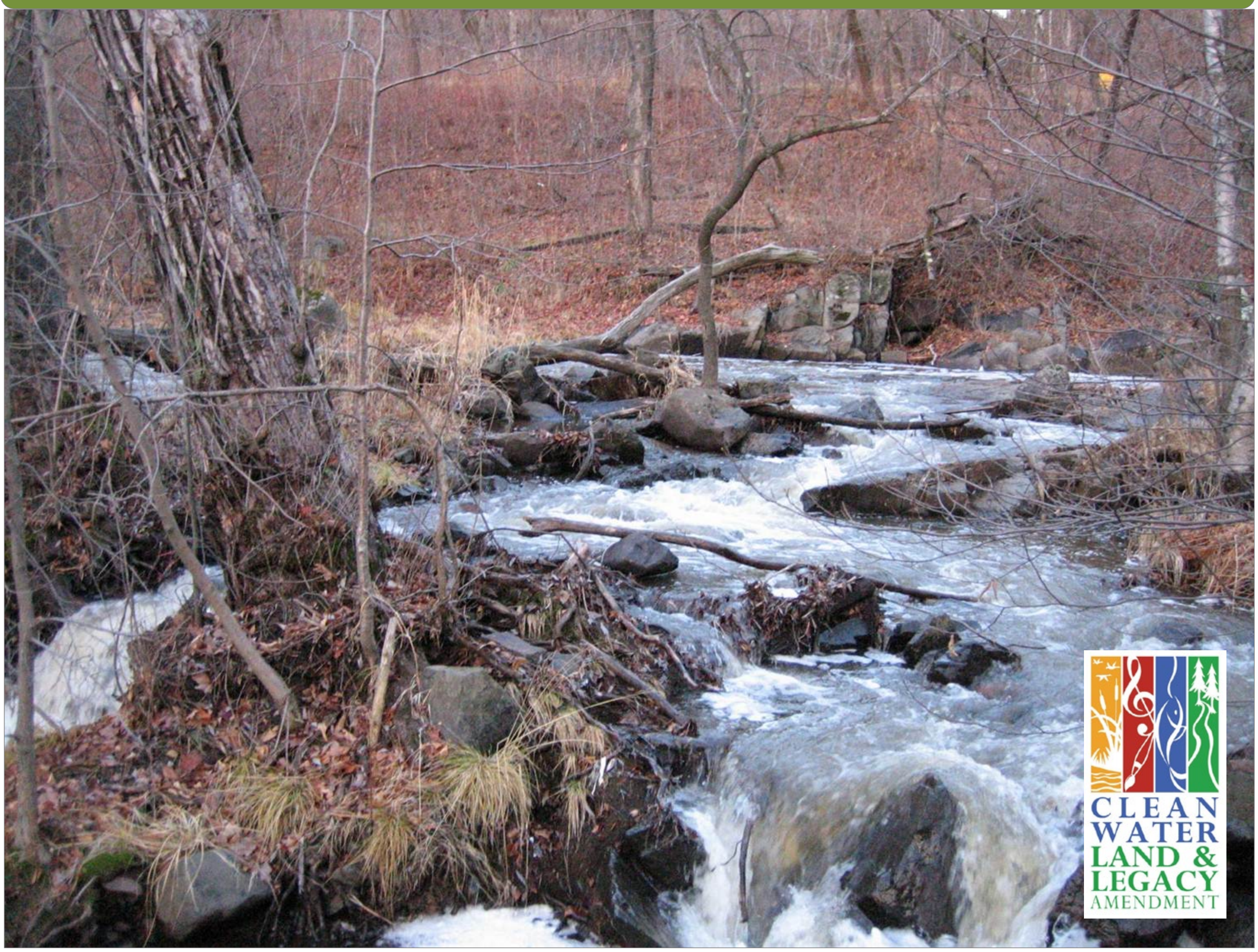
Miller Creek Water Temperature Total Maximum Daily Load

A report to address impairment of aquatic life due to elevated stream temperature.



MINNESOTA POLLUTION CONTROL AGENCY

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- City of Hermantown
- St. Louis County
- Minnesota Department of Natural Resources
- Minnesota Department of Transportation
- Minnesota Pollution Control Agency
- EPA, Mid-Continent Ecology Division
- Natural Resources Conservation Service
- Lake Superior College
- Minnesota Sea Grant
- University of Minnesota – Duluth
- University of Minnesota – Duluth, Natural Resources Research Institute (NRRI)
- University of Minnesota, St. Anthony Falls Laboratory
- Laurentian Resource Conservation & Development
- Isaak Walton League
- St. Louis River Alliance

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Acronyms

AUID	Assessment Unit ID
BMP	Best Management Practice
BTU	British Thermal Unit
C	Celsius
CFR	Code of Federal Regulations
cfs	cubic feet per second
CWA	Clean Water Act
DM	Daily Maximum
DNR	Minnesota Department of Natural Resources
EPA	U.S. Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera & Trichiptera
F	Fahrenheit
EQuIS	Environmental Quality Information System
GIS	Geographic Information System
GJ	Gigajoule (10^9 Joules)
LA	Load Allocation
LC	Load Capacity
LSC	Lake Superior College
MINUHET	Minnesota Urban Heat Export Tool
MnDOT	Minnesota Department of Transportation
MOS	Margin of Safety
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer Systems
MWAT	Maximum Weekly Average Temperature
NPDES	National Pollutant Discharge Elimination System
NRRI	Natural Resources Research Institute
RSPT	Regional Stormwater Protection Team
SAFL	St. Anthony Falls Laboratory
SDS	State Disposal System
SWCD	Soil and Water Conservation District
SWMM	Storm Water Management Model
SWPPP	Stormwater Pollution Prevention Plan
TAG	Technical Advisory Group
TMDL	Total Maximum Daily Load
UMD	University of Minnesota, Duluth
USGS	United States Geologic Survey
WCA	Wetlands Conservation Act
WLA	Wasteload Allocation
WRAPS	Watershed Restoration and Protection Strategies

Executive Summary

This report addresses the impairment of aquatic life in Miller Creek due to elevated water temperature. Miller Creek is a small, urban trout stream flowing through the cities of Duluth and Hermantown in northeastern Minnesota. The watershed includes parks, trails and residential neighborhoods, but also crisscrosses the regions retail, commercial and transportation corridors. The importance of the stream, along with other streams and natural resources of this area, is continually reinforced by the many efforts and activities undertaken by citizens, businesses, schools, and community and government organizations to protect and restore stream water quality and ecology.

Water temperature data demonstrate that problems occur in summer months, mostly from high air temperatures during periods of lower stream flows, or less frequently from runoff from summer rains that occur after high air temperatures. Elevated stream temperatures are believed to also be negatively affecting the fish and aquatic insect communities.

The Clean Water Act (CWA) requires a process to analyze and correct water problems. This is called a Total Maximum Daily Load (TMDL) study. The TMDL establishes the maximum amount of a pollutant a water body can receive on a daily basis and still meet water quality standards. The TMDL is divided into wasteload allocations (WLA) for point or permitted sources, and load allocations (LA) for nonpoint sources, which includes natural background, and a margin of safety (MOS). The heat load (pollutant) and load reductions in this TMDL are in gigajoules (GJ), a measure of energy, per day (GJ/day). An energy-based allocation was used in order to express temperature as a load-based TMDL.

This study used a variety of methods including a temperature model, a heat export model and a stormwater model. The models evaluated overall heat inputs to the stream, contributions of heat from all sources, and determined the heat limits to achieve a healthy stream. The heat analysis:

- determined actual and allowable heat inputs as a function of flow conditions;
- estimated the contributions from atmospheric heating and stormwater to the overall heat budget; and
- determined the contributions of each Municipal Stormwater Permit.

The TMDL and associated WLAs and LAs were further divided into five flow regimes: high, moist, mid, dry and low. Most heat violations occurred under “dry” flow conditions. Improvement efforts should be focused on the lower flow conditions, and especially within the stream segment from Haines Road and U.S. Highway 53 to below Miller Hill Mall, to have the greatest temperature mitigation impact. Moderate reductions of heat input from stormwater (40%) are required, under dry flow conditions. A summary of the heat loading, WLAs and LAs can be found in Table 6 in Section 4.1.7.

1. Project Overview

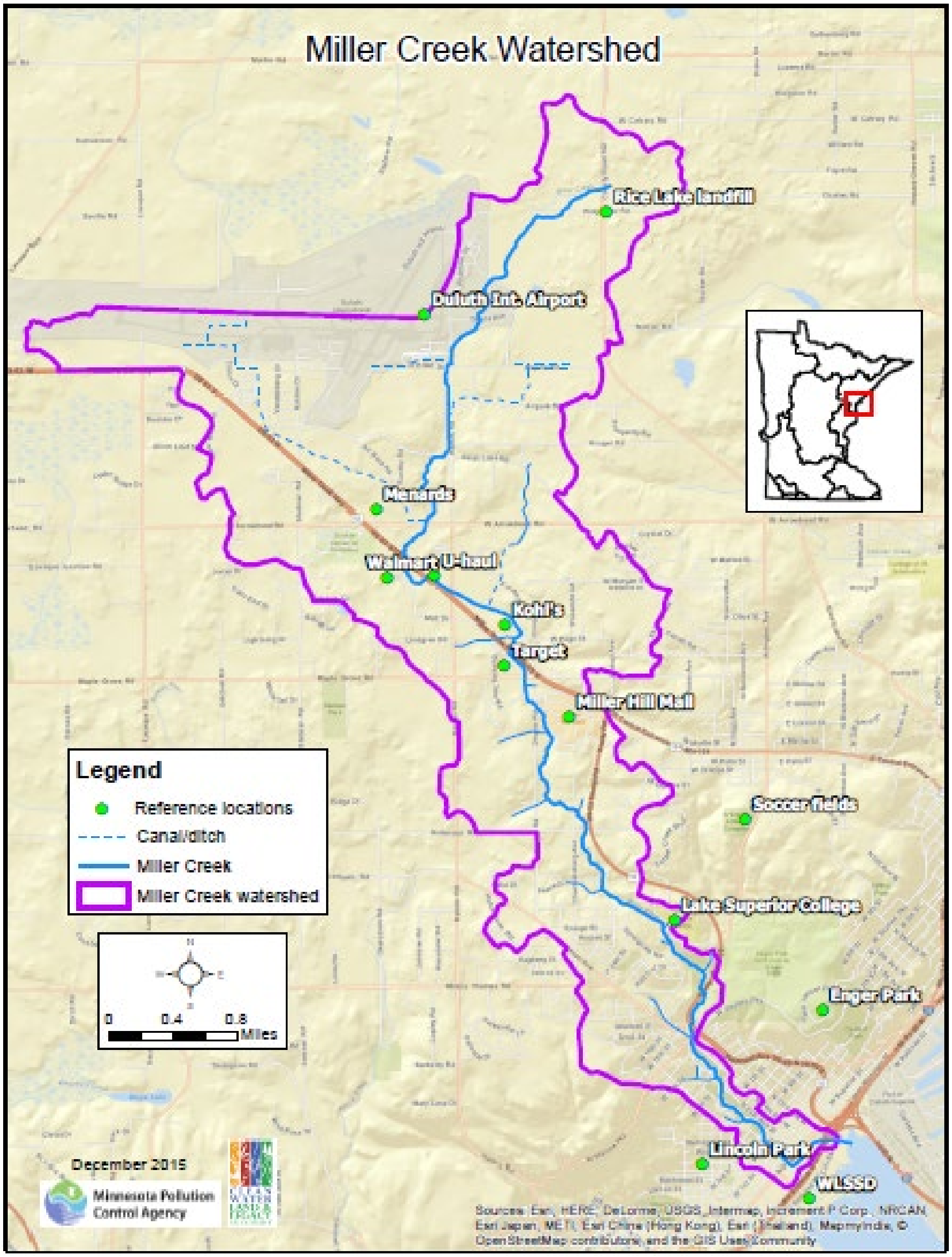
1.1 Purpose

The CWA Section 303(d) requires states to publish, every two years, a list of surface waters that do not meet water quality standards and do not support their designated uses. These waters are classified as impaired. Once a water body is placed on the impaired waters list, a TMDL must be developed for it. The TMDL provides a calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards, and allocates pollutant loads to the various sources of the pollutant.

This study serves to address the federal CWA requirement to establish a TMDL for the temperature impairment in Miller Creek. In addition, the report will serve as a resource to be used by water quality agencies, individual citizens, watershed planners, and local and state government officials to identify the key causes and implement solutions for these impairments.

Miller Creek was placed on Minnesota's 2002 Impaired Waters List for not meeting the assigned beneficial uses for aquatic life, based upon elevated water temperatures for Class 2A waters. Minnesota's chronic standard for temperature in Class 2A waters is "no material increase". For this TMDL, a numeric target for water temperature was set at 19 degrees Celsius (°C), which is equivalent to 66 degrees Fahrenheit (°F). This study focuses on temperature (heat) as a primary factor that is affecting the coldwater biotic communities. The TMDL study was completed through analysis of existing and newly collected data and field measurements, watershed modeling, calculation of loading capacity, and through developing implementation strategies to meet TMDL goals.

Figure 1: Miller Creek Watershed with locations identified in the TMDL document.



1.2 Identification of Waterbody

Miller Creek was placed on Minnesota's 2002 Impaired Waters List due to aquatic life use impairments, based upon water temperatures for Class 2A waters, as summarized in Table 1. There are additional aquatic life and aquatic recreation impairments on Miller Creek, as detailed in Table 2. Because impairments caused by elevated temperature are so different from impairments caused by more typical pollutants, these water quality impairments are not addressed in this TMDL study and will be addressed separately in the future. The TMDL for the Aquatic Recreation impairment (due to *Escherichia coli*) is anticipated to be completed in 2017 as part of the Duluth Urban Watershed Restoration and Protection Strategies (WRAPS) project. The TMDLs for the Aquatic Life impairments (due to Lack of Coldwater Assemblage, Macroinvertebrate Bioassessments, and Chloride) are anticipated to be completed in the future as part of the second cycle of the Duluth Urban Watershed WRAPS, by approximately 2025.

Table 1: Impaired designated uses for Miller Creek addressed in this TMDL study.

Name	River AUID	Year Listed	Affected Use	Pollutant or Stressor
Miller Creek	04010201-512, Headwaters to St. Louis River	2002	Aquatic Life	Water Temperature (Heat)

Table 2: Impaired designated uses for Miller Creek not addressed in this TMDL study.

Name	River AUID	Year Listed	Affected Use	Pollutant/Stressor
Miller Creek	04010201-512, Headwaters to St. Louis River	2002	Aquatic Life	Lack of Coldwater Assemblage
Miller Creek	04010201-512, Headwaters to St. Louis River	2010	Aquatic Life	Chloride
Miller Creek	04010201-512, Headwaters to St. Louis River	2012	Aquatic Recreation	*Escherichia coli*
Miller Creek	04010201-512, Headwaters to St. Louis River	2012	Aquatic Life	Aquatic Macroinvertebrate Bioassesements

1.3 Priority Ranking

The Minnesota Pollution Control Agency's (MPCA's) schedule for TMDL completions, as indicated on the 303(d) impaired waters list, reflects Minnesota's priority ranking of this TMDL. MPCA developed a state plan, Minnesota's TMDL Priority Framework Report, to meet the needs of EPA's national measure (WQ-27) under EPA's Long-Term Vision for Assessment, Restoration and Protection under the Clean Water Act Section 303(d) Program. As part of these efforts, the MPCA identified water quality impaired segments that will be addressed by TMDLs by 2022. Miller Creek, addressed by this TMDL, is part of that the MPCA prioritization plan to meet the EPA's national measure.

2. Applicable Water Quality Standards and Numeric Water Quality Targets

The criteria used for determining stream reach and lake impairments are outlined in the MPCA's document Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment: 305(b) Report and 303(d) List (MPCA 2014). Minnesota's Surface Water Quality Standards provide information on beneficial uses assigned to waterbodies, numeric and narrative standards for pollutants, and non-degradation provisions assigned to high-quality and unique waters.

Applicable water body classifications and water quality standards are specified in Minn. R. 7050. Miller Creek (headwaters to St. Louis River) is classified as a 2A stream (Minn. R. 7050.0470). The Class 2 water designation pertains to aquatic life and recreation, where Class 2A waters "shall be such as to permit the propagation and maintenance of a healthy community of cold water sport or commercial fish and associated aquatic life" (Minn. R. 7050.222).

2.1 Water Temperature

The temperature standard for Class 2A waters is a narrative statement of "no material increase" (Minn. R. 7050.0222). In order to quantify and determine a TMDL for Miller Creek, numeric temperature target values for the TMDL were chosen, based on the values set forth in U.S. Environmental Protection Agency (EPA's) *Quality Criteria for Water* (EPA 1986), which provides the following numeric temperature criteria for brook trout:

- 19 °C (66 °F) = maximum weekly average temperature (MWAT) for growth (chronic), and
- 24 °C (75 °F) = daily maximum (DM) temperature for survival of short term exposure (acute).

The MWAT temperature (19 °C) was selected as the numeric temperature target for the TMDL because there were more exceedances of the MWAT than the DM temperature in the 2007 to 2009 data set (Herb 2011). The number of exceedances for each criteria at the Miller Creek sites are shown in Table 4. Given that the exceedances generally paralleled each other over time, use of the MWAT as the target for the TMDL will also address the acute target (Figures 2, 3, and 4).

Figure 2: Miller Creek temperature exceedances 2007, MWAT and DM, Mall Drive Target.

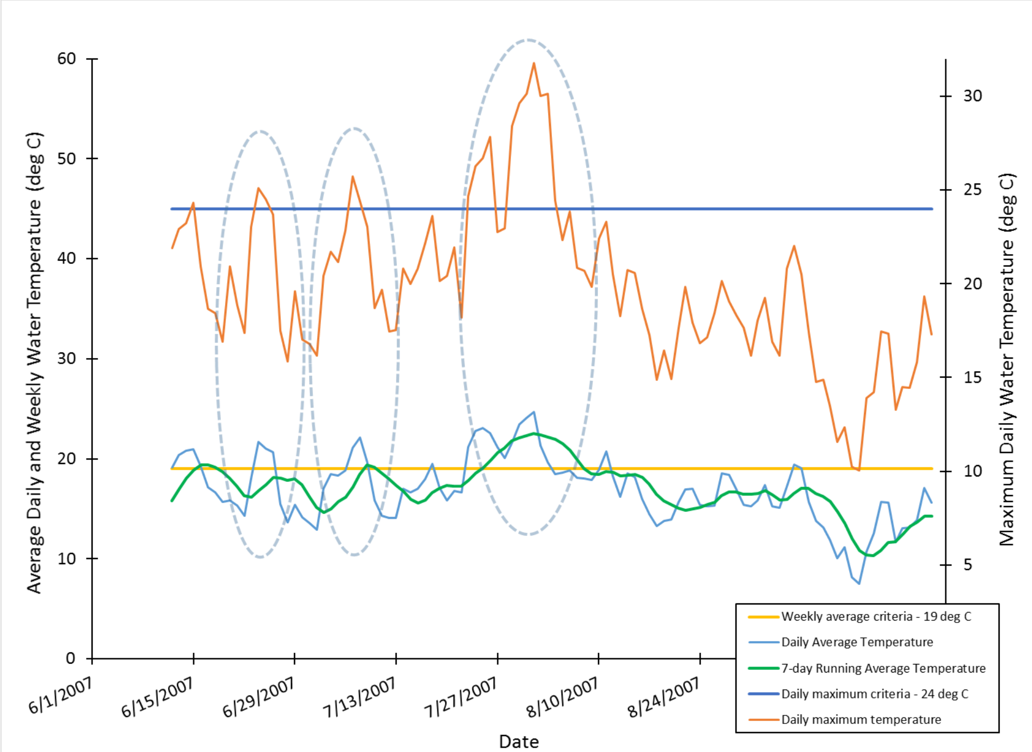


Figure 3: Miller Creek temperature exceedances 2008, MWAT and DM, Mall Drive Target.

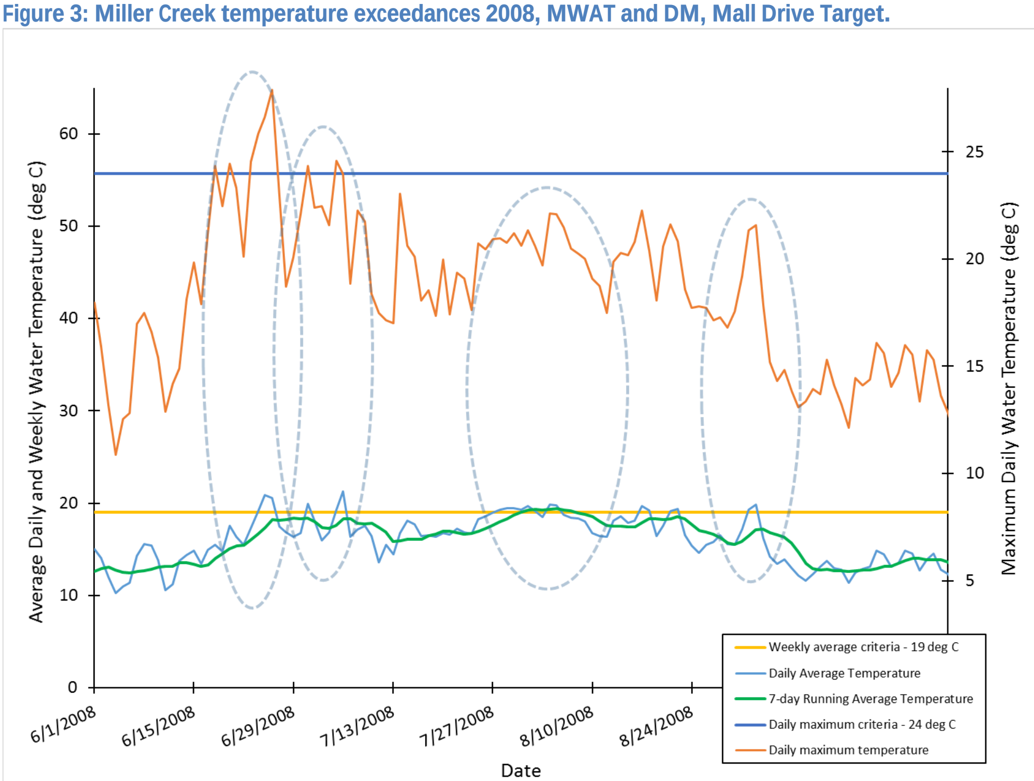
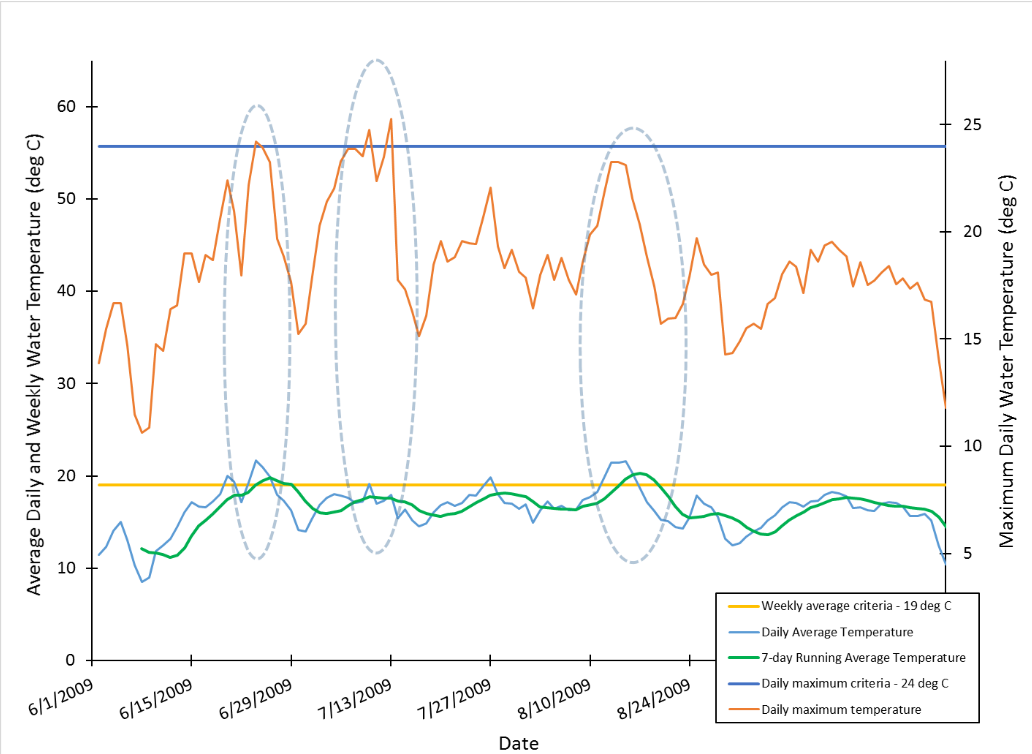


Figure 4: Miller Creek temperature exceedances 2009, MWAT and DM, Mall Drive Target.



Restoring the temperature regime will be beneficial to aquatic biota by reducing the occurrences and frequencies of thermal stress, allowing for an expanded potential range for fish movement during periods of lower flows and higher thermal stress, and lessening the reliance of biota on isolated refugia. A more favorable temperature (and flow) regime may also potentially provide conditions for greater quantity and diversity of coldwater macroinvertebrates.

3. Watershed and Waterbody Characterization

The Miller Creek Watershed is located within the municipalities of Duluth and Hermantown in northeastern Minnesota and covers 9.4 square miles (6,028 acres). The stream originates from wetlands near the Rice Lake Landfill and Duluth International Airport (Figure 1). This portion of the watershed has the lowest gradient and is the largest proportion (area) of the watershed, containing most of the wetlands and undeveloped lands. Current land uses include low to mid-density urban residential, and commercial and industrial development. The middle section of the watershed is at the heart of the urbanized area, with Miller Hill Mall and surrounding retail and commercial businesses, and a regional transportation corridor. This portion also includes low to mid-density urban residential and institutional development, and contains considerable green space along the stream corridor. The lower Piedmont and Lincoln Park neighborhoods largely make up the lower section of the watershed. This section also contains the Enger Park Golf Course, Lake Superior College (LSC) and Lincoln Park, along with commercial and industrial properties along the St. Louis River. Much of the bottom 0.5 miles of Miller Creek has been channelized and buried. Miller Creek discharges to the St. Louis River, and is within the Lake Superior Basin.

3.1 Lakes

This TMDL covers a single resource, Miller Creek, and there are no lakes in the watershed.

3.2 Streams

This TMDL covers a single stream, Miller Creek, and encompasses the entire watershed, headwaters to mouth.

3.3 Subwatersheds

Miller Creek is located in the St. Louis River Watershed. For the purposes of this TMDL, the Miller Creek Watershed has been treated as a single subwatershed entity, and was not divided into further subwatersheds.

3.4 Land Use

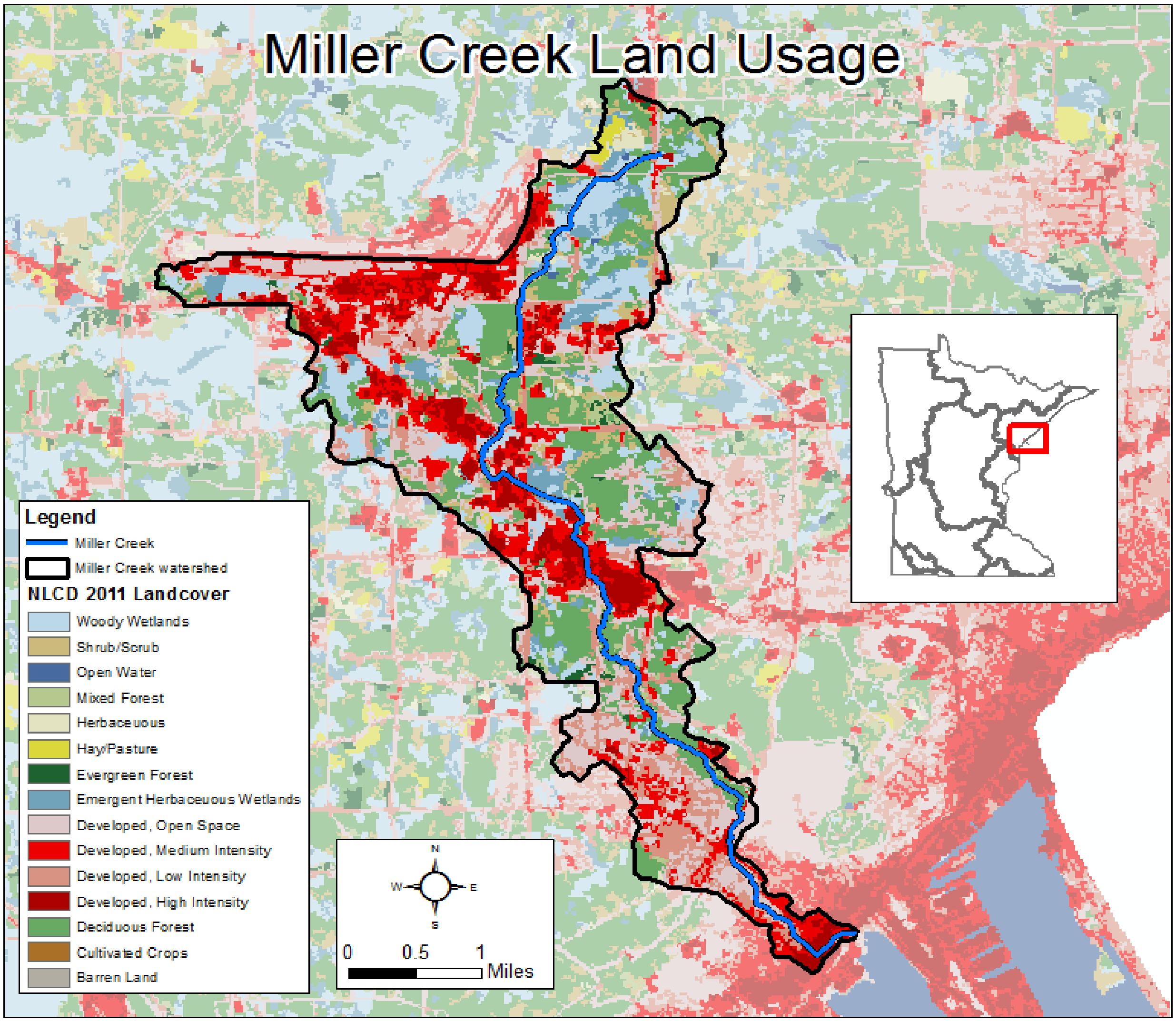
Land uses in the Miller Creek Watershed encompass a broad range of uses, as shown in Table 3 and in Figure 5.

Table 3: Land Uses in the Miller Creek TMDL study area.

Land Uses in Miller Creek Watershed	Area (acres)	Percent
Deciduous Forest	1269	21%
Developed, Open Space	1131	19%
Developed, Medium Density	998	16%
Developed, Low Density	773	13%
Woody Wetlands	611	10%
Developed, High Intensity	574	9%
Emergent Herbaceous Wetlands	274	5%
Scrub/Shrub	248	4%
Mixed Forest	55	1%
Grassland/Herbaceous	52	1%
Pasture/Hay	33	1%
Evergreen Forest	29	<1%
Open Water	9	<1%
Cultivated Crops	4	<1%
Barren Land (Rock/Sand/Clay)	3	<1%
Total =	6063	100%

Source: 2011 NLCD Data Set (USGS)

Figure 5: Land Uses within Miller Creek Watershed.



3.5 Current/Historic Water Quality

Water quality monitoring data for Miller Creek were obtained from MPCA's Environmental Quality Information System (EQuIS) database. Stream flow and stage data were obtained from the Minnesota Department of Natural Resources (DNR)/MPCA Cooperative Stream Gaging web page (Hydstra database). Stream and water chemistry data were augmented with other data collected in support of the TMDL (e.g., stream temperature, stormwater temperature, air temperature, precipitation, relative humidity, and solar radiation). No long term, continuous data set exists for Miller Creek, so data from 1997 to 2009 were analyzed to better understand the more recent data, and to establish average conditions. Data from 2007 to 2009 were used in development of the TMDL.

The following reports provide a detailed summary of data used for the TMDL and should be referred to regarding detailed data analysis and modeling underlying the TMDL:

- **Analysis of Flow Data from Miller Creek, Duluth, Minnesota,** University of Minnesota, St. Anthony Falls Laboratory (SAFL), Project Report No. 522, September 2009.

- **Analysis of Stream Temperature Data from Miller Creek, Duluth, Minnesota**, University of Minnesota, SAFL, Project Report 529, October 2009.
- **Stream Temperature Modeling of Miller Creek, Duluth, Minnesota**, University of Minnesota, SAFL, Project Report No. 535, October 2009.
- **Streamflow Modeling of Miller Creek, Duluth, Minnesota**, University of Minnesota, SAFL, Project Report No. 536, January 2010.
- **Miller Creek Macroinvertebrate, Habitat, and Temperature Report**, Natural Resources Research Institute (NRRI), University of Minnesota Duluth, NRRI Technical Report Number NRRI/TR2010/11, June 2010.
- **Characterization of Stream Temperature and Heat Loading for Miller Creek, Duluth, Minnesota**, University of Minnesota, SAFL, Project Report No. 552, August 2011.

Key findings, conclusions and recommendations from these studies include:

- Only 5% to 10% of all temperature exceedances appear to be associated with surface runoff due to rainfall, and even fewer were caused exclusively by runoff (Herb and Stephan 2009b).
- The temperature of Miller Creek is driven by atmospheric heat transfer during dry weather periods, by surface runoff during wet weather with substantial runoff, and by both mechanisms during small rainfall events (Herb et al. 2011).
- Temperature changes are most apparent in the stream from reaches with low shading, but persist for several kilometers downstream into reaches of higher shading (Herb et al. 2011).
- The temperature of Miller Creek was found to be relatively sensitive to air temperature, e.g., a 1 degree C increase in air temperature led to a 0.6 C increase in stream temperature. This sensitivity is likely due to low groundwater inputs, which tend to buffer diurnal and seasonal changes in air temperature (Herb et al. 2011).
- Wetlands provide an important role in Miller Creek through supplying the baseflow to the stream. The rapid recession in the storm hydrographs points to channel storage and surface storage in wetlands rather than in aquifers as the source of water during low flow periods. The wetlands in the upper reaches of Miller Creek therefore need to be protected because they play a key role in the hydrology during low flow periods (Erickson et al. 2010).

Please note that the supporting reports include calculations and discussions for splitting Miller Creek into two sections and developing two separate temperature TMDLs. For the purposes of submitting this Water Temperature TMDL to EPA for approval, a single TMDL was completed for the entire stream reach (headwaters to mouth). The detailed work in these reports has been and will continue to be very useful in planning and targeting implementation activities. The reports can be access through links in Appendix B or through the Miller Creek TMDL web page:
https://www.pca.state.mn.us/water/tmdl/miller-creek-water-temperature-tmdl-project

Temperature is a measure of the concentration of thermal energy (heat) in a substance such as water. Heat can enter a stream from atmospheric heat transfer and heat conduction, through the sediment, and by inputs of surface water or groundwater (Herb 2011). Figure 7 depicts the major heat flux processes in streams. The temperature impairment indicates that the stream is receiving excess heat energy for particular climate, flow conditions, and for the prescribed designated uses (for Miller Creek, as a coldwater fishery). Recent data from 2016 demonstrated a strong correlation between stream temperatures and water levels, with the strongest correlations during low flow periods and higher stream temperatures (Labuz 2017) (Figure 6).

Figure 6: Water temperatures versus water levels at Kohl's 2016 (Labuz 2017).

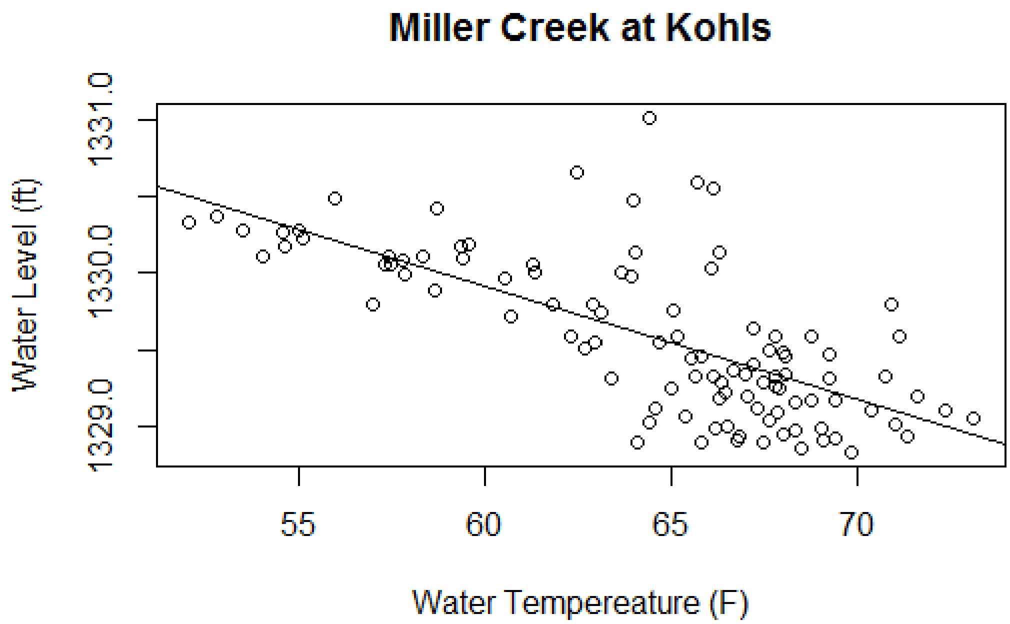
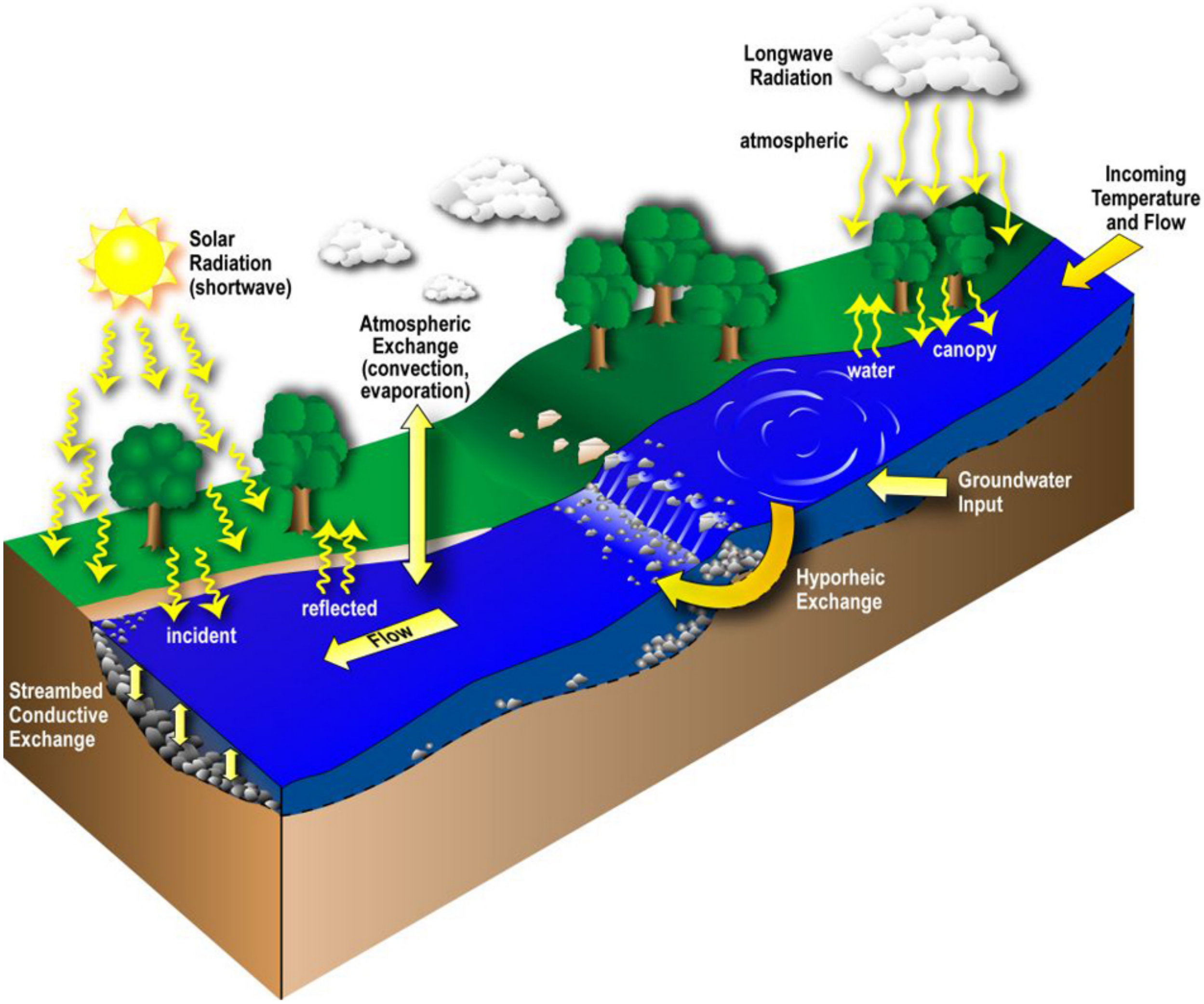
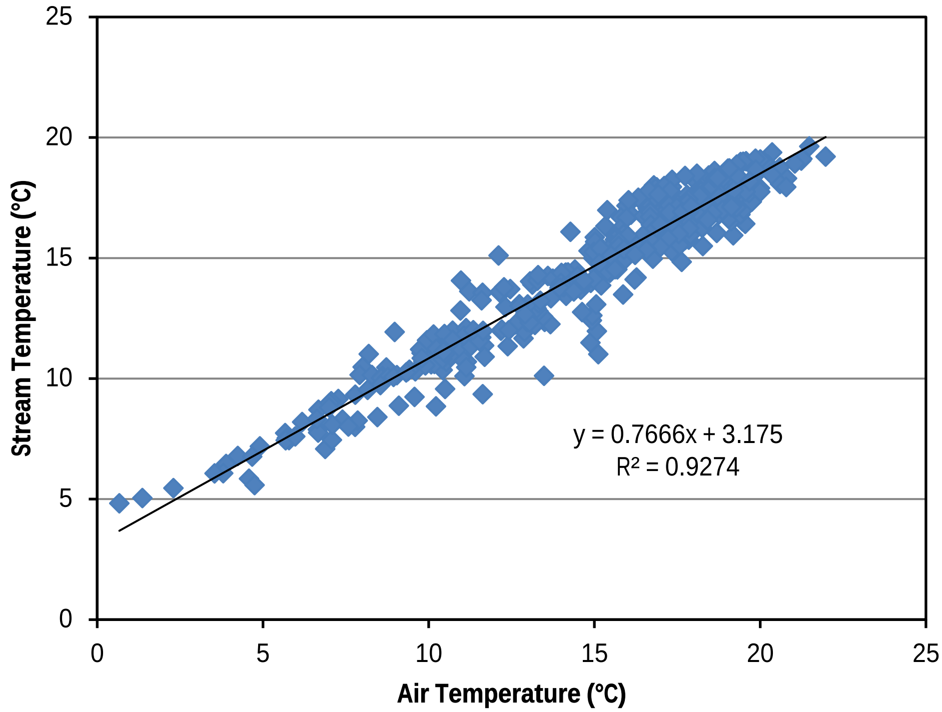


Figure 7: Major heat fluxes in streams (EPA 2010 Release, CADDIS)



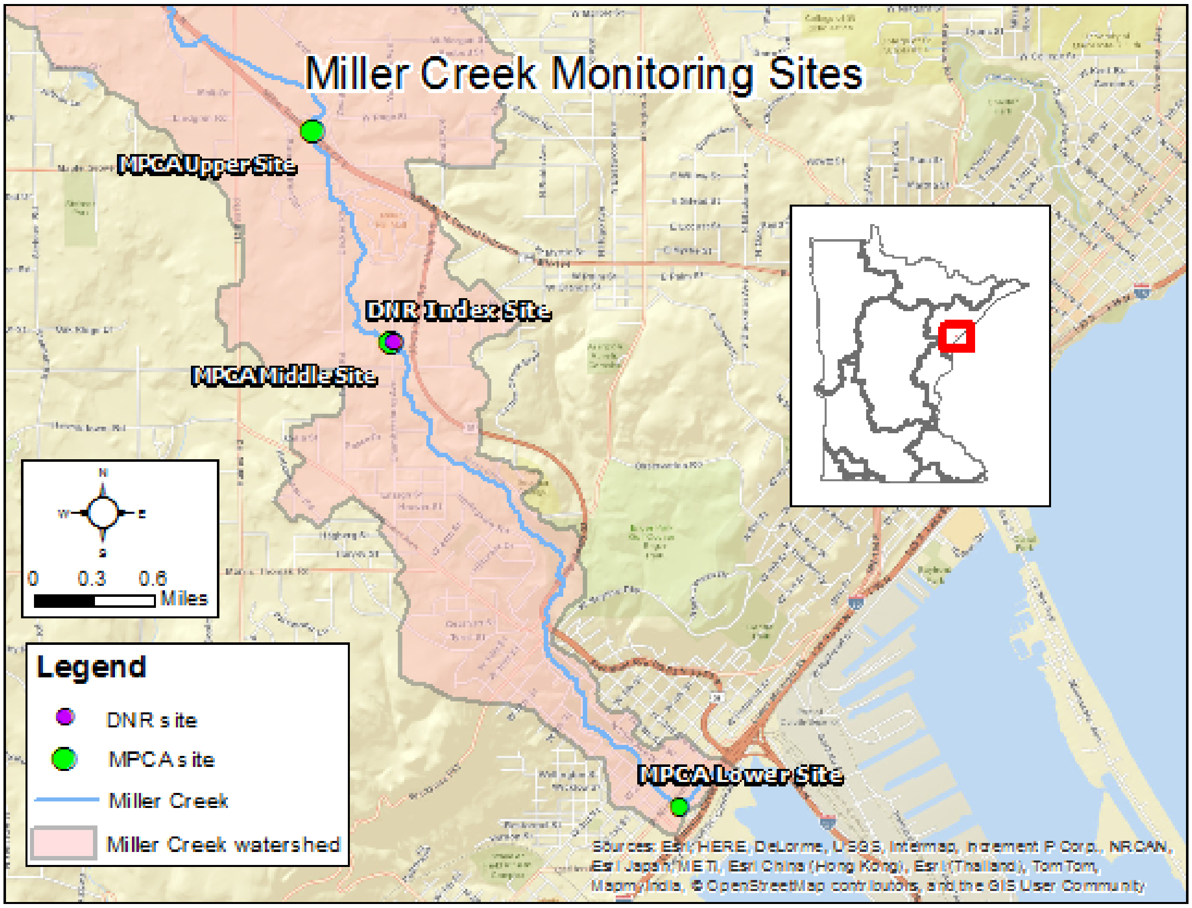
Herb and Stefan (2009b) found stream temperature in Miller Creek to be highly correlated to air temperatures at daily to annual time scales (Figure 8). This relationship was found to become stronger as stream flows become lower, less than 5 cubic feet per second (cfs), and suggests low groundwater inputs into the stream (Herb et al. 2009). Water temperature exceedances above 20 °C (68 °F) are caused mainly from strong heat transfer from the atmosphere to the stream. This is especially true for the middle reaches with low channel shading, such as the channelized section above Kohl's Department Store in Duluth (Herb 2011).

Figure 8: Weekly running average stream temperature at 26th Avenue West versus weekly running average air temperature at Duluth International Airport for 2007, 2008, and 2009 (Herb 2011).



Stream temperature exceedances were observed throughout Miller Creek, however, most exceedances occurred in the middle section of the stream, from Haines 53 to Mall Drive Target. Over half (56%) of the temperature exceedances (greater than 19 °C) occurred within this portion of the watershed. Table 4 summarizes the number of stream temperature exceedances by temperature station for 2007 to 2009 for MWAT (greater than 19 °C) and DM (greater than 24 °C) temperature targets. July and August had the most exceedances (84%), while September had no temperature exceedances during the three-year period (Herb 2011).

Figure 9: The MPCA stream stations and DNR brook trout index site (mile 3.6).



The TMDL utilizes data collected at three stream stage locations on the main stem of Miller Creek: the 'Upper' station is located between U.S. 53/TH 194 and Kohl's Department Store, the 'Middle' station is located at the crossing with Chambersburg Road, and the 'Lower' station is located at 26th Avenue West (Figure 9). Stream flow data was collected at these sites at regular and intermittent intervals in years 1997 through 2009 (Herb and Stefan 2009a).

The upper watershed contains the largest portion of land and the watershed and stream channel are less steep than the middle and lower portions, providing water a longer residence time. Analysis of flow data suggests that, on average, the flow at the middle site is about 80% of the flow volume (cfs) at the lower station, and flow at the upper station is about 70% to 75% of the lower station (i.e., total flow) (Herb and Stefan 2009a; Labuz 2017). The higher gradient stream slope and associated higher flow velocities in the lower section provide less time for the stream to respond to local climate conditions. Flow data from 2007 to 2009 indicate that 60% of the flows in Miller Creek are less than 5 cfs, 10% of flows are 0.5 cfs or less, while only 10% of flows are equal to or exceed approximately 22 cfs. The observed low flows suggest that baseflow in Miller Creek originates from the drawdown of wetland areas and from channel storage. Labuz (2017) found that stream flows during low flows were comprised of 70% surface water and 30% groundwater. Because bedrock in the Miller Creek Watershed is found at shallow depths, it is likely that the hydrogeology includes groundwater recharge from the wetlands; wetlands most likely also supply the source water for springs that exist in the watershed. It is likely that wetlands play a significant role in the hydrology of Miller Creek by reducing stormwater peak flows, absorbing and slowly releasing stormwater and supplying baseflows to the stream, and by providing areas and sources for groundwater recharge (Erickson et al. 2010).

3.5.1 Fish

The primary species of concern, brook trout (Salvelinus fontinalis), are members of the salmon family that inhabit small spring-fed streams and spring ponds. They prefer cool and clear water with sandy and gravely bottoms and moderate vegetation. In northeastern Minnesota, they inhabit the headwaters and small streams along the north shore of Lake Superior. Brook trout generally live for three to four years and typically reach six to ten inches in length. The low productivity and smallness of north shore streams prevent many trout from exceeding one foot in length. Brook trout are highly susceptible to stream degradation and climate change, including low oxygen levels due to sediments from runoff and warm waters (DNR 2009).

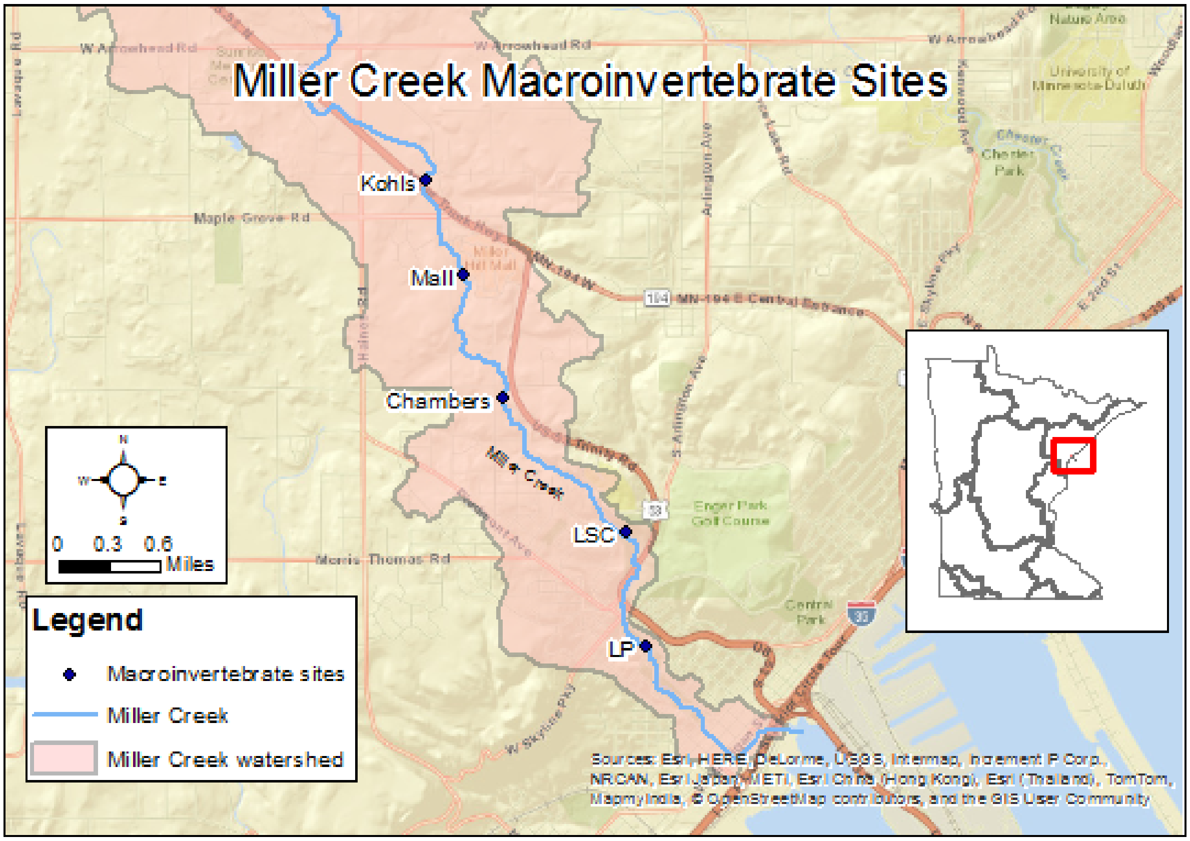
Historically, brook trout and brown trout were frequently stocked in Miller Creek between 1955 and 1973. However, no stocking has taken place since 1973. Stream station 3.6 (below Chambersburg Avenue) (Figure 9) is assessed annually for trout populations and temperature as a brook trout index station for the DNR Duluth Area Fisheries. The annual surveys indicate that the trout population has steadily declined since the early 1990s. A sharp decline during 2002 and 2003 was due to a severe winter in which the creek water froze solid in some areas and killed fish in portions of the stream (DNR 2014).

Recent fish population survey results indicate that the thermal regime remains favorable for brook trout. However, localized, short term periods of stress occur and are driven by low summer flows and radiant warming, combined with warm water inputs from impervious surfaces in the watershed. One of the biggest threats to the long-term survival of brook trout populations continues to be water quality and temperature. A major rain event and subsequent flooding in June 2012 resulted in changes to stream channel morphology and habitat within Miller Creek, including at station 3.6 (DNR 2014).

3.5.2 Macroinvertebrates

A benthic macroinvertebrate study was completed at five locations on Miller Creek in 2008 by NRRI (Figure 10). A total of 116 macroinvertebrate taxa were collected from the five sites, with up to 62 taxa found at any one site. Most of the sites have reasonably good habitat conditions for macroinvertebrates, with low embeddedness and appropriate substrate size to provide interstitial space for macroinvertebrates. However, only one of the sites (Chambersburg) had abundances of taxa sensitive to stress, especially mayflies, stoneflies and caddisflies (Ephemeroptera, Plecoptera, and Trichoptera, or EPT taxa). The other sites contained high proportions of taxa more tolerant to stress, such as Chironomidae (Diptera) and oligochaete and nematode worms (Brady and Breneman 2010).

Figure 10: Macro-invertebrate sampling sites on Miller Creek 2008.



3.5.3 Watershed Climate/Weather Variability/Atmospheric Conditions

The weather in the Duluth area can be strongly influenced by the proximity to Lake Superior and the topographic relief of Miller Creek, with over 800 feet of elevation change from the headwaters to mouth. Herb and Stefan (2009b) found that climate conditions in the upper part of the watershed (above LSC) are the most important factor in determining stream flow and stream temperature. In the summer, it is not uncommon to experience at least a 20° difference in air temperature between the headwaters area "on top of the hill" and at the confluence with the St. Louis River Estuary. The headwaters area frequently experiences warmer air temperatures in the summer and cooler in the winter. The reverse is often true for the lower section near the St. Louis River Estuary and nearby Lake Superior, with cooler air temperatures in the summer than the headwaters and warmer temperatures in the winter. For this TMDL, 2008 was found to be a typical climate year, with near normal precipitation and air temperatures (Herb 2011).

3.6 Pollutant Source Summary

3.6.1 Water Temperature

Potential sources of temperature (heat) loading in Miller Creek were investigated through field data collection, analysis and modeling, as described in Section 3.5 and in technical reports in Appendix B. Water temperature data from 2007 to 2009 identified the middle sections of Miller Creek, from the U.S. Highway 53/Haines Road to Mall Drive Target stream temperature stations, to be contributing over 50% of the total temperature exceedances (greater than 19°C), and mainly caused by the transfer of heat from the atmosphere. Data suggests that this area extends to just below Miller Hill Mall (Herb and Stefan 2009b). Exceedances in this section were largely contributed to by lack of riparian/channel shading and overhead tree canopy. Overall, stormwater runoff to the stream does cause some of the temperature exceedances; however data suggests that only a small percentage of the observed exceedances are caused by stormwater (Herb and Stefan 2009b; Herb 2011). These conclusions support earlier work by South St. Louis Soil and Water Conservation District (SWCD) under a Clean Water Partnership Grant (South St. Louis SWCD 2001). Table 4 summarizes the number of water temperature exceedances for weekly average temperatures (greater than 19 °C) and DM temperatures (greater than 24 °C). Temperature exceedances for DM were further analyzed to segregate the data into wet days and dry days, to determine the number of exceedances associated with stormwater inputs (wet days) and solar radiation inputs (dry days) (Herb 2011).

Figure 11: Stream temperature monitoring station locations 2007 to 2009, Miller Creek.

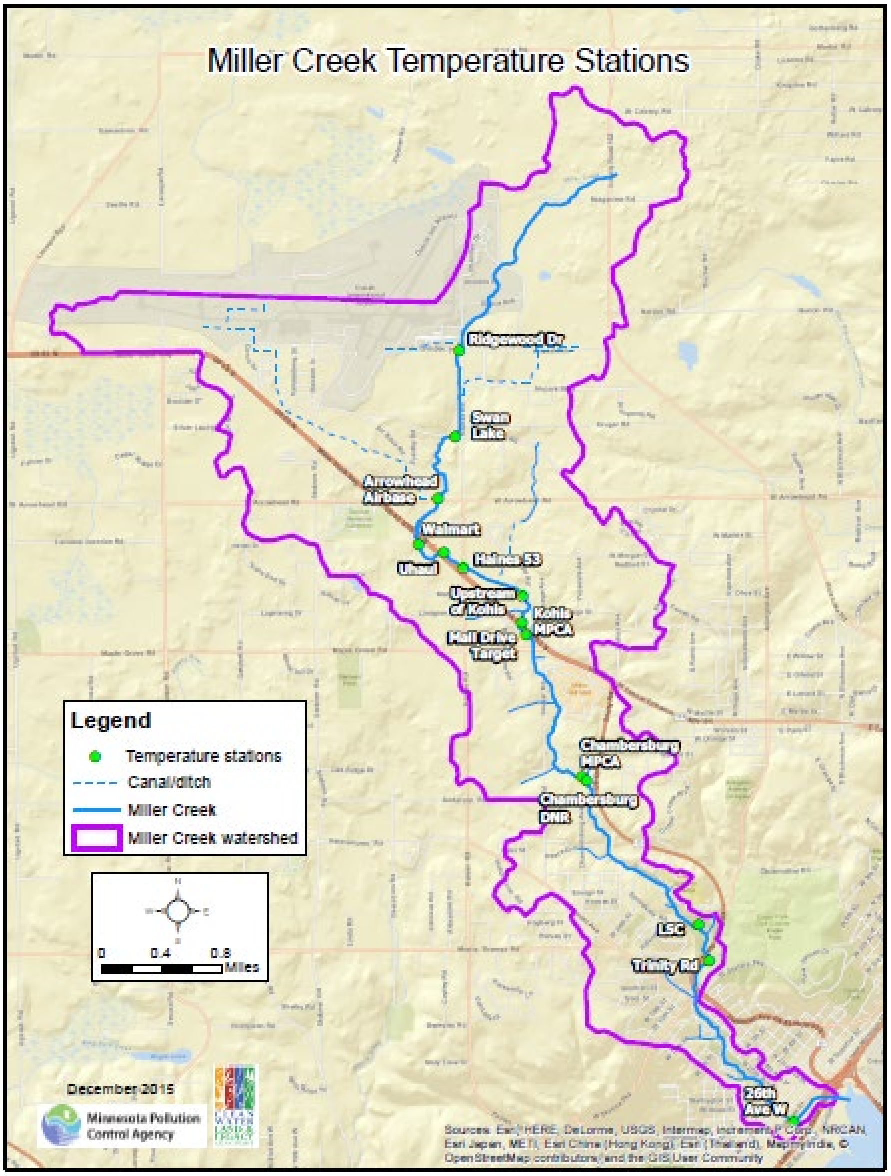


Table 4: Compilation of Weekly (T > 19 °C) and Daily (T > 24 °C) stream temperature exceedances by station and precipitation conditions (wet/dry day) (modified from Herb 2011).

Temperature Exceedances 2007 to 2009	**Weekly Exceedances (T > 19 °C)**	**Daily Exceedances (T > 24 °C)**		
Temperature Station	**Total**	**Total**	**Dry**	**Wet**
26th Avenue (downstream)	10	0	0	0
Trinity Rd	15	6	5	1
LSC	18	6	5	1
Chambersburg DNR	5	1	1	0
Chambersburg MPCA	21	7	6	1
Mall Drive Target	38	22	21	1
Kohls MPCA	46	20	17	3
Upstream of Kohls	54	16	15	1
Haines 53	36	6	6	0
Uhaul	10	0	0	0
Walmart	28	2	1	1
Arrowhead Airbase	19	9	8	1
Swan Lake	7	0	0	0
Ridgewood (upstream)	6	0	0	0
Total Exceedances =	313	95	85	10

3.6.1.1 Permitted

Stormwater discharges in Minnesota are permitted through National Pollutant Discharge Elimination System (NPDES) and State Disposal System (SDS) Permits (Permits). Stormwater runoff, which may contain heat that is transferred to receiving waters, may originate from or be conveyed through municipal separate storm sewer systems (MS4), and from runoff associated with construction and industrial activities. This includes runoff during precipitation events, and through discharges from public and private stormwater infrastructure (e.g., curb and gutter, ditches, and stormwater treatment systems). For Miller Creek, stormwater is delivered to the stream via curb and gutter, road ditches, overland runoff, and as discharges from stormwater treatment systems.

For this TMDL, the relative contribution of each permittee to Miller Creek was estimated, because separate stormwater monitoring data was not available for each permittee. It was assumed that each permittee contributed heat to Miller Creek in proportion to the total impervious surface area of each entity (Herb 2011).

3.6.1.2 Non-permitted

Atmospheric Heating: Atmospheric heat transfer to the stream is the dominant mechanism for stream temperature exceedances in Miller Creek. The section from U.S. Highway 53/Haines Road downstream to Miller Hill Mall (a largely channelized section) has lower levels of shading and exhibited the most of all temperature exceedances (in both total number and duration) (Herb and Stefan 2009b).

Unregulated stormwater runoff: Direct runoff and any stormwater that reaches the waterbody without MS4 infrastructure is considered to be non-regulated stormwater, unless regulated by other NPDES Permits. Unregulated stormwater runoff makes up only a very small fraction of total stormwater entering Miller Creek and was not quantified for this TMDL.

4 TMDL Development

A TMDL is an established value (or set of values) determining the amount of a pollutant that a waterbody can withstand without exceeding its water quality standard. A TMDL report includes the diagnostic work of: monitoring, inventory, modeling, calculating allocations, reduction strategies, and documenting a public process.

Allocations of the allowable pollutant load are also determined for the various pollutant sources. A TMDL is defined as "the sum of the individual WLA for point sources and LA for nonpoint sources and natural background sources," such that the waterbody's ability to receive pollutant loadings (Loading Capacity) is not exceeded (40 CFR 130.2). The requirements of a TMDL are described in 40 CFR 130.2 and 130.7 and Section 303(d) of the CWA.

The TMDL is developed according to the following equation:

TMDL = LC = ΣWLA + ΣLA + MOS, where:

- Σ = the sum of;
- LC = loading capacity, the greatest pollutant load a waterbody can assimilate without exceeding water quality standards;
- WLA = wasteload allocation, existing and future point source pollutant sources that would require a NPDES Permit;
- LA = load allocation, includes existing and future nonpoint sources of pollution, "natural background" contributions, and any other pollutant sources;
- MOS = margin of safety, the uncertainty in the relationship between pollutant loads and the quality of the receiving water.

The TMDL loading capacity and allocations were calculated in terms of the GJ per day (GJ/day) of heat that Miller Creek can assimilate and still maintain water temperatures below the 19°C MWAT, the numeric temperature target in the TMDL. An energy-based allocation was used in order to express temperature as a load-based TMDL. GJ is a metric term for available energy. For context, the energy of one GJ of electricity will light a 60-watt bulb continuously for six months. Or, it would require approximately 43 GJ of heat energy to raise the temperature of an Olympic-sized swimming pool (660,000 ft^3) by one degree F.

To complete a TMDL for the temperature impairment, temperature is represented as the amount of heat that would be required to raise a given volume of water a given number of degrees above 32 °F (0 °C). Heat is a form of energy that can be described in various units including BTUs (British Thermal Units) and Joules. SAFL (Herb 2011) describes the theory, computations, and modeling completed to determine the loading capacities for this TMDL. Work by Poole and Berman (2001) provides a detailed explanation of heat dynamics and mechanisms affecting stream temperature.

The amount of heat loading, in Joules of energy, to a stream is a function of the density and specific heat of water (ρ and C_p), volume (Q) and temperature (T) of water, and time (t). For any location in a stream, the heat (H) required for the stream temperature to be X degrees above freezing can be calculated as the product of ρ, C_p, Q, T, and t as shown in the equation,

$$H = \rho \times C_p \times Q, \times T \times t,$$

where ρ = 4.186 joule/gram °C and C_p = 62.4 lb/ft^3. Q is stream flow. T is either the observed or target temperature. And, t is 1 day for the TMDL. The observed load is computed with the observed temperature in °C and the loading capacity is computed with the target temperature (19 °C).

The load duration curves were computed using the flow record for Miller Creek at the 26th Avenue West monitoring site, and the target temperature of 19 °C MWAT was used. The observed heat loads were computed using the observed water temperatures and corresponding flow values.

4.1 Water Temperature

In order to characterize the water temperatures in Miller Creek, stream temperature and stormwater temperature were monitored at 25 sites from 2007 to 2009. Data from 14 sites were used for the TMDL. Overhead canopy, bank slope angle and stream orientation data were also collected at the temperature sites. Table 4 provides a summary of the temperature station data and the station locations are depicted in Figure 11.

4.1.1 Loading Capacity

The TMDL builds upon detailed data analysis and modeling that is documented in several reports that are listed in Section 3.5, with links available in Appendix B. Several models were used to calculate pollutant loading and determine necessary load reductions. The year 2008 was chosen as a baseline year because it comprised the most complete set of data for stream flows and temperatures, and it was the most representative to near normal conditions for air temperature and precipitation of the 2007, 2008 and 2009 data sets.

The Stream Network Temperature (SNTEMP) model, United States Geologic Survey (USGS) 2008, a heat transport model, was used to predict daily average and DM stream temperatures from nonpoint source heat inputs to Miller Creek, based upon current riparian shading conditions (June 2008 through September 2008). In addition, several mitigation scenarios with increased shading were also completed utilizing SNTEMP (discussed further in Section 8). Water temperatures were modeled with a focus on low flow (base flow) conditions when trout habitat becomes critical (Herb et al. 2009).

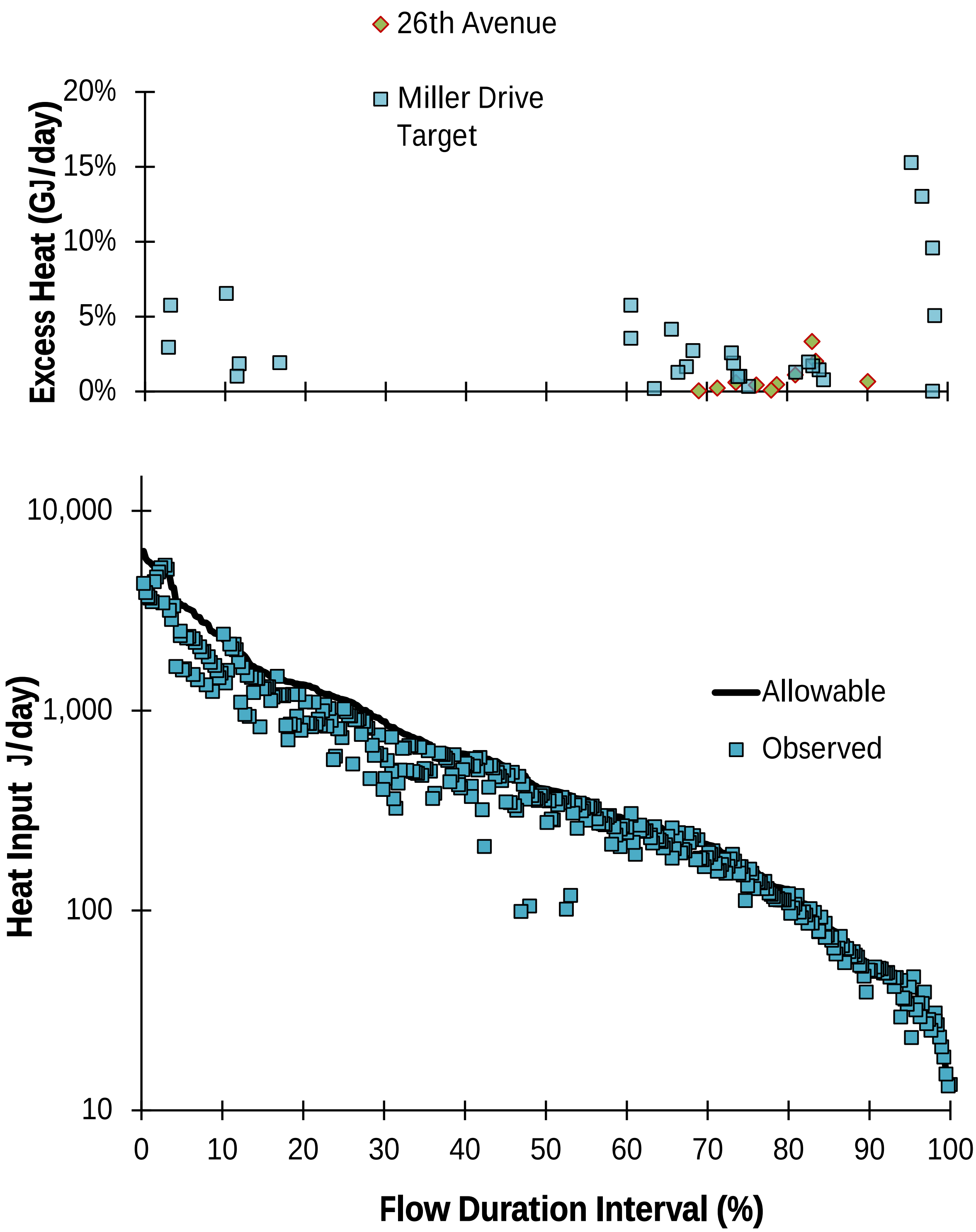
The Minnesota Urban Heat Export Tool (MINUHET), University of Minnesota, a surface runoff modeling tool, was used to predict stormwater runoff temperatures for Miller Creek. Runoff was simulated using 2008 data for typical residential and commercial subwatersheds and calibrated to observed stormwater discharge temperatures. This data was applied to the entire watershed, using runoff volumes from the SWMM model. The simulated runoff temperatures and volumes were used to estimate point source heat loadings to Miller Creek (Herb et al. 2009).

A Storm Water Management Model (SWMM), EPA, was constructed for Miller Creek to simulate continuous time series of stream flow at 15-minute intervals using observed precipitation, stream bathymetry, watershed hydrogeology, and tributary and storm sewer characteristics as input. The model was calibrated and validated against 2008 data, and is able to predict mean flows, peak flows, base flows, and storm runoff volumes. Stream alteration scenarios were also simulated using the SWMM (Erickson et al. 2010).

A load duration curve approach was used to determine the flow regimes during which thermal loads to Miller Creek exceed water quality targets. The load duration curve method is based on an analysis that encompasses the cumulative frequency of historic flow data over a specified period. Because this method uses a long-term record of daily flow volumes, virtually the full spectrum of allowable loading capacities is represented by the resulting curve. Only five points on the entire loading capacity curve are depicted (the midpoints of the designated flow zones). However, it should be understood that the entire curve represents the TMDL and is what is ultimately approved by the EPA.

Figure 12 depicts actual (observed) and allowable heat inputs to Miller Creek, plotted as a function of stream flow as load duration curves. Flow data is from the 26th Avenue West station (2007 to 2009), and excess heat data is derived from observed stream temperature values (2007 to 2009). The lower graph shows the values of observed and allowable heat inputs on a log scale. The upper graph shows the difference between the observed and allowable (excess) heat. The upper graph is scaled such that only positive values are shown (observed > allowable). Note that the highest actual heat inputs to Miller Creek are quite close to the allowable heat inputs over a wide range of flow conditions. This implies that the highest weekly average stream temperatures are close to 19 °C over a wide range of flow conditions and monitoring stations. As expected, actual heat inputs exceed the allowable most commonly at monitoring sites with the most temperature exceedances (Table 4) (e.g., Kohl's and Upstream of Kohl's MPCA temperature stations). The relatively low number of heat input exceedances in the lower section implies that excess heat inputs to Miller Creek in the upper reaches are partially mitigated in the lower section by improved shading, underground reaches, and coldwater inputs from the Chambersburg tributary and other sources. Overall, most temperature exceedances occur at lower flows (e.g., flows corresponding to a duration interval greater than 50%. The upper portion of Miller Creek has more heat exceedances than the lower portion, with most of the exceedances occurring during dry conditions (60% to 90% flow percentile) (Herb 2011).

Figure 12: Actual (observed) and allowable weekly heat loadings versus flow duration interval for Miller Creek, based on 2007, 2008, and 2009 data (modified from Herb 2011).



4.1.2 Load Allocation Methodology

The LAs represent the portion of the loading capacity that is designated for non-regulated sources of temperature (heat) to Miller Creek, as described in Section 3.6.1.2. The LA includes natural background, and all non-permitted sources, such as solar radiation & atmospheric heating and unregulated stormwater runoff. Natural background means characteristics of the waterbody resulting from the multiplicity of factors in nature, including climate and ecosystem dynamics, that affect the physical, chemical, or biological conditions in a waterbody, but does not include measurable and distinguishable pollution that is attributable to human activity or influence (https://www.revisor.mn.gov/statutes/?id=114D.15). Generally, the LA is the TMDL minus the MOS and WLAs for each flow range. For this TMDL, the LA due to atmospheric heating was calculated as the total allowable heat minus the heat fraction attributed to stormwater (Herb 2011).

Miller Creek is an urbanized watershed, with very few remaining areas without human alteration or influence. Remnant natural or least disturbed areas do exist but are scattered throughout the watershed. The land uses in the watershed (Table 3) indicate that 57% of the watershed has been altered in some manner. The remaining 43% is considered natural or regenerated landscapes. The potential exists for exceedances of water quality standards under natural background conditions (due to extended periods of high air temperatures during low stream flow conditions). However, for this TMDL, natural background sources were not quantified, and there is no evidence at this time to suggest natural background sources are a major driver of any of the impairments and/or affect the creek's ability to meet water quality standards. Natural background sources are implicitly included in the LA portion of the TMDL allocation.

4.1.3 Wasteload Allocation Methodology

Separate stormwater monitoring data was not available for each MS4 in the Miller Creek Watershed. In order to determine the relative contribution to the total thermal loading to Miller Creek for each MS4, the total impervious surface was calculated using Geographic Information System (GIS) methods. It was assumed that each MS4 contributed heat to Miller Creek in proportion to the total impervious area contained in each MS4. WLAs were calculated, where the WLA for heat (H_{wla}) was equal to the total heat allocation for a particular flow regime ($H_{a, tot}$), multiplied by the fraction of stormwater (f_{sw}) and multiplied by the fraction of impervious surface (f_{imp}) (Herb 2011).

Wastewater: There are no wastewater point sources that discharge to Miller Creek.

Municipal stormwater: The entire Miller Creek watershed is covered under NPDES MS4 Stormwater Discharge Permits (Figure 13). Seven entities are permittees under the General NPDES/SDS Permit MNR040000 for MS4s:

- city of Duluth (MS400086), the largest contributor by area;
- city of Hermantown (MS400093), the second largest contributor by area;
- Minnesota Department of Transportation ((MnDOT), MS400180), for U.S. Highway 53;
- St. Louis County (MS400158), for county roads;
- LSC (MS400225), covering its campus along Trinity Rd.;

- University of Minnesota Duluth (UMD) (MS400214), for the NRRI property; and
- city of Rice Lake (MS400151), for a small corner of the municipality.

Non-municipal stormwater: There are two individual, non-municipal stormwater permits within the watershed: Walmart Store #1757 (MN0060372) in Hermantown and Miller Hill Mall (MN0056979) in Duluth.

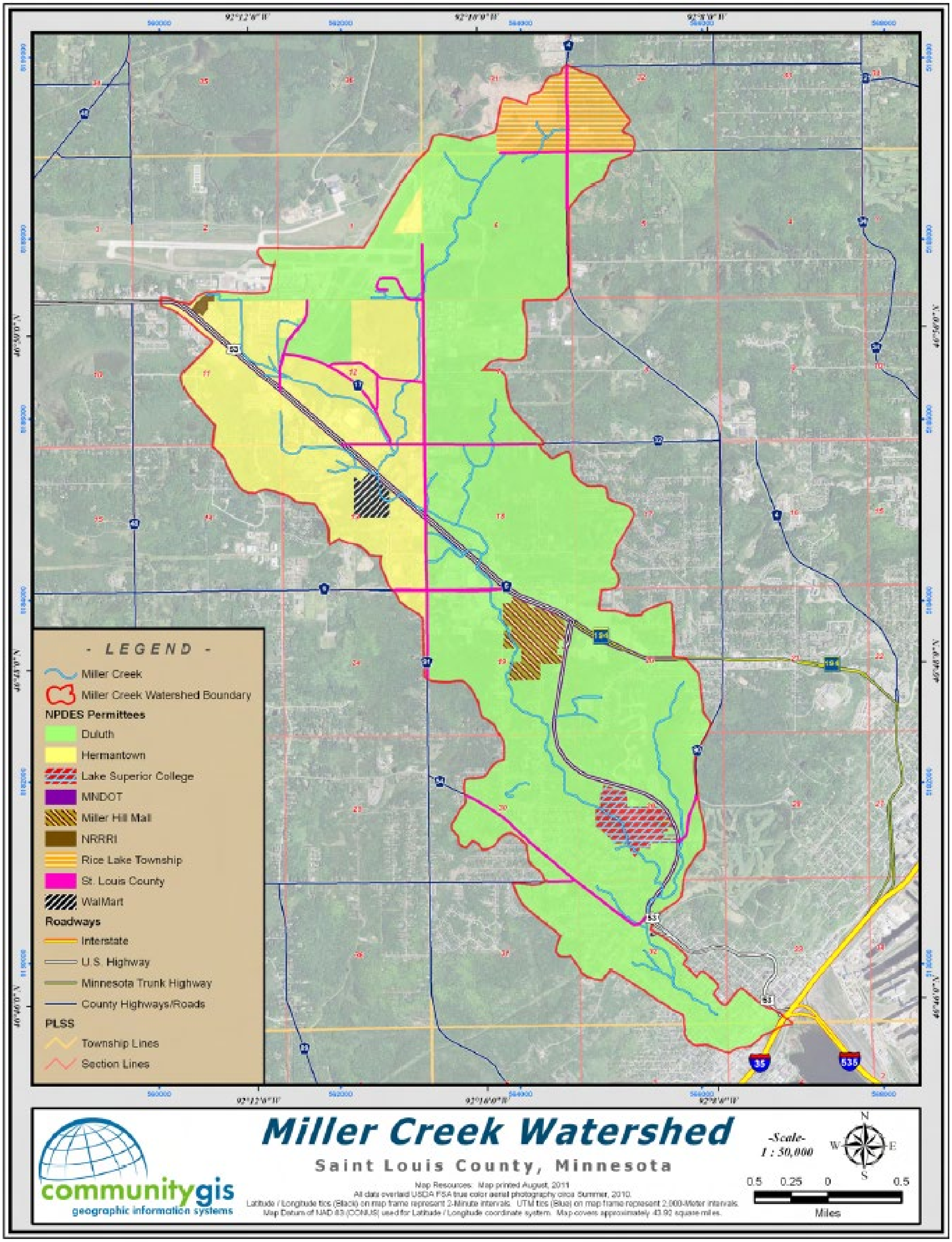
Construction stormwater: The WLA for construction stormwater is based on an estimate of the average annual percentage of the watershed being under an MPCA Construction Stormwater Permit, using the MPCA Construction Stormwater Permit data provided from 2007 through 2013 for Miller Creek Watershed. For the period from 2007 through 2013, the estimated average annual area of the watershed under the MPCA Construction Stormwater Permit was 0.14%.

The WLA for stormwater discharges from sites where there are construction activities reflects the number of construction sites of one or more acres expected to be active in the watershed at any one time, and the best management practices (BMPs) and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at construction sites are defined in the State's NPDES/SDS General Stormwater Permit for Construction Activity (MNR100001). If a construction site owner/operator obtains coverage under the NPDES/SDS General Stormwater Permit [Permit] and properly selects, installs and maintains all BMPs required under the Permit, including those related to impaired waters discharges and any applicable additional requirements found in Appendix A of the Construction General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. All local construction stormwater requirements must also be met.

Industrial stormwater: For industrial stormwater, a categorical WLA was set at 0.1% of the watershed. Acreage data is not readily available for industrial stormwater; however, the general Industrial Stormwater Permits (approximately 10) comprise only a small fraction of Miller Creek Watershed.

The WLA for stormwater discharges from sites where there is industrial activity reflects the number of sites in the watershed for which NPDES Industrial Stormwater Permit coverage is required, and the BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at the industrial sites are defined in the State's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000), facility specific Individual Wastewater Permit (MN00XXXXX), or NPDES/SDS General Permit for Construction Sand & Gravel, Rock Quarrying and Hot Mix Asphalt Production facilities (MNG490000). If a facility owner/operator obtains stormwater coverage under the appropriate NPDES/SDS Permit and properly selects, installs and maintains all BMPs required under the permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. All local stormwater management requirements must also be met.

Figure 13: MS4s within Miller Creek Watershed (South St. Louis SWCD).



4.1.4 Margin of Safety

A MOS is a requirement of all TMDLs to account for inherent uncertainties in the data, modeling and assumptions that were used. The TMDL process allows for either an explicit MOS, expressed in the TMDL as a portion of the allocations along with the WLA and LA, and/or an implicit MOS, which is incorporated through conservative assumptions in the analysis and modeling of the data.

The TMDL includes an implicit MOS, through the use of the EPA recommended (EPA 1986) chronic temperature value (19° C) instead of the acute temperature value (24° C) for brook trout in the analysis and modeling of acceptable heat loading to Miller Creek. Also, the TMDL was calculated without taking into account the installation of BMPs in the watershed. BMPs that were installed during 2007 to 2009 are partially accounted for in the load calculations, in that the BMP improvements are reflected in the monitoring data. BMPs installed after 2008 (the baseline year for model calibration) have not been accounted for in the reductions needed by each source. The TMDL is more conservative by not accounting for the recent improvements and by using a time period when loading rates were higher than existing (after 2008).

In addition to the implicit MOS, the MPCA best professional judgement defined an explicit 10% MOS to provide an accounting for uncertainties in data analysis, interpretation and modeling approximations.

4.1.5 Seasonal Variation

The critical conditions occur in summer months (June through September) when air temperatures are highest and aquatic activity (growth and reproduction) is at its greatest. Critical conditions may be further exacerbated by extended hot periods, periods with little precipitation, and rainstorms that produce heated stormwater runoff. The TMDL utilizes data collected during the period from June through September over a three-year period, from 2007 to 2009. Elevated water temperatures due to atmospheric heat transfer to the stream were found to be the dominant mechanism for temperature exceedances above 19° C MWAT. The TMDL addresses these conditions through implementation strategies that will reduce stream temperatures.

The TMDL includes the assumption that practices to reduce MWAT are expected to also lower daily peak temperatures (DM), given the strong correlation between daily peaks and weekly average temperatures, weekly average temperatures and air temperatures, and highest loading due to solar radiation.

4.1.6 Reserve Capacity

Miller Creek Watershed is completely contained within MS4 Permit coverage (Figure 13). There are no point sources to Miller Creek and none are proposed or anticipated within the watershed. Much of the new development consists of redevelopment of areas that were developed prior to stormwater management requirements. As part of any redevelopment, stormwater management practices will improve from existing conditions. The loading calculations in this TMDL allow for adequate capacity and no separate reserve capacity is required.

4.1.7 Water Temperature TMDL Summary

The observed thermal load during the monitoring period was generally less than the allowable load. When the observed load exceeded the allowable load, the observed loads were only slightly greater than the loads, as shown in Figures 14, 15, 16, and in Table 5.

Figure 14: Miller Creek actual and allowable heat 2007, Mall Drive Target.

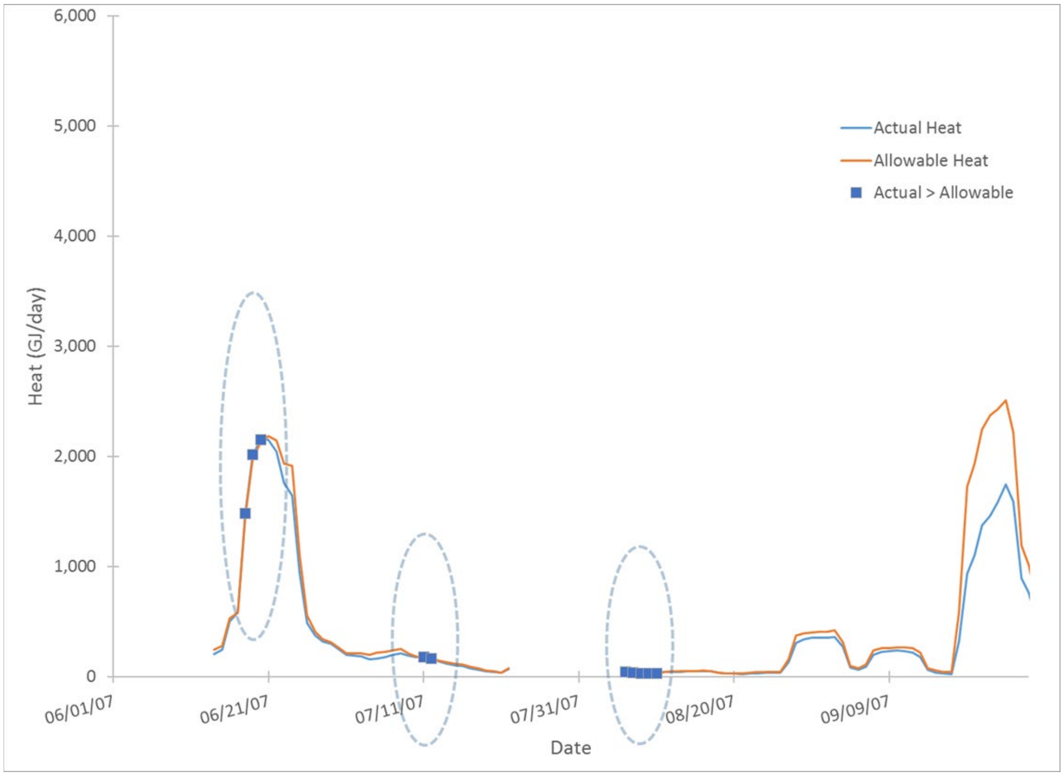


Figure 15: Miller Creek actual and allowable heat 2008, Mall Drive Target.

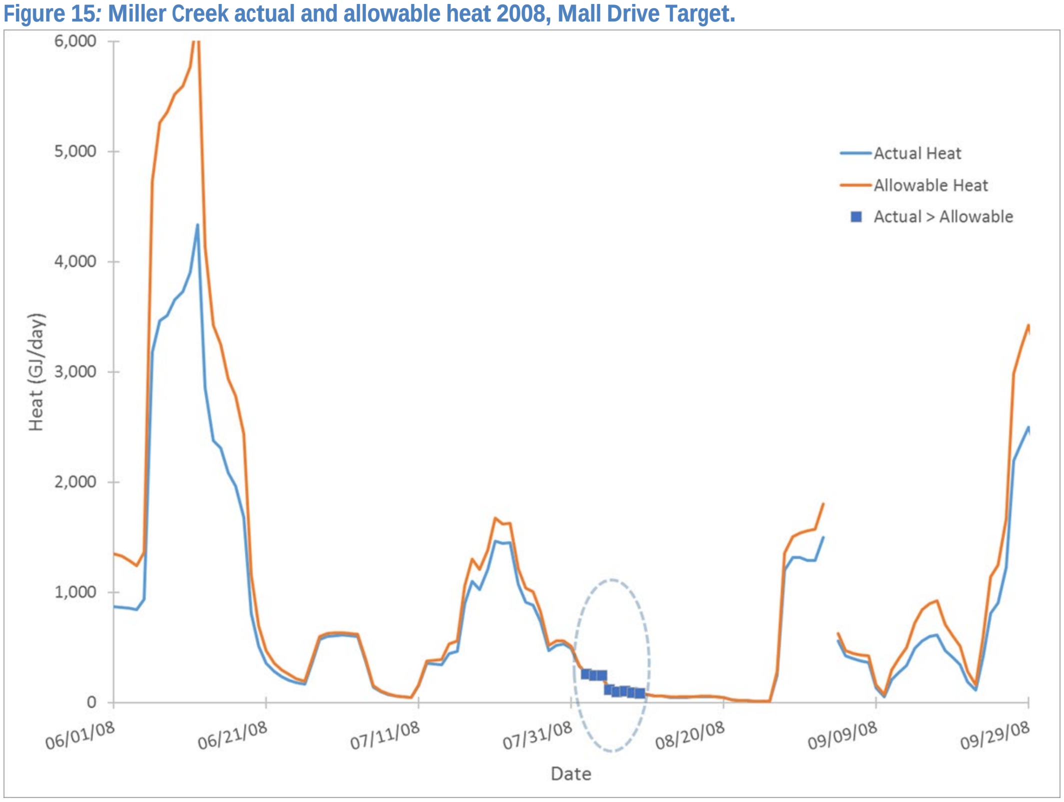


Figure 16: Miller Creek actual and allowable heat 2009, Mall Drive Target.

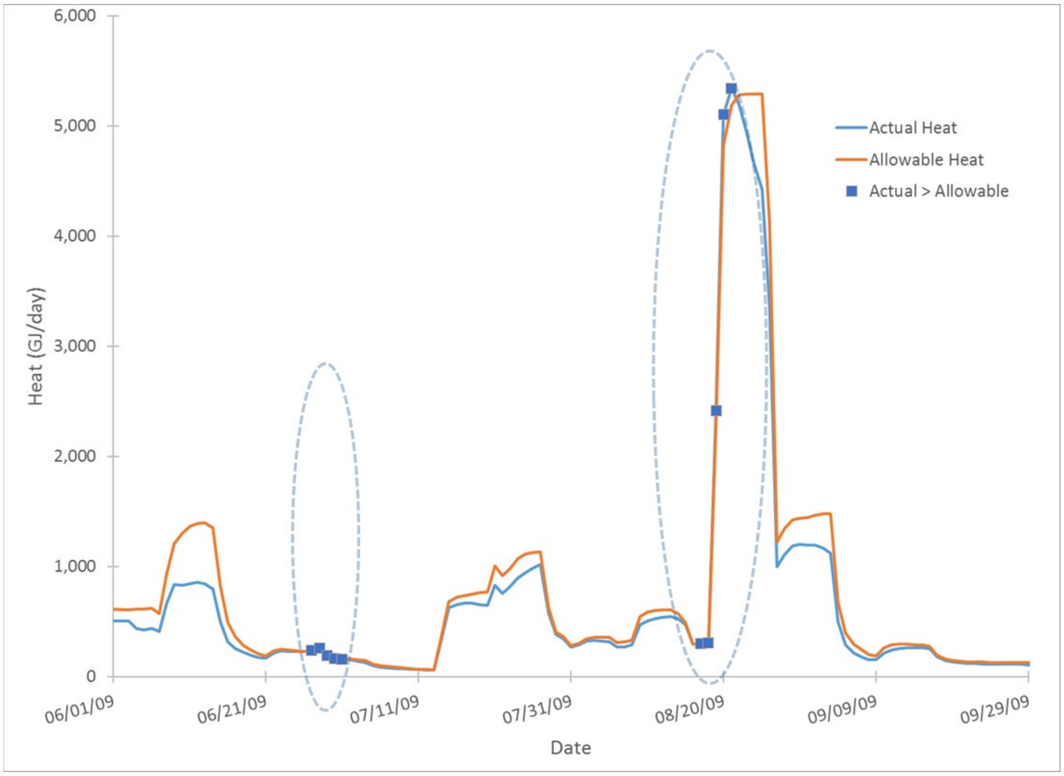


Table 5: Observed and allowable loads (GJ/day) for time periods where 7-day running average water temperatures exceeded 19 °C.

Time Period	Observed Load	Allowable Load	Amount Exceeded	Percent Exceeded
June 18 – 20, 2007	5,653	5,567	86	1.5
July 11 – 12, 2007	343	338	5	1.5
August 6 – 10, 2007*	171	156	15	9
August 2 – 9, 2008	1,249	1,234	15	1.2
June 27 – July 1, 2009	1,014	990	24	2.4
August 18 – 21, 2009	13,464	12,859	605	4.7

* Missing temperature data prior to August 6, 2007.

The water temperature LA and WLAs for Miller Creek are described in Table 6. The load and WLAs are described in terms of heat units, in GJ/day.

Table 6: Heat loading, wasteload allocations and load allocations for Miller Creek Watershed.

Miller Creek Temperature TMDL *					
Flow Duration Interval (%)	High 0-10	Moist 10-40	Mid-range 40-60	Dry 60-90	Low 90-100
Flow Range (cfs)	>11.8	3.1-11.8	1.5-3.1	0.28-1.5	< 0.28
Total Heat Capacity	**5521**	**1302**	**574**	**234**	**33**
Margin of Safety**	**552**	**130**	**57**	**23**	**3.3**
Total Waste Load Allocation	**4,014**	**865**	**299**	**92**	**10**
City of Duluth (MS40086)	2,347	506	175	54	6.1
City of Hermantown (MS400093)	821	177	61	19	2.1
City of Rice Lake (MS400151)	68	15	5.0	1.6	0.18
MN DOT (MS400180)	215	46	16	4.9	0.56
St. Louis County (MS400158)	277	60	21	6.4	0.72
UMD-NRRI (MS400214)	12	2.7	0.92	0.28	0.03
Walmart (MN0060372)	36	7.8	2.7	0.83	0.09
Miller Hill Mall (MN0056979)	200	43	14.9	4.6	0.52
Lake Superior College (MS400225)	38	8.2	2.8	0.87	0.10
Other Waste Load Allocation	**13.2**	**3.1**	**1.37**	**0.56**	**0.08**
Construction Stormwater	7.7	1.8	0.80	0.33	0.05
Industrial Stormwater	5.5	1.3	0.57	0.23	0.03
Load Allocation	**942**	**304**	**216**	**117**	**19**

* Heat units: gigajoules (GJ) per day (GJ/day)

** MOS = 10% of total heat capacity

5 Future Growth Considerations

5.1 New or Expanding Permitted MS4 WLA Transfer Process

Future transfer of watershed runoff loads in this TMDL may be necessary if any of the following scenarios occur within the project watershed boundaries:

1. New development occurs within a regulated MS4. Newly developed areas that are not already included in the WLA must be transferred from the LA to the WLA to account for the growth.
2. One regulated MS4 acquires land from another regulated MS4. Examples include annexation or highway expansions. In these cases, the transfer is WLA to WLA.
3. One or more non-regulated MS4s become regulated. If this has not been accounted for in the WLA, then a transfer must occur from the LA.
4. Expansion of a U.S. Census Bureau Urban Area encompasses new regulated areas for existing permittees. An example is existing state highways that were outside an Urban Area at the time the TMDL was completed, but are now inside a newly expanded Urban Area. This will require either a WLA to WLA transfer or a LA to WLA transfer.
5. A new MS4 or other stormwater-related point source is identified and is covered under a NPDES Permit. In this situation, a transfer must occur from the LA.

For this TMDL, allocations were established using the percentage of impervious surface for each MS4 within Miller Creek Watershed. Load transfers will be based on methods consistent with the area-weighted methodology used in setting the allocations in this TMDL. In cases where WLA is transferred from or to a regulated MS4, the permittees will be notified of the transfer and have an opportunity to comment on proposed changes.

6 Reasonable Assurance

Reasonable assurances must be provided in the TMDL that demonstrate the ability to achieve the targeted water quality goals. Several factors control reasonable assurance, including a thorough knowledge of the ability to implement BMPs, as well as the overall effectiveness of the BMPs. The implicit and explicit MOS applied to this TMDL, at the critical seasonal conditions and all portions of the flow regime, also provides reasonable assurance that the standards will be met with the allocated loadings. Local, state and federal agencies have the authority for oversight and regulation through permitting, zoning controls, and in compliance with permit(s) that they are subject to (Table 7). Permitted MS4s through the MPCA's Stormwater Program is the framework in place to ensure progress to achieving the water quality targets identified in this TMDL.

Natural background sources were not quantified for the TMDL, however there is no evidence to suggest natural background sources are a major driver of the impairments and/or affect the creek's ability to meet water quality standards.

Appendices A and B provide details on appropriate types of BMPs, targeted locations in the watershed, targeted permittees, and special considerations for implementation activities. These activities have been incorporated into the TMDL as a means to reinforce the responsibility and commitment of permittees to work to reduce thermal loading to Miller Creek. BMPs designed to address the WLA may also benefit the LA, and BMPs designed to address the LA may also benefit the WLA. BMPs to address the LA, such as riparian shading, may be a cost effective approach to reduce the thermal loading (a majority of the TMDL) to Miller Creek from atmospheric heating. BMPs to address the WLA would still be necessary, especially in the targeted areas for implementation.

Table 7: Regulatory controls in place that provide reasonable assurance allocations will be achieved.

Entity	Regulatory Authority or Control
MS4 Permittees in Miller Creek Watershed	Comprehensive Plans that guide the types and locations of development in a community Zoning Ordinances that regulate where and how development may occur, and measures to minimize environmental impacts Stormwater Utility, where applicable Adoption and/or compliance with state and federal requirements (Wetland Conservation Act (WCA), Shoreland, MS4-SWPPP, NPDES, 404 and 401 of CWA)
State Government Agencies	NPDES regulation of stormwater discharges Shoreland and Floodplain Management Wetlands management (WCA and 401)
Federal Government Agencies	404 Authority over aquatic resources
Non-Government Agencies (businesses, institutions)	Facility management plans Compliance with local, state and federal requirements

6.1 MPCA Stormwater Programs

The MPCA's MS4 General Permit requires MS4 permittees to provide reasonable assurances that progress is being made toward achieving all WLAs in TMDLs approved by the EPA prior to the effective date of the permit. In doing so, they must determine if they are currently meeting their WLA(s). If the WLA is not being achieved at the time of application, a compliance schedule is required that includes interim milestones, expressed as BMPs, that will be implemented over the current five-year permit term to reduce loading of the pollutant of concern in the TMDL. Additionally, a long-term implementation strategy and target date for fully meeting the WLA must be included.

The MPCA is responsible for applying federal and state regulations to protect and enhance water quality within the Miller Creek Watershed. The MPCA oversees all regulated MS4 entities in stormwater management accounting activities. All regulated MS4s in the Miller Creek watershed fall under the category of Phase II. The MS4 NPDES/SDS Permits require regulated municipalities to implement BMPs to reduce pollutants in stormwater runoff to the Maximum Extent Practicable.

All owners or operators of regulated MS4s (also referred to as "permittees") are required to satisfy the requirements of the MS4 General Permit. The MS4 General Permit requires the permittee to develop a Stormwater Pollution Prevention Program (SWPPP) that addresses all permit requirements, including the following six minimum control measures:

- public education and outreach
- public participation
- Illicit Discharge Detection and Elimination Program
- construction-site runoff controls;
- post-construction runoff controls; and
- pollution prevention and municipal good housekeeping measures

A SWPPP is a management plan that describes the MS4 permittee's activities for managing stormwater within their jurisdiction or regulated area. In the event a TMDL study has been completed, approved by the EPA prior to the effective date of the general permit, and assigns a WLA to an MS4 permittee, that permittee must document the WLA in their application and provide an outline of the BMPs to be implemented in the current permit term to address any needed reduction in loading from the MS4.

The MPCA requires applicants to submit their application materials and the SWPPP document to the MPCA for review. Prior to extension of coverage under the general permit, all application materials are placed on 30-day public notice by the MPCA, to ensure adequate opportunity for the public to comment on each permittee's stormwater management program. Upon extension of coverage by the MPCA, the permittees are to implement the activities described within their SWPPP, and submit annual reports to the MPCA by June 30 of each year. These reports document the implementation activities, which have been completed within the previous year, analyze implementation activities already installed, and outline any changes within the SWPPP from the previous year.

The MPCA has assigned heat loads for the TMDL to the regulated MS4s. The pollutant WLAs for each MS4 entity are outlined in Section 4.1.7 of the TMDL. The MS4 General Permit, which became effective August 1, 2013, requires permittees to develop compliance schedules for any TMDL that received the

EPA-approval prior to the effective date of the general permit. This schedule must identify the BMPs that will be implemented over the five-year permit term, timelines for their implementation, an assessment of progress, and a long term strategy for continued progress toward ultimately achieving those WLAs. MS4s will not be required to report on WLAs contained in this TMDL until the effective date of the next general permit, expected in 2018, because the TMDL for Miller Creek will be approved after the effective date of the current general permit. Updating the SWPPP to incorporate the TMDL will help to ensure that WLA reductions are implemented.

The Reasonable Assurance that the WLAs calculated for Miller Creek TMDL will be implemented is provided by regulatory actions. According to 40 CFR 122.44(d)(1)(vii)(B), the NPDES Permit effluent limits must be consistent with assumptions and requirements of all WLAs in an approved TMDL. The MPCA's stormwater program and its NPDES Permit program are the state programs responsible for ensuring that implementation activities are initiated and maintained, and effluent limits are consistent with the WLAs calculated from the TMDLs. The NPDES program requires construction and industrial sites to create the SWPPPs, which summarize how stormwater will be minimized from construction and industrial sites.

7 Monitoring Plan

Monitoring for TMDL implementation activities is important in order to measure the effectiveness of those activities implemented, and to inform future direction and choice of activities implemented (i.e., adaptive management). Monitoring should continue throughout implementation until water quality standards are attained. However, monitoring for temperature and heat energy reductions is a challenging and complex endeavor for permittees. An alternative means to measure progress toward TMDL reduction goals will be developed by the MPCA (in coordination with permittees) and applied throughout implementation.

For Miller Creek, there are a number of monitoring activities currently underway, or will be occurring in the future:

- Those parties with activities subject to NPDES/SDS Permits (MS4, CSW, ISW, and Non-municipal Stormwater Permit holders) will continue to conduct monitoring and other methods of evaluation of BMPs as a requirement of the applicable permit(s).
- DNR currently conducts, and will continue to conduct, stream population and temperature assessments on an annual basis at the brook trout index station, and at other select locations in Miller Creek.
- The MPCA installed a new stream station near the mouth of Miller Creek for stream stage and flow monitoring during 2014 to 2017. In 2017, the station equipment will be changed to a mulita-parameter water chemistry probe, collecting continuous stream temperature, specific conductivity, estimated stream flows, and precipitation. The station will be maintained into the foreseeable future by UMD-NRRI.
- Under the Watershed Approach and the WRAPS process, the MPCA and local partners will begin two years of intensive watershed monitoring in the St. Louis River Watershed, which includes Miller Creek, in 2019 as part of the second 10-year cycle of intensive watershed monitoring. Monitoring will include water chemistry parameters, biotic community health, and assessing habitat conditions. This effort will continue under the Duluth Urban WRAPS, with additional monitoring and evaluation.
- UMD-NRRI redeployed multi-parameter water chemistry probe at LSC in 2015, collecting continuous stream temperature, specific conductivity, estimated stream flows, and precipitation, with the intent to continue data collection for the foreseeable future.
- Miller Creek Watershed has been, and continues to be, a focus for research by local, state, and federal agencies, and by academic institutions. Voluntary activities implemented to reduce heat loading to Miller Creek will be tracked and reported by the MPCA, in coordination with local partners.
- As part of ongoing civic engagement activities, input from citizens and targeted groups will be collected to gauge interest, concerns, and participation in watershed-related activities by local partners, in coordination with the MPCA.

8 Implementation Strategy Summary

Table 8 provides a summary of BMPs that could potentially be implemented to provide thermal loading reductions to Miller Creek, and are creditable to both the WLA and LA. Appendix A (BMPs for MS4 Permittees) of this TMDL provides more specific details on appropriate types of BMPs, targeted locations, targeted permittees, and special considerations for implementation. The information in Appendix A is incorporated into the TMDL as a means to reinforce the responsibility and commitment of permittees to work to reduce thermal loading to Miller Creek. Additional information related to prioritized restoration and protection activities within the Miller Creek watershed can be found in the Duluth Urban Area WRAPS report (currently in development). Once completed, the Duluth Urban Area WRAPS report will be available on the St. Louis River watershed web page at: https://www.pca.state.mn.us/water/watersheds/st-louis-river

Temperature mitigation and baseflow augmentation were modeled for the Miller Creek Watershed. Increased riparian shading in the upper watershed, the lower watershed, and the entire watershed were evaluated. The largest increases in shading for potential future scenarios were in the impacted wetland above Kohl's Department Store. Increasing the shading upstream of Kohl's provides substantial reductions in DM temperatures (up to 2° C), with reductions in maximum daily temperature persisting for approximately two kilometers downstream of Kohl's (Herb et al. 2009). Stormwater runoff rate and volume controls were also evaluated, including reducing peak flow rates through wet detention basins, bottom outlet discharges, underground stormwater storage, and infiltration. Each method can provide some thermal reductions, but may be muted depending on the pre-runoff conditions, intensity and duration of runoff, and other site limitations (Herb et al. 2009).

Increasing stream baseflows may reduce stream temperatures, and provide better habitat for brook trout. While four scenarios were evaluated, increasing the channel length in the wetland above Kohl's was the most realistic and beneficial scenario. The restored channel would represent more natural stream function. Increasing the length would decrease channel slope, and increase the residence time of water, which could provide additional channel storage and result in increased baseflow (Erickson et al. 2010).

Table 8: Potential heat-reducing BMP implementation strategies.

Potential Implementation BMPs and Heat Reduction Strategies
Stormwater improvements: Develop a comprehensive stormwater management plan for Miller Hill Mall; install BMPs to newly developed, redeveloped and to existing impervious surfaces (e.g., tree trenches, wet rock cribs, underground storage, wet pond bottom outlets, rain gardens and bio-filtration); maintain existing stormwater infrastructure; reduce the amount of existing impervious surfaces (removal or replacement with pervious); disconnect direct runoff from rooftops.
Vegetation improvements: Conduct tree plantings in riparian areas; reestablish native plant communities in areas of turf grass.
Stream Restoration: Restore channel morphology and habitat on select channelized sections of Miller Creek.
Education: Outreach and education with homeowners along the stream; develop materials for Miller Hill Mall tenants and patrons. Hold public workshops, festivals, stream clean-ups.
Code: Enhanced enforcement of zoning codes; encourage low impact development practices.

Land Preservation Activities: Establish conservation easements on sensitive lands, including wetlands and riparian lands.

8.1 Permitted Sources

8.1.1 Construction Stormwater

See section 4.1.3.

8.1.2 Industrial Stormwater

See section 4.1.3.

8.1.3 MS4

The NPDES Permit requirements must be consistent with the assumptions and requirements of an approved TMDL and associated WLAs. For the purposes of this TMDL, the MS4s are required to implement additional measures that will reduce the heating to Miller Creek within their jurisdiction (See Appendix A and the Duluth Urban Area WRAPS report (currently in development). In addition, the Regional Stormwater Protection Team (RSPT), a local conglomerate of municipalities and agencies working to prevent stormwater pollution to local streams, has a mission "to protect and enhance the region's shared water resources through stormwater pollution prevention by providing coordinated educational programs, and technical assistance" (http://www.lakesuperiorstreams.org/stormwater/rspt.html). Table 8, above, provides a summary of BMPs identified during discussions on TMDL implementation. More detailed information can be found in Appendix A and in the Duluth Urban Area WRAPS Report (https://www.pca.state.mn.us/water/watersheds/st-louis-river).

Permit holders should use the list of BMPs in Appendix A to address the excess thermal loading to Miller Creek. Stormwater BMPs should be focused primarily on the developed portions of the upper watershed, targeting that portion of the watershed above LSC. Data collected for the TMDL identified the stream segment from U.S. Highway 53/Mall Drive, near Walmart to Chambersburg Avenue with the greatest exceedances of stream temperatures (See Table 3, Section 3.6). Implementation projects should utilize existing research to inform the locations and types of projects undertaken. This includes project reports from SAFL regarding temperature mitigation for Miller Creek (Herb et al. 2009) and simulations for baseflow augmentation scenarios (Erickson et al. 2010), as well as peer-reviewed research on thermal reductions from stormwater BMPs. It is important to note that BMPs designed to address the WLA may also provide benefit to the LA, and BMPs designed to address the LA may also benefit the WLA.

8.2 Non-Permitted Sources

8.2.1 Atmospheric Heating

A majority of the allocations for this TMDL have been assigned to LA, due to atmospheric heat transfer to Miller Creek. While there are no regulatory mechanisms in place to track progress and implementation towards meeting the LA for Miller Creek, many of the implementation activities, such as tree plantings, riparian vegetation management restoration of channelized stream sections will be completed by, and/or in cooperation with the MS4 entities. Projects implemented to address WLAs may also benefit LAs and those implemented to address LAs may also benefit WLAs. Table 8 and Appendix A provide a summary of activities that will lead to heat energy reductions to Miller Creek.

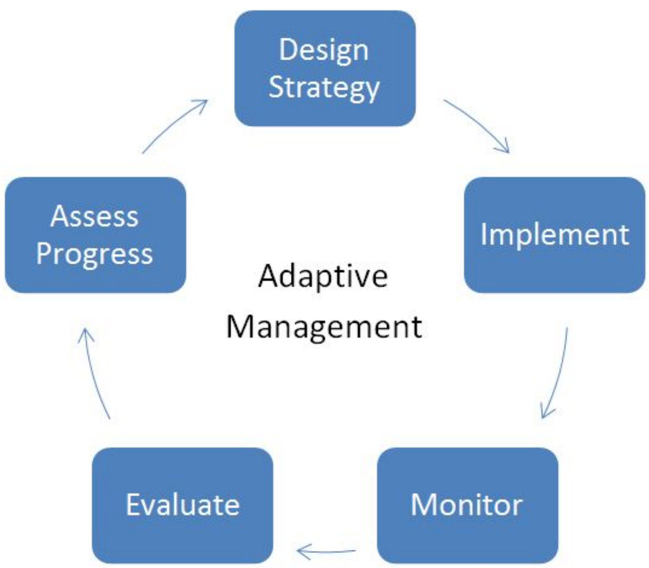
8.3 Cost

The Clean Water Legacy Act (CWLA) requires that a TMDL include an overall approximation of costs for TMDL implementation (Minn. Stat. 2007 § 114D.25). The initial estimate for implementing this TMDL ranges from $750,000 to $3,500,000, based upon cost estimates for various BMPs and other activities that will be defined in the Duluth Urban Area WRAPS report. However, this is a broad estimate and a number of factors may affect the total costs for implementation, such as the number, scope and detail of individual projects implemented to achieve the TMDL reductions.

8.4 Adaptive Management

A list of implementation elements was prepared in conjunction with TMDL development, with an emphasis on adaptive management (Figure 17). Continued monitoring and "course corrections" responding to monitoring results are the most appropriate strategy for attaining the water quality goals established in this TMDL. Management activities will be changed or refined accordingly to efficiently meet the TMDL and lay the groundwork for de-listing the impaired water body.

Figure 17: Adaptive Management.



9 Public Participation

Public involvement was an important part of the Miller Creek TMDL process. The Miller Creek Watershed has a wide variety of interested parties seeking opportunities for involvement in watershed activities, including the TMDL process.

Annual meetings were held to keep stakeholders and other interested parties informed, and annual newsletters were also developed. A Technical Advisory Group (TAG) was established at the beginning of the TMDL study and represented a broad spectrum of organizations, including MS4 permittees, government organizations, and natural resource organizations. The TAG reviewed data, provided feedback to the project manager and SWCD staff on the approaches taken for the study, and provided advice in helping to find solutions to any problems that emerged over the course of the study.

Monthly meetings of the RSPT also served as a forum for updating local entities (especially MS4s) about the progress of the TMDL Study. An opportunity for public comment on the draft TMDL report was provided via a public notice in the State Register from June 5, 2017 through July 5, 2017. An overview of all public participation efforts is summarized in Table 9.

Table 9: Public outreach activities for the Miller Creek TMDL.

What	Audience	When	Response	Notes
Flyer/Invite to Lunch Meeting	All businesses in the watershed.	February, 2008	Poor - cancelled lunch but met privately with three interested businesses.	Two Best Management Practices came out of this effort.
Four Newsletters	All homeowners and businesses in the watershed.	Annually 2007 – 2010	unknown	Approx. 2,000 households and 250 businesses received the newsletters.
Meetings	Homeowners	June & October, 2007	Poor	Due to poor response, used newsletters to keep people informed instead.
Presentation	Service corps employees at Community Action Duluth	7/23/09	Good - 15 service corps staff	Followed by a watershed clean-up.
Rain garden and rain barrel workshop	Homeowners	9/18/09	Very good - 20 in attendance	Attendees received free rain garden plants and instructions for building their own rain garden.
Brochure	All	2008-2011	Unknown	Distributed at SWCD booth at various public events including the St. Louis County fair, Harvest Fest, and Earth Trax.

South St. Louis SWCD Website	All	2008-current	Unknown	Updated information on the Miller Creek TMDL was continually provided on the SWCD website.
TAG Meetings	TAG Members	10/10/07, 3/25/08, 12/15/09, 1/21/11, 6/30/11	Good, approx. 25 in attendance at each meeting.	Meetings held annually during data collection to review data and approach. 2011 meetings held to discuss approach for calculating loading capacity, WLAs and LAs.
RSPT Meetings	RSPT members	Monthly September 2007 – current	Good, approx. 20 in attendance at each meeting.	RSPT has an agenda for each meeting and Miller TMDL updates were included on many of these agendas.
Special Topics Meeting	City of Duluth Stormwater Staff	Periodic, 2010 to 2016	Good	City of Duluth and other MS4s wanted a meeting to discuss what possible implementation strategies they could use to meet their Wasteload Allocations.
Formal MPCA 30-Day Comment Period	All interested parties	6/5/2017 – 7/5/2017	52 individual comments from six entities	Formally responded to public comments.

There is a noteworthy reduction in more formal, organized communications over the last five years. However, during this time, there continued to be significant, ongoing, informal communications with agency staff, local partners, and affected parties. It took an extended period of time to draft the TMDL based on several complicating factors, including: 1) the extreme complexity and uniqueness of a TMDL based on heat (energy), and 2) changes in the project approach several years ago, from a TMDL that addresses several pollutants to one pollutant, and changes from two temperature TMDLs to one.

10 References and Literature Cited

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Appendix A: BMPs for MS4 Permittees

Appendix A
BMPs for MS4 Permittees

BMP Categories	Target Locations	Target Permitees	Considerations
Improved Stormwater Treatment			*Note: See SAFL report 536 on baseflow augmentation scenarios and report 535 on stormwater management scenarios.*
Increase stormwater treatment	Upper watershed: commercial, industiral, and transportation areas	Duluth, Hermantown, St. Louis County, MnDOT, NRRI	Add stormwater treatment to areas lacking treatment. Reduce the need for treatment by reducing impervious surfaces or diverting potential stormwater from impervious surfaces.
	Entire watershed: residential areas	Duluth, Hermantown	Technical assistance to watershed residences (e.g., rain gardens, rain barrels, disconnecting impervious surfaces, redirecting runoff, etc.).
Retrofit existing stormwater BMPs	Upper watershed: Examples include St. Louis County ponds near Sam's Club, MnDOT at US Hwy 53/Maple Grove Rd	Duluth, Hermantown, St. Louis County, MnDOT	Evaluate existing BMPs for thermal reduction potential and implement projects based on outcomes. Miller Hill Mall completed a comprehensive Stormwater Management Plan for temperature mitigation in 2016.
Reduced Impacts from Solar Radiation			*Note: See SAFL report 535 on shading scenarios, see other common methods used.*
Improve riparian vegetation density and composition	Upper watershed: US Hwy 53/Mall Drive, near Walmart to Chambersburg Ave	Duluth, Hermantown, St. Louis County, MnDOT	Identify and prioritize projects based on existing condtions (e.g., stream orientation, bank angle, and soils).
	Upper watershed: Chambersburg Ave to Lake Superior College	Duluth, St. Louis County, Lake Superior College	Technical assistance to riparian landowners (e.g., planting trees and native plants, and reducing turfgrass areas).
	Upper Watershed: above Rice Lake Landfill to US Hwy 53/Mall Drive, near Walmart	Rice Lake, Duluth, Hermantown, St. Louis County, St. Louis County, MnDOT	Analyze stream orientation, bank angle, soils, and vegetation potential and use this information to target projects.
	Lower watershed: Lincoln Park	Duluth	Coordinate with implementation of Lincoln Park Mini Master Plan (draft 2016).
Retrofit existing stormwater BMPs, where feasible	Upper watershed: commercial, industiral, and transportation areas	Duluth, Hermantown, St. Louis County, MnDOT, Lake Superior College	Evaluate existing BMPs for thermal reduction potential and implement projects based on outcomes
Improved water retention			*Note: See SAFL report 536 on baseflow augmentation scenarios.*
Mitigate the negative effects resulting from stream channelization	Upper watershed: Examples include: Haines Rd, below Duluth International Airport; US Hwy 53/Mall Drive, near Walmart; US Hwy 53/Haines Rd to Kohl's store; Mall Drive/Burning Tree Rd to Decker Rd. Lower watershed: Enger Park Golf Course, Lincoln Park, above 3rd St	Dependent on project	Feasibility and project scope is dependent on existing conditions and limitations (e.g., adjacent infrastructure) within the stream corridor and floodplain. Stream segment from US Hwy 53/Haines Rd to Kohl's store has completed design and is awaiting funding.
Restore and maintain wetland functions	Upper watershed: Ridgewood Rd to Lake Superior College. Lower watershed: Trinity Road to Lincoln Park	Upper watershed: Rice Lake, Duluth, Hermantown, St. Louis County, MnDOT; Lower watershed: Duluth, MnDOT	Update Miller Creek Wetland Functional Assessment and use this information to implement projects that will restore and maintain wetland condition and function.
Protect coldwater source waters	Upper watershed: US Hwy 53/Mall Drive near Walmart (and/or stream areas within brook trout potential) to Lake Superior College Lower watershed: Trinity Road to Lincoln Park. Entire watershed: wetlands and tributaries.	Rice Lake, Duluth, Hermantown, St. Louis County, MnDOT	Identify cold water inputs and sources. Implement projects that will maintain cold water inputs to Miller Creek.
Promote infiltration, where appropriate	Upper watershed: commercial, industrial, transporation, and residential areas	Duluth, Hermantown, St. Louis County, MnDOT	Identifiy areas with greatest infiltration potential and implement projects based on findings.
Other			*Note: See NRRI Macroinvertebrate, Habitat, and Temperature Report, St. Louis River Watershed Stressor Identification Report (draft), and applicalble DNR Fisheries management plans.*
Thermal refuge for brook trout	Upper watershed: US Hwy 53/Mall Drive near Walmart (and/or stream areas with potential for brook trout habitat) to Lake Superior College Lower watershed: Trinity Road to Lincoln Park	Upper watershed: Hermantown, Duluth, Lake Superior College; Lower watershed: Duluth, MnDOT	Determine cold water input locations and sources. Evaluate stream channel for thermal refuge for brook trout. In conjunction with DNR Fisheries staff, use this informatation to target creation, enhancement, and protection of thermal refuges in Miller Creek.
Temporary and permanent controls of land (conservation easements, management of public lands, purchase of private lands)	Upper watershed: riparian and wetland land owners in watershed	Duluth, Hermantown, St. Louis County, MnDOT, Lake Superior College	Undeveloped parcels containing wetlands, or stream channel and tributaries, especially those under pressure for development. Developed parcels containing wetlands, stream channel or tributaries (e.g., formal or informal conservation easements).

Notes:
Upper watershed equals headwaters to Lake Superior College.
Lower watershed equals Lake Superior College to St. Louis River.

Appendix B: TMDL Supporting Documents

Analysis of Flow Data from Miller Creek, Duluth, Minnesota. University of Minnesota St. Anthony Falls Laboratory Project Report No. 522

https://www.pca.state.mn.us/sites/default/files/wq-iw10-07n.pdf

Analysis of Stream Temperature Data from Miller Creek, Duluth, Minnesota. University of Minnesota St. Anthony Falls Laboratory Project Report No. 529

https://www.pca.state.mn.us/sites/default/files/wq-iw10-07o.pdf

Stream Temperature Modeling of Miller Creek, Duluth, Minnesota. University of Minnesota St. Anthony Falls Laboratory Project Report No. 535

https://www.pca.state.mn.us/sites/default/files/wq-iw10-07p.pdf

Streamflow Modeling of Miller Creek, Duluth, Minnesota. University of Minnesota St. Anthony Falls Laboratory Project Report No. 536

https://www.pca.state.mn.us/sites/default/files/wq-iw10-07q.pdf

Characterization of Stream Temperature and Heat Loading for Miller Creek, Duluth, Minnesota. University of Minnesota St. Anthony Falls Laboratory Project Report No. 552

https://www.pca.state.mn.us/sites/default/files/wq-iw10-07s.pdf

Miller Creek Macroinvertebrate, Habitat, and Temperature Report. NRRI Technical Report Number NRRI/TR-2010/11

https://www.pca.state.mn.us/sites/default/files/wq-iw10-07r.pdf

Miller Creek Diagnostic Study and Implementation Plan: Clean Water Partnership Phase I Report, South St. Louis Soil and Water Conservation District

http://www.lakesuperiorstreams.org/archives/MILLER_final.pdf