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Travis Williams
Outdoor Discovery Center

Hope College GWRI Macatawa Watershed Annual Report – 2020-2021

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Executive Summary

The Hope College Global Water Research Institute (GWRI) partnered with the Outdoor Discovery Center and Project Clarity to monitor both lake and stream sites withing the Macatawa Watershed. The Macatawa Watershed remains impaired with respect to nutrient (phosphorous and nitrate) pollution in both Lake Macatawa and the streams that feed the lake. While there have been concerns about *E. coli* levels in the eastern parts of Lake Macatawa, the levels in Lake Macatawa did not exceed health guidelines for recreational access at the monitored timepoints during the past year. However, the streams within the watershed all show consistently high levels of *E. coli*, often exceeding health guidelines for recreational use. Measurements of chlorophyll *a* were consistent with the hypereutrophic state of Lake Macatawa, but measurements of microcystin associated with harmful algal blooms were well below health guidelines. This represents the first year of monitoring as part of the partnership between GWRI and Project Clarity. In future years, data will be placed in context with data from prior years.

Project Report

The Macatawa Watershed in southwest Michigan is a small (464 km^2) eutrophic catchment containing eight subbasins that drain through the Macatawa River into Lake Macatawa. The terminus for the watershed is an outlet to Lake Michigan (Figure 1). Lake Macatawa is a dimictic lake that has a small surface area (7.2 km^2), shallow average depth (3.6 m), and therefore, short residence time of only 65 days [Fusilier and Fusilier, 1999]. It has had water quality concerns (e.g., high phosphorus, low clarity, poor aquatic habitat) for decades [e.g., Ketelle and Uttormark, 1971; Fusilier and Fusilier, 1999; Holden, 2015] and has been studied extensively on a local scale. The Macatawa River and its perennial tributaries have similar concerns and have been classified as one of the flashiest in the state [Fongers, 2012]. This, along with soil types that are also conducive to mobility, leads to detrimental erosion and transport of large amounts of sediment throughout the fluvial system. This has led to an implementation of Total Maximum Daily Load (TMDL) limits and regulation on Phosphorous (0.05 mg/L P in Lake Macatawa) and on *E. coli* in some of the watershed's streams.

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Land usage in the Macatawa Watershed plays a large role in the current eutrophic status of Lake Macatawa. The glaciated terrain is one factor that makes the region ideal/suitable for agriculture, which constitutes roughly 44.9% [this study calculated in GIS] of the watershed's designated land use (Figure 2). Soil types ranging from sand, silt, and clay [Fongers, 2009; Van Fassen, 2008] contribute to high erosion and runoff potential which has, in part, contributed to the unfavorable health of the watershed's water bodies with high sediment, nutrient, and *E. coli* levels. The remainder of the watershed is classified as 32.7% urban and only 19.6% as natural and 2.8% as water or wetland [this study calculated in GIS]. The watershed consisted of roughly 66% agricultural land use and 15% urban in 1978 and 50% agricultural and 31% urban in 2005. While more recent land use data than 2009 is not available at this time, a similar trend of increasing urbanization and decreasing agricultural use is expected to continue, as Ottawa County and west Michigan have experienced rapid population growth since 2010 (10+%). Additionally, from 2005 to 2009 there was an increase in natural areas and wetlands from 19.2 to 22.4%. This trend may also continue as there have been numerous remediation projects led by Project Clarity, creating man-made wetlands in the watershed since 2009. Upland areas of all tributaries flowing into the Macatawa River are dominated by agricultural land use, where the downstream reaches are surrounded by urban areas. The areas that drain directly into Lake Macatawa are dominated by urban land use, except at the western end of the watershed, where forested areas increase near the shore of Lake Michigan.

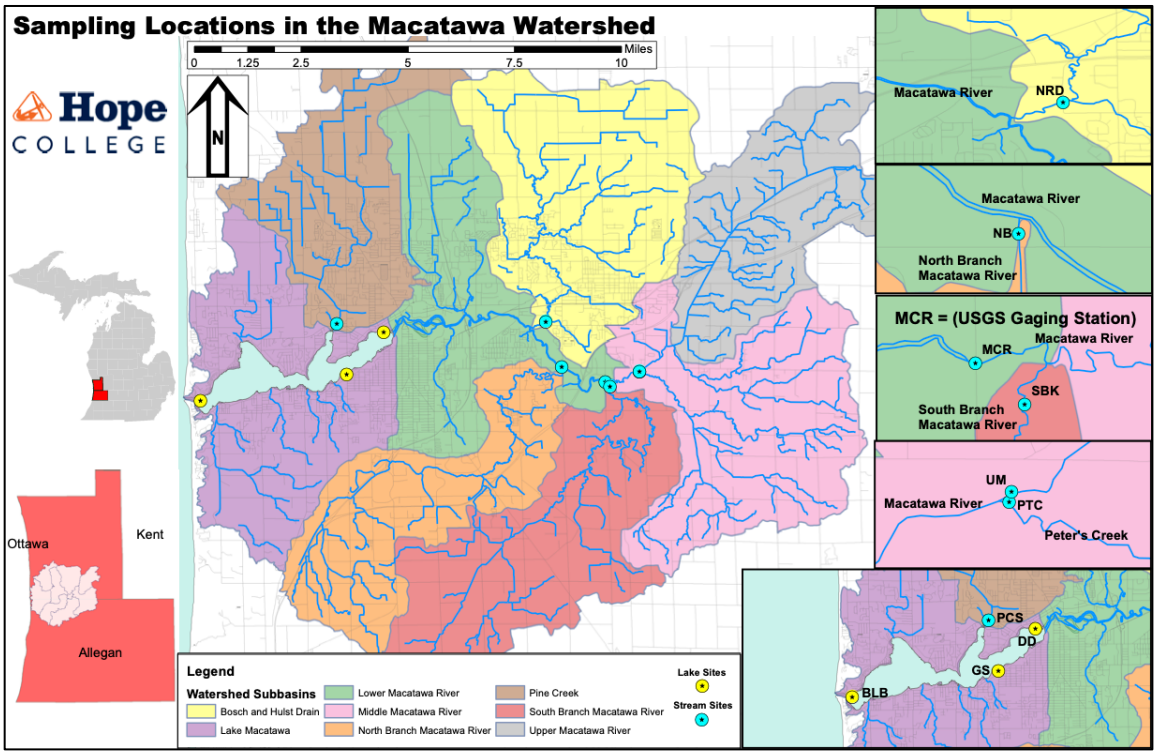

Figure 1. Macatawa Watershed map showing subbasins and current monitoring sites.

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Table 1. Macatawa Watershed Sampling Locations

Site Name	Site Abbreviation	Site Type	Watershed Basin Representation	Geographical Order (East to West)	Coordinates
Black Lake Boardwalk	BLB	Lake	N/A	10	42.772346, -86.204489
Dunton Park	DD	Lake	N/A	7	42.795571, -86.120257
Graafschap	GS	Lake	N/A	9	42.781182,-86.137389
Macatawa River	MCR	Stream	South Branch, Middle, and Upper Macatawa River	4	42.7782, -86.01842
North Branch	NB	Stream	North Branch Macatawa River	5	42.78367, -86.03822
Noordeloos	NRD	Stream	Bosch and Hulst Drain	6	42.799316, -86.045615
Pine Creek Stream	PCS	Stream	Pine Creek	8	42.79851, -86.14185
Peter's Creek	PTC	Stream	Middle Macatawa River	1	42.7822, -86.00261
South Branch	SBK	Stream	South Branch Macatawa River	3	42.77752, -86.01594
Upper Macatawa	UM	Stream	Upper Macatawa River	2	42.78249, -86.00265

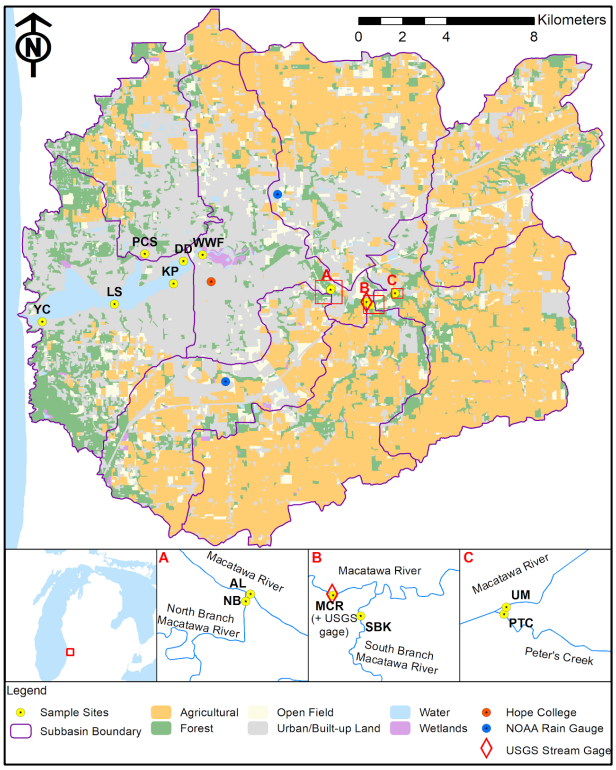

Figure 2. Macatawa Watershed Map showing land usage and 2016-2019 monitoring sites.

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Current Monitoring Activity (July 2020 – June 2021)

The Global Water Research Institute (GWRI) at Hope College is working with Project Clarity to provide long term monitoring of the Macatawa Watershed. This report describes data from the period of July 2020 through June 2021. The GWRI monitoring is meant to supplement monitoring that has occurred since 2013 by Project Clarity in collaboration with the Annis Water Resources Institute (AWRI). The GWRI monitoring overlaps AWRI monitoring of the lake (three sites; Figure 1, Table 1) and adds the following:

1. Monitoring of seven (7) stream sites within the watershed, representing the major subbasins (Figure 1, Table 1)
2. Year round monitoring to capture potential seasonality of measured parameters
3. *E. coli* monitoring

The following parameters are being monitored at each lake and stream site monthly:

1. Physiochemical: Temperature, pH, Dissolved Oxygen, Total Dissolved Solids, Turbidity, Orthophosphate (o-PO_4^{3-}), Total Phosphorous, Nitrate (NO_3^-), Ammonia (NH_4^+), Conductivity, Oxidation-Reduction Potential, Dissolved Organic Matter, Oxygen Saturation.
2. Biological: *E. coli* levels, Microcystin (Spring/Summer/Fall), Chlorophyll *a* (Spring/Summer/Fall)

All samples are nearshore, surface grabs of water. Methodology descriptions are available upon request.

This reporting period represents the first monitoring year for the GWRI in collaboration with Project Clarity. During this first year, assays related to Total phosphorous (TP), microcystin and chlorophyll *a* were developed and deployed as the assays came online. The COVID-19 pandemic impacted the speed with which these assays were developed. The TP assay was first used in the September 2020 sampling event; the chlorophyll *a* assay was first used the April 2021 sampling event, and the microcystin assay was first used in May 2021.

Measured Phosphate Levels

Two metrics for phosphate have been measured, orthophosphate and total phosphorous. Averaged over the full sampling period for all lake sites, the level of orthophosphate was 20.4 ug/L (ppb) and the level of TP was 102 ug/L. For stream sites, the average level of orthophosphate was 98.1 ug/L and the average level of TP was 170.1 ug/L (Figure 3). This demonstrates that Lake Macatawa continues to contain levels of TP that are above the TMDL of 50 ug/L, consistent with previous monitoring by AWRI. The orthophosphate levels are similar to those seen in past years of monitoring by Hope College. The stream site TP

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and orthophosphate average levels are consistently higher than lake site levels, which indicates that there is continued external loading of phosphate into Lake Macatawa from monitored subbasins in the watershed (Figure 4). The Upper Macatawa (UM) and Peter's Creek (PTC) sites have the highest values, both of which feed into the Macatawa River (MCR) site. Noordelos Creek (NRD) shows an average TP value similar to the UM and PTC sites, however, the extreme high range for NRD is much lower than for the other two sites (Figure 4). Overall, these data indicate that Lake Macatawa continues to contain total phosphorous levels above the TMDL and that external loading from streams contributes to this throughout the year (Figure 5).

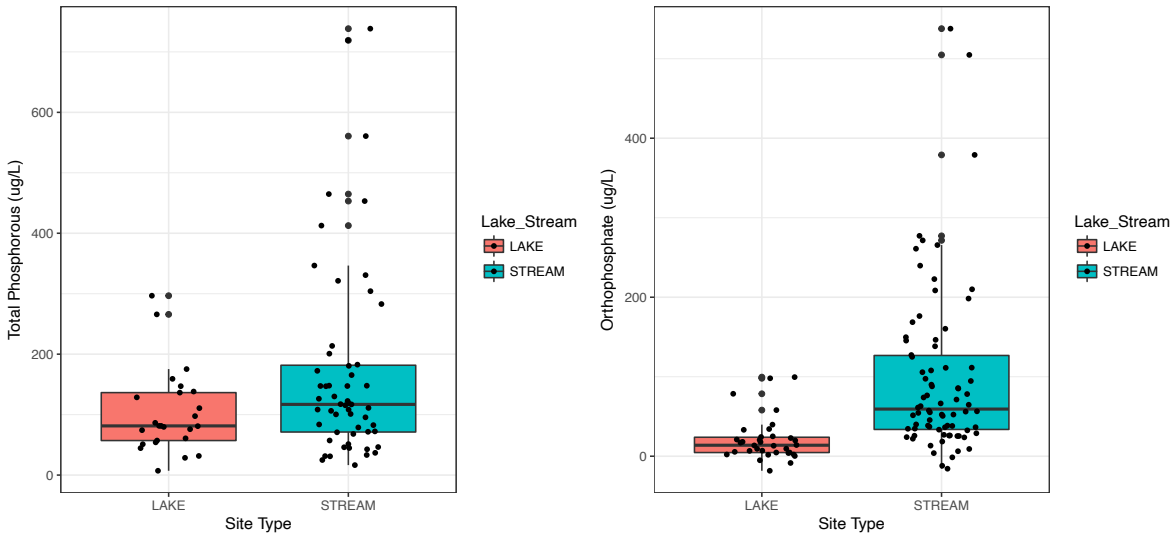

Figure 3. Phosphate levels over the full monitoring period. Total phosphorous (left) and orthophosphate (right) measurements are shown for all lake and stream sites. Stream sites have higher values for both measures as compared to lake sites. Lake sites remain over the TMDL of 50 ug/L.

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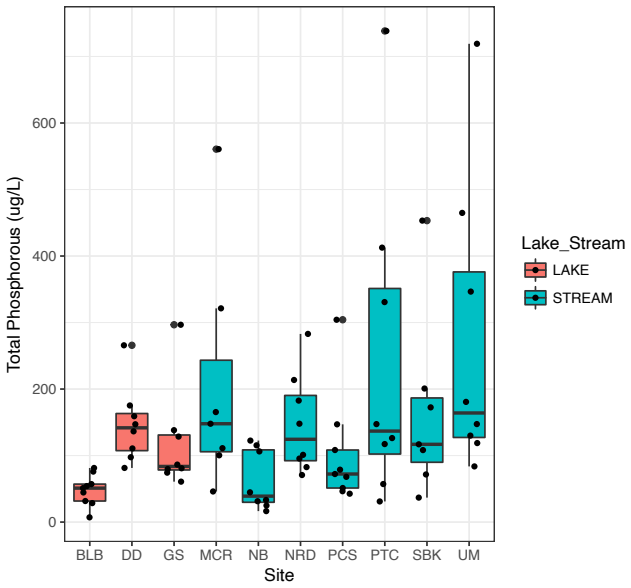

Figure 4. Total Phosphorous levels over the full monitoring period organized by location within the watershed. Total phosphorous measurements are shown for individual lake and stream sites. The eastern-most lake site (DD) shows higher TP levels than the western-most lake site (BLB). Stream sites also vary in TP content with MCR, NRD, PTC and UM showing the highest average values and ranges of TP levels.

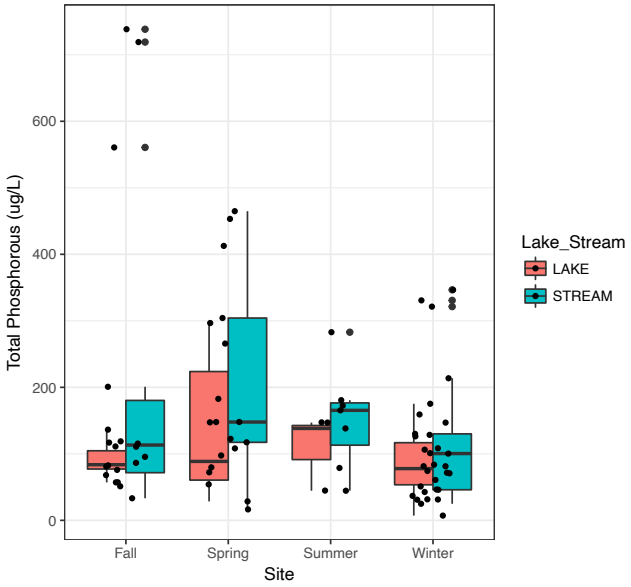

Figure 5. Total Phosphorous levels over the full monitoring period grouped by season. Total phosphorous measurements are shown for lake and stream sites in each season. Seasonal variation is observed for stream sites with the highest values and largest range of values occurring in the Spring. Lake sites show less variation, although there are very high values that occur in fall and spring.

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Measured Nitrate Levels

The Nitrate level averaged over the full sampling period for all lake sites was 1.9 mg/L (ppm). For stream sites, the average level of nitrate was 8.9 mg/L (Figure 6). Although there is not a current TMDL on nitrate levels in the lake or streams, both site types contain individual measurements of nitrate levels that are considered unhealthy for the ecosystem. Little variation in nitrate levels for individual sites is observed for the three lake sites, whereas significant variation is observed for stream sites. Peter's Creek (PTC) stands out as having the highest averaged nitrate value in the watershed (Figure 7). South Branch (SBK) has the highest measured values over the past year (outliers in Figure 7). Some seasonal variation in both lake and stream nitrate levels was observed, with the fall and summer seasons having the lowest average values (Figure 8).

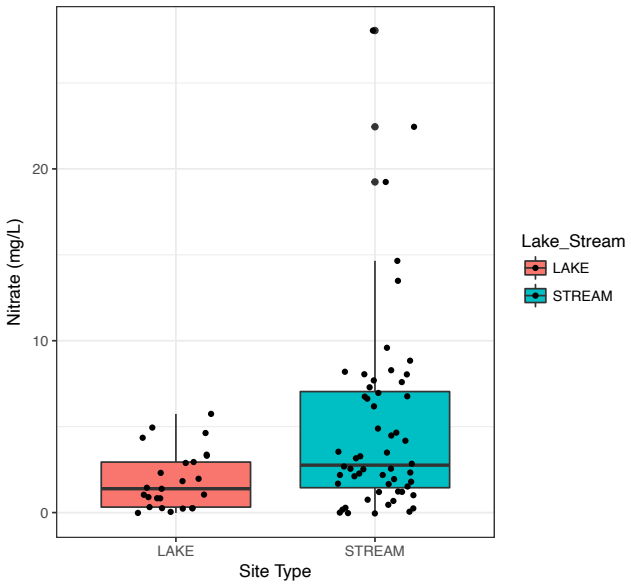

Figure 6. Nitrate levels over the full monitoring period. Nitrate (NO_3^-) measurements are shown for all lake and stream sites. The overall average nitrate levels for streams is higher than that observed in the lake sites.

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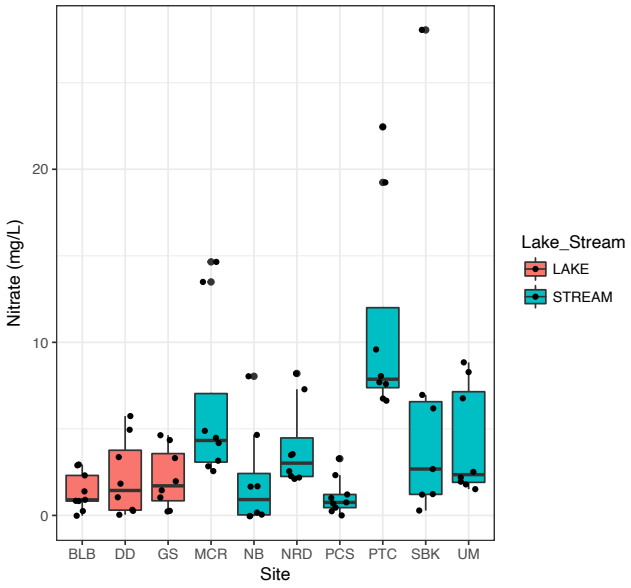

Figure 7. Nitrate levels over the full monitoring period organized by location within the watershed. Nitrate (NO_3^-) measurements are shown for individual lake and stream sites. Peter's Creek (PTC) shows the highest, consistent levels of nitrate of the monitored subbasins. In general, there is no difference in the average nitrate levels observed between lake and stream sites.

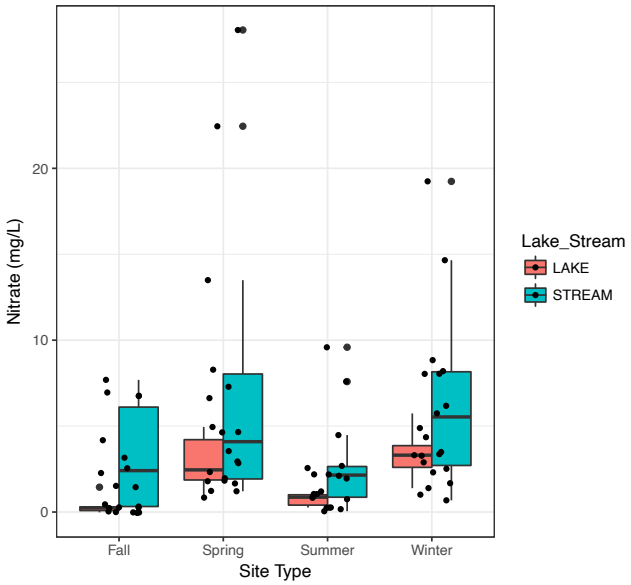

Figure 8. Nitrate levels over the full monitoring period grouped by season. Nitrate (NO_3^-) measurements are shown for lake and stream sites in each season. The highest values are observed in the Spring and Winter seasons.

Measured *E. coli* Levels

The *E. coli* level averaged over the full sampling period for all lake sites was 82.2 CFU/100 mL. For stream sites, the average level of *E. coli* was 793.8 CFU/100 mL (Figure 9). This

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indicates that lake *E. coli* levels are generally under the guidelines of 300 CFU/100 mL for total body contact and 1000 CFU/100 mL for partial body contact. However, the streams sites are consistently above the total body contact limit and exceed the partial body contact limit at times. These trends are clearly seen in individual site data for the watershed (Figure 10). All lake site samples had *E. coli* levels below the total body contact limit, which indicates that it is safe to use the lake for recreational activities. In contrast, all stream sites exceeded the total body contact limit with most also exceeding the partial body contact limit at some point through the monitoring period. There is seasonal variation in the *E. coli* levels for stream sites, with winter months having the lowest values. The levels are highest in the streams in the Summer and Fall months when recreational activity in the watershed is highest. These results are consistent with the state-imposed *E. coli* TMDL for streams in the Macatawa Watershed.

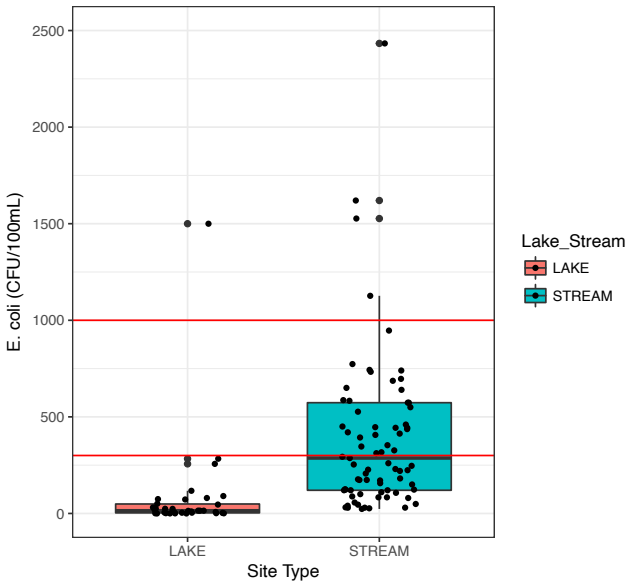

Figure 9. *E. coli* levels over the full monitoring period. *E. coli* counts in colony forming units (CFU) per 100 mL are shown for all lake and stream sites. Stream sites exceed the total body contact limit. Lake sites are generally below the contact limits. Stream sites exceed the partial body contact limit in some sampling events. Values for stream sites above 2500 CFU/mL are not shown.

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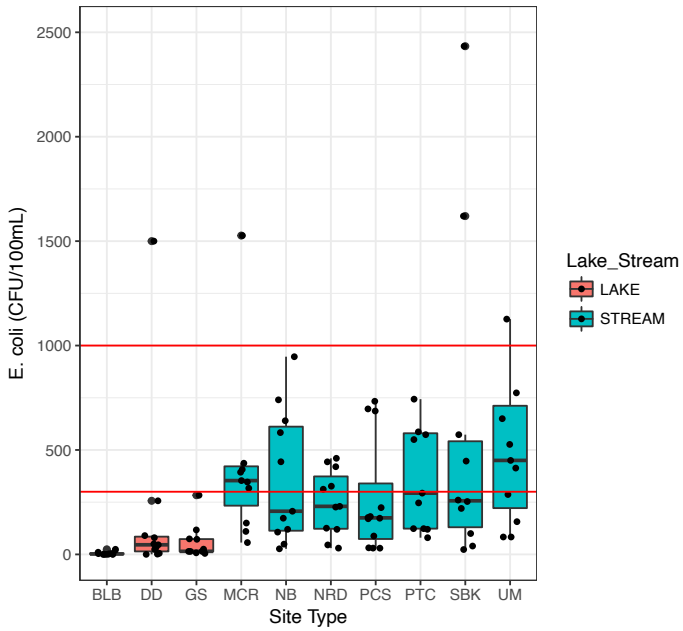

Figure 10. *E. coli* levels over the full monitoring period organized by location within the watershed. *E. coli* counts in colony forming units (CFU) per 100 mL are shown for individual lake and stream sites. Horizontal red lines indicate the total body contact limit (300 CFU/100 mL) and partial contact limit (1000 CFU/100 mL). Stream sites regularly exceed the total body contact limit. Lake sites are below the contact limits throughout the monitoring period. Values for stream sites above 2500 CFU/mL are not shown.

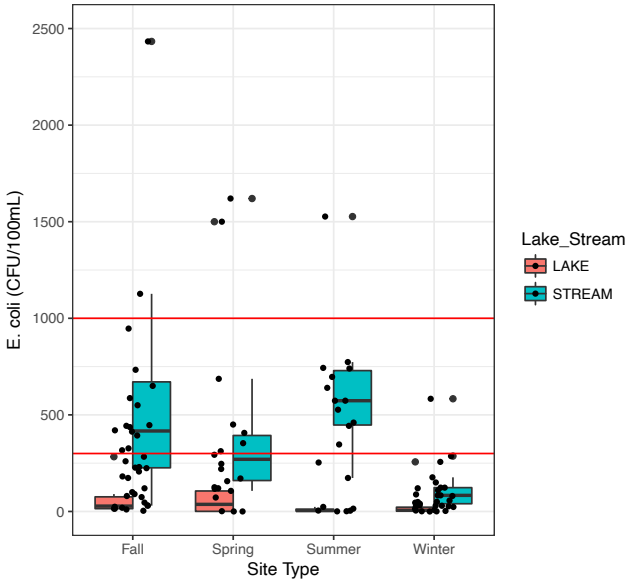

Figure 11. *E. coli* levels over the full monitoring period grouped by season. *E. coli* counts in colony forming units (CFU) per 100 mL are shown for lake and stream sites in each season. Horizontal red lines indicate the total body contact limit (300 CFU/100 mL) and partial contact limit (1000 CFU/100 mL). Stream sites show more variation than lake sites with the highest values being observed outside of Winter. Lake site values vary most in the Fall and Spring. Values for stream sites above 2500 CFU/mL are not shown.

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Measured Microcystin and Chlorophyll *a* Levels

Measurements of microcystin and chlorophyll *a* were planned to be monitored in the lake sites during the summer, fall, and spring seasons due to potential cyanobacterial bloom activity during these times. However, we did not begin monitoring chlorophyll *a* until April 2021 and microcystin until May 2021 due to the need to establish the assays in our laboratory and delays associated with the COVID-19 pandemic. Chlorophyll *a* levels averaged 0.64 mg/L (ppm) across all lake sites from April through June 2021 (Table 2). Microcystin levels averaged 0.15 ug/L (ppb) across all lake sites from May through June 2021 (Table 3). The values for chlorophyll *a* are consistent with a hypereutrophic classification of recreational surface waters in Michigan with increasing levels from May to June. The westmost lake site (BLB) showed the lowest chlorophyll *a* values. The values for microcystin are well below the 8 ug/L limit for recreational waters as recommended by the EPA through the late spring/early summer timeframe.

Table 2. Chlorophyll *a* Measurements from Lake Sites

Event 1 5/25/21		Chl-a		Chl-b		Cartanoids
Site	Avg. Conc. (ppm)	Std Conc.	Avg. Conc. (ppm)	Std Conc.	Avg. Conc. (ppm)	Std Conc.
BLB	0.31	0.2152525255	0.21	0.2312165914	0.35	0.3900321469
DD	0.36	0.1890989593	0.27	0.2783504518	0.39	0.436715377
GS	0.44	0.1677921304	0.19	0.1217842109	0.25	0.1799695175
Event 2 6/15/21		Chl-a		Chl-b		Cartanoids
Site	Avg. Conc. (ppm)	Std Conc.	Avg. Conc. (ppm)	Std Conc.	Avg. Conc. (ppm)	Std Conc.
BLB	0.26	0.03253324658	0.11	0.02931502402	0.22	0.1032326867
DD	0.74	0.3897417261	0.02	0.04549600239	0.13	0.01240104162
GS	0.84	0.06164840387	0.2	0.05639047083	0.36	0.01497968736

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Table 3. Microcystin Measurements from Lake Sites

Event 1								
Sample ID	**Sampling Date**	**OD1**	**OD2**	**Avg. OD**	**%CV**	**%B0**	**Microcystin Conc. (ppb)**	**Standard Values (ppb)**
DI Water	5/25/2021	0.834	1.285	1.0595	30.09959021	89.14598233		
Neg. Control	5/25/2021	1.309	1.068	1.1885	14.33847154	100	0.14	0
Standard 1	5/25/2021	1.077	1.099	1.088	1.429811506	91.54396298	0.18	0.2
Standard 2	5/25/2021	0.476	0.56	0.518	11.46659645	43.58435002	0.75	0.6
Standard 3	5/25/2021	0.162	0.182	0.172	8.222171874	14.47202356	1.80	2
BLB	5/25/2021	1.217	1.231	1.224	0.8087822661	102.9869584	0.13	
DD	5/25/2021	1.075	1.104	1.0895	1.882156646	91.67017249	0.18	
GS	5/25/2021	1.063	1.210	1.1365	9.146035797	95.62473706	0.16	
Event 2								
Sample ID	**Sampling Date**	**OD1**	**OD2**	**Avg. OD**	**%CV**	**%B0**	**Microcystin Conc. (ppb)**	**Standard Values (ppb)**
DI Water	6/15/21	0.057	0.067	0.062	11.40494808	4.439670605		
Neg. Control	6/15/21	1.448	1.345	1.397	5.215323914	100	0.11	0
Standard 1	6/15/21	1.212	1.154	1.183	3.466795715	84.71177945	0.18	0.2
Standard 2	6/15/21	0.605	0.568	0.587	4.460861194	41.99785177	0.70	0.6
Standard 3	6/15/21	0.14	0.158	0.149	8.542229571	10.66953097	1.85	2
BLB	6/15/21	1.248	1.233	1.241	0.8550263376	88.8292159	0.16	
DD	6/15/21	1.29	1.274	1.282	0.8825045631	91.8009309	0.15	
GS	6/15/21	1.285	1.262	1.274	1.277067606	91.19226638	0.15	

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