and a monthly average TSS concentration of 45 mg/L. Waste water treatment lagoon facilities' permit limits are up to a weekly average TSS concentration of 120 mg/L and a monthly average TSS concentration of 80 mg/L. Additionally, permits can be written to target lower limits if the specific facility is capable of performance exceeding TBELs. Table 5 lists the site specific permitted point sources in the watershed and WLAs based on their current permit limits and permitted design flows. In addition any general permits need evaluation to determine if a site specific permit is needed to address sediment loading. Based on the assessment of sources, point sources do not contribute to water quality impairment relative to sediment impacts on stream biology. Thus, the WLAs are zero percentage net reduction in sediment load. These facilities' WLAs are set at the current permit limits and conditions. The WLAs listed in this TMDL do not preclude the establishment of future point sources of sediment loading in the watershed. Any future point sources should be evaluated in light of the TMDL established and the range of flows into which any additional load will impact.

Table 5 – WLAs for site specific permitted facilities in Mussel Fork Creek watershed.

Facility	**Permit number**	WLA (tons per day) d / w / m*
City of Green City	MO-0112135	NA / 0.046 / 0.029
City of Green Castle	MO-0103322	NA / 0.014 / 0.009

**Permit limits based on current design loads where d=daily, w=weekly average, m=monthly average.*

All permitted livestock facilities (CAFOs) are non-discharging permits "MO-G01". The WLAs are set at zero (Table 2).

All other listed facilities (Table 2) have general permits. The WLAs are set at present loads and listing of permit specific BMPs. Additionally, these permits should be reevaluated to determine if general permits are sufficient to protect the impaired segment.

Stormwater runoff from all permitted facilities also discharges to the stream. Compliance with the Missouri Storm Water Permit will ensure construction sites meet the TMDL area weighted loadings. Permittees with general permits beginning with "MO-G35" and "MO-R10X" will develop a Storm Water Pollution Prevention Plan (SWPPP). The SWPPP ensures

the design, implementation, and maintenance of Best Management Practices (BMPs). EPA assumes that construction activities in the watershed will be conducted in compliance with Missouri's Storm Water Permit including monitoring and discharge limitations. Compliance with this permit should lead to sediment loadings from the construction site at or below applicable targets.

General permits with numbers beginning "MO-G64" limit backwash outfalls to settleable solids of 1.0mL/L. Without designated flows the load can not be estimated but these concentration limits give a relative measure for potential impact of sediment loading from these facilities.

8. Margin of Safety

A MOS is usually added to a TMDL to account for the uncertainties inherent in the calculations and data gathering. The MOS is intended to account for such uncertainties in a conservative manner. Based on EPA guidance, the MOS can be achieved through one of two approaches:

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

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

Available data for Mussel Fork Creek shows instances where load exceeds the TMDL (Figure 2). To account for uncertainties in the modeling an explicit 10% MOS is assigned to this TMDL. For example, at the flow probability of 0.7, the TMDL is approximately 20 tons per day. The LA would therefore be 18 tons per day and the MOS 2 tons per day.

9. Seasonal Variation

The TMDL curve represents flow under all seasonal conditions. The LA and TMDL are applicable at all flow conditions, hence all seasons. The advantage of a LDC approach is to avoid the constraints associated with using a single-flow critical condition during the development of a TMDL. Therefore, all flow conditions including seasonal variation are taken into account for TMDL calculations.

Bioassessment data used in this TMDL, was generated by MDNR's Environmental Services Program (ESP). Invertebrate sampling was collected for two seasons: Fall (September 2002 for Upper Mussel Fork, September 2004 for Lower Mussel Fork) and spring (March 2003 for Upper Mussel Fork, March 2005 for Lower Mussel Fork). Invertebrate scores of 16 or greater are judged to indicate unimpaired streams and scores less than 16 are judged to be impaired. The samples were collected at 4 sites in lower Mussel Fork Creek for both fall 2004 and spring 2005, as shown in the table 5. The samples were collected at 6 sites in upper Mussel Fork Creek for both fall 2002 and spring 2003, as shown in the table 6.

Table 6. Lower Mussel Fork Creek Invertebrate Data

Aquatic Invertebrate Scores		
Location	**Fall 2004**	**Spring 2005**
Site 1	20	20
Site 2	20	20
Site 3	20	20
Site 4	20	20

Table 7. Upper Mussel Fork Creek Invertebrate Data

Aquatic Invertebrate Scores		
Location	**Fall 2002**	**Spring 2003**
Site 1	18	16
Site 2	16	18
Site 3	14	20
Site 4	16	20
Site 5	16	16
Site 6	14	12

10. Monitoring Plans for Mussel Fork Creek

The department conducted bioassessments on upper and lower Mussel Fork Creek in 2002-2003 and 2004-2005, as well as gathering chemistry data in 2004-2005. No future monitoring has been scheduled for Mussel Fork Creek at this time. However, the department will routinely examine physical habitat, water quality, invertebrate community, and fish community data collected by the Missouri Department of Conservation under its Resource Assessment and Monitoring (RAM) Program. This program randomly samples streams across Missouri on a five to six year rotating schedule. In addition, the USGS currently collects ambient water quality data once a month on Mussel Fork near Mystic in Sullivan County. The survey gathers a variety of field and laboratory parameters at this site.

11. 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 Mussel Fork Creek on the EPA, Region 7, TMDL website: http://www.epa.gov/region07/water/tmdl_public_notice.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 Mussel Fork Creek in Sullivan, Macon, and Adair Counties, Missouri, is included on the EPA 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 al. v. EPA, No. 98-1195-CV-W in consolidation with No. 98-4282-CV-W, February 27, 2001. EPA is developing this TMDL in cooperation with the State of Missouri, and EPA is establishing this TMDL at this time to fulfill the *American Canoe* consent decree obligations. Missouri may submit and EPA may approve another TMDL for this water at a later time.

As part of the public notice process, MDNR assists EPA by providing a distribution list of interested persons to which EPA will provide an announcement of the Mussel Fork Creek TMDL. Groups that receive the public notice announcement include the Missouri Clean Water Commission, the Missouri Water Quality Coordinating Committee, Stream Team Volunteers in the county, county legislators, and potentially impacted cities, towns and facilities. The EPA public noticed this TMDL from August 18, 2006, to September 18, 2006, and the Summary of Response to Comments is posted on the EPA website: http://www.epa.gov/region07/water/apprtmdl.htm#Missouri.

12. References

Biological Assessment and Habitat Study, Lower Mussel Fork Creek, Adair and Macon Counties, 2004-2005. Department of Natural Resources, Environmental Services Program.

Biological Assessment and Habitat Study, Upper Mussel Fork Creek, Adair and Sullivan Counties, 2002-2003. Department of Natural Resources, Environmental Services Program.

Chariton River Basin – 10280201, 10280202, Department of Natural Resources, Water Protection Program, Water Quality Monitoring and Assessment Section, Watershed Information Sheet. http://www.dnr.mo.gov/env/wpp/watersheds/info/10280201-2.pdf

Effects of Suspended Sediment on Native Missouri Fishes: A Literature Review and Synthesis. 2004. K.E. Doisey and C.F. Rabeni. University of Missouri.

Quality Assurance Project Plan for Wasteload Allocations/Special Studies, 2007, MDNR.

USDA- NASS Quick Stats (Livestock) 2002 Census of Agriculture, Volume 1 Chapter 2: Missouri County Level Data
http://www.nass.usda.gov/census/census02/volume1/mo/st29_2_001_001.pdf

13. Appendices

Appendix A – Map of Mussel Fork Creek, impaired segment (upper) and sampling sites.

Appendix B – Map of Mussel Fork Creek, impaired segment (lower) and sampling sites.

Appendix C – Data for Mussel Fork Creek.

Appendix D – Development of Suspended Sediment Targets using Reference Load Duration Curves.

Appendix E – List of Sites used for TMDL methodology

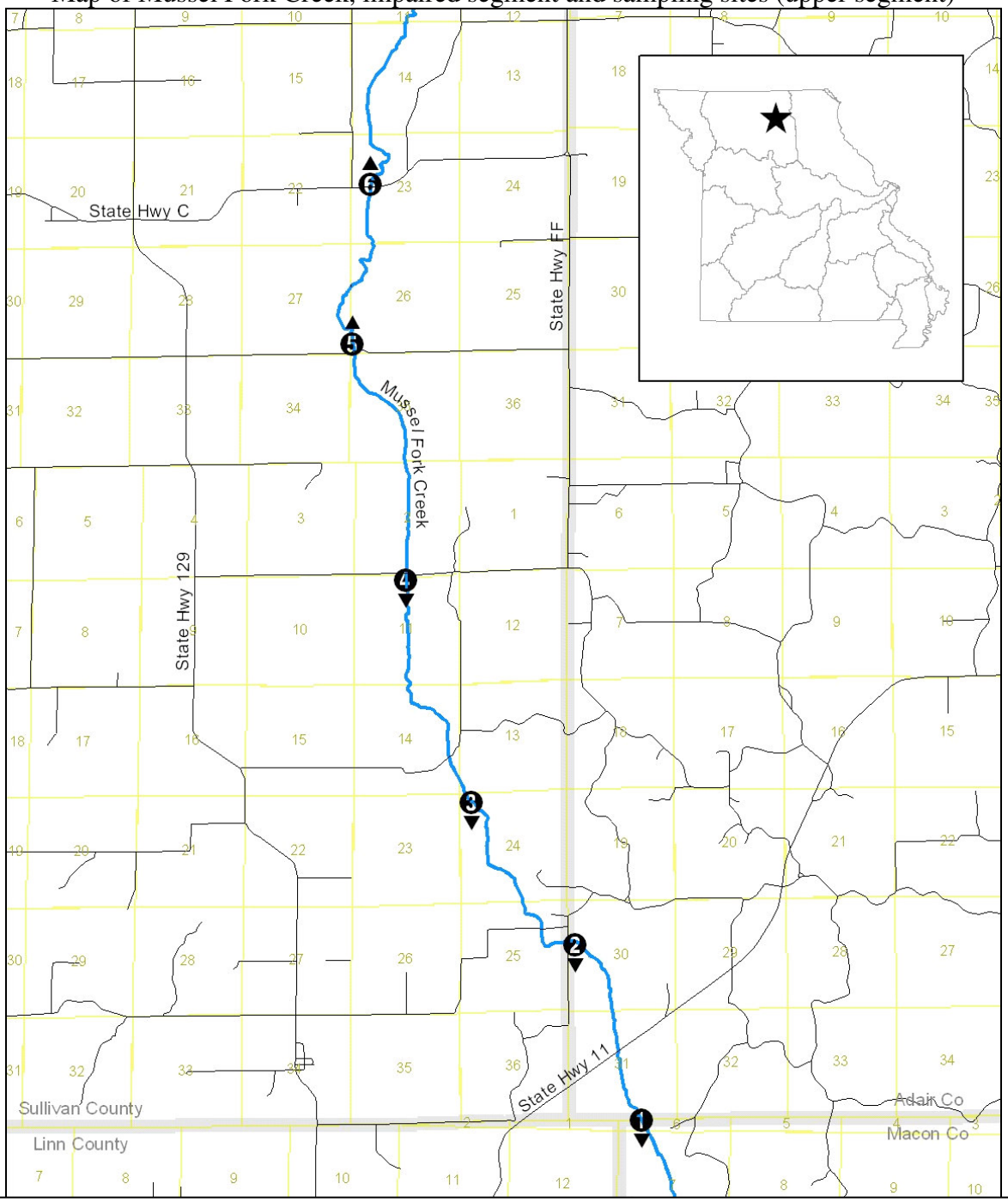
Appendix F – Biological Assessment and Habitat Study, Upper Mussel Fork Creek, Sullivan and Adair Counties, 2002-2003.

Appendix G – Biological Assessment and Habitat Study, Lower Mussel Fork Creek, Macon and Adair Counties, 2004-2005.

Appendix H – Total Maximum Daily Load Information Sheet for Mussel Fork Creek.

Appendix A

Map of Mussel Fork Creek, impaired segment and sampling sites (upper segment)

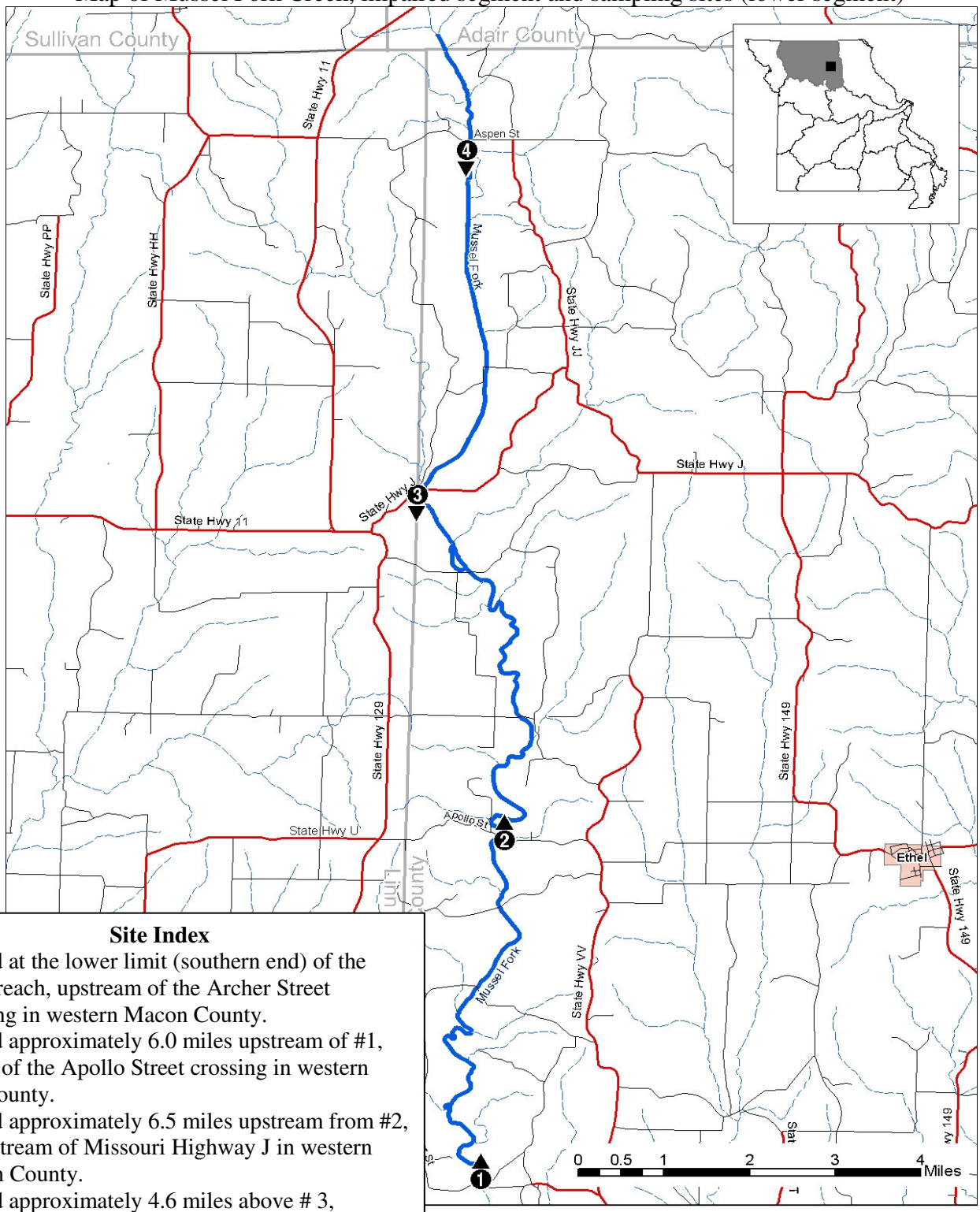


Site Index

1- located at the lower limit (southern end) of the study reach and below its confluence with Little Mussel Fork.
2- located approximately 1.8 miles upstream of #1 in a less channelized area.
3- located approximately 1.9 miles upstream from #2.
4- located approximately 2.2 miles above #3 in a mixed area.
5- located approximately 2.4 miles upstream from #4.
6- located at the northern end of the study reach, approximately 1.8 miles above #5.

Appendix B

Map of Mussel Fork Creek, impaired segment and sampling sites (lower segment)



Site Index

1- located at the lower limit (southern end) of the study reach, upstream of the Archer Street crossing in western Macon County.

2- located approximately 6.0 miles upstream of #1, upstream of the Apollo Street crossing in western Macon County.

3- located approximately 6.5 miles upstream from #2, downstream of Missouri Highway J in western Macon County.

4- located approximately 4.6 miles above # 3, downstream of Aspen Street in northwestern Macon County.

Appendix C

Lower Mussel Fork Creek Invertebrate Data

Aquatic Invertebrate Scores		
Location	**Fall 2004**	**Spring 2005**
Site 1	20	20
Site 2	20	20
Site 3	20	20
Site 4	20	20

Upper Mussel Fork Creek Invertebrate Data

Aquatic Invertebrate Scores		
Location	**Fall 2002**	**Spring 2003**
Site 1	18	16
Site 2	16	18
Site 3	14	20
Site 4	16	20
Site 5	16	16
Site 6	14	12

Note: An MSCI score of 16-20 is considered full biological sustainability, 10-14 is partial biological sustainability, and 4-8 is non-biological sustainability. Invertebrate scores of 16 or greater are judged to indicate unimpaired streams. Scores less than 16 are judged to be impaired.

Lower Mussel Fork Creek Water Chemistry Data Fall 2004

	Mussel Fork 1	Mussel Fork 2	Mussel Fork 3	Mussel Fork 4	West Locust Creek control
Ammonia as N (mg/L)	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Chloride (mg/L)	7.8	8.86	9.76	10.6	11.4
Dissolved Oxygen (mg/L)	7.8	8.3	8.2	7.3	5.8
Discharge (cubic ft/sec)	3.26	2.12	1.53	1.03	1.1
Nitrate + Nitrite as N (mg/L)	< 0.01	< 0.01	0.02	< 0.01	0.01
pH (su)	8.1	7.7	8	NA	7.7
Specific Conductivity (umhos/cm)	470	464	466	448	439
Temperature (°C)	18.7	22	12.5	17.3	15.4
Total Kjeldahl Nitrogen (mg/L)	0.57	0.51	0.39	0.42	0.6
Total Phosphorus (mg/L)	0.05	0.06	0.04	0.06	0.07
Turbidity (NTU)	8.34	6.91	3.33	15.3	8.81

Lower Mussel Fork Creek Water Chemistry Data Spring 2005

	Mussel Fork 1	Mussel Fork 2	Mussel Fork 3	Mussel Fork 4	West Locust Creek control
Ammonia as N (mg/L)	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Chloride (mg/L)	10.2	9.88	10.6	11.3	13.5
Dissolved Oxygen (mg/L)	13.2	11.9	13.1	13.8	9.3
Discharge (cubic ft/sec)	11.9	12.8	11.9	11.1	13.1
Nitrate + Nitrite as N (mg/L)	< 0.01	< 0.01	0.01	< 0.01	< 0.01
pH (su)	7.7	8.3	8.3	8.6	7.6
Specific Conductivity (umhos/cm)	390	483	469	467	470
Temperature (°C)	6.7	6.9	5.7	5.9	16.8
Total Kjeldahl Nitrogen (mg/L)	0.51	0.2	0.22	0.28	0.51
Total Phosphorus (mg/L)	0.08	0.03	0.03	0.05	0.04
Turbidity (NTU)	13.6	6.97	7.13	8.65	9.25

Upper Mussel Fork Creek Water Chemistry Data Fall 2002

	Mussel Fork 1	Mussel Fork 2	Mussel Fork 3	Mussel Fork 4	Mussel Fork 5	Mussel Fork 6
Ammonia as N (mg/L)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Chloride (mg/L)	10.5	9.71	13.4	6.7	9.12	15.3
Dissolved Oxygen (mg/L)	7.5	**3.7**	6.7	10	9.2	8.6
Discharge (cubic ft/sec)	0.03	0.05	0.03	0.05	0.05	0
Nitrate + Nitrite as N (mg/L)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
pH (su)	7.4	7.4	7.8	8.1	7.9	7.8
Specific Conductivity (umhos/cm)	519	440	422	458	403	427
Temperature (°C)	18	20.5	24	18	24.5	23
Total Kjeldahl Nitrogen (mg/L)	0.45	0.59	0.72	0.38	0.6	1.21
Total Phosphorus (mg/L)	< 0.05	0.07	0.08	< 0.05	< 0.05	0.09
Turbidity (NTU)	4.42	10	14.1	5.27	13.4	24.8

Upper Mussel Fork Creek Water Chemistry Data Spring 2003

	Mussel Fork 1	Mussel Fork 2	Mussel Fork 3	Mussel Fork 4	West Locust Creek control
Ammonia as N (mg/L)	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Chloride (mg/L)	10.2	9.88	10.6	11.3	13.5
Dissolved Oxygen (mg/L)	13.2	11.9	13.1	13.8	9.3
Discharge (cubic ft/sec)	11.9	12.8	11.9	11.1	13.1
Nitrate + Nitrite as N (mg/L)	< 0.01	< 0.01	0.01	< 0.01	< 0.01
pH (su)	7.7	8.3	8.3	8.6	7.6
Specific Conductivity (umhos/cm)	390	483	469	467	470
Temperature (°C)	6.7	6.9	5.7	5.9	16.8
Total Kjeldahl Nitrogen (mg/L)	0.51	0.2	0.22	0.28	0.51
Total Phosphorus (mg/L)	0.08	0.03	0.03	0.05	**0.04**
Turbidity (NTU)	13.6	6.97	7.13	8.65	9.25

- The ammonia standard is water temperature and pH dependent. The 2.0 mg/L estimated standard is based on typical summer water

Appendix D

Development of Suspended Sediment Targets using Reference Load Duration Curves

Overview

This procedure is used when a lotic system is placed on the 303(d) impaired waterbody 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 waterbody 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% 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

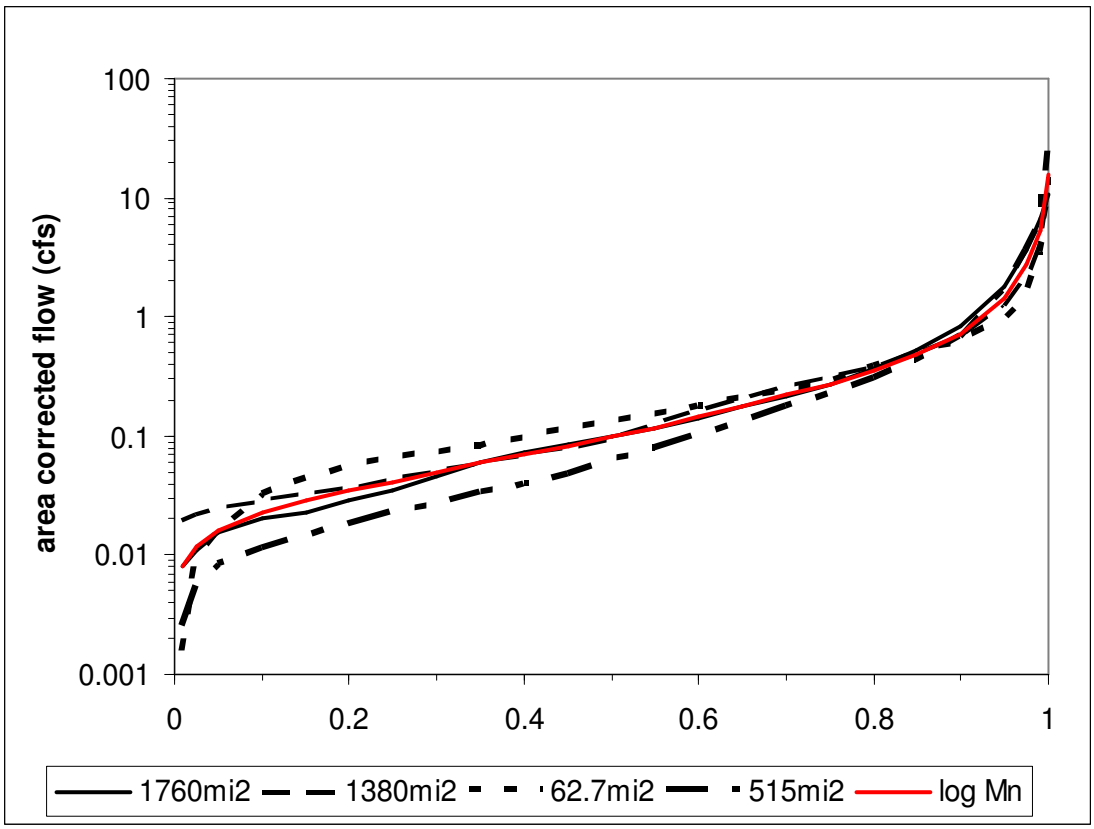
The first step in this procedure is to locate available pollutant data within the EDU of interest. These data along with the instantaneous flow measurement taken at the time of sample collection for the specific date are recorded to create the population from which to develop the load duration. Both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

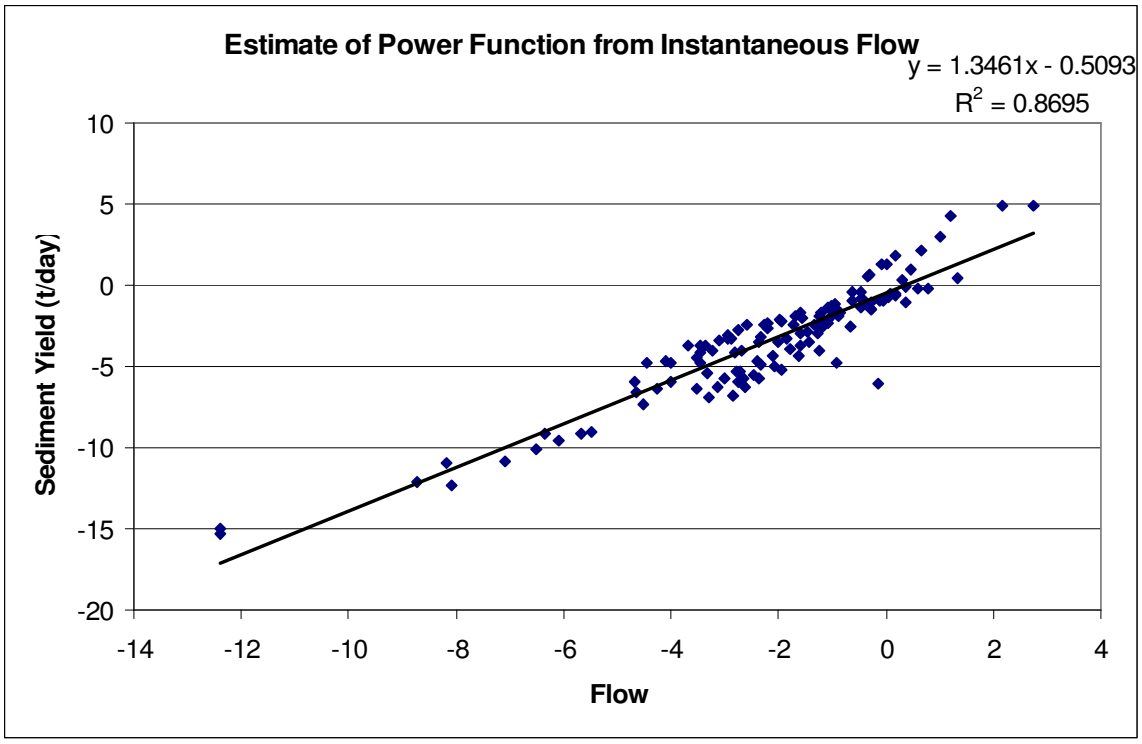
The watershed-size normalized data for the individual gages in the EDU were calculated and compared to a pooled data set including all of the gages. The results of this analysis are displayed in the following figure and table:



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:



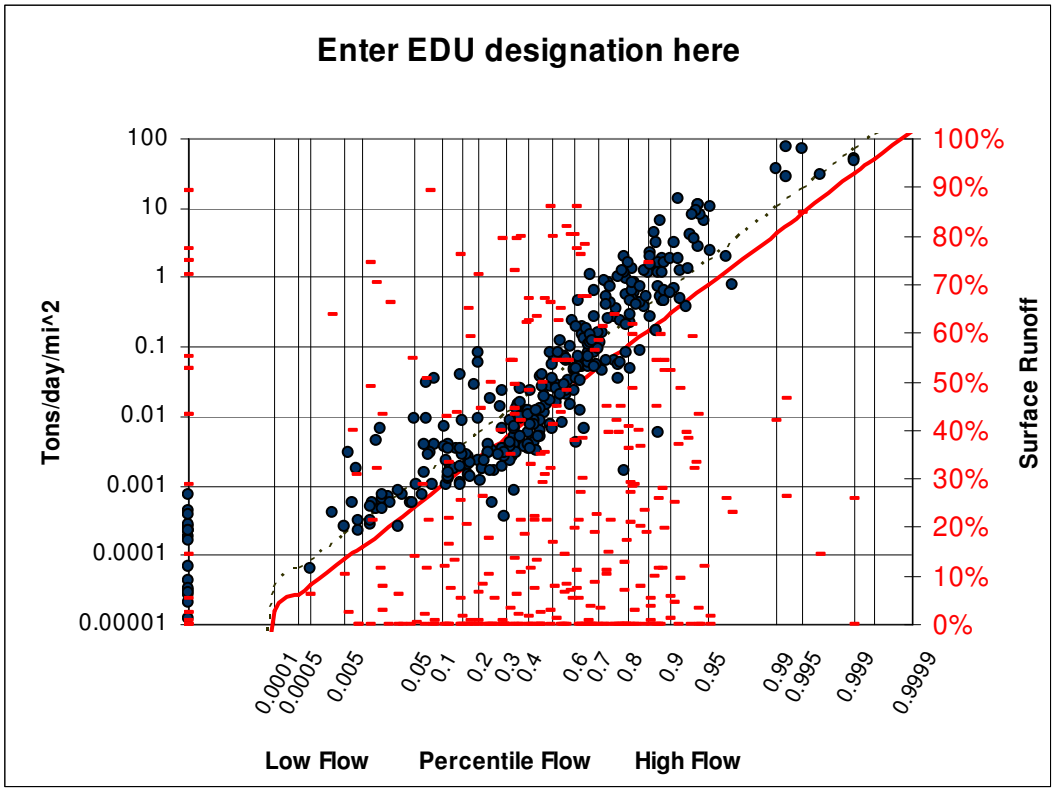
Further statistical analyses on this relationship are included in the following Table:

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%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)*

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 E
List of Sites used for TMDL methodology

USGS stream gages used to generate synthetic flow

Grand River nr Gallatin	06897500
Thompson River at Trenton	06899500
Grand River nr Sumner	06902000
East Fork Little Chariton nr Huntsville	06906300
Mussel Fork nr Mussel Fork	06906000
East Fork Little Chariton nr Macon	06906200

USGS stream sample sites used to generate EDU TMDL

Chariton River nr Prairie Hill	06905500
Mussel Fork nr Mystic	06905725
Mussel Fork nr Mussel Fork	06906000
North River nr Dunlap	06899580
Thompson River nr Mount Moriah	06898100
Weldon River nr Princeton	06898800
Little Medicine Creek nr Harris	06900100
Locust Creek nr Unionville	06900900
East Fork Little Chariton nr Macon	06906200
East Fork Little Chariton nr Huntsville	06906300
Medicine Creek nr Harris	06899950

Appendix F
Biological Assessment and Habitat Study Lower Mussel Fork Creek

BIOLOGICAL ASSESSMENT AND HABITAT STUDY

(Lower) Mussel Fork
Adair & Macon Counties

2004 - 2005

Prepared for:

Missouri Department of Natural Resources
Division of Environmental Quality
Water Protection Program
Water Pollution Control Branch

Prepared by:

Missouri Department of Natural Resources
Field Services Division
Environmental Services Program
Water Quality Monitoring Section

Mussel Fork Creek TMDL
Appendices

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ATTACHMENTS

Appendix A – Sediment TMDL Strategy Document
Appendix B – Fall 2004 Macroinvertebrate Bench Sheets
Appendix C – Spring 2005 Macroinvertebrate Bench Sheets
Appendix D – Fall 2004 Channel Width and Depth Data

1.0 Introduction

At the request of the Missouri Department of Natural Resources (**MDNR**), Water Protection Program (**WPP**), the Environmental Services Program (**ESP**), Water Quality Monitoring Section (**WQMS**) conducted a macroinvertebrate bioassessment and habitat study of Mussel Fork in southern Adair and Macon Counties in north central Missouri. This study was completed in accordance with Sediment TMDL Strategy agreed upon by the WQMS and WPP (Appendix A).

Approximately 29 miles of Mussel Fork in Sullivan, Adair, and Macon Counties are included on the 2002 303(d) list for sediment pollution from agricultural nonpoint sources. Although habitat loss is not an impact found on the 303(d) list, there are segments of Mussel Fork that have poor habitat due to channelization, vertical banks, and poor riparian zones. A previous department study (MDNR 2003a) assessed the upper 15 miles of Mussel Fork from the confluence of Little Mussel Fork in Adair County, to Section 2, Township 62 North, Range 18 West in Sullivan County. This study assesses the lower 14 miles of Mussel Fork from Section 31, Township 61 North, Range 17 West in Adair County (at the confluence of Little Mussel Creek) to Section 18, Township 58 North, Range 17 West in Macon County. The 14 miles of lower Mussel Fork addressed in this study are listed as Class C waters, water body I.D. #0674 (MDNR 2000), and constitute approximately the lower ½ of the listed segment.

1.1 Purpose

The purpose of the study was to determine if the lower Mussel Fork macroinvertebrate community is impaired and, if so, determine potential causes.

1.2 Objectives

1) Define the habitat characteristics of lower Mussel Fork.
2) Define the water quality characteristics of lower Mussel Fork.
3) Determine if the macroinvertebrate community and water qualities of lower Mussel Fork are affected by factors related to habitat loss.

1.3 Tasks

1) Conduct a habitat assessment of lower Mussel Fork.
2) Conduct a water quality assessment of lower Mussel Fork.
3) Conduct a bioassessment of the macroinvertebrate community of lower Mussel Fork.

1.4 Null Hypotheses

1) Habitat will not substantially differ between lower Mussel Fork and biocriteria reference streams within the Plains/Grand/Chariton Ecological Drainage Unit or among lower Mussel Fork stream segments.
2) Water quality will not substantially differ between lower Mussel Fork and biocriteria reference streams within the Plains/Grand/Chariton Ecological Drainage Unit or among lower Mussel Fork stream segments.
3) Macroinvertebrate assemblages will not substantially differ between lower Mussel Fork and biocriteria reference streams within the Plains/Grand/Chariton Ecological Drainage Unit or among lower Mussel Fork stream segments.

2.0 Study Area

The headwaters of Mussel Fork lie in an area between the cities of Green City and Green Castle in northeastern Sullivan County. It flows south for approximately 60-70 miles through Adair, Macon, Linn, and Chariton Counties to its confluence with the Chariton River approximately 2 miles south of Keytesville and approximately 6 miles north of the confluence of the Chariton River with the Missouri River. The entire drainage of the creek is approximately 350 square miles. The drainage basin is linear in shape stretching almost 60 miles north to south and being approximately 8 miles wide at its widest point.

Northern Missouri landforms are the result of glaciation and consist of plains and low rolling hills. Agriculture is a major industry in northern Missouri including row crops and confined animal feeding operations. In many cases row crops are planted up to the banks of streams, thereby decreasing the quality of the riparian zone and leading to unstable banks and a loss of woody debris input to the stream, which in turn results in a loss of habitat. Many of the larger streams and rivers in northern Missouri have been channelized to provide more area in the river bottoms for cropland. Channelization causes a loss of channel structure, which would normally promote the formation of good quality habitats.

2.1 Station Descriptions

Four stations were chosen systematically along lower Mussel Fork. Each station represents stream conditions locally and for an area approximately 4-5 miles upstream. See Figure 1 for a map of study locations.

Mussel Fork Station 1: (NE ¼ SE ¼ sec. 18, T. 58 N., R. 17 W.) Station 1 is located at the lower limit (southern end) of the study reach, upstream of the Archer Street crossing in western Macon County. The channel appears to be unaltered and the stream has a healthy riparian zone. Stream discharge was measured at 3.26 cfs in fall 2004 and 11.9 cfs in spring 2005. Geographic coordinates for this study station are Latitude 39° 50’ 12.8”, Longitude -92° 50’ 9.4”.

Mussel Fork Station 2: (NE ¼ sec. 29, T. 59 N., R. 17 W.) Station 2 is located approximately 6.0 miles upstream of Station 1, upstream of the Apollo Street crossing in western Macon County. Much like Mussel Fork Station 1, the channel appears to be unaltered, but the quality of the riparian zone is relatively poor, being quite poor on one side. Stream discharge was measured at 2.12 cfs in fall 2004 and 12.8 cfs in spring 2005. Geographic coordinates for this study station are Latitude 39° 53’ 49.7”, Longitude -92° 49’ 50.4”.

Mussel Fork Station 3: (NW ¼ sec. 6, T. 59 N., R. 17 W.) Station 3 is located approximately 6.5 miles upstream from Station 2, downstream of Missouri Highway J in western Macon County. The channel appears to be somewhat altered and the quality of the riparian zone is mixed, relatively pristine on one side but lacking entirely on the other. Stream discharge was measured at 1.53 cfs in fall 2004 and 11.9 cfs in spring 2005. Geographic coordinates for this study station are Latitude 39° 57’ 30.6”, Longitude -92° 50’ 58.3”.

Figure 1
Lower Mussel Fork Study Locations and Ecological Drainage Unit Map

Mussel Fork Station 4: (N ½ sec. 18, T. 60 N., R. 17 W.) Station 4 is located approximately 4.6 miles above Station 3, downstream of Aspen Street in northwestern Macon County. The channel appears to be somewhat altered and the quality of the riparian zone is mixed, quite good on one side but poor on the other. Stream discharge was measured at 1.03 cfs in fall 2004 and 11.1 cfs in spring 2005. Geographic coordinates for this study station are Latitude 40° 1' 10.1", Longitude -92° 50' 18.4".

2.2 Control Station Description

West Locust Creek: (NE ¼ sec. 11, T. 61 N., R. 21 W.) The West Locust Creek site was located upstream of Timber Road in Sullivan County southwest of Milan, Missouri. This station was just downstream from a Biocriteria Reference stream segment within the EDU. It is targeted to be part of an expanded reference section of West Locust Creek in the future. Data collected from this station was used as a control comparison to lower Mussel Fork. Stream discharge was measured at 1.1 cfs in fall 2004 and 13.1 cfs in spring 2005. Geographic coordinates for this station are Latitude 40° 06' 8.5", Longitude -93° 13' 1.7".

3.0 Methods

Mike Irwin, Randy Sarver, Steve Humphrey, Cecelia Campbell, and other staff of the Missouri Department of Natural Resources, Division of Environmental Quality, Environmental Services Program conducted this study. Samples were collected at sites that had a gradient of habitat characteristics. Sampling was conducted during the fall of 2004 and the spring of 2005. Fall sampling was conducted on September 28 and 29, 2004 and consisted of macroinvertebrate sampling, water quality sampling, habitat assessments, and stream morphology measurements at four stations on upper Mussel Fork. Spring sampling was conducted on March 22, 23, and 24, 2005 and consisted of macroinvertebrate and water quality sampling.

3.1 Habitat

Mussel Fork was placed on the 303(d) list for stream habitat degradation through excessive sedimentation. No suspended sediment data exists to directly document sediment as a significant impact to the stream. General fisheries data and the effect of sediment upon fish were the initial data to consider Mussel Fork for 303(d) listing. Sedimentation is one of many instream habitat problems associated with land use. Although instream habitat can be directly measured, the causes of the degradation can range from local scale sources to watershed scale sources. We collected habitat measures at the watershed scale, the reach scale, and the habitat scale to better allow us to evaluate the causes of poor habitat conditions.

3.1.1 Land Use

The land use conditions were summarized from land cover GIS files. These land cover files were provided by the Missouri Resource Assessment Partnership (**MoRAP**) and derived from 1991-1993 LANDSAT data.

In addition, Mussel Fork was included in a study in which the MDNR provided funding to the University of Missouri for evaluation of reference streams in Northern Missouri (Haithcoat et al.,

2003). As part of the final report to the department, a five-parameter land cover model was developed to facilitate the definition of reference streams.

3.1.2 Habitat

A standardized assessment procedure was followed as described for Glide/Pool Habitat in the Stream Habitat Assessment Project Procedure (**SHAPP**) (MDNR 2003b). The habitat assessment was conducted on Mussel Fork during the fall 2004 sample season.

3.1.3 Sinuosity

Sinuosity was used as a surrogate measure of the amount of channelization that has taken place. Sinuosity was measured using GIS and a Valley Segment Type stream coverage provided by MoRAP. For this report, sinuosity is represented as a ratio of the actual length between two points on the stream to the straight-line distance between the points. Two different methods were used to determine sinuosity. For one method, measurement points were approximately two miles apart with the sampling reach at the center, and the ratio was generated for the entire two-mile reach. For the other method, measurement points were approximately two miles apart with the sampling reach at the center, but an average ratio was generated from the ratios of two one-mile segments within the two-mile reach.

3.1.4 Stream Morphology

Lack of instream habitat can be visually observed in Northern Missouri streams that are wide and shallow. Wider, shallower streams tend to have less ability to develop pools and retain woody debris (Haithcoat et al., 2003). At each sampling station a series of 10 bank to bank transects were established. Each transect was equally spaced within the sampling reach, which is 20x the average channel width. Measurements taken at each transect included lower bank width (see the Stream Habitat Assessment Procedure for a definition of Lower Bank), wetted width, and water depth at ¼, ½, and ¾ of the distance across the wetted width. In order to document critical habitat conditions, measurements were collected during the fall low flow period.

3.2 Physicochemical Water Parameters

Physical and chemical water samples were collected from all stations during both fall and spring. Parameters collected were nitrate+nitrite-nitrogen, ammonia-nitrogen, Total Kjeldahl Nitrogen, total phosphorus, chloride, turbidity, temperature, conductivity, dissolved oxygen, pH, and discharge. WQMS personnel analyzed temperature, conductivity, dissolved oxygen, pH, and discharge in the field and turbidity in the biology laboratory. All other parameters were delivered to the ESP Chemical Analysis Section for analyses. All samples were collected according to the standard operating procedure MDNR-FSS-001: Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations (MDNR 2003c) and were recorded on an MDNR chain-of-custody (MDNR 2005a).

3.3 Biological Assessment

The biological assessment was conducted according to the Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (**SMSBPP**) (MDNR 2003d). All stations were sampled in September 2004 and March 2005. Three standard habitats of glide/pool streams (e.g. woody debris substrate, depositional substrate in non-flowing water, and rootmat substrate) were sampled at all locations.

Macroinvertebrate data were evaluated by comparison to Biological Criteria for Perennial/Wadeable (**BIOREF**) streams of the Plains/Grand/Chariton Ecological Drainage Unit (**EDU**). An EDU is an ecological area in which the aquatic biological communities and stream habitat can be expected to be similar. See Figure 1 for a map of the EDU's of Missouri.

Biological criteria are calculated separately for the fall (mid-September through mid-October) and spring (mid-March through mid-April) index periods. The SMSBPP provides details on the calculation of metrics and scoring of the multi-metric Macroinvertebrate Stream Condition Index (**MSCI**). The four core metrics of the MSCI are: Taxa Richness (**TR**); Ephemeroptera, Plecoptera, and Trichoptera Taxa (**EPTT**); Biotic Index (**BI**); and the Shannon Diversity Index (**SDI**). An MSCI score of 16-20 is considered full biological sustainability, 10-14 is partial biological sustainability, and 4-8 is non-biological sustainability. Table 1 provides scoring criteria for the fall index period and Table 2 for the spring index period.

Table 1
Biological Criteria for Glide/Pool-Fall Index Period
Plains/Grand/Chariton EDU

Metric	Score = 1	Score = 3	Score = 5
TR	< 26	26 – 51	> 51
EPTT	< 4	4 – 9	> 9
BI	> 8.60	8.60 – 7.20	< 7.20
SDI	< 1.34	1.34 – 2.68	> 2.68

Table 2
Biological Criteria for Glide/Pool-Spring Index Period
Plains/Grand/Chariton EDU

Metric	Score = 1	Score = 3	Score = 5
TR	< 26	26 – 51	> 51
EPTT	< 4	4 – 8	> 8
BI	> 8.62	8.62 – 7.24	< 7.24
SDI	< 1.26	1.26 – 2.53	> 2.53

4.0 Results and Analyses

4.1 Habitat

As noted in the methods section, habitat measures were collected at the watershed scale, the reach scale, and the habitat scale for better evaluation of the causes of poor habitat conditions.

4.1.1 Land Use

According to MoRAP land cover files, the lower reach of the Mussel Fork drainage basin, which is the subject of this report, is comprised of mainly cool season grassland (~46%), deciduous forest (~40%), and row crops (~7%). When compared to surrounding watersheds, this watershed contains more deciduous forest and cool season grassland in place of row crops.

Table 3 provides two scales of land use comparison. A broad scale comparison is provided by comparing the 14-digit hydrologic units (**HU**) for lower Mussel Fork stations with the Plains/Grand/Chariton EDU. A watershed comparison is also provided by comparing the 14-digit HU for lower Mussel Fork stations with the 14-digit HU of three nearby BIOREF streams in the EDU.

Compared to the Plains/Grand/Chariton EDU, lower Mussel Fork has about the same amount of cool season grassland, much less row crops, and much more deciduous forest. In comparison to the three selected BIOREF streams, lower Mussel Fork has the least amount of land use dedicated to row crops. Lower Mussel Fork has less cool season grassland than the Locust Creek BIOREF and West Locust Creek BIOREF but more cool season grassland than the Spring Creek BIOREF. In contrast, lower Mussel Fork has more deciduous forest than the Locust Creek BIOREF and West Locust Creek BIOREF but less deciduous forest than the Spring Creek BIOREF.

Additional land cover information is available as part of a reference watershed model developed by Haithcoat et al. (2003). Mussel Fork is not considered a reference stream, but was included as a potentially impacted stream. Mussel Fork was the highest ranked test stream, and in fact land cover parameters did as well as many reference streams. Mussel Fork was not included as a potentially impacted test stream because of general watershed problems, but solely because of past water quality problems resulting from hog manure spills from a large confined animal feeding operation in it's headwaters.

Table 3
Land Use

Watershed	% Urban	% Row Crops	% Grassland	% Forest
Lower Mussel Fork	1	7	46	40
Plains/Grand/Chariton EDU	2	28	45	18
BIOREF Locust Creek	2	10	62	20
BIOREF Spring Creek-Adair Co.	1	10	28	55
BIOREF West Locust Creek	1	10	67	15

4.1.2 Habitat Assessment

In order to determine the acceptability of habitat, the lower Mussel Fork habitat scores were compared to the habitat score from the West Locust Creek control station. According to the SHAPP, a study stream that scores 75 percent of reference stream conditions is considered to have habitat that fully supports a similar biological community.

Habitat assessment scores of all lower Mussel Fork stations were comparable to the West Locust Creek control station score (Table 4). The habitat score for Mussel Fork Station 1 was actually higher that the West Locust Creek station, exceeding the control habitat score by approximately 13 percent. Percent similarity ranged from 111 percent at Mussel Fork Station 1 to 75.5 percent at Mussel Fork Station 4.

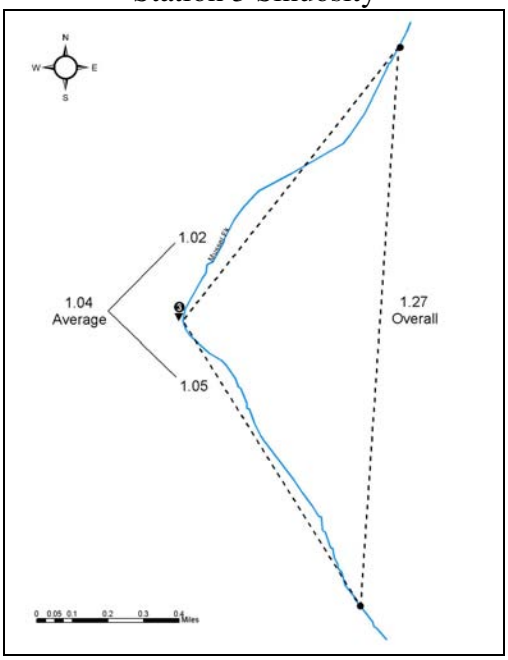
Table 4
Habitat Assessment Scores

Station	Habitat Assessment Score
Mussel Fork 1	111
Mussel Fork 2	88
Mussel Fork 3	75
Mussel Fork 4	74
Locust Creek control	98

4.1.3 Sinuosity

Table 5 (Station Reach Characteristics) lists sinuosity and channel characteristics for each sample station. Sinuosity ratios near 1 are considered potentially channelized. The sinuosity of lower Mussel Fork ranges from 1.04 to 1.64. Using the ratio for the entire reach versus using the average of the ratios from two one-mile segments yielded no difference except at Mussel Fork Station 3. While the ratio for the entire reach at Station 3 does not suggest the reach has been channelized, this may simply be a limitation of the method.

Figure 2
Station 3 Sinuosity



Each one-mile segment at Station 3 appears to be quite channelized and measuring these two segments independently and averaging the result of the two ratios may be more descriptive. Both one-mile segments approach the sampling reach from significantly different angles with the apex of the angle meeting at the Highway J bridge. Figure 2 (Station 3 Sinuosity) is a graphic representation of lower Mussel Fork Station 3 with emphasis on the two different methods of determining sinuosity. The derived line connecting the upstream and downstream points of the entire two-mile reach does not generally follow the stream. Therefore, the ratio generated using the entire two-mile reach (1.27) masks a possibly more representative degree of channelization when an average is taken for each of the two miles (1.04).

Table 5
Station Reach Characteristics

Station	*Sinuosity (miles/mile)	Likely to be Channelized
Mussel Fork 1	1.50	No
Mussel Fork 2	1.64	No
Mussel Fork 3	1.27 / 1.04**	Yes
Mussel Fork 4	1.04	Yes
West Locust Creek control	1.43	No

* Higher number equates to greater sinuosity.
**First number = entire 2 mi. reach, second number = average of two 1 mi. reaches (see Figure 2).

Based on sinuosity alone, the two downstream stations (1 & 2) are less likely to be channelized, while the two upstream stations (3 & 4) are more likely to be channelized. There is no evidence to suggest that any recent channelization has occurred on lower Mussel Fork; however, such low sinuosity values suggest historical channelization. In addition, the sinuosity values of the downstream stations are actually higher than the sinuosity value for the West Locust Creek control.

4.1.4 Stream Morphology

Station transect measurements for lower bank channel width, wetted width, and depth are provided in Appendix D.

A summary of stream width and depth measurements for lower Mussel Fork stations and the West Locust Creek control can be found in Table 6. While there are no clear progressions in channel measurement data, there are some general trends regarding channel width, wetted width, and depth. With a couple of exceptions, each of these measurements decreases in an upstream direction from the most downstream station on lower Mussel Fork.

Table 6
Stream Width and Depth Measurement Summary

Station	Average Channel Width (ft)	Average Wetted Width (ft)	Average Depth of Stream (ft)	Average Depth Standard Deviation	Channel Width / Wetted Width	Channel Width / Depth	Wetted Width / Depth
Mussel Fork 1	41.1	32.0	1.48	0.68	1.29	27.8	21.6
Mussel Fork 2	51.2	24.3	1.03	0.96	2.11	49.5	23.5
Mussel Fork 3	46.8	9.8	0.31	0.14	4.77	148.9	31.2
Mussel Fork 4	36.2	17.2	0.31	0.21	2.10	118.4	56.3
West Locust Creek control	40.8	23.3	1.41	1.18	1.75	28.9	16.5

Average channel width was highest at Station 2 at 51.2 feet and it was lowest at the most upstream station (4) at 36.2 feet. Average wetted width was highest at the most downstream station (1) and it was lowest at Station 3. Stream depth increased from upstream to downstream, averaging the lowest at 0.31 feet for both upstream stations (3 and 4) and averaging the highest at 1.48 feet for the most downstream station (1). In comparison to the West Locust Creek control station, it appears that the most downstream station on lower Mussel Fork is most similar in channel width, wetted width, and depth, whereas upstream stations are progressively less similar.

In order to be able to compare stream stations in a longitudinal stream study it is sometimes necessary to incorporate ratios of measurements. Ratios can standardize measurements so that data such as channel width can be used in a manner that allows comparison of study stations regardless of their longitudinal placement. The ratios of channel width/wetted width, channel width/average depth, and wetted width/average depth are also given in Table 6. Higher channel width/wetted width values reflect a higher likelihood that streams have less potential for riparian shading, a deficiency that can be compounded when a stream meanders within its channel. Higher width/depth ratios represent a lack of habitat heterogeneity, showing tendency toward wide and shallow.

The channel width/wetted width ratio of Station 3 was the highest at 4.77, suggestive of poor riparian shading. The channel width/wetted width ratios of Stations 2 and 4 (2.11 and 2.10 respectively) are much better but not as low as the West Locust Creek control. The channel width/wetted width ratio of Station 1 was below that of the control.

Channel width/depth ratios were much higher for Stations 3 and 4. The channel width/depth ratio for Station 2 was much lower, but only Station 1 ranked better than the control. None of the lower Mussel Fork stations ranked better than the control regarding wetted width/depth ratios, but a clear progression toward wide and shallow is evident in a downstream to upstream direction. The wetted width/depth ratio of the most upstream station (4) was more than twice that of the two most downstream stations (1 and 2) and more than three times the control.

These ratios suggest a trend of reduced riparian shading and habitat heterogeneity in an upstream direction that may represent conditions with less potential for a diverse fish and macroinvertebrate community.

Average depth is another measure that relates to habitat quality. The average depths of Mussel Fork Stations 1 and 2 (1.48 and 1.03 feet respectively) were similar to the West Locust Creek Control (1.41 feet). The average depths of Stations 3 and 4 (both 0.31 feet) are quite shallow in comparison to the average depth of the West Locust Creek control. In addition, the standard deviation of the average depths from Stations 1 and 2 show that there is good depth variability, especially when compared to Stations 3 and 4.

When width/depth ratios and average depth metrics are compared, Stations 3 and 4 rank rather poorly compared to Stations 1 and 2.

4.2 Physicochemical Results

Results from the fall 2004 sampling season can be found in Table 7 and spring 2005 in Table 8.

No violations of Missouri water quality standards occurred during the fall 2004 or spring 2005 sampling seasons at any sampling stations on lower Mussel Fork.

Table 7
Fall 2004 Physicochemical Results

	Mussel Fork 1	Mussel Fork 2	Mussel Fork 3	Mussel Fork 4	West Locust Creek control
Sample #	434866	434867	434868	434869	434870
Ammonia as N (mg/L)	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Chloride (mg/L)	7.8	8.86	9.76	10.6	11.4
Dissolved Oxygen (mg/L)	7.8	8.3	8.2	7.3	5.8
Discharge (cubic ft/sec)	3.26	2.12	1.53	1.03	1.1
Nitrate + Nitrite as N (mg/L)	< 0.01	< 0.01	0.02	< 0.01	0.01
pH (su)	8.1	7.7	8	NA	7.7
Specific Conductivity (umhos/cm)	470	464	466	448	439
Temperature (°C)	18.7	22	12.5	17.3	15.4
Total Kjeldahl Nitrogen (mg/L)	0.57	0.51	0.39	0.42	0.6
Total Phosphorus (mg/L)	0.05	0.06	0.04	0.06	0.07
Turbidity (NTU)	8.34	6.91	3.33	15.3	8.81

Table 8
Spring 2005 Physicochemical Results

	Mussel Fork 1	Mussel Fork 2	Mussel Fork 3	Mussel Fork 4	West Locust Creek control
Sample #	502960	502961	502962	502963	503171
Ammonia as N (mg/L)	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Chloride (mg/L)	10.2	9.88	10.6	11.3	13.5
Dissolved Oxygen (mg/L)	13.2	11.9	13.1	13.8	9.3
Discharge (cubic ft/sec)	11.9	12.8	11.9	11.1	13.1
Nitrate + Nitrite as N (mg/L)	< 0.01	< 0.01	0.01	< 0.01	< 0.01
pH (su)	7.7	8.3	8.3	8.6	7.6
Specific Conductivity (umhos/cm)	390	483	469	467	470
Temperature (°C)	6.7	6.9	5.7	5.9	16.8
Total Kjeldahl Nitrogen (mg/L)	0.51	0.2	0.22	0.28	0.51
Total Phosphorus (mg/L)	0.08	0.03	0.03	0.05	0.04
Turbidity (NTU)	13.6	6.97	7.13	8.65	9.25

In comparison to the West Locust Creek control site, lower Mussel Fork sampling sites faired well in fall 2004 and spring 2005. Across a variety of parameters, there was generally little difference among the sampling sites and the control. It is notable that the West Locust Creek control site had the highest chloride and total kjeldahl nitrogen values for both seasons. In addition, dissolved oxygen values for the West Locust Creek control were the lowest for both seasons as well. The West Locust Creek Control had the lowest specific conductivity in fall 2004. However, none of these differences are noteworthy. There appears to be little, if any, physicochemical differences between lower Mussel Fork and the West Locust Creek control or among the lower Mussel Fork stations.

4.3 Biological Assessment

4.3.1 Macroinvertebrate Stream Condition Index Scores

The lower Mussel Fork metric results and MSCI scores for fall 2004 and spring 2005 are found in Table 9 and Table 10 respectively. MSCI scores are calculated by scoring station metrics against the appropriate criteria in Table 1 or Table 2.

Table 9
Fall 2004 Macroinvertebrate Stream Condition Index Scores

	Mussel Fork 1	Mussel Fork 2	Mussel Fork 3	Mussel Fork 4	West Locust Creek control
Sample Number	0418760	0418763	0418764	0418765	0418761
Taxa Richness	81	74	69	55	62
EPT Taxa	22	19	15	13	14
Biotic Index	6.39	6.13	5.61	6.53	6.73
Shannon Index	3.12	3.08	2.77	2.83	2.91
MSCI Score	20	20	20	20	20
Sustainability	Full	Full	Full	Full	Full

Table 10
Spring 2005 Macroinvertebrate Stream Condition Index Scores

	Mussel Fork 1	Mussel Fork 2	Mussel Fork 3	Mussel Fork 4	West Locust Creek control
Sample Number	0503045	0503046	0503047	0503048	0503065
Taxa Richness	65	56	62	57	60
EPT Taxa	13	10	12	9	10
Biotic Index	5.79	6.04	6.65	6.8	6.72
Shannon Index	2.64	2.77	3.07	3.00	2.73
MSCI Score	20	20	20	20	20
Sustainability	Full	Full	Full	Full	Full

4.3.2 Longitudinal Analyses

For the lower Mussel Fork segment covered by this study, the biological assessment suggests no biological impairment. Exactly 100% of the MSCI scores are $\geq$ 16 (full biological sustainability). During the development of biological criteria (MDNR 2002a), it was demonstrated that wadeable perennial reference streams stations scored $\geq$ 16 about 86% of the time.

Even though no biological impairment is suggested, there are possible trends among lower Mussel Fork samples that are worth noting. In fall 2004 samples, there is a notable decrease in TR and EPTT from downstream to upstream stations. While less obvious, this trend continues in spring 2005 samples. In addition, SDI numbers decline from downstream to upstream in fall

2004 samples, but the trend is reversed in spring 2005 samples. While none of these values differ significantly from the West Locust Creek control, it does suggest that there may be some discernable biological differences among lower Mussel Fork stations that are not detected using the MSCI.

As an additional analysis tool, the Quantitative Similarity Index for Taxa (**QSI-T**) can be used to compare the biota of stations. The QSI-T compares two aquatic communities in terms of presence or absence of taxa, also taking relative abundance of each taxa into account. Values less than 65% generally indicate environmental stress and values greater than 65% are representative of natural variation (Shackleford 1988). Matrices containing QSI-T scores can be found for fall 2004 and spring 2005 in Table 11 and Table 12 respectively.

Table 11
Fall 2004 Quantitative Similarity Index for Taxa

Station	Lower Mussel Fork 1	Lower Mussel Fork 2	Lower Mussel Fork 3	Lower Mussel Fork 4	West Locust Creek CONTROL
Lower Mussel Fork 1	100				
Lower Mussel Fork 2	70.1	100			
Lower Mussel Fork 3	65.1	**54.4**	100		
Lower Mussel Fork 4	67.6	74.1	**59.1**	100	
West Locust Creek CONTROL	68	71.5	**57.7**	75.3	100

Table 12
Spring 2005 Quantitative Similarity Index for Taxa

Station	Lower Mussel Fork 1	Lower Mussel Fork 2	Lower Mussel Fork 3	Lower Mussel Fork 4	West Locust Creek CONTROL
Lower Mussel Fork 1	100				
Lower Mussel Fork 2	71.4	100			
Lower Mussel Fork 3	**49.1**	**61**	100		
Lower Mussel Fork 4	**46.2**	**50.4**	69.4	100	
West Locust Creek CONTROL	**53.8**	**47.2**	**59.7**	**59.5**	100

For fall 2004 samples, one notable QSI-T difference exists when comparing Mussel Fork Station 2 with Mussel Fork Station 3. Other notable QSI-T differences for fall 2004 exist when Mussel Fork Station 3 is compared with Mussel Fork Station 4 and the West Locust Creek control. The QSI-T difference between Mussel Fork Station 1 and 3 is only slightly greater than 65%. In summary, for fall 2004 samples, noteworthy QSI-T differences exist between lower Mussel Fork Station 3 and nearly all other stations including the West Locust Creek control.

For spring 2005 samples, notable QSI-T differences occur when comparing Mussel Fork Station 1 with Mussel Fork Stations 3 and 4. Likewise, when comparing Mussel Fork Station 2 with Mussel Fork Stations 3 and 4, a similar QSI-T difference occurs. In addition, notable QSI-T differences exist between the West Locust Creek control and all Mussel Fork Stations. In summary, for spring 2005 samples, the only comparisons without noteworthy QSI-T differences are the comparison between Mussel Fork Stations 1 and 2 and between Mussel Fork Stations 3 and 4. All other comparisons yield noteworthy differences.

4.3.3 Ecoregional Analyses

As a temporal control, West Locust Creek, Sullivan County was re-sampled during fall 2004 and spring 2005. Study streams are evaluated during time periods that potentially include drought or high-flow periods. Therefore, a low reference stream score could indicate a response to naturally low or high water levels as well as anthropogenic impacts. West Locust Creek MSCI scores (Tables 9 & 10) scored the maximum potential points (20) and did not indicate weather induced problems.

5.0 Discussion

5.1 Habitat

When compared on a broad scale to the Plains/Grand/Chariton EDU, the Mussel Fork watershed exhibited less row cropping and more grasslands and forest. A watershed scale land use comparison of lower Mussel Fork and nearby biocriteria reference streams in the same EDU showed the lower Mussel Fork watershed to be in relatively good condition.

The SHAPP suggests a gradient of habitat conditions, with a decrease in habitat quality in an upstream direction. While all Mussel Fork stations are not comparable to each other, they were all comparable to the West Locust Creek control. Mussel Fork Station 1 did exceptionally well, and Stations 1 and 2 were the most similar to the West Locust Creek control. Mussel Fork Stations 3 and 4 were similar to the West Locust Creek control, but their habitat similarity was toward the bottom of the acceptable condition. Gradients in SHAPP scores were most evident in pool variability and channel alteration categories.

Mussel Fork Stations 1 and 2 exhibited substantial sinuosity. Mussel Fork Stations 3 and 4 lacked sinuosity, suggesting historical channelization.

Stream morphology measurements suggest a lack of riparian shading at Mussel Fork Station 3. In addition, Mussel Fork Stations 3 and 4 showed a lack of heterogeneity, having lower average depths and wider, shallower characteristics than Stations 1 and 2.

5.2 Physicochemical Water Parameters

The physicochemical characteristics of lower Mussel Fork samples acquired during this study are unremarkable. Physicochemical parameter values were similar among lower Mussel Fork stations and the West Locust Creek control and no violations of Missouri Water Quality Standards were experienced or suggested.

5.3 Biological Assessment

The MSCI score generated by this biological assessment of lower Mussel Fork suggest no biological impairment. QSI-T analyses of all lower Mussel Fork stations and the selected control show some differences in macroinvertebrate communities. Whether these differences are due to differences in habitat, discharge/watershed size, or a combination of these variables along with natural variation is extremely difficult to determine with the limited data available. Additional study regarding habitat and flow characteristics in northern Missouri streams would help determine the reasons for these differences.

5.4 Macroinvertebrates and Habitat

Macroinvertebrates have been shown to have good relationships to amounts of depositional sediment (Zweig and Rabeni 2001) in rock bottom streams. However, northern Missouri streams are largely composed of materials considered to be sediment (silt and sand) by many researchers. As in many northern Missouri reference streams, the bottom substrate of lower Mussel Fork is predominately sand. The results of this study suggest that lower Mussel Fork macroinvertebrate communities are very similar to reference streams. Depositional sediment does not appear to be a significant problem in lower Mussel Fork.

Although invertebrates are responsive to changes in substrate they may not be responsive to certain habitat problems. The lack of top predator fish has been shown to have good relationship to channelized streams and the resulting lack of pools (Williamson and Todd 2005; Vokoun and Rabeni 2003; MDNR 2005b). Although there is no definitive information available to ESP, lower Mussel Fork shows some evidence of channelization and resultant shallow water depths.

6.0 Conclusions

Habitat did not differ substantially between lower Mussel Fork and biocriteria reference streams within the Plains/Grand/Chariton EDU or the West Locust Creek control. However, habitat differed longitudinally among lower Mussel Fork stations in regard to SHAPP scores, sinuosity, and stream morphology characteristics.

Physicochemical parameters did not differ substantially between lower Mussel Fork and the West Locust Creek control stream within the Plains/Grand/Chariton EDU or among lower Mussel Fork stations.

According to MSCI values for each station, macroinvertebrate assemblages did not substantially differ between lower Mussel Fork and biocriteria reference streams within the Plains/Grand/Chariton EDU or among lower Mussel Fork stream segments. While habitat and QSI-T analyses of lower Mussel Fork macroinvertebrate communities may suggest lower habitat quality at Stations 3 and 4, macroinvertebrate assemblages showed no significant effect.

7.0 Recommendations

1) Propose the lower 14 miles of the listed portion of Mussel Fork for de-listing from the 303(d) list.

2) Recognize the need for development and incorporation of satisfactory fish bioassessment protocols into the department's aquatic bioassessment program.

3) Conduct fish bioassessments of extensively channelized streams to further evaluate the relationship between protection of aquatic life designated use, habitat conditions, pool depths, and stream channel characteristics.

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Appendix G
Biological Assessment and Habitat Study Upper Mussel Fork Creek

BIOLOGICAL ASSESSMENT AND HABITAT STUDY

Upper Mussel Fork
Sullivan and Adair Counties

2002 -2003

Prepared for:

Missouri Department of Natural Resources
Water Protection and Soil Conservation Division
Water Pollution Control Program

Prepared by:

Missouri Department of Natural Resources
Air and Land Protection Division
Environmental Services Program
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1.0 Introduction

At the request of the Missouri Department of Natural Resources (**MDNR**), Water Pollution Control Program (**WPCP**), the Environmental Services Program (**ESP**), Water Quality Monitoring Section (**WQMS**) conducted a macroinvertebrate bioassessment and habitat study of Mussel Fork in Sullivan and Adair Counties in north central Missouri. Approximately 29 miles of Mussel Fork in Sullivan, Macon, and Adair Counties are included on the 1998 303(d) list for sediment pollution from agricultural nonpoint sources. Although habitat loss is not an impact found on the 303(d) list, there are segments of Mussel Fork that have poor habitat due to channelization, vertical banks, and poor riparian zones. This survey assessed the upper 15 miles of Mussel Fork from the confluence of Little Mussel Fork in Adair County, to Section 2, Township 62 North, Range 18 West, in Sullivan County. The 15 miles of upper Mussel Fork addressed in this study are listed as Class C waters, water body I.D. #0674 (MDNR 2000), and constitute approximately the upper ½ of the listed segment. On August 30, 2002 a study plan was submitted to the WPCP (Appendix A).

1.1 Purpose

The purpose of the study was to determine if the upper Mussel Fork biological community is impaired and, if so, determine potential causes.

1.2 Objectives

1) Define the habitat characteristics of upper Mussel Fork.
2) Define the water quality characteristics of upper Mussel Fork.
3) Determine if the macroinvertebrate community and water qualities of upper Mussel Fork are affected by factors related to habitat loss.

1.3 Tasks

1) Conduct a bioassessment of the macroinvertebrate community of upper Mussel Fork.
2) Conduct a water quality assessment of upper Mussel Fork.
3) Conduct a habitat assessment of upper Mussel Fork.

1.4 Null Hypotheses

1) Macroinvertebrate assemblages will not substantially differ between Mussel Fork and biocriteria reference streams within the Plains/Grand/Chariton Ecological Drainage Unit (EDU).
2) Macroinvertebrate assemblages and habitat will not differ among Mussel Fork stream segments.

2.0 Study Area

The headwaters of Mussel Fork lie in an area between the cities of Green City and Green Castle in northeastern Sullivan County. It flows south for approximately 60-70 miles through Adair, Macon, Linn, and Chariton counties to its confluence with the Chariton River approximately 2 miles south of Keytesville and approximately 6 miles north of the confluence of the Chariton River with the Missouri River. The entire drainage of the creek is approximately 350 square miles. The drainage basin is linear in shape stretching almost 60 miles north to south and being approximately 8 miles wide at its widest point.

Northern Missouri landforms are the result of glaciation and consist of plains and low rolling hills. Agriculture is a major industry in northern Missouri including row crops and confined animal feeding operations. In many cases row crops are planted up to the banks of streams, thereby decreasing the quality of the riparian zone and leading to unstable banks and a loss of woody debris input to the stream, which in turn results in a loss of habitat. Many of the larger streams and rivers in northern Missouri have been channelized to provide more area in the river bottoms for cropland. Channelization causes a loss of channel structure, which would normally promote the formation of good quality habitats.

2.1 Site Descriptions

Six stations were chosen along upper Mussel Fork. These stations were selected to maximize differences in the amount of row crops, forestland, degree of sinuosity, and riparian condition between stations. See Figure 1 for a map of study locations.

Mussel Fork Station 1: (sec. 31, T. 61 N., R. 17 W.) Station 1 is located at the lower limit (southern end) of the study reach and below its confluence with Little Mussel Fork. It lies just north of the Adair and Macon county line. It has a poor riparian zone with crops up to the stream bank and is considered channelized. Geographic coordinates for this study station are Latitude 40° 2' 14.1", Longitude -92° 50' 37.0".

Mussel Fork Station 2: (sec. 30, T. 61 N., R. 17 W.) Station 2 is located approximately 1.8 miles upstream in a less channelized area. There is more forest in the riparian zone; however row crops dominate the stream valley. Geographic coordinates for this study station are Latitude 40° 3' 37.4", Longitude -92° 51' 18.2".

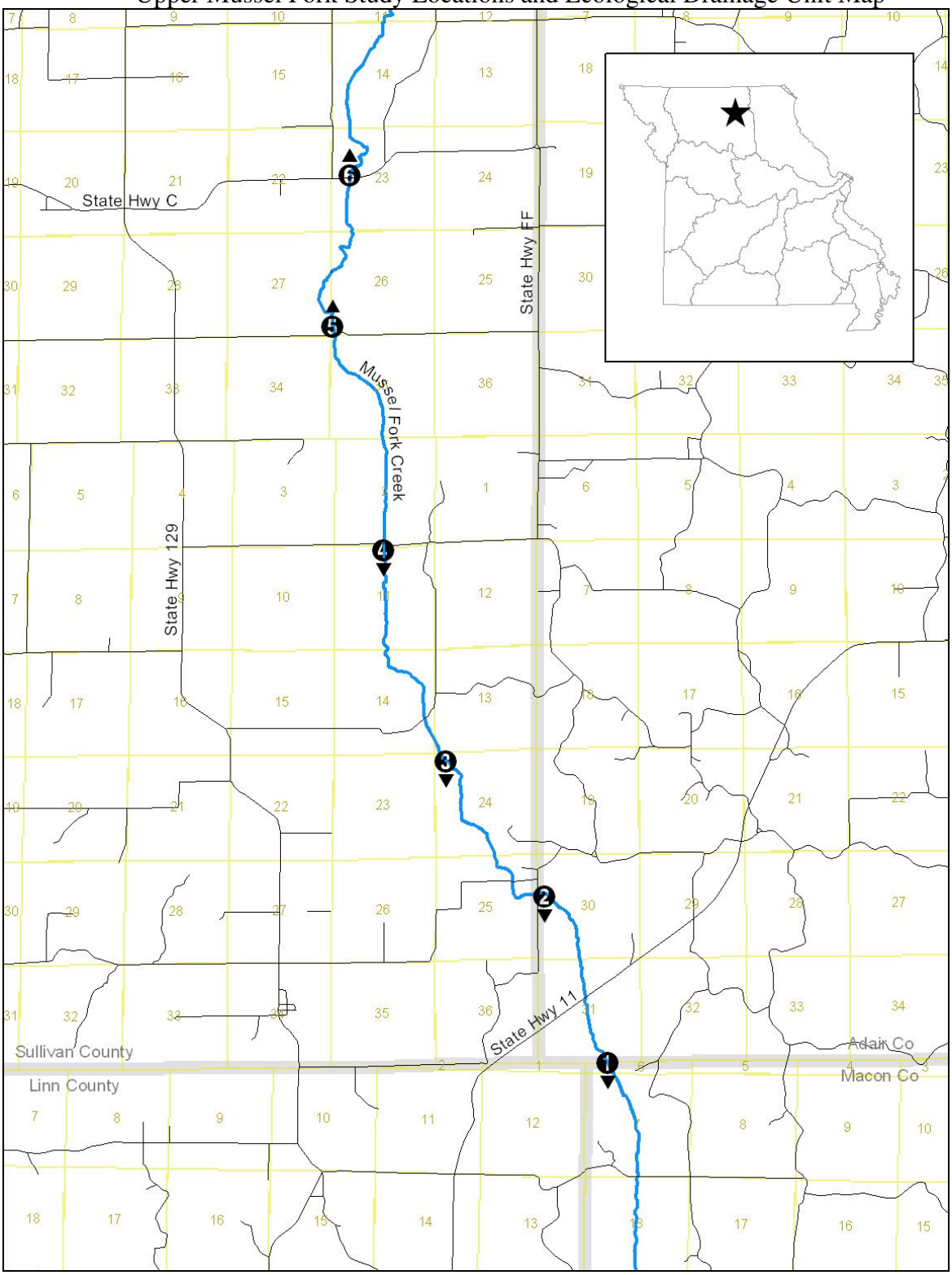
Mussel Fork Station 3: (NW ¼ sec. 24, T. 61 N., R. 18 W.) The final location of this station was different from the proposed location in the study plan because the landowner withdrew permission. Station 3 is located approximately 1.9 miles upstream from Station 2. Row crops and grassland almost wholly dominate the stream valley and riparian zone. Geographic coordinates for this study station are Latitude 40° 4' 45.4", Longitude -92° 52' 22.3".

Mussel Fork Station 4: (sec. 11, T. 61 N., R. 18 W.) Station 4 is located approximately 2.2 miles above Station 3 in a mixed area. The east side of the stream is dominated by forestland. The west is dominated by row crops, up to the edge of the stream in some cases. Geographic coordinates for this study station are Latitude 40° 6' 31.4", Longitude -92° 52' 3.4".

Mussel Fork Station 5: (sec. 26, T. 62 N., R. 18 W.) Station 5 is located approximately 2.4 miles upstream from Station 4. The creek valley here is dominated by row crops and grassland and is in a more sinuous reach of stream. Geographic coordinates for this study station are Latitude 40° 8' 23.8", Longitude -92° 53' 36.7".

Mussel Fork Station 6: (sec. 23, T. 62 N., R. 18 W.) Station 6 is located at the northern end of the study reach, approximately 1.8 miles above Station 5. This station lies on a stream segment that is the most sinuous of the study reach. The west side is dominated by forest and the east side by row crops.

Figure 1
Upper Mussel Fork Study Locations and Ecological Drainage Unit Map



This station lies 3-4 miles below the headwater area for Mussel Fork. Geographic coordinates for this study station are Latitude 40° 9' 40.2", Longitude -92° 53' 24.8".

3.0 Methods

Randy Sarver, Stuart Harlan, Carl Wakefield, Ken Lister, Steve Humphrey, and other staff of the Missouri Department of Natural Resources, Air and Land Protection Division, Environmental Services Program conducted this study. Sampling was conducted during the fall of 2002 and the spring of 2003. Fall sampling was conducted on September 16, 17, and 18, 2002, and consisted of macroinvertebrate sampling, water quality sampling, habitat assessments, and width to depth ratios measurements at six stations on upper Mussel Fork. Samples were collected at sites that had a gradient of habitat characteristics. Spring sampling was conducted on April 25 and 26, 2003, and consisted of macroinvertebrate and water quality sampling.

3.1 Habitat

Mussel Fork was 303(d) listed for stream habitat degradation through excessive sedimentation. No suspended data exists to directly document sediment as a significant impact to the stream. General fisheries data and the effect of sediment upon fish were the initial data to consider Mussel Fork for 303(d) listing. Sedimentation is one of many instream habitat problems associated with land use. Although instream habitat can be directly measured, the causes of the degradation can range from local scale sources to watershed scale sources. We collected habitat measures at the watershed scale, the reach scale, and the habitat scale to better allow us to evaluate the causes of poor habitat conditions.

3.1.1 Land Use

The land use conditions were summarized from land cover GIS files. These land cover files were provided by the Missouri Resource Assessment Partnership (MoRAP) and derived from 1991-1993 LANDSAT data. USGS aerial photographs taken within the past 10 years were also used to estimate riparian health of the sampling reach.

In addition, Mussel Fork was included in a study in which the MDNR provided funding to the University of Missouri for evaluation of reference streams in Northern Missouri (Haithcoat et al., 2003). As part of the final report to the department, a five parameter land cover model was developed to facilitate the definition of reference streams.

3.1.2 Habitat Assessment

A standardized assessment procedure was followed as described for Glide/Pool Habitat in the Stream Habitat Assessment Project Procedure (**SHAPP**) (MDNR 2003b). The habitat assessment was conducted on Mussel Fork during the September 2002 sample season.

3.1.3 Sinuosity

Sinuosity was used as a rough indicator of the amount of channelization that has taken place. Sinuosity was measured from aerial photographs of the area and is represented as a ratio of the straight line distance between two points on the stream to the length of stream between the two points.

3.1.4 Riparian Zone Condition

The riparian zone condition was visually observed and was qualitatively described as very poor, poor, good, or mixed. A very poor riparian zone condition is characterized by mostly crops and/or grassland up to the stream bank. Poor riparian zone condition is characterized by row crops planted up to the stream bank with a thin zone of trees in the riparian zone. Good riparian zone condition is characterized by little influence from row crops and abundant forest coverage. A mixed riparian zone condition is characterized by having one side of the stream rated differently than the other (e.g. very poor and good).

3.1.5 Width to Depth Ratio

Lack of instream habitat can be observed in Northern Missouri streams that are wide and shallow. Wider, shallower streams tend to have less ability to develop pools and retain woody debris (Haithcoat et al. 2003). At each sampling station a series of 10 bank to bank transects were established. Each transect was equally spaced within the sampling reach, which is 20x the average width. Measurements taken at each transect included lower bank width (see the Stream Habitat Assessment Procedure for a definition of Lower Bank), wetted width, and water depth at ¼, ½, and ¾ of the distance across the wetted width. In order to document critical habitat conditions, measurements were collected during the fall low flow period.

3.2 Physicochemical Water Parameters

Physical and chemical water samples were collected from all stations during both fall and spring. Parameters collected were nitrate+nitrite-nitrogen, ammonia-nitrogen, Total Kjeldahl Nitrogen, chloride, turbidity, temperature, conductivity, dissolved oxygen, pH, and discharge. WQMS personnel analyzed temperature, conductivity, dissolved oxygen, pH, and discharge in the field and turbidity in the biology laboratory. All other parameters were delivered to the ESP, Chemical Analyses Section for analyses. All samples were collected according to the standard operating procedure MDNR-FSS-001: Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations (MDNR 2002b) and were recorded on a MDNR chain-of-custody (MDNR 2001).

3.3 Biological Assessment

The biological assessment was conducted according to the Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (**SMSBPP**) (MDNR 2003a). All stations were sampled in September 2002 and April 2003. Three standard habitats of glide/pool streams (e.g. woody debris substrate, depositional substrate in non-flowing water, and rootmat substrate) were sampled at all locations.

Macroinvertebrate data were evaluated by comparison to Biological Criteria for Perennial/Wadeable streams of the Plains/Grand/Chariton Ecological Drainage Unit (**EDU**). An EDU is an ecological area in which the aquatic biological communities and stream habitat can be expected to be similar. See Figure 1 for a map of the EDU's of Missouri.

Biological criteria are calculated separately for the fall (mid-September through mid-October) and spring (mid-March through mid-April) index periods. The SMSBPP provides details on the calculation of metrics and scoring of the multi-metric Macroinvertebrate Stream Condition Index (**MSCI**). The four core metrics of the MSCI are: Taxa Richness (**TR**); Ephemeroptera, Plecoptera, and Trichoptera Taxa (**EPTT**); Biotic Index (**BI**); and the Shannon Diversity Index (**SDI**). An MSCI score of 16-20 is considered full biological sustainability, 10-14 is partial

biological sustainability, and 4-8 is non-biological sustainability. Table 1 provides scoring criteria for the fall index period and Table 2 for the spring index period.

Table 1
Biological Criteria for Glide/Pool- Fall Index Period
Plains/Grand/Chariton EDU

Metric	Score = 1	Score = 3	Score = 5
TR	< 25	25 - 50	> 50
EPTT	< 4	4 - 9	> 9
BI	> 8.60	8.60 – 7.19	< 7.19
SDI	< 1.34	1.34 – 2.69	> 2.69

Table 2
Biological Criteria for Glide/Pool- Spring Index Period
Plains/Grand/Chariton EDU

Metric	Score = 1	Score = 3	Score = 5
TR	< 24	24 - 48	> 48
EPTT	< 4	4 – 7	> 7
BI	> 8.62	8.62 – 7.24	< 7.24
SDI	< 1.26	1.26 – 2.52	> 2.52

4.0 Results and Analyses

4.1 Land Use

The upper reach of the Mussel Fork drainage basin, which is the subject of this report, is comprised of mainly cool season grassland (~75%), deciduous forest (~10%), and row crops (~12%). This watershed contains slightly more grassland, in place of deciduous forest and row crops, than the surrounding watersheds.

Table 3 provides two scales of land use comparison. A broad scale comparison is provided by comparing the 14 digit hydrologic units (**HU**) for upper Mussel Fork stations with the Plains/Grand/Chariton EDU. A watershed comparison is provided by comparing the 14 digit HU for upper Mussel Fork stations with the 14 digit HU of three nearby wadeable/perennial biocriteria reference streams (**BIOREF**) in the EDU. Upper Mussel Fork HU values in bold are those that potentially indicate poorer land use. No clear patterns are evident, although the HU with Mussel Fork #6 has lower forest cover.

Additional land cover information is available as part of a reference watershed model developed by Haithcoat et al. (2003). Mussel Fork is not considered a reference stream, but was included as a potentially impacted stream. Mussel Fork was the highest ranked test stream and in fact land cover parameters did as well as many reference streams. In fact, Mussel Fork was not included as a potentially impacted stream because of general watershed problems, but because of past water quality problems resulting from hog manure spills from a large confined animal feeding operation in it's headwaters.

Table 3 – Land Use

Watershed	% Urban	% Row Crops	% Grassland	% Forest

Plains Grand/Chariton EDU	0.2	30.3	53	15.2
Mussel Fork Station 1	0	7.8	65	26.9
Mussel Fork Stations 2,3,4,5	0	8.4	78.5	12.9
Mussel Fork Station 6	**0.9**	**15.9**	73.8	**8.7**
BIOREF Locust Creek	0	8.5	75.5	15.7
BIOREF Spring Creek- Adair Co.	0.4	9.7	45.6	43.9
BIOREF West Locust Creek	0	16.4	71.7	11.6

4.2 Habitat Assessment

The results of the habitat assessment are found in Table 4. Mussel Fork Station 3 is ranked lowest (71) and Station 4 the highest (95). In the SHAPP, $\geq$ 75% similarity is the guidance for considering habitats comparable between stations. Comparable habitats should be able to support comparable biological communities. When the highest Mussel Fork habitat score (Station 4) is used as the best available habitat, the lowest scoring station (Station 3) is 75% similar and at the very bottom end of comparability.

Table 4
Mussel Fork Habitat Assessment Scores

Station	Habitat Assessment Score
Mussel Fork 1	88
Mussel Fork 2	75
Mussel Fork 3	**71**
Mussel Fork 4	95
Mussel Fork 5	85
Mussel Fork 6	88

4.3 Sinuosity

Points were chosen along the length of upper Mussel Fork at one mile increments using stream miles. Sinuosity measurements near 1 are considered potentially channelized. The sinuosity of upper Mussel Fork ranges from 0.75 to 0.98. The likelihood of channelization is based on the sinuosity and visual inspection of the aerial photographs. Table 5 (Station Reach Characteristics) lists sinuosity and riparian channel characteristics for each sample station.

4.4 Riparian Zone Condition

In Table 5 the riparian zone condition is described as very poor, poor, good, or mixed. The lowest ranked riparian zone conditions are Mussel Fork Stations 3 & 5, which are rated as very poor on both stream banks. The highest ranked riparian zone conditions are Mussel Fork Stations 4 & 6, which are rated as mixed (very poor on one bank and good on the other bank).

Table 5 – Station Reach Characteristics

Station	*Sinuosity (miles/mile)	Likely to be Channelized	Riparian Zone Condition
1	0.93	Yes	Poor
2	0.82	No	Poor
3	0.89	Yes	Very Poor
4	0.98	Yes	Mixed (Very Poor/Good)
5	0.85	Yes	Very Poor
6	0.75	No	Mixed (Very Poor/Good)
*Higher number equates to less sinuosity.			

4.5 Width to Depth Ratios

Station transect measurements for lower bank channel width, wetted width, and depth are provided in Appendix D.

Some channel measurements, such as average channel width, reflect the fact that the stream width increases with increasing watershed size. The Mussel Fork study shows a clear progression in channel width data (Table 6) with the most upstream station (6) at 27.9 feet and the most downstream station (1) at 82.2 feet.

Other channel measurements, such as average depth and average wetted width, do not necessarily reflect trends associated with size. Station 5, which is toward the upstream end of the study reach, has both the greatest average depth and wetted width. These measurements indicated greater water volume by documenting the fact that water is deeper and potentially takes up more of the width of the stream than other stations. Average depth is poorest at Station 3 and Station 6. Station 6 was completely pooled during the fall 2002 sampling season.

In order to be able to do comparisons of stream stations in a longitudinal stream study it is sometimes necessary to incorporate ratios of measurements. Ratios can standardize measurements so that data such as channel width can be used in a manner that allows comparison of study stations regardless of their longitudinal placement. The ratios of channel width/wetted width, channel width/average depth, and wetted width/average depth are given in Table 6. These ratios reflect the wide shallow characteristics of the stream, which result in poorer habitat.

Mussel Fork Station #1 has a high ratio of channel width/wetted width, which demonstrates that not only is the channel the widest of all stations, but it is also approximately 7 times as wide as the stream flow within the channel. Wide channels have less potential for riparian shading, which is further diminished when stream flow meanders within the channel.

Mussel Fork Station #3 has a high ratio of wetted width/average depth, which demonstrates a relatively wide shallow stream flow indicative of poor pool habitat. Since channel measurements were taken during the summer low flow period, this station presents conditions with less potential for a diverse fish and macroinvertebrate community.

Table 6 – Stream Width and Depth Measurement Summary

Mussel Fork Station	Avg. Channel Width (ft)	Avg. Wetted Width (ft)	Avg. Depth of stream (ft)	Channel Width / Wetted Width	Channel Width / Depth	Wetted Width / Depth
1	82.2	12.1	0.37	**6.79**	**204**	30.1
2	75.3	14.9	0.37	5.05	186	36.8
3	65.9	14.0	**0.23**	4.70	**235**	**50.0**
4	49.9	16.2	0.5	3.07	94.1	30.6
5	47.4	23.5	0.93	2.01	47.5	23.6
6	27.9	7.0	**0.23**	3.98	95.1	23.8

4.6 Physicochemical Results

Results from the fall 2002 sampling season can be found in Table 7 and spring 2003 in Table 8.

The only violation of water quality standards occurred during the fall 2002 sampling season at Station 2, with a dissolved oxygen result of 3.2 mg/L. The numeric criterion is a minimum of 5.0 mg/L.

The other parameter of interest are spring 2003 phosphorus results, which were the highest at Mussel Fork Stations 5 and 6 at 0.1 and 0.11 mg/L respectively.

A comparison of spring 2003 Mussel Fork results against the biocriteria reference stream, Spring Creek, reveal that all Mussel Fork stations are higher in chloride and Total Kjeldahl Nitrogen. Mussel Fork Stations 2, 5, and 6 are higher in total phosphorus. However, Spring Creek flow and turbidity are approximately twice those of any Mussel Fork station. This indicates that rainfall, rather than watershed differences, may have been responsible for the differences in chemical parameters between Mussel Fork and Spring Creek

Table 7 – Fall 2002 Physicochemical Results

Sample Number	Station	Ammonia as N - mg/L	Chloride mg/L	Dissolved Oxygen - mg/L	Flow (cubic ft/sec)	Nitrate + Nitrite as N - mg/L	pH	Specific Conductivity umhos/cm	Temperature Degrees C	Total Kjeldahl Nitrogen mg/L	Total Phosphorus mg/L	Turbidity NTU
218103	Mussel Fk 1	< 0.05	10.5	7.5	0.03	< 0.05	7.4	519	18	0.45	< 0.05	4.42
218104	Mussel Fk 2	< 0.05	9.71	**3.7**	0.05	< 0.05	7.4	440	20.5	0.59	0.07	10
218105	Mussel Fk 3	< 0.05	13.4	6.7	0.03	< 0.05	7.8	422	24	0.72	0.08	14.1
218106	Mussel Fk 4	< 0.05	6.7	10	0.05	< 0.05	8.1	458	18	0.38	< 0.05	5.27
218107	Mussel Fk 5	< 0.05	9.12	9.2	0.05	< 0.05	7.9	403	24.5	0.6	< 0.05	13.4
218108	Mussel Fk 6	< 0.05	15.3	8.6	0	< 0.05	7.8	427	23	1.21	0.09	24.8

Table 8 – Spring 2003 Physicochemical Results

Sample Number	Station	Ammonia as N - mg/L	Chloride mg/L	Dissolved Oxygen - mg/L	Flow (cubic ft/sec)	Nitrate + Nitrite as N - mg/L	pH	Specific Conductivity umhos/cm	Temperature Degrees C	Total Kjeldahl Nitrogen mg/L	Total Phosphorus mg/L	Turbidity NTU
318657	Mussel Fk 1	< 0.03	16.5	9.7	0.33	< 0.01		443	14	0.47	0.05	4.94
318658	Mussel Fk 2	< 0.03	21.7	7.9	0.34	< 0.01		449	13.5	0.69	0.09	5.92
318659	Mussel Fk 3	< 0.03	30.3	8.2	0.25	< 0.01		436	15.6	0.77	0.07	15.3
318660	Mussel Fk 4	< 0.03	30.7	12.8	0.22	< 0.01		479	17.9	0.9	0.06	5.8
318663	Mussel Fk 5	< 0.03	29.1	8.3	0.1	< 0.01		424	13.9	1.12	**0.1**	18.6
318664	Mussel Fk 6	< 0.03	43	8.6	0.1	< 0.01		380	11.6	**1.44**	**0.11**	13.2
318662	Spring Ck 1	< 0.03	6.69	10.2	0.67	< 0.01		464	8.9	0.31	0.08	39.9

4.7 Biological Assessment

4.7.1 Macroinvertebrate Stream Condition Index Scores

The Mussel Fork metric results and MSCI scores for fall 2002 and spring 2003 are found in Table 9 and Table 10 respectively. MSCI scores are calculated by scoring station metrics against the appropriate criteria in Table 1 or Table 2.

Table 9
Fall 2002 Macroinvertebrate Stream Condition Index Scores

Sampling Station	Mussel Fk 1	Mussel Fk 2	Mussel Fk 3	Mussel Fk 4	Mussel Fk 5	Mussel Fk 6
Sample Number	0218103	0218104	0218105	0218106	0218107	0218108
Taxa Richness	67	57	50	60	64	57
EPT Taxa	13	11	8	9	7	8
Biotic Index	7.47	7.46	7.47	6.99	7.72	7.42
Shannon Index	2.86	2.48	2.7	2.66	2.82	2.68
SCI Score	18	16	14	16	16	14
Sustainability	Full	Full	Partial	Full	Full	Partial

Table 10
Spring 2003 Macroinvertebrate Stream Condition Index Scores

Sampling Station	Spring Ck 1a	Spring Ck 1b	Mussel Fk 1	Mussel Fk 2	Mussel Fk 3	Mussel Fk 4	Mussel Fk 5	Mussel Fk 6
Sample Number	0318661	0318662	0318657	0318658	0318659	0318660	0318664	0318663
Taxa Richness	68	68	52	61	61	52	48	47
EPT Taxa	10	11	6	11	9	9	5	3
Biotic Index	7.1	7.01	7.03	7.41	7.01	7.16	7.12	8.03
Shannon Index	3.2	3.08	2.31	2.76	2.82	2.54	2.71	2.54
SCI Score	20	20	16	18	20	20	16	12
Sustainability	Full	Full	Full	Full	Full	Full	Full	Partial

4.7.2 Longitudinal Analyses

In general Mussel Fork MSCI scores indicate that most of the stream stations were $\geq$ 16, which is assigned full biological sustainability.

Station 6 was consistently < 16 and assigned partial biological sustainability in both sampling seasons. The only other station to score < 16 was Station 3 during the fall 2002 sampling season.

4.7.3 Ecoregional Analyses

As a temporal control, Spring Creek, Adair County, a nearby biocriteria reference stream was re-sampled during spring 2003. Study streams are evaluated during time periods that potentially

include drought periods, and in fact Mussel Fork was sampled under these conditions. Therefore, a low reference stream score could indicate a response to natural low water levels as well as anthropogenic impacts. Spring Creek MSCI scores (Table 10) scored the maximum potential points (20) and did not indicate weather induced problems.

5.0 Discussion

Results of the bioassessment indicate that two stations failed to meet a full biological sustainability MSCI score. Station 3 received a score of 14 during the fall sampling season and Station 6 received scores of 14 and 12 respectively during the fall and spring. Scores from 10-14 are considered partial biological sustainability.

5.1 Station 3

Bioassessments at stations that have different biological sustainability categories across seasons are generally treated as indeterminate. However, when the metrics for Station 3 are examined for fall, the sample is found to be at the very top (50 taxa) of the criteria for Taxa Richness (50 = score of 3; 51 = score of 5). One additional taxa found would have allowed an MSCI score of 16. Although a combined metric error has not been calculated for wadeable perennial stream biological criteria, 89% of all duplicate samples in the ESP database have a taxa richness difference of $\geq$ 1 taxa. This allows a significant probability that a +/- 1 taxon error could place the score for Station 3 at 51 taxa, which would allow a score of 5 and a full biological sustainability score.

Habitat data for Station 3 indicated that the average depth (0.23) was among the lowest and the wetted width/average depth ratio (50) was the highest of all stations on Mussel Fork. These parameters were measured during low flow summer conditions when the amount of water is critical to aquatic organisms. This station also had the lowest (71) habitat assessment score, was observed to have a poor riparian corridor on both banks, and had sinuosity measures that indicated the potential for past channelization.

5.2 Station 6

Station 6 scores consistently equated to partial biological sustainability. Although all Mussel Fork stations fell within a Class C segment of stream, Station 6 was the most upstream and was the only station that was completely pooled during the fall sampling period. The potential macroinvertebrate habitat for this station was significantly reduced during the fall 2002 sampling by lack of water, with the effects most likely extending into the following spring. Lack of water ultimately overshadows the ability to use any other data to interpret the results of a bioassessment.

Habitat data for Station 6 indicated that the average depth (0.23) was among the lowest. Wetted width measurements (Appendix D) for Station 6 showed no water at 4 of 10 transects. In addition to lack of water, Station 6 had the highest percent urban land use (0.9), the lowest percent forest cover (8.7), and highest percent row crops of the three 14 digit watersheds that contained the 6 sampling stations. The spring 2003 water chemistry values for Station 6 were the highest of all stations for Total Kjeldahl Nitrogen (1.44 mg/L) and Total Phosphorus (0.11 mg/L).

5.3 Upper Mussel Fork Stream Segment

The overall bioassessment for the upper Mussel Fork segment covered by this study suggests no biological impairment. Exactly 75% of the MSCI scores are ≥ 16 (full biological sustainability). During the development of biological criteria (MDNR 2002a) it was demonstrated that wadeable perennial reference streams stations scored ≥ 16 about 86% of the time.

A reference watershed model developed by Haithcoat et al. (2003) ranked Mussel Fork land cover among the highest of all test streams (potentially impacted) with desirable land cover parameters similar to many reference streams. In fact, Mussel Fork was not included as a test stream because of watershed problems, but because of water quality problems resulting from a 1995 hog manure spill from a large confined animal feeding operation in it's headwaters.

Habitat is comparable throughout the longitudinal segment. As expected, some stations exhibited poorer local habitat conditions relative to other stations. All stations are comparable in habitat and are, therefore, expected to be biologically comparable. Water quantity was an important factor in Station 6, the station with the lowest MSCI scores.

Beaver dams were common along the reach from Stations 1-5. Dams were typically low height (1-2 ft. high) but created significant upstream pools. WQMS personnel attempted to minimize the influence of the pools on macroinvertebrate sampling and physical measurements. However, beavers are now, and were historically, ubiquitous in Northern Missouri streams and are an important component of stream ecology. Future studies should treat the pools as a permanent characteristic of the study stream.

Missouri Water Quality Standards numeric criteria were violated for dissolved oxygen in 1 of 12, or 8% of the measurements. Nutrient levels were highest at the most upstream stations.

5.4 Erosion Potential

Mussel Fork was originally 303(d) listed for sediment from agricultural non-point sources. Sediment load can be estimated using the Spreadsheet Tool for the Estimation of Pollutant Load (STEPL), version 2.01. The STEPL model was developed for the U.S. Environmental Protection Agency by Tetra Tech, Inc, May 2002. The model calculates soil loss in tons/year.

In a memorandum from the ESP to the WPCP, dated June 4, 2003, northern Missouri reference streams were analyzed for erosion potential using the STEPL model. Using this model, northern Missouri reference stream watershed soil loss was estimated to range from 0.23 – 1.10 tons/acre/year. Using the STEPL model, soil loss potential was also calculated for the watershed of each Mussel Fork station (Table 11). The lower Mussel Fork stations (1-3) fell within the reference stream range and the upper stations (4-6) slightly exceeded the range. A definitive relationship does not exist between soil loss and aquatic community health and there are no criteria for judging the point at which impacts can be measured. The soil loss from Mussel Fork does not differ measurably as compared to reference streams from which biological criteria have been established.

Table 11 – Mussel Fork Watershed Soil Loss

Watershed	tons/year	acres	tons/acre/year

Mussel Fork 1	47184.2	52313.7	0.9
Mussel Fork 2	39339.7	38116.8	1.0
Mussel Fork 3	35996.2	33057.6	1.1
Mussel Fork 4	32539.0	26957.4	1.2
Mussel Fork 5	27950.3	21735.6	1.3
Mussel Fork 6	21101.6	15019.1	1.4

6.0 Conclusions

Two null hypotheses were stated in the introduction: 1) Macroinvertebrate assemblages will not substantially differ between Mussel Fork and biocriteria reference streams within the Plains/Grand/Chariton Ecological Drainage Unit (EDU); and 2) Macroinvertebrate assemblages and habitat will not differ among Mussel Fork stream segments.

Null hypothesis #1 is accepted. The macroinvertebrate community of upper Mussel Fork did not substantially differ from the MSCI, which is calculated from biocriteria reference streams. Overall, upper Mussel Fork is considered fully biologically supporting.

Null hypothesis #2 is rejected. Macroinvertebrate assemblages and habitat from Station 3 and 6 did differ from Stations 1, 2, 4, and 5. Stations 3 and 6 were of lower quality relative to other stations.

7.0 Recommendations

1) Propose the upper 15 miles of the listed portion of Mussel Fork for de-listing from the 303(d) list.

2) Conduct bioassessments of extensively channeled streams to further evaluate the relationship between biological health and stream channel characteristics.

3) Conduct bioassessments of extensively row cropped watersheds to further evaluate the relationship between biological health and soil loss as predicted through use of the STEPL model.

8.0 Literature Cited

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Appendix A
Upper Mussel Fork Bioassessment Study Plan
Sullivan & Adair Counties
Missouri Department of Natural Resources
Upper Mussel Fork Bioassessment Study Plan
Sullivan & Adair Counties

August 30, 2002

Objective

This study will characterize the aquatic macroinvertebrate community and habitat in upper Mussel Fork to determine whether the stream is impaired from habitat degradation and warrants continued 303(d) listing. Our specific objectives are to determine: 1) whether there are aquatic life impairments in the stream relative to biocriteria reference streams; 2) if biological impairment is present, determine if it is related to channelized segments or segments with little riparian and heavy concentration of row crops relative to more natural segments on biocriteria reference streams; and 3) if biological impairment is present, determine if it is related to channelized segments or segments with little riparian and heavy concentration of row crops relative to unchannelized segments and segments with better riparian and lesser amount of row crop on Mussel Fork.

Null Hypotheses

1) Macroinvertebrate assemblages and habitat will not substantially differ between Mussel Fork and biocriteria reference streams within the Plains/Grand/Chariton Ecological Drainage Unit (EDU).

2) Macroinvertebrate assemblages and habitat will not differ between Mussel Fork stream segments.

Background

Mussel Fork, in Sullivan, Adair, and Macon counties, was listed as a 303(d) stream in the Total Maximum Daily Load (TMDL) listing of 1998 by the Water Pollution Control Program (WPCP). A 29-mile section of stream was originally listed for sediment impairment from agricultural non-point sources. In the proposed 2002 TMDL listing the pollutant is listed as Habitat Loss. The assessment of the 29-mile reach of 303(d) listed section of Mussel Fork will be broken into two years. In 2003 the upper 14 miles of stream (from the upstream point to the mouth of Little Mussel Fork) will be assessed. In 2004 the same approach will be applied to the lower 15 miles.

Study Design

General:

Six (6) Mussel Fork stations will be surveyed. The approximate locations are as follows: Station #1) S31, T61N, R17W @ river mile 74.9; Station #2) S30, T61N, R17W @ river mile 76.1; Station #3) SW ¼, S13, T61N, R18W @ river mile 78.3; Station #4); S11, T61N, R18W @ river mile 81.0; Station #5) S26, T62N, R18W @ river mile 83.2; and Station #6) S23, T62N, R18W @ river mile 85.1.

Each station will consist of a length approximately 20 times the average stream width, and will contain at least two pool/glide sequences, as outlined in MDNR-FSS-032. In order to assess variability among sampling stations, stream discharge, habitat assessment, and water chemistry will be determined during macroinvertebrate surveys. Sampling will be conducted during the fall of 2002 (September 15 through October 15) and spring of 2003 (March 15 through April 15).

Biological Sampling Methods: Macroinvertebrates will be sampled per the guidelines of the Semi-Quantitative Macroinvertebrate Stream Bioassessment Project Procedure (SMSBPP). Mussel Fork will be considered a glide/pool predominant streams; therefore samples will be collected from depositional (non-flowing water over depositional habitat), large woody debris, and root-mat habitats. Macroinvertebrate samples will be composites of six subsamples within non-flow and rootmat habitats and 12 subsamples within large woody debris habitat.

Habitat Sampling Methods:
1) Stream discharge will be measured at each sampling location using a Marsh-McBirney flow meter.
2) Stream habitat assessments will also be conducted within each study area following the guidelines of MDNR-FSS-032.
3) GIS analyses will be used to quantify the sinuosity, riparian, and row crop characteristics of the study segment.
4) Quantitative channel measurements of width, wetted width, and maximum water depth will be collected at Mussel Fork.

Water Quality Sampling Methods: Water samples from all sampled stations will be analyzed at the ESP laboratory for ammonia, nitrogen as NO_2 +NO_3, Total Kjeldahl Nitrogen, total phosphorus, chloride, and turbidity. Field measurements will include pH, conductivity, temperature, and dissolved oxygen.

Laboratory Methods: All samples of macroinvertebrates will be processed and identified as per MDNR-FSS-209, Taxonomic Levels for Macroinvertebrate Identification. Turbidity samples will be analyzed at the MDNR biological laboratory

Data Recording and Analyses: Macroinvertebrate data will be entered in a Microsoft Access database in accordance with MDNR-WQMS-214, Quality Control Procedures for Data Processing. Data analysis is automated within the Access database. Four standard metrics are calculated according to the SMSBPP: Total Taxa (TT); Ephemeroptera, Plecoptera, Trichoptera Taxa (EPTT); Biotic Index (BI); and the Shannon Index (SI) will be calculated for each reach. Additional metrics, such as Quantitative Similarity Index for Taxa (QSI-T) may be employed to discern differences in taxa between stations.

Macroinvertebrate data will be analyzed in two specific ways. First, a stratified comparison between habitat degraded (i.e. channelized vs. non-channelized; high density row crop/little riparian vs. low-density row crop/intact riparian) and habitat intact reaches on Mussel Fork will be performed. Secondly, the data from the Mussel Fork sites will be compared to numeric biological criteria from reference streams within the same EDU & watershed size classification.

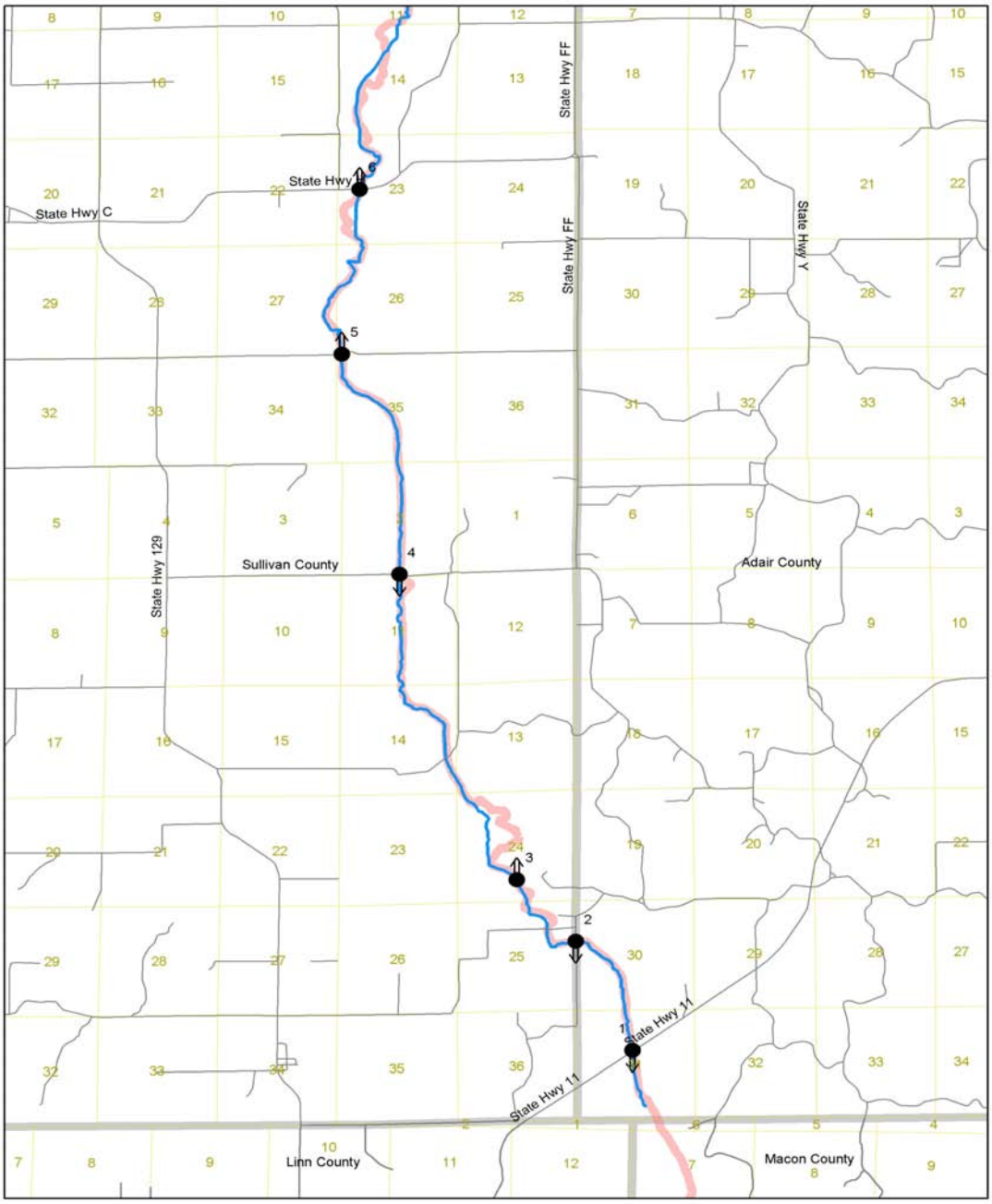
As interpretive information for biological data, the habitat scores and landscape scale characteristics will be ranked against the macroinvertebrate Stream Condition Index scores.

Data Reporting: Results of the study will be summarized and interpreted in report format.

Quality Control: As stated in the various MDNR Project Procedures and Standard Operating Procedures.

Attachments
Map of all sampling stations in this study

Upper Mussel Fork Bioassessment Study Plan
Sullivan & Adair Counties



APPENDIX B
Fall 2002
Macroinvertebrate Bench Sheets

Aquatic Invertebrate Database Bench Sheet Report

September 16, 2002 - Mussel Fk [0218103], Station #1

ORDER (Taxa)	CS	RM	SG	NF
"HYDRACARINA"				
Acarina		1	1	2
COLEOPTERA				
Oreodytes		1		
Berosus		11	2	1
Enochrus			3	
Tropisternus		-99		
Helichus lithophilus		1	3	
Scirtes		1	7	1
Dubiraphia		4		2
DIPTERA				
Culex		11		
Dasyheleinae			1	
Forcipomyiinae			2	
Ceratopogoninae		6	11	3
Ablabesmyia		8	2	19
Larsia		5		
Procladius				6
Cricotopus bicinctus		1		
Cryptochironomus				3
Dicrotendipes			17	11
Glyptotendipes			1	
Phaenopsectra			1	
Polypedilum halterale grp				13
Stenochironomus			1	
Polypedilum illinoense grp		5	3	1
Polypedilum scalaenum grp				1
Pseudochironomus		1	1	1
Cladotanytarsus		2		10
Paratanytarsus		1		
Rheotanytarsus		2	3	
Stempellinella				2
Tanytarsus		41	34	18
Dixella		5		
Zavreliella		3		
Clinotanypus				1
Thienemannimyia grp.			5	1
Labrundinia		4		5
Diptera		1		
EPHEMEROPTERA				
Callibaetis		5		
Paracloeodes			3	
Stenacron			9	
Stenonema pulchellum			1	1
Caenis latipennis		10	77	177
Leptophlebiidae			3	
Hexagenia limbata		1		7
HEMIPTERA				
Veliidae		3		

ORDER (Taxa)	CS	RM	SG	NF
Rheumatobates			3	2
Belostoma		3		
Corixidae				1
Pelocoris		-99		
LIMNOPHILA				
Lymnaeidae			1	
Physella		73	29	11
Helisoma			1	
Planorbella			1	
ODONATA				
Hetaerina		4		
Argia		11	31	4
Enallagma		93	7	
Gomphus			1	1
Progomphus obscurus				2
Libellulidae				1
Macromia		-99	2	2
Erythemis		-99	-99	-99
TRICHOPTERA				
Cheumatopsyche			6	
Hydroptilidae		2		1
Hydroptila			2	
Oxyethira		8	9	9
Nectopsyche		4	3	2
Oecetis		5		2
VENEROIDEA				
Sphaerium		1		4

Aquatic Invertebrate Database Bench Sheet Report
September 16, 2002 - Mussel Fk [0218104], Station #2

ORDER (Taxa)	CS	RM	SG	NF
"HYDRACARINA"				
Acarina		3	5	2
AMPHIPODA				
Hyalella azteca		1		
COLEOPTERA				
Berosus		1	1	2
Scirtes		24	7	1
Dubiraphia		1		3
DIPTERA				
Forcipomyiinae		1	1	
Ceratopogoninae		1		3
Ablabesmyia		12	8	11
Procladius		6		4
Corynoneura			1	
Nanocladius		1		1
Endochironomus		8		
Axarus				2
Chironomus				2
Cryptochironomus			1	6
Dicrotendipes		13	25	10
Glyptotendipes		6	25	3
Cryptotendipes				2
Paratendipes			1	
Microchironomus				2
Polypedilum halterale grp			1	6
Stenochironomus			1	
Polypedilum illinoense grp		6	2	
Polypedilum scalaenum grp		1		
Tribelos			10	
Pseudochironomus				1
Cladotanytarsus		1	1	1
Paratanytarsus		7	5	1
Stempellinella		1		
Tanytarsus		32	8	8
Thienemannimyia grp.		6	4	
Labrundinia		15	6	1
EPHEMEROPTERA				
Paracloeodes				1
Procloeon				2
Stenacron			4	
Tricorythodes		1		1
Caenis latipennis		69	96	237
Leptophlebiidae		5	2	1
Hexagenia limbata		1		6
LIMNOPHILA				
Physella		37	12	1
MEGALOPTERA				
Sialis				-99
ODONATA				

ORDER (Taxa)	CS	RM	SG	NF
Argia		17	55	1
Enallagma		23	6	
Gomphus		2		-99
Progomphus obscurus				1
Macromia				1
Erythemis		1		
Libellula				-99
TRICHOPTERA				
Hydroptila		1		
Oxyethira		3		2
Triaenodes		1		
Oecetis		2	1	
TUBIFICIDA				
Tubificidae		1		2
Aulodrilus		2		1
Enchytraeidae		1		
UNIONIDA				
Unionidae				-99
VENEROIDEA				
Sphaerium		1		-99

Aquatic Invertebrate Database Bench Sheet Report
September 17, 2002 - Mussel Fk [0218105], Station #3

ORDER (Taxa)	CS	RM	SG	NF
"HYDRACARINA"				
Acarina			1	2
COLEOPTERA				
Gyretes		1		
Tropisternus		1		
Helichus lithophilus		2	4	
Scirtes		2		
Dubiraphia		1	1	
DIPTERA				
Ormosia				2
Anopheles		4		1
Forcipomyiinae			12	
Ceratopogoninae				5
Ablabesmyia		4		2
Larsia				1
Cricotopus/Orthocladius		1		
Nanocladius		1		1
Chironomus				2
Cryptochironomus				8
Dicrotendipes		1	57	10
Glyptotendipes			21	
Cryptotendipes				3
Paratendipes				1
Polypedilum halterale grp				61
Polypedilum convictum grp		1		
Stenochironomus			1	
Polypedilum illinoense grp		4		
Polypedilum scalaenum grp		1		1
Pseudochironomus				4
Cladotanytarsus		1		43
Paratanytarsus			2	
Rheotanytarsus		3		
Stempellinella		2		18
Tanytarsus		31	16	29
Chrysops				1
Zavreliella			1	
Thienemannimyia grp.		9	7	
Labrundinia				1
EPHEMEROPTERA				
Paracloeodes		17		2
Procloeon				1
Stenacron		1	8	
Caenis latipennis		14	58	151
Leptophlebiidae		1		
Hexagenia limbata				6
LIMNOPHILA				
Physella		180	1	
ODONATA				
Coenagrionidae		53		

ORDER (Taxa)	CS	RM	SG	NF
Argia		18	17	
Enallagma		16	2	
Gomphus				2
Progomphus obscurus				-99
TRICHOPTERA				
Cheumatopsyche		1		
Nectopsyche		15		7
VENEROIDEA				
Sphaerium			1	1

Report Date: 07/22/03 **Page 2** **Mussel Fk [0218105]**

Aquatic Invertebrate Database Bench Sheet Report
September 17, 2002 - Mussel Fk [0218106], Station #4

ORDER (Taxa)	CS	RM	SG	NF
"HYDRACARINA"				
Acarina		8		3
AMPHIPODA				
Hyalella azteca		4	2	
COLEOPTERA				
Helichus lithophilus		1	1	
Scirtes		9	7	
Dubiraphia		7	1	2
DECAPODA				
Orconectes virilis		-99		
DIPTERA				
Limonia			1	
Anopheles		1		
Forcipomyiinae			2	
Ceratopogoninae		1		5
Ablabesmyia		5		5
Procladius		4		3
Cricotopus bicinctus		3		
Corynoneura		3		
Axarus				1
Cryptochironomus				4
Dicrotendipes		3	41	6
Glyptotendipes		2	4	
Cryptotendipes				1
Paralauterborniella		1		1
Nilothauma				1
Polypedilum halterale grp				11
Stenochironomus		1	5	
Polypedilum illinoense grp		9	1	4
Stictochironomus				2
Cladotanytarsus			1	24
Paratanytarsus		22	1	4
Rheotanytarsus		2		
Stempellinella		1	1	6
Tanytarsus		31	11	7
Chrysops		2	1	1
Clinotanypus		1		
Thienemannimyia grp.		8		
Labrundinia		3		
Epoicocladius				1
EPHEMEROPTERA				
Paracloeodes		1	3	4
Procloeon			1	1
Stenacron		5	23	
Stenonema femoratum			3	2
Brachycercus			1	2
Caenis latipennis		92	156	110
Leptophlebia		23	4	
Hexagenia limbata		4		86

ORDER (Taxa)	CS	RM	SG	NF
HEMIPTERA				
Rheumatobates			1	
Ranatra fusca		-99		
LIMNOPHILA				
Lymnaeidae		2		
Physella		6	2	
Ferrissia		3		
ODONATA				
Argia		12	11	
Enallagma		12	3	
Dromogomphus		2		
Gomphus			1	1
Progomphus obscurus		1		-99
Libellula		1	2	
RHYNCHOBDELLIDA				
Glossiphoniidae			-99	
TRICHOPTERA				
Nectopsyche		3		1
TUBIFICIDA				
Tubificidae				3
Aulodrilus		2	1	1
UNIONIDA				
Unionidae		-99		2
VENEROIDEA				
Sphaerium		2	1	-99

Report Date: 07/22/03 **Page 2** **Mussel Fk [0218106]**

Aquatic Invertebrate Database Bench Sheet Report
September 17, 2002 - Mussel Fk [0218107], Station #5

ORDER (Taxa)	CS	RM	SG	NF
"HYDRACARINA"				
Acarina		1		
AMPHIPODA				
Hyalella azteca		6		
COLEOPTERA				
Hydroporus		1		
Berosus		7		
Scirtes		10		
Dubiraphia		3		
DIPTERA				
Limonia			1	
Anopheles		2		
Culex		2		
Chaoborus				16
Forcipomyiinae			2	
Ceratopogoninae		7	1	
Ablabesmyia		3	3	4
Larsia		1		
Procladius				4
Nanocladius		1		1
Parakiefferiella		2		7
Paraphaenocladius			1	
Endochironomus		5		
Chironomus				13
Cladopelma				1
Cryptochironomus				12
Dicrotendipes		11	64	33
Glyptotendipes		45	58	1
Cryptotendipes				17
Nilothauma			1	
Parachironomus		1	2	
Phaenopsectra			1	
Polypedilum halterale grp			1	21
Polypedilum fallax grp			1	
Stenochironomus		1		
Polypedilum illinoense grp		23	5	1
Polypedilum scalaenum grp				1
Pseudochironomus		2	1	
Cladotanytarsus		8		8
Paratanytarsus		6	1	1
Stempellinella		1		2
Tanytarsus		11	4	7
Stratiomys		-99		
Tanypus				1
Labrundinia		5		1
EPHEMEROPTERA				
Procloeon		1		1
Stenacron		2	1	
Stenonema femoratum			1	

ORDER (Taxa)	CS	RM	SG	NF
Caenis latipennis		30	94	109
Leptophlebiidae		1		
Hexagenia limbata				2
HEMIPTERA				
Rheumatobates		12		
Trepobates		2		
Neoplea		1		
Corixidae				1
LIMNOPHILA				
Lymnaeidae		2	1	
Physella		18	18	
Helisoma		-99	1	
Planorbella		1		
ODONATA				
Argia		2	-99	
Enallagma		47	1	1
Dromogomphus				1
Macromia		1		
TRICHOPTERA				
Oecetis		1		
TUBIFICIDA				
Tubificidae				4
Aulodrilus				3
VENEROIDEA				
Pisidium				2
Sphaerium			1	2

Report Date: 07/22/03 **Page 2** **Mussel Fk [0218107]**

Aquatic Invertebrate Database Bench Sheet Report
September 17, 2002 - Mussel Fk [0218108], Station #6

ORDER (Taxa)	CS	RM	SG	NF
"HYDRACARINA"				
Acarina		13		18
AMPHIPODA				
Hyalella azteca		15		
COLEOPTERA				
Tropisternus			1	
Helichus lithophilus			5	
Scirtes		8		
Dubiraphia		3		
DECAPODA				
Orconectes immunis		1		
Orconectes virilis		-99		
DIPTERA				
Chaoborus			1	4
Ceratopogoninae		4	2	10
Ablabesmyia		2	1	7
Procladius				14
Nanocladius		1	1	
Axarus				1
Chironomus			2	1
Cryptochironomus		1		1
Dicrotendipes		4	25	13
Glyptotendipes		28	72	
Parachironomus		4		
Phaenopsectra			1	
Polypedilum halterale grp		1		14
Stenochironomus			3	
Polypedilum illinoense grp		6		
Stictochironomus				1
Cladotanytarsus				6
Paratanytarsus		11	3	
Stempellinella				9
Tanytarsus		2	9	9
Tabanus		1		
Dolichopodidae		1		2
Clinotanypus		2		
Tanypus				1
Labrundinia			1	1
EPHEMEROPTERA				
Procloeon				5
Stenacron		1	18	
Stenonema femoratum			1	1
Caenis latipennis		43	147	125
Leptophlebiidae		1		
Hexagenia limbata		2	2	34
HEMIPTERA				
Ranatra fusca		1		
Neoplea		1		
Corixidae				2

ORDER (Taxa)	CS	RM	SG	NF
Mesovelia		1		
LIMNOPHILA				
Physella		5	3	1
Helisoma		1		
Ancylidae		2	3	1
ODONATA				
Argia		13	6	
Enallagma		22		
Gomphus		2		
Progomphus obscurus				-99
RHYNCHOBDELLIDA				
Glossiphoniidae			-99	
TRICHOPTERA				
Triaenodes		7		
Oecetis		1		4
TUBIFICIDA				
Tubificidae		10		2
UNIONIDA				
Unionidae		-99		
VENEROIDEA				
Sphaerium		6	1	1
Corbicula		11		

Report Date: 07/22/03 **Page 2** **Mussel Fk [0218108]**

Appendix C
Spring 2003
Macroinvertebrate Bench Sheets

Aquatic Invertebrate Database Bench Sheet Report

March 25, 2003 - Mussel Fk [0318657], Station #1

ORDER (Taxa)	CS	RM	SG	NF
"HYDRACARINA"				
Acarina			2	
AMPHIPODA				
Hyalella azteca		1	1	
Crangonyx		-99		
COLEOPTERA				
Agabus			-99	
Oreodytes				1
Hydroporus		-99		
Berosus		1	2	1
Helichus lithophilus			3	
DIPTERA				
Dasyheleinae		2	1	3
Ceratopogoninae		14	9	61
Simuliidae		1		
Ablabesmyia		2		12
Larsia			1	
Monopelopia		9	3	38
Procladius				3
Cricotopus bicinctus		18	6	
Corynoneura		5		1
Cricotopus/Orthocladius		11	9	1
Paraphaenocladius		8	2	
Hydrobaenus		3		1
Thienemanniella		1	1	
Dicrotendipes		9	19	5
Phaenopsectra			4	
Polypedilum halterale grp			1	7
Polypedilum illinoense grp		5	23	3
Stictochironomus				2
Pseudochironomus				1
Cladotanytarsus		1	1	3
Paratanytarsus		5	2	
Rheotanytarsus		3	3	
Tanytarsus		137	159	54
Tabanus		-99	1	-99
Thienemannimyia grp.		5	4	1
Labrundinia		3		1
EPHEMEROPTERA				
Callibaetis				1
Stenacron			1	
Caenis latipennis		33	41	64
Leptophlebia		1		-99
Hexagenia limbata				1
HEMIPTERA				
Belostoma		-99		
Ranatra fusca		-99		
LIMNOPHILA				
Fossaria		2		

ORDER (Taxa)	CS	RM	SG	NF
Physella			12	17
ODONATA				
Argia				1
Enallagma		1		
Gomphus				-99
Progomphus obscurus				-99
Libellula		1	1	2
TRICHOPTERA				
Oecetis				1
TRICLADIDA				
Planariidae			1	
VENEROIDEA				
Sphaeriidae		1		3
Pisidium				1

Report Date: 10/14/03 **Page 2** **Mussel Fk [0318657]**

Aquatic Invertebrate Database Bench Sheet Report
March 25, 2003 - Mussel Fk [0318658], Station #2

ORDER (Taxa)	CS	RM	SG	NF
"HYDRACARINA"				
Acarina		6	3	2
AMPHIPODA				
Hyalella azteca		2	13	
COLEOPTERA				
Oreodytes		3		2
Berosus			1	
Enochrus			1	
Helophorus		1		
Tropisternus		1		
Scirtes		15	2	
Dubiraphia			2	4
DIPTERA				
Ceratopogoninae		2	8	43
Ablabesmyia		3	10	12
Procladius			3	4
Cricotopus/Orthocladius			1	1
Nanocladius		1		1
Paraphaenocladius		6	2	1
Hydrobaenus		1		3
Endochironomus		9	3	
Chironomus				3
Dicrotendipes		9	17	14
Glyptotendipes		10	31	
Cryptotendipes				2
Paralauterborniella				1
Paratendipes				2
Phaenopsectra		8	12	
Polypedilum halterale grp			2	16
Polypedilum illinoense grp		4	7	2
Stictochironomus				1
Pseudochironomus		1		
Cladotanytarsus			1	12
Paratanytarsus		41	16	5
Tanytarsus		1	3	52
Dolichopodidae		1		
undescribed Empididae		1		
Clinotanypus		2		
Tanypus				1
Thienemannimyia grp.		1		
Labrundinia		2		2
EPHEMEROPTERA				
Callibaetis		2		
Stenacron		5	1	
Stenonema femoratum			1	
Caenis latipennis		74	114	125
Leptophlebia		2		1
Hexagenia limbata				2
HEMIPTERA				

ORDER (Taxa)	CS	RM	SG	NF
Corixidae			1	2
LIMNOPHILA				
Fossaria		5		
Physella		36	25	4
Helisoma		1		
Ancylidae			1	
ODONATA				
Argia		12	2	1
Enallagma		12	3	
Nasiaeschna pentacantha		1		
Progomphus obscurus				1
Libellula			1	-99
TRICHOPTERA				
Polycentropus				1
Agrypnia		-99	-99	1
Pycnopsyche		-99		
Triaenodes			1	
Oecetis		3	1	1
TUBIFICIDA				
Tubificidae		2		
Aulodrilus		1	1	
Limnodrilus hoffmeisteri		1		
VENEROIDEA				
Sphaeriidae				4

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Aquatic Invertebrate Database Bench Sheet Report

March 25, 2003 - Mussel Fk [0318659], Station #3

ORDER (Taxa)	CS	RM	SG	NF
"HYDRACARINA"				
Acarina			1	
AMPHIPODA				
Hyalella azteca			4	
Crangonyx		-99		
COLEOPTERA				
Agabus		-99		
Oreodytes			3	-99
Berosus			1	
Helichus lithophilus		5		
Scirtes		1	1	
DIPTERA				
Gonomyia			1	
Ceratopogoninae		8	11	25
Ablabesmyia		11	6	2
Larsia		3	1	4
Procladius			1	1
Cricotopus bicinctus		21	3	1
Cricotopus/Orthocladius		2	3	
Nanocladius		4		
Parakiefferiella				2
Paraphaenocladius		1		
Hydrobaenus			5	
Chironomus			1	1
Dicrotendipes		2	34	7
Glyptotendipes			16	
Cryptotendipes				2
Nilothauma			3	1
Phaenopsectra			2	
Polypedilum halterale grp			5	31
Saetheria				1
Polypedilum illinoense grp		5	4	2
Polypedilum scalaenum grp				6
Stictochironomus			6	1
Pseudochironomus			10	2
Cladotanytarsus		1	7	44
Paratanytarsus		11	1	1
Rheotanytarsus		1		
Tanytarsus		82	29	50
Hemerodromia		1		
Thienemannimyia grp.			9	
Labrundinia		1		1
EPHEMEROPTERA				
Acerpenna			1	
Caenis latipennis		57	94	60
Leptophlebia		1	1	
Hexagenia limbata			1	1
HEMIPTERA				
Corixidae			2	4

ORDER (Taxa)	CS	RM	SG	NF
LIMNOPHILA				
Fossaria			2	
Physella		26	7	3
Ferrissia		1		
LUMBRICULIDA				
Lumbriculidae		2		
ODONATA				
Argia		3	1	
Enallagma		1		
Progomphus obscurus				-99
Libellula			1	
TRICHOPTERA				
Oxyethira			2	1
Agrypnia		1		
Uenoidae				-99
Nectopsyche		11	2	1
Oecetis			1	
TUBIFICIDA				
Tubificidae		1		5
Aulodrilus			5	11
VENEROIDEA				
Sphaeriidae		1		7
Pisidium			1	1
Sphaerium			1	

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Aquatic Invertebrate Database Bench Sheet Report
March 25, 2003 - Mussel Fk [0318660], Station #4

ORDER (Taxa)	CS	RM	SG	NF
"HYDRACARINA"				
Acarina		23		
AMPHIPODA				
Hyalella azteca		2	2	1
COLEOPTERA				
Laccophilus		-99		
Berosus			1	
Helichus lithophilus		3	1	
Dubiraphia		9	2	
DIPTERA				
Ceratopogoninae		7		3
Ablabesmyia		6	4	7
Procladius				9
Cricotopus bicinctus		1		
Cricotopus/Orthocladius		3	3	
Nanocladius		1		
Paraphaenocladius		4		2
Hydrobaenus			3	3
Cryptochironomus			2	3
Dicrotendipes		14	26	20
Glyptotendipes		5	6	
Phaenopsectra		15	4	
Polypedilum halterale grp		3	2	3
Polypedilum fallax grp			2	
Stenochironomus		1	2	
Polypedilum illinoense grp		4	1	
Stictochironomus			6	6
Cladotanytarsus		4	7	31
Paratanytarsus		66	9	13
Tanytarsus		29	23	13
Thienemannimyia grp.		11	21	1
Labrundinia				1
Diptera		1		
EPHEMEROPTERA				
Stenacron		1		
Caenis latipennis		82	99	164
Leptophlebia		1		2
Hexagenia limbata		2	2	3
LIMNOPHILA				
Fossaria			2	
Physella		4	8	2
Ancylidae		1	1	
MEGALOPTERA				
Sialis		1		
ODONATA				
Enallagma		3	1	1
Progomphus obscurus				2
Libellula		1		2
Plathemis		-99		

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ORDER (Taxa)	CS	RM	SG	NF
TRICHOPTERA				
Cheumatopsyche			1	
Hydroptila		2		
Limnephilidae		1		
Triaenodes		2	4	
Oecetis			4	
TUBIFICIDA				
Tubificidae		9		
Aulodrilus		2		1
Limnodrilus hoffmeisteri		2		
Enchytraeidae		1		
VENEROIDEA				
Pisidium		2		
Sphaerium		1	1	2

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Aquatic Invertebrate Database Bench Sheet Report
March 26, 2003 - Mussel Fk [0318664], Station #5

ORDER (Taxa)	CS	RM	SG	NF
"HYDRACARINA"				
Acarina		10	11	8
AMPHIPODA				
Hyalella azteca		4		
COLEOPTERA				
Oreodytes			1	
Tropisternus		-99		
Scirtes		2		
DIPTERA				
Ormosia		1		1
Chaoborus				3
Dasyheleinae			1	
Ceratopogoninae			8	13
Ablabesmyia		7	6	2
Procladius				2
Cricotopus/Orthocladius			1	
Nanocladius		9	1	
Parakiefferiella		1		6
Paraphaenocladius		2	3	1
Hydrobaenus		1	1	
Endochironomus		3	12	
Chironomus				1
Cryptochironomus			1	1
Dicrotendipes		21	96	26
Glyptotendipes		61	48	2
Cryptotendipes			1	2
Nilothauma			3	1
Phaenopsectra		3	2	
Polypedilum halterale grp			11	42
Polypedilum illinoense grp		15	12	4
Polypedilum scalaenum grp			1	
Pseudochironomus			2	1
Cladotanytarsus		1	62	64
Paratanytarsus		62	17	2
Tanytarsus		4	22	21
Thienemannimyia grp.		2	2	
Labrundinia		1		2
Diptera		1		
EPHEMEROPTERA				
Caenis latipennis		109	47	34
Leptophlebia		1		1
HEMIPTERA				
Microvelia		1		
LIMNOPHILA				
Fossaria		10	2	
Physella			2	2
LUMBRICINA				
Lumbricidae				4
ODONATA				

ORDER (Taxa)	CS	RM	SG	NF
Enallagma		3		1
Gomphus				-99
TRICHOPTERA				
Agrypnia				-99
Nectopsyche		1		
Triaenodes			1	
TUBIFICIDA				
Tubificidae		2	1	21
Limnodrilus hoffmeisteri				1
Enchytraeidae		1		12

Aquatic Invertebrate Database Bench Sheet Report
March 26, 2003 - Mussel Fk [0318663], Station #6

ORDER (Taxa)	CS	RM	SG	NF
"HYDRACARINA"				
Acarina		9	4	5
AMPHIPODA				
Hyalella azteca		15	15	1
COLEOPTERA				
Peltodytes				1
Berosus			1	
Tropisternus			1	
Scirtes			1	
Dubiraphia			1	
DIPTERA				
Pilaria				1
Ceratopogoninae		1	5	5
Ablabesmyia			5	
Procladius		8		12
Cricotopus/Orthocladius		13	10	4
Nanocladius			1	
Paraphaenocladius			1	
Psectrocladius				4
Hydrobaenus		14	13	20
Chironomus			1	24
Dicrotendipes		3	21	
Glyptotendipes		108	60	1
Parachironomus		3		1
Phaenopsectra		1		
Polypedilum halterale grp			2	5
Stenochironomus			2	
Polypedilum illinoense grp			2	
Pseudochironomus			1	
Cladotanytarsus			1	3
Paratanytarsus		2	6	1
Tanytarsus			4	3
Tabanus		4		3
Diptera		1	2	
EPHEMEROPTERA				
Caenis latipennis		52	149	12
HEMIPTERA				
Belostoma		-99		
Ranatra fusca		1		
ISOPODA				
Caecidotea		2		
LIMNOPHILA				
Fossaria			3	
Physella			21	3
Ancylidae			1	
LUMBRICINA				
Lumbricidae		1		
TRICHOPTERA				
Limnephilidae			2	

ORDER (Taxa)	CS	RM	SG	NF
Triaenodes			3	
TUBIFICIDA				
Tubificidae		7		9
Aulodrilus			1	1
Ilyodrilus templetoni		3		
Limnodrilus hoffmeisteri		7		6
Enchytraeidae		2	1	
VENEROIDEA				
Sphaeriidae		1		5
Pisidium				2

Appendix D
Fall 2002
Channel Width and Depth Data

Station 1

Transect	Channel Width (ft)	Wetted Width (ft)	Depth of stream at % of wetted width (ft):		
			25%	50%	75%
1	70.6	10.1	0.1	0.2	0.3
2	68.1	13.3	0.5	0.3	0.15
3	66.1	11.1	0.2	0.2	0.05
4	66.5	2.3	0.05	0.1	0.15
5	66.2	11.9	0.2	0.15	0.05
6	51.7	25.9	0.6	1	1.1
7	89.9	16.7	0.9	1.4	1.55
8	115	10	0.15	0.2	0.15
9	115	12.9	0.4	0.6	0.9
10	113	6.8	0.1	0.15	0.15
Average	82.2	12.1	0.3	0.4	0.4

Station 2

Transect	Channel Width (ft)	Wetted Width (ft)	Depth of stream at % of wetted width (ft):		
			25%	50%	75%
1	85	42	0.3	0.3	0.6
2	78	11.3	0.55	0.6	0.3
3	57	13	0.2	0.15	0.3
4	92	5	0.3	0.2	0.05
5	83	8	0.5	0.3	0.1
6	77	6.5	0.3	0.4	0.2
7	75	14.5	0.6	0.35	0.3
8	56	19	0.55	1.1	1.15
Average	5.3	14.9	.4	0.4	0.3
In order to characterize a homogenous stretch of stream only eight transects were measured at this station.					

Station 3

Transect	Channel Width (ft)	Wetted Width (ft)	Depth of stream at % of wetted width (ft):		
			25%	50%	75%
1	52	6	0.2	0.1	0.05
2	47	4.5	0.2	0.25	0.2
3	57	5	0.1	0.15	0.15
4	67	7.5	0.1	0.15	0.1
5	66	18	0.2	0.15	0.25
6	77	19	0.1	0.1	0.15
7	77	24.5	0.1	0.2	0.5
8	68	8	0.2	0.2	0.2
9	65	18.5	0.2	0.2	0.2
10	83	29	1.9	1.1	0.7
Average	65.9	14.0	.3	0.2	0.2

Station 4

Transect	Channel Width (ft)	Wetted Width (ft)	Depth of stream at % of wetted width (ft):		
			25%	50%	75%
1	60	36	0.5	0.5	0.4
2	52	7	0.1	0.1	0.2
3	55	10.8	1.6	1.3	0.6
4	46	40	1.3	1.1	0.8
5	60	5	0.25	0.2	0.05
6	40	12.5	0.75	0.5	0.3
7	46	15	0.4	0.5	0.6
8	53	21	0.7	0.8	1.1
9	44	9.5	0.1	0.15	0.1
10	43	5.5	0.4	0.3	0.2
Average	9.9	16.2	.6	0.5	0.4

Station 5

Transect	Channel Width (ft)	Wetted Width (ft)	Depth of stream at % of wetted width (ft):		
			25%	50%	75%
1	42	25	2.6	2.5	1.8
2	44	9	0.9	1.3	1
3	51	22	1.2	2.4	1.3
4	56	17	1.2	0.6	0.5
5	52	38	0.8	0.8	0.7
6	48	25	0.6	0.65	0.5
7	52	25.5	1.6	1.3	0.8
8	48	21	0.7	0.6	0.225
9	42	25	0.5	0.8	0.6
10	39	28	0.5	0.5	0.4
Average	7.4	23.5	1.0	1.1	0.7

Station 6

Transect	Channel Width (ft)	Wetted Width (ft)	Depth of stream at % of wetted width (ft):		
			25%	50%	75%
1	22	12.5	0.7	0.8	0.4
2	30	8	0.2	0.3	0.1
3	35	7.5	0.2	0.45	0.3
4	25	19	0.65	1.4	1.4
5	36	19.5	0.4	0.6	0.4
6	30	0	0	0	0
7	27	0	0	0	0
8	24	0	0	0	0
9	24	3.5	0.15	0.15	0.2
10	26	0	0	0	0
Average	7.9	7.0	0.2	0.3	0.2

Appendix H

Missouri Department of Natural Resources

Total Maximum Daily Load Information Sheet

For Streams with Aquatic Habitat Loss that are Listed for Sediment

Waterbody Segment at a Glance:

Location: Streams in Northern and West Central Missouri and in the Mississippi Embayment of Southeast Missouri and the Missouri and Mississippi Rivers.

Impairment: In 1998 the Department of Natural Resources listed 38 streams with habitat impairment due to agricultural nonpoint source problems. Twelve of them were delisted because new data showed they were higher quality reference streams, not impaired by sediment. One of them was retained on the list for "unknown" pollutants. The other 25 of them appear on the 2002 US EPA 303(d) list for Missouri as being impaired by "sediment".

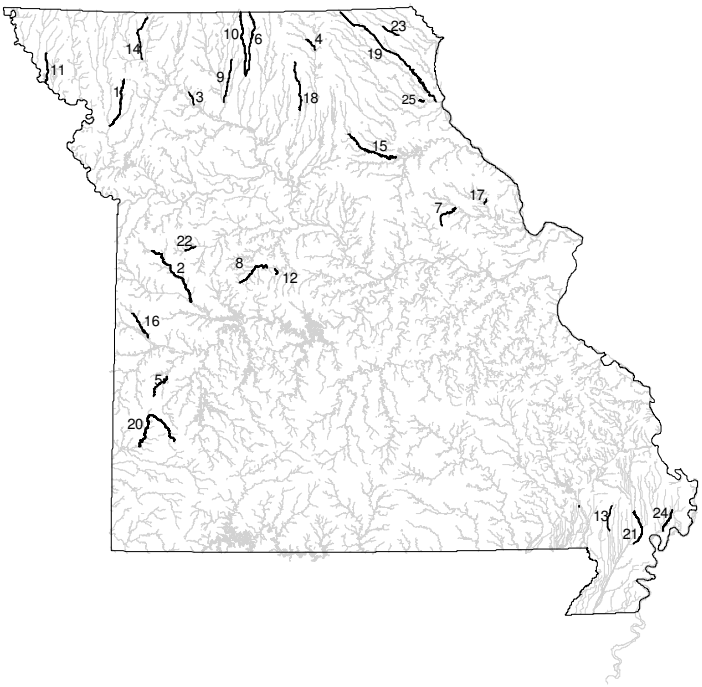
Description of the Problem

All of these waters, as per Missouri Water Quality Standards, must provide a suitable home for aquatic life. A combination of natural geology and land use in the prairie portions of the state and the Mississippi Embayment is believed to have reduced the amount and impaired the quality of aquatic habitat. The major problems are excessive rates of sediment deposition due to streambank erosion and sheet erosion from agricultural lands, loss of stream length and loss of stream channel heterogeneity due to channelization, and changes in basin hydrology that have increased flood flows and prolonged low flow conditions. Loss of tree cover in riparian zones has caused elevated water temperatures in summer and a reduction in woody debris, a critical aquatic habitat component in prairie streams. The most compelling evidence of loss or impairment of aquatic habitat is the historical change in distribution of fishes in Missouri. Many species of fish no longer appear in portions of the state where they once lived.

The department proposed changing the listing of "sediment" to "habitat loss." This change was proposed because sediment is often an important, but certainly not the only, pollutant or condition causing degradation of aquatic habitat in these streams. With this proposed change, other problems such as channelization, alteration of streambanks and riparian zones, and alteration of normal flow regimes would be included as conditions contributing to impairment. The US Environmental Protection Agency denied this change because habitat loss is "pollution", not a specific "pollutant" that can be measured and calculated. This is necessary because a TMDL (Total Maximum Daily Load) is a numeric calculation.

The department is developing a sediment protocol to determine if sediment is actually the pollutant in these streams and a standard way to measure sediment.

Missouri Streams with Loss of Habitat due to Agricultural Non-Point Source Pollution



#	Waterbody	County (lower section)	Miles affected		#	Waterbody	County (lower section)	Miles affected
1	3rd Fork Platte River	Buchanan	31.5		14	M. Fork Grand River	Gentry	25
2	Big Creek	Henry	49		15	M. Fork Salt River	Monroe	49
3	Big Muddy Creek	Daviess	8		16	Miami Creek	Bates	18
4	Blackbird Creek	Adair	10.5		17	Mill Creek	Lincoln	4
5	Clear Creek	Vernon	18		18	Mussel Fork	Macon	29
6	E. Fork Medicine Cr.	Grundy	36		19	N. Fabius River	Marion	82
7	Elkhorn Creek	Montgomery	19		20	N. Fork Spring River	Jasper	51.5
8	Flat Creek	Pettis	20		21	Old Channel Little R.	New Madrid	20
9	Honey Creek	Livingston	23		22	S. Fork Blackwater R.	Johnson	5
10	Little Medicine Creek	Grundy	40		23	S. Wyaconda River	Clark	9
11	Little Tarkio Creek	Holt	17.5		24	Spillway Ditch	New Madrid	13.5
12	Lake Creek	Pettis	5		25	Troublesome Creek	Marion	3.5
13	Lateral #2 Main Ditch	Stoddard	11.5					

For more information call or write:
Missouri Department of Natural Resources
Water Protection Program
P.O. Box 176, Jefferson City, MO 65102-0176
1-800-361-4827 or (573) 751-1300 office or (573) 751-9396 fax
Program Home Page: www.dnr.state.mo.us/deq/wpcp