Biological Assessment and Metals Characterization Report

Tiff Creek (WBID 3763), Jefferson County and Koen Creek (WBID 2171), St. Francois County, Missouri

Fall 2013 – Spring 2014

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
Division of Environmental Quality
Environmental Services Program
Water Quality Monitoring Section

TABLE OF CONTENTS

Section **Page**

1.0 Introduction 1
- 1.1 Justification 1
- 1.2 Objectives 2
- 1.3 Null Hypotheses 2

2.0 Methods 3
- 2.1 Study Timing 3
- 2.2 Study Area, Station Locations, and Descriptions 3
  - 2.2.1 Ecological Drainage Unit 6
  - 2.2.2 Land Use Description 6
- 2.3 Stream Habitat Assessment Project Procedure 6
- 2.4 Biological Assessment 7
  - 2.4.1 Macroinvertebrate Sampling, Identification and Analyses: Primary Metrics 7
  - 2.4.2 Macroinvertebrate Analyses: Secondary Metrics 8
  - 2.4.3 Physicochemical Water Sampling and Analyses 9
  - 2.4.4 Discharge 9
- 2.5 Dissolved Metals – Surface Water 9
- 2.6 Fine Sediment Characterization 10
- 2.7 Quality Control 11

3.0 Results 11
- 3.1 Stream Habitat Assessment 11
- 3.2 Biological Assessment 11
  - 3.2.1 Macroinvertebrate Community Analyses: Primary Metrics and Candidate Reference Comparison 12
  - 3.2.2 Percent Sensitive Taxa Comparison 15
  - 3.2.3 Dominant Macroinvertebrate Taxa 16
  - 3.2.4 General Water Quality Analyses 18
- 3.3 Dissolved Metals – Surface Water 20
- 3.4 Fine Sediment Characterization: Total Recoverable Cadmium, Lead and Zinc 21

4.0 Discussion 24
- 4.1 Stream Habitat Assessment 24
- 4.2 Biological Assessment 24
  - 4.2.1 Macroinvertebrate Community Analyses: Primary Metrics 24
  - 4.2.2 Macroinvertebrate Community Analyses: Secondary Metrics 25
  - 4.2.3 General Water Quality 27
- 4.3 Dissolved Metals: Surface Water 29
- 4.4 Fine Sediment Characterization: Heavy Metals 29
- 4.5 Fine Sediment Influence on Surface Water Metals 30

5.0 Conclusions 31

6.0 Recommendations 33

7.0 Literature Cited 33

TABLES

Page

Table 1 Locations and Descriptions for Tiff Creek (3763), Koen Creek (2171) and Huzzah Creek#2 Stations 3

Table 2 Percent Land Use by HUC-12 for Tiff Creek, Koen Creek, Huzzah Creek #2, and the Ozark/Black/Current EDU 6

Table 3 Stream Habitat Assessment Project Procedure Scores and Comparisons with Control Stream.....11

Table 4a Biological Criteria Reference Streams (BIOREF) Metric Scores, Individual Metric Values and Scores, Macroinvertebrate Stream Condition Index (MSCI) Scores, and Biological Support Category for Tiff Creek and Koen Creek, Fall 2013.....12

Table 4b Candidate Reference (Similar-size) Stream Biological Criteria, Individual Metric Values and Scores, ΔMacroinvertebrate Stream Condition Index (MSCI) Scores, and ΔBiological Support Categories for Tiff Creek and Koen Creek, Fall 2013 13

Table 5a Biological Criteria Reference Streams (BIOREF) Metric Scores, Individual Metric Values and Scores, Macroinvertebrate Stream Condition Index (MSCI) Scores, and Biological Support Category Tiff Creek and Koen Creek, Spring 2014.....14

Table 5b Candidate Reference (Similar-size) Stream Biological Criteria, Individual Metric Values and Scores, ΔMacroinvertebrate Stream Condition Index (ΔMSCI) Scores, and ΔBiological Support Categories for Tiff Creek and Koen Creek, Spring 2014.....14

Table 6 Percent Sensitive Taxa Distribution (Biotic Index Values) Tiff Creek, Koen Creek, and the Ozark/Meramec EDU in Fall 2013 15

Table 7 Percent Sensitive Taxa Distribution (Biotic Index Values) Tiff Creek, Koen Creek, and the Ozark/Meramec EDU, Spring 2014.....16

Table 8 Dominant Macroinvertebrate Taxa Percentage (and Rank) per Taxon for BIOREF and Tiff Creek and Koen Creek, Fall 2013 17

Table 9 Dominant Macroinvertebrate Taxa Percentage (and Rank) per Taxon for BIOREF, Tiff Creek and Koen Creek, Spring 2014 18

Table 10 Physicochemical Water Parameters in Tiff Creek and Koen Creek, Fall 2013 19

Table 11 Physicochemical Water Parameters in Tiff Creek and Koen Creek, Spring 2014 20

Table 12 Dissolved Metals (µg/L) and Hardness in Surface Water (Grab) Samples from Tiff Creek and Koen Creek, Fall 2013 22

Table 13 Dissolved Metals (µg/L) and Hardness in Surface Water (Grab) Samples from Tiff Creek and Koen Creek, Spring 2014 22

Table 14 Total Recoverable Metals Character in the Fine Sediment (<2.0mm): Cadmium, Lead, and Zinc Concentrations (mg/kg Dry Weight), Fall 2013 23

Table 15 Total Recoverable Metals Character in the Fine Sediment (<2.0mm): Cadmium, Lead, and Zinc Concentrations (mg/kg Dry Weight), Spring 2014 23

FIGURES

Page

Figure 1 Tiff Creek and Koen Creek in the Ozark/Meramec EDU, Fall 2013 and Spring 2014 4

Figure 2 Tiff Creek, Jefferson County and Koen Creek, St. Francois County Stations, Fall 2013 and Spring 2014 5

Figure 3 Illustration of Percent Sensitive Taxa Distribution (BI range) for EDU, Tiff Creek, and Koen Creek in Fall 2013 and Spring 2014 Macroinvertebrate Samples 16

Figure 4 USGS Discharge Graph for Big River near Richwoods, MO 28

ATTACHMENTS

Appendix A Macroinvertebrate Database Bench Sheets Report: Tiff Creek, Jefferson County and Koen Creek, St. Francois County.

1.0 Introduction

Tiff Creek (WBID 3763) is a small stream located in Jefferson County near Blackwell, Missouri, with a drainage area of approximately 7.6 square miles. Tiff Creek flows approximately 2.1 miles to the northwest before reaching its confluence with Big River at Blackwell. Tiff Creek is a class P stream, which means it maintains permanent flow even during periods of drought. It has designated beneficial uses for Livestock and Wildlife Watering (**LWW**); Protection of Warm Water Aquatic Life, Human Health-Fish Consumption (**AQL**); and whole-body contact (**WBC**), category B (MDNR 2014). The WBC "category B" applies to waters designated for whole body contact recreation not contained within category A. Category A is defined as:

> *Waters that have been established by the property owner as public swimming areas welcoming access by the public for swimming purposes and waters with documented existing whole body contact recreational use(s) by the public. Examples of this category include, but are not limited to: public swimming beaches and property where whole-body contact recreational activity is open to and accessible by the public through law or written permission of the landowner (MDNR 2014).*

Koen Creek (WBID 2171) is a small stream located in St. Francois County in Park Hills, Missouri with a drainage area of approximately 11.6 square miles. Koen Creek flows to the north through urban Park Hills, Missouri for approximately 1 mile at which point it reaches its confluence with Flat River Creek. It is a class C stream, which means that flow may cease during dry periods but maintains pools that support aquatic life (MDNR 2014). Koen Creek has designated beneficial uses for Livestock and Wildlife Watering (LWW); Protection of Warm Water Aquatic Life, Human Health-Fish Consumption (AQL); whole-body contact (WBC), category B; and Secondary Contact Recreation (**SCR**; MDNR 2014).

1.1 Justification

Much of Jefferson and St. Francois counties have been extensively mined for lead or barite. The presence of dissolved metals and fine sediment metals associated with mining may negatively affect the ability of a stream to support an aquatic community.

Heavy metals associated with mine related activity have been found in aquatic organisms. Crayfish and other aquatic macroinvertebrates were found to accumulate elevated concentrations of metals at mine related streams in Missouri (Besser et al. 1987, 2007; Poulton et al. 2009; Allert et al. 2008, 2009, 2011). Macroinvertebrate communities appear to be negatively affected by mining activities where elevated concentrations of metals are found in sediment pore water (Besser et al. 2007, 2009a, 2009b; Brumbaugh et al. 2007; Poulton et al. 2009; Allert et al. 2008, 2011). Heavy metals have also been found in fish of Mill Creek in an earlier study (Czarnezki and Trial 1997). Metals such as copper, iron, lead, and zinc have been detected in aquatic fauna in areas of Big River (Czarnezki et al. 1997; MDC 1997, 2006). Continued monitoring of heavy metals in fish tissue has led to present consumption advisories in the Big River watershed (Missouri Department of Health and Senior Services [**MDHSS**] 2012). Heavy metals in the surface water and fine sediment have been found in the tributaries of Big River in earlier studies. (MDNR 2010a, MDNR 2013a).

Dissolved metals were found in the surface water, and total metals exceeded probable effects thresholds (Ingersoll et al. 1996, MacDonald et al. 2000) in the fine sediment of Flat River Creek (MDNR 2001), which is the receiving stream of Koen Creek. Tiff Creek is a direct tributary to Big River near Blackwell, Missouri, in an area that has been extensively mined for barite and has been subjected to impairment due to a barite tailings dam failure (Duchrow 1978).

These potential sources of impairment, or others, may influence the ability of the streams to support the "protection of warm water aquatic life" designated beneficial use. A stream habitat assessment, biological assessment (which includes benthic macroinvertebrate community and water quality analyses), surface water dissolved metals analyses, and total metals characterization of benthic fine sediment are included in this study of Tiff Creek and Koen Creek.

This study was requested by the Missouri Department of Natural Resources (**MDNR**), Water Protection Program (**WPP**), Water Pollution Control Branch (**WPCB**). The Tiff Creek and Koen Creek 2013 – 2014 biological assessment and heavy metals characterization study was conducted by the Division of Environmental Quality (**DEQ**), Environmental Services Program (**ESP**), Water Quality Monitoring Section (**WQMS**), and Chemical Analysis Section (**CAS**).

1.2 Objectives

- Assess the stream habitat quality.
- Assess the "protection of warm water aquatic life" designated beneficial use status using the benthic macroinvertebrate community.
- Assess physicochemical water quality.
- Identify the dissolved metals concentrations in the surface water.
- Identify the heavy metals character of the fine sediment in the streams.

1.3 Null Hypotheses

1) Stream habitat quality at Tiff Creek and Koen Creek will be comparable to the stream habitat control.
2) Macroinvertebrate Stream Condition Index (**MSCI**) scores will indicate that Tiff Creek and Koen Creek are fully supporting of the beneficial use – AQL, and individual biological metrics will be within the optimum scoring range of wadeable/perennial reference stream biological criteria during the fall and spring seasons.
3) Results will not be influenced by stream size.
4) Secondary metrics (percent sensitive taxa and dominant macroinvertebrate taxa compositions) will indicate that Tiff Creek and Koen Creek have macroinvertebrate communities that are similar to BIOREF streams.
5) Physicochemical water quality parameters will be within acceptable limits as specified in Missouri's Water Quality Standards (**WQS**; MDNR 2014) and will not be notable.
6) Dissolved metals in the surface water will be within acceptable hardness-dependent limits outlined in Missouri's WQSs.

Dissolved metals were found in the surface water, and total metals exceeded probable effects fine sediment will be below threshold levels in Tiff and Koen creeks.

2.0 Methods

Kenneth B. Lister, Brandy Bergthold, Brian Nodine, and ESP personnel conducted this study. Methods and study timing are outlined in this section. The study area and station descriptions, EDUs, and land uses are identified. Stream habitat assessment procedures are discussed. Biological assessment procedures that include macroinvertebrate and physicochemical water collection methods and analyses are discussed in this section. Surface water was collected and analyzed to identify dissolved metals concentrations. Fine sediment was collected and analyzed to identify its heavy metals character.

2.1 Study Timing

Sampling was conducted in the fall of 2013 and the spring of 2014. Stream habitat assessments (**SHAPP**s) were conducted at Tiff and Koen creeks on September 18, 2013, and a SHAPP was conducted on Huzzah Creek #2 on September 19, 2013. Fall 2013 macroinvertebrate, water, and fine sediment samples were collected on September 18, 2013. All spring 2014 samples were collected on March 19, 2014. Duplicate macroinvertebrate, water, and sediment samples were collected at Tiff Creek #1 in the fall (#1a and #1b).

2.2 Study Area, Station Locations, and Descriptions

The study areas and stations are located within the Ozark/Meramec EDU (Figure 1). One station was allocated for each of the two study streams (Table 1; Figure 2). The downstream extent of Tiff Creek #1 was located approximately 100 yards upstream of its confluence with Big River. The downstream extent of Koen Creek #1 was approximately 50 yards upstream of the stream's confluence with Flat River Creek. The length of each study area was approximately 20 times the average width of each stream and consistent with the *Semi-Quantitative Macroinvertebrate Stream Bioassessment Project Procedure* (**SMSBPP**; MDNR 2012).

Table 1
Locations and Descriptions for Tiff Creek (3763), Koen Creek (2171) and Huzzah Creek #2 (SHAPP control) Stations

Station	County	Location – Section, Township, Range; UTM Coordinates	Description; WBID	Purpose; Class
Tiff Creek #1	Jefferson	SW ¼ sec. 32, T. 32 N., R. 04 E. E0709064 N4214833 (epe 6.0)	Upstream of Big River (3763) confluence	Test; P
Koen Creek #1	St. Francois	Survey 3092. T. 37 N., R. 05 E. E0719716 N4194272 (epe 8.9)	Upstream of Flat River Creek (2171) confluence	Test; C
Huzzah Creek #2	Crawford	S1/2 sec. 20, T. 36 N., R. 02 W. E660279 N4187461	Downstream from Red Bluff USFS Recreation Area	SHAPP Control; P

WBID = Water Body Identity Number; P=permanent flow; C=intermittent flow; SHAPP=Stream Habitat Assessment Project Procedure (MDNR 2010b); epe=estimated probable error of GPS readings.

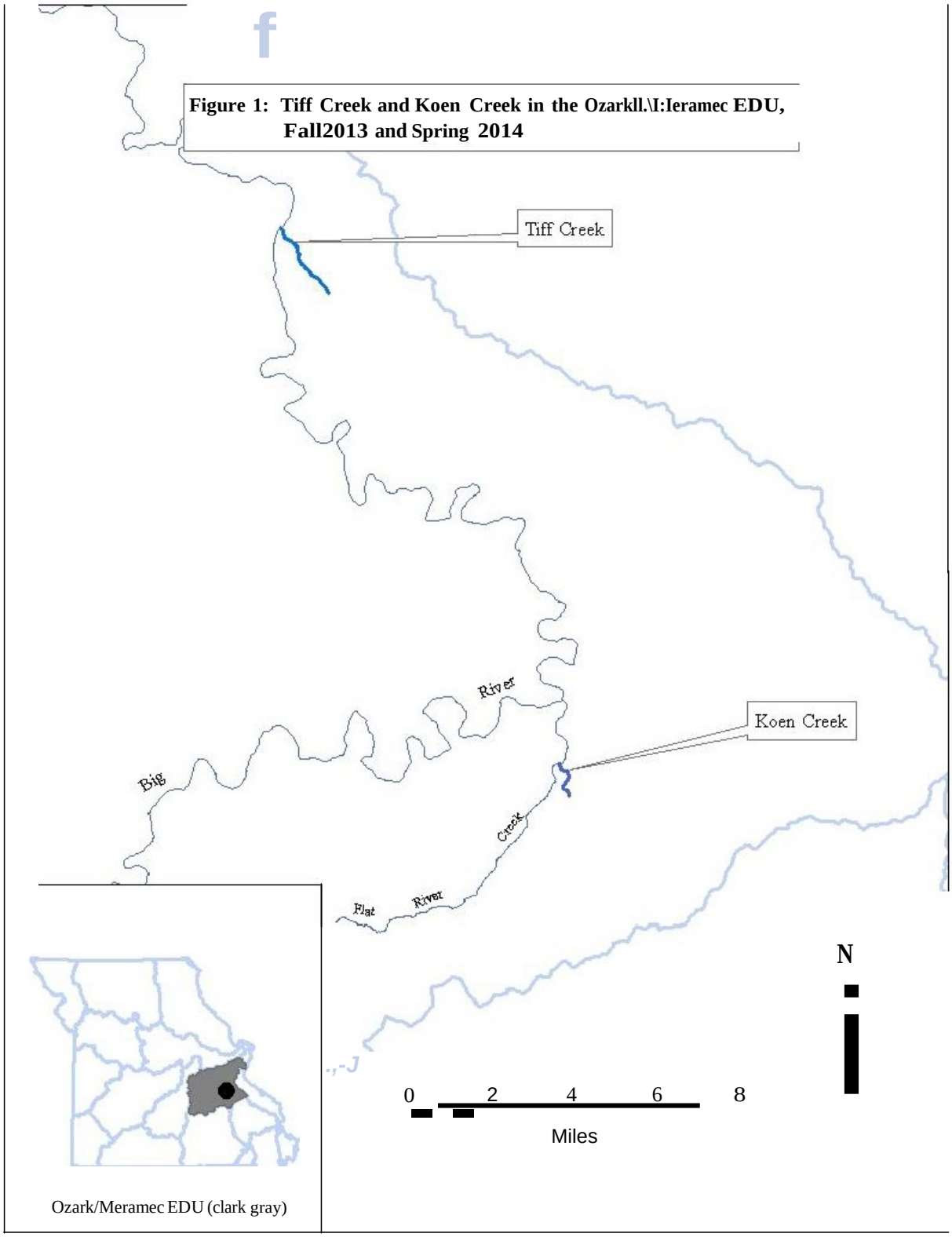


Figure 1: Tiff Creek and Koen Creek in the Ozarkll.\I:Ieramec EDU, Fall2013 and Spring 2014

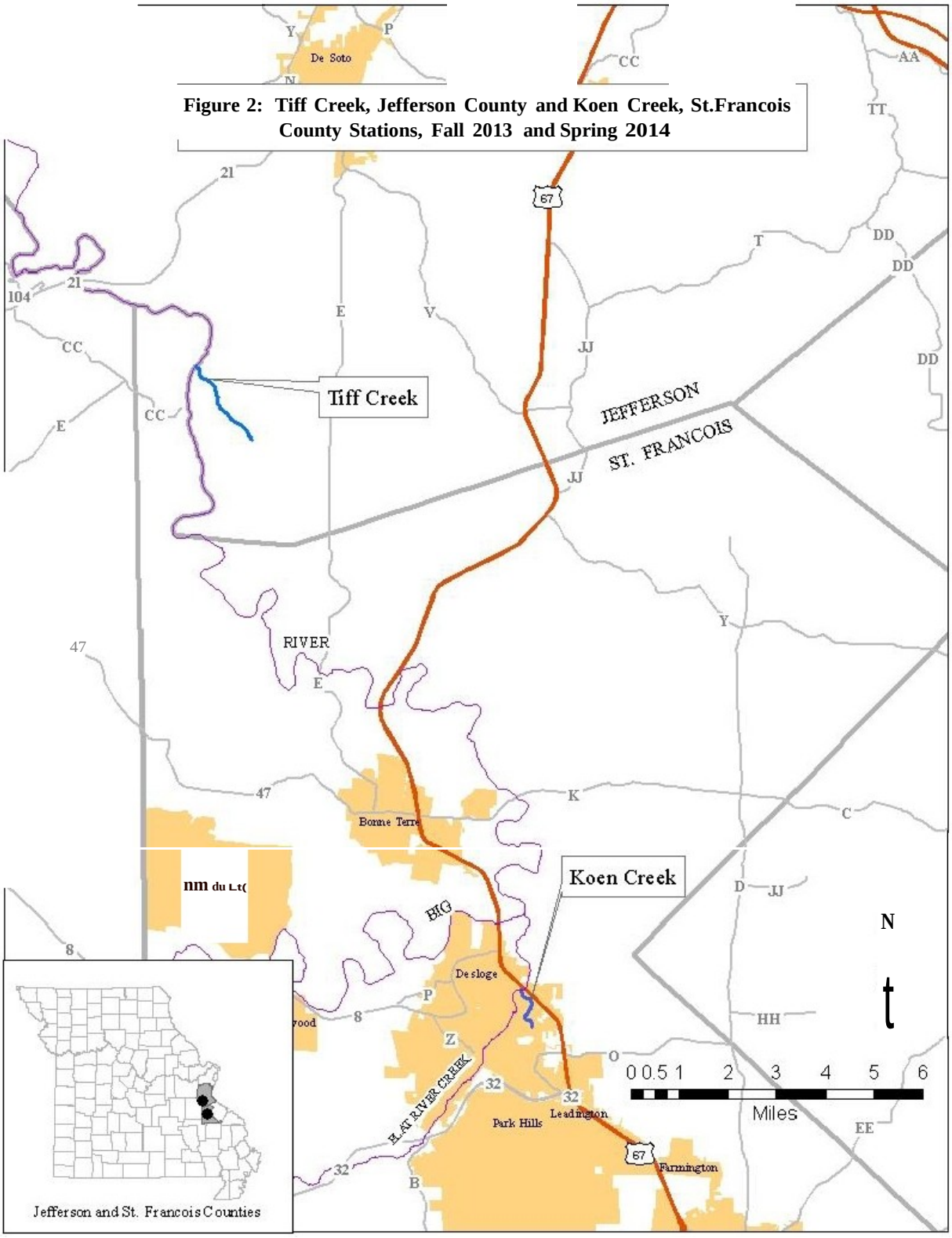


Figure 2: Tiff Creek, Jefferson County and Koen Creek, St.Francois County Stations, Fall 2013 and Spring 2014

2.2.1 Ecological Drainage Unit

Tiff Creek and Koen Creek are located in the Ozark/Meramec Ecological Drainage Unit (**EDU**; Figure 1). An EDU is an area that is delineated and identified by its natural terrestrial physiographic division and major riverine watershed components. Ecological Drainage Units are described in detail by Sowa et al. (2007). Streams of similar size within an EDU are expected to contain similar habitat conditions and biological communities. Comparisons of stream habitat, biological and physicochemical components between test streams and references, or similar-sized candidate reference streams, within the same EDU should then be appropriate.

2.2.2 Land Use Description

Land uses were described for the Tiff and Koen creek watersheds that are based on 12-digit Hydrological Unit Codes (**HUC-12**). Tiff Creek and Koen Creek land uses were compared to those in the Huzzah Creek watershed and the Ozark/Neosho EDU. The percent land use data were derived from Thematic Mapper satellite data collected between 2000 and 2004 and interpreted by the Missouri Resource Assessment Partnership (**MoRAP**).

Land uses within a stream's watershed should be considered when examining stream habitat assessment and biological assessment results (Table 2). Land uses were generally similar when Tiff Creek was compared to Huzzah Creek and the Ozark/Meramec EDU. However, Koen Creek land use was not always similar to the control or the EDU. Tiff Creek, Koen Creek, Huzzah Creek, and the Ozark/Meramec EDU were all dominated by "forest" land use, ranging from 47 to 77 percent. The "grassland" land use was in the 20 percent range at all streams and in the EDU. However, "urban, impervious, and barren" land uses were considerably greater at Koen Creek than Tiff Creek, Huzzah Creek, and the EDU due to its location within urban Park Hills, Missouri. National tailings pile is located near Koen Creek, which may have contributed to the barren land use statistic. Thus, urban or past mining practices may influence the Koen Creek bioassessment results.

Table 2
Percent Land Use by HUC-12 (*italicized*) for Tiff Creek, Koen Creek, Huzzah Creek #2, and the Ozark/Meramec EDU

Stations/ Land-Use *HUC-12*	Tiff Creek #1 *071401040303*	Koen Creek #1 *071401040108*	Huzzah Creek #2 *071401020403*	Ozark/Meramec EDU
Impervious	1.1	7.8	0.6	1.5
Urban	0.8	10.3	0.2	3.0
Barren	0.3	4.6	0.3	0.5
Crop	1.0	0.9	0.4	1.9
Grassland	23.7	27.3	20.4	27.8
Forest	68.8	47.9	77.6	62.8
Wetland	2.3	0.4	0.1	0.9
Open-water	2.1	0.8	0.4	1.4

2.3 Stream Habitat Assessment Project Procedure

The standardized *Stream Habitat Assessment Project Procedure* (**SHAPP**) was followed as described for Riffle/Pool prevalent streams (MDNR 2010b). According to the SHAPP, the

quality of an aquatic community is based on the ability of the stream to support the aquatic community. The SHAPP score from Tiff Creek and Koen Creek is expressed as a percentage of the SHAPP control. If the SHAPP score at a test station is ≥75% of the control scores, the stream habitat at that test station is considered to be comparable to the habitat of the control. Huzzah Creek #2 was used as a SHAPP control.

2.4 Biological Assessment

Sampling was conducted as described in the MDNR *Semi-Quantitative Macroinvertebrate Stream Bioassessment Project Procedure* (**SMSBPP**; MDNR 2012). A biological assessment involves examination of the macroinvertebrate community metrics and the physicochemical water results. Primary and secondary metrics are numeric descriptions of the macroinvertebrate community structure that ultimately identify the stream's ability to support its beneficial uses. Water quality parameters are compared to respective water quality standards (**WQS**; MDNR 2014) and other thresholds as applicable. Narrative descriptions and discussions clarify trends and integrate results. Biological assessments are grouped by season and station.

2.4.1 Macroinvertebrate Sampling, Identification, and Analyses: Primary Metrics

Macroinvertebrate samples were collected from multiple habitats, as described in the SMSBPP (MDNR 2012). Tiff Creek and Koen Creek are considered riffle/pool dominant streams. As such, coarse substrate (**CS**; riffle), non-flowing water over depositional substrate (**NF**), and rootmat (**RM**) habitats were sampled. In the WQMS laboratory, macroinvertebrates were acquired from subsamples of the benthic material that was collected for each habitat as described in the SMSBPP (MDNR 2012). These macroinvertebrates were then identified to specific taxonomic levels (MDNR 2010c) to provide for consistent and accurate determination of a stream's ability to support the "protection of aquatic life" (AQL) designated beneficial use category. Primary metrics generated from these macroinvertebrate data include the Macroinvertebrate Stream Condition Index (**MSCI**), which is a compilation of individual metric scores assigned to metric values. This MSCI score determines the "biological support category" for the test streams.

A stream condition index (**SCI**) using macroinvertebrates was developed as a measurement of a stream's aquatic biological integrity (Rabeni et al. 1997). The SCI was further refined to include biological criteria that were generated using wadeable/perennial reference streams (**BIOREF**) for each EDU, as described in *Biological Criteria for Perennial/Wadeable Streams* (MDNR 2002). Now called the Macroinvertebrate Stream Condition Index, a semi-quantitative rank score is developed by comparing the test stream metric values to reference criteria or scoring ranges. Ultimately, this MSCI identifies the test stream's ability to support the designated beneficial use for the protection of warm water aquatic life (AQL).

An MSCI score is developed by compiling rank metric scores that are calculated for individual metric values. The four primary biological metrics used to calculate the MSCI per station are 1) Taxa Richness (**TR**), 2) Ephemeroptera/Plecoptera/Trichoptera Taxa (**EPTT**), 3) Biotic Index (**BI**), and 4) Shannon Diversity Index (**SDI**). Each metric value for a station or stream is compared to the BIOREF scoring range (BIOREF Scoring Table, Tables 4a and 5a). The metric then receives a metric score of 5, 3, or 1 depending on where the metric value falls

relative to the BIOREF scoring range. All four metric scores are then added together to create the MSCI for each station. The MSCI scores are interpreted as follows: 20-16 = full biological support; 14-10 = partial biological support; and 8-4 = non-biological support of the AQL beneficial use designation. MSCI scores were examined by station and grouped by season (Tables 4a and 5a).

The individual biological metrics values and scores that contribute to the MSCI may be examined. Individual metric values may show trends, such as a decrease between stations or streams. Individual metric scores are usually evaluated to identify which ones contributed to the MSCI score. Variations in certain metric values and scores may identify sources of impairment.

To address potential effects that stream size may have on the biological support designation, Tiff Creek and Koen Creek metric values were compared to similar-size or "candidate reference" criteria (Tables 4b and 5b). In this case, Ozark/Meramec EDU small candidate reference stream data from the *Biological Assessment and Fine Sediment Study Report, Tributaries of Mill Creek and Mineral Fork, Fall 2008 – Spring 2009 – Fall 2009* (MDNR 2010a) were used to generate these similar-size stream criteria. Stream size will be considered to have a substantial effect on the results if the biological support category for the test stream increases or decreases from the original designation. For example, if the category changes from partial to full support of the AQL.

2.4.2 Macroinvertebrate Analyses: Secondary Metrics

Secondary metrics may highlight or support findings of the primary metrics. A "percent sensitive taxa" comparison was made between test streams and the BIOREF streams if the BI metric was outside the optimum scoring range (MDNR 2012). A comparison was also made between the "dominant macroinvertebrate taxa" (**DMT**s) in the test streams and the BIOREF streams (in aggregate) to identify variations in the macroinvertebrate community compositions (MDNR 2012). Results are arranged by season and stream.

"Percent Sensitive Taxa" is a metric that illustrates the similarities and differences between test streams and BIOREF streams based on sensitivity of taxa in the community. The percent sensitive taxa metric is based on the BI, which numerically describes the ability of an aquatic organism to tolerate nutrient/organic influences or disturbance. The BI value range is from 0 (sensitive) to 10 (tolerant). The percentage of the total number of individuals per taxon in the subsample are calculated above and between the 90th, 75th, 50th, 25th and below the 25th percentile of the range. The test stream distribution is compared to the BIOREF distribution. In this project, the "sensitive" taxa group contains taxa with BI <5.0, whereas the "tolerant" taxa group contains taxa with BI ≥7.5. The percent sensitive taxa analysis highlights differences between test stream and BIOREF macroinvertebrate communities based on sensitivity to pollution. It may also identify sources of impairment.

The 10 most abundant taxa or "dominant macroinvertebrate taxa" in the BIOREF streams of the EDU (in aggregate) were compared to their respective abundance in the test stream(s) to identify differences between reference and test stream communities. The abundance of each taxon is measured as a percentage of the total number of individuals in the sample, or samples for

BIOREF streams. The top 10 BIOREF taxa are ranked by their percentage, from high to low. That percentage is compared to the respective measures at each test stream. Deviations from the BIOREF DMT baseline are highlighted, such as taxa that are absent from the test stream, or if the abundance is less than half (or twice that) of the BIOREF percentage. The DMT metric should identify differences between the BIOREF and test stream communities and may identify sources for impairment.

A complete taxa list is available in the attached *Macroinvertebrate Database Bench Sheets Report* (Appendix A).

2.4.3 Physicochemical Water Sampling and Analyses

Physicochemical water samples were handled according to the applicable MDNR, ESP Standard Operating Procedures (**SOPs**) for sampling and analyzing physicochemical water samples. Results for physicochemical water variables were examined by season and stream.

Physicochemical water parameters consisted of field measurements and grab samples that were returned to the ESP environmental laboratory. Water was sampled according to the SOP MDNR-ESP-001 *Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations* (MDNR 2011). Temperature (°C), pH, conductivity (µS/cm), dissolved oxygen (mg/L), and discharge (cubic feet per second-**cfs**) were measured *in situ*. The ESP's CAS in Jefferson City, Missouri conducted analyses for ammonia as nitrogen (**NH_3-N**; mg/L), nitrate+nitrite as nitrogen (**NO_3+NO_2-N**; mg/L), total nitrogen (**TN**; mg/L), chloride (**Cl**; mg/L), sulfate (**SO_4**; mg/L), total phosphorus (**TP**; mg/L), and non-filterable residue (**NFR**; mg/L). Turbidity (nephelometric turbidity unit, **NTU**) was measured and recorded in the WQMS biology laboratory. All samples that were transported to ESP were kept on ice.

Surface water physicochemical results were compared to acceptable limits, suggested guidelines, or were identified as notable. Parameter results were compared to Missouri's Water Quality Standards (WQS; MDNR 2014). Interpretation of acceptable limits within the WQS may be dependent on a stream's classification and its beneficial use designation. If no Missouri standards exist, results may be compared to suggested guidelines as outlined by the United States Environmental Protection Agency's (**EPA**) December 2000, *Ambient Water Quality Criteria Recommendations for Rivers and Streams in Nutrient Ecoregion XI* (EPA 2000). Otherwise, notable results such as trends, associations with influences, or elevated concentrations compared to another stream in the EDU, may be highlighted.

2.4.4 Discharge

Stream discharge was measured using a Marsh-McBirney Flowmate 2000™ flow meter at each station. Velocity and depth measurements were recorded at each station according to SOP MDNR-ESP-113 *Flow Measurement in Open Channels* (MDNR 2013b).

2.5 Dissolved Metals – Surface Water

Surface water was collected for dissolved metals analyses. Water (grab) samples were filtered using a 0.45µm filter, preserved, and handled as outlined in MDNR-ESP-001 (MDNR 2011).

The dissolved metals included in this project were barium (**Ba**), cadmium (**Cd**), calcium (**Ca**), cobalt (**Co**), copper (**Cu**), lead (**Pb**), magnesium (**Mg**), nickel (**Ni**), and zinc **(Zn**). Hardness as $CaCO_3$ values were calculated using Ca and Mg according to (APHA) Standard Methods (2340 B, 2011) and were used to identify chronic and acute toxicity thresholds for heavy metals as described in Missouri's Water Quality Standards (MDNR 2014). These limits are based on lethality of a toxicant given long-term (chronic toxicity) or short-term (acute toxicity) exposure.

2.6 Fine Sediment Characterization

Instream deposits of benthic fine sediment (i.e. particle size <2 mm) were collected and characterized for total recoverable cadmium, lead, and zinc (mg/kg). The CAS conducted metals character analyses.

Fine sediment was collected from the test streams with a 2-ounce glass jar used to dredge the substrate no deeper than 2 inches. Three 2-ounce samples were collected from the substrate of each stream and composited into one 8-ounce glass jar. The fine sediment was subsampled from the 8-ounce jar by CAS and analyzed for total metals concentrations (mg/kg). Individual total metals concentrations and combination or mixture of metals thresholds were compared to threshold levels (mg/kg).

Individual metals concentrations were compared to Probable Effects Concentrations (**PEC**s; MacDonald et al. 2000). A PEC is a threshold level for a contaminant, above which harmful effects are likely to be observed. MacDonald et al. (2000) found PECs to be reliable for 10 metals (including cadmium, lead, and zinc) in classifying sediments as potentially toxic or nontoxic to sediment-dwelling organisms. The PEC for lead is 128 mg/kg dry weight; the PEC for cadmium is 4.98 mg/kg; and the PEC for zinc is 459 mg/kg (MacDonald et al. 2000).

Individual metals also were examined using a Probable Effects Concentration Quotient (**PEQ**; MacDonald et al. 2000, 2009; Ingersoll et al. 2001, 2002, 2009; Besser et al. 2008, 2009a). A PEQ is the total recoverable metal concentration divided by the PEC for that metal (MacDonald et al. 2000). A PEQ greater than 1.0 may indicate an increased risk of toxicity due to the concentration of that metal (Besser et al. 2009a).

The toxic effects from a mixture or combination of metals may be examined using the sum of PEQs (**∑PEQ**) or the mean PEQ. The ∑PEQ is the sum of PEQs (Ingersoll et al. 2001; Besser et al. 2009a, 2009b; MacDonald et al. 2000, 2009; Allert et al. 2011) in this case for cadmium, lead, and zinc. The mean PEQ is the ∑PEQ divided by the number of metals that were analyzed in the mixture (n=3), which may normalize the sample (Long et al. 1998; MacDonald et al. 2000; Ingersoll et al. 1998, 2001, 2002, 2009; Besser et al. 2008, 2009b).

The ∑PEQs and mean PEQs may then be compared to threshold levels (MacDonald et al. 2009) that identify a potential risk of toxicity to benthic invertebrates. Both the ∑PEQ and the mean PEQ are included for comparison, although both are individually effective in predicting potential toxicity due to a mixture or combination of metals. The thresholds (T_{10}) for cadmium, lead, and zinc are $\sum PEQ_{Cd, Pb, Zn}$ =7.92 and mean $PEQ_{Cd, Pb, Zn}$ =1.11 (MacDonald et al 2009). Metals

quotients above these thresholds suggest that the mixture or combination of metals in the fine sediment is likely to be toxic to the benthic-dwelling macroinvertebrate population.

2.7 Quality Control

Quality control was conducted in accordance with applicable MDNR SOPs and the *Semi-Quantitative Macroinvertebrate Stream Bioassessment Project Procedure* (MDNR 2012). Macroinvertebrate, surface water for physicochemical parameters and dissolved metals, and fine sediment samples were duplicated for every 10 stations sampled to identify similarities in collecting and analyzing samples. Macroinvertebrate, physicochemical water, dissolved metals, and fine sediment samples were duplicated at Tiff Creek (#1a and #1b) during the spring 2014 season.

3.0 Results

Results for stream habitat assessments, biological assessments that include macroinvertebrate community and water quality analyses, dissolved metals in surface water, and fine sediment metals character are described in this section. Results are grouped by season. Trends and notable results are highlighted.

3.1 Stream Habitat Assessment

Stream habitat assessment scores were compared as a percentage of the SHAPP control score (Table 3). Both Tiff Creek and Koen Creek stations were below the 75 percent similarity threshold. Tiff Creek #1 had a SHAPP score of 115, which equated to 71 percent of the control score of 138. Koen Creek #1 had a SHAPP score of 121, which was 74 percent of the control score. Factors contributing to the Tiff Creek habitat score were sediment deposition, riffle quality, narrow channel, and vegetative protection. At Koen Creek, low water level, narrow channels, riffle quality, and vegetative protection of the banks contributed to the lower score. The comparisons indicate that stream habitat quality and low water levels may have contributed to the depressed scores at Tiff Creek and Koen Creek.

Table 3
Stream Habitat Assessment Project Procedure (SHAPP) Scores and Comparisons with SHAPP Control Stream (in gray)

Station	SHAPP Score	Percent of SHAPP Control
Tiff Creek #1, Jefferson County	115	71
Koen Creek #1, St. Francois County	121	74
Huzzah Creek #2, Crawford County	163	SHAPP Control

3.2 Biological Assessment

Biological assessments consist of macroinvertebrate community analyses and general water quality analyses. Notable results for Tiff Creek and Koen Creek are grouped by season.

3.2.1 Macroinvertebrate Community Analyses: Primary Metrics and Candidate Reference Comparison

Tiff Creek #1 was fully supporting of the AQL designated use in the fall with an MSCI score of 16 (Table 4a). Although the station was designated as fully supporting of the AQL, the MSCI was slightly lower than the optimum MSCI. The EPTT and BI metric values contributed to the suboptimal MSCI with scores of 3. The EPTT metric value was 20, whereas the optimum scoring range was >23. The BI was 6.2, which was higher than the optimum BIOREF range of <5.6.

Koen Creek #1 was partially supporting of the AQL in the fall with an MSCI score of 14 (Table 4a). The TR, EPTT, and BI metric scores of 3 contributed to the less than optimum MSCI. Metric values for each of the three were obviously lower than the optimum BIOREF scoring range. The TR was 74 compared to the optimum range of >80. The EPTT was 13 compared to the optimum value of >23. The BI was 6.6, which was greater than the optimum value of <5.6.

Table 4a
Biological Criteria Reference Streams (BIOREF) Metric Scores, Individual Metric Values and Scores, Macroinvertebrate Stream Condition Index (MSCI) Scores, and Biological Support Category for Tiff Creek and Koen Creek, Fall 2013

Stream and Station Number	Sample No.	TR	EPTT	BI	SDI	MSCI	Support
Tiff Creek #1	132003	90(5)	**20**(3)	**6.2**(3)	3.19(5)	16	F
Koen Creek #1	132004	**74**(3)	**13**(3)	**6.6**(3)	3.26(5)	**14**	**P**
Metric Score = 5	↔	>80	>23	<5.6	>3.13	20-16	**F**ull
Metric Score = 3	↔	80-40	23-11	5.6-7.8	3.13-1.57	14-10	**P**artial
Metric Score = 1	↔	<40	<11	>7.8	<1.57	8-4	**N**on

MSCI Scoring Table (bottom) developed from BIOREF samples (*n*=10); TR=Taxa Richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index; (#) = metric score; **Bold**=less than optimum value or score.

To determine if stream size had an effect on the original fall biological support category designations, Tiff Creek and Koen Creek metric values were compared to candidate reference criteria (Table 4b; MDNR 2009). The optimum candidate reference criteria (scoring range) for each metric was slightly lower than the BIOREF criteria. Subsequently, individual metric values were closer to the optimum value ranges, with the exception of the BI. The candidate reference streams may therefore have a slightly different macroinvertebrate community than the larger BIOREF streams. However, none of the metric scores changed when the metric values were compared to the candidate reference criteria. Subsequently, the MSCI scores and support categories remained unchanged, which suggests that stream size did not have a substantial

influence on the original MSCI scores or biological support categories designated for Tiff Creek and Koen Creek in the fall.

Table 4b
Candidate Reference (Similar-size) Stream Biological Criteria, Individual Metric Values and Scores, ΔMacroinvertebrate Stream Condition Index (MSCI) Scores, and ΔBiological Support Categories for Tiff Creek and Koen Creek, Fall 2013

Stream and Station Number	Sample No.	TR	EPTT	BI	SDI	ΔMSCI	ΔSupport
Tiff Creek #1, Fall 2013	120110	90(5)	20(3)	6.2(3)	3.19(5)	16	F (NC)
Koen Creek #1, Fall 2013	120111	74(3)	13(3)	6.6(3)	3.26(5)	14	P (NC)
Metric Score=5	↔	>75	>21	<5.1	>2.97	20-16	**F**ull
Metric Score=3	↔	75-37	21-11	5.1-7.5	2.97-1.49	14-10	**P**artial
Metric Score=1	↔	<37	<11	>7.5	<1.49	8-4	**N**on

MSCI Scoring Table (in light gray) developed using small candidate reference stream samples (*n*=6, MDNR 2009). TR=Taxa Richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index; (#) = metric score; **Bold** = change; NC= no change in support category.

Tiff Creek duplicates #1a and #1b were partially supporting of the AQL in the spring with MSCI scores of 12 (Table 5a). All four metric values contributed to the less than optimum MSCI with metric scores of 3. The metric values were substantially lower than the optimum BIOREF scoring range. The TR metric values at #1a and #1b were 86 and 82, respectively, compared to the optimum BIOREF scoring range of >93. Likewise, the EPTT metric values were 22 and 23, compared to the optimum scoring range of >31. The BI metric value was 6.3 at #1a and #1b, which is 0.4 higher than the optimum score of <5.9. The SDI metric values were 2.84 and 2.59 at #1a and #1b, respectively, compared to the optimum scoring range of >3.33.

Koen Creek received an MSCI score of 10 and was designated as partially supporting of the AQL in the spring (Table 5a). When the metric values were compared to the BIOREF scoring range, the TR, BI, and SDI each received metric scores of 3, and the EPTT received a score of 1. Each of these metric values were substantially outside the optimum scoring range. The TR metric value was 64, which was 30 below the >93 needed to attain an optimum metric score. The EPTT metric value was 8, compared to the BIOREF criteria value of >31. The BI metric value was 7.4, which is 1.6 above the BIOREF optimum value of >5.9. The SDI was 3.11, which is 0.24 less than >3.33, which is necessary to reach an optimum score.

To determine if stream size had an effect on the original spring biological support category designations, Tiff Creek and Koen Creek metric values were compared to the candidate reference criteria from the spring (Table 5b; MDNR 2009). The candidate reference criteria were again slightly lower than the BIOREF criteria, suggesting that the macroinvertebrate communities in smaller streams were slightly different from the larger BIOREF stream communities. This

Table 5a
Biological Criteria Reference Streams (BIOREF) Metric Scores, Individual Metric Values and Scores, Macroinvertebrate Stream Condition Index (MSCI) Scores, and Biological Support Category Tiff Creek and Koen Creek, Spring 2014

Stream and Station Number	Sample No.	TR	EPTT	BI	SDI	MSCI	Support
Tiff Creek #1a	149801	**86(3)**	**22(3)**	**6.3(3)**	**2.84(3)**	**12**	**P**
Tiff Creek #1b	149802	**82(3)**	**23(3)**	**6.3(3)**	**2.59(3)**	**12**	**P**
Koen Creek #1	149803	**64(3)**	**8(1)**	**7.4(3)**	**3.11(3)**	**10**	**P**
Metric Score = 5	↔	>93	>31	<5.9	>3.33	20-16	**F**ull
Metric Score = 3	↔	93-47	31-15	5.9-7.9	3.33-1.67	14-10	**P**artial
Metric Score = 1	↔	<47	<15	>7.9	<1.67	8-4	**N**on

MSCI Scoring Table (bottom) developed from BIOREF samples (*n*=8); TR=Taxa Richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index; (#) = metric score; **Bold**=less than optimum value or score; QSI =81 percent similarity between 1a and1b.

Table 5b
Candidate Reference (Similar-size) Stream Biological Criteria, Individual Metric Values and Scores, ΔMacroinvertebrate Stream Condition Index (ΔMSCI) Scores, and ΔBiological Support Categories for Tiff Creek and Koen Creek, Spring 2014

Stream and Station Number	Sample No.	TR	EPTT	BI	SDI	ΔMSCI	ΔSupport
Tiff Creek #1a	149801	**86(3→5)**	22(3)	6.3(3)	2.84(3)	**12→14**	P **(NC)**
Tiff Creek #1b	149802	**82(3→5)**	23(3)	6.3(3)	2.59(3)	**12→14**	P **(NC)**
Koen Creek #1	149803	64(3)	8(1)	7.4(3)	**3.11(3→5)**	**10→12**	P **(NC)**
Metric Score=5	↔	>81	>26	<4.5	>3.00	20-16	**F**ull
Metric Score=3	↔	81-41	26-13	4.5-7.3	3.00-1.50	14-10	**P**artial
Metric Score=1	↔	<41	<13	>7.3	<1.50	8-4	**N**on

MSCI Scoring Table (in light gray) developed using small candidate reference stream samples (*n*=6, MDNR 2009). TR=Taxa Richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index; (#) = metric score; **Bold** = change due to size; NC= no change in support.

change in criteria resulted in the TR metric score to increase from 3 to 5 at both Tiff Creek #1a and #1b. The SDI metric score increased from 3 to 5 at Koen Creek. Subsequently, the spring MSCI scores increased slightly from 12 to 14 at Tiff Creek and from 10 to 12 at Koen Creek. Neither increase was sufficient to change the original partial support designations of the AQL in the spring, which suggests that stream size did not have a substantial influence on the original support designations for Tiff Creek or Koen Creek in the spring.

3.2.2 Percent Sensitive Taxa Comparison

The percent sensitive taxa comparison is another metric used to identify similarities among test stream and BIOREF stream macroinvertebrate communities. In this case, the comparisons were made between groups based on their sensitivity to organic pollution or disturbance. A sensitive taxa group (BI<5.0) and a tolerant taxa group (≥7.5) were identified for test streams the BIOREF streams (in aggregate). The percentage of sensitive and tolerant taxa within Tiff Creek and Koen Creek were compared to each group in BIOREF streams. Comparisons are arranged by season.

In the fall sample, the percent sensitive taxa comparison identified differences between the test stream communities and the BIOREF stream community (Table 6; Figure 3). Sensitive taxa made up approximately 22 percent of the Tiff Creek community and 13 percent of the Koen Creek community. By comparison, sensitive taxa accounted for nearly 30 percent of the BIOREF macroinvertebrate community. Tolerant taxa made up over 42 percent of the macroinvertebrate communities at Tiff Creek and Koen Creek. In comparison, tolerant taxa made up approximately 23 percent of the macroinvertebrate community in the BIOREF streams, in aggregate.

Table 6
Percent Sensitive Taxa Distribution (Biotic Index Values) Tiff Creek, Koen Creek, and the Ozark/Meramec EDU in Fall 2013

BI Range	Sample Number	<2.5	2.5 - 4.9	5.0 - 7.4	7.5 - 8.9	>8.9
Tiff Creek #1	132003	5.57	16.33	35.72	41.81	0.58
Koen Creek #1	132004	2.36	10.28	45.09	36.48	5.79
BIOREFs	--	11.94	17.93	46.50	20.93	2.70

Highlights illustrated in Figure 3

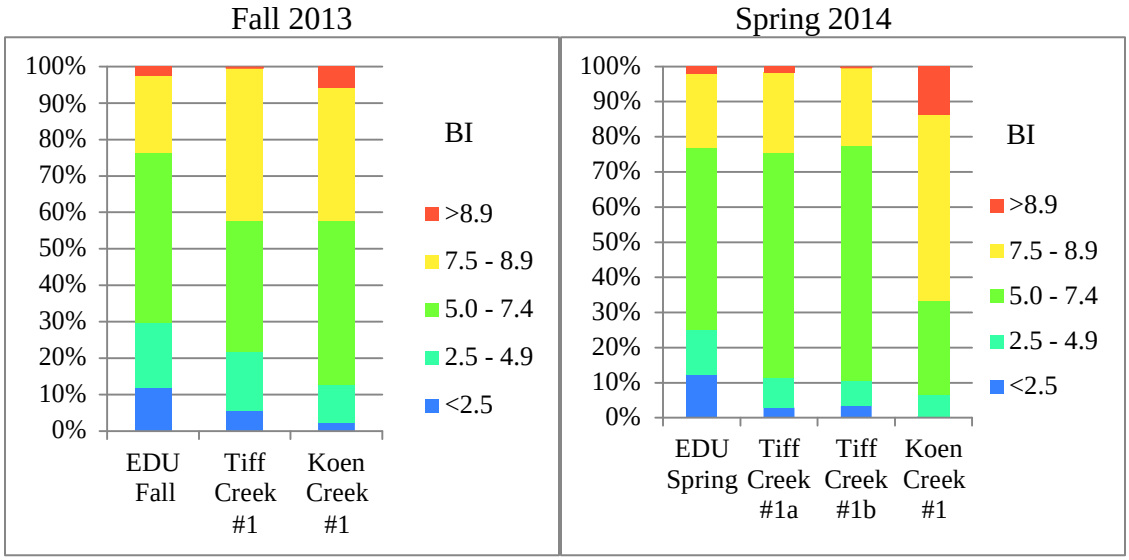
In the spring sample, the percent sensitive taxa comparisons identified differences between the test stream communities and the BIOREF streams (Table 7; Figure 3). Sensitive taxa made up approximately 10 percent of the Tiff Creek sample and approximately 6 percent of the Koen Creek sample. In contrast, sensitive taxa accounted for approximately 25 percent of the BIOREF macroinvertebrate community composition (in aggregate). Tolerant taxa made up approximately 23 percent of the Tiff Creek sample and over 65 percent of the Koen Creek sample. By comparison, tolerant taxa accounted for approximately 23 percent of the BIOREF stream communities.

Table 7
Percent Sensitive Taxa Distribution (Biotic Index Values) Tiff Creek, Koen Creek, and the Ozark/Meramec EDU, Spring 2014

BI Range	Sample Number	<2.5	2.5 - 4.9	5.0 - 7.4	7.5 - 8.9	>8.9
Tiff Creek #1a	149801	2.83	8.57	63.96	22.88	1.76
Tiff Creek #1b	149802	3.39	7.25	66.92	21.97	0.47
Koen Creek #1	149803	0.40	6.19	26.77	52.73	13.91
BIOREFs	--	12.27	12.62	52.02	20.83	2.26

Highlights illustrated in Figure 3

Figure 3: Illustration of Percent Sensitive Taxa Distribution (BI range) for EDU, Tiff Creek, and Koen Creek in Fall 2013 and Spring 2014 Macroinvertebrate Samples



3.2.3 Dominant Macroinvertebrate Taxa

The dominant macroinvertebrate taxa (DMT) of Tiff Creek and Koen Creek were compared to their presence or abundance in the top 10 DMT in BIOREF streams for fall and spring. The percentage of each taxon was based on percent abundance relative to the total number of individuals in the sample. Notable taxa are those that are at least 50 percent lower than the BIOREF taxa.

Six of the top 10 DMTs in BIOREF streams either were absent or the percentage was much lower in the fall Tiff Creek sample (Table 8). Two taxa, *Maccaffertium mediopunctatum* and *Elimia* sp., were absent from Tiff Creek. The four remaining DMT, *Tricorythodes*, *Stenelmis*, *Isonychia bicolor*, and *Caenis anceps*, were much less abundant in Tiff Creek than in the BIOREF streams.

Eight of the top 10 DMT from BIOREF streams were absent or much less abundant in the fall Koen Creek sample (Table 8). Five of these DMT, *Tricorythodes* sp., *Maccaffertium mediopunctatum*, *Elimia* sp., *Isonychia bicolor*, and *Caenis anceps*, were not found in the Koen Creek sample. *Stenelmis* sp., *Dubiraphia* sp., and *Hyalella azteca* were much less abundant in the Koen Creek sample than the BIOREF samples.

Table 8
Dominant Macroinvertebrate Taxa Percentage (and Rank) per Taxon for BIOREF and Tiff Creek and Koen Creek, Fall 2013

Dominant Taxa	BIOREF	Tiff Creek #1 132003	Koen Creek #1 132004
Tricorythodes	16.51 (1)	**3.52 (5)**	**--**
Caenis latipennis	8.74 (2)	25.16 (1)	16.22 (1)
Maccaffertium mediopunctatum	6.68 (3)	**--**	**--**
Stenelmis	6.64 (4)	**0.58 (26)**	**1.90 (15)**
Dubiraphia	5.60 (5)	**2.62 (7)**	**1.98 (14)**
Elimia	4.34 (6)	**--**	**--**
Hyalella azteca	2.88 (7)	13.06 (2)	**0.53 (23)**
Isonychia bicolor	2.85 (8)	2.37 (8)	--
Caenis anceps	2.72 (9)	**0.58 (27)**	**--**
Tanytarsus	1.91 (10)	4.16 (4)	12.11 (2)

Bold = Notable taxa are those that are at least 50 percent lower than the BIOREF taxa.

Eight of the top 10 DMT from BIOREF streams either were absent or their abundance was much reduced in the spring Tiff Creek duplicate samples (Table 9). Five taxa from at least one of the duplicate spring samples were absent; these taxa included *Stenelmis*, *Tricorythodes*, *Ephemerella invaria*, *Caenis anceps*, and *Maccaffertium mediopunctatum*. Three additional taxa, *Tanytasus* sp., Acarina, and *Paratanytarsus* sp., were much less abundant in at least one of the spring Tiff Creek samples than the BIOREF samples.

Six of the top 10 DMT found in BIOREF streams either were absent or their percentages were substantially lower in the spring Koen Creek samples (Table 9). Four of these taxa, *Tricorythodes* sp., *Ephemerella invaria*, *Caenis anceps*, and *Maccaffertium mediopunctatum*, were not found in the Koen Creek sample. Two taxa, *Stenelmis* sp. and Acarina, were found in Koen Creek, but they were much less abundant than the DMT in BIOREF streams.

Table 9
Dominant Macroinvertebrate Taxa Percentage (and Rank) per Taxon for BIOREF, Tiff Creek and Koen Creek, Spring 2014

Dominant Taxa	BIOREF	Tiff Creek #1a 149801	Tiff Creek #1b 149802	Koen Creek #1 149803
Cricotopus/Orthocladius	10.65 (1)	38.26 (1)	44.95 (1)	8.44 (2)
Stenelmis	7.80 (2)	**0.08 (51)**	--	**2.25 (11)**
Caenis latipennis	7.26 (3)	10.56 (2)	6.92 (2)	21.46 (1)
Tricorythodes	6.31 (4)	--	**0.07 (48)**	--
Ephemerella invaria	4.19 (5)	--	--	--
Tanytarsus	4.08 (6)	2.52 (5)	**1.02 (18)**	6.59 (3)
Caenis anceps	3.70 (7)	--	--	--
Acarina	3.68 (8)	1.99 (11)	**1.83 (9)**	**0.08 (38)**
Paratanytarsus	3.12 (9)	**0.69 (21)**	**0.81 (19)**	2.89 (8)
Maccaffertium mediopunctatum	2.65 (10)	--	--	--

Note: Several individual mayflies that were identified to Heptageniidae (Appendix A) may have been small *M. mediopunctatum* and subsequently influenced that taxon's percentage in both test streams. **Bold** = Notable taxa are those with a percentage at least 50 percent lower than the BIOREF taxon percentage.

3.2.4 General Water Quality Analyses

General physicochemical water quality parameters collected from Tiff Creek in the fall 2013 are presented in Table 10. No parameter exceeded or was outside WQSs (MDNR 2014). However, several parameters were notable or exceeded EPA (2000) suggested guidelines. The total nitrogen concentration was 0.61 mg/L, which exceeded EPA guidelines (0.31 mg/L). The nitrate+nitrite as nitrogen concentration was 0.55 mg/L, which exceeded the EPA suggested guideline concentration (0.093mg/L).

Koen Creek fall general water quality parameters are presented in Table 10. None of the water quality parameters exceeded or were outside WQSs (MDNR 2014). However, several parameters were notable or exceeded EPA (2000) suggested guidelines. Koen Creek conductivity was 883 µS/cm. Turbidity was 5.93 NTU, which exceeded the EPA suggested guideline (2.03 NTU). Total nitrogen was 0.33 mg/L, which was greater than the suggested EPA guideline (0.31 mg/L). The nitrate +nitrite as nitrogen concentration was 0.21 mg/L, which exceeded the EPA suggested guideline (0.093 mg/L). The Koen Creek chloride concentration was 18.2 mg/L, which was three times higher than rural Tiff Creek. The sulfate concentration

was notable at 322 mg/L, which is approximately 30 percent of the WQS (sulfate and chloride >1000 mg/L MDNR 2009).

Table 10
Physicochemical Water Parameters in Tiff Creek and Koen Creek, Fall 2013

Station Parameter	Tiff Creek #1 9-18-13	Koen Creek #1 9-18-13
Sample Number	133934	133935
Dissolved O_2	8.58	8.93
pH (Standard Units)	7.9	7.6
Conductivity (µS/cm)	450	*883
Temperature (°C)	18.0	21.0
Discharge (cfs)	1.8	<1.0
NFR	<5.0	5.0
Turbidity (NTUs)	1.52	**5.93**
Total Nitrogen	**0.61**	**0.33**
Nitrate+Nitrite as N	**0.55**	**0.21**
Ammonia-N	<0.03	<0.03
Chloride	6.56	*18.2
Sulfate	11.9	$*322_{09}$
Hardness as $CaCO_3$	280	555
Total Phosphorus	<0.01	<0.01

Units mg/L unless otherwise labeled; **Bold**=Exceed EPA (2000) suggested criteria; * = notable. Qualifiers - $\#_{09}$=Sample was diluted during analysis.

General physicochemical water quality parameters were analyzed for the Tiff Creek #1a and #1b spring 2014 samples (Table 11). All parameters were within limits specified in Missouri's WQSs (MDNR 2014). However, results for several parameters were notable, and several exceeded EPA (2000) suggested guidelines. Tiff Creek conductivity values were 521 µS/cm and 518 µS/cm at #1a and #1b, respectively. Total nitrogen was 0.53 mg/L at the duplicates, which exceeded the EPA suggested guideline (0.31 mg/L). The nitrate+nitrite as nitrogen concentration was 0.62 mg/L, which exceeded the EPA suggested guideline (0.093mg/L) in the spring.

Koen Creek spring 2014 general water quality parameters are presented in Table 11. All water quality parameters were within MDNR WQSs (MDNR 2014); however, several parameters were notable and several exceeded EPA (2000) suggested guidelines. Koen Creek conductivity was 566 µS/cm. Turbidity was 2.80 NTU, which exceeded suggested guidelines (2.03 NTU). The nitrate+nitrite as nitrogen concentration was 0.12 mg/L, which exceeded the suggested EPA

guidelines (0.093 mg/L). Total nitrogen was near, but did not exceed, the EPA suggested guideline. At nearly three times higher than rural Tiff Creek, the Koen Creek chloride concentration (33.6 mg/L) was notable. The concentration of sulfate in Koen Creek was approximately four times higher than Tiff Creek in the spring.

Table 11
Physicochemical Water Parameters in Tiff Creek and Koen Creek, Spring 2014

Station Parameter	Tiff Creek #1a 3-19-14	Tiff Creek #1b 3-19-14	Koen Creek #1 3-19-14
Sample Number	149633	149634	149635
pH (Standard Units)	8.4	8.3	8.5
Temperature (°C)	8.0	8.0	9.0
Conductivity (µS/cm)	521	518	566
Dissolved O_2	11.26	11.12	12.75
Discharge (cfs)	2.5	2.8	5.6
NFR	<5	<5	<5
Turbidity (NTUs)	<1	<1	**2.80**
Total Nitrogen	**0.53**	**0.53**	0.23
Nitrate+Nitrite as N	**0.62**	**0.62**	**0.12**
Ammonia-N	<0.03	<0.03	*0.082
Chloride	11.8	11.5	*33.6
Sulfate	12.3	11.8	*40.1
Hardness as $CaCO_3$	277	259	268
Total Phosphorus	<0.01	<0.01	<0.01

Units mg/L unless otherwise labeled; **Bold**=Exceed EPA (2000) suggested criteria; * = notable.

3.3 Dissolved Metals – Surface Water

Dissolved metals were analyzed from Tiff Creek and Koen Creek for both seasons. Surface water samples were compared to the hardness dependent acute and chronic WQS criteria (MDNR 2014). Notable concentrations, or those that appeared to be elevated compared to a relative measure, were highlighted.

Dissolved metals concentrations were not exceptional in the Tiff Creek fall surface water sample (Table 12). However, dissolved barium was substantially higher at Tiff Creek than the concentration in the fall Koen Creek sample.

Dissolved metals concentrations were notable in the Koen Creek surface water sample in the fall (Table 12). Dissolved cadmium (0.86 µg/L) exceeded the chronic toxicity threshold (0.80 µg/L; MDNR 2014). Dissolved copper was present but well below the WQS. The dissolved lead concentration (13.2 µg/L) was slightly below Missouri's WQS chronic toxicity level

(15.26 µg/L) at a hardness of 555 mg/L $CaCO_3$. Nickel and zinc were present, but their concentrations were well below their respective thresholds at a hardness of 555 mg/L $CaCO_3$.

Dissolved metals concentrations were not exceptional in the duplicate samples at Tiff Creek in the spring samples (Table 13). Dissolved barium concentrations were higher in Tiff Creek than in Koen Creek. The concentrations of metals were similar between the duplicate samples.

Dissolved metals concentrations were not exceptional in the Koen Creek spring surface water sample (Table 13). Dissolved metals either were not detected, or were detected well below WQSs (MDNR 2014). Although dissolved copper was present in detectable concentrations, it was well below the hardness dependent WQS.

3.4 Fine Sediment Characterization: Total Recoverable Cadmium, Lead, Zinc

The fine sediment sample from Tiff Creek did not contain notable heavy metals concentrations in the fall (Table 14). Total cadmium, lead, and zinc did not exceed their respective PEC thresholds at Tiff Creek in the fall fine sediment sample (Table 15).

The fine sediment sample from Koen Creek contained notable heavy metals concentrations in the fall (Table 14). Total cadmium and lead concentrations exceeded the PEC threshold in the fall. Total zinc was slightly lower than its PEC threshold. In total, the $\sum PEQ_{Cd,Pb,Zn}$ was nearly twice as high as the T_{10} threshold, and the mean $PEQ_{Cd, Pb,Zn}$ was over four times higher than the T_{10} threshold (MacDonald et al. 2009). The high lead concentration heavily influenced the combination or mixture of metals ($\sum PEQ_{Cd, Pb,Zn}$ or mean $PEQ_{Cd, Pb,Zn}$) quotients for the fall sample.

Table 12
Dissolved Metals (µg/L) and Hardness (HARD; mg/L $CaCO_3$) in Surface Water (Grab) Samples from Tiff Creek and Koen Creek, Fall 2013

Parameter/ Station	Ba	Cd	Ca (mg/L)	Co	Cu	Pb	Mg (mg/L)	Ni	Zn	HARD $CaCO_3$
Tiff Creek #1	590	<0.10	55.7	<1	<0.50	<0.50	34.3	0.82_{05}	4.70	280
Koen Creek #1	66.6	**0.86c**	123	2.26_{05}	1.74	*13.2	60.1	24.5	*160	555

Units µg/L; **Bold** = outside WQS acceptable range, **c** = chronic toxicity (MDNR 2014); * = Notable; Qualifiers - $\#_{05}$=Estimated value, detected below Practical Quantitation Limits (**PQL**).

Table 13
Dissolved Metals (µg/L) and Hardness (HARD; mg/L $CaCO_3$) in Surface Water (Grab) Samples from Tiff Creek and Koen Creek, Spring 2014

Parameter/ Station	Ba	Cd	Ca (mg/L)	Co	Cu	Pb	Mg (mg/L)	Ni	Zn	HARD $CaCO_3$
Tiff Creek #1a	625	<0.10	56.5	<1	<0.50	<0.50	32.9	1.33	6.68	277
Tiff Creek #1b	645	<0.10	52.9	<1	<0.50	<0.50	30.8	1.28	6.81	259
Koen Creek #1	46.9	<0.10	54.8	<1	0.62_{05}	<0.50	31.9	1.73	1.99	268

Units µg/L; **Bold** = outside WQS acceptable range, **c** = chronic toxicity (MDNR 2012); Qualifiers - $\#_{05}$=Estimated value detected below PQL.

Table 14
Total Recoverable Metals Character in the Fine Sediment (<2.0mm):
Cadmium, Lead, and Zinc Concentrations (mg/kg Dry Weight), Fall 2013

Parameter/ Station	Cadmium	Lead	Zinc	$\sum PEQ_{Cd,Pb,Zn}$	Mean $PEQ_{Cd,Pb,Zn}$
Tiff Creek #1 (PEQ)	0.333_{05} (<1.0)	61.90 (<1.0)	243 (<1.0)	<7.92	<1.11
Koen Creek #1 (PEQ)	**5.550_{11} (1.114)**	**1640_{09} (12.813)**	423_{09} (<1.0)	**14.850**	**4.950**
PEC Threshold	**4.98**	**128**	**459**	**T_{10}≥7.92**	**T_{10}≥1.11**

PEC=Probable Effects Concentration, MacDonald et al. 2000; **Bold**=exceeds threshold; PEQ = Probable Effects Quotient, metal value/PEC; Mean PEQ = ∑PEQ/#metals; ∑PEQ = sum PEQs; T_{10} = toxicity threshold (MacDonald et al. 2009); Qualifiers - $\#_{05}$=Estimated value, detected below PQL; $\#_{09}$=Sample was diluted during analysis; $\#_{11}$=Estimated value, matrix interference.

The fine sediment sample from Tiff Creek did not contain notable heavy metals concentrations in the spring sample (Table 15). Total cadmium, lead, and zinc did not exceed their respective PEC thresholds at Tiff Creek #1a and #1b. The heavy metals concentrations were similar between duplicates.

The fine sediment sample from Koen Creek contained notable heavy metals concentrations in the spring sample (Table 15). The fine sediment sample contained a total lead concentration that was nearly 25 times higher than the suggested PEC threshold. Total cadmium was near the PEC threshold, and total zinc was over half of the PEC. In accounting for the combination or mixture of metals, the $\sum PEQ_{Cd,\ Pb,Zn}$ was three times higher and the mean $PEQ_{Cd,\ Pb,Zn}$ was almost nine times higher than their respective threshold (T_{10}) levels. The high lead concentration heavily influenced the combination or mixture of the metals quotient for the spring sample.

Table 15
Total Recoverable Metals Character in the Fine Sediment (<2.0mm):
Cadmium, Lead, and Zinc Concentrations (mg/kg Dry Weight), Spring 2014

Parameter Station	Cadmium	Lead	Zinc	$\sum PEQ_{Cd,Pb,Zn}$	Mean $PEQ_{Cd,Pb,Zn}$
Tiff Creek #1a (PEQ)	0.381_{05} (<1.0)	77.50 (<1.0)	232 (<1.0)	<7.92	<1.11
Tiff Creek #1b (PEQ)	0.331_{05} (<1.0)	64.90 (<1.0)	213 (<1.0)	<7.92	<1.11
Koen Creek #1 (PEQ)	3.220 (<1.0)	**3180 (24.84)**	295 (<1.0)	**26.128**	**8.71**
PEC	**4.98**	**128**	**459**	**T_{10}≥7.92**	**T_{10}≥1.11**

PEC=Probable Effects Concentration, MacDonald et al. 2000; **Bold**=exceeds threshold; PEQ = Probable Effects Quotient, metal value/PEC; Mean PEQ = ∑PEQ/#metals; ∑PEQ = sum PEQs; T_{10} = toxicity threshold (MacDonald et al. 2009); Qualifiers - $\#_{05}$=Estimated value, detected below PQL.

4.0 Discussion

This study included a comprehensive two-season assessment of Tiff Creek, Jefferson County and Koen Creek, St. Francois County. Components of the project included a stream habitat assessment, biological assessment (including macroinvertebrate community assessment and general physicochemical water quality analyses), dissolved metals analyses in surface water, and total metals characterization of the benthic fine sediment.

4.1 Stream Habitat Assessment

The quality of stream habitat available in Tiff Creek and Koen Creek may have influenced the results in this study. Both streams failed to reach the 75 percent similarity threshold necessary to suggest that stream habitats were comparable to the SHAPP control (MDNR 2010b). As such, stream habitat quality may have contributed to the macroinvertebrate community composition and the subsequent biological support category designations. This habitat limitation is not to the exclusion of other stressors.

4.2 Biological Assessment

A biological assessment includes examination of the macroinvertebrate community composition and quantification of physicochemical water quality parameters necessary to gauge the health of the stream. Macroinvertebrate community analyses included determination of the biological support category designations using primary metrics, such as the MSCI, individual metric values, and scores. This biological assessment also included comparisons between similar size candidate reference communities and the test streams. Lastly, biological assessments include examination of physicochemical water quality parameters. Notable results are arranged by stream and season.

4.2.1 Macroinvertebrate Community Analyses: Primary Metrics

Macroinvertebrate community analyses using primary metrics identified Tiff Creek as fully supporting of the AQL designated use in the fall and partially supporting in the spring. The EPTT and BI metric scores were below the optimum BIOREF scoring range, which contributed to an MSCI score of 16 in the fall. The TR, EPTT, BI, and SDI metric scores contributed to the less than optimum MSCI scores of 12 at the duplicate stations in the spring. Overall, the macroinvertebrate community was smaller than BIOREF streams, made up of less sensitive taxa, more tolerant to organic influences or disturbance, and in the spring less diverse than reference streams of the EDU. The EPTT and BI scores were consistently less than optimum, suggesting that continuous organic influences or disturbance may have contributed to the community composition during both seasons; the potential effects were more pronounced in the spring.

Macroinvertebrate community analyses using primary metrics identified Koen Creek as partially supporting of the AQL during both seasons. In the fall, the TR, EPTT, and BI metric scores were less than optimal when compared to the BIOREF criteria, which contributed to an MSCI score of 14. All four metric values were less than optimum in the spring, which resulted in both duplicate samples receiving MSCI scores of 12. The TR, EPTT, and BI metric scores were consistently less than optimal, suggesting that organic influences or disturbance may have contributed to the partial support designations for both seasons.

To determine if stream size had an effect on the macroinvertebrate communities and designated biological support categories, Tiff and Koen Creek fall and spring metric values were compared to similar size candidate reference stream criteria. The candidate reference criteria (scoring ranges) for all metrics were lower than BIOREF criteria used for both seasons, which suggested that the macroinvertebrate communities in small streams are slightly different than communities in larger BIOREF streams. Smaller streams contained lower taxa richness, fewer sensitive taxa, they were more sensitive to organic pollution or disturbance, and the communities were slightly less diverse than BIOREF stream communities. When the metric comparisons were made to the candidate reference criteria, the MSCI scores did not change in the fall, but the MSCI scores increased for both Tiff and Koen creeks in the spring. These changes in MSCI scores in the spring were not, however, sufficient to change the earlier support category designations. No change in the support designation suggests that stream size did not substantially contribute to the macroinvertebrate community compositions during either season.

4.2.2 Macroinvertebrate Community Analyses: Secondary Metrics

The distribution of sensitive and tolerant taxa in Tiff Creek and Koen Creek samples was compared to the percentage of similar groupings in BIOREF streams of the EDU. Taxa sensitivity was based on the BI metric scale, which relates to sensitivity to organic pollution or disturbance. Sensitive taxa were defined in this comparison as taxa with BI values that are <5.0, and tolerant taxa have BI values >7.5. The distribution of sensitive and tolerant taxa may illustrate how the macroinvertebrate community was affected and to what extent.

Generally, the percent sensitive taxa analysis showed that the Tiff Creek macroinvertebrate community was composed of different taxa than the BIOREF streams, more so in the fall. Tiff Creek contained fewer sensitive taxa and more tolerant taxa in the fall sample. In the spring, when Tiff Creek received a partially supporting MSCI score, the stream contained fewer sensitive taxa, but also fewer tolerant taxa as it was defined (BI≥7.5). A distribution with fewer tolerant taxa suggests that the community was more similar to BIOREF streams. The reason why the BI was in the “less than optimum” range was due to a higher abundance of “midrange” (BI 5.0 – 7.4) taxa in Tiff Creek than were found in the BIOREF streams. The abundance of these midrange BI taxa contributed to the high overall BI value for the sample and the partial support designation in the spring.

Based on the percent sensitive taxa comparison, the Koen Creek macroinvertebrate community appeared to be much different than BIOREF stream communities during both seasons. Koen Creek had a substantially lower percentage of sensitive taxa (BI<5.0) and a much higher percentage of tolerant taxa (BI≥7.5) than were found in BIOREF streams. The BI values were consistently higher in Koen Creek, and there were clear distinctions between Koen Creek and the BIOREF streams based on the sensitivity distributions. The BI metric is a function of organic/nutrient enrichment or disturbance, so it is likely that these influences may have had a substantial effect on the macroinvertebrate community composition in Koen Creek. This is not to the exclusion of other influences, such as mining.

Based on examination (comparison) of DMT, it appears that the macroinvertebrate community compositions at Tiff Creek varied somewhat, and the Koen Creek community was much

different than BIOREF macroinvertebrate communities during both seasons. The DMT results were consistent with the biological support designations and identified taxa that were apparently influenced by some stressor in the streams.

The DMT comparison illustrated that 6 of 10 BIOREF DMT were absent (2 taxa) from Tiff Creek or present in lower abundance (4 taxa) than BIOREFs in the fall, and 8 out of 10 DMT were absent (5 taxa) or reduced (3 taxa) in at least one of the spring duplicates. The high number of absences in the spring coincided with the partially supporting of the AQL designation at Tiff Creek. One of the two taxa absences in the fall sample was from the order Ephemeroptera (mayflies), which is a taxa group that is generally considered to be more sensitive to pollution and disturbance, or metals contamination (Poulton et al. 2009). Four of the five missing taxa in the spring were Ephemeroptera, which is consistent with the partial support designation in the spring. Increased absences of generally more sensitive taxa coincided with the partial support of the AQL designation and suggested that Tiff Creek was affected by some influence in the spring.

In Koen Creek, 8 of 10 BIOREF DMT were absent (5 taxa) or reduced (3 taxa) in the fall, and 6 of the 10 were absent (4 taxa) or reduced (2 taxa) in the spring. Four of the five taxa absent in the fall, and all four of the taxa in the spring sample were Ephemeroptera (mayflies). The high number of absences during both seasons coincided with, and apparently contributed to, the consistent partial support of the AQL designation. A relatively high number of absences of sensitive taxa suggests that some negative influence exists in Koen Creek, and that Ephemeroptera appear to be more sensitive to that influence.

In general, Ephemeroptera were missing from more of the samples where and when the stream was considered impaired, but specifically, certain taxa were apparently affected by influences at both streams. Interestingly, *Tricorythodes* sp., *Caenis anceps*, and *Maccaffertium mediopunctatum* were not found in Koen Creek, but they were among the DMT in BIOREF streams of the Ozark/Meramec EDU during both seasons. Similarly, in Tiff Creek samples *Tricorythodes* sp. and *Caenis anceps* were much less abundant than the DMT in the BIOREF samples, and *Maccaffertium mediopunctatum* was absent from the fall sample. All three taxa were absent from at least one of the spring Tiff Creek duplicate samples. *Tricorythodes* sp., *Caenis anceps*, and *Maccaffertium mediopunctatum* appear to be intolerant of the stressor(s) that is/are impairing the streams. Ephemeroptera in general and these taxa are considered to be sensitive to mine related influences (Poulton et al. 2009).

Conversely, the percentages of *Caenis latipennis* and *Tanytarsus* sp. were much higher than the BIOREF stream percentages in the fall Koen Creek sample. Tiff Creek also had these taxa and *Hyalella azteca* present in much higher percentages. This suggests that these taxa are more tolerant to the stressor(s) than the missing and reduced taxa; their BI values are higher than taxa mentioned earlier, and thus their presence affected overall BI scores in the fall. However, this is not consistent with findings in the spring, as *Caenis latipennis* and *Tanytarsus* sp. abundances were relatively similar to BIOREF streams at Tiff Creek. Only *Caenis latipennis* was much more prevalent in the spring sample, which likely contributed to the low Koen Creek BI metric score in the spring.

Similarly, the percentage of the more tolerant *Cricotopus/Orthocladius* [group] was approximately four times higher (ca. 38 to 45 percent) in the impaired Tiff Creek sample than the BIOREF DMT (ca. 11 percent) in the spring. This group of Chironomidae is commonly more abundant in spring samples than in the fall, probably due to growth/life cycles. The group also has a BI of 6.5 which is considered elevated in developing the BI, but in developing the percent sensitive metric it is considered "midrange" (BI 5.0 to 7.4). Earlier, the percent sensitive taxa comparison suggested that Tiff Creek was impaired in the spring by a high percentage of "midrange" taxa. Prevalence of this group potentially allowed for a reduced TR, increased BI (as shown), and a reduced SDI. Ultimately, this group may have been a considerable influence on the partial support of the AQL designation at Tiff Creek in the spring. But, the prevalence of this group is apparently not due to natural life cycles alone because the percentage was much higher than what was observed among BIOREF streams. Tiff Creek conditions were such that the tolerant group could thrive. The stream also had a substantially lower percentage of sensitive taxa and fewer Ephemeroptera than the BIOREF streams in the spring, suggesting that some influence was affecting the macroinvertebrate community composition in Tiff Creek.

Interestingly, Koen Creek was impaired during both seasons, yet the percent sensitive taxa analysis showed that the elevated BI was due to an abundance of more tolerant taxa (BI≥7.5). Also, the DMT comparison showed that *Cricotopus/Orthocladius* [group] was found in a similar percentage (relative to the total number of individuals in the sample) compared to BIOREF streams. This suggests that conditions in Koen Creek may not have been sufficient for even *Cricotopus/Orthocladius* [group] to thrive, possibly due to the presence of other influences that were not present in Tiff Creek.

The differences that were found in the percent sensitive taxa comparison and the dominant macroinvertebrate taxa comparisons are consistent with the biological support category designations. These secondary metrics also thoroughly examined the macroinvertebrate communities based on sensitivity distributions and dominance of taxa in each stream. If a biotic assemblage at a test site differs from matching sites in reference condition, then the deviation may be considered to be the result of effects by known or unknown stressors (Bailey et al. 2004; Webb et al. 2014).

4.2.3 General Water Quality

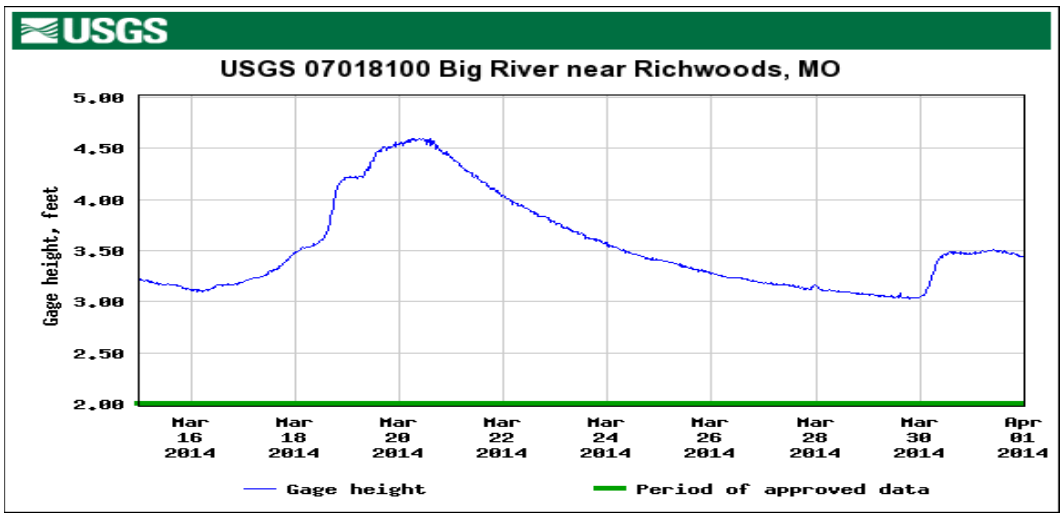
General water quality parameters in Tiff Creek and Koen Creek samples were compared to WQSs (MDNR 2014), EPA suggested guidelines, or highlighted if they were otherwise notable in each season. All measured factors were within acceptable limits if they were defined in WQSs (MDNR 2014). Currently, Missouri WQSs have no criteria for the beneficial use protection of the AQL for turbidity or nutrients, such as total nitrogen or nitrate+nitrite as nitrogen (MDNR 2014). Therefore, results were compared to the EPA suggested guidelines (EPA 2000) or to a relative measure/stream in the EDU. Several parameters exceeded EPA suggested guidelines or were notable.

None of the general water quality parameters exceeded WQSs (MDNR 2014) in the Tiff Creek fall and spring samples; however, two parameters consistently exceeded EPA suggested guidelines (EPA 2000). Total nitrogen and nitrate+nitrite as nitrogen concentrations were

consistently elevated when compared to EPA suggested guidelines. At present, the rural Jefferson County Tiff Creek watershed is mainly woodland with some pasture. Elevated nutrients can be indicators of mine related influences, urban influences, or agricultural practices. A potential contributor of these constituents may be mine related, as this stream is near Blackwell, Missouri, an area that has been extensively mined for barium in the past. Ultimately, these elevated parameters may have influenced the macroinvertebrate community and resulted in the partial support of the AQL designation in the spring.

All general water quality parameters were within acceptable WQSs for the protection of AQL (MDNR 2014) in Koen Creek. However, several measured factors consistently exceeded EPA suggested guidelines or were notable in both seasons. Turbidity was above the EPA suggested guideline (EPA 2000) during the fall and spring. Total nitrogen was above the EPA suggested guidelines in fall, and near the threshold in the spring. Nitrate+nitrite as nitrogen concentrations were consistently above EPA suggested guidelines in the Koen Creek samples. Conductivity was notable at 883 µS/cm compared to 450 µS/cm at Tiff Creek in the fall, but both streams maintained similar conductivity levels (mid 500s) in the spring. Other notable water quality features included chloride concentrations that were three times higher in Koen Creek than Tiff Creek during the fall and spring. Sulfate concentrations were approximately 30 times higher in Koen Creek than Tiff Creek in the fall and nearly four times higher in the spring. A rain event prior to sampling (Figure 4) may have influenced some of the physicochemical parameters in the spring; however, most concentrations were somewhat similar to the fall. The Koen Creek watershed is located in urban Park Hills, Missouri, and receives runoff from the National Tailings Pile to the east. Any of these elevated constituents may be due to urban influences or mine related practices. Nutrients or associated constituents may have affected the macroinvertebrate community and contributed to the consistent partial support of the AQL designated beneficial use in Koen Creek

Figure 4: USGS Discharge Graph for Big River near Richwoods, MO.
Sampled March 19, 2014



Courtesy of United States Geological Service (USGS 2014): Real time water data

4.3 Dissolved Metals: Surface Water

Surface waters were sampled and analyses were conducted to identify dissolved metals concentrations in Tiff Creek and Koen Creek during both seasons. Results were compared to hardness dependent chronic and acute toxicity criteria that are defined in Missouri's WQS (MDNR 2014), or they were highlighted if notable.

Dissolved metals concentrations in fall and spring Tiff Creek samples were not elevated compared to WQSs. Dissolved barium concentrations were consistently detected in Tiff Creek, ranging from 9 to 13 times higher than Koen Creek. However, there is no Missouri WQS criterion assigned to barium for the designated beneficial use for the protection of AQL (MDNR 2014). Tiff Creek, as the colloquial name implies, has had a long association with barite (i.e. tiff) mining. It is located near the confluence with Big River at Blackwell, Missouri, an area that has been extensively mined for barite in the past. Big River near Blackwell was subjected to a barite tailings pond collapse in 1975 that resulted in fine sediment loading and temporary impairment of the macroinvertebrate community (Duchrow 1978). Other dissolved metals concentrations were not exceptional in either season. There was not an obvious association between dissolved metals concentrations and the fully supporting designation in the fall or the partial support of the AQL designation in the spring.

Three dissolved metals concentrations were notable in the surface water sample from Koen Creek during the fall, but none of the metals was exceptional in the spring sample. The concentration of dissolved cadmium exceeded the chronic WQS (MDNR 2014) in the fall. Lead was near chronic WQS in the fall, but it was not detected in the spring sample. The concentration of zinc was approximately one-third of the chronic and acute WQS in the fall, but it was barely above detectable concentrations in the spring. Copper was also present in both seasons, but well below WQS limits. These results identified several dissolved metals associated with lead mining that intermittently exceeded, or were near, WQS limits. A rain event prior to sampling in the spring (Figure 4) may have influenced the results, and it suggests that the source for these metals may not directly be due to runoff. Intermittently elevated concentrations of dissolved metals may have influenced the macroinvertebrate community composition and the partial support for the protection of the AQL designation at Koen Creek for both seasons.

4.4 Fine Sediment Characterization: Heavy Metals

Benthic fine sediments (<2.0 mm) in Tiff Creek and Koen Creek were characterized for total metals concentrations in fall and spring samples. Total cadmium, lead, and zinc concentrations were determined and compared to Probable Effects Concentration (PEC) thresholds to identify potential threats due to elevated individual metals concentrations (MacDonald et al. 2000). If individual concentrations were elevated, the potential toxicity due to a combination or mixture of metals was examined by comparing concentrations to the $\sum PEC_{Cd, Pb, Zn}$ and mean $PEC_{Cd, Pb, Zn}$ thresholds (MacDonald et al. 2009). Results are arranged by season.

Benthic fine sediment collected from Tiff Creek did not contain exceptional concentrations of cadmium, lead, or zinc. None of the concentrations exceeded their respective PECs. The metals concentrations identified for the fall were similar to those from the spring, despite being from different sample locations within Tiff Creek. These results suggest that fine sediment does not

normally contain heavy metals in Tiff Creek. The concentrations in the spring duplicate samples were similar to each other, suggesting that the samples were consistently collected and accurately analyzed. Heavy metals (i.e. cadmium, lead, zinc) in the fine sediment were not obvious contributors to the designated biological support categories during either season.

Benthic fine sediment in Koen Creek contained several heavy metals that exceeded, or were near, individual and combination or mixture of metals thresholds in the fall and spring samples. Total cadmium concentrations exceeded the PEC threshold in the fall, and the spring concentration was near the PEC. Total lead concentrations in the fine sediment were approximately 13 times higher than the PEC threshold in the fall and approximately 25 times higher in the spring. The total zinc concentration in the fall was near the PEC threshold, but it was lower in the spring. All three of the individual metals concentrations exceeded or were near thresholds in the fall, but lead was the only individual metal that exceeded the threshold during both seasons. The combination or mixture of metals quotients exceeded thresholds during both seasons. The $\sum PEQ_{Cd, Pb, Zn}$ was 15 times higher than the threshold in the fall and 26 times higher than the threshold in the spring. The more conservative (normalized) mean $PEQ_{Cd, Pb, Zn}$ was five times higher than the threshold in the fall and nine times higher than the threshold in the spring. This suggests that the combination or mixture of metals may have had an effect on the macroinvertebrate community composition. However, the quotients, which identify potential effects due to a combination or mixture of heavy metals, were heavily influenced by the very high concentrations of lead that were found in the fine sediment during both seasons. Regardless, exceedance of the individual and combination threshold values suggests that heavy metals contamination in the fine sediment is potentially toxic and may have influenced the macroinvertebrate community composition. These heavy metals (and copper) in the fine sediment were well related concentrations in fish of Flat River Creek and Big River (Gale et al. 2004). Heavy metals in the fine sediment may have contributed to the continuous partial support of the AQL designation in Koen Creek.

The metals character of fine sediment in Koen Creek fluctuated somewhat between seasons. The concentration of lead exceeded the PEC in both seasons, but cadmium and zinc concentrations in the spring were approximately half of the fall concentrations. The sediment samples were not collected from the same locations in the fall as in the spring, which may suggest that the fine sediment bearing heavy metals may not be evenly distributed in Koen Creek, with the exception of lead. It is possible that fine sediment containing cadmium, lead, and zinc is deposited by Flat River Creek during high flows. Flat River Creek contained lead and zinc in its fine sediment during a past study (MDNR 2001). Similarly, the Koen Creek watershed includes a substantial portion of National Tailings Pile and has a long history of mine related activity. Runoff of mine related material during rain events might contribute to the fine sediment loading and subsequent elevated metals concentrations.

4.5 Fine Sediment Metals Influence on Surface Water Metals

Heavy metals found in the fine sediment at Koen Creek may have contributed to the elevated dissolved metals concentrations in the fall surface water sample. Total cadmium, lead, and zinc concentrations exceeded, or were near, PEC thresholds in the fine sediment, whereas dissolved cadmium, lead, and zinc concentrations exceeded or were near WQS thresholds. As mentioned

by Brumbaugh (2009), localized physical and chemical conditions may allow for the release of metals from fine sediment particles into the pore water. Also, they found that pore water and surface water metals concentrations were not remarkably different, which suggested there was an exchange of metals between the pore water and surface water. Dissolved metals concentrations decreased from fall to spring possibly due to sampling after a rain event (Figure 4). Researchers have found strong negative correlations between sediment or pore water metals concentrations and aquatic biota (Gale et al. 2004; Besser et al. 2009a; Poulton et al. 2009). It is possible that dissolved metals concentrations in the surface water were associated with total metals in the fine sediment and were influenced by physicochemical variations including low flow or high flow.

5.0 Conclusions

The objectives have been addressed. The stream habitat, macroinvertebrate community, and physicochemical water quality have been assessed; dissolved metals concentrations in the surface water and fine sediment (metals) character have been identified.

Testing of the null hypotheses resulted in the following:

1) Stream habitat quality at Tiff Creek and Koen Creek will be comparable to the stream habitat control. This null hypothesis was rejected. Stream habitat quality at Tiff Creek and Koen Creek was not comparable to the SHAPP control stream.

2) Macroinvertebrate Stream Condition Index (**MSCI**) scores will indicate that Tiff Creek and Koen Creek are fully supporting of the beneficial use – AQL, and individual biological metrics will be within the optimum scoring range of wadeable/perennial reference stream biological criteria during the fall and spring seasons.

   This hypothesis was rejected. Tiff Creek was fully supporting of the AQL in the fall and partially supporting in the spring. Koen Creek was partially supporting of the AQL in the fall and spring sample seasons.

3) Results will not be influenced by stream size. This hypothesis was not rejected. Comparisons between Tiff Creek or Koen Creek and small candidate reference streams from the Ozark/Meramec EDU illustrated that stream size did not substantially contribute to their original biological support designations.

4) Secondary metrics (percent sensitive taxa and dominant macroinvertebrate taxa compositions) will indicate that Tiff Creek and Koen Creek have macroinvertebrate communities that are similar to BIOREF streams.

   This hypothesis was rejected. Secondary metrics (percent sensitive taxa distribution and dominant macroinvertebrate taxa composition) illustrated that the Tiff Creek partial support designation in the spring may have been due in part to the abundance of a particular group of Chironomidae that is prevalent in the spring that are “mid-range” tolerant taxa. However, seasonal abundance is not the

obvious contributor to the MSCI in the spring. Tiff Creek also contained fewer sensitive taxa, and many generally sensitive Ephemeroptera were absent compared to BIOREF DMT in the spring. Koen Creek macroinvertebrate communities were composed of fewer sensitive taxa and more tolerant taxa than BIOREF stream communities. Many generally sensitive BIOREF DMT were absent from Koen Creek samples in both seasons, which suggests continuous and potentially substantial impairment.

5) Physicochemical water quality parameters will be within acceptable limits as specified in Missouri's Water Quality Standards (**WQS**; MDNR 2014) and will not be notable.

This hypothesis was rejected. Physicochemical water quality parameters were within acceptable MDNR WQSs (2014). However, several measured factors exceeded EPA (2000) suggested guidelines or were notable at both streams in both seasons.

Tiff Creek total nitrogen and nitrate+nitrite as nitrogen exceeded EPA guidelines during both seasons.

Koen Creek turbidity, total nitrogen, and nitrate+nitrite as nitrogen exceeded EPA suggested guidelines, and chloride and sulfate concentrations were notable in the fall. Turbidity and nitrate+nitrite as nitrogen exceeded EPA guidelines, and ammonia, chloride, and sulfate concentrations were notable in the spring.

6) Dissolved metals in the surface water will be within acceptable hardness-dependent limits outlined in Missouri's WQSs.

This hypothesis was not rejected for Tiff Creek but rejected for Koen Creek. Dissolved metals concentrations were not detected, or were well below Missouri WQSs at Tiff Creek during both seasons. However, dissolved barium concentrations were indicative of past barite mining in the watershed.

Several dissolved metals exceeded WQSs (MDNR 2014) in Koen Creek during the fall, but none of the metals were elevated in the spring sample.

7) Heavy metals (i.e. cadmium, lead, zinc) concentrations associated with benthic fine sediment will be below threshold levels in Tiff and Koen creeks.

This hypothesis was not rejected for Tiff Creek, but rejected for Koen Creek. Tiff Creek benthic fine sediment did not contain heavy metals concentrations that exceeded thresholds during either season. Koen Creek fine sediments contained heavy metals that exceeded or were near threshold levels during both seasons.

6.0 Recommendations

- Stream habitat quality should be assessed throughout the watershed.
- Consider conducting additional biological assessments in the Tiff Creek and Koen Creek watershed.
- Surface water should be sampled throughout the Koen Creek watershed to determine the source and extent of elevated dissolved metals concentrations.
- Fine sediment in the streams should be characterized for heavy metals throughout the Koen Creek watershed to determine the extent of metals contamination.
- Sources of fine sediment should be identified and the sediment prevented from entering the Koen Creek.
- Pore water should be sampled using peepers, or other long-term sample devices, to identify dissolved metals throughout Koen Creek.

7.0 Literature Cited

Allert, A.L., J.F. Fairchild, R.J. DiStefano, C.J. Schmitt, J.M. Besser, W.G. Brumbaugh, and B.C. Poulton. 2008. Effects of lead-zinc mining on crayfish (*Orconectes hylas*) in the Black River watershed, Missouri, USA. Freshwater Crayfish 16:97-11.

Allert, A.L., J.F. Fairchild, R.J. DiStefano, C.J. Schmitt, W.G. Brumbaugh, and J.M. Besser. 2009. Ecological effects of lead mining on Ozark streams: In-situ toxicity to woodland crayfish (*Orconectes hylas*). Ecotoxicology and Environmental Safety 72:1207-1219.

Allert, A.L., R.J. DiStefano, C.J. Schmitt, J.F. Fairchild, and W.G. Brumbaugh. 2011. Effects of mining-derived metals on riffle-dwelling crayfish in southwestern Missouri and southeastern Kansas of the Tri-State Mining District, USA. U.S. Geological Survey, Columbia Environmental Research Center, 4200 New Haven Road, Columbia, Missouri 65201 and Missouri Department of Conservation, 1110 College Avenue, Columbia, Missouri 65211. Submitted to U.S. Fish and Wildlife Service, Columbia Ecological Services Office, 101 Park DeVille Drive, Suite A, Columbia Missouri 65203. August 11, 2011. 106 pp.

American Public Health Association [cited in text *Standard Methods (Method Number, EPA Approved Date*)]. 2012. Standard methods for the examination of water and wastewater, 22nd edition. Edited by Bridgewater et al. American Public Health Association, 800 I Street, NW, Washington, DC 20001-3710.

Bailey, R.C., R.H. Norris, and T.B. Reynoldson. 2004. Bioassessment of freshwater ecosystems: using the reference condition approach. Springer – Verlag, New York.

Besser, J.M. and C.F. Rabeni. 1987. Bioavailability and toxicity of metals leached from lead mine tailings to aquatic invertebrates. Environmental Toxicology and Chemistry 6:879-890. (120.2R.64).

Besser, J.M., W.G. Brumbaugh, T.W. May, and C.J. Schmitt. 2007. Biomonitoring of lead, zinc, and cadmium in streams draining lead-mining and non-mining areas, southeast Missouri, USA. Environmental Monitoring and Assessment 129:227-241. doi:10.1007/s10661-006-9356-9.

Besser, J.M., W.G. Brumbaugh, C.D. Ivey, C.G. Ingersoll, and P.W. Moran. 2008. Biological and chemical characterization of metal bioavailability in sediments from Lake Roosevelt, Columbia River, Washington USA. Archives of Environmental Contamination and Toxicology 54:557-570.

Besser, J.M., W.G. Brumbaugh, A.L. Allert, B.C., C.J. Schmitt, and C.G Ingersoll. 2009a. Ecological impacts of lead mining on Ozark streams-toxicity of sediment and pore water. Ecotoxicology and Environmental Safety 72:516-526.

Besser, J.M., W.G. Brumbaugh, D.K. Hardesty, J.P. Hughes, and C.G. Ingersoll. 2009b. Assessment of metal-contaminated sediments from the Southeast Missouri (SEMO) mining district using sediment toxicity tests with amphipods and freshwater mussels. Natural Resource Damage Assessment and Restoration Program, (**NRDAR**) Administrative Report 08-NRDAR-02, submitted to U.S. Fish and Wildlife Service (USFWS). U.S. Geological Survey, Columbia Environmental Research Center, Columbia, Missouri. 59 pp. + app.

Brumbaugh, W.G., T.W. May, J.M. Besser, A.L. Allert, and C.J. Schmitt. 2007. Assessment of elemental concentrations in streams of the New Lead Belt in Southeastern Missouri, 2002-05. U.S. Geological Survey, Scientific Investigations Report 2007-5057. 57 pp.

Czarnezki, J. and L. Trial. 1997. Water quality investigation of Mill Creek, Washington County, Missouri 1996. Missouri Department of Conservation. Fish and Wildlife Research Center, 1110 South College Avenue, Columbia, Missouri. 11 pp.

Duchrow, R.M. 1978. The Effects of Barite Tailings Pond Dam Failure Upon the Water Quality of Mill Creek and Big River, Washington County, Missouri. D-J Project F-19-R, Missouri Department of Conservation, Columbia, Missouri. 48 pp.

Gale, N.L., C.D. Adams, B.G. Wixson, K.A. Loftin, and Huang, Y. 2004. Lead, zinc, copper, and cadmium in fish and sediment s from Big River and Flat River Creek of Missouri's Old Lead Belt. Env. Geochem. and Health 26:37-49.

Ingersoll, C.G., P.S. Haverland, E.L. Brunson, T.J. Canfield, F.J. Dwyer, C.E. Henke, N.E. Kemble, D.R. Mount, and R.G. Fox. 1996. Calculation and evaluation of sediment effect concentrations for the amphipod *Hyalella azteca* and the midge *Chironomus riparius*. J. Great Lakes. Res. 22:602-623.

Ingersoll, C.G., E.L. Brunson, F.J. Dwyer, D.K. Hardesty, and N.E. Kemble. 1998. Use of sublethal endpoints in sediment toxicity tests with the amphipod Hyalella azteca. Environmental Toxicology and Chemistry 17:1508-1523.

Ingersoll, C.G., D.D. MacDonald, N. Wang, J.L. Crane, L.J. Field, P.S. Haverland, N.E. Kemble, R.A. Lindskoog, C. Severn, and D.E. Smorong. 2001. Predictions of sediment toxicity using consensus-based freshwater sediment quality guidelines. Archives of Environmental Contamination and Toxicology 41:8-21.

Ingersoll, C.G., D.D. MacDonald, W.G. Brumbaugh, B.T. Johnson, N.E. Kemble, J.L. Kunz, T.W. May, N. Wang, J.R. Smith, D.W. Sparks, and S.D. Ireland. 2002. Toxicity assessments of sediments from the Grand Calumet River and Indiana Harbor Canal in northwestern Indiana. Archives of Environmental Contamination and Toxicology 43:153-167. Doi:10.1007/s00244-001-0051-0.

Ingersoll, C.G., N.E. Kemble, J.L. Kunz, W.G. Brumbaugh, D.D. MacDonald, and D. Smorong. 2009. Toxicity of sediment cores collected from the Ashtabula River in Northeastern Ohio, USA, to the amphipod *Hyalella azteca*. Archives of Environmental Contamination and Toxicology 57:315-329. doi:10.1007/s00244-009-9332-9.

Long, E.R., L.J. Field, and D.D. MacDonald. 1998. Predicting toxicity in marine sediments with numerical sediment quality guidelines. Environmental Toxicology and Chemistry 17:714-727.

MacDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Archives of Environmental Contamination and Toxicology 39:20-31.

MacDonald, D.D., D.E. Smorong, C.G. Ingersoll, J.M. Besser, W.G. Brumbaugh, N. Kemble, T.W. May, C.D. Ivey, S. Irving, and M. O'Hare. 2009. Development and evaluation of sediment and pore-water toxicity thresholds to support sediment quality assessments in the Tri-State Mining District (TSMD), Missouri, Oklahoma, and Kansas. Prepared by United States Geological Survey, Columbia, Missouri and MacDonald Environmental Sciences Ltd., Nanaimo, BC for the United States Environmental Protection Agency, Dallas, Texas; USEPA Kansas City, Missouri; and USFWS, Columbia, Missouri. 210 pp.

Missouri Department of Conservation. 1997. Big River basin inventory and management plan. Missouri Department of Conservation, Fisheries Division. Jefferson City, Missouri. 106 pp.

Missouri Department of Conservation. 2006. Big River watershed basin information: Online. Prepared by Kevin Meneau. 1997. St. Louis Region. Missouri Department of Conservation, Jefferson City, Missouri. http://www.mdc.mo.gov/fish/watershed/big/habitat/

Missouri Department of Health and Senior Services. 2012. 2012 Missouri fish advisory. Bureau of Environmental Epidemiology, Missouri Department of Health and Senior Services, P.O. Box 570, Jefferson City, Missouri 65102. http://health.mo.gov/living/environment/fishadvisory/index.php.

Missouri Department of Natural Resources. 2001. Biological Assessment and Sediment Study: Flat River (Flat River Creek), St. Francois County. Division of Environmental Quality, Environmental Services Program, Water Quality Monitoring Section. A Final Report to MDNR, Water Pollution Control Program. 40 pp. + app.

Missouri Department of Natural Resources. 2002. Biological Criteria for Wadeable/Perennial Streams of Missouri. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 32 pp

Missouri Department of Natural Resources. 2009. Title 10. Rules of Department of Natural Resources Division 20-Clean Water Commission, Chapter 7-Water Quality. 10 CSR 20-7.031 Water Quality Standards. September 30, 2009. 150 pp.

Missouri Department of Natural Resources. 2010a. Biological assessment and fine sediment study report: Tributaries of Mill Creek and Mineral Fork, Washington County, Fall 2008 – Spring – Fall 2009. Missouri Department of Natural Resources, Division of Environmental Quality, Environmental Services Program, Water Quality Monitoring Section. P.O. Box 176, Jefferson City, Missouri 65102. 48 pp. + app.

Missouri Department of Natural Resources. 2010b. Stream habitat assessment project procedure. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 40 pp.

Missouri Department of Natural Resources. 2010c. Taxonomic levels for macroinvertebrate identifications. MDNR-ESP-209. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 33 pp.

Missouri Department of Natural Resources. 2011. Required/recommended containers, volumes, preservatives, holding times, and special sampling considerations. MDNR-ESP-001. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 24 pp.

Missouri Department of Natural Resources. 2012. Semi-quantitative macroinvertebrate stream bioassessment project procedure. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 29 pp.

Missouri Department of Natural Resources. 2013a. Biological assessment and fine sediment study report, tributaries of Mill Creek and Mineral Fork, part II: Pond Creek, Shibboleth Branch, and Tributary of Mineral Fork, Washington County. Fall 2010 – Spring 2011. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri. 65012. 55 pp. + app.

Missouri Department of Natural Resources. 2013b. Flow measurements in open channels. MDNR-ESP-113. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 13 pp.

Missouri Department of Natural Resources. 2014. Title 10. Rules of Department of Natural Resources Division 20-Clean Water Commission, Chapter 7-Water Quality. 10 CSR 20-7.031 Water Quality Standards. January 29, 2014. 150 pp.

Poulton, B.C., A.L. Allert, J.M. Besser, C.J. Schmitt, W.G. Brumbaugh, and J.F. Fairchild. 2009. A macroinvertebrate assessment of Ozark streams located in lead-zinc mining areas of the Viburnum Trend, in southeastern Missouri, USA. Environmental Monitoring and Assessment. DOI 10.1007/s10661-009-0864-2

Rabeni, C.F., R.J. Sarver, N. Wang, G.S. Wallace, M. Weiland, and J.T. Peterson. 1997. Biological criteria for streams of Missouri. Missouri Cooperative Fish and Wildlife Research Unit, University of Missouri-Columbia, Columbia, Missouri. 261 pp.

Sowa, S.C., G. Annis, M.E. Morey, and D.D. Diamond. 2007. A GAP analysis and comprehensive conservation strategy for riverine ecosystems of Missouri. Ecol. Mono. 77(3), pp. 301-334.

United States Environmental Protection Agency. 2000. Ambient Water Quality Criteria Recommendations. Information Supporting the Development of State and Tribal Nutrient Criteria for River and Streams in Nutrient Ecoregion XI.

Webb, J.A., E.L. King, T.B. Reynoldson, and M. Padgham. 2014. Bayesian reference conditions models achieve comparable or superior performance to existing standard techniques. Freshwater Science 33(4):1272-1285.

Submitted by: K

Environmental Specialist
Water Quality Monitoring Section
Environmental Services Program

Date: 10/22/2015

Approved by: Lynn Milberg

Section Chief, Water Quality Monitoring Section
Environmental Services Program

LM:klc

c: Trish Rielly, Water Protection Program
Jackson Bostic, Southeast Regional Office Director

Appendix A

Macroinvertebrate Database Bench Sheets Report:
Tiff Creek, Jefferson County and Koen Creek, St. Francois County.

(Grouped by season and station)

Aquid Invertebrate Database Bench Sheet Report

Tiff Cr [132003], Station #1, Sample Date: 9/18/2013 11:00:00 AM

CS = Coarse: NF = Nonflow: RM = Rootmat: -99 = Presence

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	5	7	5
AMPHIPODA			
Gammarus	3	1	6
Hyalella azteca			204
BASOMMATOPHORA			
Ancylidae	1	4	1
Menetus		1	3
COLEOPTERA			
Berosus		2	
Dineutus			-99
Dubiraphia		17	24
Ectopria nervosa		1	3
Macronychus glabratus			8
Optioservus sandersoni	33	2	
Psephenus herricki	5	1	
Stenelmis	5	1	3
DECAPODA			
Orconectes luteus	1		
Orconectes medius	2		
Orconectes virilis			1
DIPTERA			
Ablabesmyia		6	8
Antocha	2		
Brillia	1		
Ceratopogoninae		1	
Chrysops		2	
Cladotanytarsus	1	22	
Clinocera	1		
Corynoneura	1		
Cricotopus/Orthocladius	2	1	5
Cryptochironomus		3	
Dicrotendipes			8
Gonomyia	1		
Hemerodromia	22	1	2
Labrundinia		1	1
Micropsectra			4
Microtendipes	2		
Nilothauma		1	
Parakiefferiella	1	17	
Paralauterborniella		1	
Parametriocnemus	24		
Paratanytarsus	1		8
Paratendipes		2	
Phaenopsectra			1
Polypedilum flavum	2		1
Polypedilum scalaenum grp		2	
Procladius		1	
Pseudosmittia		1	

Aquid Invertebrate Database Bench Sheet Report

Tiff Cr [132003], Station #1, Sample Date: 9/18/2013 11:00:00 AM

CS = Coarse: NF = Nonflow: RM = Rootmat: -99 = Presence

ORDER: TAXA	CS	NF	RM
Rheotanytarsus	24	1	1
Simulium	48		
Stempellina		2	
Stempellinella	15	17	5
Stenochironomus		1	3
Tanytarsus	17	32	16
Thienemanniella	2		
Thienemannimyia grp.	18		6
Tipula	1	1	
Tribelos		1	
EPHEMEROPTERA			
Baetis	10		
Caenis anceps	6	1	2
Caenis latipennis	220	156	17
Eurylophella		14	17
Hexagenia limbata		2	
Isonychia bicolor	37		
Leptophlebiidae		3	19
Maccaffertium pulchellum	35		
Procloeon		4	4
Stenonema femoratum		3	
Tricorythodes	55		
HEMIPTERA			
Belostoma			1
Corixidae		4	
Microvelia	1		1
ISOPODA			
Caecidotea	1	1	3
Caecidotea (Blind & Unpigmented)		1	
LUMBRICINA			
Lumbricina	5		
MEGALOPTERA			
Nigronia serricornis	17		
Sialis		-99	
ODONATA			
Argia		6	
Basiaeschna janata			-99
Calopteryx	1		2
Enallagma			2
Gomphidae		2	
Hagenius brevistylus	5	1	
Hetaerina			5
Macromia			1
TRICHOPTERA			
Cheumatopsyche	107		
Chimarra	2		
Helicopsyche	17		
Hydropsyche	1		
Limnephilidae			-99

Aquid Invertebrate Database Bench Sheet Report

Tiff Cr [132003], Station #1, Sample Date: 9/18/2013 11:00:00 AM

CS = Coarse: NF = Nonflow: RM = Rootmat: -99 = Presence

ORDER: TAXA	CS	NF	RM
Mystacides	1	3	
Oecetis	1	6	12
Polycentropus			1
Triaenodes			22
TRICLADIDA			
Planariidae		1	1

Aquid Invertebrate Database Bench Sheet Report

Koen Cr [132004], Station #1, Sample Date: 9/18/2013 12:40:00 PM

CS = Coarse: NF = Nonflow: RM = Rootmat: -99 = Presence

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina			3
AMPHIPODA			
Crangonyx			1
Hyalella azteca			7
BASOMMATOPHORA			
Ancylidae	1		3
Physella	3	1	
COLEOPTERA			
Agabus	1		
Berosus	2	1	8
Dubiraphia	2		24
Dytiscidae		2	2
Helichus basalis	1		
Scirtidae	1		1
Stenelmis	20		5
DIPTERA			
Ablabesmyia		21	12
Ceratopogoninae	1		
Chironomus	3	21	6
Corynoneura	28		
Cricotopus/Orthocladius			5
Cryptochironomus	1	4	
Dicrotendipes	2	69	6
Hemerodromia	31		13
Labrundinia		1	2
Micropsectra	29		2
Microtendipes	6	1	
Nanocladius			1
Natarsia	1		
Nilotanypus	1		1
Parachironomus			1
Paramerina	2		2
Parametriocnemus	63	1	2
Paratanytarsus	4	8	41
Paratendipes	6	6	6
Pericoma	1		
Phaenopsectra		3	7
Polypedilum aviceps	2		
Polypedilum flavum	26		1
Polypedilum illinoense grp			2
Polypedilum scalaenum grp	2		
Polypedilum tritum			1
Procladius		1	
Psectrocladius			1
Rheotanytarsus			3
Stenochironomus			1
Stictochironomus	7	3	
Stratiomyidae	1		

Aquid Invertebrate Database Bench Sheet Report

Koen Cr [132004], Station #1, Sample Date: 9/18/2013 12:40:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Tabanus	-99		
Tanytarsus	21	87	51
Thienemannimyia grp.	75	1	7
Tipula	23		
Tribelos	2		
Zavrelimyia	1		
EPHEMEROPTERA			
Acerpenna			1
Caenis latipennis	49	135	29
Callibaetis			1
Centroptilum	7	1	
Stenacron	-99		
Stenonema femoratum	14	25	9
HEMIPTERA			
Microvelia	4		11
Rhagovelia			2
ISOPODA			
Lirceus	15		5
LUMBRICINA			
Lumbricina	-99	-99	
ODONATA			
Argia	3		1
Calopteryx	1		7
Enallagma			25
Epitheca (Epicordulia)			-99
TRICHOPTERA			
Cheumatopsyche	55		3
Chimarra	50		
Hydropsyche	4		
Hydroptila	1		1
Oecetis		1	1
Polycentropus	1		
Triaenodes			5
TRICLADIDA			
Planariidae	9		2
TUBIFICIDA			
Enchytraeidae	2		
Tubificidae	1	2	1

Aquid Invertebrate Database Bench Sheet Report

Tiff Cr [149801], Station #1a, Sample Date: 3/19/2014 12:15:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	17	5	4
AMPHIPODA			
Gammarus	1		3
Hyalella azteca			62
BASOMMATOPHORA			
Ancylidae		1	
Lymnaeidae		1	
Menetus		3	
Physella		1	1
COLEOPTERA			
Dineutus			1
Dubiraphia		8	3
Dytiscidae		1	
Ectopria nervosa		1	
Macronychus glabratus			5
Microcylloepus pusillus			1
Optioservus sandersoni	34		5
Psephenus herricki	1		
Stenelmis			1
DECAPODA			
Orconectes luteus			1
DIPTERA			
Ablabesmyia		2	3
Antocha	3		
Ceratopogoninae		12	5
Chironomidae	1		1
Cladotanytarsus	2		
Clinocera	1		
Corynoneura	4	4	2
Cricotopus/Orthocladius	322	123	55
Cryptotendipes		1	
Diamesa	43		
Dicrotendipes	1	10	5
Forcipomyiinae			1
Hemerodromia	15	13	1
Labrundinia		1	
Micropsectra	1		
Microtendipes			1
Orthocladius (Euorthocladius)	2		
Parakiefferiella	4	15	2
Paralauterborniella		1	
Parametriocnemus	4		
Paratanytarsus			9
Polypedilum aviceps	1		
Polypedilum scalaenum grp		1	4
Prosimulium	2		
Rheotanytarsus	3		2
Simulium	1		

Aquid Invertebrate Database Bench Sheet Report

Tiff Cr [149801], Station #1a, Sample Date: 3/19/2014 12:15:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Stempellinella	21	4	2
Stenochironomus	1		4
Tanytarsus	21	5	7
Thienemanniella	3		
Thienemannimyia grp.	4		13
Tipula	1	1	1
Tribelos		3	
Tvetenia bavarica grp	5		
EPHEMEROPTERA			
Acentrella	1		
Caenis latipennis	36	102	
Centroptilum	9	3	18
Eurylophella bicolor		2	26
Heptageniidae	11	1	
Isonychia bicolor	9		
Leptophlebiidae			1
Maccaffertium pulchellum	7		
Stenacron			7
Stenonema femoratum		3	5
HEMIPTERA			
Aquarius			1
ISOPODA			
Caecidotea			2
LUMBRICINA			
Lumbricina	5	1	1
MEGALOPTERA			
Nigronia serricornis	3		1
Sialis		1	1
ODONATA			
Argia		1	1
Basiaeschna janata			1
Calopteryx			1
Enallagma			1
Gomphidae	1		
PLECOPTERA			
Amphinemura	9		
Clioperla clio			1
TRICHOPTERA			
Cheumatopsyche	29	1	1
Chimarra	1		
Cyrnellus fraternus			1
Helicopsyche	11		12
Mystacides		3	
Oecetis			6
Polycentropus		1	4
Psychomyia	1		1
Pycnopsyche			1
Triaenodes			7
TUBIFICIDA			

Aquid Invertebrate Database Bench Sheet Report

Tiff Cr [149801], Station #1a, Sample Date: 3/19/2014 12:15:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Limnodrilus hoffmeisteri			1
Tubificidae		4	7
VENEROIDA			
Pisidiidae			1

Aquid Invertebrate Database Bench Sheet Report

Tiff Cr [149802], Station #1b, Sample Date: 3/19/2014 12:15:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	19	4	4
AMPHIPODA			
Crangonyx	2		
Gammarus	-99		10
Hyalella azteca		1	82
BASOMMATOPHORA			
Ancylidae	2		
Lymnaeidae		3	-99
Menetus	2		1
Physella			2
COLEOPTERA			
Agabus			-99
Dubiraphia		10	7
Dytiscidae		1	
Microcylloepus pusillus	1		
Optioservus sandersoni	28		
DECAPODA			
Orconectes virilis			-99
DIPTERA			
Ablabesmyia		8	1
Antocha	1		
Ceratopogoninae	1	15	1
Chironomidae	2		
Corynoneura	5	4	9
Cricotopus bicinctus	1		
Cricotopus/Orthocladius	430	177	56
Cryptochironomus		5	
Diamesa	76	1	
Dicrotendipes		13	6
Eukiefferiella	5		
Eukiefferiella brehmi grp	3		
Hemerodromia	13	14	6
Hexatoma	1		
Micropsectra			2
Orthocladius (Euorthocladius)	11		
Parakiefferiella	5	17	
Paramerina			2
Parametriocnemus	3		1
Paratanytarsus	1	2	9
Polypedilum aviceps	3		
Polypedilum scalaenum grp		5	
Prosimulium	5		
Rheocricotopus	1		
Rheotanytarsus	5		1
Stempellinella	12	10	
Stenochironomus			3
Sympotthastia			1
Tabanus		1	

Aquid Invertebrate Database Bench Sheet Report

Tiff Cr [149802], Station #1b, Sample Date: 3/19/2014 12:15:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Tanytarsus	10	3	2
Thienemanniella	7		2
Thienemannimyia grp.	2	2	2
Tipula	-99	-99	-99
Tribelos		1	
Tvetenia bavarica grp	5		
EPHEMEROPTERA			
Acentrella	1		
Caenis latipennis	8	67	27
Centroptilum		4	12
Eurylophella enoensis		3	15
Heptageniidae			1
Isonychia bicolor	9		
Leptophlebia			1
Maccaffertium pulchellum	24		4
Stenacron		1	
Stenonema femoratum		4	
Tricorythodes		1	
ISOPODA			
Caecidotea			8
Caecidotea (Blind & Unpigmented)		1	
LUMBRICINA			
Lumbricina	-99	-99	
MEGALOPTERA			
Nigronia serricornis	1		-99
ODONATA			
Argia		2	1
Basiaeschna janata	-99		-99
Calopteryx			-99
Gomphidae		1	1
PLECOPTERA			
Amphinemura	5		
TRICHOPTERA			
Ceratopsyche morosa grp	-99		
Cheumatopsyche	39	-99	2
Chimarra	3		
Helicopsyche	7	6	23
Neophylax	1		
Nyctiophylax			-99
Oecetis	1	2	5
Polycentropus			1
Psychomyia	1		
Pycnopsyche			-99
Triaenodes			10
TUBIFICIDA			
Enchytraeidae			1
Tubificidae		2	

Aquid Invertebrate Database Bench Sheet Report

Koen Cr [149803], Station #1, Sample Date: 3/19/2014 2:30:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	1		
AMPHIPODA			
Crangonyx	25	7	94
Hyalella azteca		3	3
BASOMMATOPHORA			
Ancylidae	2	3	
Physella	7	1	5
COLEOPTERA			
Berosus	2		
Dubiraphia		1	
Ectopria nervosa	3		
Helichus basalis	1		
Stenelmis	26		2
DECAPODA			
Orconectes luteus	1		
DIPTERA			
Ablabesmyia	2	6	1
Ceratopogoninae	4	1	
Chironomus	5	42	
Cladotanytarsus		2	
Clinocera	6		
Corynoneura	1		
Cricotopus/Orthocladius	87	2	16
Cryptochironomus		1	
Diamesa	1		
Dicrotendipes	14	10	4
Eukiefferiella	29	1	2
Glyptotendipes		1	
Hemerodromia	4		1
Hydrobaenus	28	10	2
Limnophila			1
Microtendipes	1	1	3
Nilotanypus	3	4	1
Parametriocnemus	14		2
Paraphaenocladius			1
Paratanytarsus	14	3	19
Paratendipes	13		
Phaenopsectra	2	1	
Polypedilum aviceps			1
Polypedilum scalaenum grp	7		
Psectrocladius		1	
Pseudochironomus	1		
Stempellinella	1	1	
Stictochironomus	6	5	
Sympotthastia	1		
Tabanus	-99		
Tanytarsus	21	50	11
Thienemannimyia grp.	15		11

Aquid Invertebrate Database Bench Sheet Report

Koen Cr [149803], Station #1, Sample Date: 3/19/2014 2:30:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Tipula	6		1
Tribelos	1		
Tvetenia bavarica grp	7		1
EPHEMEROPTERA			
Caenis latipennis	150	78	39
Centroptilum		1	
Stenonema femoratum	39	4	
HEMIPTERA			
Microvelia			6
ISOPODA			
Caecidotea	2		31
Caecidotea (Blind & Unpigmented)		2	1
Lirceus	14	12	34
LUMBRICINA			
Lumbricina	9		1
ODONATA			
Calopteryx			1
TRICHOPTERA			
Cheumatopsyche	5		1
Chimarra	2		2
Polycentropus	2	1	1
Rhyacophila	1		
Triaenodes			3
TRICLADIDA			
Planariidae	24		14
TUBIFICIDA			
Enchytraeidae	15	4	1
Limnodrilus hoffmeisteri	9	3	
Tubificidae	21	8	2