Final Duluth Urban Area Watershed Restoration and Protection

TETRA TECH

MINNESOTA POLLUTION CONTROL AGENCY

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Key Terms

Assessment Unit Identifier (AUID): The unique water body identifier for each water body or river reach comprised of the USGS eight-digit Hydrologic Unit Code (HUC) plus a three-character code unique within each HUC.

Aquatic life impairment: The presence and vitality of aquatic life is indicative of the overall water quality of a stream. A stream is considered impaired for impacts to aquatic life if the fish Index of Biotic Integrity (IBI), macroinvertebrate IBI, dissolved oxygen, turbidity, or certain chemical standards are not met.

Aquatic recreation impairment: Streams and beaches are considered impaired for impacts to aquatic recreation if fecal bacteria standards are not met. Lakes are considered impaired for impacts to aquatic recreation if total phosphorus, chlorophyll-a, or Secchi disc depth standards are not met.

Hydrologic Unit Code (HUC): A Hydrologic Unit Code (HUC) is assigned by the USGS for each watershed. HUCs are organized in a nested hierarchy by size. For example, the Saint Louis River watershed is assigned a HUC8 of 04010201 and the Saint Louis Bay watershed is assigned a HUC10 of 0401020116.

Impairment: Water bodies are listed as impaired if water quality standards are not met for designated uses including aquatic life, aquatic recreation, and aquatic consumption.

Index of Biotic Integrity (IBI): A method for describing water quality using characteristics of aquatic communities, such as the types of fish and invertebrates found in the water body. It is expressed as a numerical value between 0 (lowest quality) to 100 (highest quality).

Protection: This term is used to characterize actions taken in watersheds of waters not known to be impaired to maintain conditions and beneficial uses of the water bodies.

Restoration: This term is used to characterize actions taken in watersheds of impaired waters to improve conditions, eventually to meet water quality standards and achieve beneficial uses of the water bodies.

Source (or Pollutant Source): This term is distinguished from 'stressor' to mean only those actions, places or entities that deliver/discharge pollutants (e.g., sediment, phosphorus, pathogens).

Stressor (or Biological Stressor): This is a broad term that includes both pollutant sources and non-pollutant sources or factors (e.g., altered hydrology, dams preventing fish passage) that adversely impact aquatic life.

Total Maximum Daily Load (TMDL): A calculation of the maximum amount of a pollutant that may be introduced into a surface water and still ensure that applicable water quality standards for that water are met. A TMDL is the sum of the waste load allocation for point sources, a load allocation for nonpoint sources and natural background, an allocation for future growth (i.e., reserve capacity), and a margin of safety as defined in the Code of Federal Regulations.

Executive Summary

The State of Minnesota has adopted a watershed approach to address the state's 80 major watersheds, denoted by an 8-digit hydrologic unit code or HUC. This watershed approach incorporates water quality assessment, watershed analysis, public participation, planning, implementation, and measurement of results into a 10-year cycle that addresses both restoration and protection. The scientific findings regarding water quality conditions and strategies for addressing them are incorporated into a Watershed Restoration and Protection Strategy (WRAPS) report. This WRAPS report addresses the waterbodies within the Duluth Urban Area in northeastern Minnesota. This watershed contains a portion of the St. Louis River major watershed (HUC 04010201), a portion of the Lake Superior South Watershed (HUC 04010102), and includes all of the developed areas in the Duluth area and surrounding communities. The watershed is 141 square miles and lies within the Northern Lakes and Forest ecoregion. The dominant land use is residential and the dominant land cover is forest.

Fourteen assessment units in the watershed were assessed by the Minnesota Pollution Control Agency (MPCA) to identify impaired waters and waters in need of protection. Seven stream reaches were identified as having impaired aquatic recreation due to elevated bacteria levels, and four reaches were identified as having impaired aquatic life due to elevated total suspended solids (TSS) levels. Five Lake Superior beaches are also impaired due to high levels of *Escherichia coli (E. coli).* All impaired streams and beaches require restoration activities. In addition, all waters in the watershed require protection in some capacity, including those listed as impaired. A variety of factors were considered in protection efforts including: stream biological integrity, water quality, instream temperature sensitivity to climate change, development pressure, and potential impacts to Lake Superior.

Restoration and protection strategies for implementation in the Duluth Urban Area watershed aim to improve water quality in impaired streams and preserve, enhance, and protect water quality in non-impaired waters. Strategies include: stormwater management improvements, addressing sources of untreated wastewater (e.g., failing septic systems, leaky infrastructure), stream crossing and culvert improvements, wetland management, streambank stabilization and riparian management, pet and wildlife waste management, land use planning and ordinance development, forest management, and education and outreach efforts. Targeted geographic areas for implementation include Keene Creek, Merritt Creek, Miller Creek, Chester Creek, Tischer Creek, and Amity Creek watersheds. These watersheds are recommended for early implementation efforts.

A Core Team of local, state, and federal resource management agency staff participated in the WRAPS process and provided valuable input. The WRAPS report is supported by and summarizes previous work including the St. *Louis River Monitoring and Assessment Report* (MPCA 2013), *Lake Superior - South Monitoring and Assessment Report* (MPCA 2014), the *St. Louis River Watershed Stressor Identification* (MPCA 2016), the *Lake Superior - South Stressor Identification Report* (MPCA 2017a), the *Revised Duluth Urban WRAPS HSPF Model* (Tetra Tech 2019), Duluth Urban Area Streams TMDL (MPCA 2020), the draft simulation of watershed response to climate change (Tetra Tech 2017), *Duluth Urban Streams, An Implementation Focuses Assessment of Six Streams* (SSLSWCD 2017), and others.

What is the WRAPS Report?

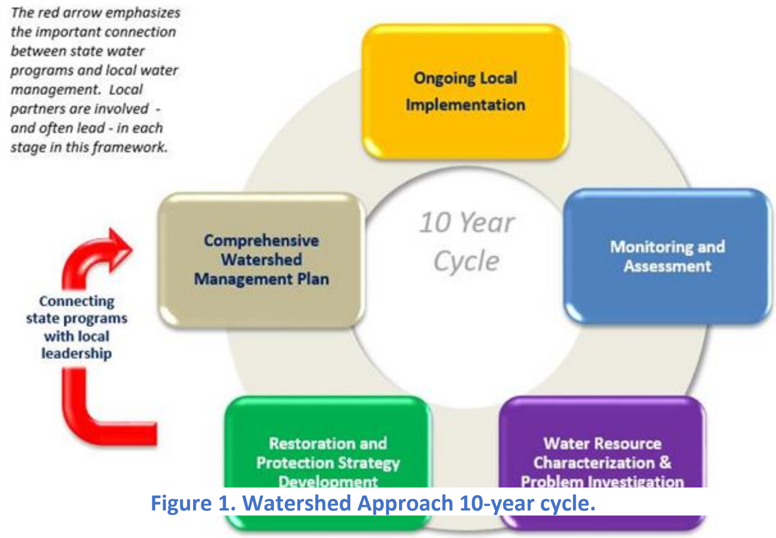


Figure 1. Watershed Approach 10-year cycle.

Minnesota has adopted a watershed approach to address the state's 80 major watersheds. The Minnesota Watershed Approach incorporates **water quality assessment, watershed analysis, public participation, planning, implementation,** and **measurement of results** into a 10-year cycle that addresses both restoration and protection (Figure 1).

As part of the watershed approach, the MPCA developed a process to identify and address threats to water quality in each of these major watersheds. This process is called WRAPS development. WRAPS reports have two parts: impaired waters have strategies for restoration, and waters that are not impaired have strategies for protection.

Waters not meeting state standards are listed as impaired and Total Maximum Daily Load (TMDL) studies are developed for them. TMDLs are incorporated into WRAPS. The watershed approach process facilitates a cost-effective and comprehensive characterization of multiple water bodies and overall watershed health, including both protection and restoration efforts. A key aspect of this effort is to develop and utilize watershed-scale data and other tools to identify strategies and actions for point and nonpoint source pollution that will cumulatively achieve water quality targets. For nonpoint source pollution, this report informs local planning efforts, but ultimately the local partners decide what work will be included in their local plans. This report also serves as a watershed plan to partially address the Environmental Protection Agency's (EPA's) Nine Minimum Elements of watershed planning, helping to qualify applicants for Clean Water Act Section 319 implementation funds.

1. Watershed Background and Description

The Duluth Urban Area WRAPS was created in recognition of the area's physical characteristics and role as the largest metropolitan area in Northeastern Minnesota. The Duluth Metropolitan Area (DMA), includes nine communities, and is split into two major watersheds. As the western terminus of Lake Superior, the DMA is also a major population center and transportation and transshipment hub for railroads, motor vehicles, commercial and recreational ship traffic. The DMA functions as a cohesive whole, with a high degree of daily mobility based on employment, trade and place of residence. The local governments recognize their shared interests by participating in planning organizations like the Metropolitan Interstate Committee, the Harbor Technical Advisory Committee, and the Regional Storm Water Protection Team. The Duluth Urban Area WRAPS is an extension of that same idea applied to the management of watersheds.

For the purposes of this plan, the "Duluth Urban Area Watershed" consists of the portions of the St. Louis River major watershed (HUC 04010201) and the Lake Superior South Watershed (HUC 04010102) that include all of the developed areas in the Duluth area and surrounding communities from Mission Creek to the Lester River (Figure 2). The remaining portions of the St. Louis River Watershed and Lake Superior South Watershed are being addressed as part of separate WRAPS efforts applicable to each of those specific watersheds.

The Duluth Urban Area Watershed is in Northeastern Minnesota in the Lake Superior Basin, and in the Northern Lakes and Forests ecoregion. The watershed is 141 square miles and covers portions of Carlton and St. Louis counties. The entire study area of this WRAPS is in the St. Louis River Area of Concern (AOC) designated under Annex Two of the United States and Canada Great Lakes Water Quality Agreement in 1987. In addition to the restoration and protection strategies defined in this WRAPS, the EPA and other federal and state agencies are working to restore the beneficial uses within the Area of Concern, pursuant to separate and additional plans and activities primarily focused on the St. Louis River Estuary.

The dominant land use in the watershed is residential and the dominant land cover is forest (Figure 3 and Table 1). Various types of development constitute the majority of the remaining land cover, with grassland/shrub, outcrops and wetlands each making up less than 5% of the watershed as a whole. The watershed includes 16 designated trout streams, and is well known for its abundance of scenic and high quality waters. However, 11 trout streams and several beaches do not meet water quality standards for aquatic life or recreational uses.

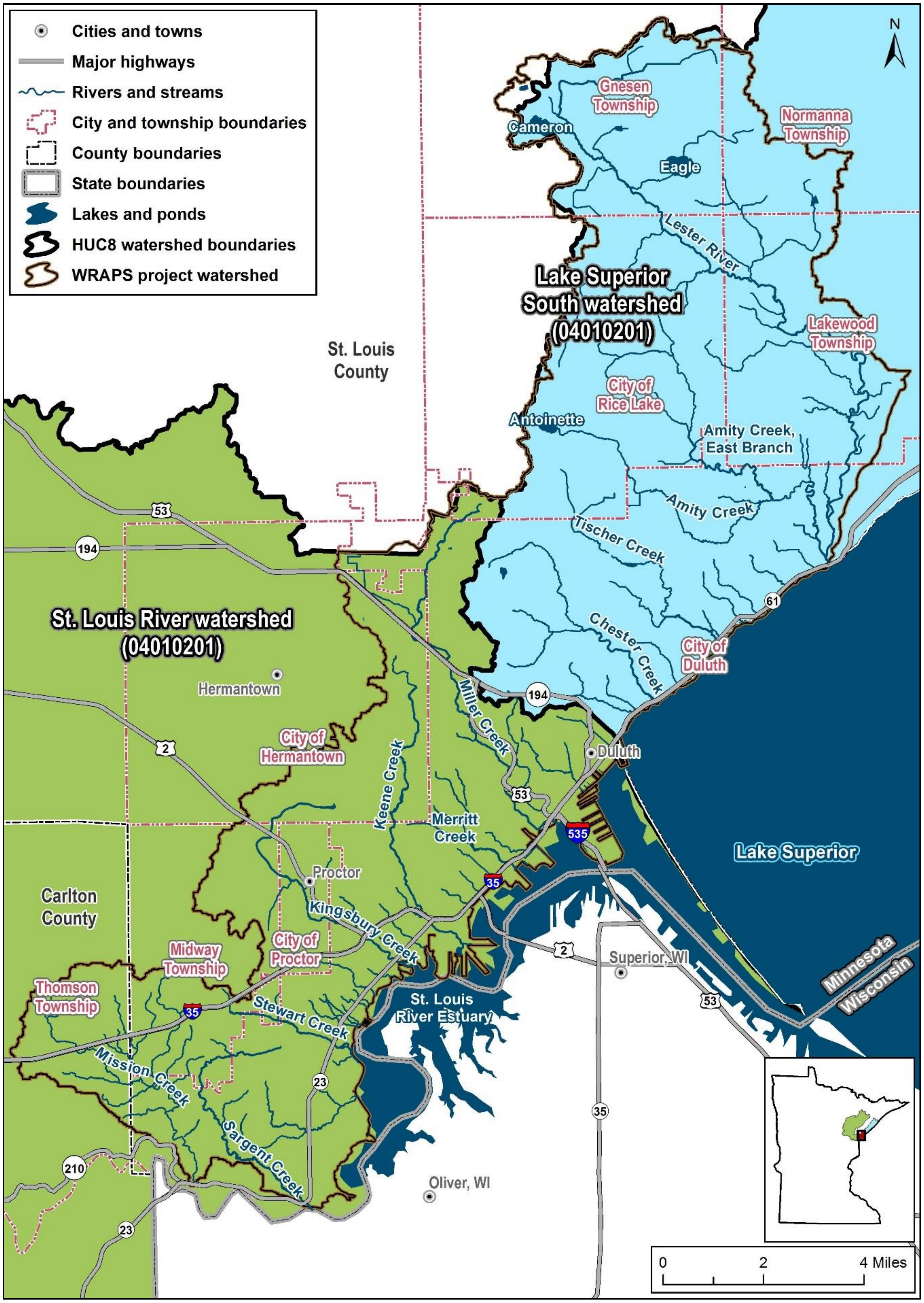


Figure 2. Duluth Urban Area Watershed.

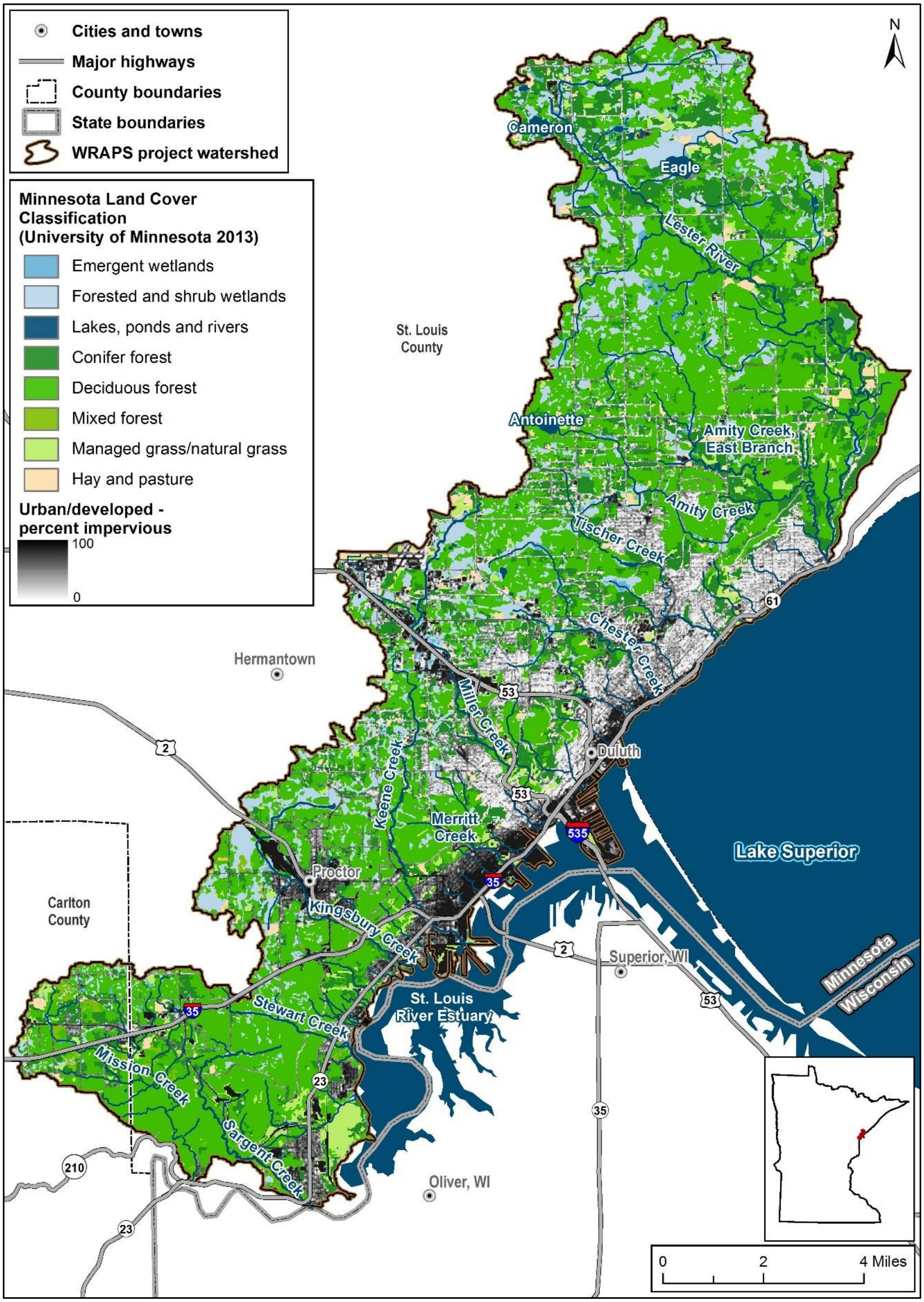


Figure 3. Land use in the watershed.

Table 1. Land use/land cover summary (University of Minnesota 2013)

See Figure 4 and Figure 5 for stream locations.

Water Body Name (AUID)	Use Class [a]	Watershed Areas (acres)	Percent of Watershed (%)													
			Natural Land Covers								Developed/Disturbed Land Covers					
			Deciduous Forest	Conifer Forest	Mixed Forest	Managed/Natural Grass	Forested and Shrub Wetlands	Emergent Wetlands	Lakes, Ponds, and Rivers	*Total Natural Land Cover*	Hay and Pasture	0 – 25% Impervious	26 – 50% Impervious	51 – 75% Impervious	76 – 100% Impervious	*Developed/Disturbed Land Cover*
32nd Ave W Creek (04010201-No AUID)	-	507	5	20	0	6	0	0	0	*31*	2	16	9	11	31	*69*
37th Ave E Creek (04010102-No AUID)	-	40	0	55	0	13	0	0	0	*68*	0	16	10	6	0	*32*
40th Ave E Creek (04010102-999)	-	308	3	28	0	15	0	0	0	*46*	4	32	12	4	2	*54*
41st Ave W Creek (04010201-No AUID)	-	293	32	2	0	2	6	0	0	*42*	0	2	5	15	36	*58*
43rd Ave E Creek (04010102-999)	-	537	13	15	0	9	0	0	0	*37*	3	42	16	2	0	*63*
44th Ave W Creek (04010201-999)	-	261	18	1	0	2	0	1	0	*22*	0	3	7	20	48	*78*
47th Ave E Creek (04010102-999)	-	434	13	13	0	1	0	0	0	*27*	0	50	17	5	1	*73*
49th Ave W Creek (04010201-No AUID)	-	736	25	7	0	3	1	0	0	*36*	3	2	7	16	36	*64*
58th Ave E Creek (04010102-999)	-	345	14	7	0	1	0	0	0	*22*	0	48	23	6	1	*78*
62nd Ave W Creek (04010102-999)	-	632	44	8	0	9	2	0	0	*63*	0	5	12	12	8	*37*
68th Ave W Creek (04010201-No AUID)	-	88	54	0	0	7	0	2	0	*63*	3	3	8	14	9	*37*

Water Body Name (AUID)	Use Class [a]	Watershed Areas (acres)	Percent of Watershed (%)													
			Natural Land Covers								Developed/Disturbed Land Covers					
			Deciduous Forest	Conifer Forest	Mixed Forest	Managed/Natural Grass	Forested and Shrub Wetlands	Emergent Wetlands	Lakes, Ponds, and Rivers	*Total Natural Land Cover*	Hay and Pasture	0 – 25% Impervious	26 – 50% Impervious	51 – 75% Impervious	76 – 100% Impervious	*Developed/Disturbed Land Cover*
82nd Ave W Creek (04010201-999)	-	436	43	12	0	2	1	1	0	*59*	1	4	10	14	12	*41*
84th Ave W Creek (04010201-No AUID)	-	29	32	24	0	31	0	1	0	*88*	0	4	2	2	4	*12*
85th Ave W Creek (04010201-No AUID)	-	95	52	25	0	12	1	0	0	*90*	0	2	3	3	2	*10*
Amity Creek (04010102-511)	2A	10,568	55	17	0	2	8	1	1	*84*	3	7	5	1	0	*16*
Bent Creek (04010102-999)	-	291	0	7	0	0	0	0	0	*7*	0	60	28	5	0	*93*
Bowser St Creek (04010201-No AUID)	-	147	10	15	0	5	0	1	0	*31*	4	8	13	14	30	*69*
Brewery Creek (04010102-C14)	2B	1,093	11	14	0	2	3	0	0	*30*	1	32	18	10	9	*70*
Buckingham Creek (04010201-A62)	2B	811	37	22	0	2	1	0	1	*63*	2	24	6	3	2	*37*
Chester Creek (04010102-545)	2A	4,315	37	15	0	1	14	3	0	*70*	2	13	9	4	2	*30*
Clarkhouse Creek (04010201-999)	-	359	9	10	0	3	1	0	0	*23*	0	29	15	10	23	*77*
Coffee Creek (04010201-A83)	2B	884	27	12	0	5	2	1	1	*48*	3	19	14	8	8	*52*
E Br Amity Creek (04010102-540)	2A	5,237	59	15	0	2	9	2	1	*88*	2	5	4	1	0	*12*

Water Body Name (AUID)	Use Class [a]	Watershed Areas (acres)	Percent of Watershed (%)													
			Natural Land Covers								Developed/Disturbed Land Covers					
			Deciduous Forest	Conifer Forest	Mixed Forest	Managed/Natural Grass	Forested and Shrub Wetlands	Emergent Wetlands	Lakes, Ponds, and Rivers	*Total Natural Land Cover*	Hay and Pasture	0 – 25% Impervious	26 – 50% Impervious	51 – 75% Impervious	76 – 100% Impervious	*Developed/Disturbed Land Cover*
Gogebic Creek (04010201-999)	-	149	79	4	0	2	2	0	0	*87*	0	4	4	3	2	*13*
Greys Creek (04010102-999)	-	341	1	11	0	0	0	0	0	*12*	2	43	25	12	6	*88*
Heard St Creek (04010201-No AUID)	-	76	7	30	0	8	1	1	0	*47*	0	6	15	24	8	*53*
Keene Creek (04010201-627)	2A	4,029	39	14	0	2	13	2	1	*71*	2	7	8	7	5	*29*
Kingsbury Creek (04010201-626)	2A	6,012	35	11	1	2	20	1	1	*71*	2	3	6	9	9	*29*
Knowlton Creek (04010201-985)	2B	1,362	57	10	1	3	9	1	1	*82*	1	1	4	5	7	*18*
Lenroot Creek (04010201-999)	-	198	74	6	0	0	11	0	0	*91*	0	2	3	3	1	*9*
Lester River (04010102-549)	2A	34,240	48	20	0	2	15	2	2	*89*	3	4	3	1	0	*11*
Merritt Creek (04010201-987)	2B	1,412	42	11	0	4	7	0	0	*64*	1	13	8	6	8	*36*
Miller Creek (04010201-512)	2A	6,212	19	14	0	2	13	2	1	*51*	4	15	11	9	10	*49*
Mission Creek (04010201-640)	2B	6,954	57	12	4	3	4	1	1	*82*	2	2	5	5	4	*18*

Water Body Name (AUID)	Use Class [a]	Watershed Areas (acres)	Percent of Watershed (%)													
			Natural Land Covers								Developed/Disturbed Land Covers					
			Deciduous Forest	Conifer Forest	Mixed Forest	Managed/Natural Grass	Forested and Shrub Wetlands	Emergent Wetlands	Lakes, Ponds, and Rivers	*Total Natural Land Cover*	Hay and Pasture	0 – 25% Impervious	26 – 50% Impervious	51 – 75% Impervious	76 – 100% Impervious	*Developed/Disturbed Land Cover*
Morgan Park Creek (04010201-999)	-	578	68	10	1	0	2	0	0	*81*	0	3	6	6	4	*19*
Oregon Creek (04010102-No AUID)	-	508	0	2	0	2	0	0	0	*4*	1	42	29	15	9	*96*
Sargent Creek (04010201-848)	2A	1,964	73	3	6	3	4	0	0	*89*	1	1	3	3	3	*11*
Stewart Creek (04010201-884)	2A	1,108	74	2	2	0	9	1	0	*88*	0	3	5	3	1	*12*
Tischer Creek (04010102-544)	2A	4,767	28	23	0	1	8	2	1	*63*	2	18	12	4	1	*37*
US Steel Creek (04010201-999)	-	1,857	52	5	1	17	2	1	0	*78*	0	2	5	7	8	*22*

a. Not all streams are assessed, therefore no use class assigned (indicated as -).

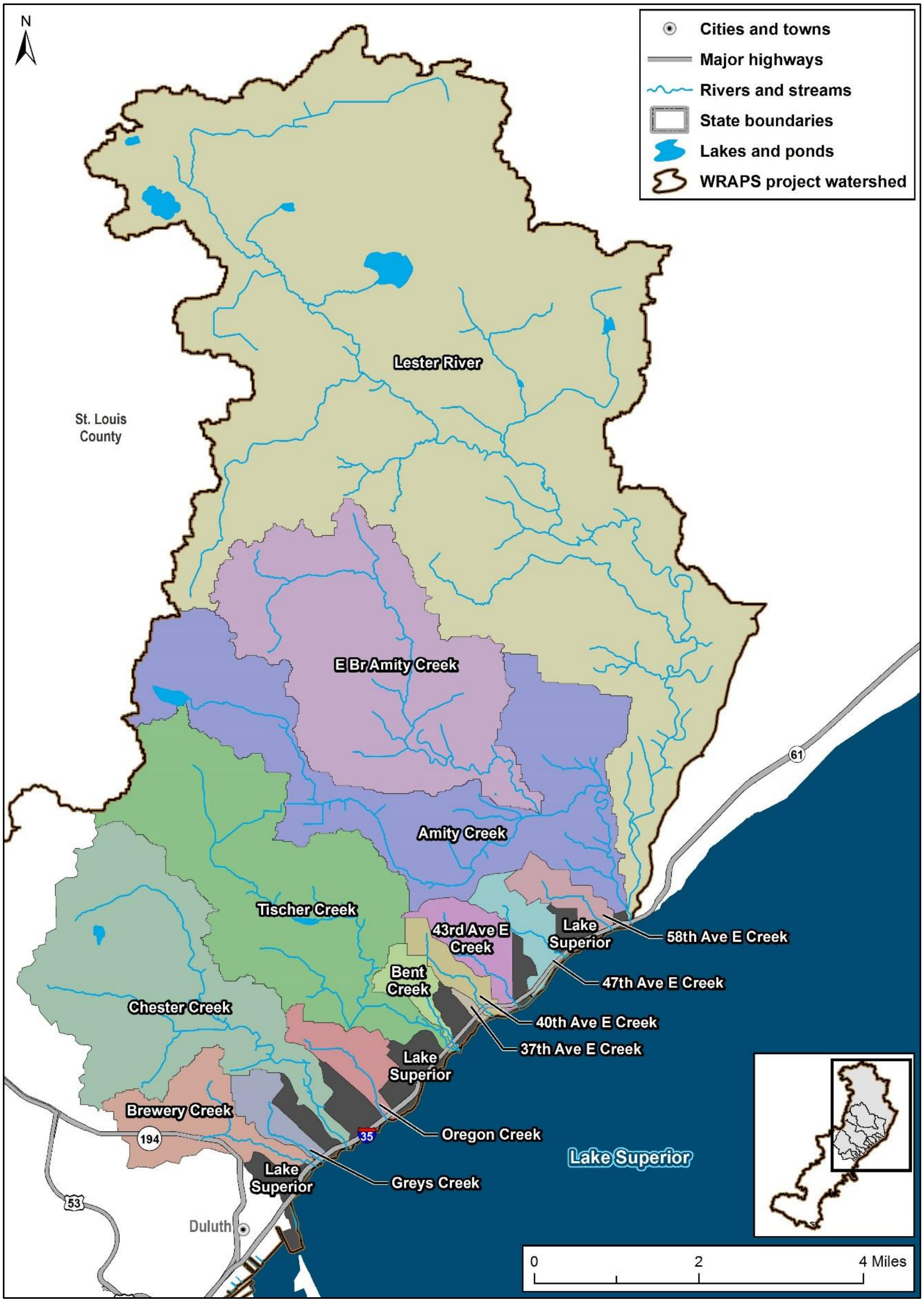


Figure 4. City of Duluth– Frontal Lake Superior streams.

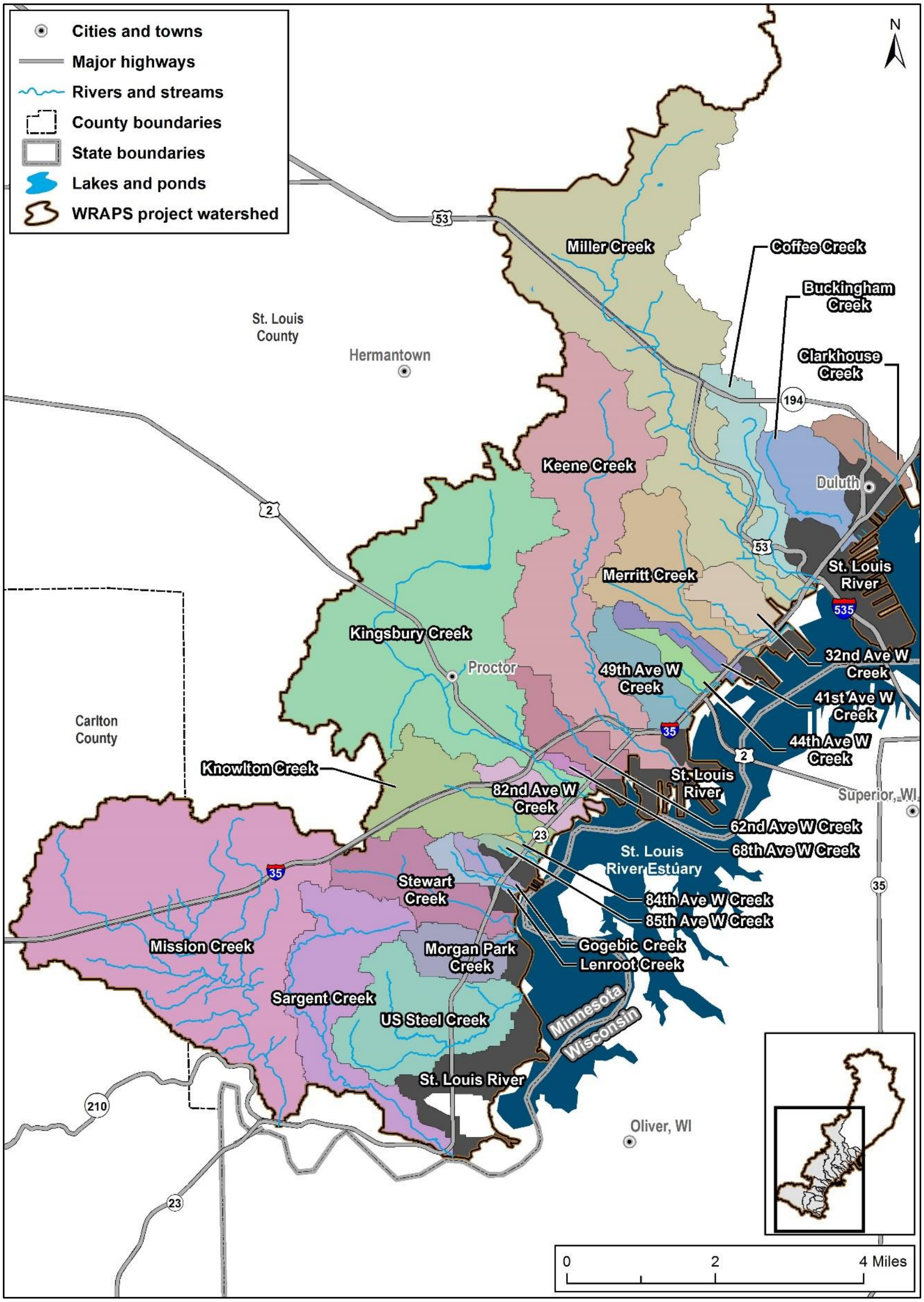


Figure 5. St. Louis River Estuary streams.

2. Watershed Conditions

The watershed is dominated by a stream network of small perennial and intermittent streams draining to the St. Louis River Estuary and Lake Superior. The watershed transitions in stream morphology from slower flowing, meandering gravel bed streams upstream of the bluff line to high gradient, faster flowing bedrock-controlled streams near the estuary and Lake Superior. The watershed contains the Duluth Urban Area with varying levels of development in each stream's watershed (Figure 3 and Table 1). Development is typically densest near the St. Louis River Estuary and along Lake Superior.

2.1 Condition Status

The MPCA assesses the water quality of streams and lakes based on each water body's ability to support aquatic life (e.g., fish and macroinvertebrates) and aquatic recreation (e.g., fishing and swimming). Data from the water bodies are compared to state standards and targets. Water bodies that meet targets are considered to be unimpaired and are the focus of protection efforts; water bodies that do not meet at least one target are considered to be impaired and are the focus of restoration efforts. Waters not yet assessed continue through a process of data collection and evaluation and can be candidates for protection work. In the watershed, there are 11 impaired streams and 5 impaired beaches on the 2018 impaired waters list (Figure 6). Two of the beaches (Clyde Avenue Boat Landing and Leif Erikson Park) are located near outlets of impaired streams, and the potential exists for some relationship between the impaired beach and the adjacent impaired stream. A more recent data review also indicates Boy Scout Landing Beach is triggering impairment. That beach is listed on the 2020 draft impaired waters list.

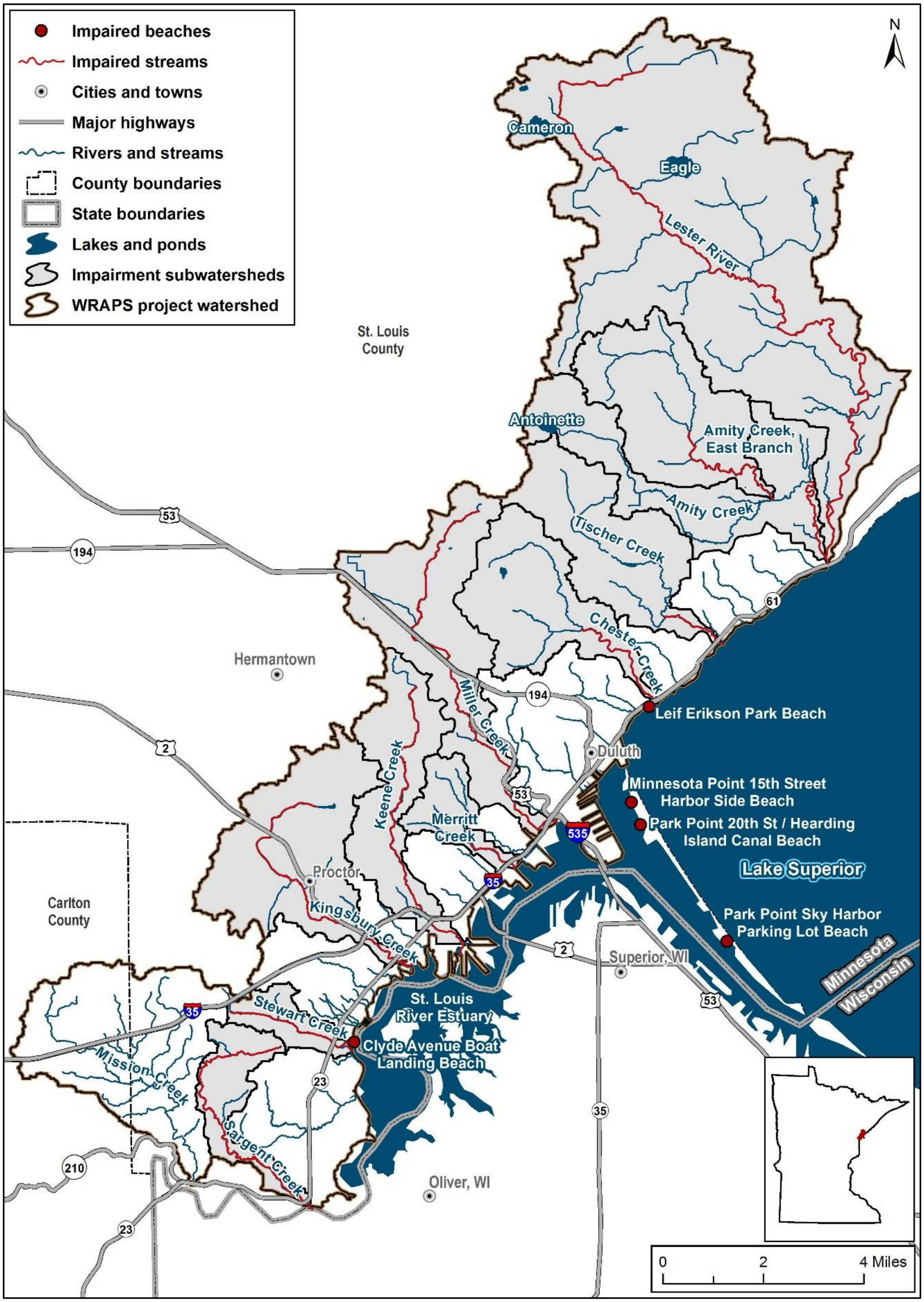


Figure 6. Impaired waters (2018 impaired waters list). Note: Boy Scout Landing Beach was proposed impaired on the 2020 draft impaired waters list.

Streams

Fourteen assessment units in the watershed were assessed by the MPCA to identify impaired waters and waters in need of protection (Table 2; MPCA 2013, MPCA 2014). Waters that did not meet targets for fish assemblage, macroinvertebrate assemblage, dissolved oxygen, turbidity, chloride, pH, or ammonia were considered not meeting the aquatic life beneficial use. Waters that did not meet the targets for fecal indicator bacteria were not meeting the aquatic recreation beneficial use; levels of the bacteria *E. coli* were used to approximate the amount of fecal contamination in surface waters. Seven stream reaches were identified as having impaired aquatic recreation due to bacteria and four reaches were identified as having impaired aquatic life due to TSS.

Water quality data are summarized in this section and represent data collected between 2007 and 2016 at sites with greater than five sample points. In addition to the assessed waters in Table 2, there are many other streams in the Duluth Urban Area Watershed (Figure 4 and Figure 5). Water quality summaries are provided for these streams when available. Note that the water quality summaries include data that were unavailable for the MPCA's assessments and are reflected in Table 2 (i.e., data collected after the assessment took place).

The number of *E. coli* exceedances at each sample site is provided in Figure 7. Exceedances of the *E. coli* individual sample water quality standard (1,260 org/100 mL) reflect the impaired status of several streams. While not included in the figure, exceedances of the monthly geometric mean water quality standard (126 org/100 mL) also occur.

Figure 8 and Figure 9 summarize the water quality data by stream for TSS and phosphorus. These box and whisker plots provide the median concentration and show the variability in sample concentrations. Several sites show high concentrations of phosphorus (greater than 0.05 mg/L); however, there are no known impairments related to high nutrient concentrations and associated algal growth. TSS data suggest that several streams may be threatened by high sediment loadings and may require additional restoration strategies. Applicable TSS water quality standards are 10 mg/L for 2A streams or 15 mg/L for 2B streams in this region, depending on the stream.

Figure 10 summarizes chloride concentrations in monitored streams. Lester River and Buckingham Creek have the lowest monitored concentrations; several streams have higher concentrations of chloride, with Miller Creek and Chester Creek having the highest monitored levels.

Table 2. Assessment status of streams (MPCA 2013, MPCA 2014)

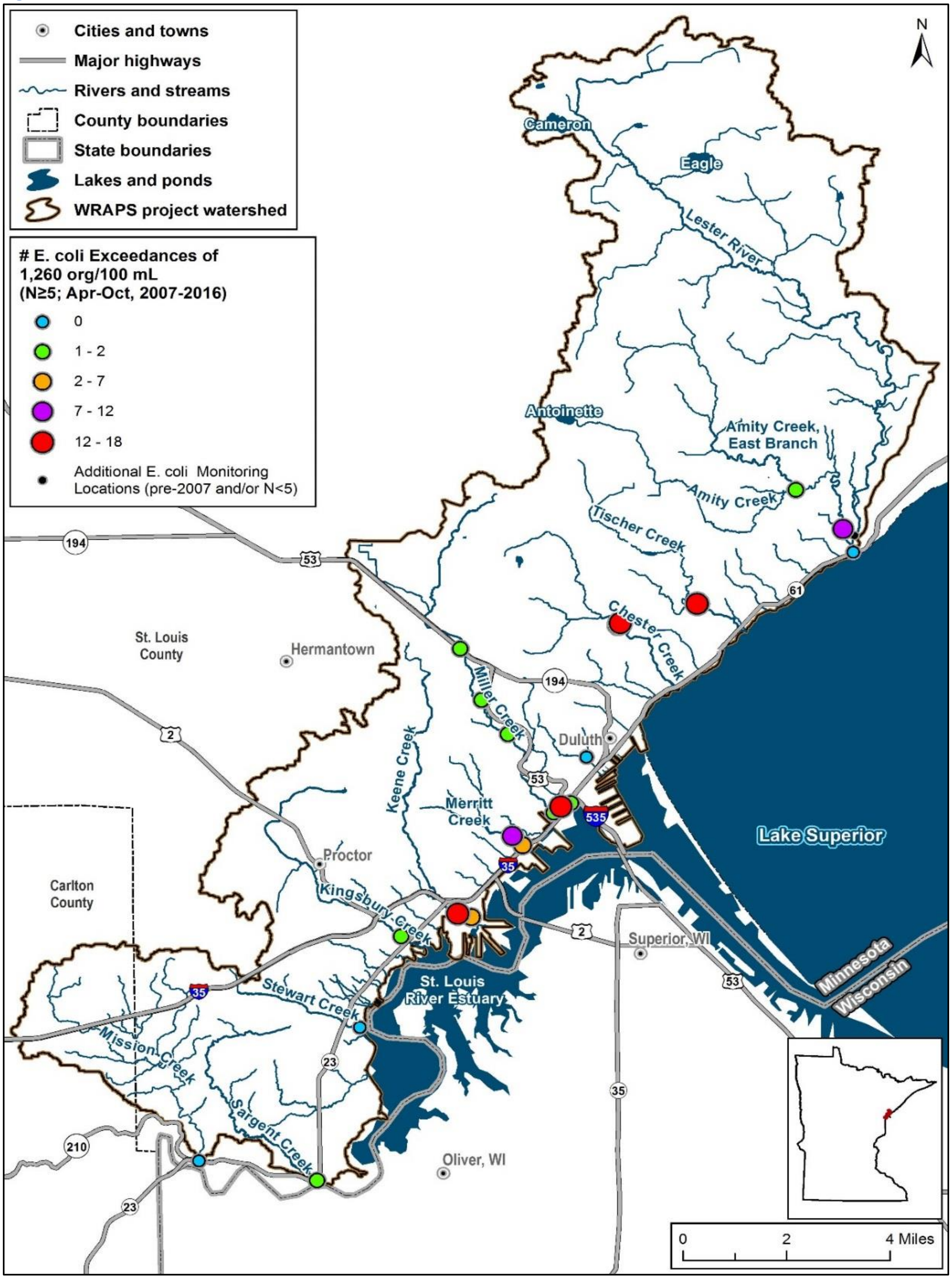
HUC10 Subwatershed	AUID (Last 3 digits)	Stream	Reach Description	Aquatic Life								Aquatic Recreation
				Fish Index of Biotic Integrity	Macroinvertebrate Index of Biotic	Dissolved Oxygen	Turbidity/TSS	Chloride	pH	NH_3	Pesticides	Bacteria
City of Duluth – Frontal Lake Superior (0401010204)	511	Amity Creek	Unnamed Creek to Lester River	Sup	Sup	Sup	Imp	Sup	Sup	Sup	NA	NA
	540	Amity Creek, East Branch	Unnamed Creek to Amity Creek	Sup	Sup	Sup	Imp	Sup	Sup	Sup	NA	IF
	543	Tischer Creek	Unnamed Creek to Unnamed Creek	Sup	Sup	NA	Sup	NA	NA	NA	NA	NA
	544	Tischer Creek	Unnamed Creek to Lake Superior	IF	Sup	IF	--[a]	Sup	Sup	Sup	NA	Imp
	545	Chester Creek	East Branch Chester Creek to Lake Superior	Sup	Sup	Sup	IF	Sup	Sup	Sup	NA	Imp
	549	Lester River	T52 R14W S23, North Line to Lake Superior	Sup	Sup	Sup	Imp	Sup	Sup	Sup	NA	Sup
St. Louis Bay (0401020116)	512	Miller Creek [b]	Headwaters to Lake Superior	Sup	Imp	Sup	IF	Imp	Sup	Sup	NA	Imp
	567	Mission Creek	S5, South Line	Sup	NA	NA	NA	NA	NA	NA	NA	NA
St. Louis Bay (cont.) (0401020116)	626	Kingsbury Creek [c]	Mogie Lake to St. Louis River	Imp	Imp	NA	IF	Sup	NA	Sup	NA	IF
	627	Keene Creek	Headwaters to St. Louis River	Sup	Sup	Sup	Sup	NA	Sup	Sup	NA	Imp

HUC10 Subwatershed	AUID (Last 3 digits)	Stream	Reach Description	Aquatic Life								Aquatic Recreation
				Fish Index of Biotic Integrity	Macroinvertebrate Index of Biotic	Dissolved Oxygen	Turbidity/TSS	Chloride	pH	NH_3	Pesticides	Bacteria
	640	Mission Creek	T48 R15W S8, North Line to St. Louis River	NA	NA	NA	NA	NA	NA	Sup	NA	IF
	848	Sargent Creek	Headwaters to St. Louis River	NA	NA	NA	NA	NA	NA	Sup	NA	Imp
	884	Stewart Creek	T49 R15W S21, West Line to St. Louis River	NA	NA	NA	NA	NA	NA	Sup	NA	Imp
	987	Unnamed Creek (Merritt Creek)	Unnamed Creek to St. Louis River	NA	NA	IF	Sup	NA	Sup	IF	NA	Imp

Sup = found to meet the water quality standard, Imp = does not meet the water quality standard and therefore, is impaired, IF = the data collected was insufficient to make a finding, NA = not assessed

a. The monitoring and assessment report (MPCA 2013, MPCA 2014) identifies exceedances of the water quality standard; however, subsequent assessment determined that there was no aquatic life use impairment.
b. Additional impairments on Miller Creek are for aquatic life due to high water temperature and lack of a cold water assemblage.
c. TSS was deemed the stressor and a TMDL for TSS was completed.

Figure 7. Stream *E. coli* exceedances.



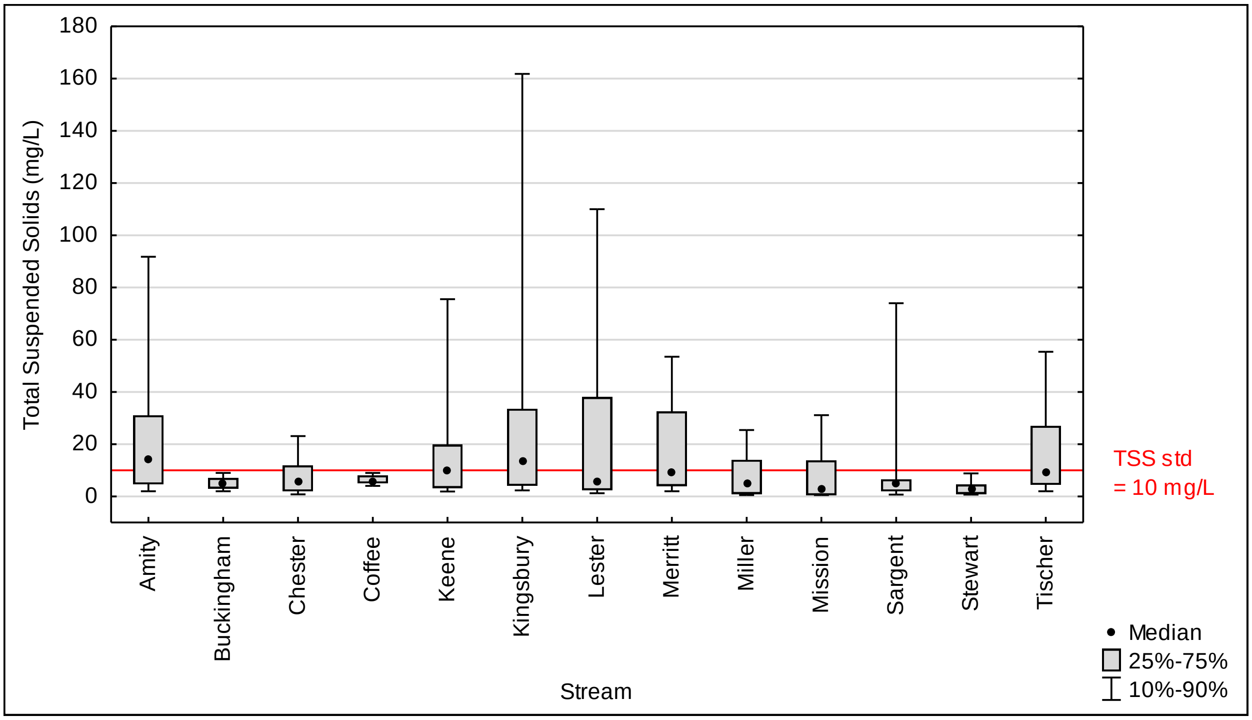


Figure 8. Total suspended solids concentrations by stream, April–September, 2007–2016.

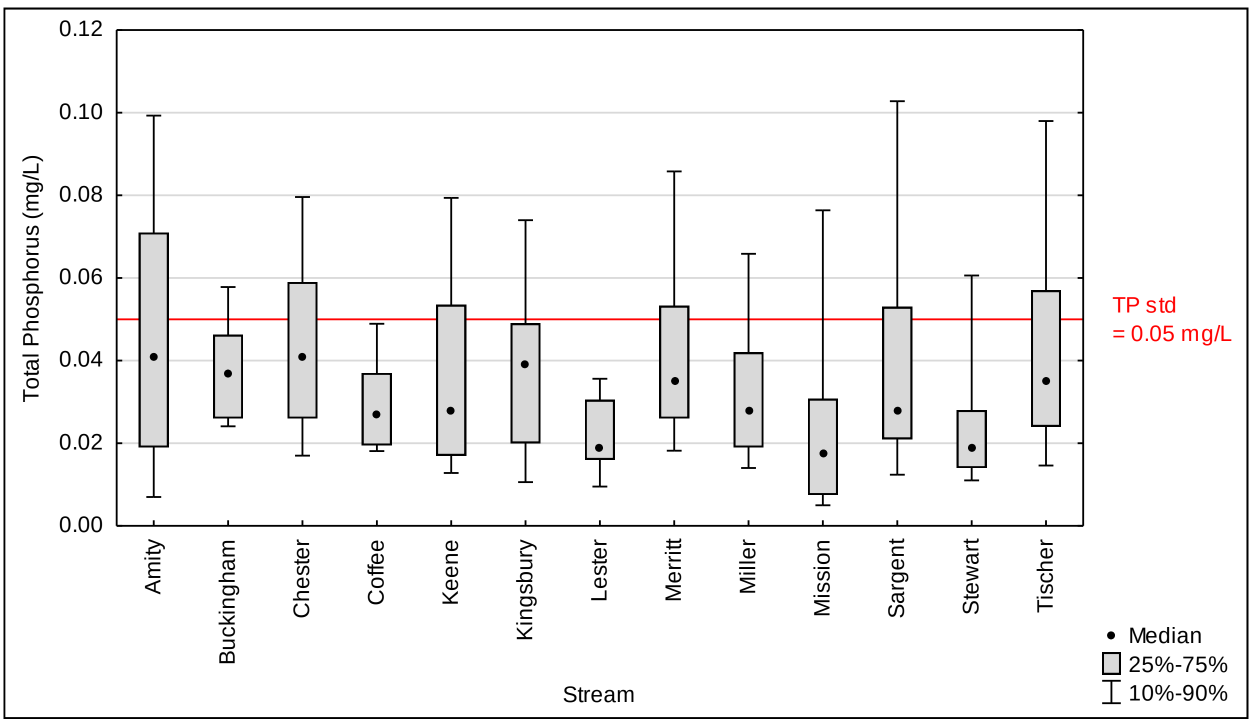


Figure 9. Total phosphorus concentrations by stream, April–September, 2007–2016.

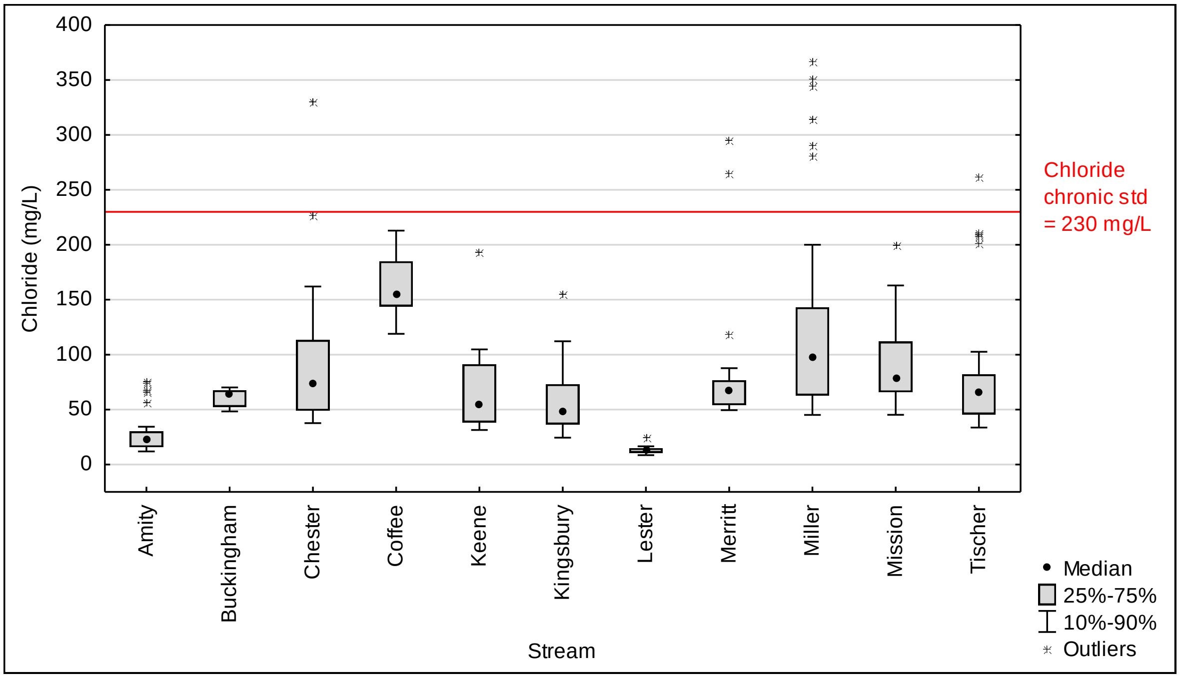


Figure 10. Chloride concentrations by stream, 2007–2016.

Beaches

Elevated fecal bacteria levels pose a human health threat, and beaches closed due to contamination can negatively impact tourism and the local economy. Routine beach monitoring to quantify *E. coli* bacteria levels is conducted by the Minnesota Department of Health (MDH) and partners at various locations as part of the Beaches Environmental Assessment and Coastal Health (BEACH) Act of 2000. This assessment includes monitoring sites along the St. Louis River Estuary and Lake Superior shoreline. The MDH conducts follow-up sampling after a high result from a routine beach sample. Re-sampling after a high result could bias results with a greater number of data being collected during periods of higher concentrations of *E. coli*. This could impact the percent of samples exceeded. MPCA assessment staff have indicated this bias is not likely with the data reviews and process. Samples and re-samples are evaluated during the initial assessment process and reviewed by a second team of external experts. The overall outcomes of supporting versus non-supporting sites show consistency in results over years of review.

E. coli water quality standards are applicable to recreational uses of beaches between April 1 and October 31. The standards are documented in the BEACH Act Rule and include:

- 126 organisms per 100 mL of water not to be exceeded as the geometric mean of not less than five samples in a calendar month.
- 235 organisms per 100 mL of water not to be exceeded by 10% of all samples taken in a calendar month, individually.

E. coli levels above water quality standards were observed at five beaches in the watershed (Figure 11), and were ultimately placed on the 303(d) list of impaired water bodies (Table 3).

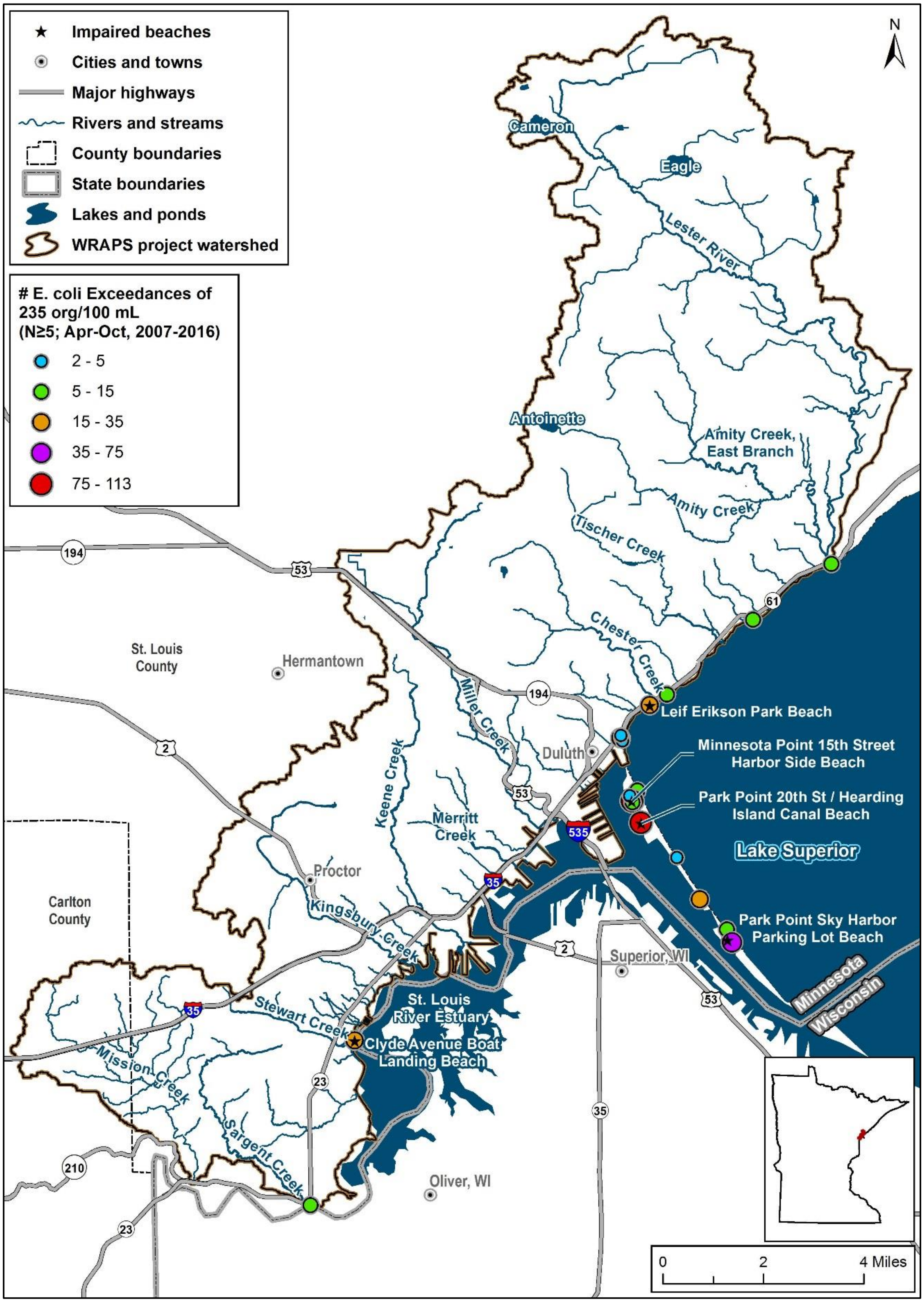


Figure 11. Beach *E. coli* exceedances.

Table 3. *E. coli* impaired beaches (2018 list of impaired waters)

Beach Name	Beach ID	Location Description
Leif Erickson Park Beach	04010102-C21	Near the outlet of Chester Creek
Clyde Avenue Boat Landing Beach	04010201-A91	Near the outlet of Stewart Creek
Park Point Sky Harbor Parking Lot Beach	04010201-A87	On the estuary side of Park Point; no bacteria impaired streams nearby
Park Point 20th St/Hearding Island Canal Beach [a]	04010201-A89	
Minnesota Point 15th St Harbor Side Beach	04010201-A90	

a. Regular monitoring is no longer occurring at this beach.

Lakes

Lakes are assessed for their ability to support aquatic recreation based on the level of eutrophication in the lake, which is determined by water transparency and levels of phosphorus and chlorophyll. Phosphorus is a nutrient that plants and algae need to grow, and chlorophyll is a measure of the amount of algae in the water. Eagle Lake, located in the headwaters of the Lester River, was assessed for the ability to support aquatic recreation (Table 4). Eagle Lake was found to meet the eutrophication standards. In addition to Eagle Lake, there are six other lakes or ponds in the watershed, not including Lake Superior and St. Louis Bay. Cameron and Antoinette are in the Lester River Subwatershed, Unnamed is in the Tischer Creek Subwatershed, and Twin, Lower Twin, and Upper Twin are in the Buckingham Creek Subwatershed. These lakes have not been assessed.

Table 4. Lake assessment status

HUC10 Subwatershed	Lake ID	Lake	Mean TP (µg/L)	Mean Chl-a (µg/L)	Secchi Mean (m)	Aquatic Recreation
City of Duluth – Frontal Lake Superior (0401010204)	69-0238-00	Eagle	32.7	9.4	2.8	Fully supporting

2.2 Water Quality Trends

Water quality trend information is provided for streams (Lester River and Amity Creek) and beaches. There are very limited water quality data on lakes in this watershed; therefore, trends in lake water quality are not discussed.

Streams

Long-term water quality data (1973 through 2016) were evaluated for the Lester River for pollutants of interest. The Lester River has the longest water quality data record in the watershed. The only significant trends are decreasing TSS and phosphorus concentrations, and increasing chloride concentrations in 1973 through 2010 (Table 5). There are no trends in the more recent period of 1995 through 2010.

Table 5. Lester River water quality trends

Analysis from *Lake Superior–South Watershed Monitoring and Assessment Report* (MPCA 2014). Analysis was performed on June–August medians, except for chloride which are year-round medians, using the Seasonal Kendall Test for Trends. Trends shown are significant at the 90% confidence level.

Parameter	Lester River above Superior St, Lester Park, Duluth (S000-258)	
	1973–2010	1995–2010
Total suspended solids	Decreasing	No trend
Phosphorus, total	Decreasing	No trend
Nitrate + nitrite	No trend	No trend
Ammonia	No trend	No trend
Biochemical oxygen demand	No trend	No trend
Chloride	Increasing	– [a]

a. Not enough data to evaluate trends over time.

TSS concentrations in Amity Creek (site S001-757) have fluctuated over time, with a maximum concentration of over 1,000 mg/L recorded in 2015 (Figure 12). Small scale improvements in water quality will take time to be noticeable on a graph such as Figure 12.

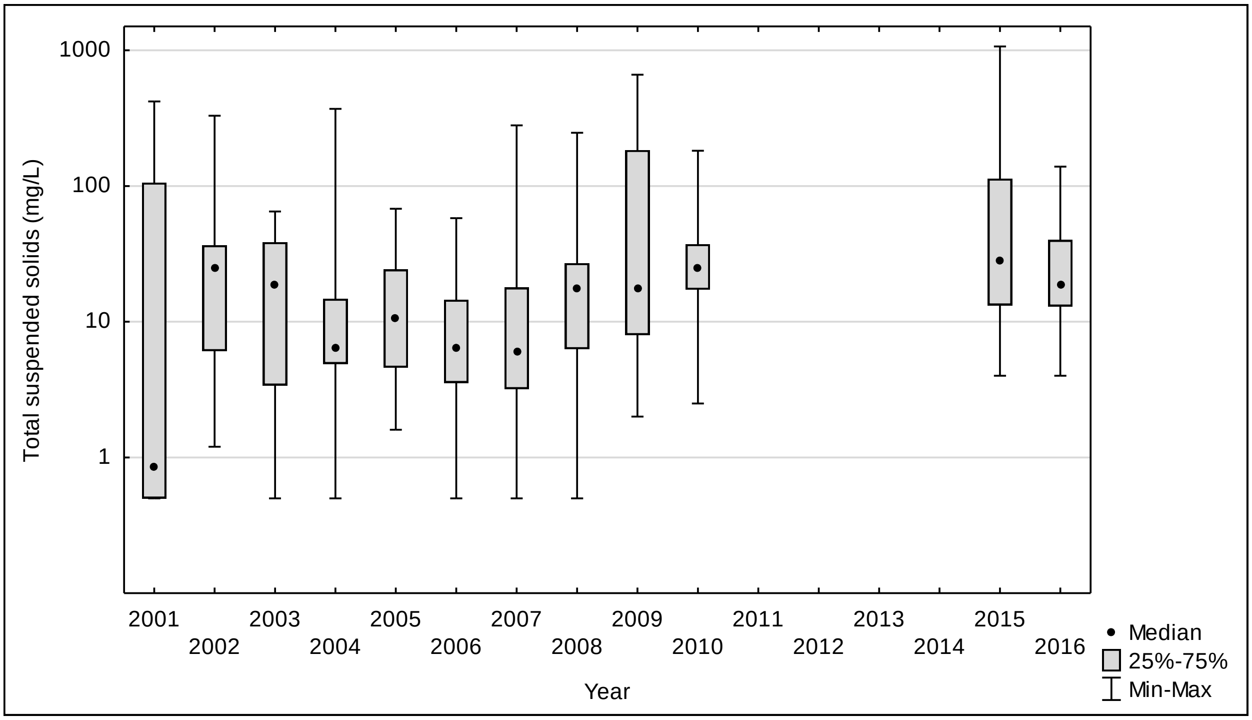


Figure 12. TSS concentrations (April–September) by year on Amity Creek on first bridge on Occidental Blvd, Duluth (S001-757).

Beaches

Beach *E. coli* data (2003 through 2016) were evaluated to describe trends in *E. coli* concentrations. A trend of increasing *E. coli* concentration (Kendall Tau correlation analyses on geometric means, $p<0.05$) was observed at the following Lake Superior beach monitoring sites in Duluth (Figure 14):

- St. Louis Bay, Park Point, Sky Harbor Lot (B004)
- Park Point, Lafayette Community Club (B005)
- Park Point at 13th Street (B006)
- Duluth Lake Walk Rest Rooms, Canal Park (B008)
- Leif Erikson Park (B009)
- 42nd Avenue (B010)
- Lester River mouth (B011)

Exceedances of the maximum *E. coli* standard were observed at all of the monitored beaches, and the annual percent of the *E. coli* measurements that exceed the maximum standard (235 org/100 mL) has increased (Kendall Tau correlation analysis, $p<0.05$) since 2003 at 4 of these sites (Figure 13):

- St. Louis Bay, Park Point, Sky Harbor Lot (B004)
- Park Point at 13th Street (B006)
- Duluth Lake Walk Rest Rooms, Canal Park (B008)
- Lester River mouth (B011)

Completion of beach TMDLs in the Duluth area will provide further evaluation and interpretation of beach water quality data.

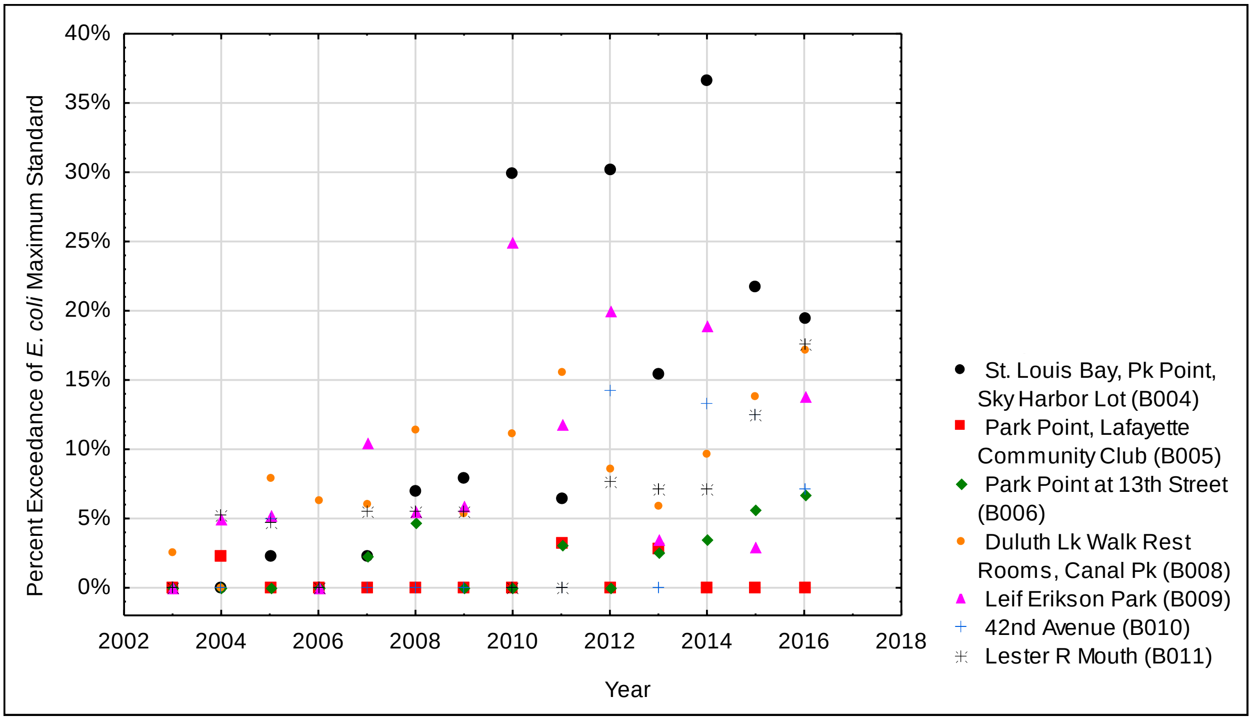


Figure 13. Percent exceedance of *E. coli* maximum standard (235 org/100 mL) in Duluth area beaches for sites with increasing trends.

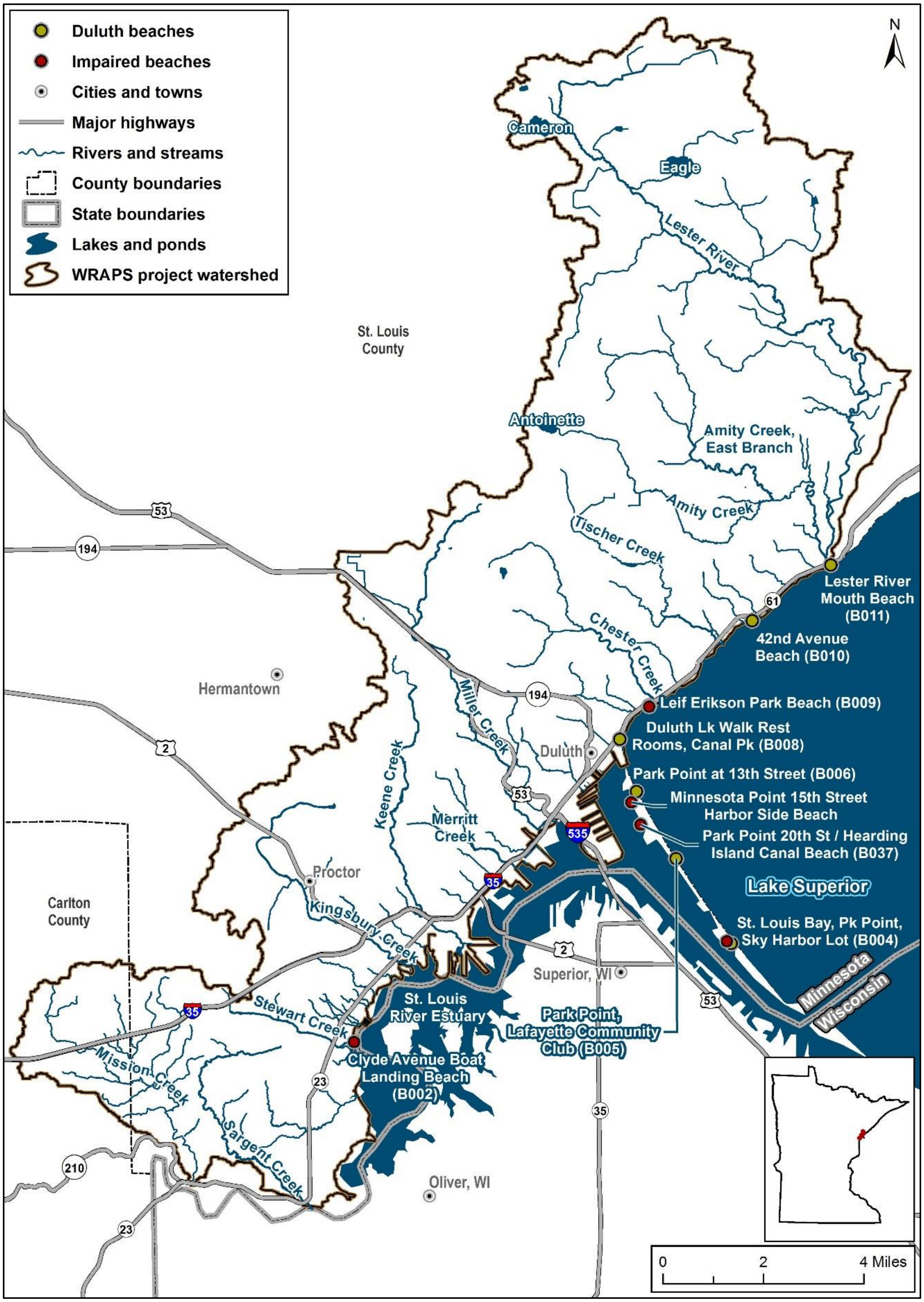


Figure 14. Duluth area beaches.

2.3 Stressors and Sources

In order to develop appropriate strategies for restoring or protecting water bodies, the stressors and sources impacting or threatening them must be identified and evaluated. In the Duluth Urban Area Watershed there are water quality issues related to many different stressors and pollutants, including high levels of turbidity/TSS and high levels of fecal bacteria (i.e., *E. coli*). Stressors and sources have been identified and evaluated as part of several watershed studies including: *St. Louis River Monitoring and Assessment Report* (MPCA 2013), *Lake Superior - South Monitoring and Assessment Report* (MPCA 2014), *St. Louis River Watershed Stressor Identification* (MPCA 2016), *Lake Superior - South Stressor Identification Report* (MPCA 2017a), and the *Revised Duluth Urban WRAPS HSPF Model* (Tetra Tech 2019).

Biological stressor identification is done for streams with either fish or macroinvertebrate impairments, (see Table 2) and encompasses both evaluation of pollutants and non-pollutant-related factors as potential stressors (e.g., altered hydrology, fish passage, habitat). Biotic impairments (i.e., based on aquatic macroinvertebrate or fish bioassessments) were identified in Kingsbury Creek and Miller Creek; these streams were further evaluated for the cause of impairment as part of the stressor identification process (MPCA 2016). Table 6 summarizes the probable stressors evaluated for each biota impaired stream.

Table 6. Summary of probable stressors to the biota impaired streams (MPCA 2016)

Candidate Cause	Kingsbury Creek	Miller Creek
Elevated Water Temperatures	•	•
Low Dissolved Oxygen	•	--
TSS / Turbidity	•	x
Chloride Toxicity / Specific Conductivity	○	•
Poor Physical Habitat Conditions	•	--
Copper and Lead Toxicity	○	--
Altered Hydrology	○	○

Key: • = confirmed stressor, ○ = potential stressor, X = eliminated candidate cause
-- = stressor not assessed

Pollutant Sources

A Hydrologic Simulation Program-Fortran (HSPF) watershed model was developed to simulate watershed scale hydrology and water quality (Tetra Tech 2019) at a storm sewer catchment scale. Model catchments were based on storm sewer catchments from the City of Duluth and stormwater information from the City of Hermantown, Department of Natural Resources (DNR) Level 8 and 9 catchments, and available Light Detection and Ranging (i.e., LiDAR) elevation data. Pollutant loading derived from the HSPF model are presented as loads normalized to watershed area in Figure 15 through Figure 17 for chloride, phosphorus, and TSS.

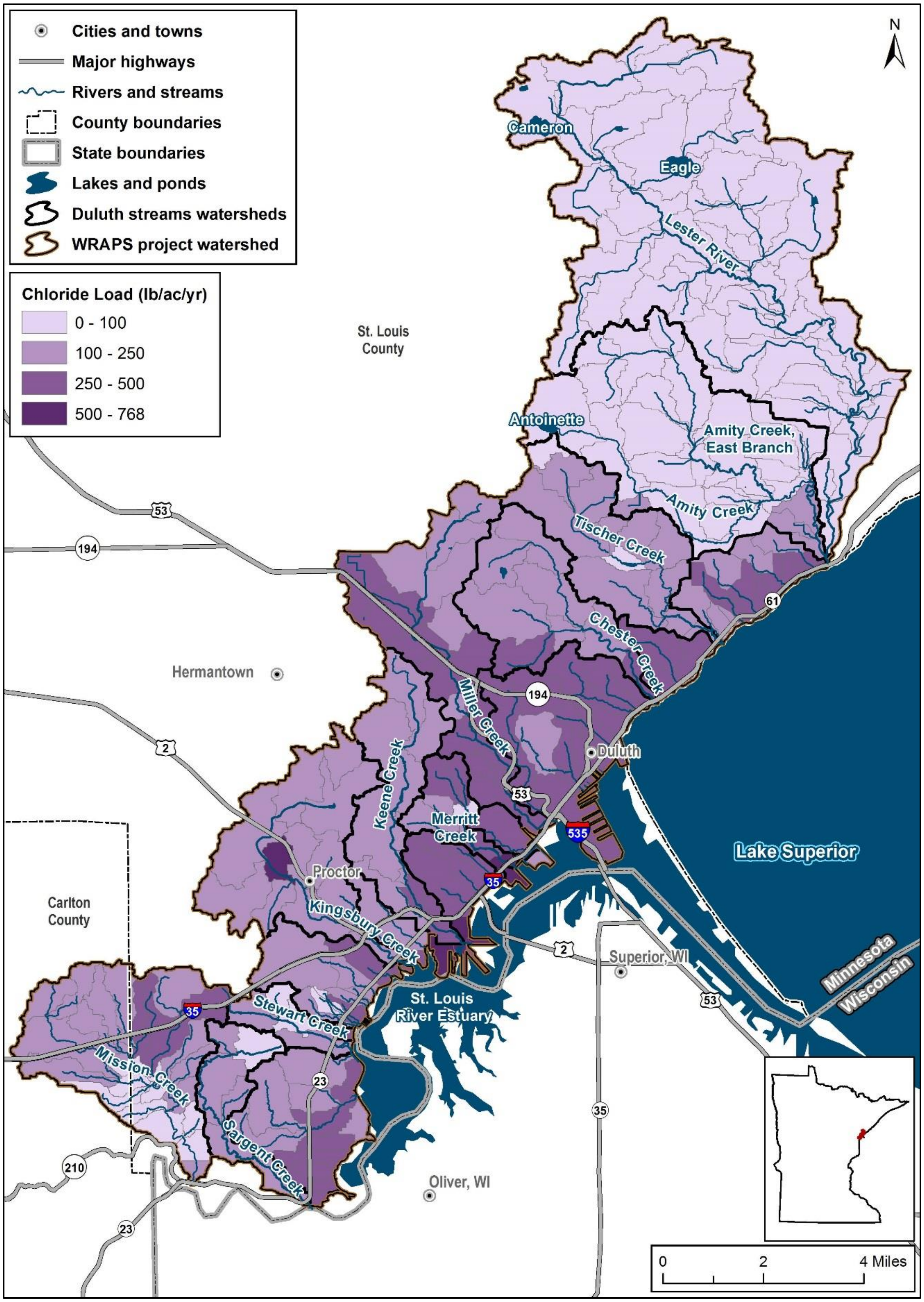


Figure 15. Chloride load per model catchment from HSPF.

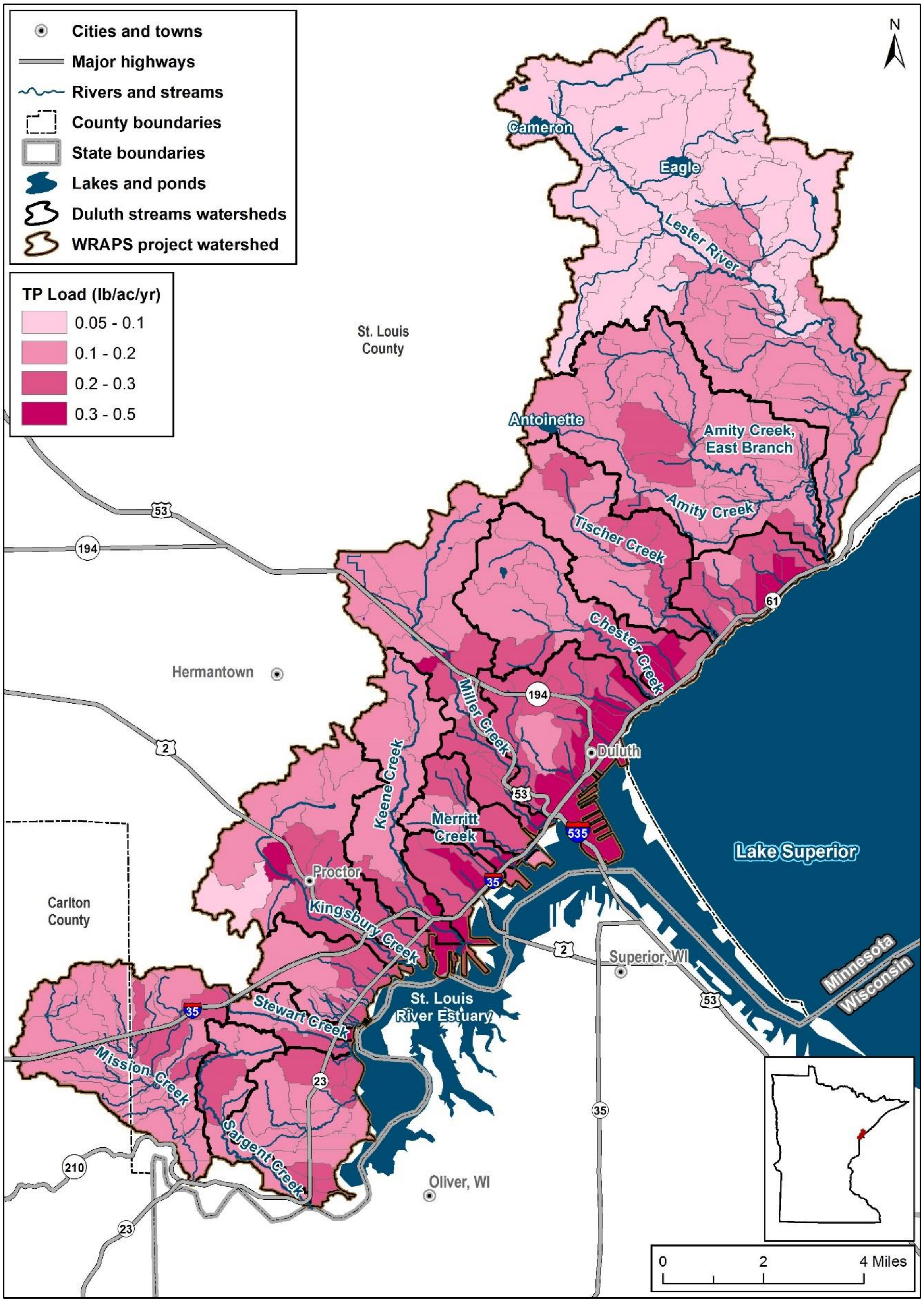


Figure 16. Phosphorus load per model catchment from HSPF.

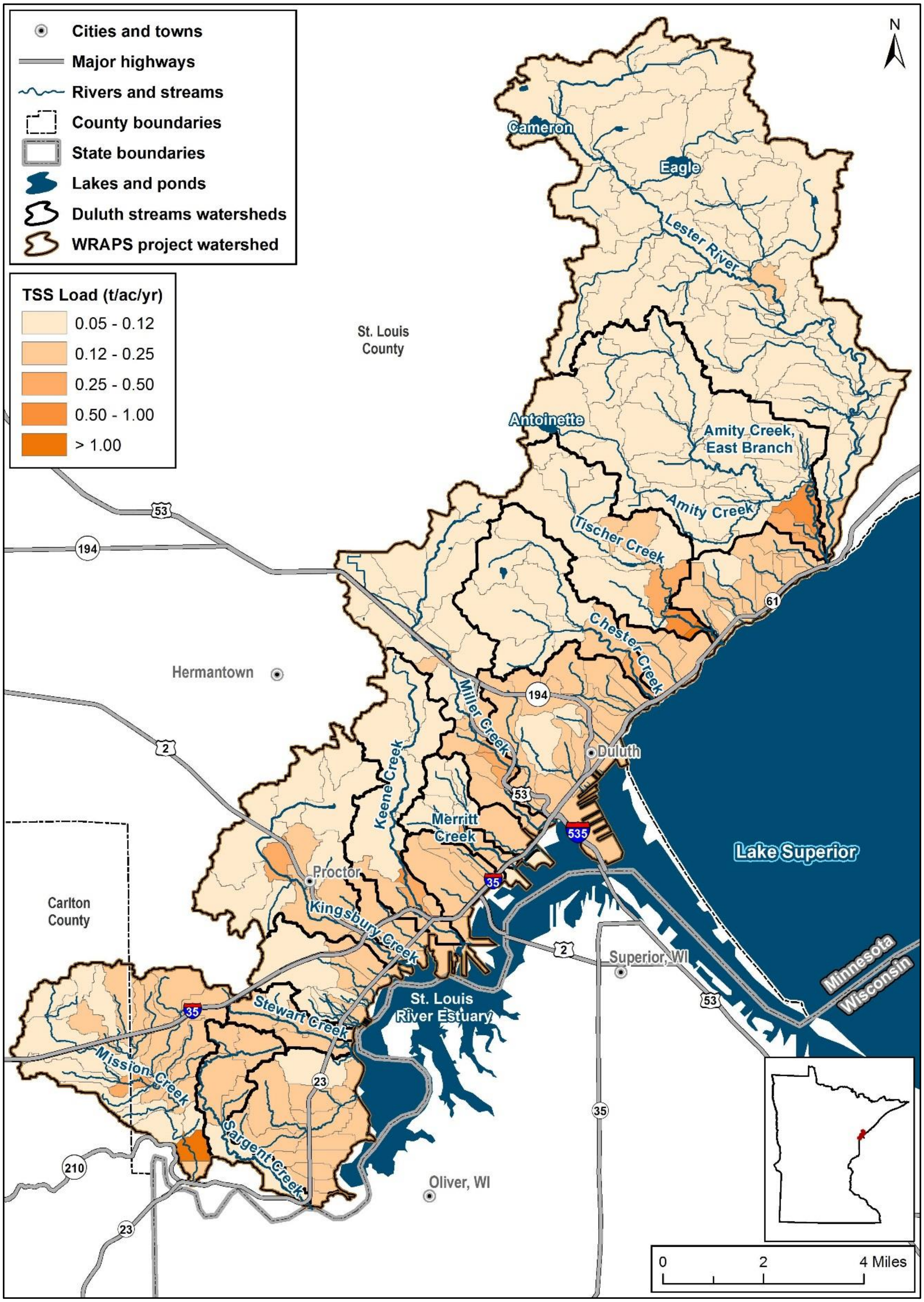


Figure 17. TSS load per model catchment from HSPF.

Sediment loading in the watershed is the result of both watershed and near-channel sources. Watershed sediment loading rates, or yields, vary widely from place to place and are influenced by local conditions such as soil erodibility, slope, and precipitation patterns. Loading rates from urban land are typically higher due to the effects of flow concentration from impervious surfaces, higher runoff volumes, and erosion hotspots in ditches and ephemeral headwater channels receiving flow from storm drains. Clay lacustrine soils and high slope areas also contribute to watershed loads.

Near-channel sources include bluff and bank erosion and channel scour. Bluff and bank erosion is a significant source of sediment loading throughout the North Shore (Wick 2013, Nietzel 2014). Bluffs, however, are likely only a major source during high flow events such as spring snow melt and major precipitation events. Near-channel erosion is, in part, the result of historic and current land alterations. These activities, like clearing of forests, roads, and development, have changed the hydrology of the watershed resulting in increased snowmelt and runoff rates and increased peak flows and volumes. This change in hydrology sets in motion the channel evolution process, which results in the river changing its form to accommodate this change in hydrology.

The amount of sediment loss on an average annual basis was estimated using the Bank Assessment for Nonpoint source Consequences of Sediment (BANCS) model for many streambanks in the watershed (SSLSWCD 2017). The BANCS model combines Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) measurements to estimate an erosion rate. Measurements are completed at an individual bank scale and extrapolated to a reach scale. At each assessment bank, characteristics such as plant root depth and density, bank height, and bank angle were used to calculate a BEHI score, and the location of dominant channel flow relative to the bank or depositional properties and other channel characteristics were used to calculate a NBS score. BEHI and NBS relationship curves developed for the BANCS model were then used to predict a bank recession rate. Figure 18 includes the estimated near-channel sediment loads by stream reach for five of the streams; Jennings et al. (2017) developed a similar assessment for Amity Creek (Figure 19).

Stream connectivity, geomorphology, and in-stream temperatures were further evaluated in Amity, Chester, Keene, Merritt, Miller, and Tischer creeks to support WRAPS development (see Appendix B; SSLSWCD 2017). Stream crossings with roads and trails can block fish passage if culverts are damaged, undersized or improperly placed, stressing fish populations. In total, 213 stream crossings were identified on the six study streams (SSLSWCD 2017). Of these, 114 were considered barriers to fish passage and given a score to prioritize removal and replacement (Figure 20). Overall, the Tischer Creek Subwatershed contained the greatest number of crossings and barriers per stream mile, while the Amity Creek Subwatershed contained the least.

Figure 18. Estimated tons of sediment per foot per year for five subwatersheds in Duluth, estimated using BANCS model.

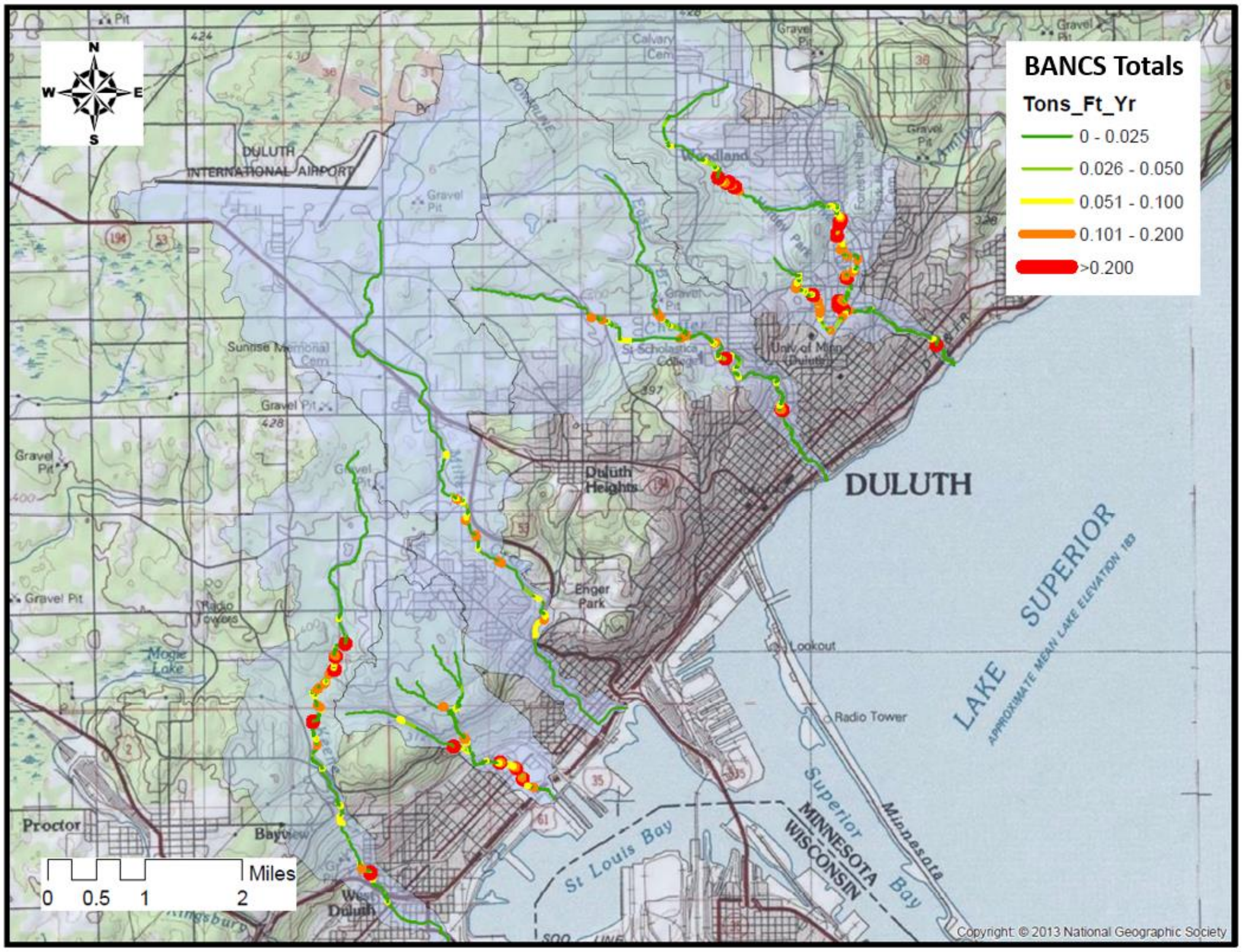
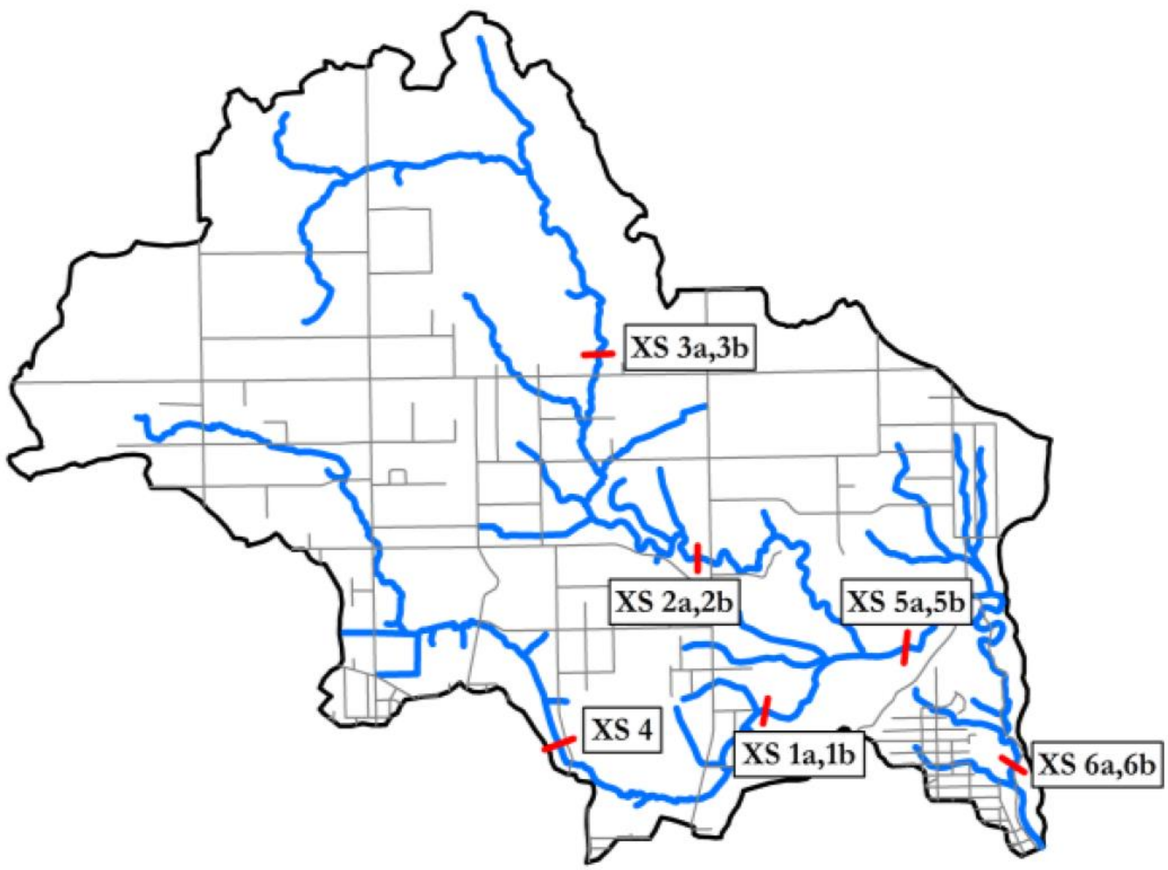


Figure from SSLSWCD 2017.



XS	Reach	Reach Level of Concern	Feature	Condition	BEHI	NBS	Erosion Category
1a	AM-10	Moderate	Riffle	Unstable	Moderate	High	4
1b	AM-10	Moderate	Riffle	Reference	Low	Moderate	2
2a	EB-2	High	Pool	Unstable	Moderate	High	5
2b	EB-2	High	Riffle	Reference	Low	Low	1
3a	EB-5	Low	Riffle	Reference	Low	Low	1
3b	EB-5	Low	Pool	Reference	Moderate	High	2
4	AM-14	Low	Riffle	Reference	Low	Low	1
5a	AM-9	Very High	Pool	Unstable	High	Very High	4
5b	AM-9	Very High	Riffle	Reference	Low	Low	1
6a	AM-2	High	Riffle	Reference	Low	Moderate	5
6b	AM-2	High	Riffle	Unstable	Moderate	Moderate	3

Figure 19. Amity Creek sediment loading summary.
Figure and table from Jennings et al. 2017, higher erosion category scores indicate higher level of erosion.

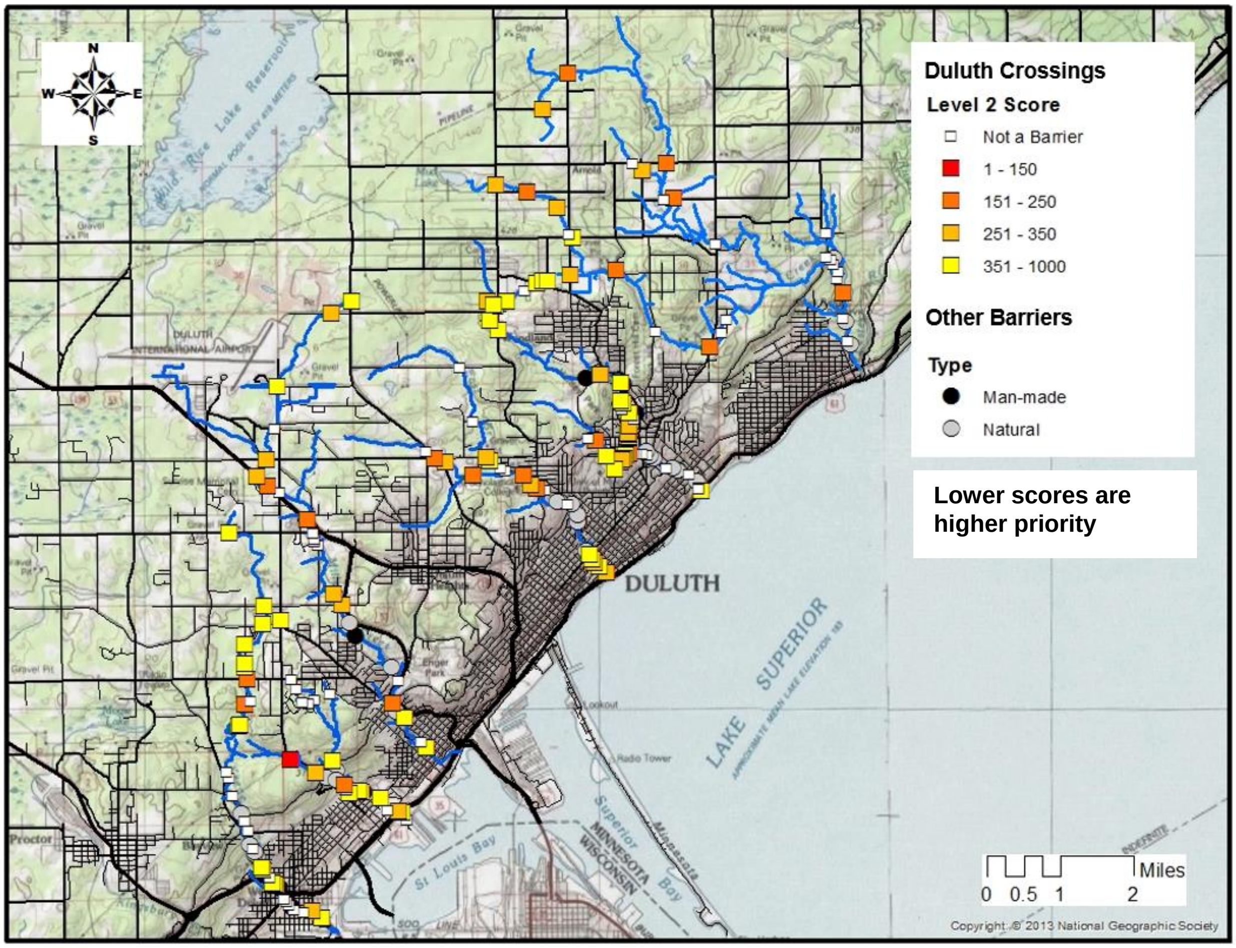


Figure 20. Road crossings within the six study subwatersheds in Duluth.
Each crossing is assigned a score based on priority for replacement, removal, and/or repair if it was identified as a barrier to fish passage. Figure from SSLSWCD 2017.

An evaluation of continuous stream temperature data dating back to 1994 for each of the six streams yielded a score that infers trout survivability with scores greater than 90 considered harmful to trout (SSLSWCD 2017; Figure 21). Each temperature logger was assigned a score by dividing the *Summer Average Temperature* by *Percent of Time in the Growth Range Temperatures*. The highest scoring (more threatened) sites were located in lower Chester Creek, middle Tischer Creek and upper Amity Creek. The healthiest (lowest) score was found at a site in the headwaters of Tischer Creek. Warmer in-stream temperatures are typically a result of low baseflow conditions, stormwater runoff during warm summer months, and lack of shade. A lack of shade can be due to low levels of riparian cover, a wide stream channel, and ponded or slow moving water within the channel.

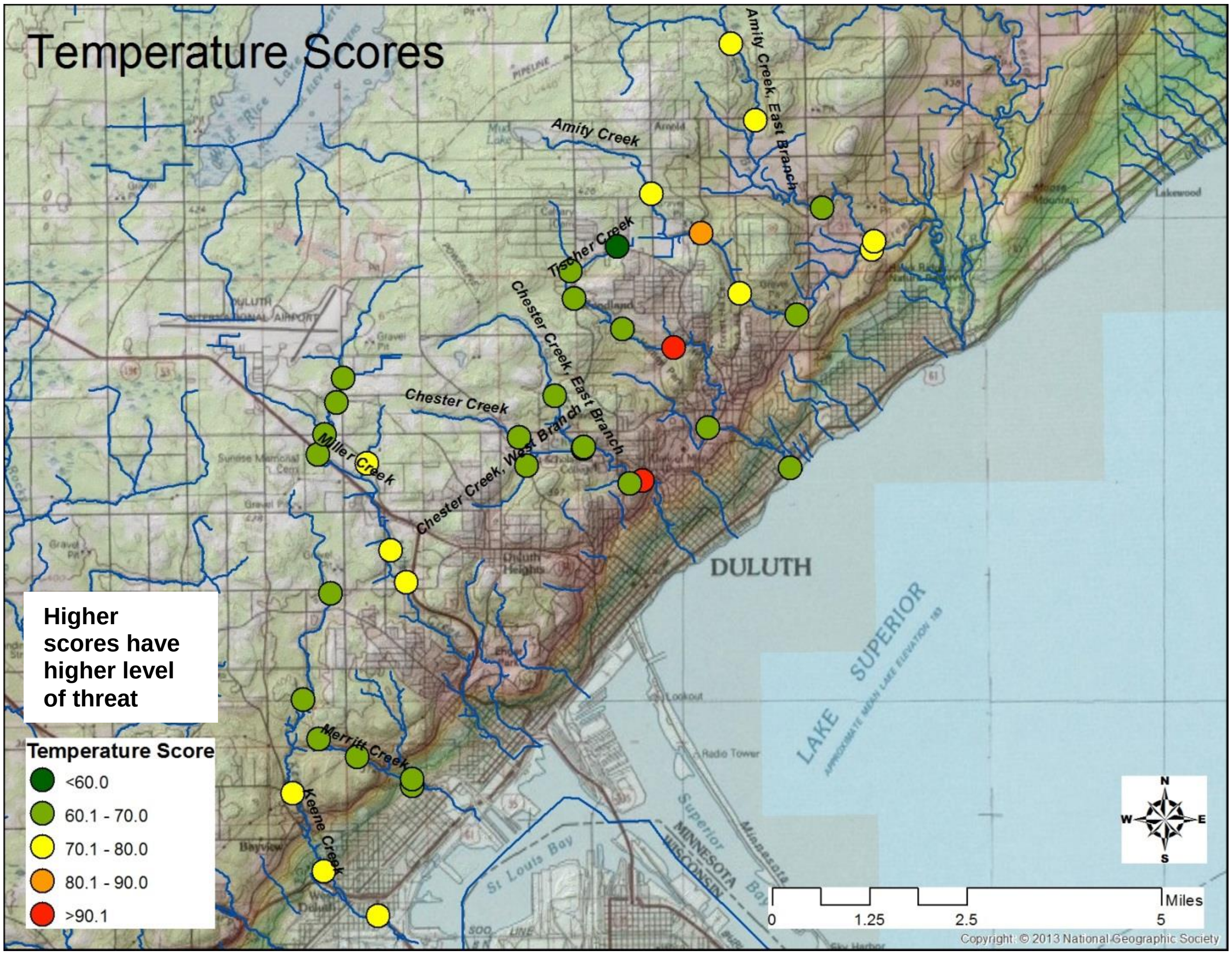


Figure 21. Temperature scores for continuous temperature records in the six Duluth study streams.
Scores greater than 90 are considered harmful to trout. Figure from SSLSWCD 2017.

Sources of *E. coli* in streams and beaches are widespread and often intermittent. Threats to the watershed include stormwater runoff, wastewater (leaky infrastructure and individual septic systems), other wastewater collection systems (e.g., portable toilets), pets, birds and wildlife. Some sources pose a greater risk to human health than others.

As part of TMDL and WRAPS development, the City of Duluth provided helpful insights and data on sources of *E. coli*. A large portion of the city's sanitary sewer is aged and the material of these pipes increases the likelihood of wastewater leaks into the environment, becoming a potential source of *E. coli*. The City of Duluth has been evaluating and lining or upgrading wastewater stream crossings as needed; these upgraded crossings are identified in Figure 22. In addition, septic systems can be found in the less developed areas and also within the developed portions when homes are not connected to regional sewer services. Septic systems that function properly do not contribute *E. coli* to surface waters. Septic systems that discharge untreated sewage to the land surface are considered an imminent public health threat (IPHT) and can contribute *E. coli* to surface waters. In addition, limited bathroom facilities are available in parks, mainly due to vandalism, and there are known homeless populations who camp in the floodplain of urban streams in Duluth, especially in the lower urban subwatersheds; these populations often do not have access to bathing or bathroom facilities.

Stormwater, while not a direct source of *E. coli*, acts as a delivery mechanism for *E. coli* in the watershed. Stormwater runoff from impervious areas such as roads, driveways, and rooftops, can directly connect the location where *E. coli* is deposited on the landscape to surface waters. Stormwater can also wash off waste left behind by pets and wildlife. Sediment found in stormwater can also harbor naturalized *E. coli*.

No specific information is available on wildlife populations in the impaired streams or their potential to impact *E. coli* loadings. However, deer, beaver, bear, mink, raccoon, and other wildlife populations have been noted throughout the watershed. Large concentrations of seagulls, geese, other types of waterfowl, and common Minnesota birds are found throughout the watershed.

Point sources in the watershed consist primarily of regulated stormwater sources from MS4s. MS4s are defined as the conveyance systems that includes ditches, roads, storm sewers, stormwater ponds, etc. Entities with regulated MS4s include:

- Duluth
- Hermantown
- Midway Township
- Proctor
- Rice Lake
- University of Minnesota Duluth
- Lake Superior College
- St. Louis County (road authority)
- Minnesota Department of Transportation (road authority)

A regulated MS4 is required to create a Stormwater Pollution Prevention Program that addresses the following six minimum control measures:

1. Public education and outreach, which includes teaching citizens about better stormwater management,
2. Public participation: including citizens in solving stormwater pollution problems,
3. A plan to detect and eliminate illicit discharges to the storm sewer system,
4. Construction-site runoff controls,
5. Post-construction runoff controls,
6. Pollution prevention and municipal “good housekeeping” measures such as inspecting and maintaining infrastructure, covering salt piles and street-sweeping.

There is also one industrial stormwater facility in the Kingsbury Creek Subwatershed (Wisconsin Central Ltd [MN0000361, a subsidiary of Canadian National Railway]) that is required to address TSS loadings as described in the TMDL.

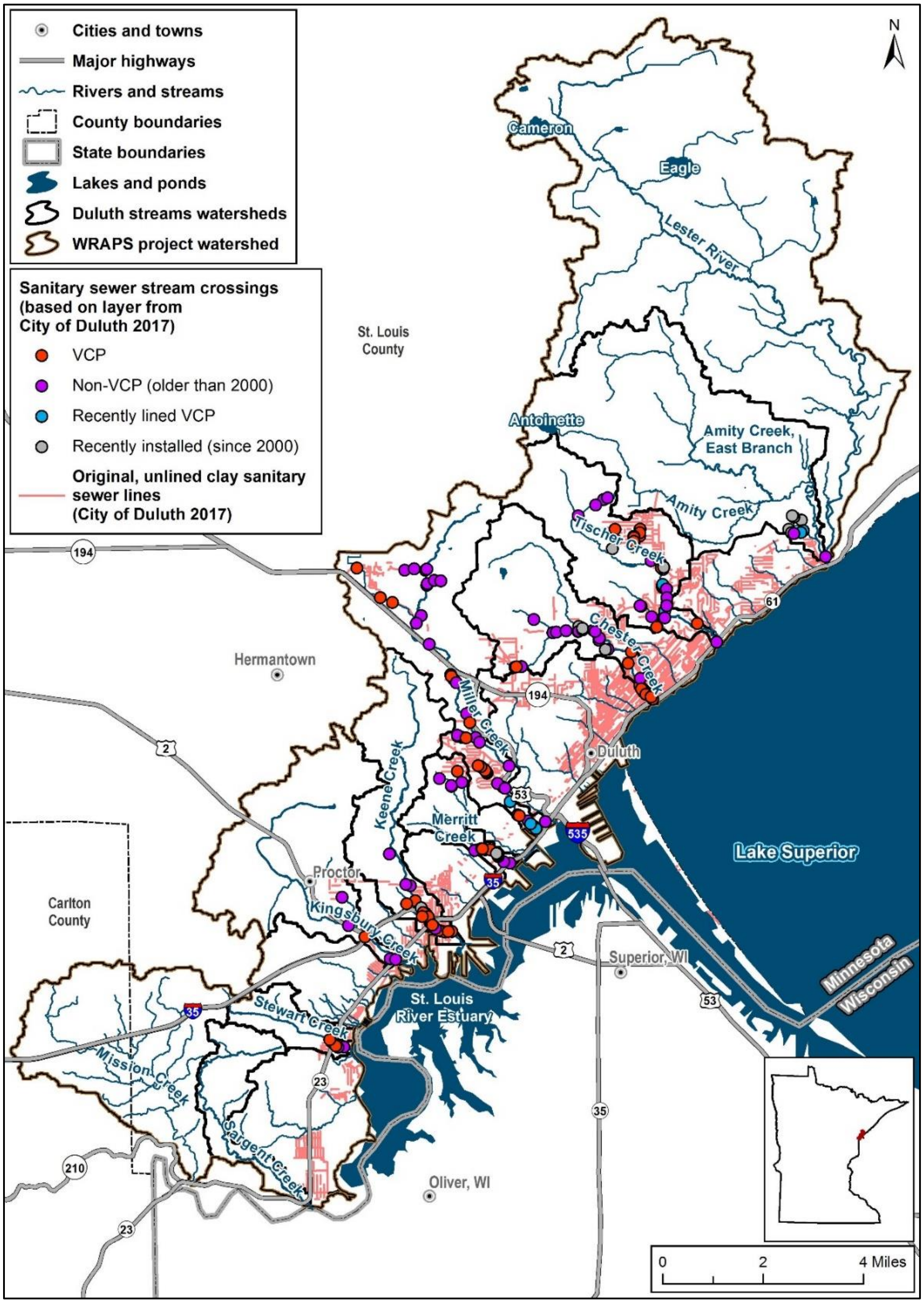


Figure 22. Sanitary sewer and stream crossings.

Note: VCP = vitrified clay pipe

2.4 TMDL Summary

The Clean Water Act and EPA regulations require that TMDLs be developed for waters that do not support their designated uses. A TMDL is a plan to attain and maintain water quality standards in waters that are not currently meeting them.

TMDLs are not developed for non-pollutant stressors including poor physical habitat conditions. In addition, impairments caused by elevated water temperatures and low dissolved oxygen are being deferred at this time to allow for additional investigation. Specific to Miller Creek, TMDLs for the aquatic life impairments due to lack of cold water assemblage, macroinvertebrate bioassessments, and chloride are anticipated to be completed in the future, by approximately 2027.

E. coli TMDLs were developed for the aquatic recreation stream impairments that are indicated by high *E. coli* concentrations. A number of beaches are also listed as having impaired aquatic recreation due to high levels of *E. coli*. These beaches are being addressed through a separate TMDL process and are not yet completed. TSS TMDLs were developed for aquatic life use impairments due to turbidity or for which TSS was identified as a primary stressor. Elevated temperatures in Miller Creek are discussed in detail in the *Miller Creek Water Temperature Total Maximum Daily Load* (MPCA 2017b). Recommendations addressing this impairment are reflected in Section 3.3.

Table 7 includes the water bodies with completed TMDLs, and Appendix A provides a summary of the TMDLs.

Table 7. Completed TMDLs in the Duluth Urban Area Watershed

HUC10 Subwatershed	Stream/Reach (AUID)	Affected Designated Use	Cause/Indicator of Impairment	TMDL Pollutant(s)
City of Duluth – Frontal Lake Superior (0401010204)	Amity Creek (511)	Aquatic Life	Turbidity/TSS	TSS
	Amity Creek, East Branch (540)	Aquatic Life	Turbidity/TSS	TSS
	Tischer Creek (544)	Aquatic Recreation	*E. coli*	*E. coli*
	Chester Creek (545)	Aquatic Recreation	*E. coli*	*E. coli*
	Lester River (549)	Aquatic Life	Turbidity/TSS	TSS
St. Louis Bay (0401020116)	Miller Creek (512)	Aquatic Recreation and Aquatic Life	*E. coli*	*E. coli*
			Temperature	Water Temperature (Heat)
	Kingsbury Creek (626)	Aquatic Life	Fish Index of Biotic Integrity Macroinvertebrate Index of Biotic Integrity	TSS
	Keene Creek (627)	Aquatic Recreation	*E. coli*	*E. coli*
	Sargent Creek (848)	Aquatic Recreation	*E. coli*	*E. coli*
	Stewart Creek (884)	Aquatic Recreation	*E. coli*	*E. coli*
	Unnamed Creek (Merritt Creek; 987)	Aquatic Recreation	*E. coli*	*E. coli*

2.5 Protection Considerations

All waters in the watershed require protection in some capacity, including those listed as impaired. Protection considerations are based on identifying those waters that are particularly threatened or vulnerable as well as those that are of the highest value and quality. Depending on the type of consideration, protection strategies may differ. For example, areas with high levels of imperviousness would benefit from stormwater retrofits to decrease runoff, while less populated areas with high development pressure may benefit from stricter new development and construction ordinances.

The South St. Louis Soil and Water Conservation District (SSLSWCD) prioritized protection activities based on a scoring system for Keene, Merritt, Miller, Chester, Tischer and Amity Creeks (see Appendix B; SSLSWCD 2017). Overall reach scores were calculated using incising ratios, riparian condition, channel condition, and geomorphic data (Figure 23). Reaches with low overall scores were determined to be vulnerable to impairment and should be considered for protection, and reaches with high scores are considered high value and high quality and are therefore prioritized for protection efforts (Table 8). Further prioritization of areas for targeted implementation of road crossing improvements and riparian management was conducted and incorporated into the restoration and protection strategies (see Section 3.3).

A variety of other factors can also be considered in protection efforts including:

- Stream biological integrity
- Water quality
- Instream temperature sensitivity to climate change
- Development pressure
- Potential impacts to Lake Superior

Each of these factors is discussed below.

Table 8. Prioritized stream reaches (SSLSWCD 2017)

Type of Action Needed	Stream Name	Location	Condition	Additional Information
Protection Activities	Tischer	Upstream of London Road	Highest quality stream reaches	--
	Tischer	Upstream of East 4th Street in Congdon Park		
	Tischer	Downstream of Vermillion Road in Congdon Park		
	Keene	Upstream of Skyline Parkway		
	Keene	Downstream of Keene Creek Park		
	Keene	Downstream of Morris Thomas Road		
Improvement Activities	Tischer	Downstream of West Arrowhead Road	Incised, riprap, lack of habitat, eroding stream banks	Low priority road crossing barrier, brook trout present in 2013 (upstream reach)

Type of Action Needed	Stream Name	Location	Condition	Additional Information
	Tischer, West Branch	West Branch, between West St. Marie Street and Norton Street	Constricted valley, riprap on banks, poor habitat, invasive riparian species	2 low priority and 1 medium priority road crossing barriers
	Keene	Keene Creek Park, near trail	Incised channel, significant bank erosion, pooling water causing warming	Warming water temperatures, 7% stressful temperatures (upstream reach), brook trout are present (upstream reach), high priority crossing (upstream reach)
	Merritt	East Branch – 1/3rd mile upstream of Skyline Parkway	Incised channel, invasive species, over-widened channel, aggradation	Warming water temperatures
	Miller	Up and downstream of Anderson Road	Lawns mowed to stream edge, no shade, stream bank erosion	Medium priority road crossing barrier, brook trout present in 1968, slightly warming water temperature

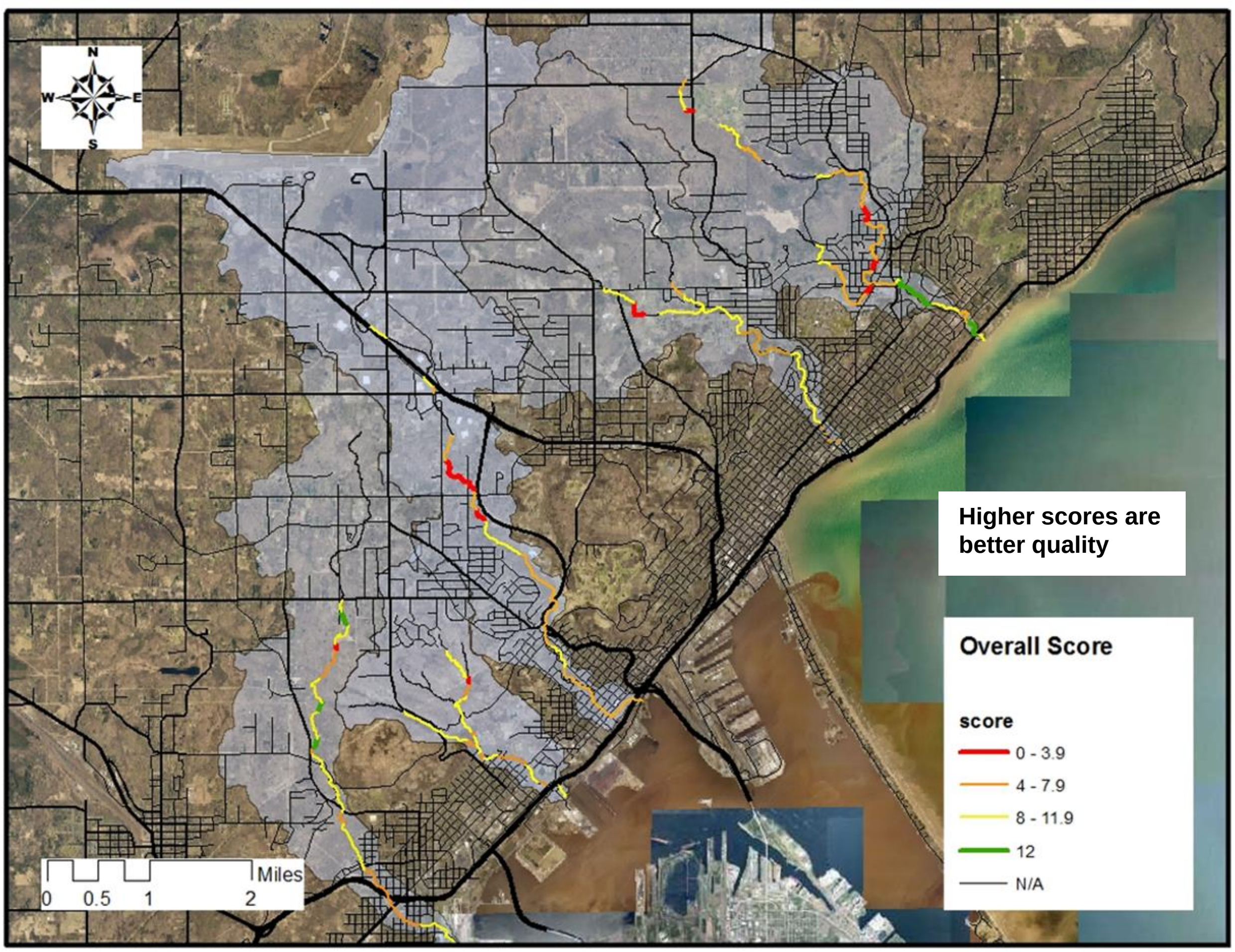


Figure 23. Overall reach scores (SSLSWCD 2017).

Stream Biological Integrity

Stream vulnerability was determined based on their index of biotic integrity (IBI) scores (Figure 24 and Figure 25). In the figures below, the blue markers ("> upper confidence limit") indicate streams that are comfortably meeting threshold targets and are of the highest quality. The red markers ("< lower confidence limit") indicate streams that do not meet the targets. The green and purple markers ("> or < threshold") indicate streams with IBI scores that are close to the targets and are considered threatened and vulnerable to becoming impaired. These streams are vulnerable and should be considered for protection because (1) they have a high potential for restoration, and (2) they are potentially vulnerable to impairment in the future. Those streams that are unimpaired for aquatic life but may be threatened based on the IBI data include:

- Tischer Creek
- Chester Creek
- Mission Creek

It is also important to protect those resources that are of the highest quality to maintain diversity and the biological integrity of the watershed. Those streams that are of highest quality include:

- Lester River
- Keene Creek
- Miller Creek

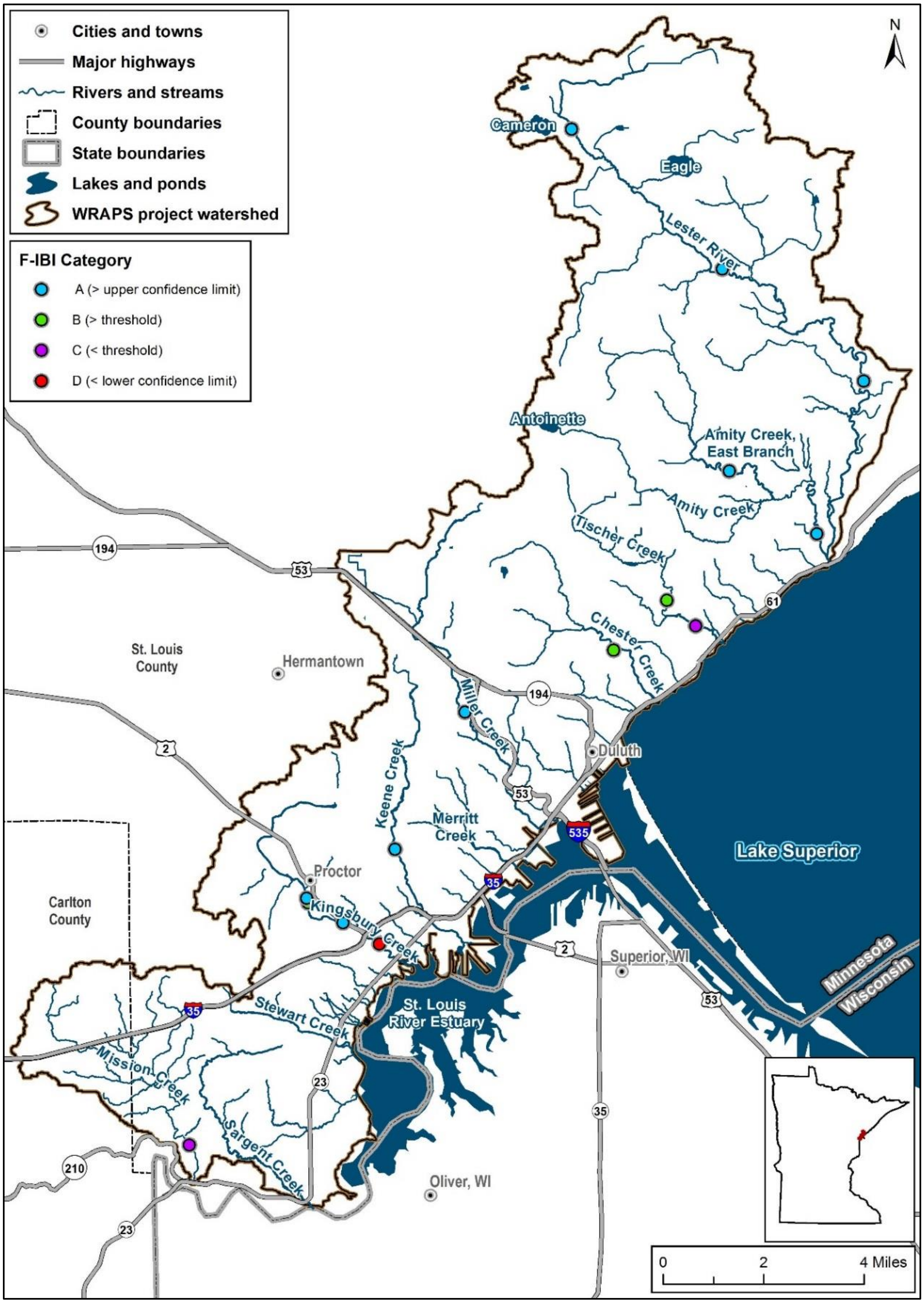
Water Chemistry

Water quality can also be a factor in the type of protection needed. Creeks and rivers in the watershed that have high sediment concentrations should be considered for protection strategies, and restoration in some cases, as they are potentially vulnerable to impairment. Streams with high TSS concentrations (Figure 8) that are currently identified as unimpaired for aquatic life due to sediment include:

- Sargent Creek
- Keene Creek
- Merritt Creek
- Miller Creek
- Mission Creek
- Chester Creek
- Tischer Creek

There were limited data on lakes in the watershed; however, Eagle Lake was assessed and is meeting water quality standards. In addition, Lake Superior is an Outstanding International Resource Value Water in Minn. R. ch. 7052. Lake Superior is recognized by the United Nations and international treaties as one of the world's premiere, large oligotrophic freshwater lakes. As such, protection of the Lake is considered a priority.

Figure 24. FIBI categories.



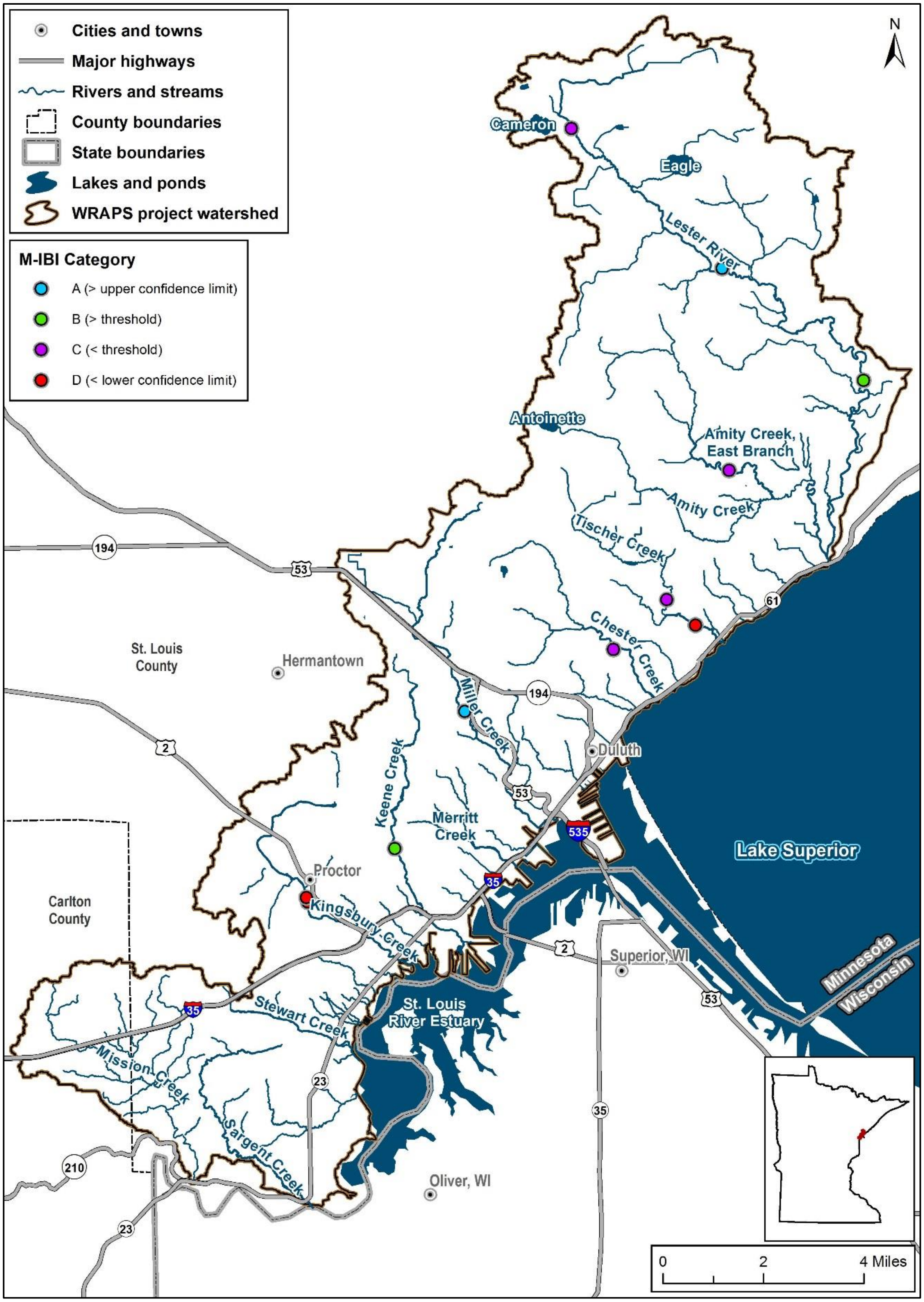


Figure 25. MIBI categories.

In-Stream Temperature Sensitivity to Climate Change

Stream vulnerability to climate change was determined by evaluating projected increases in water temperature by mid-century (i.e., centered around 2040) as a result of climate change. Streams with higher projected temperatures are considered at risk of not being able to support healthy cold water fish communities. A climate change analysis was conducted with the HSPF model application using projected future climate conditions, based on global climate model simulations released by the Intergovernmental Panel on Climate Change (2017). For the stream temperature sensitivity analysis presented here, simulated average maximum July water temperatures were evaluated with respect to the lethal temperature of 77 degrees Fahrenheit (F) and the stress temperature of 68 degrees F for brook trout (MPCA 2017a). Maximum July temperatures were used to represent the worst-case scenario likely to be experienced by stream organisms. Over a 20-year simulation period (1995 through 2015) to represent historical conditions and a 30-year simulation period (2025 through 2055) to represent mid-century conditions, the maximum simulated July temperatures of each stream were averaged to produce one value per stream for historical conditions and one value per stream for mid-century conditions.

In the 1995 through 2015 period, simulated average maximum July water temperatures in trout streams range from 65 to 75 degrees F, and are highest in Merritt Creek and Miller Creek. By mid-century (2025 to 2055), maximum July temperatures are expected to increase by 2.3 degrees F on average, and 10 streams are expected to have average maximum July temperatures between 76 and 77 degrees F (Table 9 and Figure 27). Because the reported temperatures represent *average* maximum July water temperatures, the overall maximum water temperatures in these streams will likely be greater than 77 degrees F, which is the lethal temperature for brook trout. All of the streams are likely to have temperatures that exceed the stress temperature for brook trout.

Lester River, Amity Creek, and East Branch Amity Creek appear to maintain the lowest in-stream temperatures under the climate change scenario; this scenario assumes the same land use/land cover as the historic scenario. The watersheds of these streams have low imperviousness (less than 3.5%) compared to the watersheds of the other trout streams (Figure 27). Imperviousness in the other watersheds ranges from 4% to 19%, with little difference in projected maximum July water temperatures among the streams. Other factors that can influence water temperatures include watershed size, riparian land cover, and interactions between groundwater and surface water. An empirical study of North Shore streams found that stream water temperatures were positively affected by air temperature, watershed size, percentage of woody wetlands in the vicinity of a stream, and stream latitude; stream temperatures were negatively affected by soil permeability (Johnson 2015). The authors conclude that, “adaptation strategies that increase stream shading with coniferous cover and enhance base flows by maintaining low levels of impervious surface cover could improve the potential for maintaining brook trout populations in the future.”

Lester River, Amity Creek, and East Branch Amity Creek should be prioritized for protection efforts to ensure that anthropogenic effects are minimized and that climate change mitigation strategies are put in place when appropriate. Increased impervious coverage in these watersheds risks increases in water temperatures and potential loss of suitable trout habitat.

Table 9. Predicted average maximum July temperatures at mid-century of designated trout streams

Assumes identical land use/land cover under both scenarios.

Stream	Historic Average Maximum July Temperature (degrees F)	Predicted Average Maximum July Temperature at Mid-Century (degrees F)	Change (degrees F)
Lester River	66.0	69. 0	3.0
Amity Creek	69.2	71. 9	2.7
E Br Amity Creek	71.0	74. 2	3.2
Mission Creek	73.9	75. 9	2.0
Sargent Creek	73.9	75. 9	2.0
Chester Creek	74.0	76. 2	2.2
Kingsbury Creek	73.9	76. 5	2.6
Knowlton Creek	74.0	76. 5	2.5
Tischer Creek	74.1	76. 5	2.4
Coffee Creek	73.8	76. 5	2.7
Keene Creek	74.4	76. 6	2.2
Stewart Creek	74.1	76. 7	2.6
Miller Creek	75.4	76. 9	1.5
Buckingham Creek	74.3	76. 9	2.6
Merritt Creek	75.3	77. 0	1.7

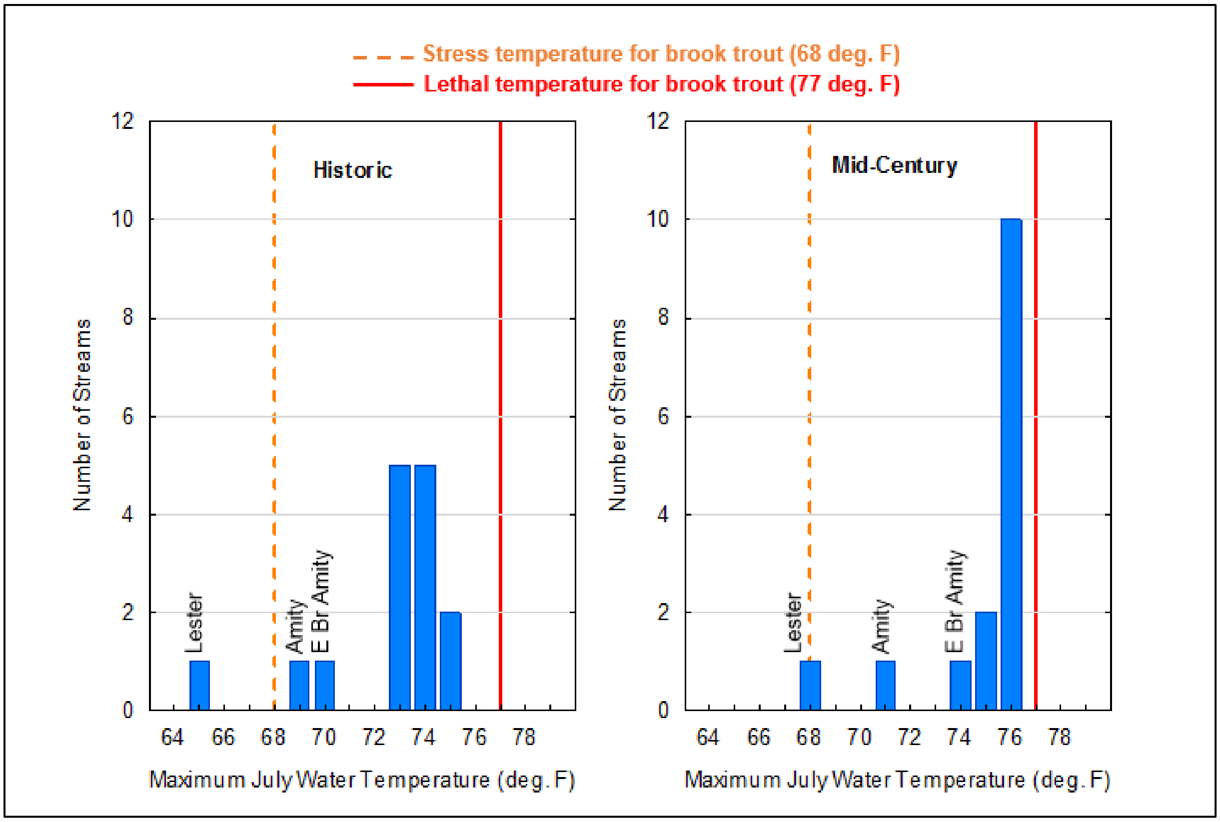


Figure 26. Simulated historic and mid-century average water temperatures of designated trout streams. Temperatures are the average of the simulated maximum July water temperatures for the historic (1995–2015) and mid-century (2025–2055) time periods.

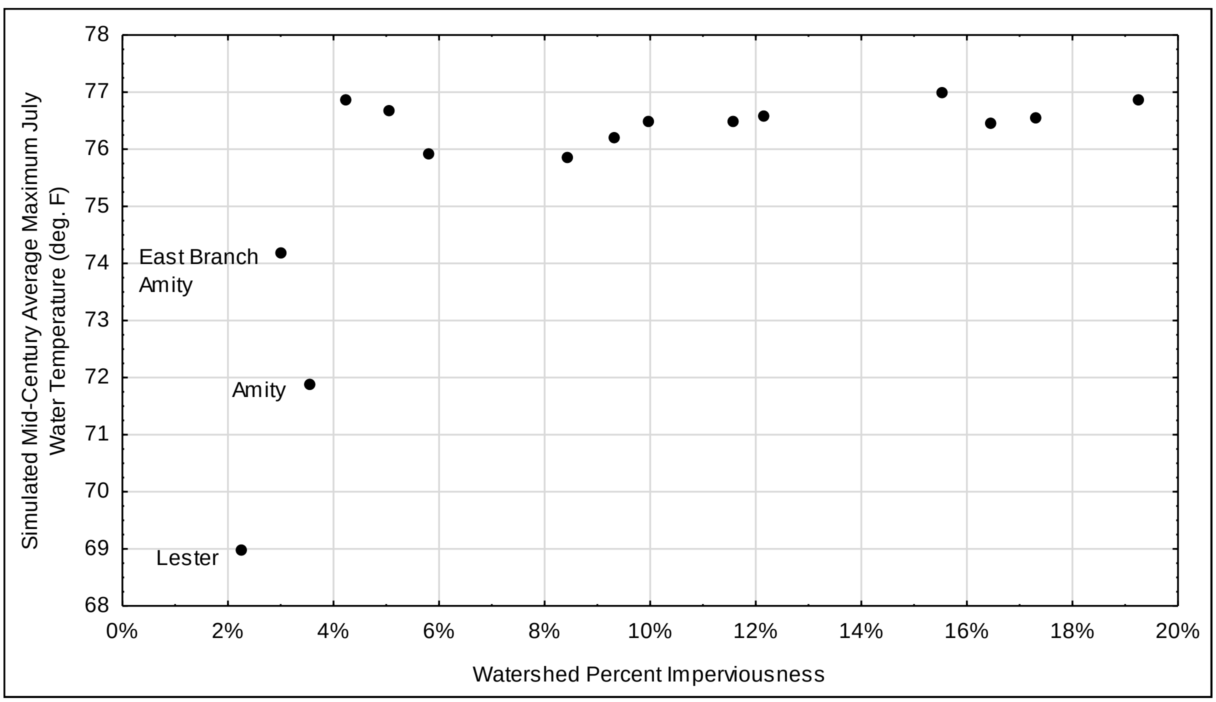


Figure 27. Simulated mid-century average maximum July water temperatures versus subwatershed percent imperviousness. Unlabeled streams include those streams listed in Table 9 excepting Lester River, Amity Creek, and East Branch Amity Creek.

Development Pressures

Existing and future development pressures are a factor in protection considerations. Currently, the City of Duluth is the most densely populated city in Northeastern Minnesota and contains approximately 40% of the population of St. Louis County. Major developed areas require roads and other infrastructure that increase stormwater volumes and potential for pollutant loading by increasing imperviousness and stormwater connectivity (i.e., sewers). Imperviousness (Figure 28) can lead to environmental degradation such as erosion caused by higher peak flows and stormwater volumes, and increased in-stream temperatures resulting in less cold water fish habitat.

Areas with development pressure should be considered for protection efforts. While the City of Duluth is expected to maintain a steady increase of population, the surrounding communities with available land and supportive development policies are expected to see much higher population increases. Development and infrastructure are also expected to increase in these areas as a result.

Protection of high quality natural and water resources will be dependent upon ordinance development and enforcement, conservation easements, land acquisition, and education and outreach.

Potential Impacts to Lake Superior

Nearshore activity can have significant impacts on the quality of Lake Superior. Pollutant loading, groundwater use, industry, tourism and fish passage barriers should all be assessed to determine opportunities to protect Lake Superior by reducing and minimizing their impacts. The Lake Superior Lakewide Action and Management Plan (LAMP) for 2015 through 2019 identifies nine lakewide objectives that seek to protect the physical, biological and chemical integrity of Lake Superior. The Lake Superior ecosystem is in good condition, however, there are serious threats, including: aquatic invasive species, climate change, reduced habitat connectivity between open lake and tributaries, chemical contaminants, substances of emerging concern, and habitat destruction.

The LAMP plan also identifies large urban areas and areas with mining activities as places, which are likely to have the most significant disturbance of groundwater flow systems and contamination (Lake Superior Partnership 2016). This can impact water quality of streams, river, nearshore lake environments, and drinking water sources.

The LAMP includes 74 management actions to address these threats to water quality and achieve lakewide objectives. The LAMP also recommends the development of a nearshore framework as an action item to address areas of highest vulnerability for protection. Protection efforts in the watershed should align with LAMP strategies when possible. Efforts to improve water quality in tributary streams will reduce pollutant loading to and prevent degradation of Lake Superior. Members of the Lake Superior Partnership, including federal, state, provincial and tribal agencies, from both the U.S. and Canada work closely with others to manage and protect their portions of the Lake Superior ecosystem (Lake Superior Partnership 2016).

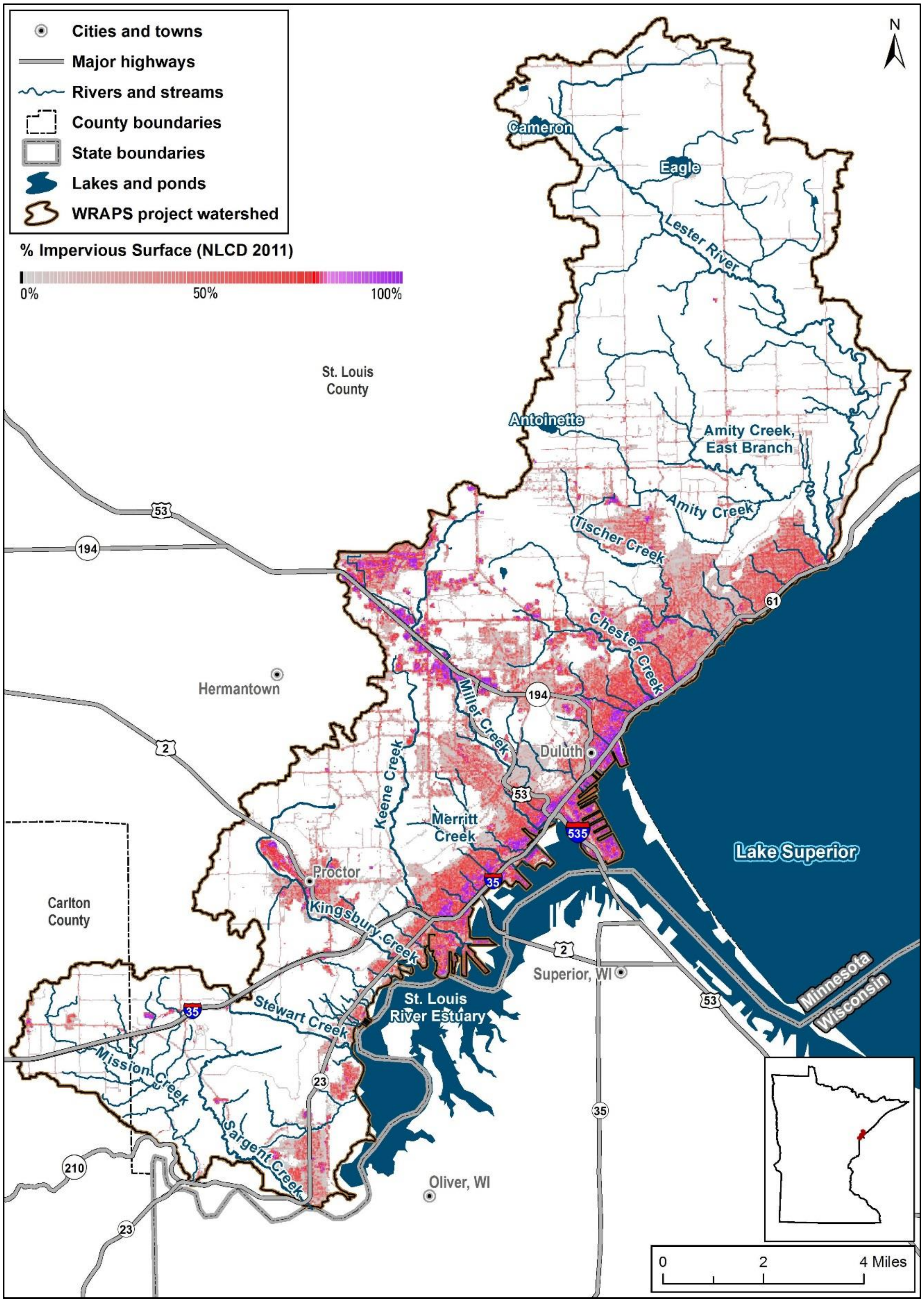


Figure 28. Impervious surfaces in the Duluth watershed.

3. Prioritizing and Implementing Restoration and Protection

The Clean Water Legacy Act (CWLA) requires that WRAPS reports summarize priority areas for targeting actions to improve water quality, and identify point and nonpoint sources of pollution with sufficient specificity to prioritize and geographically locate watershed restoration and protection actions. In addition, the CWLA requires including implementation strategies and actions that are capable of cumulatively achieving needed pollutant load reductions.

This section of the report provides the results of such prioritization and strategy development. Because many of the nonpoint source strategies outlined in this section rely on voluntary implementation by landowners, land users, and residents of the watershed, it is imperative to create and protect social capital (trust, networks and positive relationships) with those who will be needed to voluntarily implement best management practices. Thus, ongoing public participation is a part of the overall plan for moving forward.

The implementation strategies, including associated scales of adoption and timelines, provided in this section are based on what is known at this time and, thus, should be considered approximate. Furthermore, many strategies are predicated on needed funding being secured. As such, the proposed actions outlined are subject to adaptive management—an iterative approach of implementation, evaluation and course correction.

3.1 Targeted Geographic Areas

The primary purpose of this section is to identify targeted or critical areas in which to focus implementation activities during the first 10 years of implementation. The SSLSWCD completed an assessment of Duluth streams that prioritized restoration and protection activities in the watersheds (see Appendix B; SSLSWCD 2017). This analysis was completed for Keene Creek, Merritt Creek, Miller Creek, Chester Creek, Tischer Creek, and Amity Creek, all of which are considered targeted geographic areas for the initial 10 years of the Duluth Urban Area WRAPS implementation (Figure 29).

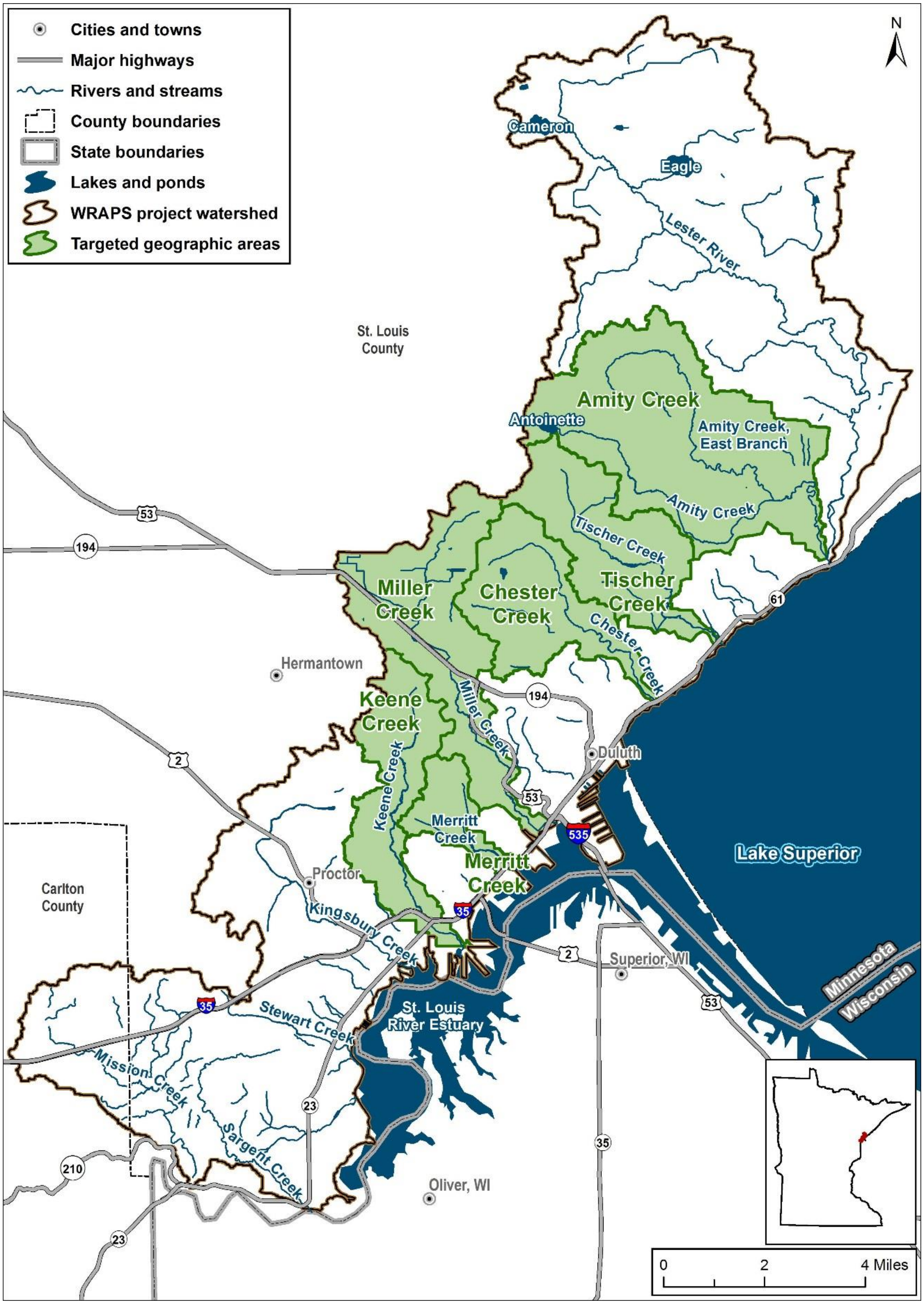


Figure 29. Targeted geographic areas.

3.2 Public and Partner Participation

Accomplishments and Future Plans

Activity within the Duluth Urban Area community is highly integrated with its local water resources as evident from the numerous trout streams that run through the city, the popular Duluth Lakewalk and attractions in Canal Park and surrounding areas, beaches, and much more. Despite this, some lack of understanding of the connection between human activity on the land and resulting water quality remains. Education and outreach activities can work to fill this gap and ensure the protection of the watershed.

Many organizations and efforts exist in the watershed to engage citizens in the watershed with water quality improvements and protection efforts. Several of these efforts were catalyzed by the flooding event in 2012. Examples of existing groups that are conducting water quality-based public participation include:

- County soil and water conservation districts
- Duluthstreams.org
- Duluth Streams Corps
- Minnesota Sea Grant
- Environmental centers: Hartley Nature Center, Great Lakes Aquarium
- Fish and wildlife groups: Trout Unlimited, Steelhead Club, Arrowhead Fly Fishers
- Sustainable Twin Ports
- Lake Superior Cold Water Coalition
- Non-profit groups: Izaak Walton League, St. Louis River Alliance, NERR/Lake Superior Reserve

Two additional entities have been formed in the watershed to address water quality concerns on a watershed wide scale. The Duluth Urban Watershed Advisory Committee (DUWAC) is a voluntary group of local governments and organizations that was formed to improve collaboration among local governments, focused on watershed management. Objectives of DUWAC include:

- Sharing information
- Fostering collaboration and engagement
- Development of a voluntary organization focused on improving watershed management

The DUWAC is facilitated by Minnesota Sea Grant and the Natural Resources Research Institute (NRRI). As part of the creation of this committee in 2015, Sea Grant and NRRI met with each of the 10 communities to discuss Minnesota's Watershed Framework, the upcoming Duluth Urban Streams TMDLs and WRAPS process and reports, and their role in that process. The first two years of effort with the committee focused on increasing the knowledge of the members to improve their capacity to effectively participate in the TMDL and WRAPS process, and determining a preferred model for watershed management in this region. When the committee selected a voluntary cooperation approach to regional watershed management, each community was met with individually to discuss work to-date, the approach used to select the approach, and any questions or concerns from the community. DUWAC meets on a regular basis to enact the above objectives.

The Regional Stormwater Protection Team (RSPT) has been in existence for over 20 years and is a collaboration between local MS4s and partnering agencies and organizations. It operates under the mission of protecting and enhancing the regions shared water resources through stormwater pollution prevention by providing coordinated educational programs and technical assistance. The RSPT allows MS4s to meet permit requirements by collaborating to produce effective and targeted outreach. For example, the team has released a series of public service announcement commercials for homeowners and residents to learn about stormwater issues and how they can help to protect and restore shared water resources.

WRAPS Development

During the development of the Duluth Urban Area WRAPS, additional stakeholder input was gathered from Core Team participants at several meetings including:

- Three meetings with the Duluth Urban Area and Lake Superior – South Core Team for technical advice and strategy prioritization on January 24, April 3, and June 13 of 2017.
- Duluth Urban Watershed Advisory Committee meeting for input on protection and restoration site prioritization on June 22, 2017.
- Members of the Core Team, Duluth Urban Watershed Advisory Committee, Regional Stormwater Protection Team, regulated MS4s, and others participated in a meeting on October 26, 2017, to discuss requirements and opportunities.
- Focused meeting with the City of Duluth, St. Louis County, and representatives from Duluth Urban Watershed Advisory Committee (Jesse Schomberg and Tiffany Sprague) on November 11, 2017, to discuss urban issues.

Also included in the prioritization of restoration and protection strategies were comments from a public MPCA session held on October 31, 2012, after major flood events in the area.

Public Notice for Comments

An opportunity for public comment on the draft WRAPS report was provided via a public notice in the *State Register* from March 19, 2018 through April 18, 2018. An extension for comment was provided April 19 through June 18, 2018. Comments were reviewed and incorporated into a revised document. To briefly summarize, BWSR staff requested clarification on entities responsible for actions/tasks and a comment on buffer law that required no change. MDH staff noted clarifications on beach data, beach monitoring methods, naturalized *E. coli*, sediment sources of e.coli and use of beach data in MPCA assessments. University of Minnesota NRRI staff provided numerous edits to clarify or improve the text language and concepts, and suggested improvements to data represented in Tables or Figures. There were also remarks related to the development of the HSPF model inputs and reference documents provided by the SWCD staff. No edits were made to those reference documents as MPCA staff were not the authors and the materials were reference documents supporting the WRAPS. Lastly, a citizen provided several ideas related to strategies for stream improvements. Many of these related to education and outreach or other specific topical areas and were incorporated into the specific strategy. A few items were more complex and required approvals and/or infrastructural and budget changes not within the scope of the WRAPS, for example, developing a new Duluth-wide citizen violations reporting website. These were not listed in the WRAPS but forwarded to city staff for their consideration. All comments received and specific responses to each comment are available in one document on the Duluth Urban Streams Watershed web page https://www.pca.state.mn.us/water/duluth-urban-area-streams-watershed.

3.3 Restoration and Protection Strategies

This section provides a summary of implementation strategies and actions for both restoration and protection. During the development of the WRAPS, existing plans and assessments were referenced and provided meaningful, local knowledge to the selection of the following restoration and protection strategies including:

- *Duluth Urban Streams: An Implementation Focused Assessment of Six Streams* (see Appendix B; SSLSWCD 2017). Assessed Amity, Chester, Keene, Merritt, Miller, and Tischer Creek to identify areas of restoration and protection priority in the watershed. The assessment used data from both USGS and DNR Fisheries as well as field observations along each creek.
- *Amity Creek Stressor Identification* (Jennings et al. 2017). Assessed Amity Creek to determine stressors and sources of pollution in the watershed.
- *St. Louis River Watershed Stressor Identification Report* (MPCA 2016). Determined stressors and sources of pollutants and provided recommendations for activities in the watershed.
- *Lake Superior – South Watershed Stressor Identification Report* (MPCA 2017a). Determined stressors and sources of sediment and provided recommendations for activities in the watershed.
- *Miller Creek Water Temperature Total Maximum Daily Load* (MPCA 2017b). Identified implementation activities that could be used to meet temperature TMDL requirements.
- *Northeastern Minnesota Compensation Siting: Alternative Wetland Mitigation Options* (Tetra Tech 2015). Included summary of potential alternative wetland mitigation activities.

Strategies and actions are organized into tables. There are several strategies that apply across the entire watershed; these are provided in a watershed wide summary (Table 10). Stream-specific strategies are then provided by HUC10 for the City of Duluth–Frontal Lake Superior (Table 11) and St. Louis Bay (Table 12). Figure 4 and Figure 5 provide the location of each stream. The summary tables include the following information:

- ***Water Quality – Current Conditions:*** "Current" condition is interpreted as the baseline condition over the evaluation period for the pollutant or non-pollutant stressor when available. Current loads are presented in Appendix A as part of the TMDL summaries and current concentrations can be estimated from figures provided in Section 2.

- ***Water Quality – Goals / Targets and Estimated % Reduction:*** Includes a percent reduction of pollutant needed to meet the water quality goal/target that is derived from water quality standards (see Appendix A).
- ***Strategy and Strategy Type:*** These columns provide possible strategies to be used for both protection and restoration. Strategies outline the method, approach, or combination of approaches that could be taken to achieve water quality goals.
- ***Estimated Adoption Rates:*** These columns tie to the strategies column and generally describe the magnitude of effort that it will take to achieve the 10-year milestones and ultimate implementation goal. These estimates are meant to describe approximately "what needs to happen" but does not detail precisely "how" goal attainment will be achieved (the latter is left to subsequent planning steps). These estimates are an approximation only and subject to adaptive management. Note that some water bodies do not have any planned activity during the first 10 years. These water bodies are lower priority (not included in Section 3.1), and activities are expected to take place in the future.
- ***Governmental Units with Primary Responsibility:*** Identifies the governmental units with primary responsibility. Other government entities as well as stakeholders, non-profits, and non-governmental organizations will likely support these strategies.
- ***Estimated Year to Achieve Water Quality Targets:*** This applies to the water body, specifically the year it is reasonably estimated that applicable water quality targets will be achieved. These dates are based on the level of implementation needed to achieve standards, watershed priorities, and best professional judgement and are derived from TMDLs for restoration efforts. Activities related to protection efforts are ongoing.

Achieving the goals of this WRAPS will require partnerships and collaboration, in addition to financial resources. Governmental units with primary implementation responsibility include counties (St. Louis and Carlton), SWCDs (St. Louis and Carlton), municipalities (cities and townships), MPCA, DNR, Board of Water and Soil Resources (BWSR), and MDH.

Government agencies with secondary responsibilities include the Minnesota Department of Agriculture, U.S. Department of Agriculture Natural Resources Conservation Service, U.S. Department of Agriculture Forest Service, and U.S. Fish and Wildlife Service, U.S. Geological Survey, EPA, and U.S. Army Corps of Engineers. These agencies will work with private landowners and other agencies and project partners to support implementation of this WRAPS. In addition, many other partners are anticipated to participate with implementation including:

- Watershed groups (e.g., Regional Stormwater Protection Team and Duluth Urban Watershed Advisory Committee)
- Non-profits (e.g., Trout Unlimited, Minnesota Land Trust)

- Universities
- Land and business owners
- Tribal governments and organizations

The WRAPS will rely on available funding sources to implement projects and programs. Comprehensive Watershed Management planning through the Board of Water and Soil Resources One Watershed One Plan program provides a more consistent access to state generated funds. The level of implementation proposed for the first 10 years is significantly higher than existing efforts and will require new sources of funding for local capacity and capital improvement projects. Potential funding sources for implementation activities include:

- Clean Water Fund, part of the Clean Water, Land, and Legacy Amendment
- Outdoor Heritage Fund, part of the Clean Water, Land, and Legacy Amendment
- Legislative-Citizen Commission on Minnesota Resources
- Local government cost-share and loan programs
- Minnesota Lake Superior Coastal Program
- Federal grants and technical assistance programs
- Conservation Reserve Program and NRCS cost-share programs
- Federal Section 319 program for watershed improvements
- Great Lakes Restoration Initiative
- National Fish and Wildlife Foundation
- Minnesota Clean Water Partnership Loans

Table 10. Watershed wide strategies and actions. Cell shading key: pink = restoration; green = protection; white = watershed wide.

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate											
HUC10 Sub-watershed	Water body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
All	All	St. Louis and Carlton	Varies, see Section 2	Varies, see Section 2	--	Address discharges of untreated wastewater	NPDES permit coverage and compliance. Televise, evaluate, monitor and replace as necessary any leaking public or private sewer lines. Inspect sanitary sewers for inflow and infiltration. Inspect stream crossings for leaks. Upgrade leaky wastewater infrastructure. Conduct water quality sampling to identify *E. coli* hot spots Use microbial source tracking to identify and target bacteria sources. Inspect livestock operations and provide rules, education and training. Consider expanding public bathroom availability.	Permit application, five year reissuance cycle Cities and sanitary districts conduct inspections and upgrades as funds are available	Compliance with discharge permits Complete inspections and upgrades of all stream crossings for *E. coli*-impaired waters Determine opportunities to increase access to public bathroom facilities	Compliance with discharge permits Replace sanitary sewers in high priority areas	# of crossings, linear feet of sanitary sewer			X	X				Ongoing
						Stormwater management	Construction and Industrial Stormwater permits coverage and compliance. Conduct studies in urban areas for stormwater retrofitting to reduce stormwater rates, volumes, and pollutant loading; identify cost-effective best management practices. Address areas of high imperviousness to reduce peak flow rates and runoff volumes. Implement extended detention in upper portion of watersheds. Implement green infrastructure and stormwater management practices to address altered hydrology and reduce loading. Identify and protect areas of high infiltration or storage. Reduce connected imperviousness. Evaluate ecosystem benefits and avoided costs (i.e., flood damage reduction, treatment of stormwater) associated with maintenance of natural landscapes and green infrastructure. Institutionalize operation and maintenance procedures for road ditches.	Permit applications, SWPP compliance rates Most new construction requires stormwater management Existing condition HSPF model has been developed at a stormwater catchment scale	Stormwater retrofit study Updated watershed model Updated ecoservices and related economic benefits (true cost) models	Stormwater management provided for the majority of watershed Mimic presettlement depressional and vegetative water storage capabilities	% treated	X	X	X	X				

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate											
HUC10 Sub-watershed	Water body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
All (cont.)	All	St. Louis and Carlton	Varies, see Section 2	Varies, see Section 2	--	Stormwater management (cont.)	Improve the predictive capability of watershed models, update calibration of existing watershed and water quality model(s) with new data. Evaluate and model stream and stormwater water quality. Strengthen or repair underground pipes, tunnels and infrastructure. Identify mechanisms to address private ownership of underground infrastructure. Identify locations where undermining, mass soil movement or scouring are threats to structural stability, infrastructure and the protection of water quality. Develop contingency plans for addressing risk and catastrophic failure.	See above	See above	See above	See above	X	X	X	X				Ongoing
						Stream crossing and culvert improvements	Complete public and private culvert inventories to identify and prioritize sources of sediment and/or barriers to stream connectivity and passage. Upgrade and replace culverts identified as barriers to fish passage (Figure 20). Properly size and place bridges and culverts for flow, stream stability, and fish passage. Identify/prioritize the rehabilitation of problematic road or trail and stream intersections. Coordinate with transportation departments to ensure bridge or culvert replacements are designed and constructed to eliminate fish passage and erosion problems.	Partial culvert inventory completed for priority streams	Complete culvert inventory and assessment of fish passage and erosion potential for all unmapped streams	Mitigate fish passage barriers and erosion	# of crossings improved	X	X	X		X			
						Address subsurface sewage treatment systems (SSTS)	Create and maintain a database of individual sewage treatment systems (i.e., owner, age, installer, size, location, construction technique, maintenance records, etc.). Inventory and assess the potential for septic systems/private wastewater systems to be sources of *E. coli* and nutrients. Replace all systems deemed imminent threat to public health (ITPH). Support increased compliance inspections (in addition to current point of sale inspections). Landowner-focused education and outreach on septic system maintenance and compliance. Additional setbacks in sensitive areas.	Point of sale septic system inspections Carlton County maintains a septic system database	Inventory and assess septic systems in *E. coli*-impaired and lake watersheds Upgrade all ITPH systems Investigate potential for connecting to regional wastewater system Compliance with Minn. R.ch.7080	100% compliance for all septic systems	% of septic systems in compliance	X			X				

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate											
HUC10 Sub-watershed	Water body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
All (cont.)	All	St. Louis and Carlton	Varies, see Section 2	Varies, see Section 2	--	Wetland management	Complete mapping and valuation of existing wetlands and assessment of wetland functions. Determine priority locations for wetland preservation/conservation, restoration, or quality improvements. Restore wetlands to increase storage and provide flood control and protection of down-gradient property/infrastructure. Evaluate and conserve wetlands in source water areas or headwaters. Use tools such as conservation easements, purchase of development rights, tax incentives and in-lieu of compensatory wetland mitigation. Permanent protection of large tracts of land focused on sensitive species habitats, aquatic buffers, shoreline habitat, upland high priority areas, and areas with significant natural heritage value as described in Tetra Tech 2015. Restoration of large-scale wetland hydrology using ditch blocks or similar, which may restore hydrology and natural fluctuations in the water table over a large area as described in Tetra Tech 2015. Reconstruct road embankments by replacing road bed with more porous medium to allow hydrologic connectivity (for example, a road along a stream where the road cuts the stream off from its floodplain, or where a road transects a wetland and cuts off hydrologic connection) as described in Tetra Tech 2015.	--	Identify priority wetlands and funding sources	Complete assessment of wetland functions Priority wetlands for protection identified and conservation measures implemented	Acres of wetland	X	X			X	X		Ongoing
						Streambank stabilization and riparian management	Address watershed sources of sediment first when possible to potentially reduce need for downstream projects (see Stormwater Management). Geomorphic assessments to prioritize restoration opportunities as needed. Restoration of channelized streams and ditches (re-meander, connect to floodplains). Address channel incision (e.g., grade control). See Section 2.3. Address erosion in lake and stream near-shore areas (bioengineering, lake shoreline revegetation, etc.). Adopt No Adverse Impact (NAI) principles.	Buffer Law has required compliance schedule Utilization of LiDAR and improved topographic products to improve flood plain and conveyance mapping	Buffers for all stream reaches consistent with Buffer Law and shoreland ordinances Geomorphic assessments in Kingsbury Creek, Mission Creek, Sargent Creek, and Lester River	Bluff, bank, and stream stabilization and lakeshore revegetation that addresses high priority locations	# of projects; linear feet	X	X	X		X	X		

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate											
HUC10 Sub-watershed	Water body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
									Adopt NAI or its functional equivalent										
All (cont.)	All	St. Louis and Carlton	Varies, see Section 2	Varies, see Section 2	--	Streambank stabilization and riparian management (cont.)	Address road crossings (direct erosion) and install controlled stream crossings (ATV, trails, etc.). Evaluate altered hydrology as the underlying cause of channel scour, bank instability and water quality impairments. Establish and maintain long term, permanent, streamflow gage sites covering the range of watersheds. Maintain vegetation along stream corridors and in floodplains as part of a natural healthy ecosystem. Apply the state buffer law and Shoreland Management Act to provide shade for trout streams, contributing to lower in-stream water temperatures. Complete watershed water budgets, accounting for wetlands, depressional areas, ditches, gullies, floodplain soils, aquifers, and vegetation. Use water budgets to target BMPs that reduce hydrologic extremes (i.e., extreme high or low flows).	Stream restoration work has been conducted on several streams (e.g., Chester Creek, Amity Creek, Kingsbury Creek, etc.)	See above	See above	See above	X	X	X		X	X		Ongoing
						Pet and wildlife waste management	Expand current pet waste management programs to reduce pollutant loading. Consider additional pet waste disposal stations in high traffic areas with educational signage connecting pet waste and pollutant loading to streams. Evaluate livestock, horses, poultry and other animal concentrations as potential bacteria sources. Identify high concentrations of urban wildlife, including birds. Use DNA source typing to identify and target bacteria sources. Adjust land use practices that encourage nuisance animal or bird populations (i.e., large grassed areas, food waste, and spilled grain). Employ multi-faceted management strategies to discourage nuisance wildlife populations (e.g., increased vegetative buffers around open water, sterilization, predator decoys and electronic deterrents).	--	Enhanced pet waste and wildlife management programs Complete source assessment information for *E. coli*-impaired streams	Vegetated buffers for majority of open waters	% of vegetated buffers		X	X				X	

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate											
HUC10 Sub-watershed	Water body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
							Increase the number and availability of trash receptacles in areas frequented by the public and ensure adequate trash removal. Conduct *E. coli* source assessments as needed. Use DNA source typing to identify sources and guide implementation activities.												
All (cont.)	All	St. Louis and Carlton	Varies, see Section 2	Varies, see Section 2	--	Land use planning and ordinances	Consider institutionalizing watershed management to eliminate waste and duplicative efforts, and increase funding, resources and project impact. Develop watershed-based plan as per the recommendations of DUWAC Enroll lands with high water resource value into the Duluth Natural Areas Program. Research, map and rank the value of undeveloped land in the upper watersheds. Protect riparian (stream and lake), wetland and high quality upland areas using easements, restrictive covenants, low impact development, tax incentives, purchasing of development rights, and other conservation tools. Evaluate and potential reserve or purchase blocks of forested lands as places providing valuable ecosystem services (i.e., water storage, purification, infiltration). Inventory tax forfeited and other publicly controlled lands on a watershed- by-watershed basis to determine which properties provide key flood control or ecosystem services. Utilize audit tools like [EPA's Water Quality Scorecard] or Sea Grant's "Barriers to Green Infrastructure" to systematically address ordinance deficiencies and gaps. Monitor and enforce illegal ATV and off-road vehicle use. Monitor and enforce no dumping regulations at sites used for illegal dumping. Explore a common set of ordinances to be used in the region by all permitting authorities Develop a comprehensive climate change vulnerability assessment for key assets in each watershed (e.g., bridges, trails, lake walk, drinking water, WLSSD, parks, etc.).	Regional watershed partnership (DUWAC)	Enhanced pet waste management ordinances Watershed-based plan Develop and implement regional strategy to address tax forfeited lands Enroll portions of Amity Creek and others into Duluth Natural Areas Program	Compliance with ordinances Implementation of watershed-based plan(s) Enroll highest quality areas into Duluth Natural Areas Program or other permanent conservation programs	% of updated ordinances and compliance rate # of plans Progress towards watershed entity # and acreage of enrolled areas	X	X	X	X	X	X		Ongoing
						Forest management	Encourage tree and forest preservation on private and public properties. Support ordinances that protect forest ecosystem values.	--	Forests formally recognized as components of	Urban tree program	% of program developed	X	X	X		X			

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate											
HUC10 Sub-watershed	Water body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
							Formally recognize forests as components of urban stormwater and watershed protection systems. Use urban trees/street trees as part of a comprehensive stormwater program. Identify, remove and replace urban trees impacted by storm damage and opportunistic invasive species such as Buckthorn and Japanese Knotweed. Develop and implement forest stewardship plans for private lands (Sustainable Forestry Incentive Act).		urban stormwater systems Review ordinances and existing programs and identify gaps Complete inventory of ash trees	Forest stewardship plans for private lands Implementation of tree replacement plan	# and % of plans produced % of plan developed and implement-ed								
All (cont.)	All	St. Louis and Carlton	Varies, see Section 2	Varies, see Section 2	--	Forest management (cont.)	Inventory black ash in buffer and woody wetland areas and determine potential impacts to water resources if extensive tree loss and/or removal occurs. Recognize that 100% loss is unlikely, and that survivors are valuable as seed sources for restoration. Conduct research to find a suitable tree species to fill the ecological niche of ash trees. Continue forestry education, outreach and training efforts.	--	See above	See above	See above	X	X	X		X			Ongoing
						Education and outreach	Encourage development of watershed stewardship groups (at the stream scale) for residents and landowners (e.g., Master Water Steward program). Continue implementation of a watershed and water quality education and outreach programs focused on riparian users/owners, municipal operations, stakeholders and residents, pet owners, importance of protection, and tourists. Encourage programs that educate the public on how their actions impact water quality. Coach homeowners on the benefits of natural landscapes and green infrastructure (i.e., native vegetation, trees, reduced yard size, rain barrels, and rain gardens). Adopt an incremental and sequenced approach to conservation adaptation. Enhance current signage to better connect actions (e.g., wildlife feeding, improper pet waste management, yard waste disposal, trash pickup, etc.) to water quality. Enhance landowner education and outreach on the benefits of buffers for stream and lake protection. Facilitate education and outreach on reducing the potential for *E. coli* bacteria (i.e., proper waste disposal, pet waste disposal and signage to prevent feeding of wildlife).	Existing programs that support MS4 permits Existing education programs	1-2 citizen-led watershed stewardship groups formed Continue implementation of a watershed and water quality education and outreach program	1-2 citizen-led watershed stewardship groups or umbrella organizations formed (akin to neighborhood associations) Continue implementation of a watershed and water quality education and outreach program	# of groups; progress made to create groups # of outreach efforts	X	X	X	X	X	X		

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate											
HUC10 Sub-watershed	Water body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
							Conduct education and outreach to users of the Superior Hiking Trail, Munger Trail, and other trail visitors on erosion and trash/litter pick up, wildlife feeding. Expand current programs at high volume visitor sites and trailheads. Support citizen science and educational tools like the Lake Superior Streams website, Crowdhydrology and MPCA's Citizen Stream Monitoring Program. Examine and expand prospects for citizens to engage in restoration, protection and watershed monitoring programs. Use the Adopt-a-River and Duluth Stream Corps models as mechanisms to encourage engagement and stewardship of streams and riparian areas. Educate snow removal companies on proper snow removal and storage practices.												

Table 11. Stream-specific strategies and actions for the City of Duluth–Frontal Lake Superior (401010204)

Protection Restoration

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate											
HUC10 Sub-watershed	Water Body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
City of Duluth – Frontal Lake Superior (401010204)	Amity Creek (-511)	St. Louis	Turbidity/TSS **TSS TMDL**	See Section 2 and Appendix A	60% reduction (see Appendix A)	Streambank stabilization and riparian management	Implement site specific recommendations on high priority reaches in the *Amity Creek Stressor Identification Report* (Jennings et al. 2017; see Appendix B of the *Duluth Urban Area Streams TMDLs*). See watershed wide strategies.	Weber Stream Restoration Initiative projects Graves Road Creek stabilization Upper Amity Creek bank stabilization Bank restoration along Seven Bridges Road	Stabilize streambanks downstream of stormwater treated areas (see stormwater management)	Stabilize 2,000-4,000 linear feet of streambank	Linear feet		X	X		X	X		2048

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate											
HUC10 Sub-watershed	Water Body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
						Stormwater management	Identify areas in the contributing drainage area that could benefit from stormwater retrofits, BMPs or new infrastructure. Implement practices to mitigate peak flows and volumes. See watershed wide strategies.	Lakeside neighborhood stormwater runoff reduction project	Stormwater retrofit study Implement practices to provide treatment for 25% of the untreated watershed area (urban areas)	Stormwater management provided for majority of watershed	% treated	X	X	X					
						Stream crossing and culvert improvements	Replace, remove or repair road crossing at Woodland Avenue, Seven Bridges Road - 3rd bridge, Nelson Road, Jean Duluth Road, and Thomas Road and other barriers as identified in Figure 20. See watershed wide strategies.	10 culverts replaced in 2012 (entire Amity watershed)	Address 6 stream crossings	Address stream crossings that are high priority barriers to fish passage	# of crossings	X				X	X		
						Land use planning and ordinances	Incorporate low impact development standards for new development. Enhance existing ordinances and land use plans to include additional water quality and water resource protection including surface water-groundwater interactions. See watershed wide strategies.	--	Review of existing ordinances and identify areas for enhancement	Updated ordinances that increase water quality and watershed protection	# of ordinances updated	X				X			

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate											
HUC10 Sub-watershed	Water Body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
City of Duluth – Frontal Lake Superior (401010204) (cont.)	Amity Creek (-511)	St. Louis	Temperature, others	See Section 2	--	Streambank stabilization and riparian management	Address stream reaches that are warming, specifically the headwaters (see Figure 21). Protect the floodplain and riparian corridor canopy and understory to improve the microclimate and effective stream shade, and prepare for future climate change impacts. Identify and protect coldwater refugia (i.e., baseflow sources, seeps, and artesian springs).	--	Conduct study to identify areas of thermal loading to Amity Creek	Address all reaches showing increases in temperature	# of reaches addressed		X			X			Ongoing
							See watershed wide strategies.												
	Amity Creek, East Branch (-540)	St. Louis	Turbidity/TSS **TSS TMDL**	See Section 2 and Appendix A	60% reduction (see Appendix A)	Streambank stabilization and riparian management	Implement site specific recommendations on high priority reaches in the *Amity Creek Stressor Identification Report* (Jennings et al. 2017; see Appendix B of *the Duluth Urban Area Streams TMDLs*). Restoration between stream mile 0.1-1.3 as a stable channel with a riffle pool sequence (stream type C). Construction of a new channel with the appropriate dimension, pattern, and profile based on a stable reference condition (see SSLSWCD 2017). See watershed wide strategies.	--	Stabilize streambanks downstream of stormwater treated areas (see stormwater management) Restoration between stream mile 0.1-1.3	Stabilize 6,000-7,000 linear feet of streambank	Linear feet		X	X		X	X		2048
						Stormwater management	Identify areas within the watershed that could benefit from stormwater retrofits, BMPs or new infrastructure. Implement practices to mitigate peak flows and volumes. See watershed wide strategies.	--	Stormwater retrofit study Implement practices to provide treatment for 25% of the untreated watershed area (urban areas)	Stormwater management provided for majority of watershed	% treated	X	X	X					
						Stream crossing and culvert improvements	Replace, remove or repair road crossing located at West Tischer Road and other barriers as identified in Figure 20. See watershed wide strategies.	10 culverts replaced in 2012 (entire Amity watershed)	Address 1 priority crossing (West Tischer Road)	Address stream crossings that are high priority barriers to fish passage	# of crossings	X	X	X		X			
						Land use planning and ordinances	Incorporate low impact development standards for new development. Enhance existing ordinances and land use plans to include additional water quality and water resource protection, including surface water-groundwater interactions. See watershed wide strategies.	--	Review of existing ordinances and identify areas for enhancement	Updated ordinances that support water quality and watershed protection	# of updated ordinances	X		X					

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
HUC10 Sub-watershed	Water Body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current Strategy Adoption Level, if Known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Estimated Adoption Rate: Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
City of Duluth – Frontal Lake Superior (401010204) (cont.)	Amity Creek, East Branch (-540) (cont.)	St. Louis	Temperature, others	See Section 2	--	Streambank stabilization and riparian management	Restoration between stream mile 0.1-1.3 to include (see SSLSWCD 2017): • Decreasing the width/depth ratio • Increasing groundwater recharge by creating floodplain access for flood waters • Stabilizing stream banks so that riparian trees can mature and provide better shade Address stream reaches that are warming, specifically the headwaters (see Figure 21). Protect the floodplain and riparian corridor canopy and understory to improve the microclimate and effective stream shade, and prepare for future climate change impacts. Identify and protect coldwater refugia (i.e., baseflow sources, seeps, and artesian springs). See watershed wide strategies.	--	Restoration between stream mile 0.1-1.3	Address all reaches showing increases in temperature	Linear feet		X	X		X			Ongoing
						See watershed wide strategies.													
	Chester Creek (-545)	St. Louis	*E. coli* ***E. coli* TMDL**	See Section 2 and Appendix A	92% *E. coli* reduction (see Appendix A)	Address discharges of untreated wastewater	Improve access to public restroom access along Chester Creek. See watershed wide strategies.	--	Consider installing additional permanent restrooms. Complete inspections and upgrades of all stream crossings for *E. coli*-impaired waters	Replace sanitary sewers in high priority areas	# of crossings			X	X				2048
						Address subsurface sewage treatment systems (SSTS)	See watershed wide strategies.	--	Inventory and assess septic systems Upgrade all ITPH systems Investigate potential for connecting to regional wastewater system	100% compliance for all septic systems	% of septic systems in compliance	X							
						Stormwater management	Identify areas in the contributing drainage area that could benefit from stormwater retrofits, BMPs or new infrastructure. Implement practices to disconnect imperviousness and provide water quality treatment. See watershed wide strategies.	--	Stormwater retrofit study Implement 2 neighborhood scale projects	Stormwater management provided for majority of watershed	% treated	X	X	X					

Waterbody and Location: HUC10 Sub-watershed	Waterbody and Location: Water Body (ID)	Waterbody and Location: Location and Upstream Influence Counties	Water Quality: Parameter	Water Quality: Current Conditions	Water Quality: Goals / Targets and Estimated % Reduction	Strategies	Strategy Type	Estimated Adoption Rate: Current Strategy Adoption Level, if Known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Estimated Adoption Rate: Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	Estimated Year to Achieve Water Quality Target
							Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					*Governmental Units with Primary Responsibility*							
City of Duluth – Frontal Lake Superior (401010204) (cont.)	Chester Creek (-545) (cont.)	St. Louis				Pet and wildlife waste management	See watershed wide strategies.	--	Inventory wildlife populations in the watershed Enhanced pet waste and wildlife management programs	Vegetated buffers for majority of open waters	% with vegetated buffers		X	X		X			2048
						Education and outreach	See watershed wide strategies.	--	Outreach campaign that addresses sources of *E. coli*	Conduct focused outreach every 5-years	# of focused outreach		X	X					
			E. coli ***E. coli* TMDL**	See Section 2 and Appendix A	92% *E. coli* reduction (see Appendix A)	Land use planning and ordinances	Update ordinances to include enforcement of pet waste ordinances. Update ordinances as needed to require vegetated buffers on open waters.	--	Updated ordinances as needed	Compliance with ordinances	% of updated ordinances and compliance rate	X		X					
			Sediment, temperature, others	See Section 2	--	Streambank stabilization and riparian management	Riparian restoration downstream of Kenwood Ave, between Kenwood Ave and the confluence with East Branch Chester Creek, and between Triggs Ave and Arrowhead Road on the East Branch. Remove and control invasive species in riparian areas downstream of Kenwood Avenue, between Kenwood Avenue and the confluence of the East Branch, and between Triggs Avenue and Arrowhead Road on the East Branch of Chester. Evaluate the effect of beaver dams on Chester Creek miles 2.6-3.6. Develop strategies to discourage or relocate beavers that pose significant threats to public safety, property or stream connectivity and water quality while balancing potential impacts to water storage and flow. Restore the stream to a natural meandering channel with a low width/depth ratio (E channel). Reduce stormwater runoff from nearby impervious surfaces and increase groundwater recharge. Restore to natural channel and riparian corridor (900 feet), remove remnant dam structures on mile 1.4-1.6 of Chester Creek (Chester Park). Address stream reaches that have higher threat to warming (see Figure 21).	Three stream restoration projects in 2016 using natural channel design principles; included toe-wood methods to create a floodplain bench Removal of dam structures and stream restoration of Chester Creek (Chester Park) in 2017	Restoration of river miles 1.4-1.6 and 2.6-3.6 Invasive species management	Address all reaches showing increases in temperature Restoration projects on 7 stream locations as described in SSLSWCD 2017 (Appendix B)	# of reaches addressed # of restoration projects		X	X		X	X		Ongoing

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
HUC10 Sub-watershed	Water Body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current Strategy Adoption Level, if Known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Estimated Adoption Rate: Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
City of Duluth – Frontal Lake Superior (401010204) (cont.)	Chester Creek (-545) (cont.)	St. Louis	Sediment, temperature, others	See Section 2	--	Streambank stabilization and riparian management (cont.)	Protect the floodplain and riparian corridor canopy and understory to improve the microclimate and effective stream shade, and prepare for future climate change impacts. Identify and protect coldwater refugia (i.e., baseflow sources, seeps, and artesian springs). Restoration of priority reaches as described in SSLSWCD 2017 and Figure 23. See watershed wide strategies.	--	See above	See above	See above	X	X		X	X			Ongoing
						Stream crossing and culvert improvements	Replace, remove or repair road crossing located at Thurber and Norton Roads and other barriers as identified in Figure 20. See watershed wide strategies.	--	--	Address stream crossings that are high priority barriers to fish passage	# of crossings	X	X	X		X			
						See watershed wide strategies.													
	Lester River (-549)	St. Louis	Turbidity/TSS **TSS TMDL**	See Section 2 and Appendix A	60-90% TSS reduction (see Appendix A)	Streambank stabilization and riparian management	Implement sediment reduction strategies in Amity Creek, a significant tributary to Lester River. Conduct geomorphic analysis to identify high priority sediment sources. See watershed wide strategies.	--	Amity Creek sediment reductions	Amity Creek sediment reductions Complete geomorphic analysis Stabilize streambanks and bluffs as needed	# of sediment reductions % of geomorphic analysis completed # of banks and bluffs		X	X		X	X		2048
						Stormwater management	Address flooding after large stormwater events along Jean Duluth and Lismore Roads by implementing cost effective stormwater BMPs and/or green infrastructure. Identify areas in the contributing drainage area that could benefit from stormwater retrofits, BMPs or new infrastructure Implement practices to mitigate peak flows and volumes. See watershed wide strategies.	--	--	Stormwater management along Jean Duluth and Lismore roads and for majority of watershed	% of stormwater manage-ment completed	X	X	X					
						Land use planning and ordinance	Incorporate low impact development and larger setback standards into new development (e.g., Troy Brett Trail neighborhood). Enhance existing ordinances and land use plans to include additional water quality and water resource protection. See watershed wide strategies.	--	--	Review and update ordinances that support water quality and watershed protection	# of ordinances reviewed and updated	X		X					

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate											
HUC10 Sub-watershed	Water Body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
City of Duluth – Frontal Lake Superior (401010204) (cont.)	Lester River (-549) (cont.)	St. Louis	Turbidity/TSS **TSS TMDL**	See Section 2 and Appendix A	60-90% TSS reduction (see Appendix A)	Education and outreach	Educate homeowners associations (e.g., Troy Bret Trail neighborhood) on proper lawn care, setbacks, and waste disposal.	--	--	Produce and distribute homeowner association education materials	# of home-owners educated		X	X					2048
			Temperature, others	See Section 2	--	Streambank stabilization and riparian management	Address stream reaches that are warming, specifically the headwaters (see Figure 21). Protect the floodplain and riparian corridor canopy and understory to improve the microclimate and effective stream shade, and prepare for future climate change impacts. Identify and protect coldwater refugia (i.e., baseflow sources, seeps, and artesian springs). See watershed wide strategies	--	--	Address all reaches showing increases in temperature	# of reaches addressed		X			X			Ongoing
							See watershed wide strategies.												
	Tischer Creek (-543 and -544)	St. Louis	*E. coli* ***E. coli* TMDL**	See Section 2 and Appendix A	89% *E. coli* reduction (see Appendix A)	Address discharges of untreated wastewater	See watershed wide strategies.	2 stream crossings have been lined or upgraded by Duluth	Complete inspections and upgrades of all stream crossings for *E. coli*-impaired waters	Replace sanitary sewers in high priority areas	# of crossings			X	X				2048
						Address subsurface sewage treatment systems (SSTS)	See watershed wide strategies.	--	Inventory and assess septic systems Upgrade all ITPH systems Investigate potential for a regional wastewater system	100% compliance for all septic systems	% of septic systems in compliance	X							
						Stormwater management	Identify areas in the contributing drainage area that could benefit from stormwater retrofits, BMPs or new infrastructure. Implement practices to disconnect imperviousness and provide water quality treatment. See watershed wide strategies.	--	Stormwater retrofit study Implement 2 neighborhood scale projects	Stormwater management provided for majority of watershed	% treated	X	X	X					
						Pet and wildlife waste management	See watershed wide strategies.	--	Inventory wildlife populations in the watershed Enhanced waste management programs	Vegetated buffers for majority of open waters	% with vegetated buffers		X	X		X			

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate											
HUC10 Sub-watershed	Water Body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
City of Duluth – Frontal Lake Superior (401010204) (cont.)	Tischer Creek (-543 and -544) (cont.)	St. Louis	*E. coli* ***E. coli* TMDL**	See Section 2 and Appendix A	89% *E. coli* reduction (see Appendix A)	Education and outreach	See watershed wide strategies.	--	Outreach campaign that addresses sources of *E. coli*	Conduct focused outreach every 5-years	# of outreach efforts		X	X					2048
						Land use planning and ordinances	Update ordinances to include enforcement of pet waste ordinances. Update ordinances as needed to require vegetated buffers on open waters.	--	Updated ordinances as needed	Compliance with ordinances	% of updated ordinances and compliance rate	X		X					
			Sediment, temperature, others	See Section 2	--	Land use planning and ordinance	Incorporate low impact development standards into new development along Rice Lake Corridor. Use stream protection techniques like MDNR Trout Stream Access easements to protect the highest quality segments of Tischer Creek (see Appendix B). See watershed wide strategies.	--	Review of ordinances	Updated ordinances that support water quality and watershed protection Easements along high quality reaches	% of updated ordinances # of easements	X		X					Ongoing
						Stream crossing and culvert improvements	Replace, remove or repair road crossing of West Tischer and the Abandoned Maryland Street and other barriers as identified in Figure 20. See watershed wide strategies.	--	Address 2 stream crossings	Address stream crossings that are high priority barriers to fish passage	# of crossings	X	X	X		X			
						Streambank stabilization and riparian management	Address warming of stream temperatures as linked to Hartley Pond (e.g., redesign pond outlet, increase shade, etc.). Consider restoration of mile 3.3-4.0 to a natural, low width/depth ratio through current impoundment to improve temperatures after conducting a comprehensive feasibility assessment. Restoration of priority reaches as described in SSLSWCD 2017 and Figure 23 including West Branch, between West St. Marie Street and Norton Street and downstream of West Arrowhead Road.	--	Feasibility study for Hartley Pond	Address all reaches showing increases in temperature Restoration projects on 6 stream locations as described in SSLSWCD 2017 (Appendix B)	% of reaches addressed # of priority restoration projects completed		X	X		X	X		

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
HUC10 Sub-watershed	Water Body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current Strategy Adoption Level, if Known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Estimated Adoption Rate: Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
City of Duluth – Frontal Lake Superior (401010204) (cont.)	Tischer Creek (-543 and -544) (cont.)	St. Louis	Sediment, temperature, others	See Section 2	--	Streambank stabilization and riparian management (cont.)	Natural riparian buffer and revegetate riprap between the confluence of the West Branch and Wallace and downstream of Hartley Pond. Remove and control invasive species in riparian buffer. Address stream reaches that are warming (see Figure 21). Protect the floodplain and riparian corridor canopy and understory to improve the microclimate and effective stream shade, and prepare for future climate change impacts. Identify and protect coldwater refugia (i.e., baseflow sources, seeps, and artesian springs). See watershed wide strategies.	--	See above	See above	See above		X	X		X	X		Ongoing
							See watershed wide strategies.												
	Eagle Lake (69-0238-00)	St. Louis	Nutrients and chlorophyll	See Section 2	--		See watershed wide strategies.												Ongoing
	Leif Erickson Park Beach (-C21)	St. Louis	*E. coli*	See Section 2	Reduce # of beach closings to zero	TMDL implementation	Address *E. coli* loading from Chester Creek (see Chester Creek).												To be deter-mined during TMDL develop-ment
						TMDL development	Complete TMDL development for impaired beaches.	--	Complete TMDLs and implementation plan	TMDL completed	% of TMDL completion			X					
						Stormwater management	Implement stormwater management opportunities to treat direct runoff to beaches. Ensure practices do not attract additional wildlife.	--	--	Stormwater retrofit plan All direct runoff receives treatment	% of plan completed % of treated runoff		X	X				X	
						Land use planning and ordinances	Increase trash receptacles on beaches. Ensure availability of adequate bathroom/shower facilities near public beaches with high traffic. See watershed wide strategies.	--	--	Updated facilities as needed to address *E. coli* sources (bathrooms, pet waste, trash)	# of new and updated facilities			X				X	
						Education and outreach activities	Education and outreach on reducing *E. coli* at beaches (i.e., proper waste disposal, pet waste disposal and signage to prevent feeding of wildlife). See watershed wide strategies.	--	Outreach campaign that addresses sources of *E. coli*	Conduct focused outreach every 5-years	# of outreach efforts		X	X				X	

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
HUC10 Sub-watershed	Water Body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate				Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
								Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units								
City of Duluth – Frontal Lake Superior (401010204) (cont.)	Leif Erickson Park Beach (-C21) (cont.)	St. Louis	*E. coli*	See Section 2	Reduce # of beach closings to zero	Pet and wildlife waste management	See watershed wide strategies.	--	--	Enhanced pet waste and wildlife management program	% of programs enhanced		X	X				X	
	58th Ave E Creek (-999) 47th Ave E Creek (-999) 43rd Ave E Creek (-999) 40th Ave E Creek (-999) 37th Ave E Creek (No AUID) Bent Creek (999) Oregon Creek (No AUID) Chester Creek (-545) Greys Creek (-999) Brewery Creek (-C14) Unimpaired lakes		Varies	See Section 2	--		See watershed wide strategies.												Ongoing

Table 12. Stream specific restoration and protection strategies for St. Louis Bay (4010201116)

Protection   Restoration

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate											
HUC10 Sub-watershed	Water body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
St. Louis Bay (4010201116)	Kingsbury Creek (-626)	St. Louis	Aquatic macro-invertebrate and fishes bio-assessments (elevated water temperature, low dissolved oxygen, TSS/turbidity, poor physical habitat conditions) **TSS TMDL**	See Section 2 and Appendix A	60% TSS reduction (see Appendix A)	Reduce industrial wastewater discharges	Reduce point source loading per TMDL (see Appendix A).	--	Permit compliance	Permit compliance	Compliance rate			X					2048
						Streambank stabilization and riparian management	Complete geomorphic assessment of creek and determine priority sediment sources. Increase tree cover and shade to restore appropriate stream temperatures for trout and other cold water species. Focus restoration in the Proctor-area. Restore channelized and ditched stream segments to provide sinuosity and lower width to depth ratios. Provide riffles. Address areas with stagnant water near Proctor. Stabilize 5 high loading banks as identified in the Stressor Identification Report (MPCA 2016). Improve riparian buffers to provide shade and remain consistent with state buffer requirements. See watershed wide strategies.	--	Buffers for all stream reaches consistent with Buffer Law	Restoration of channelized segments in Proctor area Shade provided for stream channel 5 banks stabilized Additional stabilization as needed	# of segments restored Linear feet # stabilized banks		X	X		X	X		
						Stream crossing and culvert improvements	See watershed wide strategies.	--	--	Address stream crossings that are high priority	# of crossings	X	X	X		X			
						Stormwater management	Impervious surface disconnection. Reduce peak stream flows and runoff volumes. Stormwater management to treat runoff from untreated areas in the City of Proctor and along the Canadian National rail yard. Establish a riparian buffer and discourage snow storage immediately adjacent to Kingsbury Creek. Ensure that land use practices do not contribute to warming of water. Reduce nutrient loading from developed areas. See watershed wide strategies.	--	--	Stormwater management provided for majority of watershed (developed portions)	% of watershed	X	X	X					
						Education and outreach	Improve education and outreach in the developed areas near Proctor. Focus efforts on nutrient reduction, benefit of green infrastructure, riparian shade, and stormwater management good housekeeping (e.g., leaf litter management). See watershed wide strategies.	--	--	Education program	# of outreach efforts		X	X					

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
HUC10 Sub-watershed	Water body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current Strategy Adoption Level, if Known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Estimated Adoption Rate: Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
St. Louis Bay (4010201116) (cont.)	Kingsbury Creek (-626) (cont.)	St. Louis				Land use planning and ordinances	Enhance existing ordinances and land use plans to include additional water quality and water resource protection.	--	--	Updated ordinances that support water quality and watershed protection	# of updated ordinances			X					2048
			Varies	See Section 2	--	See watershed wide strategies.													Ongoing
	Miller Creek (-512)	St. Louis	Temperature, lack of cold water assemblage, aquatic macro-invertebrate bio-assessments **Temperature TMDL**	See Section 2 and Appendix A	10% heat unit reduction (See Appendix A)	Implement TMDL implementation activities	See *Miller Creek Water Temperature TMDL* (MPCA 2017b).												2030
						Restoration of stream processes and watershed functions	Increase baseflow augmentation by reconnecting the stream channel with its floodplain above Kohls department store. Restore channel morphology and habitat on select channelized sections of Miller Creek. Restore and maintain wetland functions.	--	Restoration of wetland above Kohls Identify coldwater inputs, key spawning areas and thermal refuges Complete/update wetland functional assessment	Increased baseflow and improved stream morphology	Acres or linear feet of restoration		X	X		X			
						Riparian management (improve riparian vegetation density and composition)	Increase tree and shrub cover and shading at impacted wetland above Kohl's department store. Conduct tree and shrub plantings in riparian areas. Reestablish native plant communities in areas of turf grass. Increase tree cover and shade at Lincoln Park. Increase tree cover and shade and remove invasive species upstream of Maple Grove Road, behind Miller Hill Mall, and downstream of Hwy 53. Without sacrificing safety or access, reduce or eliminate lawns in the riparian corridor throughout Lincoln Park.	--	Targeted increases in shade along creek and wetlands in Lincoln Park, upstream of Maple Grove Road behind Miller Hill Mall, along Mall Drive, and downstream of Hwy 53	Identify, prioritize, and complete shading projects based on existing conditions (e.g., stream orientation, bank angle, soils, vegetation) Technical assistance to riparian landowners	# of shading projects # of land-owners		X						

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate											
HUC10 Sub-watershed	Water body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
St. Louis Bay (4010201116) (cont.)	Miller Creek (-512) (cont.)	St. Louis	Temperature, lack of cold water assemblage, aquatic macro-invertebrate bio-assessments **Temperature TMDL**	See Section 2 and Appendix A	10% heat unit reduction (See Appendix A)	Stormwater management	Reduce peak flow rates. Incorporate bottom outlet discharges, underground stormwater storage, and infiltration. 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 (commercial, industrial, institutional, and residential structures). Provide technical assistance to homeowners (e.g., rain barrels, rain gardens, disconnecting and reducing impervious, redirecting runoff, etc.). Implement comprehensive stormwater management plan for Miller Hill Mall.		Begin implementation of Miller Hill Mall stormwater plan Identify opportunities for stormwater retrofits in the Upper Watershed (Duluth, Hermantown, St. Louis County, MnDOT, Lake Superior College) Identify areas of untreated stormwater for improved management Evaluate existing BMPs for thermal reduction potential	Stormwater management provided for majority of watershed (developed portions)	% of watershed	X	X	X					2048
						Education and outreach	Outreach and education with homeowners along the stream, including technical assistance for increased riparian vegetation and stormwater management. Develop materials for Miller Hill Mall tenants and patrons. Hold public workshops, festivals, stream clean-ups.		Miller Hill Mall education materials (e.g., signage) Outreach campaign that addresses sources of thermal loading	Ongoing outreach and education Technical assistance	# of outreach efforts # of tenants and patrons assisted		X	X					
						Land use planning and ordinances	Enhanced enforcement of zoning codes. Encourage low impact development practices. Establish conservation easements on sensitive lands, including wetlands, riparian lands, and coldwater source areas.		Review ordinances and identify potential enhancements	Easements on priority natural areas and buffers Updated ordinances that support water quality and watershed protection	# of easements # of updated ordinances	X		X					
			E. coli ***E. coli* TMDL**	See Section 2 and Appendix A	70% *E. coli* reduction (see	Address discharges of untreated wastewater	See watershed wide strategies.	1 stream crossings has been lined or	Complete inspections and upgrades of all stream crossings for *E. coli*-impaired waters	Replace sanitary sewers in high priority areas	# of crossings			X	X				2048

HUC10 Sub-watershed (Waterbody and Location)	Water body (ID)	Location and Upstream Influence Counties	Parameter (Water Quality)	Current Conditions	Goals / Targets and Estimated % Reduction	Strategies	Strategy Type (Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.)	Current Strategy Adoption Level, if Known (Estimated Adoption Rate)	Interim 10-year Milestone	Suggested Goal	Units	Counties (Governmental Units with Primary Responsibility)	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	Estimated Year to Achieve Water Quality Target
					Appendix A)			upgraded by Duluth											
St. Louis Bay (4010201116) (cont.)	Miller Creek (-512) (cont.)	St. Louis	*E. coli* ***E. coli* TMDL**	See Section 2 and Appendix A	70% *E. coli* reduction (see Appendix A)	Address subsurface sewage treatment systems (SSTS)	See watershed wide strategies.	--	Inventory and assess septic systems Upgrade all ITPH systems Investigate potential for connecting to regional wastewater system	100% compliance for all septic systems	% of septic systems in compliance	X							2048
						Stormwater management	Identify areas in the contributing drainage area that could benefit from stormwater retrofits, BMPs or new infrastructure. Implement practices to disconnect imperviousness and provide water quality treatment. See watershed wide strategies.	--	Stormwater retrofit study Implement 3 neighborhood scale projects	Stormwater management provided for majority of watershed	% treated	X	X	X					
						Pet and wildlife waste management	See watershed wide strategies.	--	Inventory wildlife populations in the watershed Enhanced pet waste and wildlife management programs	Vegetated buffers for majority of open waters	% with vegetated buffers		X	X		X			
						Education and outreach	See watershed wide strategies.	--	Outreach campaign that addresses sources of *E. coli*	Conduct focused outreach every 5-years	# of outreach efforts		X	X					
						Land use planning and ordinances	Update ordinances to include enforcement of pet waste ordinances. Update ordinances as needed to require vegetated buffers on open waters.	--	Updated ordinances as needed	Compliance with ordinances	% of updated ordinances and compliance rate	X		X					
			Chloride, aquatic macro-invertebrate bio-assessments	See Section 2	Unknown	Regional chloride strategy	Develop regional chloride strategy in collaboration with Twin Cities Metropolitan Area Chloride Project. A statewide draft plan is also available to guide actions. Conduct monitoring of surface and groundwater. Determine sources of high chloride; address those that do not impact health and safety.	Monitoring is underway	Develop chloride TMDLs as needed	Develop and implement regional chloride strategy	% of strategy drafted and implement-ed	X		X	X				To be deter-mined during TMDL develop-ment

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate											
HUC10 Sub-watershed	Water body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
			Sediment, others	See Section 2	--	Stream crossing and culvert improvements	Replace, remove or repair road crossing of Skyline Parkway/N 24th Avenue W and other barriers as identified in Figure 20. See watershed wide strategies.	--	Upgrade crossing at Skyline Parkway/N 24th Ave W	Address stream crossings that are high priority barriers to fish passage	# of crossings	X	X	X		X			Ongoing

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate											
HUC10 Sub-watershed	Water body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
St. Louis Bay (4010201116) (cont.)	Miller Creek (-512) (cont.)	St. Louis	Sediment, others	See Section 2	--	Streambank stabilization and riparian management	Naturalize the stream segment through Lincoln Park, using fewer rock and concrete structures. Restoration of creek up and downstream of Anderson Road to address lawns mowed to stream edge, no shade, stream bank erosion, medium priority road crossing barrier, and slightly warming water temperature. Restoration of priority reaches as described in SSLSWCD 2017 and Figure 23. See watershed wide strategies.	Work has begun on Lincoln Park project	Restore 2 high priority locations	Restoration projects on 6 stream locations as described in SSLSWCD 2017 (Appendix B) Address all reaches showing increases in temperature	# of projects completed % of reaches addressed	X	X	X		X	X		Ongoing
							See watershed wide strategies.												
	Keene Creek (-627)	St. Louis	*E. coli* ***E. coli* TMDL**	See Section 2 and Appendix A	87% *E. coli* reduction (see Appendix A)	Address discharges of untreated wastewater	See watershed wide strategies.	--	Complete inspections and upgrades of all stream crossings for *E. coli*-impaired waters	Replace sanitary sewers in high priority areas	# of crossings			X	X				2048
						Address subsurface sewage treatment systems (SSTS)	See watershed wide strategies.	--	Inventory and assess septic systems Upgrade all ITPH systems Investigate potential for connecting to regional wastewater system	100% compliance for all septic systems	% of septic systems in compliance	X							
						Stormwater management	Identify areas in the contributing drainage area that could benefit from stormwater retrofits, BMPs or new infrastructure. Implement practices to disconnect imperviousness and provide water quality treatment. See watershed wide strategies.	--	Stormwater retrofit study Implement 2 neighborhood scale projects	Stormwater management provided for majority of watershed	% treated	X	X	X					
						Land use planning and ordinances	Update ordinances to include adoption and enforcement of pet waste ordinances. Update ordinances as needed to require vegetated buffers on open waters.	--	Updated ordinances as needed	Compliance with ordinances	% of updated ordinances and compliance rate	X		X					

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate											
HUC10 Sub-watershed	Water body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
St. Louis Bay (4010201116) (cont.)	Keene Creek (-627) (cont.)	St. Louis	*E. coli* ***E. coli* TMDL**	See Section 2 and Appendix A	87% *E. coli* reduction (see Appendix A)	Pet and wildlife waste management	Monitor runoff from Keene Creek Dog Park and implement BMP practices to address potential bacteria or *E. coli* loading. See watershed wide strategies.	--	Monitor runoff from the dog park and implement practices to address loading Inventory wildlife populations in the watershed Enhanced pet waste and wildlife management programs	Vegetated buffers for majority of open waters	% with vegetated buffers		X	X		X			2048
						Education and outreach	See watershed wide strategies.	--	Outreach campaign that addresses sources of *E. coli*	Conduct focused outreach every 5-years	# of outreach efforts		X	X					
			Sediment, others	See Section 2	--	Streambank stabilization and riparian management	Riparian restoration downstream of South Central Avenue. Keene Creek stream relocation and habitat restoration; acquire conservation easements. Restoration of priority reaches as described in SSLSWCD 2017 and Figure 23 including downstream of Keene Creek Park, near trail to address channel incision, significant bank erosion, and pooling water causing warming. Address stream reaches that are warming (see Figure 21). Protect the floodplain and riparian corridor canopy and understory to improve the microclimate and effective stream shade, and prepare for future climate change impacts. Identify and protect coldwater refugia (i.e., baseflow sources, seeps, and artesian springs). See watershed wide strategies.	--	Restore 1 high priority reach	Restoration projects on 8 stream locations as described in SSLSWCD 2017 (Appendix B) Address all reaches showing increases in temperature	# of projects completed % of reaches addressed	X	X	X		X	X		Ongoing
						Stream crossing and culvert improvements	Replace, remove or repair road crossing acting as fish passage barriers as identified in Figure 20. See watershed wide strategies.	--	Address one high priority stream crossing (i.e., fish barriers)	Address stream crossings that are high priority barriers to fish passage	# of crossings	X	X	X		X			
							See watershed wide strategies.												

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate											
HUC10 Sub-watershed	Water body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
St. Louis Bay (4010201116) (cont.)	Sargent Creek (-848)	St. Louis	*E. coli* ***E. coli* TMDL**	See Section 2 and Appendix A	45% *E. coli* reduction (see Appendix A)	Address discharges of untreated wastewater	See watershed wide strategies.	--	--	Complete inspections and upgrades of all stream crossings for *E. coli*-impaired waters Replace sanitary sewers in high priority areas	# of crossings			X	X				2048
						Address subsurface sewage treatment systems (SSTS)	See watershed wide strategies.	--	--	Inventory and assess septic systems Upgrade all ITPH systems Investigate potential for connecting to regional wastewater system 100% compliance for all septic systems	% of septic systems in compliance	X							
						Stormwater management	Identify areas in the contributing drainage area that could benefit from stormwater retrofits, BMPs or new infrastructure. Implement practices to disconnect imperviousness and provide water quality treatment. See watershed wide strategies.	--	--	Stormwater retrofit study Stormwater management provided for majority of watershed	% treated	X	X	X					
						Pet and wildlife waste management	See watershed wide strategies.	--	Inventory wildlife populations in the watershed Enhanced pet waste and wildlife management programs	Vegetated buffers for majority of open waters	% with vegetated buffers		X	X		X			
						Education and outreach	See watershed wide strategies.	--	Outreach campaign that addresses sources of *E. coli*	Conduct focused outreach every 5-years	# of outreach efforts		X	X					

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
HUC10 Sub-watershed	Water body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
St. Louis Bay (4010201116) (cont.)	Sargent Creek (-848) (cont.)	St. Louis	*E. coli* ***E. coli* TMDL**	See Section 2 and Appendix A	45% *E. coli* reduction (see Appendix A)	Land use planning and ordinances	Update ordinances to include enforcement of pet waste ordinances. Update ordinances as needed to require vegetated buffers on open waters.	--	Updated ordinances as needed	Compliance with ordinances	% of updated ordinances and compliance rate	X		X					2048
			Sediment, temperature, others	See Section 2	--		See watershed wide strategies.												Ongoing
	Stewart Creek (-884)	St. Louis	*E. coli* ***E. coli* TMDL**	See Section 2 and Appendix A	44% *E. coli* reduction (see Appendix A)	Address discharges of untreated wastewater	See watershed wide strategies.	--	--	Complete inspections and upgrades of all stream crossings for *E. coli*-impaired waters Replace sanitary sewers in high priority areas	# of crossings # of replace-ments			X	X				2048
						Address subsurface sewage treatment systems (SSTS)	See watershed wide strategies.	--	--	Inventory and assess septic systems Upgrade all ITPH systems Investigate potential for connecting to regional wastewater system 100% compliance for all septic systems	% of septic systems in compliance	X							
						Stormwater management	Identify areas in the contributing drainage area that lack stormwater management and that could benefit from stormwater retrofits, BMPs or new infrastructure. Implement practices to disconnect imperviousness and provide water quality treatment. See watershed wide strategies.	--	--	Stormwater retrofit study Stormwater management provided for majority of watershed	% treated	X	X	X					

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate											
HUC10 Sub-watershed	Water body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
St. Louis Bay (4010201116) (cont.)	Stewart Creek (-884) (cont.)	St. Louis	*E. coli* ***E. coli* TMDL**	See Section 2 and Appendix A	44% *E. coli* reduction (see Appendix A)	Pet and wildlife waste management	See watershed wide strategies.	--	Inventory wildlife populations in the watershed Enhanced pet waste and wildlife management programs	Vegetated buffers for majority of open waters	% with vegetated buffers		X	X		X			2048
						Education and outreach	See watershed wide strategies.	--	Outreach campaign that addresses sources of *E. coli*	Conduct focused outreach every 5-years	# of outreach efforts		X	X					
						Land use planning and ordinances	Update ordinances to include adoption and enforcement of pet waste ordinances. Update ordinances as needed to require vegetated buffers on open waters.	--	Updated ordinances as needed	Compliance with ordinances	% of updated ordinances and compliance rate	X		X					
			Sediment, others	See Section 2	--		See watershed wide strategies.												Ongoing
	Merritt Creek (-987)	St. Louis	*E. coli* ***E. coli* TMDL**	See Section 2 and Appendix A	85% *E. coli* reduction (see Appendix A)	Address discharges of untreated wastewater	See watershed wide strategies.	--	Complete inspections and upgrades of all stream crossings for *E. coli*-impaired waters	Replace sanitary sewers in high priority areas	# of crossings			X	X				2048
						Address subsurface sewage treatment systems (SSTS)	See watershed wide strategies.	--	Inventory and assess septic systems Upgrade all ITPH systems Investigate potential for connecting to regional wastewater system	100% compliance for all septic systems	% of septic systems in compliance	X							
						Stormwater management	Identify areas in the contributing drainage area that lack stormwater management and implement practices to disconnect imperviousness and provide water quality treatment. See watershed wide strategies.	--	Stormwater retrofit study Implement 2 neighborhood scale projects	Stormwater management provided for majority of watershed	% treated	X	X	X					
						Pet and wildlife waste management	See watershed wide strategies.	--	Inventory wildlife populations in the watershed Enhanced waste and management programs	Vegetated buffers for majority of open waters	% with vegetated buffers		X	X		X			

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
HUC10 Sub-watershed	Water body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
St. Louis Bay (4010201116) (cont.)	Merritt Creek (-987) (cont.)	St. Louis	*E. coli* ***E. coli* TMDL**	See Section 2 and Appendix A	85% *E. coli* reduction (see Appendix A)	Education and outreach	See watershed wide strategies.	--	Outreach campaign that addresses sources of *E. coli*	Conduct focused outreach every 5-years	# of outreach efforts		X	X					2048
						Land use planning and ordinances	Update ordinances to include adoption and enforcement of pet waste ordinances. Update ordinances as needed to require vegetated buffers on open waters.	--	Updated ordinances as needed	Compliance with ordinances	% of updated ordinances and compliance rate	X		X					
			Sediment, others	See Section 2	--	Streambank stabilization and riparian management	Riparian restoration downstream of I-35 to address lack of canopy species and invasive reed canary grass. Restoration of priority reaches as described in SSLSWCD 2017 and Figure 23 including East Branch – 1/3rd mile upstream of Skyline Parkway. Address stream reaches that are warming (see Figure 21). Protect the floodplain and riparian corridor canopy and understory to improve the microclimate and effective stream shade, and prepare for future climate change impacts. Identify and protect coldwater refugia (i.e., baseflow sources, seeps, and artesian springs). See watershed wide strategies.	--	Restore 1 high priority stream reach Protect groundwater source areas, artesian water sources, and headwater wetlands Use conservation tools such as easements, purchase of development rights, and tax incentives	Restoration projects on 4 stream locations as described in SSLSWCD 2017 (Appendix B) Address all reaches showing increases in temperature	# of projects completed % of reaches addressed	X	X	X		X	X		Ongoing
						Stream crossing and culvert improvements	Replace, remove or repair road crossing at Superior Hiking Trail and other barriers as identified in Figure 20. See watershed wide strategies.	--	Upgrade crossing at the Superior Hiking Trail	Address high priority stream crossings (i.e., fish barriers)	# of stream crossings	X	X	X		X			
						See watershed wide strategies.													
	Impaired beaches (-A91, -A87, -A89, and -A90)	St. Louis	*E. coli*	See Section 2	Reduce # of beach closings to zero	TMDL implementation	Address *E. coli* loading from Stewart Creek (see Stewart Creek)					X	X	X	X	X			To be deter-mined during TMDL develop-ment
						TMDL development	Complete TMDL development for impaired beaches.	--	Complete TMDLs and implementation plan	TMDLs completed	% of TMDL completion				X			X	
						Address discharge of untreated wastewater	Ensure compliance with discharge permits. See watershed wide strategies.	--	Compliance with discharge permits	Compliance with discharge permits	Compliance rate			X	X				
						Stormwater management	Implement stormwater management opportunities to treat direct runoff to beaches. Ensure practices do not attract additional wildlife.	--	Stormwater retrofit plan	All direct runoff receives treatment	% receiving treatment		X	X				X	

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate											
HUC10 Sub-watershed	Water body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
St. Louis Bay (4010201116) (cont.)	Impaired beaches (-A91, -A87, -A89, and -A90) (cont.)	St. Louis	*E. coli*	See Section 2	Reduce # of beach closings to zero	Monitoring	Monitor and determine the potential of ballast water, gray water, and recreational and commercial boating as sources of *E. coli* in near shore areas and at beaches; address sources as needed. Conduct microbial source tracking to determine sources of *E. coli* where no data exist.	--	Microbial source tracking project Complete study on ballast water	Target source reductions as needed	# of reductions		X	X	X			X	To be deter-mined during TMDL develop-ment
						Land use planning and ordinances	Enhance current pet waste ordinances to include enforcement. Consider increased placement of trash receptacles on beaches. Ensure availability of adequate bathroom/shower facilities near beaches. Recognize and discourage landscaping practices that encourage nuisance bird and wildlife populations (i.e., places without natural cover for predators). See watershed wide strategies.	Updated bathroom facility being constructed at Park Point beach	Develop plan for bathroom/shower facilities, as needed Encourage natural landscaping designs that minimize lawns	Updated facilities as needed to address *E. coli* sources (bathrooms, pet waste, trash)	# of new and updated facilities			X					
						Education and outreach activities	Educate boat owners on proper disposal of waste to reduce *E. coil* loading in the harbor. Education and outreach on reducing *E. coli* at beaches (i.e., proper waste disposal, pet waste disposal and signage to prevent feeding of wildlife). See watershed wide strategies.	--	Outreach campaign that addresses sources of *E. coli*	Conduct focused outreach every 5-years	# of outreach efforts		X	X				X	
						Pet and wildlife waste management	See watershed wide strategies.	--	Enhanced pet waste and wildlife management programs	Programmatic activities that address wildlife and pet waste	# of activities		X	X				X	
	Mission Creek (-640)	St. Louis and Carlton	Varies	See Section 2	--	Streambank stabilization and riparian management	Address severe streambank slumping and habitat degradation as a result of altered hydrology. Utilize DNR's red clay stability analysis to minimize uses that accelerate natural slope failure rates or mass wasting on Mission Creek. See watershed wide strategies.	--	--	Restored stream channel Updated ordinances as needed	# of projects; linear feet # of updated ordinances		X			X			Ongoing
							See watershed wide strategies.												
	Bucking-ham Creek (-A62)	St. Louis	Varies	See Section 2	--	Land use planning and ordinances	Manage water appropriations to maintain continuous flows. See watershed wide strategies.	--	--	Restored stream flows	# of efforts to maintain or restore flow			X		X			Ongoing
							See watershed wide strategies.												

Waterbody and Location			Water Quality			Strategies	Strategy scenario showing estimated scale of adoption to meet 10-year milestone and final water quality targets. Scenarios and adoption levels may change with adaptive management.					Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate											
HUC10 Sub-watershed	Water body (ID)	Location and Upstream Influence Counties	Parameter	Current Conditions	Goals / Targets and Estimated % Reduction		Strategy Type	Current Strategy Adoption Level, if Known	Interim 10-year Milestone	Suggested Goal	Units	Counties	SWCDs	Cities/Townships	MPCA	DNR	BWSR	MDH	
St. Louis Bay (4010201116) (cont.)	Coffee Creek (-A83)	St. Louis	Varies	See Section 2	--	Land use planning and ordinances	Evaluate and where appropriate, protect riparian, wetland and high quality upland areas using easements, restrictive covenants, low impact development, tax incentives, and purchasing of development rights, and other conservation tools above Skyline Parkway. See watershed wide strategies.	--	--	Conservation measures for priority areas	# of measures	X		X					Ongoing
						Streambank stabilization and riparian management	Restore creek to shaded, free-flowing natural channel to reduce erosion and bank slumping. See watershed wide strategies.	--	--	Restored stream channel	# of projects; linear feet		X			X			
							See watershed wide strategies.												
	Knowlton Creek (-985)	St. Louis	Varies	See Section 2	--	Streambank stabilization and riparian management	Evaluate the effectiveness of the recently completed channel restoration project on Knowlton Creek. See watershed wide strategies.	--	--	Multi-year monitoring results and lessons learned	% effective		X	X		X			Ongoing
						Stormwater management	Protect source water areas above I-35. Reduce runoff and sediment transport and restore cold-water stream habitat to trout stream. See watershed wide strategies.	--	--	Stormwater management provided for majority of watershed	% treated	X	X	X					
							See watershed wide strategies.												
	US Steel Creek (-999)	St. Louis	Varies	See Section 2	--	Stormwater management	Manage flows to protect on-site vaults or pollutants sequestered as part of the US Steel Creek Superfund cleanup.	--	--	Stormwater management provided for site	% treated			X	X				Ongoing
							See watershed wide strategies.												
	41st Ave W Creek, 49th Ave W Creek, 68th Ave W Creek, 84th Ave W Creek, and 85th Ave W Creek (No AUID) 44th Ave W Creek (-999) 62nd Ave W Creek (-999) 82nd Ave W Creek (-999) Gogebic Creek (-999) Lenroot Creek (-999) Morgan Park Creek (-999) Unimpaired lakes		Varies	See Section 2	--		See watershed wide strategies.												Ongoing

4. Monitoring Plan

Monitoring of flow and water quality are needed to refine source assessments, further focus implementation strategies identified as part of the WRAPS process, inform protection efforts for all unimpaired uses, and evaluate the effect of improvements for those resources that show declining trends in water quality. New data can also be used to further improve watershed modeling efforts. Monitoring is also a critical component of an adaptive management approach and can be used to help determine when a change in management is needed. This section describes recommended monitoring activities in the watershed, subject to available resources and in consideration of other priorities.

It is the intent of the implementing organizations in this watershed to make steady progress in terms of pollutant reduction for impaired waters. Accordingly, as a general guideline, progress benchmarks are established for this watershed that assume improvements will occur resulting in a water quality pollutant concentration decline each year for impaired waters equal to approximately 3% to 4% of the starting (i.e., long-term) pollutant concentration. Factors that may mean slower progress include: limits in funding or landowner acceptance, challenging fixes (e.g., unstable bluffs and ravines, invasive species) and unfavorable climatic factors. Conversely, there may be faster progress for some impaired waters, especially where high-impact fixes are slated to occur. Monitoring efforts will also be used to evaluate water quality trends and ensure protection efforts are being effectively implemented.

Existing Monitoring

The St. Louis River Watershed is scheduled for intensive watershed monitoring (IWM) in 2019 and the Lake Superior – South Watershed is scheduled for IWM in 2022 as part of the MPCA's watershed approach. IWM provides for the evaluation of the overall health of the state's water resources, an assessment of the state's waters for aquatic life, recreation, and consumption use support on a rotating 10-year cycle, and an identification of waters in need of protection efforts to prevent impairment. Several other monitoring entities exist within the watershed including:

- County soil and water conservation districts
- State agencies (e.g., MPCA, DNR, MDH Beach Program)
- Federal agencies (e.g., EPA, U.S. Department of Agriculture Forest Service, and U.S. Fish and Wildlife Service, and U.S. Geological Survey)
- Citizen monitors
- Site-specific monitoring led by the University or special interest groups

Monitoring Needs

This section describes recommended monitoring activities in the watershed, subject to available resources and in consideration of other priorities. These activities may be in part, conducted by the MPCA as part of future monitoring efforts or by local partners and other interested stakeholders.

Monitoring and data collection are needed to address many different issues in the watershed including:

- Source assessment and implementation targeting in *E. coli*-impaired streams; additional sampling sites and synoptic surveys are needed (Chester, Tischer, Merritt, Stewart, Sargent, Miller, and Keene). Microbial source tracking could be used to further evaluate sources of *E. coli* and target restoration activities. The City of Duluth is currently undertaking a monitoring study to assess sources of *E. coli* to Keene Creek and Tischer Creek. Microbial source tracking is a component of this work.
- Regular monitoring of streams for *E. coli* when streams are accessed for bathing or swimming purposes.
- Geomorphic assessments for streams with high sediment concentrations (Kingsbury [upstream portion], Lester, Mission, and Sargent).
- Continued bank erosion estimates in Amity Creek and other streams over time to measure sediment loss.
- Long-term continuous flow monitoring at multiple sites to allow for further calibration of watershed and water quality models.
- Regional chloride monitoring to support future TMDLs and planning efforts.
- Support for potential temperature and dissolved oxygen modeling work in Kingsbury Creek.
- Increased frequency of biological monitoring in impaired reaches.

As implementation activities are conducted in the watershed, an evaluation of the before and after conditions can be useful to aid in future project planning. In addition to flow and water quality monitoring, a broader assessment of ecological function and restoration could be used to assess various components of the stream system and overall effectiveness of the implementation activity. Guidelines for implementation monitoring may need to be developed that are watershed-specific.

5. References and Further Information

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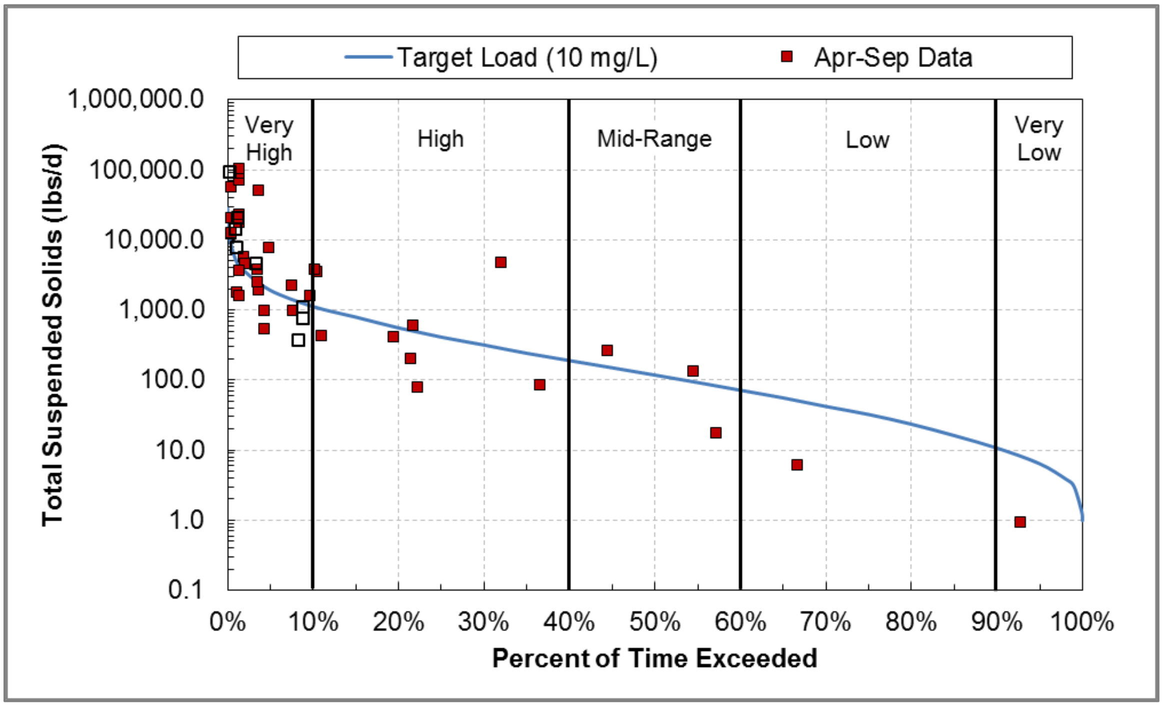
Appendix A – TMDL Summaries

Total Suspended Solids

Kingsbury Creek (04010201-626)



TSS load duration curve, Kingsbury Creek (04010201-626).

Hollow points indicate samples during months when the standard does not apply.

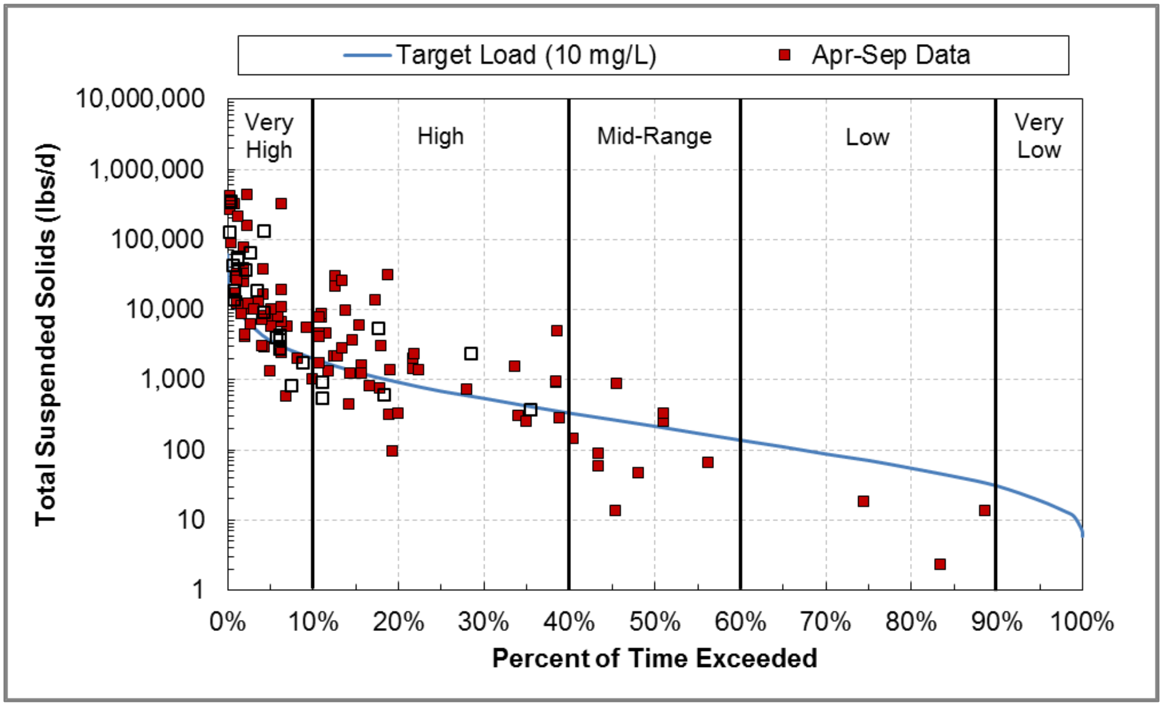
TSS TMDL summary, Kingsbury Creek (04010201-626)

TMDL Parameter		Very High (21–523 cfs)	High (4–21 cfs)	Mid-Range (1–4 cfs)	Low (0.2–1 cfs)	Very Low (0.02–0.2 cfs)
		Flow Regime				
		TSS Load (lbs/day)				
Wasteload Allocation	Wisconsin Central Ltd (MN0000361) [a]	42	9.1	2.6	0.71	0.14
	Duluth City MS4 (MS400086)	47	10	2.9	0.79	0.16
	Hermantown City MS4 (MS400093)	44	9.5	2.7	0.74	0.15
	Midway Township MS4 (MS400146)	26	5.6	1.6	0.44	0.088
	Proctor City MS4 (MS400114)	108	23	6.6	1.8	0.36
	St. Louis County MS4 (MS400158)	13	2.8	0.81	0.22	0.044
	MnDOT Outstate District MS4 (MS400180)	16	3.3	0.96	0.26	0.052
	Industrial Stormwater (MNR050000) [b]	0.17	0.037	0.011	0.0029	0.00058
	Construction Stormwater (MNR100001) [b]	0.17	0.037	0.011	0.0029	0.00058
Load Allocation	Near-channel	611	132	38	10	2.0
	Non-MS4 watershed runoff	813	175	50	14	2.7
MOS		191	41	12	3.2	0.64
Loading Capacity		**1,912**	**412**	**118**	**32**	**6.4**

a. See TMDL for details on actions needed to demonstrate consistency with Wisconsin Central Ltd.'s WLA.

b. It is assumed that loads from permitted construction and industrial stormwater sites that operate in compliance with general permits are meeting the WLA.

Amity Creek (04010102-511)



TSS load duration curve, Amity Creek (04010102-511).

Hollow points indicate samples during months when the standard does not apply.

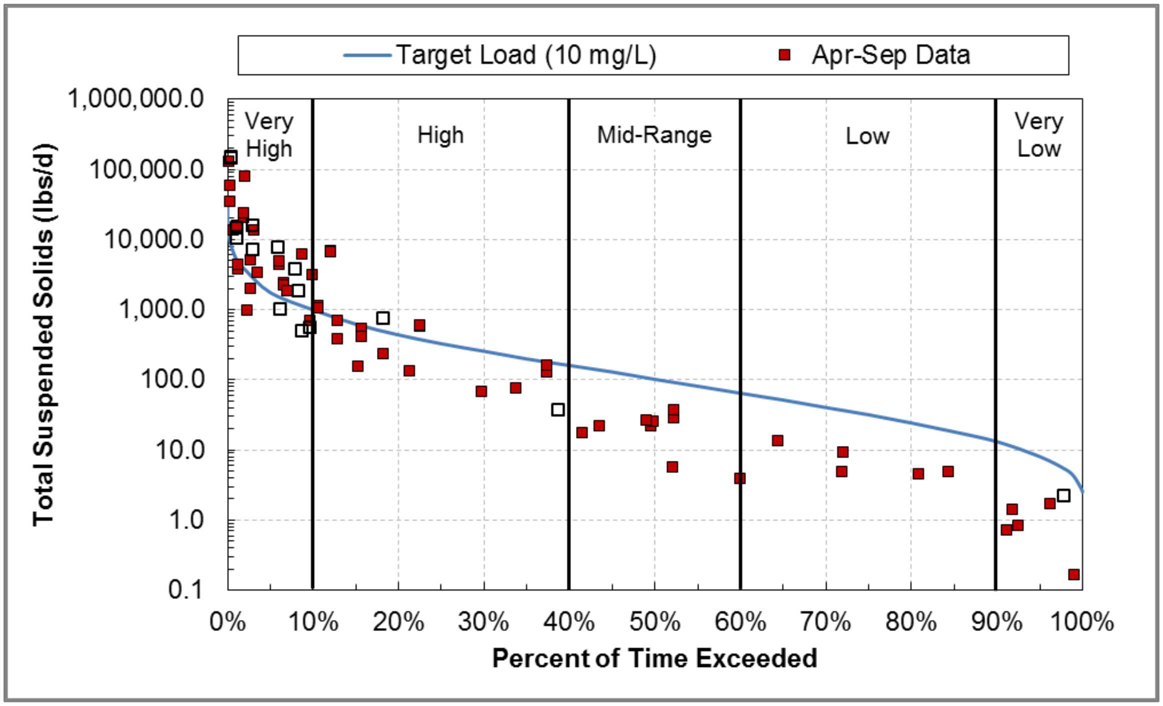
TSS TMDL summary, Amity Creek (04010102-511)

TMDL Parameter		Flow Regime				
		Very High (37–1,128 cfs)	High (6–37 cfs)	Mid-Range (3–6 cfs)	Low (0.6–3 cfs)	Very Low (0.1–0.6 cfs)
		TSS Load (lbs/day)				
Wasteload Allocation	Duluth City MS4 (MS400086)	135	26	8.2	2.7	0.71
	Rice Lake City MS4 (MS400151)	124	24	7.5	2.4	0.65
	St. Louis County MS4 (MS400158)	5.6	1.1	0.34	0.11	0.030
	Industrial Stormwater (MNR050000) [a]	0.32	0.062	0.020	0.0064	0.0017
	Construction Stormwater (MNR100001) [a]	0.32	0.062	0.020	0.0064	0.0017
Load Allocation	Near-channel	1,030	197	62	20	5.4
	Non-MS4 watershed runoff	1,955	373	118	38	10
MOS		361	69	22	7.1	1.9
Loading Capacity		**3,611**	**689**	**218**	**71**	**19**

a. It is assumed that loads from permitted construction and industrial stormwater sites that operate in compliance with the permits are meeting the WLA.

-: No data

Amity Creek, East Branch (04010102-540)



TSS load duration curve, Amity Creek, East Branch (04010102-540).

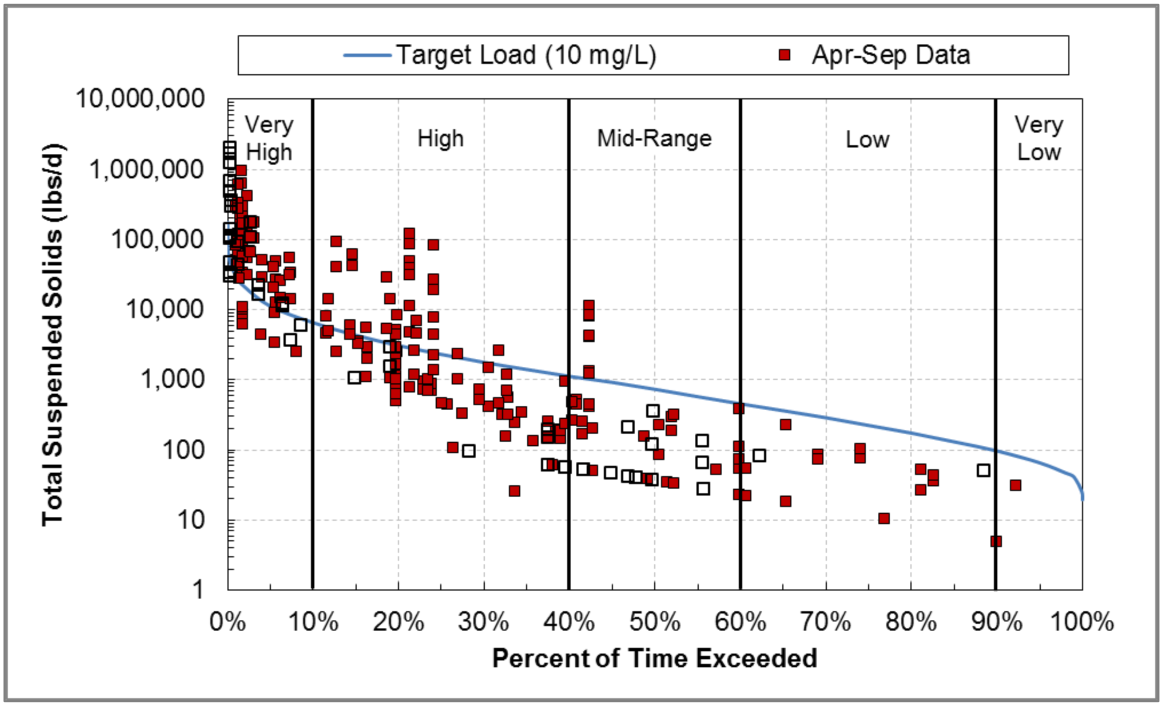
Hollow points indicate samples during months when the standard does not apply.

TSS TMDL summary, Amity Creek, East Branch (04010102-540)

TMDL Parameter		Flow Regime				
		Very High (18–540 cfs)	**High (3–18 cfs)**	**Mid-Range (1–3 cfs)**	**Low (0.2–1 cfs)**	**Very Low (0.05–0.2 cfs)**
		TSS Load (lbs/day)				
Wasteload Allocation	Duluth City MS4 (MS400086)	24	4.6	1.4	0.44	0.11
	Rice Lake City MS4 (MS400151)	90	17	5.2	1.6	0.42
	St. Louis County MS4 (MS400158)	1.9	0.35	0.11	0.034	0.0086
	Industrial Stormwater (MNR050000) [a]	0.16	0.030	0.0092	0.0029	0.00073
	Construction Stormwater (MNR100001) [a]	0.16	0.030	0.0092	0.0029	0.00073
Load Allocation	Near-channel	332	62	19	6.0	1.5
	Non-MS4 watershed runoff	1,133	211	66	21	5.2
MOS		176	33	10	3.2	0.81
Loading Capacity		**1,758**	**328**	**102**	**32**	**8.1**

a. It is assumed that loads from permitted construction and industrial stormwater sites that operate in compliance with the permits are meeting the WLA.

Lester River (04010102-549)



TSS load duration curve, Lester River (04010102-549).

Hollow points indicate samples during months when the standard does not apply.

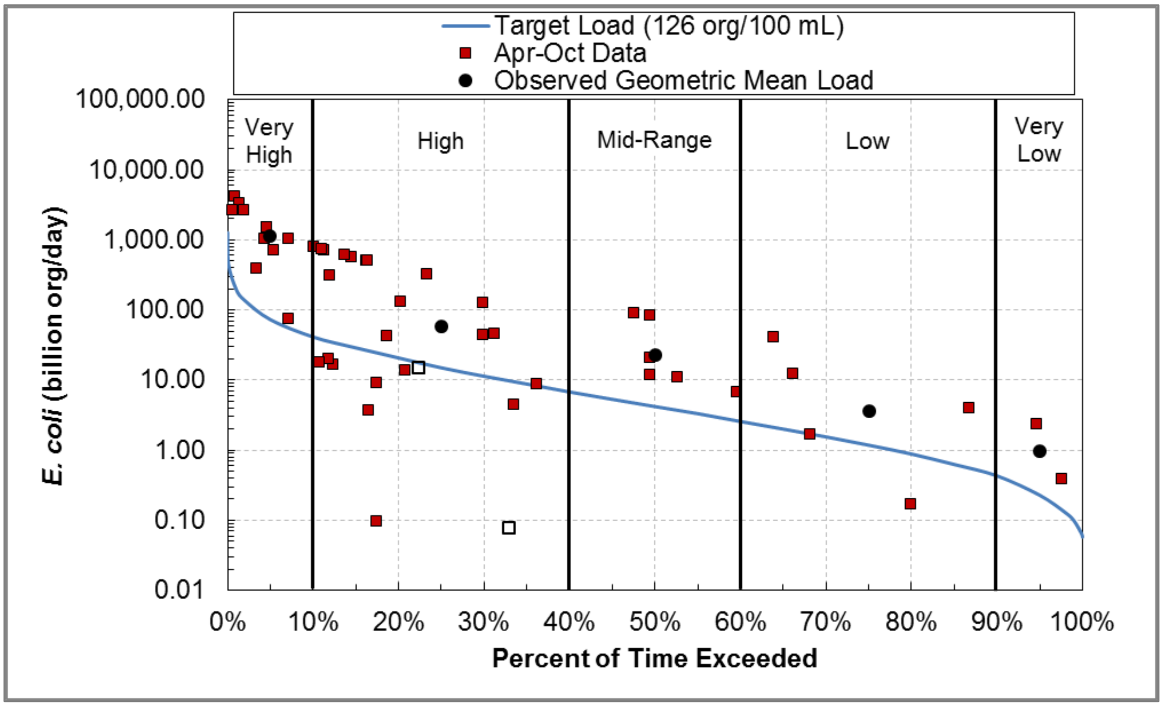
TSS TMDL summary, Lester River (04010102-549)

TMDL Parameter		Flow Regime				
		Very High (122–3,259 cfs)	High (21–122 cfs)	Mid-Range (8–21 cfs)	Low (2–8 cfs)	Very Low (0.4–2 cfs)
		TSS Load (lbs/day)				
Wasteload Allocation	Duluth City MS4 (MS400086)	137	28	8.9	2.7	0.80
	Rice Lake City MS4 (MS400151)	150	31	9.8	3.0	0.88
	University of Minnesota, Duluth MS4 (MS400214)	0.029	0.0059	0.0019	0.00057	0.00017
	St. Louis County MS4 (MS400158)	5.3	1.1	0.3	0.11	0.031
	MnDOT Outstate District MS4 (MS400180)	0.13	0.026	0.0083	0.0025	0.00074
	Industrial Stormwater (MNR050000) [a]	1.0	0.21	0.066	0.020	0.0059
	Construction Stormwater (MNR100001) [a]	1.0	0.21	0.066	0.020	0.0059
Load Allocation	Near-channel	3,484	719	228	70	21
	Non-MS4 watershed runoff	6,323	1,305	414	126	37
MOS		1,122	232	74	22	6.6
Loading Capacity		**11,222**	**2,316**	**735**	**224**	**66**

a. It is assumed that loads from permitted construction and industrial stormwater sites that operate in compliance with the permits are meeting the WLA.

E. coli

Keene Creek (04010201-627)



***E. coli* load duration curve, Keene Creek (04010201-627).**

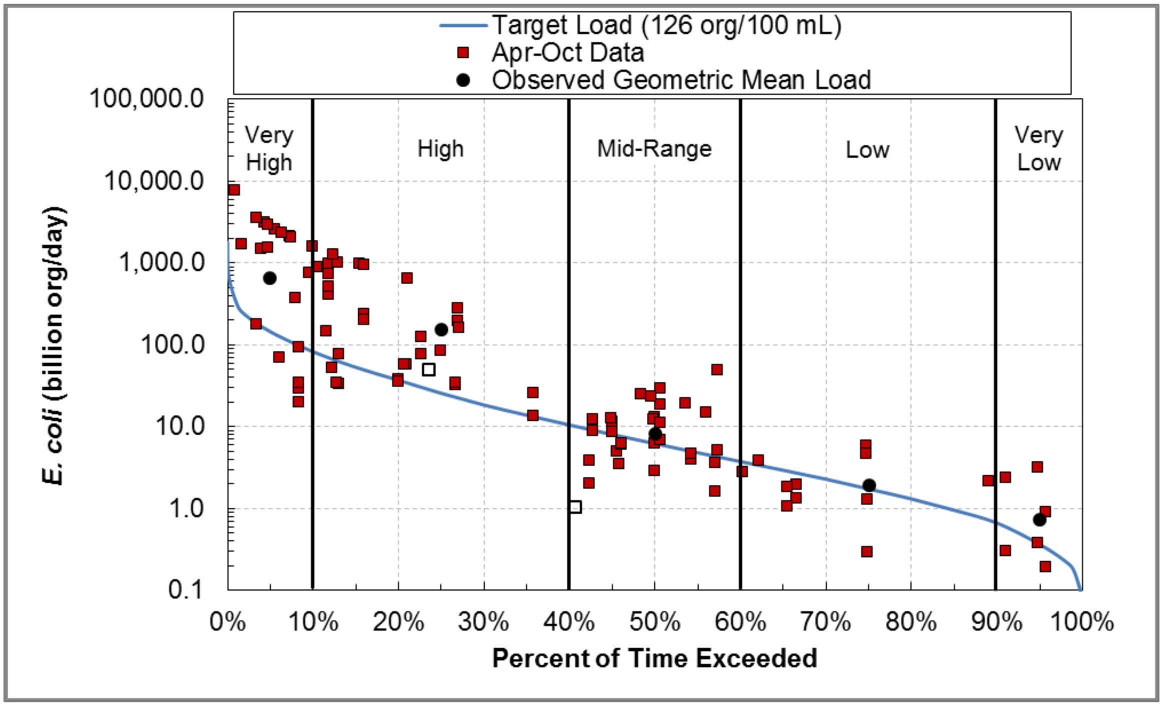
Hollow points indicate samples during months when the standard does not apply.

***E. coli* TMDL summary, Keene Creek (04010201-627)**

TMDL Parameter		Flow Regime				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		***E. coli* Load (billion org/day)**				
Wasteload Allocation	Duluth City MS4 (MS400086)	9.1	1.9	0.52	0.15	0.029
	Hermantown City MS4 (MS400093)	6.1	1.3	0.35	0.10	0.019
	St. Louis County MS4 (MS400158)	0.76	0.16	0.044	0.013	0.0024
	MnDOT Outstate District MS4 (MS400180)	0.95	0.20	0.055	0.016	0.0030
Load Allocation		49	10	2.8	0.80	0.15
MOS		7.3	1.5	0.42	0.12	0.023
Loading Capacity		**73**	**15**	**4.2**	**1.2**	**0.23**
Maximum monthly geomean (org/100 mL)		961				
Overall estimated percent reduction [a]		87%				

a. Calculated by comparing the highest observed (monitored) monthly geometric mean concentration from the months that the standard applies to the geometric mean standard, as a concentration, (monitored – standard/monitored). See TMDL for more information.

Miller Creek (04010201-512)



***E. coli* load duration curve, Miller Creek (04010201-512).**

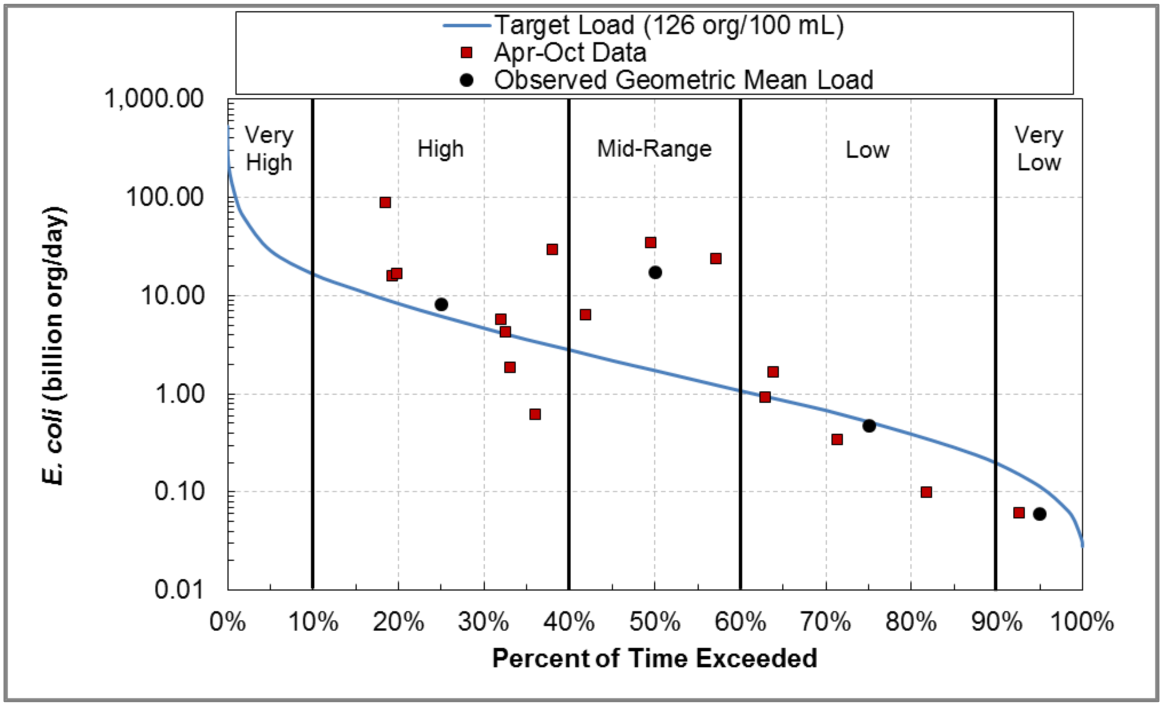
Hollow points indicate samples during months when the standard does not apply.

***E. coli* TMDL summary, Miller Creek (04010201-512)**

TMDL Parameter		Flow Regime				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		***E. coli* Load (billion org/day)**				
Wasteload Allocation	Duluth City MS4 (MS400086)	39	7.3	1.7	0.48	0.10
	Hermantown City MS4 (MS400093)	12	2.2	0.53	0.15	0.031
	Rice Lake City MS4 (MS400151)	1.0	0.18	0.044	0.012	0.0025
	Lake Superior College MS4 (MS400225)	0.55	0.10	0.025	0.0067	0.0014
	University of Minnesota, Duluth MS4 (MS400214)	0.13	0.025	0.0060	0.0016	0.00035
	St. Louis County MS4 (MS400158)	1.6	0.31	0.073	0.020	0.0042
	MnDOT Outstate District MS4 (MS400180)	3.1	0.57	0.14	0.037	0.0079
Load Allocation		69	13	3.1	0.82	0.18
MOS		14	2.6	0.62	0.17	0. 036
Loading Capacity		**140**	**26**	**6.2**	**1.7**	**0.36**
Maximum monthly geomean (org/100 mL)		418				
Overall estimated percent reduction [a]		70%				

a. Calculated by comparing the highest observed (monitored) monthly geometric mean concentration from the months that the standard applies to the geometric mean standard, as a concentration, (monitored – standard/monitored). See TMDL for more information.

Sargent Creek (04010201-848)



E. coli load duration curve, Sargent Creek (04010201-848).

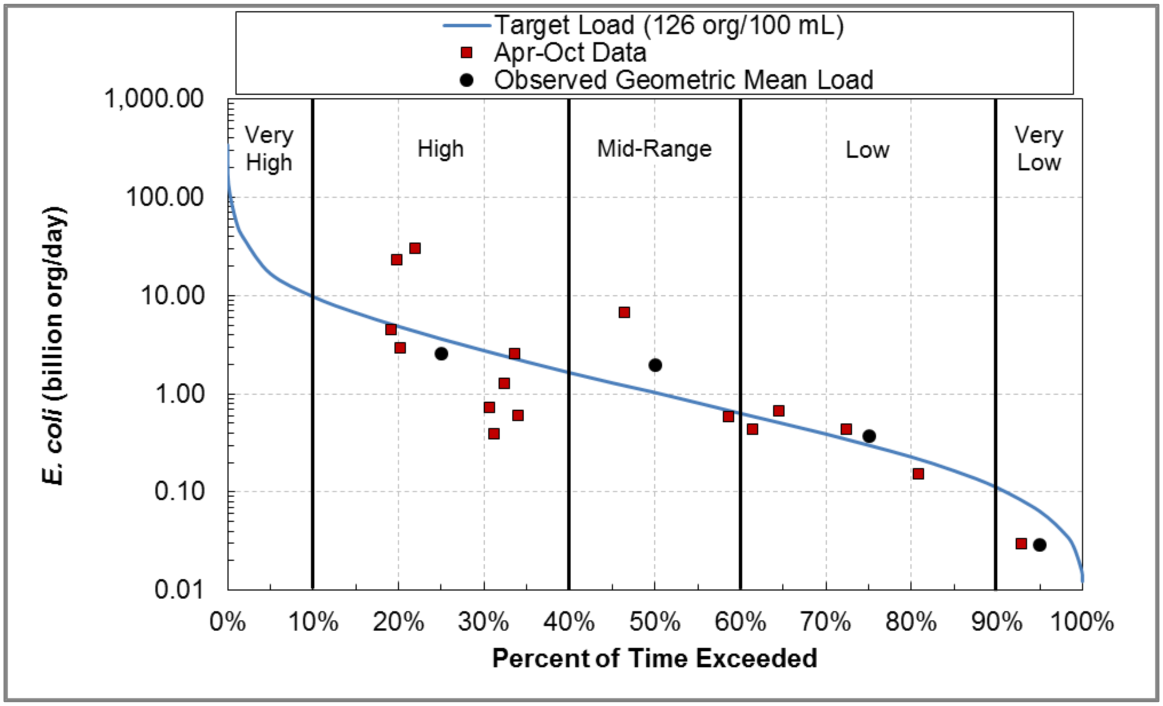
E. coli TMDL summary, Sargent Creek (04010201-848)

TMDL Parameter		Very High	High	Mid-Range	Low	Very Low
		Flow Regime				
		E. coli Load (billion org/day)				
Wasteload Allocation	Duluth City MS4 (MS400086)	1.9	0.40	0.11	0.034	0.0072
	Midway Township MS4 (MS400146)	0.51	0.11	0.030	0.0091	0.0019
	MnDOT Outstate District MS4 (MS400180)	0.11	0.023	0.0064	0.0019	0.00041
Load Allocation		24	5.0	1.4	0.42	0.089
MOS		2.9	0.62	0.17	0.052	0.011
Loading Capacity		29	6.2	1.7	0.52	0.11
Maximum monthly geomean (org/100 mL)		228				
Overall estimated percent reduction [a]		45%				

a. Calculated by comparing the highest observed (monitored) monthly geometric mean concentration from the months that the standard applies to the geometric mean standard, as a concentration, (monitored – standard/monitored). See TMDL for more information.

-: No data

Stewart Creek (04010201-884)



E. coli load duration curve, Stewart Creek (04010201-884).

E. coli TMDL summary, Stewart Creek (04010201-884)

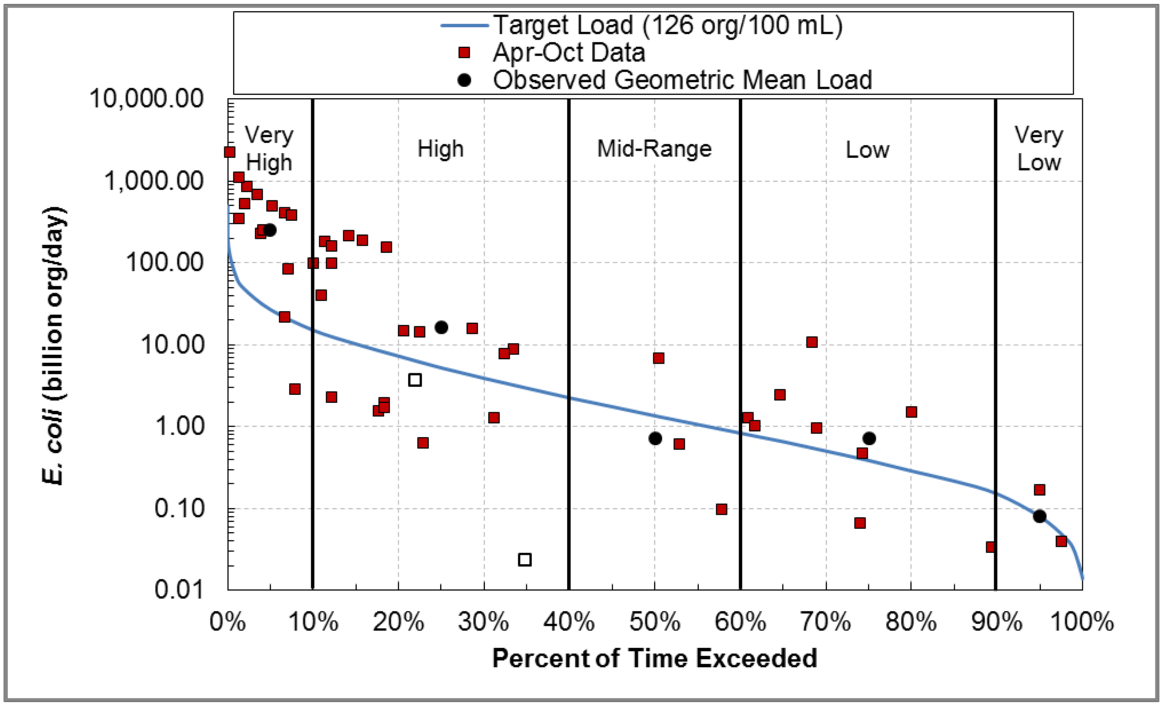
TMDL Parameter		Very High	High	Mid-Range	Low	Very Low
		E. coli Load (billion org/day)				
Wasteload Allocation	Duluth City MS4 (MS400086)	1.3	0.28	0.078	0.024	0.0050
	Midway Township MS4 (MS400146)	0.22	0.047	0.013	0.0039	0.00084
	Proctor City MS4 (MS400114)	0.068	0.014	0. 0040	0.0012	0.00026
	MnDOT Outstate District MS4 (MS400180)	0.18	0.039	0.011	0.0032	0.00069
Load Allocation		14	2.9	0.79	0.24	0.051
MOS		1.7	0.36	0.10	0.030	0.0064
Loading Capacity		**17**	**3.6**	**1.0**	**0.30**	**0.064**
Maximum monthly geomean (org/100 mL)		226				
Overall estimated percent reduction [a]		44%				

Flow Regime: Very High, High, Mid-Range, Low, Very Low.

a. Calculated by comparing the highest observed (monitored) monthly geometric mean concentration from the months that the standard applies to the geometric mean standard, as a concentration, (monitored – standard/monitored). See TMDL for more information.

-: No data

Unnamed Creek (Merritt Creek; 04010201-987)



E. coli load duration curve, Unnamed Creek (Merritt Creek; 04010201-987).

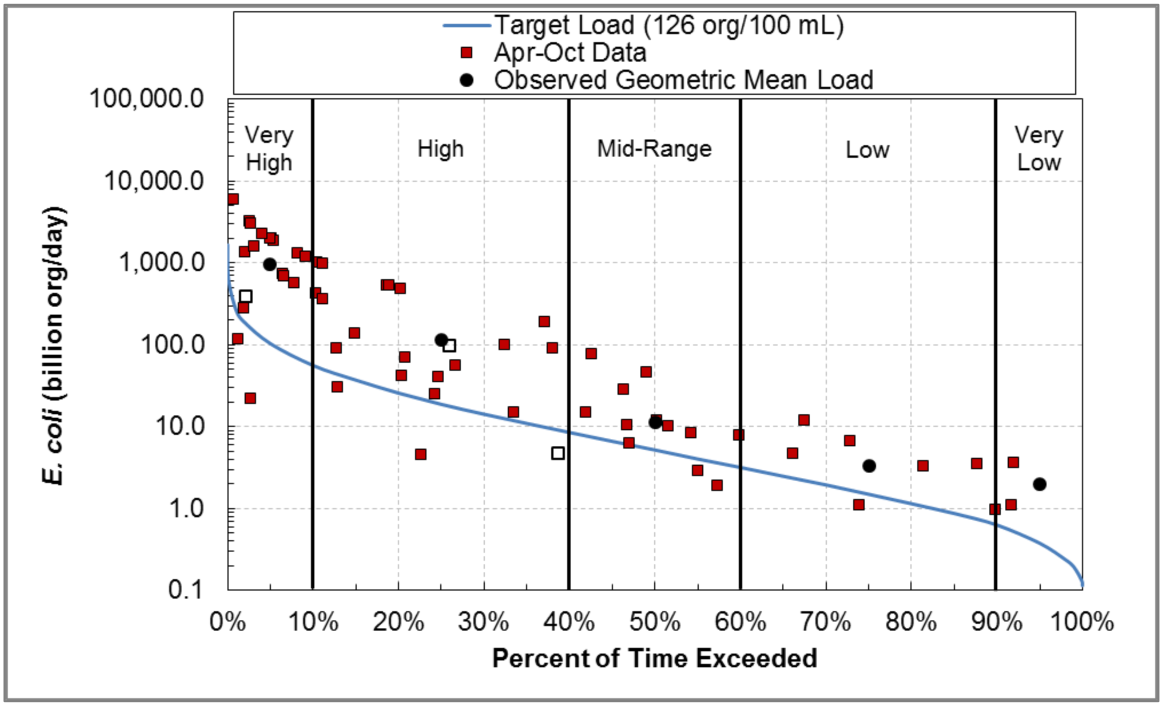
Hollow points indicate samples during months when the standard does not apply.

E. coli TMDL summary, Unnamed Creek (Merritt Creek; 04010201-987)

TMDL Parameter		Flow Regime				
		Very High	High	Mid-Range	Low	Very Low
		E. coli Load (billion org/day)				
Wasteload Allocation	Duluth City MS4 (MS400086)	7.1	1.4	0.37	0.10	0.021
	Hermantown City MS4 (MS400093)	0.63	0.12	0.033	0.0091	0.0019
	St. Louis County MS4 (MS400158)	0.48	0.092	0.025	0.0069	0.0014
	MnDOT Outstate District MS4 (MS400180)	0.41	0.080	0.021	0.0060	0.0012
Load Allocation		16	3.0	0.81	0.23	0.047
MOS		2.7	0.52	0.14	0.039	0.0080
Loading Capacity		**27**	**5.2**	**1.4**	**0.39**	**0.080**
Maximum monthly geomean (org/100 mL)		858				
Overall estimated percent reduction [a]		85%				

a. Calculated by comparing the highest observed (monitored) monthly geometric mean concentration from the months that the standard applies to the geometric mean standard, as a concentration, (monitored – standard/monitored). See TMDL for more information.

Tischer Creek (04010102-544)



E. coli load duration curve, Tischer Creek (04010102-544).

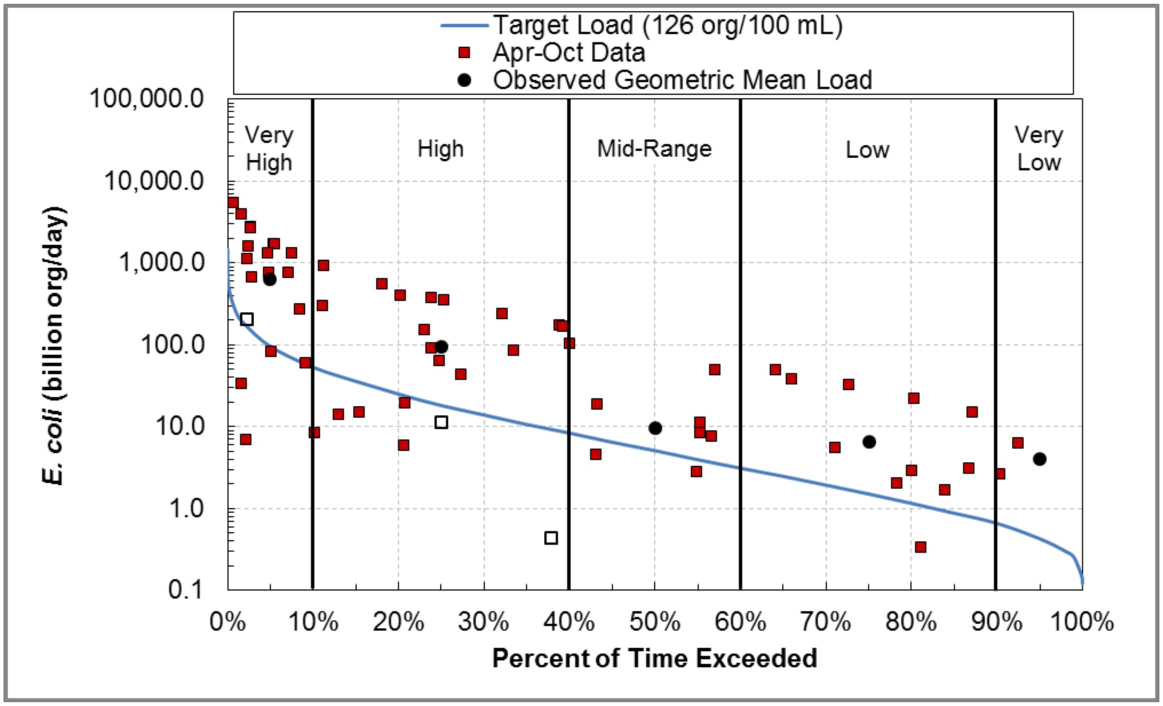
Hollow points indicate samples during months when the standard does not apply.

E. coli TMDL summary, Tischer Creek (04010102-544)

TMDL Parameter		Very High	High	Mid-Range	Low	Very Low
		Flow Regime				
		E. coli Load (billion org/day)				
Wasteload Allocation	Duluth City MS4 (MS400086)	24	4.4	1.2	0.35	0.088
	Rice Lake City MS4 (MS400151)	6.4	1.2	0.32	0.092	0.023
	University of Minnesota, Duluth MS4 (MS400214)	1.4	0.25	0.070	0.020	0.0051
	St. Louis County MS4 (MS400158)	1.4	0.25	0.067	0.019	0.0049
	MnDOT Outstate District MS4 (MS400180)	0.026	0.0047	0.0013	0.00037	0.000093
Load Allocation		61	11	3.0	0.87	0.22
MOS		10	1.9	0.52	0.15	0.038
Loading Capacity		**104**	**19**	**5.2**	**1.5**	**0.38**
Maximum monthly geomean (org/100 mL)		1,193				
Overall estimated percent reduction [a]		89%				

a. Calculated by comparing the highest observed (monitored) monthly geometric mean concentration from the months that the standard applies to the geometric mean standard, as a concentration, (monitored – standard/monitored). See TMDL for more information.

Chester Creek (04010102-545)



E. coli load duration curve, Chester Creek (04010102-545).

Hollow points indicate samples during months when the standard does not apply.

E. coli TMDL summary, Chester Creek (04010102-545)

TMDL Parameter		Flow Regime				
		Very High	High	Mid-Range	Low	Very Low
		E. coli Load (billion org/day)				
Wasteload Allocation	Duluth City MS4 (MS400086)	24	4.5	1.3	0.38	0.11
	Rice Lake City MS4 (MS400151)	0.24	0.046	0.013	0.0038	0.0011
	University of Minnesota, Duluth MS4 (MS400214)	0.0093	0.0017	0.00049	0.00014	0.000041
	St. Louis County MS4 (MS400158)	0.62	0.12	0.033	0.010	0.0028
	MnDOT Outstate District MS4 (MS400180)	0.030	0.0056	0.0016	0.00047	0.00013
Load Allocation		62	12	3.2	0.96	0.27
MOS		10	1.8	0.51	0.15	0.043
Loading Capacity		**96**	**18**	**5.1**	**1.5**	**0.43**
Maximum monthly geomean (org/100 mL)		1,494				
Overall estimated percent reduction [a]		92%				

a. Calculated by comparing the highest observed (monitored) monthly geometric mean concentration from the months that the standard applies to the geometric mean standard, as a concentration, (monitored – standard/monitored). See TMDL for more information.

Water Temperature (Heat)

Miller Creek (04010201-512)

The following table was provided by MPCA 2017b.

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

Appendix B – Duluth Urban Streams – An Implementation Focused Assessment of Six Streams

Duluth Urban Streams

An Implementation Focused Assessment of Six Streams – 2017

Appendix B

Prepared for: Minnesota Pollution Control Agency
525 South Lake Avenue, Suite 400, Duluth, MN 55802

Prepared by: South St. Louis Soil and Water Conservation District
215 North First Avenue East, Room 301, Duluth, MN 55802

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Goal

The South St. Louis Soil and Water Conservation District (SWCD) completed an assessment of Duluth streams that prioritized restoration and protection work. Streams were broken into reaches. Data was collected to assess the health of each reach and to identify causes of the current condition. This data was used to prioritize restoration and protection activities. Prioritized implementation will result in greater outcomes for individual projects and better health for the whole watershed.

Introduction

Duluth lies within the Lake Superior and St. Louis River watersheds. Streams here are unique and flow from wetlands in their headwaters through the City and finally make a steep fall to enter Lake Superior or the St. Louis River Estuary. Sixteen streams within Duluth are designated trout streams. During the Duluth WRAPS process, six streams were chosen from across the City to be studied in detail. These streams are Keene Creek, Merritt Creek, Miller Creek, Chester Creek, Tischer Creek, and Amity Creek (Figure 1). Each of these streams have individual impairments, stressors and special features, and each flows through a unique watershed with differing land cover, geology, and development. All of these distinctive features have resulted in six distinct streams each of which will be discussed in its own chapter of this report. Unstable reaches have been identified within each watershed that are leading to degraded habitat, accelerated erosion, increased sediment loads, and increased water temperatures. These are areas where restoration and protection efforts should be focused. All efforts to improve stream health and enhance habitat should use the five components of watershed health (hydrology, geomorphology, connectivity, water quality, and biology) as a framework for setting goals and objectives for restoration and protection to ensure a systemic approach is chosen (cite the instream flow council).

The South St. Louis Soil and Water Conservation District performed the following assessment from May 2016 to May 2017.

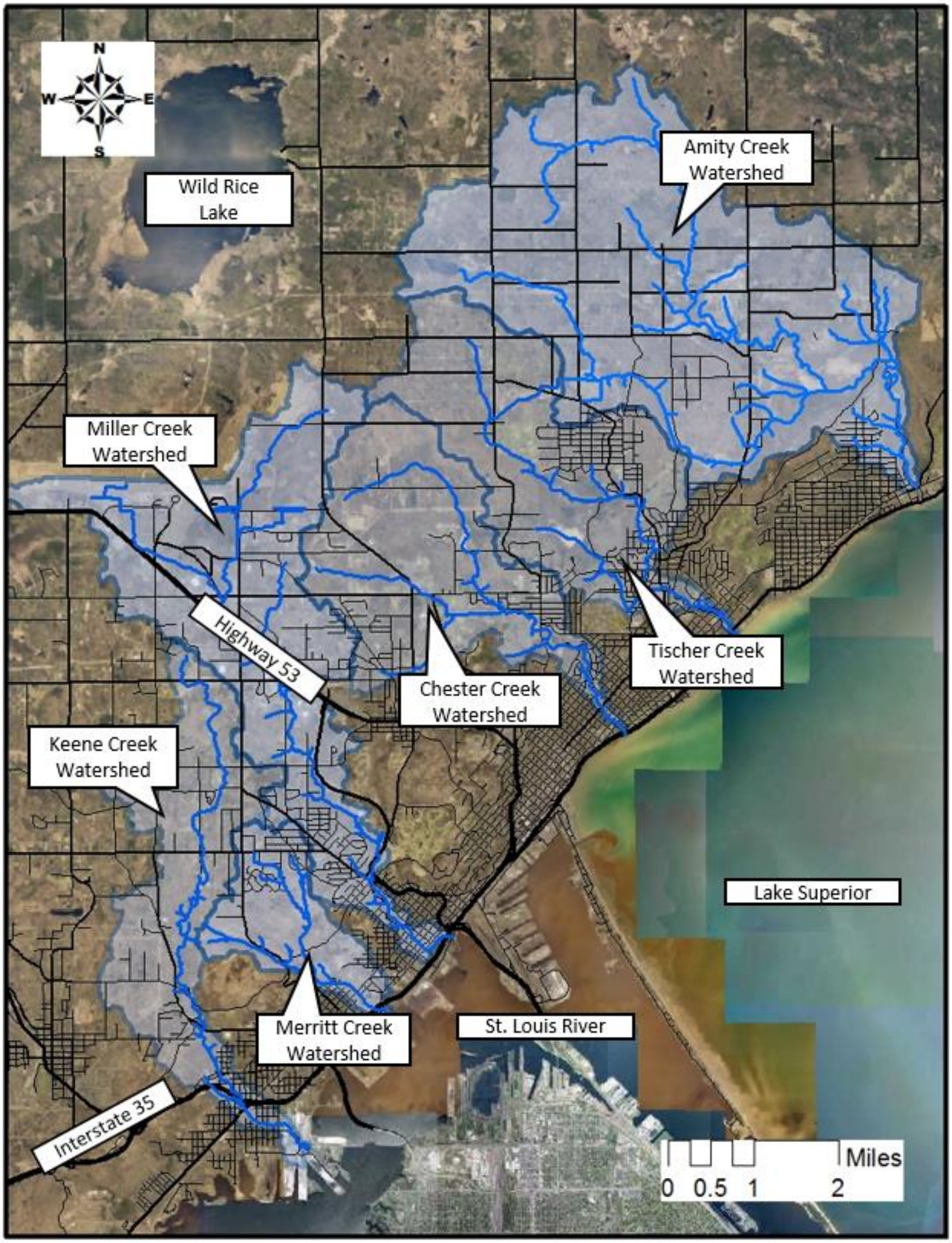


Figure 1. The six study watersheds in Duluth.

Recommendations

The recommendations listed here are based on data found in this report. Explanations of reasons why specific reaches and crossings are priorities, follow these summaries. The methods used to collect and analysis all data is explained in here and in Appendix 1.

Road Crossing Replacement, Removal, or Repair

These road crossings are the highest priority crossings for recommended for replacement, removal, or repair within the six study watersheds (including Amity Creek).

Stream	**Street Name**
Merritt	Superior Hiking Trail
Miller	Skyline Parkway/N 24th Ave W
Amity	Woodland Ave
West Tischer	Abandoned Maryland St
East Amity	West Tischer Rd

Riparian Restoration

These reaches are recommended for riparian restoration based on results from the five study watersheds. Descriptions of each reach can be found in the report for that watershed.

Stream	Reach Name	Location
Keene	2	Downstream of South Central Avenue
Merritt	1	Downstream of I-35
Miller	2	Lincoln Park
Miller	14	Behind Miller Hill Mall
Miller	16	Upstream of Maple Grove Road
Miller	17	Downstream of Highway 53 near Target
Chester	8	Downstream of Kenwood Avenue
Chester	10	Between Kenwood Avenue and the confluence of the East Branch
Chester	T-2	East Branch—Between Triggs Avenue and Arrowhead Road
Tischer	9	Between the confluence of the West Branch and Wallace
Tischer	18	Downstream of Hartley Pond

Protection

These reaches are recommended for protection as they are in the best quality of all reaches in the five study watersheds in Duluth.

Stream Name	**Reach Name**	Total Score	Location
Tischer	2	12	Upstream of London Road
Tischer	6	12	Upstream of East 4th Street in Congdon Park
Tischer	7	12	Downstream of Vermillion Road in Congdon Park
Keene	12	12	Upstream of Skyline Parkway
Keene	14	12	Downstream of Keene Creek Park
Keene	20	12	Downstream of Morris Thomas Road

Restoration

These reaches are recommended for stream restoration based on results from the five study watersheds. These reaches are not listed in order of priority and are all recommended restoration sites. A description of the current conditions and the recommendations for restoration for each site is listed for each reach within the specific watershed report.

Stream Name	Reach Name	Location
Keene	3	Within Irving Park, downstream of 57th Avenue West
Keene	4	Between 57th Avenue West and Grand Avenue
Keene	5	Between Grand Avenue and Greet Street (include the dog park)
Keene	6	Between Greet Street and Cody Street
Keene	8	Downstream of Highland Street
Keene	17	Keene Creek Park in Hermantown
Keene	Upper Watershed	Adjacent to Okerstrom Road upstream of Morris Thomas Road
Keene	Upper Watershed	Engwall's Pond, Upstream of Hermantown Road
Merritt	T-3, T-4, T-9, and T-12	East Branch—extending from the confluence with the mainstem to upstream of Skyline Parkway
Merritt	4 and 5	Mainstem—Upstream of Grand Avenue and adjacent to Wheeler Athletic Complex
Merritt	9	Mainstem—Upstream of the confluence
Merritt	7	Mainstem—Between West 8th Street and the railroad tracks
Miller	1	Between Interstate 35 to the alley downstream of West 3rd Street
Miller	5 and 6	Upstream of Trinity Road near Skyline Parkway to downstream of Lake Superior College
Miller	9	Between Lake Superior College and Erickson Road
Miller	11	Up and downstream of Anderson Road
Miller	12 and 13	Downstream of Chambersburg Avenue to Miller Hill Mall
Miller	19	Between Haines Road and Burning Tree Road
Chester	2	Between Superior Street and East 4th Street
Chester	4	Between East 8th Street and Skyline Parkway
Chester	6	Chester Park
Chester	9	Up and downstream of Kenwood
Chester	12	Downstream of Madison Avenue
Chester	13 and 14	Upstream of Madison Avenue
Chester	T-3	East Branch—Up and downstream of Arrowhead Road
Tischer	11	Downstream of West Arrowhead Road
Tischer	14	Between East St. Andrews Street and Glen Avon Park
Tischer	16	Upstream and downstream of Fairmont Street
Tischer	19	Hartley Pond
Tischer	22, 23, 24, 25 and 26	Within Ridgeview Golf Course and upstream of the downstream Howard Gnesen
Tischer	T-1	West Branch, between West St. Marie Street and Norton Street

Additional Data Sources

USGS

Data from the USGS work in Duluth is summarized for each study watershed. A summary can be found in each watershed report and specific data from assessments completed in 2013 can be found in the corresponding reach descriptions.

Fitzpatrick, F. A., M. C. Peppler, M. M. DePhilip, and K. E. Lee. 2006. *Geomorphic Characteristics and Classification of Duluth-Area Streams, Minnesota*. Reston, Virginia. U.S. Geological Survey.

Fitzpatrick, F. A., C. A. Ellison, C. R. Czuba, B. M. Young, M. M. McCool, and J. T. Groten. 2016. *Geomorphic Responses of Duluth-Area Streams to the June 2012 Flood, Minnesota*. Reston, Virginia. U.S. Geological Survey.

Minnesota Department of Natural Resources—Fisheries

Minnesota DNR Fisheries data is presented in each watershed report and within the reach descriptions for corresponding reaches. This data was collected from stream management plans, shared data sources, and personal communication with the Minnesota DNR Duluth Area Fisheries office.

Methods

Connectivity

Connectivity is a major determinant to stream health. Connectivity is determined in multiple ways. Lateral connectivity refers to a stream's ability to access the floodplain and is assessed using the incision ratio, described in the stream parameters section of this report. Vertical connectivity refers to a stream's ability to interact with ground water. Finally, longitudinal connectivity refers to the connectivity of the stream throughout its entire length. Longitudinal connectivity is important for continuity of water and sediment transport downstream and for movement of fish and aquatic organisms both up and downstream. Longitudinal connectivity was evaluated by performing a stream crossing assessment on all stream road crossings in each of the six study watersheds and noting the location of natural and man-made barriers.

Stream Road Crossings

The MN DNR Stream Crossing Basic Assessment form was used to collect data for each road crossing. The Stream Crossing Prioritization Matrix (SCPM) was used to identify crossings that are barriers to sediment transport and aquatic organism passage, and then to identify crossings that likely have the highest impact on stream function based on conditions upstream and downstream of the crossing.

Natural and Other Man-Made Barriers

Natural and man-made barrier locations were noted within each watershed during field assessments and through desktop analysis using LiDAR. Bedrock waterfalls were considered to be natural barriers and were most commonly located in the lower sections of the watersheds. Man-made barriers included of low head dams, concrete-encased utility lines and other man-made features that create a jump barrier for fish.

Geomorphology

Rapid field assessments were completed for five of the six study streams within Duluth in summer of 2016. Amity Creek watershed was not assessed in detail by the SWCD because a geomorphic assessment was performed in this watershed. The goal of this assessment work was to gather data that would aide in the identification of stream reaches that are in the worst and best condition. To complete field assessments SWCD staff walked each stream and any major tributaries from the mouth to the headwaters, collecting data and noting conditions. Streams were broken into reaches based on the data collected. These reaches help to identify differing areas throughout the watershed.

Stream Parameters

Stream type, valley type, channel condition (Pfankuch), riparian condition, incision ratio (IR), and the Bank Assessment for Non-point source Consequences of Sediment (BANCS) model (Rosgen, 2001) were chosen parameters because each aids the practioner to in concluding the overall reach health and the reason a stream reach is unhealthy or healthy. These parameters are easily collected during a rapid field assessment. More complete surveys of reaches, such as a Rosgen- level 3 survey, should be completed prior to determining the details and extents of a stream restoration project. Each of the collected parameters also supplements already collected water quality and biological data.

Stream Type

Stream type was classified using the Rosgen method (Rosgen, 1994). Each stream reach is given a letter to designate the stream type (based on slope, width, pattern) and a number, which identifies the dominate sediment type. Classifying reaches by stream type allows clear communication. When stream types are present in a valley type for which they are not found in a stable state, instability is indicated. Stream type was assessed visually while in the field. For a description of Rosgen classification methods and for a brief description of each stream type found in Duluth streams see Appendix 1.

Stream Channel Succession/Channel Evolution

Stream channels experience many changes that may cause them to become unstable. Changes in stream stability can eventually lead to changes in stream type. Channel succession scenarios have been documented showing unstable channels changing stream type, sometimes multiple times, until the channel reaches a stable state. These scenarios (Figure 2) are used to determine the potential stream type of a reach and the stability of that reach. These scenarios along with data collected in the field, explain the direction of stream movement and the potential stream type to which a channel should be restored. Reaches throughout Duluth are experiencing multiple channel succession scenarios and are at multiple stages within these scenarios. During the channel succession process erosion to the stream banks and bed occurs at increased rates. Habitat is degraded and land is lost. (Rosgen, 2009)

Level III: River Stability Prediction Forms & Worksheets

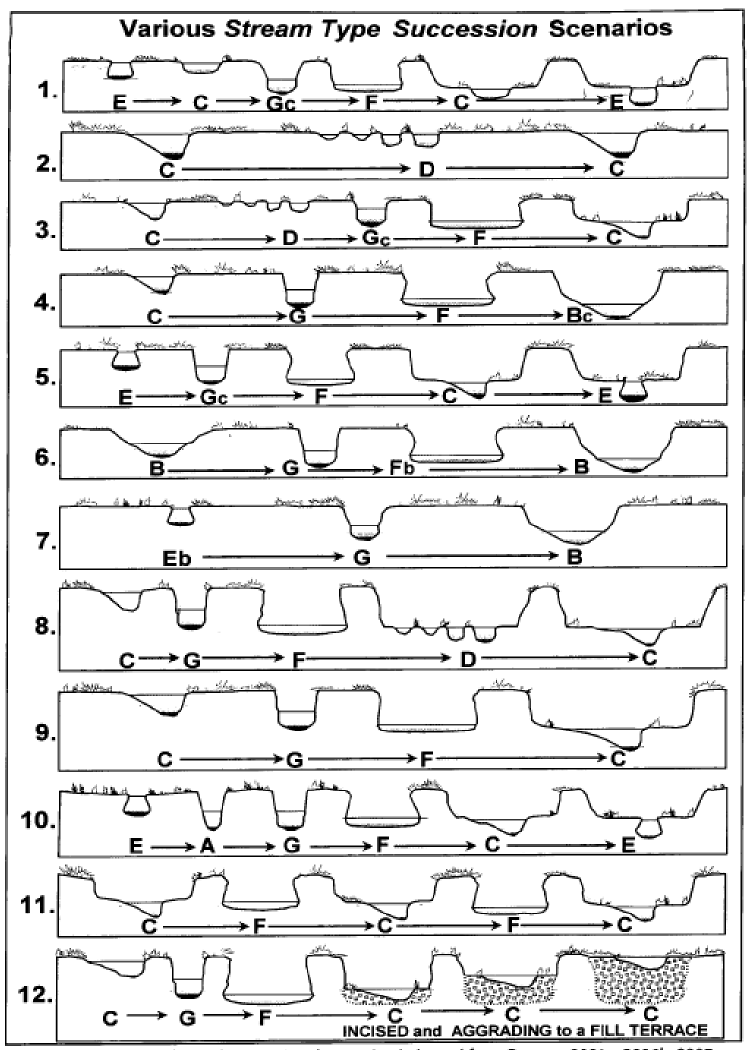


Figure 3-14. Various channel successional scenarios (adapted from Rosgen, 2001a, 2006b, 2007; USEPA, 2006). **Note:** These various scenarios represent actual rivers.

 River Stability Field Guide Page 3-112

Figure 2. Dave Rosgen's stream succession scenarios show the transition of a stream from unstable forms to a stable form. Source: Dave Rosgen, River Stability Field Guide, 2008.

Valley Type

Valley type was assigned to each stream reach using the Rosgen method (Rosgen, 2014b). Valley type is determined by confinement, the shape of the valley, the slope, and the material. A valley type was assigned to each stream reach and when paired with the stream type can indicate instability. When performing restoration it is critical to know the valley type to help determine the appropriate stream type. Valley type was assessed visually while in the field and through desktop analysis using LiDAR. Descriptions of each valley type found in Duluth and classification methodology are included in Appendix 1.

Channel Condition

Channel condition was evaluated visually using the parameters listed in the Pfankuch Channel Stability Rating form (Appendix 1, figure 7). The erodibility, material, vegetation, and deposition of the upper and lower banks and the stream channel were visually assessed. A score of “excellent, “good”, “fair”, or “poor” was given. Assigning a channel condition to each reach allows the practitioner to know the overall health of the channel and why the reach is healthy or unhealthy. A more in depth description of the Pfankuch Channel Stability Rating form and a copy of the form can be found in Appendix 1.

Incision Ratio

Incision Ratio (IR), also known as Bank Height Ratio (BHR), was used to measure the connection of a stream to its floodplain. The elevation of the floodplain is known as the bankfull elevation. The bankfull elevation is the elevation of the water during a bankfull flood event, which occurs between the 1.1 and 1.8 annual peak flood frequency. Only on streams where IR equals 1.0, is this elevation the height from the channel bottom to top of bank. IR is calculated by dividing the low bank height by the bankfull height and was determined visually during field assessments. In stable streams that are laterally connected to their floodplain IR=1.0. If IR is greater than 1.0, the channel is incised. In larger flood events, the ability of a stream to spread out over a floodplain reduces stress on the channel through the following processes: 1.) the roughness provided by the floodplain allows energy dissipation. 2.) The increased capacity provided by the floodplain mitigates depth in the main channel, thus reducing stress on the bed and banks. Floodplain connectivity also promotes fine particle deposition on the floodplain, instead of in the stream channel, which helps maintain deep pools and water quality. (Rosgen, 2014a)

In incised streams the inability of larger floods to access the floodplain increases sheer stress on the channel bed and banks. As channels become more incised, the steep banks begin to collapse and the channel moves toward an over-widened, yet still incised state. The result of this process is excessive deposition of eroded sediments, which reduces the diversity and quality of habitat for fish and other organisms and which leads to increased turbidity and water temperature and overall decreased water quality. A channel will continue on this channel evolution process of changing its dimension, pattern and profile through accelerated erosion rates until it reaches a stable form that is once again connected to a floodplain. This process can take decades or centuries and results in annual sediment loads that can be orders of magnitude greater than those of a stable stream.

Additional Variables

Other variables were noted qualitatively for each reach during field assessments. The following is a list of these variables. Descriptions of each can be found in Appendix 1.

- Habitat condition—including pool depth, pool-to-pool spacing, and riffle length
- Channel blockage
- Aggradation and down-cutting
- Presence of game and non-game fish species
- Additional geomorphology Variables

Riparian Condition

Riparian condition was determined for each reach of stream. A healthy riparian zone along a stream provides stability to the banks, provides shade to keep water temperatures cool, and can add allochthonus material to the stream, which provides food for invertebrates and habitat to fish. For these reasons, a score of “excellent”, “good”, “fair”, or “poor” was assigned to each reach for riparian condition. This score was assigned visually based on the parameters outlined in Appendix 1.

Stream Bank Erosion

Stream bank erosion adds sediment to the stream which can increase turbidity levels. Amity is the only stream of the six study watershed (Keene, Merritt, Miller, Chester, Tischer, and Amity) that is impaired for turbidity; therefore, a separate geomorphic assessment was completed. Although turbidity levels in these Duluth streams is not of high concern, sediment input from bank erosion can cause other issues in the channel. Sediment fills in pools that native trout use as thermal refuges during the summer and as resting places. Sediment also covers gravels where trout lay eggs. This sediment can suffocate eggs and young. Excess sediment can embed gravels reducing the amount of spawning habitat. As stream bank erosion occurs and sediment enters the stream channel, land is being lost. Property owners may lose their yard, the stream may encroach on structures and homes, and road crossings can fail. High rates of bank recession/erosion occur when a stream meander contacts a steep valley wall. If bank recession/erosion occurs on a larger scale it can be indicative of larger channel instability issues.

The Bank Assessment for Non-point source Consequences of Sediment (BANCS) model (Rosgen, 2001) was used to calculate streambank erosion in the Duluth study streams. BANCS scores are based on a visual assessment of bank erodibility (BEHI) and the amount of near bank sheer stress (NBS) directed at the bank. The result is an estimated volume of sediment, both suspended and bedload, entering the stream each year. Stream bank erosion is an important parameter because it allows the practitioner to identify excess sediment input, stream channel instability, and priority sites for restoration. BANCS was used to determine sources of in-stream and near-channel sources of sediment. External sources of sediment were not assessed as no obvious signs of external sources were observed and because urban streams typically have low off-channel sediment contribution. A description of the BANCS method can be found in Appendix 1.

Overall Reach Scores

Overall scores for each reach were calculated by combining the results of each of the stream parameters (IR, riparian condition, channel condition, and BANCS) (Table 1). Many other factors are also related to the overall health and condition of a stream reach, yet were noted qualitatively and could not easily be given a numerical score. These factors were considered for each reach and are noted in each individual reach description, found in the watershed reports.

To score each parameter (IR, riparian condition, channel condition, and BANCS), a score from zero to three was assigned. Then scores were added for the overall reach score. Details on the scoring of each parameter can be found in Appendix 1. The overall score was used to identify reaches to protect and restore, but was not the only factor used when making recommendations.

Table 1. Scores categories for the overall reach score.

Score	Category
12	Excellent
8-11	Good
4-7	Fair
<4	Poor

Water Quality

Stream Water Temperature

Water temperature is a major factor in determining the health and function of trout streams. Impacts caused by climate change and increasing urbanization put higher pressure on these cold water resources. An analysis of all available water temperature data was completed to locate protection areas in the City where groundwater is being sourced and water temperatures are decreasing and to locate areas where temperatures are increasing and where restoration activities may be focused. Water temperature not only effects the presence of trout but also influences other water quality parameters such as dissolved oxygen and the amount of harmful algae (U.S. Geological Survey).

Water temperatures on trout streams are often analyzed based on brook trout survivability. Brook trout (*Salvelinus fontinalis)* are sensitive to water temperature (Raleigh) as are slimy sculpin (*Cottus cognatus*) (Edwards and Cunjak). Together they are the most sensitive species to water temperature in Duluth streams. Water temperature is the leading limiting factor for brook trout and other species of trout presence and survivability in Duluth streams.

Continuous water temperature data dating back to 1994 was compiled for the six study streams to determine if stream temperatures are in the healthy/growth range of coldwater sensitive species and to determine where warm stressful temperatures occur. Loggers were deployed at different locations between June 1st and Septemeber 30th, throughout the watersheds in differing years from 1994 to present (Figure 3 and Table 2).

Temperature data in trout streams can be analyzed and evaluated in many different ways. Factors like average temperature, temperature fluctuation, and percent of time in the “stress”, “growth”, or “lethal” range can all be analyzed for different time periods or for different species’ specific temperature ranges. MPCA biologists are currently testing different models that predict the presence and abundance of coldwater species like brook trout, which is often needed as an indicator of stream health for coldwater streams (John Sandberg, Minnesota Pollution Control Agency, personal communication). This method was used in the Duluth study streams. Details of this method and how it was applied to the study streams in Duluth can be found in Appendix 1.

Temperature data at specific logger locations alone does not completely show where stream temperatures are warming or cooling or the rate at which that is happening, nor does it help pinpoint the land-use impacts that may be causing water temperatures to change or locations within watersheds that need to be protected or restored in order to increase the presence and/or abundance of brook trout and other coldwater species. Change in temperature per drainage area of each temperature logger was determined to address this issue.

To help visualize where stream temperatures are changing the most, the drainage area at each temperature monitoring site was delineated and the *change in temperature score from the next upstream temperature logger* was attributed to each drainage area. In this way we can identify stream reaches or areas on the landscape that are disproportionately increasing or decreasing stream temperatures.

The methods for this process are explained in Appendix 1.

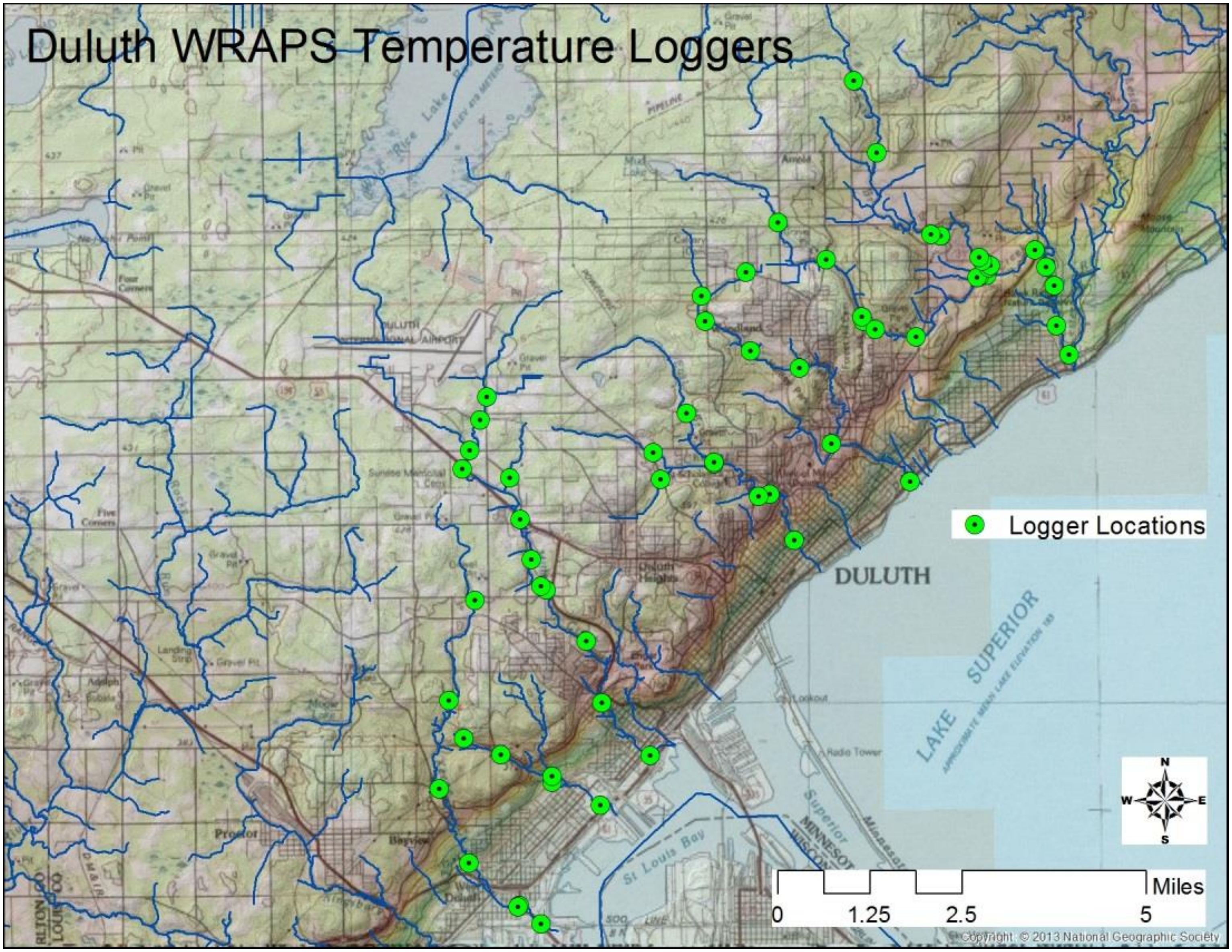


Figure 3. Location of all temperature loggers in the six study streams (Keene, Merritt, Miller, Chester, Tischer and Amity Creeks) since 1994.

Table 2. Water temperature logger locations and the years since 1994 in which data was collected at each site in the six study watersheds throughout Duluth.

Stream	Stream Mile	Site Description	UTM X	UTM Y	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Amity Creek	0.1	Upstream of mouth in Lester Park	575673	5187843																							x
Amity Creek	0.5	Upstream of 1st Skyline Pkwy bridge	575412	5188476																		x					
Amity Creek	1.1	Downstream of 3rd Skyline Pkwy bridge	575362	5189340																							x
Amity Creek	1.4	Downstream of 4th Skyline Pkwy bridge	575173	5189746																							x
Amity Creek	2.3	Upstream of last Skyline Pkwy bridge	574939	5190126																							x
Amity Creek	3.1	Upstream of East Branch	573885	5189578									x	x	x												
Amity Creek	3.8	Reference Reach #1	573715	5189539																	x	x	x	x			
Amity Creek	3.9	Reference Reach #2	573671	5189520																	x	x		x			
Amity Creek	4.7	Jean Duluth Road	572343	5188224									x	x	x												x
Amity Creek	5.6	Vermillion Road	571176	5188557									x	x	x												
Amity Creek	6.1	Vermillion Rd downstream of beaver dam	571450	5188380																		x	x				
Amity Creek	6.3	Vermillion Rd upstream of beaver dam	571149	5188662																	x	x	x				
Amity Creek	6.5	Woodland Ave	570364	5189912									x	x	x												
Amity Creek	7.8	Arnold Road	569322	5190724									x	x	x											x	x
Amity Creek, East Branch	0.1	Upstream of Mouth	573934	5189733									x	x	x						x	x		x			
Amity Creek, East Branch	0.15	Habitat Project Site #2	573952	5189784																	x	x	x	x			
Amity Creek, East Branch	0.2	Habitat Project #3 Under Powerline	573774	5189880																	x	x		x			
Amity Creek, East Branch	0.3	Habitat Project #4 Upstream of Powerline	573710	5189955																	x	x		x			
Amity Creek, East Branch	1.3	Evergreen Road	572864	5190432									x	x	x												x
Amity Creek, East Branch	1.7	Downstream Jean Duluth Rd.	572664	5190468																		x				x	
Amity Creek, East Branch	3.6	West Tischer Road	571472	5192251									x	x	x												x
Amity Creek, East Branch	4.8	Eagle Lake Road	570968	5193828									x	x	x												x
Chester Creek	0.6	Superior Hiking Trail Bridge Pool	569681	5183781																							x
Chester Creek	1.4	Downstream of Ponds	569143	5184786					x	x	x	x	x							x	x			x			
Chester Creek	1.6	Upstream of Ponds	568888	5184737					x	x	x		x							x	x	x					
Chester Creek	2.6	Toledo St	567913	5185451					x	x	x	x	x														
Chester Creek	3.6	Rice Lake Rd	566588	5185685					x	x	x	x	x														
Chester Creek, East Branch	0.1	Toledo St	567925	5185488					x	x	x	x	x														
Chester Creek, East Branch	1	MacFarlane Rd	567325	5186546					x	x	x	x	x														
Chester Creek, West Branch	0.2	Rice Lake Rd	566746	5185103							x																x
Keene Creek	0.3	Channelized reach near mouth	564134	5175376																	x	x	x				
Keene Creek	0.5	Central Avenue	563667	5175793							x	x															
Keene Creek	0.7	Irving Park	563636	5175756																	x	x		x			
Keene Creek	1.5	Cody Street	562559	5176712							x	x														x	x
Keene Creek	2.6	Skyline Parkway	561915	5178333							x	x								x							x
Keene Creek	4.1	Okerstrom Road	562125	5180267							x	x															x
Keene Creek	5.8	Anderson Road	562695	5182459							x	x															x
Merritt Creek	0.3	Upstream of Michigan St	565441	5177977																						x	x
Merritt Creek	1.1	RR tracks off 40th Ave W	564377	5178480											x	x	x										
Merritt Creek	2	Powerlines off Haines Rd	563252	5179085											x	x	x									x	
Merritt Creek	2.5	Headwaters of Mary Lane Dr	562446	5179447													x										x
Merritt Creek, Trib 1	0	Upstream of RR tracks	564379	5178620													x									x	x
Miller Creek	0.4	Downstream of 26th Ave W by bus garage	566531	5179073																						x	x
Miller Creek	1.5	Below Skyline Parkway in Lincoln Park	565469	5180212																						x	x
Miller Creek	2.5	Lake Superior College	565122	5181564																						x	x
Miller Creek	3.6	Chambersburg Road	564253	5182685							x	x	x	x	x	x	x	x	x	x	x	x			x	x	x
Miller Creek	3.7	09LS003	564132	5182762																x							
Miller Creek	4.2	Behind JC Penny	563931	5183348	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x							
Miller Creek	4.8	98LS001	563680	5184225					x																		
Miller Creek	6.1	Downstream of Walmart	562423	5185338													x	x	x	x							
Miller Creek	7	Swan Lake Rd	562810	5186402							x	x	x	x	x	x	x	x									
Miller Creek, Trib 1	0.2	Sunby Rd	563447	5185143											x		x	x									
Miller Creek, Trib 2	0.1	West Arrowhead Rd	562571	5185743											x	x	x	x									
Miller Creek, Trib 3	0.1	Airpark Blvd	562951	5186908											x		x	x									
Tischer Creek	0.1	Upstream of London Rd.	572207	5185062							x	x	x													x	x
Tischer Creek	1.5	Woodland Ave	570490	5185882							x	x	x														x
Tischer Creek	3.3	Below Hartley Pond	569788	5187549							x	x	x														x
Tischer Creek	4	Above Hartley Pond	568722	5187921							x	x	x														
Tischer Creek	4.3	Above Hartley Rd. off Marshall St.	555797	5170919																						x	x
Tischer Creek	4.9	Upstream of Howard Gnesen Rd	567732	5188564							x	x	x													x	x
Tischer Creek	6	Calvary Rd.	568621	5189638							x	x	x													x	x
Tischer Creek, Trib 10	0.1	Charles Rd	567648	5189122							x																
				COUNT	1	1	1	1	8	7	22	19	24	12	17	6	11	7	3	7	12	14	5	8	1	14	28

Results

Connectivity

Stream Road Crossings

Two hundred thirteen stream road crossings were assessed throughout Duluth on all six streams and their major tributaries using the methods described above (Figure 4). The 213 road crossings ranged in condition and in amount of impact to the stream. A majority of road crossings (66%) were within the healthy width range (road crossing width compared to stream width). And most road crossings had streams with a fair channel condition upstream (60%). Of the 213 total crossings, 114 (54%) were considered barriers in the initial round of sorting and were given individual scores using the level 2 matrix. 26% of crossings received low priority scores. 15% had medium priority scores. 12% had high priority scores. And 1% (1 crossing) received a very high priority score based on the level 2 matrix (Table 3). Because each watershed contains differing lengths of stream, data is represented as crossings per stream mile (Table 4). Tischer Creek watershed contained the greatest number of crossings per stream mile and barriers per stream mile, while the Amity Creek watershed contained the least.

The five highest priority crossings were located throughout Duluth (Table 5). These road crossings are recommended for replacement, removal, and/or repair as soon as funding is available. These crossings are the highest priority when ranked individually. If multiple crossings along a stream, or if multiple crossings along one road that crosses multiple watersheds could be addressed at one time priorities may change. Priority lists for each watershed are listed in the specific watershed report.

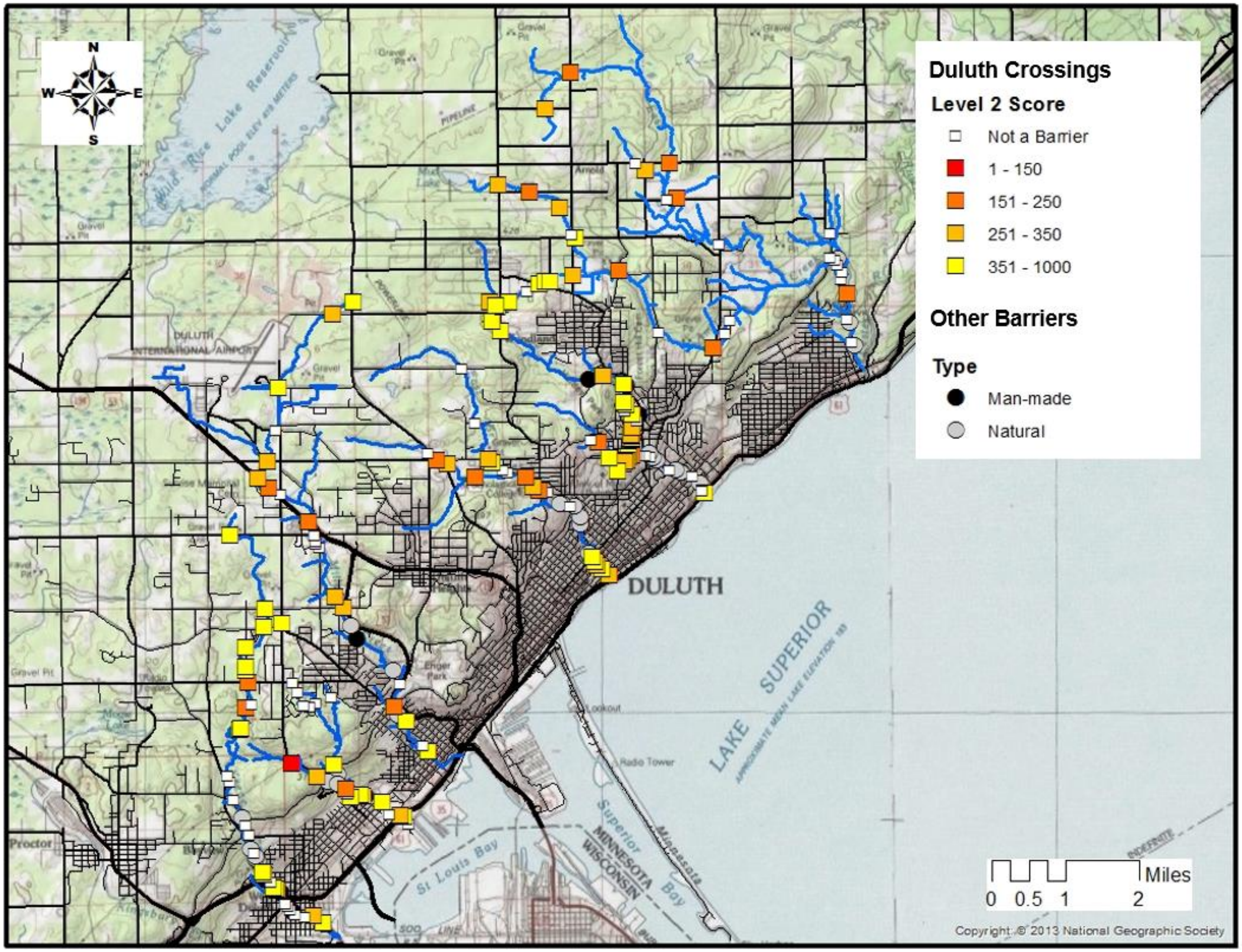


Figure 4. Road crossings within the six study watersheds in Duluth. Each crossing is assigned a score based on priority for replacement, removal, and/or repair if it was identified as a barrier to fish passage. The lower the score, the higher the priority.

Table 3. The number of road crossings acting as barriers within each of the six study watersheds within Duluth.

Watershed	Total Number of Crossings	Percent Barriers	Low Priority	Medium Priority	High Priority	Very High Priority
Keene	33	55%	45%	3%	6%	
Merritt	18	56%	33%	11%	6%	6%
Miller	23	57%	17%	22%	17%	
Chester	21	62%	19%	29%	14%	
Tischer	40	63%	45%	13%	5%	
Amity	29	45%	3%	17%	24%	
Total	213	54%	26%	15%	12%	1%

Table 4. The number of crossings and road crossing barriers are calculated per stream mile to normalize the data.

Watershed	Stream Miles	Crossings per Stream Mile	Road Crossing Barriers per Stream Mile
Keene	11	3.1	1.7
Merritt	7	2.6	1.4
Miller	19	1.2	0.7
Chester	12	1.8	1.1
Tischer	10	3.9	2.5
Amity	27	1.1	0.5
Total	85	1.9	1.1

Table 5. The five highest priority stream road crossings within the six study watersheds in Duluth. The lower the score the higher the priority to replace or address the stream road crossing.

Stream	Street Name	Score
Merritt	Superior Hiking Trail	135
Miller	Skyline Parkway/N 24th Ave W	160
Amity	Woodland Ave	160
West Tischer	Abandoned Maryland St	165
East Amity	West Tischer Rd	165

Natural and Other Man-made Barriers

Many natural bedrock barriers were located throughout the six study watersheds. Bedrock barriers were often located in the middle of the watersheds where the streams transitioned between the flat head waters and Lake Superior or the St. Louis River Estuary. Other man-made barriers in each study watershed in Duluth were most often concrete-encased utility lines. These utility lines were observed in the Keene Creek, Merritt Creek, and Miller Creek watersheds. The Keene Creek watershed also has a large concrete barrier within the dog park. Hartley dam as well as low head dams acts as barriers in the Tischer Creek watershed. The Chester Creek watershed contains two historic dams within Chester Park. These dams will be removed in the fall of 2017 as part of the stream restoration project being implemented by the SWCD.

Geomorphology

Stream Parameters

Throughout the five study streams in Duluth, streams were broken into reaches based on stream type, channel condition, valley type, IR, and riparian condition. BANCS scores were assigned to specific reaches based on the erosion conditions.

One hundred sixty nine reaches were visually assessed throughout the five study streams and major tributaries (Keene, Merritt, Miller, Chester and Tischer). Of these reaches, 49% had an estimated IR of 1 and are connected to the floodplains, while 51% had an IR greater than 1 and are not connected to the floodplain. The channel condition of the visually assessed reaches were mostly good (35%) or fair (45%). Reaches had a range of vegetation conditions, but a majority scored good (36%) or fair (31%). Valley type differed greatly, with 23% being alluvial. Stream type also varied greatly. By observing the channel conditions of reaches for each stream type, it was concluded that specific stream types had reaches of only good and excellent channel condition (A streams), while other stream types had reaches of only fair and poor channel condition (F streams). Similar relationships are seen in most North Shore watersheds. F channels are often not connected to the floodplain and therefore received a channel condition score of poor and fair. A channels are most often found in bedrock valleys and are therefore very stable and in good to excellent condition with minimal erosion. Not only is channel condition correlated to stream type, it is also correlated to IR. One of the many parameters affecting channel condition is IR. Stream reaches that are laterally connected to the floodplain (IR of 1) will most often have good and excellent channel condition scores, but as incision increases, it is likely that fewer reaches have a channel condition of good or excellent (Figure 5).

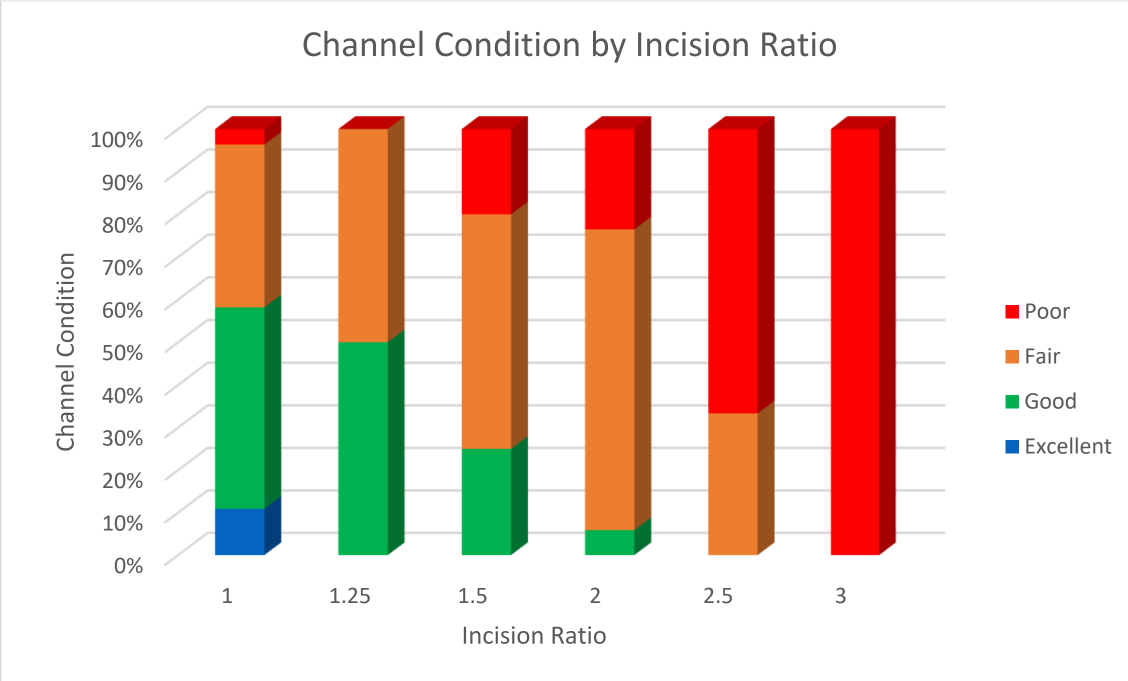


Figure 5. Channel condition compared to Incision Ratio for all reaches within the 5 study streams.

Riparian Condition

Riparian restoration is recommended in reaches where the stream is stable (has a channel condition of good or excellent), but the riparian condition is in poor or fair condition. Riparian restoration is only recommended in reaches of good or excellent channel condition because if a stream is not stable restoring the riparian zone will not address the true impairment cause, and riparian restoration could be potentially hampered due to lateral migration of the still unstable channel. In most reaches in the study watersheds if the stream is in a poor or fair condition, the riparian condition is also in poor or fair condition. Therefore few reaches are recommended for riparian restoration alone. Although multiple reaches are recommended for riparian restoration in each watershed report, only one reach met the criteria of being in good or excellent channel condition and poor or fair riparian condition (Table 6). This reach, located on Miller Creek, is the highest priority for riparian restoration of all reaches assessed in the five study streams.

Table 6. The highest priority reach for riparian restoration.

Stream	Reach Name	Location	Reason for Condition
Miller	2	Lincoln Park	Lawns mowed to the stream edge, limited shade, few canopy trees, restricted valley due to bedrock and concrete and rock walls

Although only one reach meets the criteria of being in good or excellent channel condition with a poor of fair riparian condition, other reaches are also recommended for riparian restoration as restoration is unfeasible in the reach, or because riparian restoration could make large impacts to the stream's health. Duluth streams often have stressful water temperatures for trout. Water temperatures are often increased due to a lack of canopy vegetation providing shade to the channel. For this reason, many reaches are recommended for revegetation in the riparian zone.

Stream	Reach Name	Location	Reason for Condition
Keene	2	Downstream of South Central Avenue	Invasive species, trail encroaching floodplain
Merritt	1	Downstream of I-35	No canopy species, invasive reed canary grass is the dominant species
Miller	14	Behind Miller Hill Mall	Invasive reed canary grass dominates, altered valley, limited canopy species
Miller	16	Upstream of Maple Grove Road	Invasive reed canary grass dominates, altered valley due to road embankments, narrow riparian zone width
Miller	17	Downstream of Highway 53 near Target	Invasive reed canary grass dominates, constricted valley due to road embankments
Chester	8	Downstream of Kenwood Avenue	Crossings and other encroachments are present, invasive species dominate
Chester	10	Between Kenwood Avenue and the confluence of the East Branch	Mowed lawns, invasive species
Chester	T-2	East Branch—Between Triggs Avenue and Arrowhead Road	No shade, mowed lawns, reed canary grass is dominant
Tischer	9	Between the confluence of the West Branch and Wallace	Riprap, confined buffer because of the road
Tischer	18	Downstream of Hartley Pond	No canopy species, no shade, invasive species

Stream Bank Erosion

Seven hundred seventy four total reaches, ranging from 15 to 2,500 feet in length, were assessed across the five study streams to analyze stream bank erosion using the Bank Assessment for Non-point source Consequences of Sediment (BANCS) method (Appendix 1). Stream bank erosion was not concentrated in specific locations but rather was occurring throughout the watersheds (Figure 6) in Duluth. Of the total amount of sediment entering the five study streams in Duluth, from in-stream and near-channel sources, the majority of the sediment input is concentrated in a small number of reaches/length of stream (50% of the total sediment comes from just 7% of the total stream length). This trend was true in each watershed alone as well and gives hope that through prioritized restoration, large reductions can be made in sediment input and turbidity in Duluth streams. The top five BANCS reaches contribute over 8% of the total sediment, but make up less than 1% (0.3 miles) of the total linear length of streams assessed. Three of these top five sediment contributing sites are in the Tischer Creek watershed. The Tischer Creek watershed contributes the greatest rate of sediment from in-stream and near-channel sources to the stream (0.027 tons per foot per year) out of the five Duluth study streams (Table 7). Merritt Creek contributes the second highest amount of sediment per foot of stream annually at a rate of 0.016 tons per foot per year. The Duluth watersheds were compared to other North Shore streams. Tischer Creek had high sediment inputs compared to all other watersheds (Figure 7).

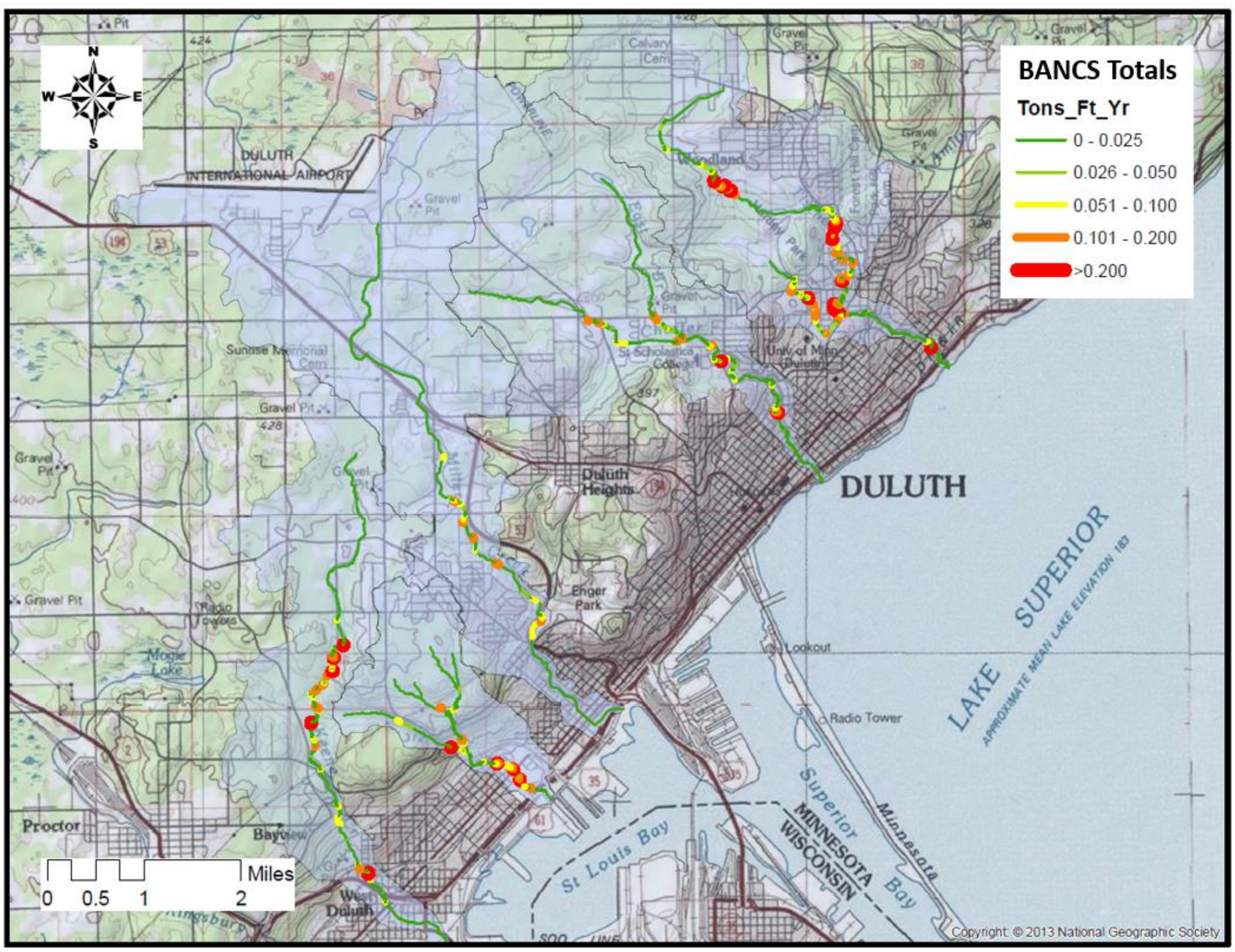


Figure 6. BANCS totals in tons per feet per year for the five study watersheds in Duluth.

Table 7. Amount of sediment input in tons per foot per year and total tons in each study watershed in Duluth.

Watershed	Tons/Foot/Year	Total Tons
Tischer	0.027	1237
Merritt	0.016	461
Keene	0.009	491
Chester	0.008	450
Miller	0.007	365
Total	0.013	3005

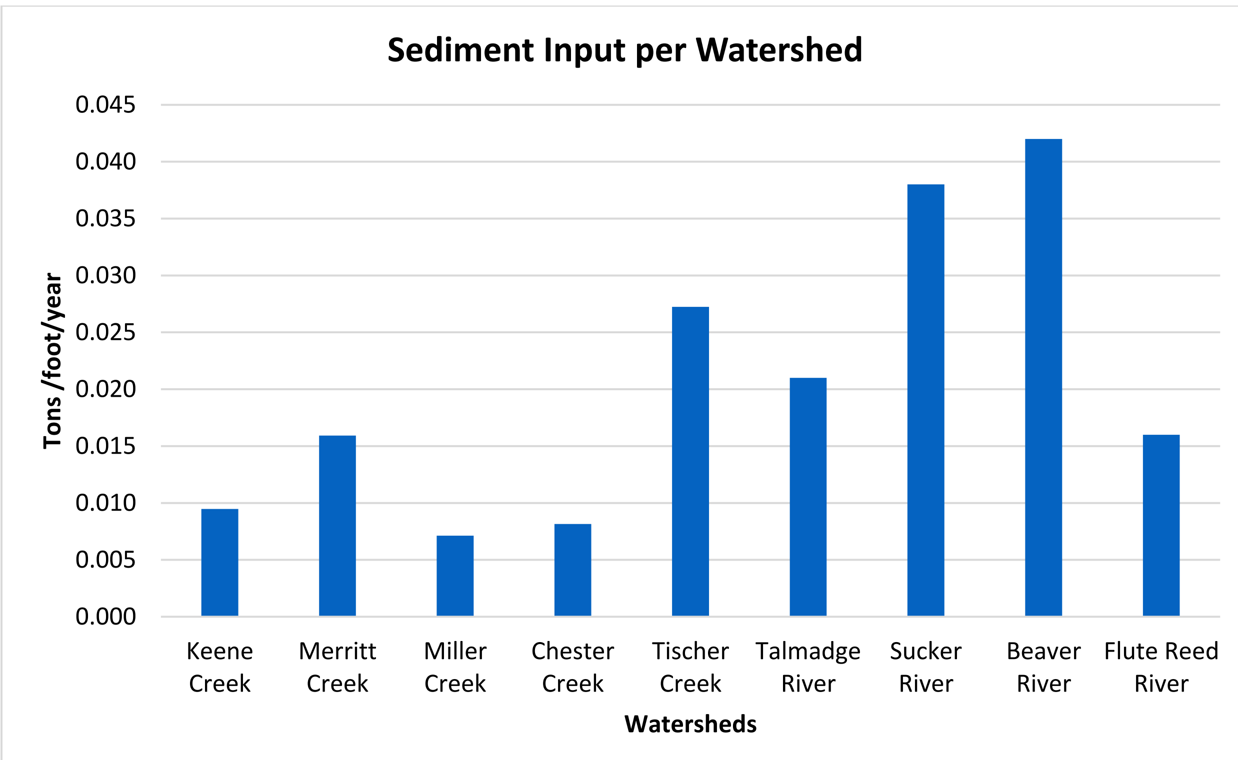


Figure 7. Amount of sediment input in tons per foot per year for watersheds in Duluth and along the North Shore.

Overall Reach Scores

Overall reach scores were calculated using IR, riparian condition, channel condition, and BANCS data. The methods used for each parameter and the methods used to combine the parameters into the overall reach score are explained in this report and in Appendix 1.

Based on this analysis the reach in the worst health is located on West Tischer Creek, upstream of West St. Marie Street. This reach is greatly incised and the stream and valley walls are lined with riprap. The five worst reaches have scores ranging from 1.9 to 3. These reaches are all incised and had poor or fair channel condition scores (Table 8). The reaches with the worst overall scores are recommended as priority sites for restoration. However, before restoration activities are implemented, the health of the upstream reaches should be taken into account, as these upstream reaches affect the health of the reaches downstream.

Restoration is recommended at these sites as well as other sites throughout each watershed.

Table 8. The reaches in the worst condition in Duluth based on the overall reach score.

Stream Name	Reach Name	Total Score	Location	Explanation	Supplementary Information
Tischer, West Branch	T-1	1.9	West Branch, between West St. Marie Street and Norton Street	Constricted valley, riprap on banks, poor habitat, invasive riparian species	2 low priority and 1 medium priority road crossing barriers
Keene	17	2.6	Keene Creek Park, near trail	Greatly incised, significant bank erosion, pooling water causing warming	Warming water temperatures, 7% stressful temperatures (upstream reach), brook trout are present (upstream reach), high priority crossing (upstream reach)
Tischer	11	2.7	Downstream of West Arrowhead Road	Incised, riprap, lack of habitat, eroding stream banks	Low priority road crossing barrier, brook trout present in 2013 (upstream reach)
Merritt	T-12	3	East Branch – 1/3rd mile upstream of Skyline Parkway	Greatly incised, invasive species, over-widened channel, aggradation	Warming water temperatures
Miller	11	3.1	Up and downstream of Anderson Road	Lawns mowed to stream edge, no shade, stream bank erosion	Medium priority road crossing barrier, brook trout present in 1968, slightly warming water temperature

Six stream reaches in Duluth had overall reach scores of 12 (Table 9). This is the highest score possible. The reach must have a channel condition and riparian condition score of excellent, be connected to the floodplain, and be contributing little or no sediment to the stream in order to be given an overall score of 12. These six reaches are located in the Keene Creek and Tischer Creek Watersheds (Figure 8). Descriptions of each of these reaches can be found in the report for the specific watershed.

Table 9. The reaches in the best condition based on the overall reach score.

Stream Name	**Reach Name**	Total Score	Location
Tischer	2	12	Upstream of London Road
Tischer	6	12	Upstream of East 4th Street in Congdon Park
Tischer	7	12	Downstream of Vermillion Road in Congdon Park
Keene	12	12	Upstream of Skyline Parkway
Keene	14	12	Downstream of Keene Creek Park
Keene	20	12	Downstream of Morris Thomas Road

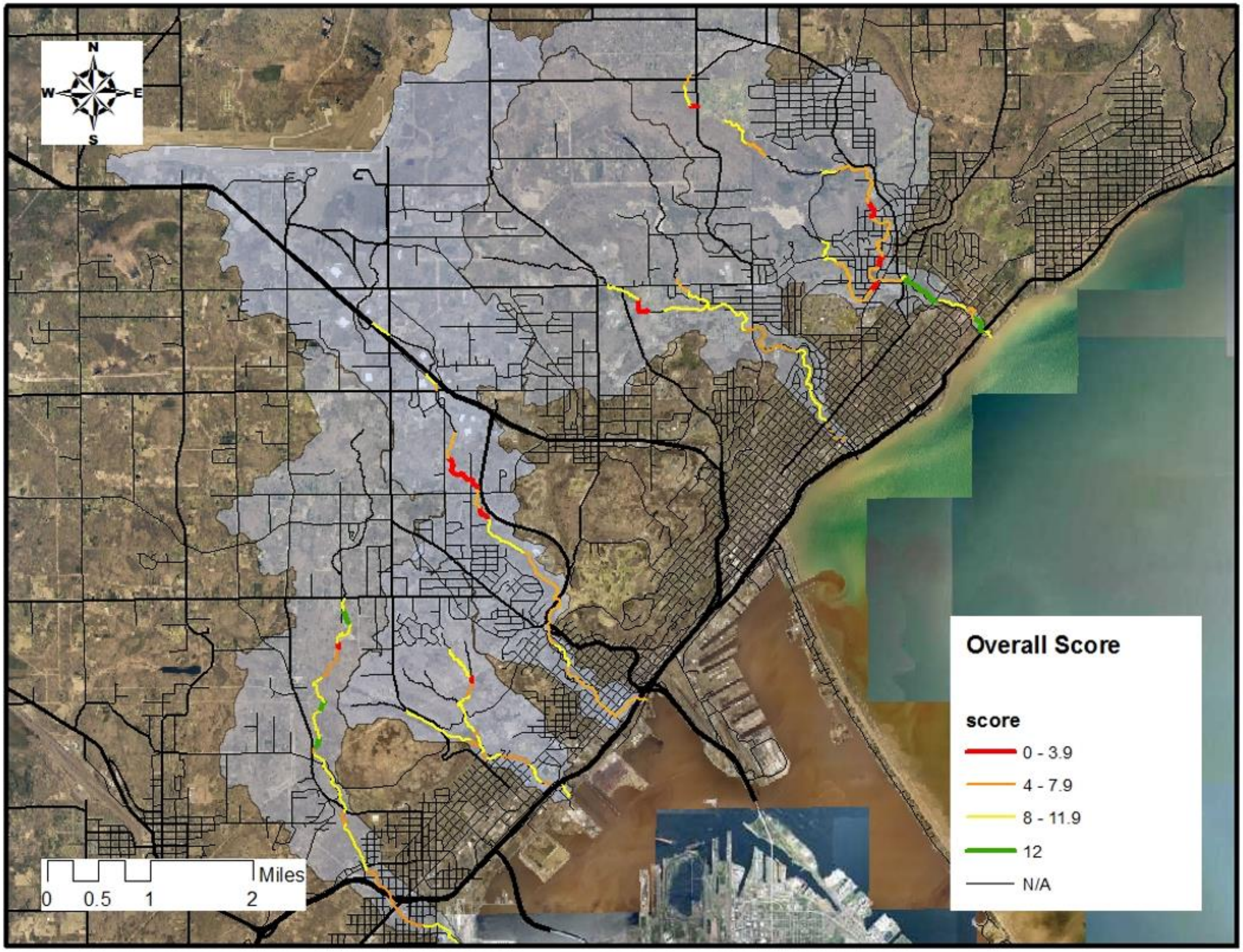


Figure 8. Overall scores for the five watersheds in Duluth.

Water Quality

Stream Water Temperature

Temperature Score

Water temperature data, collected through use of continuous loggers, was analyzed for the six study streams using methods described above. Each temperature logger was assigned a score by dividing the *Summer Average Temperature* by *Percent Growth*. These scores ranged from 60 to greater than 90. Scores of greater than 90 are considered harmful to trout. Reaches with scores ranging from 60 to 70 are suitable for brook trout and had few temperature readings considered stressful to brook trout (the indicator species). About half of the sites had healthy scores between 60 and 70. Conversely, a few sites scored poorly including lower Chester Creek, middle Tischer Creek and upper Amity Creek (Figure 9). The healthiest score was assigned to a site in the headwaters of Tischer Creek.

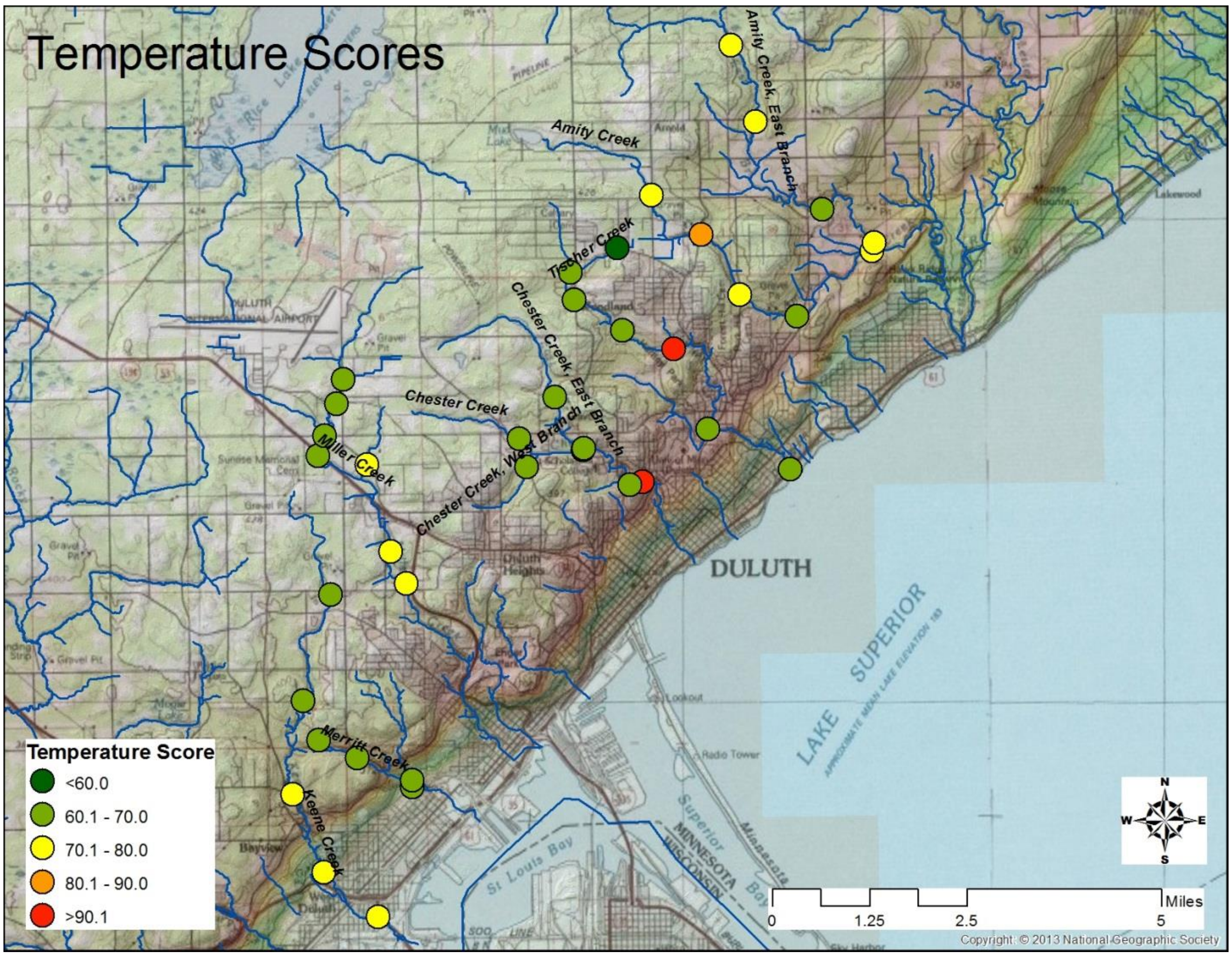


Figure 9. Map of all computed temperature scores for continuous temperature records in the six Duluth study streams.

Sub-watershed Temperature Rating

The size of each individual temperature monitoring drainage area varied widely, from over four square miles to 0.04 square miles. In order to normalize the temperature changes that were taking place within these streams the temperature change for each sub-watershed was divided by that sub-watershed's area in square miles. The results were used to identify which areas and land-uses within Duluth are disproportionately warming or cooling stream temperatures (Figure 10).

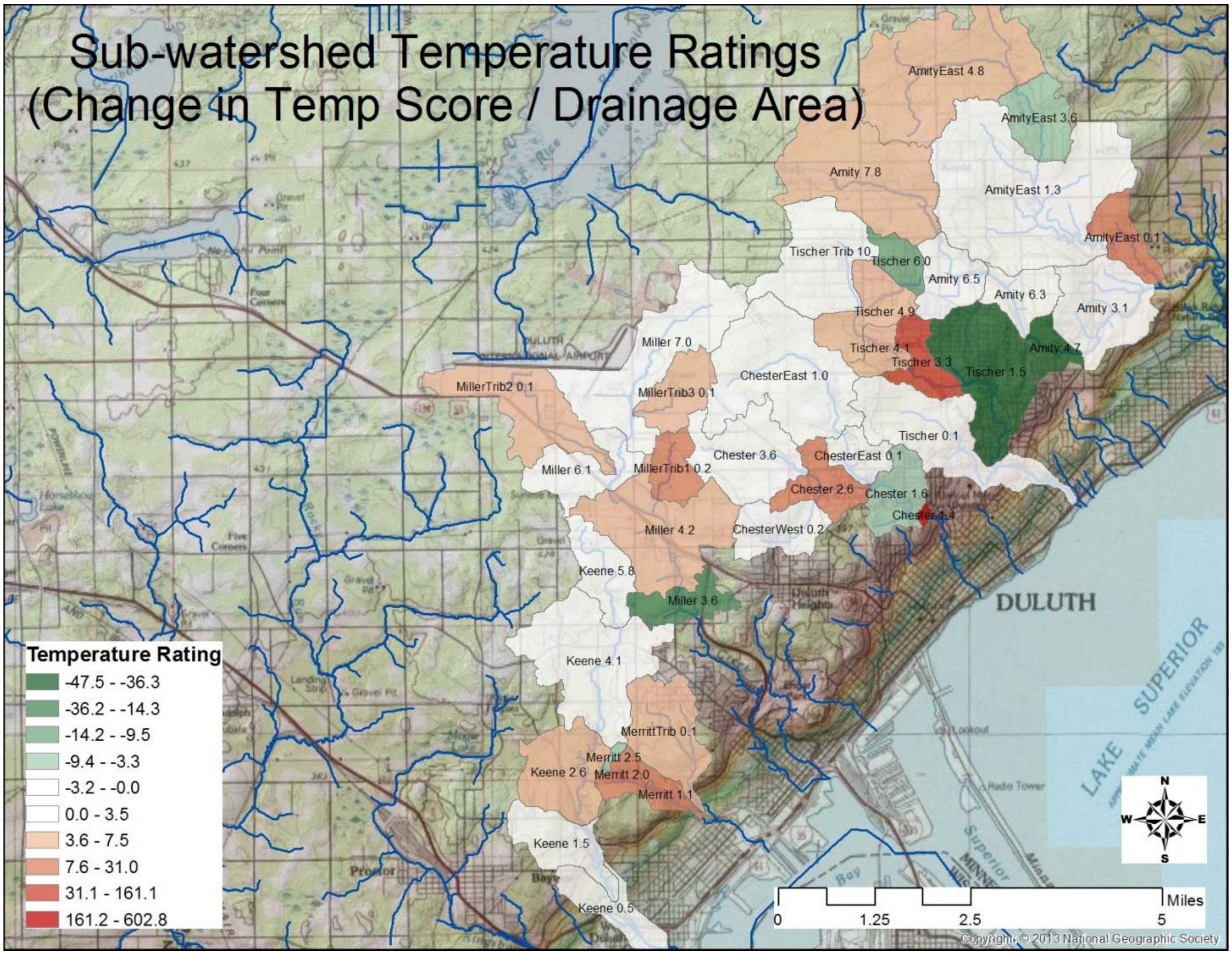
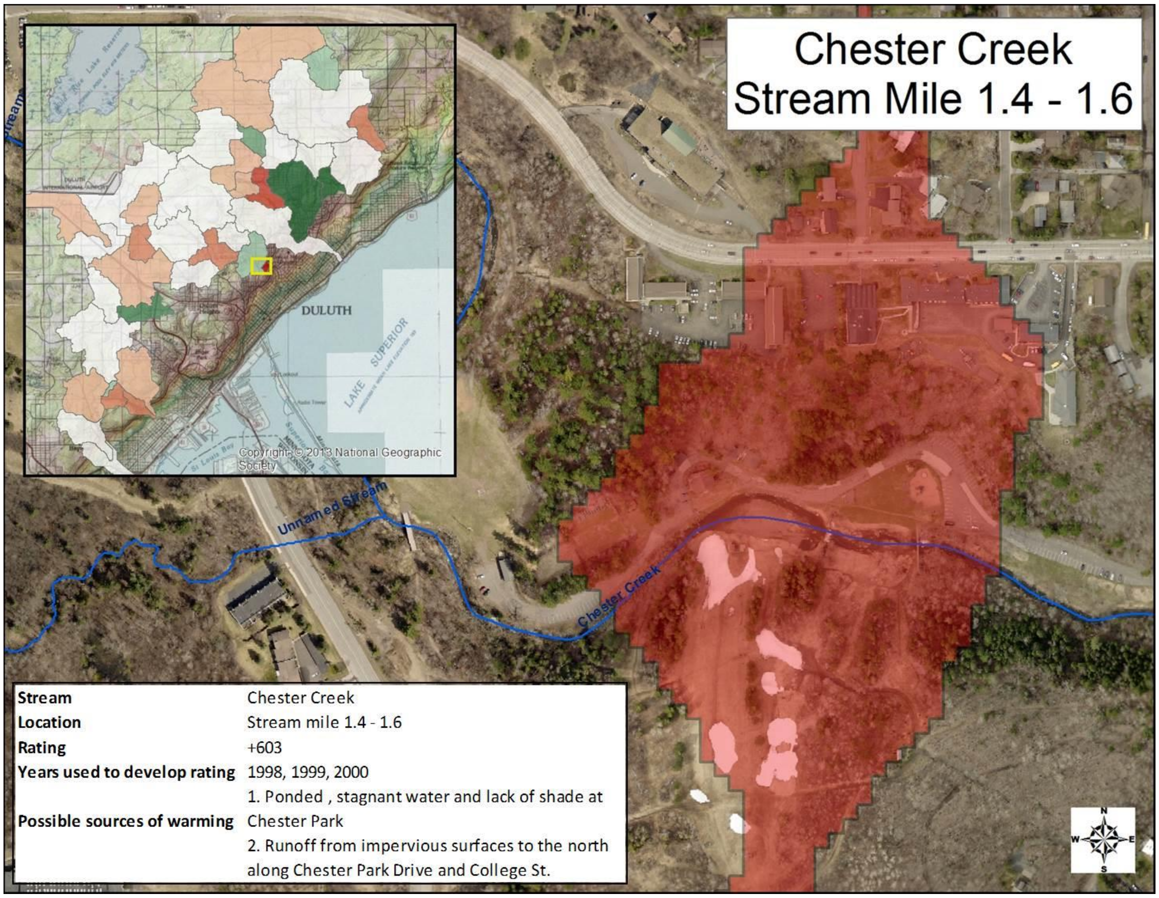


Figure 10. Map showing the temperature rating for each temperature monitoring sub-watershed in Duluth. Dark green symbolizes stream temperatures are decreasing rapidly per square mile of drainage area. Red indicates the opposite – temperatures are increasing rapidly. No color indicates that stream temperatures are changing very little within that particular sub-watershed.

The results show several specific Duluth sub-watersheds in which it would be appropriate to pursue restoration or protection strategies to address water temperatures. The following is a short list of the highest priority areas where water temperatures are warming disproportionately and where restoration efforts should be focused. Potential sources of warming are identified, as well as implementation concepts aimed at decreasing stream temperatures.

Chester Creek between stream mile 1.4 and 1.6

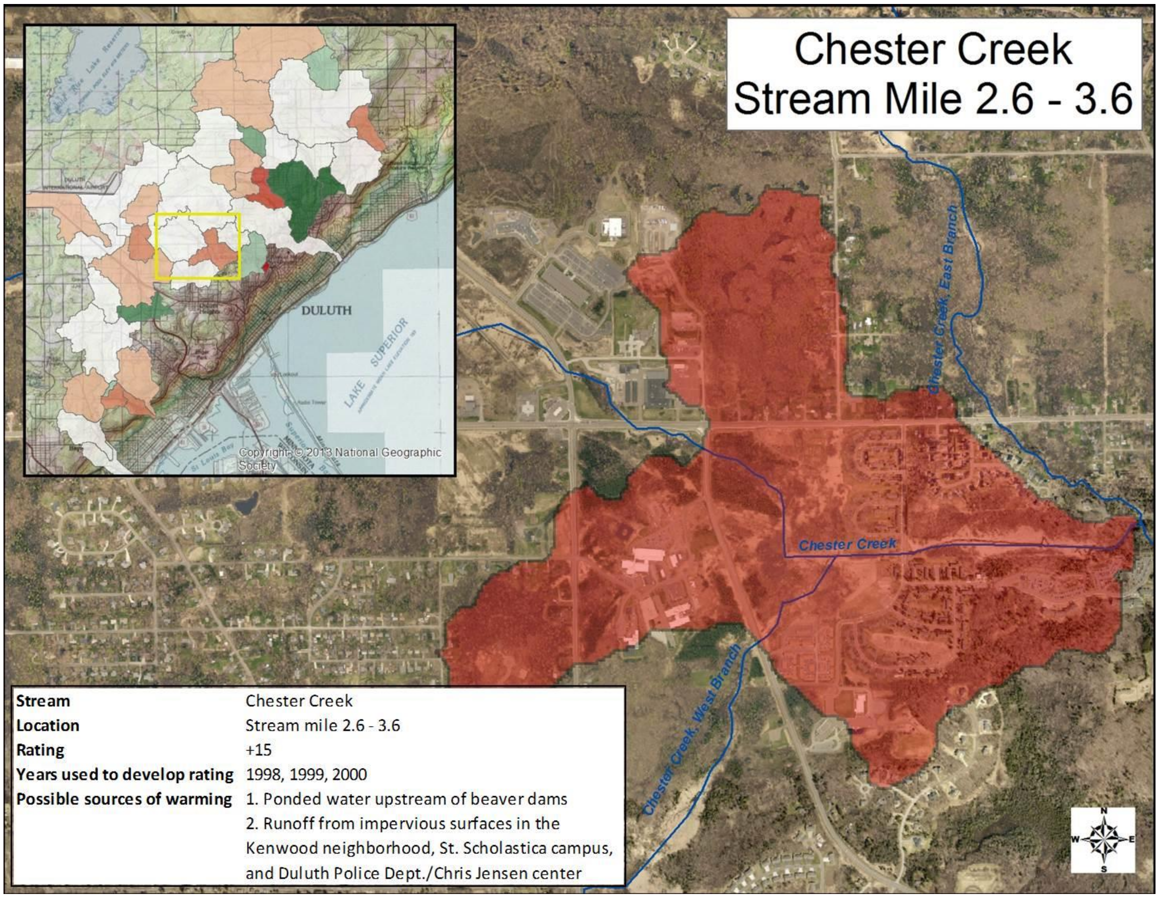


The Chester Creek sub-watershed between stream miles 1.4 and 1.6 (Reach 6) contains the dams and ponded water in Chester Park, and is well known to cause increased stream temperatures. The water temperature data analyzed for this report was collected from June to September between 1998 and 2000 (when the dams in the park were still functioning). During those three years, the average temperature score increased from 68 on the upstream side of the dams to 92 on the downstream side, resulting in a temperature rating of +603 for the 0.04 mile^2 sub-watershed.

The flood of 2012 severely damaged the dams and reduced the size of the impoundments. Thus the dams have a lesser impact today than during pre-flood times. Nevertheless, stream temperatures are increasing in this reach due to the ponding of water, over-widened areas, a lack of adequate shade, and runoff from impervious surfaces.

Removal of the remnant dam structures and restoration of a natural stream channel and riparian corridor through this reach is recommended. Restoration in this reach is in fact scheduled to take place in the fall of 2017 through a joint effort by the MN DNR, South St. Louis SWCD, and the City of Duluth.

Chester Creek between stream mile 2.6 and 3.6



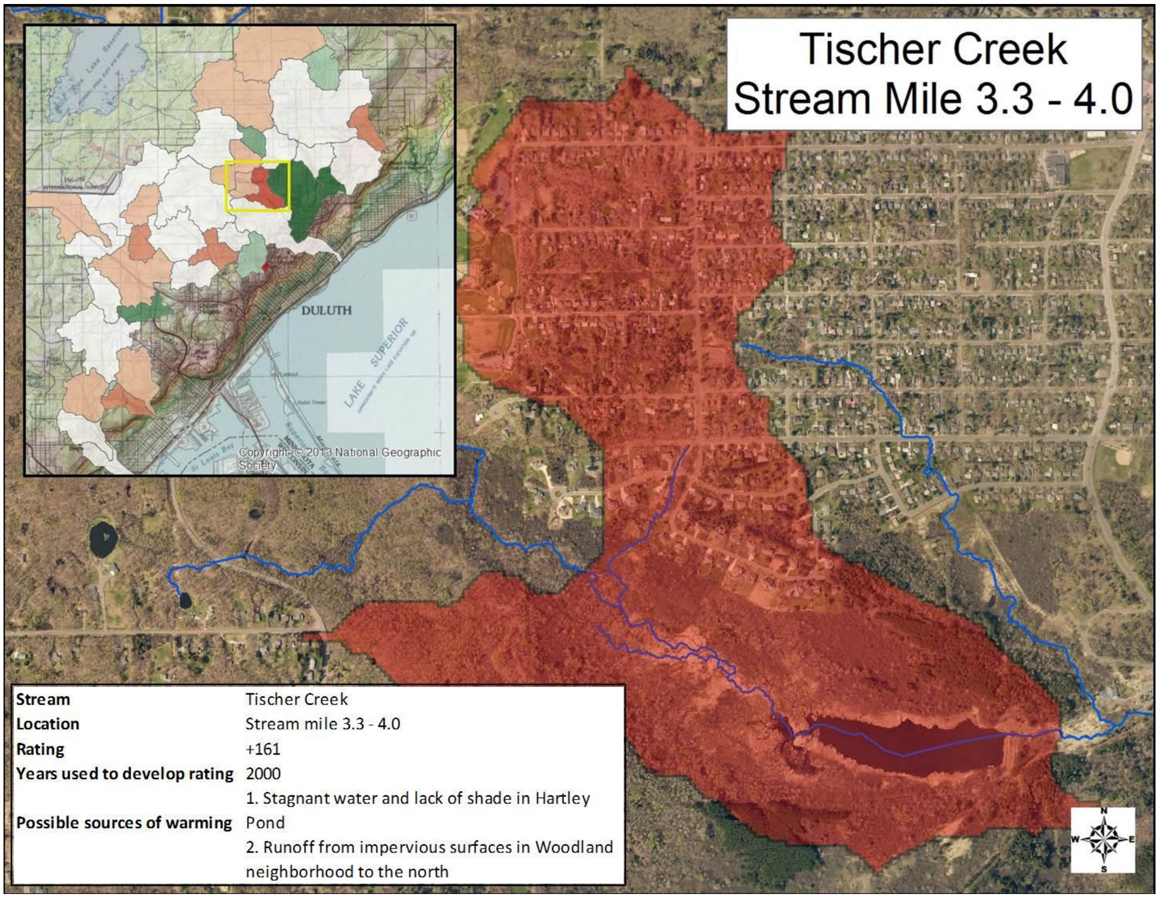
Similar to the Chester Park reach, the temperature data that was analyzed for this site was collected from 1998 to 2000. During this period the average temperature score increased from 64 on the upstream end (Rice Lake Rd) to 73 on the downstream end (just upstream of the confluence with the East Branch of Chester Creek). This change resulted in a temperature rating of +15 per square mile, which is the fifth worst temperature rating within the Duluth study streams.

There are multiple potential sources of warming within this sub-watershed, including a significant number of beaver dam impoundments near the confluence of the West Branch of Chester Creek and runoff from impervious surfaces. The stream channel is ditched for approximately 2000 linear feet on either side of Madison Avenue, causing stream incision and widening in areas.

Restoration of a natural meandering stream with a low width/depth ratio, an E channel, is recommended in this reach of Chester Creek. Efforts at minimizing beaver activity would also help decrease stream temperatures and improve longitudinal connectivity in the system. Storm water projects that reduce the runoff potential from nearby impervious surfaces and increase groundwater recharge are also recommended to reduce stream temperatures.

A restoration project is to be completed in this reach in 2018 by Minnesota Trout Unlimited, in conjunction with the SWCD.

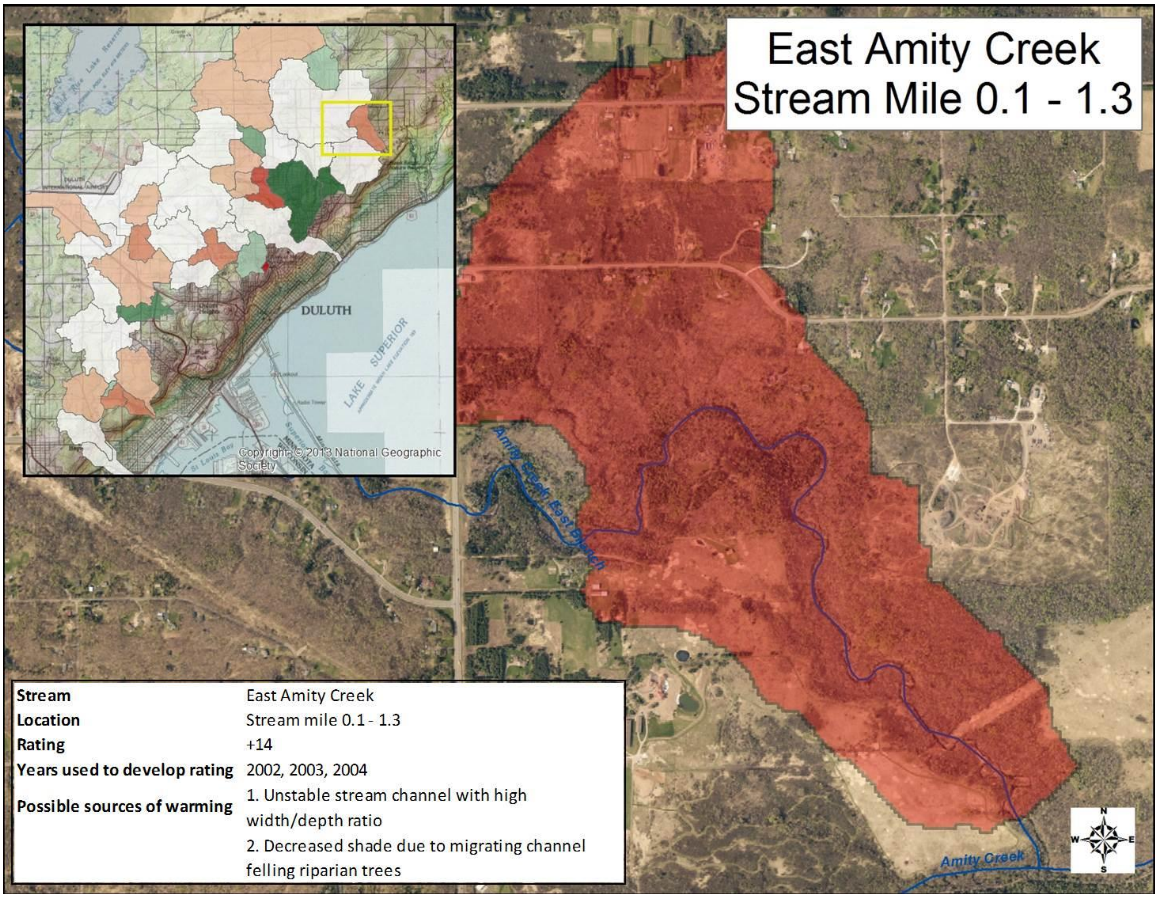
Tischer Creek between stream mile 3.3 and 4.0



The pond at Hartley Park is a well-known detriment to stream temperature and connectivity. The year 2000 had the most continuous temperature monitoring sites in the watershed and thus data from that year was used for this analysis. The sub-watershed between stream miles 3.3 and 4.0 has a drainage area of 0.52 square miles. The temperature score increased from 63 upstream of the pond to 147 just downstream of the pond, generating a temperature rating of +161/square mile – the second highest increase in water temperature in the six study streams.

A large surface area, top-water outlet, and lack of shading almost certainly points to the shallow pond in Hartley Park as causing the increased water temperatures observed in Tischer Creek in this sub-watershed. An additional potential source of warming is the runoff from impervious surfaces in the Woodland neighborhood to the northwest of the pond, although this area is mainly residential and unlikely to have a significant impact on stream temperatures. Restoration of a natural, low width/depth stream channel (stream type E) through the current impoundment is recommended to decrease stream temperatures. Hartley Pond is a valued community resource; however restoration options exist such that the current pond would remain mostly intact. The Hartley Park mini masterplan recommends commissioning a feasibility study to assess such options.

East Amity Creek between stream mile 0.1 and 1.3



Data from 2002 to 2004 was used to analyze stream temperatures in the Amity Creek watershed. The data shows that water temperatures are warming rapidly in East Amity Creek between stream miles 0.1 and 1.3. Average temperature scores increase from 67 at the upstream end of the reach (Evergreen Rd) to 74 at the downstream end near the confluence with mainstem Amity Creek, giving this 0.55 square mile sub-watershed a temperature rating of +14.

This sub-watershed is almost entirely rural and forested, making it unlikely that stream temperatures are increasing due to upland disturbances. The *Amity Creek Stressor Identification (Geomorphology Report)* completed by Geenen and Jennings (2017) described this reach as unstable and a high sediment source. Visual observations of the stream channel confirm that the channel is migrating rapidly, undercutting riparian trees and decreasing shade. Large sediment supplies are creating transverse bars and an over-widened channel, resulting in increased potential for warming water temperatures.

Restoration of a stable channel with a riffle pool sequence (stream type C) is recommended in this stretch of East Amity Creek. Construction of a new channel with the appropriate dimension, pattern, and profile based on a stable reference condition would benefit water temperatures by: 1) decreasing the width/depth ratio 2) increasing groundwater recharge by creating floodplain access for flood waters 3) stabilizing stream banks so that riparian trees can mature and provide better shade.

Restoration and Protection

Stream restoration is a complex process that benefits from a holistic watershed approach. The focus of restoration should be on addressing the biological and physical functions of the stream systems. Setting goals and specific objectives on the various components will reduce the likelihood that addressing one component could have a negative impact on a different process. A useful framework for setting these objectives and thinking about interrelated processes is the Five Components of Riverine systems developed by the Instream Flow Council (Annear 2004). It is also essential that sufficient field data collection has been completed to identify the channel condition, the cause of the instability, and a stable channel form.

When prioritizing restoration at a reach where excess sediment is a primary driver of instability, longitudinal connectivity and sediment transport must be considered. When upstream sources of sediment are addressed first the risk to downstream restoration projects is greatly decreased.

Protection strategies should be focused on areas in which the stream is stable, the riparian corridor is in a healthy condition, and water temperatures are suitable for trout and other sensitive species. Protection strategizes could include working with city or county zoning offices to change policy, obtaining a stream easement through the Minnesota Department of Natural Resources, and working with landowners to reduce impacts to the reach.

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