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Michigan Department of Environment, Great Lakes, and Energy
Water Resources Division
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Staff Report

Biological surveys and water chemistry sampling of selected stations in the Thornapple River watershed in Barry, Eaton, Ionia, and Kent Counties, Michigan: 2015-2018

Introduction

Biological and physical habitat conditions of 31 selected sites in the Thornapple River in Barry, Eaton, Ionia, and Kent Counties were assessed by staff of the Michigan Department of Environment, Great Lakes, and Energy (EGLE), Water Resources Division (WRD), Surface Water Assessment Section (SWAS); and Permits Section, from July-September of 2015-2018 (Table 1, Figure 1). Nine sites were surveyed in 2015, outside of the normal assigned monitoring year, and three of those sites were resampled in 2018 to meet Objective 3 (below; Appendices 1 and 2, Figure 2). In 2017 and 2018 water chemistry was collected at an additional 23 stations by the Permits Section (Tables 2 and 3, Figure 3). The remainder of the surveys were conducted in the normal monitoring year: 2018 (Appendices 3-6). *E. coli* monitoring was also conducted in 2018 in the watershed and those results are summarized in a separate report (Rippke, 2019).

The primary objectives of the biological assessments were to:

1) Assess the current condition of individual water bodies and determine if Michigan Water Quality Standards (WQS) are being met.
2) Evaluate the Thornapple River below the Irving Impoundment following berm failure.
3) Assess changes in the macroinvertebrate and habitat condition in the Coldwater River in areas where unauthorized drain work was conducted.
4) Evaluate statewide biological community status and temporal trends.
5) Provide supporting data for the development and issuance of National Pollutant Discharge Elimination System (NPDES) permits.
6) Identify nonpoint sources of water quality impairment.

Watershed Information

Geography

The Thornapple River (04050007) is a tributary to the Lower Grand River, with the confluence just east of Grand Rapids, Michigan (Figure 1). The highest density of human habitation is near the confluence with the Grand River, in the Grand Rapids metropolitan area.

The entire Thornapple River watershed is within the Southern Michigan Northern Indiana Till Plains (SMNITP) ecoregion, which broadly covers the majority of the southern half of the Lower Peninsula of Michigan (Omernik and Gallant, 1988). In terms of the United States Geological Survey landscape ecosystem types, the Thornapple River watershed is composed of Lansing, Cassopolis Ice-Contact Ridges, and Battle Creek Outwash Plain subsections (Albert, 1995). The eastern portion of the watershed is in the Lansing ecosystem subsection, where soils are rich loams. Presettlement vegetation would have supported beech and maple forests with occasional pockets of forested wetlands, which formerly occupied about 22 percent of the

area. Most uplands in the fertile Lansing subsection have been converted to agriculture while most wetlands were deforested and converted to pastureland. Drainage by tiling and ditching was necessary to support agriculture in many areas, and as a result, many stream headwaters that were once sprawling wetlands are now drainage ditches and maintained drains with low gradient (less than 1 meter elevation drop per kilometer). Topography is gently rolling in the Lansing subsection.

The southwestern portion of the watershed, most in Barry County, is a patchwork of the Cassopolis Ice-Contact Ridges and Battle Creek Outwash Plain subsections. These ecosystems are composed of sand and gravel outwash plains with numerous small lakes and wetlands, broken by steep gradient ice-contact ridges and end-moraines. The steep terrain results in higher gradient streams, such as Glass Creek and Fall Creek, which have an overall gradient of 2.0 to 2.5 meters elevation loss per kilometer. Well drained portions originally supported tall-grass prairies, oak-hickory forests, and oak savannahs such as those being restored and preserved at the Pierce Nature Preserve southwest of Hastings, and the Barry State Game Area, which encompasses 17,000 acres in the Glass Creek vicinity. Farming was not sustainable in this area and efforts were largely abandoned in the 1920s and 1930s, resulting in the reforestation of abandoned fields, but residential areas are expanding. The main channel of the Thornapple River near the confluence of the Grand River occupies a former glacial outwash channel that is about 30 meters lower than the surrounding plains. Because of the deep soils, streams tend to trench deeply and have steep eroding banks in high gradient areas, for example, High Bank Creek.

Hydrology

Water velocity, stream morphology, and flow are influenced by the gradient, or slope, of the stream. Flow conditions of the river at survey sites are a key factor in determining aquatic macroinvertebrate and fish community composition. The slope, described as meters of elevation change over 1 kilometer of stream length, was calculated within each National Hydrography Dataset reach that contained a survey site (Table 1).

Several dams and impoundments remain in place on the main stem Thornapple River that dramatically affect the hydrology of the river, including five dams (Ada, Cascade, Middleville, LeBarge (Caledonia), and Irving [See Rippke, 2015 for more information] that take advantage of natural gradient changes in the river to generate hydroelectric power. In February 2018 the Irving Dam power canal spillway berm failed, causing the impoundment to drain Figure 4, see Objective 2). About one year later, in early 2019, the berm had been repaired and the impoundment returned to previous water levels.

Historic wetland destruction is a major issue that continues to affect water quality in the Thornapple River. Overall, the Thornapple watershed has lost about 50 percent of its presettlement extent of wetland area, and some sub-basins have lost as much as 82 percent of their original wetland area (Table 4) (Fizzell, 2015). The drainage of wetlands was mainly conducted to allow farming of these productive soils. But these activities resulted in the creation of ditches that require maintenance to continue draining the land. The loss of half the presettlement wetlands has had a negative impact on aquatic ecosystems, including the loss of flood plain access to fish; loss of groundwater infiltration; increased flashiness (flow variability); and increased flow velocity and erosive energy during floods where overly deep stream channels cause diminished overflow into flood plains. The periodic dredging and straightening of these ditches that were formed in places formerly occupied by wetlands also removes niche habitats that are important to fish and macroinvertebrates.

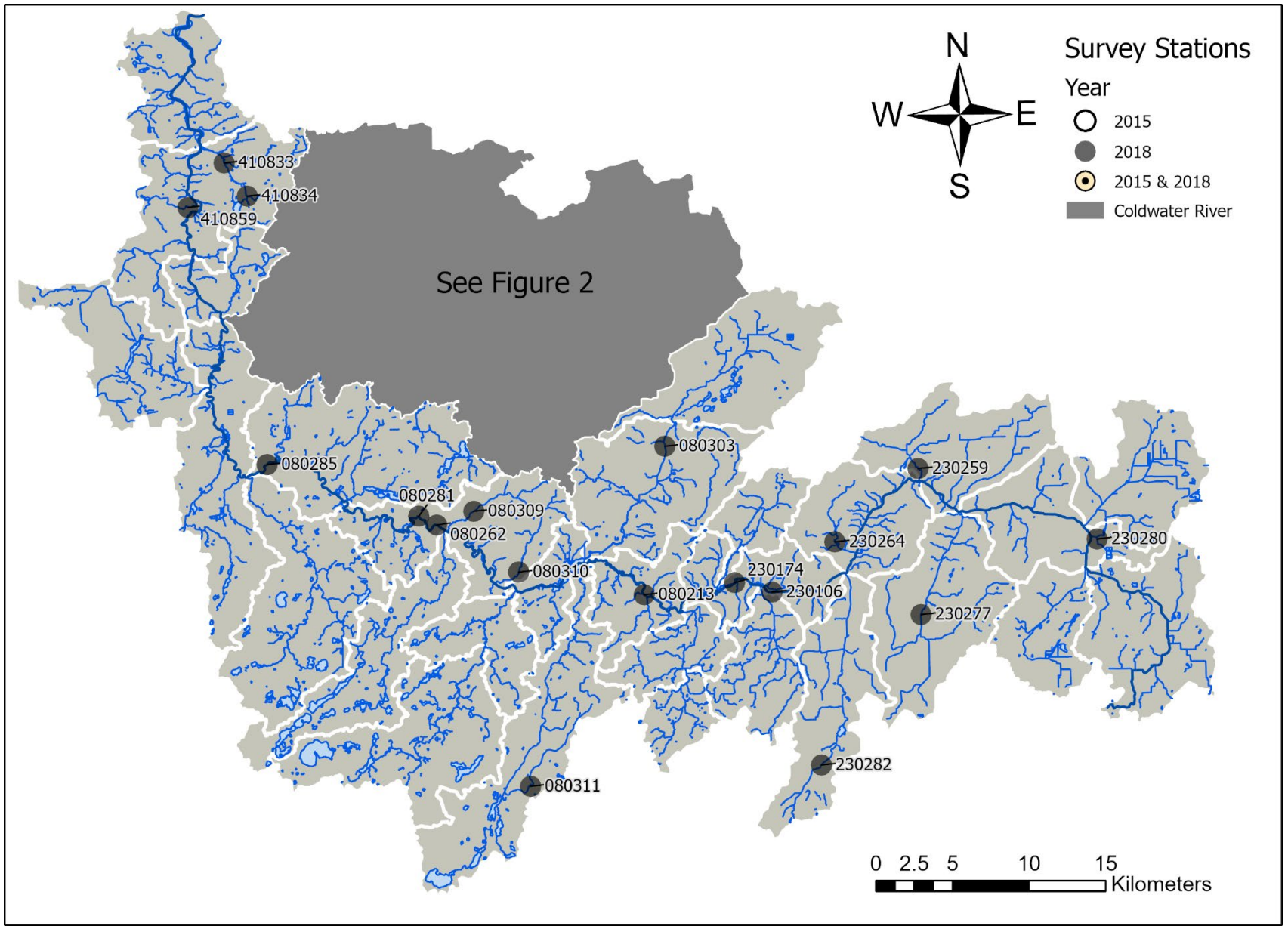

Figure 1. Map of survey sites, by year, in the Thornapple watershed area. See Figure 2 for Coldwater River sites.

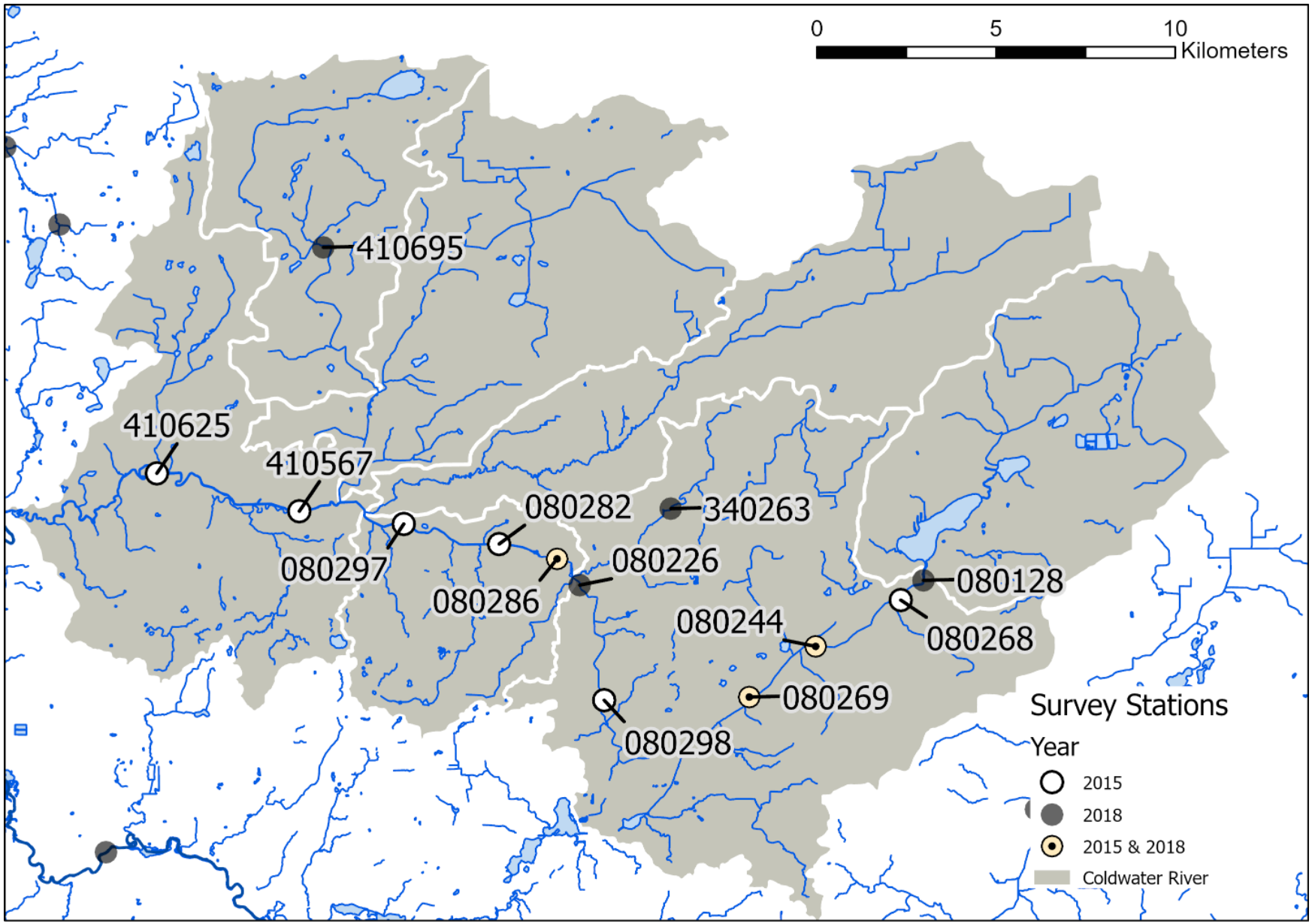

Figure 2. Coldwater River survey site locations, by year of sampling.

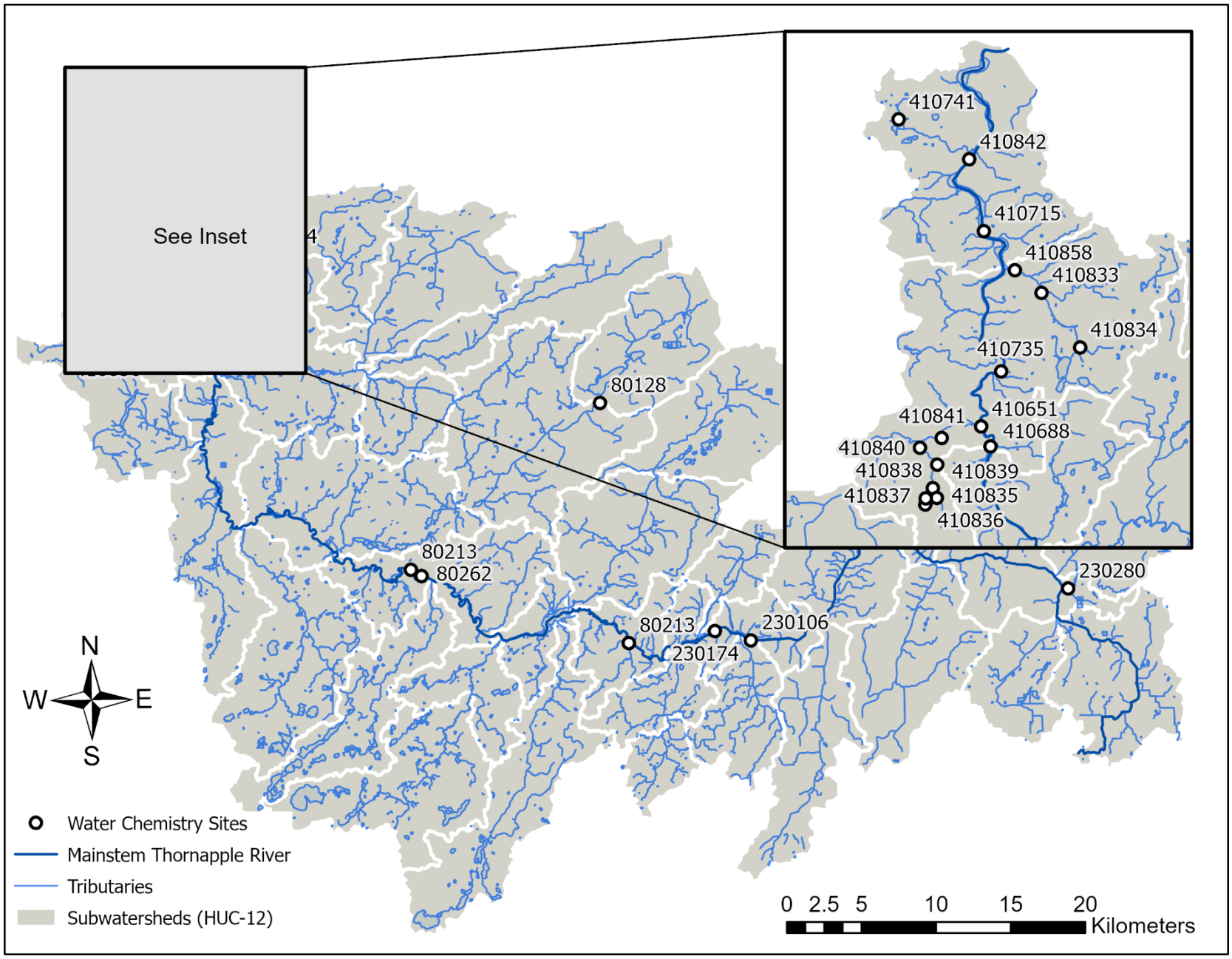

Figure 3. Locations of water chemistry monitoring sites for Objective 5.

Figure 4. Exposed sediment above Irving Dam, after earthen berm was breached and the impoundment had drained in February 2018.

Land Cover

Land cover, or the types of vegetation or anthropogenic uses covering the land, has a bearing on stream hydrology, sediment transport (erosion), and water temperature. For example, agricultural land cover types generally lose more topsoil by sheet and gully erosion than a forested land would, while developed land with its impervious surfaces would generally increase runoff and decrease infiltration during precipitation or snow melt events. The Thornapple watershed is predominantly agricultural land, with 42 percent cultivated land and an additional 18 percent pastureland (National Oceanic and Atmospheric Administration [NOAA], 2011). Overall, developed land is only 5 percent of the watershed, but is locally more common, such as in the portion of the Thornapple River that is near the city of Grand Rapids, where developed land is about 46 percent of that sub-basin. Land cover and human population characteristics by subwatershed are found in Table 4.

Historical Sampling Efforts and Information

Prior to this 2015-2018 study, the Thornapple watershed was surveyed at 27 sites by EGLE staff in 2013. Sites scored excellent at 4 sites, acceptable at 20 sites, and poor at 3 sites. Poor macroinvertebrate communities were found at sites located at Mud Creek upstream of Saddlebag Road, Little Thornapple downstream of M-43, and Little Thornapple downstream of Harwood Road. At that time, habitat was generally categorized as good, based on the average habitat score of 110 for the watershed. Fish community was sampled at three sites in 2013 and was not meeting the coldwater fish designated use at all three sites (Quaker Brook, Duck Creek, and Pratt Lake Creek) (Rippke, 2015).

Methods

The macroinvertebrate community and physical habitat were qualitatively assessed at 31 stations (Table 1) using the SWAS Procedure 51 (Creal et al., 1996; MDEQ, 1990) for wadeable streams. If a station is at a road crossing, it is sampled upstream unless otherwise noted. The macroinvertebrate communities were assessed and scored with metrics that rate water bodies from excellent (+5 to +9) to poor (-5 to -9). Scores from +4 to -4 are rated acceptable. Negative scores in the acceptable range are considered tending towards a poor rating, while positive scores in the acceptable range are tending towards an excellent rating. Habitat evaluations are based on 10 metrics, with a maximum total score of 200. A station with a habitat score greater than 154 is characterized as having excellent habitat, 105-154 is good, 56-104 is marginal, and less than 56 is poor. Where available, macroinvertebrate community scores are used to determine attainment of the Other Indigenous Aquatic Life and Wildlife (OIALW) designated use. Habitat scores and individual metrics are used to help better understand the biological community scores.

Site Selection

Two site-selection methods were used to assess the Thornapple River watershed: (1) stratified random; and (2) targeted. Randomly selected sites were assigned to support the SWAS Status (5 sites) and Trend (2 sites) Program. Status sites will be used to estimate the statewide support status for the OIALW designated use component of Rule 100 (R 323.1100(e)) of the Part 4 Rules, WQS, promulgated under Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended. Trend sites in the Thornapple River watershed will be used to facilitate a measurement of statewide biological community temporal trends (MDEQ, 2015). Targeted sites (24 sites) are chosen through the "Targeted Monitoring Request" process, which involves stakeholders from across Michigan submitting monitoring requests and includes requests from EGLE staff. All survey types are considered when assessing support of the OIALW designated use at the local stream reach level.

Summary of Findings by Monitoring Objective

Objective 1: Assess the current status and condition of individual waters of the state and determine whether Michigan WQS are being met.

In 2015 and 2018, aquatic macroinvertebrate community and habitat assessments were conducted at a total of 31 stations and all sites scored in the acceptable to excellent range. Habitat score ranged from 56 (marginal) to 165 (excellent) (Table 1 and Appendices 1, 3, and 4). Macroinvertebrate community scores ranged from -4 (low acceptable) to +8 (excellent) (Table 1 and Appendices 2, 5, and 6).

Objective 2: Evaluate the Thornapple River below the Irving Impoundment following berm failure.

In 2013 the Thornapple River at Irving Road, below the Irving dam and impoundment, scored excellent (+6) for macroinvertebrate community and good for habitat (122) (Rippke, 2015). In 2018, following the breach of the impoundment, the macroinvertebrate community remained in excellent condition and even increased slightly (+8), while the habitat rating declined to marginal (99). The decline in habitat score was related to increased sediment deposits, resulting in a poor score for the sediment deposition habitat metric in 2018, while prior to the breach and subsequent sediment movement, the site had scored excellent in that metric. This corresponded with a decreased amount of epifaunal substrate (available cover for macroinvertebrates) with scores for that metric falling from good condition in 2013 to the marginal category in 2018. It was also observed that cobble was a dominant substrate of the stream bed in 2013 (approximately 30 percent of the survey area), but in 2018 cobble was only 3 percent of the

survey area. In 2018 the substrate was estimated to be 90 percent sand. The cobble would have provided habitat niches for macroinvertebrates and was likely buried in sediment released during the breach and during heavy precipitation in the following year.

Objective 3: Assess changes in the macroinvertebrate and habitat condition in the Coldwater River in areas where unauthorized drain work was conducted.

Nine macroinvertebrate and habitat surveys were conducted in the Coldwater River watershed, downstream of Jordan Lake (Lake Odessa, Michigan), in 2015. The purpose of this sampling was to document conditions following unauthorized drain maintenance activities including tree canopy removal and dredging, which resulted in a complaint in January 2015. The entire mainstem Little Thornapple River (including the vicinity of M-43) is actively maintained by the Barry County Drain Commission under Michigan's Drain Code (Public Act 40 of 1056, as amended) (Barry County Drain Commission Web site). Macroinvertebrate community and habitat conditions were monitored post-disturbance at 5 sites where the activities directly occurred (labelled with a letter "a" in Table 1), and 4 sites downstream of the activity (indicated by the letter "b" in Table 1). The downstream sites would also be impacted by the activities, although indirectly. Overall conclusions are as follows:

- In the 2015 surveys, directly impacted sites had macroinvertebrate scores ranging from -3 to +2 (acceptable). Downstream sites had scores that were generally higher; from +1 to +5 (acceptable to excellent).
- The macroinvertebrate community at Coldwater River at Messer Road was coincidentally also monitored in 2013 (Rippke, 2015). The macroinvertebrate community at this site scored +6 (excellent) in 2013 and fell to acceptable in 2015 and 2018 (scores of +2 and 0, respectively) following drain maintenance activities (Figure 5). This site was directly impacted by channel dredging activities and as the most downstream impacted site, also received indirect impacts from the in-stream sediment disturbances and bank modifications upstream. In 2013, long cobble and gravel riffles were present at this survey location providing valuable habitat. Likely a direct result of drain activities, in 2018, these riffles were composed of sand and gravel, with cobble no longer present in the center of the stream channel and only at the edges.
- The Little Thornapple River upstream of M-43 rated low acceptable in 2015 (-3), with the score increasing to 0 in 2018 (Figure 6).
- The macroinvertebrate community scores at the Little Thornapple River upstream of M-43 (080269) and Rush Road (080244) each improved between 2015 and 2018 surveys, indicating some recovery (Figure 7). No 2013 surveys were conducted at either site so no pre-disturbance baseline data exists. In-stream structures to improve habitat were noted at Rush Road, and tree planting had occurred upstream of M-43.
- Habitat scores at all three sites, which were monitored in both 2015 and 2018, improved slightly during that time, also indicating recovery after the 2015 disturbance. In-stream habitat was largely limited to aquatic macrophytes, with little or no large woody debris, no undercut banks, and little overhanging vegetation.
- The impacts of this drain maintenance project are likely to continue to be present at all sites in the form of potential increased sediment movement and flashiness resulting from tree removal. Improvement in the habitat and macroinvertebrate communities would also likely continue to occur as the stream banks recover vegetation either naturally or through restoration activities, unless another disturbance occurs.

Figure 5. Coldwater River looking east (upstream) from Messer Road in January 2015, before drain work started.

Figure 6. Little Thornapple River mainstem, looking north (upstream) from M-43 in April 2015, after drain work disturbance.

Figure 7. Upstream view of Little Thornapple River from Rush Road in April 2015 after drain work (left) and recovering in 2018 (right).

Objective 4: Evaluate statewide biological community status and statewide temporal trends.

Beginning in 2016, the WRD decreased the sampling effort used to develop statistical assessment evaluations of macroinvertebrate communities in rivers and streams at the watershed scale in favor of obtaining statewide estimates only. In 2018 four randomly selected sites (Table 1) were sampled in the Thornapple River to support statewide attainment status calculation for the OIALW designated use. The macroinvertebrate communities at these sites scored from -1 (acceptable) to +5 (excellent).

Two stations (Table 1) are statewide trend stations and will be sampled every five years. Statewide trend information cannot be summarized until after 2021, when enough data have been collected. On a per site basis, Pratt Lake Creek at Wingeier Ave SE (410695) scored acceptable in 2008, 2013, and 2018 (+1, -2, and +1, respectively) (Rippke, 2010; 2015). Mud Creek at Davenport Road (080303) also had an acceptable macroinvertebrate rating (+2) in 2008, and an acceptable rating (0) in both 2013 and 2018 (Rippke, 2010; 2015).

Objective 5: Provide supporting data for the development and issuance of NPDES permits

Targeted monitoring was conducted at select surface water sites (Table 2, Figure 3) in the vicinity of facilities that are authorized to discharge under an NPDES permit or Groundwater Discharge Permit to assess the macroinvertebrate community, habitat quality, and nutrients to assist with development of NPDES permits. The facilities targeted include the Potterville Wastewater Treatment Plant (WWTP) (MIG580413), Vermontville WWTP (MI0024261), Nashville WWTP (MI0020075), Lakewood WW Authority WWTP (MI0042978), Hastings WWTP (MI0020575), Lacks Enterprises Inc.-GWCU (MI0057849), Campau Lake WWTP (GW1810223 and MI0060242), and Caledonia WWTP (GW1810026 and MI0060195).

The macroinvertebrate community and habitat quality were assessed at eight locations in 2018. Habitat quality was rated marginal to excellent with no observed nutrient issues. The macroinvertebrate community was rated acceptable to excellent. The habitat and macroinvertebrate community results for this objective are found in Appendices 4 and 6. Water chemistry samples in 2017 and 2018 focused on assessing nutrients and total hardness to aid in Water Quality-Based Effluent Limit development and are summarized in Table 3. All water chemistry results were within the range found at reference sites in the SMNITP ecoregion (Lundgren, 1994).

Objective 6: Identify nonpoint sources of water quality impairment.

In addition to the issues with sediment movement and accumulation noted in Objective 2 (downstream of Irving Dam) and Objective 3 (Coldwater River drain maintenance), old and undersized culverts continue to be an issue throughout the watershed (**Figure 8**; also see photos contained in Rippke, 2015). Additionally, the following nonpoint source related issues were noted:

- Bank erosion 5 feet above the water line was noted at Site 230277 (Little Thornapple River downstream of West Kinsel Highway.
- Messer Brook upstream of Darby Road (340263) had only one riffle, and the cobble that would normally provide macroinvertebrate habitat was covered with dead plant matter (likely algae or moss).
- Erosion, deep soft sediments, and a double culvert clogged with sediment continue to be noted at Pratt Lake Creek at Wingeier Avenue (410695) (also see Rippke, 2015).

- Cattle with unrestricted access were noted on Cole Wright Helms Drain in a pasture north of West Santee Highway. No surveys were conducted in this location (coordinates: 42.669518; -84.867550). A revisit to this site is recommended prior to submitting a complaint to the Michigan Department of Agriculture and Rural Development, if warranted.

Conclusions and Future Monitoring Recommendations

Macroinvertebrate communities scored acceptable to excellent at all sites, while habitat rated from marginal to excellent. Future monitoring is recommended at the Coldwater River upstream of Messer Road (080286), Little Thornapple River upstream of M-43 (080269), and Rush Road (080244) to evaluate recovery of those areas after the drain modification activities that occurred in 2015. Biological surveys are also recommended in Messer Brook, due to drain activities that have occurred there.

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Table 1. Survey site locations, reason (targeted, trend, or status), stream slopes (in meters per kilometer), and results of biological surveys. Sites directly impacted by drain maintenance activities (Objective 3), are marked by the letter "a" in the site column; sites downstream of the activities are marked "b." Gray shaded rows were surveyed in both 2015 and 2018 to support Objective 3.

Site/WQX	Reason	Years	Water body	Road Name	Longitude	Latitude	Slope	Macroinvertebrate Score and Rating	Habitat Score and Rating
230277	Targeted	2018	Little Thornapple River	W Kinsel Hwy	-84.9063	42.5972	0.8	-1 (Acceptable)	79 (Marginal)
230259	Targeted	2018	Darken and Boyer Drain	W Needmore Hwy	-84.9071	42.6831	1.6	-2 (Acceptable)	106 (Good)
230282	Targeted	2018	Lacey Creek	W Five Point Hwy	-84.9870	42.5095	0.7	-3 (Acceptable)	95 (Marginal)
230264	Targeted	2018	Thompson Creek	W Gresham Hwy	-84.9742	42.6406	3.9	+2 (Acceptable)	155 (Excellent)
230174	Status	2018	Thornapple River	N Mason Rd	-85.0543	42.6174	1.1	+5 (Excellent)	147 (Good)
080303	Trend	2018	Mud Creek	Davenport Rd	-85.1087	42.6980	0.7	0 (Acceptable)	114 (Good)
080311	Status	2018	Unnamed Trib	Bird Rd	-85.2183	42.4989	0.3	+4 (Acceptable)	119 (Good)
[a]080244	Status/ Targeted	2015	Little Thornapple River	Rush Rd	-85.1832	42.7396	1.0	+1 (Acceptable)	56 (Marginal)
[a]080244	Trend/ Targeted	2018	Little Thornapple River	Rush Rd	-85.1832	42.7396	1.0	+4 (Acceptable)	82 (Marginal)
[a]080268	Targeted	2015	Little Thornapple River	N Wellman Rd	-85.1540	42.7510	0.0	+3 (Acceptable)	108 (Good)
[a]080269	Targeted	2015	Little Thornapple River	M 43 (upstream)	-85.2060	42.7270	0.3	-3 (Acceptable)	76 (Marginal)
[a]080269	Targeted	2018	Little Thornapple River	M 43 (upstream)	-85.2060	42.7270	0.3	0 (Acceptable)	88 (Marginal)
[a]080298	Targeted	2015	Coldwater River	M 43	-85.2555	42.7266	0.6	+2 (Acceptable)	60 (Marginal)
[a]080286	Targeted	2015	Coldwater River	Messer Rd	-85.2711	42.7622	0.8	+2 (Acceptable)	97 (Marginal)
[a]080286	Targeted	2018	Coldwater River	Messer Rd	-85.2711	42.7622	0.8	0 (Acceptable)	104 (Marginal)
[b]080282	Targeted	2015	Coldwater River	N Broadway Rd	-85.2908	42.7660	0.8	+5 (Excellent)	110 (Good)
[b]080297	Targeted	2015	Coldwater River	Freeport Ave SE	-85.3233	42.7713	3.2	+4 (Acceptable)	149 (Good)
[b]410567	Targeted	2015	Coldwater River	Baker Ave SE	-85.3589	42.7747	1.1	+3 (Acceptable)	102 (Marginal)
[b]410625	Targeted	2015	Coldwater River	Morse Lake Ave SE	-85.4074	42.7845	1.4	+1 (Acceptable)	122 (Good)
080226	Targeted	2018	Coldwater River	E Brown Rd	-85.2635	42.7555	0.6	+3 (Acceptable)	119 (Good)
340263	Status	2018	Messer Brook	Darby Rd	-85.2322	42.7746	1.7	-1 (Acceptable)	86 (Marginal)
410695	Trend	2018	Pratt Lake Creek	Wingeier Ave SE	-85.3500	42.8410	1.3	+1 (Acceptable)	114 (Good)

Site/WQX	Reason	Years	Water body	Road Name	Longitude	Latitude	Slope	Macroinvertebrate Score and Rating	Habitat Score and Rating
080309	Targeted	2018	Butler Creek	E Woodlawn Ave	-85.2614	42.6609	5.0	+4 (Acceptable)	114 (Good)
080310	Status	2018	Unnamed Trib	River Rd	-85.2261	42.6249	4.3	+5 (Excellent)	165 (Excellent)
080285	Targeted	2018	Thornapple River	W Irving Rd	-85.4257	42.6894	0.8	+8 (Excellent)	99 (Marginal)
410859	Targeted	2018	Trib to Thornapple	Orlee St	-85.4875	42.8407	6.4	-2 (Acceptable)	118 (Good)
410834	Targeted	2018	Campau Lake Outlet	off Dujunado Court SE	-85.4400	42.8473	1.7	-3 (Acceptable)	115 (Good)
410833	Targeted	2018	McCords Creek	off Lilly Ridge Dr Private	-85.4584	42.8669	14.8	+5 (Excellent)	122 (Good)
230280	Targeted	2018	Able Drain	Gresham Hwy	-84.7654	42.6402	2.6	-4 (Acceptable)	61 (Marginal)
080128	Targeted	2018	Little Thornapple R	E Brown Road	-85.1462	42.7559	0.0	+1 (Acceptable)	111 (Good)
230106	Targeted	2018	Thornapple River	N Ionia Rd	-85.0246	42.6116	0.0	+1 (Acceptable)	106 (Good)
080213	Targeted	2018	Thornapple River	end of Greggs Crossing Rd	-85.1264	42.6108	1.0	+3 (Acceptable)	157 (Excellent)
080262	Targeted	2018	Thornapple River	Tyden Park (Hastings)	-85.2910	42.6530	0.5	+8 (Excellent)	147 (Good)
080281	Targeted	2018	Thornapple River	off W State Rd (Riverside Cemetery)	-85.3052	42.6583	0.0	+5 (Excellent)	160 (Excellent)

Table 2. Locations of water chemistry sites to support Objective 5.

Site/WQX	Stream Name	Road Crossing	Latitude	Longitude
410834	Campau Lake Outlet	east of Campau Lake WWTP	42.847256	-85.440026
410838	Emmons Drain	off South Costner Ct SE	42.797411	-85.51177
410839	Emmons Drain	WWTP Drive	42.805723	-85.50966
410840	Emmons Drain	84th Street SE	42.811871	-85.518012
410841	Emmons Drain	Cherry Valley Avenue SE	42.815238	-85.507334
410651	Emmons Drain	Thornapple River Drive SE	42.819269	-85.488171
410835	Emmons Lake Inlet	off walking path	42.793815	-85.50996
410833	McCords Creek	Lilly Ridge Dr. Pvt.	42.866858	-85.458387
410858	McCords Creek	Thornapple Bayou Dr SE	42.874933	-85.471288
410688	Thornapple River	84th Street SE	42.81212	-85.483686
410735	Thornapple River	Park in Alaska	42.838939	-85.478359
410715	Thornapple River	Doubloon Drive SE	42.889042	-85.486266
410842	Thornapple River	Thornapple River Drive SE	42.914659	-85.493107
410836	Unnamed Inlet 1	Park Street	42.791596	-85.51561
410837	Unnamed Inlet 2	In Park	42.793756	-85.515389
080213	Thornapple River	end of Greggs Crossing Road	42.610841	-85.124639
230106	Thornapple River	upstream of North Ionia Road	42.611716	-85.024773
230280	Able Drain	upstream of Gresham Highway	42.640214	-84.765358
230174	Thornapple River	downstream of North Mason Road	42.617605	-85.054354
080281	Thornapple River	off West State Road (Riverside Cementary)	42.65635	-85.302075
080128	Little Thornapple River	upstream of Brown Road	42.7558544	-85.143904
410741	Walden Lake	off private drive	42.929022	-85.527392
080262	Thornapple River	Tyden Park (Hastings)	42.652475	-85.293219

Table 3. Results of water chemistry samples collected in the Thornapple River watershed in 2017 and 2018 (Objective 5).

Site/WQX	Stream Name	Sample Date	Units	Ortho-phosphorus	Total Phosphorus	Calcium	Magnesium	Hardness-Calculated
410834	Campau Lake Outlet	6/26/2018	mg/l	NA	0.068	NA	NA	NA
410838	Emmons Drain	9/12/2017	mg/l	0.051	0.15	NA	NA	NA
410839	Emmons Drain	9/12/2017	mg/l	0.043	0.071	NA	NA	NA
410840	Emmons Drain	9/12/2017	mg/l	0.022	0.038	NA	NA	NA
410841	Emmons Drain	9/12/2017	mg/l	0.031	0.055	NA	NA	NA
410651	Emmons Drain	9/12/2017	mg/l	0.019	0.034	NA	NA	NA
410835	Emmons Lake Inlet	9/12/2017	mg/l	0.11	0.13	NA	NA	NA
410833	McCords Creek	6/26/2018	mg/l	NA	0.04	NA	NA	NA
410858	McCords Creek	6/26/2018	mg/l	NA	0.032	NA	NA	NA
410688	Thornapple River	9/12/2017	mg/l	0.015	0.028	NA	NA	NA
410735	Thornapple River	9/12/2017	mg/l	0.012	0.027	NA	NA	NA
410715	Thornapple River	9/12/2017	mg/l	0.016	0.035	NA	NA	NA
410842	Thornapple River	9/12/2017	mg/l	<0.010	0.029	NA	NA	NA
410836	Unnamed Inlet 1	9/12/2017	mg/l	0.031	0.047	NA	NA	NA
410837	Unnamed Inlet 2	9/12/2017	mg/l	0.023	0.051	NA	NA	NA
080213	Thornapple River	8/2/2018	mg/l	NA	0.046	NA	NA	NA
230106	Thornapple River	8/2/2018	mg/l	NA	0.059	NA	NA	NA
230280	Able Drain	8/2/2018	mg/l	NA	0.062	NA	NA	NA
230174	Thornapple River	8/2/2018	mg/l	NA	0.055	NA	NA	NA
080281	Thornapple River	8/2/2018	mg/l	NA	0.035	NA	NA	NA
080128	Little Thornapple River	8/2 & 8/3/2018	mg/l	NA	0.034	39	18	170
410741	Walden Lake	8/2/2018	mg/l	NA	NA	65	22	250
080262	Thornapple River	8/3/2018	mg/l	NA	NA	69	25	270

Table 4. Percent generalized land cover (NOAA, 2011), percent of 30-meter riparian buffer with natural vegetation (derived from NOAA, 2011), percent wetland lost since presettlement (Fizzell, 2015), and human population information (U.S. Census Bureau 2010; 2012) at the subwatershed level. Only subwatersheds sampled in this study are shown. Biological survey sites within each subwatershed and total subwatershed area are also listed.

Sites/WQX	Subwatershed Name	Area (Square Miles)	Developed Land Cover (%)	Agricultural Land Cover (%)	Wetland Land Cover (%)	Forested Land Cover (%)	Other Land Covers (%)	Riparian Buffer with Natural Vegetation (%)	Lost Wetland (% since Pre-settlement)	Human Population
230277	Fish Creek-Little Thornapple River	30.5	5.4	74.4	8.4	11.4	0.4	48.4	19	2,001
230280	Hayes Drain-Thornapple River	21.0	7.3	71.6	6.5	13.7	0.9	46.6	24	2,424
230259	Darken and Boyer Drain-Thornapple River	24.2	4.9	78.2	6.7	10.0	0.3	37.5	50	985
230282	Lacey Creek	24.7	4.8	65.9	11.1	17.0	1.2	57.9	18	1,428
230264	Thompson Creek-Thornapple River	20.0	4.7	73.8	9.3	11.8	0.4	49.9	19	761
230106, 230174	Scipio Creek-Thornapple River	50.8	6.3	57.8	14.7	19.5	1.6	69.1	4	4,600
080303	Mud Creek	31.1	4.6	67.8	11.8	15.1	0.7	55.9	6	949
080311	High Bank Creek	34.1	6.2	54.9	12.5	21.8	4.7	56.6	6	2,324
080213	Thornapple Lake-Thornapple River	23.2	7.0	50.0	15.1	23.5	4.3	61.4	6	2,065
080128, 080244, 080268, 080269	Woodland Creek-Little Thornapple River	80.9	6.1	75.1	9.3	8.9	0.6	41.7	9	4,744
080226, 080298, 340263	Messer Brook-Coldwater River	78.7	5.3	73.7	6.9	13.6	0.6	41.8	14	3,940
410695	Pratt Lake Creek	17.8	8.0	71.9	8.2	10.0	2.0	34.8	28	1,006

Sites/WQX	Subwatershed Name	Area (Square Miles)	Developed Land Cover (%)	Agricultural Land Cover (%)	Wetland Land Cover (%)	Forested Land Cover (%)	Other Land Covers (%)	Riparian Buffer with Natural Vegetation (%)	Lost Wetland (% since Pre-settlement)	Human Population
080282, 080286, 080297, 410567, 410625	Coldwater River	210.4	5.9	53.6	10.1	29.0	1.4	68.7	7	19,075
080262, 080281, 080309, 080310	Butler Creek-Thornapple River	113.2	20.8	43.9	8.2	25.1	2.1	58.4	3	30,816
080285	Algonquin Lake-Thornapple River	38.9	8.1	43.0	10.8	34.1	4.0	59.8	8	5,462
410833, 410834, 410859	McCords Creek-Thornapple River	133.4	20.6	42.2	6.5	24.9	5.8	50.8	13	38,272