

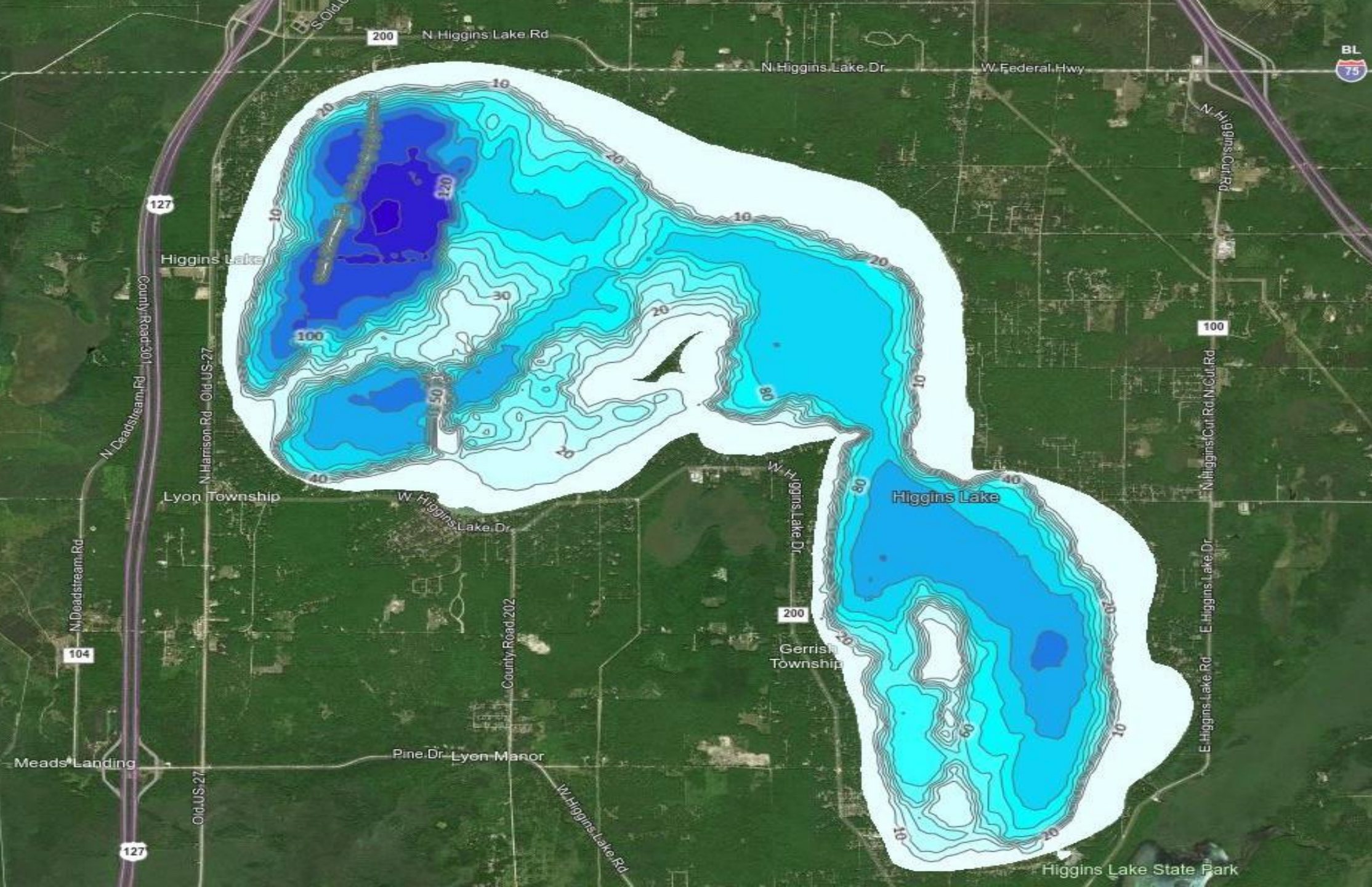
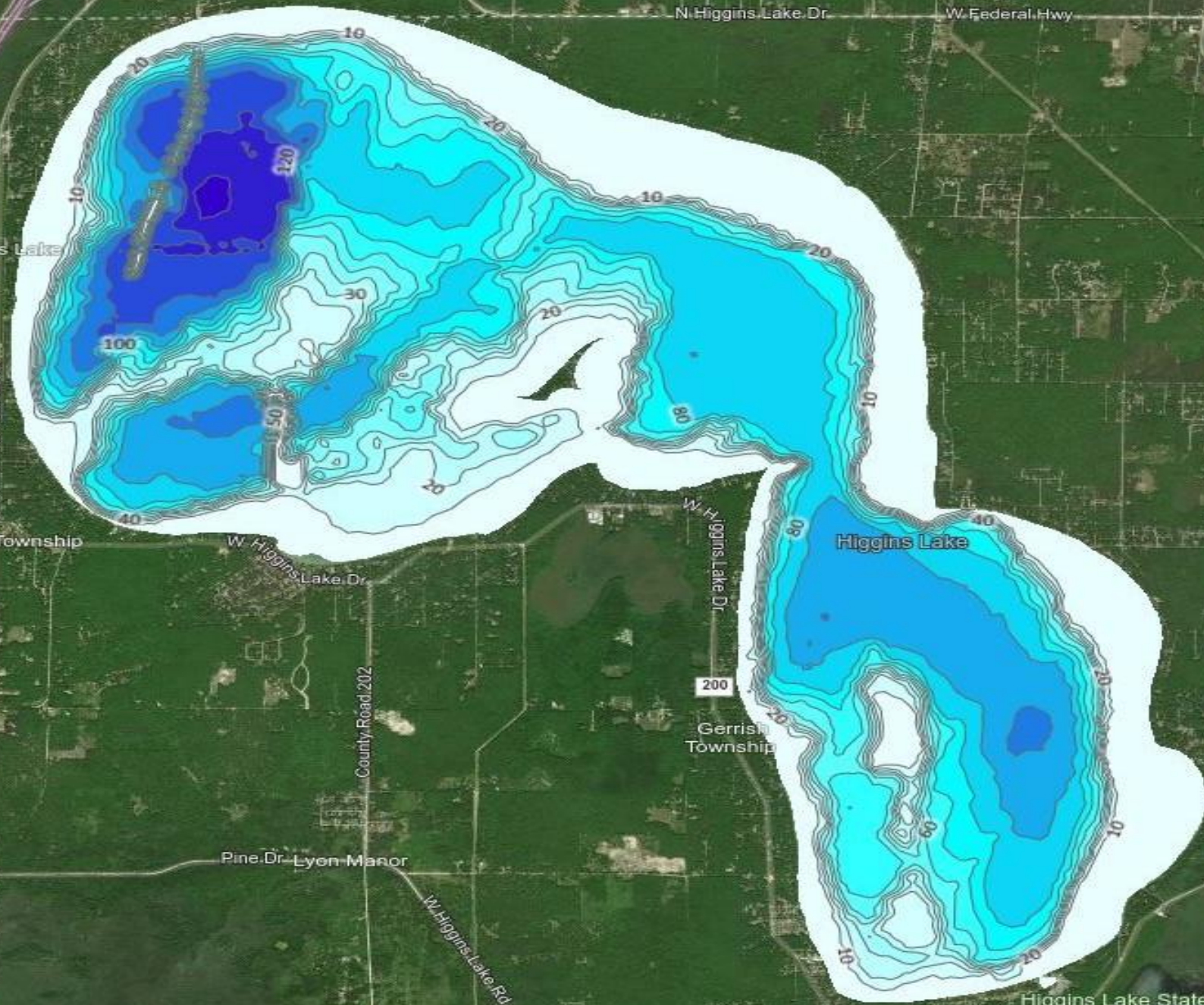
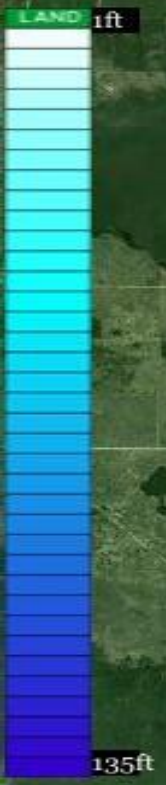


Dr. Jennifer Jermalowicz-Jones, CLP
Restorative Lake Sciences

HIGGINS LAKE IMPROVEMENT PLAN

Higgins Lake Physical Characteristics

- ① 10, 201 acres in surface area
- ① Mean depth = 30.4 feet
- ① Maximum depth = 135 feet
- ① Fetch = 6.5 miles
- ① Shoreline length = 22.2 miles w/island
- ① Water volume = 542,509.7 acre-feet
- ① Legal lake level (1982) = 1,154.11 feet above sea level



Higgins Lake

Roscommon County, MI
Boat Ramp Map

Legend

● Boat Ramp

Higgins Lake North State Park Ramp

B&B Sports Center & Marina Ramp

Higgins Lake

Maplehurst Dr. Road End Ramp

DNR Ramp Higgins Lake West

Magnolia Ave Road End Ramp

Townline Rd. North Road End Ramp

Kelly Ave Road End Ramp

Gerrish Township Park Ramp

Higgins Lake South State Park Ramp

127

75

18



Higgins Lake Immediate Watershed


- 28,783 acres
- 3x lake surface area
- Within larger Muskegon River Watershed



Higgins Lake

Roscommon County, MI
Watershed Map

Legend

 Higgins Lake Watershed

Higgins Lake



Higgins Lake

Roscommon County, MI
Inlet Sampling Location Map
August 2019

Legend

- Big Creek
- Big Creek Upstream
- East Inlet
- North Creek Inlet
- Outlet

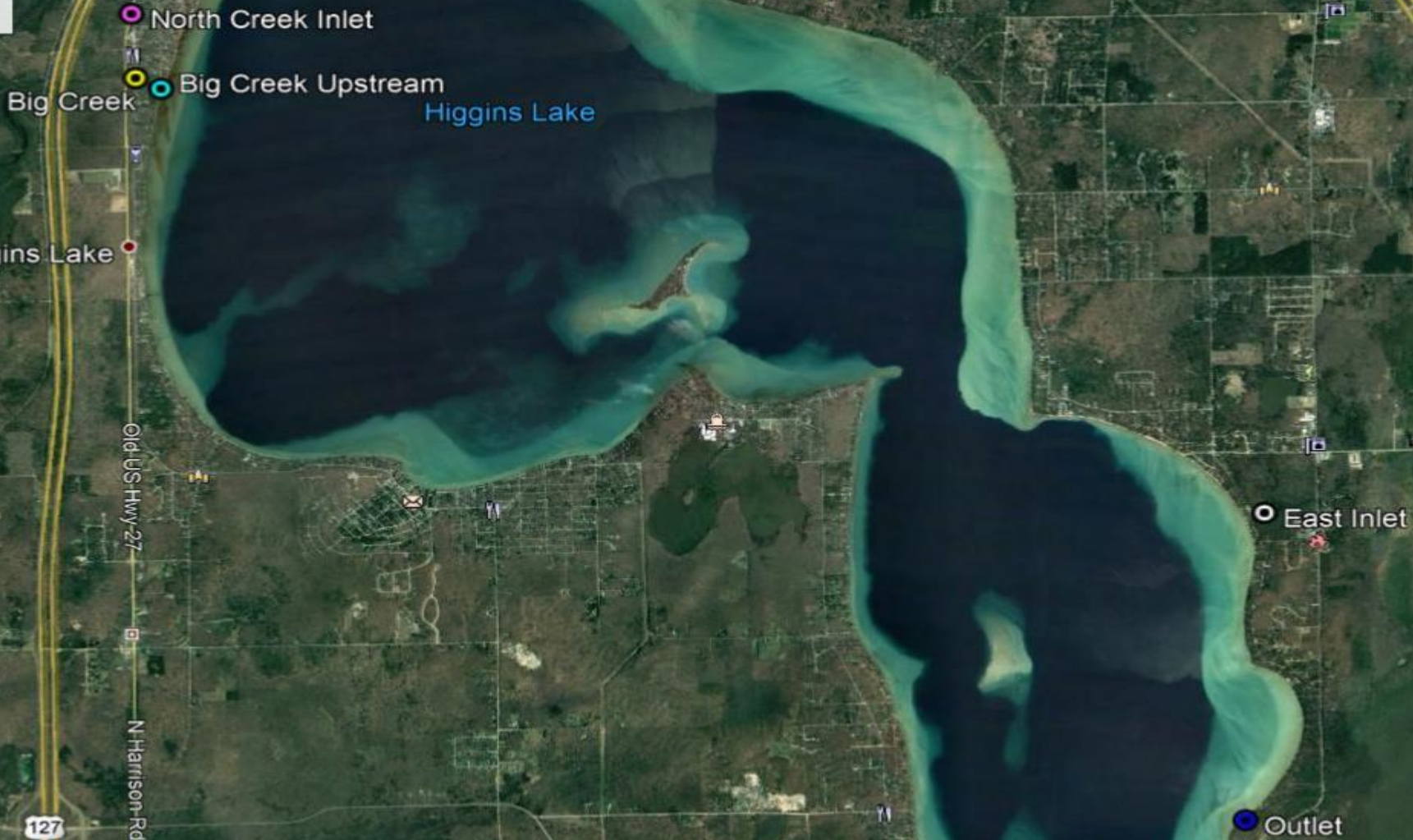


Table 25. Physical water quality parameters for the major tribs flowing into Higgins Lake (October 16, 2019).

Tributary	Water Temp (°C)	pH (S.U.)	Conduct (mS/cm)	DO (mg/L)	TDS (mg/L)
North Creek	7.5	8.5	282	9.1	180
East Creek	--	--	--	--	--
Big Creek	8.1	8.4	202	8.5	129

***East Creek samples could not be collected due to lack of flow.**

Table 26. Chemical water quality parameters for the major tribs flowing into Higgins Lake (October 16, 2019).

Tributary	TP (mg/L)	TKN (mg/L)	TIN (mg/L)	NO3- (mg/L)	NO2- (mg/L)	NH3 (mg/L)	TSS (mg/L)
North Creek	0.016	0.9	0.029	<0.10	<0.10	0.029	<10
East Creek	--	--	--	--	--	--	--
Big Creek	0.027	0.8	0.033	<0.10	<0.10	0.033	12

***East Creek samples could not be collected due to lack of flow.**

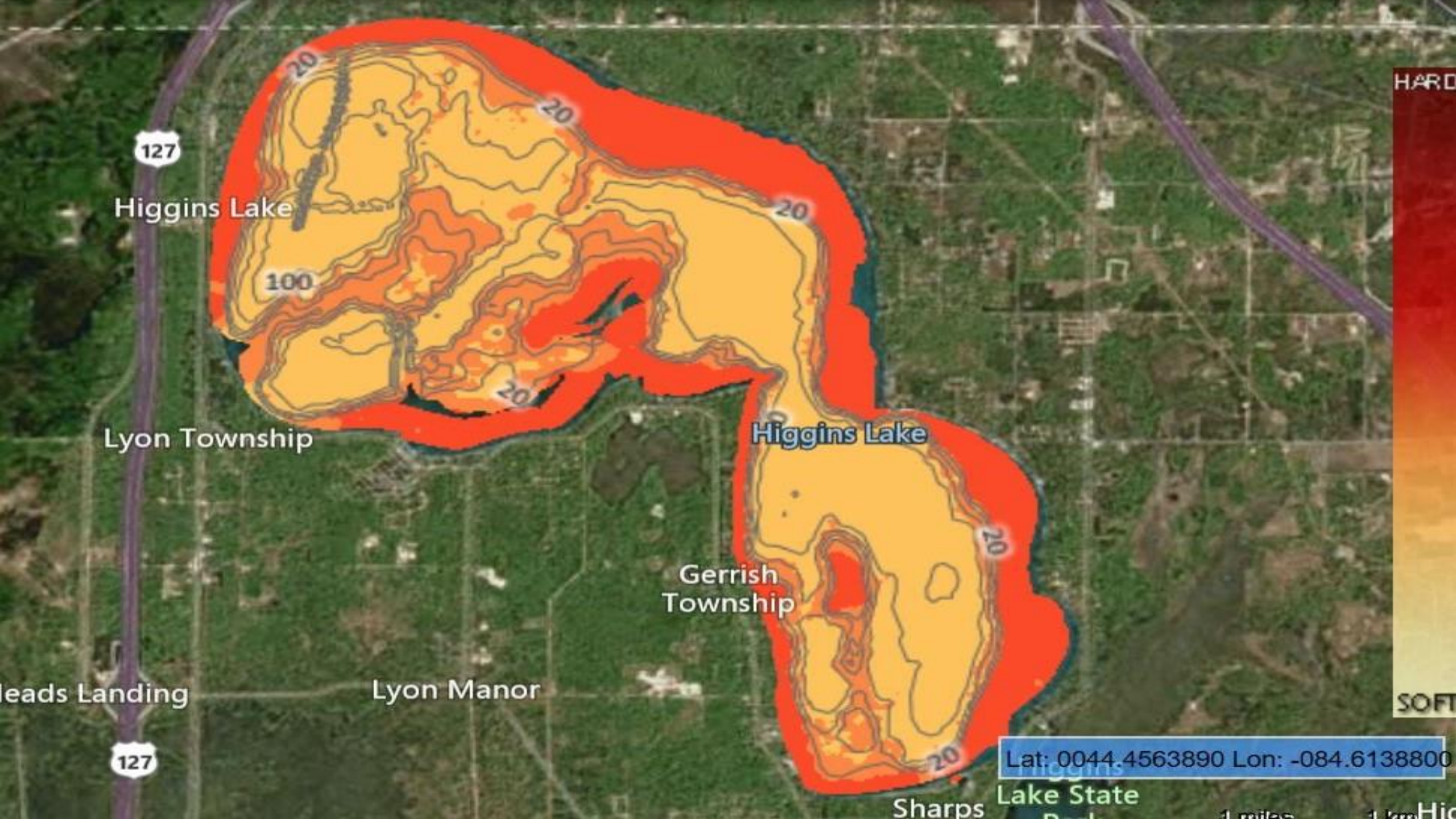



Table 1. Higgins Lake relative hardness of the lake bottom by category or hardness and percent over of each category (relative cover).

Lake Bottom Relative Hardness Category	# GPS Points in Each Category (Total =77,360)	% Relative Cover of Bottom by Category
0.0-0.1	13	0.02
0.1-0.2	38	0.05
0.2-0.3	40,342	52.2
0.3-0.4	12,852	16.6
>0.4	24,115	31.2




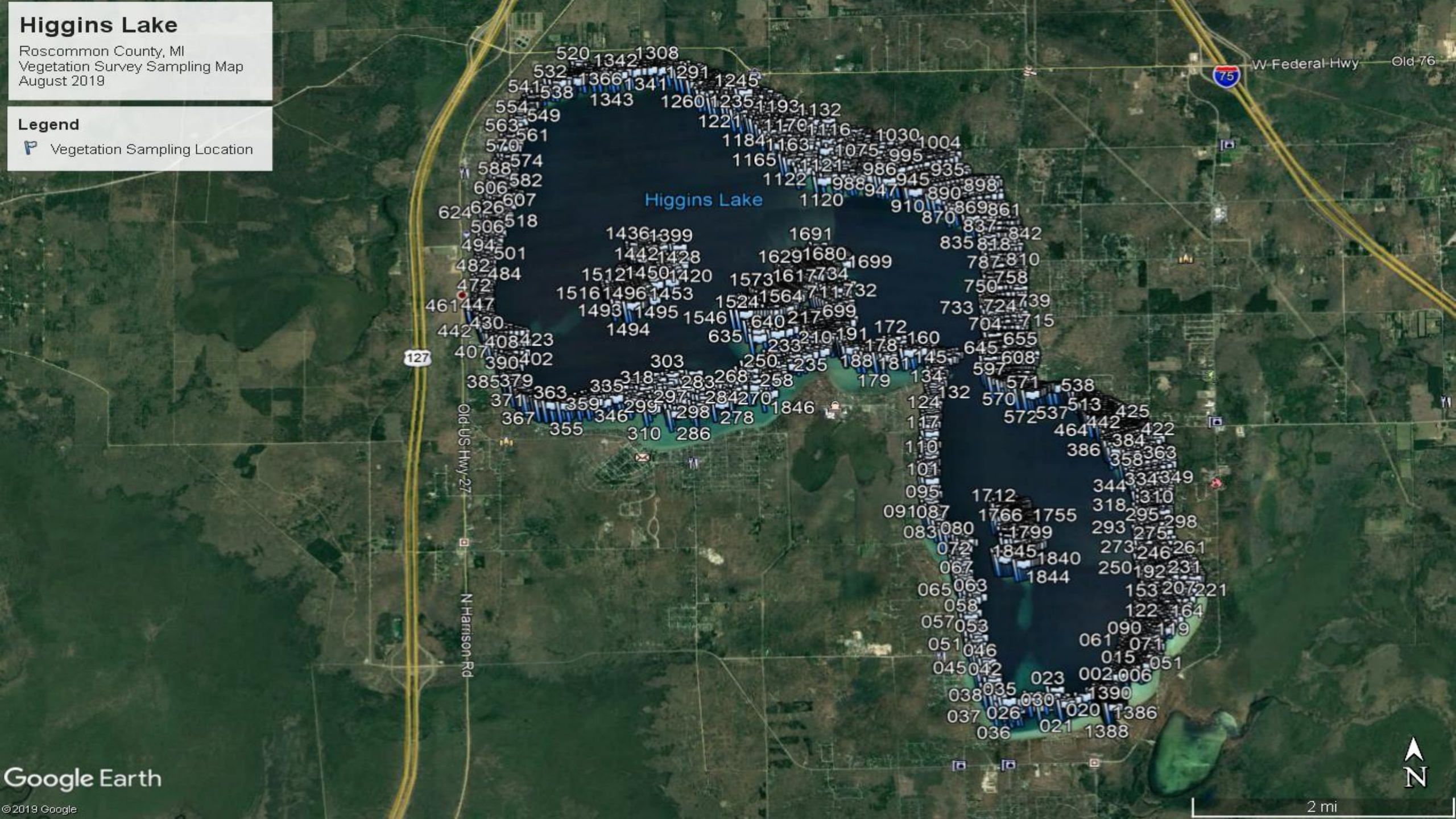
Higgins Lake Aquatic Vegetation

Higgins Lake

Roscommon County, MI
Vegetation Survey Sampling Map
August 2019

Legend

 Vegetation Sampling Location



Invasive Aquatic Plant Species

- ◉ Eurasian Watermilfoil = 21.1 acres
- ◉ Starry Stonewort = 2.5 acres (most in South Lagoon)



Starry Stonewort



Eurasian Watermilfoil



BW

100

Rosco

BL

75

50

BL

75

0

127

Higgins Lake

100

Lyon Township

Higgins Lake

Gerrish
Township

Lyon Manor

s Landing

127

Higgins
Lake State

Lat: 0044.4654680 Lon: -084.7539550

1 miles

1 km

Table 14. Higgins Lake aquatic vegetation biovolume by bottom cover category (relative cover on August 21-23, 2019).

Aquatic Vegetation Biovolume Cover Category	% Relative Cover of Bottom by Category
0-5%	96.0
5-20%	2.8
20-40%	0.3
40-60%	0.1
60-80%	0.1
>80%	0.7

Native Aquatic Plant Species

- ⦿ A total of 20 native aquatic plant species
- ⦿ Quite diverse for a large lake!
- ⦿ 18 submersed and 2 emergent species
- ⦿ Macro alga Chara, most common
- ⦿ Large-leaf and Variable-leaf Pondweed second most common
- ⦿ Emergents include cattails and spike rushes

Table 15. Higgins Lake native aquatic vascular plants (August 21-23, 2019). Note: RLS also found the aquatic moss (*Taxiphyllum* sp.) which is non-vascular.

<i>Native Aquatic Plant Species Name</i>	<i>Native Aquatic Plant Common Name</i>	<i>Higgins Lake Frequency</i>	<i>Native Aquatic Plant Growth Habit</i>
<i>Chara vulgaris</i>	Muskgrass	50.1	Submersed, Rooted
<i>Tolypella</i> sp.	Native Stonewort	0.2	Submersed, Rooted
<i>Stuckenia pectinatus</i>	Sago Pondweed	3.4	Submersed, Rooted
<i>Potamogeton zosteriformis</i>	Flat-stem Pondweed	0.04	Submersed, Rooted
<i>Potamogeton illinoensis</i>	Illinois Pondweed	6.5	Submersed, Rooted
<i>Potamogeton perfoliatus</i>	Clasping-leaf Pondweed	0.3	Submersed, Rooted
<i>Potamogeton richardsonii</i>	Clasping-leaf Pondweed	0.5	Submersed, Rooted
<i>Potamogeton amplifolius</i>	Large-leaf Pondweed	7.5	Submersed, Rooted
<i>Potamogeton gramineus</i>	Variable-leaf Pondweed	7.5	Submersed, Rooted
<i>Potamogeton pusillus</i>	Slender Pondweed	0.7	Submersed, Rooted
<i>Potamogeton foliosus</i>	Leafy Pondweed	0.2	Submersed, Rooted
<i>Potamogeton natans</i>	Floating-leaf Pondweed	0.5	Submersed, Rooted
<i>Potamogeton praelongus</i>	White-stem Pondweed	0.08	Submersed, Rooted
<i>Potamogeton diversifolius</i>	Waterthread Pondweed	0.04	Submersed, Rooted
<i>Myriophyllum sibiricum</i>	Northern Watermilfoil	0.2	Submersed, Rooted
<i>Elodea canadensis</i>	Common Waterweed	1.2	Submersed, Rooted
<i>Vallisneria americana</i>	Wild Celery	2.5	Submersed, Rooted
<i>Najas guadalupensis</i>	Southern Naiad	5.0	Submersed, Rooted
<i>Typha latifolia</i>	Cattails	0.04	Emergent
<i>Eleocharis acicularis</i>	Spikerush	0.04	Emergent

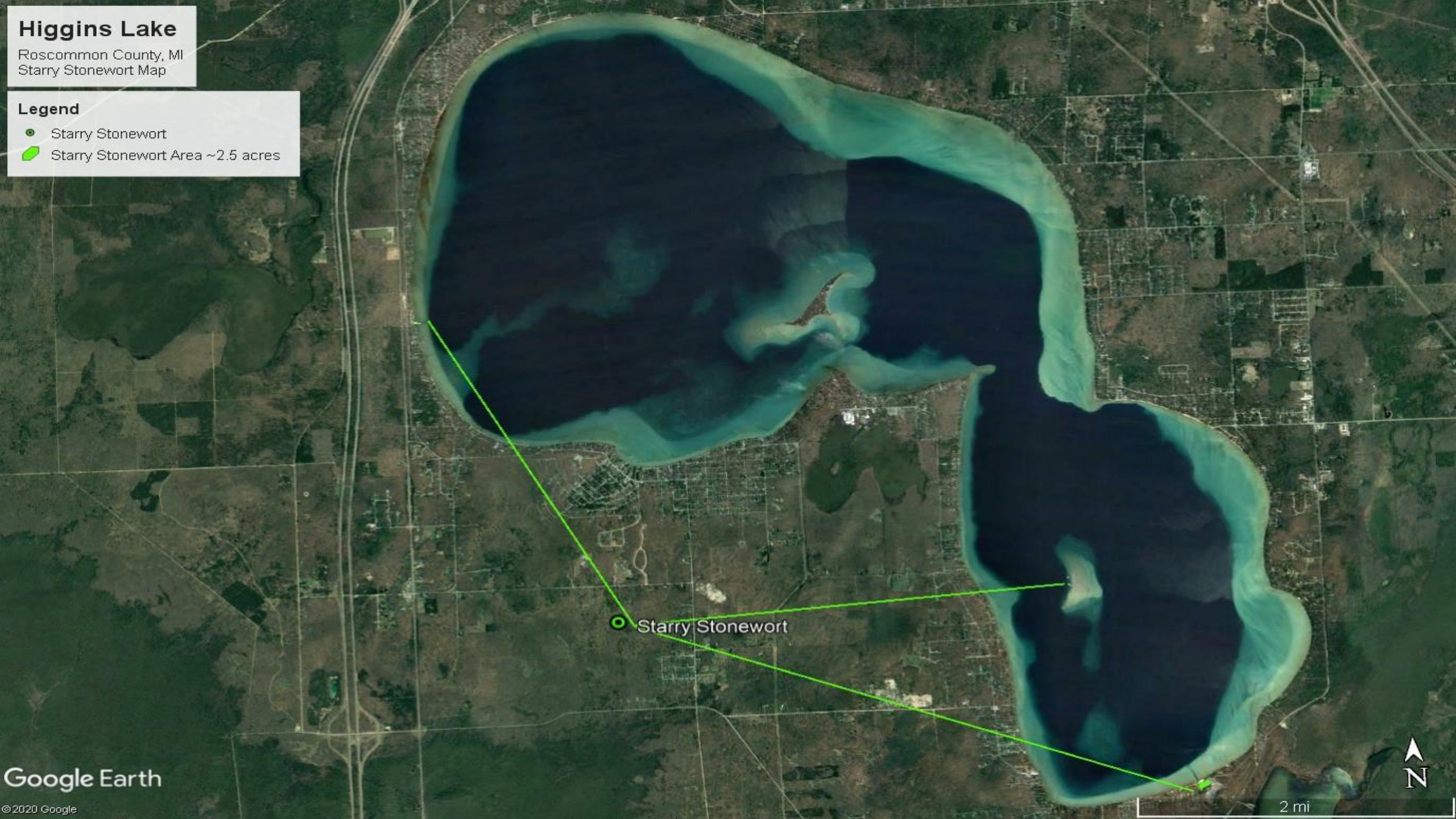
Higgins Lake

Roscommon County, MI
Starry Stonewort Map

Legend

- Starry Stonewort
- Starry Stonewort Area ~2.5 acres

● Starry Stonewort

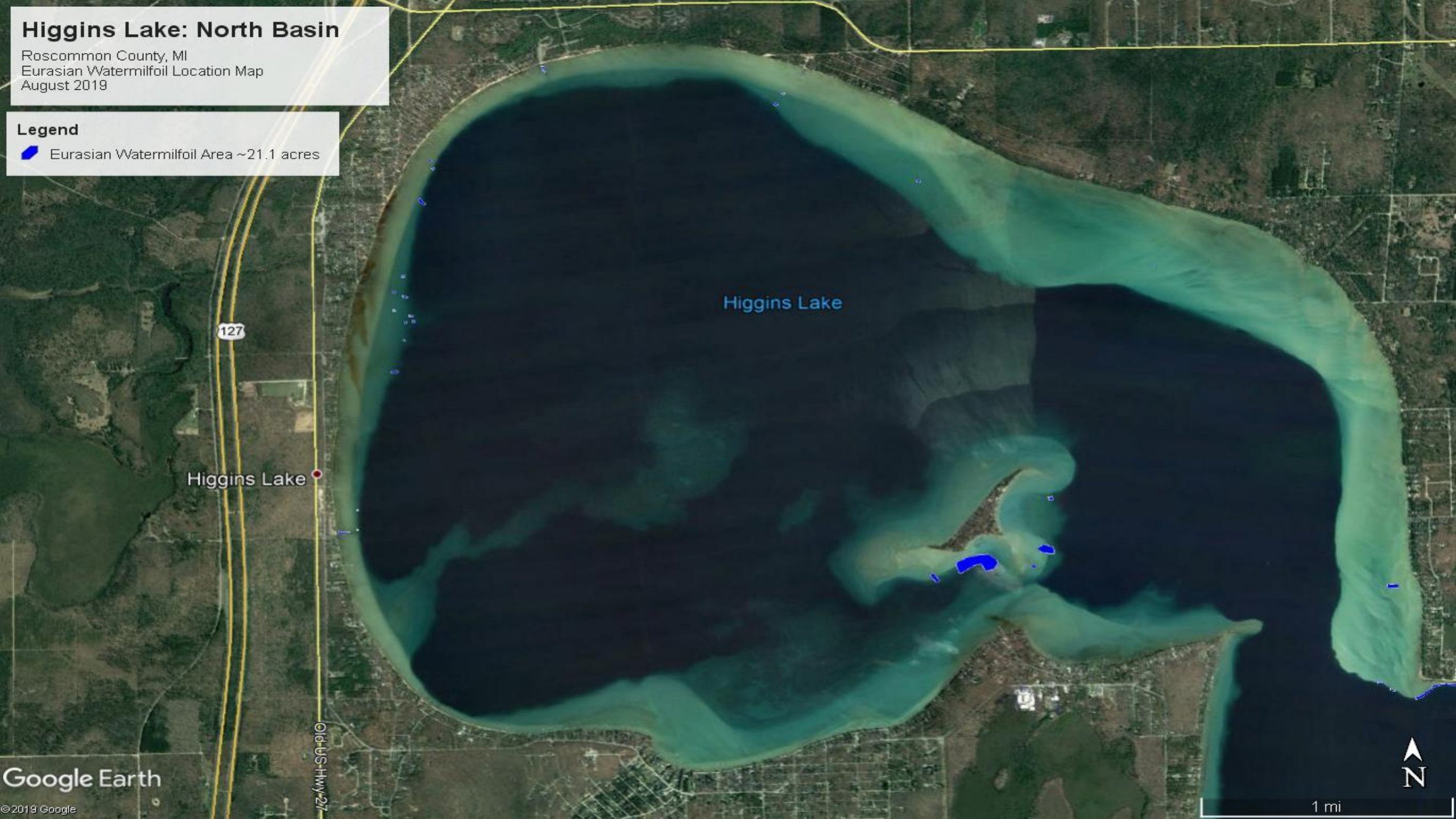


Higgins Lake: North Basin

Roscommon County, MI
Eurasian Watermilfoil Location Map
August 2019

Legend

 Eurasian Watermilfoil Area ~21.1 acres



Higgins Lake: South Basin

Roscommon County, MI
Eurasian Watermilfoil Location Map
August 2019

Legend

 Eurasian Watermilfoil Area ~21.1 acres




Higgins Lake Water Quality

Higgins Lake

Roscommon County, MI
Water Quality Sampling Location Map
August 2019

Legend

 Water Quality Sampling Site



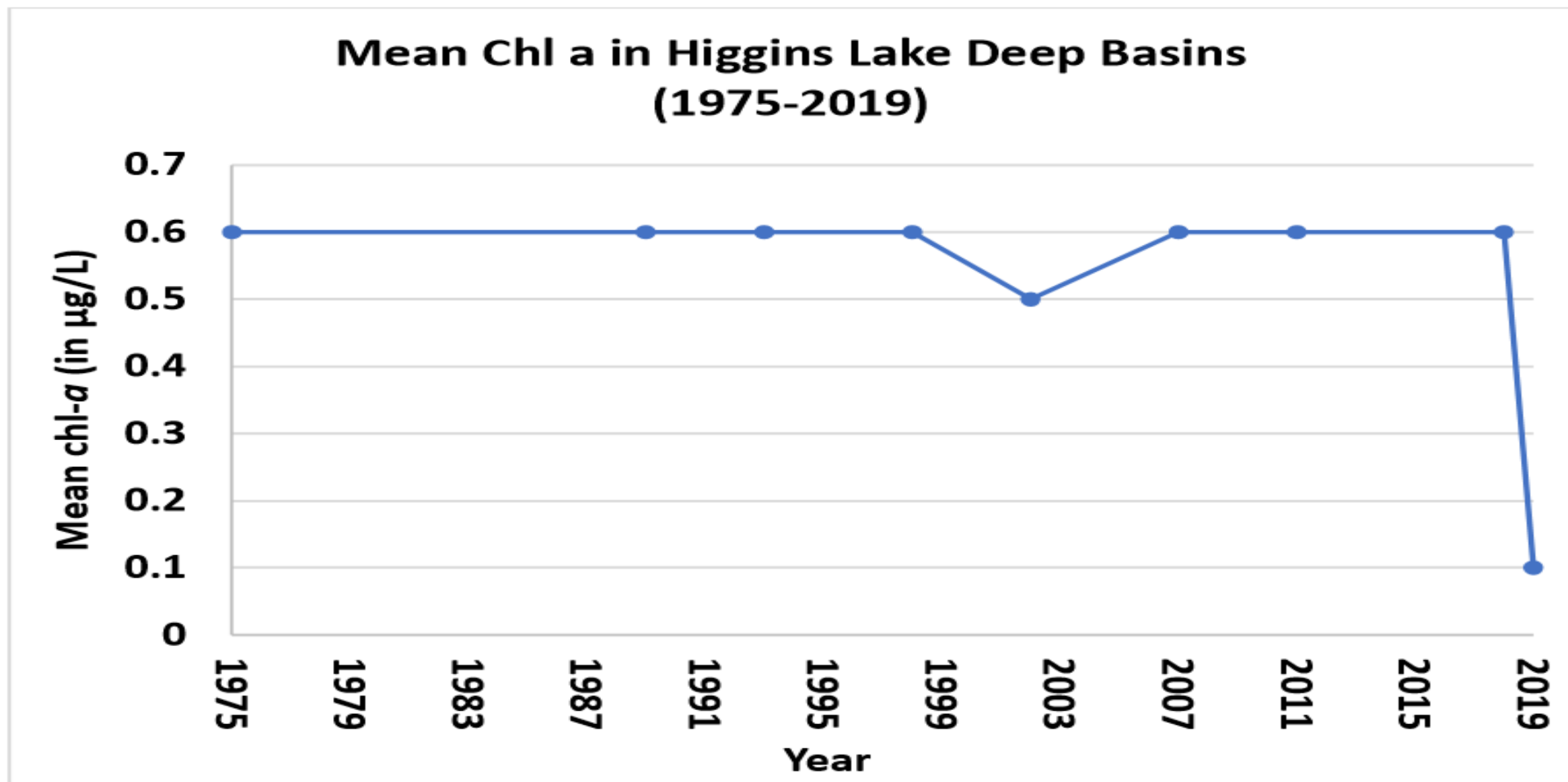


Figure 9. Trends in mean chlorophyll- α with time in Higgins Lake (1975-2019). Data from USEPA (1975), CLMP (2001-2018), and RLS (2019).

Mean Secchi Transparency in Higgins Lake (1975-2019)

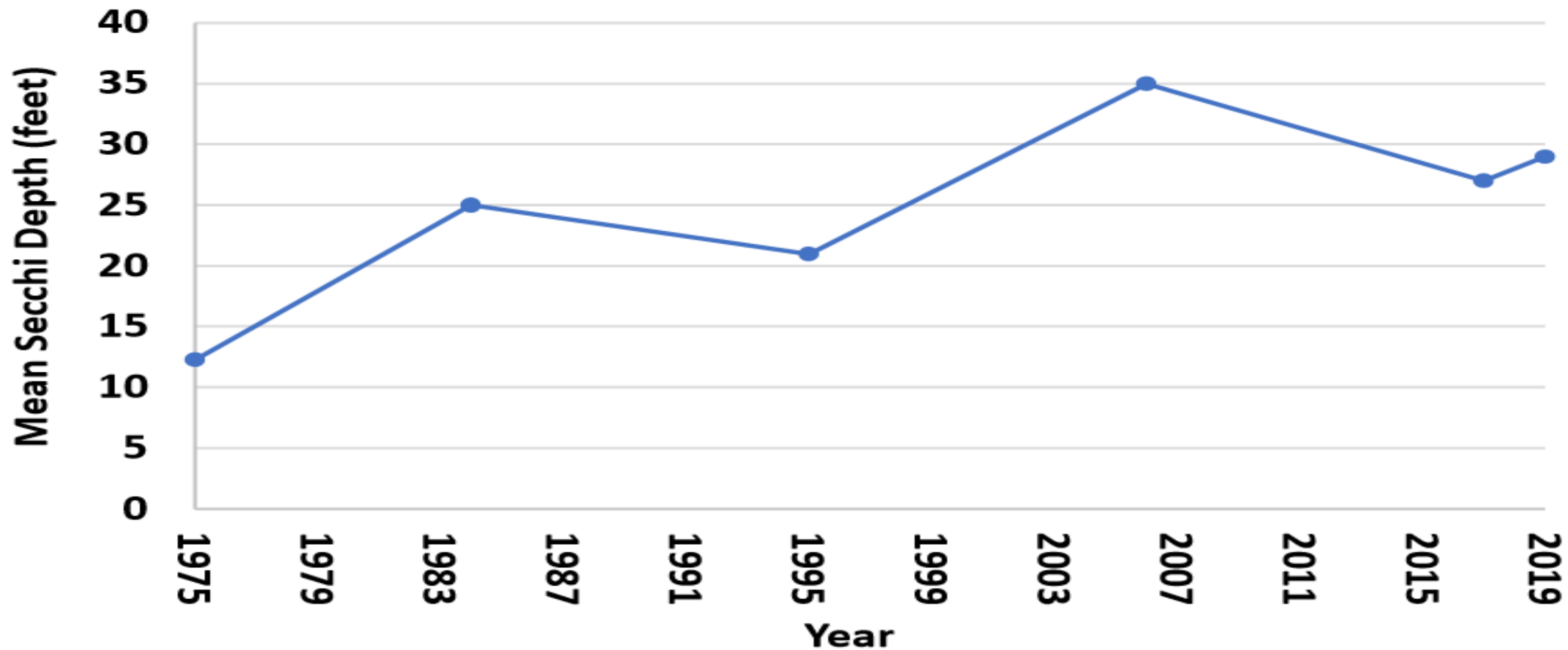


Figure 11. Trends in Secchi transparency with time in Higgins Lake (1975-2019). Data from USEPA (1975), CLMP (2001-2018), and RLS (2019).

Table 4. Higgins Lake physical water quality parameter data collected at deep basin #1 (August 22, 2019).

Depth (ft)	Water Temp (°C)	DO (mg/L)	DO Sat (%)	pH (S.U.)	Conduc. (mS/cm)	TDS (mg/L)	Turb. (NTU)	Secchi Depth (ft)
0	23.0	8.5	103	8.0	266	129	0.4	28.5
50	12.5	11.0	107	8.0	273	136	0.4	
100	8.9	3.0	25.2	7.6	295	147	0.5	

Table 5. Higgins Lake chemical water quality parameter data collected at deep basin #1 (August 22, 2019).

Depth (m)	TKN (mg/L)	TIN (mg/L)	TP (mg/L)	Ortho-P (mg/L)	NH3 (mg/L)	NO2- (mg/L)	NO3- (mg/L)	TSS (mg/L)	Chl-a (µg/L)	Talk (mg/L)
0	0.50	<0.010	<0.010	<0.010	<0.010	<0.10	<0.10	--	0.411	98
50	<0.50	<0.010	<0.010	<0.010	<0.010	<0.10	<0.10	--	--	91
100	<0.50	<0.010	0.011	<0.010	<0.010	<0.10	<0.10	14	--	100

Table 6. Higgins Lake physical water quality parameter data collected at deep basin #2 (August 22, 2019).

Depth (m)	Water Temp (°C)	DO (mg/L)	DO Sat (%)	pH (S.U.)	Conduc. (mS/cm)	TDS (mg/L)	Turb. (NTU)	Secchi Depth (ft)
0	23.1	8.5	103	8.1	266	129	0.4	29.0
50	12.2	11.0	106	8.0	275	137	0.4	
100	8.8	2.9	25.1	7.5	297	147	0.7	

Table 7. Higgins Lake chemical water quality parameter data collected at deep basin #2 (August 22, 2019).

Depth (m)	TKN (mg/L)	TIN (mg/L)	TP (mg/L)	Ortho-P (mg/L)	NH3 (mg/L)	NO2- (mg/L)	NO3- (mg/L)	TSS (mg/L)	Chl-a (µg/L)	Talk (mg/L)
0	<0.50	<0.010	<0.010	<0.010	<0.010	<0.10	<0.10	20	0	91
50	<0.50	<0.010	<0.010	<0.010	<0.010	<0.10	<0.10	--	--	86
100	<0.50	0.031	0.028	<0.010	0.031	<0.10	<0.10	<10	--	110

Table 8. Higgins Lake physical water quality parameter data collected at deep basin #3 (August 22, 2019).

Depth (m)	Water Temp (°C)	DO (mg/L)	DO Sat (%)	pH (S.U.)	Conduc. (mS/cm)	TDS (mg/L)	Turb. (NTU)	Secchi Depth (ft)
0	23.0	8.8	103	8.2	264	128	0.3	29.0
67	10.5	10.4	104	8.0	279	140	0.5	
135	6.8	2.5	23.5	7.7	308	150	1.4	

Table 9. Higgins Lake chemical water quality parameter data collected at deep basin #3 (August 22, 2019).

Depth (m)	TKN (mg/L)	TIN (mg/L)	TP (mg/L)	Ortho-P (mg/L)	NH3 (mg/L)	NO2- (mg/L)	NO3- (mg/L)	TSS (mg/L)	Chl-a (µg/L)	Talk (mg/L)
0	<0.50	<0.010	<0.010	<0.010	<0.010	<0.10	<0.10	--	0	99
67	<0.50	<0.010	<0.010	<0.010	<0.010	<0.10	<0.10	--	--	97
135	<0.50	0.019	0.011	<0.010	0.019	<0.10	<0.10	16	--	120

Table 10. Higgins Lake physical water quality parameter data collected at deep basin #4 (August 22, 2019).

Depth (m)	Water Temp (°C)	DO (mg/L)	pH (S.U.)	Conduc. (mS/cm)	TDS (mg/L)	Turb. (NTU)	Secchi Depth (ft)
0	23.0	8.7	8.1	266	128	0.3	29.5
53	12.1	9.7	8.1	274	136	0.5	
106	8.7	3.4	7.8	299	147	0.9	

Table 11. Higgins Lake chemical water quality parameter data collected at deep basin #4 (August 22, 2019).

Depth (m)	TKN (mg/L)	TIN (mg/L)	TP (mg/L)	Ortho-P (mg/L)	NH3 (mg/L)	NO2- (mg/L)	NO3- (mg/L)	TSS (mg/L)	Chl-a (µg/L)	Talk (mg/L)
0	<0.50	<0.010	<0.010	<0.010	<0.010	<0.10	<0.10	--	0	92
53	<0.50	<0.010	0.043	<0.010	<0.010	<0.10	<0.10	--	--	97
106	<0.010	<0.010	<0.010	<0.010	<0.010	<0.10	<0.10	20	--	140

Table 12. Higgins Lake physical water quality parameter data collected at deep basin #5 (August 22, 2019).

Depth (m)	Water Temp (°C)	DO (mg/L)	pH (S.U.)	Conduc. (mS/cm)	TDS (mg/L)	Turb. (NTU)	Secchi Depth (ft)
0	22.1	9.5	8.0	266	129	0.4	29.5
43	14.0	9.8	7.8	273	135	0.4	
87	7.9	4.9	7.6	276	138	0.6	

Table 13. Higgins Lake chemical water quality parameter data collected at deep basin #5 (August 22, 2019).

Depth (m)	TKN (mg/L)	TIN (mg/L)	TP (mg/L)	Ortho-P (mg/L)	NH3 (mg/L)	NO2- (mg/L)	NO3- (mg/L)	TSS (mg/L)	Chl-a (µg/L)	Talk (mg/L)
0	<0.50	<0.010	<0.010	<0.010	<0.010	<0.10	<0.10	--	0	89
43	<0.50	<0.010	<0.010	<0.010	<0.010	<0.10	<0.10	--	--	83
87	<0.50	<0.010	<0.010	<0.010	<0.010	<0.10	<0.10	--	--	89



Higgins Lake Aquatic Biota

Table 18. Zooplankton taxa and count data from Higgins Lake Deep Basin #1 (August 21-23, 2019).

Cladocerans	Count	Copepods	Count	Rotifers	Count
<i>Daphnia longiremis</i>	23	<i>Cyclops sp.</i>	12	<i>Keratella sp.</i>	9
<i>Leptodiptomus sp.</i>	20	<i>Mesocyclops edax</i>	63		
<i>Bosmina sp.</i>	9	<i>Acanthocyclops sp.</i>	8		
<i>Ceriodaphnia sp.</i>	9	<i>Nauplius (var)</i>	7		
<i>Diaphanosoma sp.</i>	14				

Table 19. Zooplankton taxa and count data from Higgins Lake Deep Basin #2 (August 21-23, 2019).

Cladocerans	Count	Copepods	Count	Rotifers	Count
<i>Daphnia longiremis</i>	25	<i>Cyclops sp.</i>	15	<i>Keratella sp.</i>	4
<i>Leptodiptomus sp.</i>	6	<i>Mesocyclops edax</i>	35		
<i>Bosmina sp.</i>	22	<i>Acanthocyclops sp.</i>	0		
<i>Ceriodaphnia sp.</i>	11	<i>Nauplius (var)</i>	9		
<i>Diaphanosoma sp.</i>	7				

Table 20. Zooplankton taxa and count data from Higgins Lake Deep Basin #3 (August 21-23, 2019).

Cladocerans	Count	Copepods	Count	Rotifers	Count
<i>Daphnia longiremis</i>	12	<i>Cyclops sp.</i>	17	--	--
<i>Leptodiptomus sp.</i>	0	<i>Mesocyclops edax</i>	33		
<i>Bosmina sp.</i>	31	<i>Acanthocyclops sp.</i>	1		
<i>Ceriodaphnia sp.</i>	5	<i>Nauplius (var)</i>	7		
<i>Diaphanosoma sp.</i>	2				

Table 21. Zooplankton taxa and count data from Higgins Lake Deep Basin #4 (August 21-23, 2019).

Cladocerans	Count	Copepods	Count	Rotifers	Count
<i>Daphnia longiremis</i>	8	<i>Cyclops sp.</i>	12	--	--
<i>Leptodiptomus sp.</i>	13	<i>Mesocyclops edax</i>	13		
<i>Bosmina sp.</i>	39	<i>Acanthocyclops sp.</i>	5		
<i>Ceriodaphnia sp.</i>	8	<i>Nauplius (var)</i>	16		
<i>Diaphanosoma sp.</i>	0				

Table 22. Zooplankton taxa and count data from Higgins Lake Deep Basin #5 (August 21-23, 2019).

Cladocerans	Count	Copepods	Count	Rotifers	Count
<i>Daphnia longiremis</i>	2	<i>Cyclops</i> sp.	19	<i>Keratella</i> sp.	1
<i>Leptodiptomus</i> sp.	5	<i>Mesocyclops edax</i>	13		
<i>Bosmina</i> sp.	37	<i>Acanthocyclops</i> sp.	2		
<i>Ceriodaphnia</i> sp.	13	<i>Nauplius</i> (var)	6		
<i>Diaphanosoma</i> sp.	4				

Table 23. Macroinvertebrates found in Higgins Lake, Roscommon County, MI (August 21-23, 2019).

Site S1	Family	Genus or Species	Number	Common name
	Chironimidae	<i>Chironomus</i> spp.	2	Midges
	Planorbidae	<i>Planorbis</i> sp.	3	Wheel snails
	Dreissenidae	<i>Dreissena polymorpha</i>	3	Zebra mussels
	Dreissenidae	<i>Dreissena bugensis</i>	1	Quagga mussels
	Lymnaeidae	<i>Lymnaea</i> sp.	7	Right-handed snail
	Physidae	<i>Physa</i> spp.	6	Left-handed snail
	Viviparidae	<i>Vivaparus mallaetus</i>	1	Chinese mystery snail
	Viviparidae	<i>Vivaparus gorgianus</i>	1	Banded Mystery snail
		Total	15	
Site S2	Family	Genus	Number	Common name
	Planorbidae	<i>Planorbis</i> sp.	9	Wheel snails
	Chironomidae	<i>Chironomus</i> spp.	12	Midges
	Dreissenidae	<i>Dreissena polymorpha</i>	3	Zebra mussels
	Lymnaeidae	<i>Lymnaea</i> sp.	4	Right-handed snail
	Physidae	<i>Physa</i> spp.	5	Left-handed snail
		Total	9	
Site S3	Family	Genus	Number	Common name
	Pleuroceridae	<i>Pachychilus</i> sp.	1	Jute snails
	Planorbidae	<i>Planorbis</i> sp.	6	Wheel snails
	Perlidae	<i>Capnia</i> sp.	2	Stonefly larvae
	Cyrenidae	<i>Corbicula fluminea</i>	1	Asian clam
		Total	7	
Site S4	Family	Genus	Number	Common name
	Pleuroceridae	<i>Pachychilus</i> sp.	1	Jute snails
	Chironomidae	<i>Chironomus</i> sp.	6	Midges
	Dreissenidae	<i>Dreissena polymorpha</i>	1	Zebra mussels
	Perlidae	<i>Capnia</i> sp.	1	Stonefly larvae
		Total	7	
Site S5	Family	Genus	Number	Common name
	Chironomidae	<i>Chironomus</i> spp.	4	Midge
	Planorbidae	<i>Planorbis</i> sp.	2	Wheel snails
	Dreissenidae	<i>Dressena bugensis</i>	1	Quagga mussels
		Total	6	

Table 24. Fish stocking history in Higgins Lake (MDNR; 1979-2019).

Year	Fish Stocked	# Fish Stocked	Average Length Range (inches)
1979	Lake Trout; Brown Trout	50,000;17,000	4.9;6.7
1980	Lake Trout; Brown Trout	50,000;25,000	4.9;6.9
1981	Lake Trout; Splake; Brown Trout	25,000; 22,000;25,000	5.2; 5.7-6.1;5.1-7.2
1982	Splake; Lake Trout; Brown Trout; Atlantic Salmon	25,000; 25,000;20,000;1,629	7.2- 7.4;5.5;6.7;4.5
1983	Splake; Brown Trout	50,000;26,900	5.7-6.3;5.2
1984	Lake Trout	125,798	3.2-29.7
1985	Splake; Lake Trout; Brown Trout	25,000; 25,000;20,330	5.2;5.2;6.3
1986	Rainbow Trout; Brown Trout	8,000;4,600	6.9;7.1
1987	Lake Trout; Brown Trout	1,550;17,672	7.4-20.9;6.7-7.2
1991	Rainbow Trout; Lake Trout; Brown Trout	7,055; 34,900; 65,000	6.7; 5.2;5.8-6.7
1995	Rainbow Trout	81,644	2.9
2006	Rainbow Trout	2,000	7.7
2008	Rainbow Trout	27,400	6.3-7.0
2009	Rainbow Trout	32,300	6.7
2010	Rainbow Trout; Brown Trout	25,528;12,008	5.9;4.0-5.1
2011	Rainbow Trout; Brown Trout	25,900;15,000	5.8-6.4;4.0
2012	Rainbow Trout; Lake Trout	30,000;40,000	6.9;6.0
2013	Rainbow Trout; Lake Trout	30,498;45,000	7.1;4.9-5.5
2014	Rainbow Trout; Lake Trout	31,000;39,388	6.8;5.6
2015	Rainbow Trout; Lake Trout	31,000;31,300	6.1-6.5;5.4
2016	Rainbow Trout; Lake Trout	30,000;35,944	6.5;5.9-6.5
2017	Rainbow Trout; Lake Trout	40,377;40,158	6.1-6.2;5.6
2018	Rainbow Trout; Lake Trout; Brown Trout	60,000;40,500;25,000	3.4-7.1;5.0;7.2
2019	Rainbow Trout; Lake Trout; Brown Trout	27,500;31,973;25,000	7.2;5.3;7.4



Higgins Lake Management & Improvement Recommendations

Recommended Future Actions

- ⦿ Pursue lake-wide sewer system
- ⦿ Inventory specific erosion sites and develop site-specific mitigation options
- ⦿ Continue regular (annual) lake vegetation surveys
- ⦿ Continue regular (seasonal) water quality sampling of lake deep basins and algal population (offshore and nearshore)
- ⦿ Consider a lake-wide workshop to educate riparians and lake users

Table 27. List of Higgins Lake proposed improvement methods with primary and secondary goals and locations for implementation.

Proposed Improvement Method	Primary Goal	Secondary Goal	Where to Implement
Installation of lake-wide sewer	To reduce nutrients inputs from septic systems	To improve nearshore water quality parameters	Lake-wide
DASH boat removal of invasive milfoil and Starry Stonewort in lake and Lagoon	Remove invasives in lake and Lagoon at South State Park	Use in place of aquatic herbicides	Entire lake where invasives present
Bi-annual water quality monitoring of lake and drains	Monitor lake health over time	Use long-term and current data to drive management decisions relative to BMP's	Lake deep basins and major tributaries
Development of Early Detection Rapid Response Protocol for new invasives	Generate a clear strategy for dealing with new invasives that may be found in the lake	Allow for less long-term spread of any new invasives with early detection	Entire lake
Boat launch washing stations	To reduce entry of invasives into Higgins Lake	To reduce exit of invasives from Higgins Lake	At ALL public access sites noted in this report.
Swimmer's Itch control with continued merganser population control	Reduce presence of parasite from mergansers	Reduce merganser population which also reduces nutrients and bacteria in lake	Entire lake
Annual lake surveys pre- and post-treatment	To determine efficacy of DASH treatments on invasives	To determine ability of native aquatic vegetation biodiversity to recover post-management implementation	Entire lake

Shoreline Erosion Inventory	To determine individual properties that need shoreline erosion stabilization practices	Reduce associated solids and nutrients that enter lake	Lake-wide; Entire shoreline
Riparian/Community Education	To raise awareness of lake issues and empower all to participate in lake protection	Long-term sustainability requires ongoing awareness and action	Entire lake community and those who frequent the lake; may also include relevant MDNR and other stakeholders

Table 28. Higgins Lake proposed lake management program costs. NOTE: All items are estimates only and are likely to change based on acquisition of formal quotes from qualified vendors.

Proposed Higgins Lake Improvement Item	Estimated Annual Costs
Professional services (limnologist management of lake, aquatic vegetation surveys, DASH oversight, education) ⁴	\$33,000
Boat washing stations	~\$20,000 per site
DASH boat removal of current invasive EWM and SS	~\$50,000
Early Detection Rapid Response Protocol Guide	~\$7,000
Continued water quality sampling of lake deep basins and 3 major tributaries	~\$15,000
Continued Swimmer's Itch Control	~\$10,000
Contingency ⁵	\$13,500
Total Annual Estimated Cost	\$148,500