Understanding Nonpoint Source Pollution and Public Perceptions: A Study of the Black Lake Watershed

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Spring 2024

Land Acknowledgement

Before the arrival of settler Europeans, the northern portion of Michigan's Lower Peninsula was and continues to be the home of the Three Fires Confederacy of Ojibwe, Odawa, and Potawatomi peoples. This community of Indigenous people lived on their ancestral lands for hundreds of years, maintaining villages along the Lake Michigan and Huron shorelines, along the Inland Waterway, and around the Black Lake Watershed. The Anishinaabe people have and continue to protect, restore, and respect the land, water, creatures, and people of this beautiful region.

As students of the University of Michigan School for Environment and Sustainability, we recognize the first and most steadfast stewards of this area. During our time in the Black Lake Watershed, we engaged with community members, some of whom are Indigenous people, in official and unofficial capacities to gather an understanding of the community we are serving. We are honored to contribute to the further protection of the Black Lake Watershed and are committed to engaging in the thoughtful care and consideration of all people, lands, waters, and beings for the next seven generations. We collectively understand that this acknowledgment does not absolve settler-colonial privilege or diminish colonial structures of violence at any level.

Tip of the Mitt Watershed Council Land Acknowledgement:
We would like to recognize that our service area lies within the traditional homelands of the Anishinaabek. We will continue to work alongside them to honor and protect this area for the next seven generations.

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List of Acronyms

BLA - Black Lake Association
BLPS - Black Lake Preservation Society
BMP - Best Management Practices
CFP - Commercial Forest Program
EGLE - Michigan Department of Environment, Great Lakes and Energy
EPA - Environmental Protection Agency
ERCOL - Elk River Chain of Lakes
FAMD - Factor Analysis of Mixed Data
HAB - Harmful Algal Bloom
MDARD - Michigan Department of Agriculture and Rural Development
MDNR - Michigan Department of Natural Resources
QFP - Qualified Forest Program
RSX - Road/Stream Crossing
SEAS - School for Environment and Sustainability
SIDMA - Social Indicator Data Management Analysis
TOMWC - Tip of the Mitt Watershed Council

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Executive Summary

As graduate students at the University of Michigan School for Environment and Sustainability and consultants to the Tip of the Mitt Watershed Council, we studied nonpoint source pollution causing degraded water quality and harmful algal blooms in Northern Michigan's Black Lake Watershed. To determine the location and impact of this nonpoint source pollution, we conducted four geographic inventories: analyzing streambank erosion, road/stream crossings, agricultural activity, and forestry operations, all of which are the most frequent contributors to nonpoint source pollution. A priority parcel analysis and critical areas analysis complemented the four geographic inventories and identified priority areas for conservation within the watershed. In addition, we created and implemented a social indicator survey for Black Lake Watershed residents to understand current practices, behaviors, beliefs, and attitudes toward water protection strategies. The combination of quantitative and qualitative information informed our recommendations for Tip of the Mitt Watershed Council and the Black Lake Watershed community.

Key findings include:

Social Indicator Survey: A gap exists in the watershed resident's awareness of the consequences of poor water quality, the types of pollutants impairing waterways, and the sources of pollutants impairing waterways.

Streambank Erosion: Two sites ranked severe, with many Upper Black River areas having high greenbelt potential.

Road/Stream Crossings: 57.1% of assessed sites ranked as moderate to major severity for crossing condition and pollution potential, aligning closely with the 61.2% across the watershed.

Agriculture Activity: 26% of agriculture sites pose a high priority for nonpoint source pollution, mainly along the Rainy River.

Forestry Operations: 12.76% of all forest land is protected under Qualified Forest Programs, Commercial Forest Programs, and State Parks, while the Watershed itself is composed of 47% forest land.

Priority Parcel Analysis: 66% of the total watershed acreage is protected lands and there are only 8 parcels deemed high priority for protection.

Critical Areas Analysis: Combining results from Road/Stream Crossings, Agriculture, and Streambank inventories identified 11 critical areas, primarily within a 10 km radius southwest of Black Lake.

These findings led to the following key recommendations:

- Launch education campaigns to inform residents about the consequences of poor water quality, the types of pollutants impairing waterways, and the sources of pollutants impairing waterways to ameliorate the current awareness gaps in the Black Lake Watershed.
- Encourage greenbelt development on properties along the Upper Black River between Tower Pond and Kleber Dam to help prevent further streambank erosion and pollutant loading.
- Resurvey road/stream crossings (especially moderate to major sites) to properly allocate resources for reducing runoff potential and removing possible aquatic barriers and invasive species to improve overall ecosystem productivity.
- Perform ground truthing surveys of agricultural activity sites and logging sites to gain a better understanding of the site condition and potential pollutant loading.

The data gathered from the four geographic inventories, priority parcel analysis, critical areas analysis, and the social indicator survey will be incorporated into the Tip of the Mitt Watershed Council's Black Lake Watershed Management Plan. While awaiting the completion of the watershed management plan, the Black Lake Watershed community can utilize these recommendations to guide their community-based and organization-based efforts to improve watershed health. Beyond the Black Lake Watershed, this research and our recommendations are designed for communities facing nonpoint source pollution and degrading water quality, especially for communities without consistent access to researchers or funding.

Chapter 1: Problem Definition and Background

Cultural Background

The Black Lake Watershed holds a deep historical and cultural significance as the ancestral and contemporary homelands of the Three Fires Confederacy of the Ojibwe, Odawa, and Potawatomi peoples. Long before the arrival of European settlers, the Anishinaabe people cared for this land through farming, fishing, and forest management.[1] Beyond subsistence practices, the tribes living in the region practiced rich community gatherings that involved sharing cooking traditions, music, dances, art, and songs that are still practiced today. As settlers took over the lands of these Indigenous communities, the Anishinaabe people, their traditions, and culture were threatened. Their resilience allowed them to adapt and survive amidst countless threats brought on by the colonization of the United States. To reclaim their treaty rights, many tribes sought federal recognition from the federal government. Within the Black Lake Watershed, there are no federally recognized tribes, but the watershed boundaries are directly adjacent to the reservation lands of Little Traverse Bands of Odawa Indians.

Situated in the northern lower peninsula of Michigan, the Black Lake Watershed spans 350,000 acres (547 square miles) in Cheboygan, Montmorency, Otsego, and Presque Isle counties. Renowned for its recreational opportunities including swimming, boating, and fishing, the watershed nurtures a self-sustaining sturgeon population amidst its diverse ecosystems.[2] These qualities attract many tourists, seasonal, and year-long residents who participate in the strong community around Black Lake.[3] While the population of a watershed is difficult to measure, the estimated population is made up of roughly 21,416 people of predominantly White descent (95.2%) with American Indian/Alaskan Native having the second highest representation (1.6%). The median income last recorded in 2021 was $52,226.[4] This income is lower than the state average of $63,202 as well as the country's average of $70,784.[5,6]

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[1] "History - Ocqueoc Township." Ocqueoc Township, 13 Jan. 2023, ocqueoctwpmi.gov/history/. Accessed 2 Apr. 2024.

[2] "Black Lake." *Tip of the Mitt Watershed Council*, www.watershedcouncil.org/black-lake.html. Accessed 16 Mar. 2023.

[3] Huron Pines Resource Conservation and Development Council. *Black Lake Watershed Stewardship Initiative Nonpoint Source Pollution Management Plan*. June 2002.

[4] U.S. Census Bureau Quickfacts: Otsego County, Montmorency County, Presque Isle County, and Cheboygan County, Michigan. (n.d.). https://www.census.gov/quickfacts/fact/table/otsegocountymichigan,montmorencycountymichigan,presqueislecountymichigan,cheboygancountymichigan/PST045222 (Calculated using proportions of county within the Black Lake Watershed)

[5] U.S. Census Bureau Quickfacts: Michigan. (n.d.-a). https://www.census.gov/quickfacts/fact/table/MI/INC110221

[6] Kollar, J. S. and M. (2022, September 13). Income in the United States: 2021. Census.gov. https://www.census.gov/library/publications/2022/demo/p60-276.html

The community surrounding the Black Lake Watershed has made major commitments to safeguarding its waters for recreational enjoyment and ecological preservation. Some residents consider the watershed to be "part of their soul" and prioritize protecting their water and advocate for the significance of this resource to their cultural, ecological, recreational, and economic way of life.[7] Organizations such as the Tip of the Mitt Watershed Council (TOMWC), the Black Lake Association, the Black Lake Preservation Society, Sturgeon for Tomorrow, and Huron Pines work tirelessly to protect this community's watershed.

TOMWC's mission is to advocate for northern Michigan's waters by protecting the lakes, streams, wetlands, and groundwater in their area of service through advocacy, education, water quality monitoring, research, and restoration actions. They do this by working locally, regionally, and throughout the Great Lakes Basin to empower others to make positive changes. They have led multiple watershed advisory committees including the Black Lake Watershed Advisory Committee since 2021.[8,9] Through watershed advisory committees, TOMWC develops cooperative relationships and collaborates with surrounding communities to advance water quality and northern Michigan's local economy.[10]

The Black Lake Association, founded in 1928, and the Black Lake Preservation Society, founded in 2018, work to engage year-round and seasonal residents in community-building and conservation efforts. These two organizations serve as the key communicators amongst lake residents, and help monitor the watershed's quality and health. The Black Lake Association provides basic ground rules for all members and the community at large, which include prohibiting the use of harmful pesticides and herbicides, encouraging routine septic system evaluations, and limiting the amount of lawn grooming along the beachfront. The described actions and mission provided on the website are consistent with the standard functions of lake associations in the state of Michigan. Several Black Lake residents created an additional lake association in 2014, the Black Lake Preservation Society, with the desire to increase environmental advocacy taking place in the watershed. The Preservation Society's "sole mission…is to protect and preserve the ecology of Black Lake, its tributaries and watershed through advocacy and program development; and to operate in a transparent, professional and neighborly manner."[11] Both the Black Lake Association and the Black Lake Preservation Society participate in the Black Lake Watershed Advisory Committee. The Advisory Committee brings interested participants within the watershed together to distribute information and updates about the watershed throughout the year. The committee will also be providing valuable input and feedback throughout the development of the Black Lake Watershed Management Plan and will

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[7] Quote shared by an individual at the Black Lake Watershed Advisory Committee Meeting on August 14th, 2023

[8] "Advisory Committees." *Tip of the Mitt Watershed Council*, www.watershedcouncil.org/watershed-advisorycommittees.html. Accessed 16 Mar. 2023.

[9] "Youth Education." *Tip of the Mitt Watershed Council*, www.watershedcouncil.org/youth-education.html. Accessed 16 Mar. 2023.

[10] Tip of the Mitt Watershed Council. *Black Lake Watershed Management Planning.* 2022.

[11] Black Lake Preservation Society. BLACK LAKE PRESERVATION SOCIETY. (n.d.). Retrieved February 1, 2023, from https://www.blacklakepreservationsociety.org/

serve as a vehicle to assist with implementation. Beyond the two operating lake associations and the Advisory Committee in the Black Lake Watershed, this community has benefitted from collaboration with other organizations including Huron Pines and Sturgeon for Tomorrow.[12]

Environmental Background

Michigan has a unique responsibility to address water quality issues because it is surrounded by the Great Lakes, which contain 20% of the world's surface freshwater, and contains 11,000 inland lakes.[13] Michigan's inland lakes not only provide significant economic revenue through recreation and tourism, but they also supply clean drinking water and ecological resources.[14] Understanding how and why water quality issues arise and affect these inland lakes is key to maintaining the many benefits these waters provide.

In Michigan and across the country, water quality issues are becoming more prevalent, including in bodies of water that are not normally susceptible to these issues, such as those with cooler water temperatures and more undisturbed watersheds.[15] In particular, harmful algal blooms (HABs) have been occurring more frequently in areas with a previous history of high water quality. Anthropogenic activities such as urban development and agriculture can lead to an overabundance of nutrients through runoff and erosion that encourage algae growth in lakes and surrounding tributaries. Temperature plays an important role in algal growth as warmer water temperatures encourage bloom formation. Climate change, which has increased global temperatures both on land and water, plays a significant role in the timing and frequency in which HABs form. As the Earth continues to warm due to climate change, seasons will lengthen and the time frame that HABs can form will increase. Beyond temperature, climate change is predicted to increase precipitation as well as facilitate greater run-off and erosion events.[16]

The ninth largest lake in Michigan, Black Lake, has been impacted by anthropogenic activities despite being categorized as a pristine northern lake due to its location and characteristics, including high water quality and healthy ecosystems. Soon after annual HABs emerged in the lake, they tested positive for microcystin, a toxic chemical that is produced by blue-green algae. The lake is oligotrophic, meaning it is relatively low in plant nutrients but contains high amounts of oxygen in the deeper parts of the lake.[17] This lake characteristic makes HABs surprising

[12] "Black Lake Watershed." *Tip of the Mitt Watershed Council*, www.watershedcouncil.org/black-lakewatershed.html. Accessed 16 Mar. 2023.
[13] "Learn about Inland Lakes and Streams." *Www.michigan.gov*, www.michigan.gov/egle/public/learn/inland-lakes-and-streams. Accessed 2 Apr. 2023.
[14] Fuller, Erin, et al. *Protecting Michigan's Inland Lakes: A Guide for Local Governments*.
[15] Brooks, B. W., Lazorchak, J. M., Howard, M. D. A., Johnson, M.-V. V., Morton, S. L., Perkins, D. A. K., Reavie, E. D., Scott, G. I., Smith, S. A., & Steevens, J. A. (2016). Are harmful algal blooms becoming the greatest inland water quality threat to public health and aquatic ecosystems? *Environmental Toxicology and Chemistry*, *35*(1), 6–13. https://doi.org/10.1002/etc.3220
[16] United States Environmental Protection Agency. (2023, July 26). Climate Change Indicators: Weather and Climate | US EPA. US EPA. https://www.epa.gov/climate-indicators/weather-climate
[17] Tip of the Mitt Watershed Council. *Black Lake Watershed Management Planning.* 2022.

because oligotrophic lakes do not foster the typical conditions for HABs to occur. The lake itself measures a maximum depth of 50 feet with an elevation of 610 feet.[18]

Black Lake resides in the Black Lake Watershed which comprises roughly 37.7% of the Cheboygan River Watershed (1,461 square miles).[19] In total, 19 subwatersheds make up the Black Lake Watershed (Figure 1.2).Black Lake's headwaters are in the Upper Black River in Montmorency and Otsego County. Other tributaries include Fisher, Stewart, and Stoney Creek on the south end as well as the Rainy River and Cold Creek, which share a mouth on Black Lake. Cains Creek comes in on the north side of the lake and Mud Creek flows in on the west. The lake's outlet is the Lower Black River, which flows towards the Cheboygan River and then into Lake Huron. The upper reaches of the Upper Black River and its tributaries have excellent brook trout fisheries. Lake sturgeon rearing facilities exist in five counties throughout the state, including the Black River facility, to encourage an increase in sturgeon populations within the area. The Black River Sturgeon facility, in collaboration with Michigan State University and the Michigan Department of Natural Resources, works to understand the preferred ecology and impediments to population growth of lake sturgeon.[20]

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[18] U.S. Geological Survey Geographic Names Information System: Black Lake (Michigan). Retrieved April 10, 2023, from https://edits.nationalmap.gov/apps/gaz-domestic/public/summary/621515

[19] Tip of the Mitt Watershed Council. *Black Lake Watershed*. 2022.

[20] "Lake Sturgeon Management," Michigan Department of Natural Resources, 2016, https://www.michigan.gov/dnr/managing-resources/fisheries/sturgeon

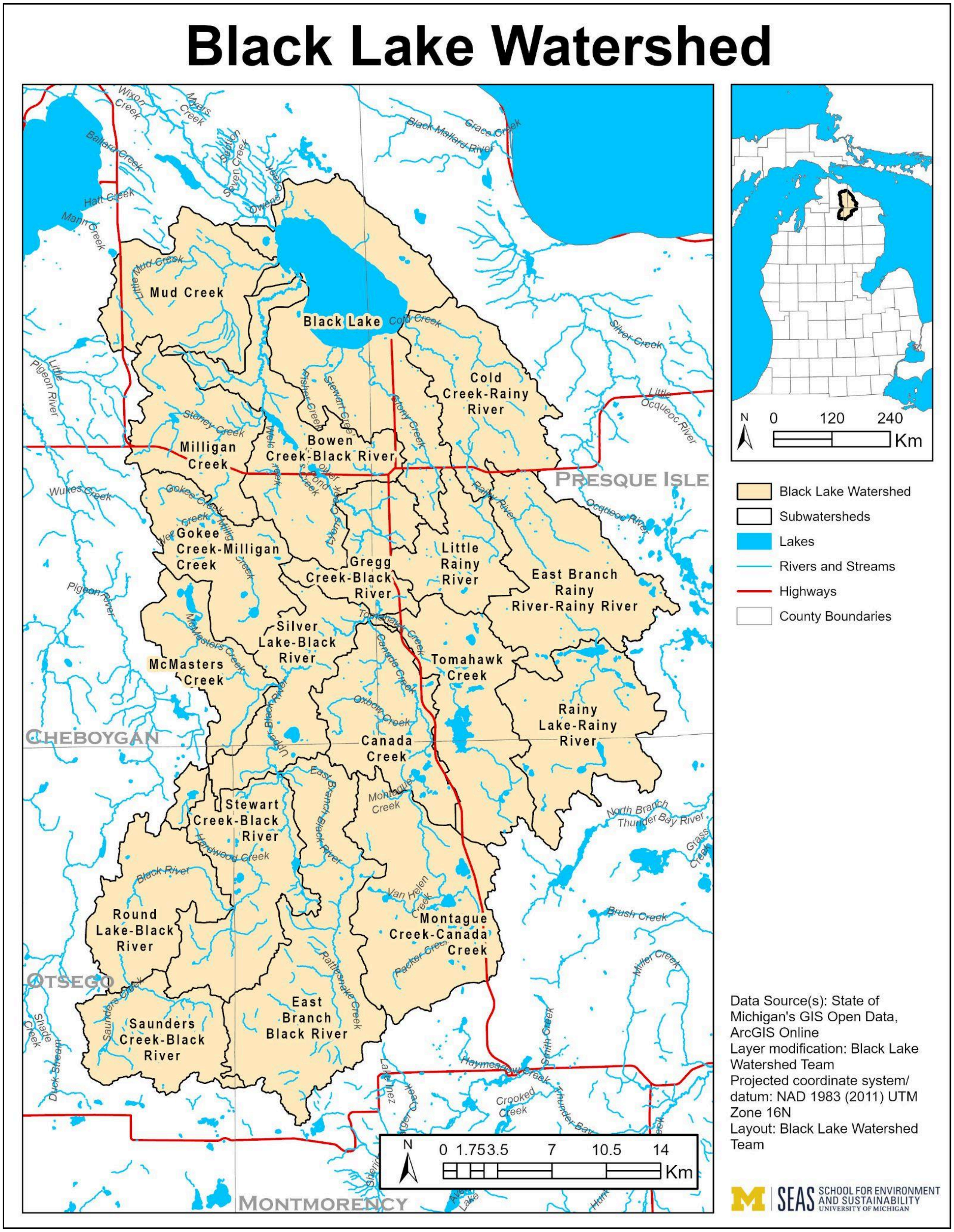

Figure 1.1. Map of Black Lake Watershed

Much of the Black Lake watershed is forested land (47%) and wetlands (31%) (Figure 1.2 and Table 1.1). Despite the significant amount of forestry and wetland land cover in the watershed, approximately 88% of Black Lake's shoreline is developed.

Typical contributors to nonpoint source pollution—agriculture and urban areas—accounted for about 10.05% of the watershed's area in 2021. With very few significant changes in land cover classes from 2001 through 2021 (Table 1.1), the water quality issues in the Black Lake Watershed appeared to occur from other causes. The only notable land cover change occurred within the shrub class, yet there is no reason to believe such a transition would lead to water quality issues. Beyond this limited land cover change, the Black Lake Watershed and this region of northern Michigan remains a relatively pristine ecosystem, including the Pigeon River Country State Forest, which is the largest block of contiguous, undeveloped wildlands in the lower peninsula of Michigan.[21] Due to the natural characteristics of this watershed, the emergence of HABs is alarming and highly motivating for TOMWC and the broader community to address.

[21]"Pigeon River Country State Forest." Michigan.gov, 2024, www.michigan.gov/dnr/places/state-forests/prc. Accessed 2 Apr. 2024.

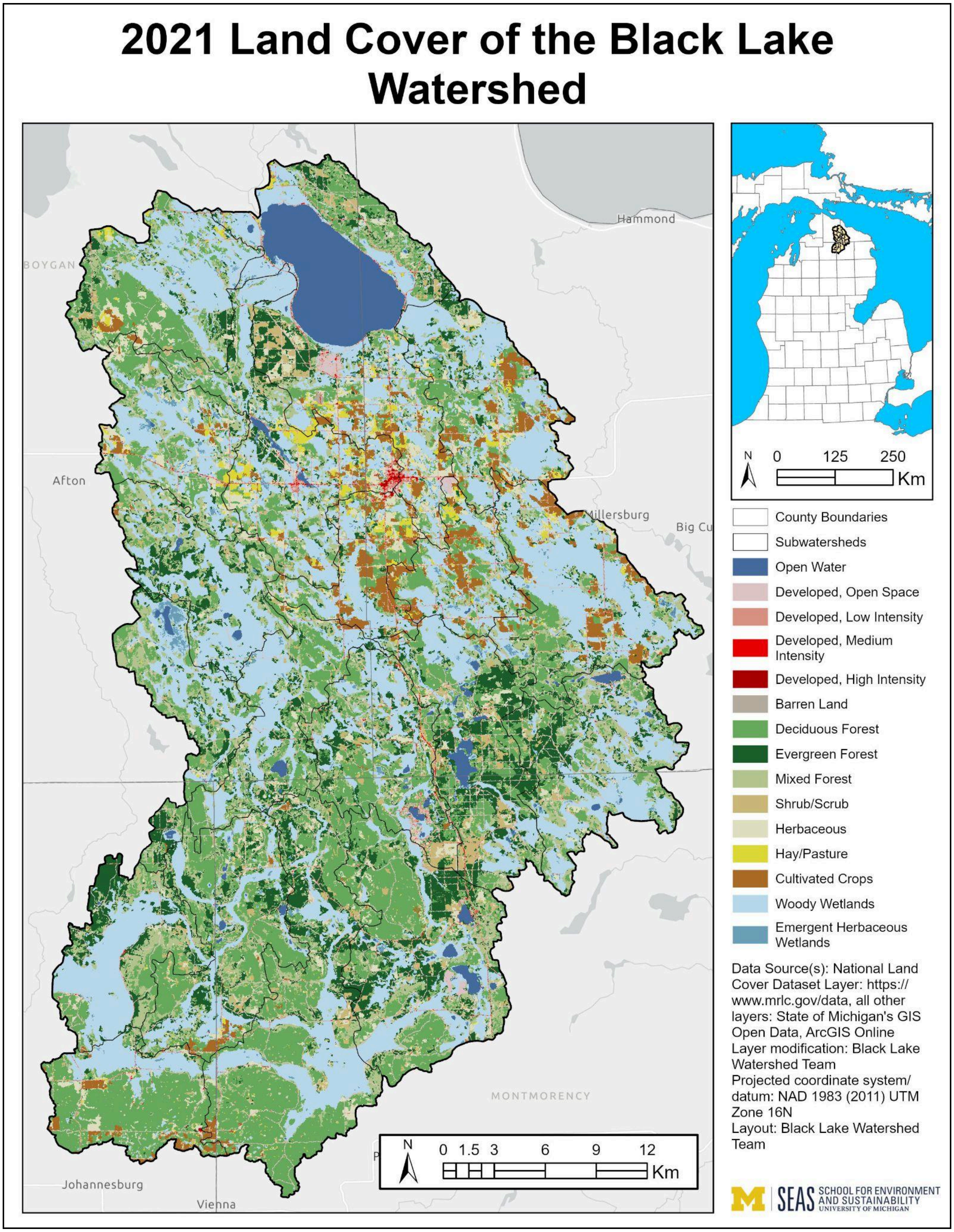

Figure 1.2. Black Lake Watershed Land Cover in 2021

Table 1.1. Percentage of Land Cover Classes in the Black Lake Watershed from 2001-2021

Land Cover Class	**2001**	**2004**	**2006**	**2008**	**2011**	**2013**	**2016**	**2019**	**2021**	**Percent Change 2001 - 2021**
Open Water	3.88	3.94	3.86	3.87	3.93	3.97	3.87	3.76	3.74	-0.04
Developed, Open Space	3.84	3.84	3.83	3.83	3.83	3.82	3.83	3.80	3.80	-0.01
Developed, Low Intensity	1.22	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	0.01
Developed, Medium Intensity	0.16	0.16	0.16	0.17	0.17	0.18	0.18	0.21	0.21	0.36
Developed, High Intensity	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.57
Barren Land	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.06	0.06	0.13
Deciduous Forest	23.63	23.58	23.25	23.38	23.29	23.35	23.13	23.73	23.77	0.01
Evergreen Forest	11.51	11.46	11.30	10.83	10.36	10.18	10.09	10.37	10.69	-0.07
Mixed Forest	12.65	12.68	12.79	12.84	12.78	12.76	12.82	12.82	12.76	0.01
Shrub/Scrub	2.08	2.37	2.63	2.68	2.39	2.82	3.60	3.01	2.65	0.27
Herbaceous	6.13	5.87	5.76	5.89	6.75	6.39	5.75	5.45	5.53	-0.10
Hay/Pasture	1.44	1.43	1.44	1.49	1.48	1.49	1.43	1.43	1.41	-0.02
Cultivated Crops	2.77	2.81	3.05	3.10	3.15	3.21	3.36	3.36	3.36	0.21
Woody Wetlands	29.68	29.55	29.48	29.74	29.74	29.75	29.84	29.83	29.75	0.00
Emergent Herbaceous Wetlands	0.93	1.00	1.15	0.89	0.82	0.78	0.78	0.90	1.00	0.07

Water Quality Standards

Water quality standards are the foundation of the water quality-based pollution control program mandated by the Clean Water Act.[22] The Environmental Protection Agency's Handbook for Developing Watershed Plans to Restore and Protect Our Waters describes water quality standards as the goals, pollution limits, and protection requirements for each waterbody**.** Meeting these limits helps to ensure that waters will remain useful to humans and aquatic life. Standards also

[22] Goodwin, K. (2024). Michigan Water Quality Standards. Michigan.gov. https://www.michigan.gov/egle/about/organization/water-resources/glwarm/water-quality-standards#:~:text=Designated%20uses%20include%3A%20agriculture%2C%20navigation

drive water quality restoration activities by aiding in determining which waterbodies must be addressed, what level of restoration is required, and which activities need to be modified to ensure that the water body meets its minimum standards.

The TOMWC's Comprehensive Water Quality Monitoring (CWQM) Program measures levels of specific conductivity, pH, dissolved oxygen, nitrate-nitrogen, total nitrogen, total phosphorus, and chloride every three years since 1995 during the springtime in Black Lake and the Upper Black River.[23] The Watershed Council's Volunteer Lake Monitoring (VLM) Program also monitors water transparency, chlorophyll-a, and water temperatures each summer in Black Lake from June through August. Additional water chemistry monitoring was conducted by both TOMWC and the Black Lake Preservation Society in 2018 in six previously unmonitored tributaries. In 2017, TOMWC conducted a Black Lake Shoreline survey to help identify the activities along the lake that could potentially pose a risk to the water quality of the watershed. Through this survey, TOMWC found that the loss of native vegetation, human-made infrastructure, and human-made waste all pose the greatest threats to Black Lake's water quality.

Water Quality Parameter Descriptions[24]

This section contains descriptions of the various water quality parameters that have been collected in the Black Lake Watershed and associated EGLE requirements for each parameter.

Total Dissolved Solids (TDS)

Due to a lack of conductivity standards within the state, measuring total dissolved solids is utilized. EGLE Part 4 Water Quality Standards (WQS) Rule 51 provides a framework for regulating total dissolved solids (TDS) concentrations with a TDS maximum of 750 mg/L.

pH and Dissolved Oxygen

EGLE Part 4 WQS states that pH should be within 6.5 and 9 in all surface waters of Michigan and a minimum of 5 mg/L of dissolved oxygen is needed for warm water lakes while 7 mg/L is needed for cold water lakes.

Temperature

EGLE Part 4 WQS set monthly maximum temperatures for streams supporting cold-water fish at 65° Fahrenheit for May, 68° Fahrenheit for both July and August, and 56° Fahrenheit for October. It also set monthly maximum temperatures for streams supporting warm-water fish at 70° Fahrenheit for May, 83° Fahrenheit for July, 81° Fahrenheit for August, and 64° Fahrenheit for October.

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[23] Tip of the Mitt Watershed Council. "Comprehensive Water Quality Monitoring." Tip of the Mitt Watershed Council, watershedcouncil.org/projects/comprehensive-water-quality-monitoring/. Accessed 19 Apr. 2024.
[24] Tip of the Mitt Watershed Council. Black Lake Tributary Study: An assessment of six rivers and streams that supply Black Lake. 2018.

Phosphorus, Nitrogen, and Chloride Trends

There is no numerical standard for nutrient concentration limits for surface waters in Michigan, and regulation is limited to the following standards from EGLE Part 4 WQS Rule 60. Phosphorus from point source discharges should have a maximum monthly average of 1 milligram per liter of total phosphorus (TP) unless other limits are deemed appropriate by the department. For streams in Northern Michigan, a total phosphorus concentration of 12 micrograms per liter or less is considered ideal to minimally impact conditions, protect designated uses, and provide flexible management.[25] The recommended amount of total nitrogen in Northern Michigan is 440 micrograms per liter and the recommended amount of chloride is 230 micrograms per liter and 860 micrograms per liter for chronic toxicity and acute toxicity respectively.[26,27]

Chlorophyll-a Concentrations

Chlorophyll-a concentrations display the amount of algae that is growing in a waterbody. Higher concentrations indicate that there is an excess amount of algae present, which can be due to runoff, fertilizers, or septic waste as these provide the nutrients needed for excess algal growth. Lower concentrations indicate healthier water quality as algal formation is not as apparent.

Black Lake Nutrient Trends

Black Lake has repeatedly measured below the TP standard of 12 micrograms per liter since 1987.[28] TP trends have fluctuated over the past several decades, reaching a high in 1998 at 11.4ug/L and most recently dropping to a low of 4.3ug/L (Figure 1.4).

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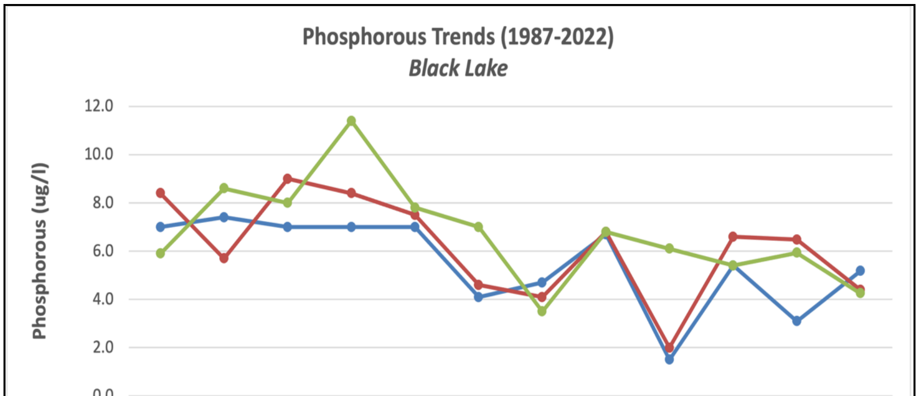
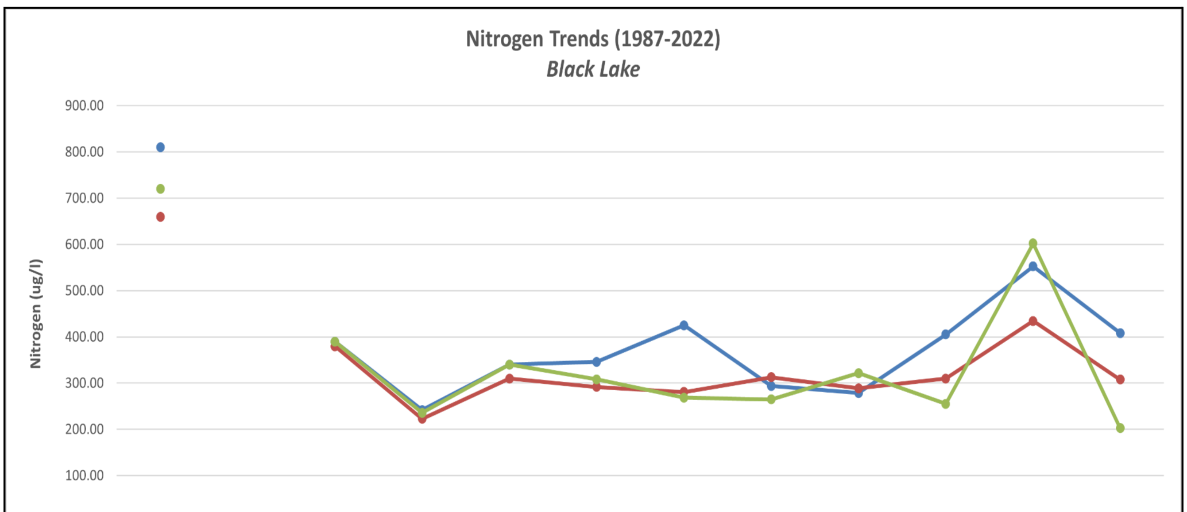
[25] United States Environmental Protection Agency. (2000). *Ecoregion VIII: Nutrient Poor Largely Glaciated Upper Midwest and Northeast*.
[26] Tip of the Mitt Watershed Council. *Black Lake Tributary Study: An assessment of six rivers and streams that supply Black Lake*. 2018.
[27] United States Environmental Protection Agency. (2013). *Road Salt TMDLs and Road Salt Reduction Strategies in New Hampshire.*
[28] CWQM Water Quality Data. 27 May 2022.



	1987	1992	1995	1998	2001	2004	2007	2010	2013	2016	2019	2022
Bottom	7.0	7.4	7.0	7.0	7.0	4.1	4.7	6.7	1.5	5.4	3.1	5.2
Middle	8.4	5.7	9.0	8.4	7.5	4.6	4.1	6.8	2.0	6.6	6.5	4.4
Surface	5.9	8.6	8.0	11.4	7.8	7.0	3.5	6.8	6.1	5.4	5.9	4.3

Figure 1.3. Black Lake Phosphorous Trends from 1987-2022[26]

Total nitrogen remained relatively steady below the recommended amount of nitrogen (440 micrograms per liter) until 2019 when it gradually increased from an average of 297ug/L in 2013 to 602.57ug/L at the surface, which may have signified a weather event (Figure 1.5).



	1987	1992	1995	1998	2001	2004	2007	2010	2013	2016	2019	2022
Bottom	810.00		390.00	242.00	340.00	346.00	425.00	294.00	279.00	405.40	552.73	408.23
Middle	660.00		380.00	223.00	310.00	292.00	281.00	313.00	289.00	310.10	434.75	307.81
Surface	720.00		390.00	236.00	340.00	308.00	269.00	265.00	322.00	255.40	602.57	202.86

Figure 1.4. Black Lake Nitrogen Trends from 1987-2022[26]

Chloride can be seen on a downward trend in 2007 going from a middle reading of 6.82mg/L to 4.02mg/L in 2022 (Figure 1.6).

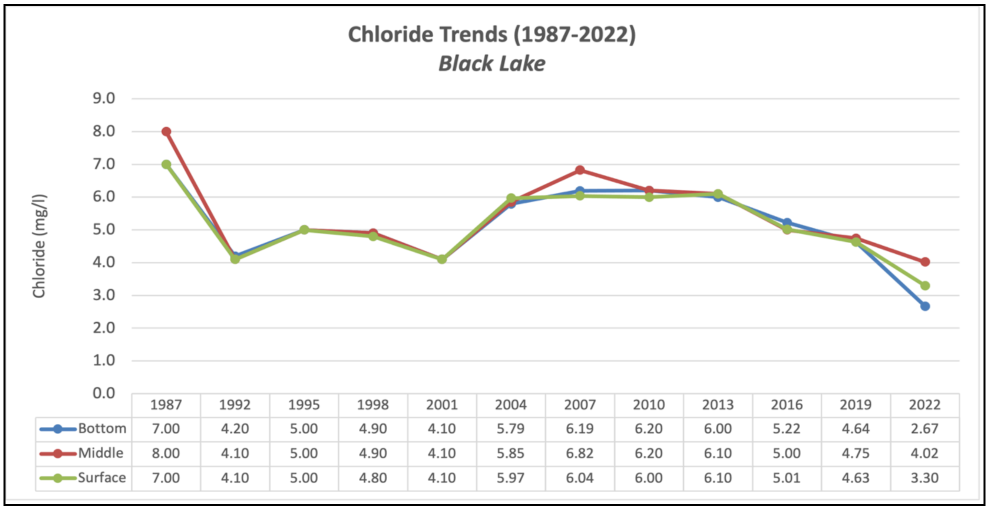


Figure 1.5. Black Lake Chloride Trends from 1987-2022[26]

Black Lake measured the highest Chlorophyll-a concentration in 1990 with an average of 2.77ug/L and again in 2012 with an average of 2.19ug/L. From 2001 to 2009 and 2014 to 2020, concentrations were the lowest with the most recent measurement being 0.37ug/L (Figure 1.7). Overall, the low concentrations are not a cause for concern, however, it raises the question of why these HABs are forming if chlorophyll-a concentrations are not reflecting the outbreaks.

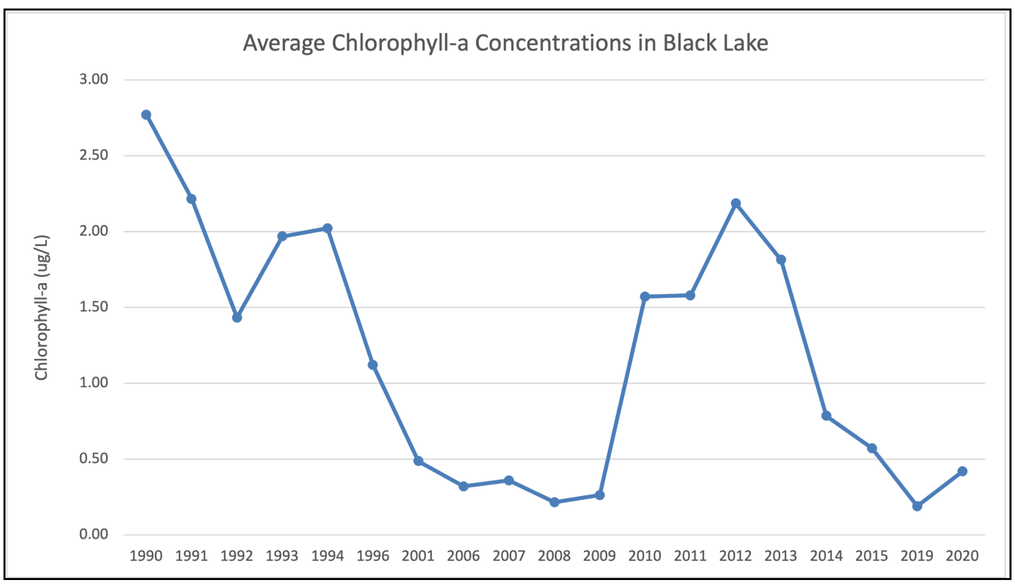


Figure 1.6. Average Chlorophyll-a concentrations in Black Lake 1990-2020 collected by Black Lake volunteers[29]

Overall, the trends observed in Black Lake are not very alarming and most recorded data meet the water quality parameters previously mentioned. However, with relatively normal levels, it

[29] VLM Comprehensive Database with QAPP Quality Controls. 4 May 2021.

raises the question of why the lake has been experiencing HABs over the last several years since the data does not directly point to concerning findings.

Water Quality Parameters of Subwatersheds

The previously explored tributary study by Tip of the Mitt Watershed Council in 2018 covered six subwatersheds: Stony Creek, Cold Creek, Fisher Creek, Rainy River, Stewart Creek, and Cains Creek. Monitoring sites (Figure 1.8) provide baseline data although many sites were dry or did not have information for August (temperature, dissolved oxygen, conductivity, and pH). All of the respective tributary data as well as in-depth summaries of the data can be seen in Appendix 1. Table 1.4 summarizes the study by identifying which streams met the water quality parameters. Sites that had varying data (some meeting standards, some not meeting standards) are represented by a yellow "Varied" box while consistently not met parameters are represented by a red "Not Met" box. Sites that consistently meet the parameters are represented by a green "All Sites" box.

All monitoring sites did not meet the set limits in at least three different parameters throughout the study. Stewart Creek, Rainy River, and Cold Creek all had parameters that were consistently not met in higher amounts than Cain's Creek, Stony Creek, and Fisher Creek's monitoring sites. Because all sites had varying levels of recorded data, it is fair to say that the health of the overall water bodies are unknown given that some monitoring sites recorded parameters that were within the limits while others did not.

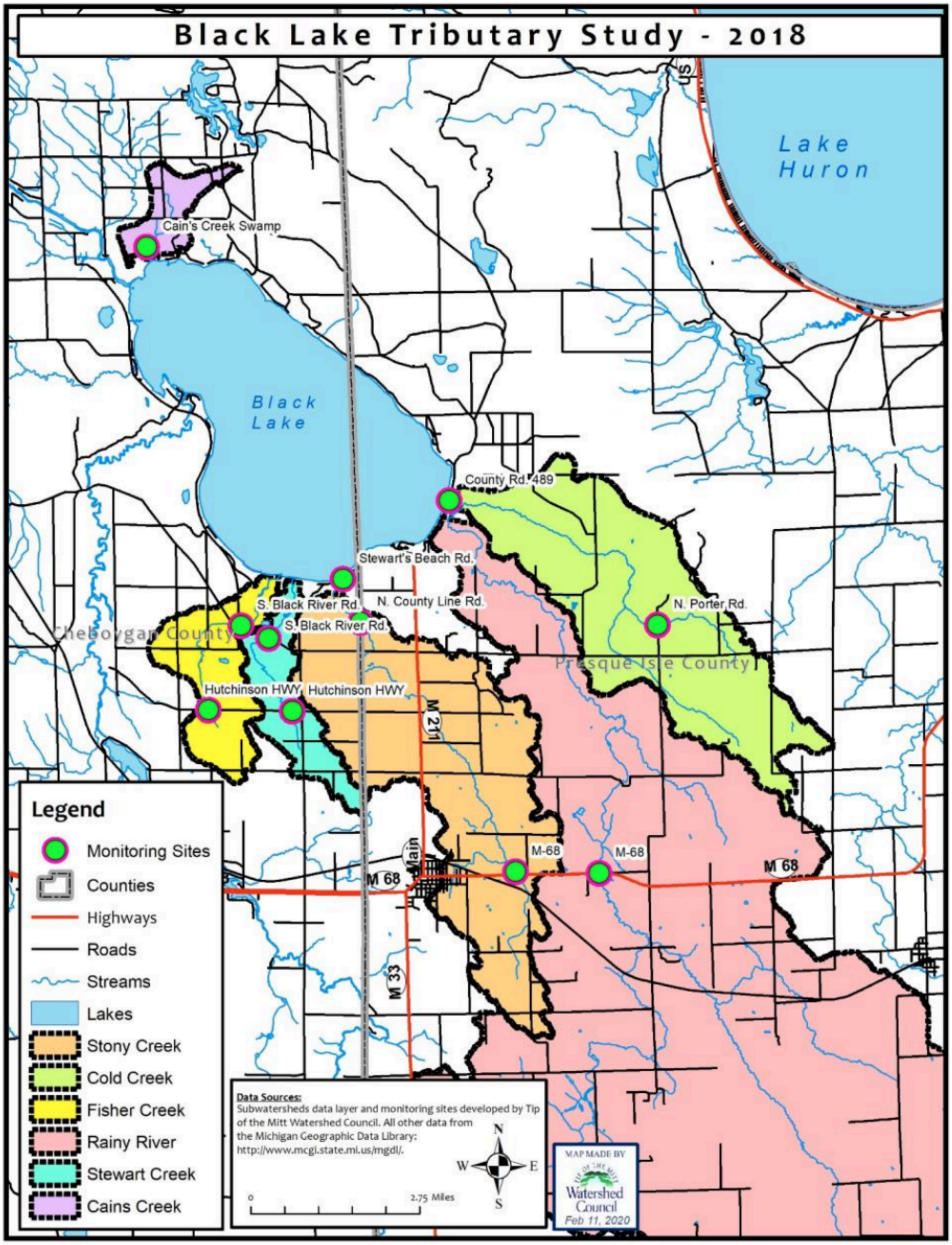


Figure 1.7. Black Lake Tributary Study Monitoring Locations [30]

[30] Tip of the Mitt Watershed Council. *Black Lake Tributary Study: An assessment of six rivers and streams that supply Black Lake*. 2018.

Table 1.2. Water Quality Parameters From Tributary Study

		Monitoring Sites					
Water Quality Parameters	**Limit**	Cain's Creek	Fisher Creek	Stewart Creek	Stony Creek	Rainy River	Cold Creek
TDS	**750 mg/L**	All Sites	All Sites	All Sites	All Sites	All Sites	All Sites
pH	**6.5-9**	All Sites	All Sites	All Sites	All Sites	All Sites	All Sites
Dissolved O_2	**5-7 mg/L****	All Sites	Varied	All Sites	Varied	Not Met	All Sites
Temperature	**Varies****	All Sites	Varied	All Sites	Varied	Varied	All Sites
Phosphorous	**12 µg/L**	Varied	All Sites	Varied	Varied	Varied	Varied
Nitrogen	**440 µg/L**	Varied	Varied	Varied	Varied	Varied	Not Met
Chloride	**5 mg/L**	Varied	Varied	Not Met	Varied	Slightly Elevated	Slightly Elevated

**Note: Dissolved O_2 varies based on cold or warm water fisheries

**Note: Temperature varies based on month

Designated Uses

Water quality standards are developed for designated or beneficial uses to aid in protecting those uses and implementing policies and procedures that keep high-quality waters from degrading.[31] The EPA's handbook describes designated or beneficial uses as descriptions of water quality expectations or water quality goals. A designated use is a legally recognized description of a desired use of the waterbody. State and tribal governments are primarily responsible for designating uses of water bodies within their jurisdictions. Two types of criteria are used to measure whether standards are being met. Numeric criteria set numeric limits for water quality

[31] Tip of the Mitt Watershed Council. (2017). *Burt Lake Watershed Management Plan*.

parameters and narrative criteria are non-numeric descriptions of desirable or undesirable water quality conditions.[31]

The State of Michigan has established a set of designated uses that can be measured for impairment based on the water quality standards described in the previous section. Rule 100 of the water quality standards states that all surface waters of the State are designated for, and shall be protected for, eight particular uses described in Table 1.2.[31]

Table 1.3. Surface Water Designated Uses in the State of Michigan[31]

Designated Use	General Definition
Agriculture	Livestock watering, irrigation, and crop spraying
Navigation	Navigation of inland waters
Warmwater fishery	Supports warmwater species
Coldwater fishery	Support coldwater species
Other Indigenous aquatic life and wildlife	Supports other indigenous animals, plants, and macroinvertebrates
Partial body contact recreation	Supports boating, wading, and fishing activities
Total body contact recreation	Supports swimming activities between May 1 to October 31
Public water supply*	Surface waters meet human cancer and non-cancer values set for drinking water
Industrial water supply	Water utilized in industrial or commercial applications
Fish Consumption	There is a statewide, mercury-based fish consumption advisory that applies to all of Michigan's inland lakes, including those within the Mullett Lake Watershed.

The State of Michigan has also developed water quality standards to help determine if designated uses are impaired (Table 1.3).[31]

Table 1.4. Water Quality Standards in the State of Michigan[31]

Parameter	Water Quality Standards	Designated Uses Affected
Dissolved Solids	Not to exceed 500 mg/L monthly average or 750 mg/L at any time as a result of controllable point sources	All
pH	Between 6.5 to 9.0	All
Taste or odor producing substances	The surface waters of the state shall contain no taste-producing or odor-producing substances in concentrations which impair or many impair their use for a public, industrial, or agricultural water supply source or which impair the palatability of fish as measured by test procedures approved by the department.	Public Water Supply* Industrial Water Supply Agricultural Water Supply Fish Consumption
Toxic substances (selected shown here; see rule for complete listing)	DDT and metabolites: below 0.00011 µg/L Mercury, including methylmercury: below 0.0013 µg/L PCBs (class): below 0.00012 µg/L 2,3,7,8 - TCDD: below 0.0000000031 µg/L	All but navigation
Radioactive substances	Pursuant to U.S. nuclear regulatory commission and EPA standards	All but navigation
Plant nutrients	Phosphorus: 1 mg/L maximum monthly average for permitted point source discharges. Regulation for surface waters is limited to the following narrative standard from Rule 60 (323.1060): "nutrients shall be limited to the extent necessary to prevent stimulation of growth of aquatic rooted, attached, suspended, and floating plants, fungi or bacteria which are or may become injurious to the designated uses of the waters of the state."	All
Microorganisms	30-Day Geometric Mean: below 130 *E. coli* per 100 ml	Total body contact
	Daily Maximum Geometric Mean: 300 *E. coli* per 100 ml	Total body contact
	Daily Maximum Geometric Mean: below 1,000 *E. coli* per 100 ml	Partial body contact
	Human sewage discharges (treated or untreated) below 200 fecal coliform per 100 ml 30-day mean or 400 fecal coliform per 100 ml in 7 days or less	Total body contact
Dissolved oxygen	Minimum 7 mg/L for coldwater designated streams, inland lakes, and Great Lakes/connecting waters; minimum 5 mg/L for all other waters	Cold water fishery
	Minimum 5 mg/L daily average	Warm water fishery
Temperature	Natural daily and seasonal temperature fluctuations shall be preserved:	Cold water fishery
	Maximum monthly averages for inland lakes (ºF): J 45 | F 45 | M 50 | A 60 | M 70 | J 75 | J 80 | A 85 | P 80 | O 70 | N 60 | D 50	Other indigenous aquatic life and wildlife
	Maximum monthly averages for warm water streams in this watershed (ºF): J 38 | F 38 | M 41 | A 56 | M 70 | J 80 | J 83 | A 81 | P 74 | O 64 | N 49 | D 39	Warm water fishery
	Maximum monthly averages for cold water streams in this watershed (ºF): J 38 | F 38 | M 43 | A 54 | M 65 | J 68 | J 68 | A 68 | P 63 | O 56 | N 48 | D 40	Cold water fishery

The status of a designated use in a watershed can be met, impaired, threatened, or under review/unknown. The use is unimpaired if the available physical and analytical data indicates that all applicable water quality standards are being consistently met. If the available data indicates that water quality standards are not being consistently met, then the designated use is considered to be impaired. If an assessment unit is expected to not meet a particular designated use within the next two years (Integrated Report listing cycle), it is identified as threatened. A use that is designated as under review or unknown means there is insufficient physical or analytical data available to determine a status for the use and that additional studies are necessary.[31]

The Clean Water Act (CWA) requires Michigan to prepare a biennial report on the quality of its water resources as the principal means of conveying water quality protection/monitoring information to the United States EPA and the United States Congress. The Water Quality and Pollution Control in Michigan, Sections 303(d), 305(b), and 314 Integrated Report satisfies the listing requirements of Section 303(d) and the reporting requirements of Section 305(b) and 314 of the CWA.[32] The Section 303(d) list includes Michigan water bodies that are not attaining one or more designated uses and require the establishment of Total Maximum Daily Loads (TMDLs) to meet and maintain Water Quality Standards.[31]

In 2022, the state enacted a statewide mercury TMDL. Several water bodies are listed as not meeting the fish consumption designated use because of state fish consumption advisories that have been issued. This may be due to elevated fish tissue levels of mercury and PCBs in some species as a result of atmospheric deposition of these pollutants. This issue is being addressed at the state and regional levels and is beyond the scope of the Black Lake Watershed Management Plan.[31]

Designated Uses in the Black Lake Watershed

The Black Lake Watershed includes water bodies designated to be used as cold water and warm water fisheries. The coldwater fishery lakes and streams are considered designated trout streams or designated trout lakes for the State of Michigan and only apply to the Michigan Department of Natural Resources. There are various water bodies in Michigan designated and protected as coldwater fisheries including the following:

1. All inland lakes identified as coldwater fisheries in the Coldwater Lakes of Michigan publication by the Department of Natural Resources.
2. All Great Lakes and their connecting waters, except for the entire Keweenaw waterway, including Portage lake, Houghton county, and Lake St. Clair.

[32] Michigan Department of Environment, Great Lakes, and Energy. (2022). *Water Quality and Pollution Control in Michigan 2022 Sections 303(d), 305(b), and 314 Integrated Report*.

3. All lakes listed in the publication Designated Trout Lakes and Regulations by the director of the Department of Natural Resources.

4. All waters listed in the publication Designated Trout Streams for the State of Michigan by the director of the Department of Natural Resources.[31]

Coldwater streams and lakes within the Black Lake Watershed, such as Rainy River, Stony Creek, and Fisher Creek, are therefore designated and protected for coldwater fisheries. Two sites within the watershed, Kleber and Tower Pond are 303(d) listed, designated as impaired bodies of water due to current mercury levels not safe for consumption.[33]

While the majority of assessed surface waters in the Black Lake Watershed are currently meeting all of the designated uses of the State, the watershed remains vulnerable to nonpoint source pollution and other environmental stressors. Existing and future activities will invariably create a risk of degradation to some or all of the designated uses. Thus, it is critical to enact preventative and restorative actions to ensure future use of watershed resources.

The uncertainty around the source of HABs occurring in Black Lake, other water quality issues, and the lack of an EPA and Michigan Department of Environment, Great Lakes and Energy (EGLE) approved watershed management plan for the Black Lake Watershed has led to increasing public support for an approved management plan, according to TOMWC. Establishing a baseline of public perception and attitudes towards water quality issues, water protection, and water management will allow for organizations to effectively address public concerns. A more informed community and an approved watershed management plan for Black Lake will be key to addressing water quality issues and implementing watershed protection strategies and initiatives.

[33] Michigan Department of Environment, Great Lakes, and Energy. (2022). Statewide Mercury TMDL 2022 Locations. www.michigan.gov/egle/-/media/Project/Websites/egle/Documents/Programs/WRD/GLWARM/TMDL-statewide/2022-Statewide-Mercury-TMDL-Locations.pdf?rev=703537f56c634bb585de62d423dbcc45&hash=219BE0B2FA7A42D2E543D5BE91290F1D

Chapter 2: Project Description, Goals, and Objectives

Project Description

As water quality concerns have increased within the Black Lake Watershed over the past several years, TOMWC and members of the two Black Lake associations started to advocate for a watershed management plan. The primary purpose of a watershed management plan is to guide watershed coordinators, resource managers, policy makers, and community organizations to restore and protect the quality of lakes, rivers, streams, and wetlands by providing specific recommendations. A significant component of the watershed management planning process is conducting resource inventories that assess different types of nonpoint source pollution and surveying the watershed residents to understand the perspectives of major stakeholders. Considering this need for insightful data and recommendations for how to manage, mitigate, and effectively adapt to these water quality issues, TOMWC collaborated with the University of Michigan's School for Environment and Sustainability (SEAS). We, as four SEAS graduate students, gathered and analyzed data from watershed inventories and social indicator surveys to provide concrete recommendations for TOMWC. This information will directly inform the content and direction of the Black Lake Watershed management plan and guide actions and protocols of TOMWC.

Project Goals

The overall goal of this project is to contribute positively and effectively to TOMWC and the Black Lake Watershed community by providing quantitative and qualitative data as well as a capacity to understand the current environmental status of the Black Lake Watershed.

This overall goal was accomplished by completing a comprehensive assessment of nonpoint source pollution throughout the watershed. This assessment included performing field surveys and inventories to document and evaluate nonpoint source pollution originating from streambank erosion, road/stream crossings (RSX), agriculture activity and forestry management.

Specifically, the following goals were achieved:

1) Determine relative pollutant contributions from high priority tributaries and their associated watersheds to gain an understanding of high pollutant loading areas throughout the watershed. We did this by completing field surveys to document and evaluate nonpoint source pollution originating from streambank erosion, RSX, agricultural activity, and forestry management.

2) Identify land parcels to be prioritized for protection. To accomplish this goal, we completed a GIS-based priority parcel analysis to rank properties.

3) Determine attitudes, beliefs, and behaviors of watershed residents related to water quality to form a baseline of public perception. We achieved this by surveying residents, visitors, and local officials using the US EPA Social Indicators Data Management and Analysis tool (SIDMA Tool).

Theory of Change

A Theory of Change is a model that depicts a set of expected outcomes following predetermined intervention strategies. The model provides a guide on how to successfully complete each of our project goals and can potentially be a template for other lakes that are experiencing similar socio-ecological effects. Included are the various factors that are linked together to address the individual goals of the project and how it will be accomplished (Figure 2.1).

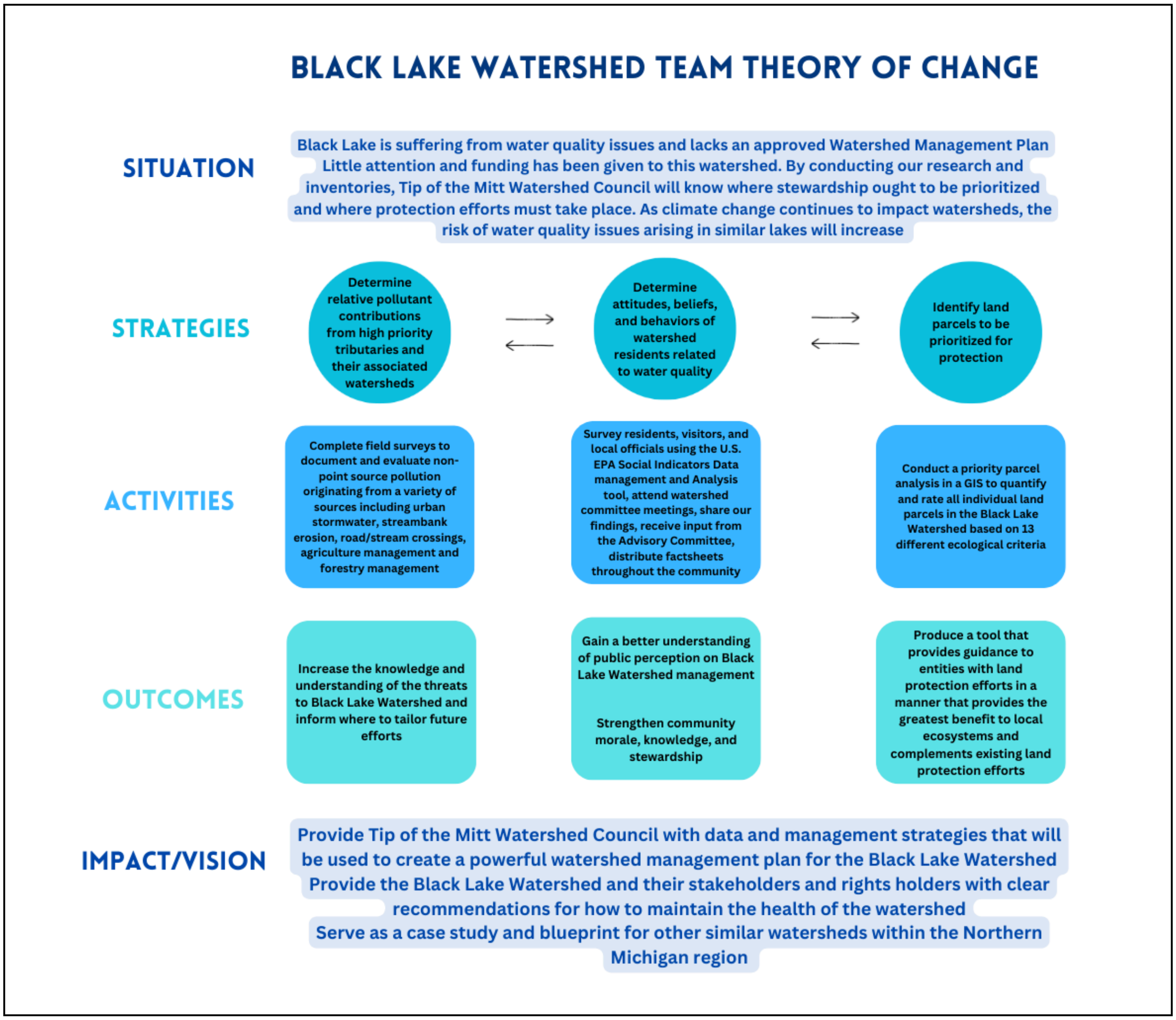


Figure 2.1. Theory of Change Model

Project Significance

A significant aspect of our project was identifying potential nonpoint source pollution that might contribute to the annual harmful algal blooms (HABs) in Black Lake. The exact drivers and mechanisms behind these blooms remain elusive, hindering proactive solutions to the issue. By investigating the role of nonpoint source pollution in HABs, we aimed to develop effective mitigation strategies and propose local ordinances for the residents of Black Lake.

Black Lake holds a unique status as a pristine inland lake, making our findings invaluable not only for addressing its specific challenges, but also as a model for similar northern inland lakes with minimal human disturbances, limited runoff, and no direct connections to major waterways.

Chapter 3: Methods

Methods Overview

This project aligns with our positions as researchers to work as boundary spanners for the Black Lake community. As boundary spanners, we straddle the divide between information users (stakeholders) and information producers (us as researchers).[34] It is important to be able to take our research and properly convey it to the public in a respectful yet informative manner. As we met with local organizations and gave presentations throughout this project, we needed to provide the entities who conduct land protection efforts and water stewardship within the Black Lake Watershed with up-to-date information as we collected it. Keeping the public informed strengthens not only the trust between us and the respective parties but also shows that even outsiders of the Black Lake Watershed want what is best for it.

To accomplish our project goals, two distinct forms of research were conducted for this project. First, extensive watershed inventory surveys were conducted that measured the impact caused by road-stream crossings, stream banks, agricultural lands, and forestry lands to determine their potential relative pollutant contributions. This work was heavily informed by Michigan's Department of the Environment, Great Lakes, and Energy (EGLE) non-point source protocols and experienced specialists from the EGLE office. Along with this, an analysis of priority parcels and critical areas within the watershed was performed to understand where remediation efforts could be targeted.

Second, we conducted a social indicator survey with Black Lake Watershed residents, including those living on Black Lake and those residing throughout the watershed and subwatersheds. Following the format of the EGLE's Social Monitoring Survey format and protocols, residents were surveyed using an online survey format that maintains anonymity and records their responses within the Social Indicators Data Management and Analysis (SIDMA) tool. Once collected, the data was analyzed and shared with TOMWC for continued use and monitoring. These survey results serve as the public perception baseline for TOMWC to continue to track.

Beyond these two project approaches, we conducted direct community engagement through formal and informal meetings. As graduate researchers, we presented our plans, research approaches, and preliminary findings to the Black Lake Watershed Advisory Committee four times throughout 2023 and 2024. In addition to sharing our progress, we facilitated discussions with the members of the committee, where we asked for their input, insights, feedback, and recommendations.

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[34] Goodrich, K. A., Sjostrom, K. D., Vaughan, C., Nichols, L., Bednarek, A., & Lemos, M. C. (2020). Who are boundary spanners and how can we support them in making knowledge more actionable in sustainability fields? *Current Opinion in Environmental Sustainability*, *42*, 45–51. https://doi.org/10.1016/j.cosust.2020.01.001

Social Indicator Survey Methods

The Black Lake Watershed Resident Survey was distributed to residents, landowners, renters, stakeholders, and other engaged citizens in the Black Lake Watershed. There were two separate methods for distributing this survey to the largest number of Black Lake Watershed Residents possible. This survey was conducted at a broad scale to gather as many responses and engagements with the survey as possible.

Information Collected in Survey

The information collected in the survey collected the respondents' attitudes, behaviors, knowledge, and beliefs in the following subject areas:
-Rating of water quality
-Water resources
-Water impairments
-Sources of water pollution
-Consequences of poor water quality
-Practices to improve water quality
-Opinions of specific water practices
-Making decisions for the respondent's property
-Demographic data
-Sources of water quality information
-Septic system care

Reaching the Black Lake Watershed Advisory Committee Members

Emails were forwarded from us by TOMWC to all 85 members of the Black Lake Watershed Advisory Committee. To ensure success, we utilized a "four-wave design." In this method, the initial contact email included background information and a link to the Black Lake Watershed Residents Survey (Appendix 2). This initial survey distribution occurred in June 2023. The second, third, and fourth email contacts served as reminders to engage in the Watershed Resident Survey. These subsequent correspondences provided a smaller section on background information and a link to the Black Lake Watershed Residents Survey. Every three weeks, stakeholders with known email addresses received an email, reminding them to complete the survey. This reminder correspondence was sent three times before the survey closed to the public in September 2023.

Reaching other Black Lake Watershed Residents:

Black Lake Association members, Black Lake Preservation Society members, and general Black Lake residents accessed the survey through a website link shared through association or society presidents, social media content on the TOMWC's Facebook and Instagram accounts and website, and in-person meetings and community engagements (Appendix 3). The link to the survey was included in both lake association newsletters and through the lake associations'

Facebook pages. This method of distribution resulted in a broader, more diverse set of survey results.

Selection of Survey Population

The target population for this survey consisted of resident landowners and renters in the Black Lake Watershed area. This survey population had an oversample of individuals from the Black Lake Association membership lists, the Black Lake Preservation Society membership lists, and the Black Lake Watershed Advisory Committee membership, rights holders, and stakeholders lists. We recognize that engaging with this population resulted in a bias for older, wealthier, and/or more educated persons being surveyed, and fewer renters, as compared to the general population. Providing the link through social media and the TOMWC's website was an attempt to mitigate some of this bias. We utilized the summer months of June, July, August, and September of 2023 to capture as many responses from the watershed residents as possible. During this period of the year, watershed residents were more likely to enjoy and engage with the watershed, perhaps making them more likely to participate in this survey.

Survey Questions

This survey was meant to be comparable to prior survey information collected and utilized by TOMWC, such as the Elk River Chain of Lakes Watershed Residents Survey and the Lake Charlevoix Watershed Survey. This comparability allowed us to improve our data collection and ultimately our knowledge of this area of the state. We were able to measure changes in varying watersheds over the years. This will also contribute to the larger known data set collected for the Great Lakes Basin. To guarantee this comparability, we utilized the SIDMA Tool to create the survey, just as TOMWC has done to collect watershed resident data in the past.

The survey contained 11 sections with questions to determine the public's awareness of and attitudes toward water quality. Additionally, these questions collected information on how well citizens in the watershed understand specific Best Management Practices (BMPs) and asked about their constraints for implementing those BMPs in the Black Lake Watershed. Thirteen demographic questions were also included. For a list of the survey questions, please see the survey instrument included in Appendix 2.

Most questions provide respondents with multiple choices of answers from which to choose. There were seven questions with a written option. There was also space available for comments at the end of the survey. All comments were transcribed and reported to the TOMWC.

Quality Control

This survey underwent evaluation by the University of Michigan's Institutional Review Board (IRB) to evaluate the quality and security of the Black Lake Watershed Resident Survey. This survey was submitted for review on April 21, 2023. The survey was promptly approved by the Institutional Review Board with minor revisions necessary.

Given that this survey was distributed through email addresses and the internet, we were watchful of robot responses, AI responses, or responses from those outside of our survey sample. We continually monitored the responses to discard any false survey submissions. We monitored survey responses by coding quality, which was assessed by randomly selecting one of every ten survey submissions. This survey was checked for suspicious responses and if suspicious responses were found, all survey submissions were checked.

Data Management and Analysis

The responses from submitted surveys were automatically recorded and stored in the SIDMA tool. The SIDMA Tool generated indicator scores for four areas: awareness, attitudes, constraints, and behavior. These scores were useful when compared to other audiences and surveys. TOMWC and our team will maintain the SIDMA Tool surveys and data analysis electronically. The data analysis will continue to be securely maintained by TOMWC for five years.

Road/Stream Crossings Inventory Methods

We performed a road/stream crossing inventory in the Black Lake Watershed. Priority was given to conducting inventories at RSX that were deemed a “time-sensitive” matter before navigating any sites. “Time-sensitive” is subjective and may include reasons such as possible obstructions to the structure, dangerous risks including power lines in the stream, or the presence of HABS. It is an umbrella term based on the personal opinion of the surveyor. We visited the 39 sites marked as “time sensitive” and in varying conditions within the watershed.

These inventories followed the Great Lakes Road/Stream Crossing Inventory protocol established (2011) by the U.S. Forest Service, U.S. Fish and Wildlife Service, Michigan Department of Natural Resources, Wisconsin Department of Natural Resources, Huron Pines, Conservation Resource Alliance, Michigan Technological University, and road commissions (Appendix 4).

- Field work was performed from August 7th to August 25th in 2023.
- Equipment used to collect data included a digital GPS camera, Sontek FlowTracker, measuring tape, compass, and other standard field equipment. Data was collected on iPads which were connected to cell phone hotspots when available for better accuracy of GPS points.
- Site sketches were hand-drawn using a paper datasheet. Site sketches were photographed and stored in the Survey123 form. They were also scanned in as high-resolution PDFs and stored on the TOMWC server.
- Photographs were taken at each RSX of the culvert inlet and outlet, upstream and downstream conditions near the culvert, and road approaches on both sides.
- Field data was collected using Survey123 on smartphones and/or tablets to enhance post-processing.

- Pollutant loading estimates for sediment were calculated by applying the formulas that accompany the Great Lakes Road/Stream Crossing Inventory. Pollutant loading estimates for phosphorus and nitrogen were determined by applying an overall phosphorus concentration of 0.0005 lbP/lb of soil and a nitrogen concentration of 0.001 lbN/lb of soil. Soil texture was determined and a correction factor was used to better estimate nutrient nutrient-holding capacity of the soil. Sand is the dominant soil texture for the Black Lake Watershed, thus a correction factor of 0.85 was used. The Survey123 form developed by the Michigan Department of Natural Resources (DNR) was used in the field to record measurements that replicate the Stream Crossing Data Sheet (appendix 4).
- The data was also uploaded to https://great-lakes-stream-crossing-inventory-michigan.hub.arcgis.com/ in collaboration with the Michigan DNR.
- RSX were ranked/prioritized according to their severity (minor, moderate, major) concerning nonpoint source pollution threats and barriers to aquatic species passage. For simplicity, sites that were ranked severe were considered major, and sites with "moderate-to major" were considered "moderate."
- GPS coordinates and the alpha-numeric codes will identify RSX when they are displayed in final reports.
- Sites that did not contain usable data were disregarded from the analysis (usable data meaning measurable as some structures were noted without any collected data from the site).
- Fish passage was only considered at the sites that were updated and if updated sites did not have any fish passage data, their score was subjective based on the surveyor.

Additional Analysis: Multivariate Analysis of Road/Stream Crossing Data

We also utilized FAMD (Factor Analysis of Mixed Data) to analyze the acquired RSX data set that contains both categorical and continuous variables. FAMD is useful when analyzing data sets that contain quantitative and qualitative data which reflects the categories of RSX sites. FAMDs help identify possible relationships between different variables. To conduct this analysis, R packages "FactoMineR" and "factoextra" were installed. Categorical variables were then changed to an ordinal formation. For the variable Invasive.Species, a ranking system was implemented: 1 = "Low", 2 and 3 = "Intermediate", and 4 = "High." For the variable Road.Condition, a ranking system was also implemented: 0 = "Good", 2 = "Fair", and 4 = "Poor." Rows that contained "NA" values were omitted from all analyses. 40 data points were originally collected (4 to include the sites that were not accessible for our project, and 1 site that was mistakenly resurveyed outside of Black Lake's watershed boundary) but do not take away from the results obtained from the analysis.

Forestry Desktop Analysis Methods

We conducted a forestry inventory desktop analysis for the Black Lake Watershed by reviewing recent watershed-wide land-cover datasets, collaborating with the Natural Resources Conservation Service (NRCS), Michigan Agriculture Environmental Assurance Program, American Forest Foundation (American Tree Farm System), Michigan Department of Agriculture & Rural Development (MDARD) and Department of Natural Resources (DNR).

Forest management plans aid in the security of watershed health, economic services, and social benefits. Outside of county, state, and national designation of protected forests, they are promoted towards private property through various incentive programs. These programs seek to have positive impacts on the water, soil, and other natural resources provided by the landowners' forests. The DNR, American Forest Foundation (AFS), Michigan Department of Agriculture and Rural Development (MDARD), and National Resource Conservation Service (NRCS) are responsible for maintaining these programs (Table 3.1).

The inventory desktop analysis used the following steps developed and used previously by TOMWC:

1) Prioritize subwatersheds for inventories:
    - Acquire and compile the most current land cover data available.
    - Identify areas within the watershed with forest land cover using the 2019 National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP).
    - Assess forest land cover change over time within the watersheds.
    - Consult with the State of Michigan Forest Resources Division to understand area forest management goals, standards, and regulations for soil and water quality practices, BMPs, and voluntary and mandatory programs.
    - Acquire spatial data of areas with Forest Stewardship Programs or Forestry Management Plans and create a map of parcels enrolled.

Table 3.1. Private landowners tax incentive programs for forestry management as described by Tip of the Mitt Watershed Council

Program	**Affiliate**	**Description**
Commercial Forest Program (CFP)	DNR	This program reduces property taxes on private lands with at least 40 contiguous acres of forest. A forest management plan (including BMPs) is required to enroll, but compliance with the plan is not enforced. Landowners must allow public access for hunting, fishing, and trapping.
Qualified Forest Program (QFP)	MDARD	This program reduces property taxes on private lands with at least 20 contiguous acres of forest. A forest management plan (including BMPs) is required to enroll. Allowing public access is not a requirement on land enrolled in the QFP.
Forest Stewardship Program	DNR	The program offers cost-share for the development of a forest management plan (including BMPs) with the help of a private consulting forester. The plan can then be used for enrollment in tax- incentive programs like the Commercial Forest Program (CFP) or Qualified Forest Program (QFP). Landowners can also get a sign that gives public recognition of their conservation efforts.
American Tree Farm System	American Forest Foundation (AFS)	The program guides landowners in creating a forest management plan, which can be used for enrollment in tax- incentive programs like the CFP or QFP. It also requires members to follow all state designated BMPs for forest management, and landowners receive a sign that gives public recognition of their conservation efforts. The landowners' forest must be between 10-10,000 acres.
Michigan Agriculture Environmental Assurance Program (MAEAP)	MDARD	Requires landowners to develop a management plan and follow Michigan BMPs. The management plan can be used for enrollment in tax- incentive programs like the CFP or QFP. Landowners also receive a sign that gives public recognition of their conservation efforts.
Environmental Quality Incentives Program (EQIP)	NRCS	Offers cost-share to landowners to help fund conservation-oriented practices, including the development of forest management plans, planting trees and shrubs, creating early successional habitat, marking timber in preparation for sale, and other practices

Stream Bank Erosion Methods

We performed a streambank survey using methodologies developed and used extensively by TOMWC staff for similar surveys.[35] These methodologies were employed to document and assess streambank erosion. These surveys were carried out from August 7th to August 25th in 2023.

Desktop and Field Survey Methods
The streambank surveys document conditions and activities at riverside properties that will potentially impact water quality and the stream ecosystem. Streambank conditions were surveyed in the navigable river sections by traveling in two kayaks on each side of the river. The stream reach that was inventoried was the Black River between Kleber Dam and Tower Plant and Tower Pond. This area was inventoried due to the high concentration of properties along the river banks. To gain a better idea of streambank erosion in areas that are less developed within the watershed, a desktop analysis was also conducted by TOMWC summer interns. The desktop analysis was conducted for the Fisher, Stewart, Stony, Rainy, and Cold tributaries to flag any points of erosion. The sites from this desktop analysis were determined by apparent magnitude and visited from August 7th to August 25th in 2023. Streambank conditions for these sites were surveyed by spot-checking the sites found to have erosion from the desktop analysis.

Streambank conditions 500' upstream and 500' downstream at each crossing were documented. Erosion, streambank alterations, tributary streams, and the presence of invasive species were documented for all streamside properties. All data was documented using Survey123, with data on the form found in Appendix 6. A survey was filled out completely at each location where streambank erosion is found (multiple erosion sites for one property went on the same form). GPS coordinates, greenbelts, streambank alterations, invasive species, and tributary information for each property were recorded in the form. Photographs of each property were stored in the form.

Shoreline alterations were surveyed and noted with the following abbreviated descriptions:

SB = steel bulkhead (i.e., seawall)
BB = boulder bulkhead
CB = concrete bulkhead RR = rock rip-rap
WB = wood bulkhead
BR = Mixed boulder/rock riprap
BH = permanent boathouse
BS = beach sand
G = groin
DP = discharge pipe

[35] Tip of the Mitt Watershed Council. (2017). *Burt Lake Watershed Management Plan*.

The problem trend, which is the trend of the erosion identified, was identified as decreasing, stable, or increasing. Decreasing or stable problem trends were identified by physical indicators including new plant growth in previously eroding areas and other evidence that the streambank slope is not actively eroding but rather has reached a temporary or permanent equilibrium. Increasing problem trends were identified as slopes that are too unstable to support new growth of plants and that have active rivulets and gullies along their face.

Common or emerging invasive species occurring in the riparian area and that are visible from the river channel were noted on field datasheets. Invasive species that were noted, but are not limited to, are purple loosestrife, invasive Phragmites, Japanese knotweed, common and glossy buckthorn, and European frog-bit. Tributary streams were noted on the field datasheets and included in a separate column in the database. Additional information regarding shoreline property features or shoreline conditions recorded on field data sheets was included in the database in a "comments" column. Site sketches were done by hand and photographed to be included in the form.

Data Processing

Upon completing field work, all field data from Survey123 was downloaded and stored on the TOMWC server. Points and information collected using Survey123 were overlaid with county parcel data. The linked field and equalization data allowed streambank conditions documented during the survey to be referenced by property identification number or property owner name. Erosion severity calculations were made using data collected in the field and the scoring system found below.

The final products of the streambank survey include a comprehensive database stored on the TOMWC's server, a complete set of GPS digital photographs, GIS data layers of streambank parcels including both county equalization and streambank survey data, and a map displaying results. The streambank survey database contains a sequential listing of properties. The database contains all data collected in the field and identification numbers that correspond to those in GIS data layers and on hard-copy maps. Data was presented in the WMP via a map and a table with GPS coordinates.

Table 3.2. Streambank Erosion Scoring System

Condition of bank	Points		Soil type or texture	Points
Toe and upper bank eroding	5		Sand	3
Toe undercutting	3		Gravel	2
Toe stable, upper bank eroding	1		Stratified	2
			Clay, loam	1
Problem trend	**Points**		**Vegetative cover on bank slope**	**Points**
Increasing	5		0-10%	5
Combination	3		10-50%	3
Decreasing or stable	1		50-100%	1
Side-slope of bank	**Points**		**Apparent cause of erosion**	**Points**
1:1 (vertical)	5		Light access traffic	1
1:2 or 1:3	2		Obstruction in river	1
1:4 or flatter	1		Bank seepage	1
			Gullying by side channels	1
			Bend in river	2
			Wave action (impoundments)	2
			Road-stream crossing (runoff)	3
			Moderate access traffic	3
			Heavy access traffic (foot, horse, etc.)	5
Length of eroded bank	**Points**		**Mean height of eroded bank**	**Points**
More than 50 feet	5		More than 20 feet	7

20 to 50 feet	3		10 to 20 feet	5
Less than 20 feet	1		5 to 10 feet	3
			Less than 5 feet	1
Depth of river	**Points**		**Current**	**Points**
3 feet or more	2		Fast	2
Less than 3 feet	1		Slow	1
			Total Points for Site	

Total score indicates the severity of the erosion:

More than 36 = severe
30 to 36 = moderate
Less than 30 = minor

Sediment loads for major streambank erosion were determined by using a Direct Volume Method for each erosion site. Lateral recession rates (LRR) ranged from 0.03 to 0.4, depending on severity, and an average soil weight density for loamy sand/sandy loam of 100.

$$\frac{\text{(eroding area) x (lateral recession rate) x (density)}}{\text{2000 lbs/ton}} = \text{erosion in tons/year}$$

The eroding area is in square feet, the lateral recession rate is in feet/year, and density is in pounds/cubic feet (pcf).

To determine the phosphorus loads, the following formula was used:

Sediment (T/year) x .0005 lbP/lb x 2000 lb/T x soil correction factor (.85)

To determine the nitrogen loads, the following formula was used:

Sediment (T/year) x .001 lbN/lb x 2000 lb/T x soil correction factor (.85)

Agriculture Survey Methods

An agriculture survey was completed using the Animal Feeding Operations Inventory developed by EGLE to identify feeding operation activity in the Black Lake Watershed (Appendix 7). TOMWC interns completed the desktop analysis and we completed ground truthing during August 7th to August 25th of 2023. Sub watersheds within the Black Lake Watershed were chosen based on the percentage of land containing croplands and pastures from common land units provided by EGLE. The subwatersheds containing agricultural land were inventoried.

The desktop analysis consisted of analyzing aerial photographs taken from Google Earth and Michigan Imagery Services to identify the location and characteristics of animal feeding operations (AFOs). ArcGIS Pro was used for the analysis and all data was stored in a geodatabase on the Watershed Council's servers as well as the SharePoint file managed by EGLE. The Fishnet tool was utilized to create a grid of the area of interest for ease of analysis. The AFOs were identified based on the characteristics laid out in the Animal Feeding Operations Inventory (Appendix 7). The AFOs were then prioritized based on the following ranking system:

High Priority

- Any size dairy or beef operations in close proximity to water bodies with:
    - Observable drainage pathways leading to surface waters from identified sources
    - No manure storage found, or,
    - Storage is lacking, or otherwise disorganized
- Operations with potential livestock access issues

Medium Priority

- Hobby farms with:
    - Potential access issues
    - Observable drainage pathways leading to surface waters from identified sources
- Any size or type of AFO with manure storage structures near the water body, but no strong evidence of water quality impacts observable via aerials.

Low Priority

- Any size or type of AFO not near the observable connection to the water body.

After the desktop analysis was completed by TOMWC interns, we encountered issues in accessing the geospatial data gathered. The layers created to identify parcels containing agricultural activity and characteristics of the parcels had broken data sources that we were not able to access. The only data available was the GPS points for 32 sites that were identified as having agricultural land. These 32 sites were ground-truthed by the team from August 7th to 25th of 2023 to determine the status of the area. This followed the Field Check Methodology from the Animal Feeding Operations Inventory (Appendix 7) to confirm the proximity to a water body, type, size, storage, and maintenance of the AFOs identified. During the ground truthing, it was found that many of the sites identified in the desktop analysis did not contain agricultural activity, so we redid the desktop analysis. After the desktop analysis was completed the second time, the data that was gathered from the ground truthing was matched with the desktop analysis through the GPS points of the 32 sites and the GPS points for the common land units used in the desktop analysis.

Priority Parcel Analysis Methods

One of the most effective tools for long-term water quality protection is permanent protection of land, particularly sensitive lands such as those containing wetlands. Although the watershed already contains protected land owned by governments and conservancies, there remain many land parcels in sensitive areas that should be protected to safeguard the watershed's lakes, streams, wetlands, and groundwater. A "Priority Parcel Analysis" was performed in ArcGIS Pro by TOMWC staff to quantify and rate all individual land parcels in the Black Lake watershed based on multiple ecological criteria using methodology developed by TOMWC[36]. The analysis produced a tool that guides land conservancies, governmental entities, and others with permanent land protection efforts in a manner that provides the greatest benefit to local ecosystems, while also complementing existing land protection efforts. Descriptions of selection criteria and the scoring system used to determine priority parcels are described below.

Parcel Size: Larger blocks of contiguous land typically have higher ecological value due to their potential to harbor a greater diversity of habitat types and species. Larger parcels are also more time and cost-effective to protect than smaller parcels. The selection threshold for parcel size criteria during this process was 10 acres. The larger the parcel, the more points it will receive.

Groundwater Recharge Potential: Groundwater discharge is essential for maintaining the healthy cold water fisheries that prevail in Northern Michigan. Land with highly permeable soils allows precipitation to percolate relatively quickly through the soils and recharge groundwater supplies. Predominant soil type and associated permeability was determined for each parcel using the physical properties found in county soil surveys. Parcels were scored based on acreage containing soils with high ground water recharge potential, with the minimum threshold set at one acre.

Presence of Wetlands: Wetlands provide a variety of important functions that contribute to the health of surface waters, including fish and wildlife habitat, water quality protection, flood control, and erosion prevention. Digital GIS data layers containing results of the National Wetlands Inventory (NWI) were used to determine the presence of wetlands on individual parcels. Parcels were scored based on wetland acreage identified in the NWI, with any parcel with wetlands scoring at least one point.

Lake and Stream Riparian Ecosystems: Activities on land immediately adjacent to a waterbody are critically important to maintaining water quality and ecological health. Properties with lake or stream shorelines were given scores based on the total shoreline distance contained within the parcel. Properties with at least 100 feet of shoreline were prioritized for protection.

[36]Tip of the Mitt Watershed Council. (2017). *Burt Lake Watershed Management Plan*.

Steep Slopes: Areas with steep slopes are at greater risk of erosion, particularly when developed. To prevent erosion and reduce sedimentation of surface waters in the watersheds, land parcels with steep slopes should be permanently protected. GIS data from the State of Michigan was used to determine the highest percent slope on a parcel and scored accordingly. Properties with slopes greater than 20% will receive points.

Protected Land Adjacency: Properties adjacent to protected lands such as State Forests or conservancy lands have a high ecological value because they provide a buffer to preexisting protected lands and increase the contiguous protected area, which essentially expands the biological corridor for species migration and interaction. Protected lands include properties owned by the federal government, tribal governments, the State of Michigan, local governments, universities, land conservancies, and private owners (conservation easements). Properties bordering protected lands were scored based on the number of adjacent protected land parcels.

Presence of State or Federally Listed Threatened or Endangered Species: Threatened and endangered species represent an important aspect of biodiversity. The Michigan Natural Features Inventory developed a probability model and rarity index based on existing threatened and endangered species information, called the Biological Rarity (Biorarity) Index. Properties within or touching upon the model's grid cells that have a high probability of threatened and endangered species occurrence scored points; receiving a higher score as the rarity index number increases.

Proximity to Development: Properties near urban areas have a high conservation value due to the imminent threat of development. Because these properties are near population centers, they have the greatest potential for public use and provide the most gain in terms of ecosystem preservation. NOAA CCAP (Coastal Change Analysis Program) land cover data and MGDL municipal boundary data were used to identify urban areas and growth corridors. Parcels were scored based on proximity to these areas.

Natural Land Cover Types: Land in its natural state is more ecologically valuable than altered land because natural land cover tends to contain a greater diversity of habitat and species, and is more resilient to invasion by non-native species. NOAA's CCAP land cover dataset was used to determine a percent coverage of natural land cover types for each parcel. Parcels with greater than 50% natural land cover received points.

Drinking Water Protection Areas: Wellhead protection areas are critical recharge zones that maintain aquifer water supplies and sustain local municipal drinking water systems. Development within these areas can jeopardize water sources by contaminating water supplies or inhibiting the infiltration of rainwater. Points were assigned to parcels that lie within wellhead protection areas and based on the percentage of the parcel within the area.

Exceptional Resources: This criteria provides a fixed, two point score increase to any parcel adjacent to an exceptional resource. Exceptional resources are locally occurring conditions that are rare, vulnerable to degradation, and have high intrinsic value. The following were identified as critical resources for this analysis: critical dunes, blue-ribbon trout streams, forests with an average age of greater than 90 years, and undeveloped lakes.

Criteria for Prioritization and Scoring:

1. Parcel Size (acreage) (GIS Field “acre_scr”)
    a. Acres >= 10 AND acres < 20 — 1 pts
    b. Acres >= 20 AND acres < 40 — 2 pts
    c. Acres >= 40 AND acres < 80 — 3 pts
    d. Acres >= 80 — 4 pts
2. Groundwater Recharge Potential (acreage) (GIS Field “gw_rcg_scr”)
    a. Groundwater Recharge Acres >= 0 AND < 5 — 1 pts
    b. Groundwater Recharge Acres >= 5 AND < 10 — 2 pts
    c. Groundwater Recharge Acres >= 10 AND < 20 — 3 pts
    d. Groundwater Recharge Acres >= 20+ — 4 pts
3. Wetland Preservation (acreage) (GIS Field “wetld_scr”)
    a. Wetland Acres > 0 AND < 2 — 1 pts
    b. Wetland Acres >= 2 AND < 5 — 2 pts
    c. Wetland Acres >= 5 AND < 10 — 3 pts
    d. Wetland Acres >= 10+ — 4 pts
4. Lake Shoreline/Riparian Protection (linear feet) (GIS Field “Lk_Scr”)
    a. Lake Shore Distance > 100’ AND < 200’ — 1 pts
    b. Lake Shore Distance >= 200’ AND < 400’ — 2 pts
    c. Lake Shore Distance >= 400’ AND < 600’ — 3 pts
    d. Lake Shore Distance >= 600’ — 4 pts
5. River and Stream Shoreline/Riparian Protection (linear feet) (GIS Field “stream_scr”)
    a. Stream Distance >= 100’ AND < 500’ — 1 pts
    b. Stream Distance >= 500’ AND < 1000’ — 2 pts
    c. Stream Distance >= 1000’ AND < 2000’ — 3 pts
    d. Stream Distance >= 2000’ — 4 pts
6. Steep Slopes for Erosion Prevention (GIS Field “slope_scr”)
    a. Slopes >= 20 and < 30% — 1 pts
    b. Slopes >= 30 and < 35% — 2 pts
    c. Slopes >= 35 and < 40% — 3 pts
    d. Slopes > 40% — 4 pts
7. Proximity to Protected Lands (Wildlife Corridors) (GIS Field “protct_scr”)
    a. Parcel edge within 250’ of conservation lands — 1 pts
    b. Abutting conservation land — 2 pts

c. Linking conservation land 3 pts
d. Adjacent to conservancy lands and doubles size 4 pts

8. Threatened/Endangered Species (using MNFI model) (GIS Field “endang_scr”)
   a. Probability = 'Low' AND "RI" >= 3 AND "RI" < 4 1 pts
   b. Probability = 'Low' AND "RI" >=4 2 pts
   c. Probability = 'Moderate' AND "RI" >=0 3 pts
   d. Probability = 'High' AND "RI" >=0 4 pts
9. Proximity to Development (CCAP land cover = “Developed”) (GIS Field “devpres_scr”)
   a. Adjacent to any “developed” land cover 1 pts
   b. Within 2.5 miles of City Development or .75 miles of non-incorporated development 2 pts
   c. Within .75 miles of City Development 3 pts
   d. Within City Development 4 pts
10. Natural Land Cover Types (CCAP = non-agriculture, non-developed) (GIS Field “NatPct_Scr”)
    a. Natural Land Cover >= 50% AND < 70% 1 pts
    b. Natural >= 70% AND < 80% 2 pts
    c. Natural Land Cover >= 80% AND < 90% 3 pts
    d. Natural Land Cover >= 90% 4 pts
11. Drinking Water Protection Areas (GIS Field “wellHD_scr”)
    a. Wellhead Protection Area >= 1% and < 20% 1 pts
    b. Wellhead Protection Area >= 20% and < 35% 2 pts
    c. Wellhead Protection Area >= 35% and < 50% 3 pts
    d. Wellhead Protection Area > 50% 4 pts
12. Exceptional Resources (Multiple GIS Fields)
    a. Lakeshore w/Shoreline <= 25 parcels/mile average 2 pts
    b. Intersects a Blue Ribbon Trout Stream 2 pts
    c. Intersects Critical Dune Habitat 2 pts

All land parcels in the Black Lake watershed were analyzed and scored using the twelve listed criteria for a total of 47 points possible. The scores for each criterion were summed to produce a total “priority” score for each land parcel. Priority rankings of high, medium, and low were assigned to parcels based on priority scores. Rankings vary for each analysis depending on results and natural groupings and breaks in the data. The rankings were split into five equal-interval categories representing priorities for permanent land protection. The categories are in the following table:

Table 3.3. Ranking Categories for Priority Parcel Analysis

Priority for Permanent Land Protection	**Parcel Score Range**
Very Low	0-6
Low	7-11
Moderate	12-22
High	23-29
Very High	30+

GIS data layers developed during the prioritization process contained both county equalization information and priority criteria scores for all parcels in the watershed. The GIS data, associated databases, and maps were made available to local land conservancies, state agencies, and local governments to prioritize land protection activities and guide landscape development planning. Permanent protection or low-impact development in high-priority areas will help maintain the ecological integrity of the most sensitive areas and protect water resources throughout the watershed. Results of the Priority Parcel Analysis also provide valuable assistance in conservation efforts to protect threatened and endangered species, as well as to improve wildlife corridors throughout the watershed.

Determining Critical Areas Methods

Critical areas are the areas within a watershed with the greatest need for restoration. Critical areas were determined after all resource inventories were complete and the results were tabulated. The methodology for determining critical areas is based on a ranking system used previously by TOMWC.[31] The watershed was divided into one-mile square grid cells and each cell was scored based on multiple criteria. For each criterion, the percent coverage within individual grid cells was determined and a score was assigned to the cell. Scores for all criteria were summed to produce a total score. Critical areas were determined based on areas where grid cells scored in the highest tier(s) (tiers created by the scores of each cell; higher scores = higher tier). However, personal knowledge of problematic watershed areas by surveyors, committee members, natural resource professionals, and others were taken into account when developing the final critical areas map (e.g. areas with notable pollution).

1. Developed base GIS data layer for analysis. Utilized the one square mile gridded data layer for groundwater recharge developed in the Groundwater Inventory and Mapping Project (a cooperative effort between the Water Bureau - Michigan Department of Environmental Quality, USGS - Michigan Water Science Center and Michigan State

University Institute of Water Research, RS & GIS and Biosystems and Agricultural Engineering) to perform an assessment of critical areas. Selected all cells that intersect the Black Lake Watershed in a GIS and exported to make a new layer that will be used throughout the assessment.

2. Urban land cover. Determined all areas classified as urban or residential in the most recent land-cover dataset. Used the following system for grid cells:
    a. Urban/residential >= 10% and < 25% SCORE = 1
    b. Urban/residential >= 25% and < 40% SCORE = 2
    c. Urban/residential >= 40% and < 55% SCORE = 3
    d. Urban/residential >= 55% SCORE = 4
3. Agricultural landcover. Determined all areas classified as agriculture in the most recent land-cover dataset. Used the following system for grid cells:
    a. Agriculture >= 10% and < 25% SCORE = 1
    b. Agriculture >= 25% and < 40% SCORE = 2
    c. Agriculture >= 40% and < 55% SCORE = 3
    d. Agriculture >= 55% SCORE = 4
4. Problematic agricultural activity. Used agricultural inventory information from the WMP, used the following system for scoring:
    a. Prob ag sites = 1 and acreage < 20 SCORE = 1
    b. Prob ag sites = 1 and acreage > 20 SCORE = 2
    c. Prob ag sites > 1 and acreage < 20 SCORE = 3
    d. Prob ag sites > 1 and acreage > 20 SCORE = 4
5. Problematic forestry activity. Used forestry inventory information from the WMP, used the following scoring system:
    a. Prob forest sites = 1 and acreage < 10 SCORE = 1
    b. Prob forest sites = 1 and acreage > 10 SCORE = 2
    c. Prob forest sites > 1 and acreage < 10 SCORE = 3
    d. Prob forest sites > 1 and acreage > 10 SCORE = 4
6. Road stream crossings (RSX). Used RSX inventory information from WMP, used the following scoring system:
    a. Severe sites = 1 SCORE = 1
    b. Severe sites = 2 SCORE = 2
    c. Severe sites = 3 SCORE = 3
    d. Severe sites >= 4 SCORE = 4
7. Streambank erosion. Used streambank erosion inventory information from WMP, used the following scoring system:
    a. Severe sites = 1 SCORE = 1
    b. Severe sites = 2 SCORE = 2
    c. Severe sites = 3 SCORE = 3
    d. Severe sites >= 4 SCORE = 4

8. Poor greenbelts (GB). Used shoreline survey information from WMP, used the following scoring system:
    a. Poor GB >= 5 parcels and < 10 SCORE = 1
    b. Poor GB >= 10 parcels and < 20 SCORE = 2
    c. Poor GB >= 20 parcels and < 30 SCORE = 3
    d. Poor GB >= 30 SCORE = 4
9. Shoreline erosion. Used shoreline survey information from WMP, used the following scoring system:
    a. Severe erosion >= 2 parcels and <= 4 SCORE = 1
    b. Severe erosion > 4 parcels and <= 7 SCORE = 2
    c. Severe erosion > 7 parcels and <= 10 SCORE = 3
    d. Severe erosion > 10 SCORE = 4
10. Shoreline nutrient pollution. Used shoreline survey information from WMP (strong indicators = heavy algae growth ratings including MH, H, and VH; as well as septic leachate detector strong signals), used the following scoring system:
    a. Strong indicators >= 5 parcels and < 10 SCORE = 1
    b. Strong indicators >= 10 parcels and < 20 SCORE = 2
    c. Strong indicators >= 20 parcels and < 30 SCORE = 3
    d. Strong indicators >= 30 SCORE = 4
11. Steep slopes. Used slope maps made with digital elevation models, used the following scoring system:
    a. Slopes >= 20 and < 30% SCORE = 1
    b. Slopes >= 30 and < 35% SCORE = 2
    c. Slopes >= 35 and < 40% SCORE = 3
    d. Slopes >= 40 SCORE = 4
12. Water quality impairments. Compiled water quality information from all sources were used to perform this assessment, though only data from 1990 to present was used. Poor water quality indicators used for this assessment include: dissolved oxygen < 7 mg/L; pH < 6.5 and > 9.0; total phosphorus > 30 ug/L; total nitrogen > 500 ug/L; suspended solids > 40 mg/L; chloride > 30 mg/L; E. coli > 300 organisms/100 mL; and macroinvertebrate community rating = poor.
    a. Poor WQ indicators >= 2 parcels and < 5 SCORE = 1
    b. Poor WQ indicators >= 5 parcels and < 10 SCORE = 2
    c. Poor WQ indicators >= 10 parcels and < 15 SCORE = 3
    d. Poor WQ indicators >= 15 SCORE = 4

A final GIS map was created to visualize the different areas deemed critical and in need of restoration. The results will help to prioritize management efforts within the Black Lake Watershed. The criteria that was omitted during the ranking process was forestry activity due to performing only a desktop analysis. Agricultural activities were included even though ground truthing is needed as high priority sites were identified from the desktop analysis.

Chapter 4: Results

Social Indicator Survey

Surveyed Population Information

The Black Lake Watershed Resident Social Indicator Survey was available online from June 16, 2023 through September 30th, 2023. The survey garnered 42 individual responses.

The surveyed population demographics are compared to the demographics of the Black Lake Watershed counties in Table 4.1, indicating a significantly more educated, older subsection of the watershed resident population, although a similar racial breakdown. When asked if the surveyed individuals made the home and lawn care decisions in their household, 85% responded “yes.” The large majority (72.5%) do not utilize professional lawn care services. The majority (59%) of respondents live in an isolated, rural, non-farm residence (Table 4.2). When asked where they seek information regarding water quality issues, most survey respondents selected internet and newsletters/brochures/factsheets, providing guidance for the best strategies TOMWC can communicate information (Table 4.3).

Table 4.1. Demographic Comparison between Surveyed Populations (highlighted) and Counties in the Black Lake Watershed

Demographics	Surveyed Population	Otsego County	Montmorency County	Presque Isle County	Cheboygan County
Age	63.5	44.8	56	55.7	51.6
Race (Percentage of White People)	94.70%	95.80%	96.20%	96.20%	92.50%
Education (Bachelor's Degree or higher)	87.10%	26.80%	14.30%	19.20%	22.70%

Table 4.2. Location of Residences of the Surveyed Population with Predominant Location Highlighted

Location of Residence	Percentage of Surveyed Population
In an isolated, rural, non-farm residence	59%
Rural subdivision or development	25.6%
In a town, village, or city	15.4%
On a farm	0%

Table 4.3. Sources that Survey Respondents Seek for Water Quality Issue Information with Top Sources Highlighted

Source	Percent of responses
Internet	70%
Newsletters/Brochures/Factsheet	63%
Workshops/demonstrations/meetings	32.5%
Conversations with others	30%
Newspapers/magazines	27.5%
Radio	2.5%
None of the above	2.5%

Survey Results

48.8% of the surveyed population rated the current health of the Black Lake Watershed as "Good" and 24.4% stated "Very good," resulting in the large majority believing the watershed is in good health. Yet when asked what is the trend for conditions in the Black Lake Watershed, 58.5% claimed the watershed was "Slowly worsening," indicating significant concern for the future of the watershed.

Surveyed Population Awareness

Consequences of Poor Water Quality

The "Consequences of Poor Water Quality" section asked participants to rank various consequences on a scale ranging from "Not a Problem" (1) to "Severe Problem" (3). The consequences of poor water quality that were perceived to be the most severe problems in the

Black Lake Watershed were excessive aquatic plants or algae and the loss of desirable fish species (Table 4.4). Polluted swimming areas and contaminated drinking water were ranked as the least problematic consequences of poor water quality.

Table 4.4. Survey Respondents' Mean Scores of the Potential Consequences of Poor Water Quality in the Black Lake Watershed

Potential Consequence of Poor Water Quality	Mean	SD
Excessive aquatic plants or algae	2.66	0.91
Loss of desirable fish species	2.55	1.03
Reduced beauty of lakes or streams	1.86	0.91
Reduced opportunities for water recreation	1.81	0.91
Contaminated fish	1.65	0.94
Polluted swimming areas	1.55	0.79
Contaminated drinking water	1.32	0.75

Water Impairments

The "Water Impairments" perceived to pose the greatest threat to the Black Lake Watershed were phosphorus and invasive aquatic plants while Salt, TDS, Chlorides, and trash or debris were deemed to pose the lowest threat to water quality (Table 4.5).

Table 4.5. Survey Respondents' Mean Scores of the Potential Water Impairments in the Black Lake Watershed

Water Impairments	Mean	SD
Phosphorus	3	0.82
Invasive aquatic plants and animals	2.92	0.84
Algae in the water	2.79	0.77
Habitat alteration harming local fish	2.77	0.99
Nitrogen	2.61	0.78
Sedimentation (dirt and soil) in the water	2.28	0.89
Toxic materials in the water	2.1	1.02
Bacteria and viruses in the water (such as E.coli / coliform)	2.04	0.92
Salt / TDS / Chlorides	1.81	0.98
Trash or debris in the water	1.79	0.81

Sources of Water Pollution

The most problematic sources of water pollution from the surveyed population's perspective were the excessive use of lawn fertilizers and/or pesticides and improperly maintained septic systems while the least problematic sources were discharges from industries into lakes and streams and discharges from sewage treatment plants.

Table 4.6. Survey Respondents' Mean Scores of the Potential Sources of Water Pollution

Potential Sources of Water Pollution	Mean	SD
Excessive use of lawn fertilizers and/or pesticides	2.88	0.93
Improperly maintained septic systems	2.84	0.86
Droppings from geese, ducks and other waterfowl	2.79	0.87
Removal of riparian vegetation	2.66	0.9
Soil erosion from shorelines and/or streambanks	2.61	0.9
Yard maintenance	2.57	1.04
Septic disposal	2.43	1.07
Drainage/filling of wetlands	2.31	1.04
Land development or redevelopment	1.97	0.9
Soil erosion from farm fields	1.94	0.93
Street salt and sand	1.84	0.93
Stormwater runoff from rooftops and/or parking lots	1.84	0.82
Stormwater runoff from streets and/or highways	1.83	0.95
Littering/illegal dumping of trash	1.65	0.88
Soil erosion from construction sites	1.63	0.76
Discharges from industry into streams and lakes	1.6	0.97
Discharges from sewage treatment plants	1.53	0.88

Practices to Improve Water Quality

Measuring awareness through one final focal point, the "Practices to Improve Water Quality" survey section asked participants about their level of experience with various practices that improve water quality. The most used practices were following the manufacturer's instructions when fertilizing a lawn or garden and following pesticide application instructions for a lawn or garden, yet many practices were deemed familiar to the participants, garnering many high mean scores (Table 20). The least used practices were using porous pavement and creating a rain garden.

Table 4.7. Survey Respondents' Mean Scores of the Practices to Improve Water Quality in the Black Lake Watershed

Practices to Improve Water Quality	Mean	SD
Following the manufacturer's instructions when fertilizing lawn or garden	3.52	0.58
Follow pesticide application instructions for lawn and garden	3.48	0.59
Plant trees/shrubs	3.34	0.79
Use phosphate free fertilizer	3.33	0.66
Restore native plant communities	3.24	0.91
Plant vegetated riparian buffer	3.03	1.05
Use rain barrels	2.81	0.49
Use porous pavement	2.79	1.18
Create a rain garden	2.03	1.03

Surveyed Population Attitudes and Willingness to Take Action

Water Quality Related Attitudes

To determine water quality related attitudes, participants were asked to determine their level of agreement with each water quality related statement (Table 4.8). Notably, participants agreed most with the following statements: "The way that I care for my lawn and yard can influence water quality in local streams and lakes," "The quality of life in my community depends on good water quality in local streams, rivers and lakes," "Using recommended management practices on farms improves water quality," and "It is my personal responsibility to help protect water quality." These statements indicate attitudes and desires to protect the local ecosystem and watershed at large. The statement "I would be willing to pay more to improve water quality (for example: through local taxes or fees)" garnered the lowest mean score, indicating negative attitudes toward monetary investments into improving water quality.

Table 4.8. Water Quality Related Attitudes in the Black Lake Watershed

Statements to Determine Water Quality Related Attitudes	Mean	SD
The way that I care for my lawn and yard can influence water quality in local streams and lakes.	4.75	0.44
The quality of life in my community depends on good water quality in local streams, rivers and lakes.	4.72	0.55
Using recommended management practices on farms improves water quality.	4.7	0.46
It is my personal responsibility to help protect water quality.	4.7	0.46
My actions have an impact on water quality.	4.65	0.48
It is important to protect water quality even if it slows economic development.	4.5	0.64
I would be willing to change the way I care for my lawn and yard to improve water quality.	4.35	0.74
I would be willing to change management practices to improve water quality.	4.23	0.78
I would be willing to pay more to improve water quality (for example: though local taxes or fees)	3.77	1.01

Willingness to Take Action

94.3% of the participants are willing or already practice regular septic system servicing while 97.2% of the participants indicated that they are already or willing to try proper septic sizing (Table 4.9).

Table 4.9. Willingness to Try Regular Septic System Servicing in the Black Lake Watershed

Willingness to Try Regular Septic System Servicing	Percent of Surveyed Participants
Yes or already do	94.30%
Maybe	5.70%
No	0%

Table 4.10. Willingness to Try Proper Septic System Sizing in the Black Lake Watershed

Willingness to Try Proper Septic Sizing	**Percent of Surveyed Participants**
Yes or already do	97.20%
Maybe	2.80%
No	0%

Surveyed Population Constraints to Behavior Change and Adopting Key Practices

Constraints to Behavior Change

"Concerns about resale value" and "Approval of my neighbors" proved to be the largest constraints to behavior change, while "Personal out-of-pocket expenses" was the lowest, indicating that the financial burden of behavior change is not constraining the respondents' behavior.

Table 4.11. Potential Constraints to Behavior Change in the Black Lake Watershed

Potential Constraint to Behavior Change	**Mean**	**SD**
Concerns about resale value	3.76	0.63
Approval of my neighbors	3.69	0.79
The need to learn new skills or techniques	3.53	0.89
Not being able to see a demonstration of the practice before I decide	3.53	0.88
Don't know where to get information and/or assistance about those practices	3.51	0.74
No one else I know is implementing the practice	3.51	0.8
Environmental damage caused by practice	3.42	1.09
Lack of available information about a practice	3.21	0.95
My own physical abilities	3.05	1.11
Not having access to the equipment that I need	3.03	1.08
Personal out-of-pocket expense	2.8	1.14

Specific Constraints to Adopting Key Practices

For both regular septic system servicing and proper septic system sizing, participants were asked if there were any barriers that limited their ability to implement each practice. The largest constraints to regular septic system servicing were the “Physical or health limitations” and that the practice is “Hard to use with my farming system”, while “Cost” and “Don’t know how to do it” were determined to be the smallest constraints (Table 4.12). The practice of proper septic system sizing shared the same largest constraints (Table 4.13), while “Cost” and “The features of my property make it difficult” were the two smallest constraints.

Table 4.12. Specific Constraints to Regular Septic System Servicing in the Black Lake Watershed

Specific Constraints to Regular Septic System Servicing	Mean	SD
Physical or health limitations	3.97	0.17
Hard to use with my farming system	3.97	0.18
Insufficient proof of water quality benefit	3.86	0.52
Desire to keep things the way they are	3.84	0.52
The features of my property make it difficult	3.81	0.54
Lack of equipment	3.81	0.64
Time required	3.79	0.54
Don't know how to do it	3.78	0.59
Cost	3.45	0.87

Table 4.13. Specific Constraints to Proper Septic System Sizing in the Black Lake Watershed

Specific Constraints to Proper Septic System Sizing	Mean	SD
Hard to use with my farming system	3.97	0.18
Physical or health limitations	3.81	0.64
Insufficient proof of water quality benefit	3.74	0.77
Lack of equipment	3.7	0.75
Desire to keep things the way they are	3.68	0.83
Time required	3.68	0.79
Don't know how to do it	3.68	0.79
The features of my property make it difficult	3.59	0.95
Cost	3.38	1.05

Social Indicator Score Comparison

Following this, we compare the social indicator scores demonstrated by the 2023 Black Lake Watershed Residents with the social indicator scores demonstrated by the 2016 Elk River Chain of Lakes (ERCOL) Watershed Residents. These two watershed communities were surveyed using very similar Social Indicator Surveys with the same Social Indicator Criteria, making this an effective comparison. This comparison creates a scale by which readers can understand the social indicator scores and provides readers with an increased level of context.

Notably, the Black Lake Watershed Residents received lower social indicator scores than the ERCOL Watershed Residents in three of the four awareness criteria, indicating a gap in the Black Lake Watershed Residents' awareness. Aside from awareness, the Black Lake Watershed Residents scored high indicator scores compared to the ERCOL Watershed Residents in attitudes and willingness to take action category and in the constraints to behavior change and adopting key practices category (Table 4.14).

Table 4.14. Social Indicator Score Compared Between Black Lake and ERCOL Watershed Resident Surveys

Social Indicator Category	**Social Indicator Criteria**	**Black Lake Watershed Residents**	**ERCOL Watershed Residents**
Awareness	Consequences of Poor Water Quality	1.26	1.34
	Water Impairments	1.48	1.53
	Sources of Water Pollution	1.54	1.55
	Practices to Improve Water Quality	1.89	1.79
Attitudes and Willingness to Take Action	Water Quality- Related Attitudes	4.49	4.11
	Willingness to Take Action	1.98	1.76
Constraints to Behavior Changes and Adopting Key Practices	Constraints to Behavior Change	3.36	3.11
	Constraints to Adopting Key Practices	3.75	3.58

Surveyed Population Trusted Sources of Information

As a final, closed-ended question, participants were asked to share their level of trust in a variety of information sources, which helps to inform the best information mediums to use throughout the development of the BLWMP. Participants placed significant trust in the TOMWC, Local Lake Associations, Soil and Water Conservation District, the U.S. Environmental Protection Agency, and University Extension and little trust in Lawn Care Companies and Local Community Leaders (Table 4.15). The high level of trust in TOMWC and Local Lake Associations may have been influenced by the methods of survey distribution. The survey was distributed by TOMWC and shared through Local Lake Associations, perhaps creating a more biased sample of survey respondents.

Table 4.15. Respondents' Trust in Information Sources where the mean score indicates trust level in descending order

Information Source	Mean Score
Tip of the Mitt Watershed Council	3.27
Local Lake Associations	3.25
Soil and Water Conservation District	3.17
U.S. Environmental Protection Agency	3.12
University Extension	3.11
Black Lake Watershed Advisory Committee	3.06
State agricultural agency	2.81
State environmental agency	2.85
Environmental groups	2.71
Local government	2.5
Local tribes	2.46
Local garden center	2.21
Local community leader	2.1
Lawn care company	1.87

Lastly, survey respondents had the opportunity to share additional thoughts, comments, and concerns at the end of the survey. Individuals mentioned a variety of topics including harmful algal blooms, poor septic maintenance and inability to access septic system information, run-off and application of lawn care chemicals, and the communication disconnect that can occur from a seasonal watershed resident population. To see the Open Comments, please see Appendix 8.

Road/Stream Crossings (RSX)

Pollutant potential is high at RSXs and increases when their condition deteriorates. When structures, such as culverts, bridges, and fords, begin displaying signs of failure, such as structural problems due to improper installation, all aspects of fluvial ecosystems have the potential to be impacted. Pollution that exists as a result of poor RSX conditions pose health effects to aquatic organisms and has the possibility of introducing metals, bacteria, excessive nutrients, and other nonpoint source pollutants into surrounding streams. Increased sedimentation because of crossings poses the greatest threat to fluvial ecosystems as it worsens water quality as well as impacts the overall habitat.[37] Monitoring RSXs and updating inventories are critical to watershed management to further understand the risks that fluvial ecosystems are exposed to. Information retained from these inventories helps identify sediment pollution that may be entering nearby waterways. Consistently updating these inventories allows for officials to document any changes that may have occurred over time.

Over 200 RSX sites have been identified within the Black Lake Watershed using the Great Lakes Stream Crossing Dashboard, however of these there were only 165 total sites that contained usable data (Figure 4.2). Usable data means that the Great Lakes Stream Crossing Inventory Protocol was followed when updating sites. Sites are assigned a severity ranking reflecting erosion, pollution potential, and fish passage, automatically calculated based on built-in formulas within the Survey123 app. Of the 165 sites, 64 (38.8%) were considered "minor" severity, 73 (44.2%) were considered "moderate" severity, and 28 (17%) were considered "major" severity. Out of 165 sites, 25 are considered "time sensitive" and should have immediate attention. "Time sensitive" is subjective and manually input into the Survey123 form. Reasoning may be due to possible obstructions to the structure, failing roadways, dangerous risks such as power lines in the stream, the presence of HABs, low fish passage, etc.

Figure 4.1. Examples of RSXs visited

[37] Road & Stream Crossings. *Tip of the Mitt Watershed Council*. Retrieved November 25, 2023, from https://watershedcouncil.org/our-work/watershed-protection/fish-passage/crossings/

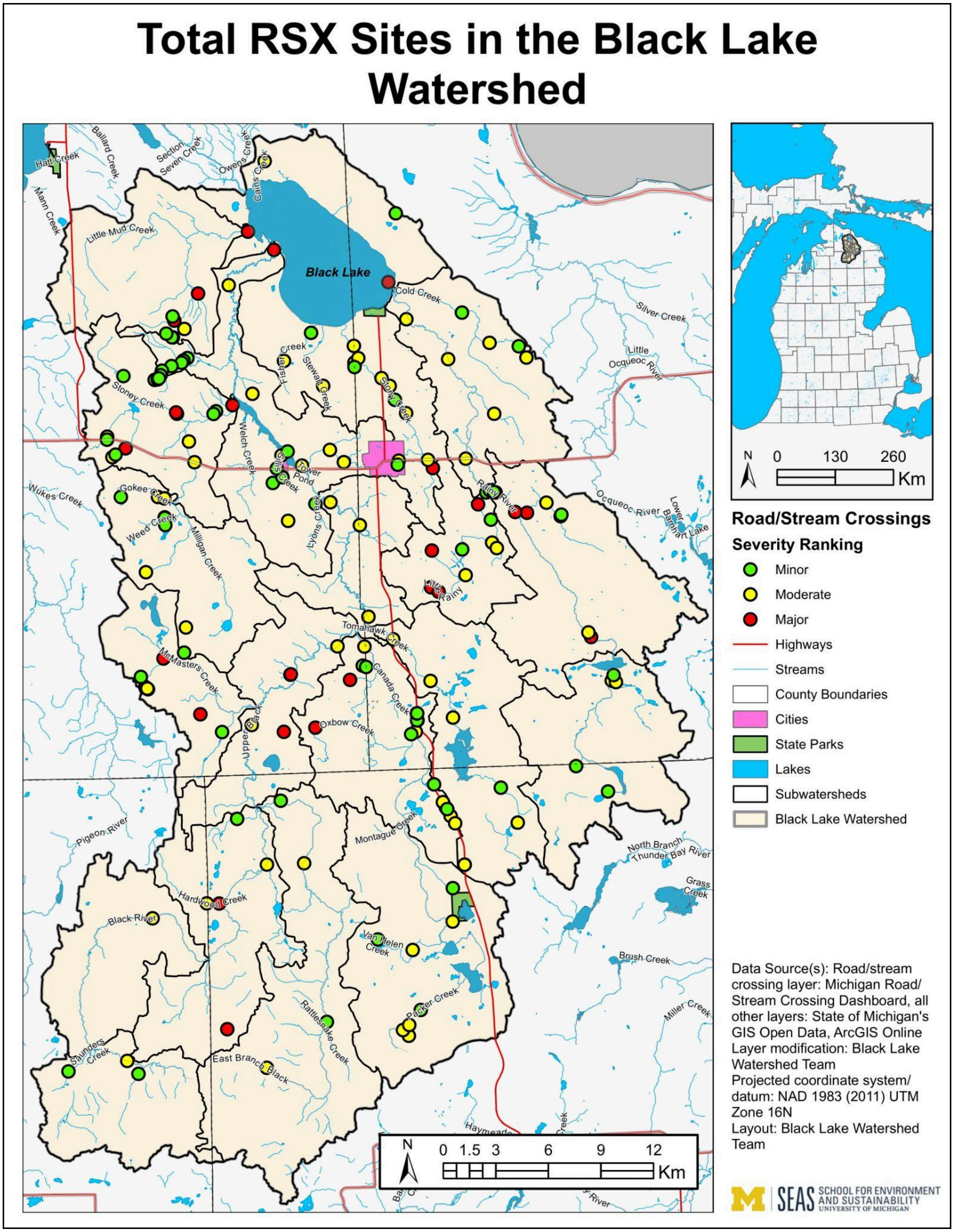


Figure 4.2. All RSX Sites (old and new data) within the Black Lake Watershed

Table 4.16. Number of RSX Sites within the Subwatershed of the Black Lake Watershed for each RSX Severity Ranking (old and new data)

	Road/Stream Crossing Severity Ranking			
Subwatershed	Minor	Moderate	Major	Total
Black Lake**	5	11	3	19
Bowen Creek-Black River**	11	7	1	19
Milligan Creek**	9	4	4	17
Canada Creek**	8	4	2	14
Tomahawk Creek	2	9	0	11
East Brank Rainy River-Rainy River**	4	3	3	10
Little Rainy River**	3	3	4	10
Gokee Creek-Black River	5	4	0	9
Cold Creek-Rainy River**	2	6	0	8
Montague Creek-Canada Creek**	3	5	0	8
McMasters Creek**	2	2	3	7
Mud Creek**	2	2	3	7
Rainy Lake-Rainy River	3	2	0	5
Silver Lake-Black River	0	2	3	5
Stewart Creek-Black River	1	2	2	5
East Branch Black River**	2	2	0	4
Butler Creek-Black River	0	3	0	3
Saunders Creek-Black River**	2	1	0	3
Round Lake-Black River	0	1	0	1
All Subwatersheds	**64**	**73**	**28**	**165**

**Note: two asterisks denote subwatersheds that contain time sensitive sites
***Note: “severe” rankings were an option for severity rankings; for simplicity of this project, “severe” rankings were joined with “major” rankings

RSX Sites Visited

Only 39 of the total 200 RSX sites were visited based on the criteria laid out in the methods section. Of these sites, 35 were able to be successfully updated and were located in 11 of the 19 total subwatersheds. Of the 35 sites, 15 were considered “minor” severity (42.9%), 9 were considered “moderate” severity (25.7%), and 11 were considered “major” severity (31.4%) (Figure 4.3). 25 of the 35 sites visited changed from their previous ranking from the last time they were surveyed (71%). Of the 25, 19 decreased in severity (76%) while 6 increased in severity (24%) (Table 4.17). The change in ranking is reflected by the colors indicated in the table. Grey sites did not change in ranking, green sites decreased in severity ranking, and red sites increased in severity ranking. 18 of the 35 sites were still deemed time sensitive after further analysis of the collected data.

Table 4.17. Comparison of Site Rankings Before and After Revisiting

	Road/Stream Crossing Severity Ranking	
Site ID	**Previous Ranking**	**Current Ranking**
Snake Trail #2**	Major	Major
Logging road south of 68**	Major	Minor
CC04	Major	Moderate
CC06	Moderate	Major
Clark bridge fields access rd	Major	Major
ER01.5	Major	Minor
KC01	Major	Minor
LR00.75	Major	Major
LR01	Moderate	Minor
LR02.7	Moderate	Moderate
LR04	Moderate	Major
LR04.5	Moderate	Major
MB09.5	Major	Major
MB09.7	Major	Minor
MB10.2	Major	Moderate

MB10.3	Major	Moderate
MB10.5	Moderate	Major
MB21	Major	Moderate
MB24	Moderate	Minor
MB26	Moderate	Minor
MB33	Major	Moderate
MC08	Moderate	Minor
MC09	Minor	Minor
RR02	Moderate	Moderate
RR09	Moderate	Major
RR11	Moderate	Minor
SC03	Moderate	Moderate
SC04	Major	Moderate
SC05A	Major	Minor
SC05B	Major	Major
SC08	Moderate	Minor
SC10	Moderate	Major
SC15	Major	Minor
SC16	Moderate	Minor
URB LR03	Minor	Minor

**Note: asterisks denote sites where there was no Site ID and the Crossing Name was used instead

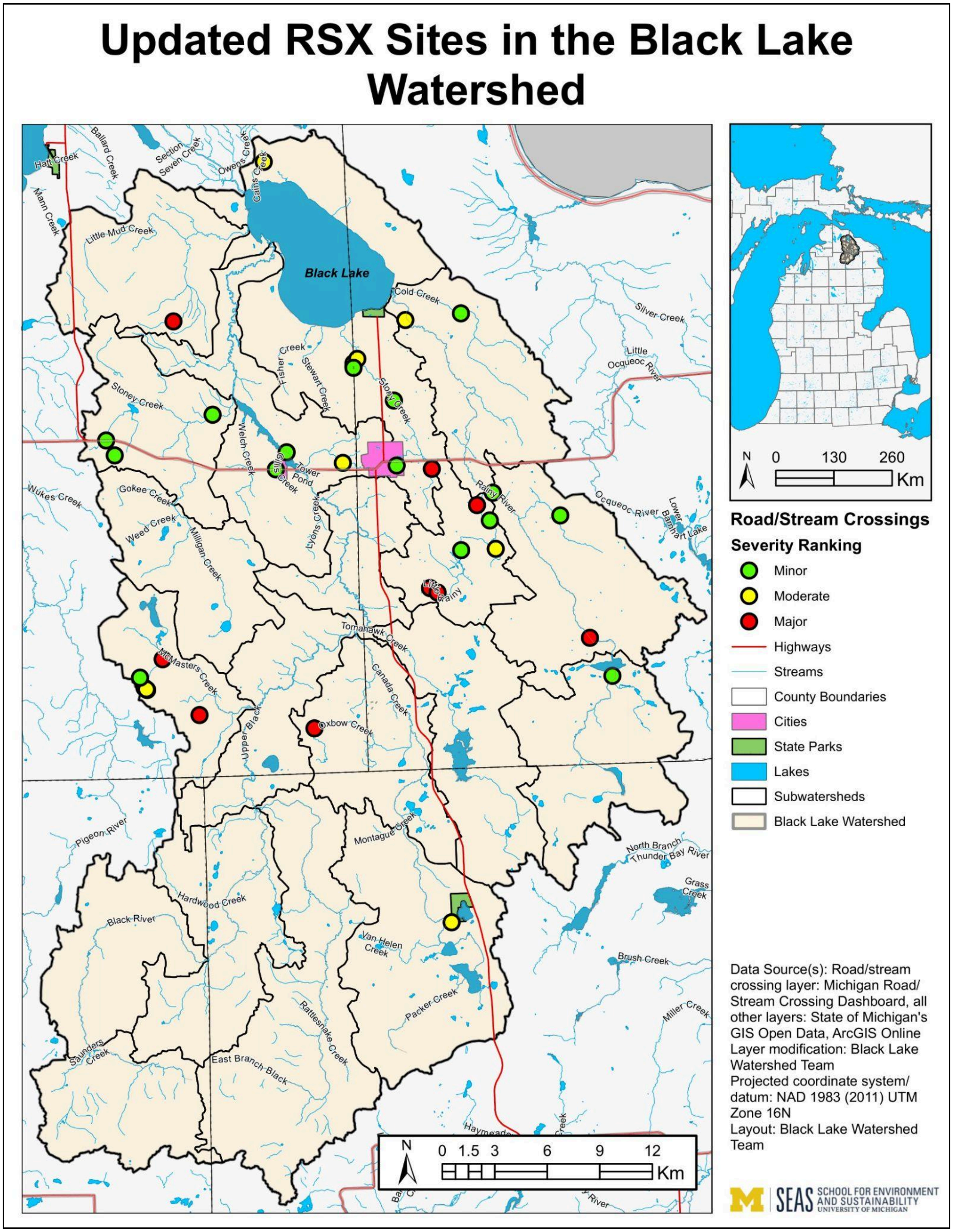


Figure 4.3. RSX Sites within the Black Lake Watershed that were Updated in 2023

Table 4.18. RSX Sites Updated in 2023

	Road/Stream Crossing Severity Ranking			
Subwatersheds	Minor	Moderate	Major	Total
Black Lake**	3	3	2	8
Little Rainy River**	2	1	3	6
McMasters Creek**	1	2	3	6
Bowen Creek-Black River**	2	1	0	3
East Branch Rainy River**	2	0	1	3
Milligan Creek**	3	0	0	3
Cold Creek-Rainy River**	1	1	0	2
Canada Creek**	0	0	1	1
Montague Creek-Canada Creek	0	1	0	1
Mud Creek**	0	0	1	1
Rainy Lake-Rainy River	1	0	0	1
All Subwatersheds	**15**	**9**	**11**	**35**

**Note: asterisks denote subwatersheds that contain time sensitive sites
***Note: "severe" rankings were an option for severity rankings; for simplicity of this project, "severe" rankings were joined with "major" rankings

RSXs are imperative to the survival of aquatic species. Because of the risks that impacted crossings pose towards aquatic life, i.e. interfering with travel, mating, resource availability, and risk to additional dangers, fish passage is recorded to determine aquatic organisms' ability to freely move amongst the site. These variables at a site are measured and given fish passage scores. Scores can be interpreted as follows: "0" = most species and life stages cannot pass at most flows; "0.5" = some species and life stages cannot pass at most flows; "0.9" = barrier at high flows; "1" = not a barrier. Of the 35 RSX sites visited, only 11.4% of sites posed no barrier at any time. 34.3% of the time there was a barrier at high flows, with over half (54.3%) threatening some or all species from passing regardless of flow (Table 4.18).

Table 4.19. Fish Passage Score Rankin of RSX Sites Updated in 2023

	Fish Passage Scores			
Subwatershed	Score: 0	Score: 0.5	Score: 0.9	Score: 1
Black Lake	2	4	2	0
Little Rainy River	1	0	5	0
McMasters Creek	3	2	1	0
Bowen Creek-Black River	0	0	2	1
East Branch Rainy River	0	1	2	0
Milligan Creek	1	1	0	1
Cold Creek-Rainy River	1	0	0	1
Canada Creek	0	0	0	1
Montague Creek	1	0	0	0
Mud Creek	1	0	0	0
Rainy Lake-Rainy River	1	0	0	0
All Subwatersheds	**11**	**8**	**12**	**4**

Pollutant loading estimates (Sediment Tons/yr) were automatically generated within the Survey123 app for the Great Lakes Road/Stream Crossing Inventory. Pollutant loading estimates for Phosphorus lbs/year were calculated by applying an overall phosphorus concentration of 0.0005 lbP/lb of soil. Pollutant loading estimates for Nitrogen lbs/year were calculated by applying an overall nitrogen concentration of 0.001 lbN/lb of soil. The texture of soil influences the nutrient holding capacity, therefore to better estimate pollutant loadings of phosphorus and nitrogen, a correction factor of 0.85 was used to represent the dominant soil texture (sand/silty loam).[38] Notably, the Little Rainy River subwatershed had the highest pollutant loading and the Gokee Creek-Black River subwatershed had the second highest. The Round Lake-Black River subwatershed reported no pollutant loadings (Table 13).

[38] Streambank Erosion. *NRCS, WI.* Field Office Technical Guide.

Table 4.20. Pollutant Loading for all RSX Sites within Subwatersheds in the Black Lake Watershed

	Pollutant Loading Estimate		
Subwatershed	Sediment tons/yr	Phosphorus lb/yr	Nitrogen lb/yr
Little Rainy River	52	44	88
Gokee Creek-Black River	40	34	67
Black Lake	35	29	59
Stewart Creek-Black River	27	23	46
Silver Lake-Black River	26	22	44
Bowen Creek-Black River	19	17	33
Milligan Creek	16	13	27
East Branch Rainy River-Rainy River	16	13	26
Canada Creek	14	12	24
Tomahawk Creek	14	12	24
Montague Creek-Canada Creek	12	10	21
Cold Creek-Rainy River	11	9	19
East Branch Black River	11	9	18
Mud Creek	6	5	10
McMasters Creek	5	4	8
Saunders Creek-Black River	4	4	7
Butler Creek-Black River	2	2	3
Rainy Lake-Rainy River	2	2	3
Round Lake-Black River	0	0	0
Total	**312**	**264**	**527**

Factor Analysis of Mixed Data (FAMD)

The FAMD helped to visualize and understand the relationship between invasive species abundance and other variables. The most prominent features of an FAMD are its “dimensions.” Dimensions are variables that are otherwise not accounted for within the dataset but still contribute to it, such as weather conditions and temperature. The purpose of dimensions is to explain variance in a dataset. FAMD is a multivariate statistical analysis that compares possible associations between quantitative and qualitative variables of a dataset. As mentioned in the methods section, data that we collected at RSX sites were tabulated and specific measured variables were included in the FAMD analysis (such as the invasive species abundance, the water velocity, the size of the structure, etc.). The full study can be accessed in Appendix 10. A scree plot was initially created to identify the dimensions that most explained the variability (Figure 4.4). In simple terms, Dim (dimension) 1 is able to explain 26.55% of the variance within the RSX data and Dim 2 is able to explain roughly 16.04%.

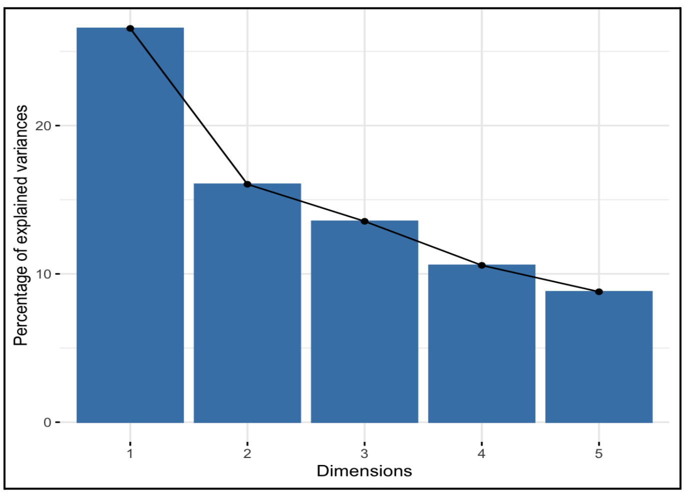


Figure 4.4. Five dimensions and their associated percentage of the variability in they explain in the RSX data

Figure 4.5 displays all of the variables, both categorical and continuous. It can be seen that Structure.Height contributes the most to Dim 1 and Road.Condition contributes the most to Dim 2. When a variable “contributes” to a dimension, it is explaining how much it accounts for the variation within the data. Invasive.Species appears to contribute nearly the same to Dim 1 as it does Dim 2, meaning there are possible relationships between both dimensions.

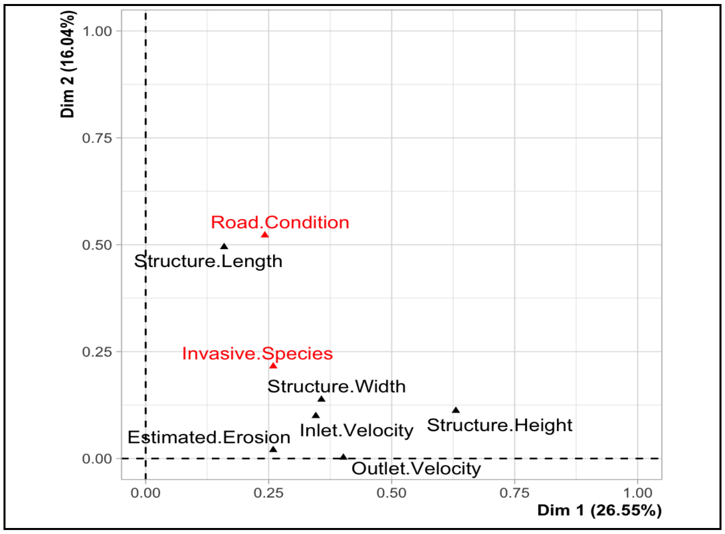


Figure 4.5. Graph of categorical (red: road condition and invasive species abundance) and continuous (black: structure length, width, height, estimated erosion, and inlet/outlet velocity) variables.

Figure 4.6 displays our two categorical variables and their rankings. The dashed lines help to visualize the separation between positive and negative contributions between variables. For example, the horizontal line helps separate what variables contribute positively or negatively to Dim 2, while the vertical line separates the variables that contribute positively or negatively to Dim 1. “Poor” road conditions appear to contribute the most to Dim 1 as well as “Good” road conditions and “Intermediate” and “High” species abundance. “Low” invasive species and “Fair” road conditions contribute negatively to Dim 1. “Low” invasive species abundance negatively contributes the most to Dim 2, however “Intermediate” invasive species also contributes negatively. “Fair” road conditions contribute positively along with “Good” road conditions and “High” invasive species to Dim 2. There is an almost linear relationship seen between the invasive species rankings in this figure in respect to the road conditions (despite the poor road condition) which means that there may be a possible interdependence between the two variables.

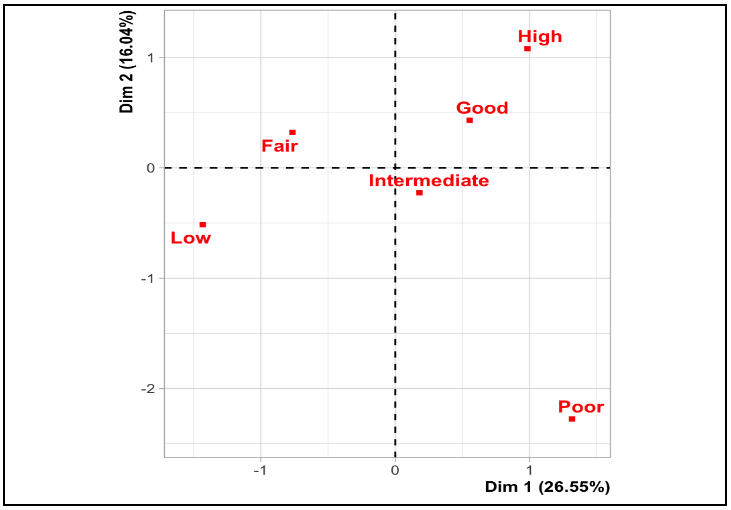


Figure 4.6. Graph of categorical variables (road condition and invasive species abundance)

The final figure (Figure 4.7) depicts the species abundance for each site. Clusters are based on invasive species abundance. Outliers exist for all clusters, but appear to be relatively close to their respective grouping. This graph represents the information depicted in Figure 4.6 but displays how the individual data points are positioned in respect to their invasive species abundance. “High” invasive species clusters contribute positively to Dim 1 as do “Intermediate” invasive species; however, “Low” invasive species contribute the most to Dim 2 (negatively to both Dim 2 and Dim 1). To conclude the analysis, it is apparent that the sites that were revisited have more characteristics in common than what someone would expect from reading the raw data (based on the created clusters), and that there is an obvious trend of similarity regarding invasive species abundance and other variables at RSX sites. This analysis helped determine that there may be an underlying pattern to invasive species abundance given that there are clusters of data formed in relation to the other documented characteristics of RSX sites (road condition, structure height, width, estimated erosion, etc.). The FAMD analysis was not necessary for our project, however it was completed for a previous course.

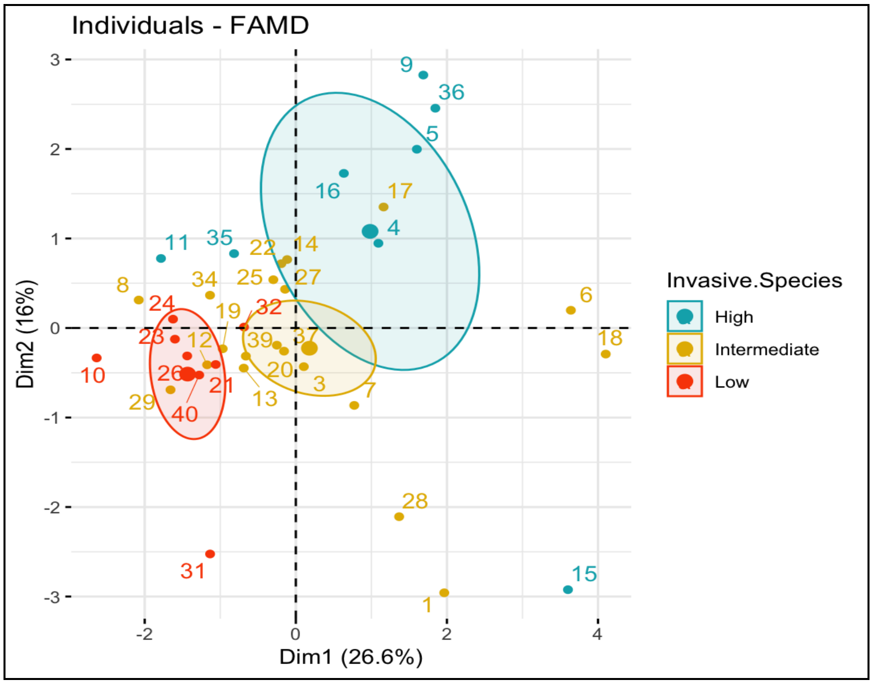


Figure 4.7. Individual data in respect to invasive species abundance

Forestry

As discussed in the methods section under Forestry, a desktop inventory was performed on forested areas within the Black Lake watershed. This inventory aimed to locate forested lands enrolled within management programs. The programs observed were the Qualified Forest Program (QFP) and the Commercial Forest Program (CFP). These are voluntary tax incentive programs for private landowners offered through the Michigan Department of Resources (MDNR). Information was collected from the Michigan Geographic Data Library as well as correspondence with MDARD.

Figure 4.8 presents all forest cover within the Black Lake watershed. The forest types range from deciduous, mixed and evergreen forest, accounting for 47% of the watershed's land cover.

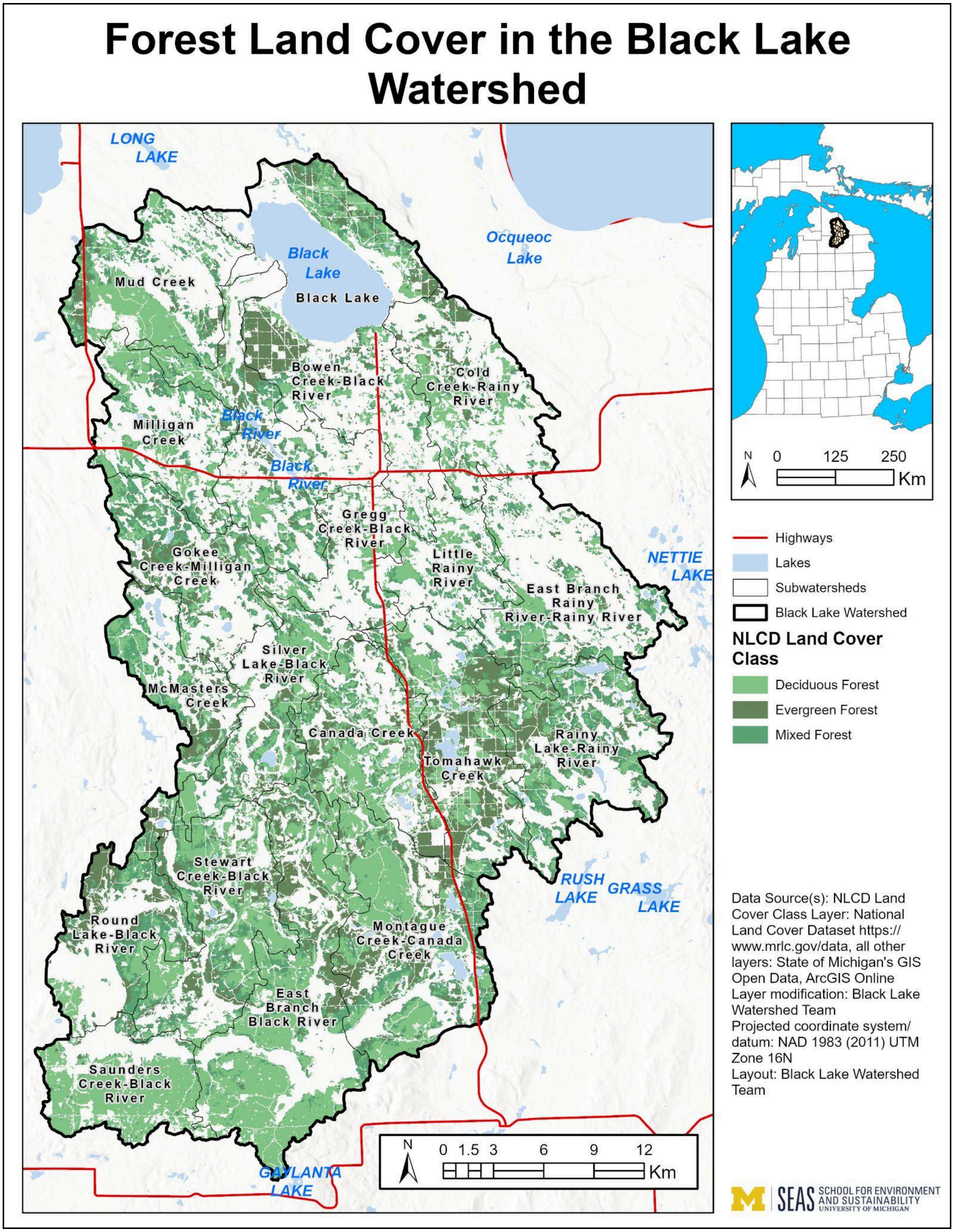


Figure 4.8. Forest Land Cover of the Black Lake Watershed

There are no national forest lands within the watershed, therefore only state parks were included. QFP and CFPs on private land account for 12,463.5 acres of the Black Lake Watershed. In total, CFPs, QFPs and state parks combined account for about 12,887 acres of managed forest land out of 165,000 acres of forest land cover. Therefore, 7.8% of all forested land is managed through those three indicators. The managed forest land can be found below in Table 4.21 and seen in Figure 4.9.

There are two state parks, Onaway State Park and Cheboygan State Park, in the counties of Montmorency (Cheboygan State Park) and Presque Isle (Onaway State Park), accounting for 423.7 acres managed by the DNR. The Commercial Forest Program accounted for 4.9% of the managed forest in Black Lake's watershed, which is 630.54 acres within 12 parcels in the southern end of the watershed. Qualified Forest Program accounted for 91.8% of the acres managed through the three program chosen. This is a sum of 11,832.97 acres of the forested land in the watershed.

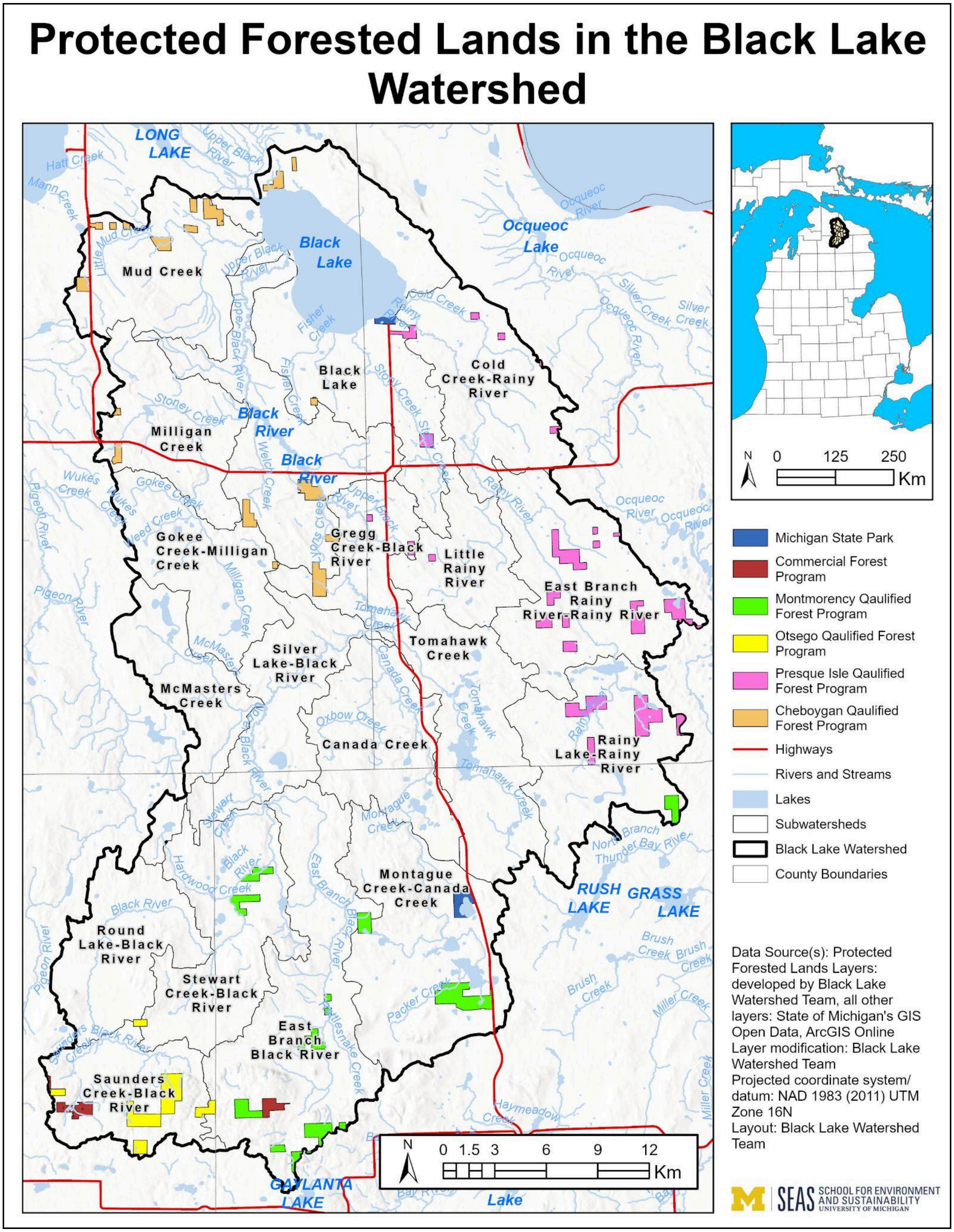


Figure 4.9. QFPs, CFP and state parks protected forest land in the Black Lake Watershed

Table 4.21. Management type, county, acres and parcels enrolled within the watershed

Form of Management	County	Acres	Parcels Enrolled	Total Acres Protected
State Park	Otsego	0	0	423.69
	Cheboygan	0	0	
	Montmorency	290.28	1	
	Presque Isle	133.41	1	
Qualified Forest Program	Presque Isle	4288.45	57	11832.97
	Cheboygan	2485.92	35	
	Otsego	1722.18	10	
	Montmorency	3336.42	49	
Commercial Forest Program	Presque Isle	0	0	630.54
	Cheboygan	0	0	
	Otsego	403.54	6	
	Montmorency	227	6	
Total Acres Protected within the watershed				**12887.2**

Stream Bank Erosion

Streambank erosion is a naturally occurring process that removes sediment and other materials from the bank of a stream. When this process is accelerated, the stream system can be altered and can have detrimental impacts on the health of the stream and the watershed as a whole[39]. The inventory conducted in the Black Lake Watershed provides insight into where streambank erosion is occurring and provides guidance on where targeted action can be taken to address pollutant loading from streambank erosion within the watershed. As stated in our methods, a desktop analysis of Fisher Creek, Stewart Creek and Stony Creek was performed and identified erosion spots along these creeks were visited along with the shoreline of the Upper Black River between Kleber Dam and Tower Pond.

Upper Black River

[39] Stream Bank Erosion and Control. (n.d.). WASHTENAW COUNTY CONSERVATION DISTRICT. Retrieved March 3, 2024, from https://www.washtenawcd.org/stream-bank-erosion-and-control.html

A total of 43 sites were identified to have erosion occuring along the Upper Black River between Tower Pond and Kleber Dam (Figure 4.10). Of these sites, a majority (72%) had 51-100% bank vegetation cover and 81% had an increasing problem trend (Figure 4.11). None of the sites along the Upper Black River had a decreasing problem trend, but eight of them had a stable problem trend. One or more streambank structures were present at 33 sites, with 24 having a dock and 15 having riprap present (Figure 4.12).

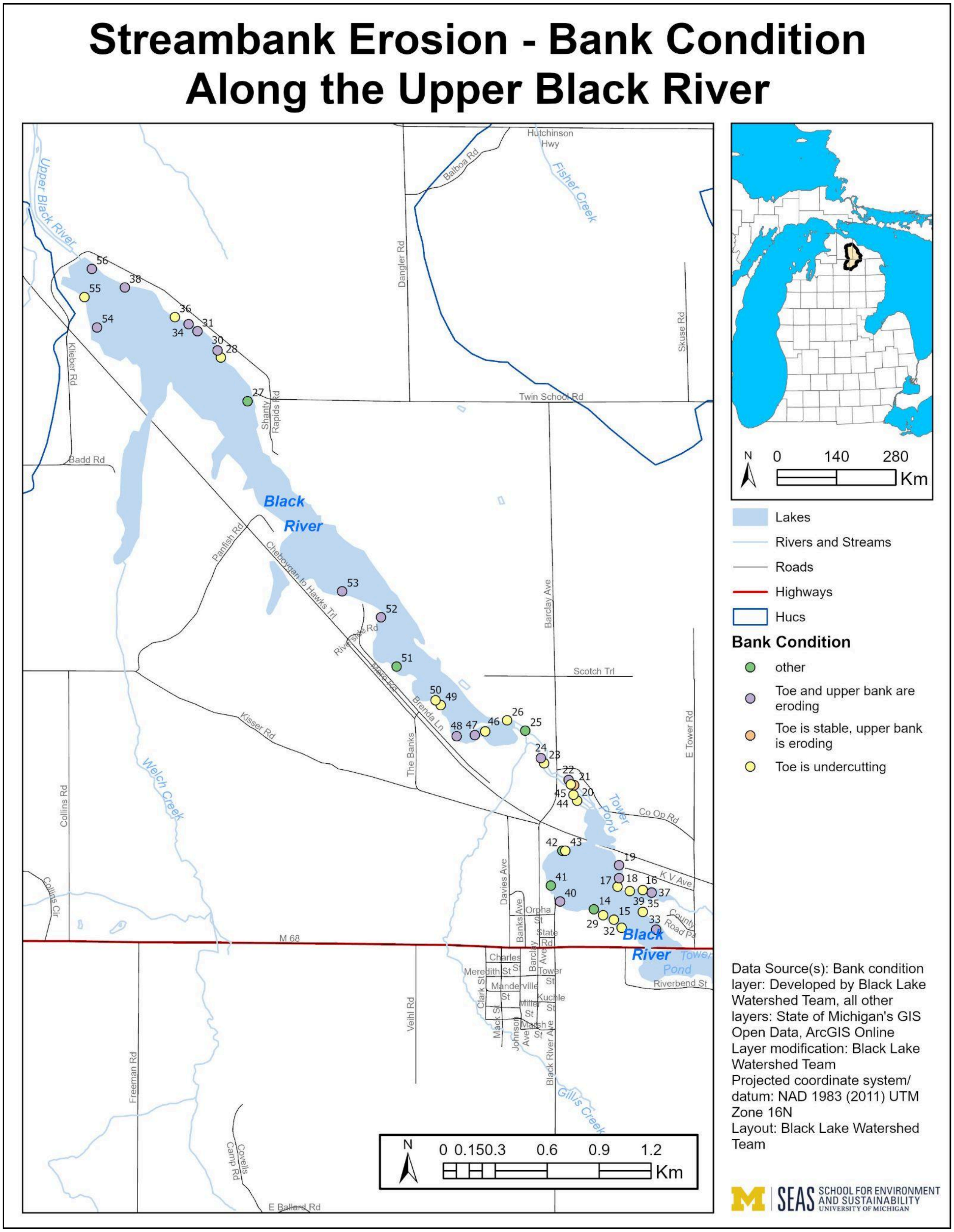


Figure 4.10. Bank condition for streambank erosion sites located along the Black River

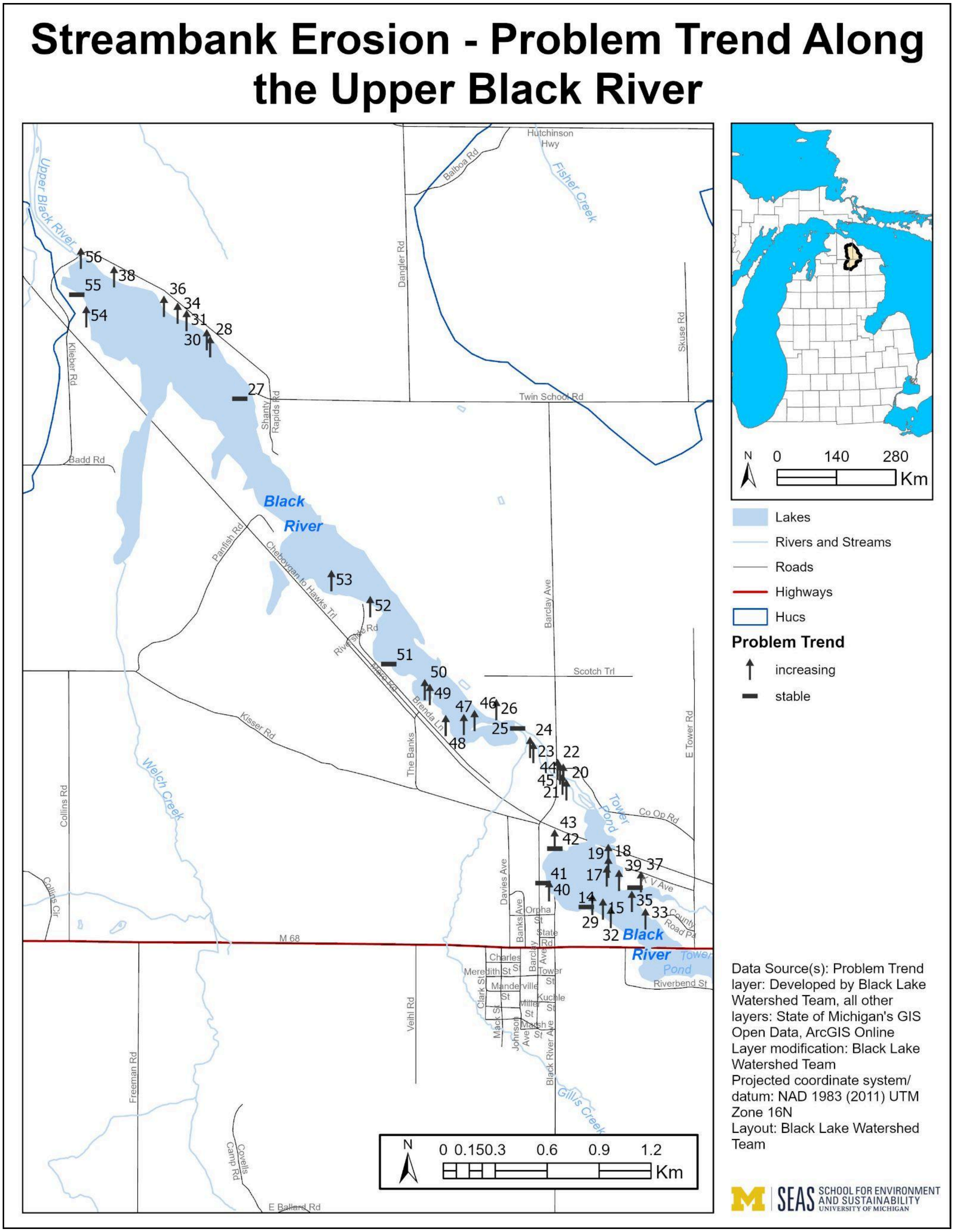


Figure 4.11. Bank condition for streambank erosion sites located along the Black River

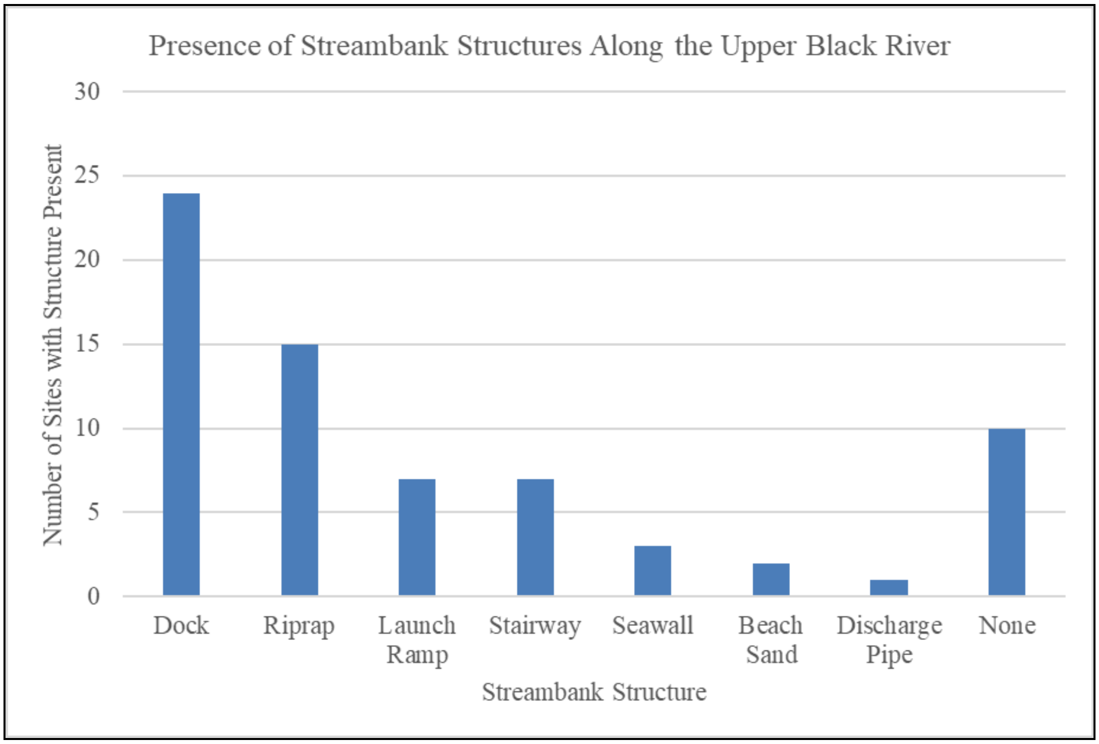


Figure 4.12. Presence of streambank structures at erosion sites along the Upper Black River

Greenbelt scores were given to all sites based on what percentage of the shoreline the greenbelt covered. For the purpose of this inventory, greenbelts were defined as a buffer of vegetation along the streambank between the water and shoreline development. The two most common scores were 0 (no greenbelt present) and 3 (extends 25-75% of shoreline) which 12 sites had (Figure 4.13).

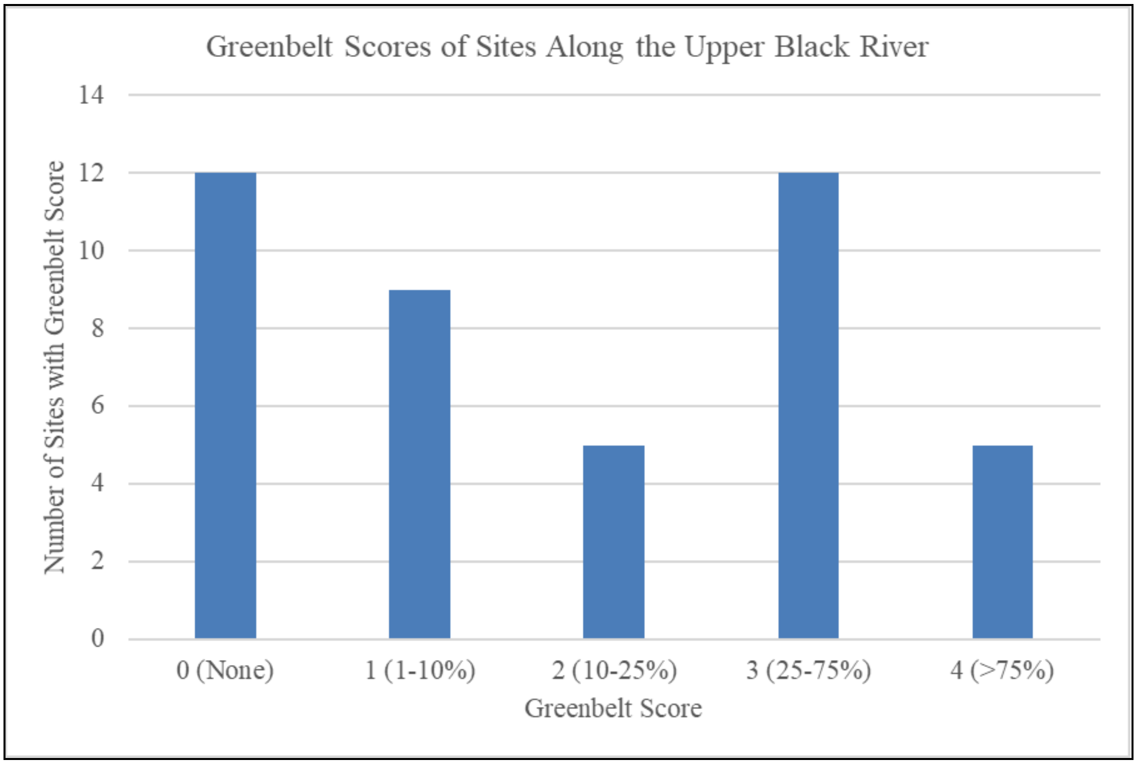


Figure 4.13. Greenbelt scores based upon the percentage of the shoreline the greenbelt extends for sites along the Upper Black River

Rainy River

The desktop analysis that was performed for the tributaries in the Black Lake Watershed found eight sites of erosion along the Rainy River (Figure 4.14). All eight of these sites were visited during August 2023 and any erosion present was documented. Seven of the eight sites had erosion occurring, with five of them having 0-10% of vegetation present on the bank. The problem trend for six out of the eight sites is increasing, with only one site decreasing and another site seeing a combination of increasing and decreasing at the site (Table 4.22).

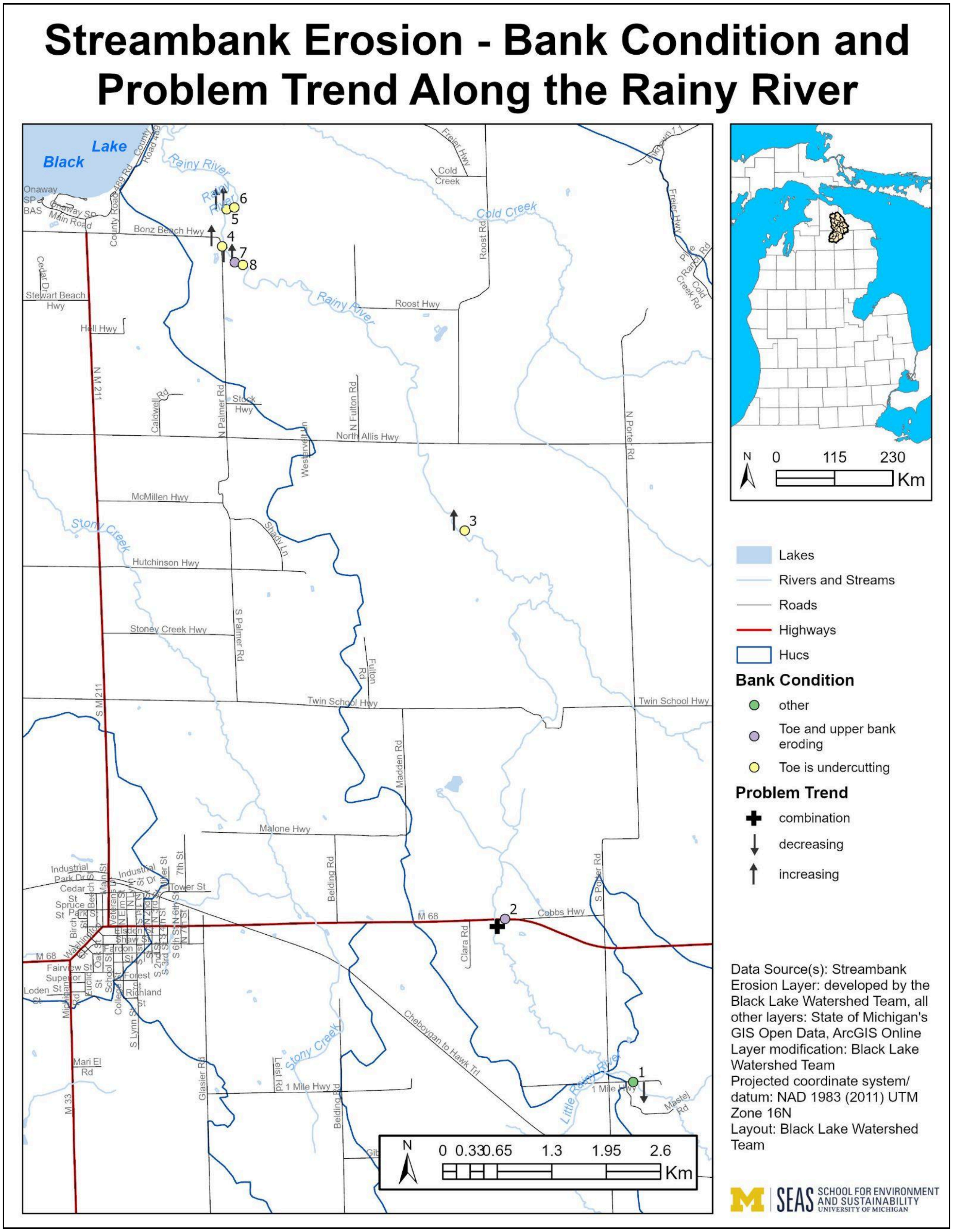


Figure 4.14. Bank condition and problem trend for streambank erosion sites located along the Rainy River

Table 4.22. Percentage of bank with vegetation, bank condition and problem trend of streambank erosion sites along the Rainy River

Site ID	Bank Vegetation Cover	Bank Condition	Problem Trend
1	51-100%	no erosion	decreasing
2	11-50%	toe and upper bank are eroding	combination
3	51-100%	toe is undercutting	increasing
4	0-10%	toe is undercutting	increasing
5	0-10%	toe is undercutting	increasing
6	0-10%	toe is undercutting	increasing
7	0-10%	toe and upper bank are eroding	increasing
8	0-10%	toe is undercutting	increasing

Fisher Creek, Stewart Creek and Stony Creek

The desktop analysis performed for the tributaries in the Black Lake Watershed found two sites of erosion along Fisher Creek, two sites of erosion along Stewart Creek and one site of erosion along Stony Creek (Figure 4.15). All of these sites were visited in August of 2023. All of these sites had 51-100% vegetation bank cover. Only two of the sites saw erosion occurring, one on Fisher Creek and one on Stewart creek, all of the others saw no erosion occurring with a decreasing or stable problem trend. The erosion occurring at the Fisher Creek site has a decreasing problem trend and the erosion occurring at the Stewart Creek site has an increasing problem trend (Table 4.23).

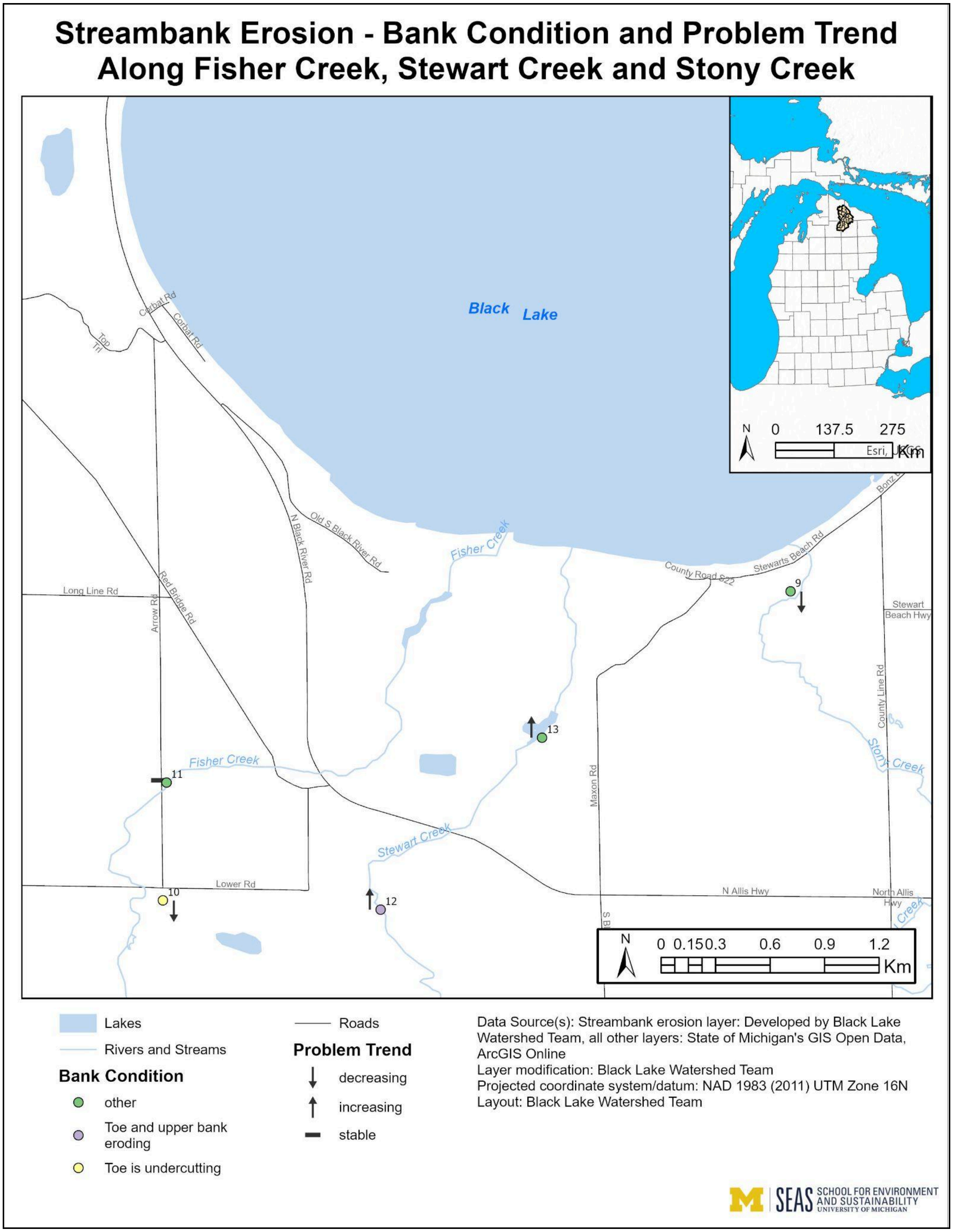


Figure 4.15. Bank condition and problem trend for streambank erosion sites located along Fisher Creek, Stewart Creek, and Stony Creek

Table 4.23. Percentage of bank with vegetation, bank condition and problem trend of streambank erosion sites along Stony Creek, Fisher Creek and Stewart Creek

Site ID	Stream	Bank Vegetation Cover	Bank Condition	Problem Trend
9	Stony Creek	51-100%	no erosion	decreasing
10	Fisher Creek	51-100%	toe is undercutting	decreasing
11	Fisher Creek	51-100%	no erosion	stable
12	Stewart Creek	51-100%	toe and upper bank are eroding	increasing
13	Stewart Creek	51-100%	no erosion	increasing

Severity of erosion was given a ranking of minor, moderate or severe based upon our scoring criteria described in the methods section. This incorporated various aspects of the site to come up with a total score, with total scores below 30 being deemed minor, total scores between 30 and 36 being deemed moderate and total scores above 36 being deemed severe. Of the 56 sites visited within the watershed, only two sites were given a ranking of severe. A majority of the sites, 38, were given a ranking of minor and 16 were given a ranking of moderate (Table 4.24).

Table 4.24. Total number of sites of erosion severity ranking for each tributary surveyed

	Severity of Erosion		
Tributary	Minor	Moderate	Severe
Upper Black River	31	11	1
Rainy River	2	5	1
Fisher Creek	2	0	0
Stewart Creek	2	0	0
Stony Creek	1	0	0
Total Sites	**38**	**16**	**2**

Sediment loadings were calculated for each site using a direct volume method. This was then used to determine estimated pollutant loadings from phosphorus and nitrogen. Upper Black River has the most amount of pollutant loadings, with more nitrogen loadings. The total amount of pollutant loading from streambank erosion in the Black Lake Watershed was 229.76 pounds per year of phosphorus and 459.53 pounds per year of nitrogen.

Table 4.25. Sediment and nutrient loadings for each tributary surveyed

Tributary	**Number of Sites**	**Sediment Loads (tons/year)**	**Phosphorus Loads (lbs/year)**	**Nitrogen Loads (lbs/year)**
Upper Black River	43	257.62875	218.9844375	437.968875
Rainy River	8	12.5	10.625	21.25
Fisher Creek	2	0.03	0.0255	0.051
Stewart Creek	2	0.15	0.1275	0.255
Stony Creek	1	0.00105	0.0008925	0.001785
Total		**270.3098**	**229.76333**	**459.52666**

Agriculture

The agriculture inventory consisted of a desktop analysis of the 2008 common land units showing individual contiguous farming parcels in the Black Lake Watershed, as laid out in our methods section. This inventory aims to identify where agriculture activity is present and determine the associated potential locations of nonpoint source pollution.

150 parcels were found to contain agricultural activity, with the majority of sites concentrated in the northern part of the Black Lake Watershed, just south of Black Lake (Figure 4.16). The Black Lake subwatershed had the most amount of agricultural activity, with 29 sites identified. Gregg-Creek Black River, Little Rainy River, and Bowen Creek-Black River had the next highest number of sites with 22, 20 and 19 sites respectively (Figure 4.17)

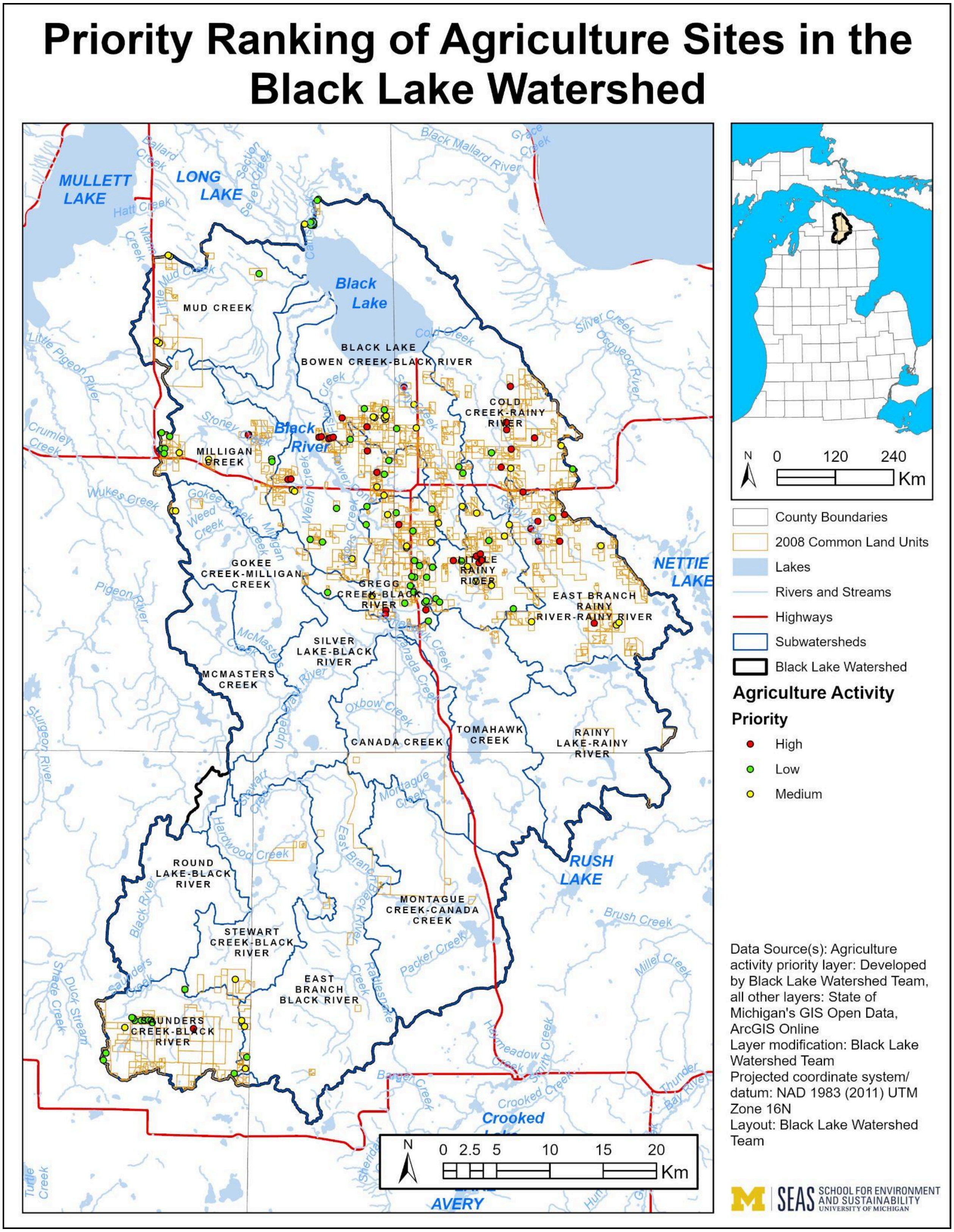


Figure 4.16. Locations and priority ranking of agriculture activity locations within the Black Lake Watershed

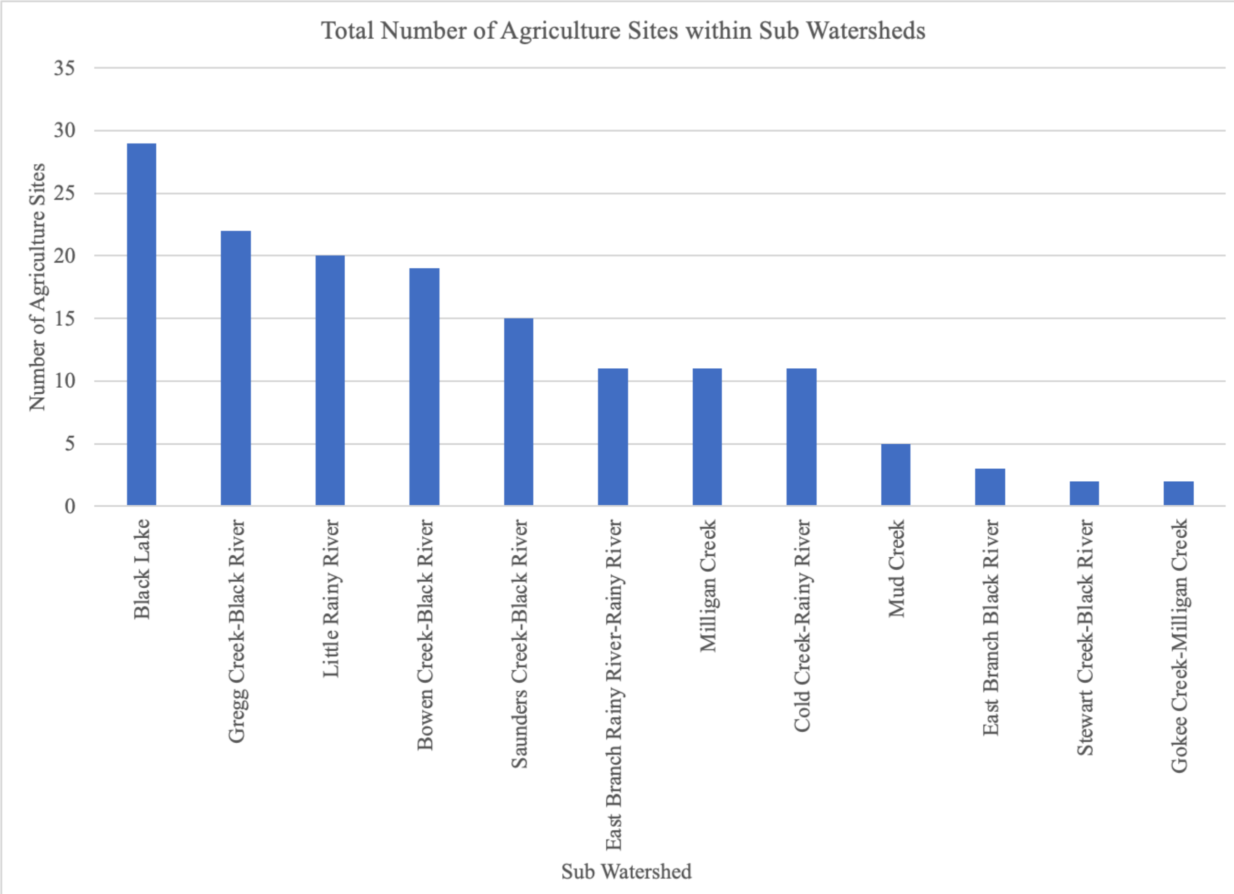


Figure 4.17. Total number of agriculture sites within sub watersheds of the Black Lake Watershed

Of the 150 sites identified, 93 of them were located adjacent to a body of water. 17 of these sites were located adjacent to the Rainy River. The Black River and Little Rainy River each had 12 located adjacent to them. The operation type of the identified site and an associated size of operation was given to all sites. The most common operation was unknown operation, which were parcels that had agricultural activity present in the form of animals and structures, but were unable to identify what kind of operation was being run. There were 34 hobby operations, 5 beef operations and one dairy operation. The size of the operations were determined by the number of animals and buildings seen at the site in the aerial imagery as described in Appendix 7. The most common size was also unknown, which were operations that spanned multiple overlapping parcels or where we were unable to identify the number of buildings located within the parcels. There was one large sized operation, 16 medium sized operations, 49 small sized operations, and 29 hobby operations.

Table 4.26. Number of agricultural sites for each operation type and size

	Size of Operation					
Type of Operation	Hobby	Large	Medium	Small	Unknown	**Grand Total**
Beef			4	1		**5**
Dairy				1		**1**
Hobby	25			5	4	**34**
Unknown	4	1	12	42	51	**110**
Grand Total	**29**	**1**	**16**	**49**	**55**	**150**

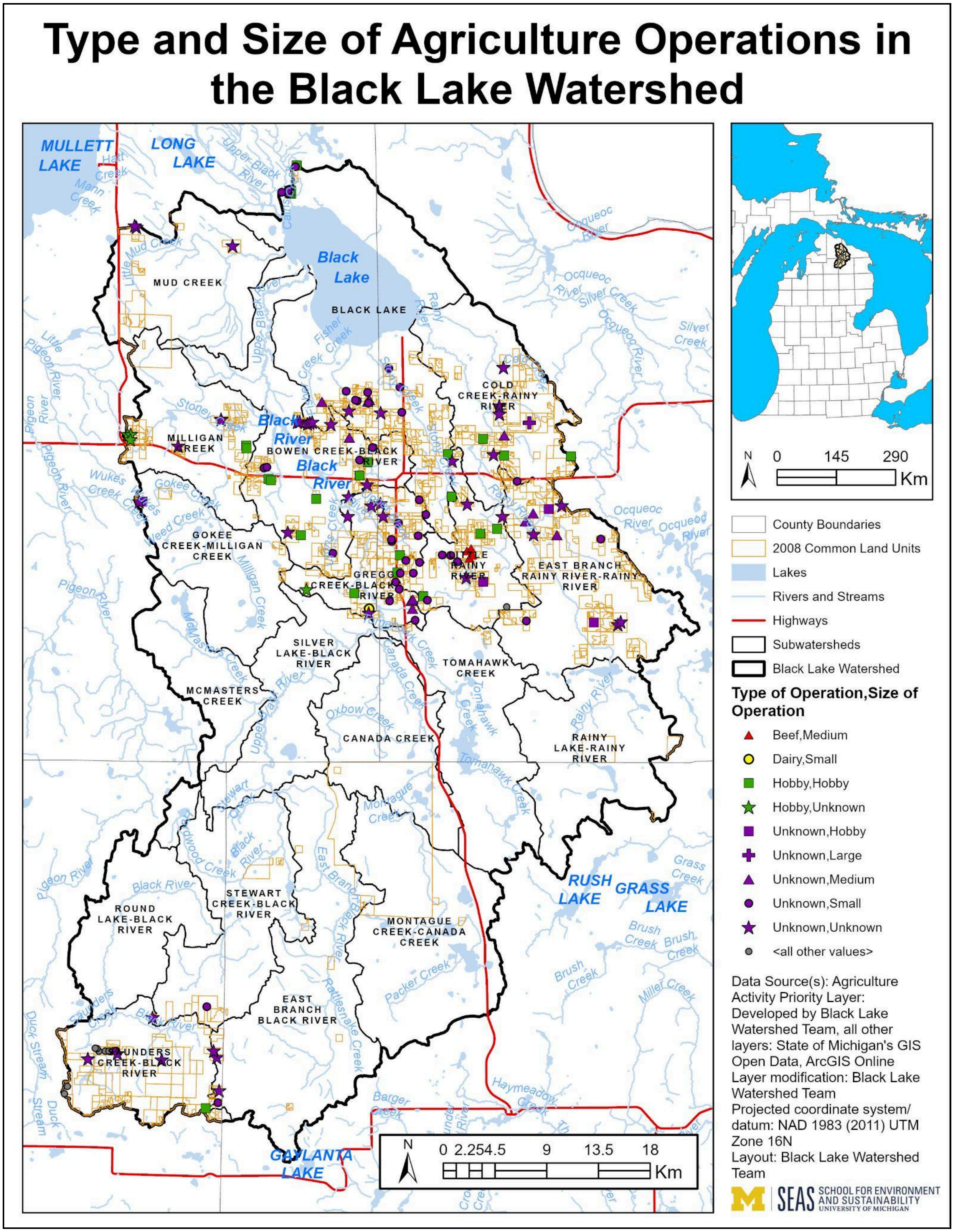


Figure 4.18. Type and size or operations at agriculture sites within the Black Lake Watershed

The quality of manure storage structures present at the site and the maintenance of the site were also evaluated using the methods outlined in Appendix 7. Most of the sites had good or fair storage quality, 51% and 30% of sites respectively. Of the 22 sites with poor storage quality, 19 of them were adjacent to a body of water and 32% of those were located adjacent to the Rainy River. Most of the sites also had good or fair maintenance quality, 37% and 39% of sites respectively. Of the 29 sites with poor maintenance quality, 27 of them were located adjacent to a body of water. Of these sites, 22% of those were located adjacent to the Rainy River and 15% were located adjacent to Tower Pond.

A ranking of priority was given to all agricultural sites identified based upon the type and size of operation at the site, the adjacency to a body of water and the quality of storage and maintenance. Of the 150 sites, 68 were given low priority, 45 were given medium priority and 37 were given high priority. All of those deemed high priority are located adjacent to a body of water and 16% of those also have poor maintenance and storage quality. 30% of the sites ranked high priority are located adjacent to the Rainy River, which are 11 of the total 17 sites located adjacent to the Rainy River.

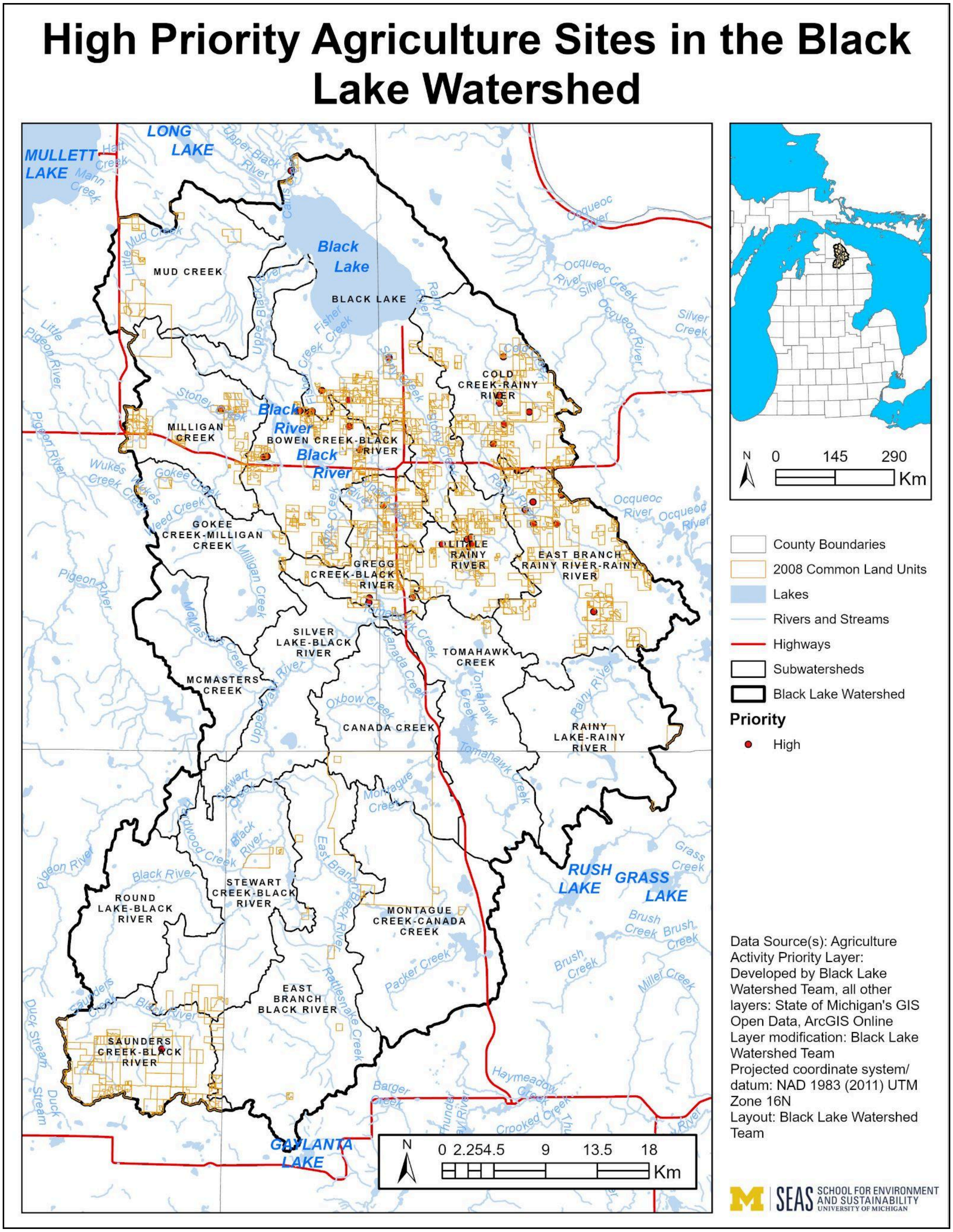


Figure 4.19. All high priority agriculture sites within subwatersheds in the Black Lake Watershed

Priority Parcel Analysis

A parcel analysis identifies parcels in the watershed that are vulnerable to land use changes and would most benefit the water quality of the watershed if permanently protected by land conservancies, governmental entities, or others with permanent land protection efforts. This analysis guides where protection efforts should be prioritized and gives insight into currently protected lands within the watershed. The Black Lake Watershed contains 8,308 parcels with an average of 41.69 acres per parcel. A majority of the watershed (66%) is already protected land controlled by various organizations including the Michigan DNR, the US Fish and Wildlife Service, the Little Traverse Conservancy, and Private Landowners easements with Headwaters Land Conservancy or Little Traverse Conservancy (Table 4.27, Figure 4.20). Conservation easements were assigned low priority in the map shown in Figure 4.20, but were considered protected parcels in the analysis due to land conservancies asking for their easements to be omitted from public maps. Of the 5 priority parcel levels, the largest category is moderate priority which covers 16% of the watershed, followed by low priority with 10% of the watershed. The three least common priority levels are high, very low and very high covering 3%, 2% and 1% of the watershed respectively. The very high parcels have an average parcel size of 467.45 acres, which is 11 times larger than the watershed average (Table 4.27).

Table 4.27. Total number of parcels and acreage of each priority parcel level and corresponding watershed percentage.

Priority Parcel Level	**Number of Parcels**	**Total Acres**	**Average Acres per Parcel**	**Percent of Watershed***
Very Low	899	10,230.44	11.38	2.95
Low	3,288	35,059.1	10.66	10.12
Moderate	2,180	56,124.11	25.75	16.20
High	45	11,857.66	263.50	3.42
Very High	8	3,739.63	467.45	1.08
Protected	1,888	229,365	121.49	66.22
Total	**8,308**	**346,375.9**	**41.69**	**100**

* Percentages based on total acreage

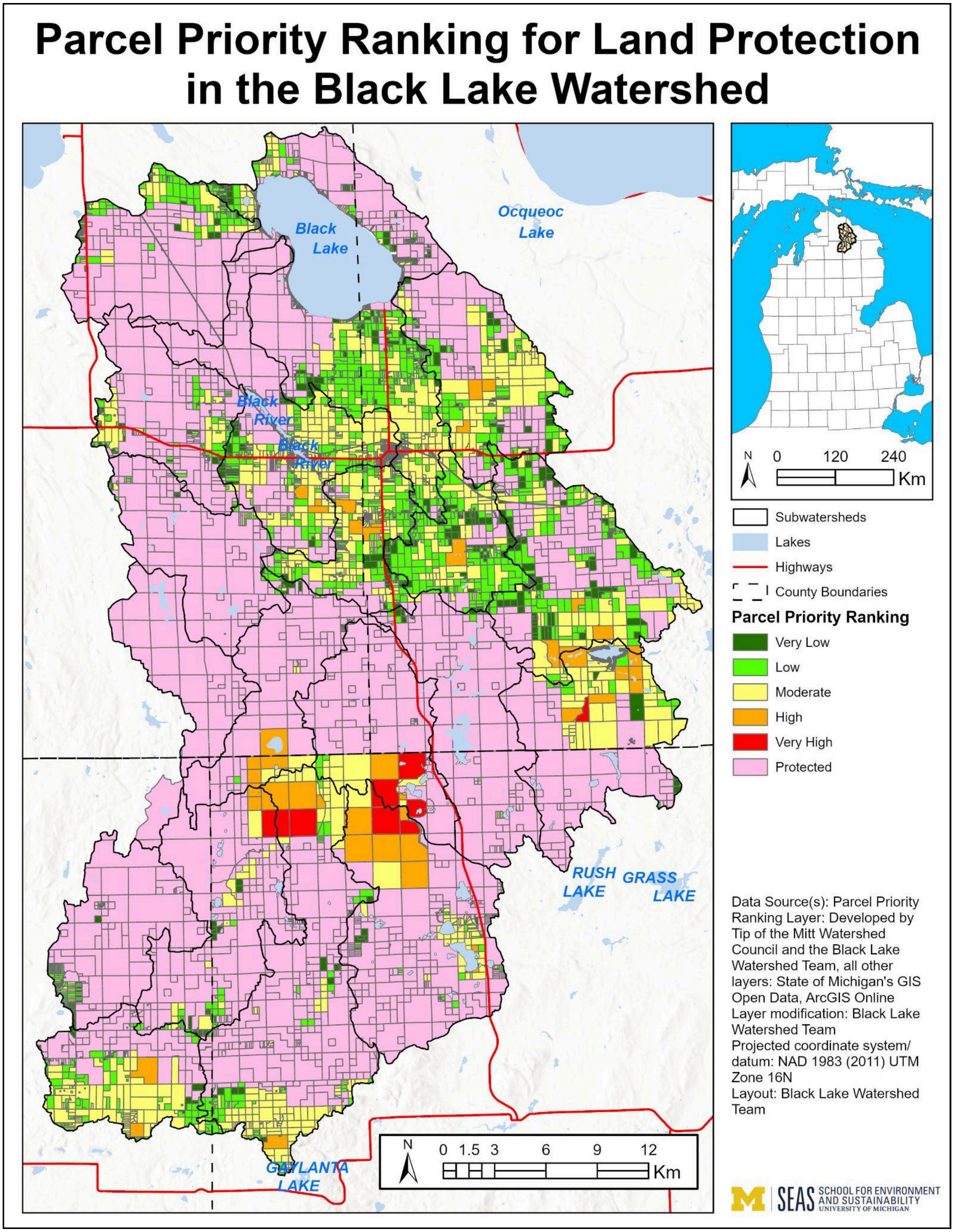


Figure 4.20. Ranking of priority parcels for land protection in the Black Lake Watershed

Much of the unprotected land is concentrated in the area surrounding Onaway below Black Lake and the parcels deemed very high priority are concentrated in the northern part of Montmorency County. All of the subwatersheds contained protected parcels, with Round Lake-Black River and Tomahawk Creek subwatersheds containing the most protected acreage, containing 22,426 and 20,078 acres respectively. These parcels account for 96% of the Round Lake-Black River subwatershed and 95% of the Tomahawk Creek subwatershed. McMasters Creek subwatershed has the highest percentage of protected acres; 100% of all acres in the subwatershed are protected.

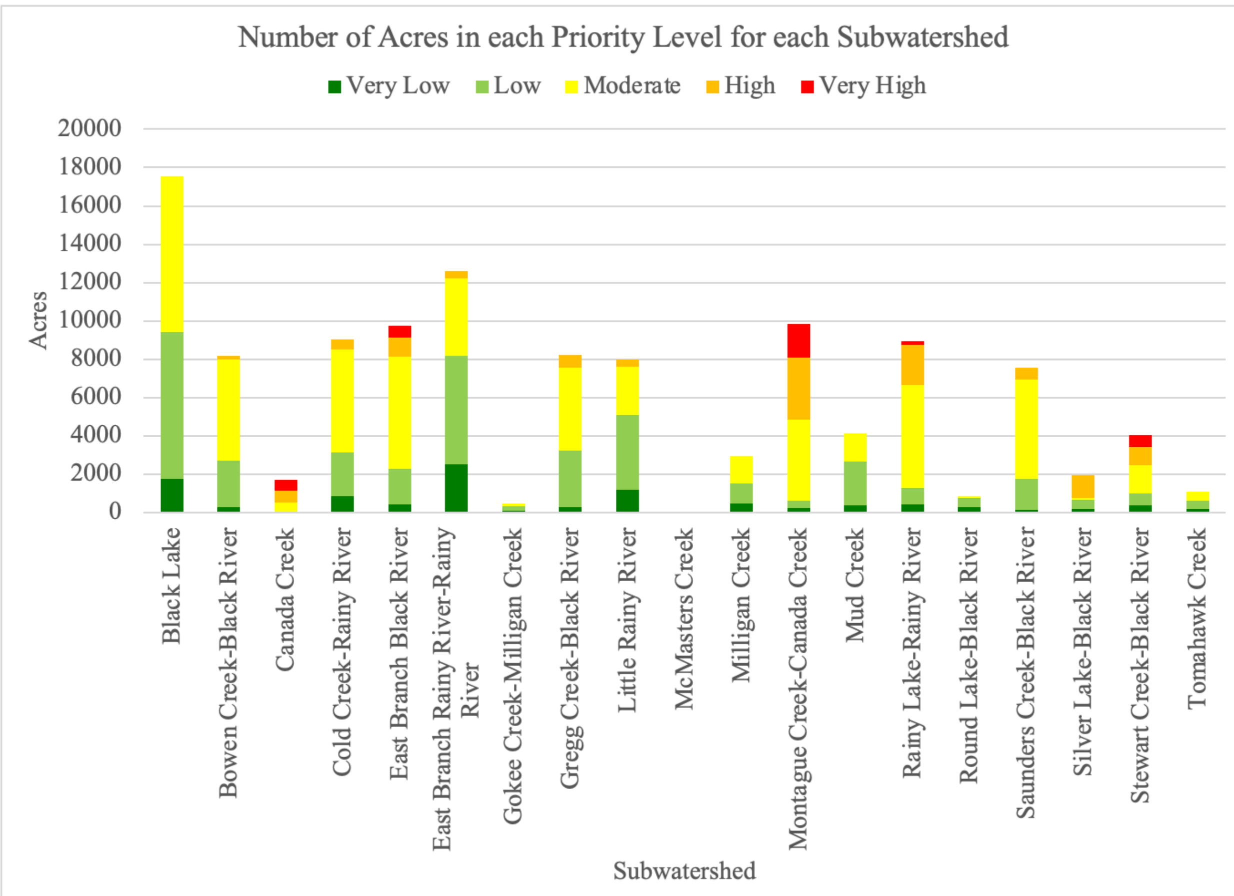


Figure 4.21. Total number of parcels in each priority level for all sub watersheds in the Black Lake Watershed.

Only 5 subwatersheds contained parcels deemed very high priority. Montague Creek-Canada Creek subwatershed had the highest number with four parcels containing 1,753 acres. East Branch Black River, Stewart Creek-Black River, Canada Creek, and Rainy Lake-Rainy River subwatersheds each contained one parcel with a very high priority level containing 637, 635, 560, and 154 acres respectively. This illustrates only a few areas within the watershed are highly vulnerable to land use changes.

Critical Areas Analysis

The critical areas analysis identified areas throughout the watershed with the greatest need for restoration. As stated in the methods section, areas were determined once all resource inventories were completed. There were 16 identified areas that presented a need for the most restoration and/or need for attention. The 16 areas include three regions of RSX, three areas with high priority agriculture sites, three streambank erosion areas with increasing problem trends, two sites that have low greenbelt scores, and five tributary sites that did not meet required water quality standards during the TOMWC tributary study. Areas that were identified were within 12 of the 19 subwatersheds. Critical RSXs spanned across 9 of the 19 subwatersheds and high priority agricultural sites spanned across 5. The forestry inventory was not included in the analysis as ground truthing is needed to identify possible areas of concern.

The subwatersheds and their respective sources can be seen in Table 4.28. The critical areas analysis identified three RSX regions that had a high abundance of sites ranking “Major.” An area of RSX sites is identified about 10 Km south of Tower. Three different areas with high priority agriculture sites were identified, primarily along the Rainy River. On the Rainy River alone, there are 11 agriculture sites deemed high priority as well as increased streambank erosion trends and “Major” RSX sites. A number of high priority agriculture sites and “Major” RSXs are located along the Little Rainy River. Near the Rainy River-Cold Creek confluence there are several streambank erosion sites with increasing problem trends as well. Other concerns are seen surrounding Tower and Kleber Pond and neighboring tributaries. Several high priority agriculture sites in addition to low greenbelt scores and RSXs ranking “Major” make up the area seen between the city of Tower and Black Lake’s shorelines. Looking at all inventories together, the regions surrounding both the Black River and Rainy River are identified as the most critical areas within the watershed.

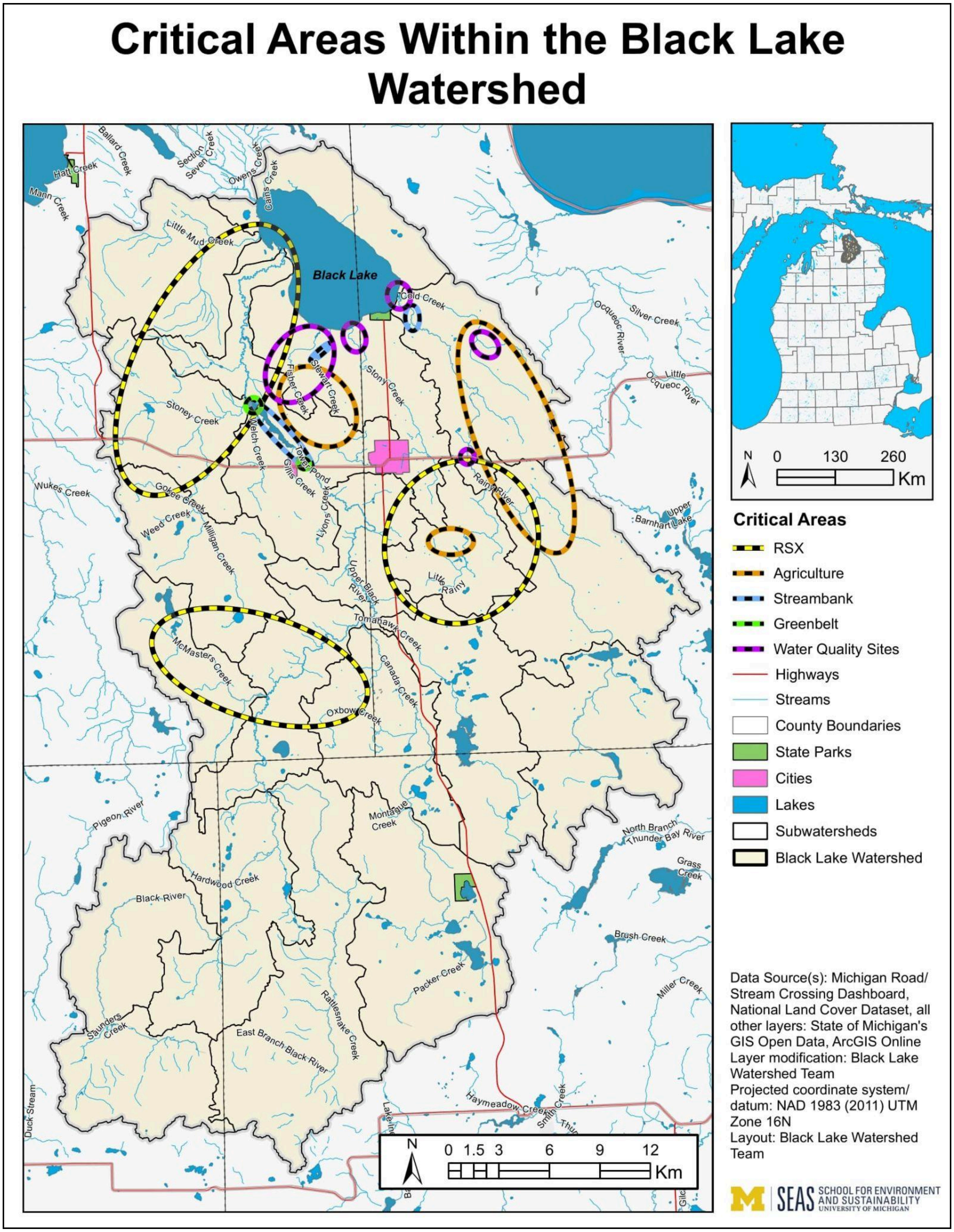


Figure 4.22. Critical Areas identified in the Black Lake Watershed

Table 4.28. Critical Areas Identified in the Black Lake Watershed

Source	Critical Area Subwatershed	Critical Area Location
RSX/Hydrologic Disruption	Black Lake Watershed	Stony Creek
	Bowen Creek-Black River Watershed	Upper Black River
	Canada Creek Watershed	Canada Creek, Oxbow Creek
	East Branch Rainy River-Rainy River Watershed	Rainy River
	Little Rainy River Watershed	Little Rainy River
	McMasters Creek Watershed	McMasters Creek
	Milligan Creek Watershed	Milligan Creek, Stoney Creek
	Mud Creek Watershed	Little Mud Creek
	Silver Lake-Black River Watershed	Upper Black River
Streambank Degradation	Black Lake Watershed	Increasing erosion along Stewart Creek
	Bowen Creek-Black River Watershed	Low greenbelt scores and increasing erosion on Kleber Pond and the Black River between Kleber Dam and M-68
	Cold Creek-Rainy River Watershed	Increasing erosion along Rainy River
Agriculture	Black Lake Watershed	Poor maintenance and storage near Fisher Creek, Stewart Creek
	Bowen Creek-Black River	Poor maintenance and storage near Fisher Creek, Stewart Creek
	Cold Creek-Rainy River Watershed	Cold Creek, Rainy River
	East Branch Rainy River-Rainy River Watershed	Rainy River

	Little Rainy River Watershed	Little Rainy River
[Tributary Sites]	Black Lake Watershed	Fisher Creek, Stewart Creek, Stony Creek,
	Cold Creek-Rainy River	Cold Creek, Rainy River

Chapter 5: Discussion and Recommendations

Social Indicator Survey

The results of the Social Indicator Survey demonstrate a clear concern for the present and future health of the Black Lake Watershed. This demonstrated concern ensures that Tip of the Mitt Watershed Council (TOMWC) can move forward under the assumption there will be substantive community participation and high levels of potential receptiveness. The term “Black Lake Watershed Resident/s” refers to only those represented in the survey responses, not all Black Lake Watershed residents.

Compared to the results of the 2016 Elk River Chain of Lakes (ERCOL) Social Indicator Survey, Black Lake Watershed Residents scored lower in most awareness categories. Black Lake Watershed Residents scored lower than the ERCOL Watershed Residents in the following awareness categories: awareness of the consequences of poor water quality, the types of pollutants impairing waterways, and the sources of pollutants impairing waterways. Black Lake Watershed Residents scored higher in their awareness of the practices needed to improve water quality. Many surveyed Black Lake Watershed Residents actively utilize practices such as planting trees/shrubs and following fertilizer instructions. The trend of Black Lake Watershed Residents achieving lower awareness scores than the ERCOL Residents provides an opportunity for education by TOMWC. To ameliorate the current awareness gaps in the Black Lake Watershed, TOMWC could steer education campaigns to inform residents about the consequences of poor water quality, the types of pollutants impairing waterways, and the sources of pollutants impairing waterways. In order to take advantage of existing programs, TOMWC might host a special water quality information session during a Black Lake Watershed Advisory Committee Meeting or dedicate one of their “Ice Breaker Speaker Series” to water quality issues in pristine, Northern Michigan watersheds. To connect to Black Lake Watershed Residents’ greatest areas of concern, TOMWC might discuss and emphasize the risk of excessive aquatic plants and algae, the loss of desirable species, and the reduction in opportunities for water recreation during these education campaign efforts. As shown in the survey results, Black Lake Watershed residents view TOMWC as a trusted source of information, meaning TOMWC can serve as effective messengers to deploy these educational campaigns.

Black Lake Watershed Residents demonstrated positive water quality-related attitudes, such as understanding that the quality of life in a community depends on the health of the watershed and acknowledging that individual actions have impacts on water quality. They also indicated high levels of willingness to take action. Compared to the ERCOL Watershed Residents indicator scores, the Black Lake Watershed Residents scored considerably higher in both attitudes and willingness. To continue and take advantage of these high indicator scores, TOMWC can continue to promote and encourage actions such as regular septic system servicing and proper septic system sizing. One statement, "I would be willing to pay more to improve water quality (for example: through local taxes or fees)" garnered the greatest level of disagreement. To address this concern, TOMWC could increase their messaging around watershed investments, stating that potential local taxes and fees will preserve the beauty and economic value of watershed residents' homes and properties.

Black Lake Watershed Residents indicated limited constraints to behavior changes and limited constraints to adopting new and specific environmental practices with considerably higher indicator scores than the ERCOL Watershed Residents. Notably, Black Lake Watershed Residents shared concerns regarding resale value of homes and approval from their neighbors if they were to change their present behaviors by installing a greenbelt along their lakeshore property instead of a grass lawn, for example. Both of these concerns pertain to public perception. Discussing constraints to certain practices, Black Lake Watershed Residents shared they experienced physical or health limitations and that the practices are hard to use with their farming system. TOMWC might limit the constraints of Black Lake Watershed Residents by hosting a skills sharing workshop to create greater community understanding to combat concerns of public perception, forming a practice implementation team to assist those with physical or health limitations, and partnering with local farmers to navigate the constraints faced by fellow farmers trying to adopt certain practices. In this component of the Social Indicator Survey, the inherent bias of the survey begins to appear. Surprisingly, the personal out-of-pocket expenses of behavior changes garnered the lowest mean score, indicating participation from individuals of a higher socio-economic status. The financial burdens of certain behavior changes, such as replacing faulty septic systems or regular septic system servicing, are well documented.[40] This financial barrier to behavior change must be addressed by TOMWC because it is likely a major concern for those not represented in this survey. The lack of the financial concern demonstrated by the survey participants is due to bias.

Black Lake Watershed Residents indicated different trust levels in different information sources. TOMWC received the highest mean score, displaying the watershed residents' immense trust in the organization. This trust validates and encourages the continued efforts of the Watershed Council throughout the development and completion of the BLWMP. Local community leaders

[40]Natasha Blakely, "Rights vs. Regulations: Property Rights Big Barrier to Septic System Codes," Michigan Public, March 2, 2021, https://www.michiganpublic.org/environment-science/2021-03-02/rights-vs-regulations-property-rights-big-barrier-to-septic-system-codes

and lawn care companies received the lowest trust levels from survey participants. We encourage TOMWC to utilize their own messenger power as the BLWMP is completed and published.

The results of this quantitative survey aligned with our qualitative observations and informal interactions. People in this region are, on average, highly aware and are willing to take action and change behavior. Having an engaged, motivated, and willing community will facilitate more adoption of sustainable actions in the entire watershed. Often, highly engaged community members act as environmental leaders, facilitating important discussions, providing feedback, and distributing recommendations to other residents around the watershed. By tapping into a supportive social network, the Black Lake Watershed Advisory Committee might form environmental teams within the community that hold individuals accountable and provide resources to facilitate the necessary behavior changes. The environmental behavior researcher Henk Staats and their colleagues contributed significantly to this concept through the creation of "Eco-Teams," determining that teams provided multiple forms of motivation for individuals to take on more sustainable behaviors.[41] The prevalence of highly motivated individuals in the Black Lake Watershed may prove to be their largest asset. The establishment of Black Lake Watershed "eco-teams" can lower concerns regarding approval from neighbors or the resale value of their home. As more watershed residents adopt environmental practices such as updated septic systems or the establishment of shoreline green belts, the public perception concerns will decrease. Beyond this, "eco-teams" provide ample opportunities for knowledge sharing and increased cooperative actions, whether in advocating for a BLWMP or increased septic system funding avenues for those in financial need.

We acknowledge the inherent limitations that these results contain due to low response rates and a non-representative sample. When compared to the general populations of the counties within the Black Lake Watershed, the surveyed respondents were older and more highly educated than the average county citizen. We recognize that these results are strongly biased toward waterfront residents due the survey distribution methods and are not indicative of the watershed as a whole. These results can inform Lake Association education campaigns and various policy efforts, but should not be taken to reflect the watershed as a whole. To address this existing bias, TOMWC will be doing an additional mailing survey to supplement these results and garner a greater more representative sample.

Despite the limitations that exist in the survey responses, it remains crucial that we explore the findings of this survey to gather insights into a portion of the Black Lake Watershed Community.

[41]Staats, H., Harland, P., & Wilke H. (2004). Effecting durable change: A team approach to improve environmental behavior in the household. Environment and Behavior, 36: 341-367.

Table 5.1. Social Indicator Survey Recommendations

Social Indicator Survey Topic	Recommendations for TOMWC
Awareness	**Direct education campaigns to address resident awareness gaps on water quality consequences, pollutants, and their sources in the Black Lake Watershed** -Provide special water quality information sessions during a Black Lake Watershed Advisory Committee Meeting -Dedicate an “Ice Breaker Speaker Series” on water quality issues in pristine, Northern Michigan watersheds, including harmful algal blooms -Emphasize the risk of excessive aquatic plants and algae, the loss of desirable species, and the reduction in opportunities for water recreation during these education campaigns
Attitudes and Willingness to Take Action	**Facilitate, promote and encourage actions such as regular septic system servicing and proper septic system sizing** -Increase messaging around watershed investments and emphasize that potential local taxes and fees will preserve the beauty and economic value of watershed residents’ homes and properties
Constraints to Behavior Change and Adopting Key Practices	**Limit the real and perceived constraints of Black Lake Watershed Residents** -Host a skills sharing workshop to create greater community understanding to combat concerns of public perception -Form a practice implementation team to assist those with physical or health limitations -Provide access to grants and funding to lessen the financial burden of behavior changes -Partner with local farmers to navigate the constraints faced by fellow farmers trying to adopt certain practices

Road/Stream Crossings

RSXs fell into three categories based on their overall condition: “Minor,” “Moderate” and “Major,” and could be considered “time sensitive” based on the severity of the site. As mentioned in the results section, 18 sites were still considered a “time sensitive” matter after we surveyed the area. This means that nearly half of the sites were no longer considered “time sensitive” and could have been addressed prior to us updating the site. Issues that could have been addressed to remove a site’s time sensitivity could include fixing the structure, implementing new infrastructure, removing debris from the stream, etc. For the total watershed, 25 sites were considered “time sensitive,” meaning 72% of the sites that were most recently visited need to have immediate attention. All sites impact the watershed uniquely based on the frequency of usage, the type of crossing that is present, and, most importantly, their overall condition. Addressing sites based on their need of maintenance is an important first step in allocating resources. However, sites that were no longer deemed a time sensitive matter (i.e. repaired, no longer a crossing that exhibits concerning characteristics) are still critical to address and revisit, especially sites that were ranked moderate or major.

Over 40% of all sites in the Black Lake Watershed have not been updated within the Stream Crossing Dashboard since 2015. Of the sites surveyed, 71% of sites changed in severity ranking. This highlights the importance of resurveying sites as many are subject to change. Extrapolating over 100 RSX sites suggests that nearly 30 of them may experience a decline in their ranking if they were visited.

Since some sites haven't been revisited in recent years, only the ones that were resurveyed were included in the fish passability section of the results. Current stream crossing conditions impact 88.6% of aquatic life, emphasizing the need for timely assessment. Fish passage is crucial both at the individual and ecosystem levels. Poor fish passage directly impacts migration, affecting food webs. Habitat fragmentation, degradation, altered hydrology, and poor crossing design can lead to species loss and create issues for other species in the ecosystem. It's crucial to properly assess and address RSXs that impact fish passability to mitigate future passage threats. Mitigation strategies may involve crossing designs that prioritize ecological connectivity. Challenges may arise with such designs due to the effects of climate change and its unpredictability with weather patterns, posing threats to aquatic life's need for thermoregulation.

When discussing the results of the RSX inventories, it's crucial that we address limitations, particularly regarding site accessibility. Among the 39 selected sites for resurvey, we encountered four either on private property or that we simply couldn't locate. We faced accessibility challenges with several sites located off main roads or inaccessible by standard vehicles. Physical barriers and steep inclines prevented us from accessing the sites and using essential tools for survey updates. We encountered obstacles in recording water velocity at many sites, which required us to perform a float test instead of using a Flow Tracker. Consistent weather conditions during the surveys raise questions about potential variations under different conditions. Many sites lacked measurable flows or were dry, impacting our ability to estimate erosion and pollutant loadings accurately. It was crucial for us to carefully evaluate RSXs in poor condition but with little water present to produce more accurate assessments of erosion potential and pollutant loadings in the watershed.

Technological difficulties interfered with data collection. Some sites were challenging to locate due to a lack of cellular service. Other technological issues included categories that did not automatically calculate values for variables, such as fish passability. During data analysis, we observed that some sites were missing this crucial variable, so we assigned rankings based on collected data and visual observations.

Another significant limitation is our ability to interpret the condition of the crossing. Although we ranked a site as 'major' and a time-sensitive matter, others may not share the same assessment. While proper training was conducted before fieldwork, because no project personnel had prior experience with RSXs and updating inventories, the severity, or lack thereof, of sites was interpreted based on our observations and personal interpretations of the current conditions.

FAMD

Invasive species can dramatically alter ecosystems as they fight for the same resources as native species. It is expected to see an increase of nearly 36% of invasive species between 2005 and 2050.[42] As seen in Figure 4.5, the FAMD suggests that the presence of plant invasive species is determined by many factors within a specific site, especially the condition of the road. Previous studies support this with one explaining that "Evidence suggests that roads can have an important effect on the spread of invasive plant species…[and] show[s] that a small change in conditions of the environment favoring the invasive species can change the case for the road…".[43] Another study addresses vehicle usage and its role in floral invasive species abundance. Their results reveal how "primary dispersal of [an invasive species] interacts with secondary dispersal by vehicles' airflow, dependent on traffic volume" which suggests that roads more heavily traveled are at a higher risk of introducing invasive species.[44] This is interesting as roads that are less traveled have less consistent upkeep/maintenance and tend to harbor more invasive species as a result. The study concludes with the importance of general maintenance (i.e. mowing) along high-use roads as well as isolated populations in the area.[40]

[42] IUCN. (2022). Invasive alien species and climate change. https://www.iucn.org/resources/issues-brief/invasive-alien-species-and-climate-change
[43] Deeley B, Petrovskaya N. Propagation of invasive plant species in the presence of a road. J Theor Biol. (2022). doi: 10.1016/j.jtbi.2022.111196. Epub 2022 Jun 16. PMID: 35716722.
[44] Lemke, A., Kowarik, I., & von der Lippe, M. (2018). How traffic facilitates population expansion of invasive species along roads: The case of common ragweed in Germany. Journal of Applied Ecology, 56(2), 413–422. https://doi.org/10.1111/1365-2664.13287

Together, these studies portray a possible positive feedback loop between road usage and invasive plant species abundance in *both* scenarios; as roads are more heavily traveled, invasive species may become more abundant due to vehicular airflow as well as roads that are less traveled that have less consistent upkeep. Roads that receive more traffic compared to others will inevitably deteriorate and harbor the appropriate conditions needed for invasive species to spread even further. On the contrary, roads that are less traveled and do not receive the same amount of upkeep due to its lack of usage will also harbor more invasives. It is possible that variables such as traffic and/or general maintenance/upkeep may have been the missing linkage in understanding the role between RSXs and invasive species. Overall, further studies are needed to understand the impacts of confounding variables on both RSXs and invasive species abundance.

A major limitation of this analysis is that only data from updated sites was utilized. The insights derived from the analysis are drawn from only a portion of the data that would be available if all RSX sites were considered. It would be valuable to rerun the FAMD once all RSXs in the watershed are updated to compare the findings of the analysis.

Table 5.2. Road/stream Crossing Recommendations

Topic	**Recommendations for TOMWC**
Major and Moderate Ranking Sites	**Identify strategies to mitigate runoff from RSXs** -Resurvey major and moderate RSX sites to understand how many need further assistance -Document failing or inadequate infrastructure and communicate needed repairs to parties with the adequate resources to do so (structural as well as their respective roadways i.e. filling in damaged roads) -Suggesting the implementation of diversions away from nearby streams, such as barriers or native vegetation to reduce runoff potential
Habitat Degradation	**Encourage fish passage and ecosystem productivity** -Address and remove barriers to aquatic organisms as well as clear debris from crossings -Remove invasive species and advocate for stronger invasive species management to prevent further habitat degradation

Forestry

Although CFP and QFP were the programs chosen to represent, there are other existing voluntary management programs for private landowners. These two programs are the best indicators for management because the other programs in Table 3.1 overlap the identified programs. Spatial data can not be released because of privacy rights of the landowners for the other programs. Therefore, the usage of CFP and QFP ensure that the same acres will not be accounted for twice.

The key limitation was accessible data. This is in regards to privacy concerns for private landowners as well as availability to geospatial data layers online. Spatial data for the various programs for landowners (Table 3.1) can not be shared therefore, the maps offered from this inventory can not account for all programs offering protection in some sense. In addition, this inventory only represents protected forest land as parcels located within the CFP, QFP and State Parks. There are State Forests within the watershed and are omitted from this inventory due to inaccessible downloadable and usable geographic information. This gap reinforces the recommendation for windshield surveys to supplement this desktop analysis.

Table 5.3. Forestry Activity Recommendations

Topic	**Recommendations for TOMWC**
Windshield Survey	**Conduct thorough windshield surveys in the watershed** -Confirm the condition of the forest rather than just the location of the protected forest, resulting in specific recommendations curated towards water health on specific properties -Locate logging sites within the watershed and the condition of those locations
Consistent New Enrollment	**Encourage Watershed Residents to enroll in public or private forestry conservation programs** -Emphasize the direct positive impacts of conserved forests on the watershed health, preventing further development, and maintaining the health of the forest ecosystem -Promote the private landowners tax incentive programs

Stream Bank Erosion

Upper Black River

Along the Upper Black River between Tower Pond and Kleber Dam, 43 locations had streambank erosion occurring. Of these 43 locations, none of the sites had a decreasing problem trend illustrating that streambank erosion will likely continue to occur if action is not taken. This section of the Upper Black River contains many shoreline properties which increases the likeliness of a structure being present at a location. 33 of the sites had at least one structure present, with 72% having a dock present and 45% having riprap present. Structures such as riprap can help to minimize streambank erosion by providing armor protection for the bank, but other hard structures can cause streambank erosion to increase by disrupting the natural flow of sediments and water along the bank. The high percentage of docks present leads to concerns that they may be causing increased streambank erosion. Having a greenbelt present along the shoreline can help to prevent erosion by providing the shoreline with a buffer zone of vegetation. 72% of the 43 sites had a greenbelt present which were given a score between 1-4. The most common greenbelt score was a 3, which 12 sites were given, however the next highest score was a 1, which 9 sites were given. This means that properties along the shoreline have the potential to improve their current greenbelts to further prevent streambank erosion. Increasing property owner awareness of how to maintain a healthy streambank along this section of the river can help to address the erosion occurring. This can aid in the development of greenbelts along the shoreline and the removal of hard structures contributing to erosion. Providing property owners with resources on how they can implement various stabilization and protection measures will also help increase the likelihood that action will be taken to address streambank erosion.

Rainy River

Of the 8 sites identified to have erosion occurring, 5 of them had 0-10% vegetation cover and an increasing problem trend. These 5 sites were all located at an outer bend along the stream and the erosion appeared to be from natural causes. This indicates that erosion will continue to occur at these sites and will likely accelerate with the lack of vegetation cover. All 8 of the sites had erosion occurring at the toe, with 5 having undercutting occurring as well. Undercutting causes vegetation roots to be exposed and can eventually cause trees and shrubs to fall into the stream, greatly impacting stream and watershed health. Placing riprap along the bank toe at all of these sites can help to reduce undercutting and provide protection for vegetation along the bank.

Fisher Creek, Stewart Creek and Stony Creek

Of the 5 sites identified along these three creeks, only two of them had erosion occurring, one along Fisher Creek and one along Stewart Creek. All 5 of these sites had 51-100% vegetation cover and only the two sites along Stewart Creek had an increasing problem trend. From this we can conclude that streambank erosion along these three streams will likely decrease. The two sites along Stewart Creek should be monitored so that action can be taken if erosion begins to increase.

Of the 56 total sites that were surveyed for streambank erosion, only two of them were given a ranking of severe. One of these sites is along the Rainy River and the other is along the Upper Black River. These two sites should be given priority and the appropriate stabilization and protection measures should be implemented to prevent further erosion. Priority should also be given to the moderate sites along the Upper Black River, as many of these sites had an increasing problem trend meaning the situation could become worse.

There were a few inherent limitations of our streambank erosion inventory, including time and site accessibility constraints. We did not have time to survey all tributaries in the Black Lake Watershed for erosion so there may be sections where streambank erosion is occurring and was not documented. Many of the sites that were visited from the desktop portion of our inventory did not have erosion occuring which could mean the aerial imagery used was outdated and did not give a current representation of streambank erosion along those tributaries.

Table 5.4. Streambank Erosion Recommendations

Topic	Recommendations for TOMWC
Shoreline Property	**Educate property owners on shoreline management and encourage greenbelt implementation.** -Encourage advisory committee members to educate their friends, colleagues, and other community members with properties along the Upper Black River on greenbelt benefits and implementation strategies -Create factsheets/handouts for property owners on stabilization and protection strategies that can be implemented for streambank erosion and who can help implement said strategies
Severe and Moderate Ranking Sites	**Determine a targeted implementation strategy to mitigate further erosion.** -Visit severe and moderate sites with an increasing problem trend to determine a targeted implementation strategy

Agriculture

In the Black Lake Watershed, 150 parcels were identified to have agricultural activity present. The Black Lake subwatershed had the most amount of agriculture activity with 29 sites located within the subwatershed. The agriculture activity occurring in the watershed is mainly hobby or small sized operations (52%), there was only one large sized operation. Hobby and small sized operations generally have less runoff occurring than larger operations, but they have a higher chance of having poor storage and maintenance qualities. Of the total 150 sites, 62% were located adjacent to a body of water. With half of all agriculture sites in the watershed adjacent to water, there is a higher chance of nonpoint source pollution from agriculture activity entering the waterways. 19 of these sites adjacent to water had poor storage quality, and 27 of these sites have poor maintenance quality. Only 37 of the 150 total sites were given a high priority, all of these sites were located next to a body of water. These 37 sites should be visited to gain a better understanding of the agricultural activity occurring and what can be implemented to reduce the chance of nonpoint source pollution entering the waterways from these sites.

The Rainy River had the most agricultural sites adjacent to it, with 17 sites. 32% of the sites with poor storage quality were located next to the Rainy River and 22% of the sites with poor maintenance quality were located next to the Rainy River. Of the total 17 sites along the Rainy River, 11 of them were given high priority. Due to this, nonpoint source pollution may be entering the Rainy River from agriculture activity in the area and should be prioritized during surveys to gain a better understanding of what is actually happening at these sites.

There were a few inherent limitations of our agriculture inventory, including time and site accessibility constraints. There were issues with accessing data from the agriculture inventory that was completed by the TOMWC interns and many of the sites identified to have agriculture activity that were visited did not have agriculture activity occurring there. This led to the desktop portion of the survey being redone which led us to not have time to survey the sites identified on the ground. The sites identified are private property so sites that were visited were surveyed from public roads adjacent to the land parcel. This could have led to not being able to get a full understanding of the activity occurring and the potential of nonpoint source pollution occurrences. A majority of the site operations were deemed unknown, which were parcels that had agricultural activity present but the kind of operation was unable to be identified. A majority of the site sizes were deemed unknown also, which were operations that spanned multiple overlapping parcels and the number of buildings located in the parcels were unable to be identified. This leads to a majority of the sites having non descriptive data which could lead to inaccurate prioritization for these sites.

Table 5.5. Agriculture Activity Recommendations

Topic	Recommendations for TOMWC
Ground Truthing	**Perform a ground truthing survey to further understand the agriculture activity in the watershed.** -Visit all high priority sites -Give priority to the sites along the Rainy River
Runoff	**Encourage implementation of practices that reduce runoff** -Encourage agriculture land owners to implement practices to reduce runoff including planting native vegetation, reducing livestock access to waterways and improving manure storage -Create factsheets/handouts for property owners on the benefits of reducing runoff and who can help them implement best management practices -Encourage the involvement in various programs that help implement best management practices such as the Great Lake Restoration Initiative[45] and Regional Conservation Partnership Program with NRCS,[46] the Conservation Reserve Program and Conservation Reserve Enhancement Program with United States Department of Agriculture Farm Service Agency,[47] and the Michigan Agriculture Environmental Assurance Program (MAEAP) through MDARD.[48] The Cheboygan, Presque Isle, Montmorency and Otsego conservation districts can also help landowners in their involvement in the previously mentioned programs.

[45] USDA NRCS. "Great Lakes Restoration Initiative | Natural Resources Conservation Service." Www.nrcs.usda.gov, 5 Dec. 2023, www.nrcs.usda.gov/programs-initiatives/great-lakes-restoration-initiative. Accessed 22 Apr. 2024.
[46] USDA NRCS. "Regional Conservation Partnership Program." Natural Resources Conservation Service, www.nrcs.usda.gov/programs-initiatives/rcpp-regional-conservation-partnership-program. Accessed 22 Apr. 2024.
[47] USDA Farm Service Agency. "Conservation Programs." Usda.gov, 2013, www.fsa.usda.gov/programs-and-services/conservation-programs/index. Accessed 22 Apr. 2024.
[48] State of Michigan Department of Agriculture and Rural Development. "Michigan Agriculture Environmental Assurance Program." Michigan.gov, 2023, www.michigan.gov/mdard/environment/maeap. Accessed 22 Apr. 2024.

Priority Parcel Analysis

The analysis conducted for the Black Lake Watershed found that 66% of the total 350,000 acres in the watershed is already protected land controlled by various organizations including the Michigan DNR, the US Fish and Wildlife Service, the Little Traverse Conservancy, and Private Landowners easements with Headwaters Land Conservancy or Little Traverse Conservancy. The rest of the unprotected parcels were given a priority level of very low, low, moderate, high and very high. This designates if the parcel is vulnerable to land use changes, with very low being not vulnerable and very high being very vulnerable. Only 8 parcels were given a level of very high priority, four of which are located in the Montague Creek-Canada Creek subwatershed. These parcels account for a little over 1% of the watershed, but have an average parcel size of 467.45 acres which is 11 times larger than the average parcel size in the watershed of 41.69 acres. This illustrates that protecting these few highly vulnerable parcels can greatly benefit the water quality health of the watershed due to their large average parcel size. Two other categories, protected and high priority level, also contain a higher average parcel acreage than the watershed average. The 1,888 parcels that are protected have an average parcel size of 121.49 acres, causing the majority of the watershed to be protected. The 45 parcels deemed high priority have an average size of 263.50 acres, which also illustrates that protecting these few parcels will have great impact on the watershed health.

There were a few inherent limitations in our priority parcel analysis, including using outdated GIS data and time constraints. The Michigan Natural Features Inventory provided the Biorarity Index Feature layer but they no longer update this data. The most recent update was from 2013 so it may include outdated information.

Table 5.6. Priority Parcel Recommendations

Topic	**Recommendations for TOMWC**
High and Very High Priority Parcels	**Encourage the protection of specific parcels and locations that offer great benefit to watershed health quality.** -Visit high and very high priority parcels to determine feasibility of protection, giving priority to large parcels near Montague Creek, Canada Creek and East Branch Black River -Encourage the protection of parcels, giving priority to parcels that lead to the greatest benefit

Critical Areas Analysis

The critical areas analysis provides a baseline on what areas should be attended to first when addressing the water quality issues being experienced throughout the watershed. Interestingly, many areas identified as critical were within 10km of Black Lake itself. This is important as it is possible that these areas may be a factor in the HABs that have become more prevalent in recent years. Extrapolating from this data, it's conceivable that addressing these critical areas could have a positive impact on mitigating HAB occurrences. The reference sites for the tributary study were marked in Figure 4.24 to visualize their location in respect to the identified critical areas which happened to be located in close proximity to the sites found in the analysis. The high priority agricultural areas, poor RSX conditions and increasing streambank problem trends noted in the analysis may be contributing to the poor water quality measured at the monitoring sites. We recommend monitoring the sites that were utilized in the tributary study to document changes as different strategies are implemented throughout the watershed to address the growing water quality issues.

Critical areas may benefit from certain BMPs depending on the site. Recommendations for the critical areas analysis reflect the recommendations provided by the individual inventories to avoid repetitiveness.

There were significant limitations to this analysis. The current map depicts both recent and outdated information. As previously mentioned, over 40% of the RSX sites have not been updated since 2015. It is difficult to assume what areas truly are in need of the most attention due to the lack of recent available data. This is also relevant in regards to the forestry and agriculture inventories. Ground truthing is needed for both agriculture and forestry inventories to identify what areas are in need of attention. Although high priority agricultural areas were taken into consideration for the critical areas analysis, these sites (once ground truthed) may not be as serious as noted through the desktop analysis. The same applies with the forestry inventory as ground truthing is needed to determine what areas significantly need to be addressed.

Table 5.7. Critical Areas Recommendations

Topic	**Recommendations for TOMWC**
Critical Areas	**Ground truth and determine BMPs for individual inventories based on current conditions.** -See recommendations for RSX, streambank, agriculture, and forestry inventories -Allocate resources to sites deemed critical

Chapter 6: Conclusion

As TOMWC begins constructing the Black Lake Watershed Management Plan, this report will serve as a foundational component, enabling TOMWC to expand upon our efforts and foster deeper engagement with the Black Lake Watershed community. From our resource inventories, we determined water quality issues may be arising from poor road/stream crossing conditions, increasing trends of streambank erosion and the presence of high impact agricultural activity. Our critical areas analysis identified critical areas within 10 kilometers of Black Lake which may be a factor in the HABs as an increasing problem trend. We strongly advocate for TOMWC to conduct visits and monitoring of all high-priority parcels and critical areas outlined in our findings. Moreover, it is imperative for TOMWC to enhance community education in the Black Lake Watershed, ensuring equitable access to information on water quality, HABs, environmental behavior change, and securing funding for septic systems and shoreline property improvements. The upcoming second edition of the Black Lake Watershed Resident Survey will further document any changes over the next year and reach a broader sample of the watershed community. With these recommendations, we envision the development of a robust and practical watershed management plan that will offer essential guidance to watershed coordinators, resource managers, policymakers, and community organizations in their efforts to restore and safeguard the Black Lake Watershed. Additionally, we, as researchers, hope for this document to serve as a model for other communities grappling with poor water quality and harmful algal blooms in similar watersheds, informing their actions.

Appendix

Appendix 1. Black Lake Tributary Study Visuals and Data

Stony Creek

There were three total sites monitored at Stony Creek. Monitoring sites with data measured below the Rule 51 TDS Maximum of 750mg/L with an average of 280mg/L. Recorded pH showed an average of 7 which falls within the Michigan WQS of 6.5-9. Stony Creek at Stewart's Beach Rd. initially met the WQS dissolved oxygen of 7mg/L during May (9mg/L) and didn't meet it again until October (~11mg/L) while at N. County Line Rd. levels were consistently low until October when it then measured at 9mg/L. All sites exceeded July and August temperature standards for a cold-water fishery but were within the standards for May and October. All sites measured far below the EPA's chloride toxicity levels, however an influx is seen during the months of August and October, suggestive of some pollution being introduced or a rain event. Stony Creek at N. County Line Rd. measured the highest at 237.5 µg/L in August which is far above the EPA's suggested TP concentrations of 12µg/L. The site was never below the EPA's suggested TP concentrations, however the other two sites were. Stony Creek at M-68 was consistently below the 12µg/L. Stony Creek at Stewart's Beach Rd. was also below the 12µg/L except for the month of August where it read ~16µg/L. Stony Creek at N. County Line Rd. consistently did not meet the EPA's TN reference condition of 440 µg/L reaching a high of ~1400µg/L. Its levels were lower during the months of May and October, however there is a difference of roughly 1000µg/L between May and July as well as about 700µg/L between August and October.

Cold Creek

Cold Creek was monitored at N. Porter Rd. The site measured below the Rule 51 TDS Maximum of 750mg/L with an average of 270mg/L between May and October. The site's pH was relatively consistent and increased from 7.6 to 7.8 from May to October which is within the Michigan WQS of 6.5-9. Dissolved oxygen remained above the 5mg/L required for warm-water fisheries. Recorded temperatures are consistent with the set standards for a warm-water fishery. Chloride levels were slightly above the EPA's toxicity level of 5mg/L ranging from 6mg/L in May to 11.5 in October. TP concentrations were elevated in May at 17µg/L exceeding the EPA's suggested concentrations of 12µg/L but decreased to 10µg/L in October. TN concentrations exceed the TN reference condition of 440 µg/L for minimally impacted conditions for Northern Michigan in May at 650µg/L and in October at 1650µg/L.

Fisher Creek

There were two sites monitored at Fisher Creek. Fisher Creek at Hutchinson Highway was dry during July and August providing minimal data to compare. Both sites measured below the Rule 51 TDS Maximum of 750mg/L with an average of 250mg/L. Recorded pH at S. Black River Rd. showed an average of 8 which falls within the Michigan WQS of 6.5-9. Fisher Creek at S. Black River Rd. initially met the WQS dissolved oxygen of 7mg/L during May (9mg/L), however dropped below the WQS in July and August, and increased to 11mg/L in October. Fisher Creek at Hutchinson Highway was slightly elevated above the temperature standards for a cold-water fishery in May while at S. Black River Rd. standards were never exceeded. Fisher Creek at Hutchinson Highway measured below the EPA's chloride toxicity levels, however at S. Black River Rd. levels were over tenfold likely due to an impoundment of a golf course. TP concentrations were consistently below the EPA's suggested concentrations of 12µg/L with Hutchinson Highway reading the highest in October at ~8µg/L. TN concentrations were consistently below the EPA's TN reference condition of 440µg/L except for at Hutchinson Highway where it was measured at ~1300µg/L in October.

Rainy River

One site was monitored at Rainy River (another site at the Rainy River/Cold Creek confluence). The site at M-68 was below the Rule 51 TDS Maximum of 750mg/L, however fluctuated from ~150mg/L in May to averaging ~300mg/L July through October. Rainy River's pH measured at about 7.7 in October which falls within the Michigan WQS of 6.5-9. Dissolved oxygen concentrations were too low to meet the WQS dissolved oxygen of 7mg/L for coldwater fisheries at 4.7mg/L. Temperatures were consistent with the temperature standards for a cold-water fishery for the months of May and October but exceeded July and August. Chloride levels measured slightly above the EPA's toxicity level of 5mg/L averaging 7mg/L May through October. TP concentrations exceed the EPA's suggested concentrations of 12µg/L July through October peaking at 24µg/L in August which is likely due to a weather event. TN concentrations consistently exceed the TN reference condition of 440 µg/L for minimally impacted conditions for Northern Michigan and steadily increase from 500 µg/L in May to 1100 µg/L in October.

Stewart Creek

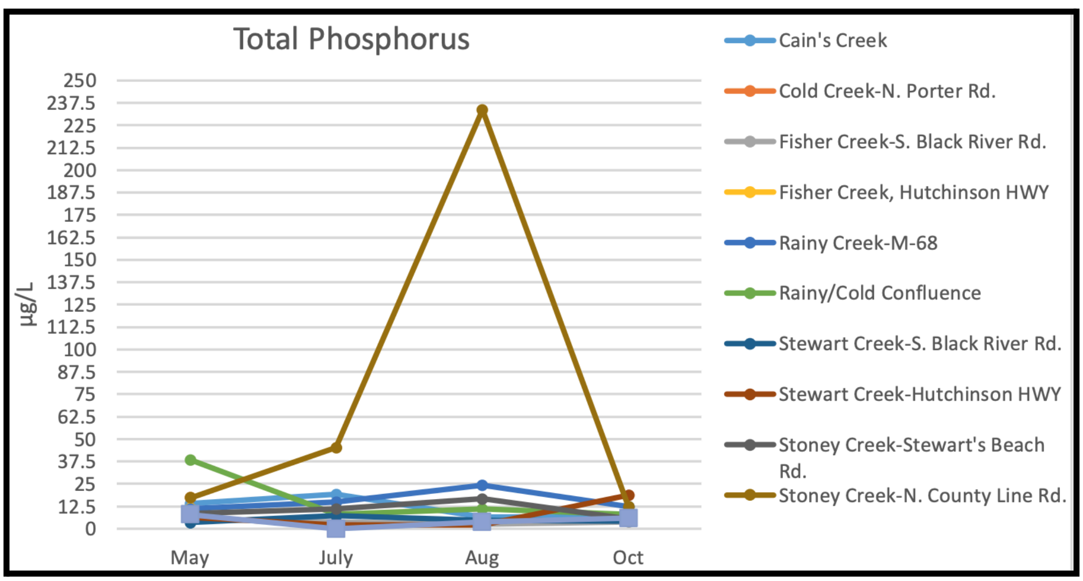
Two sites were measured at Stewart Creek: S. Black River Rd. and Hutchinson Highway. Both sites were below the Rule 51 TDS Maximum of 750mg/L although Stewart Creek at S. Black River Rd. measured the highest in July at ~375mg/L. The sites also fluctuated in pH with S. Black River Rd. measuring the most basic at 8.3 which still falls within the Michigan WQS of 6.5-9. Dissolved oxygen decreased between May and July but still remained above the 5mg/L required for warm water fisheries. Throughout all months of the study, Stewart Creek was below the temperature maximums set for warm water streams, although in July at S. Black River Rd. temperatures almost exceed the limit. Both sites exceed the EPA's chloride toxicity levels especially at S. Black River Rd. where it has the second highest chloride levels maintaining around 25mg/L over the course of the study. Hutchinson Highway decreases from 12.5mg/L in

May to ~5mg/L in July and increases to 23mg/L in October. TP concentrations at each site are well below the EPA's suggested concentrations of 12µg/L until October when there is an increase to 19µg/L seen at Hutchinson Highway. TN concentrations at each site were exceptionally higher than the TN reference condition of 440 µg/L for minimally impacted conditions for Northern Michigan. Stewart Creek at Hutchinson Highway had the highest TN concentrations in July and August measuring at 2411.4 µg/L and 3178.4 µg/L respectively. At S. Black River Rd., TN concentrations were below 440 µg/L for May and August, however exceeded the standards in July and October.

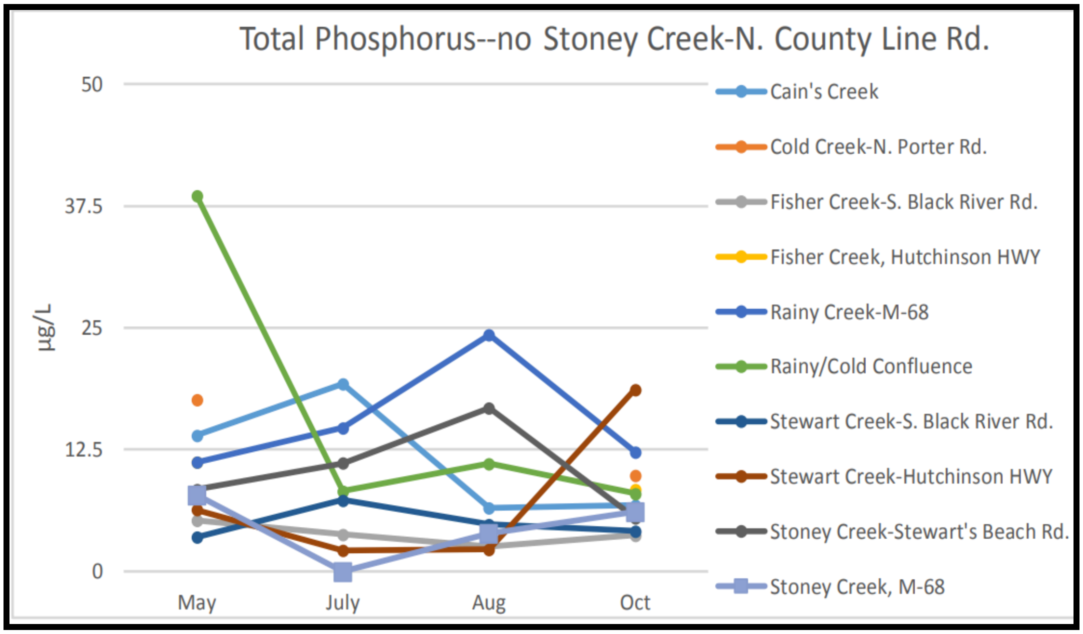
Cain's Creek

Only one site was monitored at Cain's Creek. Data measured below the Rule 51 TDS Maximum of 750mg/L with an average of 230mg/L. Recorded pH showed an average of 7.8 which falls within the Michigan WQS of 6.5-9. Dissolved oxygen averaged 9mg/L which is above the 5mg/L required for waters that are not coldwater designated streams. Throughout all months of the study, Cain's Creek was below the temperature maximums set for warm water streams. Chloride levels are low and below the EPA's toxicity levels but increase between May and June (2mg/L to ~10mg/L). TP levels exceed the EPA's suggested concentrations of 12µg/L during the months of May and June (~15µg/L) but decrease during the months of August and October (6µg/L). The TN level exceeded the USEPA TN reference condition of 440 µg/L for minimally impacted conditions for Northern Michigan streams in May and October.

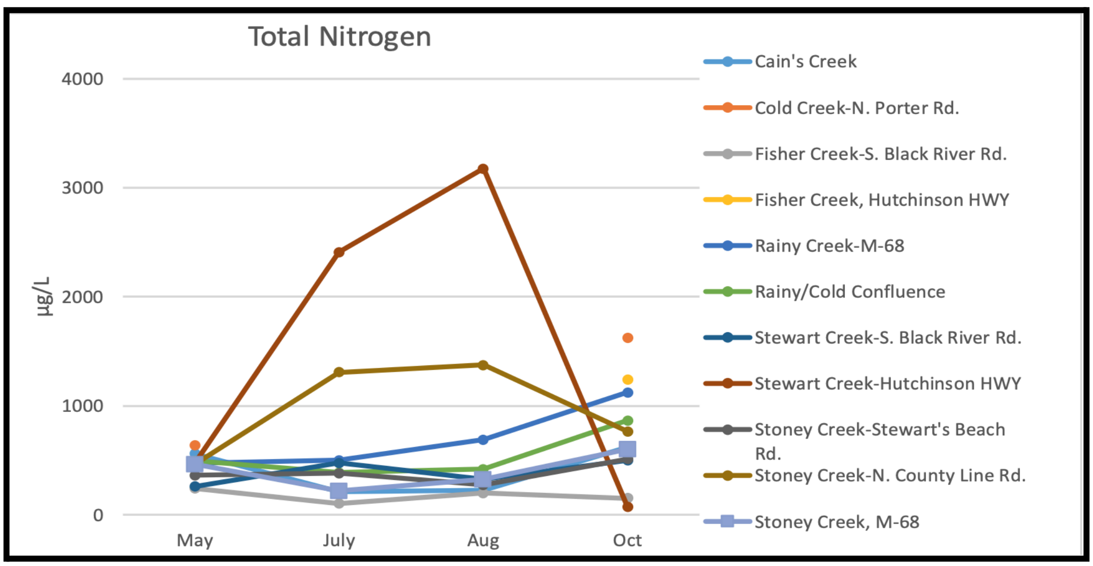
2018 Total Phosphorous Levels in Black Lake Tributaries



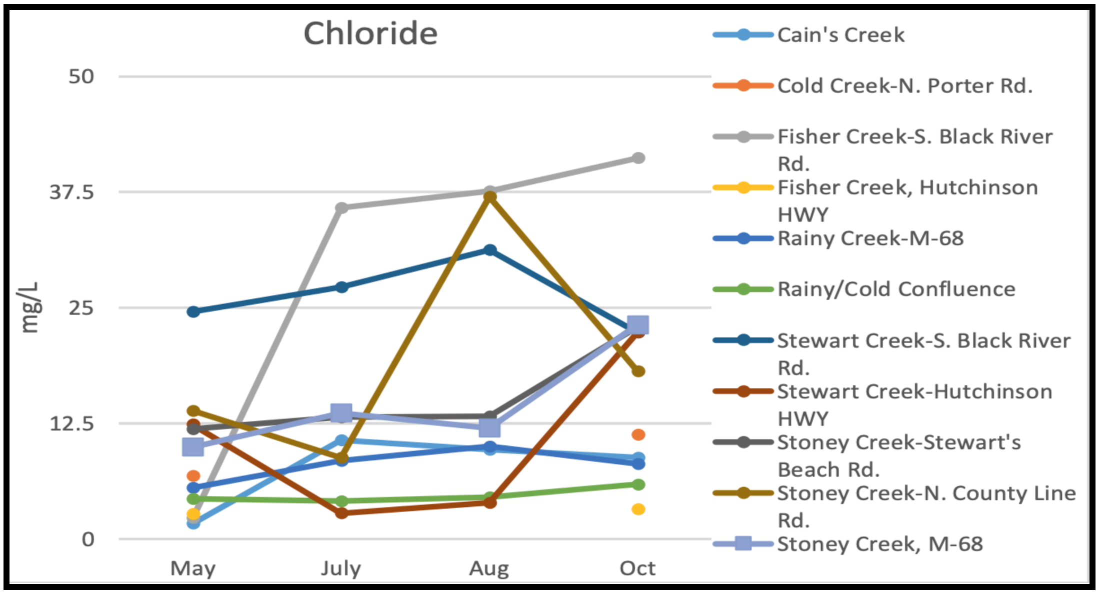
2018 Total Phosphorous Levels in Black Lake Tributaries Without Stoney Creek at N. County Line Rd.



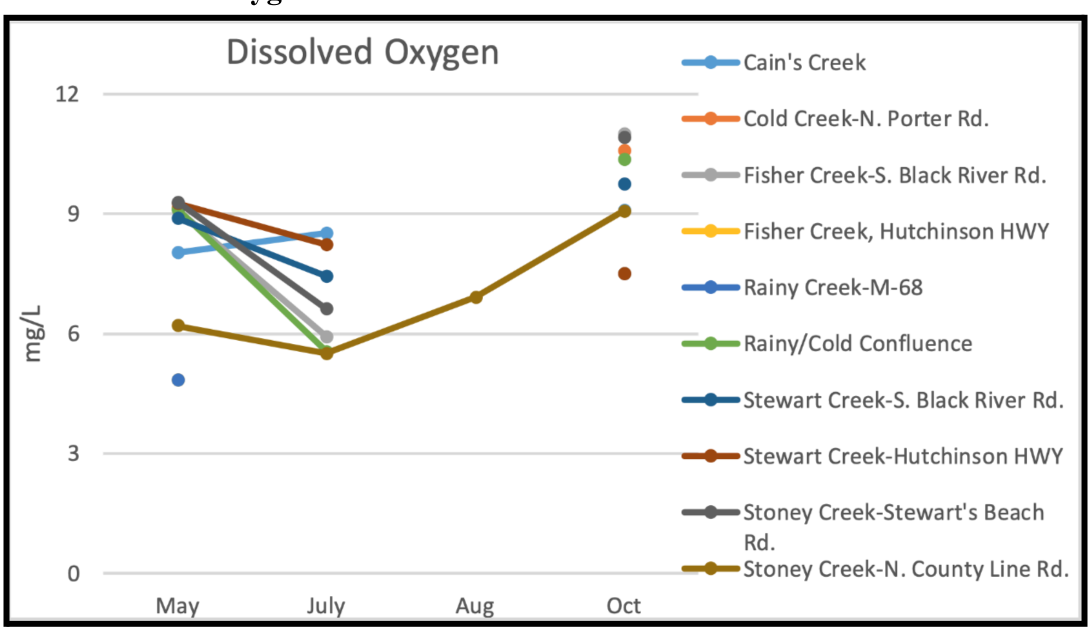
2018 Total Nitrogen Levels in Black Lake Tributaries



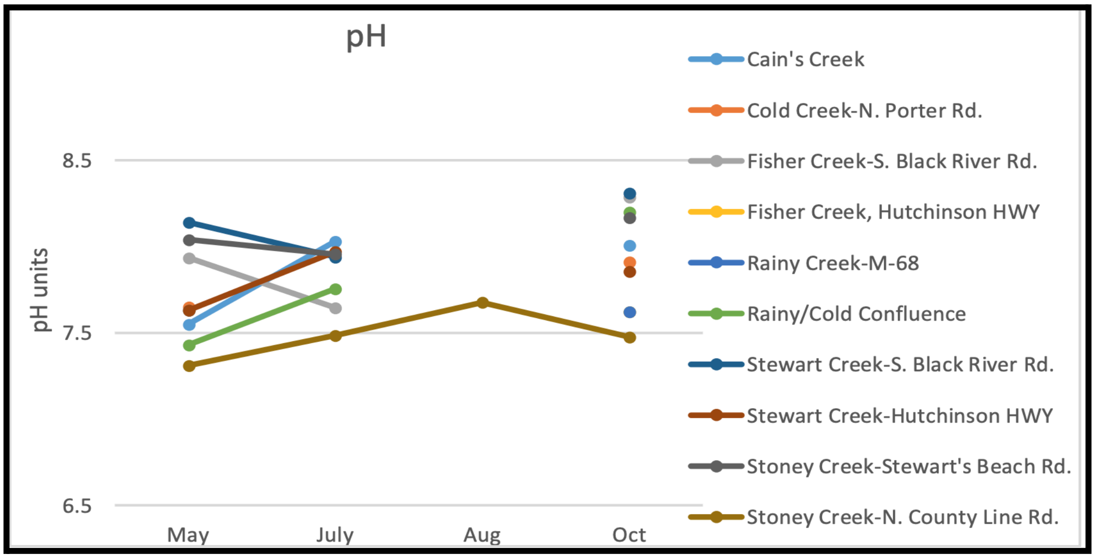
2018 Chloride Levels in Black Lake Tributaries



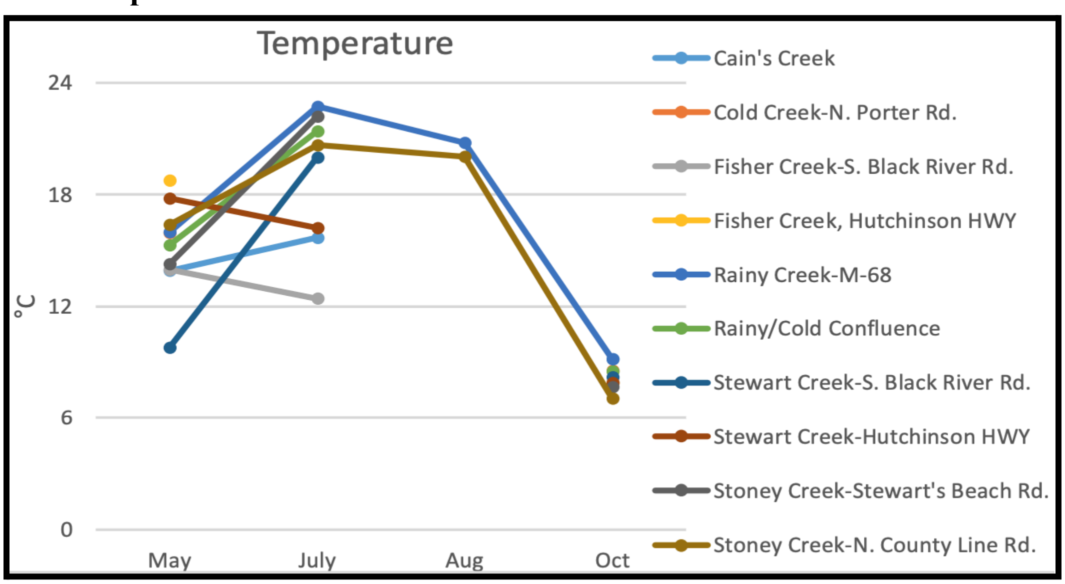
2018 Dissolved Oxygen Levels in Black Lake Tributaries



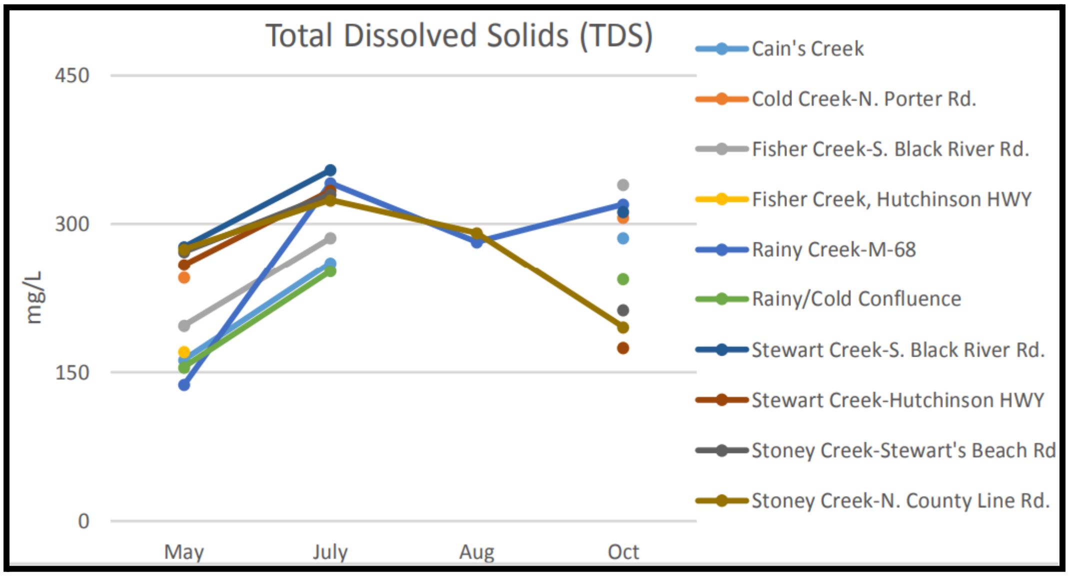
2018 pH Levels in Black Lake Tributaries



2018 Temperature Records of Black Lake Tributaries



2018 Total Dissolved Solids (TDS) Concentrations of Black Lake Tributaries



Appendix 2. Advance and Reminder Emails sent to the Black Lake Watershed Advisory Committee

Advance Email

Dear Black Lake Watershed Resident,

We need your help to better understand the current status of the Black Lake Watershed. Tip of the Mitt Watershed Council and students from the University of Michigan School for Environment and Sustainability are working to protect water quality of the Black Lake Watershed. As someone who makes decisions on the management of your property, your insights are particularly important and valuable, and we would greatly appreciate your participation in a survey. This will help us learn how we might best serve the needs of landowners and homeowners in the watershed.

Please complete this survey if you are a homeowner or renter within the Black Lake Watershed.
[Insert Survey Link]

Your participation in the survey is completely voluntary. Let me assure you that your responses will remain confidential. Responses for all watershed residents completing the survey will be analyzed together, and no individual responses will be identified in any way. Your name will not be used in any report although you can request a copy of the final report so that you are able to see the full results.

Your participation in this survey is very important, to ensure we understand the management activities and the needs and interests of the community in the watershed. If you have any questions about the survey please contact me. Please complete one survey per person.
Thank you in advance for your help.

Let's work together to protect the water quality of the Black Lake Watershed.

Sincerely,

Dana Pflughoeft
University of Michigan SEAS Graduate Student Tip
of the Mitt Watershed Council Consultant
blacklakewatershedteam@umich.edu
231-645-4628

First Reminder Email

Dear Black Lake Watershed Resident,

Recently, a link to an online survey asking for your thoughts about watershed and land management issues was sent to you. Your response is important to accurately represent the opinions about these issues in the Black Lake Watershed.

Here is the link to the survey: [insert survey]

Please complete one survey per person. The survey population is limited to homeowners and renters in the Black Lake Watershed.

If you have already completed the survey, please accept my sincere thanks. If not, please take approximately 20 minutes to complete the survey soon. If you have any questions about the survey, please contact me. I am glad to answer your questions.

Let's work together to protect the water quality of the Black Lake Watershed.

Thank you for your help.

Dana Pflughoeft
University of Michigan SEAS Graduate Student Tip
of the Mitt Watershed Council Consultant
blacklakewatershedteam@umich.edu
231-645-4628

Second Reminder Email

Dear Black Lake Watershed Resident,

About three weeks ago, I sent an email including a link to a survey asking for your input on land and water issues in the Black Lake Watershed.

Here is the link again to the Black Lake Watershed Residents survey [insert link to survey].

Please complete one survey per person. The survey population is limited to homeowners and renters in the Black Lake Watershed.

Your response is important to accurately represent the opinions about these issues in the Black Lake Watershed. To be sure that the results are representative of the interests and opinions of the watershed, we need to hear from you. If you have already completed the survey, please accept my sincere thanks. If not, please take approximately 20 minutes to complete the survey soon. If you have any questions about the survey, please contact me. I am glad to answer your questions.

Let's work together to protect the water quality of the Black Lake Watershed.

Thank you for your help.

Dana Pflughoeft
University of Michigan SEAS Graduate Student Tip
of the Mitt Watershed Council Consultant
blacklakewatershedteam@umich.edu
231-645-4628

Final Reminder

Dear Black Lake Watershed Resident,

I am writing one final time to encourage you to complete and submit the Black Lake Watershed Residents Survey. If you have already returned the survey, thank you! If not please take a few moments to complete and submit the survey.

Here is the link to the survey: [link to survey]

I understand this survey may not be a top priority, or that you may be hesitant to share information about your land management practice. This survey is important because information received will be used to serve the needs of landowners in your area. By participating in this survey, you will help shape our outreach programs and technical services. Let's work together to protect the water quality of the Black Lake Watershed.

Please complete one survey per person. The survey population is limited to homeowners and renters in the Black Lake Watershed.

Please be assured that your responses will be confidential. Your name and answers will NOT be used in any reports or correspondence with the public.

Feel free to contact me if you have any questions, concerns, or comments. I would appreciate hearing from you.

Thank you for your help.

Dana Pflughoeft
University of Michigan SEAS Graduate Student Tip
of the Mitt Watershed Council Consultant
blacklakewatershedteam@umich.edu
231-645-4628

Appendix 3. Social Survey Social Media Posts

First, Second, and Third Social Media Post:

[Include QR code to the survey in all forms of public engagement] Text to Accompany Images on Facebook, Instagram, and Newsletters:
We need your help to better understand the current status of the Black Lake Watershed. Tip of the Mitt Watershed Council and students from the University of Michigan School for Environment and Sustainability are working to protect water quality of the Black Lake Watershed. As someone who makes decisions on the management of your property, your insights are particularly important and valuable, and we would greatly appreciate your participation in a survey. This will help us learn how we might best serve the needs of landowners and homeowners in the watershed.

By participating in this survey, you will help shape outreach programs and technical assistance options that may be provided. Your participation in this survey is completely voluntary. You may choose not to answer any question or stop participating in the online survey at any time. By completing and submitting this survey, you are consenting to be part of this research project. Responses will be confidential.

Take the survey with this link: [Insert Link]

Let’s work together to protect the water quality of the Black Lake Watershed.

Appendix 4. Great Lakes Stream Crossing Inventory Instructions

Great Lakes Stream Crossing Inventory Instructions

This protocol was developed, reviewed, and tested by the following organizations: Michigan DNR, U.S. Forest Service, Trout Unlimited, Wisconsin DNR, U.S. Fish & Wildlife Service, Huron Pines, Conservation Resource Alliance, Michigan Technological University, and road commissions. Funding for development and testing was provided by the U.S. Forest Service, U.S. Fish & Wildlife Service, and The Nature Conservancy.

This document is a guide to completing the *Stream Crossing Data Sheet* (new version forthcoming) and the Great Lakes Stream Crossing Inventory Survey, a Survey 123 application. Please use the below link to MI DNR ArcGIS HUB site or contact Mike Rubley (RubleyM1@michigan.gov) for access to the Survey 123 application. Careful attention to this guidance will ensure consistent crossing assessments, which is critical for identifying problems and prioritizing remediation.

The document can be accessed through the link below.

https://www.midnr.com/Publications/pdfs/ArcGISOnline/Guides/Stream_Crossing/Great_Lakes_Stream_Crossing_Inventory_Instructions.pdf

Appendix 5. Stream Crossing Data Sheet for Road Stream Crossing Inventory

Stream Crossing Data Sheet

Site ID:________________

Location Information

Stream Name:_____ Stream Flow Type: Perennial Intermittent Ephemeral Concentrated Wetland Flow
HUC 12 Watershed Code:___________________ Reach Code:_______________________________
Crossing Name:___________________________ Name of Observer(s): ________________________
Data Source/Affiliation:_____________________Date:______________________________________
GPS Waypoint:______________ GPS Lat/Long:____________________ Bearing:_______________
State:_____________ County:____________ Township:__________ Range:_________ Sec:_______
Adjacent Landowner Information:_____________________ Additional Comments:_____________
Utilities Present: Buried Gas Lines Gas Fiber Optic Overhead Lines Municipal Lines
Road/Crossing Owner: Federal State County Township City Tribal Private
Other:____________

Crossing Information

Road/Crossing Surface: Paved Gravel Sand Native Surface Grass/Vegetated
Condition: New Pavement or Well Graded Old Pavement or Rutted Broken Pavement or Rilled/Gullied Impassible
Road Core Integrity: Good Fair Poor
Frequent Road Overtopping: Yes No Unknown **Diversion Potential:** Yes No
Structure/Stream Alignment: Good Alignment Fair Alignment Poor Alignment
Structure Skew: No Skew Moderate Skew Major Skew
Road Width at Culvert (ft):____________________Structure Length (ft):[1]_____________________
Location of Low Point: **At Stream** **Other** **Runoff Path:** **Roadway** **Ditch**
Left Approach: Length (ft):_______Slope: <1% 1-5% 6-10% >10% **Ditch Vegetation:** None Partial Heavy
Right Approach: Length (ft):______Slope: 0% 1-5% 6-10% >10% **Ditch Vegetation:** None Partial Heavy

Upstream Embankment Fill Depth (ft):___Slope: Gentle (3:1, 15^0, 33%) Moderate (2:1, 22.5^0, 41%) Steep (1:1, 45^0, 100%) Gentle (0:1, 90^0)
Inlet Armoring/Rip-rap: None Gravel Rock Concrete Metal Woody Vegetation Other:________
Is Bank Armoring/Rip-rap Functional at the Inlet or Upstream Side: Good Fair Poor
Downstream Embankment Fill Depth (ft):_______Slope: Gentle (3:1, 15^0, 33%) Moderate (2:1, 22.5^0, 41%) Steep (1:1, 45^0, 100%) Gentle (0:1, 90^0)
Outlet Armoring/Rip-rap: None Gravel Rock Concrete Metal Woody Vegetation
Other:______
Is Bank Armoring/Rip-rap Functional at the Outlet or Downstream Side: Good Fair Poor
Use a new row for each distinct gully/erosion location. Note prominent streambank erosion within 50 feet of crossing.

Location of	Erosion Dimensions (ft)	Eroded Material	Material

Erosion Ditch, approach, or streambank Left or right facing downstream	**Length**	**Width**	**Depth**	**Reaching Stream?**		**Eroded** Sand, Silt, Clay, Gravel, Loam, Sandy Loam or Gravelly Loam.
				Yes	**No**	
				Yes	**No**	
				Yes	**No**	
				Yes	**No**	
				Yes	**No**	

If there is erosion occurring, can corrective actions, such as road drainage measures, be installed to address the problem? **Y** **N**

Extent of Erosion: Minor Moderate Severe Stabilized

Erosion Notes:

[1]- Fill out for primary culvert (culvert #1). If multiple culverts are used, number each and use embedded table. Form Date: May 11, 2021

Structure Information

Crossing Type: Culvert(s) no.:_________ Ford Dam Bridge Other:_________________

Crossing Use: Road Railroad Farm Crossing Trail Driveway Decommissioned Road Other:______

Additional Crossing Use: Not Applicable Wetland Equalization/Cross Drainage High Water Relief Portable Bridge Engineered Structure Other:

____

Structure Shape: Round Square/Rectangle Open Bottom Square/Rectangle Pipe Arch Native Bottom Arch Ellipse

Other:____

Structure Material: **Metal** **Concrete** **Plastic** **Wood** **Rock** **Clay** **Other:_____________**

Structure Interior: Smooth Corrugated

Structure Width (ft):[1]________________________________

Bridge Wetted Width (ft): ______________________________

Structure Height (ft): [1]________________________________

Substrate in Structure: None Sand Gravel Rock Mixture

Stream Flow: None < ½ Bankfull < Bankfull = Bankfull > Bankfull

Crossing Affected by Impoundment No Upstream Downstream

Multiple Culverts/Spans				
Number the culverts/spans left to right, facing downstream. Include #s in site sketch on back page				
Culvert/ Span #	**Width (ft) Length (ft) Height (ft)**			**Material**

Inlet Type: Projecting Mitered Headwall Apron Wingwall 10-30°
Wingwall 30-70° Wingwall >70° Trash Rack Headwall and Wingwall Other
____

Wingwall Material: Not Applicable Wood Logs Concrete Steel
Other___________________

Structure Inlet Water Depth (ft): [1]_____________ **Embedded Depth (ft):**[1]_____________________

Water Velocity (ft/sec): [1].________________ **Upstream Pond (if present) Length:**______________

Width:_____________________ **Sediment Wedge Present:** Yes No

Outlet Type: At Stream Grade Cascade over Riprap Freefall into Pool Freefall onto Riprap
Outlet Apron Other____________________

Structure Outlet **Water Depth (ft):** [1]_____________**Embedded Depth (ft):**[1]________________

Water Velocity (ft/sec): [1]________________ **Velocity Measured With:** Meter or Float
Test **Velocity Measured at** Surface or____________ ft Below Surface **Perch Height (ft):** [1] ________ or
NA **Scour Pool (if present) Length:** ______ **Width:** _______ **Depth:**_______ **Sediment Deposit:** Yes
No

Plugged:_______**%** Inlet In Structure Outlet **Crushed:**________**%** Inlet In Structure Outlet

Rusted Through? Yes No

General Condition:

❑ No deficiencies. New structure or nearly new condition.

❑ Not new, but no noticeable corrosion, abrasion, chipping, spalling, or cracking. No shape changes such as barrel distortion (bowing, bending, warping), bulging, inlet or outlet damaged.

❑ Light superficial corrosion or abrasion or chipping or spalling or cracking. No shape changes (described above).

- ❑ Moderate deterioration from corrosion or abrasion (small rust flakes or indication that rust is slightly deeper than the surface level) or cracking or spalling or chipping (few minor cracks or localized chipping in the concrete). OR minor shape changes (described above).
- ❑ Moderate to major deterioration from corrosion or abrasion (less than 5% of the structure has small holes or is nearly rusted through) or cracking or spalling or chipping (several small cracks or moderate chipping in the concrete). OR Moderate shape changes (described above).
- ❑ Major deterioration from corrosion or abrasion (5-10% of the structure is rusted through) or cracking or spalling or chipping (medium sized cracks, widespread chipping, exposed metal reinforcement). OR Major shape changes (described above) reducing the capacity of the structure by less than 30%. OR segment disconnection (segments of concrete or metal culvert disconnecting internally) but no evidence of water piping.
- ❑ Major deterioration from corrosion or abrasion (10-50% of the length of structure is rusted through) or cracking or spalling or chipping (large chunks sloughing off, large cracks, exposed metal reinforcement). OR Major shape changes (described above) reducing the capacity of the structure by up to 50%. OR segment disconnection with evidence of water piping under or around the culvert.
- ❑ Severe deterioration from corrosion or abrasion (more than 50% of the structure is rusted through) or cracking or spalling or chipping (more than 50% of the structure is compromised). Or Major shape changes (described above) reducing the capacity of the structure by greater than 50%. OR Segment disconnect causing major subsurface erosion/piping and/or partial fill failure and/or sink holes in the fill.
- ❑ Deterioration, shape changes, or segment disconnection more severe than the previous category to the extent that the road manager should be contacted to determine if the road should be closed.

❑ Road closed. Impassible. Partial or full crossing failure.

Representative Reach (measured in a riffle outside of zone of influence of crossing)

Reach Location: Upstream Downstream **Distance From Crossing (ft):_____________________**

Bankfull Width (ft):___________ Wetted Width (ft): ____________Water Depth (ft): ____________

Water Velocity (ft/sec): _______________

Velocity Measured With: Meter or Float Test

Velocity Measured at Surface or __________ft Below Surface

Dominant Substrate: Clay Organics Silt Sand Gravel Cobble Boulder Bedrock

Channel Stability Assessment

Indicators of Channel Equilibrium

❑ The channel has a well-defined bankfull contour that clearly demarcates an obvious, well connected floodplain near the bankfull elevation throughout most of the reach. In sand bed systems, there is often fresh sand deposition on or forming this bank.

❑ Perennial riparian vegetation is abundant and well established along the bankfull contour, but not below it.

❑ There is leaf litter, thatch, or wrack in most pools (if pools are present)

❑ The channel contains embedded woody debris of the size and amount consistent with what is naturally available in the riparian area.

❑ There is little or no active undercutting or burial of riparian vegetation.

❑ If mid-channel bars and/or point bars are present, they are not densely vegetated with perennial vegetation.

❑ There are channel pools, the spacing between pools tends to be regular and the bed is not planar (flat or uniform gradient) through the reach.

❑ The larger bed material supports abundant mosses or periphyton.

Indicators of Active Degradation

❑ The channel is characterized by deeply undercut banks with exposed living roots of trees or shrubs.

❑ There are abundant bank slides or slumps.

❑ The lower banks are uniformly scoured and not vegetated.

❑ The channel elevation below the road is much lower in elevation than above the road. The road has stopped a headcut from progressing up stream <u>(all other factors should be assessed away from the road).</u>

❑ Riparian vegetation is declining in stature or vigor, or many riparian trees and shrubs along the banks are leaning or falling into the channel <u>(do not consider trees from outside of the bank that have fallen into the channel or an occasional wind-tripped bank tree).</u>

❑ An obvious historic floodplain has recently been abandoned, as indicated by the age structure of its riparian vegetation.

❑ The channel bed appears scoured to bedrock or dense clay.

❑ Head cuts, “nick points” are present.

❑ In-stream infrastructure such as bank stabilization structures or fish habitat structures are exposed or being undercut by the stream.

Indicators of Active Aggradation

❑ There is an active floodplain with fresh splays of coarse sediment (sand and larger that is not vegetated) deposited in the current or previous year.

❑ There are partially buried living tree trunks or shrubs along the banks.

❑ Perennial terrestrial or riparian vegetation is encroaching into the channel or onto channel bars below the bankfull contour.

❑ There are avulsion channels on the floodplain or adjacent valley floor.

Overall Channel Stability

❑ Equilibrium

❑ Degradation

❑ Aggradation

Entrenchment

❑ Entrenched

❑ Moderately Entrenched

❑ Slightly Entrenched

Photos – enter photo number in blank corresponding to location

❑ Inlet___________ ❑Upstream Conditions____________ ❑ Downstream Conditions______________

❑ Outlet __________❑Road Approach – Left __________ ❑ Road Approach – Right______________

❑Representative Reach_________________________

Channel Stability Assessment

Do you believe there is a time-sensitive maintenance need at the site? Yes No **Why?____________**

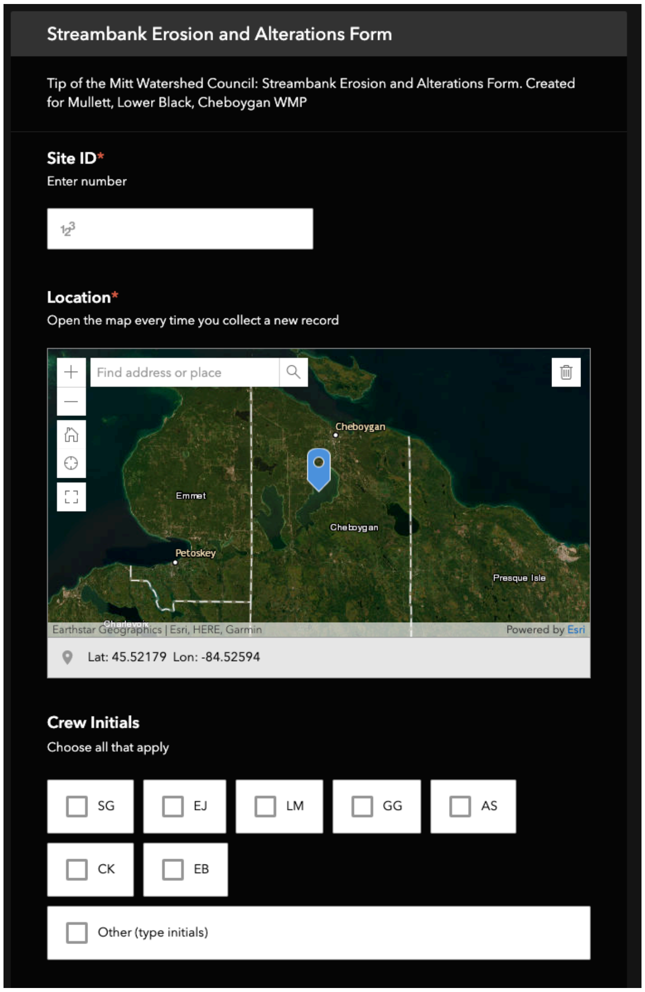
Were any non-native invasive species observed at the site? Yes No **If yes, what species were observed?_______________**

Site Comments: *(Describe any site factors or context unique to the site not captured in the above protocol. Record the cause of any of the issues noted above (plugging, ponding, sediment deposition, etc…). If upstream sediment deposition is observed, please indicate here. Factors unique to fords should be recorded here: wetted width across the ford, approach armoring, streambed armoring.)*

Site Sketch

Draw an overhead sketch of crossing. Be sure to mark North on the map and to indicate the direction of flow. Include major features documented on form, such as erosion sites, multiple culverts, scour pool, impounded water, etc.

Appendix 6. Survey123 Form for Streambank Erosion Inventory



Streambank Erosion and Alterations Form

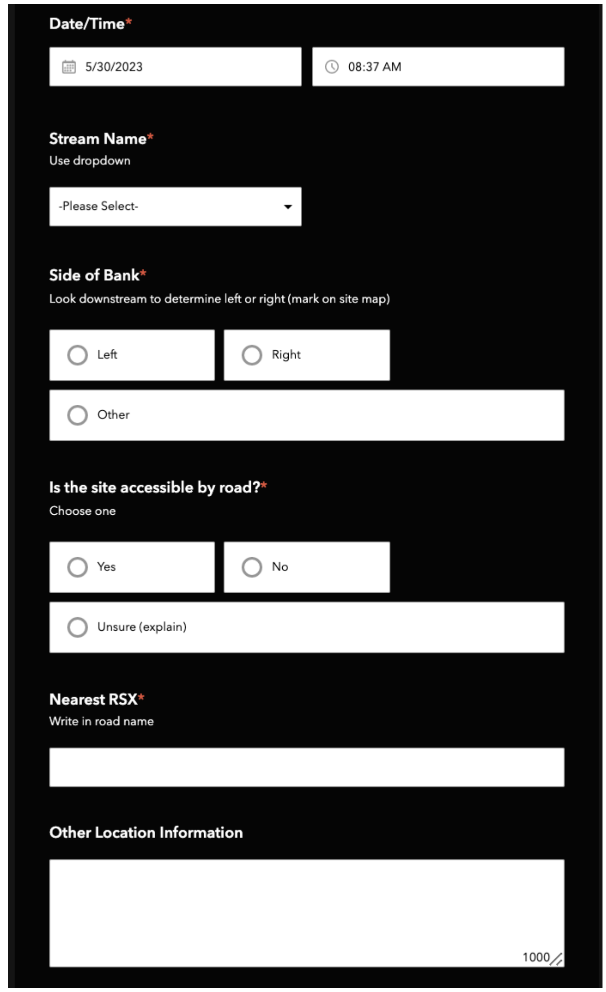
Tip of the Mitt Watershed Council: Streambank Erosion and Alterations Form. Created for Mullett, Lower Black, Cheboygan WMP

Site ID*
Enter number

Location*
Open the map every time you collect a new record

Crew Initials
Choose all that apply

SG EJ LM GG AS CK EB Other (type initials)



Date/Time*
5/30/2023 08:37 AM

Stream Name*
Use dropdown

-Please Select-

Side of Bank*
Look downstream to determine left or right (mark on site map)

Left Right Other

Is the site accessible by road?*
Choose one

Yes No Unsure (explain)

Nearest RSX*
Write in road name

Other Location Information

1000

Bank Condition*
Choose one

- ○ Toe is undercutting
- ○ Toe is stable; upper bank eroding
- ○ Toe and upper bank are eroding
- ○ Other

Bank Vegetative Cover*

- ○ 0-10%
- ○ 11-50%
- ○ 51-100%

Problem Trend*

- ○ Increasing
- ○ Decreasing
- ○ Combination
- ○ Stable

Other Comments about the Bank Condition

1000

Apparent Cause of Bank Erosion*
Choose all that apply

- ☐ Obstruction in river
- ☐ Bank seepage
- ☐ Gullying of bank from side channels
- ☐ Bend in river
- ☐ Road/stream crossing runoff
- ☐ Access traffic (write light, medium, or heavy in Other field)
- ☐ Wave action
- ☐ Other or Traffic Type

Length of Eroded Bank*
Estimate or measure using feet

Average Height of Eroded Bank*
Feet

Slope of Bank-vertical*
Choose one

- ○ 1:1
- ○ 1:2
- ○ 1:3
- ○ 1:4 or flatter

Approximate Width of River Where Erosion Occurs*
Feet

[ ]

Approximate Depth of River*
Feet

[ ]

How far away from the bank was river depth measured or estimated?*
Preferable get estimate 4' from the bank

[4]

Current

- ○ Fast
- ○ Slow
- ○ Other

Soil type or texture

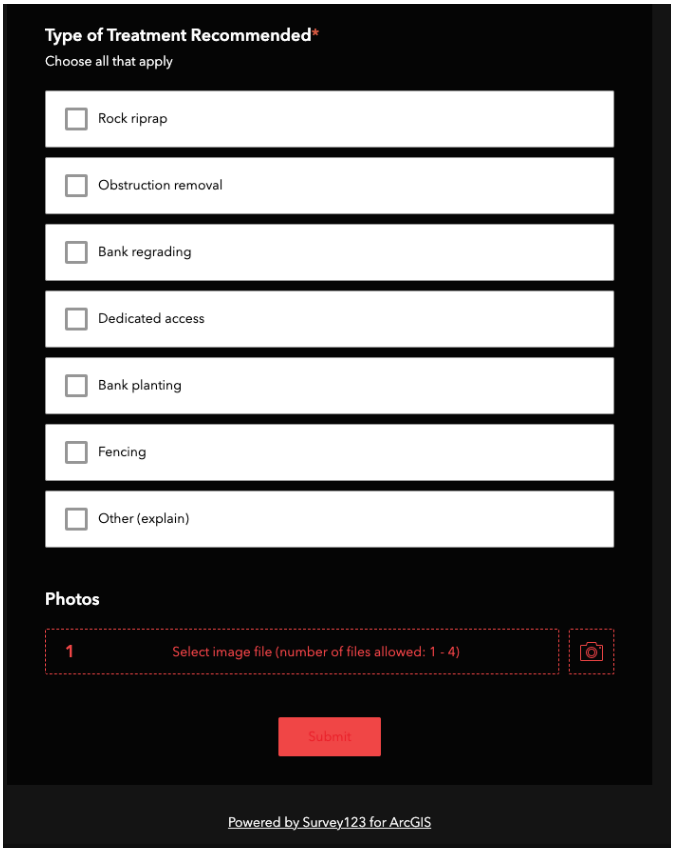
- ○ Sand
- ○ Gravel
- ○ Stratified
- ○ Clay, loam
- ○ Other

Streambank Structures
Choose all that apply

- ☐ Hardened seawall (describe in Other)
- ☐ Dock
- ☐ Launch/Ramp
- ☐ Stairway
- ☐ Rock rip-rap
- ☐ Boulder rip-rap
- ☐ Mixed rock and boulder rip rap
- ☐ Beach sand
- ☐ Discharge pipe
- ☐ None

Has native vegetation been removed?*
Choose one

○ Yes ○ No



Type of Treatment Recommended*

Choose all that apply

- [ ] Rock riprap
- [ ] Obstruction removal
- [ ] Bank regrading
- [ ] Dedicated access
- [ ] Bank planting
- [ ] Fencing
- [ ] Other (explain)

Photos

1 Select image file (number of files allowed: 1 - 4)

Submit

Powered by Survey123 for ArcGIS

Appendix 7. Animal Feeding Operations Inventory

Animal Feeding Operations Inventory

Purpose

Animal feeding operations (AFOs) are potentially significant contributors of nonpoint source (NPS) pollutants. This paper outlines an approach for cataloging, evaluating, and prioritizing AFOs within a Geographic Information System (GIS), for inclusion in a nine-element watershed management plan. This paper only looks at the AFO itself and not at the land application of manure.

The primary objective of an AFO inventory is to establish a prioritized list of locations, which stakeholders can use to systematically contact landowners about the incorporation of best management practices (BMPs) within their operation. The incorporation and systematic response to specific information within a watershed management plan allows stakeholders to develop implementation proposals that are more competitive.

Recommended Data Layers

The evaluation of AFOs within a watershed should always begin with a desktop analysis. The compilation of the following data layers is recommended when identifying AFOs within the planning area:

- Subwatershed Boundaries - the United State Geologic Survey (USGS) has created a nested set of watersheds for the entire country known as the hydrologic unit codes (HUCs). The twelve digits HUCs are the smallest unit in this cataloging system and are referred to as a subwatershed. Subwatersheds typically range in size from 10,000 to 40,000 acres. The location of AFOs should be compiled at the subwatershed level.
- Aerial Photographs - High resolution imagery (<1 ft. resolution) is critical in identifying and preliminarily evaluating the condition of an AFO. ArcMap provides good medium and high resolution aerial photographs. Aerial photographs are accessed within ArcMap in the following location: file>add data> add base maps. Medium resolution aerial photographs are activated at scales from 1:54,000 to 1:3,001 and are good for initial identification of AFOs. High resolution aerial images are activated at a 1:3,000 scale or less, and provide for a detailed evaluation of the site.

  High resolution photographs can also be obtained using the SIGGIS street view and birds eye add in tool bar. This tool provides high resolution aerial and bird's eye view photographs by simply clicking on the desired location in the ArcMap environment. A pop-up box with the image will appear. This tool should be used in tandem with the previously mentioned images, because point locations cannot be added onto the images derived from the SIGGIS tool. The tool provides the same images, with the advantage of a faster loading rate than ArcMap. The SIGGIS add in tool can be downloaded from the following location:
  http://www.arcgis.com/home/item.html?id=cb1bd2804d0f42d2b903952c2d781170
- Confined Animal Feed Operations (CAFOs) – Facilities that house a large number of animals or are found to be a significant contributor of pollutants are required to obtain a National Pollution Discharge Elimination System (NPDES) permit from Michigan's Department of

Environmental Quality (MDEQ). The number of animals needed to qualify as a large operation depends on the type of animal housed at the facility, see appendix B. Locational information is required as part of the permit, therefore all CAFOs within the subwatershed can and should be mapped. CAFOs locations can be obtained using MDEQ's MiWaters Site Map Explorer at: https://miwaters.deq.state.mi.us/nsite/. Click on the filter tab and select "Concentrated Animal Feeding Operation" under "Site Type". Then zoom in to the area of interest. Pink dots indicate CAFO locations. If there is a number in the pink dot this indicates more than one CAFO is located in this area. Zoom in further to get the exact location of the CAFOs.

- Waterbodies - An important step in this process is to identify what sites are in proximity to waterbodies. It is important to consider the potential impacts these facilities have on the different type of aquatic systems within a watershed. Shapefiles identifying the rivers, wetlands and lakes within the planning area should be incorporated into this process. Proximity to waterbodies should be included as part of the AFOs spatial datasets attribute table.
- Road Network - The road network within the planning area is needed. Maps with the location of the AFOs are printed and used to navigate the subwatershed during the windshield survey.
- Public Land Survey (Sections) - Using a grid overlay is optional, but recommended as it provides a way of systematically moving through a subwatershed. This is particularly important if the identification of AFOs can't be completed in one session. Sections are approximately 640 acres and are recommended as the grid overlay but, other grids systems can certainly be used.
- Topographic Data- elevation data of all AFOs should be evaluated, with particular attention paid to facilities in proximity to waterbodies. Contours or digital elevation models (DEMs) can be used. It is important to understand the direction water is likely flowing when runoff occurs on the site and how that runoff maybe impacting water quality.

Indicators of Animal Operations

AFOs can be easily identified using aerial photographs. The following section discusses some of the distinguishing characteristics that help to identify an AFO. These characteristics are interrelated and should be used as in conjunction with each other when evaluating if an operation is an AFO.

Manure Storage Structures

Animals produce waste and larger AFOs collect animal waste in manure storage structures. Manure storage structures are typically square or rectangular in shape (Figure 1), although older structures can be circular and elevated (Figure 2).

Manure storage structures typically appear to be holding a dark or turbid fluid but sometime may appear empty. Although manure storage structures are a very distinct feature, some AFOs have manure storage beneath the structures that house the animals. Similarly, smaller AFOs will not have manure storage structures, but will have areas where the manure is piled. Therefore, this feature may not be present on all AFOs.

Figure 1. A typical small manure storage structure

Figure 2. An older empty circular manure storage structure

Building Types

AFOs are typically long linear white buildings of varying sizes, depending on the number of animals they are housing. Figure 3 shows a larger AFO. It is also important to consider the kind of animal that may be present. The presence of the ring in Figure 4 indicates that horses are likely kept at this facility.

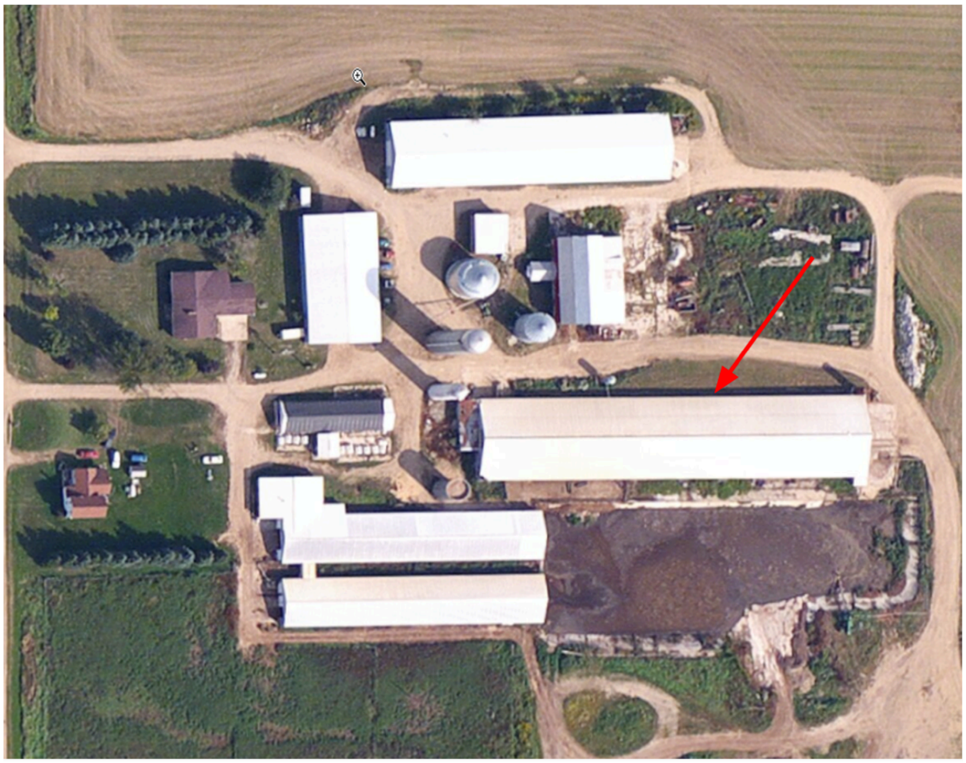


Figure 3. Larger operation with typical white structures of an AFO.

Figure 4. A small horse facility with a discernable exercise ring.

Feedlots/Bare Earth Areas

The presence of animals can result in the loss of ground vegetation. Patches of bare earth are a characteristic of AFOs (Figures 5 and 6).

Figure 5. Patches of bare earth.

Figure 6. Patches of bare earth area associated with AFO.

Feed Storage

There are three characteristic feed storage structures found on AFOs: bagged silage, silos, and silage bunkers. Bagged silage are typically long white tube like structures but can also be rectangular in shape (Figure 7). Silos are the classic tall cylindrical structures associated with agricultural operations (Figure 7).

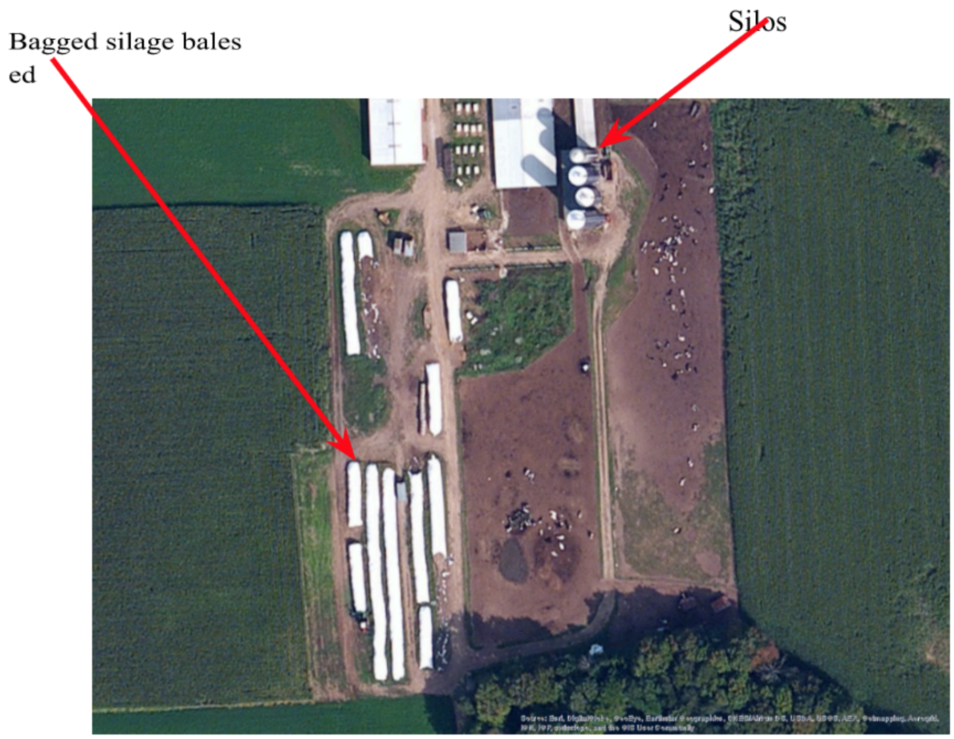


Figure 7. Typical form of bagged silage bales and silos on an AFO.

Figure 8. Example of the foil like appearance of a silage bunker.

Depending on the angle of the sun, the surface of a silage bunker can take on a tin foil like appearance (Figure 8). Another way of distinguishing silage bunkers are a series of circles, which are car tires piled on top to help keep the material covering the feed in place (Figure 17).

Feeder Stations

Feed for animals are often placed in feeder stations. Figure 9 shows several feeder stations out in a feedlot. An indicator typically associated with feeder stations is patches of bare earth. In a pasture setting, feeder stations are often moved around, and the bare earth areas have a distinct circular and/or rectangular pattern (Figure 10).

Figure 9. Feeder stations in feedlot

Figure 10. Feeder station outlines in pasture

Identification of Potential Sources of NPS Pollutants within AFOs

While reviewing aerial photographs for evidence of potential animal feeding operations you can also begin to identify sources of nonpoint source pollutants that have the potential to impact water quality. The items listed below should be considered when attempting to locate sources of nonpoint source pollutants at animal feeding operations:

- Proximity to water body
    - The closer a potential source is to a water body, the likelihood of it impacting water quality usually increases. The areas adjacent to water bodies and the connected upland area should be reviewed with an especially close eye.
    - Are there areas of bare, disturbed soil along surface waters? Does the stream channel become overly wide relative to other areas upstream and downstream at these sites? These could be areas where animals have direct access to surface water (It's possible

some aerials might even show animals accessing the stream at the time the picture was taken).

- Look for signs of fencing or other barriers that would indicate animals are not allowed direct access to streams.

Figure 11: Arrows indicate areas of bare soil where animals may have access to the stream. Banks appear disturbed.

- Review the features that indicate the site is an animal feeding operation. Look for any obvious drainage pathways near feed lots, pasture areas, silos, bunkers, or other impervious surfaces to surface water.

Figure 12: Arrows indicate natural drainage path from a feedlot area through a field to surface water.

Figure 13: Disturbed areas show temporary locations for animal feeding. Arrow indicates drainage flow path from feeding area, potentially transporting nutrients and pathogens to surface water.

- Manure Storage
    - Search the site for potential manure storage infrastructure, including above ground storage structures and earthen manure storage structures.
        - Above ground storage structures are often tall, circular structures (Depending on the lighting in the aerial photograph, you may be able to judge how full the structure is, which could give insight on the number of animals present). Are there any drainage pathways nearby leading to surface waters?

Figure 14: Arrow indicates above ground manure storage structure.

- Earthen manure storage structure are lined, pond-like structures. Are they located close to surface water bodies?

Figure 15: Arrow indicates earthen manure storage structure.

- If there are no signs of storage structures, look for areas where equipment have frequented (bare soil) or other sectioned-off areas where manure piles could be kept. Piles might be visible from aerials.

- Silage Storage
  - Search the site for bunkers or silos. If these are in close proximity to water bodies or there are obvious drainage pathways leading to surface waters these could be sources.

Figure 16: Arrow indicates silos, potential sources of nutrients

Figure 17: Orange arrows indicate silage storage bunkers. Blue arrows show cows in close proximity to stream.

- Look at the site as a whole. Do buildings and equipment appear to be in good condition? Are things neat and orderly? Review the general management practices in place. If things overall look disorganized, there could be problems.

Prioritization

Using evidence collected during review of aerial photographs, sites can be prioritized based on the likelihood that water quality is being negatively impacted. The type of animal operation, the size of the operation, and the management practices being utilized at AFOs can be used to determine how severe that impact may be and what sites should be referred for further follow-up (site visit, drive by during windshield survey).

Type

Below are examples of different types of animal feeding operations including dairy, beef, poultry, swine, and hobby farms. Characteristics of each are noted, as well as the size.

- Dairy

Figure 18: Dairy operation

Characteristics that indicate this is a potential dairy operation include:

- ○ Presence of a circular storage structure for liquid manure
- ○ Silos for storing feed
- ○ Red arrow indicates milking parlor structure with direct road access for trucks
- ○ Top of the image shows hutches for calves
- ○ Limited pasture area
- ○ *Based on the size and number of structures, this operation is categorized as "Medium"

- Beef

Figure 19: Potential beef operation

Characteristics that indicate this is a potential beef operation include:

- No obvious milking parlor building
- No obvious liquid manure storage structures
- Larger areas for pasture
- *Based on the size of structures, this is categorized as a “Small” beef operation

- Poultry:

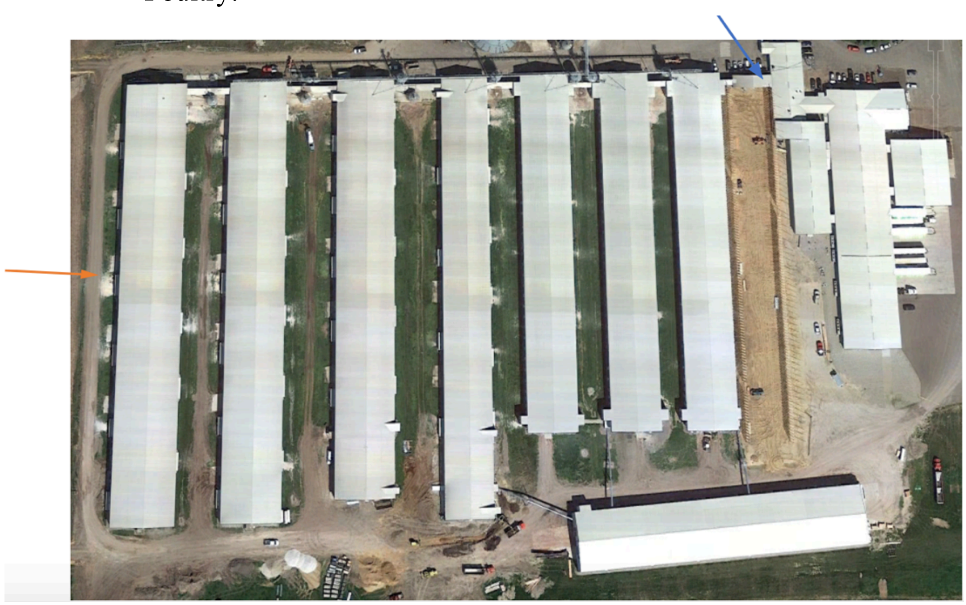


Figure 20: Poultry operation

Characteristics that indicate this is a potential poultry operation include:

- Fans lining the outside of long building with nearby dust/feather piles (see red arrow)
- Long buildings are connected to a more central building for processing. Easy road access as well (see blue arrow)
- *Based on the size and number of structures present this operation would be categorized as "Large"

- Swine

Figure 21: Swine operation (with visible manure storage structure)

Characteristics that indicate this is a potential swine operation include:

- Presence of circular manure storage structure (for slurry manure)
- Red arrow indicates feeders positioned at end of buildings
- Blue arrow indicates fans (without dust piles nearby)
- No on-site processing building
- Easy truck access.
- Based on the size and number of structures present this operation would be categorized as "Medium"

Example 2 below has no additional manure storage, but still has all other above characteristics.

Figure 22: Potential swine operation (without visible manure storage structure).

- Hobby (horse, miscellaneous)

Figure 23: Potential hobby farm (sheep)

Characteristics that indicate this is a potential hobby farm operation include:

- Pasture area
- No sizable structures for storing manure
- No sizable structures to house animals

Size

Large, medium, and small classifications are based on the numbers provided in Appendix B, which are the regulatory definitions of large, medium, and small CAFOs.

- Large
- Medium
- Small
- Hobby

Storage

- How is manure and silage being stored? Is it sufficient?

Maintenance

Orderly vs disorganized

High Priority

- Any size dairy or beef operations in close proximity to water bodies with:
  - Observable drainage pathways leading to surface waters from identified sources
  - No manure storage found, or,
  - Storage is lacking, or otherwise disorganized
- Operations with potential livestock access issues

Medium Priority

- Hobby farms with:
  - Potential access issues
  - Observable drainage pathways leading to surface waters from identified sources
- Any size or type AFO with manure storage structures near the water body, but no strong evidence of water quality impacts observable via aerials.

Low Priority

- Any size or type of AFO not near observable connection to the water body.

AFO Field Check Methodology

Once aerial photograph identification and prioritization of animal feeding operations has been completed a field check should be performed to determine if the information gathered and conclusions made are accurate. The intent of the field check is not to do an on the ground inspection of every site but to drive by the identified sites and check the potential sources that can be observed either from the road or from within an adjacent stream. Reprioritization might be necessary based on the information gathered while performing the field check. Appendix C is an example of a field data sheet that could be used to collect the necessary data. At least two people should perform the field check. This allows one person to drive and another to make observations. However, it might be beneficial to have a third person to navigate. Prior to performing the field check the most efficient route to the sites should be identified.

Confirming Potential Sources

Proximity to water body

- Confirm the presence or absence of nearby water bodies identified on aerial photographs. If a water body has been identified adjacent to the site, walk the water body to identify potential sources of pollutants and complete the appropriate sections of the Pollutant Source Identification Data Sheet (Appendix D). This includes identifying if there is a vegetated buffer between the operation and the surface water which could help reduce pollutant impacts in a run off event. If the water has an odor, sheen, or distinct color change it is probable that there is a pollutant source nearby. Potential sources of pollutants that can be observed from the surface water include:

        - Evidence of livestock access such as disturbed soil along the banks and widening of the stream. Also look for fences or other barriers that would restrict cattle access.
        - Pipes directly discharging to the surface water or run off paths from the operation into the surface water.
    - If there are road side ditches adjacent to the site follow them and determine if they have a surface water connection and if they do complete the appropriate sections of the Pollutant Source Identification Data Sheet (Appendix D).

Type

- Determine or confirm if the operation is dairy, beef, swine, poultry, or hobby/horse.

Size

- Confirm the size of the operation. Are there new buildings that are not on the aerials?

Storage

- How are manure, and silage being stored? Is silage covered?

Maintenance and storage

- To the best of your ability from what you can see from the road document the overall cleanliness and organization of the site.
    - Note if buildings and equipment appear to be maintained.

Reprioritization

Once the field check has been completed use this additional information and determine if the sites have been prioritized correctly or if they need to be reprioritized based on the prioritization methodology.

Appendix B

Regulatory Definitions of Large CAFOs, Medium CAFO, and Small CAFOs

A **Large CAFO** confines at least the number of animals described in the table below.

A **Medium CAFO** falls within the size range in the table below and either:

- has a manmade ditch or pipe that carries manure or wastewater to surface water; **or**
- the animals come into contact with surface water that passes through the area where they're confined.

If an operation is found to be a significant contributor of pollutants, the permitting authority may designate a medium-sized facility as a CAFO.

A **Small CAFO** confines fewer than the number of animals listed in the table **and** has been designated as a CAFO by the permitting authority as a significant contributor of pollutants.

Animal Sector	Size Thresholds (number of animals)		
	Large CAFOs	**Medium CAFOs[1]**	**Small CAFOs[2]**
cattle or cow/calf pairs	1,000 or more	300 - 999	less than 300
mature dairy cattle	700 or more	200 - 699	less than 200
veal calves	1,000 or more	300 - 999	less than 300
swine (weighing over 55 pounds)	2,500 or more	750 - 2,499	less than 750
swine (weighing less than 55 pounds)	10,000 or more	3,000 - 9,999	less than 3,000
horses	500 or more	150 - 499	less than 150
sheep or lambs	10,000 or more	3,000 - 9,999	less than 3,000
turkeys	55,000 or more	16,500 - 54,999	less than 16,500
laying hens or broilers (liquid manure handling systems)	30,000 or more	9,000 - 29,999	less than 9,000
chickens other than laying hens (other than a liquid manure handling systems)	125,000 or more	37,500 - 124,999	less than 37,500
laying hens (other than a liquid manure handling systems)	82,000 or more	25,000 - 81,999	less than 25,000
ducks (other than a liquid manure handling systems)	30,000 or more	10,000 - 29,999	less than 10,000
ducks (liquid manure handling systems)	5,000 or more	1,500 - 4,999	less than 1,500

[1]Must also meet one of two "method of discharge" criteria to be defined as a CAFO or may be designated.
[2] Never a CAFO by regulatory definition, but may be designated as a CAFO on a case-by-case basis.

Appendix C

Animal Feeding Operation Survey Data Sheet					**Site ID #:**			
NOTES: Use one data sheet per GPS location.					**Date:**			
					Photo numbers:			
Watershed:					**Investigator(s):**			
GPS	**Lat:**		**Long:**		**Site Address:**			
Proximity to Water Body								
Adjacent to a water body?								
Road side ditch that connects to a water body?								
*If answered yes to the either question above complete the appropriate sections of the Pollutant Source Identification Data Sheet								
Notes:								
Type of Operation								
Aerial Information	Dairy	Beef	Swine	Poultry	Hobby	Unknown		
Field Check Information	Dairy	Beef	Swine	Poultry	Hobby	Unknown		
Notes:								
Size of Operation								
Aerial Information	Large	Medium	Small	Hobby	Unknown			
Field Check Information	Large	Medium	Small	Hobby	Unknown			
Notes:								
Storage								
Aerial Information	Good	Fair	Poor					
Field Check Information	Good	Fair	Poor					
Notes:								
Maintenance								
Aerial Information	Good	Fair	Poor					
Field Check Information	Good	Fair	Poor					
Notes:								
Priority								
Aerial Information	High	Medium	Low					
Field Check Information	High	Medium	Low					
Notes:								

Appendix D

Pollutant Source Identification Data Sheet Instructions

NOTE: This data sheet is set up to collect all necessary parameters to use the Spreadsheet Tool for Estimating Pollutant Loads (STEPL) program to calculate pollutant load estimates. Section 319 and 205(j) grantees should submit this form as part of a Quality Assurance Project Plan (QAPP) document to the Department of Environmental Quality (DEQ) Nonpoint Source (NPS) Program for approval. NPS Program staff is available to help select the appropriate pollutant source sections to include on the field data sheet.

<u>Suggested Equipment checklist</u>

Maps with waterways and roads labeled
Field data sheets (many copies or electronic data recorder)

Clipboard
Pens/pencils
GPS unit
Tape measure (100 ft)
Folding ruler (6 ft)
Camera with extra batteries
Compass
Waders, hip boots, or wading shoes
Traffic cones
Brush clearing tools
First aid kit
Insect repellant/sunscreen
Lunch/snacks/water for long field day

General tips

Follow these guidelines to gather information for documenting nonpoint sources for inclusion in a watershed management plan. This form should be used to document pollutant sources and should not be used as a general watershed characterization form. For example, if you come across a road stream crossing and do not see any pollutant sources to document (e.g. no noticeable erosion), then you do not need to fill out this form for that site. While there is no section for documenting high quality areas for protection it would be beneficial to note those areas in the comment box at the end of the field form.

This form should be used as a walking inventory is conducted but could be used in conjunction with a driving or kayak inventory. It is unrealistic and unnecessary to try to walk an entire watershed to document all potential pollutant sources. Therefore, to be the most efficient with this form, it should be used in areas that have already been prioritized based on other methods (i.e., Total Maximum Daily Load areas and waters on the state's nonattainment list should be a priority as well as other known sources that have already been documented).

In general, face downstream when determining "left bank" or "right bank." The only exception is when you are documenting erosion locations at a road stream crossing, in which case always face the crossing to determine left/right bank.

Photographic documentation

Taking pictures and documenting where the pictures are taken is a highly useful tool and strongly recommended. Make an effort to get a representative set of photos for each site and take detailed notes.

Site specific information

As field inventories are conducted, site specific Global Positioning System (GPS) information should be recorded in the decimal degrees format using the World Geodetic System (WGS) 1984 geographic coordinate system.

Determining the number of "years present"
The number of years a problem has been present is needed to get an estimate of annual pollutant loads. Use your best professional judgment to estimate the number of years. It may be helpful to speak with nearby landowners or to look at aerial photos.

Determining erosion severity
Erosion severity has been divided into four categories: slight, moderate, severe, or very severe. Technically, the categories are based on the following rates:

Category	Erosion rate (feet/year)
Slight	0.01-0.05
Moderate	0.06-0.2
Severe	0.3-0.5
Very severe	> 0.5

Determining the severity of erosion is somewhat subjective. Use other observations throughout the watershed to determine if the erosion is slight, moderate, severe, or very severe compared to other locations. Gathering information from sites where Best Management Practices (BMP) can be implemented should be a priority activity. Funding BMPs at severe/very severe erosion sites will generally be favored over funding BMPs at slight/moderate erosion sites. Slight/moderate erosion sites should not be the main focus of inventory work.

Determining the "soil texture" type
Determining soil texture can be a difficult task and is a required parameter for calculating pollutant loads for potential nonpoint pollution sources. Therefore, soil texture has been divided into four categories. Choose between the following four general categories:

1. Clay – feels sticky, malleable material
2. Silt – feels smooth, very fine particles
3. Sand – feels gritty
4. Organic – muck, mixture of coarse leaf and wood material

Use the table to match the general soil texture category with the STEPL category.

General soil texture identified in field	**STEPL Category to use for calculations**
Clay	Clay
Silt	Silt loam
Sand	Fine sandy loam
Organic (mixture of detritus, sand, silt, and clay)	Organic

To fill out the data sheet and obtain the most accurate information in an organized manner, it is important to COMPLETELY fill out the data sheet. After field work is complete it may be difficult to determine if a blank field means that the item was not assessed or whether it was not applicable. Instead of leaving a field blank, write NA for items that were not applicable.

All length measurements should be made in feet and recorded to the nearest 0.1 foot. Do not record inches, even for measurements that are less than one foot. For example, record 0.5 feet instead of 6 inches. Measurements longer than 20 feet should be rounded to the nearest foot if you are not confident in the precision of the measurement.

The following instructions for each section are organized in the same order as the field data sheet.

Be sure to fill in the general information at the top of each field sheet including watershed, tributary name, GPS coordinates, site identification, date, photo numbers (so later you can keep track of what photos went with each site), and the names/initials of the people in the field crew. Next, since this field form will only be used to DOCUMENT POTENTIAL POULLUTANT SOURCES, you will circle all of the appropriate source categories that apply to your location.

SECTION 1. ROAD RUNOFF

http://ridgetoriver.com/land_use.html

Figure 3. Road runoff has the potential to increase the amount of nonpoint source pollution that enters water bodies.

A road running parallel to (or close to) a water body would be the first indication that road runoff may be a potential pollutant source. A visual cue that it is a source would be rills (see definition page 8) running from the road surface (Figure 3 and Figure 4a).

Road surface: Circle the type of road surface. Unimproved refers to any two-track or dirt road.

Length contributing to runoff: Estimate the length of road contributing to runoff.

Distance of road from water: Estimate the distance of the road from the water body.

Years erosion present: Use your best professional judgment to determine the number of years the observed erosion has been present (see page 2).

Soil texture: Determine if the soil is mostly clay, sand, silt, or organic material. See the bottom of page 2 for more guidance.

SECTION 2. GULLY EROSION

Location: Face downstream and determine if the observed erosion is on the left bank or right bank.

Apparent cause: There are several possible causes of gully erosion. Some common examples include overland runoff due to poor vegetation cover, overgrazing, human activities, improper land use, or improper irrigation design.

Soil texture: Determine if the soil is mostly clay, sand, silt, or organic material. See the bottom of page 2 for more guidance.

Erosion top/bottom width/depth/length: Measure the top and bottom width of the erosion area along with the depth and length. Measurements should be rounded to the nearest 0.1 foot.

Years erosion present: Use your best professional judgment to determine the number of years the observed erosion has been present (see page 2).

SECTION 3. INADEQUATE RIPARIAN BUFFER

Only fill out this section if there is an inadequate buffer and there is opportunity to restore the riparian area. For example, if the lack of buffer is due to a roadway and runoff is observed, then SECTION 2. ROAD RUNOFF should be filled out, not this section. The adequacy of a buffer will depend on soil type, slope, and upland land use so an adequate buffer width at one site may not be the appropriate width at a different site. For example, the Natural Resources Conservation Service filter strip standard requires a minimum of 20 feet between water bodies and cropland. However, if the riparian area is steeply sloped, the filter strip may need to be wider than 20 feet.

Existing buffer/filter strip dimensions: Facing downstream, estimate the current width and length of the buffer area on the left bank and the right bank. If there are miles of inadequate buffer than estimate current conditions as best as you can. Aerial photos may help get a more accurate estimate.

Length of buffer needed: Estimate the length of buffer needed on the left bank and right bank. If miles of buffer are needed it is suggested to take a GPS reading at the upstream point and at the downstream point and use aerial photos in conjunction with walking the site to get an accurate estimate.

Estimated contributing acreage: Use aerial photos to estimate the amount of acreage contributing nonpoint source pollution for the left and/or right bank.

Riparian habitat: Circle the description of habitat for each bank.

Upland land use: Determine the current upland land use on the left and right bank. This refers to the area beyond the riparian zone.

SECTION 4. LIVESTOCK ACCESS

Location: Face downstream and determine if the observed livestock access is on the left bank or right bank.

Aquatic vegetation/algal blooms: Determine if there is: no increased plant/algal growth, slight, moderate, or extensive growth downstream of the livestock access to the water.

Soil texture: Determine if the soil is mostly clay, sand, silt, or organic material. See the description at the bottom of page 2 for more guidance.

Number/type of animal: Determine the approximate number of animals that have access to the watercourse and write down what animals are present. It is important to estimate the number of animals to get an idea of how significantly the livestock access could impact water quality.

Erosion type (select all that apply): If you observe livestock access, but no erosion, then circle "none" for the erosion type. If you observe erosion, determine if the type of erosion is a rill, streambank, or gully (can circle more than one category if applicable). A rill is the initial sign of erosion and is most common on slopes. Rills are much smaller than a gully (Figure 4a). Determine if the rill exhibits minor, moderate, or severe erosion. For streambank erosion that is a direct result of livestock access, measure the height and length of the eroding bank and determine the erosion severity (Remember, if the streambank erosion is not associated with livestock access, then if would fall under SECTION 4. STREAMBANK EROSION, not SECTION 5. LIVESTOCK ACCESS). A gully erodes sharply into the soil and it is often difficult to step across (Figure 4b). Measure the top/bottom erosion width, depth, and length.

http://en.wikipedia.org/wiki/Rill http://www.fs.fed.us/GRAIP/gallery/Gully1.jpg

Figure 4. An example of a rill (a) compared to the size of a gully (b).

Years erosion present: Use your best professional judgment to determine the number of years the observed erosion has been present (see page 2).

Length of access: Estimate the total length of streambank where the livestock have access and round to the nearest 0.1 foot.

SECTION 5. AGRICULTURAL RUNOFF

Location: Face downstream and determine if the observed agricultural runoff is on the left bank or right bank.

Potential pollutant source (circle all that apply): If you observe a potential nonpoint agricultural source of pollution, determine if it is from cropland/pasture manure runoff, cropland erosion/runoff, or feedlot erosion/runoff (circle more than one category if applicable). For cropland/pasture manure runoff, determine if the erosion/runoff severity is slight, moderate, severe, or very severe. For cropland erosion/runoff, the type of tillage needs to be identified. The field form separates tillage practice into three general categories: no-tillage, reduced tillage, and conventional tillage. Descriptive text and pictures for tillage examples that fall into these categories are provided (Figure 5). Also, determine the type of crop, estimate acreage of the source (again, may be more accurate to utilize aerial photos), and erosion/runoff severity (slight, moderate, severe, or very severe). For feedlot erosion/runoff, estimate the number of animals and note the type of animal. Estimate the distance of the source from the water (round to the nearest 0.1 foot). Determine if the severity of the erosion/runoff is slight, moderate, severe, or very severe. Estimate the area of the source in acres. To estimate acreage it may be easier to use aerial photos to obtain accurate size estimates for lots. Estimate the percent of the feedlot that is paved and select the appropriate range.

http://www.ars.usda.gov/images/docs/9372_9566/image003.gif

No-till fields: crops are planted without disturbing the soil through tillage

http://www.extension.iastate.edu/CropNews/2009/0302alkahsi.htm

No-till soybeans planted in corn residue.

Strip tillage (falls into no-till category): a form of tillage where only narrow strips are tilled

http://www.extension.org/pages/28317/reducing-tillage-to-save-fuel

Strip tillage was used to prepare this field for corn planting.

General photo depicting a side-by-side comparison of a no-till field versus conventional tillage practices.

http://www.ok.gov/conservation/Conservation_Districts/Garfield_County_No-Till_Conference_2011.html
No-till soybeans growing in wheat residue.

http://extension.oregonstate.edu/malheur/agriculture/watershed-management
Strip tilled corn planted in wheat residue.

Reduced tillage: method of soil tillage which leaves at least 30% crop residue on the soil surface

http://farmconnection.wordpress.com/
After planting – corn (circled in red) growing after being planted into 30% soybean residue.

Conventional tillage: the traditional method of farming in which the soil is prepared for planting by tillage practices that result in less than 30% residue cover

http://www.tifton.uga.edu/sewrl/radio/gibbover.htm

http://oregonprogress.oregonstate.edu/spr99/images/snapbeans.jpg

Figure 5. Tillage practices vary in the amount of crop residue left on the field.

http://www.extension.umn.edu/cropenews/2008/08MNCN28.html

Before planting – surface residue coverage after stalk chopping and chisel plowing in a field of corn residue.

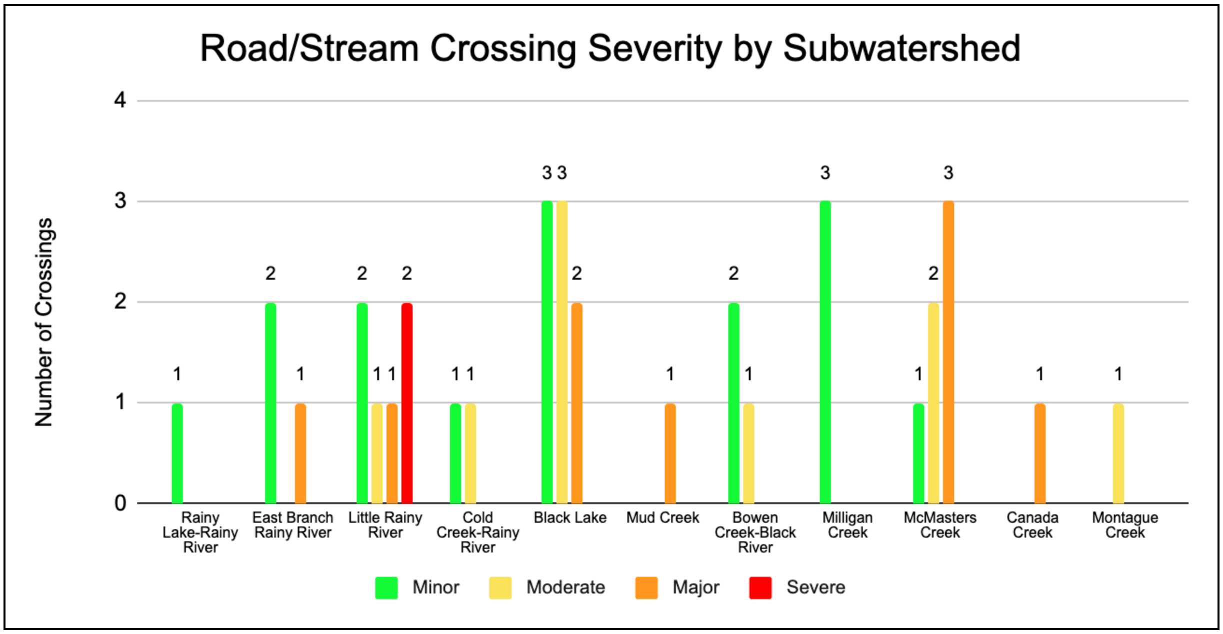
http://www.avanzi.unipi.it/ricerca/quadro_gen_ric/solil_tillage/image_soli_tillage/Image15.jpg

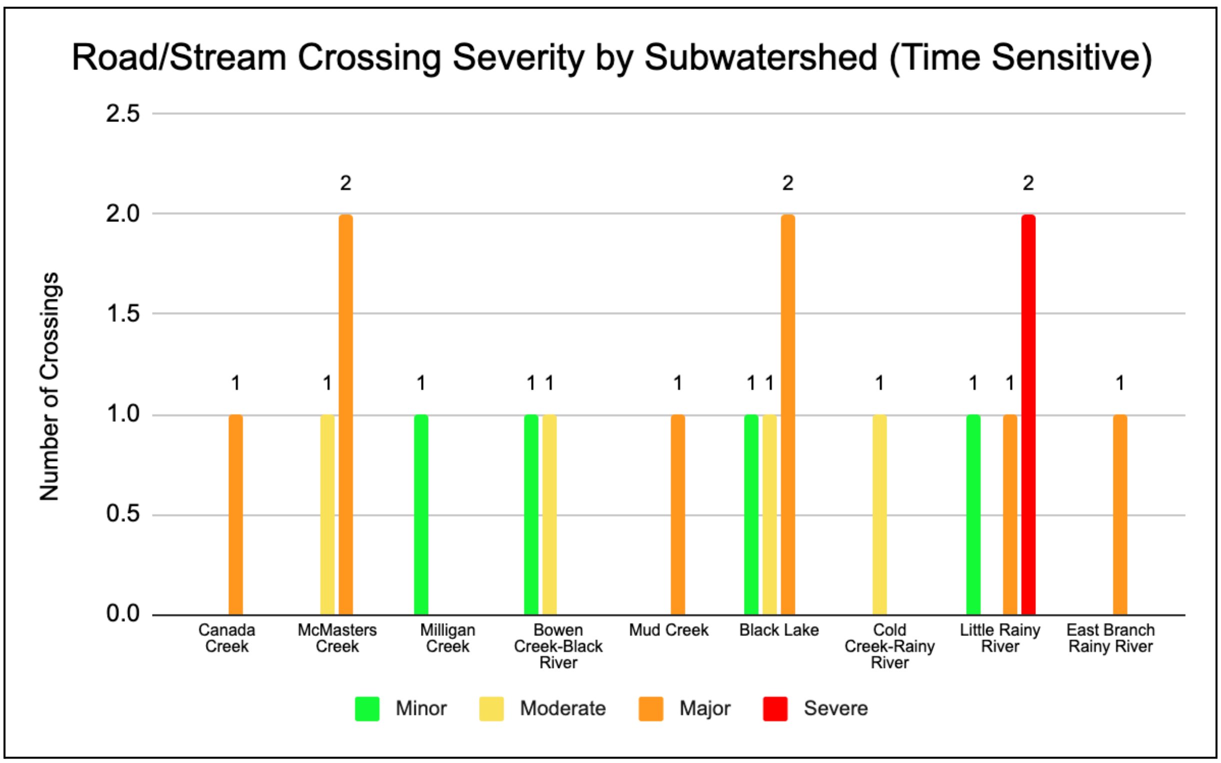
Appendix 8. Social Indicator Survey Open Comment Section

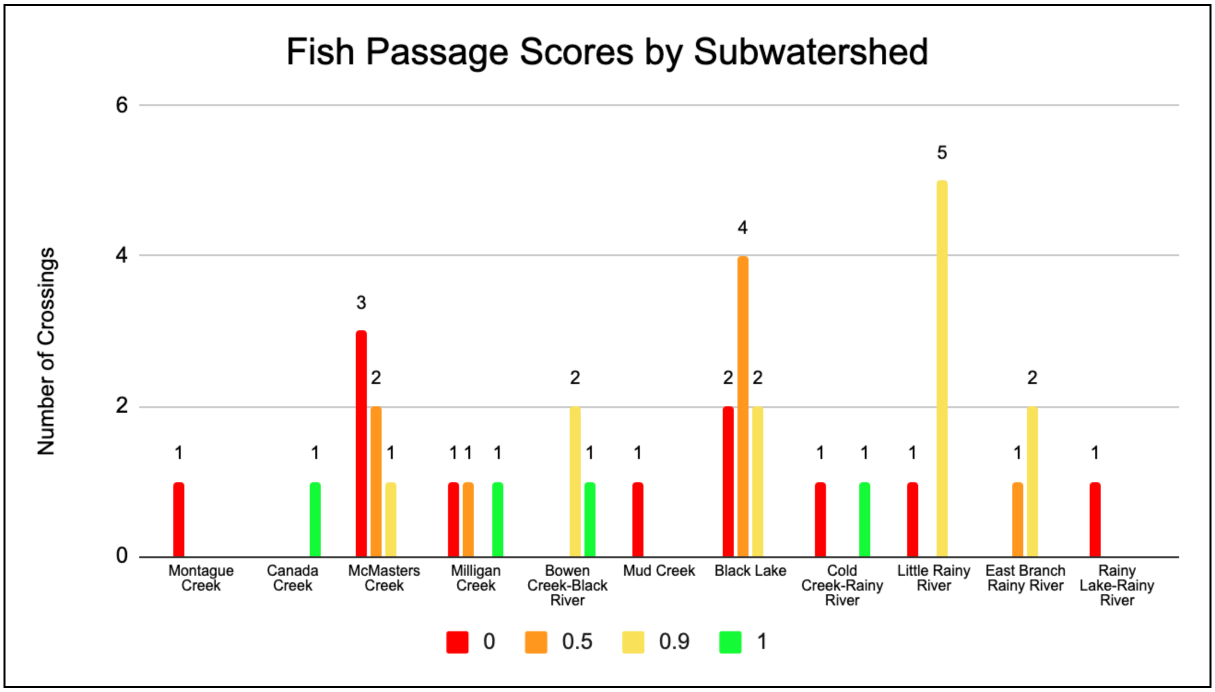
Survey Participant	Open Comment
1	"You didn't mention **HABS** which is our biggest threat"
2	"Some of the questions were worded in such a way to be confusing. I am a member of all the organizations listed but could only choose one. I think the government should handle inspections but not maintenance. I work for a Michigan science-related research agency and **septics** are likely to be regulated soon in the future. I do not know when my septic tanks were installed. I have 2 and that information was not available when we bought the property and is not listed in Cheboygan County records."
3	"Farm and agricultural practices should be regulated to enforce poor water quality from **runoff and application**"
4	"Surveys should be distributed through more than one outlet on Facebook. Currently, I've only seen it on Black Lake Preservation Society, which is a private,

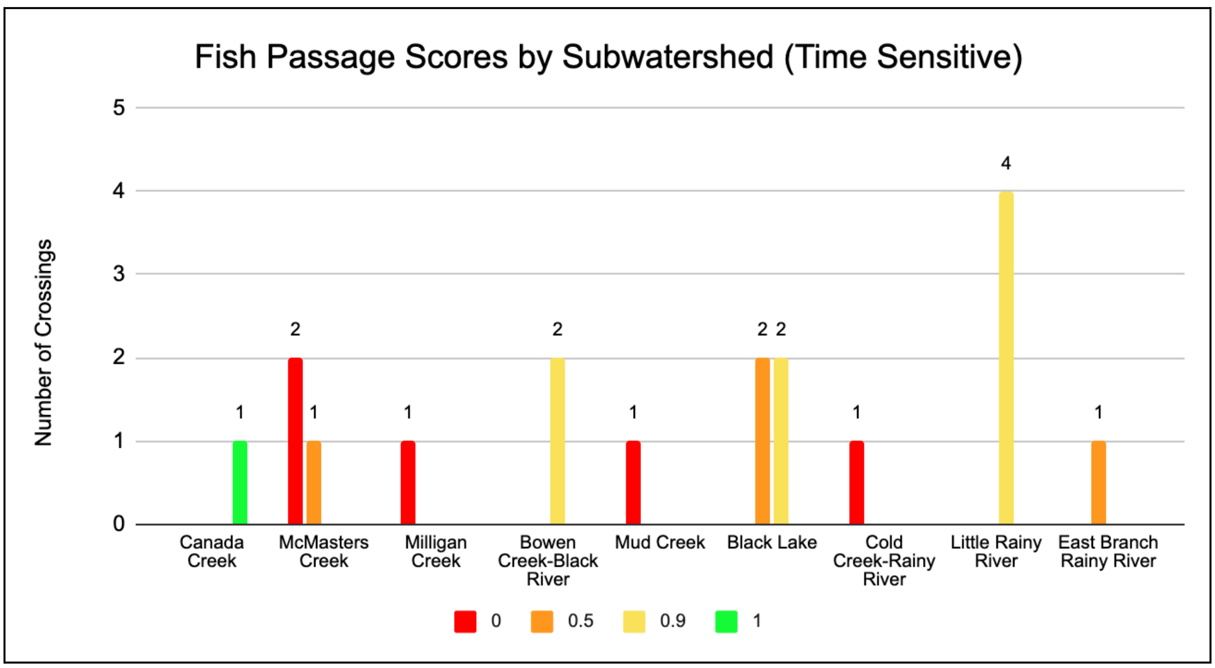
	restricted page. Also, membership in organizations listed is not limited to a single organization. I'm a member of both the Black Lake Association and Tip of the Mitt. Comment re last question - I think that local authorized agency inspection is a good idea, but maintenance of a septic system is the homeowners responsibility.”
5	“You seem convinced that septic systems are THE issue in the watershed. There are other problems. We get significant lakefront erosion because the Alverno dam is not lowered in the winter. There is nothing I can do to prevent erosion of my lakefront until that issue is addressed.”
6	“Great survey”
7	“**A significant number of residents are seasonal, so problems, options and local opinions are frequently not communicated effectively.** This makes even discussing local issues difficult, not to mention any consideration of possible solution alternatives. This appears to me to be a governmental choice. One example is the utility billing regulations that require seasonal residents to pay a significant premium for services. This discourages any ownership in local problem definition and solution suggestions. Additionally, lack of local utility service {water and sewer} means these are individually addressed, or perhaps ignored until a crisis occurs.”
8	“I’d like to learn more about protecting water quality of Black Lake and local watersheds”
9	“Native wildlife will continue to use the lake and have some impact on swimmers;_ however, the eradication of filtering plants, **poorly maintained or inadequate septic systems and the overuse of pesticides and fertilizers continue unabated.** It is a shame that so many lake residents are advocates of restoring the lake quality and yet continue to blacktop their driveways and ignore their gardening and septic practices. I do believe that mandated inspections at the sale of a home and perhaps at intervals with penalties for failure will be helpful to investigate if homeowners cannot be compelled through education to curb these practices.”
10	“Thank you for the opportunity to have input”
11	“UAW for 50 years and look at all the **beautiful lawns** from our lake. Two biggest problems”
12	“**Chemicals used for home maintenance** need to be addressed also”
13	“We need to manage clean water but not at the expense of wasted land. I see too much amazing property in the area wasted with drainage mounds.”
14	“Black Lake has severe swimmers itch problems that need to be addressed ASAP.”

Appendix 9. RSX Graphs


Road/Stream Crossing Severity by Subwatershed
Number of Crossings
4
3
2
1
0
Rainy Lake-Rainy River
East Branch Rainy River
Little Rainy River
Cold Creek-Rainy River
Black Lake
Mud Creek
Bowen Creek-Black River
Milligan Creek
McMasters Creek
Canada Creek
Montague Creek
Minor
Moderate
Major
Severe


Road/Stream Crossing Severity by Subwatershed (Time Sensitive)
Number of Crossings
2.5
2.0
1.5
1.0
0.5
0.0
Canada Creek
McMasters Creek
Milligan Creek
Bowen Creek-Black River
Mud Creek
Black Lake
Cold Creek-Rainy River
Little Rainy River
East Branch Rainy River
Minor
Moderate
Major
Severe


Fish Passage Scores by Subwatershed
Number of Crossings
0
2
4
6
Montague Creek
Canada Creek
McMasters Creek
Milligan Creek
Bowen Creek-Black River
Mud Creek
Black Lake
Cold Creek-Rainy River
Little Rainy River
East Branch Rainy River
Rainy Lake-Rainy River
0
0.5
0.9
1


Fish Passage Scores by Subwatershed (Time Sensitive)
Number of Crossings
0
1
2
3
4
5
Canada Creek
McMasters Creek
Milligan Creek
Bowen Creek-Black River
Mud Creek
Black Lake
Cold Creek-Rainy River
Little Rainy River
East Branch Rainy River
0
0.5
0.9
1

Appendix 10. Multivariate FAMD Analysis Report

Multivariate Analysis of Invasive Species and Road/Stream Crossings in the Black Lake Watershed

Analysis and writing produced by Andrea Behrmann
12 December, 2023

This report and its findings will be briefly mentioned in the final deliverable of my current masters project, but not as in depth as this paper. Its purpose is to provide a baseline understanding of possible interactions between RSXs and invasive species.

Abstract: To aid Tip of the Mitt Watershed Council in creating a Watershed Management Plan (WMP) for the Black Lake Watershed in Northern Michigan, road/stream crossing (RSX) inventories were updated by the Black Lake Watershed Master's Project Team. Multiple variables were measured and updated to represent the current state of RSX sites that were previously identified as "time-sensitive" and/or in need of maintenance. An FAMD and Cluster Analysis were conducted to further explore the relationship between most measurable variables to determine interconnectedness with a focus specifically on invasive species abundance. Invasive species are detrimental to ecosystems, especially in delicate ecosystems like Black Lake, and it's important to understand the consequences that follow their overall existence.

Introduction

Black Lake is located in the northern, lower peninsula of Michigan in the Black Lake Watershed. The watershed covers 350,000 acres (547 square miles) in Cheboygan, Montmorency, Otsego, and Presque Isle counties. This area is well-known for the recreational opportunities, including swimming, boating and fishing. The watershed also provides the necessary conditions, ecosystems, and climate for the Black Lake self-sustaining sturgeon population.

Black Lake is currently suffering from water quality issues that have only surfaced in recent years. Since 2018, annual harmful algal blooms have been observed and tested positive for microcystin, a toxic chemical that is produced by blue-green algae. Despite the blooms that typically occur around late summer/early fall, water quality remains high. The uncertainty around the source of these HABs and the lack of an Environmental Protection Agency (EPA) and Michigan Department of Environment, Great Lakes and Energy (EGLE) approved watershed management plan for the Black Lake Watershed has led to increasing public support for an approved management plan.

Alongside Tip of the Mitt Watershed Council, EGLE, the DNR (Department of Natural Resources), and other Black Lake organizations, collaboration with University of Michigan master's students has been progressive in addressing the water quality issues that Black Lake has been experiencing. Extensive watershed inventory surveys were conducted that measured the impact caused by road stream crossings (RSX), stream banks, stormwater infrastructure, agricultural, and forestry lands to determine their potential relative pollutant contributions. This analysis will focus on RSXs in particular and their individual roles in pollutant loading with regard to specifically the presence of invasive species, as well as water flow, structure size, and road conditions. The RSX inventory (Fig. 1) was the most widespread given the number of tributaries to Black Lake and took the longest to update because of this. The symbology of the points represent the overall condition of the crossing and possible deterioration. Sites were predetermined and chosen based on if the site was a time sensitive matter/needed maintenance. The Michigan Stream Crossing Dashboard as well as their ArcGIS shapefile were used to identify these. The overarching goal of this research paper is to understand the possible relationships present between all previously mentioned variables, but most importantly the role of invasive species and its impact on other variables.

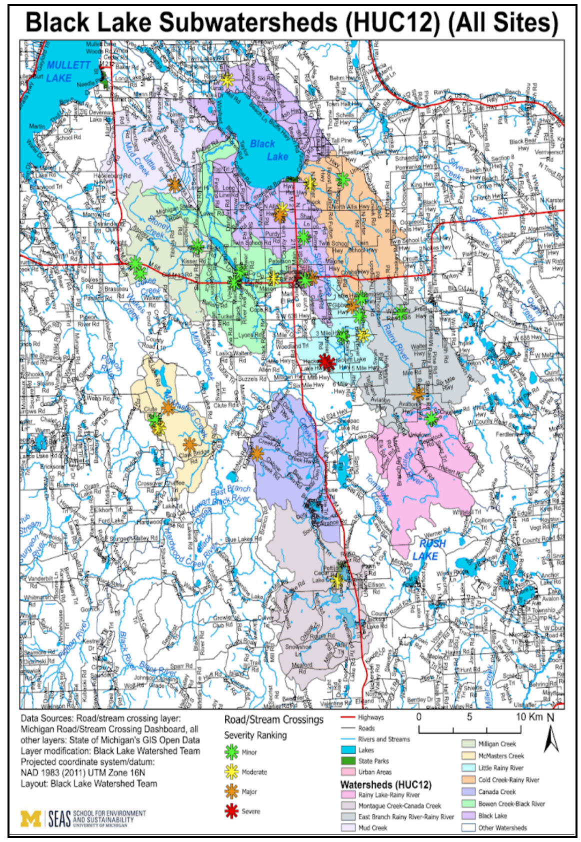


Figure 1. RSX sites

Dataset and Collection

Data was collected from 36 sites in total (40 originally, however 4 were either private property or could not be located due to being physically inaccessible). Each site was evaluated using the methods outlined in the DNR's RSX Inventory instructions and can be accessed online due to its lengthy stature: Great Lakes Road Stream Crossing Inventory Instructions (hyperlinked) (DNR, 2020). All information/data can be found on the Great Lakes Stream Crossing Dashboard (hyperlinked). Upon visiting the sites, information regarding the crossing, stream, road, embankments, approaches, erosion, and representative reach/riffle were recorded along with the total summary (if applicable). Needed equipment included waders, a Flow Tracker, yard stick, transect, cleaning supplies, a notebook to recreate the site, and iPads to record the information in Survey123. The estimated erosion (tons/year) is automatically calculated by the Survey123 form and takes into account the approaches (left and right) of the crossing as well as any present erosion at the site both on the structure itself or within the surrounding stream. The approaches were identified by facing downstream and identifying left and right this way. Road Condition was measured based on the interpretation of all team members. Road Condition ranged from good (0), fair (2), or poor (4). Waterflow was measured on both the inlet and outlet side of structures using a Flow Tracker (ft/sec) (0.2 feet above sea floor), however if no flow was present or if a site were inaccessible to measure with the Flow Tracker a float test was performed (ft/sec) and was observed at the surface. The total number of invasive species was recorded at all sites (if any were present). The structural length, width, and height were all recorded if feasible (feet). Their measurements included total size, i.e. above and below water. If accessibility was an issue, specific measurements were estimated.

Analysis

An FAMD (Factor Analysis of Mixed Data) was initially utilized to analyze the data set that contains both categorical and continuous variables. To conduct this analysis, R packages "FactoMineR" and "factoextra" needed to be installed. Categorical variables were then changed to an ordinal formation. For the variable Invasive.Species, a ranking system was implemented: 1 = "Low", 2 and 3 = "Intermediate", and 4 = "High." For the variable Road.Condition, a ranking system was also implemented: 0 = "Good", 2 = "Fair", and 4 = "Poor." Rows that contained "NA" values were omitted from all analyses.

A cluster analysis was also performed on the data set, however categorical variables were removed to identify any formed groupings. To perform the cluster analysis, the Canberra distance was first calculated. The Canberra distance "calculates the sum of the absolute differences between the components of the two points, divided by the sum of their absolute values" (Eskandar, 2023). This method was chosen over the Euclidean method as it is more robust to outliers (which was seen when utilizing the Euclidean method). To account for different units, the data was scaled. Scaling removes any dominating values and allows for an equal contribution from all variables.

Results

FAMD

A screeplot was initially created to identify the dimensions that most explained the variability within the data set (Figure 2). This was to assure myself that the correct number of dimensions were included in the graphs produced by running an FAMD. Most notably, Dimension 1 (Dim 1) explains the most variability at 26.55%, however the following dimensions explain less than 20%. Dimension 2 (Dim 2) follows with the second highest explanation of variability at 16.04.

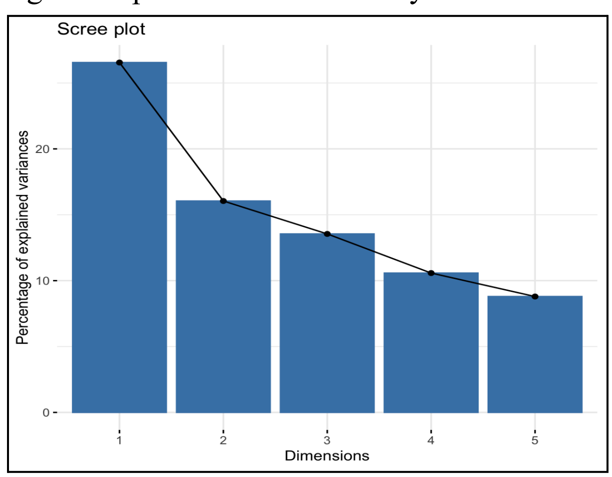


Figure 2. Scree plot

When performing an FAMD, several plots are generated to account for the information utilized. Essentially a PCA for the quantitative variables and an MCA for the qualitative, all of the respective graphs are automatically created. Figure 3 displays all of the variables, both categorical and continuous. It can be seen that Structure.Height contributes the most to Dim 1. Road.Condition contributes the most to Dim 2, however Structure.Length closely follows. It is interesting to see that Invasive.Species contributes nearly the same to Dim 1 as it does Dim 2.

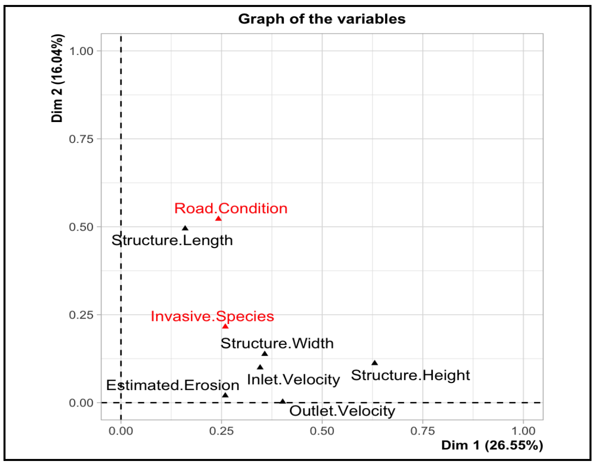


Figure 3. Graph of categorical and continuous variables

A graph of the categories (Figure 4) displays our two categorical variables and their rankings. "Poor" road conditions appears to contribute the most to Dim 1 although "Good" road conditions along with "Intermediate" and "High" species abundance contribute positively to Dim 1 as well. "Low" invasive species and "Fair" road conditions contribute negatively to Dim 1. "Low" invasive species abundance negatively contributes the most to Dim 2, however "Intermediate" invasive species also contributes negatively. "Fair" road conditions contributes positively along with "Good" road conditions and "High" invasive species to Dim 2. What is interesting to see is the almost linear relationship seen between the invasive species rankings in this figure in respect to the road conditions.

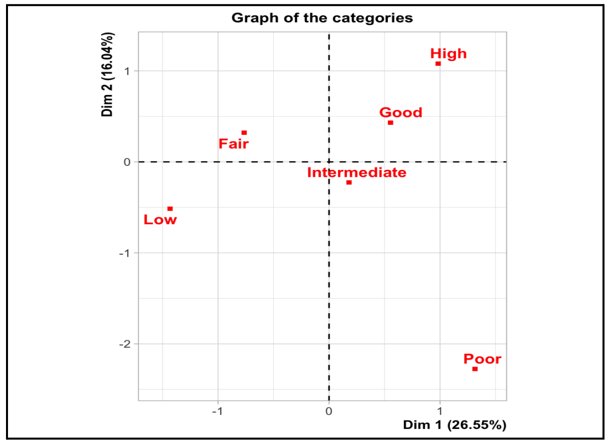


Figure 4. Graph of categorical variables

A graph solely made up of the quantitative variables (Figure 5) shows how each variable contributes to Dim 1 and Dim 2. This information repeats what is seen in Figure 2, but removes the categorical variables. It is still true that Structure.Height contributes the most to Dim 1, yet many other variables contribute to it as well. All variables contribute positively to Dim 1 except Estimated.Erosion. Structure.Length still contributes the most to Dim 2, however Structure.Height and Estimated.Erosion contribute as well. Outlet.Velocity, Inlet.Velocity, and Structure.Width contribute negatively to Dim 2.

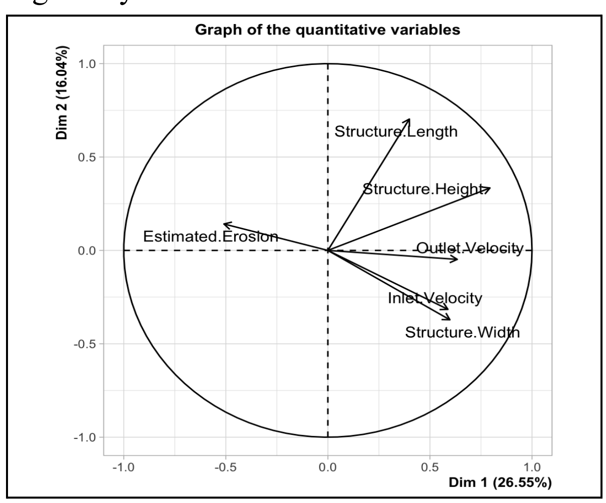


Figure 5. Graph of quantitative variables

The final figure (Figure 6) depicts each row of data (site). Clusters are based on invasive species abundance. Outliers exist for all clusters, but appear to be relatively close to their respective grouping. This graph represents the information depicted in Figure 3 but displays how the individual data points position themselves in respect to their invasive species abundance. “High” invasive species clusters contribute positively to Dim 1 as do “Intermediate” invasive species, however; “Low” invasive species contributes the most to Dim 2 (negatively to both Dim 2 and Dim 1).

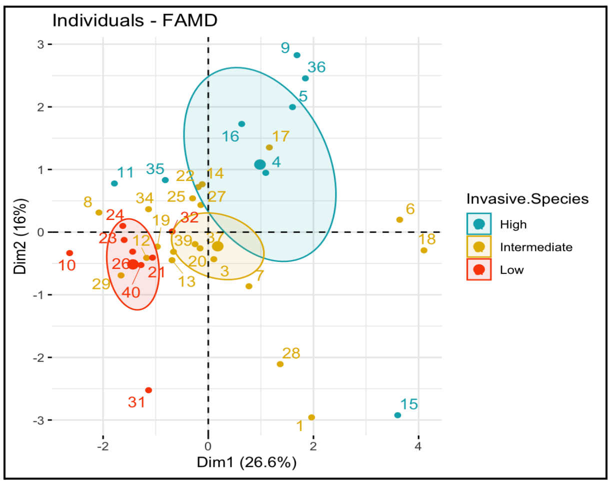


Figure 6. Individual data in respect to invasive species abundance

Cluster Analysis

A cluster analysis was also performed on the data set, however categorical variables were removed to identify any formed groupings. To perform the cluster analysis, the Canberra distance was first calculated. The Canberra distance “calculates the sum of the absolute differences between the components of the two points, divided by the sum of their absolute values” (Eskandar, 2023). This method was chosen over the Euclidean method as it is more robust to outliers (which was initially seen when utilizing the Euclidean method). To account for different units, the data was scaled. Scaling removes any dominating values and allows for an equal contribution from all variables.

Overall, two large clusters are apparent, however four smaller clusters can be seen as well (Figure 7). It appears that the two main clusters represent the sites that contribute the most to Dim 1 or Dim 2. It is possible that the amount of invasive species and road conditions of each site play a part in determining the formation of the smaller clusters. Overall, the distances between each site are not drastically different. It is noted that there are more sites in the first cluster than the second cluster.

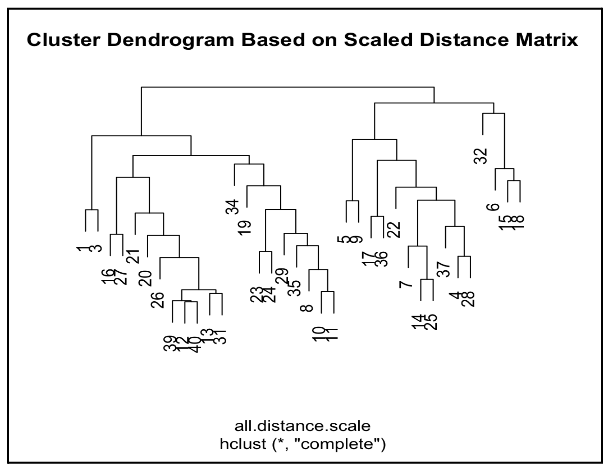


Figure 7. Cluster dendrogram based on Canberra distance

Discussion

The implications of these findings suggest that invasive species may be dependent on factors within a specific site, especially that of the road condition. Previous studies support this with one explaining that “Evidence suggests that roads can have an important effect on the spread of invasive plant species…[and] show[s] that a small change in conditions of the environment favouring the invasive species can change the case for the road…" (Deeley, 2022). Another study addresses vehicle usage and its role in invasive species abundance. Their results reveal how "primary dispersal of [an invasive species] interacts with secondary dispersal by vehicles' airflow, dependent on traffic volume" which suggests that roads more heavily traveled are at a higher risk of introducing invasive species (Lemke, 2019). This also supports the notion that roads that are less traveled consequently have less consistent upkeep/maintenance and will harbor more invasive species. The study concludes with the importance of general maintenance (i.e. mowing) along high-use roads as well as isolated populations in the area (Lemke, 2019).

Together, these studies portray a possible positive feedback loop between road usage and invasive species abundance; as roads are more heavily traveled, invasive species may become more abundant due to vehicular airflow. Roads that receive more traffic compared to others will inevitably deteriorate and harbor the appropriate conditions needed for invasive species to spread even further. It can be seen that some variables (dimensions) that were not measured during data collection explain the contribution of the variables that were accounted for. It is possible that variables such as traffic and/or general maintenance/upkeep may have been the missing linkage in understanding the role between RSXs and invasive species. Overall, further studies are needed to understand the impacts of confounding variables on both RSXs and invasive species abundance

Closing Statement

Because I am not an invasive species specialist (nor are any of my project mates), it is very possible that there may have been more invasive species at sites that were not accounted for and for that, we do recommend revisiting all sites. Given the nature of our overall project, we recommend that all sites be visited regardless, making time-sensitive ones the initial priority.

References

Deeley, B., Petrovskaya, N. (2022). Propagation of invasive plant species in the presence of a road, *Journal of Theoretical Biology, Volume 548,*111196,ISSN 0022-5193. https://doi.org/10.1016/j.jtbi.2022.111196.

DNR. (2020, August 26). *Great Lakes Road Stream Crossing Inventory Instructions.* https://www2.dnr.state.mi.us/Publications/pdfs/ArcGISOnline/Guides/Stream_Crossing/Great_Lakes_Stream_Crossing_Inventory_Instructions.pdf

Eskandar, S. (2023, March 26). *Exploring common distance measures for machine learning and Data Science: A Comparative Analysis*. Medium. https://medium.com/@eskandar.sahel/exploring-common-distance-measures-for-machine-learning-and-data-science-a-comparative-analysis-ea0216c93ba3#:~:text=Canberra%20distance%20calculates%20the%20sum,outliers%20than%20other%20distance%20measures.

Kassambara, Galpaccru, Riad, & Visitor. (2017, September 24). *FAMD - factor analysis of mixed data in R: Essentials*. STHDA. http://www.sthda.com/english/articles/31-principal-component-methods-in-r-practical-guide/115-famd-factor-analysis-of-mixed-data-in-r-essentials/

Lemke, A, Kowarik, I, von der Lippe, M. How traffic facilitates population expansion of invasive species along roads: The case of common ragweed in Germany. *J Appl Ecol*. 2019; 56: 413–422. https://doi.org/10.1111/1365-2664.13287

R Code

```
> rsx <- read.csv("rsx.mva.csv")
> rsx <- na.omit(rsx)

>install.packages("FactoMineR")
>install.packages("factoextra")

>library(FactoMineR)
>library(factoextra)

>rsx_famd <- FAMD(rsx)
>fviz_screeplot(rsx_famd)
>fviz_mfa_ind(rsx.famd,
            habillage = "Invasive.Species",
            palette = c("#00AFBB", "#E7B800",
           "#FC4E07"),
            addEllipses = TRUE, ellipse.type =
           "confidence",
            repel = TRUE)

>rsx.fix <- rsx[,-4: -5]

>all.distance.scale = dist(scale(rsx.fix),
method = "canberra")

>plot(hclust(all.distance.scale, main =
"Cluster Dendogram based on scaled distance
matrix", sub = NULL, xlab = NULL, ylab =
NULL, yaxt = "n")
```