Michigan Department of Environment, Great Lakes, and Energy
Water Resources Division

Three Total Maximum Daily Loads for Total Copper for Portions of the Trap Rock River Watershed Houghton County, Michigan

INTRODUCTION

Section 303(d) of the federal Clean Water Act and the United States Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations (Title 40 of the Code of Federal Regulations, Part 130) require states to develop Total Maximum Daily Loads (TMDL) for water bodies that are not meeting Water Quality Standards (WQS). The TMDL process establishes the allowable loadings of a pollutant to a water body based on the relationship between pollutant sources and in-stream water quality conditions. TMDLs provide a basis for determining the pollutant reduction necessary from point and/or nonpoint sources to restore and/or maintain water quality.

The purpose of this TMDL is to identify allowable levels of total copper that will result in the attainment of the applicable WQS in the Trap Rock River watershed located in Houghton County, Michigan.

PROBLEM STATEMENT

For the Trap Rock River watershed, the reaches identified in the 2020 Section 303(d) list (Goodwin, 2020) as not meeting the Other Indigenous Aquatic Life and Wildlife designated use due to total copper are as follows:

Water body name: **Calumet Lake**
AUID: 040201030303-02
Impaired designated use: Other Indigenous Aquatic Life and Wildlife
Cause: Copper
Source: Mine Tailings
Size: 9.38 Miles
Location Description: Calumet Lake at Calumet. Includes a small portion of Slaughterhouse Creek downstream to STORET 310463.
TMDL Year(s): To be determined[1]

Water body name: **Trap Rock River**
AUID: 040201030303-05
Impaired designated use: Other Indigenous Aquatic Life and Wildlife
Cause: Copper
Source: Mine Tailings
Size: 9.4 Miles
Location Description: Trap Rock River downstream of the Scales Creek confluence
TMDL Year(s): 2022

[1] TMDL development date will be post 2022, based on future prioritization processes.

Water body name: Kearsarge Creek, Slaughterhouse Creek, and Scales Creek
AUID: 040201030303-08
Impaired designated use: Other Indigenous Aquatic Life and Wildlife
Cause: Copper
Source: Mine Tailings
Size: 4.3 Miles
Location Description: Includes Kearsarge Creek, Slaughterhouse Creek from the Kearsarge Creek confluence to the Scales Creek confluence, and Scales Creek from the Slaughterhouse Creek confluence downstream to the Trap Rock River.
TMDL Year(s): 2022

Water body name: **Slaughterhouse Creek**
AUID: 040201030303-13
Impaired designated use: Other Indigenous Aquatic Life and Wildlife
Cause: Copper
Source: Mine Tailings
Size: 1.2 Miles
Location Description: Includes: Slaughterhouse Creek from Mining Pond downstream to the confluence with Fulton Creek.
TMDL Year(s): 2022

AUID stands for Assessment Unit Identifier. Michigan uses the National Hydrography Database coding scheme (1:24,000 resolution) to georeference water bodies when generating the Sections 305(b) and 303(d) lists. The 12-digit Hydrologic Unit Code (HUC) is used as a default when listing streams and rivers to facilitate record keeping and mapping. Each 12-digit HUC base assessment unit may be split into multiple assessment units if site-specific information supports a smaller assessment unit. These smaller assessment units are identified by a dash and number (i.e. -06) after the 12-digit HUC. An assessment unit may consist of all water bodies in a 12-digit HUC (as a maximum) or specific stream segments or lakes in a 12-digit HUC (Goodwin, 2020).

The Keweenaw Peninsula is in the northwestern portion of Michigan's Upper Peninsula and is known locally as "copper country" due to the extensive elemental, mass copper deposits ("native copper") throughout the area. By the late 1880s, mining operations deforested most of the Keweenaw Peninsula and numerous stamp mills were constructed in the headwaters of several Keweenaw Peninsula streams for processing copper ore. The byproduct of the stamp mills' rock crushing activities was a coarse, dark aggregate called stamp sands. Extensive copper stamp sand piles are found throughout the woods, along streambeds, and the Lake Superior shoreline (Figure 1). As a result of the stamp sand deposits, copper concentrations in several water bodies in the Upper Peninsula exceed the WQS for the Other Indigenous Aquatic Life and Wildlife designated use and therefore require TMDL development.

Figure 1. Stamp sand deposits along Kearsarge Creek, Trap Rock River watershed, in 2000.

The reaches indicated above were originally listed on either the 2008 or 2010 Section 303(d) list based on water chemistry monitoring indicating total copper concentrations exceeded WQS. The subsequent monitoring of the watershed in 2011 for the development of site-specific WQS confirmed the need for a TMDL for AUIDs 040201030303-05, 040201030303-08, and 040201030303-13. The monitoring also indicated that although copper levels were high at STORET station 310463 (downstream of Calumet Lake), dissolved organic carbon (DOC) concentrations were also elevated, and thus a Site-Specific Criteria for copper was developed but was not approved by the USEPA. Therefore, 040301030303-02 (Calumet Lake) will remain on the nonattainment list until more lake specific data can be collected and an appropriate TMDL written in the future if data suggest it is necessary.

This document addresses the remaining three (040201030303-05, 040201030303-08, and 040201030303-13) of the four impaired reaches in the Trap Rock River watershed, which covers approximately 43 square miles. Calumet Lake forms the headwaters of Slaughterhouse Creek. Slaughterhouse Creek then flows approximately three miles before it reaches a pond that is a historic mine portal, immediately south of Copper City (Figure 2). This portal is likely fed by groundwater that travels through miles of historic mine workings. The creek then flows a little more a mile and over Queen Anne Falls to the confluence of Kearsarge Creek. Kearsarge Creek is an intermittent tributary that flows over the Keweenaw fault and through a short, deeply incised valley segment. Downstream of the Kearsarge Creek confluence, Slaughterhouse Creek continues 0.2 miles where it meets with and becomes Scales Creek. Scales Creek flows 1.7 miles to the confluence with the Trap Rock River. The Trap Rock River's headwaters begin approximately 10 miles upstream of the confluence with Scales Creek and then flows 8 miles to Torch Lake.

Most of the land use in the Trap Rock River watershed consists of forest (64%) and wetlands (16%) (Table 1) (United States Geological Survey [USGS], 2006]. The municipalities with land area in the Trap Rock River watershed and within the individual TMDL reaches are listed in Table 2.

Table 1. Land use within the Trap Rock River watershed (USGS catchment information, 2006).

Land Use Classification	Entire Watershed	Reach A	Reach B	Reach C
Open Water	0.2%	2.6%	0.4%	0.0%
Developed, Open Space	3.5%	7.2%	2.6%	3.5%
Developed, Low Intensity	3.7%	7.9%	3.0%	4.8%
Developed, High or Medium Intensity	1.6%	5.4%	0.5%	2.3%
Forest	64.4%	42.5%	64.8%	58.3%
Baren Land, Shrub/Scrub and Grassland/Herbaceous	2.8%	1.4%	3.3%	3.6%
Pasture/Hay	4.8%	0.0%	2.1%	9.5%
Cultivated Crops	3.3%	0.0%	0.5%	6.4%
Wetlands	15.7%	33.1%	22.6%	11.7%
Total	**100%**	**100%**	**100%**	**100%**

Table 2. Municipalities located within the Trap Rock River watershed TMDL reaches, Houghton County, Michigan.

Municipality	Percentage of Trap Rock River Watershed	Percentage of Reach A Watershed	Percentage of Reach B Watershed	Percentage of Reach C Watershed
Allouez Twp.	14.8	0	0	0
Calumet Twp.	37.5	99.6	86.5	24.4
Houghton Twp.	6.5	0.4	0	0
Osceola Twp.	3.2	0	0	6.7
Schoolcraft Twp.	35.7	0	13.5	68.9
Sherman Twp.	2.3	0	0	0

NUMERIC TARGET

The impaired designated use addressed by this TMDL is “Other Indigenous Aquatic Life and Wildlife.” At a minimum, all surface waters of the state are protected for all of the following designated uses: agriculture, navigation, industrial water supply, warmwater fishery, other indigenous aquatic life and wildlife, partial body contact recreation, and fish consumption (Rule 100 [R 323.1100], Designated Use, of the Part 4 rules, WQS, promulgated under Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended [NREPA]). Rule 57 (R 323.1057), Toxic Substances, of the Part 4 rules, states that toxic substances shall not be present in the surface waters of the state at levels that are or may become injurious to the public health, safety, or welfare; plant and animal life; or the designated uses of the waters.

Modification of aquatic life criteria values to reflect local environmental conditions is permitted under Subrule r(ii) of R 323.1057. Under this subrule, site-specific aquatic life values may be derived using a recalculation, water effect ratio (WER), or resident species procedures. A WER procedure accounts for the effects of water quality variables such as hardness or DOC on metal bioavailability. The Michigan Department of Environment, Great Lakes, and Energy (EGLE, formerly Michigan Department of Environmental Quality [MDEQ]) staff conducted a regional study in Michigan’s Upper Peninsula to develop a procedure for calculating a WER that could be used to develop site-specific WQS for copper (MDEQ, 2007). This procedure was used to calculate site-specific criteria. Details are included in the document “Development of Site-Specific Aquatic

Life Values for Total Copper for Water Bodies in the Upper Peninsula of Michigan" (Lipsey, 2013), which was reviewed and approved by the USEPA.

Five site-specific WQS were calculated for the Trap Rock River watershed and three are the numeric targets for the TMDLs in this document. The first TMDL target applies to the portion of Slaughterhouse Creek that includes the mine portal downstream to the confluence of Fulton Creek. This stretch of Slaughterhouse Creek will be referred to as Reach A for the remainder of the report (red reach, Figure 2). A site-specific WQS of 8 micrograms per liter (µg/L) was calculated for Reach A. The second TMDL target applies to Kearsarge Creek, Slaughterhouse Creek from the confluence with Kearsarge Creek downstream to the confluence of Scales Creek, and Scales Creek from this confluence to the confluence of the Trap Rock River. This stretch of the Trap Rock River watershed will be referred to as Reach B for the remainder of the report (purple reach, Figure 2). A site-specific WQS of 12 µg/L was calculated for Reach B. The third TMDL target applies to the Trap Rock River from the confluence with Scales Creek downstream to its confluence with Torch Lake. It does not include any of the tributaries within this reach of river. This stretch of the Trap Rock River will be referred to as Reach C for the remainder of the report (bright blue reach, Figure 2). A site-specific WQS of 7 µg/L was calculated for Reach C. For all three TMDLs the target is equal to the site-specific Final Chronic Value (FCV) because it is the most conservative value of the applicable WQS.

Decision criteria for use in determining the extent (distance of stream reach included) to which a site-specific WQS was applied is detailed in the site-specific criteria document (Lipsey, 2013) and includes availability of water quality data (hardness, DOC, copper, and total organic carbon [TOC]) and landscape feature considerations.

DATA DISCUSSION

Water Sampling Data

A total of 115 water samples were taken at 16 stations throughout the Trap Rock River watershed (Figure 2; Appendix A) from October 1991-September 2011. Most recently, nine stations (Table 3) were sampled monthly from June-September 2011. Total Copper, TOC, DOC, and Total Hardness as measured by total calcium and total magnesium ions were collected at each station. Water samples were collected and analyzed according to USEPA approved methods.

Table 3. Station locations for 2011 water quality sampling in the Trap Rock River watershed.

STORET	AUID	Water Body	Location	Latitude	Longitude	TMDL Reach data applies to
310354	040201030303-08	Kearsarge Creek	upstream of Slaughterhouse Creek confluence	47.27500	-88.39100	Reach B
310338	040201030303-08	Scales Creek	u/s Valley Road crossing	47.26720	-88.36980	Reach B
310467	040201030303-12	Scales Creek	u/s of Slaughterhouse Creek	47.27170	-88.39050	NA[2]
310466	040201030303-08	Slaughterhouse Creek	below Queen Ann Falls	47.27470	-88.39070	NA[1]
310463	040201030303-03	Slaughterhouse Creek	Calumet Lake Outlet	47.25950	-88.43680	NA[1]
310464	040201030303-11	Slaughterhouse Creek	upstream of Fulton Creek	47.28230	-88.39450	Reach A
310341	040201030303-05	Trap Rock River	Valley Road crossing	47.24990	-88.37120	Reach C
310382	040201030303-05	Trap Rock River	Angman Road	47.23000	-88.38276	Reach C
310415	040201030303-05	Trap Rock River	Rimfetti Road	47.20708	-88.39062	Reach C

A site-specific WQS of 8 µg/L was calculated for Reach A (Figure 2; Table 4). The geometric mean of the copper data collected at Station 310464 was 18 µg/L and thus exceeded the site-specific WQS. All data are in Appendix A.

A site-specific WQS of 12 µg/L was calculated for Reach B, using data from Station 310338 on Scales Creek (Figure 2; Table 4). A site-specific WQS of 13 µg/L was also calculated for Kearsarge Creek at sampling Station 310354. Total hardness and DOC values were similar between Stations 310338 and 310354 and thus the most conservative site-specific WQS was chosen for the reach. The geometric mean of the copper data collected at Stations 310338 and 310354 each exceeded the site-specific WQS. Data from two additional stations (310353 and 310392) sampled prior to 2011 also resulted in geometric means exceeding the site-specific WQS. All data are in Appendix A.

A site-specific WQS of 7 µg/L was calculated for Reach C using data from Station 310341 (Figure 2; Table 4). DOC data were also collected from Kearsarge Creek at sampling Stations 310382 and 310415. The resultant site-specific WQS for each station was 7 µg/L and 8 µg/L, respectively. Total hardness and DOC values were similar between these three stations and thus

[2] NA- Data from this station does not apply to one of the reaches addressed in this TMDL

the most conservative site-specific WQS was chosen. The geometric mean of the copper data collected at Stations 310341, 310382, and 310415 each exceeded the site-specific WQS. All data are in Appendix A.

Macroinvertebrate Sampling Data

Macroinvertebrate community and habitat surveys at Stations 310345, 310466, 310409, 310354, 310392, 310467, 310353, 310338, 310412, 310341, 310382, and 310415 in the Trap Rock River watershed indicate the macroinvertebrate communities are meeting the biological integrity requirements of the Michigan WQS (Table 5).

Table 4. Data summary of current WQS, site-specific WERs, site-specific WQS to be applied, and summary of water quality data in tributaries within the Trap Rock River watershed.

STORET #	AUID	Water Body Name	Station Location	Mini-mum DOC (mg/L[3])	Geomean Hardness all available data (mg/L)	Original WQS (µg[4]/L)	SMAV[5] WER based on min DOC	WQS with WER (µg/L)	Geomean Copper all available data (µg/L)	n[6]	Site-Specific WQS to be applied (µg/L)	303(d) status
310456	040201030303-01	Fulton Creek	along snowmobile trail (W)	na	33	5	na	**na[7]**	12	2	**NA[8]**	**Insufficient Information**
420105	040201030303-01	Fulton Creek	along snowmobile trail (W)	na	20	3	na	**na**	52	3	**NA**	
310465	040201030303-01	Fulton Creek	Upstream of Slaughterhouse	na	86	12	na	**na**	7	4	**NA**	
310409	040201030303-09	Mud Creek	Copper City	na	76	11	na	na	7	4	**NA**	**Insufficient Information**
310463	040201030303-02	Slaughterhouse Creek	Calumet Lake Outlet	9.7	101	14	5.2	**49[9]**	27	8	**NA**	**TMDL Needed**
310345	040201030303-11	Slaughterhouse Creek	Philipsville	na	114	15	na	na	4	5	**NA**	**Meets WQS**
310464	040201030303-13	Slaughterhouse Creek	upstream of Fulton Creek	3.3	55	8	1.4	**8**	18	8	**8**	**TMDL (Reach A)**
310466	040201030303-08	Slaughterhouse Creek	below Queen Ann Falls	5.2	69	10	2.5	**17**	11	8	**17**	**Meets WQS**
310467	040201030303-12	Scales Creek	Upstream of Slaughterhouse Cr.	3.3	72	10	NA	**NA**	3	6	**NA**	**Meets WQS**
310338	040201030303-08	Scales Creek	Upstream of Valley Road crossing	4.0	69	10	1.8	**12**	22	16	**12**	**TMDL (Reach B)**
310353	040201030303-08	Scales Creek	50 yds downstream Valley Road	na	70	10	na	na	25	2		
310392	040201030303-08	Kearsarge Creek	Downstream of remediation site	na	86	12	na	na	34	1		
310354	040201030303-08	Kearsarge Creek	Upstream of Slaughterhouse Cr. confluence	3.8	80	11	1.7	13	46	9		
310412 & 310352	040201030303-04	Trap Rock River	Wood Bush Rd.	na	60	9	na	na	3	4	**NA**	**Meets WQS**
310341	040201030303-05	Trap Rock River	Valley Rd.	3.1	57	8	1.3	**7**	14	12	**7**	**TMDL**

[3] mg/l =milligrams per liter
[4] µg/L=micrograms per liter
[5] Species Mean Acute Value
[6] n=number of hardness and copper values used for geometric mean
[7] na= not available
[8] NA= not applicable
[9] This site specific criteria was not approved by EPA and thus the acute original WQS value applies.

310382	040201030303-05	Trap Rock River	Angman Rd.	2.8	66	9	1.1	7	12	8		**(Reach C)**
310415	040201030303-05	Trap Rock River	Rimfetti Rd,	2.9	69	10	1.1	8	14	8		

Table 5. Macroinvertebrate data collected from Trap Rock River watershed, Keweenaw County, Michigan.

AUID	Storet	Water Body Name	Station Location	Date Sampled	Procedure 51 Rating and Score	Report #
040201030303-11	310345	Slaughterhouse Creek	Philipsville	6/27/2001	Excellent (+6)	MI/DEQ/SWQ-02/005
040201030303-11	310345	Slaughterhouse Creek	Philipsville	7/29/1991	Good	MI/DEQ/SWQ-92/040
040201030303-08	310466	Slaughterhouse Creek	below QA Falls	6/16/2006	Excellent (+7)	MI/DEQ/WB-07/080
040201030303-08	310466	Slaughterhouse Creek	below QA Falls	7/29/1991	Good	MI/DEQ/SWQ-92/040
040201030303-09	310409	Mud Creek	Copper City	6/20/2006	Acceptable (+2)	MI/DEQ/WB-07/080
040201030303-08	310354	Kearsarge Creek	upstream of confluence of Slaughterhouse Creek	6/16/2006	Acceptable (+1)	MI/DEQ/WB-07/080
040201030303-08	310354	Kearsarge Creek	upstream of confluence of Slaughterhouse Creek	6/16/2011	Acceptable (+2)	MI/DEQ/WRD-12/018
040201030303-08	310354	Kearsarge Creek	upstream of confluence of Slaughterhouse Creek	7/29/1991	Poor	MI/DEQ/SWQ-92/040
040201030303-08	310392	Kearsarge Creek	downstream remediation site	6/6/2000	Acceptable (+2)	MI/DEQ/SWQ-02/005
040201030303-12	310467	Scales Creek	upstream Slaughterhouse Creek	6/13/2007	Excellent (+7)	MI/DEQ/WRD-12/027
040201030303-08	310353	Scales Creek	upstream Valley Road crossing	7/30/1991	Fair	MI/DEQ/SWQ-92/040
040201030303-08	310338	Scales Creek	50 yds downstream Valley Road	6/16/2006	Acceptable (+4)	MI/DEQ/WB-07/080
040201030303-08	310338	Scales Creek	50 yds downstream Valley Road	6/22/2001	Acceptable (0)	MI/DEQ/SWQ-02/005
040201030303-04	310412	Trap Rock River	Wood Bush Road	7/30/1991	Good	MI/DEQ/SWQ-92/040
040201030303-05	310341	Trap Rock River	Valley Road crossing (W)	7/30/1991	Good	MI/DEQ/SWQ-92/040
040201030303-05	310382	Trap Rock River	Angman Road	6/26/2001	Acceptable (+4)	MI/DEQ/SWQ-02/005
040201030303-05	310415	Trap Rock River	Rimfetti Road	6/15/2011	Excellent (+6)	MI/DEQ/WRD-12/018

SOURCE ASSESSMENT

As noted above, the Keweenaw Peninsula is known locally as “copper country” due to the extensive copper deposits throughout the area. The area has a unique, complex geology that includes a large igneous uplifted fault line that bisects the peninsula. The largest copper mining operations in the world were located along this fault line during the 19th century. Early Native Americans mined copper from small pits along the Keweenaw Fault, and the first systematic copper mining operation started in 1846 near Eagle River, Michigan. By the late 1880s, mining operations deforested most of the Keweenaw Peninsula and numerous stamp mills were constructed in the headwaters of several Keweenaw Peninsula streams for processing copper ore. The byproduct of the stamp mills’ rock crushing activities was a coarse, dark aggregate called stamp sands. Extensive copper stamp sand piles are found throughout the woods, along streambeds, and the Lake Superior shoreline (Figure 1). Stamp sand deposits affect stream biota by burying in-stream habitat and leaching cupric ions into the water column. Groundwater that flows through stamps sands may also be a significant source of copper to surface water because copper ions are released from the stamp sands more readily in the acidic, anoxic conditions underground (Kotke, 2011). When the groundwater reaches surface waters, the dissolved copper remains mobile in the less stable oxygenated surface water conditions, due to DOC complexes, and their ability to bind and transport dissolved copper (Ford et al., 2007). There are countless abandoned mines throughout the Keweenaw Peninsula that serve as conduits for venting groundwater that may contain high concentrations of copper.

As a result of the stamp sand deposits, there are increased water column copper concentrations in several water bodies that have low hardness and low pH values. The lower the hardness, the less magnesium and calcium ions are available to bind with copper. The lower the pH, the more dissolved copper is released into the water column, and dissolved copper contributes to aquatic toxicity. Thus, copper concentrations in several water bodies in the Upper Peninsula exceed WQS for the other indigenous aquatic life and wildlife designated use and therefore require TMDL development.

Several historical copper mining operations are located in the Trap Rock River watershed near the historic settlements of Kearsarge, Copper City, and Centennial Heights. Several abandoned mine shafts serve as conduits for venting groundwater. Waste rock piles and stamp sand deposits have been found in several areas adjacent to streams and both can be sources of copper, especially stamp sands. Sources of copper could include Calumet Lake, which was a historical dumping area for mine tailings since surface waters were used in the mining of copper. A poor rock pile lay adjacent to the mine portal near Phillipsville, but it was crushed and removed by the property owner approximately ten years ago. However, the mine portal is likely one place where groundwater from surrounding mines reaches Slaughterhouse Creek. Venting groundwater that travels through the remaining stamps along Kearsarge and Scales Creeks may also be a source of copper.

Northern Houghton County Water and Sewer Authority (National Pollutant Discharge Elimination System [NPDES] permit MI0043982) is the only point source discharger in the Trap Rock River watershed (MiWaters, 2020). They intermittently discharge combined sewer overflow water during snow melt and severe wet weather events to St. Louis Creek and an unnamed tributary to Hammel Creek. These are tributaries to the Trap Rock River, downstream of the Scales Creek confluence. They are neither a known nor likely source of total copper.

The Michigan Department of Transportation (MDOT) has a statewide NPDES Individual Storm Water Permit (MI0057364) to cover storm water discharges from their Municipal Separate Storm Sewer System. This statewide permit requires the permittee to reduce the discharge of pollutants to the maximum extent practicable and employ Best Management Practices to

comply with TMDL requirements. The area covered by the MDOT statewide permit in the Trap Rock River watershed is minimal and the runoff from the state roads is not expected to be a source of copper to the watershed.

Finally, the last known source of copper is the Osceola Mine located at the headwaters of Hammel Creek. Hammel Creek is the most downstream tributary to the Trap Rock River before the confluence with Torch Lake. Site-specific WQS for this tributary were developed in 2002 using the WER method of comparing the toxicity of copper in site water to the toxicity of laboratory water (MDEQ, 2002). A site-specific FCV of 85 µg/L was developed for Hammel Creek. Copper data were collected in Hammel Creek as part of the 2002 study. The most downstream station was 0.5 miles upstream of the confluence with the Trap Rock River. The copper concentrations ranged from 8.2 µg/L to 15 µg/L (geometric mean = 10 µg/L). This is before mixing with the larger Trap Rock River, which would provide some dilution.

As an additional tool in determining potential sources of total copper to the Trap Rock River watershed, a load duration curve analysis, as outlined by Cleland (2002), was developed for each sampling station within the three TMDL reaches. A load duration curve considers how flow conditions relate to a variety of potential pollutant sources (point and nonpoint sources). The load duration curves for each station sampled in the Trap Rock River watershed are included in Appendix B. All historical flows available from the USGS gage (#04043050) on the Trap Rock River near Lake Linden, Michigan, and individual flow measurements taken at Station 310354 in 2011 and Station 310353 in 2007 (Appendix C) were used to develop the load duration curves.

The data indicate that exceedances of the WQS are observed during wet and dry weather events (Appendix B). Note that dots above the curve on the left side of each figure are indicative of total copper WQS exceedances during wet weather conditions (higher flows) and dots above the curve to the right side of the figure indicate total copper WQS exceedances during dry weather conditions (lower flows). Exceedances of the WQS occurred during all flow conditions. This would be expected since the primary source of copper to the watershed is stamp sands within the streambed and through which groundwater flows. This would occur during all flow conditions.

LOADING CAPACITY DEVELOPMENT

The loading capacity (LC) represents the maximum daily loading that can be assimilated by the water body while still achieving WQS. As indicated in the Numeric Target section, the targets for these Trap Rock River total copper TMDLs are site-specific aquatic FCV WQS of 8 µg/L for Reach A, 12 µg/L for Reach B, and 7 µg/L for Reach C (Figure 2; Table 4).

Concurrent with the selection of numeric concentration endpoints, development of the LC requires identification of the critical conditions. The “critical condition” is the set of environmental conditions (e.g., flow) used in developing the TMDL that result in attaining WQS and has an acceptably low frequency of occurrence. The critical conditions for the applicability of WQS in Michigan are given in Rule 90 (R 323.1090). For FCV values, such as for copper, R 323.1090 specifies that WQS shall apply at all flows equal to or exceeding the design flows. The design flow for copper is equal to the lowest of the 12 monthly 95% exceedance flows. The 95% exceedance flow is the flow equal to or exceeded 95% of the time for the specified month.

The LC is the sum of individual waste load allocations (WLA) for point sources and load allocations (LA) for nonpoint sources and natural background levels to assure WQS are met. In addition, the LC must include a margin of safety (MOS), either implicitly within the WLA or LA, or explicitly, that accounts for uncertainty in the relation between pollutant loads and the quality of the receiving water body. Conceptually, this definition is denoted by Equation 1.

(Equation 1) LC = ∑WLAs + ∑LAs + MOS

EGLE's Hydrologic Studies Unit used USGS gage Station 04043050 on the Trap Rock River near Lake Linden, Michigan, and watershed ratios to estimate a 95% exceedance flow for Slaughterhouse Creek at Station 310464 of 0.9 cubic feet per second (cfs) (0.58 million gallons per day [mgd]). Using Equation 2, the WQS of 0.008 mg/L, the 95% exceedance flow (mgd), and a conversion factor (8.34), the **LC** for **Reach A** of the Trap Rock River watershed was calculated as **0.04 pounds per day (lbs/day)** of total copper.

(Equation 2) LC (Individual Reach) = WQS (mg/L) x 95% Exceedance Flow (mgd) x 8.34

For Scales Creek at Station 310338, the flows from the same USGS gage station and the rating curve developed using the actual measured discharge measurements in Appendix C, were used to estimate a 95% exceedance flow of 1.2 cfs (0.78 mgd). Using Equation 2, the WQS of 0.012 mg/L, the 95% exceedance flow (mgd), and a conversion factor (8.34), the **LC** for **Reach B** of the Trap Rock River watershed was calculated as **0.08 lbs/day** of total copper.

The Hydrologic Studies Unit used the same USGS gage station and watershed ratios to estimate a 95% exceedance flow for the Trap Rock River at Station 310415 of 10 cfs (6.46 mgd). Using Equation 2, the WQS of 0.007 mg/L, the 95% exceedance flow (mgd), and a conversion factor (8.34), the **LC** for **Reach C** of the Trap Rock River watershed was calculated as **0.38 lbs/day** of total copper.

The next step is to calculate the current load at each of the three stations. Using Equation 3, the geometric mean of all total copper water samples taken at Station 310464 from 2007 to 2011 from Slaughterhouse Creek (0.018 mg/L; Table 4), the estimated 95% exceedance flow of the tributary at Station 310464 (0.58 mgd), and a conversion factor (8.34), it is estimated that the **current total load of copper** at critical conditions in **Reach A** is **0.09 lbs/day**.

(Equation 3) Current Loading at Critical Conditions = Geometric Mean Copper Samples (mg/L) x 95% Exceedance Flow (mgd) x 8.34

Using Equation 3, and the geometric mean of all total copper water samples taken at Station 310338 from 2007 to 2011 from Scales Creek (0.022 mg/L; Table 4), the estimated 95% exceedance flow of the tributary at Station 310338 (0.78 mgd), and a conversion factor (8.34), it is estimated that the **current total load** of copper in **Reach B** is **0.14 lbs/day**.

Using Equation 3, and the geometric mean of all total copper water samples taken at Station 310415 from 2007 to 2011 from the Trap Rock River (0.014 mg/L; Table 4), the estimated 95% exceedance flow of the tributary at Station 310415 (6.46 mgd), and a conversion factor (8.34), it is estimated that the **current total load** of copper in **Reach C is 0.75 lbs/day.**

WLAs

The WLA component of the TMDL defines the fraction of the LC for total copper from point sources. There are two NPDES permitted facilities upstream or within the impaired reaches of the Trap Rock watershed (MiWaters, 2020). North Houghton County Water and Sewer Authority (NPDES permit MI0043982) intermittently discharges combined sewer overflow water during snow melt and severe wet weather events to St. Louis Creek and an unnamed tributary to Hammel Creek. These are tributaries to the Trap Rock River, downstream of the Scales Creek confluence. They are neither a known nor likely source of total copper.

The MDOT has a statewide NPDES Individual Storm Water Permit (MI0057364) to cover storm water discharges from their Municipal Separate Storm Sewer System. This statewide permit

requires the permittee to reduce the discharge of pollutants to the maximum extent practicable and employ Best Management Practices to comply with TMDL requirements. There is an estimated 0.16 square miles of state roads in the Trap Rock River watershed. This area was estimated using a 50-foot right-of-way on either side of the center line of the road and the number of miles of state roads within the watershed (8.59 miles). The area covered by the MDOT statewide permit is minimal and the runoff from the state roads is not expected to be a source of copper to the watershed.

Neither NPDES permit within the Trap Rock River watershed are known or expected sources of copper to the impaired water bodies and thus did not receive a WLA. The WLA in this TMDL is 0 lbs/day (Table 6).

LAs

The LA component of the TMDL defines the fraction of the LC for total copper from nonpoint sources. For Reach A of the Trap Rock River watershed, a reduction in total copper loading from nonpoint sources equal to 0.05 lbs/day is necessary to meet the TMDL (Table 6). For Reach B of the Trap Rock River watershed, a reduction in total copper loading from nonpoint sources equal to 0.06 lbs/day is necessary to meet the TMDL (Table 6). For Reach C of the Trap Rock River watershed, a reduction in total copper loading from nonpoint sources equal to 0.37 lbs/day is necessary to meet the TMDL (Table 6).

Table 6. Summary of WLA and LA for Total Copper in the Trap Rock River watershed.

Source Category	Reach A Current Total Copper Estimated Load (lbs/day)	Reach A Target Total Copper Load (lbs/day)	Reach B Current Total Copper Estimated Load (lbs/day)	Reach B Target Total Copper Load (lbs/day)	Reach C Current Total Copper Estimated Load (lbs/day)	Reach C Target Total Copper Load (lbs/day)
WLA Components						
MDOT Statewide MS4 (#MI0057364)	0	0	0	0	0	0
North Houghton County Water and Sewer Authority (# MI0043982)	0	0	0	0	0	0
WLA Subtotal	0	0	0	0	0	0
LA Components						
Forested, Wetland, Developed Open Space, Low, Medium, and High Intensity Development, Pasture and Cultivated Crops, Grassland, Barren Land, Water etc.	0.09	0.036	0.14	0.072	0.75	0.342
LA Subtotal	0.09	0.036	0.14	0.072	0.75	0.342
MOS		.004		.008		.038
LC Total	**0.09**	**0.04**	**0.14**	**0.08**	**0.75**	**0.38**

MOS

The MOS accounts for any uncertainty or lack of knowledge concerning the relationship between pollutant loading and water quality, including the pollutant decay rate if applicable. The MOS can be either implicit (i.e., incorporated into the WLA or LA through conservative assumptions) or explicit (i.e., expressed in the TMDL as a portion of the loadings). For this Total Copper TMDL an implicit and explicit MOS were used. An implicit MOS applies because conservative assumptions were made in the development of site-specific WQS. The minimum DOC value of the four samples analyzed from each station sampled in the Trap Rock River watershed during 2011 was used for development of the Species Mean Acute Value (SMAV) WER using Equation 1. The lower the DOC value, the lower the resultant WER will be and thus result in a more conservative site-specific WER. In addition, if two of the four samples had the minimum DOC value, we chose the sample that had the minimum hardness value. This would be the most conservative approach since the FCV increases as hardness increases.

We were also conservative when applying a site-specific WQS to a reach of stream. If DOC data were collected at two sampling stations within the same stream reach and total hardness and DOC values were similar between these two stations, the most conservative site-specific WQS was chosen to be applied to that reach.

We also incorporated an explicit MOS. Because of the limited data set (4 samples within one year) of DOC data available to develop site-specific WQS, we set aside 10% of the LC of each reach as the MOS to ensure that the allocations of this TMDL are protective (Table 6).

SEASONALITY

Seasonality in this TMDL is addressed using a numeric target that is equal to the WQS, which applies throughout the year. The WQS is targeted to be met at flows greater than or equal to the 95% exceedance flow, which should occur 95% of the time. In addition, the load duration curves included in Appendix B and explained in the source assessment section, indicate that water was collected during all flow conditions.

MONITORING

Future monitoring by EGLE of the Trap Rock River macroinvertebrate community and water quality will take place as resources allow as part of the five-year rotating basin monitoring and/or if restoration activities take place to remediate sources of copper.

REASONABLE ASSURANCE

To address the total copper exceedances due to portions of the Trap Rock River watershed flowing through stamp sands, the Houghton-Keweenaw Conservation District (funded by EGLE), United States Department of Agriculture, Natural Resources Conservation Service, and USEPA completed remediation activities in Kearsarge Creek and Scales Creek. The remediation goal was to isolate stamp sand deposits from the streams by stabilizing the stream banks and capping and revegetating the upland areas. The Houghton-Keweenaw Conservation District contracted the Natural Resources Conservation Service to stabilize one 2.5-acre deposit in the Kearsarge Creek watershed in 1998 using Section 319 nonpoint source funds. The USEPA stabilized another 19-acre deposit along Scales Creek (between the Slaughterhouse Creek and Trap Rock River watersheds) in 2005 using Superfund Program funds. Section 319 funded the pre- and post-restoration water and biological surveys (MDEQ, 2006).

These restorations improved the in-stream habitat conditions and benthic macroinvertebrate communities in both streams. In Kearsarge Creek, total macroinvertebrate taxa tripled, sensitive

macroinvertebrate taxa returned, and copper concentrations fell by more than 50% (MDEQ, 2006). In Scales Creek copper concentrations decreased, and total macroinvertebrate taxa increased by 40%. In 2011, the macroinvertebrate community in Kearsarge Creek continued to rate acceptable (2) (Noffke, 2012). No additional data were collected in 2017.

Currently, the Trap Rock River watershed does not have an active watershed group and there is no Section 319 approvable watershed plan. However, in 1999 the Houghton-Keweenaw Conservation District completed an EGLE-approved watershed plan that meets Clean Michigan Initiative criteria (Albee, 1999). This watershed plan could be built upon to develop a Section 319-approvable watershed plan. The Trap Rock River watershed is rather remote and future development is not expected within the watershed. Currently, there are no further remediation activities planned to address total copper concentrations in the Trap Rock River watershed. As resources allow, EGLE will continue to investigate site-specific sources of copper from past mining practices in the watershed and evaluate whether remediation of the stamp sands is feasible.

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May 2021

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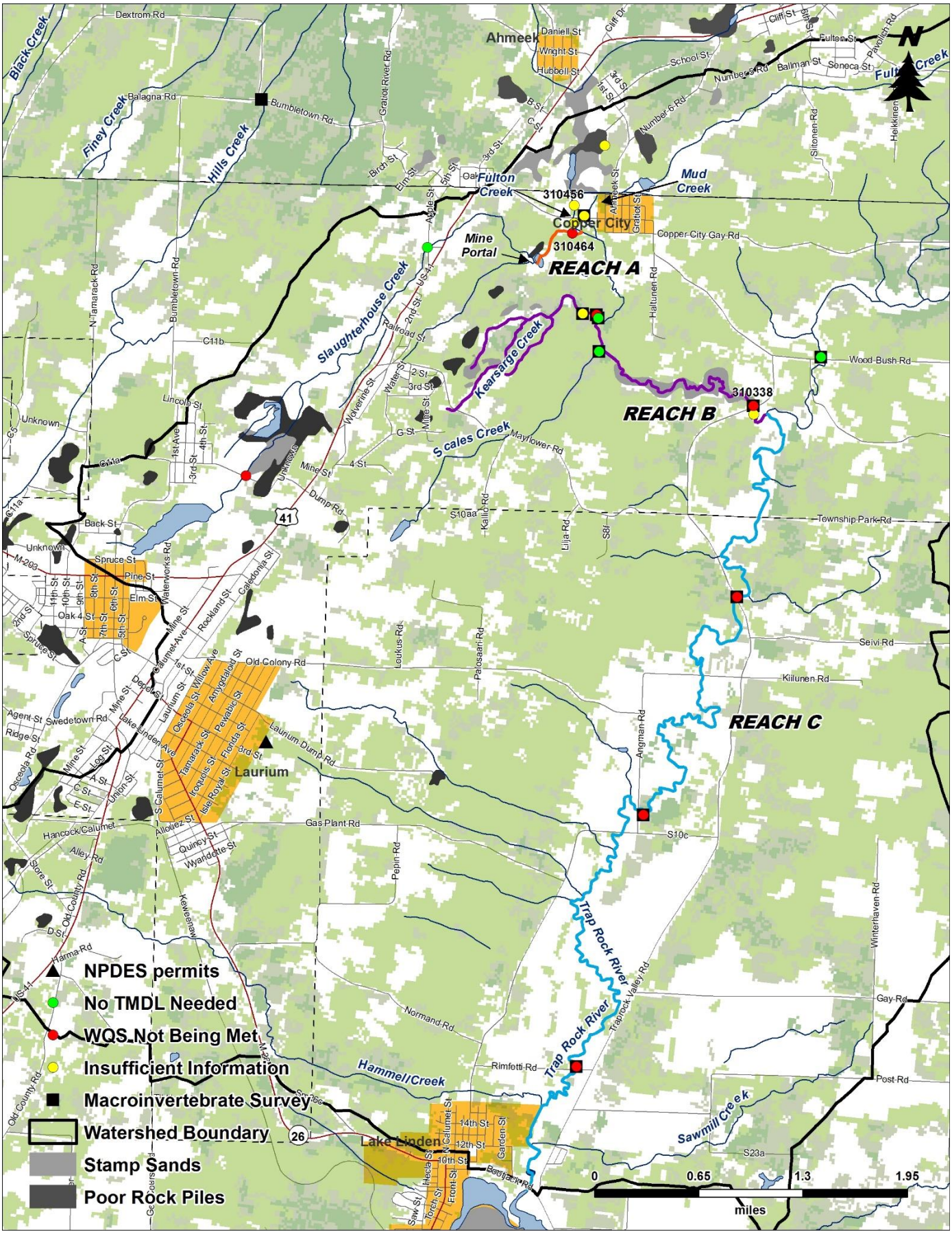


Figure 2. Trap Rock River watershed sampling stations, Houghton County, Michigan.

Appendix A. Analytical results for water samples collected from the Trap Rock River watershed, Keweenaw County, Michigan.

Storet	AUID	Water Body	Location	Latitude	Longitude	County	Date	Hard-ness (mg/L)	DOC (mg/L)	TOC (mg/L)	Copper (ug/L)
310456	040201030303-01	Fulton Creek	along snowmobile trail (W)	47.2848	-88.3944	Houghton	6/19/06	37	na	8.5	11
310456	040201030303-01	Fulton Creek	along snowmobile trail (W)	47.2848	-88.3944	Houghton	6/7/09	30	na	6.1	13
310465	040201030303-01	Fulton Creek	u/s of Slaughterhouse Creek	47.2832	-88.3943	Houghton	6/13/07	83	na	5.2	7.2
310465	040201030303-01	Fulton Creek	u/s of Slaughterhouse Creek	47.2832	-88.3943	Houghton	6/14/07	96	na	4.8	7.8
310465	040201030303-01	Fulton Creek	u/s of Slaughterhouse Creek	47.2832	-88.3943	Houghton	6/11/08	71	na	5.3	9.2
310465	040201030303-01	Fulton Creek	u/s of Slaughterhouse Creek	47.2832	-88.3943	Houghton	6/7/09	96	na	4.4	6.1
310354	040201030303-08	Kearsarge Creek	Slaughterhouse Cr.	47.275	-88.391	Houghton	7/29/91	88	na	--	125
310354	040201030303-08	Kearsarge Creek	Slaughterhouse Cr.	47.275	-88.391	Houghton	6/16/06	81	na	4.7	47
310354	040201030303-08	Kearsarge Creek	Slaughterhouse Cr.	47.275	-88.391	Houghton	6/13/07	90	na	3.8	44
310354	040201030303-08	Kearsarge Creek	Slaughterhouse Cr.	47.275	-88.391	Houghton	6/11/08	68	na	4.1	51
310354	040201030303-08	Kearsarge Creek	Slaughterhouse Cr.	47.275	-88.391	Houghton	6/9/09	63	na	4.5	56
310354	040201030303-08	Kearsarge Creek	Slaughterhouse Cr.	47.275	-88.391	Houghton	7/15/09	81	na	5.6	54
310354	040201030303-08	Kearsarge Creek	upstream of Slaughterhouse Cr. confluence	47.27500	-88.39100	Houghton	6/21/11	66.3	5	6.2	64.4
310354	040201030303-08	Kearsarge Creek	upstream of Slaughterhouse Cr. confluence	47.27500	-88.39100	Houghton	7/22/11	91.8	4.4	4.7	45
310354	040201030303-08	Kearsarge Creek	upstream of Slaughterhouse Cr. confluence	47.27500	-88.39100	Houghton	8/16/11	94.5	3.8	4.2	24
310354	040201030303-08	Kearsarge Creek	upstream of Slaughterhouse Cr. confluence	47.27500	-88.39100	Houghton	9/19/11	88.6	4.2	4.6	40.5
310392	040201030303-08	Kearsarge Creek	d/s remediation site	47.27508	-88.39283	Houghton	6/6/00	86	na	na	34
420105	N/A	Kingston mine Discharge (W)		47.2903	-88.3906	Keweenaw	6/21/01	18	na	na	64
420105	N/A	Kingston mine Discharge (W)		47.2903	-88.3906	Keweenaw	6/16/06	20	na	3.0	51
420105	N/A	Kingston mine Discharge (W)		47.2903	-88.3906	Keweenaw	6/7/09	21	na	2.3	43
310409	040201030303-09	Mud Creek	Copper City	47.2839	-88.393	Houghton	6/19/06	77	na	13	5.2
310409	040201030303-09	Mud Creek	Copper City	47.2839	-88.393	Houghton	6/13/07	84	na	11	3.7
310409	040201030303-09	Mud Creek	Copper City	47.2839	-88.393	Houghton	6/11/08	68	na	16	16
310409	040201030303-09	Mud Creek	Copper City	47.2839	-88.393	Houghton	6/7/09	77	na	12	6.5
310338	040201030303-08	Scales Creek	u/s Valley Road crossing	47.2672	-88.3698	Houghton	7/30/91	81	na	na	31

Appendix A Continued. Analytical results for water samples collected from the Trap Rock River watershed, Keweenaw County, Michigan.

Storet	AUID	Water Body	Location	Latitude	Longitude	County	Date	Hard-ness (mg/L)	DOC (mg/L)	TOC (mg/L)	Copper (ug/L)
310338	040201030303-08	Scales Creek	u/s Valley Road crossing	47.2672	-88.3698	Houghton	4/3/07	40	na	6.1	23
310338	040201030303-08	Scales Creek	u/s Valley Road crossing	47.2672	-88.3698	Houghton	5/17/07	73	na	8.8	21
310338	040201030303-08	Scales Creek	u/s Valley Road crossing	47.2672	-88.3698	Houghton	5/30/07	63	na	7.5	23
310338	040201030303-08	Scales Creek	u/s Valley Road crossing	47.2672	-88.3698	Houghton	6/13/07	79	na	5.8	22
310338	040201030303-08	Scales Creek	u/s Valley Road crossing	47.2672	-88.3698	Houghton	6/14/07	76	na	5.0	20
310338	040201030303-08	Scales Creek	u/s Valley Road crossing	47.2672	-88.3698	Houghton	7/12/07	76	na	4.2	22
310338	040201030303-08	Scales Creek	u/s Valley Road crossing	47.2672	-88.3698	Houghton	9/14/07	83	na	4.3	21
310338	040201030303-08	Scales Creek	u/s Valley Road crossing	47.2672	-88.3698	Houghton	9/27/07	82	na	7.0	20
310338	040201030303-08	Scales Creek	u/s Valley Road crossing	47.2672	-88.3698	Houghton	10/17/07	63	na	10	29
310338	040201030303-08	Scales Creek	u/s Valley Road crossing	47.2672	-88.3698	Houghton	10/22/07	57	na	10	34
310338	040201030303-08	Scales Creek	u/s Valley Road crossing	47.2672	-88.3698	Houghton	6/11/08	71	na	6.5	25
310338	040201030303-08	Scales Creek	u/s Valley Road crossing	47.2672	-88.3698	Houghton	6/30/10	85	na	6.7	19
310338	040201030303-08	Scales Creek	u/s Valley Road crossing	47.26720	-88.36980	Houghton	6/21/11	56.4	9.2	9.1	21.7
310338	040201030303-08	Scales Creek	u/s Valley Road crossing	47.26720	-88.36980	Houghton	7/22/11	79.7	6.3	5.9	20.3
310338	040201030303-08	Scales Creek	u/s Valley Road crossing	47.26720	-88.36980	Houghton	8/16/11	70.1	4.2	4.7	15.6
310338	040201030303-08	Scales Creek	u/s Valley Road crossing	47.26720	-88.36980	Houghton	9/19/11	67.6	4	4.3	15.3
310353	040201030303-08	Scales Creek	50 yds d/s Valley Road	47.26645	-88.3697	Houghton	7/29/91	81	na	5.8	25
310353	040201030303-08	Scales Creek	50 yds d/s Valley Road	47.26645	-88.3697	Houghton	6/22/01	71	na	na	27
310353	040201030303-08	Scales Creek	50 yds d/s Valley Road	47.26645	-88.3697	Houghton	6/16/06	69	na	5.8	23
310467	040201030303-12	Scales Creek	u/s of Slaughterhouse Creek	47.2717	-88.3905	Houghton	6/13/07	66	na	9.9	6.1
310467	040201030303-12	Scales Creek	u/s of Slaughterhouse Creek	47.2717	-88.3905	Houghton	6/11/08	49	na	9.5	7.7

Appendix A Continued. Analytical results for water samples collected from the Trap Rock River watershed, Keweenaw County, Michigan.

Storet	AUID	Water Body	Location	Latitude	Longitude	County	Date	Hard-ness (mg/L)	DOC (mg/L)	TOC (mg/L)	Copper (ug/L)
310467	040201030303-12	Scales Creek	u/s of Slaughterhouse Creek	47.27170	-88.39050	Houghton	6/21/11	51.4	12	14	1.1
310467	040201030303-12	Scales Creek	u/s of Slaughterhouse Creek	47.27170	-88.39050	Houghton	7/22/11	95	7.4	8	4
310467	040201030303-12	Scales Creek	u/s of Slaughterhouse Creek	47.27170	-88.39050	Houghton	8/16/11	100	3.8	4.1	3.4
310467	040201030303-12	Scales Creek	u/s of Slaughterhouse Creek	47.27170	-88.39050	Houghton	9/19/11	86.4	3.3	3.6	2.3
310345	040201030303-11	Slaughterhouse Creek	Philipsville	47.2806	-88.4137	Houghton	7/29/91	107	na	na	4.4
310345	040201030303-11	Slaughterhouse Creek	Philipsville	47.2806	-88.4137	Houghton	6/22/01	108	na	na	3.3
310345	040201030303-11	Slaughterhouse Creek	Philipsville	47.2806	-88.4137	Houghton	6/13/07	125	na	9.3	3.5
310345	040201030303-11	Slaughterhouse Creek	Philipsville	47.2806	-88.4137	Houghton	6/14/07	130	na	9.4	3.4
310345	040201030303-11	Slaughterhouse Creek	Philipsville	47.2806	-88.4137	Houghton	6/11/08	95	na	8.8	5.2
310464	040201030303-13	Slaughterhouse Creek	u/s of Mud creek (W)	47.2823	-88.3945	Houghton	6/13/07	62	na	5.4	18
310464	040201030303-13	Slaughterhouse Creek	u/s of Mud creek (W)	47.2823	-88.3945	Houghton	6/14/07	64	na	5.2	17
310464	040201030303-13	Slaughterhouse Creek	u/s of Mud creek (W)	47.2823	-88.3945	Houghton	6/11/08	73	na	6.4	17
310464	040201030303-13	Slaughterhouse Creek	u/s of Mud creek (W)	47.2823	-88.3945	Houghton	6/7/09	71	na	6	15
310466	040201030303-10	Slaughterhouse Creek	below Queen Ann Falls	47.2747	-88.3907	Houghton	7/29/91	86	na	na	25
310466	040201030303-10	Slaughterhouse Creek	below Queen Ann Falls	47.2747	-88.3907	Houghton	6/16/06	66	na	6.5	12
310466	040201030303-10	Slaughterhouse Creek	below Queen Ann Falls	47.2747	-88.3907	Houghton	6/13/07	74	na	5.7	9.9
310466	040201030303-10	Slaughterhouse Creek	below Queen Ann Falls	47.2747	-88.3907	Houghton	6/11/08	72	na	7.9	13
310466	040201030303-10	Slaughterhouse Creek	below Queen Ann Falls	47.2747	-88.3907	Houghton	6/9/09	77	na	7.3	11
310466	040201030303-10	Slaughterhouse Creek	below Queen Ann Falls	47.27470	-88.39070	Houghton	6/21/11	64.2	7.5	8.8	12.1
310466	040201030303-10	Slaughterhouse Creek	below Queen Ann Falls	47.27470	-88.39070	Houghton	7/22/11	91.6	6.9	7.3	9.8
310466	040201030303-10	Slaughterhouse Creek	below Queen Ann Falls	47.27470	-88.39070	Houghton	8/16/11	60.3	5.5	5.9	9.9

Appendix A Continued. Analytical results for water samples collected from the Trap Rock River watershed, Keweenaw County, Michigan.

Storet	AUID	Water Body	Location	Latitude	Longitude	County	Date	Hard-ness (mg/L)	DOC (mg/L)	TOC (mg/L)	Copper (ug/L)
310466	040201030303-10	Slaughterhouse Creek	below Queen Ann Falls	47.27470	-88.39070	Houghton	9/19/11	52.7	5.2	5.6	9.2
310463	040201030303-02	Slaughterhouse Creek	Calumet Lk. Outlet	47.2595	-88.4368	Houghton	7/30/91	91	na	na	50
310463	040201030303-02	Slaughterhouse Creek	Calumet Lk. Outlet	47.2595	-88.4368	Houghton	6/11/08	48	na	17	67
310463	040201030303-02	Slaughterhouse Creek	Calumet Lk. Outlet	47.2595	-88.4368	Houghton	6/7/09	115	na	10	35
310463	040201030303-02	Slaughterhouse Creek	Calumet Lk. Outlet	47.2595	-88.4368	Houghton	7/15/09	118	na	17	46
310463	040201030303-02	Slaughterhouse Creek	Calumet Lk. Outlet	47.2595	-88.4368	Houghton	8/12/09	129	na	13	15
310463	040201030303-02	Slaughterhouse Creek	Calumet Lk. Outlet	47.25950	-88.43680	Houghton	6/21/11	94.8	9.7	11	23.4
310463	040201030303-03	Slaughterhouse Creek	Calumet Lk. Outlet	47.25950	-88.43680	Houghton	7/22/11	118	13.7	15.4	19
310463	040201030303-02	Slaughterhouse Creek	Calumet Lk. Outlet	47.25950	-88.43680	Houghton	8/16/11	108	15.5	17.2	4.8
310463	040201030303-02	Slaughterhouse Creek	Calumet Lk. Outlet	47.25950	-88.43680	Houghton	9/19/11	106	11.8	48.3	76.9
310464	040201030303-13	Slaugtherhouse Creek	upstream of Fulton Creek	47.28230	-88.39450	Houghton	6/21/11	65.5	7.1	8.2	14.3
310464	040201030303-13	Slaugtherhouse Creek	upstream of Fulton Creek	47.28230	-88.39450	Houghton	7/22/11	74.2	6.2	6.9	17.8
310464	040201030303-13	Slaugtherhouse Creek	upstream of Fulton Creek	47.28230	-88.39450	Houghton	8/16/11	31.5	3.8	4.1	22
310464	040201030303-13	Slaugtherhouse Creek	upstream of Fulton Creek	47.28230	-88.39450	Houghton	9/19/11	26.4	3.3	3.4	27.1
310341	040201030303-05	Trap Rock River	Valley Road crossing	47.2499	-88.3712	Houghton	7/30/91	71	na	na	16.1
310341	040201030303-05	Trap Rock River	Valley Road crossing	47.2499	-88.3712	Houghton	5/17/07	NA	na	8.8	NA
310341	040201030303-05	Trap Rock River	Valley Road crossing	47.2499	-88.3712	Houghton	5/30/07	56	na	8.3	16
310341	040201030303-05	Trap Rock River	Valley Road crossing	47.2499	-88.3712	Houghton	7/12/07	71	na	3.6	14
310341	040201030303-05	Trap Rock River	Valley Road crossing	47.2499	-88.3712	Houghton	9/14/07	67	na	5.5	10
310341	040201030303-05	Trap Rock River	Valley Road crossing	47.2499	-88.3712	Houghton	9/27/07	65	na	8.0	14
310341	040201030303-05	Trap Rock River	Valley Road crossing	47.2499	-88.3712	Houghton	10/17/07	46	na	12	19
310341	040201030303-05	Trap Rock River	Valley Road crossing	47.2499	-88.3712	Houghton	10/22/07	38	na	12	21
310341	040201030303-05	Trap Rock River	Valley Road crossing	47.2499	-88.3712	Houghton	10/26/07	42	na	9.1	17
310341	040201030303-05	Trap Rock River	Valley Road crossing	47.24990	-88.37120	Houghton	6/21/11	48	10	11	16
310341	040201030303-05	Trap Rock River	Valley Road crossing	47.24990	-88.37120	Houghton	7/22/11	74.6	6.2	6.7	14.4
310341	040201030303-05	Trap Rock River	Valley Road crossing	47.24990	-88.37120	Houghton	8/16/11	67.9	3.9	4.4	11.4
310341	040201030303-05	Trap Rock River	Valley Road crossing	47.24990	-88.37120	Houghton	9/19/11	64.6	3.1	3.4	9.4
310382	040201030303-05	Trap Rock River	Angman Rd.	47.23	-88.38276	Houghton	7/13/08	67	na	4.9	13

Appendix A Continued. Analytical results for water samples collected from the Trap Rock River watershed, Keweenaw County, Michigan.

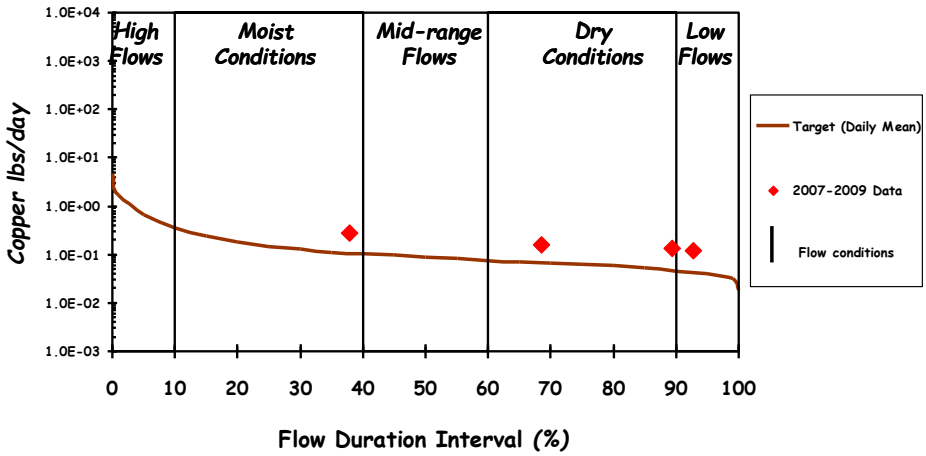
Storet	AUID	Water Body	Location	Latitude	Longitude	County	Date	Hard-ness (mg/L)	DOC (mg/L)	TOC (mg/L)	Copper (ug/L)
310382	040201030303-05	Trap Rock River	Angman Rd.	47.23	-88.38276	Houghton	9/8/08	76	na	5.9	16
310382	040201030303-05	Trap Rock River	Angman Rd.	47.23	-88.38276	Houghton	6/7/09	74	na	4.5	12
310382	040201030303-05	Trap Rock River	Angman Rd.	47.23	-88.38276	Houghton	8/12/09	84	na	3.3	11
310382	040201030303-05	Trap Rock River	Angman Rd.	47.23000	-88.38276	Houghton	6/21/11	49	9.7	10	16.5
310382	040201030303-05	Trap Rock River	Angman Rd.	47.23000	-88.38276	Houghton	7/22/11	46.6	5.1	5.3	12.6
310382	040201030303-05	Trap Rock River	Angman Rd.	47.23000	-88.38276	Houghton	8/16/11	73	3.4	3.7	9.9
310382	040201030303-05	Trap Rock River	Angman Rd.	47.23000	-88.38276	Houghton	9/19/11	67.3	2.8	3	7.9
310412	040201030303-04	Trap Rock River	Wood Bush Rd.	47.2718	-88.361	Houghton	7/30/91	61	na	na	1.9
310412	040201030303-04	Trap Rock River	Wood Bush Rd.	47.2718	-88.361	Houghton	8/2/05	63	na	6.97	4
310412	040201030303-04	Trap Rock River	Wood Bush Rd.	47.2718	-88.361	Houghton	6/13/07	67	na	6.4	2.5
310412	040201030303-04	Trap Rock River	Wood Bush Rd.	47.2718	-88.361	Houghton	6/11/08	51	na	7.8	2.7
310412	040201030303-04	Trap Rock River	Wood Bush Rd.	47.2718	-88.361	Houghton	6/7/09	61	na	6.7	2
310415	040201030303-05	Trap Rock River	Rimfetti	47.20708	88.39062	Houghton	7/13/08	74	na	4.8	16
310415	040201030303-05	Trap Rock River	Rimfetti	47.20708	88.39062	Houghton	9/8/08	77	na	2.8	11
310415	040201030303-05	Trap Rock River	Rimfetti	47.20708	88.39062	Houghton	6/7/09	71	na	4.4	15
310415	040201030303-05	Trap Rock River	Rimfetti	47.20708	88.39062	Houghton	8/12/09	81	na	3.2	11
310415	040201030303-05	Trap Rock River	Rimfetti	47.20708	-88.39062	Houghton	6/21/11	47.1	10	11	21.2
310415	040201030303-05	Trap Rock River	Rimfetti	47.20708	-88.39062	Houghton	7/22/11	76.7	5	5.2	15.3
310415	040201030303-05	Trap Rock River	Rimfetti	47.20708	-88.39062	Houghton	8/16/11	65.9	3.4	3.7	11.8
310415	040201030303-05	Trap Rock River	Rimfetti	47.20708	-88.39062	Houghton	9/19/11	67.7	2.9	3.2	11.5

Appendix B. Total copper load duration curves for selected stations in the Trap Rock River watershed, Houghton County, Michigan.

Slaughterhouse Creek upstream of Fulton Creek

Load Duration Curve *(2007-2009 Data)*

STORET Station: 310464

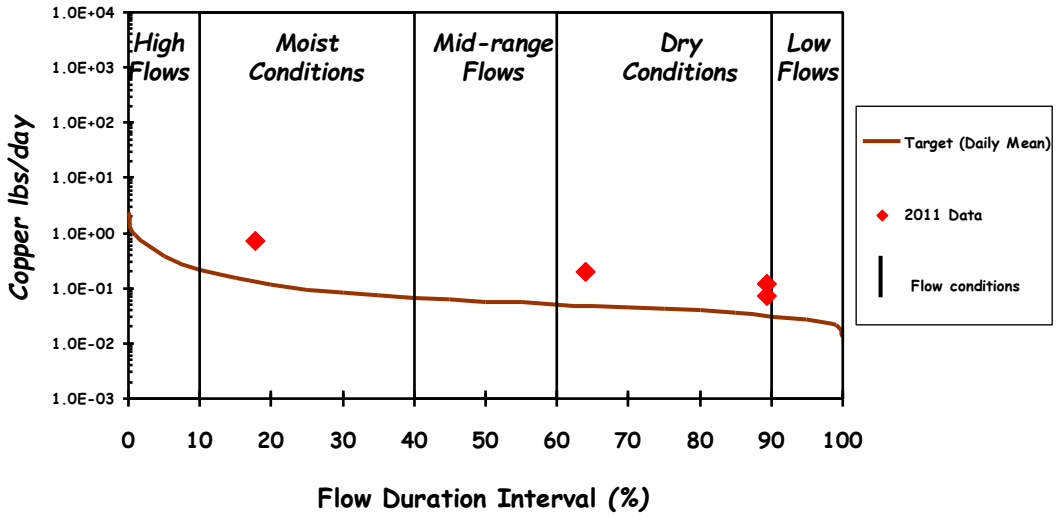


Copper Data & USGS Gage 04043050 Duration Interval *3.12 square miles*

Kearsage Creek upstream of Slaughterhouse Creek confluence

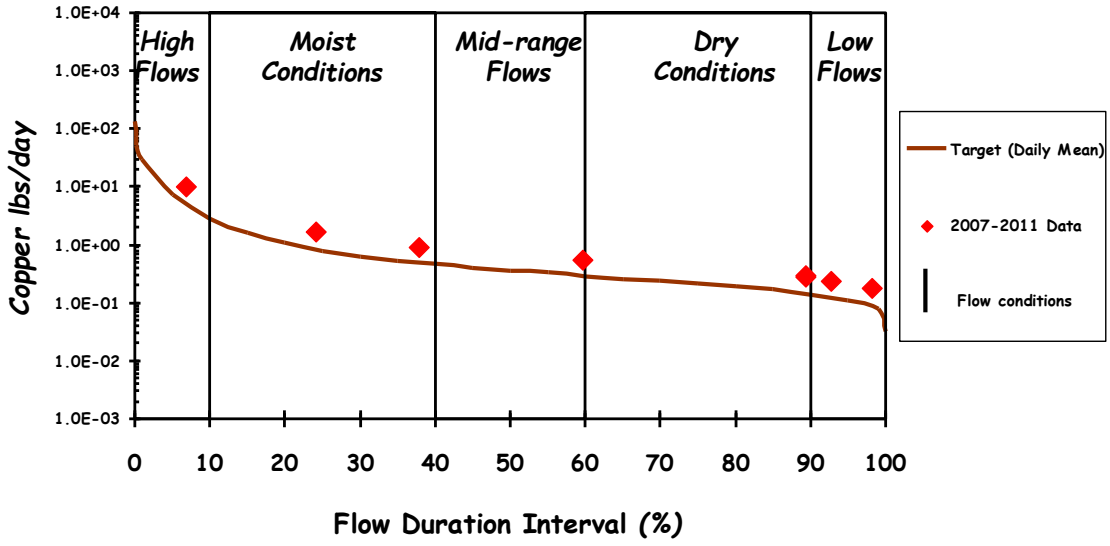
Load Duration Curve *(2011 Data)*

STORET Station: 310354



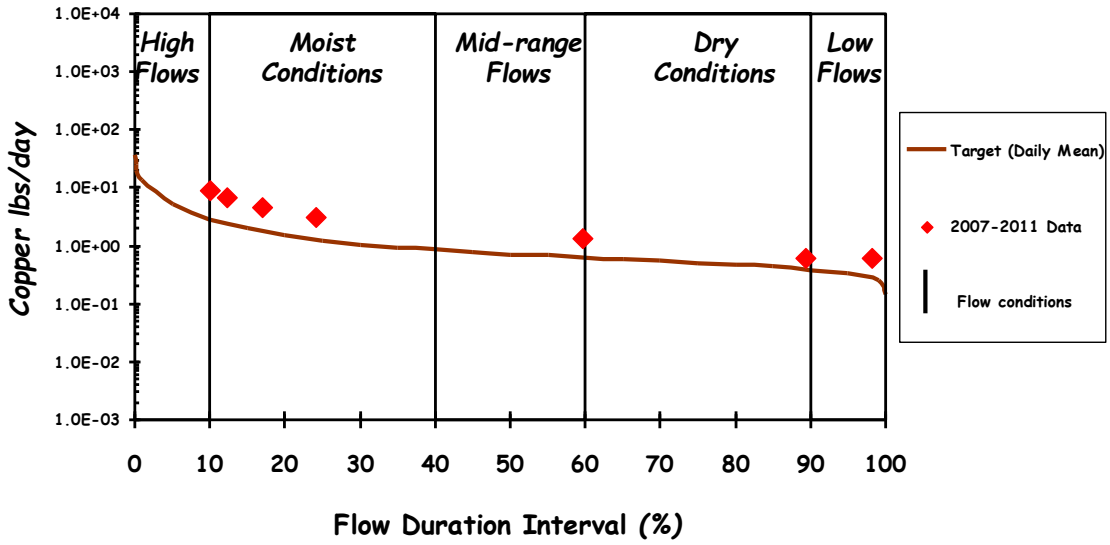
Copper Data & USGS Gage 04043050 Duration Interval *0.64 square miles*

Scales Creek at Valley Road Crossing
Load Duration Curve *(2008-2011 Data)*
STORET Station: 310353



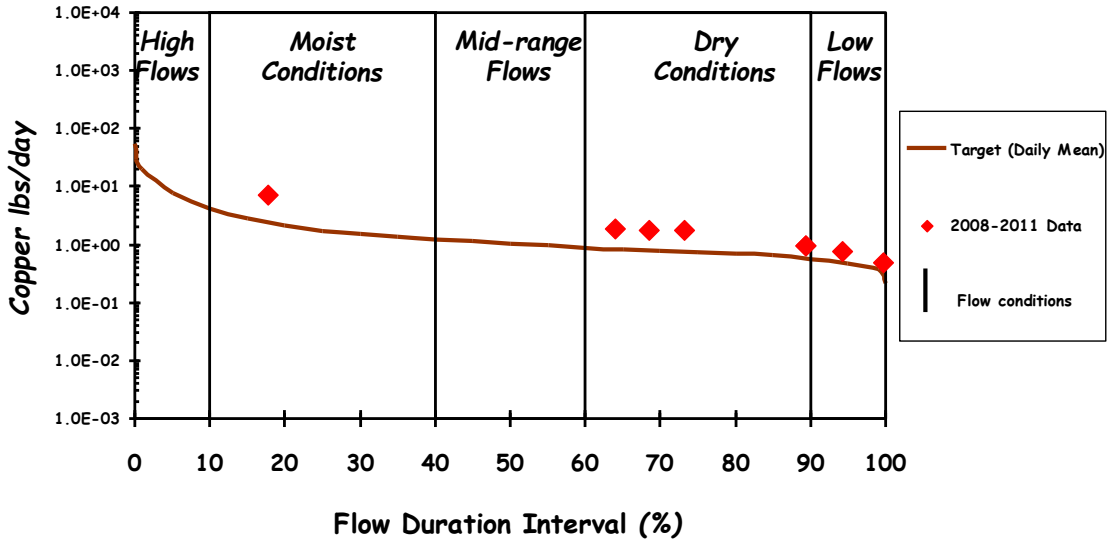
Copper Data & USGS Gage 04043050 Duration Interval *8.5 square miles*

Trap Rock River at Valley Road Crossing
Load Duration Curve *(2007-2011 Data)*
STORET Station: 310341



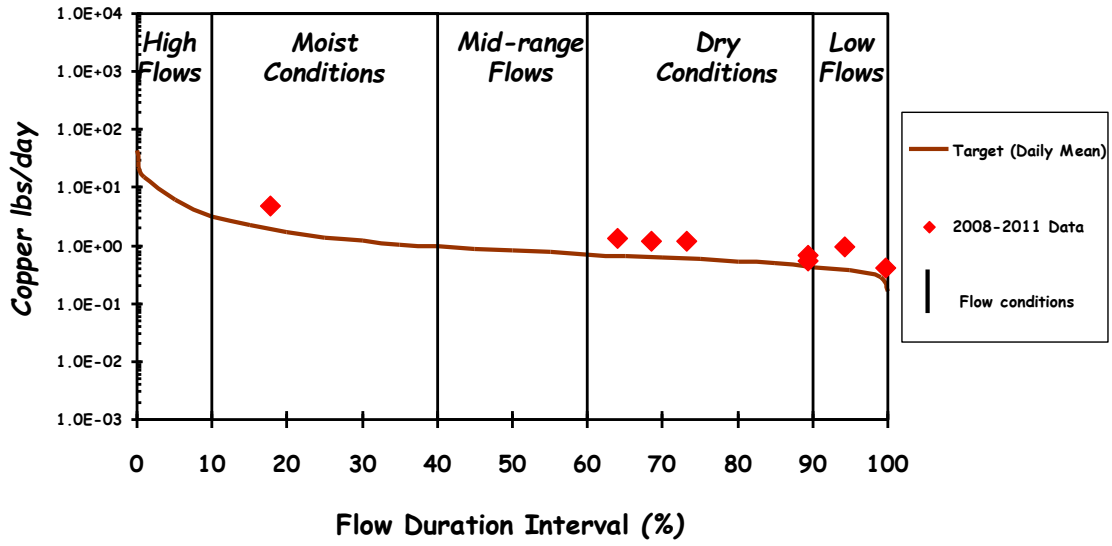
Copper Data & USGS Gage 04043050 Duration Interval *25.3 square miles*

Trap Rock River at Rimfetti Road
Load Duration Curve *(2008-2011 Data)*
STORET Station: 310415



Copper Data & USGS Gage 04043050 Duration Interval *36.8 square miles*

Trap Rock River at Angman Road
Load Duration Curve *(2008-2011 Data)*
STORET Station: 310382



Copper Data & USGS Gage 04043050 Duration Interval *28.6 square miles*

Appendix C. Tape down and discharge measurements used to develop flow rating curves for development of load duration curves for the Trap Rock River watershed.

STREAM NAME	LOCATION	STORET	DATE	TIME (ET)	dis (feet, inches)	Stage Height (feet)	DISCHARGE (cfs)
Kearsarge Creek	Upstream of Slaughterhouse Creek Confluence	310354	06/21/11	1120	1' 3.25"	15.25	1.68
			07/22/11	0943	1' 5.75"	17.75	1.79
			08/16/11	0945	1' 7.00"	19.00	0.54
			09/19/11	0940	1' 6.00"	18.00	0.28
Scales Creek	Downstream of Valley Road Crossing	310353	5/17/2007	na	na	5.75	9.07
			5/30/2007	na	na	6	17.22
			7/12/2007	na	na	3.25	1.22
			9/27/2007	na	na	4.75	3.47

na = not available.