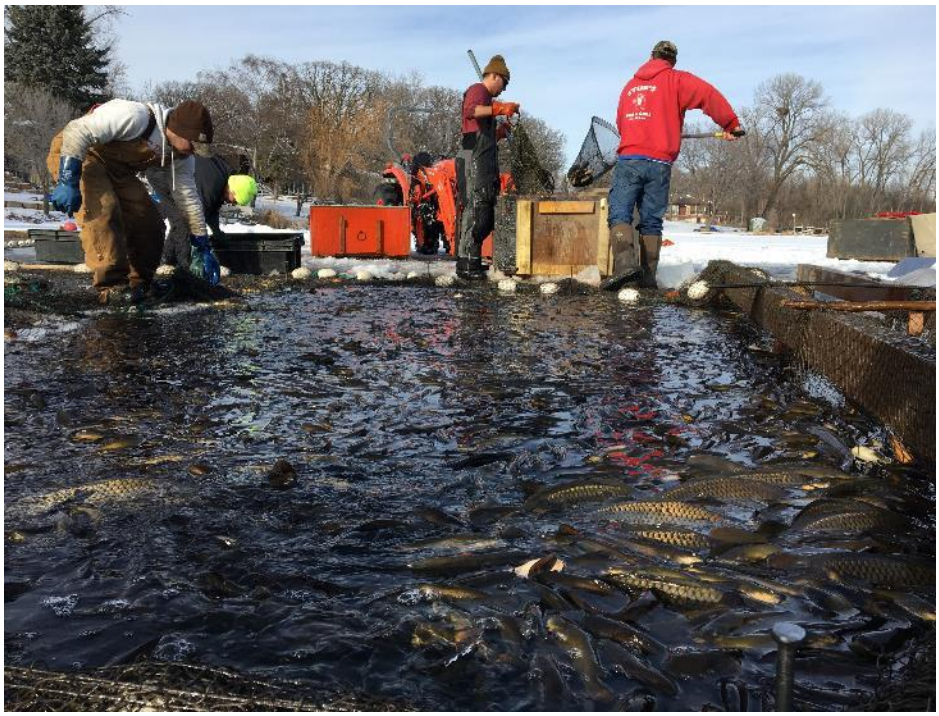
Twin Lake Carp Management
Project Summary Final Report



Prepared for:

SHINGLE CREEK
WATERSHED MANAGEMENT COMMISSION
MINNESOTA POLLUTION CONTROL AGENCY
SEPTEMBER 2019

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Minnesota Pollution Control Agency

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Acknowledgments

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Photo: Carp tracking on the Twin Lake chain of lakes, Crystal, Robbinsdale, and Brooklyn Center, Minnesota, April 2017.

Cover: Harvesting common carp on Middle Twin Lake, Crystal, Minnesota, January 2018.

All photos and graphics: Wenck Associates, Inc., unless noted.

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Executive Summary

The Twin Lake chain of four lakes located in suburban Hennepin County, Minnesota in the Twin Cities Metro Area are impaired by excess nutrients. All four – Upper, Middle, and Lower Twin Lakes and Ryan Lake – were listed as Impaired Waters in 2002 with two of the four – Lower Twin and Ryan – subsequently removed from the Impaired Waters list due to improved water quality. Upper Twin Lake, a very shallow lake, remains hypereutrophic and turbid, and is one of the largest sources of phosphorus to Middle Twin. TMDLs were completed on all the lakes and substantial effort has occurred to date targeting and reducing watershed sources of nutrients. Management efforts are now turning to addressing internal loading sources within the lakes.

Common carp (*Cyprinus carpio*) are a widespread aquatic invasive species that can have direct and indirect deleterious effects on lake ecosystems and were known to be present in high numbers in the chain of lakes. Common carp uproot and displace aquatic macrophytes, reduce habitat structure, and increase sediment resuspension in lake ecosystems which result in increased turbidity, sediment phosphorus release, and poor water quality conditions. A growing body of research shows that reducing carp densities within a waterbody below a critical threshold and preventing successful recruitment have the potential to benefit water quality conditions and aide in lake restoration efforts.

This project was intended to reduce the biomass of carp in the chain of lakes, limit future recruitment, and manage lake submersed aquatic vegetation (SAV) response to reduce internal phosphorus loads and increase water clarity. Project objectives were:

- Assess the carp population and estimate current densities;
- Track seasonal movement and migrations of carp within the chain of lakes;
- Locate and evaluate carp overwintering, spawning and nursery habitats;
- Implement controls to reduce recruitment and movement of carp into the system;
- Reduce carp biomass in the system; and
- Develop aquatic vegetation management response strategies.

Population estimates confirmed a large abundance of common carp and densities above critical impairment thresholds within the system. Radio telemetry tracking demonstrated high mobility of the carp populations among the lakes suggesting that carp are able to move easily among the waterbodies and into/out of the system during seasonal high water levels. Tracking also located over wintering habitats and aided in identifying potential spawning and nursery habitats within the Twin Lakes watershed. An estimated 14,450 ponds pounds of carp were removed from the system, or about 44% of the overall removal goal, and about 15,000 pounds of black bullhead, another bottom-feeding fish. Permanent carp barriers were installed in two locations to prevent the fish from moving upstream from Shingle Creek into the lake system, and to prevent access to a nursery location in a wetland connected to Upper Twin Lake via a road culvert. Curly-leaf pondweed was treated in year one; year two density did not warrant treatment.

Water quality monitoring has not yet identified any significant improvement in water quality or clarity. However, shallow lakes such as Upper Twin typically exist in one of two conditions: a clear-water state and a turbid water state. These lakes can "flip" rapidly between these states when certain tipping points are achieved. As carp continue to be removed, that tipping point eventually will be met and the lake should flip to a clear water condition.

1.0 Section 319 Final Report

1.1 GRANT SUMMARY REPORT

Grant project summary

Project title: Twin Lake Carp Management Project

Organization (Grantee): Shingle Creek Watershed Management Commission

Project start date: 12/1/2015 Project end date: 8/30/2019 Report submittal date: 9/27/19

Grantee contact name: Judie Anderson Title: Administrator

Address: 3235 Fernbrook Lane N

City: Plymouth State: MN Zip: 55447

Phone number: 763-553-1144 Fax: 763-553-9326 Email: judie@jass.biz

Basin (Red, Minnesota, St. Croix, etc.)
/Watershed & 8 digit HUC:: Upper Mississippi 07010206 County: Hennepin

Project type (check one):

- ☐ Clean Water Partnership
- ☐ Total Maximum Daily Load (TMDL)/Watershed Restoration or Protection Strategy (WRAPS) Development
- ☒ 319 Implementation
- ☐ 319 Demonstration, Education, Research
- ☐ TMDL/WRAPS Implementation

Grant funding

Final grant amount: $99,992.26 Final total project costs: $210,091.93

Matching funds: Final cash: $110,099.67 Final in-kind: $ Final Loan: $

MPCA project manager: Karen Evens

Executive summary of project (300 words or less)

This summary will help us prepare the Watershed Achievements Report to the Environmental Protection Agency. (Include any specific project history, purpose, and timeline.)

Problem (one paragraph)

The purpose of the project was to reduce and manage the common carp population in the Twin Lake chain of lakes to reduce internal phosphorus load and increase water clarity. The Twin and Ryan Lakes chain of four lakes is located in the highly urbanized Shingle Creek watershed in Hennepin County, Minnesota. The chain starts with Upper Twin, which is connected to Middle Twin by a short channel through a wetland. Middle Twin and Lower Twin are two bays of a single lake separated by a narrow throat. Lower Twin outlets into Ryan Creek and then into Ryan Lake, which ultimately outlets into Shingle Creek and then the Mississippi River. The lakes are impaired by excess nutrients conveyed from urban stormwater and from internal load from sediment, aquatic vegetation, and rough fish. A Total Maximum Daily Load (TMDL) study and Implementation Plan for excess nutrients were completed and approved in 2007 and significant external total phosphorus (TP) load reductions have been achieved. Lower Twin and Ryan have since been delisted due to improved water quality. However, Upper Twin continues to have poor water quality and clarity, and its outflow continues to be the largest source of phosphorus to Middle Twin. Shallow Upper Twin is impacted by an excessive population of common carp.

Waterbody improved (one paragraph)

This project removed nearly half the estimated biomass of common carp in the four lake chain of Upper (North), Middle, and Lower (South) Twin Lakes and Ryan Lake, and fish barriers were installed to prevent recolonization from Shingle Creek. Additional removels will be completed in the future to meet the goal of reducing the biomass density below the desired 100 kg/ha. Curly-leaf pondweed was chemically treated on Upper Twin in year one, but a cold and snowy winter limited its growth and no teatment was necessary in year two. Residents reported improvements in water clarity early in the season in year two, but a combination of unusual precipitation and temperature patterns in late spring led to filementous algae growth. Water quality will continue to be routinely monitored post-project.

Project highlights (one paragraph)

Carp tagging and radio tracking successfully located breeding and overwintering locations and allowed for winter seining to remove about one-third the target biomass. With additonal removals from spawning and shoaling areas, about 14,450 pounds have been removed, or 44% of the goal biomass. The tracking also verified the suspicion that carp were moving freely between the lakes and Shingle Creek downstream. Carp barriers were installed to limit access to spawning areas in upstream wetlands and prevent recolonization from Shingle Creek, downstream of Ryan Lake. The project also successfully raised lakeshore owners' awareness about shallow lake ecology and the importance of managing rough fish and invasive vegetation.

Results.

Removed 14,450 ponds pounds of carp, or about 44% of the overall removal goal, and about 15,000 pounds of black bullhead from the lake system. Permanent fish barriers were installed to prevent recolonization from outside the lake system and to limit access to a spawning area. Curly-leaf pondweed was treated in year one; year two density did not warrant treatment.

Partnerships (Name all partners and indicate relationship to project)

Shingle Creek Watershed Management Commission: lead partner
City of Crystal: host partner
City of Brooklyn Center: host partner
City of Robbinsdale: host partner
City of Minneapolis: host partner
Minnesota Pollution Control Agency: funding partner
Minnesota DNR: permitting and technical review partner

Pictures

Incorporated into report

1.2 WORK PLAN REVIEW

1.2.1 Approved Work Plan Changes

None made.

1.2.2 Report by Activity/Task

The overarching goal of this project was to reduce and manage the common carp population in the Twin and Ryan Lake chain of lakes to reduce internal phosphorus load and increase water clarity. More specifically goals were: 1) Understand the estimated number and biomass of common carp in the lake system; 2) Understand immigration/migration in the lake system; 3) Determine locations where spawning and overwintering occur; 4) Significantly reduce the numbers and biomass of common carp in the lake system; 5) Prevent or limit reproduction of common carp in the lake system; and 6) Identify potential aquatic vegetation response to improved water clarity and options for future aquatic vegetation management needs.

Objective 1: Understand life history of carp within the study system

Task A: Population/biomass Estimate

Two mark and recapture surveys were conducted in September 2016 using electrofishing techniques to determine a population estimate and carp biomass within the lake system. A follow up survey was completed in July 2017, and a fourth was completed in July 2018 after the first round of carp harvesting. The population assessment was completed using the mark and recapture/electrofishing technique. The linear regression model and procedure outlined in Bajer and Sorenson (2012) was used to estimate the current population and biomass. The estimated total biomass pre-harvest was just over 25,800 kg (56,800 lbs). Literature and lake management experience suggest that carp and other rough fish can have negative impacts to water quality and the ecosystem when the biomass of the carp exceeds 100 kilograms per hectare (kg/ha). Both Upper and Middle Twin are estimated to be well above the critical biomass threshold. Lower Twin was estimated to be below the critical threshold, but because the lakes are interconnected and fish can migrate easily, all three basins are likely being impacted by carp.

To set a removal goal, it was assumed that the current biomass would double over time, to account for growth and maturation of the younger fish. The difference between twice the current biomass and the target biomass at 100 kg/ha was set as the removal goal. That goal is 33,100 pounds.

Task B: Carp Migration Tracking
During mark and recapture surveying activities, 40 carp were tagged with radio transmitter markers. Efforts to tag equal proportions of fish per lake were attempted, however, fish capture and size ultimately affected how many fish could be tagged for a given lake. Relatively equal males to females were tagged within the system and fish of various sizes were tagged. An automated reader was installed at the outflow of the lake system to track immigration/emigration. The tagged carp were periodically tracked (monthly during the non-spawning season and biweekly to weekly during spawning season) using both automated and portable trackers to identify spawning and overwintering locations and to better understand emigration and immigration.

Objective 2 Control reproduction and immigration and emigration of the carp population.

Task A: Aeration system installation
Research conducted by Dr. Peter Sorensen at the University of Minnesota suggests that carp can reproduce very successfully in shallow lakes that experience severe hypoxia. Upper Twin is shallow (max depth <10 feet) and experiences frequent winter kills. To help protect the vulnerable pan fish during winter hypoxia, the intent of the project was to install an aeration system in Upper Twin Lake. After resolving various logistical difficulties and lakeshore property owner concerns, ultimately the host City of Brooklyn Center declined to take on the legal liability for the aerator. The aeration system was not installed.

Task B: Installation of fish barriers
The carp tracking verified the suspicion that carp were moving into and out of the lake system via Ryan Creek. A fish barrier was installed on the weir of Ryan Creek as it flows under France Avenue North. Ryan Creek is the outlet of the Twin chain, and flows in and out of Ryan Lake downstream to Shingle Creek. Tracking also indicated that carp were moving into a connected wetland upstream of Upper Twin Lake, potentially to spawn. Another barrier was installed at the street culvert that connects the wetland to the lake.

Objective 3 Carp removal from the system.

Task A: Remove carp from the system.
The Commission worked with the commercial fishermen assigned to this area to undertake a winter seine. Tracking indicated a dense school of fish on the west side of Middle Twin Lake. The seine haul occurred on 1/18/2018. Two large holes were cut in the ice (one on the east shoreline and the other on the west shoreline areas) on Middle Twin Lake. The net was deployed under the ice on the east side of the lake at 9:00 am and was pulled westward where it began to surface through around 10:30 am. The initial 100-150 feet of the seine was damaged and did not fish properly. A rusted steel drum and barb wire fencing were tangled in the net and likely cut part of the net, suggesting that debris impacted the seine haul. However, an estimated 10,643 pounds of carp were removed, along with about 15,000 pounds of black bullhead, another common bottom feeder that can also have negative effects on water quality.

An additional seine was attempted in January 2019, but due to equipment problems the fisherman was unable to get set up before the fish dispersed. As an alternative, it had been previously noted that carp tended to congregate in Ryan Creek at the outlet of Lower Twin Lake, waiting for the water to be high enough to get over the outlet weir. This weir, where Ryan Creek passes under France Avenue in a culvert, was one of the locations where a carp barrier was installed as part of this project. Commission consulting staff devised a method using block nets and seines and made several hauls, removing an estimated 3,800 pounds of carp. Between the winter seining and the creek removals, about 14,450 pounds have been removed, or 44% of the goal biomass. The Commission will continue to remove carp form Ryan Creek and other congregation areas until the goal is met.

Objective 4 Vegetation management plan.

Task A: Water quality monitoring.
Biweekly water quality monitoring was completed in 2018 on all three basins of Twin Lake as well as Ryan Lake. Monthly sampling was completed on the three basins in 2019. Parameters that were measured were total phosphorus (TP), soluble reactive phosphorus (ortho-P), total suspended solids (TSS), and chlorophyll-a (chl-a). In the deeper Middle Twin and Ryan Lakes hypolimnetic (deep) water

samples were collected and tested for TP and ortho-P. In addition to these chemical parameters, the physical profile of the lakes were assessed in the deepest part of the lake. A profile typically consisted of taking measurements starting at the water's surface and continuing every meter (or half meter in shallow lakes) throughout the entire water column. A multimeter probe was used to collect dissolved oxygen (DO; mg/L), DO %, temperature, pH, oxidation reduction potential (ORP) and specific conductivity at each step in the profile. Additionally, a Secchi disk reading was taken during every assessment to relate the relative level of water transparency. The data were compiled and reported in the Commission's annual Water Quality Report.

Task B: Vegetation survey and management plan.
Prior to undertaking the carp removal project, previous SAV point-intercept surveys were evaluated to better understand the existing issues with aquatic invasive species (AIS). Survey results demonstrate a biological impaired vegetation community across all three basins. Species richness, abundance and spatial coverage all decrease across the growing season due to decreased water clarity over the growing season. Currently, curlyleaf pondweed (CLP) is the only dominant vegetative AIS species in Twin Lake system (most notable in the Upper Twin basin). Point-intercept surveys were conducted in 2016 (Upper) and 2012 (Middle & Lower). These were used to develop an Aquatic Vegetation Management Plan (AVMP) for review and approval by the DNR. The AVMP documents current conditions and potential future management actions depending on the aquatic vegetation response as water clarity improves. The DNR approved the AVMP, and issued a variance for Upper Twin Lake allowing the Commission to treat more than the state limit of 15% of the lake surface area if necessary. In spring 2018, the DNR and Commission staff delineated a 9.4 acre CLP stand on Upper Twin Lake that was subsequently treated with endothall, In spring 2019 the DNR and Commission staff conducted an invasive plant survey and found very sparse stands of CLP as well as some stands that were dead. Harsh conditions during the 2018-2019 winter, including a significant and long-lasting snowpack on the lake surface limited light penetration, which inhibited CLP growth under the ice. No treatment was performed. Another survey will be completed in spring 2020 to determine if additional CLP treatment is necessary.

Task C: Submit data to EQuIS.
Water quality monitoring data was submitted to EQuIS on a timely basis.

Task D: Prepare QAPP.
Commission and MPCA staff prepared a QAPP, which was approved.

Objective 5: Community engagement and meetings.

Task A: Outreach activities to inform and engage community.
There was a considerable amount of communication with lakeshore residents as well as the communities at large. Owners of all properties on the lake were invited to a public meeting on December 13, 2017, held at the Crystal Community Center and which was well attended. Commission staff regularly sent out project update emails to the lake association chairs, who forwarded them on to their association members and posted on their association Facebook and websites. A number of lakeshore residents walked out on the frozen lake to observe the winter seining. The seining event was highlighted on local cable channel 12, which provides cable television service to northwestern Hennepin County suburbs. https://ccxmedia.org/news/water-quality-project-targets-carp-on-middle-twin-lake/. The Commission also created and maintained two project pages on its website. http://www.shinglecreek.org/twin-lake-carp-management.html.

Objective 6: Administration/Semiannual and Final Reports.

Task A: Administration/Semiannual and Final Reports.
Quarterly invoices, semiannual reports, and the final report were prepared and submitted in a timely manner.

1.3 GRANT RESULTS

1.3.1 Measurements

Between the winter seining and the creek removals, about 14,450 pounds of carp have been removed, or 44% of the goal biomass. Results of monitoring data are presented in the following sections of this report. However, none of the lakes showed any statistically significant improvement in water quality as measured by TP or chl-a concentration, or in water clarity as measured by Secchi depth.

1.3.2 Products

Project products were installed BMPs, the Aquatic Vegetation Management Plan, monitoring data, a final report, and presentations.

1.3.3 Public Outreach and Education

There was a considerable amount of communication with lakeshore residents as well as the communities at large. Owners of all

properties on the lake were invited to a public meeting on December 13, 2017, held at the Crystal Community Center and which was well attended. Commission staff regularly sent out project update emails to the lake association chairs, who forwarded them on to their association members and posted on their association Facebook and websites. A number of lakeshore residents walked out on the frozen lake to observe the winter seining. The seining event was highlighted on local cable channel 12, which provides cable television service to northwestern Hennepin County suburbs. https://ccxmedia.org/news/water-quality-project-targets-carp-on-middle-twin-lake/. The Commission also created and maintained two project pages on its website. http://www.shinglecreek.org/twin-lake-carp-management.html.

1.3.4 Long-term Results

Capacity-Building. The Commission developed a method to continue to harvest carp from the lake system from Ryan Creek that can be completed annually at low cost. Lakeshore property owners are now more aware of carp management benefits, and have contacted Commission staff when they observe carp shoaling or spawning.

Partnerships. Good relationships with the lake associations were created.

Dissemination of Project Results. Results have been shared with the Commission and cities, the lake associations, and the DNR. Results have been posted on the Commission's website.

Applicability to Other Audiences/Locations. Control of rough fish is an important component of shallow lake management. Commission staff have shared findings and strategies with other lake managers, as well as learned from their experiences.

Lessons Learned. For logistical reasons, winter seining can be complicated. By the time a commercial fisherman can get mobilized, the fish may have dispersed from the congregation. The market for carp is seasonal, and does not necessarily coincide with optimal winter seining times.

1.4 FINAL EXPENDITURES

Funding Source	Cost
Section 319 Grant	$99,992.26
Shingle Creek WMC	110,099.67
TOTAL	$210,091.93

2.0 Carp Management

2.1 BACKGROUND

The goal of this project was to reduce and manage the common carp population in the Twin and Ryan Lake chain of lakes to reduce internal phosphorus load and increase water clarity. More specifically goals were: 1) Understand the number and biomass of common carp in the lake system; 2) Understand immigration/ migration in the lake system; 3) Determine locations where spawning and overwintering occur; 4) Significantly reduce the number and biomass of common carp; 5) Prevent or limit reproduction of common carp in the lake system; and 6) Identify potential aquatic vegetation response to improved water clarity and options for future aquatic vegetation management needs.

2.2 POPULATION ESTIMATE

2.2.1 Method

The common carp (*Cyprinus carpio*) is among the most widespread and damaging aquatic invasive species in North America (Sorensen and Bajer 2011, Weber and Brown 2009) with the ability to rapidly colonize a waterbody (Koehn 2004) and significantly alter habitat, water quality conditions and nutrient dynamics within a lake (Huser et al. 2016, Bajer et al. 2009). Due to their ecological impact, recent efforts have focused on determining ecological density thresholds (Bajer et al. 2009) in which vegetation and improved water quality conditions return. Bajer et al. suggest that significant impacts of common carp are observed at densities of about 100kg/ha (89 lbs/acre), therefore, populations persisting at or above this threshold would benefit from population reductions.

Determining the number and density of carp has been difficult using standard sampling protocols. Recent techniques using a standardized boat electrofishing survey methodology have proven effective at determining the abundance and density of common carp with lake ecosystems (Bajer et al. 2012). Comparing lake population estimates to the critical threshold quantifies the need for active carp management while allowing targeted removal goals to be established to ensure populations are reduced below critical thresholds.

Initial population estimates began on September 2, 2016 with electro-boat shocking on Lower Twin Lake (Figure 2.1). Fisheries information and shocking time were recorded. The left pelvic fin was clipped on all captured Lower Twin common carp. Boat shocking continued September 9, 2016 on Middle and Upper Twin Lakes. The right pelvic fin was clipped on Upper Twin carp and the right pectoral fin on Middle Twin carp. The second assessment was conducted on September 29 and coincided with radio tag implanting on select carp. Only one fish initially fin-clipped on Middle Twin was recaptured on Middle Twin. A third sample session was completed in July 2017 and a fourth in July 2018 after the first round of carp harvesting. Fisheries and shocking related information are shown in Table 2.1.

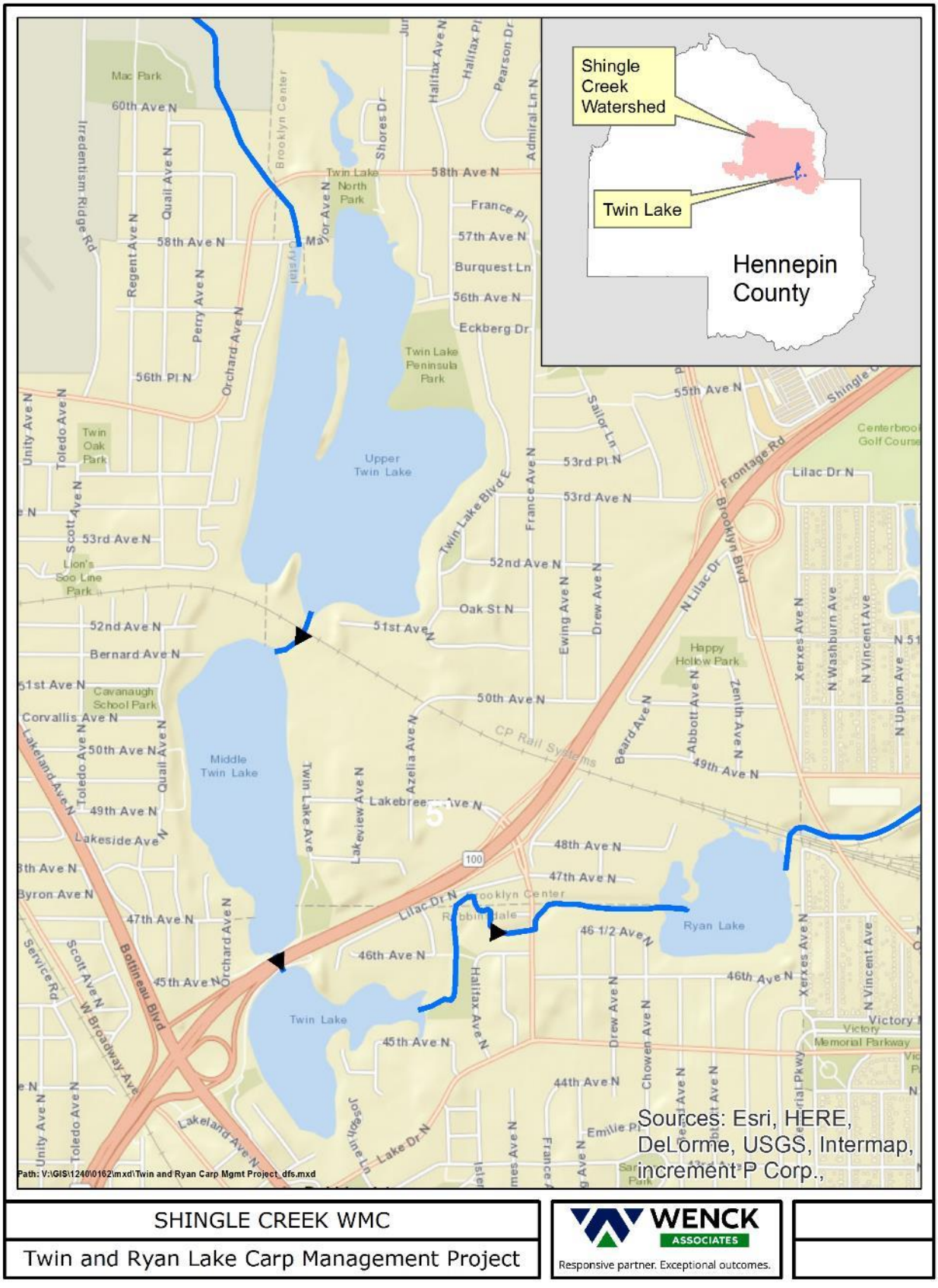


Figure 2.1. Twin Lake carp management project location.

The linear regression model and procedure outlined in Bajer and Sorenson (2012) was used to estimate the current population and biomass. The average of the pre-harvest population assessment surveys estimates a population of about 14,300 common carp, with the largest number of individuals found within the Upper basin. The estimated total biomass pre-harvest was just over 25,800 kg (56,800 lbs) (Table 2.2). Literature and lake management experience suggest that carp and other rough fish can have negative impacts to water quality and the ecosystem when the biomass of the carp exceeds 100 kilograms per hectare (kg/ha). Both Upper and Middle Twin are estimated to be well above the critical biomass threshold. Lower Twin was estimated to be below the critical threshold, but because the lakes are interconnected and fish can migrate easily, all three basins are likely being impacted by carp.

Table 2.1. Population estimate fish sampling results.

Lake	Date	n	Shock Time (hour)	Average Weight (kg)	Estimated Density (carp/ha)	Biomass mean (kg/ha)	Estimated Population Size
Upper	9/9/2016	41	0.9	1.2	217.61	261.8	10,233
Upper	9/29/2016	48	0.8	1.3	285.64	367.5	13,432
Upper	7/27/2017	27	0.88	1.8	147.55	272.3	6,939
Upper	7/30/2018	20	1	1.73	97.24	168.2	4,573
Middle	9/9/2016	24	0.7	1.2	164.53	190.8	3,729
Middle	9/29/2016	23	0.5	1.5	219.70	337.3	4,979
Middle	7/27/2017	13	0.72	1.5	88.08	131.3	1,996
Middle	7/30/2018	12	1	2.03	59.56	120.9	1,350
Lower	7/27/2017	7	0.6	1.6	57.99	91.9	690
Lower	9/2/2016	6	0.9	1.0	34.44	35.6	410
Lower	9/29/2016	5	0.5	1.9	50.14	95.7	597
Lower	7/30/2018	6	0.7	1.47	43.41	63.8	516

Table 2.2. Estimated average carp population, density, and biomass.

Lake	Average Population Size (# carp)	Average Biomass Density (kg/ha)	Average Total Biomass (kg)
Upper	10,201	301	18,362
Middle	3,568	220	6,422
Lower	565	74	1,018
TOTAL	14,334	198	25,802

2.2.2 Setting a Removal Goal

A biomass density goal of 100 kg/ha is used to establish the minimum harvesting goal. Using a cross multiple equation, the minimum target removal goal can be calculated thusly:

$$Individuals\ to\ Remove = \ Current\ Pop.Size - (\frac{Current\ Pop.Size}{Current\ Biomass\ Density} * Biomass\ Density\ Goal\ )$$

Solving the equation:

$$Individuals\ to\ Remove = \ 14{,}334\ individuals - (\frac{14{,}334\ individuals}{198\frac{kg}{ha}} * \ 100\frac{kg}{ha})$$

$$Individuals\ to\ Remove = 7{,}095$$

However, this modeling exercise doesn't account for the annual growth and increase in biomass of individual carp within the system. Data from the DNR Lake Finder (https://www.dnr.state.mn.us/lakefind/index.html) was used to estimate typical average common carp weights at about 10-11 lbs. or 4.5-5.0 kg. Using this same frame of reference, the carp in Twin Lake could be expected on average to at least double in biomass. To account for this growth potential, several removal rate scenarios (Table 2.3) were considered, with the biomass doubles scenario selected as the removal target.

Table 2.3. Minimum target removal goal scenarios.

Average Weight Scenario	Targeted Removal #s			
	Individuals	Biomass (kg)	Biomass (lbs)	% of population
Current	7,095	9,933	28,191	49%
Biomass Doubles	10,715	15,000	33,069	75%
Biomass Triples	11,921	16,690	36,795	83%

2.3 CARP TRACKING

Common carp are a relatively long-lived species suggesting that population reduction and control may need a removal component to reverse the deleterious impacts once recruitment areas have been blocked. Large congregations of carp have been observed during spawning migrations and overwintering shoals and are behaviors that make carp vulnerable to targeted removals. To successfully remove large aggregations of carp researchers have utilized a Judas technique. This technique implants radio tags into a few individuals in the population that can be followed to determine where aggregations form to better target removal operations. In carp management, the Judas technique is often paired with winter seining events to remove target goals of carp (Bajer et al. 2011).

We implanted radio tags in select individuals within each of the three basins to conduct tracking to 1) locate potential overwintering habitats, 2) locate potential spawning and nursery locations and 3) understand seasonal movements among the three basins and the watershed. Radio tag implanting (Figure 2.2) coincided with the second mark and recapture assessment on 9/29/2016. A total of 40 fish were implanted with radio tags. Efforts to tag equal proportions of fish per lake were attempted, however, fish capture and size ultimately affected how many fish could be tagged for a given lake. Relatively equal males to females were tagged within the system and fish of various sizes were tagged. Each transmitter was uniquely coded for individual tracking and was implanted inside the body cavity near the pelvic fin with an external antenna to assist with transmitter detection. Carp were temporarily anesthetized prior to implanting radio tags, revived after implantation was complete and held in holding tanks until carp had recovered. They were then released back into the lake in which they were initially collected. A unique radio frequency was assigned to each fish and length, weight, sex information was recorded.

The initial tracking effort began on 9/30/2016. The primary objective of this tracking event was to determine any initial mortality post-surgery and to test out tracking equipment and methods. Three of the four fish tagged from Lower Twin lake were located. One was located in Lower Twin and the other two fish were located in the outlet channel or downstream wetland complex. Therefore, two fish left the system and it is possible the remaining Lower Twin tagged fish that was not located also had left the system.

Figure 2.2. Implanting radio tags in anesthetized carp.

Sixteen of 17 Middle Twin carp were located. Eleven of the 16 were tracked to be within Middle Twin with most fish moving back to areas where carp were captured the day before. Five of the 16 carp had relocated into Upper Twin Lake. Ten of 19 Upper Twin carp were found to be within Upper Twin. Logistic constraints limited the tracking effort on Upper Twin and the status of the other 9 fish was unknown, however, since these fish were not located in Middle or Lower Twin lakes it is likely that they were other areas of Upper Twin Lake not assessed.

Following the initial tracking event, tracking was completed monthly, and increased to weekly or even daily during perceived spawning and overwintering timeframes and in the leadup to winter seining removal events. There are two open water wetland systems on the north end of Upper Twin that are connected to the lake by culverts and channels. No carp were observed to move into these wetlands, and no tagged carp were located in these wetlands. Lower Twin outlets into Ryan Creek, which flows to Ryan Lake. Ryan Lake discharges into the lower branch of Ryan Creek, and flows though that channel and then into storm sewer to Shingle Creek, where there is a known population of common carp. Tagged carp were found periodically in Ryan Lake. A single stationary tracking unit was placed along Ryan Creek to track carp out of and back into the Twin Lake system. Data from this unit was downloaded during every mobile tracking event and reviewed for possible movements.

For tracking events where not all the tagged fish were found or otherwise accounted for, tracking was also conducted along Ryan Creek, Ryan Lake and in a few instances, locations along Shingle Creek, Palmer Lake, Eagle Lake and Pike Lake. Radio tags not located within the Twin Lakes were fish that either 1) were simply not detected during a tracking event, 2) left the system through the outlet, or 3) were harvested by fisherman or natural predators (i.e. eagles). Fish that were not located during a tracking event but then were observed during subsequent events were likely missed by trackers. Fish repeatedly not found and not observed at the completion of the project were logged as having left the system. Where a radio tag was logged in a single, unmoving location multiple events in a row was taken to indicate that the radio tag was either 1) rejected by the fish, 2) the fish died, or 3) the tag was removed by a fisherman or predator.

Figure 2.3 shows how the carp tend to school during the winter and spring months. In January, the tagged carp tended to congregate at the deepest parts of Upper and especially the deeper Middle Twin Lake. The large gathering in Middle Twin on the January panel on Figure 2.2 is the location where the January 2018 winter seining event occurred. By February and March, when there are periodic snow melt events, the fish tended to congregate around the outfalls of the large storm sewers discharging warmer, more oxygenated water into the lake. By April they were more dispersed, and the tagged fish were frequenting the shallow margins of Upper Twin Lake where there may be new vegetative growth and where spawning may occur.

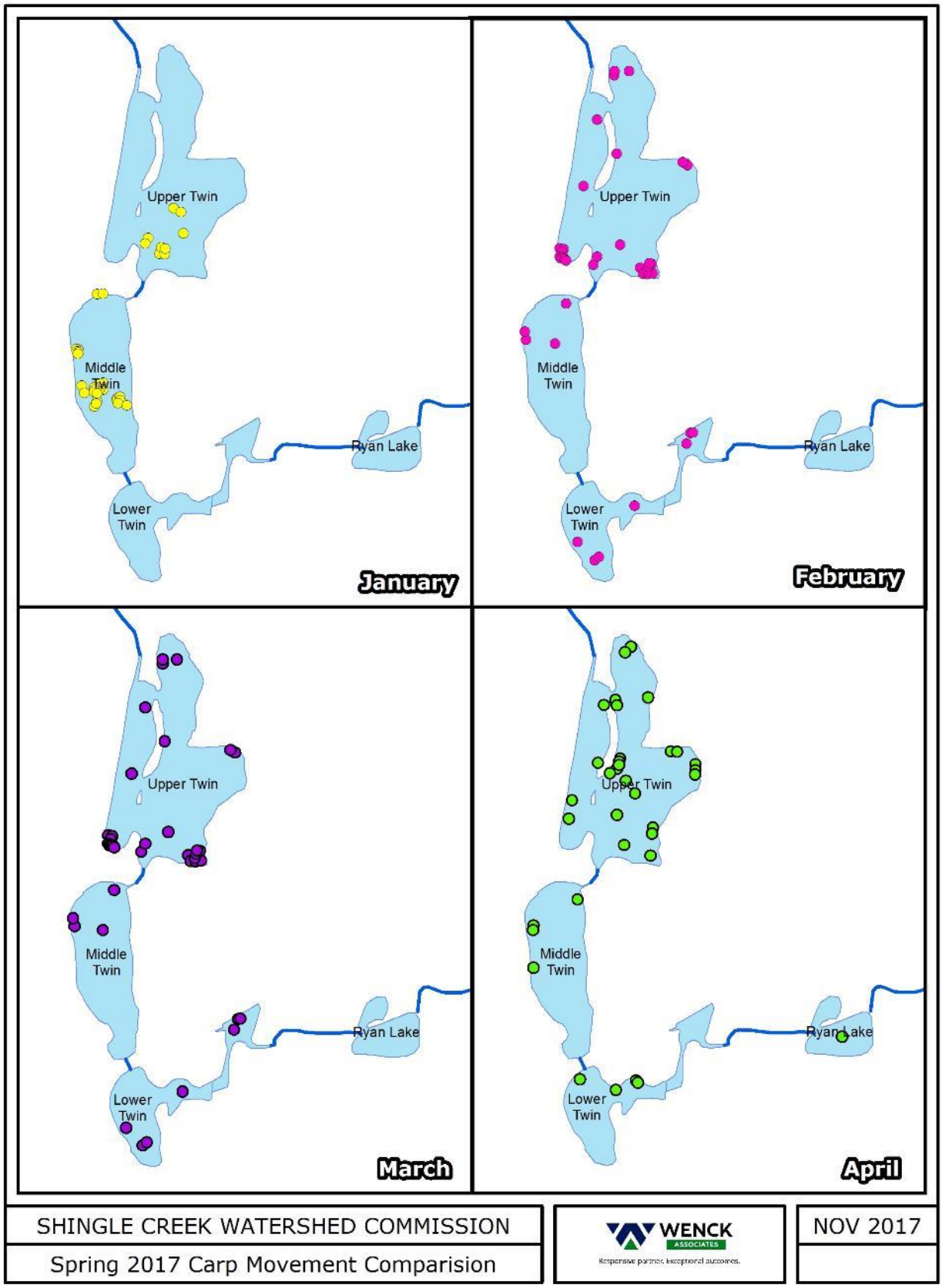


Figure 2.3. Spring 2017 carp movement by month.

2.4 CARP REMOVALS

2.4.1 Removals

Radio tracking identified a dense aggregation in Middle Twin Lake in January 2018. Arrangements were made with the commercial fishermen assigned to this territory to complete a winter seining. The seine haul occurred on 1/18/2019. Two large holes were cut in the ice (one on the east shoreline and the other on the west shoreline areas) on Middle Twin Lake. The net was deployed under the ice on the east side of the lake at 9:00 am and was pulled westward where it began to surface through around 10:30 am. The initial 100-150 feet of the seine was damaged and did not fish properly. A rusted steel drum and barb wire fencing was tangled in the net and likely cut part of the net, suggesting that debris impacted the seine haul. It is also possible that the net lifted off the bottom of the lake and allow fish to escape the seine haul. A sharp bathymetry change or debris can cause the net to lift from the bottom.

Ten fish species were observed during the seine haul: black bullhead, common carp, bluegill, black crappie, northern pike, largemouth bass, walleye, white sucker, yellow perch and bowfin. Black bullhead and common carp were removed, and all other fish were returned to the water (Figure 2.4). Carp were measured to estimate weight and the total biomass removed. A handful of larger carp were observed in the seine haul than was predicted in population modeling, thus it is likely that the biomass of carp in the system was underpredicted. An estimated 10,643 pounds of carp were removed, and an estimated 15,000 pounds of black bullhead, another bottom feeder. A second winter seine was planned in January 2019. While the carp schooled in the same location as January 2018, the commercial fisherman had equipment issues and was unable to mobilize before the school dispersed during a sudden warm snap.

Two alternate methods were used in spring 2019 to accomplish additional removals. The first capitalized on the propensity of carp to assemble in the Lower Twin Lake outlet channel, Highway 100 wetland, and Ryan Creek just upstream of the France Avenue outlet weir where a fish barrier was installed in fall 2018 (Figures 2.5 and 2.6). It is theorized that the fish are waiting for spring high water levels to make it easier to swim over the weir and through Ryan Creek to Ryan Lake to spawn. Commission staff devised a method to trap the carp in the channel just upstream of the barrier using a block net, then to use a seine to net the trapped carp. This was successfully completed twice. An additional effort was thwarted when a large spring storm the night before the removal increased the volume and velocity of lake outflow, which undermined the barrier footing. The trapped carp were able to slip under the footing and over the weir. Their estimated biomass was counted as removed as they can no longer return to the Twin Lake system, and the barrier footing has been reinforced.

The second method was simply trolling the shallows of Upper and Lower Twin Lake with an electrofishing boat in the areas where tracking had suggested they congregate during the spawning season. Some of the females caught during these removals were dissected and were found to be laden with eggs.

While the biomass removed during these alternate methods was less than winter seining, this method can be much more responsive to school movements and be completed at lower cost per effort. The Commission intends to continue these methods to bring down the carp population to a much more manageable density.

Figure 2.4. Winter seining.

Figure 2.5. Sorting fish netted from Ryan Creek.

Table 2.4. Carp removals to date.

Removal Date	# Carp Individuals	Average Weight (lbs)	Total Weight (lbs)	Method
1/19/2018	2661	4	10,643	Winter seine
3/4/2019	0	0	0	Winter seine
4/18/2019	200	4	800	Under barrier
4/26/2019	89	3.98	354	E-boat
5/2/2019	162	4.71	763	E-boat
5/16/2019	206	4.5	927	Ryan Creek
5/23/2019	211	4.5	950	Ryan Creek
TOTAL	3,529 (38%)		14,437 (44%)	
Goal	10,715		33,069	

Figure 2.6. The outlet of Lower Twin Lake.

2.5 CONTROL REPRODUCTION AND MIGRATION

2.5.1 Carp Barriers

The carp tracking verified the suspicion that carp were moving into and out of the lake system via Ryan Creek. A fish barrier (Figure 2.7) was installed on the weir of Ryan Creek as it flows under France Avenue North. Ryan Creek is the outlet of the Twin chain, and flows in and out of Ryan Lake downstream to Shingle Creek. Tracking also indicated that carp were moving into a connected wetland across Bass Lake Road, upstream of Upper Twin Lake, potentially to spawn. Another barrier was installed in the channel just downstream of the Bass Lake Road culvert (Figure 2.8).

2.5.2 Aeration

Research conducted by Dr. Peter Sorensen at the University of Minnesota suggests that carp can reproduce very successfully in shallow lakes that experience severe hypoxia. Upper Twin is shallow (max depth <10 feet) and experiences frequent winter kills. To help protect the vulnerable pan fish during winter hypoxia, the intent of the project was to install an aeration system in Upper Twin Lake. After resolving various logistical difficulties and lakeshore property owner concerns, ultimately the host City of Brooklyn Center declined to take on the legal liability of the aeration system. The aerator was not installed.

Figure 2.7. The fish barrier on Ryan Creek at France Avenue.

Figure 2.8. The fish barrier at Bass Lake Road.

3.0 Lake Response

3.1 VEGETATION MONITORING

It was expected that improvements in lake clarity may drive a response in submersed aquatic vegetation (SAV), including aquatic invasive species (AIS) known to be present in the lakes. The exact nature of that response was unpredictable, so the project included surveys of existing SAV conditions and the preparation of an Aquatic Vegetation Management Plan.

Baseline surveys for the three basins of Twin Lake are shown in Figures 3.1, 3.2, and 3.3. These surveys were done by both point-intercept transects and by continuous sonar readings. Computer software is used to overlay a grid of points across the entire lake that are the predetermined sampling locations. At each survey location a double sided weighted 14 tine rake is thrown from the boat, allowed to sink, and then retrieved across the lake bottom to represent approximately 1 m^2 of vegetation sampling. For each rake toss, vegetation is removed from the rake, identified to the species level, placed in a perforated bucket, weighed and assigned a proportion of the total biomass based on visual approximation (e.g. 80% of total weight was curly-leaf pondweed (CLP) and 20% of total weight was coontail). All biomass values are reported in wet weights (kg). The continuous sonar data was processed using CiBioBase software (cibiobase.com) to map water depth and vegetation biovolume. Biovolume differs from biomass in that it provides context to vegetation water column saturation. The higher the biovolume the more saturated the water column is with vegetation.

Surveys were done in late spring and then again in early fall, after senescence of any curly-leaf pondweed. Survey points where CLP was detected are shown in yellow, with the size of the symbol indicating estimated biomass. Biovolume of SAV is illustrated by a color ramp.

The survey results demonstrate a biologically-impaired vegetation community across all three basins. Species richness, abundance and spatial coverage all decrease across the growing season due to decreased water clarity over the growing season. Currently, CLP is the only dominant vegetative AIS species in Twin Lake system, most notable in the Upper Twin basin. The surveys were used to develop an Aquatic Vegetation Management Plan (AVMP) for review and approval by the DNR. The AVMP documents current conditions and potential future management actions depending on the aquatic vegetation response as water clarity improves. The DNR approved the AVMP, and issued a variance for Upper Twin Lake allowing the Commission to if necessary treat more than the state limit of 15% of the 117 acre lake surface area.

In spring 2018, the DNR and Commission staff delineated a 9.4 acre area of CLP on Upper Twin Lake that was subsequently treated with endothall, In spring 2019 the DNR and Commission staff conducted an invasive plant survey and found very sparse stands of CLP as well as some stands that were dead. Harsh conditions during the 2018-2019 winter, including a significant and long-lasting snowpack on the lake surface limited light penetration, which inhibited CLP growth under the ice. No treatment was performed. Another survey will be completed in spring 2020 to determine if additional CLP treatment is necessary.

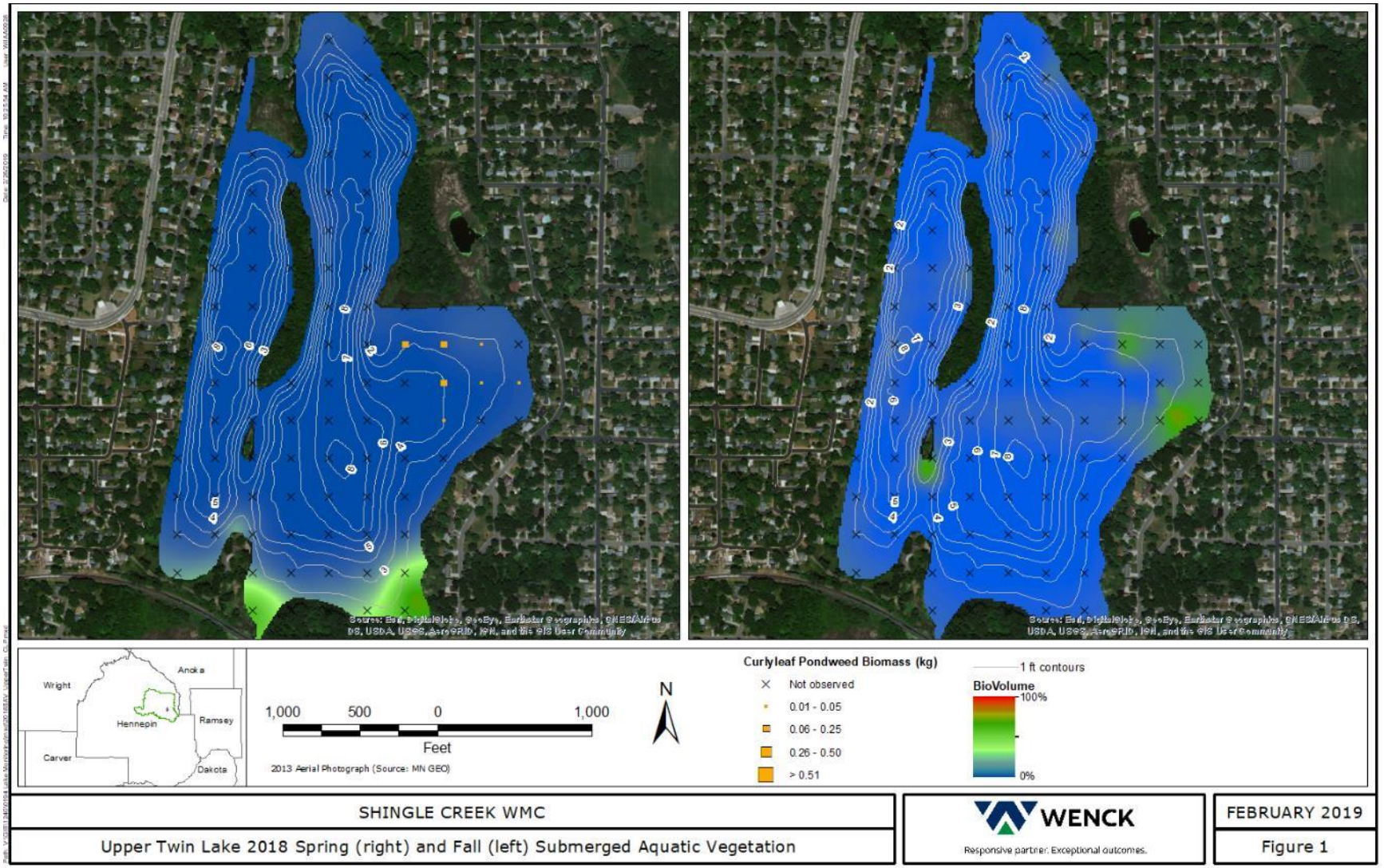


Figure 3.1. Upper Twin Lake SAV survey results.

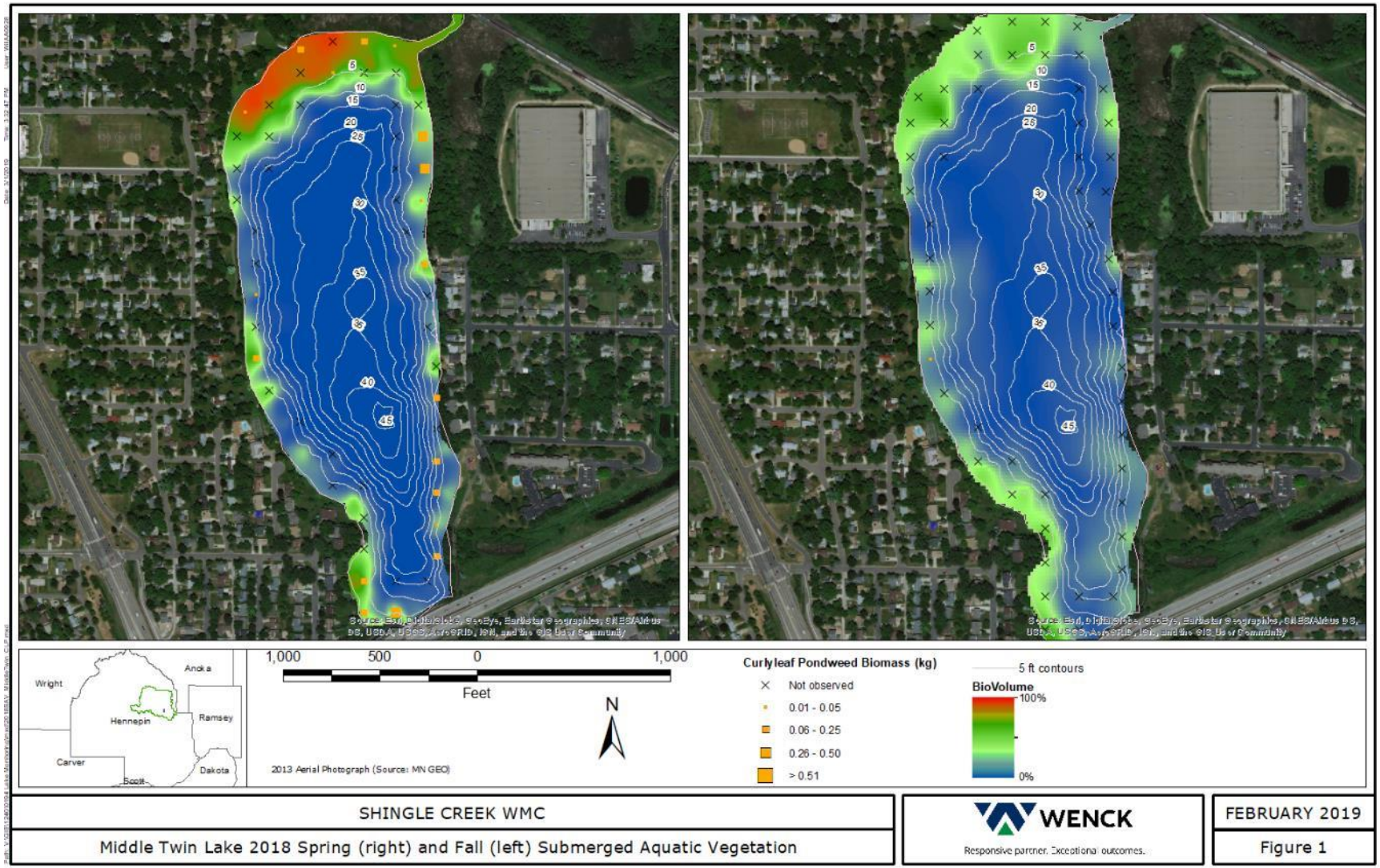


Figure 3.2. Middle Twin Lake SAV survey results.

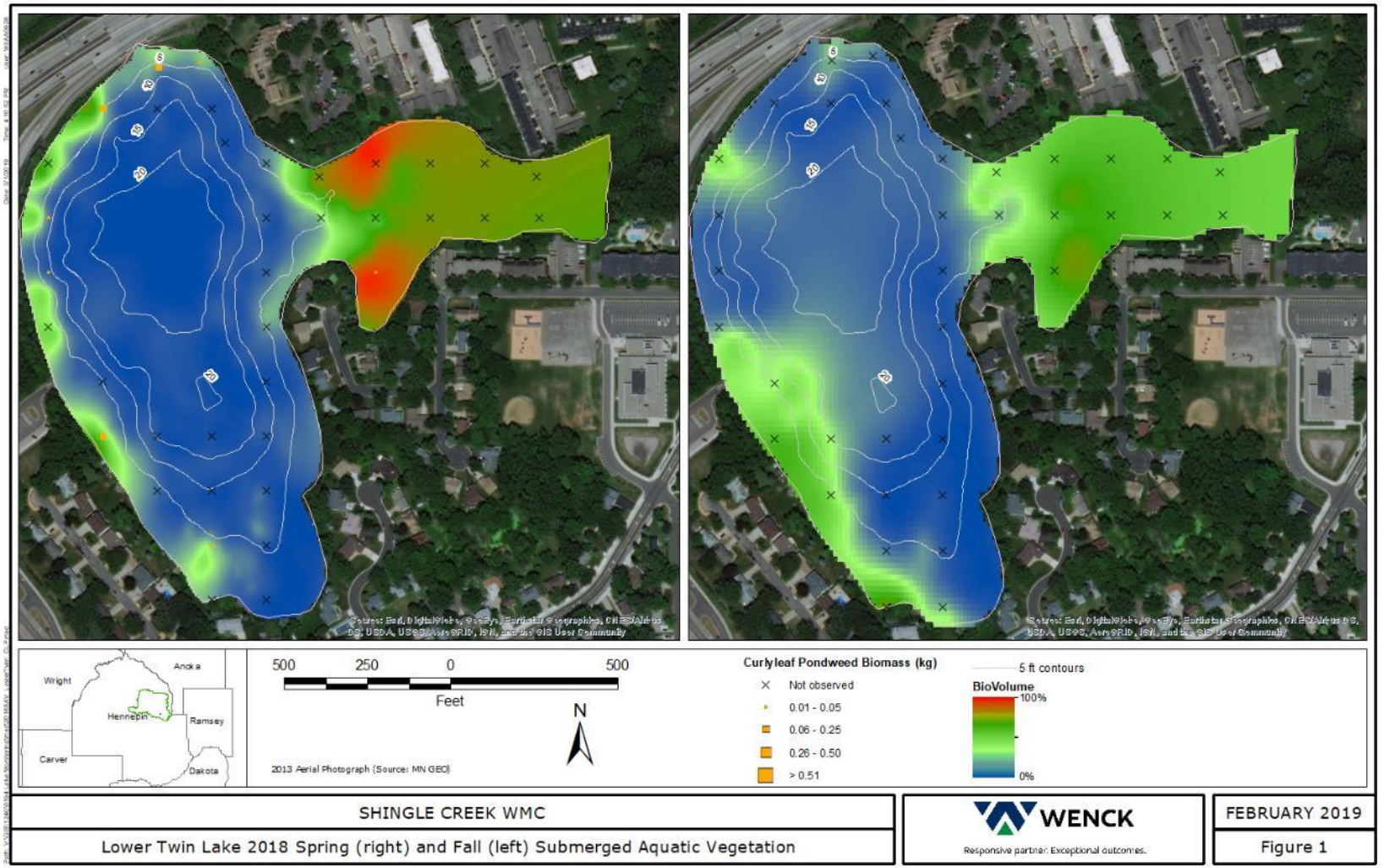


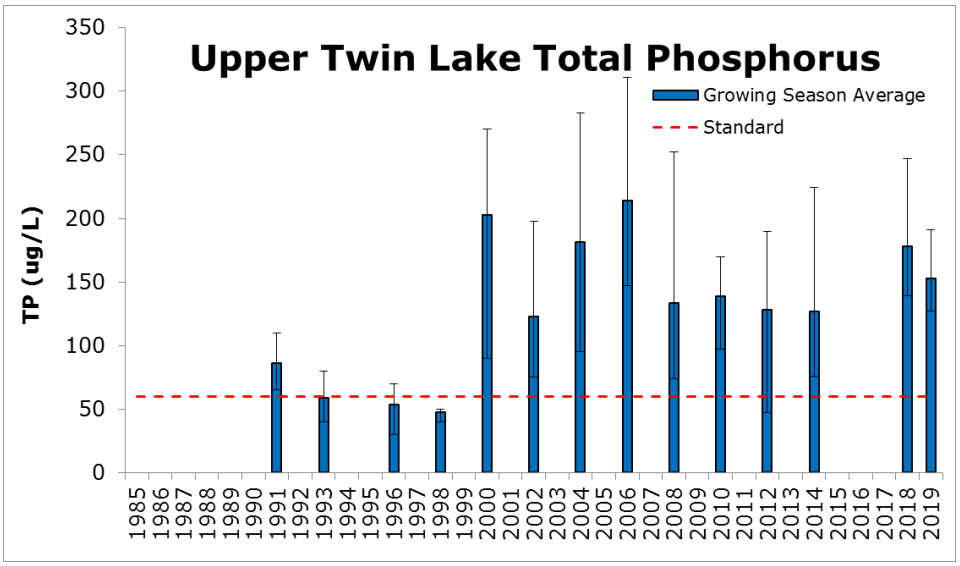
Figure 3.3. Lower Twin Lake SAV survey.

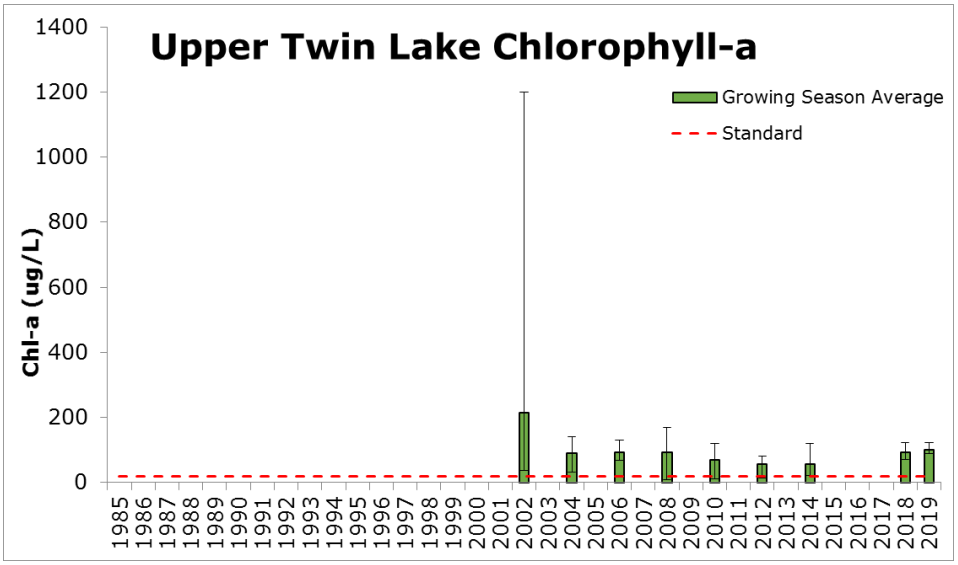
3.2 WATER QUALITY MONITORING

Biweekly water quality monitoring was completed in 2018 on all three basins of Twin Lake as well as Ryan Lake. Monthly sampling was completed on the three basins in 2019. Parameters that were measured were total phosphorus (TP), soluble reactive phosphorus (ortho-P), total suspended solids (TSS), and chlorophyll-a (chl-a). In the deeper Middle Twin and Ryan Lakes hypolimnetic (deep) water samples were collected and tested for TP and ortho-P. In addition to these chemical parameters, the physical profile of the lakes were assessed in the deepest part of the lake. A profile typically consisted of taking measurements starting at the water's surface and continuing every meter (or half meter in shallow lakes) throughout the entire water column. A multimeter probe was used to collect dissolved oxygen (DO; mg/L), DO%, temperature, pH, oxidation reduction potential (ORP) and specific conductivity at each step in the profile. Additionally, a Secchi disk reading was taken during every assessment to relate the relative level of water transparency. The data were compiled and reported in the Commission's annual Water Quality Report.

Figures 3.4 through 3.6 show historic water quality in the three basins of Twin Lake. The data are summer growing season averages, May 1 to September 30. The whiskers on each bar show the range of data, with the top of the whisker representing the highest recorded concentration that year. For Secchi depth, the X-axis is flipped to be on top rather than on the bottom. The axis represents the surface water level, and the bars represent the depth of clarity. The whiskers again show the range of data, and the bottom of the whisker indicates the best water clarity recorded that year.

No significant immediate water quality response was noted in any of the lakes. Because of annual variability more years of data will be necessary to determine whether there is a trend for improvement.





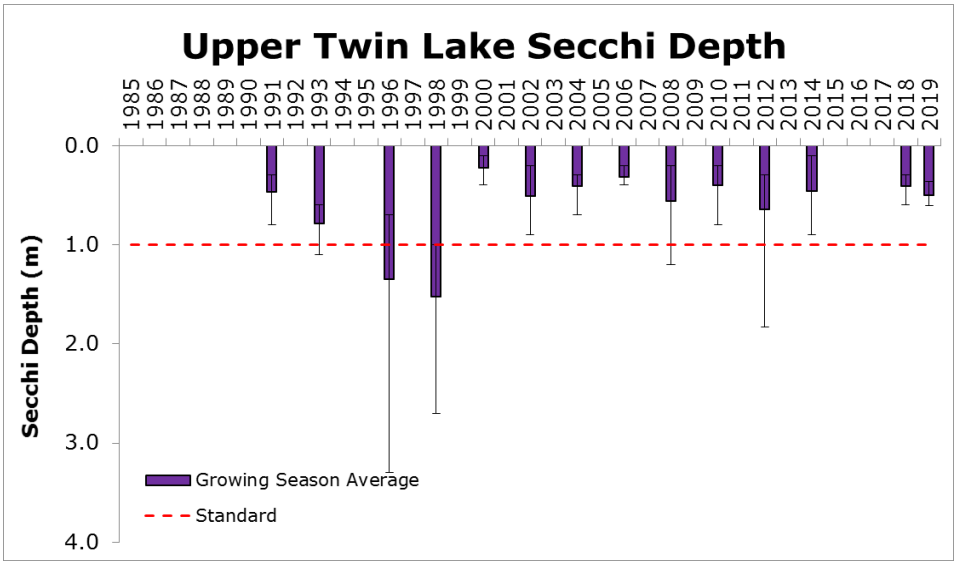
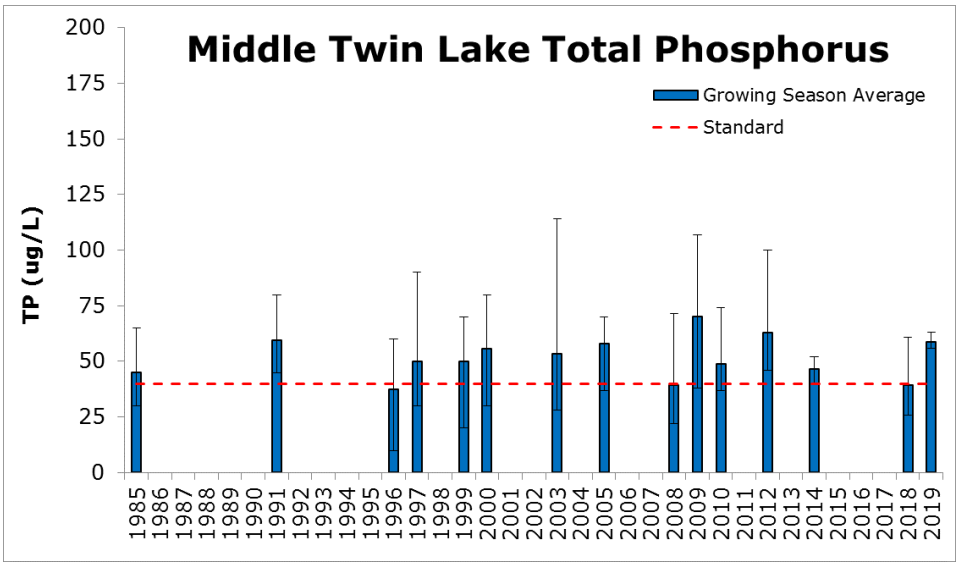
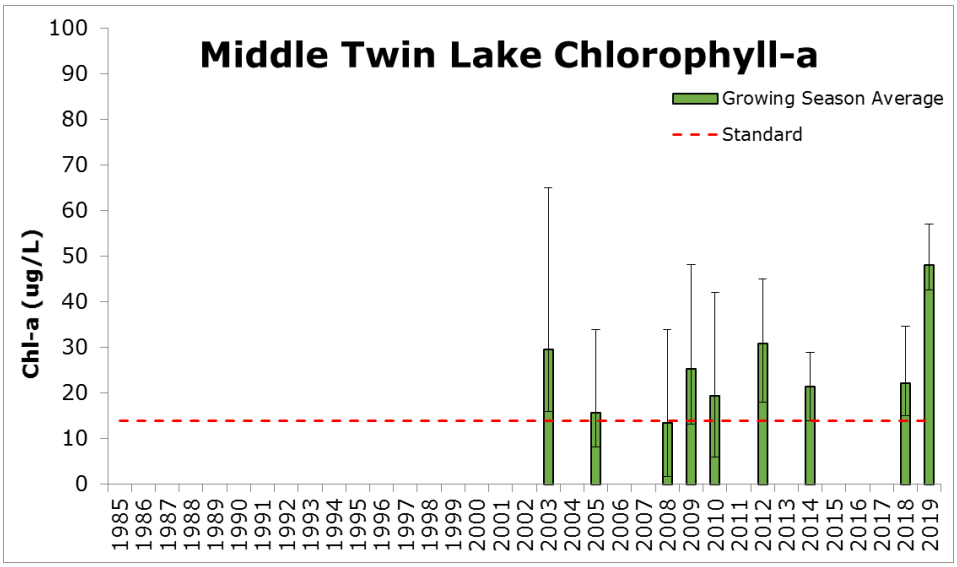


Figure 3.4. Upper Twin Lake historic water quality.





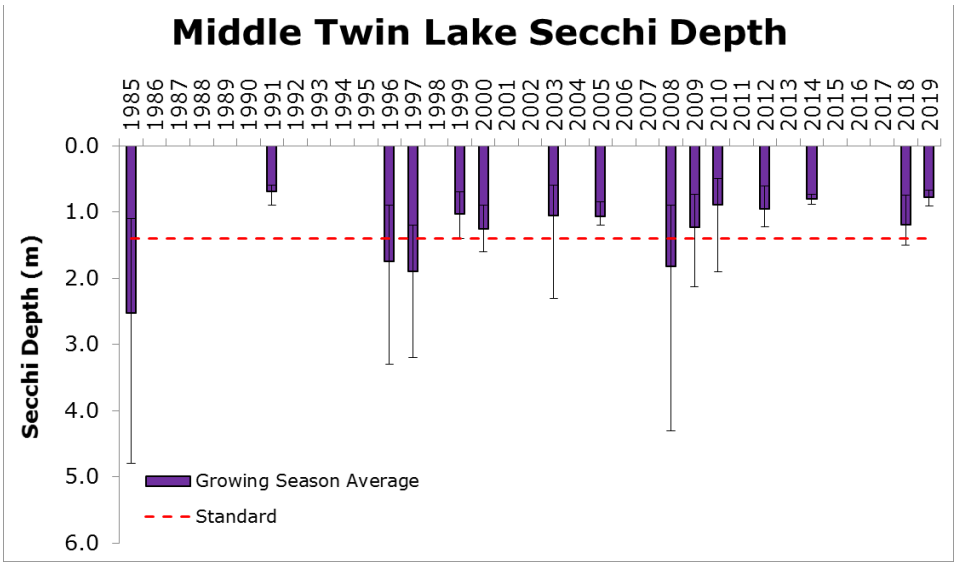
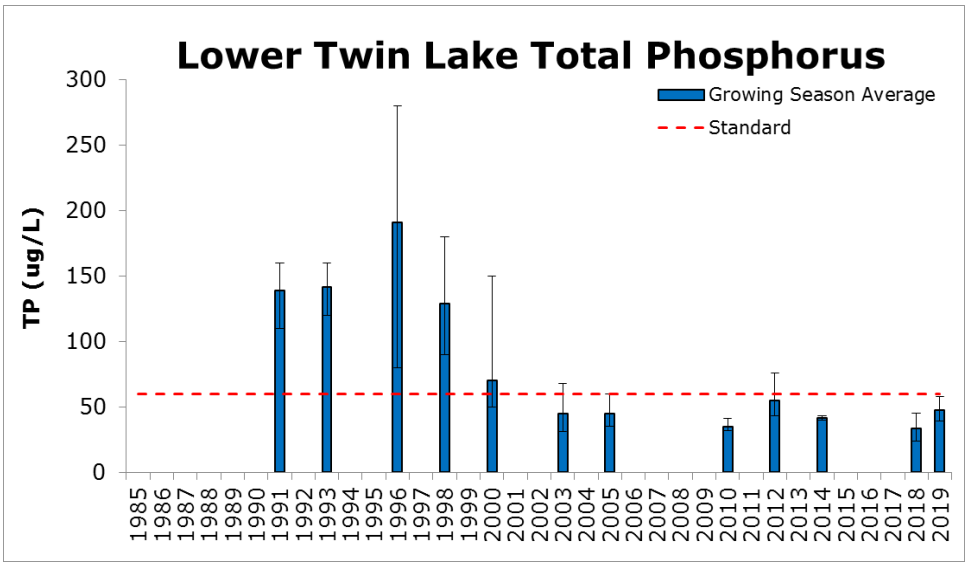
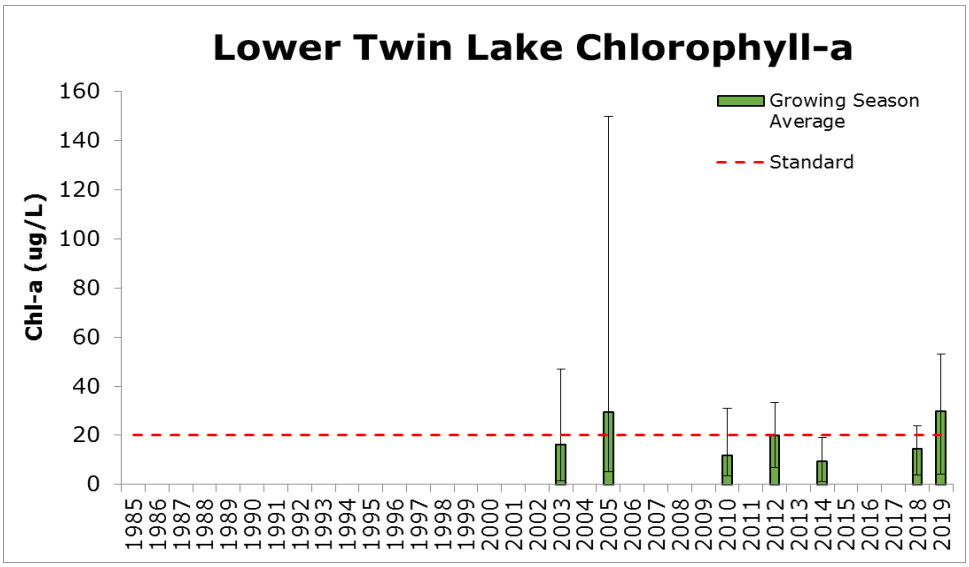


Figure 3.5. Middle Twin Lake historic water quality.





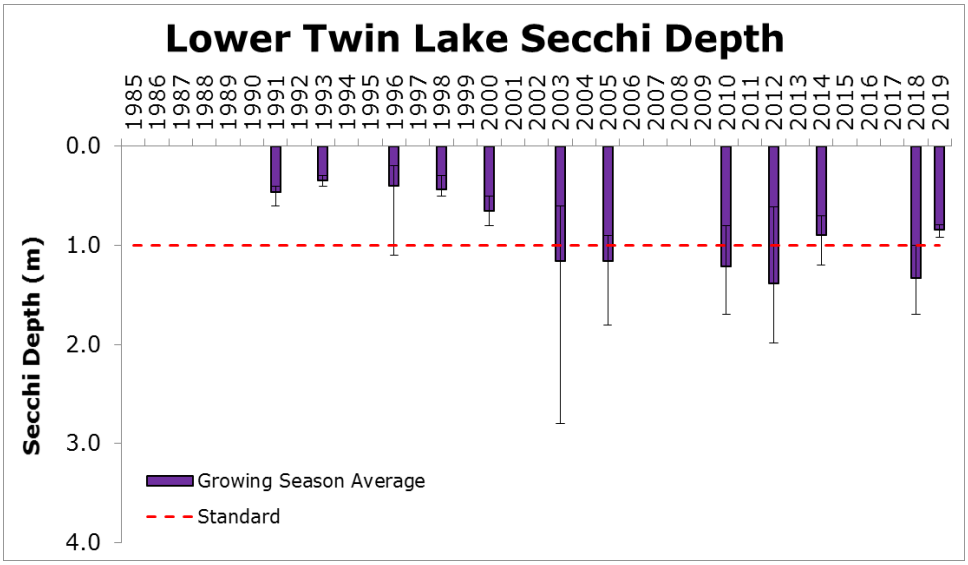


Figure 3.6. Lower Twin Lake historic water quality.

4.0 References

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