Stressor Identification Update

St. Louis River Watershed

Cycle 2 - Deferred Impairments

January 2026

Introduction/Goals

Monitoring is essential to determining whether lakes and streams meet water quality standards designed to protect and/or restore healthy aquatic ecosystems. The Stressor Identification (SID) process is designed to study and diagnose negative impacts on fish and aquatic macroinvertebrate communities.

Accordingly, the St. Louis River Watershed Cycle 2 SID work focused on a few select subwatersheds (Table 1). Several of the focus watersheds include impairments that were originally sampled during Cycle 1 monitoring efforts but were deferred to Cycle 2 due to the lack of appropriate standards for channelized (e.g. ditched) streams (Figure 2). The other focus watershed, the Midway River, was selected based on the need to protect high-quality water bodies threatened by a variety of stressors. The Midway River Watershed Protection Study presents goals and strategies for protecting and restoring coldwater habitat.

Figure 1. Unnamed Tributary to St. Louis River (left) and Penobscot Creek (right) are two impaired streams covered in this report.

What have we learned about stream health in the St. Louis River Watershed?

The St. Louis River Watershed was first sampled intensively for biology by Minnesota Pollution Control Agency (MPCA) in 2009 and revisited in 2019 for Cycle 2 efforts. In Cycle 1, 24 streams were listed as impaired for biological indicators (fish and/or aquatic macroinvertebrates). The St. Louis River Watershed Stressor Identification Report for Cycle 1 was completed in 2016 for all 24 impairments. The Cycle 2 St. Louis River Watershed Assessment and Trends Update Report summarizes the findings from the recent monitoring work completed in the St. Louis River Watershed. This SID report is a follow-up effort to the Cycle 2 assessment work, intended to address any new impairment listings, deferred impairment listings, or special projects initiated by regional MPCA staff and local partners.

Part 1: Cycle 2 Areas of Study

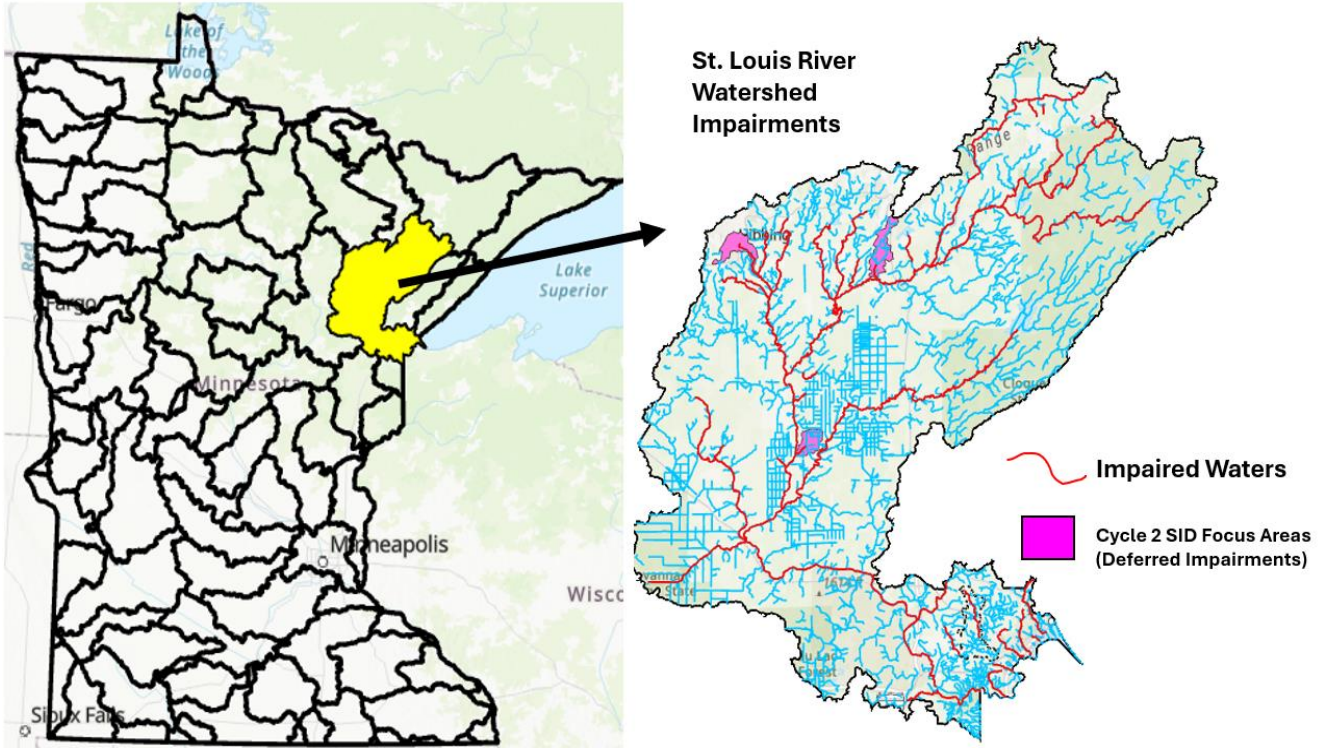
1.1 Deferred Impairments from Cycle 1

Three stream impairments were added to the impaired waters list as "Deferred Impairments" following Cycle 2 assessment monitoring (Table 1). These streams were originally sampled in 2009 during Cycle 1, but official assessment decisions were delayed due to the lack of an appropriate standard for modified (channelized) streams. Cycle 2 SID monitoring was completed for each of the deferred impairments to determine the most probable cause(s) of impairment. Locations of the deferred impairments are shown in Figure 2.

Table 1: Deferred impairments covered in this Cycle 2 SID Report

Waterbody Name	Waterbody ID (WID)	Impaired Reach Length (miles)	Location Description	Impairments
Unnamed Creek	04010201-A19	1.76	Unnamed Ck to St Louis R	Aquatic Macroinvertebrate Community
Long Lake Creek	04010201-A25	2.23	Long Lake Creek	Aquatic Macroinvertebrate Community
Penobscot Creek	04010201-553	4.21	Headwaters to T57 R20W S21, south line	Aquatic Macroinvertebrate Community Fish Community

Figure 2. Map showing areas of focus for Cycle 2 SID Monitoring (purple watersheds)



Part 2: Stressor Identification for Deferred Impairments

2.1 - Penobscot Creek (WID 04010201-553)

2.1.1 - Biological Community Summary

Penobscot Creek (04010201-553) originates from a series of iron ore mining tailings basins and is culverted underground beneath the city of Hibbing before ultimately flowing into Barber Creek (Figure 4). The watershed area of this stream is roughly 18 square miles, but the exact size is difficult to calculate due to the presence of tailings basins in its headwaters, which have drastically altered the drainage. Two assessable biological monitoring stations are located on the impaired stream reach; 09LS070 and 98LS013 (Figure 3). Station 15EM021 is also located on this reach but does not contain any data suitable for assessments. Reportable visits for each of the two assessable stations occurred over a decade apart (1998 to 2009).

This reach is listed as impaired for failing to meet both the fish and macroinvertebrate Index of Biological Integrity (F-IBI and M-IBI) standard established for warmwater streams. Most of the available biological data for this watershed is over a decade old, but official impairment listings were deferred until 2021 when applicable biological standards became available for channelized streams. The monitoring station used for assessment purposes (09LS070) is located on a natural channel (nonchannelized) portion of the stream. However, the upper half of Penobscot Creek flows through an altered channel, either ditched or culverted subsurface. Over 50% of the assessed water body ID (WID) segment is channelized, requiring specific standards to evaluate the fish and macroinvertebrate communities.

F-IBI scores at both monitoring stations were well below the General Use (GU) standard of 42, symptomatic of an impaired fish community. The F-IBI score at 09LS070, sampled in 2009, was very low (9) as only four species were sampled, and overall fish abundance was extremely low. F-IBI results were notably higher at 98LS013 (32) even though this sampling reach is set within a channelized portion of the stream. The fish communities at both stations were dominated by tolerant and semi-tolerant species; Brook Stickleback, White Sucker, and Creek Chub. Longnose Dace were present in good numbers at station 98LS013, resulting in a higher overall F-IBI at this station. Fish sampling at 98LS013 was completed in 1998, therefore the data were unable to be factored into the most recent assessment process. However, these results can still be useful for evaluating differences in fish community structure and health.

Aquatic macroinvertebrate scores (e.g. M-IBI results) are only available for one of the two biological monitoring stations (09LS070) and are based on two sampling visits from September of 2009. The M-IBI scores were similar between the two visits (23.5 and 26.4) and are well below the GU standard of 51. The macroinvertebrate community at this station was dominated by three taxa; Oligochaeta (aquatic worms), Polypedilum (midges), and Acerpenna (baetid mayflies). Due to the dominance of these three taxa, all of which are tolerant of poor water quality and physical habitat conditions, M-IBI metric scores were extremely low in categories related to overall species distribution and general tolerance characteristics.

Figure 3: Penobscot Creek Watershed with effluent discharge locations and biological/WQ monitoring stations

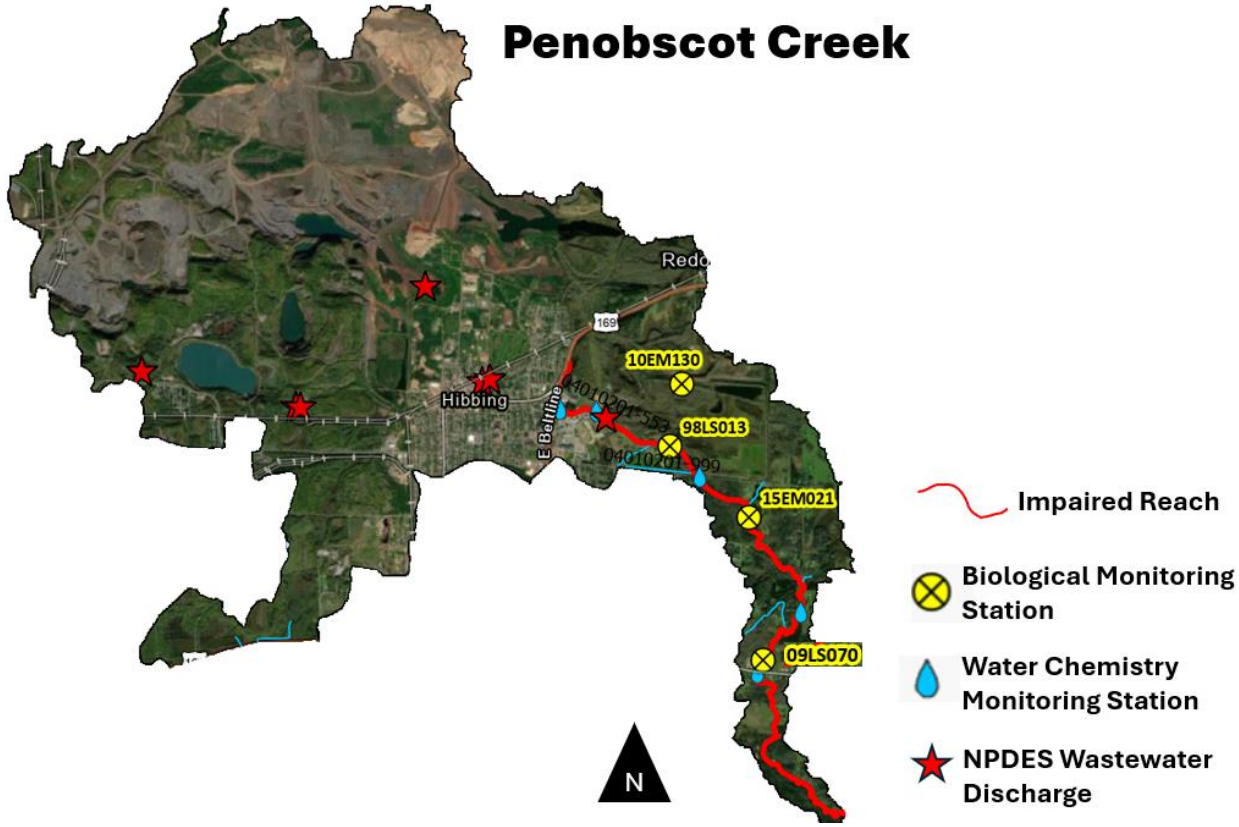
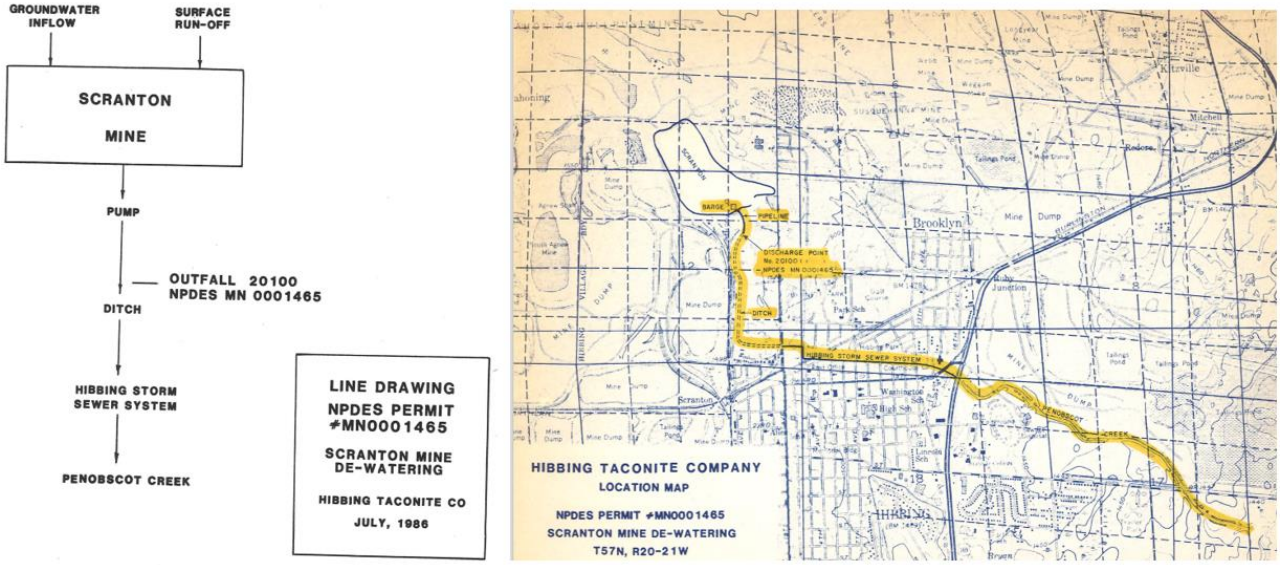


Figure 4: Schematic diagram and map detailing mine pit dewatering effluent delivery to Penobscot Creek



2.1.2 - Other Notable Impairments in Penobscot Creek Watershed

In addition to the aquatic life impairments, portions of Penobscot Creek are currently listed as impaired for water quality parameters related to aquatic recreation (body contact) standards. Cycle 1 water quality assessments of Penobscot Creek (completed 2011) resulted in an impairment listing for elevated concentrations of Escherichia Coli (*E. coli*) bacteria. The bacteria impairment is not considered a contributing cause to degraded fish or macroinvertebrate communities but serves as an indicator of poor water quality and human health exposure risk (e.g. swimming and body contact recreation). A total maximum daily load (TMDL) study will be developed for this impairment to identify all contributing sources of *E. coli* bacterial in the watershed and develop strategies for meeting water quality standards.

2.1.3 - What stressors to aquatic life are a concern in Penobscot Creek?

Penobscot Creek originates from a highly altered headwaters landscape, flows through and underneath a highly urbanized area, and is channelized for most of its length. Based on this highly impacted watershed setting, the potential stressors contributing to biological impairments in this water body are numerous and diverse. This section provides a brief overview of the candidate stressors evaluated during the SID process for Penobscot Creek.

Water chemistry concerns related to mining land uses, urbanization, and stream channel modifications were evaluated as potential candidate causes for impairment. Specific parameters included elevated specific conductivity, elevated pH, elevated total suspended solids (TSS), nitrate (NO_3) toxicity, low dissolved oxygen (DO), excess nutrient levels, and toxicity from heavy metals. Mining related discharges to Penobscot Creek are regulated and monitored through several National Pollutant Discharge Elimination System (NPDES) permits issued to Hibbing Taconite Co. The MPCA has issued several enforcement penalties to this permit holder for violations related to wetland and stream impacts; however, none of these violations occurred within the Penobscot Creek Watershed.

Altered hydrology was identified as a candidate cause for impairment due to the high percentage of urban and industrial land cover within the watershed. In addition, this watershed is heavily channelized and much of the flood-storage capacity has been reduced due to stream channel incision (down-cutting) and riparian wetland loss. The complete removal of headwaters tributary streams due to mining and urban development, including continuous mine pit dewatering discharges due to creek, further modify the hydrological properties of this watershed.

Poor physical habitat conditions were also identified as candidate causes for impairment based on poor Minnesota Stream Habitat Assessment (MSHA) scores. Both biological monitoring stations are directly or indirectly (observed in an upstream stream reach) impacted by eroding stream banks, stream channelization, and sedimentation. Specific habitat limitations will be discussed in detail in the following section.

2.1.4 - Evaluating Candidate Causes for Impairment in Penobscot Creek

The following section provides analysis and discussion of the candidate causes for fish and macroinvertebrate impairment in Penobscot Creek. Based on the available data and analysis performed, candidate causes are ultimately confirmed, eliminated, or considered inconclusive as contributing to the impaired condition. A complete summary of final SID outcomes is included in Table 2.

Candidate Cause #1 - Elevated Total Suspended Solids Concentrations

Concentrations of TSS observed in Penobscot Creek are elevated above natural background levels, particularly during periods of higher streamflow. Roughly 40% (23 of 59) of grab samples collected between years 2009-2023 exceeded the TSS standard of 15 mg/L assigned to this stream class. The MPCA typically classifies streams with a 25% exceedance rate as "impaired" for this parameter. However, many of the TSS results for Penobscot Creek fell narrowly outside the 10-year assessment window and were not considered usable for the most recent water quality assessments. Despite the inability to use these older results for official assessment purposes, the complete TSS data set (historic and contemporary data) indicate a systemic water quality issue related to excess suspended sediment, particularly during elevated streamflow periods.

TSS results display a seasonal pattern of elevated concentrations in the late spring and summer months. No streamflow data are available for this watershed, but elevated concentrations of TSS are typically observed during spring snowmelt periods and following moderate to heavy nonwinter precipitation events. The photos in Figure 5 provide visual examples of elevated TSS concentrations during moderate to high streamflow conditions.

Sources contributing to elevated TSS concentrations include streambank erosion, streambed scouring, altered hydrology, and overland runoff from urban and industrialized areas within the watershed. Approximately 1.75 miles of Penobscot Creek has been channelized (ditched) for nearly a century. The earliest aerial photos available (1941) show a Penobscot Creek as a ditched stream just below the city of Hibbing, where it first emerges from city storm sewer. The present-day stream channel remains ditched and extremely over-widened. In addition, the creek is severely entrenched within steeply sloping valley walls because of ditching through mining waste rock spoil piles. During high flow events or flood-stage, Penobscot Creek is unable to access a floodplain in these locations, and erosive forces are directed towards the banks and bed of the channel.

Areas of significant bank erosion can be found throughout the nonchannelized portion of Penobscot Creek as well. Steeply sloping, exposed streambanks with little to no vegetative bank protection are common in portions of the creek with high sinuosity (Figure 6). Poor rigor and diversity of riparian vegetation is one of the drivers of bank erosion and stream channel instability, as many areas lack mature trees and are dominated by noxious and invasive herbaceous plant varieties.

Fish and macroinvertebrate biological metric data support elevated TSS as a stressor of concern. Both communities were dominated by taxa considered to be neutral, tolerant, or very tolerant of elevated TSS concentrations. All fish species sampled in Penobscot Creek except for one (Longnose Dace) are neutrally tolerant elevated TSS concentrations. Longnose Dace is a species classified as intolerant of TSS, however, only two individuals were sampled, and this species was only present at the upstream biological monitoring station. A few intolerant macroinvertebrate taxa (2) were observed at station 98LS013, but far more tolerant taxa (8) and an equal number of very tolerant taxa (2) were present. Overall, the biota in Penobscot Creek exhibit a tolerant trending response to elevated TSS, with some indication that intolerant species could be more abundant if TSS concentrations are reduced.

Elevated TSS concentrations is **confirmed** as a cause of fish and macroinvertebrate IBI impairment in Penobscot Creek. This decision is based on the high exceedance rate of the TSS water quality standard (40% exceedance rate if historic data are included) and the relatively low numbers of intolerant fish and macroinvertebrates found at both biological monitoring stations.

Figure 5: Elevated TSS concentrations at moderate flows and streambank erosion due to channel incision and poor bank protection

Candidate Cause #2 – Degraded Physical Habitat

The MSHA protocols were used to evaluate physical habitat conditions at both Penobscot Creek biological monitoring stations. MSHA results are summarized in five main categories: Land Use, Riparian, Substrate, Cover, and Channel Morphology (e.g. stream channel stability). Total scores are reported on a scale of 0 to 100, with high scores indicating higher quality habitat (Figure 6).

Overall MSHA scores for both Penobscot Creek stations were fair to below average and indicate marginal or sub-par physical habitat conditions within the impaired reach (09LS070 = 55.1/100 and 98LS013 = 40.8/100). Station 98LS013 scored poorly in 4 out of 5 major MSHA categories, with notably low metric scores related to channel morphology, substrate conditions, and surrounding land use. The entirety of station 98LS013 is located within a channelized (ditched) portion of Penobscot Creek, which factors heavily into the poor channel stability, channel development, and substrate conditions observed at this station. No coarse substrates were observed at this sampling location and the reach was dominated by sand and silt.

Station 09LS070 is in the lower portion of the watershed where the stream channel has not been ditched. The presence of a natural, sinuous stream channel at this monitoring location led to slightly improved MSHA metric scores related to channel morphology at this location. However, scores for this metric remain “fair” due to a lack of riffle habitats within the reach and areas of streambank erosion noted at outer bends. A lack of riffle habitat can limit the diversity of fish and macroinvertebrate taxa found within a stream reach and creates an environment more favorable to “generalist” taxa, which can thrive in a wide variety of habitats. Additional habitat stressors identified at station 09LS070 included moderate substrate embeddedness (sand and silt covering coarse gravel and cobble substrates) and sparse cover for fish and macroinvertebrates.

Based on these poor physical habitat scores and relative lack of habitat sensitive biota in Penobscot Creek, poor habitat conditions are **confirmed** as a contributing stressor to fish and macroinvertebrate impairments. Poor habitat conditions in Penobscot Creek are the product of heavily ditched watershed, poor riparian management, and an altered flow regime.

Figure 6: MSHA scores for Penobscot Creek biological monitoring stations (09LS070 and 98LS013)

Figure 7: Examples of poor habitat conditions related to stream channelization in the impaired reach of Penobscot Creek

Candidate Cause #3 - Low Dissolved Oxygen/Excess Nutrients/Eutrophication

DO data are available for Penobscot Creek in the form of single discrete measurements (spot measurements) and short-term continuous monitoring periods ranging from two to five weeks in duration. Based on existing data, minimum DO concentrations within the impaired reach are sufficient for supporting sensitive fish and aquatic macroinvertebrate communities. A total of 74 spot DO measurements have been collected from Penobscot Creek within the past 20 years resulting in zero readings below the 5 mg/L warmwater DO standard. In addition, no sub 5 mg/L readings were observed during 48 days of continuous monitoring conducted during July and August of 2022 and 2023 (Figure 8 and Figure 9).

Several DO concentrations on the upper end of the range of results are noteworthy. In 2009 and 2010, values of 14.5 mg/L and 14.0 mg/L were reported during summer afternoon sampling visits. DO concentrations in this range are not common in healthy Northeastern Minnesota streams and could be a sign of eutrophic conditions. However, the potential for eutrophic conditions is not validated by continuous monitoring data. Multi-parameter YSI sondes were deployed at several locations in 2022 and 2023 to record temperature, specific conductivity, DO, and pH at 30-minute intervals during mid-summer low flow conditions. This period of the year tends to be the most prone to low DO concentrations and/or high diurnal DO flux (i.e. difference between daily minimum and maximum concentrations). The range between daily minimum and maximum DO concentrations during the two continuous monitoring periods remained around 2.0 to 2.5 mg/L, which is a normal range in NE Minnesota streams.

Phosphorus concentrations (total phosphorus or "TP") in surface water is a main driver of primary production and stressors related to river eutrophication. Historic TP data from Penobscot Creek from the late 1970's and early 1980's show elevated TP concentrations exceeding the state of Minnesota water quality standard of 0.055 mg/L. During this period, the Hibbing Wastewater Treatment Plant (WWTP) North unit discharged to Penobscot Creek just downstream of the HWY 169 crossing. This discharge ceased around 2006, and by 2009 TP in-stream TP concentrations decreased substantially, a trend that appears to be continuing based on the most recent sampling completed in 2022 and 2023 (Figure 10). Since 2011, 92% of samples have met the TP standard and the only exceedance was narrowly above the standard at 0.057 mg/L.

DO data collected within the impaired reach offer adequate evidence to **eliminate** low DO concentrations as a cause of fish and macroinvertebrate impairment in Penobscot Creek. The minimum DO water quality standard is met under all flow conditions. There are some signs of elevated DO flux/eutrophication in the existing data, but TP concentrations are trending downward now that the Hibbing WWTP no longer discharges to this water body. In addition, the recent continuous monitoring data did not show any signs of elevated DO flux/eutrophication.

Figure 8: Continuous Dissolved Oxygen Data collected in Penobscot Creek (6/28/22 - 7/25/22)

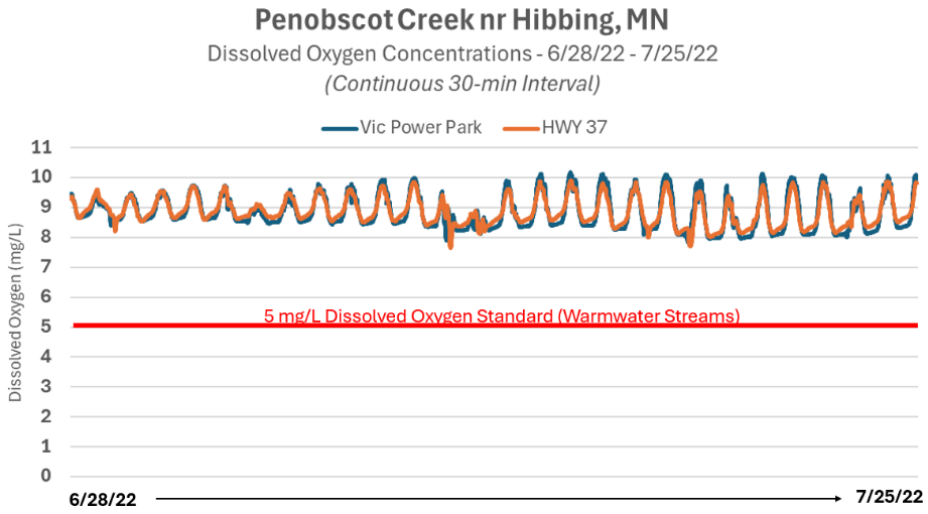


Figure 9: Continuous Dissolved Oxygen Data collected in Penobscot Creek (7/18/22 - 8/22/22

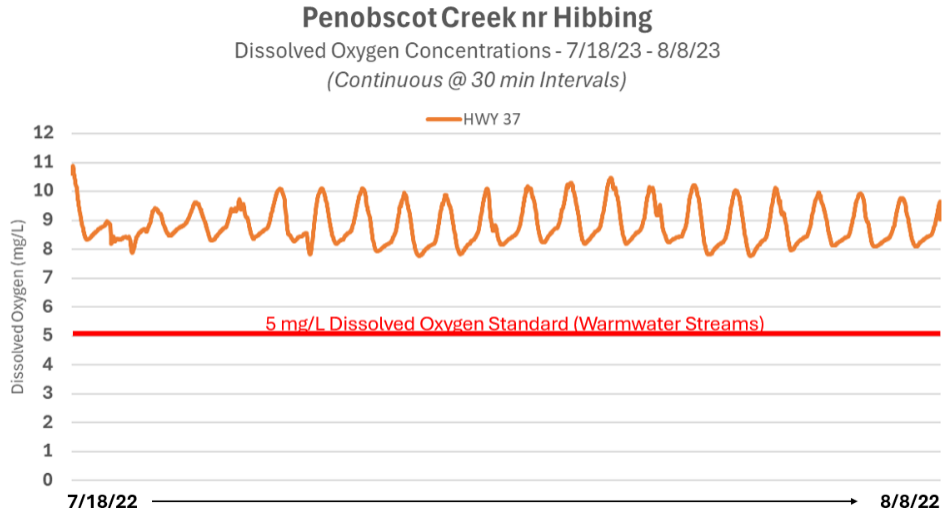
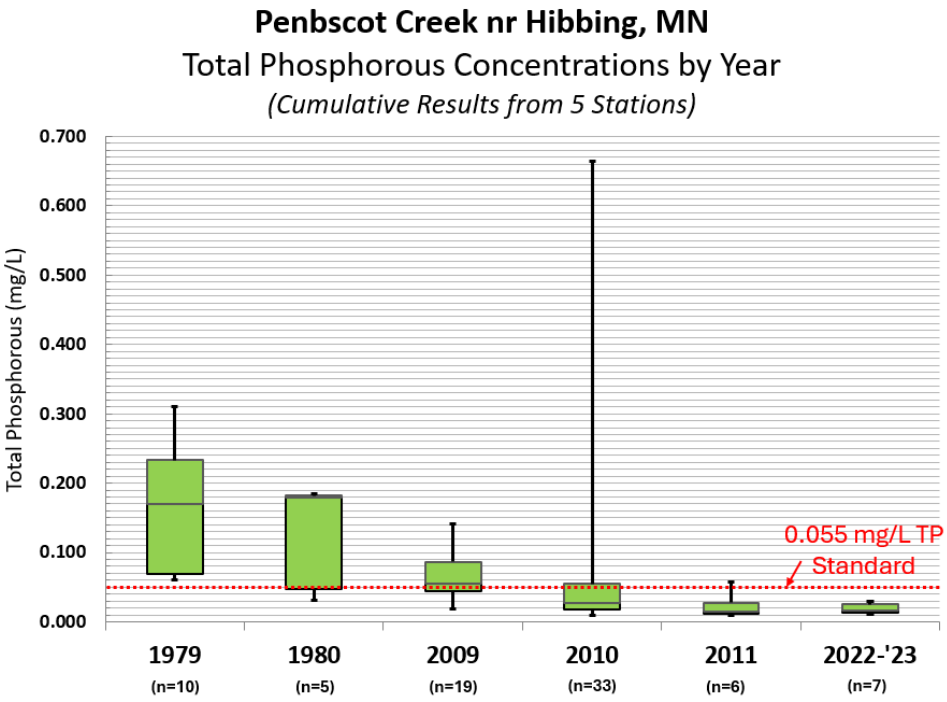


Figure 10: TP concentrations measured in Penobscot Creek 1979-2023



Candidate Cause #4 - Nitrate Toxicity

Chronic exposure to elevated NO_3 concentrations can be harmful to fish and macroinvertebrates. Symptoms include reduced growth and activity, reproductive issues, tissue damage, and increased mortality. Currently, the MPCA does not have an aquatic life-based water quality standard for NO_3; however, a standard is in development. The draft proposed NO_3 criteria for the protection of aquatic life include an acute value (maximum standard) of 60 mg/L NO3 for a one-day duration concentration for all Class 2 waters. Additionally, the draft chronic values are 8 mg/L N NO3 mg/L for Class 2B (warmwater)

and 5 mg/L N NO3 for Class 2A (coldwater) for concentrations based on a four-day duration. For more details see: Aquatic Life Water Quality Standards Technical Support Document for Nitrate.

Penobscot Creek is classified as a 2B (warmwater) stream, meaning the applicable draft standard for NO_3 is 8 mg/L. A total of 81 samples for NO_3 have been collected from Penobscot Creek, covering five individual monitoring stations along the water body and a sample date range of 1979 to 2023 (n=81, max=11 mg/L, avg=1.59 mg/L, min=0.04 mg/L) The majority of the samples (65 of 81) were collected in between 2009 and 2023 (n=65, max=11 mg/L, min=0.04 mg/L).

NO_3 concentrations are elevated in Penobscot Creek compared to minimally impacted reference streams in the greater St. Louis River Watershed, which are typically well below 1 mg/L (MPCA, 2016). Potential sources contributing to elevated NO_3 levels in Penobscot Creek include legacy WWTP impacts (effluent ceased circa 2009), urban stormwater runoff, inflow/infiltration (I&I) along city sewer lines, and dewatering of mine tailing basins in the headwaters of the creek.

All but one NO_3 sampling result plotted well below the 8 mg/L draft aquatic life standard. Based on these results, NO_3 concentrations are not expected to be chronic or acute stressor to aquatic life. A single exceedance of the draft standard, a result of 11 mg/L, was recorded on 8/30/2012 at station S000-594 (Dupont Road). This sampling result is questionable based on comments provided by the Minnesota Department of Health Lab, which performed the analysis (comment: “Lab sample temperature = 5.4°C, which may be warmer than preservation protocol”). This result is further called into question since it is an extreme outlier among the other 80 sample results. Discounting the 11 mg/L result, over 90% of the remaining results were below 3 mg/L and the maximum value drops to 4.5 mg/L.

Symptoms of NO_3 toxicity are typically more evident in macroinvertebrate communities compared to fish. The macroinvertebrate community of Penobscot Creek includes a mix of tolerance levels to elevated NO_3 concentrations, but over 50% of the taxa found in this stream are considered either tolerant or very tolerant to NO_3. Conversely, less than 2% of the taxa are classified as intolerant or very intolerant to this stressor.

NO_3 toxicity cannot be confirmed or eliminated as a cause of biological impairments in Penobscot Creek and will remain **inconclusive**. This decision is based on several factors. First, NO_3 concentrations in this water body are considerably higher than minimally impacted streams in the region, with concentrations as high as 4.5 mg/L recorded and potentially higher (11 mg/L result was flagged for lab quality control issues). These elevated sampling results raise the possibility for some level of impact on fish and macroinvertebrate communities. In addition, the proposed water quality standard of 8 mg/L remains in draft status and cannot be used as rule until it is finalized. NO_3 toxicity will remain **inconclusive** until a water quality standard is finalized. Additional sampling is recommended to determine if the 11 mg/L result represents an actual spike in NO_3 concentration, or if the result was entirely due to sample transport issues and/or lab error.

Candidate Cause #5 - Metals Toxicity

While some metals are essential as nutrients, all metals can be toxic at some level and some metals are toxic in minute amounts. Impairments result when metals are biologically available at toxic concentrations affecting the survival, reproduction, and behavior of aquatic organisms. Metals

commonly linked to toxic effects include arsenic, cadmium, chromium, copper, lead, inorganic mercury, nickel, selenium, and zinc. Additional information related to toxicity and applicable water quality standards can be found in the Cycle 1 St. Louis River Watershed Stressor Identification Report. There are numerous sources in the Penobscot Creek Watershed with potential to contribute to increased concentrations of metals, including urban runoff, landfills, municipal and industrial point sources, and mining operations.

Minnesota's water quality standards for metals are listed at three levels of impact and expsure; chronic standard (CS), maximum standard (MS), and final acute value (FAV). The specific toxicology guidelines for each of these standards is explained in table 2.

Table 2: Descriptions of toxicity standard levels used in Minnesota water quality standards

Chronic Standard (CS)	The highest water concentration or fish tissue concentration of a toxicant or effluent to which aquatic life, humans, or wildlife can be exposed indefinitely without causing chronic toxicity
Maximum Standard (MS)	The highest concentration of a toxicant in water to which aquatic organisms can be exposed for a brief time with zero to slight mortality
Final Acute Value (FAV)	Represents the concentration of a substance that is expected to protect nearly all aquatic species from short-term (acute) toxic effects

Limited data are available to evaluate concentrations of heavy metals in the surface waters of Penobscot Creek. Most of the available sampling results are from the late 1970's, and while the results may still be valid, they will be used with caution to evaluate current stressor-response relationships. The following paragraphs provide a short summary of metals concentrations found in Penobscot Creek and potential for impact to aquatic life.

Aluminum

Six grab samples were collected in the summer of 2023 to evaluate total aluminum concentrations under baseflow conditions. Results ranged from 80.7 to 247 µg/L with a median value of 122.7 µg/L. Minnesota water quality standards for aluminum established a CS of 87 µg/L for class 2B (warmwater) streams, a MS of 360 µg/L, and a FAV of 1,496 µg/L. Aluminum concentrations in Penobscot Creek exceeded the CS in five of six (83%) samples collected. Based on available data, aluminum concentrations frequently exceed the CS, and the duration of exposure is potentially significant enough to trigger a chronic toxicity effect in aquatic life.

Aluminum occurs naturally within the environment, often found in sediments originating from peat deposits and wetlands. Some streams near Penobscot Creek exhibit high concentrations of aluminum in surface waters despite little anthropogenic disturbance within their contributing watersheds. In the case of Penobscot Creek, elevated aluminum concentrations are likely due to a combination of natural and anthropogenic factors. Municipal WWTP discharges to the creek ceased circa 2009, so contributions from this source were not represented in the 2023 samples. As part of a 1981 permit application for re-issuance of an NPDES permit, an aluminum sample was collected from the mine pit effluent continuously pumped into Penobscot Creek, resulting in a concentration of 56 ug/L. Based on this single sample result, mine pit effluent is likely a contributing source of aluminum loading to the creek, but concentrations appear to be below the CS value based on limited information available.

Aluminum toxicity is **inconclusive** as a cause of biological impairment in Penobscot Creek. Frequent exceedance of the CS threshold provides evidence that aluminum toxicity may be one of the limiting factors, however, some samples were below the CS threshold, and it is unclear whether the magnitude and duration of exposure is significant enough to be problematic.

Arsenic

Five arsenic samples were collected from Penobscot Creek in 1979. Most of the results were below the detection limit of 0.05 µg/L. The maximum value recorded was 6.7 µg/L. This individual sample exceeds the CS (2 µg/L) but is well below the MS (360 µg/L) and FAV (720 µg/L) threshold. Based on these limited results, it is unlikely that arsenic toxicity is causing biological impairment in Penobscot Creek, but this stressor remains **inconclusive** based on the limited sampling results and lack of recent sampling activity.

Cadmium

Five cadmium samples were collected from Penobscot Creek in 1979. Results ranged from a minimum concentration of 0.04 µg/L to a maximum of 0.12 µg/L. All results were safely below the CS of 2.7 µg/L (calculated using average hardness values from Penobscot Creek). Based on these limited results, it is unlikely that cadmium toxicity is causing biological impairment in Penobscot Creek, but this stressor remains **inconclusive** based on the limited sampling results and lack of recent sampling activity.

Copper

Five copper samples were collected from Penobscot Creek in 1979. Results ranged from a minimum concentration of 1.9 µg/L to a maximum of 7.9 µg/L. All results were safely below the CS of 19 µg/L (calculated using average hardness values from Penobscot Creek). Based on these limited results, it is unlikely that copper toxicity is causing biological impairment in Penobscot Creek, but this stressor remains **inconclusive** based on the limited sampling results and lack of recent sampling activity.

Lead

Five lead samples were collected from Penobscot Creek in 1979. Results ranged from a minimum concentration of 1.4 µg/L to a maximum of 7.9 µg/L. All results were below the CS of 13 µg/L (calculated using average hardness values from Penobscot Creek). Based on these limited results, it is unlikely that lead toxicity is causing biological impairment in Penobscot Creek, but this stressor remains **inconclusive** based on the limited sampling results and lack of recent sampling activity.

Nickel

Five nickel samples were collected from Penobscot Creek in 1979. Results ranged from a minimum concentration of 1 µg/L to a maximum of 1.9 µg/L. All results were well below the CS of 297 µg/L (calculated using average hardness values from Penobscot Creek). Based on these limited results, it is unlikely that nickel toxicity is causing biological impairment in Penobscot Creek, but this stressor remains **inconclusive** based on the limited sampling results and lack of recent sampling activity.

Sulfate

Elevated sulfate concentrations in surface waters of the St. Louis River Watershed have been widely documented. A variety of anthropogenic activities on the landscape can result in elevated sulfate concentrations, including wastewater from mining or industrial processes, and runoff from urban and agricultural areas. The issue of sulfate toxicity is covered extensively in the Cycle 1 St. Louis River Watershed Stressor Identification Report.

Minnesota does not currently implement a water quality standard for sulfate based on protecting fish and aquatic macroinvertebrates communities. During the Cycle 1 SID study for the St. Louis River Watershed, potential impairments related to sulfate toxicity were evaluated using several standards from other US states (see Table 9 in the St. Louis River Watershed Stressor Identification Report). Many of these standards are based on calculations that incorporate chloride and hardness values into the final standard. Based on the standards presented in Table 2 and chloride/hardness values observed in Penobscot Creek, the applicable sulfate standard for this water body would fall between 124 mg/L and 1,871 mg/L

Sulfate concentrations were routinely monitored in Penobscot between the years of 2010 and 2023. Results range from a minimum of 21.4 mg/L to a maximum pf 87.3 mg/L (median =74 mg/L). While these results are elevated compared to natural background concentrations for this area, the values fall below the most protective standard listed in Table 2 (124 mg/L). Based om this information, sulfate toxicity can be **eliminated** as a cause of fish and macroinvertebrate impairments in Penobscot Creek.

Candidate Cause #6 – Elevated pH

High or low pH effects on biology include decreased growth and reproduction, decreased biodiversity, and damage to skin, gills, eyes, and organs. Values of pH outside the range of 6.5 to 9 or highly fluctuating values are stressful to aquatic life (EPA, 2012). Minnesota's pH standard for Class 2B (warmwater) streams (which includes Penobscot Creek) is 6.5 as a daily minimum and 9.0 as a daily maximum.

Penobscot Creek pH data exist in two formats, instantaneous (e.g. spot or "grab") samples collected with a calibrated field probe, and short-term continuous (e.g. 2 week) measurements collected at 30-miunte intervals. A total of 79 spot measurements of pH were collected in Penobscot Creek between the years 1979 and 2013. Roughly 97% (77 of 79) of the spot measurements meet the applicable water quality standard. The average pH value of 7.92 is elevated compared to natural background values for the region, likely due to mine pit water being pumped into this water body.

The maximum pH standard (9.00) was narrowly exceeded at two monitoring locations on June 23, 2011. A pH of 9.12 was recorded at location S006-545, which is located in the extreme headwaters of the creek immediately downstream of the location where it "daylights" or emerges from the city sewer line after being pumped from the mine tailings basins upstream. Roughly 3 miles downstream at station S000-593, a pH measurement of 9.03 was recorded, with only a 10-minute gap between sampling times. Station S000-593 is located just upstream of the impaired biological monitoring location. These data suggest pH values were decreasing from upstream to downstream, and the source of elevated pH may be linked to disturbances in the headwaters (pit pumping, urban runoff, wastewater).

Continuous pH measurements were collected at 30-minute intervals at two Penobscot Creek locations in the summer of 2022 and 2023. A total of 47 monitoring days of were recorded over this period, accumulating 7,174 distinct measurements of pH between the two locations. All of the pH values recorded during the continuous monitoring period met the water quality standard (min = 7.52; max = 8.54, avg. = 8.24).

Fish populations exposed to elevated pH levels show symptoms of decreased biodiversity and/or physical deterioration of skin, eyes, gills, and organs. No DELT (Deformities, Eroded fins, Lesions, or Tumors) were observed during either of the fish sampling visits to stations 09LS070 or 98LS013. Fish taxa richness and overall abundance were low at both stations, particularly 09LS070. Only four species and 16 total fish were collected at station 09LS070, while 8 species and 20 individuals were collected at 98LS013.

Despite symptoms of biological response to a pH stressor (low biodiversity/abundance), the water quality data overwhelmingly indicate compliance with the water quality standard and support **eliminating** pH toxicity as a cause of impairment. Low fish abundance and biodiversity can be linked to numerous confounding stressors, including several with strong supporting evidence in this watershed (poor habitat conditions, elevated TSS concentrations).

Candidate Cause #7 - Altered Hydrology

Magnitude, timing, and seasonal changes of stream discharge (flow) shape the characteristics of a river system. Flow variability over the course of a season sustains aquatic life and is a critical component of physical channel characteristics and the transport of sediment, nutrients, and potential water-borne contaminants. In a typical year, free-flowing rivers will be influenced by a wide range of flow conditions, from large floods to extreme low flows, with each flow rate playing a role in the overall function of the aquatic ecosystem. Flow conditions are closely connected to weather patterns, watershed land use and land cover, and in some cases, direct discharges of wastewater from treatment plants or industrial facilities that utilize process wastewater.

The natural flow regime of Penobscot Creek has been modified by several anthropogenic factors that will prove difficult to mitigate. First, the entireity of the creek's headwaters has been heavily altered by iron ore mining pits, spoil piles, and an associated network ditches and pumps. Headwaters streams play a critical role in determining the quality of quantity of downstream waters. Removal or alteration of headwaters streams is frequently linked to water quality impairments and degraded fish and macroinvertebrate communities.

The replacement of headwaters streams and wetlands with mine tailings basins disrupts natural watershed processes. Open-pit mines excavated below the water table require constant de-watering, which lowers surrounding regional water table and drains water away from surface-water systems in the area. If mine pits are de-watered into an adjacent stream, the discharge rates in that particular stream will be artificially increased. If the receiving water body is a small headwaters stream, effluent flows can be proportiately much higher than the water provided to the channel by surface water or natural groundwater flow.

Penobscot Creek is a small stream that receives a continuous effluent discharge from a series of ore mining tailings basins. Water is pumped from the Scranton Mine Pit and travels through a ditch and the Hibbing storm sewer system before entering Penobscot Creek. The estimaged discharge rate is around 3 cubic feet per second (cfs) based values reprted within a 1981 NPDES permit application. The volume of mine pit water discharged to the creek is not continuously measured by the permit holder, and no flow measurements have been collected to determine the ratio of natural streamflow inputs versus effluent inputs.

Increases in discharge due to mine pit dewatering are less visually evident during high flow periods (snowmelt and rain events) but still must be considered a potential impact on stream habitat, streambank stability, and the ability of aquatic life to carry out various stages of their life cycle. Artificially increasing streamflow in headwaters is often detrimental to stream channel condition and stability, as removes or degrades habitat features shaped by a wide range of flow conditions in healthy, functioning streams. MSHA habitat scores related to in-stream cover habitat (logs, vegetation, coarse substrates) were rated "fair" at both Penobscot Creek biological monitoring stations, a deficiency that could be related to the lack of flow ranges.

The direct impacts of artificially elevated baseflow on aquatic life are difficult to tease out from other confounding stressors. Fish and aquatic macroinvertebrates benefit from a stream conditions shaped by a wide-range of flow conditions found in streams with natural hydrological patterns shaped by wet and dry cycles. When these cycles are altered by a continuous discharge, certain physical habitat features such as sediment point bars and low velocity side channel habitats are likely to be less available to biota and may reduce the number of specialist species dependent on those habitat features.

Altered hydrology is **confirmed** as a contributing cause to biological impairment Penobscot Creek. The connections between altered hydrology and impaired biota in this watershed are indirect and manifest mostly through stream channel instability (channel incision, eroding streambanks) and the natural processes absent due to the lack of headwaters streams.

2.1.5 - Summary of Stressor Identification for Penobscot Creek (04010201-553)

The fish and macroinvertebrate community in Penobscot Creek is being stressed by **poor physical habitat**, **elevated TSS concentrations**, and **altered hydrology**. Inconclusive stressors include NO_3 toxicity, and aluminum toxicity.

Table 3: Summary of SID Results for Penobscot Creek

Penobscot Creek / Impaired AUID 04010201-553		
Candidate Cause	**Result**	**Summary**
Total Suspended Solids	•	Roughly 40% of TSS samples exceed WQ standard
Poor Physical Habitat	•	Excess fine substrate, lack of quality cover habitat, bank erosion
Low Dissolved Oxygen	**X**	Continuous and spot DO measurements all met standard
Nitrate Toxicity	○	Concentrations elevated but below draft standard
Altered Hydrology	•	Mine pit dewatering and ditching alter natural hydrology
Metals Toxicity	○	Most metals unlikely as cause / Aluminum toxicity inconclusive
Elevated pH	**X**	A few minor exceedances of standard, vast majority of time within healthy pH range
Key: • = Confirmed stressor ○ = Potential Stressor X = eliminated candidate cause		

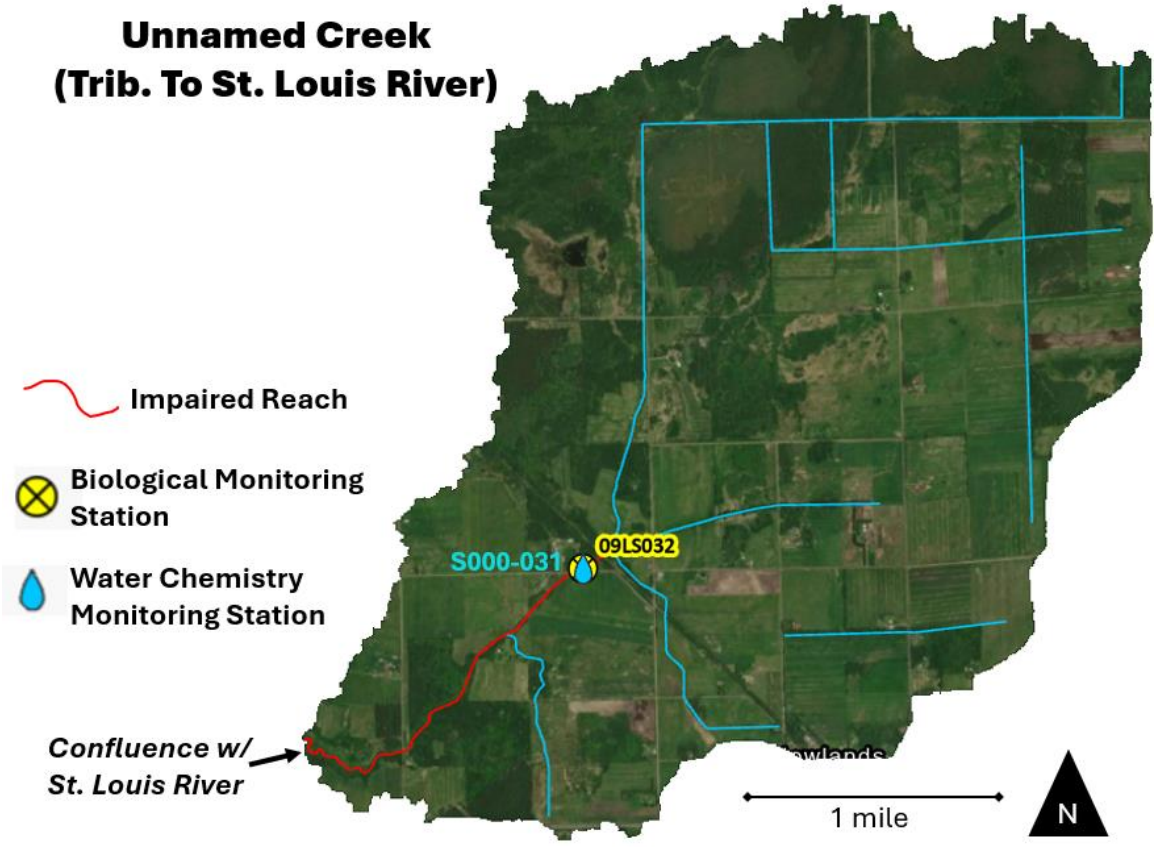
2.2 - Unnamed Creek (WID 04010201-A19)

2.2.1 - Biological Community Summary

Unnamed Creek (hereafter referred to as “Shaw Creek”) is a small warmwater stream, just outside of the community of Meadowlands, Minnesota. It drains a watershed of roughly seven square miles with a landscape that is a mix of agricultural land use (hay/pasture), wetlands, and forest. Shaw Creek (WID 04010201-A19) was first monitored in 2009 and added to the impaired waters list in 2021 for failing to meet the M-IBI standard for modified (ditched) warmwater streams.

This stream has one biological monitoring station, 09LS032, located in the upper portion of the watershed adjacent to Dart Rd (Figure 11). It has been sampled one time each for fish and aquatic macroinvertebrates, with both samples occurring in 2009. The fish results were deemed nonreportable due to insufficient capture. The M-IBI score is approximately 6 points below impairment threshold for streams classified as “modified” (e.g. ditched). The sampling crew observed excess sediment in runs and pools, which is affirmed by the taxa present; snails, a tolerant riffle beetle genus, and a midge taxon adapted to standing water with muddy substrates were found to be dominant. The assessment conclusion was nonsupport for aquatic life based on the macroinvertebrate results.

Figure 11: Map of Unnamed Creek (Shaw Creek) monitoring stations



2.2.2 - Candidate Causes for Impairment

A list of candidate causes for the impairment was developed based on watershed conditions and anticipated stressors. Candidate causes evaluated include Elevated TSS, Low DO and/or Eutrophication, Poor Physical Habitat, and Altered Hydrology. Water samples, continuous water quality monitoring, and habitat assessments were collected within the impaired reach to obtain relevant information for evaluating each candidate cause. The results and final decisions for each candidate cause are summarized below.

Candidate Cause #1 – Elevated TSS Concentrations

Limited data are available for this parameter, but all TSS samples and transparency tube samples met applicable water quality standards. Samples collected during high flow periods (snowmelt) and baseflow did not show problematic concentrations of TSS. Based on this information, elevated TSS can be eliminated as a cause of biological impairment.

Candidate Cause #2 – Low Dissolved Oxygen/Eutrophication

Low DO levels do not appear to be a primary stressor. This parameter was measured using several methods. A continuous water quality meter was deployed for several weeks during July and August of 2020. Streamflow conditions at the time were characterized as “moderate flow” (Figure 12). DO concentrations remained above the 5 mg/L warmwater DO standard for most of the deployment period. For several hours, DO concentrations did fall below 5 mg/L but recovered to suitable levels shortly after. Point measurements of DO were also collected several times during baseflow conditions and values were suitable for warmwater biota. DO concentrations may be limiting as discharge decreases to zero flow or intermittent conditions. In this case, altered hydrology and limited streamflow is the driving factor and low DO is simply a symptom of an altered hydrology stressor. Low DO can be eliminated as a direct cause of impairment.

Candidate Cause #3 – Poor Physical Habitat Conditions

Physical habitat conditions within the impaired reach of Shaw Creek are degraded and display a clear negative impact on the macroinvertebrate community. The overall MSHA score of 50.05 (out of a possible 100) is indicative of poor habitat conditions, and extremely low metric scores were given in categories related to substrate quality and stream channel condition. The stream channel containing the biological monitoring station is ditched and disconnected from its floodplain (e.g. incised). As a result, there is a lack of natural channel features (riffles, runs, pools). Only two substrate types were present within the biological monitoring reach, sand and silt. Healthy macroinvertebrate assemblages rely on a diversity of substrate types, particularly coarse materials like gravel and cobble.

The quality and diversity of habitat types are extremely limited, and macroinvertebrate community metrics indicate the biota present are highly tolerant of poor substrate conditions and lack of diverse habitat types. Poor habitat conditions are **confirmed** as a cause of macroinvertebrate impairment in Shaw Creek.

Candidate Cause #4 – Altered Hydrology

Altered hydrology, specifically lack of stream flow, is the most obvious direct cause of the macroinvertebrate IBI impairment and is **confirmed** as a stressor in Shaw Creek. This stressor also plays a significant role in the poor habitat conditions and channel stability issues observed within the impaired reach. The Shaw Creek Watershed is heavily ditched upstream of the biological monitoring site, and many acres of bogs and wetlands in its headwaters have been ditched to increase drainage efficiency. This extensive network of ditches has altered the natural hydrology of this watershed, leading to "flashy" hydrological conditions during which snowmelt and rainfall pass through the system of ditches at an artificially rapid rate and do not infiltrate and replenish and sustain baseflow conditions.

The stream channel was almost entirely dry at the biological monitoring location during a visit in the summer of 2023 (see photo in Figure 13). According to the Minnesota Department of Natural Resources (DNR), after a very wet winter and spring in early 2023, Minnesota "quickly slid into an extraordinary dry spell" from mid-May through August, with many sites receiving less than half their normal precipitation.

2.2.3 - Summary of stream health and recommendations in Unnamed Ck. (Shaw Ck.)

The macroinvertebrate community in Shaw Creek is being stressed by a combination of poor **physical habitat** and **altered hydrology**. The extensive network of ditches in the headwaters of this watershed limits hydrologic storage capacity resulting in "flashy" streamflow and long periods of intermittent flow at the biological sampling location. The channelized condition of the biological sampling reach contributes to the poor habitat conditions observed within the channel. Exposed, steep, sloughing streambanks were observed throughout the sampling reach, increasing sedimentation and reducing substrate quality. The entire reach is composed of fine substrates (sand, silt), which limits habitat diversity and presents severe limitations for the macroinvertebrate community.

Table 4: Summary of SID Results for Unnamed Trib. to St. Louis River (Shaw Ck)

Unnamed Creek (Shaw Creek) / Impaired AUID 04010201-A19		
Candidate Cause	Result	**Summary**
Total Susp. Solids (TSS)	**X**	All samples met TSS and transparency standard
Poor Physical Habitat	•	Excess fine substrate, lack of pools, eroding stream banks
Low Dissolved Oxygen	**X**	Continuous and spot DO measurements met warmwater standard
Altered Hydrology	•	Impaired reach intermittent/dry in 2023. Significant ditching
Key: • **= confirmed stressor** ○ **= Potential Stressor X = eliminated candidate cause**		

Figure 12: Shaw Creek during a period of moderate flow. Water quality parameters (DO and TSS) were found to be suitable under normal and elevated flow conditions

Figure 13: Dry stream channel in Shaw Creek (July 2023)

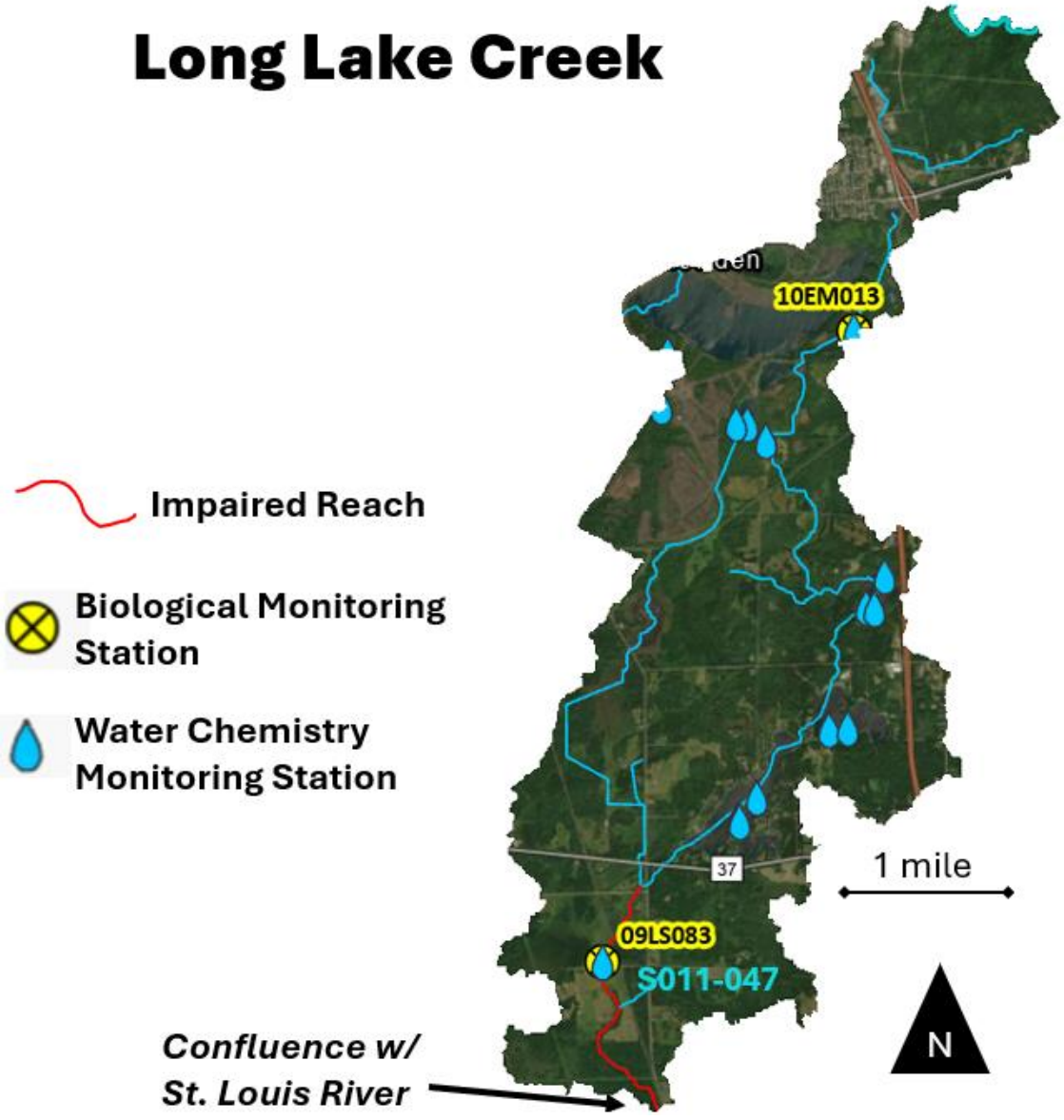
2.3 – Long Lake Creek (WID 04010201-A25)

2.3.1 - Biological Community Summary

Long Lake Creek (04010201-A25) is located near Kearny, Minnesota and drains a watershed area of just under 12 square miles. The impaired reach of this stream has one biological monitoring station, 09LS083, which was sampled for both fish and macroinvertebrates in 2009 (

Figure 14). The fish community was not determined to be impaired, as several sensitive wetland taxa (Iowa Darter, Northern Redbelly Dace, Blacknose Shiner) were present in the sample. However, the macroinvertebrate community scored 23 points below the GU threshold and failed to meet the warmwater M-IBI threshold. The macroinvertebrate community was hyper dominated by a tolerant mayfly taxon and snails. The poor M-IBI score resulting in an impairment listing going into effect in 2019.

Figure 14: Map of impaired reach of Long Lake Creek monitoring stations



2.3.2 - What stressors are of concern in Long Lake Creek?

A list of candidate causes for the impairment was developed based on watershed conditions and anticipated stressors. Water samples, continuous water quality monitoring, and habitat assessments were collected within the impaired reach to obtain relevant information for evaluating each candidate cause. Candidate causes evaluated include Elevated TSS, Low DO and/or Eutrophication, Poor Physical Habitat, and Elevated Specific Conductivity. A short discussion of applicable data and final decisions for each candidate cause are summarized below. Additional data can be provided upon request.

Candidate Cause #1 – Elevated Total Suspended Solids

TSS samples and transparency tube measurements were collected on five occasions during a range of flow conditions. All samples met the 15 mg/L TSS water quality standards for supporting warmwater aquatic life. Based on these results, elevated TSS was **eliminated** as a candidate cause of the macroinvertebrate impairment.

Candidate Cause #2 – Poor Physical Habitat

Stream habitat conditions within the impaired reach are mixed and appear to be improving since the original 2009 sampling event. The overall MSHA score of 56 (out of 100) indicate fair habitat conditions. Several habitat parameters, such as surrounding land use, riparian habitat quality, and in-stream cover received higher than average scores during the 2009 visit and are not likely to be contributing to the impaired condition. Conditions for these variables were also favorable during SID follow-up monitoring in 2022 and 2023.

Conversely, habitat metrics related to in-stream substrate quality scored poorly in 2009, and likely factor heavily into in the impaired macroinvertebrate assemblage. The biologists completing the survey reported a reach dominated by sand and silt at the time of sampling. Substrate conditions were more favorable during follow-up visits to the station in 2022 and 2023, as some areas of gravel were apparent in faster moving areas (riffles, runs. However, most areas were still heavily impacted by siltation and much of the coarse substrate was still heavily embedded by sand and silt.

The macroinvertebrate community within the impaired reach reflects the poor benthic habitat conditions caused by siltation and coarse substrates heavily embedded with fine material (silt/sand). Nearly half of the macroinvertebrate taxa sampled at this location are classified as *tolerant* or *very tolerant* (45% and 43%, respectively) to high levels of embeddedness.

Based on the poor MSHA scores for substrate quality and the abundance of macroinvertebrate taxa tolerant of embedded substrate found at this monitoring station, poor physical habitat can be **confirmed** as a cause of macroinvertebrate impairment.

Figure 15: MSHA results for station 09LS083 on the impaired reach of Long Lake Creek. Metric scores ranked poorly for stream substrate quality and channel morphology

Figure 16: Photographs of stream substrate at station 09LS083 on the impaired reach of Long Lake Creek. Note heavy siltation (left) and embedded gravel substrates (right)

Candidate Cause #3 – Low Dissolved Oxygen/Eutrophication

DO was measured through deployment of continuous monitoring equipment in 2022 and 2023. Each deployment covered several weeks during summer low flow periods. DO concentrations at the impaired biological sampling station ranged from 6-9 mg/L and did not show any signs of excess eutrophication. These DO concentrations are adequate for supporting warmwater aquatic biota and are not indicative of eutrophication. Samples were analyzed for TP concentrations during continuous monitoring deployments, and all values met the water quality standard. Additional TP samples were collected (n=4) and results ranged from 0.024 – 0.044 mg/L, all below the water quality target of 0.055 mg/L for this type of stream.

Based on continuous and spot DO measurements, low DO concentrations and eutrophication are **eliminated** as a candidate cause of the macroinvertebrate impairment.

Candidate Cause #4 – Elevated Specific Conductivity/Ionic Strength

Specific conductivity values in Long Lake Creek are elevated above natural background levels. Measurements collected during summer low flow conditions ranged from 437 to 624 µs/cm. Background levels for Northeast Minnesota rarely exceed 300 µs/cm. Higher concentrations of sulfate and chloride were present in the samples and are likely contributing factors to the elevated specific conductivity readings. However, concentrations of chloride and sulfate were well below problematic levels.

Diagnosing elevated specific conductivity as a confirmed stressor is difficult due the possibility of confounding factors that can trigger a similar biological response, but it cannot be ruled out. Elevated specific conductivity is considered **inconclusive** as a stressor in this watershed.

2.3.3 - Summary of Stressor Identification for Long Lake Creek (WID 04010201-A25)

The macroinvertebrate community in Long Lake Creek is being stressed by poor **physical habitat** resulting from excess fine substrate and embeddedness. Coarse substrates are present within the impaired sampling reach but are heavily embedded with sand and silt. Streambanks are stable and riparian habitat conditions appear to be improving based on a comparison of 2009 photos with present day imagery. This stream is a good candidate for additional monitoring to determine macroinvertebrate IBI scores are showing improvement since the 2009 sampling event.

Table 5: Summary of SID Results for Long Lake Creek

Long Lake Creek / Impaired AUID 04010201-A25		
Candidate Cause	Result	**Summary**
Total Suspended Solids	**X**	All samples met TSS and transparency standard
Poor Physical Habitat	•	Excess fine substrate. Conditions improving? Consider re-sample
Low Dissolved Oxygen	**X**	Continuous and spot DO measurements met warmwater standard
Sp. Cond./Ionic Strength	○	Impaired reach intermittent/dry in 2023. Significant ditching
Key: • = **confirmed stressor** ○ = **Potential Stressor X = eliminated candidate cause**		