Burt Lake Tributary Monitoring Study

By Tip of the Mitt Watershed Council

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SUMMARY

The water quality and ecosystem of Burt Lake are influenced by activities occurring in upstream areas of the watershed. Due to concerns about potential water quality impacts from upstream sources, the Burt Lake Preservation Association sponsored the Burt Lake Tributary Monitoring Study, which was conducted by Tip of the Mitt Watershed Council. The study was designed to assess the relative impacts of major tributaries to Burt Lake by monitoring water quality and measuring discharge. Eight sites on the following tributaries were included in the study: the Crooked River, Maple River, Carp Creek, White Goose Creek, Sturgeon River, and Indian River.

Field data were collected in April and November of 2011 immediately following storm events with the objective of determining maximum pollutant concentrations in streams as a result of stormwater runoff. Dissolved oxygen, conductivity, pH, and water temperature were measured in the field with a multi-sensor probe and water samples were collected and analyzed for orthophosphates, total phosphorus, nitrate-nitrogen, total nitrogen, dissolved organic carbon, chloride, total suspended solids, and *E. coli*. Stream discharge was also measured at each site. Discharge and parameter concentration values were used to calculate pollutant loadings for all sites, as well as percentages of discharge and load contributed by individual tributaries.

No serious water quality problems were found in the Burt Lake tributaries; bacteria concentrations were low and all complied with state standards; nutrient, chloride, and conductivity levels were low and in typical ranges for streams of Northern Michigan; suspended solids were generally low and indicative of clear waters; water temperatures were low and dissolved oxygen concentrations sufficiently high to sustain cold-water fisheries and pH within the range required by the state. Discharge data showed that the Sturgeon River contributed the greatest volume of water to Burt Lake, nearly 50% on average, followed by the Maple River at 28%, while White Goose Creek contributed the least. Pollutant load calculations showed disproportionately high contributions of phosphorus and nitrogen from the Maple River, phosphorus and chloride from White Goose Creek, dissolved organic carbon from the Crooked River, and chloride and suspended solids from the Sturgeon River.

The disproportionate nutrient load from the Maple River could be the result of greater agricultural land cover in its watershed or abundant allochthonous material entering the river channel from the dominant natural landcover types. The disproportionately high chloride loads entering Burt Lake from the Sturgeon River and White Goose Creek may simply reflect the higher percentage of urban land cover in their respective watersheds. There is no obvious explanation for the high dissolved organic carbon load from the Crooked River. Unexpectedly, nitrogen and solid loads were found to decrease in a downstream direction on the Sturgeon River.

Additional monitoring of the same tributaries and other minor inlet streams is needed to more accurately assess the impacts of individual tributaries to Burt Lake and develop a nutrient budget. Tributaries should be surveyed for erosion and severe erosion should be addressed. A no wake zone should be instituted for the Crooked River. Urban and agricultural pollution sources in the tributary watersheds should be investigated. Riparian land owners and watershed residents of tributary streams should be encouraged to adopt best management practices that protect water quality.

INTRODUCTION

Background:

Burt Lake is a large oligotrophic lake (>17,000 acres) located in the middle of a chain of lakes and rivers called the Inland Waterway, which originates near Petoskey, Michigan and flows over 40 miles across the tip of the mitt before emptying into Lake Huron at Cheboygan. The water quality and ecosystem of Burt Lake are influenced by a number of upstream water bodies and associated watersheds, including Round Lake, Crooked Lake, Pickerel Lake, Douglas Lake, the Maple River, the Sturgeon River, the Crooked River, and Carp Creek. Due to concerns about potential water quality impacts from upstream sources, the Burt Lake Preservation Association (BLPA) sponsored a tributary study to evaluate the impacts of all the major tributaries of Burt Lake, which was conducted by Tip of the Mitt Watershed Council (TOMWC). The Burt Lake Tributary Monitoring Study was designed to assess the relative impacts of individual tributaries of Burt Lake by monitoring water quality and measuring discharge multiple times throughout the course of one to three years. The following tributary rivers and streams were included in the study: the Crooked River, the Maple River, Carp Creek, White Goose Creek, the Sturgeon River, and the Indian River.

During the 2010 “State of Burt Lake” meeting, BLPA members expressed concern about the negative impacts that rivers and streams were having on Burt Lake, particularly excessive sediment loads from the Crooked River and urban pollution in various parts of the watershed. Pollutants associated with roads, such as leaking fluids from automobiles, and those associated with houses, such as septic leachate, are among the sources of pollution associated with urban areas. Urban areas that potentially degrade the water quality of streams that flow into Burt Lake include: Alanson, Indian River, Pellston, Petoskey, and Wolverine. Residential development in the riparian zone of the tributary streams also has negative impacts on water quality and the stream ecosystem, particularly the Crooked and Sturgeon Rivers. In addition, agricultural activity in the Burt Lake watershed may contribute pollutants to the tributary streams, such as nutrients from fertilizers and animal waste or sediments from soil erosion.

Study Area:

Burt Lake is located in the northern tip of the Lower Peninsula of Michigan; in Burt and Tuscarora Townships of east-central Cheboygan County. Based on digitization of aerial orthophotography provided by Cheboygan County Equalization (2008), the shoreline of Burt Lake measures 35.07 miles and lake surface area totals 17,436 acres. Burt Lake is approximately 9.5 miles long and nearly 5 miles across at its widest point. A prominent lobe called Colonial Point extends out from the west shore toward the middle of the lake, to the south of which lie Maple, Bullhead, and Poverty Bays (Figure 1). In the northeast corner, Greenman Point extends southward, sheltering White Goose Bay to the east.

Bathymetry maps from the State of Michigan show the deepest area located directly out from Colonial Point with a maximum depth of 73 feet. Tip of the Mitt Watershed Council water quality monitoring data have confirmed this maximum depth. According to digitized bathymetry maps acquired from the Michigan Geographic Data Library, approximately 64% of the lake exceeds 20 feet of depth. Broad shallow plateaus are found on the west central side between Maple and Poverty Bays as well as in the north end of the lake.

Burt Lake is a drainage lake with water flowing into and out of the lake. The primary inlets include the Maple and Crooked Rivers to the west, the Sturgeon River in the southeast corner and Carp Creek in the north end. The only outlet is the Indian River in the southeast corner. Extensive wetland areas are located adjacent to the lake between Maple and Poverty Bays on the west-central shoreline and at the northern end of the lake.

Based on a watershed boundary map layer developed by Tip of the Mitt Watershed Council using GIS (Geographical Information System) data from the Michigan Geographical Data Library, the Burt Lake watershed encompasses approximately 371,173 acres of land and water. The watershed stretches from the City of Gaylord in the south to the village of Levering to the north and contains a number of other regionally important water bodies including Crooked, Douglas, Larks, Munro, Pickerel, and Round Lakes (Figure 2). A watershed ratio of 20.29 was calculated by

Figure 1. Burt Lake: Features and Depths

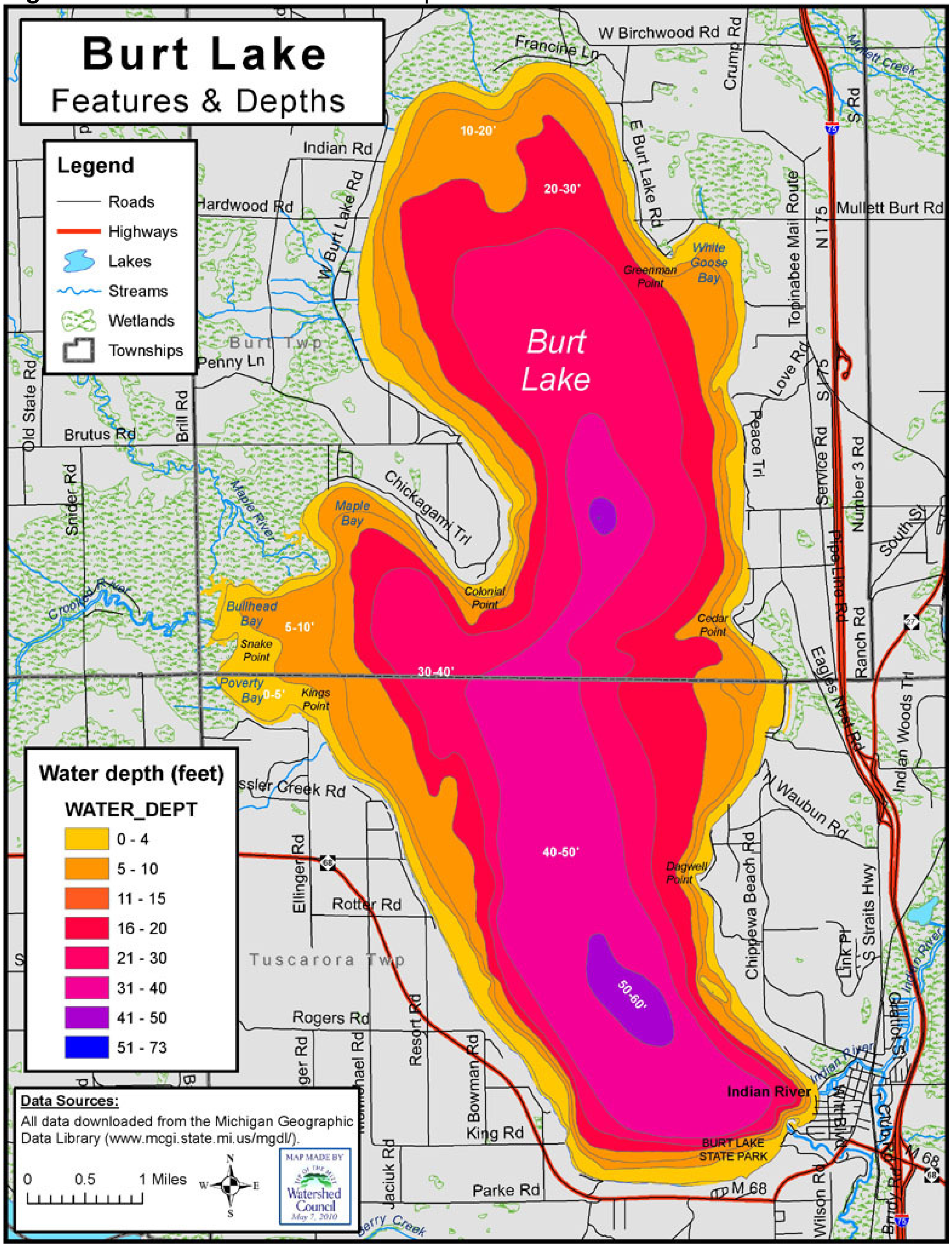
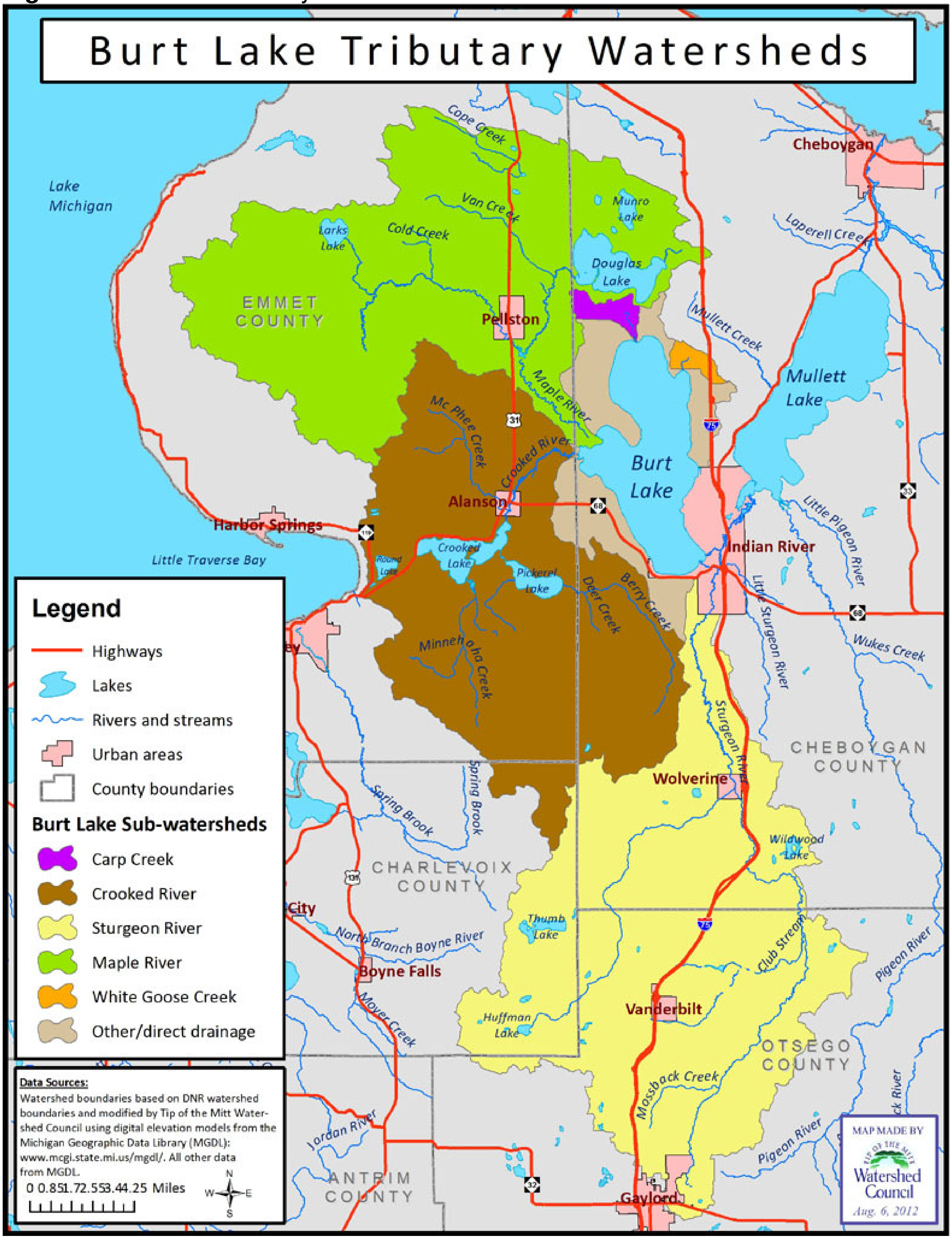


Figure 2. Burt Lake tributary watersheds.



dividing the lake surface area into the watershed area (not including the lake), indicating that there are over 20 acres of watershed area for each acre of Burt Lake water surface area. This ratio provides a statistic for gauging susceptibility of lake water quality to changes in watershed land cover. Relative to other lakes in Northern Michigan, Burt Lake has a high watershed ratio and therefore, a strong buffer to protect the lake from impacts associated with watershed development.

Land cover statistics were generated for the watershed using remote sensing data from the Coastal Great Lakes Land Cover project (Table 1). Based on 2006 data, the majority of the watershed's landcover is natural; consisting primarily of forest, wetlands, and grassland. There is relatively little agricultural landcover in the watershed (~9%) and even less urban (~3.7%). However, both of these land-cover types increased by approximately one percent between 2000 and 2006.

Table 1. Burt Lake watershed land-cover statistics.

Land Cover Type	2000 Acreage	2000 Percent	2006 Acreage	2006 Percent	Change (%)
Agriculture	31374.86	8.45	33904.15	9.13	0.68
Barren	929.78	0.25	671.65	0.18	-0.07
Forested	186825.07	50.30	193792.82	52.18	1.88
Grassland	55628.32	14.98	35674.85	9.61	-5.37
Scrub/shrub	11600.79	3.13	14106.14	3.80	0.67
Urban	9278.47	2.50	13546.24	3.65	1.15
Water	28320.59	7.63	27980.16	7.53	-0.09
Wetland	47409.78	12.77	51713.13	13.92	1.16
TOTAL	371367.66	100.00	371389.15	100.00	NA

<u>Water Quality of Burt Lake</u>

The water quality of Burt Lake has been monitored consistently for decades through TOMWC's Comprehensive Water Quality Monitoring (CWQM) and Volunteer Lake Monitoring (VLM) programs. Burt Lake water quality data date back to 1987 for the CWQM program and 1986 for the VLM program. Data from both programs indicate that water quality has been and remains high in Burt Lake.

Phosphorus is a nutrient that is necessary for a healthy aquatic ecosystem, but excess can lead to problematic algae and plant growth. Typically, large, deep, high-quality lakes of Northern Michigan like Burt have total phosphorus concentrations of less than 10 parts per billion (ppb). Total phosphorus concentrations measured as part of the CWQM program have rarely been above 10 ppb and, in fact, have gradually decreased from about 10 ppb in the late 1980s to less than 5 ppb in 2010 (Figure 3). This drop in phosphorus is largely attributed to invasive zebra mussels that have altered the natural nutrient cycle in Burt Lake by filter-feeding on plankton, though it may also be the result of decreased inputs from anthropogenic sources, such as malfunctioning septic systems or fertilizers.

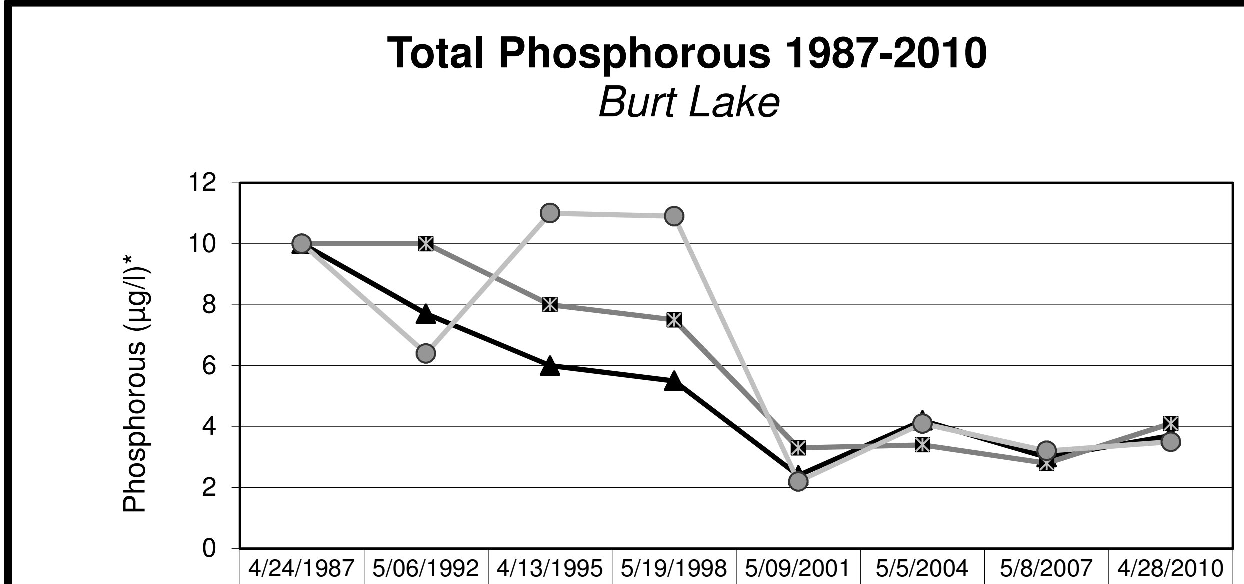
Conductivity is a measure of the ability of water to conduct an electric current, which is dependent upon the concentration of charged particles (ions) dissolved in the water, including chloride. It is a particularly useful parameter to monitor because research shows that conductivity levels increase as urbanization in a watershed increases. CWQM program data show that conductivity levels in Burt Lake increased steadily from 1987 to 2004, decreased substantially in 2007, but appeared to be on the rise again in 2010 (Figure 4). Although it is uncertain as to why levels decreased in 2007, the overall trend indicates that human activity in the watershed is increasing and potentially impacting the water quality of Burt Lake.

Volunteers monitor Burt Lake during summer months by measuring water clarity and chlorophyll-a concentrations. Water clarity and chlorophyll-a data are used to determine the lake's trophic status index score, which is a measure of a lake's biological productivity. Based on trophic status index values generated from the volunteer data, Burt Lake was a mesotrophic lake (i.e., moderately productive), but gradually dropped into the oligotrophic category (i.e., low biological productivity) where it has remained since 1999 (Figure 5). Large, high-quality lakes in Northern Michigan are often classified as oligotrophic, typically with low nutrient levels and abundant oxygen throughout the lake. Similar to phosphorus, this decline in biological productivity is thought related to invasive zebra mussels.

<u>Water quality of the Burt Lake tributaries:</u>

Considering the ecological importance of the Inland Waterway and its value to local economies, surprisingly little water quality data has been collected from its major thoroughfares, such as the Crooked and Indian Rivers. The Mullett Lake Watershed

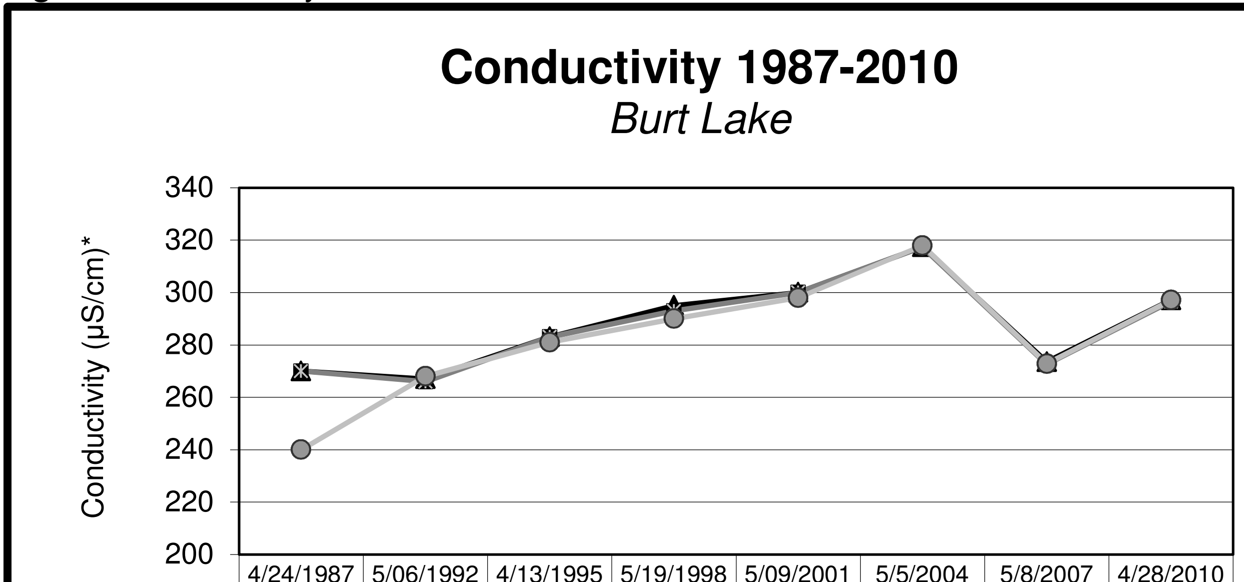
Figure 3. Phosphorus trends in Burt Lake.



	4/24/1987	5/06/1992	4/13/1995	5/19/1998	5/09/2001	5/5/2004	5/8/2007	4/28/2010
Surface	10.0	7.7	6.0	5.5	2.4	4.2	3.0	3.7
Middle	10.0	10.0	8.0	7.5	3.3	3.4	2.8	4.1
Bottom	10.0	6.4	11.0	10.9	2.2	4.1	3.2	3.5

**Total phosphorus measured in ug/l, which is milligrams per liter or parts per billion.*

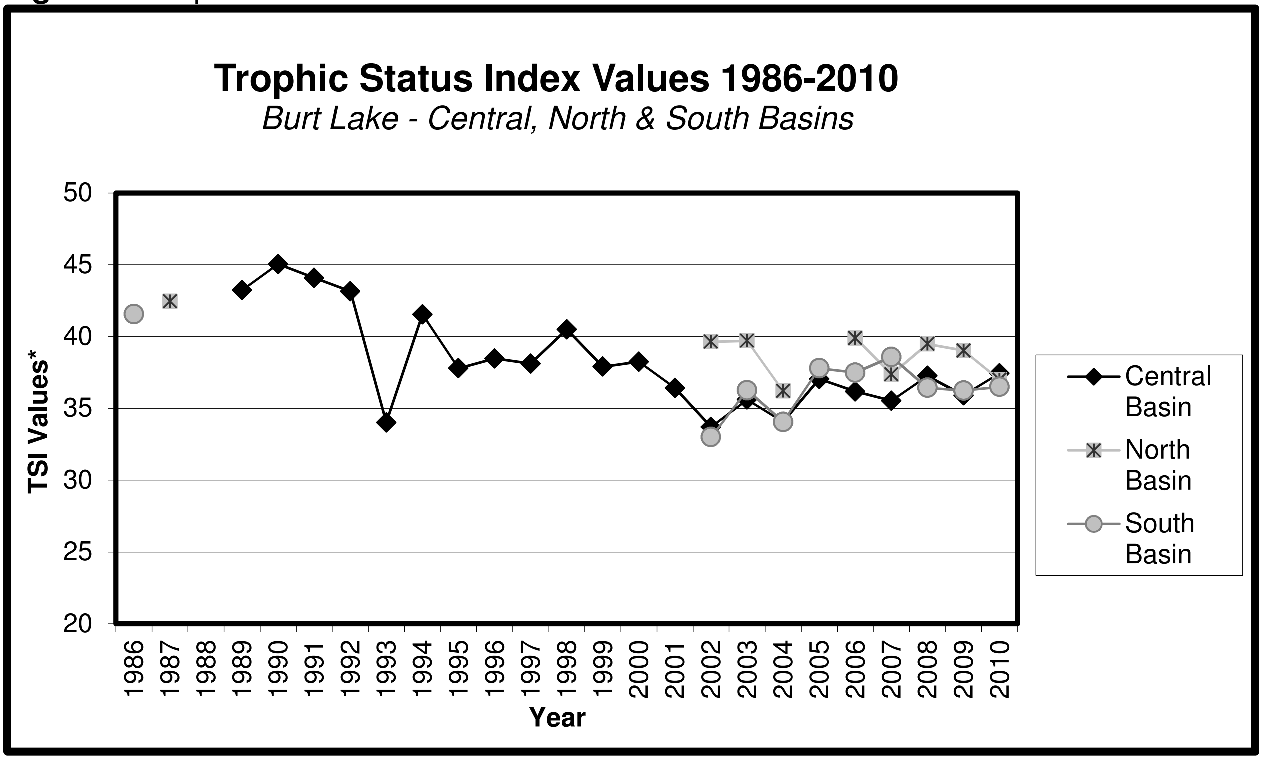
Figure 4. Conductivity trends in Burt Lake.



	4/24/1987	5/06/1992	4/13/1995	5/19/1998	5/09/2001	5/5/2004	5/8/2007	4/28/2010
Surface	270	267	283	295	300	317	274	297
Middle	270	266	283	293	300	317	273	297
Bottom	240	268	281	290	298	318	273	297

**Conductivity measured in uS/cm, which is microsiemens per centimeter.*

Figure 5. Trophic status index data for Burt Lake.



**TSI determines trophic status of lake: 0-38 = oligotrophic (low productive system), 39-49 = mesotrophic (moderately productive system), and 50+ = eutrophic (highly productive system).*

Nonpoint Source Management Plan indicated that water quality testing performed by the Surface Water Quality Division of the Michigan Department of Natural Resources (MDNR) in 1988 showed quality in the Indian River to be high, though specific results were not found (NEMCOG 1989). A more recent study of the Mullett Lake tributaries also found no evidence of water quality impairment in the Indian River (TOMWC, 2008). However, the Mullett Lake tributary study did find that phosphorus loads in the Indian River increased downstream of the urban area of Indian River. No water quality information was found for the Crooked River.

The Sturgeon River is an important cold-water fishery and valuable natural and recreational resource in the DNR's Pigeon River Country special management unit, resulting in extensive water quality and biological data collection by regulatory agencies and others. Over 50 chemical and physical parameters (see Appendix A for full list) have been monitored by regulatory agencies, primarily the Michigan Department of Environmental Quality (MDEQ). In addition, the Sturgeon River has been assessed comprehensively in terms of in-stream habitat, riparian vegetation, fish populations, and aquatic macroinvertebrate communities by the MDEQ and Tip of the Mitt Watershed Council volunteers. Although not nearly as extensive, similar data sets are also available for the Maple River, which also sustains a healthy cold-water fishery.

Of the available water quality data, the Sturgeon and Maple Rivers can be most accurately and quickly assessed using the information gathered from aquatic macroinvertebrate surveys. In general, greater diversity in the macroinvertebrate community indicates higher water quality and a healthier stream ecosystem. In 2011, eight new sites on the Sturgeon and Maple Rivers were added to the Tip of the Mitt Volunteer Stream Monitoring Program. Volunteers now sample these sites every spring and fall. Results from this program show that biological diversity in these rivers is high relative to other streams in the program (Table 2). MDEQ macroinvertebrate data for the Sturgeon and Maple Rivers, which were collected by experienced aquatic biologists, show even greater diversity in these river systems (Table 3).

Table 2. Macroinvertebrate data from volunteer monitoring.

Stream Name	Total Taxa Average*	EPT Taxa Average*	Sensitive Taxa Average*
Bear River	17.6	7.2	3.2
Boyne River	16.4	9.1	5.1
Eastport Creek	21.3	7.7	3.2
Horton Creek	17.5	8.0	3.7
Jordan River	20.1	11.9	7.1
Kimberly Creek	21.0	7.9	3.8
Maple River	**24.0**	**9.0**	**3.8**
Milligan Creek	18.6	9.4	5.9
Mullett Creek	20.7	7.5	3.0
Pigeon River	18.8	8.5	5.2
Russian Creek	14.1	4.4	1.6
Stover Creek	16.6	4.5	1.9
Sturgeon River	**20.0**	**10.1**	**5.6**
Tannery Creek	14.7	5.5	2.1
ALL STREAMS	18.7	7.9	3.9

** Diversity indices include:* ***total taxa*** *= the total number of macroinvertebrate families found;* ***EPT taxa*** *= the number of families in the pollution-sensitive insect orders (mayflies, stoneflies, and caddisflies); and* ***sensitive taxa*** *= the number of families most sensitive to non-point source pollution.*

Table 3. MDEQ macroinvertebrate data from the Sturgeon and Maple Rivers.

Location/Parameter	Date	Total Diversity*	EPT Diversity*	Sensitive Families*
Sturgeon River, Poquette Rd	7/13/2005	28	16	8
Sturgeon River, Poquette Rd	8/23/2000	22	11	5
Sturgeon River, Whitmarsh Rd	8/23/2000	21	9	6
Sturgeon River, Sturgeon Valley Rd	7/13/2005	26	12	7
Club Creek, Sturgeon Valley Rd	8/23/2000	15	8	4
Club Creek, Fontinalis Club	7/13/2005	30	15	8
Sturgeon River, Cornwall Grade	7/12/2005	35	17	7
Sturgeon River, Cornwall Grade	8/23/2000	27	12	5
Sturgeon River, Trowbridge Rd	8/9/1991	33	13	7
Sturgeon River, Straits Hwy	8/9/1991	26	13	9
Sturgeon River North Branch, Shire Rd	7/14/2005	35	11	8
Sturgeon River North Branch, Shire Rd	8/23/2000	24	11	6
Sturgeon River, Scott Rd	8/9/1991	31	14	8
Sturgeon River, Rondo Rd	7/12/2005	31	15	9
Sturgeon River, Rondo Rd	8/9/1991	30	12	8
Sturgeon River, White Rd	8/16/2010	29	12	6
Sturgeon River, Fisher Woods Rd	7/12/2005	35	16	9
STURGEON AVERAGE		**28**	**13**	**7**
Maple River, Maple River Rd	6/1/2005	37	20	10
Maple River, Maple River Rd	8/16/2010	42	18	9
Maple River, East Branch, Douglas Rd	6/1/2005	38	13	4
Maple River, West Branch, Robinson Rd	6/1/2005	37	18	9
MAPLE AVERAGE		**39**	**17**	**8**

** Diversity indices include:* ***total taxa*** *= the total number of macroinvertebrate families found;* ***EPT taxa*** *= the number of families in the pollution-sensitive insect orders (mayflies, stoneflies, and caddisflies); and* ***sensitive taxa*** *= the number of families most sensitive to non-point source pollution.*

Little water quality data are available for Carp Creek and no data were found for Goose Island Creek. Carp Creek data were limited to three studies performed by students at the University of Michigan Biological Station. The physical and chemical parameters that were monitored as part of these studies show typical levels for streams in this region and no signs of water quality impairment (e.g., high dissolved oxygen levels, low chloride concentrations, etc. Table 4). The constant low water temperatures recorded in these studies are evidence of large groundwater inputs that form Carp Creek and influence the northern end of Burt Lake.

Table 4. Water quality data from relevant UMBS studies of Carp Creek.

Parameter*	Location	Date of Study	Author	Data
Temperature, summer average (ºC)	Multiple locations	1990	Straw, J.	11-13
Depth, average (meters)	Multiple locations	1990	Straw, J.	0.5
pH, average	Multiple locations	1997	Frank et. al	8
Dissolved oxygen, average (mg/l)	Multiple locations	1990	Straw, J.	8.3
Conductivity, average (µS)	Multiple locations	1990	Straw, J.	285
Temperature (ºC)	out of ground	1985	Schultz, K.	10.5
Dissolved oxygen (mg/l)	out of ground	1985	Schultz, K.	8.6
pH	out of ground	1985	Schultz, K.	6.8
Conductivity (µS)	out of ground	1985	Schultz, K.	326
Dissolved oxygen (% sat.)	out of ground	1985	Schultz, K.	77.6
Calcium carbonate (mg/l)	out of ground	1985	Schultz, K.	164
Ammonia (mg/l)	out of ground	1985	Schultz, K.	1
Chloride (mg/l)	out of ground	1985	Schultz, K.	0
Silicon dioxide (mg/l)	out of ground	1985	Schultz, K.	5.1
Temperature (ºC)	downstream, near Burt Lake	1985	Schultz, K.	10.8
Dissolved oxygen (mg/l)	downstream, near Burt Lake	1985	Schultz, K.	9.2
pH	downstream, near Burt Lake	1985	Schultz, K.	7.2
Conductivity (µS)	downstream, near Burt Lake	1985	Schultz, K.	323
Dissolved oxygen (% sat.)	downstream, near Burt Lake	1985	Schultz, K.	83
Calcium carbonate (mg/l)	downstream, near Burt Lake	1985	Schultz, K.	162
Ammonia (mg/l)	downstream, near Burt Lake	1985	Schultz, K.	4.4
Chloride (mg/l)	downstream, near Burt Lake	1985	Schultz, K.	4.4
Silicon dioxide (mg/l)	downstream, near Burt Lake	1985	Schultz, K.	5

**Units: ºC=degrees Celsius, mg/l=milligrams per liter, µS=microsiemens % sat=percent saturation.*

METHODS

<u>Field Data Collection:</u>

Water quality and discharge data were collected from eight sites on streams flowing into or out of Burt Lake during April and November of 2011. Sample sites included the Crooked River at both M68 and near the mouth, the Maple River at Brutus Road, Carp Creek near the mouth, White Goose Creek near the mouth, the Indian River at the outlet, and the Sturgeon River at White Road (north) and also near the mouth (Figure 6). Data were also collected from sites on the Plymouth Beach and Harbor Woods Canals during the spring sample event, but dropped from the project due to lack of flow (spring data for canals in Appendix B). Field data were collected immediately following precipitation events with the objective of determining maximum pollutant concentrations in streams as a result of stormwater runoff.

At each site, surface grab samples were collected in the middle of the stream with separate containers for chemical, suspended solid, and bacteriological analysis. Acid-rinsed 125 milliliter Nalgene containers were used to collect water samples for chemical analysis and were rinsed three times with stream water (both bottle and cap) prior to collecting the sample. Clean 500 milliliter Nalgene bottles were used to collect water samples for total suspended solids measurements, which were also rinsed three times with stream water at the site prior to collecting the water sample. Sterilized containers, acquired from the Emmet County Health Department were used to collect water samples for bacteriological analysis, filling once and capping per instructions provided by the Health Department. All water samples were immediately placed in a cooler containing ice.

Water samples collected for bacteriological analysis were delivered directly to the Health Department Laboratory in Gaylord, where they were analyzed to determine the number of *Escherichia coli* (*E. coli*) per 100 milliliters. Water samples collected for chemical analysis were frozen upon returning to the Watershed Council office while samples collected for total suspended solids measurements were refrigerated; both were transported to the University of Michigan Biological Station (UMBS) at a later date.

Figure 6. Burt Lake tributary study monitoring sites.

Water samples collected sent to the UMBS were analyzed for orthophosphates ($PO4^-$), total phosphorus (TP), nitrate-nitrogen ($NO3^-$), total nitrogen (TN), dissolved organic carbon (DOC), chloride (CL^-), and total suspended solids (TSS).

Physical parameters, including dissolved oxygen, specific conductivity, pH, and water temperature, were measured using a Hydrolab MiniSonde®. The MiniSonde® was calibrated prior to field work using methods detailed in the manual; dissolved oxygen was calibrated with the percent saturation method using current barometric pressure, specific conductivity was calibrated using a standard solution of 447 microSiemens/cm, and pH was calibrated using standard buffer solutions of 7 and 10 units pH. At each monitoring site the MiniSonde® was lowered into the water at mid-channel to approximately half the total depth, readings saved to memory in the Surveyor4a handheld unit and also recorded on a field datasheet. Upon returning to the office, data were transferred from the Surveyor4a to a computer and consolidated in a Microsoft Excel® workbook.

After monitoring water quality, stream discharge was measured at each site. A nylon measuring tape was suspended across the stream channel perpendicular to the direction of flow. Then, flow velocity and water depth were measured at irregular intervals across the stream channel. Intervals were selected based upon changes in depth and current velocity. Prior to recording flow velocity, the velocity sensor of a Marsh McBirney digital current meter was adjusted to six tenths the depth at each location across the channel. An adjustable wading rod was used where depths were less than six feet and a multi-section rod was used at depths greater than six feet (in the Crooked, Sturgeon, and Indian Rivers), which required manual adjustment to place the velocity sensor at six-tenths of the depth. All data were recorded on a field datasheet and later inputted into a Microsoft Excel® workbook.

<u>Data Processing:</u>

Pollutant loadings were calculated for each sample event at all sites using discharge and pollutant concentration values. The total stream discharge was calculated by multiplying the width, average depth and average current velocity for each transect section, and then summing the calculated discharge of all sections. Pollutant loads were calculated by multiplying discharge (in cubic meters per second), the pollutant's measured concentration, and a conversion factor (190.48 for parameters measured in parts per million or 0.1905 for those in parts per billion). The percentages of discharge and pollutant load contributed by each inlet tributary were calculated using data from the most downstream site.

RESULTS

Bacteria:

Bacteriological analysis results ranged from zero *E. coli* bacteria per 100 milliliters in the Indian River to 79.4 in White Goose Creek (Table 5). Rule 62 (R 323.1062) of DEQ Part 4 Water Quality Standards has a provision for E. coli concentrations in surface water: "All waters of the state protected for total body contact recreation shall not contain more than 130 *Escherichia coli* (*E. coli*) per 100 milliliters, as a 30-day geometric mean." Rule 62 also states: "At no time shall the waters of the state protected for total body contact recreation contain more than a maximum of 300 *E. coli* per 100 milliliters." All samples complied with State standards.

Table 5. Bacteria concentrations in Burt Lake tributaries.

	Crooked River, M68	**Crooked River, Mouth**	**Maple River, Brutus Rd**	**Carp Creek, Mouth**	**White Goose Creek, Mouth**	**Sturgeon River, White Rd**	**Sturgeon River, Mouth**	**Indian River, Outlet**
E. coli* **4-2011**	6.3	28.5	25.6	3	3.1	9.8	4.1	0
E. coli* **11-2011**	17.3	17.3	36.9	57.6	79.4	30.9	29.5	2

*Reported in units of *E. coli* bacteria per 100 milliliters.

Nutrients:

Phosphorus concentrations, both soluble and total, were generally very low in the Burt Lake tributaries (below 10 parts per billion). Soluble reactive phosphorus is the portion of the phosphorus that is readily available for uptake by algae and higher aquatic plants. DEQ Part 4 Water Quality Standards do not include nutrient concentration limits for surface waters. Regulation for surface waters is limited to the following passage from Rule 60 (323.1060): "nutrients shall be limited to the extent necessary to prevent stimulation of growths 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." A total phosphorus concentration of 12 parts per billion (ppb) or less for streams in the Northern Michigan ecoregion is preferred by the United States Environmental Protection Agency (USEPA) "because it is likely associated with minimally impacted conditions, will be protective of designated uses, and provides management flexibility” (USEPA, 2001). The highest concentrations occurred in White Goose Creek and the Maple River, exceeding the recommended 12 ppb threshold two times (Table 6).

Table 6. Phosphorus concentrations in Burt Lake tributaries.

	Soluble Reactive Phosphorus*			Total Phosphorus*		
Sample Site	**Apr-11**	**Nov-11**	**Avg.**	**Apr-11**	**Nov-11**	**Avg.**
Crooked River, M68	0.5	3.6	2.1	5.8	3.6	4.7
Crooked River, Mouth	0.5	2.9	1.7	6.9	4.1	5.5
Maple River, Brutus Rd	0.5	3.8	2.2	11.5	6.2	8.9
Carp Creek, Mouth	1.4	2.2	1.8	4.1	7.4	5.8
White Goose Creek	2.2	10.5	6.4	9.2	19.6	14.4
Sturgeon River, White Rd	0.5	3.0	1.8	6.6	3.0	4.8
Sturgeon River, Mouth	0.5	3.2	1.9	7.0	4.4	5.7
Indian River, Outlet	0.5	3.7	2.1	2.6	8.7	5.7

**all units in ug/l (parts per billion). Avg. = average.*

Nitrate is a water soluble form of nitrogen that can be used by plants and a portion of total nitrogen. Similar to phosphorus, nitrogen concentrations were generally highest in the Maple River and White Goose Creek (Table 7). Total nitrogen and nitrate-nitrogen concentrations documented in this study, as well as total phosphorus, were typical for streams in this region as demonstrated by averaged river data from the CWQM program (Table 8). Nutrient concentrations in the streams were at times higher than what has been documented in Burt Lake through the CWQM program, which is not unusual as streams in Northern Michigan generally have higher levels of nutrients than large, deep lakes. The USEPA total nitrogen reference condition of 440 ppb for minimally impacted conditions for Northern Michigan streams was exceeded in five samples (USEPA, 2001).

Organic matter in lakes and streams originating from sources throughout the watershed can be measured by analyzing water samples for dissolved organic carbon (DOC), concentrations in streams ranging from less than one to 50 mg/l (Mulholland, 2003). DOC is not monitored in the CWQM program, but DOC concentrations documented in this study were within the range of 1-18 mg/l from studies of other Midwest streams (Royer and David 2003, and Volk et. al 2002). The; higher levels at some sites could be indicative of wetlands in their respective watersheds (Table 9).

Table 7. Nitrogen concentrations in Burt Lake tributaries.

	Nitrate-Nitrogen*			Total Nitrogen*		
Sample Site	**Apr-11**	**Nov-11**	**Avg.**	**Apr-11**	**Nov-11**	**Avg.**
Crooked River, M68	174.6	168.2	171.4	476	352	414.0
Crooked River, Mouth	145.7	245.8	195.8	438	417	427.5
Maple River, Brutus Rd	151.1	405.6	278.4	564	556	560.0
Carp Creek, Mouth	62.3	127.6	95.0	181	175	178.0
White Goose Creek	41.0	396.3	218.7	417	617	517.0
Sturgeon River, White Rd	193.7	384.3	289.0	502	388	445.0
Sturgeon River, Mouth	215.3	340.1	277.7	330	394	362.0
Indian River, Outlet	96.6	85.3	91.0	190	355	272.5

**all units in ug/l (parts per billion), Avg. = average.*

Table 8. Nutrient, chloride, and conductivity data from the CWQM program.

	TP*	**$NO3^{-*}$**	**TN***	**CL^{-} ***	**Conductivity***
All rivers – Low	1.0	28	202	3.3	222
All rivers – High	14.3	1122	1567	14.5	405
All rivers – Average	5.1	245	425	8.7	305
Burt Lake – Low	2.2	51	236	5.0	240
Burt Lake – High	11.0	150	430	11.6	318
Burt Lake – Average	6.0	104	297	7.7	286

**TP = total phosphorus, $NO3^{-}$ = nitrate-nitrogen, TN = total nitrogen, CL^{-} = Chloride. Chloride reported in mg/l (parts per million), all other units in ug/l (parts per billion).*

Table 9. Dissolved organic carbon concentrations in the Burt Lake tributaries.

	Dissolved Organic Carbon*		
Sample Site	**Apr-11**	**Nov-11**	**Avg.**
Crooked River, M68	3.9	4.4	4.2
Crooked River, Mouth	6.7	13.3	10.0
Maple River, Brutus Rd	10.0	5.0	7.5
Carp Creek, Mouth	4.9	5.2	5.1
White Goose Creek	13.0	4.2	8.6
Sturgeon River, White Rd	6.8	4.6	5.7
Sturgeon River, Mouth	7.1	4.9	6.0
Indian River, Outlet	3.4	9.2	6.3

**Dissolved organic carbon reported in mg/l (parts per million).*

Chloride, Conductivity, and Total Suspended Solids:

Chloride, a component of salt, is present naturally at low levels in Northern Michigan surface waters due to the marine origin of the underlying bedrock (typically < 5 part per million). Michigan has not set limits for chloride in surface waters, though the USEPA recommends that 230 parts per million (ppm) be established for chronic toxicity and 860 ppm for acute toxicity (USEPA, 2012). Although current chloride levels in Northern Michigan are generally far below the USEPA toxicity thresholds, increases are indicative of other pollutants associated with human activity (such as automotive fluids from roads or nutrients/ bacteria from septic systems) reaching our waterways. Chloride concentrations in the Burt Lake tributaries were well below toxicity thresholds recommended by the USEPA (Table 10). The highest chloride concentrations occurred in White Goose Creek, where levels were above high values documented in streams in the CWQM program on two occasions (Table 8).

Conductivity is not specifically addressed in DEQ Part 4 Water Quality Standards, though Rule 51 (323.1051) provides a framework for regulating total dissolved solid (TDS) concentrations from point source discharge. TDS in mg/l (ppm) can be estimated from specific conductivity readings by using the widely applied multiplication factor of 0.67. Estimated TDS concentrations for all conductivity measurements from Burt Lake tributaries were well below the Rule 51 TDS maximum of 750 PPM. Conductivity levels in the Burt Lake tributaries were also below the high recorded in rivers in the CWQM program (405 μS, Table 8).

Measuring suspended solids is a way to determine the amount of sediment and other particles in water bodies, which is done by filtering, drying, and weighing the particles in a given volume of water. Michigan rules do not have numerical limits for suspended solids, but rather a narrative standard that states “that waters of the state shall not have any of the following unnatural physical properties in quantities which are or may become injurious to any designated use: turbidity, color, oil films, floating solids, foam, settleable solids, suspended solids, and deposits.” Water is generally considered to be clear when total suspended solids measure 20 mg/l or less, cloudy between 40 and 80 mg/l, and dirty when over 150 mg/l. Total suspended solids in the tributaries were found to be well below the 20 mg/l level in most cases, indicating clear waters (Table 10). The highest total suspended solid readings occurred in the Sturgeon River in the fall of 2011, but were still below what is generally considered to be cloudy.

Table 10. Chloride, conductivity, and suspended solids in Burt Lake tributaries.

	Chloride*			**Conductivity***			**Total Suspended Solids***		
Sample Site	**Apr-11**	**Nov-11**	**Avg.**	**Apr-11**	**Nov-11**	**Avg.**	**Apr-11**	**Nov-11**	**Avg.**
Crooked River, M68	7.8	8.8	8.3	269	276	273	4.5	4.4	4.5
Crooked River, Mouth	7.2	7.6	7.4	259	284	271	3.5	5.5	4.5
Maple River, Brutus Rd	3.2	6.0	4.6	182	241	211	2.5	1.8	2.2
Carp Creek, Mouth	2.5	5.1	3.8	261	269	265	2.5	4.3	3.4
White Goose Creek	13.4	21.5	17.5	249	328	288	1.0	2.0	1.5
Sturgeon River, White Rd	11.5	13.3	12.4	298	353	326	30.9	10.7	20.8
Sturgeon River, Mouth	12.2	15.0	13.6	302	360	331	30.0	9.3	19.7
Indian River, Outlet	10.4	11.5	11.0	277	299	288	1.0	1.0	1.0

**Chloride and total suspended solids reported in mg/l (parts per million), conductivity in microSiemens. Avg. = average.*

Dissolved Oxygen, Temperature, and pH:

Dissolved oxygen concentrations in the Burt Lake tributaries ranged from 9.07 to 11.90 ppm (Table 11), consistently above the DEQ Part 4 Water Quality Standards minimum dissolved oxygen concentration of 7 ppm for sustaining a cold-water fishery. Water temperatures ranged from 5.87° to 8.81° Celsius, the warmest temperatures occurring in Carp Creek and the coldest, on average, in the Sturgeon River (Table 11). According to DEQ Part 4 Water Quality Standards, monthly maximum temperatures for streams capable of supporting cold water fish are set at 54° Fahrenheit (12.22° Celsius) for April, 65° (18.33° Celsius) for May, and 63° (17.22° Celsius) Fahrenheit for September. None of the temperatures recorded exceeded state limits. Hydrogen ion concentration, expressed as pH, ranged from 7.62 to 8.65 in the Burt Lake tributaries (Table 11), falling within the range of 6.5 to 9.0 required for all Michigan surface waters according to DEQ Part 4 Water Quality Standards, Rule 53 (323.1053).

Table 11. Dissolved oxygen, temperature, and pH in Burt Lake tributaries.

	Dissolved Oxygen*			Temperature*			pH*		
Sample Site	**Apr-11**	**Nov-11**	**Avg.**	**Apr-11**	**Nov-11**	**Avg.**	**Apr-11**	**Nov-11**	**Avg.**
Crooked River, M68	10.70	11.46	11.08	7.01	7.46	7.24	8.65	8.38	8.52
Crooked River, Mouth	10.98	11.09	11.04	7.61	7.53	7.57	8.38	8.13	8.25
Maple River, Brutus Rd	10.60	10.92	10.76	7.79	7.00	7.40	8.47	7.94	8.20
Carp Creek, Mouth	10.38	9.95	10.16	8.81	8.67	8.74	8.45	7.98	8.22
White Goose Creek	9.17	9.07	9.12	7.82	5.87	6.84	7.80	7.62	7.71
Sturgeon River, White Rd	11.48	11.59	11.53	6.25	6.46	6.36	8.55	8.31	8.43
Sturgeon River, Mouth	11.48	11.66	11.57	6.18	6.42	6.30	8.50	8.31	8.40
Indian River, Outlet	11.90	11.03	11.47	6.29	8.81	7.55	8.41	8.56	8.49

**Temperature in °Celsius, dissolved oxygen in mg/l or parts per million, Avg. = average.*

Discharge:

Discharge measurements ranged from 2.5 cubic feet per second (cfs) for White Goose Creek to 492 cfs for the Sturgeon River (Table 12). Combined (total) inputs into Burt Lake from the Sturgeon River, Crooked River, Maple River, Carp Creek, and White Goose Creek averaged 802 cfs while output from the Indian River averaged 613 cfs. During both sampling events, combined discharge inputs were greater than the output. The Sturgeon River contributed the greatest volume of water to Burt Lake, nearly 50% on average, followed by the Maple River at 28%, while White Goose Creek contributed the least (Table 13 & Figure 7). On average, discharge increased from upstream to downstream locations on the Crooked and Sturgeon Rivers, though the discharge at the White Road (upstream) site on Sturgeon River was higher than at the mouth during the fall monitoring event.

Table 12. Discharge measurements from Burt Lake tributaries.

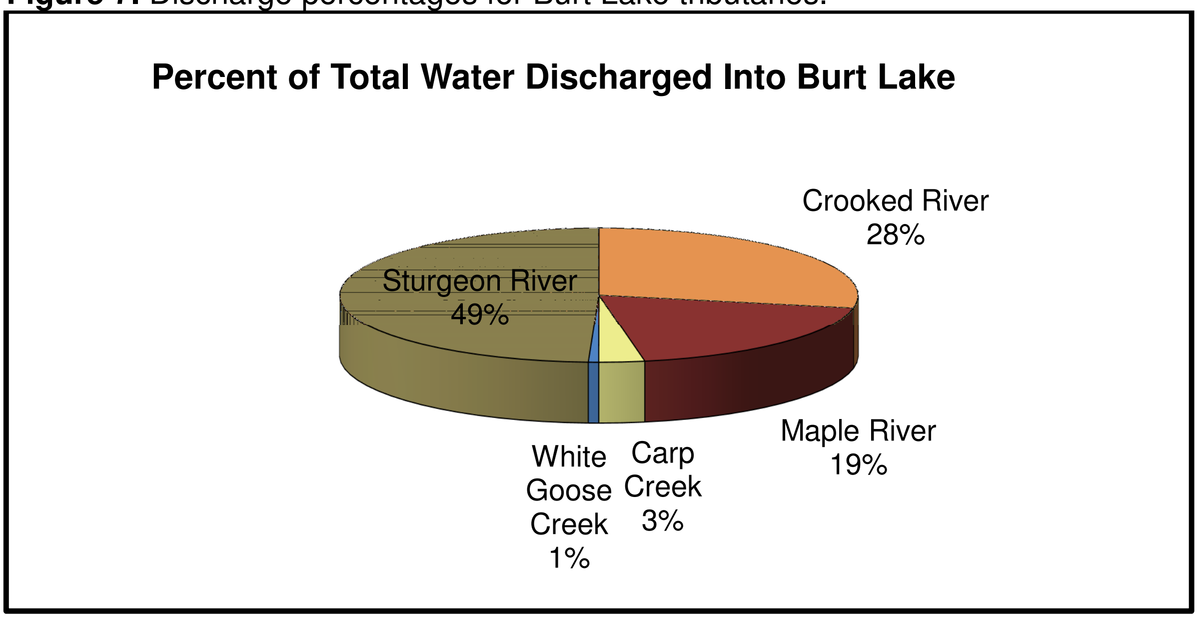
	Discharge (cfs)*			Discharge (cms)*		
Sample Site	**Apr-11**	**Nov-11**	**Avg.**	**Apr-11**	**Nov-11**	**Avg.**
Crooked River, M68	77.1	200.6	138.9	2.18	5.68	3.93
Crooked River, Mouth	180.5	248.6	214.5	5.11	7.04	6.07
Maple River, Brutus Rd	218.7	98.7	158.7	6.19	2.79	4.49
Carp Creek, Mouth	24.5	20.5	22.5	0.70	0.58	0.6
White Goose Creek	8.5	2.5	5.5	0.24	0.07	0.16
Sturgeon River, White Rd	461.3	320.8	391.0	13.06	9.08	11.07
Sturgeon River, Mouth	491.9	308.8	400.4	13.93	8.75	11.34
TOTAL INPUTS[ǂ]	924.1	679.1	801.6	26.2	19.2	22.7
OUTPUT, Indian River	566.7	658.8	612.7	16.05	18.66	17.35

**Units: cfs = cubic feet per second and cms = cubic meters per second. Avg. = average.*
[ǂ]Total input is the sum of discharge from the Sturgeon, Crooked and Maple Rivers, Carp and White Goose Creeks.

Table 13. Percent of discharge from Burt Lake tributaries.

	Discharge Percentage		
Sample Site	**Apr-11**	**Nov-11**	**Avg.**
Crooked River	19.53	36.61	28.07
Maple River	23.67	14.53	19.10
Carp Creek	2.66	3.02	2.84
White Goose Creek	0.92	0.36	0.64
Sturgeon River	53.23	45.48	49.35

Figure 7. Discharge percentages for Burt Lake tributaries.



Pollutant Loadings:

Total phosphorus loads in the Burt Lake tributaries ranged from 0.3 pounds per day (lbs/day) in White Goose Creek to 18.6 lbs/day in the Sturgeon River (Table 14). These data show that net total phosphorus load inputs from the Burt Lake tributaries exceeded outputs following the 2011 storm events by an average of 9.1 lbs/day. The percentage of phosphorus contributed by the Maple River and White Goose Creek was high (Table 15 & Figure 8), relative to what these streams contributed in terms of discharge (Table 13 & Figure 7).

Table 14. Nutrient loads in the Burt Lake tributaries.

	Total Phosphorus Load*			Total Nitrogen Load*			Dissolved Organic Carbon Load*		
Sample Site	**Apr-11**	**Nov-11**	**Avg.**	**Apr-11**	**Nov-11**	**Avg.**	**Apr-11**	**Nov-11**	**Avg.**
Crooked River, M68	2.4	3.9	3.2	198	381	289	1635	4761	3198
Crooked River, Mouth	6.7	5.5	6.1	426	559	493	6483	17832	12157
Maple River, Brutus Rd	13.6	3.3	8.4	665	296	481	11820	2661	7240
Carp Creek, Mouth	0.5	0.8	0.7	24	19	22	651	574	613
White Goose Creek	0.4	0.3	0.3	19	8	14	596	56	326
Sturgeon River, White Rd	16.4	5.2	10.8	1249	671	960	16870	7959	12414
Sturgeon River, Mouth	18.6	7.3	13.0	876	656	766	18838	8162	13500
TOTAL INPUTS*	39.8	17.2	28.5	2010	1539	1775	38388	29286	33837
OUTPUT, Indian River	7.9	30.9	19.4	581	1261	921	10484	32691	21588

** Total input is the sum of discharge from the Sturgeon, Crooked and Maple Rivers, Carp and White Goose Creeks.*

Table 15. Nutrient input percentages from Burt Lake tributaries.

	Total Phosphorus (%)			Total Nitrogen (%)			Dissolved Organic Carbon (%)		
Sample Site	**Apr-11**	**Nov-11**	**Avg.**	**Apr-11**	**Nov-11**	**Avg.**	**Apr-11**	**Nov-11**	**Avg.**
Crooked River	16.9	32.0	24.4	21.2	36.3	28.8	16.9	60.9	38.9
Maple River	34.1	19.2	26.6	33.1	19.2	26.2	30.8	9.1	19.9
Carp Creek	1.4	4.8	3.1	1.2	1.3	1.2	1.7	2.0	1.8
White Goose Creek	1.1	1.5	1.3	1.0	0.5	0.7	1.6	0.2	0.9
Sturgeon River	46.6	42.6	44.6	43.6	42.6	43.1	49.1	27.9	38.5

Total nitrogen loads in the Burt Lake tributaries ranged from 8 lbs/day in White Goose Creek to 1,249 lbs/day in the Sturgeon River (Table 14). These data show that net total nitrogen load inputs from the Burt Lake tributaries exceeded outputs following storm events by an average of 854 lbs/day. Interestingly, the total nitrogen load at the upstream site on the Sturgeon River was greater than at the mouth. As was the case with phosphorus loads, the percentage of total nitrogen contributed by the Maple River was high (Table 15 & Figure 9) relative to what it contributed in terms of discharge (Table 13 & Figure 7).

Dissolved organic carbon loads in the Burt Lake tributaries ranged from 56 lbs/day in White Goose Creek to 18,838 lbs/day in the Sturgeon River (Table 14). The averaged dissolved carbon load from the Crooked River was nearly as high as that of the Sturgeon River. These data show that net dissolved organic carbon load inputs from the Burt Lake tributaries exceeded outputs following storm events by an average of 12,249 lbs/day. The percentage of dissolved organic carbon contributed by the Crooked River was very high (Table 15 & Figure 10), relative to what it contributed in terms of discharge (Table 13 & Figure 7).

Figure 8. Total phosphorus load percentages for Burt Lake tributaries.

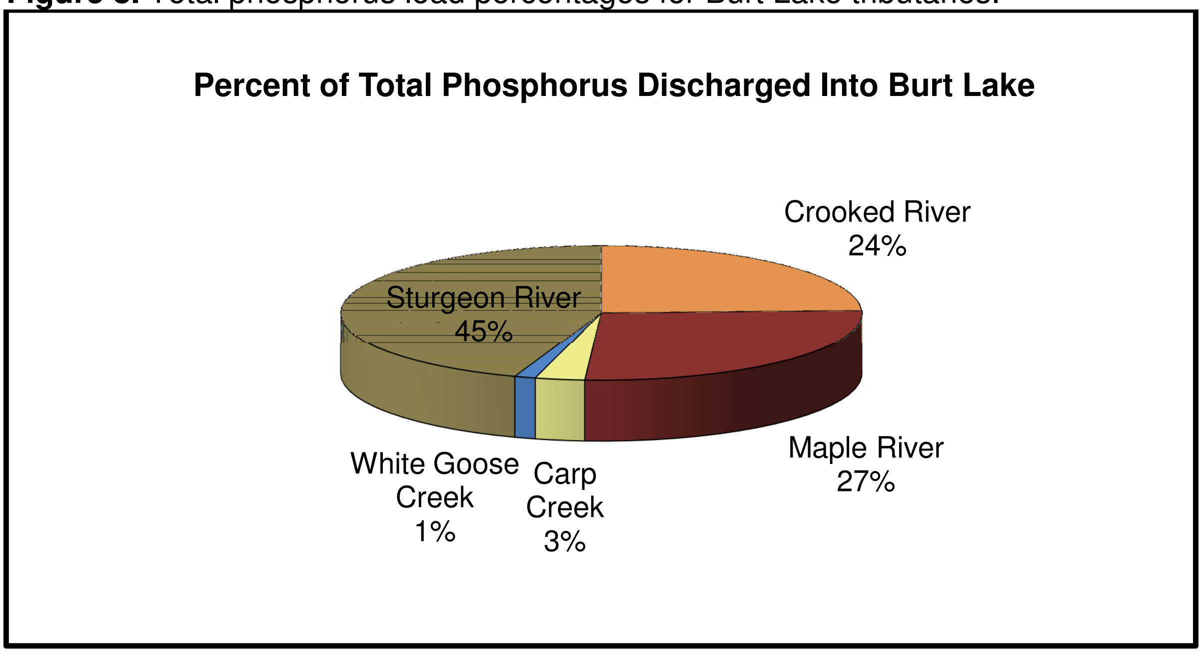


Figure 9. Nitrogen load percentages for Burt Lake tributaries.

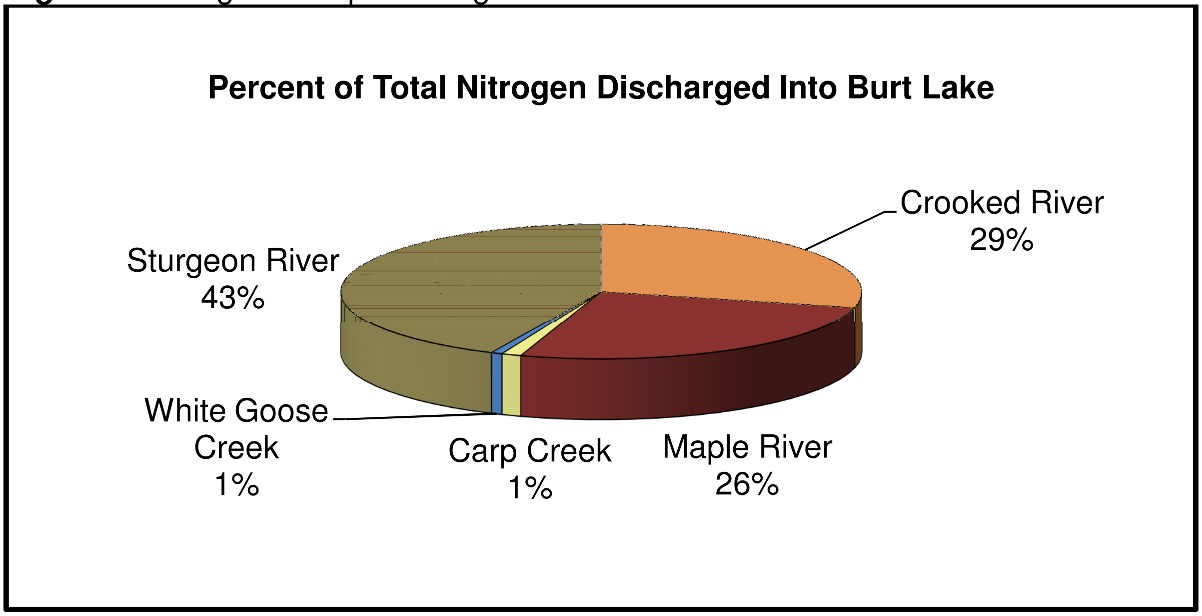
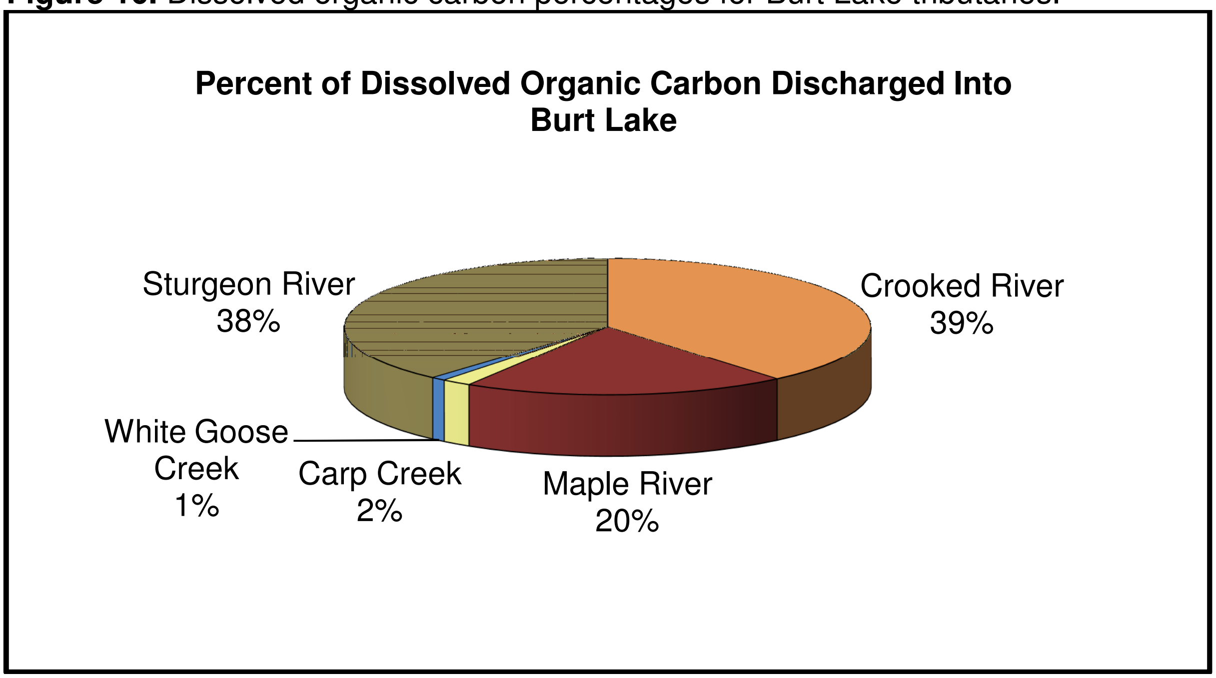


Figure 10. Dissolved organic carbon percentages for Burt Lake tributaries.



The total suspended solid loads in the Burt Lake tributaries ranged from 27 lbs/day in White Goose Creek to 79,596 lbs/day in the Sturgeon River (Table 16). These data show that net suspended solid load inputs from the Burt Lake tributaries exceeded outputs following storm events by an average of 52,022 lbs/day. Similar to the total nitrogen load, the suspended solid load at the upstream site on the Sturgeon River was great than at the mouth during the fall 2011 event. The percentage of total suspended solids contributed by the Sturgeon River was very high (Table 17 & Figure 11), relative to what it contributed in terms of discharge (Table 13 & Figure 7).

The chloride loads in the Burt Lake tributaries ranged from 287 lbs/day in White Goose Creek to 32,369 lbs/day in the Sturgeon River (Table 16). These data show that net chloride inputs from the Burt Lake tributaries exceed outputs following storm events, with an average of 5,333 lbs/day of chloride accruing in the Burt lake ecosystem during the 2011 sampling events. The percentage of chloride contributed by the Sturgeon River and White Goose Creek was high (Table 17 & Figure 12), relative to what they contributed in terms of discharge (Table 13 & Figure 7).

Table 16. Suspended solid and chloride loads in Burt Lake tributaries.

	Total Suspended Solids Load*			**Chloride Load***		
Sample Site	**Apr-11**	**Nov-11**	**Avg.**	**Apr-11**	**Nov-11**	**Avg.**
Crooked River, M68	1872	4761	3317	3245	9523	6384
Crooked River, Mouth	3407	7374	5391	7008	10190	8599
Maple River, Brutus Rd	2949	958	1954	3775	3193	3484
Carp Creek, Mouth	331	475	403	331	563	447
White Goose Creek	46	27	36	615	287	451
Sturgeon River, White Rd	76886	18512	47699	28615	23011	25813
Sturgeon River, Mouth	79596	15491	47544	32369	24986	28678
TOTAL INPUTS*	86328	24325	55327	44098	39219	41659
OUTPUT, Indian River	3057	3553	3305	31789	40864	36326

**Total inputs is the sum of loads from the Sturgeon River, Crooked River, Maple River, Carp Creek, and White Goose Creek.*

Table 17. Suspended solid and chloride percentages from Burt Lake tributaries.

	Total Suspended Solids (%)			**Chloride (%)**		
Sample Site	**Apr-11**	**Nov-11**	**Avg.**	**Apr-11**	**Nov-11**	**Avg.**
Crooked River	3.9	30.3	17.1	15.9	26.0	20.9
Maple River	3.4	3.9	3.7	8.6	8.1	8.4
Carp Creek	0.4	2.0	1.2	0.8	1.4	1.1
White Goose Creek	0.1	0.1	0.1	1.4	0.7	1.1
Sturgeon River	92.2	63.7	77.9	73.4	63.7	68.6

Figure 11. Suspended solid load percentages from Burt Lake tributaries.

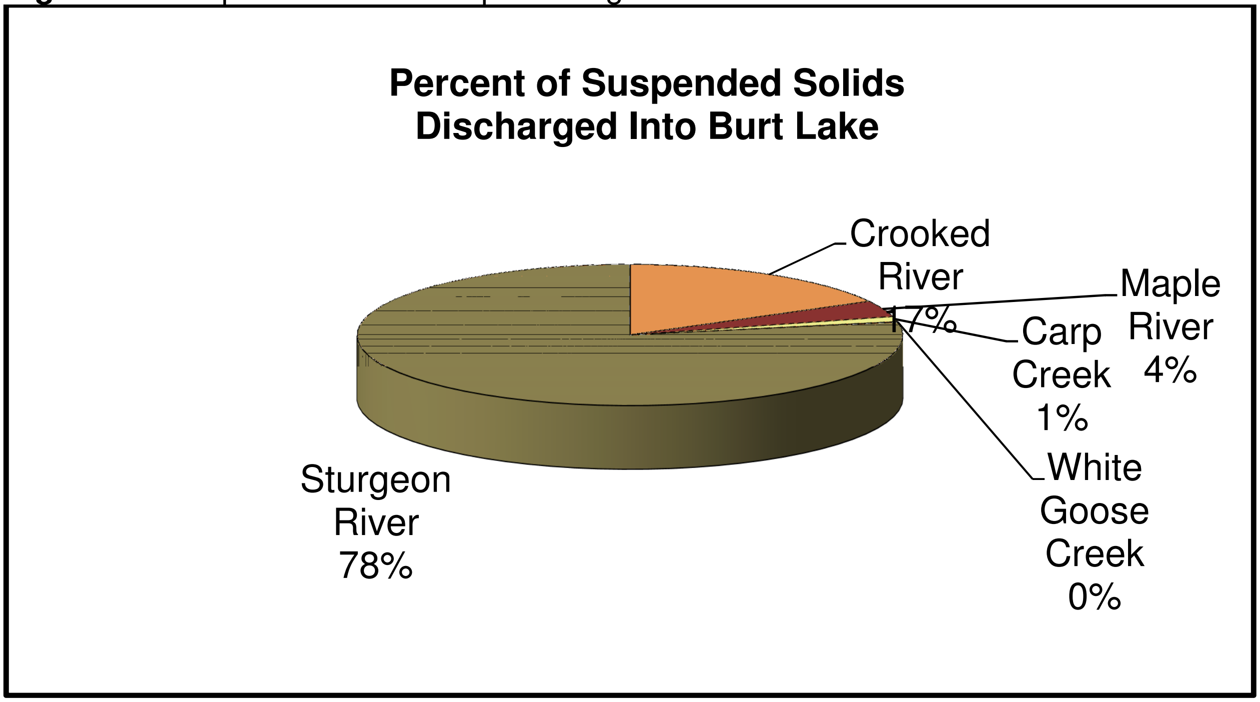
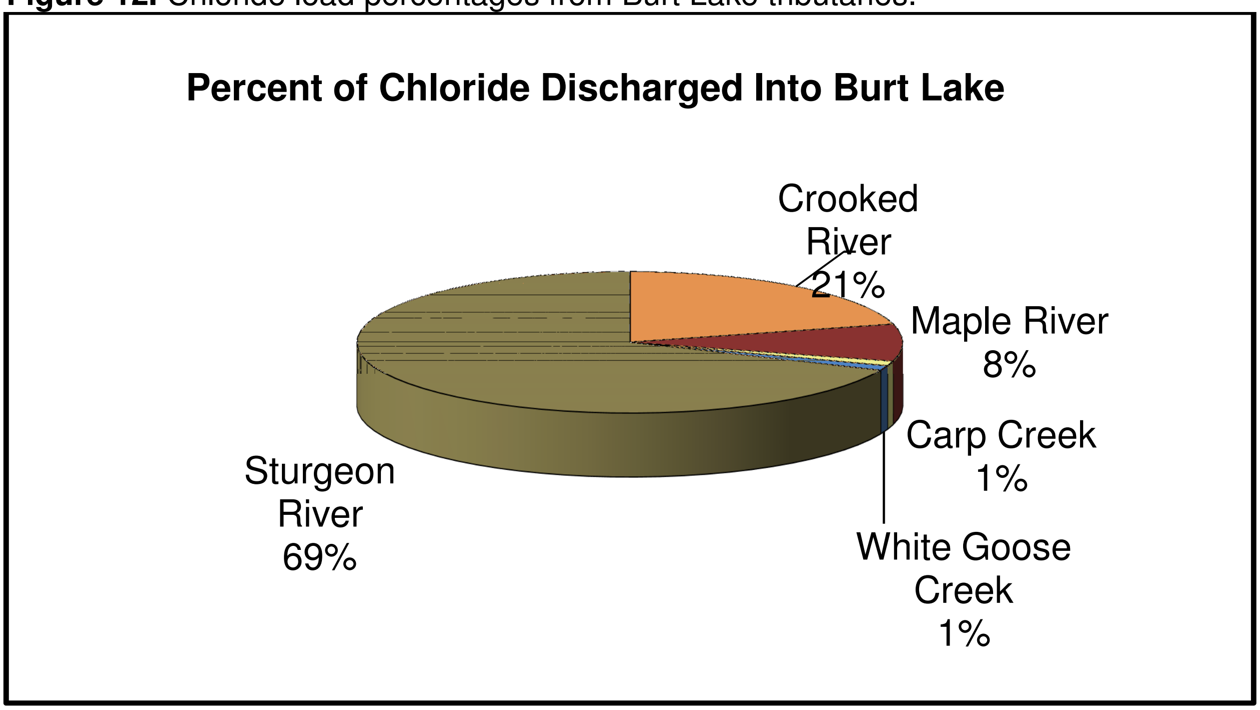


Figure 12. Chloride load percentages from Burt Lake tributaries.



DISCUSSION

Bacteria:

E. coli is a species of fecal coliform bacteria that is specific to fecal material from humans and other warm-blooded animals. *E. coli* is commonly used to monitor surface waters because it is considered a good indicator of health risk from body contact in recreational waters. Results showed low *E. coli* concentrations in the Burt Lake tributaries, much lower than the maximum allowed by state standards. The *E. coli* concentrations in the Sturgeon River were also low in spite of the fact that it flows through a portion of the community of Indian River in its lower section. The highest levels were recorded in White Goose Creek, which flows through a residential area, and the second highest readings came from Carp Creek, which has a largely undeveloped watershed. In both cases, wildlife (e.g., rodents, waterfowl, etc.) is believed to be the source of most bacteria, though the possibility of bacteriological contamination by humans and pets is more likely in White Goose Creek.

Nutrients:

Unnaturally high nutrient levels, particularly phosphorus, can cause problems in Northern Michigan surface waters due to excessive plant and algae growth. Nutrient data from all the Burt Lake tributaries showed low nutrient concentrations that are typical of northern Michigan streams. The highest total phosphorus and total nitrogen levels were found in White Goose Creek, which could be the result of adjacent residential land use or the extensive wetland complex upstream of Burt-Mullett Lake Road. The highest DOC (dissolved organic carbon) concentrations were recorded in the Crooked River, White Goose Creek, and Maple River. The high DOC levels probably reflect the influence of wetlands in these stream ecosystems as research has shown that in-stream DOC concentrations are influenced by wetlands in the watershed; as the amount of wetlands increases, DOC levels tend to increase (Echardt and Moore 1990).

Chloride, Conductivity, and Total Suspended Solids:

Chloride is an excellent indicator of human disturbance in a watershed because many products associated with human activities contain chloride (e.g., de-icing salts, water softener salts, fertilizers, and bleach) and it is a "mobile ion," meaning it is not removed by chemical or biological processes in soil or water. Research by Herlihy et al. (1998) found that "chloride concentration is a good surrogate indicator for general human disturbance in the watershed". Research shows that conductivity is also a good indicator of human impacts on aquatic ecosystems because levels usually increase as urbanization of a watershed increases (Jones and Clark 1987, Lenat and Crawford 1992). Chloride is related to conductivity in that it is a major inorganic anion in water.

In general, both chloride and conductivity levels were low in the Burt Lake tributaries. The highest chloride and conductivity levels were found in White Goose Creek and the Sturgeon River, which may reflect urban and residential land use in the lower reaches of these streams. However, readings were far below levels that adversely impact aquatic life.

Sediments (aka dirt) in surface waters can have a variety of negative impacts on aquatic ecosystems. Large amounts of dirt in water can degrade aquatic habitat, interfere with navigation, harm aquatic life, and impair water quality. Analysis of suspended solids is a way to measure dirt and other particles in water bodies, and quantify negative impacts. Most Burt Lake tributaries showed very low suspended solid levels. The Sturgeon River had much higher levels than other tributaries, but was still below what is considered high enough to give the water a cloudy appearance.

Due to high gradients that cause streambank and channel erosion, at least a portion of the suspended solids in the Sturgeon River is probably natural. However, increased development in the river's riparian areas, as well as recreational activities, has likely accelerated erosion in some parts of the river. Recent reconnaissance by Tip of the Mitt Watershed Council staff revealed numerous occurrences of severe streambank erosion in the Sturgeon River.

Dissolved Oxygen, Temperature, and pH:

Dissolved oxygen, temperature, and pH are very influential parameters in terms of a stream's water quality. Low dissolved oxygen levels, high water temperatures, or highly acidic or alkaline waters can quickly degrade a stream ecosystem. All temperature readings were low enough and dissolved oxygen concentrations high enough to sustain a cold water fishery. In addition, pH readings in all tributaries were in a healthy range that is typical for Northern Michigan streams.

Discharge and Pollutant Loadings:

Discharge measurements and pollutant loading calculations provide a greater understanding of impacts of individual inlet tributaries on the water quality of Burt Lake. By viewing the data in terms of percentage contributions, inlet tributaries contributing more than their share of nutrients, sediments, and chloride were discernible. Pollutant load calculations showed disproportionately high contributions of phosphorus and nitrogen from the Maple River, phosphorus and chloride from White Goose Creek, dissolved organic carbon from the Crooked River, and chloride and suspended solids from the Sturgeon River.

The disproportionate nutrient load from the Maple River could be the result of greater agricultural land cover in its watershed or may be the result of abundant allochthonous material (e.g., leaves, sticks, etc.) entering the river channel from the dominant natural landcover types (Table 18). The disproportionately high chloride loads entering Burt Lake from the Sturgeon River and White Goose Creek may simply reflect the higher percentage of urban land cover in their respective watersheds. There is no obvious explanation for the high dissolved organic carbon load from the Crooked River.

Monitoring results from upstream and downstream locations on the Crooked and Sturgeon Rivers provide data for determining longitudinal changes in the stream system. Approximate river mile distance between sample sites is 4.25 miles on the Crooked River and 4.0 miles on the Sturgeon River. On average, discharge increased from upstream to downstream, though the discharge at the White Road (upstream) site on Sturgeon River was higher than at the mouth during the fall monitoring event. As

Table 18. Land-cover* in Burt Lake tributary watersheds.

Land-cover Type	Burt Acres	Burt Percent	Sturgeon Acres	Sturgeon Percent	Crooked Acres	Crooked Percent
Agriculture	33904	9.1	9098	7.2	9603	9.9
Barren	672	0.2	136	0.1	337	0.3
Forested	193793	52.2	74691	59.2	55462	56.9
Grassland	35675	9.6	14302	11.3	9182	9.4
Scrub/Shrub	14106	3.8	6055	4.8	3652	3.7
Urban	13546	3.6	5783	4.6	3547	3.6
Water	27980	7.5	1435	1.1	4028	4.1
Wetland	51713	13.9	14565	11.6	11580	11.9
TOTAL	371389	100.0	126066	100.0	97392	100.0
Land-cover Type	**Maple Acres**	**Maple Percent**	**Carp Acres**	**Carp Percent**	**White Goose Acres**	**White Goose Percent**
Agriculture	13216	12.3	0	0.0	98	7.9
Barren	147	0.1	0	0.0	0	0.0
Forested	50183	46.6	1375	76.4	556	45.2
Grassland	10533	9.8	75	4.2	74	6.0
Scrub/Shrub	3379	3.1	65	3.6	36	2.9
Urban	3108	2.9	43	2.4	62	5.0
Water	5074	4.7	1	0.0	0	0.0
Wetland	22041	20.5	240	13.3	405	32.9
TOTAL	107682	100.0	1800	100.0	1232	100.0

**Land-cover data from 2006 (NOAA CCAP).*

would be expected, pollutant loads generally increased uniformly from upstream to downstream locations in both the Crooked and Sturgeon River. However, nitrogen loads decreased moving downstream in the Sturgeon River during both sampling events and suspended solid loads, in tandem with discharge, decreased during the fall event.

There is uncertainty as to why nitrogen loads in the Sturgeon River decreased in the stream reach between the White Road and the mouth. Nitrogen reductions are typically the result of in-stream ecosystem processes, such as deposition, uptake by plants, and denitrification. Deposition and plant uptake undoubtedly occur in this section of the river, though there is probably little denitrification as it occurs only in anaerobic environments. Another possible explanation is that dilution occurred from low-nitrogen water inputs in the stream reach, though it is doubtful that inputs in this limited section of the river would be sufficient to alter the nitrogen concentration of the entire river. Furthermore, water inputs would more likely increase the river’s nitrogen load due to nutrient pollution from adjacent urban areas. Interestingly, this same phenomenon of decreasing nitrogen loads in a downstream direction was observed in a recent assessment of the Indian River (TOMWC 2008).

The decrease in suspended solid loads from White Road to the mouth of the Sturgeon River could be attributed to deposition between the two locations due to a decrease in gradient and therefore, energy for sediment transport. The decreased sediment load could have also been the result of greater storm flow at the upper site (causing channel scouring and streambank erosion, and with greater energy for sediment transport) that had not yet reached the mouth.

Due to limited data, a nutrient budget for Burt Lake was not developed. However, preliminary results imply that Burt Lake is a large sink that removes substantial amounts of nutrients and sediments from the Inland Waterway and other tributaries as averaged inputs were consistently greater than outputs (Tables 14 and 16). As water in large drainage systems moves through lakes and reservoirs, nutrient loads typically decrease as a result of physical and biological processes, such as deposition and biological uptake. A recent study of the balance of all phosphorus entering and leaving Torch Lake, Antrim County indicated that 90% of the input phosphorus ends up as sediment at the bottom of the lake and is not recycled (Endicott et al. 2006). Considering that groundwater and atmospheric inputs, as well as direct overland drainage areas along the lakeshore, were neither monitored nor accounted for, the actual nutrient and sediment load reduction as water passes through Burt Lake would likely be even greater.

Recommendations:

1. Continue monitoring tributaries in terms of both water quality and discharge to more accurately assess the impacts of individual tributaries to Burt Lake, as well as longitudinal changes in the streams. Additional data are needed, both following storms and during base-flow conditions, to collect a more representative data set.
2. Include other minor inlet tributaries in future tributary monitoring efforts to fill data gaps. Although the inlet tributaries monitored during this survey accounted for a majority of the Burt Lake watershed, some were missed and have possibly never been monitored. The minor inlet streams include Hassler Creek to the south of King's Point, a small creek in Poverty Bay and a handful of small creeks on the northwest side of the lake. Monitoring additional inlet streams would provide a more comprehensive nutrient loading data set and would help determine if there are any specific water quality issues in these streams that are impacting the water quality of Burt Lake.
3. Develop a nutrient budget to determine the amount of nutrients and sediments that are sequestered in Burt Lake. Ideally, data should be collected over a period of several years, sampling throughout all seasons and hydrologic conditions (i.e., low, normal and high discharge). Monitoring in other seasons and under a variety of discharge conditions would provide a stronger foundation for quantifying utilization and deposition of nutrients and sediments in Burt Lake. The data and nutrient budget can also be used to monitor changes over time.
4. Conduct streambank erosion surveys in the tributaries to document eroding streambanks and prioritize remedial actions.
5. Address erosion in the tributaries to reduce sedimentation in Burt Lake. Data show disproportionate suspended solid inputs from the Sturgeon River, which are likely related in part to observed streambank erosion. Efforts should be made to stabilize eroding streambanks and reduce sediment inputs on the Sturgeon and other tributaries where streambank erosion is occurring.

6. Pursue a “no wake” designation for the Crooked River to prevent streambank erosion, protect the stream ecosystem, and reduce sediment inputs to Burt Lake. Numerous residents have reported that accelerated erosion is occurring in the Crooked River channel due to high speed boat traffic.
7. Investigate chloride sources in the Sturgeon River and White Goose Creek. Stormwater runoff from urban and residential areas, malfunctioning septic systems, and fertilizers are all potential sources of pollution that should be examined in these sub-watersheds.
8. Determine whether nutrient pollution is occurring in the Maple River. Conduct water quality monitoring further upstream, examine land use practices in the watershed, and survey the river’s riparian corridor for nutrient sources.
9. Encourage riparian owners in all streams throughout the Burt Lake watershed to adopt best management practices that benefit the water quality. Fertilizers should be applied sparingly, if at all, in riparian areas. Stormwater should be held and treated on site, septic systems should be properly maintained, and eroded areas should be stabilized and replanted. Greenbelts are particularly important for protecting water quality and should be maintained at the greatest width possible. Greenbelts effectively absorb surface runoff and by doing so filter out pollutants, reduce peak stream discharge during rain events, provide shade to maintain water temperatures necessary for cold water fisheries and prevent erosion. Naturally vegetated stream banks also provide critical habitat and a food energy source for both aquatic and terrestrial organisms. Research has shown that optimal greenbelt width for stream protection to be 100 feet or more, but that greenbelts of 35 feet of width provide many benefits to stream water quality and biology (Wenger 1999).

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Appendix A. Parameters monitored at sites on the Sturgeon and Maple Rivers.

Location/Parameter*	Sturgeon River, Poquette Rd	Sturgeon River, Whitmarsh Rd	Sturgeon River, Sturgeon Valley Rd	Club Creek, Sturgeon Valley Rd	Club Creek, Fontinalis Club	Sturgeon River, Cornwall Grade	Sturgeon River, Trowbridge Rd	Sturgeon River, Straits Hwy	Sturgeon River North Branch, Shire Rd	Sturgeon River, Scott Rd
Alkalinity	yes	yes	yes	yes	yes	yes	no	no	yes	no
Aluminum	yes	yes	yes	yes	yes	yes	no	no	yes	no
Antimony	yes	yes	yes	yes	yes	yes	no	no	yes	no
Aquatic Macroinvertebrates	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Arsenic	yes	yes	yes	yes	yes	yes	no	no	yes	no
Barium	yes	yes	yes	yes	yes	yes	no	no	yes	no
Beryllium	yes	yes	yes	yes	yes	yes	no	no	yes	no
Biological Oxygen Demand	yes	yes	yes	yes	yes	yes	no	no	yes	no
Boron	yes	yes	yes	yes	yes	yes	no	no	yes	no
Cadmium	yes	yes	yes	yes	yes	yes	no	no	yes	no
Calcium	yes	yes	yes	yes	yes	yes	no	no	yes	no
Carbon, Total Organic	yes	yes	yes	yes	yes	yes	no	no	yes	no
Chemical Oxygen Demand	yes	yes	yes	yes	yes	yes	no	no	yes	no
Chloride	yes	yes	yes	yes	yes	yes	no	no	yes	no
Chlorophyll-a	no	no	no	no	no	no	no	no	no	no
Chromium	yes	yes	yes	yes	yes	yes	no	no	yes	no
Cobalt	yes	yes	yes	yes	yes	yes	no	no	yes	no
Conductance, Specific	yes	yes	yes	yes	yes	yes	no	no	yes	no
Copper	yes	yes	yes	yes	yes	yes	no	no	yes	no
Discharge (flow)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Fish	no	no	no	no	no	no	yes	yes	no	yes
Habitat, In-stream	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Hardness, Calcium	no	no	no	no	no	no	no	no	no	no
Hardness, Total	yes	yes	yes	yes	yes	yes	no	no	yes	no
Iron	yes	yes	yes	yes	yes	yes	no	no	yes	no
Lead	yes	yes	yes	yes	yes	yes	no	no	yes	no
Lithium	yes	yes	yes	yes	yes	yes	no	no	yes	no
Magnesium	yes	yes	yes	yes	yes	yes	no	no	yes	no
Manganese	yes	yes	yes	yes	yes	yes	no	no	yes	no
Mercury	yes	yes	yes	yes	yes	yes	no	no	yes	No

Location/Parameter*	Sturgeon River, Poquette Rd	Sturgeon River, Whitmarsh Rd	Sturgeon River, Sturgeon Valley Rd	Club Creek, Sturgeon Valley Rd	Club Creek, Fontinalis Club	Sturgeon River, Cornwall Grade	Sturgeon River, Trowbridge Rd	Sturgeon River, Straits Hwy	Sturgeon River North Branch, Shire Rd	Sturgeon River, Scott Rd
Molybdenum	yes	yes	yes	yes	yes	yes	no	no	yes	no
Nickel	yes	yes	yes	yes	yes	yes	no	no	yes	no
Nitrogen, Ammonia	yes	yes	yes	yes	yes	yes	no	no	yes	no
Nitrogen, Kjedahl	yes	yes	yes	yes	yes	yes	no	no	yes	no
Nitrogen, Nitrite (mg/l)	no	no	no	no	no	no	no	no	no	no
Nitrogen, Nitrite + Nitrate	yes	yes	yes	yes	yes	yes	no	no	yes	no
Nitrogen, Total Organic	no	no	no	no	no	no	no	no	no	no
Oxygen, Dissolved	no	no	no	no	no	no	no	no	no	no
pH	no	no	no	no	no	no	no	no	no	no
Phenolics, Total Recoverable	no	no	no	no	no	no	no	no	no	no
Phosphorus, Soluble Reactive	no	no	no	no	no	no	no	no	no	no
Phosphorus, Total	yes	yes	yes	yes	yes	yes	no	no	yes	no
Potassium	yes	yes	yes	yes	yes	yes	no	no	yes	no
Residue, Total	no	no	no	no	no	no	no	no	no	no
Residue, Total Nonfiltrable	no	no	no	no	no	no	no	no	no	no
Riparian Vegetation	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Selenium	yes	yes	yes	yes	yes	yes	no	no	yes	no
Silicate	no	no	no	no	no	no	no	no	no	no
Silver	yes	yes	yes	yes	yes	yes	no	no	yes	no
Sodium	yes	yes	yes	yes	yes	yes	no	no	yes	no
Solids, Total Dissolved	yes	yes	yes	yes	yes	yes	no	no	yes	no
Strontium	yes	yes	yes	yes	yes	yes	no	no	yes	no
Sulfate	no	no	no	no	no	no	no	no	no	no
Sulfur	yes	yes	yes	yes	yes	yes	no	no	yes	no
Temperature	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Thallium	yes	yes	yes	yes	yes	yes	no	no	yes	no
Titanium	yes	yes	yes	yes	yes	yes	no	no	yes	no
Turbitidy	no	no	no	no	no	no	no	no	no	no
Vanadium	yes	yes	yes	yes	yes	yes	no	no	yes	no
Zinc	yes	yes	yes	yes	yes	yes	no	no	yes	no

**Yes indicates that the parameter has been monitored/measured at the given location on that river.*

Location/Parameter*	Sturgeon River, Haakwood Camp	Sturgeon River, Rondo Rd	Sturgeon River, White Rd	Sturgeon River, Fisher Woods Rd	Sturgeon River, M68	Maple River, Maple River Rd	Maple River, East, Robinson Rd	Maple River, Douglas Lake Rd	Maple River, Robinson Rd	Maple River, Camp Rd	Maple River, Ely Bridge Rd
Alkalinity	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Aluminum	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Antimony	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Aquatic Macroinvertebrates	no	yes	yes	yes	no	yes	no	yes	yes	no	no
Arsenic	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Barium	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Beryllium	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Biological Oxygen Demand	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Boron	no	no	no	yes	no	yes	yes	yes	yes	no	no
Cadmium	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Calcium	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Carbon, Total Organic	no	no	no	yes	yes	yes	yes	yes	yes	no	yes
Chemical Oxygen Demand	no	no	no	yes	no	yes	yes	yes	yes	no	yes
Chloride	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Chlorophyll-a	no	no	no	no	yes	no	no	no	no	no	no
Chromium	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Cobalt	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Conductance, Specific	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Copper	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Discharge (flow)	yes	yes	yes	yes	no	yes	no	yes	yes	yes	no
Fish	no	yes	no	no	no	no	no	no	no	no	no
Habitat, In-stream	yes	yes	yes	yes	no	yes	no	yes	yes	yes	no
Hardness, Calcium	no	no	no	no	yes	no	no	no	no	no	no
Hardness, Total	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Iron	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Lead	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Lithium	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Magnesium	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Manganese	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Mercury	no	no	no	yes	yes	yes	yes	yes	yes	no	no

**Yes indicates that the parameter has been monitored/measured at the given location on that river.*

Location/Parameter*	Sturgeon River, Haakwood Camp	Sturgeon River, Rondo Rd	Sturgeon River, White Rd	Sturgeon River, Fisher Woods Rd	Sturgeon River, M68	Maple River, Maple River Rd	Maple River, East, Robinson Rd	Maple River, Douglas Lake Rd	Maple River, Robinson Rd	Maple River, Camp Rd	Maple River, Ely Bridge Rd
Molybdenum	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Nickel	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Nitrogen, Ammonia	no	no	no	yes	yes	yes	yes	yes	yes	no	yes
Nitrogen, Kjedahl	no	no	no	yes	yes	yes	yes	yes	yes	no	yes
Nitrogen, Nitrite (mg/l)	no	no	no	no	yes	no	no	no	no	no	no
Nitrogen, Nitrite + Nitrate	no	no	no	yes	yes	yes	yes	yes	yes	no	yes
Nitrogen, Total Organic	no	no	no	no	yes	no	no	no	no	no	no
Oxygen, Dissolved	no	no	no	no	yes	no	no	no	no	no	no
pH	no	no	no	no	yes	no	no	no	no	no	no
Phenolics, Total Recoverable	no	no	no	no	yes	no	no	no	no	no	no
Phosphorus, Soluble Reactive	no	no	no	no	yes	no	no	no	no	no	no
Phosphorus, Total	no	no	no	yes	yes	yes	yes	yes	yes	no	yes
Potassium	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Residue, Total	no	no	no	no	yes	no	no	no	no	no	no
Residue, Total Nonfiltrable	no	no	no	no	yes	no	no	no	no	no	no
Riparian Vegetation	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	no
Selenium	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Silicate	no	no	no	no	yes	no	no	no	no	no	no
Silver	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Sodium	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Solids, Total Dissolved	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Strontium	no	no	no	yes	no	yes	yes	yes	yes	no	no
Sulfate	no	no	no	no	yes	no	no	no	no	no	no
Sulfur	no	no	no	yes	no	yes	yes	yes	yes	no	no
Temperature	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	no
Thallium	no	no	no	yes	no	yes	yes	yes	yes	no	no
Titanium	no	no	no	yes	yes	yes	yes	yes	yes	no	no
Turbitidy	no	no	no	no	yes	no	no	no	no	no	no
Vanadium	no	no	no	yes	yes			yes	yes	no	no
Zinc	no	no	no	yes	yes			yes	yes	no	no

Footnote: **Yes* indicates that the parameter has been monitored/measured at the given location on that river.

Appendix B. Water quality data for Plymouth Beach and Harbor Woods Canals.

Sample Site	Date	Time	Depth (meters)	Water Temperature (º Celsius)	Dissolved Oxygen (mg/L)*	Specific Conductivity (µS/cm)*	pH
Plymouth Beach	4/24/2011	10:48:13	0.8	7.13	11.96	481.1	8.04
Harbor Woods	4/24/2011	9:09:07	0.7	7.38	11.73	310.2	8.37
	Date	**Time**	**Depth (meters)**	**Soluble Reactive Phosphorus (PO4-P in µg/L)***	**Total Phosphorus (µg/L)***	**Nitrate-Nitrogen (NO3-N in µg/L)***	**Total Nitrogen (mg/L)***
Plymouth Beach	4/24/2011	10:48:13	0.8	<1.0	15.2	118.3	0.449
Harbor Woods	4/24/2011	9:09:07	0.7	<1.0	4.2	97.0	0.218
	Date	**Time**	**Depth (meters)**	**Chloride (mg/L)***	**Total Suspended Solids (mg/L)***	**Dissolved Organic Carbon (mg/L)***	**Bacteria (E. coli as #/100ml)***
Plymouth Beach	4/24/2011	10:48:13	0.8	65.0	2.5	10.64	1
Harbor Woods	4/24/2011	9:09:07	0.7	13.3	2.1	3.38	<1.0

*mg/L = milligrams per liter or parts per million, µg/L = micrograms per liter of parts per billion, µS/cm = microSiemens per centimeter, bacteria measured as number of Escherichia coli per 100 milliliters of sample.