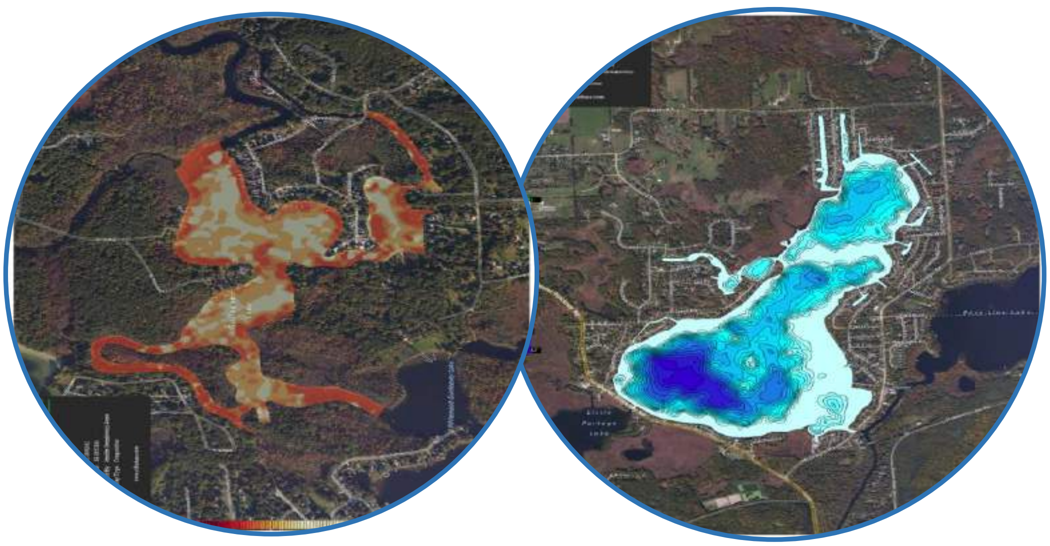
PBWOA Lakes Aquatic Vegetation Management Recommendations & Lakes Health Study Livingston and Washtenaw Counties, Michigan September, 2015



Provided for: Portage, Base, and Whitewood, Owner's Association (PBWOA), Inc.

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DISCLAIMER: THE ACRONYM "PBWOA" USED THROUGHOUT THIS DOCUMENT REFERS TO THE CHAIN OF LAKES IN THIS STUDY ALONG WITH THE INTERCONNECTING CANALS AND THE SECTIONS OF HURON RIVER.

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September, 2015

1.0 EXECUTIVE SUMMARY

The PBWOA lakes are a unique set of interconnected inland lakes that share the Huron River and therefore lie within the Huron River watershed. The current study evaluates the water quality, aquatic vegetation, lake bathymetry, and shoreline soils of nearly 1,659 acres of the following lakes: Zukey, Strawberry, Gallagher, Little Portage, Big Portage, Baseline, Whitewood, Tamarack, and the connecting canals and Huron River. In March of 2015, the Portage, Base, and Whitewood Owner's Association (PBWOA), Inc. retained Restorative Lake Sciences to evaluate the overall baseline health of these lakes and prepare a written report with aquatic vegetation and general water quality management recommendations.

The PBWOA lakes range in surface area from 19-655 acres with Tamarack Lake being the smallest and Big Portage Lake the largest. Big Portage Lake also has the longest shoreline distance of 11.9 miles whereas Tamarack Lake has the shortest at 1.3 miles. The watershed size also differed greatly among the lakes from the smallest (56.2 acres) with Tamarack Lake to the largest (264,695 acres) for Baseline Lake. This is because there is significantly more river area draining into Baseline Lake than into Tamarack Lake. Interestingly though, the lake with the highest watershed to lake ratio were the Whitewood Lakes with a ratio of 3,446:1 which is very high and makes the lakes quite vulnerable to pollution and nutrient inputs.

All of the PBWOA lakes are classified as eutrophic lakes which means that they contain high nutrients, algae, and weed growth, but also possess good water clarity. Zukey Lake is the only exception with low nutrients, low weed growth, and good water clarity. There are 61 major soil types immediately surrounding the shorelines of the PBWOA lakes; however only the Houghton and Carlisle Mucks present threats to water quality through ponding of the soils during heavy rains along with areas that contain high slopes (> 12%) that may lack vegetation and may be prone to soil erosion along the shorelines.

There are 5 invasive submersed and emergent aquatic plant species in and around the PBWOA lakes that are recommended for management with selective aquatic herbicides since they are an imminent threat to the PBWOA lakes ecosystems. There are approximately 66.1 combined acres of invasive watermilfoil and 92 combined acres of starry stonewort in the PBWOA lakes that threaten the 18-26 native aquatic plant species found in the PBWOA lakes. If not addressed soon, these invasives will reduce native biodiversity, will threaten navigation and recreation, and may also decrease waterfront property values.

2.0 LAKE ECOLOGY BACKGROUND INFORMATION

2.1 Introductory Concepts and Information

Limnology is a multi-disciplinary field which involves the study of the biological, chemical, and physical properties of freshwater ecosystems. A basic knowledge of these processes is necessary to understand the complexities involved and how management techniques are applicable to current lake issues. The following terms will provide the reader with a more thorough understanding of the forthcoming lake management recommendations for the PBWOA lakes.

2.1.1 Lake and River Hydrology

Aquatic ecosystems include rivers, streams, ponds, lakes, and the Laurentian Great Lakes. There are thousands of lakes in the state of Michigan and each possesses unique ecological functions and socio-economic contributions (O'Neil and Soulliere 2006). In general, lakes are divided into four categories:

- Seepage Lakes,
- Drainage Lakes,
- Spring-Fed Lakes, and
- Drained Lakes.

Some lakes (seepage lakes) contain closed basins and lack inlets and outlets, relying solely on precipitation or groundwater for a water source. **Seepage lakes** generally have small watersheds with long hydraulic retention times which render them sensitive to pollutants. **Drainage lakes receive significant water quantities from tributaries and rivers. Drainage lakes contain at least one inlet and an outlet and generally are confined within larger watersheds with shorter hydraulic retention times. As a result, they are less susceptible to pollution. Spring-fed lakes rarely contain an inlet but always have an outlet with considerable flow.** The majority of water in this lake type originates from groundwater and is associated with a short hydraulic retention time. Drained lakes are similar to seepage lakes, yet rarely contain an inlet and have a low-flow outlet. The groundwater and seepage from surrounding wetlands supply the majority of water to this lake type and the hydraulic retention times are rather high, making these lakes relatively more vulnerable to pollutants. The water quality of a lake may thus be influenced by the quality of both groundwater and precipitation, along with other internal and external physical, chemical, and biological processes. **The majority of the PBWOA lakes may be categorized as spring-fed drainage lakes as many contain springs but also receive inflows from the Huron River through connecting canals that are a part of the Huron River system.**

2.1.2 Biodiversity and Habitat Health

A healthy aquatic ecosystem possesses a variety and abundance of niches (environmental habitats) available for all of its inhabitants. The distribution and abundance of preferable habitat depends on limiting our influence from development, while preserving sensitive or rare habitats. As a result of this, **undisturbed or protected areas generally contain a greater number of biological species and are considered more diverse.** A highly diverse aquatic ecosystem is preferred over one with less diversity because it allows a particular ecosystem to possess a greater number of functions and contribute to both the intrinsic and socio-economic values of each lake. Healthy lakes have a greater biodiversity of aquatic macroinvertebrates, aquatic macrophytes (plants), fishes, phytoplankton, and may possess a plentiful yet beneficial benthic microbial community (Wetzel, 2001).

2.1.3 Watersheds and Land Use

A **watershed** is defined as an area of land that drains to a common point and is influenced by both surface water and groundwater resources that are often impacted by land use activities. **In general, larger watersheds possess more opportunities for pollutants to enter the eco-system, altering the water quality and ecological communities.** In addition, watersheds that contain abundant development and industrial sites are more vulnerable to water quality degradation since from pollution which may negatively affect both surface and ground water. Since many inland lakes in Michigan are relatively small in size (i.e. less than 300 acres), they are inherently vulnerable to nutrient and pollutant inputs, due to the reduced water volumes and small surface areas. As a result, the living (biotic) components of the smaller lakes (i.e. fishery, aquatic plants, macro-invertebrates, benthic organisms, etc.) are highly sensitive to changes in water quality from watershed influences**. Land use activities** have a dramatic impact on the quality of surface waters and groundwater.

In addition, the **topography of the land** surrounding a lake may make it vulnerable to nutrient inputs and consequential loading over time. Topography and the morphometry of a lake dictate the ultimate fate and transport of pollutants and nutrients entering the lake. **Surface runoff** from the steep slopes surrounding a lake will enter a lake more readily than runoff from land surfaces at or near the same grade as the lake. In addition, lakes with steep drop-offs may act as collection basins for the substances that are transported to the lake from the land.

Land use activities, such as residential land use, industrial land use, agricultural land use, water supply land use, wastewater treatment land use, and storm water management, can influence the watershed of a particular lake. All land uses contribute to the water quality of the lake through the influx of **pollutants from non-point sources or from point sources. Non-point sources** are often diffuse and arise when climatic events carry pollutants from the land into the lake. **Point-source pollutants** are discharged from a pipe or input device and empty directly into a lake or watercourse.

Residential land use activities involve the use of lawn fertilizers on lakefront lawns, the utilization of septic tank systems for treatment of residential sewage, the construction of impervious (impermeable, hard-surfaced) surfaces on lands within the watershed, the burning of leaves near the lakeshore, the dumping of leaves or other pollutants into storm drains, and removal of vegetation from the land and near the water. In addition to residential land use activities, agricultural practices by vegetable crop and cattle farmers may contribute nutrient loads to lakes and streams. Industrial land use activities may include possible contamination of groundwater through discharges of chemical pollutants.

3.0 PBWOA LAKES PHYSICAL AND WATERSHED CHARACTERISTICS

3.1 The PBWOA Lakes Basins

The PBWOA Lakes (shown collectively in Figure 1) are located in the following areas and have the associated characteristics displayed in Table 1:

Figure 1. Aerial view of the PBWOA lakes in Livingston and Washtenaw Counties, Michigan.

PBWOA Lake Name	Surface Area (acres)	Shoreline Perimeter (miles)	Watershed Area (acres)	Watershed: Lake Ratio
Zukey (Hamburg Township) Livingston County T.1N, R.5E, Sec. 21,22,27,28	152	3.5	1,657	10.9:1
Strawberry (Hamburg Township) Livingston County T.1N, R.5E, Sec. 27,28	253	3.9	229,426	907:1
Gallagher/Loon Lakes (Hamburg Township) Livingston County T.1N, R.5E, Sec. 28,32,33	96.4	5.3	249,156	2,585:1
Little Portage Lake (Dexter Township) Washtenaw County T.1S, R.4E, Sec. 2,11	95.5	2.7	56,895	596:1
Big Portage Lake (Dexter Township) Washtenaw County T.1S, R.4E, Sec. 1,2;(Putnam Township) Livingston County T.1N, R.4E, Sec. 25,36;(Hamburg Township), Livingston County T.1N, R.5E, Sec 31	655	11.9	77,093	118:1
Baseline Lake (Webster Township) Washtenaw County T.1S,R.5E Sec.5,6;(Hamburg Township) Livingston County T.1N, R.5E, Sec. 31,32	255	3.2	264,695	1,038:1
Whitewood Lakes (Hamburg Township) Livingston County T.1N, R.5E, Sec. 32	72.5	3.0	249,845	3,446:1
Tamarack Lake (Hamburg Township) Livingston County T.1N, R.5E, Sec. 31,32	19	1.3	56.2	3:1

Table 1. PBWOA lakes and watersheds physical characteristics (RLS, 2015).

Summary of the PBWOA Lakes Physical Characteristics:

The PBWOA lakes range in surface area from 19-655 acres with Tamarack Lake being the smallest and Big Portage Lake the largest. Big Portage Lake also has the longest shoreline distance of 11.9 miles whereas Tamarack Lake has the shortest at 1.3 miles. The watershed size also differed greatly among the lakes from the smallest (56.2 acres) with Tamarack Lake to the largest (264,695 acres) for Baseline Lake. This is because there is significantly more river area draining into Baseline Lake than into Tamarack Lake. Interestingly though, the lake with the highest watershed to lake ratio were the Whitewood Lakes with a ratio of 3,446:1 which is very high and makes the lakes quite vulnerable to pollution and nutrient inputs. **Modernized depth contour maps of each lake and canals are shown in Figures 2-9 below. In order to obtain these maps, scientists at RLS had to scan the entire bottom of each lake and canal in order to account for all bottom areas. Note that the deepest areas are denoted by the deepest shade of blue and the shallowest areas in each lake are represented by the lightest shade of blue on all of the maps. The depth legend at the left of each map marks the maximum depth recorded on each lake during the depth scan.**

All lake scans were recorded using a Lowrance® HDS® 9 GPS unit with a 83-200 kHz transducer and GIS-based BIOBASE® software to produce aquatic vegetation and bottom contour maps. Some of the PBWOA lakes were scanned on June 22-23, 2015 and some were scanned on August 6, 2015. Individual scanning dates are listed on the individual lake maps.

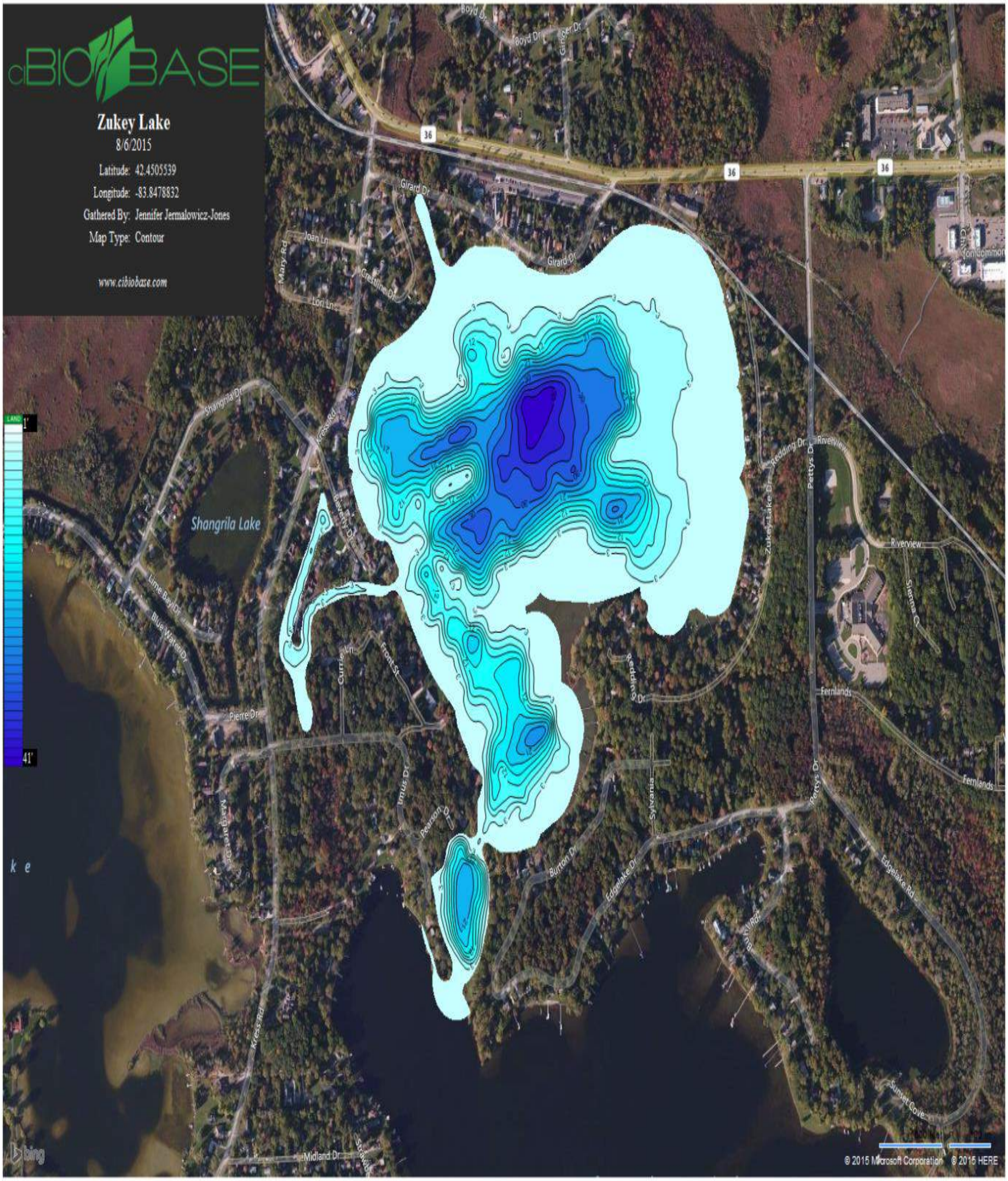

Figure 2. Modernized depth contour map of Zukey Lake, Livingston County, MI.

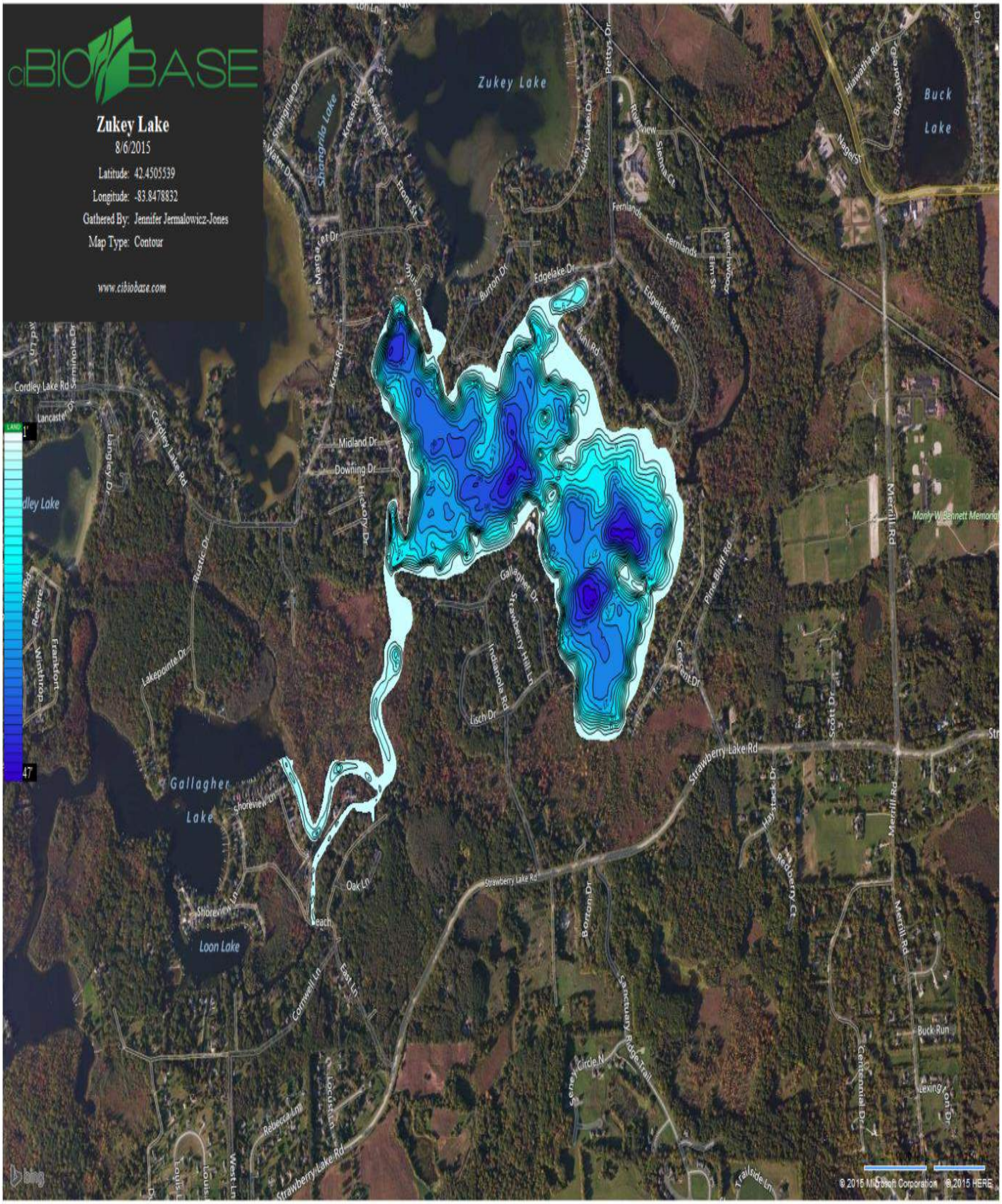

Figure 3. Modernized depth contour map of Strawberry Lake, Livingston County, MI.

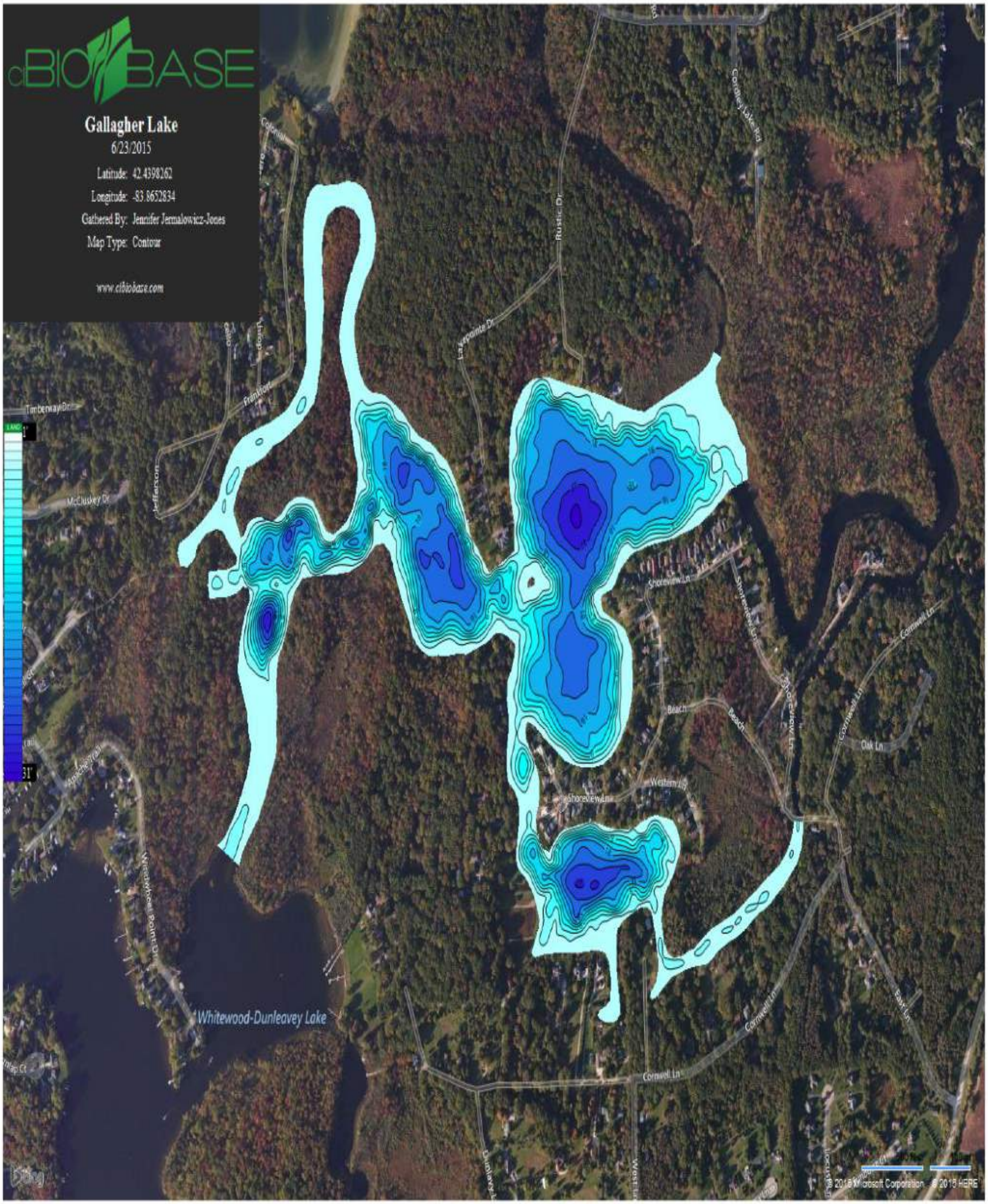

Figure 4. Modernized depth contour map of Gallagher and Loon Lakes, Livingston County, MI.

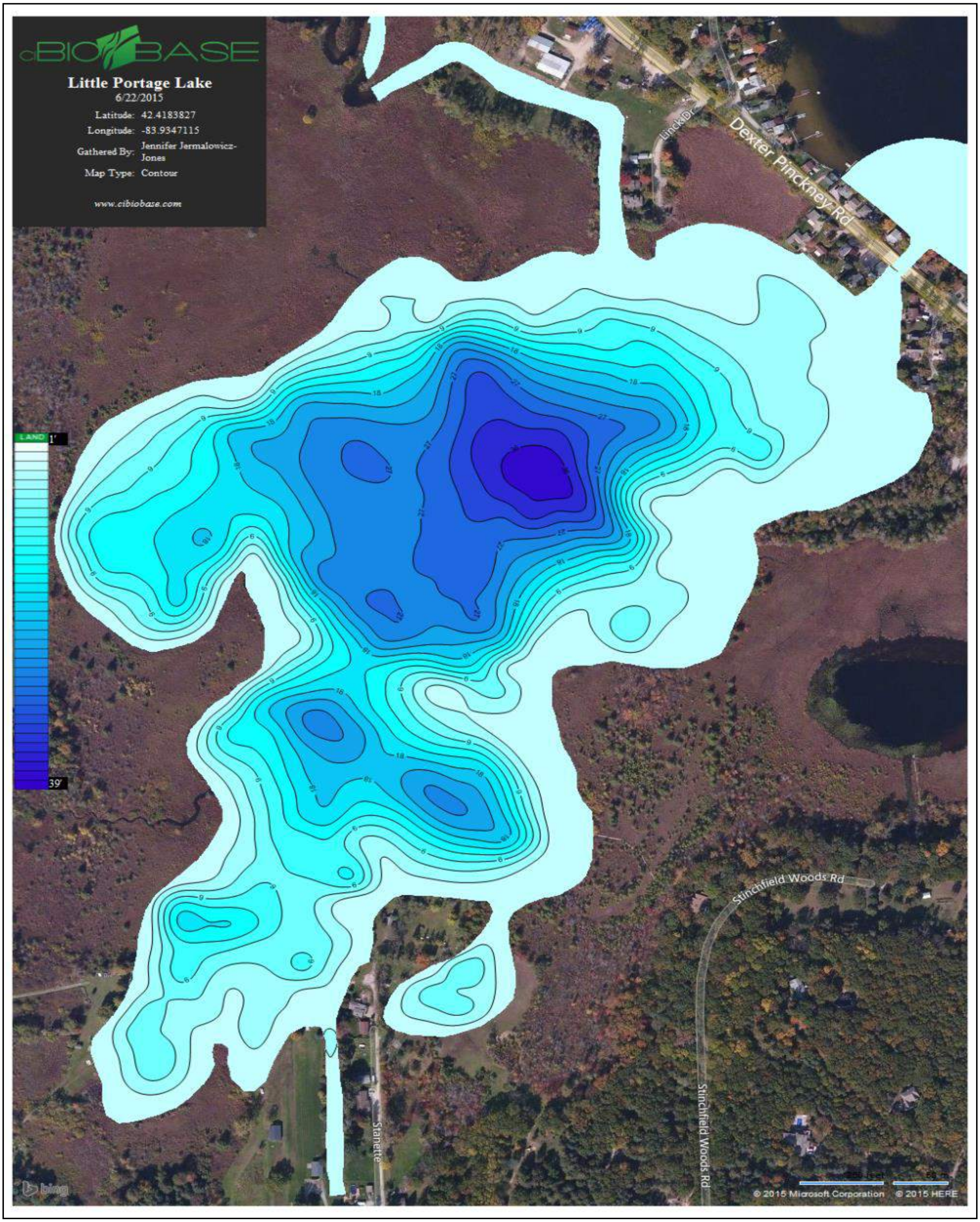

Figure 5. Modernized depth contour map of Little Portage Lake, Washtenaw County, MI.

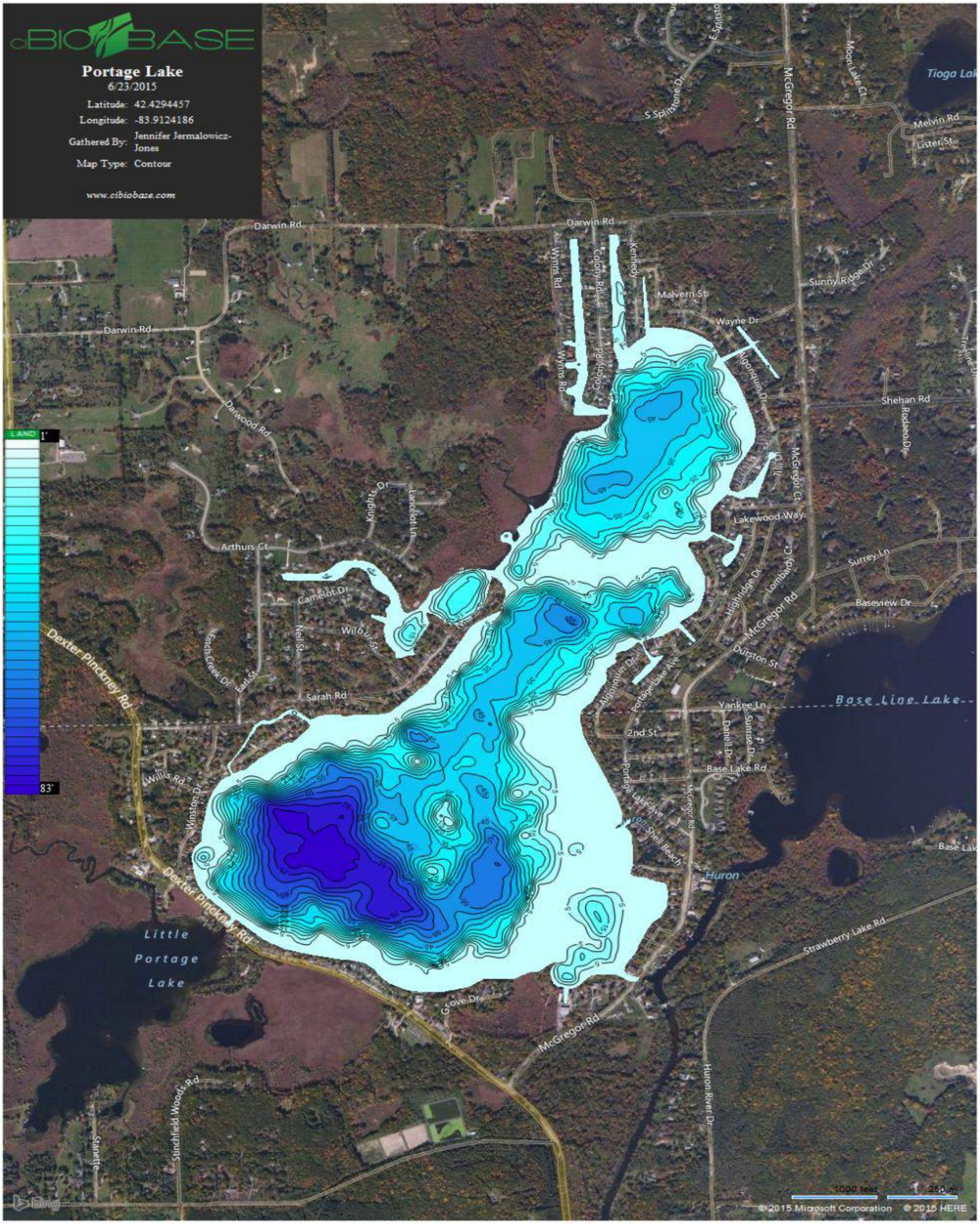

Figure 6. Modernized depth contour map of Big Portage Lake, Livingston and Washtenaw Counties, MI.

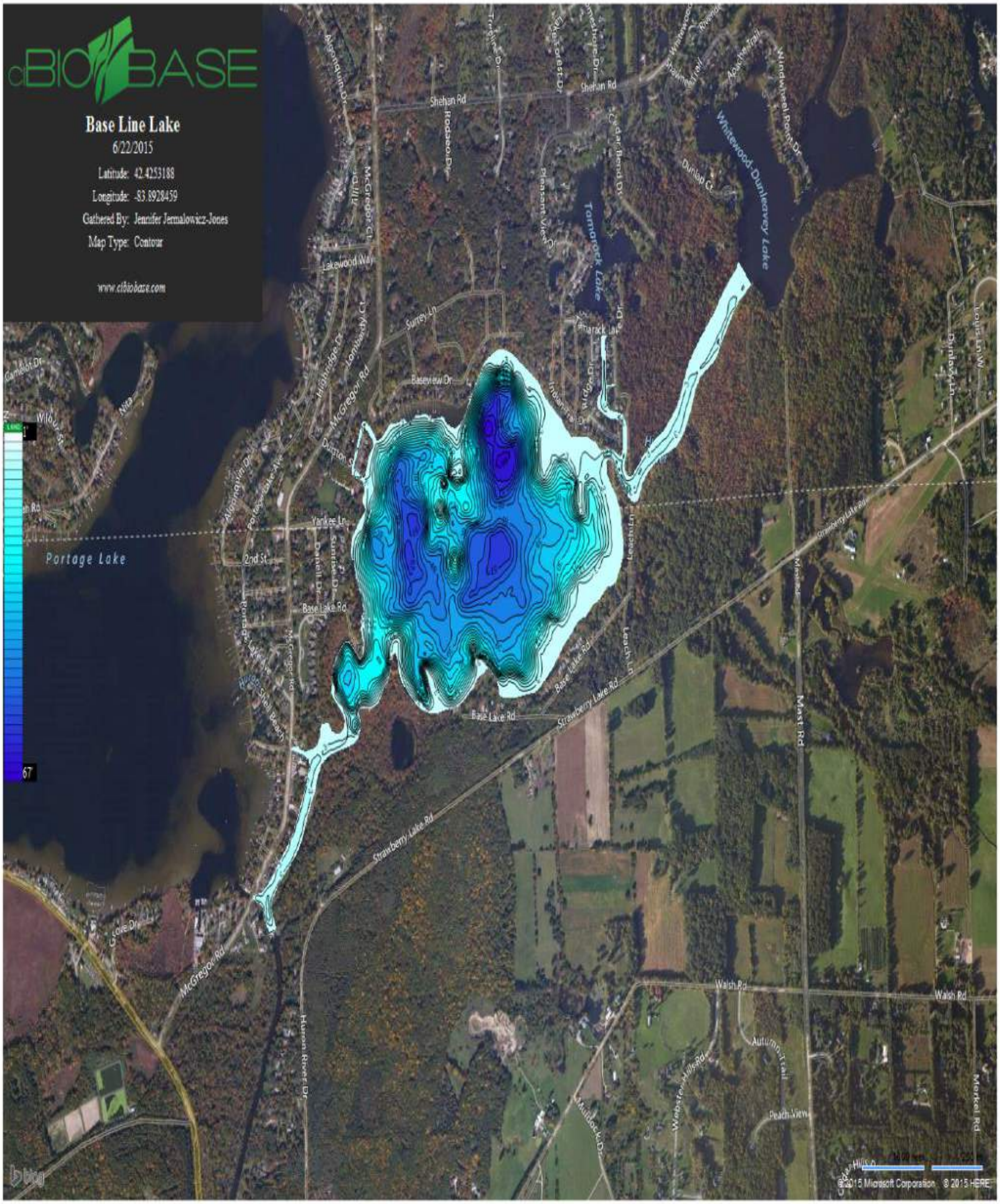

Figure 7. Modernized depth contour map of Baseline Lake, Livingston and Washtenaw Counties, MI.

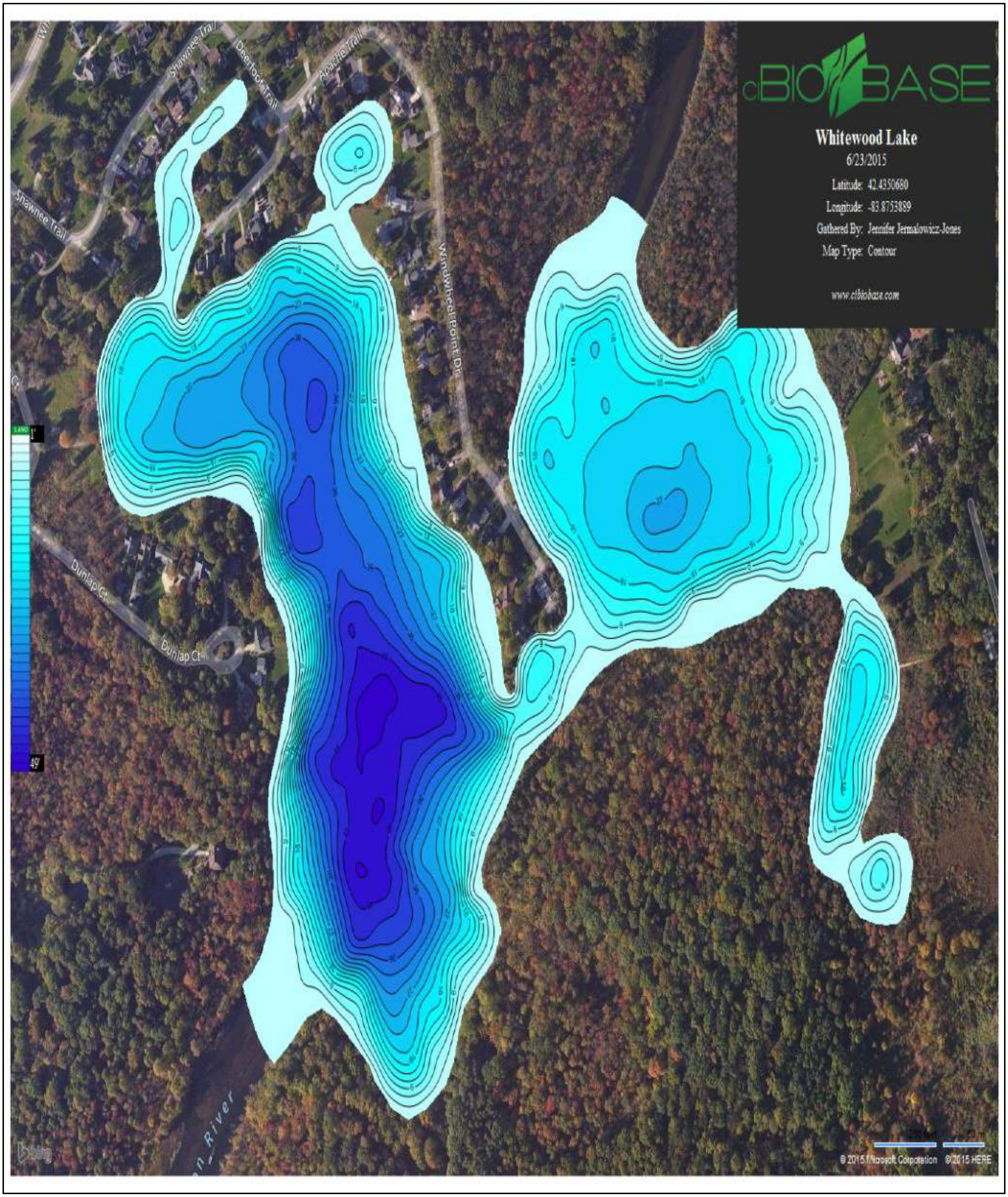

Figure 8. Modernized depth contour map of Whitewood Lakes, Livingston County, MI.

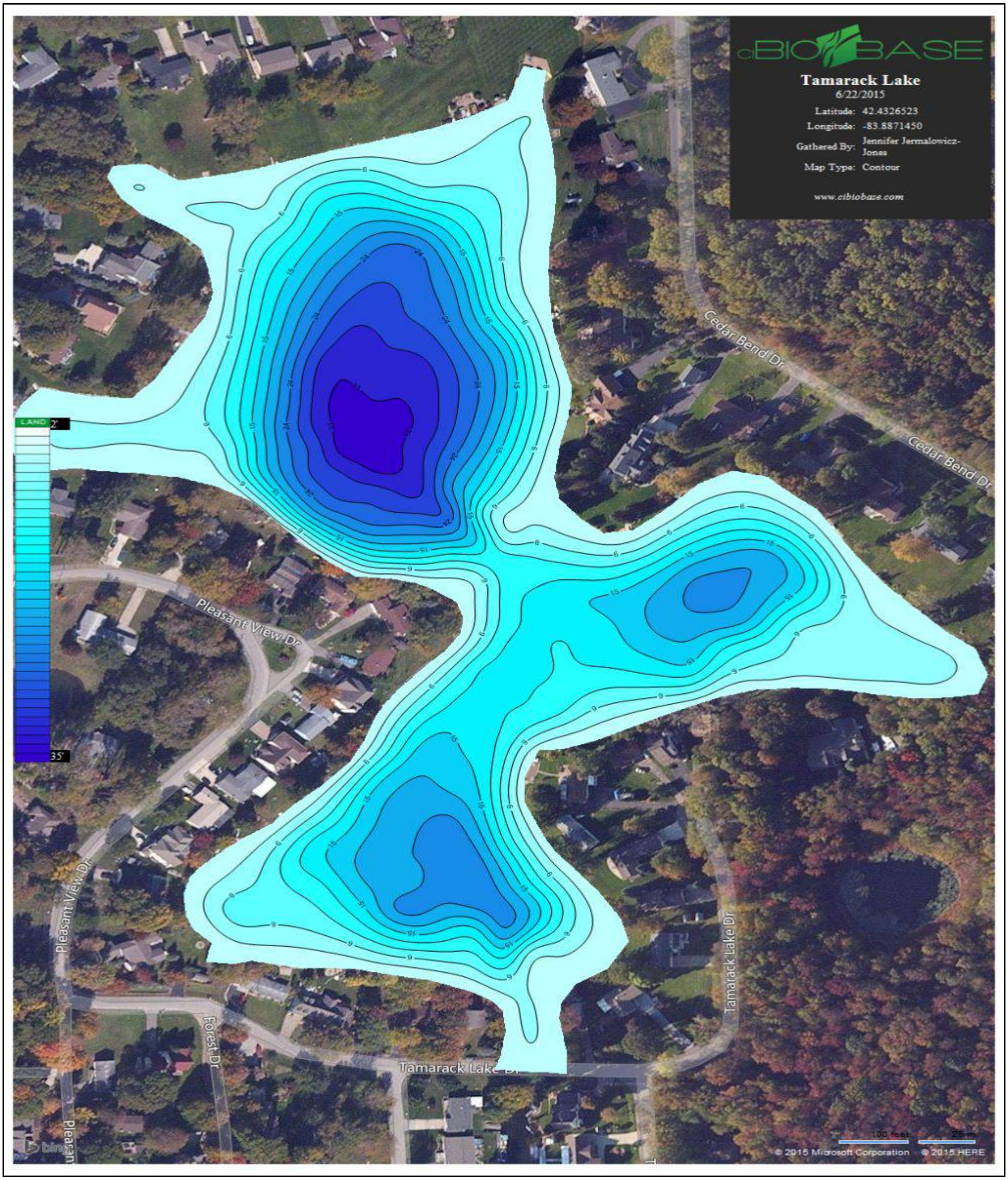

Figure 9. Modernized depth contour map of Tamarack Lake, Livingston County, MI.

3.2 PBWOA Lakes Extended and Immediate Watershed and Land Use Summary

A watershed is defined as a region surrounding a lake that contributes water and nutrients to a waterbody through drainage sources. Watershed size differs greatly among lakes and also directly affects lake water quality. Large watersheds with much development, numerous impervious or paved surfaces, abundant storm water drain inputs, and surrounding agricultural lands, have the potential to contribute significant nutrient and pollution loads to aquatic ecosystems.

All of the PBWOA lakes share a common extended watershed which is the Huron River Watershed (Figure 10). The Huron River watershed is approximately 575,999 acres (900 mi^2) in area and includes portions of 7 counties, including Livingston, Washtenaw, Oakland, Ingham, Jackson, Wayne, and Monroe Counties in Michigan (http://www.hrwc.org). The PBWOA lakes extended watershed consists of natural lands, farms, urban and industrial land, suburban land, and numerous inland lakes, rivers, and streams.

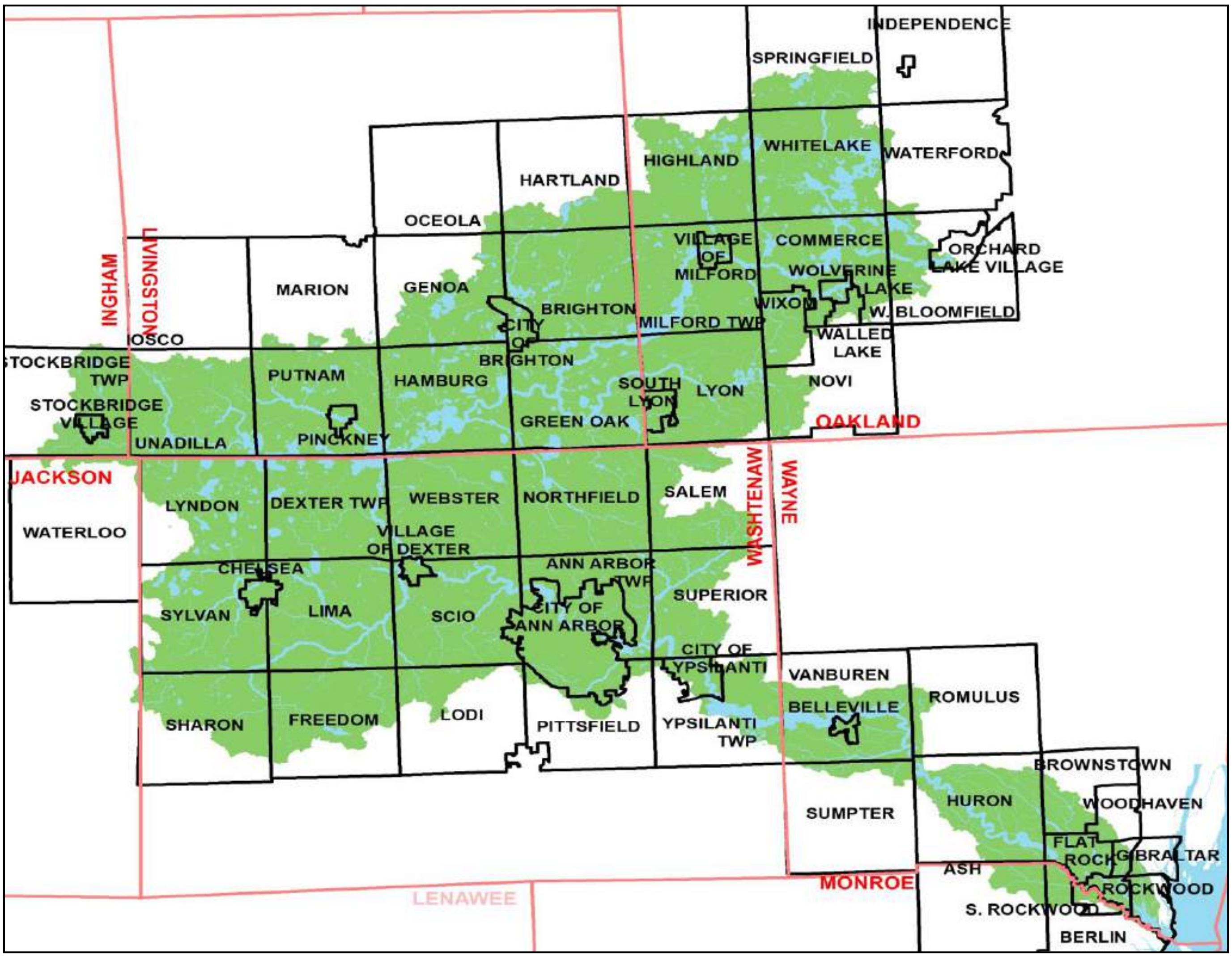

Figure 10. A map showing the entire Huron River extended watershed area (adapted from the Huron River Watershed Council Online database).

The size of each PBWOA lake immediate watershed can be found in Table 1 above. **The immediate watershed consists of the area around the lake which directly drains to the lake. The majority of the land uses within each of the watersheds consists of mixed-residential, open space, suburban, farms, wetlands, forests, and industrial. Immediate watershed maps for each lake are shown below in Figures 11-18.**

Figure 11. Zukey Lake Immediate Watershed Boundary (RLS, 2015).

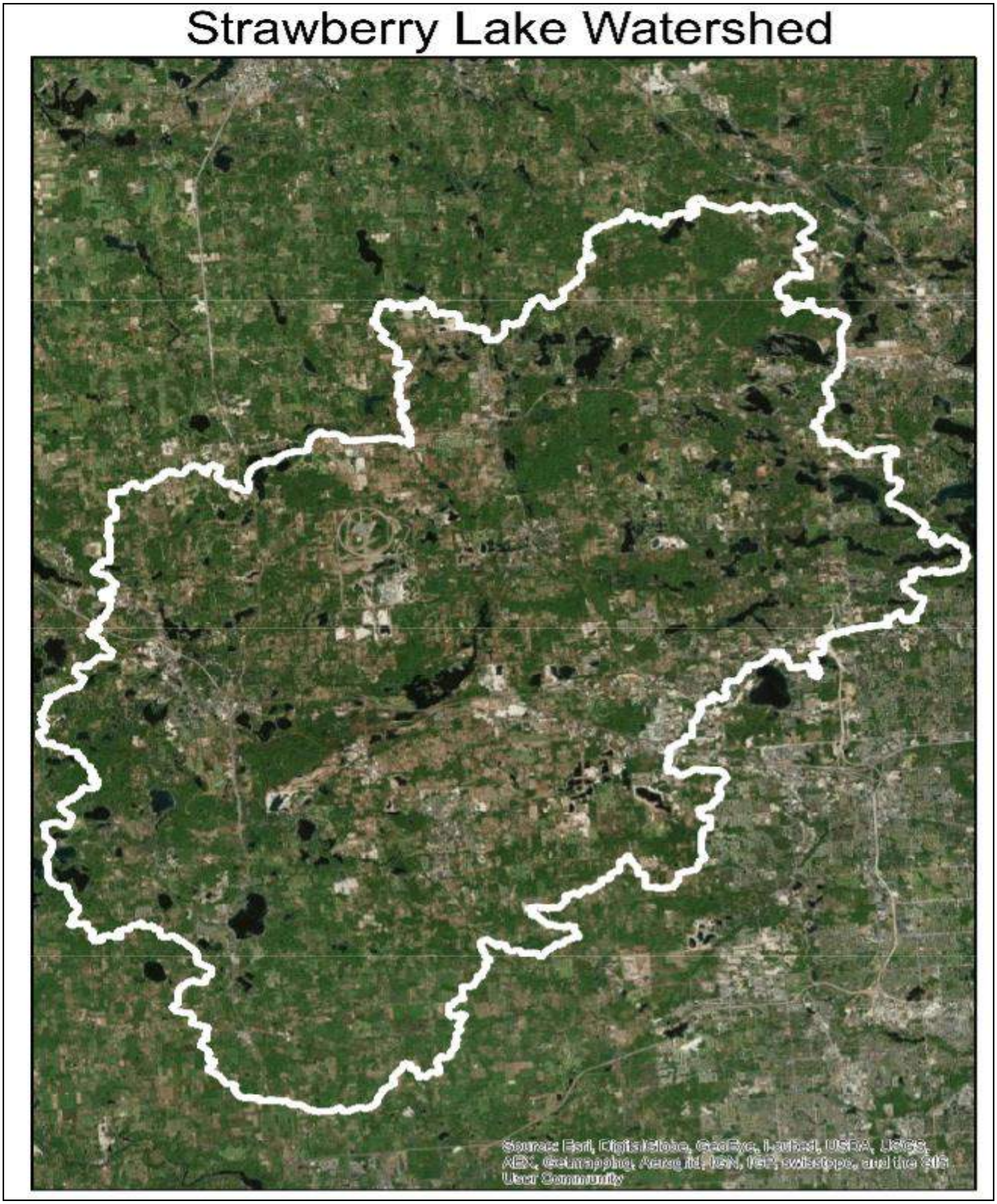

Figure 12. Strawberry Lake Immediate Watershed Boundary (RLS, 2015).

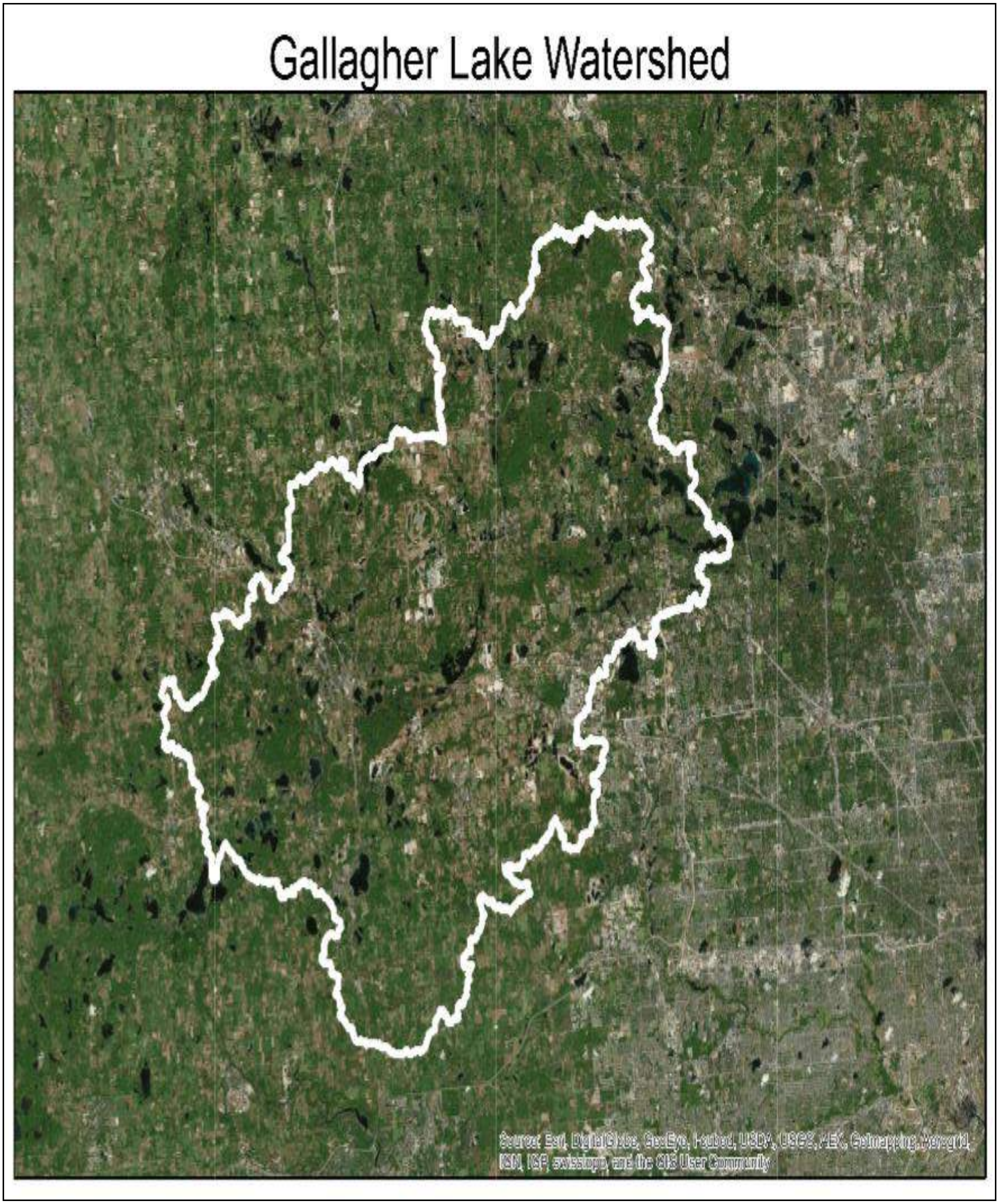

Figure 13. Gallagher Lake Immediate Watershed Boundary (RLS, 2015).

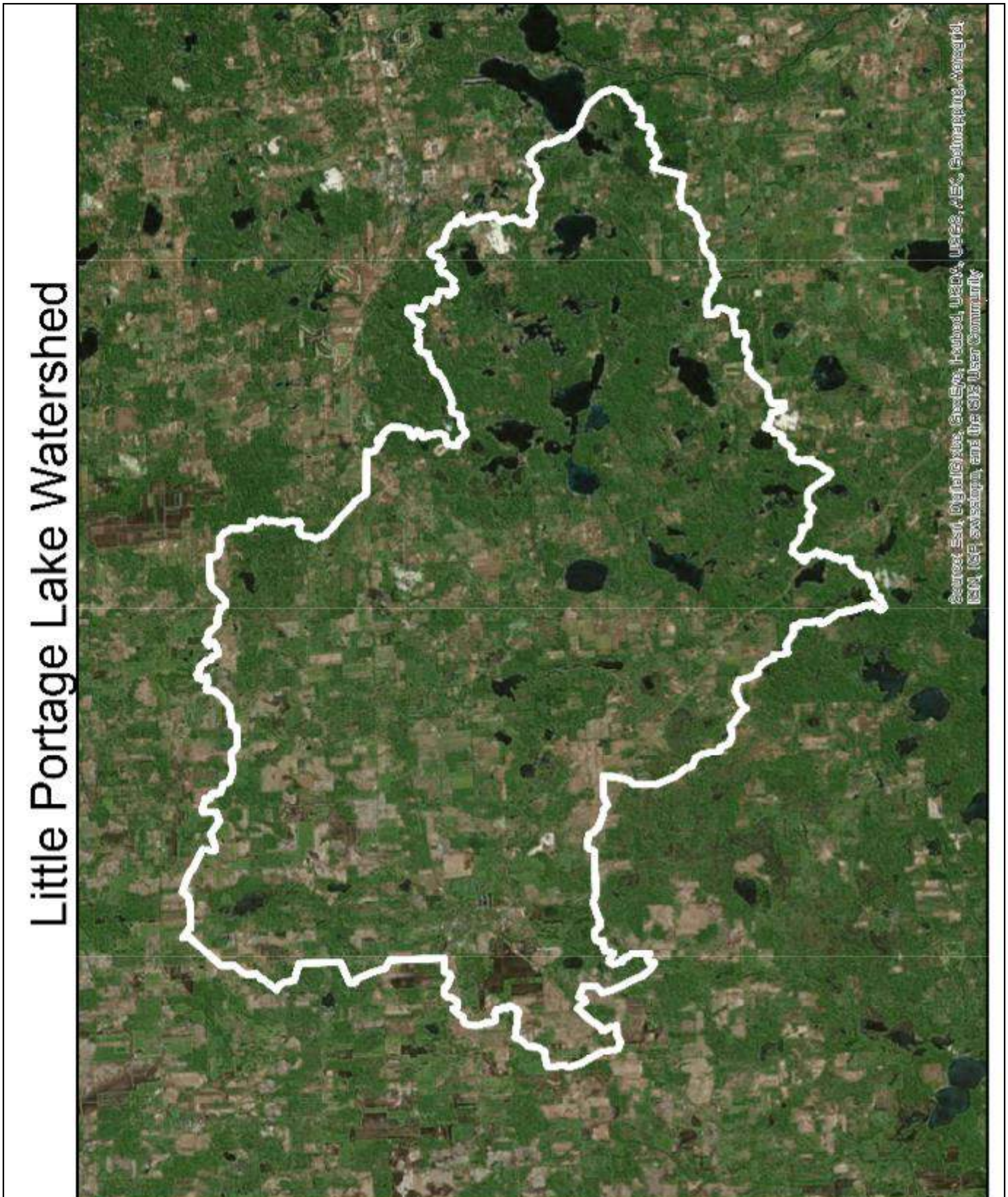

Figure 14. Little Portage Lake Immediate Watershed Boundary (RLS, 2015).

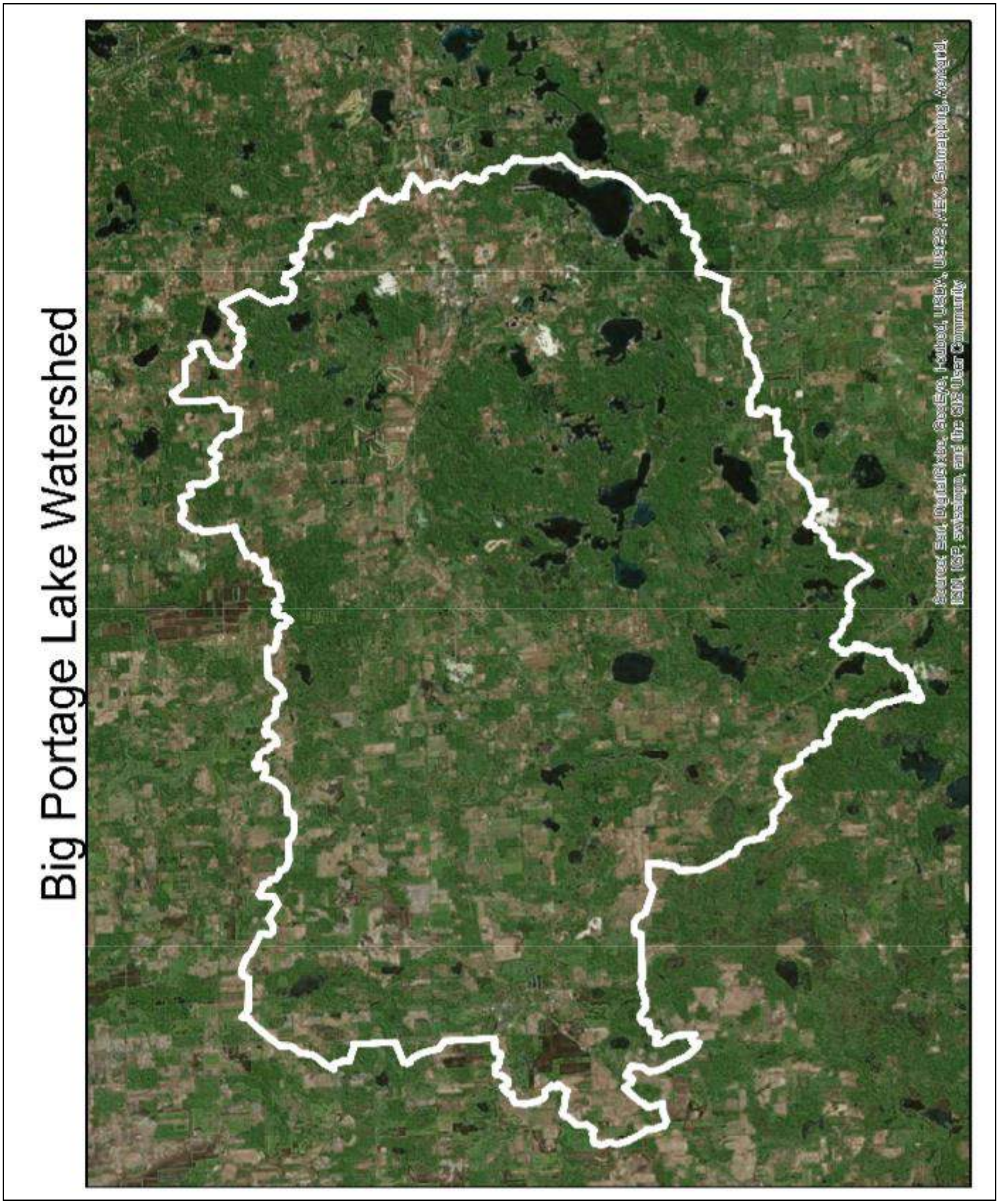

Figure 15. Big Portage Lake Immediate Watershed Boundary (RLS, 2015).

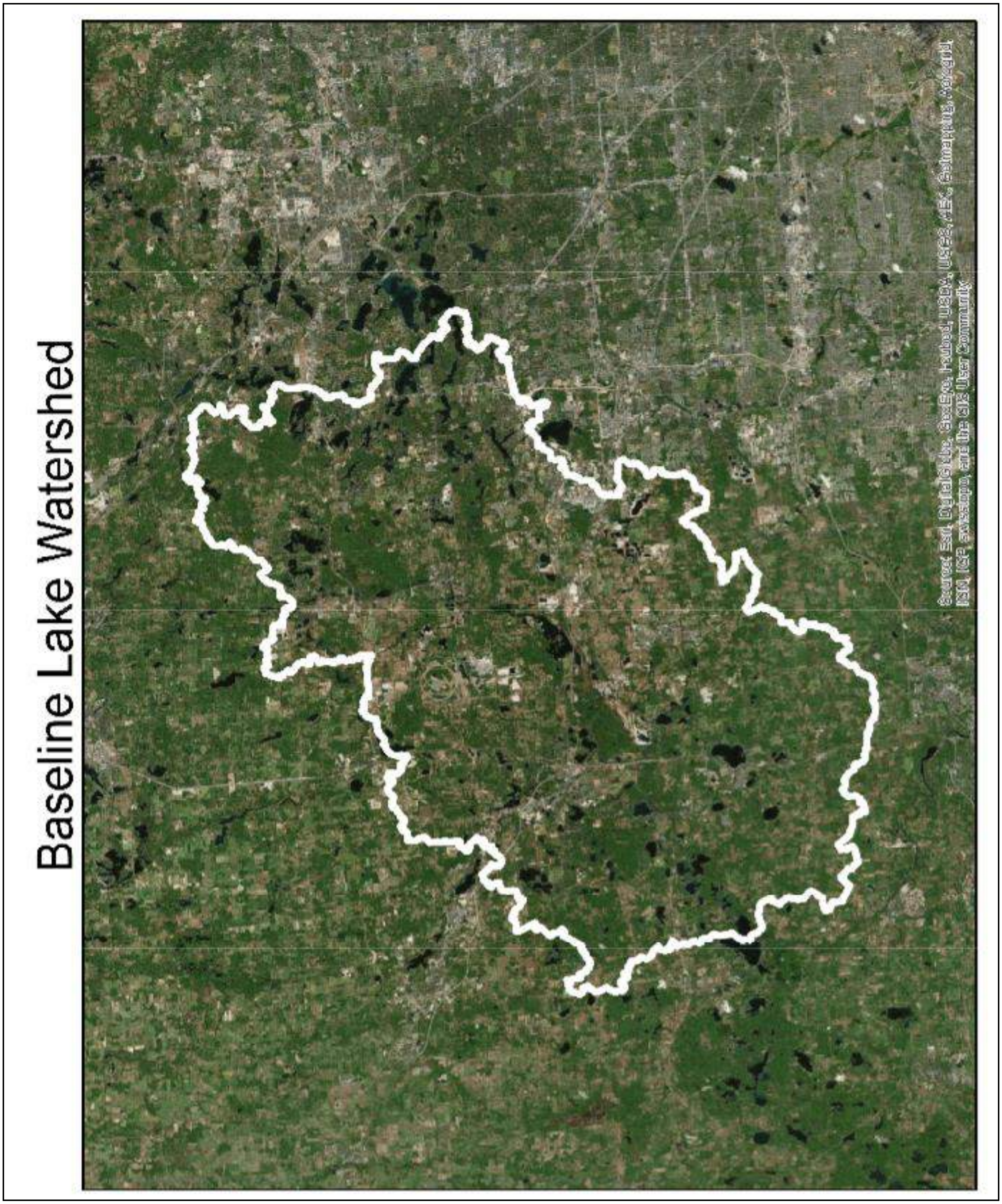

Figure 16.   Baseline Lake Immediate Watershed Boundary (RLS, 2015).

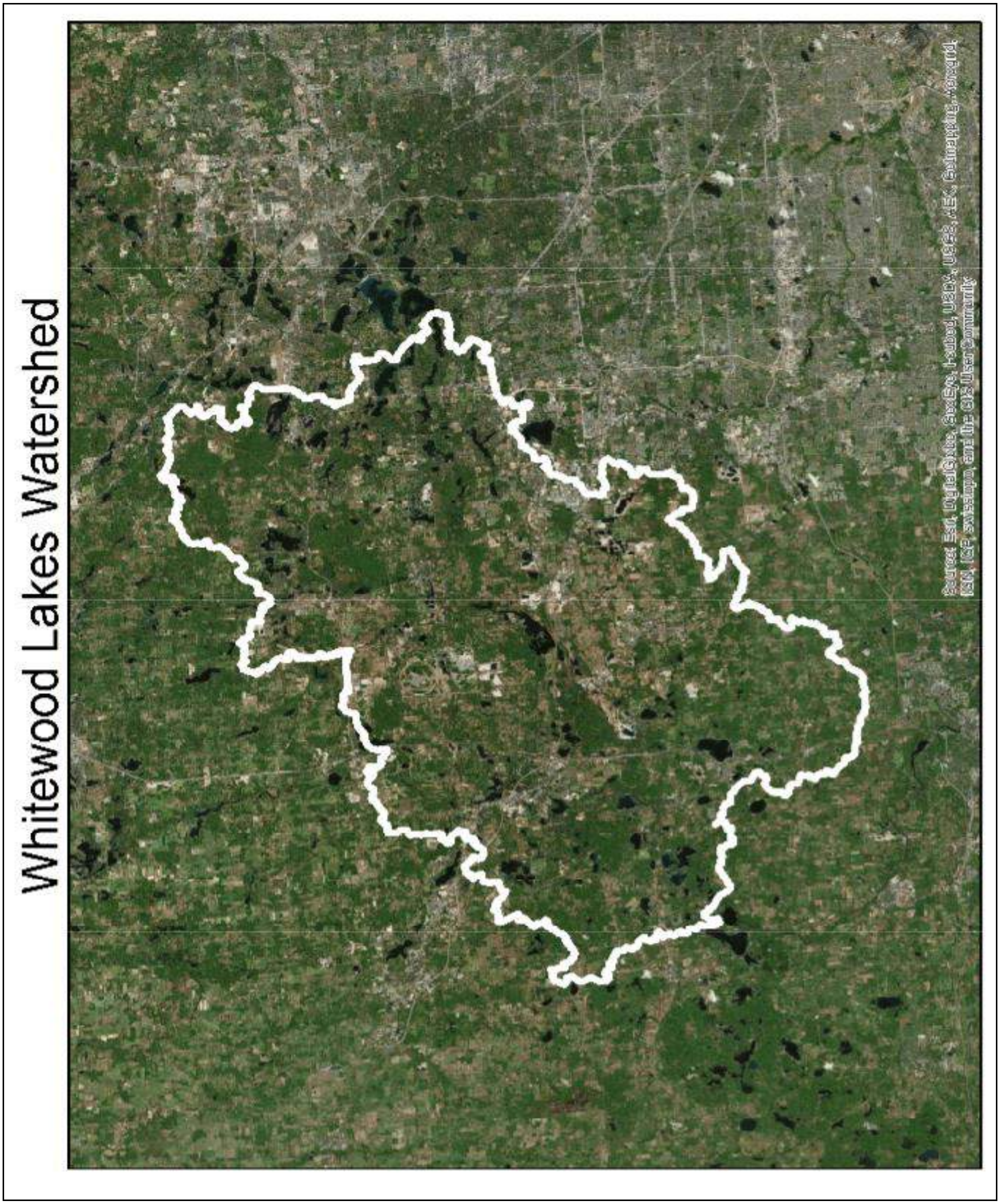

Figure 17. Whitewood Lakes Immediate Watershed Boundary (RLS, 2015).

Figure 18. Tamarack Lake Immediate Watershed Boundary (RLS, 2015).

3.3 PBWOA Lakes Shoreline Soils

There are **61 major soil types immediately surrounding all of the PBWOA lakes** which may impact the water quality of the lakes and also dictate the particular land use activities within the area. Figure 19 (created with data from the United States Department of Agriculture and Natural Resources Conservation Service, 1999) demonstrates the different soil types and locations around PBWOA lakes. Table 2 below shows the impaired soil types around each lake and the locations. Maps for each lake are available from the NRCS web soils survey website.

All areas that contain high slopes (>12%) are where runoff may be a factor in water quality degradation, transporting sediments and nutrients to the lakes. This is especially true in non-vegetated areas where soils can be directly transported to the lake from the uplands via runoff. Accordingly, every effort to implement low impact development (LID) techniques for construction of pervious surfaces and construction of septic systems close to the lake should be followed.

Areas that contain Houghton or Adrian mucks which are ponded soils that are very poorly drained also negatively affect water quality. Ponding occurs when water cannot permeate the soil and accumulates on the ground surface which then may runoff into nearby waterways and carry nutrients and sediments into the water. Excessive ponding of such soils may lead to flooding of some low-lying shoreline areas, resulting in nutrients entering the lake via surface runoff since these soils do not promote adequate drainage or filtration of nutrients.

PBWOA Lake Name	Impaired Shoreline Soils and Locations
Zukey Lake	Houghton Muck (N, W shores), Carlisle Muck (NE shore)
Strawberry Lake	Carlisle Muck (N, S, E, W shores), Boyer-Oshtemo loamy sands 12-18% slopes (S shore)
Gallagher Lake/Loon Lake	Houghton Muck (W, S shores), Carlisle Muck (E, SW shore)
Little Portage Lake	Houghton Muck (N, S, W, E shores), Oshtemo loamy sands 6-12% slopes (W, S shores)
Big Portage Lake	Houghton Muck (E, S, SW shores), Carlisle Muck (N, W, SW shores)
Baseline Lake	Houghton Muck (SW shore), Carlisle Muck (N, NE, shores)
Whitewood Lake	Houghton Muck (N, W shores), Carlisle Muck (W, S, E, shores)
Tamarack Lake	Carlisle Muck (N, S, E, W, shores)

Table 2. PBWOA lakes shoreline impaired soil types and locations.

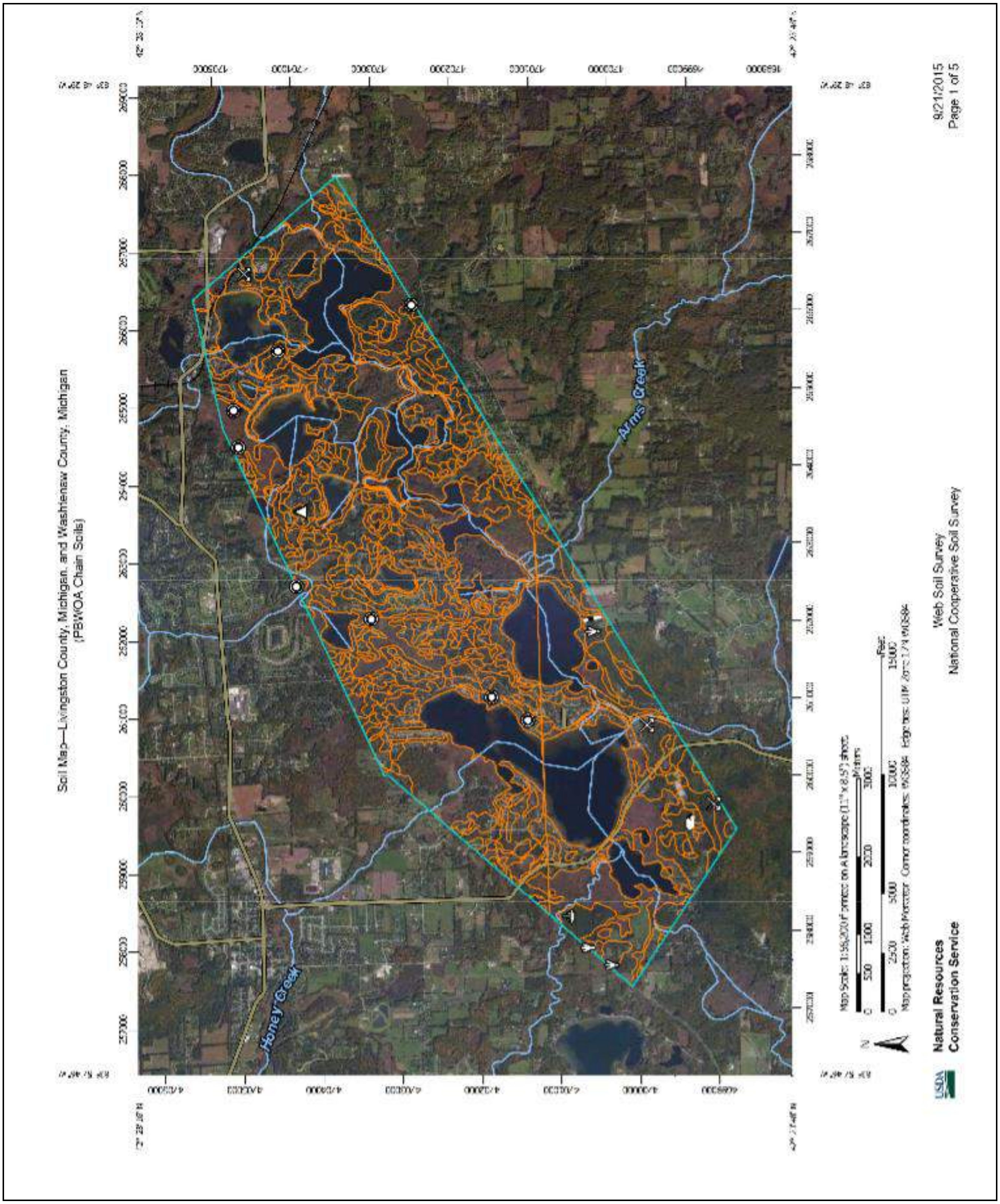

Figure 19. PBWOA lakes shoreline soils map (NRCS-USDA Soils survey data).

4.0 PBWOA LAKES WATER QUALITY

Water quality is highly variable among Michigan's inland lakes, although some characteristics are common among particular lake classification types. The water quality of each lake is affected by both land use practices and climatic events. Climatic factors (i.e. spring runoff, heavy rainfall) may alter water quality in the short term; whereas, anthropogenic (man-induced) factors (i.e. shoreline development, lawn fertilizer use) alter water quality over longer time periods. Since many lakes have a fairly long hydraulic residence time, the water may remain in the lake for years and is therefore sensitive to nutrient loading and pollutants. Furthermore, lake water quality helps to determine the classification of particular lakes (Table 3). Lakes that are high in nutrients (such as phosphorus and nitrogen) and chlorophyll-*a*, and low in transparency are classified as **eutrophic**; whereas those that are low in nutrients and chlorophyll-*a*, and high in transparency are classified as **oligotrophic**. Lakes that fall in between these two categories are classified as **mesotrophic**. All of the **PBWOA lakes are classified as eutrophic lakes which means that they contain high nutrients, algae, and weed growth, but also possesses good water clarity. Zukey Lake is the only exception with low nutrients, low weed growth, and good water clarity.**

Lake Trophic Status	*Total Phosphorus ($\mu g\ L^{-1}$)*	*Chlorophyll-a ($\mu g\ L^{-1}$)*	*Secchi Transparency (feet)*
Oligotrophic	< 10.0	< 2.2	> 15.0
Mesotrophic	10.0 – 20.0	2.2 – 6.0	7.5 – 15.0
Eutrophic	> 20.0	> 6.0	< 7.5

Table 3. Lake Trophic Status Classification Table (MDNR)

4.1 Water Quality Parameters

Parameters such as, but not limited to, dissolved oxygen, water temperature, oxidative reduction potential, conductivity, turbidity and total dissolved solids, pH, total alkalinity, total phosphorus, total Kjeldahl nitrogen, sediment % organic matter, chlorophyll-*a*, algal species, and Secchi transparency, respond to changes in water quality and consequently serve as indicators of change. **During this study, RLS collected water samples from within the deepest basin of each lake and brought them to the laboratory for analysis. The deep basin results are discussed below and are presented in Tables 4-12. Additional river water samples were also collected and are displayed in Table 13. All water samples and readings were collected on August 10, 2015 with the use of a Van Dorn horizontal water sampler and Hanna® multi-meter probe with parameter electrodes, respectively.**

4.1.1 Dissolved Oxygen

Dissolved oxygen is a measure of the amount of oxygen that exists in the water column. In general, dissolved oxygen levels should be greater than 5 mg L^{-1} to sustain a healthy warm-water fishery. Dissolved oxygen concentrations may decline if there is a high biochemical oxygen demand (BOD) where organismal consumption of oxygen is high due to respiration. Dissolved oxygen is generally higher in colder waters. Dissolved oxygen is measured in milligrams per liter (mg L^{-1}) with the use of a dissolved oxygen meter and/or through the use of Winkler titration methods. During the summer months, dissolved oxygen at the surface is generally higher due to the exchange of oxygen from the atmosphere with the lake surface, whereas dissolved oxygen is lower at the lake bottom due to decreased contact with the atmosphere and increased biochemical oxygen demand (BOD) from microbial activity. A decline in the dissolved oxygen concentrations to near zero may result in an increase in the release rates of phosphorus (P) from lake bottom sediments.

4.1.2 Water Temperature

A lake's water temperature varies within and among seasons, and is nearly uniform with depth under the winter ice cover because lake mixing is reduced when waters are not exposed to the wind. When the upper layers of water begin to warm in the spring after ice-off, the colder, dense layers remain at the bottom. This process results in a "thermocline" that acts as a transition layer between warmer and colder water layers. During the fall season, the upper layers begin to cool and become denser than the warmer layers, causing an inversion known as "fall turnover".
In general, shallow lakes will not stratify and deeper lakes may experience single or multiple turnover cycles. Water temperature is measured in degrees Celsius (ºC) or degrees Fahrenheit (ºF) with the use of a submersible thermometer.

4.1.3 Conductivity and Oxidative Reduction Potential

Conductivity is a measure of the amount of mineral ions present in the water, especially those of salts and other dissolved inorganic substances. Conductivity generally increases with water temperature and the amount of dissolved minerals and salts in a lake. Conductivity is measured in micro ohms per centimeter (µmho cm^{-1}) with the use of a conductivity probe and meter.
Baseline parameter data such as conductivity are important to measure the possible influences of land use activities (i.e. road salt influences) on lakes over a long period of time, or to trace the origin of a substance to the lake in an effort to reduce pollutant loading.

The oxidation-reduction potential (ORP or E_h) of lake water describes the effectiveness of certain atoms to serve as potential oxidizers and indicates the degree of reductants present within the water. In general, the E_h level (measured in millivolts) decreases in anoxic (low oxygen) waters. Low E_h values are therefore indicative of reducing environments where sulfates (if present in the lake water) may be reduced to hydrogen sulfide (H_2S). Decomposition by microorganisms in the hypolimnion may also cause the E_h value to decline with depth during periods of thermal stratification. The E_h values for the PBWOA lakes ranged from -22.8-192.7 mV from the bottom to the surface.

4.1.4 Turbidity and Total Dissolved and Suspended Solids

Turbidity is a measure of the loss of water transparency due to the presence of suspended particles. The turbidity of water increases as the number of total suspended particles increases. Turbidity may be caused by erosion inputs, phytoplankton blooms, storm water discharge, urban runoff, re-suspension of bottom sediments, and by large bottom-feeding fish such as carp. Particles suspended in the water column absorb heat from the sun and raise water temperatures. Since higher water temperatures generally hold less oxygen, shallow turbid waters are usually lower in dissolved oxygen. Turbidity is measured in Nephelometric Turbidity Units (NTU's) with the use of a turbimeter. The World Health Organization (WHO) requires that drinking water be less than 5 NTU's; however, recreational waters may be significantly higher than that.

Total Dissolved Solids

Total dissolved solids (TDS) are the measure of the amount of dissolved organic and inorganic particles in the water column. Particles dissolved in the water column absorb heat from the sun and raise the water temperature and increase conductivity. Total dissolved solids are often measured with the use of a calibrated meter in mg L^{-1}. Spring values are usually higher due to increased watershed inputs from spring runoff and/or increased planktonic algal communities.

4.1.5 pH

pH is the measure of acidity or basicity of water. pH is measured with a pH electrode and pH-meter in Standard Units (S.U). The standard pH scale ranges from 0 (acidic) to 14 (alkaline), with neutral values around 7. Most Michigan lakes have pH values that range from 6.5 to 9.5. Acidic lakes ($pH < 7$) are rare in Michigan and are most sensitive to inputs of acidic substances due to a low acid neutralizing capacity (ANC).

4.1.6 Total Alkalinity

Total alkalinity is the measure of the pH-buffering capacity of lake water. Lakes with high alkalinity (> 150 mg L^{-1} of $CaCO_3$) are able to tolerate larger acid inputs with less change in water column pH. Many Michigan lakes contain high concentrations of $CaCO_3$ and are categorized as having "hard" water. Total alkalinity is measured in milligrams per liter of $CaCO_3$ through an acid titration method. Total alkalinity may change on a daily basis due to the re-suspension of sedimentary deposits in the water and respond to seasonal changes due to the cyclic turnover of the lake water.

4.1.7 Total Phosphorus

Total phosphorus (TP) is a measure of the amount of phosphorus (P) present in the water column. Phosphorus is the primary nutrient necessary for abundant algae and aquatic plant growth. Lakes which contain greater than 0.20 mg L^{-1} of TP are defined as eutrophic or nutrient-enriched. TP concentrations are usually higher at increased depths due to the higher release rates of P from lake sediments under low oxygen (anoxic) conditions. Phosphorus may also be released from sediments as pH increases. Total phosphorus is measured in micrograms per liter (µg L^{-1}) with the use of a chemical auto analyzer.

4.1.8 Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is the sum of ammonia (NH_4^+) and organic nitrogen forms in freshwater systems. Much nitrogen (amino acids and proteins) also comprises the bulk of living organisms in an aquatic ecosystem. Nitrogen originates from atmospheric inputs (i.e. burning of fossil fuels), wastewater sources from developed areas (i.e. runoff from fertilized lawns), agricultural lands, septic systems, and from waterfowl droppings. It also enters lakes through groundwater or surface drainage, drainage from marshes and wetlands, or from precipitation (Wetzel, 2001). In lakes with an abundance of nitrogen (N: P > 15), phosphorus may be the limiting nutrient for phytoplankton and aquatic macrophyte growth. Alternatively, in lakes with low nitrogen concentrations (and relatively high phosphorus), the blue-green algae populations may increase due to the ability to fix nitrogen gas from atmospheric inputs. Lakes with a mean TKN value of 0.66 mg L^{-1} may be classified as oligotrophic, those with a mean TKN value of 0.75 mg L^{-1} may be classified as mesotrophic, and those with a mean TKN value greater than 1.88 mg L^{-1} may be classified as eutrophic.

4.1.9 Chlorophyll-a and Algae

Chlorophyll-*a* is a measure of the amount of green plant pigment present in the water, often in the form of planktonic algae. High chlorophyll-a concentrations are indicative of nutrient-enriched lakes. Chlorophyll-*a* concentrations greater than 6 µg L^{-1} are found in eutrophic or nutrient-enriched aquatic systems, whereas chlorophyll-*a* concentrations less than 2.2 µg L^{-1} are found in nutrient-poor or oligotrophic lakes. Chlorophyll-*a* is measured in micrograms per liter (µg L^{-1}) with the use of an acetone extraction method and a spectrometer. The chlorophyll-*a* concentrations in the PBWOA lakes were determined by collecting a composite sample of the algae throughout the water column at the deep basin sites from just above the lake bottoms to the lake surfaces.

Algal genera from a composite water sample collected over the deep basins of PBWOA lakes were analyzed under a compound brightfield microscope. Genera are listed here in the order of most abundant to least abundant (Table 14).

4.1.10 Secchi Transparency

Secchi transparency is a measure of the clarity or transparency of lake water, and is measured with the use of an 8-inch diameter standardized Secchi disk. Secchi disk transparency is measured in feet (ft.) or meters (m) by lowering the disk over the shaded side of a boat around noon and taking the mean of the measurements of disappearance and reappearance of the disk. Elevated Secchi transparency readings allow for more aquatic plant and algae growth. Eutrophic systems generally have Secchi disk transparency measurements less than 7.5 feet due to turbidity caused by excessive planktonic algae growth. Secchi transparency is variable and depends on the amount of suspended particles in the water (often due to windy conditions of lake water mixing) and the amount of sunlight present at the time of measurement.

4.1.11 Sediment Organic Matter

Organic matter (OM) contains a high amount of carbon which is derived from biota such as decayed plant and animal matter. Detritus is the term for all dead organic matter which is different than living organic and inorganic matter. OM may be autochthonous or allochthonous in nature where it originates from within the system or external to the system, respectively. Sediment OM is collected with a hand-held Ekman dredge and measured with the ASTM D2974 Method and is usually expressed in a percentage (%) of total bulk volume. Many factors affect the degradation of organic matter including basin size, water temperature, thermal stratification, dissolved oxygen concentrations, particle size, and quantity and type of organic matter present.

Depth ft.	Water Temp ºC	DO mg L^{-1}	pH S.U.	Cond. µS cm^{-1}	Turb. NTU	Total Kjeldahl Nitrogen mg L^{-1}	Total Alk. mgL^{-1} $CaCO_3$	Total Phos. mg L^{-1}	Total Diss. Sol. mg L^{-1}	Chl-a µg L^{-1}	Secchi Trans. (ft.)	% Sed OM
0	25.2	8.0	8.5	410	0.9	0.51	168	<0.010	312	--	13.2	N/A
41	14.0	7.1	8.5	410	1.8	0.50	170	0.024	300	0.934		N/A
82	9.8	1.0	7.8	430	3.1	0.55	169	0.050	242	--		16

Table 4. Big Portage Lake water quality parameter data collected in the deep basin August 10, 2015.

Depth ft.	Water Temp ºC	DO mg L^{-1}	pH S.U.	Cond. µS cm^{-1}	Turb. NTU	Total Kjeldahl Nitrogen mg L^{-1}	Total Alk. mgL^{-1} $CaCO_3$	Total Phos. mg L^{-1}	Total Diss. Sol. mg L^{-1}	Chl-a µg L^{-1}	Secchi Trans. (ft.)	% Sed OM
0	25.0	8.0	8.5	455	0.9	0.64	156	<0.010	364	--	11.2	N/A
15	22.0	7.1	8.5	450	2.2	1.80	162	0.055	361	2.14		N/A
32	14.2	2.1	7.8	434	3.4	2.50	163	0.610	324	--		22

Table 5. Little Portage Lake water quality parameter data collected in the deep basin August 10, 2015.

Depth ft.	Water Temp ºC	DO mg L^{-1}	pH S.U.	Cond. µS cm^{-1}	Turb. NTU	Total Kjeldahl Nitrogen mg L^{-1}	Total Alk. mgL^{-1} $CaCO_3$	Total Phos. mg L^{-1}	Total Diss. Sol. mg L^{-1}	Chl-a µg L^{-1}	Secchi Trans. (ft.)	% Sed OM
0	25.5	7.5	8.5	529	0.8	<0.50	164	0.011	178	--	13.0	N/A
35	14.2	6.5	8.4	439	2.7	0.58	166	0.062	129	3.07		N/A
70	10.2	3.3	7.9	442	3.9	1.20	170	0.130	200	--		20

Table 6. Baseline Lake water quality parameter data collected in the deep basin August 10, 2015.

Depth ft.	Water Temp ºC	DO mg L^{-1}	pH S.U.	Cond. µS cm^{-1}	Turb. NTU	Total Kjeldahl Nitrogen mg L^{-1}	Total Alk. mgL^{-1} $CaCO_3$	Total Phos. mg L^{-1}	Total Diss. Sol. mg L^{-1}	Chl-a µg L^{-1}	Secchi Trans. (ft.)	% Sed OM
0	25.2	8.0	8.5	489	0.6	<0.50	170	<0.010	250	--	13.5	N/A
16	20.2	6.5	8.5	489	1.9	1.9	168	0.048	260	4.63		N/A
32	14.1	3.2	8.0	460	3.1	3.20	169	0.20	260	--		19

Table 7. Tamarack Lake water quality parameter data collected in the deep basin August 10, 2015.

Depth ft.	Water Temp ºC	DO mg L^{-1}	pH S.U.	Cond. µS cm^{-1}	Turb. NTU	Total Kjeldahl Nitrogen mg L^{-1}	Total Alk. mgL^{-1} $CaCO_3$	Total Phos. mg L^{-1}	Total Diss. Sol. mg L^{-1}	Chl-a µg L^{-1}	Secchi Trans. (ft.)	% Sed OM
0	25.5	7.9	8.4	504	0.6	<0.50	168	0.016	243	--	10.0	N/A
25	23.1	7.0	8.2	525	2.6	<0.50	168	0.045	250	0.267		N/A
50	14.5	3.0	7.8	400	3.9	<0.50	170	0.170	294	--		21

Table 8. Whitewood Lakes water quality parameter data collected in the deep basin August 10, 2015.

Depth ft.	Water Temp ºC	DO mg L^{-1}	pH S.U.	Cond. µS cm^{-1}	Turb. NTU	Total Kjeldahl Nitrogen mg L^{-1}	Total Alk. mgL^{-1} $CaCO_3$	Total Phos. mg L^{-1}	Total Diss. Sol. mg L^{-1}	Chl-a µg L^{-1}	Secchi Trans. (ft.)	% Sed OM
0	26.0	7.7	8.5	459	0.5	0.61	162	0.018	286	--	7.1	N/A
13.5	24.6	6.0	8.5	460	1.9	0.75	158	0.065	286	0.890		N/A
27	18.2	3.0	8.5	460	2.9	1.10	156	0.210	300	--		21

Table 9. Gallagher Lake water quality parameter data collected in the deep basin August 10, 2015.

Depth ft.	Water Temp ºC	DO mg L^{-1}	pH S.U.	Cond. µS cm^{-1}	Turb. NTU	Total Kjeldahl Nitrogen mg L^{-1}	Total Alk. mgL^{-1} $CaCO_3$	Total Phos. mg L^{-1}	Total Diss. Sol. mg L^{-1}	Chl-a µg L^{-1}	Secchi Trans. (ft.)	% Sed OM
0	26.0	7.9	8.5	460	0.6	<0.50	165	0.013	276	--	8.9	N/A
13.5	22.0	6.9	8.2	460	1.5	0.50	167	0.035	300	0.178		N/A
27	18.5	3.3	8.0	460	2.7	0.55	169	0.092	320	--		20

Table 10. Loon Lake water quality parameter data collected in the deep basin August 10, 2015.

Depth ft.	Water Temp ºC	DO mg L^{-1}	pH S.U.	Cond. µS cm^{-1}	Turb. NTU	Total Kjeldahl Nitrogen mg L^{-1}	Total Alk. mgL^{-1} $CaCO_3$	Total Phos. mg L^{-1}	Total Diss. Sol. mg L^{-1}	Chl-a µg L^{-1}	Secchi Trans. (ft.)	% Sed OM
0	26.2	7.5	8.6	460	0.5	<0.50	168	0.020	300	--	8.0	N/A
20	24.2	6.0	8.2	460	1.9	0.80	165	0.045	300	0.356		N/A
40	17.1	2.0	7.8	450	2.9	1.60	166	0.27	320	--		26

Table 11. Strawberry Lake water quality parameter data collected in the deep basin August 10, 2015.

Depth ft.	Water Temp ºC	DO mg L^{-1}	pH S.U.	Cond. µS cm^{-1}	Turb. NTU	Total Kjeldahl Nitrogen mg L^{-1}	Total Alk. mgL^{-1} $CaCO_3$	Total Phos. mg L^{-1}	Total Diss. Sol. mg L^{-1}	Chl-a µg L^{-1}	Secchi Trans. (ft.)	% Sed OM
0	24.2	7.6	8.6	471	0.5	<0.50	157	<0.010	313	--	10.0	N/A
19	20.1	5.5	8.3	470	1.4	0.50	155	0.010	312	2.00		N/A
38	14.5	0.0	8.2	471	2.8	0.52	164	0.013	326	--		7.8

Table 12. Zukey Lake water quality parameter data collected in the deep basin August 10, 2015.

PBWOA River Section	***Total Kjeldahl Nitrogen mg L^{-1}***	***Total Phos. mg L^{-1}***
Strawberry to Gallagher	<0.50	0.015
Gallagher to Whitewood	1.20	0.016
Whitewood to Baseline	<0.50	0.013
Baseline to the Dam	<0.50	0.013

Table 13. Huron River sections water quality parameter data collected August 10, 2015.

Summary of Water Quality Data:

All of the PBWOA lakes were sampled in mid-August over the deep basins which allowed for the determination of water quality during thermal stratification which is when nutrient concentrations are usually highest and dissolved oxygen concentrations are usually lowest at the lake bottom. All of the PBWOA lakes have hard water with total alkalinities > 150 mg L^{-1} $CaCO_3$. Additionally, all are above neutral pH. All of the lakes experienced a sharp decline in dissolved oxygen beyond the mid-depth during the sampling period and had between 0-3.2 mg L^{-1} dissolved oxygen at the bottom. Turbidity values were fairly low overall (range 0.5-3.9 NTU) with higher values recorded at the lake bottom which is common due to resuspension of lake sediments. Secchi disk transparency varied among lakes and ranged from a low of 7.1 feet at Gallagher Lake to a high of 13.2 feet at Big Portage Lake. Total dissolved solids varied among the lakes and ranged from a low of 129 mg L^{-1} to a high of 364 mg L^{-1} with Baseline Lake and Little Portage Lake having the lowest and highest values, respectively. Total phosphorus (TP) concentrations differed among lakes and among depths within lakes. In general, TP concentrations were lower at the surface than at the bottom. Surface TP concentrations ranged from < 0.010-0.610 mg L^{-1} with Zukey Lake having the lowest overall TP values and Little Portage Lake having the highest values. Total Kjeldahl nitrogen concentrations were less variable and ranged from < 0.50-3.2 mg L^{-1} with Whitewood Lakes having the lowest values and Tamarack Lake having the highest values. The river sections all had low nutrient concentrations which is not surprising given the fast flow rates. Sediment % organic matter was overall low and ranged from 7.8-26% which means that the lakes contain more mineral than organic bottom. Chlorophyll-*a* concentrations also varied among lakes and ranged from 0.178-3.07 µg L^{-1} with Loon Lake having the lowest value and Baseline Lake having the highest value. Table 14 below shows the relative types of algae found in each of the lakes sampled.

PBWOA Lake Name	Algal Community
Zukey Lake	*Scenedesmus* sp., *Ulothrix* sp., *Chlorella* sp., *Haematococcus* sp., *Rhizoclonium* sp., *Gleocystis* sp., *Pediastrum* sp., *Spirogyra* sp., *Euglena* sp., and *Chloromonas* sp.; the Cyanophyta (blue-green algae): the Bascillariophyta (diatoms): *Synedra* sp., *Cymbella* sp., *Navicula* sp., *Fragilaria* sp., and *Tabellaria* sp.
Strawberry Lake	*Scenedesmus* sp., *Ulothrix* sp., *Chlorella* sp., *Rhizoclonium* sp., *Gleocystis* sp., *Pediastrum* sp., *Haematococcus* sp., *Spirogyra* sp., and *Chloromonas* sp. the Cyanophyta (blue-green algae): *Oscillatoria* sp., and *Anabaena* sp.,; the Bascillariophyta (diatoms): *Synedra* sp., *Navicula* sp., *Fragilaria* sp., *Rhoicosphenia* sp., and *Tabellaria* sp.
Gallagher Lake/Loon Lake	*Scenedesmus* sp., *Ulothrix* sp., *Cladophora* sp., *Chlorella* sp., *Rhizoclonium* sp., *Gleocystis* sp., *Pediastrum* sp., *Haematococcus* sp., *Spirogyra* sp., *Euglena* sp., and *Chloromonas* sp. the Cyanophyta (blue-green algae): *Oscillatoria* sp.; the Bascillariophyta (diatoms): *Navicula* sp., *Fragilaria* sp., *Synedra* sp., *Cymbella* sp., *Rhoicosphenia* sp., and *Tabellaria* sp.
Little Portage Lake	*Scenedesmus* sp., *Ulothrix* sp., *Chlorella* sp., *Rhizoclonium* sp., *Gleocystis* sp., *Pediastrum* sp., *Haematococcus* sp., *Spirogyra* sp., and *Chloromonas* sp. the Cyanophyta (blue-green algae): *Oscillatoria* sp.; the Bascillariophyta (diatoms): *Synedra* sp., *Navicula* sp., *Fragilaria* sp., *Rhoicosphenia* sp., and *Tabellaria* sp.
Big Portage Lake	*Cladophora* sp., *Chlorella* sp., *Haematococcus* sp., *Rhizoclonium* sp., *Gleocystis* sp., *Scenedesmus* sp., *Pediastrum* sp., *Spirogyra* sp., *Euglena* sp., and *Chloromonas* sp. the Cyanophyta (blue-green algae): *Oscillatoria* sp.; the Bascillariophyta (diatoms): *Navicula* sp., *Fragilaria* sp., *Synedra* sp., *Cymbella* sp.
Baseline Lake	*Cladophora* sp., *Chlorella* sp., *Scenedesmus* sp., *Rhizoclonium* sp., *Gleocystis* sp., *Pediastrum* sp., *Haematococcus* sp., *Spirogyra* sp., *Euglena* sp., and *Chloromonas* sp.; the Cyanophyta (blue-green algae): *Oscillatoria* sp.; the Bascillariophyta (diatoms): *Navicula* sp., *Fragilaria* sp., *Synedra* sp., and *Cymbella* sp.
Whitewood Lakes	*Scenedesmus* sp., *Ulothrix* sp., *Chlorella* sp., *Rhizoclonium* sp., *Gleocystis* sp., *Pediastrum* sp., *Haematococcus* sp., *Spirogyra* sp., and *Chloromonas* sp. the Cyanophyta (blue-green algae): *Oscillatoria* sp.; the Bascillariophyta (diatoms): *Navicula* sp., *Fragilaria* sp., *Synedra* sp., *Cymbella* sp., *Rhoicosphenia* sp., and *Tabellaria* sp.
Tamarack Lake	*Haematococcus* sp., *Euglena sp., Ulothrix sp., Mougeotia* sp., *Merismopedia* sp., *Spirogyra* sp., and *Chloromonas* sp. the Cyanophyta (blue-green algae): *Oscillatoria* sp.; the Bascillariophyta (diatoms): *Synedra* sp., *Navicula* sp., *Fragilaria* sp., *Cymbella* sp., and *Tabellaria* sp.

Table 14. PBWOA lakes algal community composition (August, 2015).

4.2 PBWOA Lakes Aquatic Vegetation Communities

Aquatic plants (macrophytes) are an essential component in the littoral zones of most lakes in that they serve as suitable habitat and food for macroinvertebrates, contribute oxygen to the surrounding waters through photosynthesis, stabilize bottom sediments (if in the rooted growth form), and contribute to the cycling of nutrients such as phosphorus and nitrogen upon decay. In addition, decaying aquatic plants contribute organic matter to lake sediments which further supports healthy growth of successive aquatic plant communities that are necessary for a balanced aquatic ecosystem. An overabundance of aquatic vegetation may cause organic matter to accumulate on the lake bottom faster than it can break down. Aquatic plants generally consist of rooted submersed, free-floating submersed, floating-leaved, and emergent growth forms. The emergent growth form (i.e. cattails, native loosestrife) is critical for the diversity of insects onshore and for the health of nearby wetlands. Submersed aquatic plants can be rooted in the lake sediment (i.e. milfoils, pondweeds), or free-floating in the water column (i.e. Coontail). Nonetheless, there is evidence that the diversity of submersed aquatic macrophytes can greatly influence the diversity of macroinvertebrates associated with aquatic plants of different structural morphologies (Parsons and Matthews, 1995). Therefore, it is possible that declines in the biodiversity and abundance of submersed aquatic plant species and associated macroinvertebrates, could negatively impact the fisheries of inland lakes. Alternatively, the overabundance of aquatic vegetation can compromise recreational activities, aesthetics, and property values.

4.2.1 PBWOA Lakes Exotic Aquatic Macrophytes

Exotic aquatic plants (macrophytes) are not native to a particular site, but are introduced by some biotic (living) or abiotic (non-living) vector. Such vectors include the transfer of aquatic plant seeds and fragments by boats and trailers (especially if the lake has public access sites), waterfowl, or by wind dispersal. In addition, exotic species may be introduced into aquatic systems through the release of aquarium or water garden plants into a water body. An aquatic exotic species may have profound impacts on the aquatic ecosystem.

Eurasian Watermilfoil (*Myriophyllum spicatum*; Figure 20) is an exotic aquatic macrophyte first documented in the United States in the 1880's (Reed 1997), although other reports (Couch and Nelson 1985) suggest it was first found in the 1940's. In recent years, this species has hybridized with native milfoil species to form hybrid species. Eurasian Watermilfoil has since spread to thousands of inland lakes in various states through the use of boats and trailers, waterfowl, seed dispersal, and intentional introduction for fish habitat. **Eurasian Watermilfoil is a major threat to the ecological balance of an aquatic ecosystem through causation of significant declines in favorable native vegetation within lakes (Madsen et *al*. 1991), in that it forms dense canopies and may limit light from reaching native aquatic plant species (Newroth 1985; Aiken et *al*. 1979).** Additionally, Eurasian Watermilfoil can alter the macroinvertebrate populations associated with particular native plants of certain structural architecture (Newroth 1985). **It has been found in the PBWOA lakes and has likely hybridized with native milfoil species.**

Starry stonewort (*Nitellopsis obtusa*; Figure 21) is an invasive macro alga that has invaded many inland lakes of Michigan and was originally discovered in the St. Lawrence River. **It has been found in many areas of the PBWOA lakes**. The "leaves" appear as long, smooth, angular branches of differing lengths. The alga has been observed in dense beds at depths beyond several meters and can grow to heights in excess of a few meters. It prefers clear alkaline waters and has been shown to cause significant declines in water quality and fishery spawning habitat.

Purple Loosestrife (*Lythrum salicaria*; Figure 22) is an invasive (i.e. exotic) emergent aquatic plant that inhabits wetlands and shoreline areas of the PBWOA lakes. *L. salicaria* has showy magenta-colored flowers that bloom in mid-July and terminate in late September. The seeds are highly resistant to tough environmental conditions and may reside in the ground for extended periods of time. It exhibits rigorous growth and may out-compete other favorable native emergents such as cattails (*Typha latifolia*) or native swamp loosestrife (*Decodon verticillatus*) and thus reduce the biological diversity of localized ecosystems. The plant is spreading rapidly across the United States and is converting diverse wetland habitats to monocultures with substantially lower biological diversity.

The PBWOA lakes also contained the emergent Giant Common Reed (*Phragmites australis*; Figure 23). *Phragmites* is an imminent threat to the surface area of PBWOA lakes since it may grow submersed in water depths of $\geq$ 2 meters (Herrick and Wolf, 2005), thereby drying up wetland habitat and reducing lake surface area. In addition, large, dense stands of *Phragmites* accumulate sediments, reduce habitat variability, and impede natural water flow (Wang et *al*., 2006).

Lastly, the PBWOA lakes also contained the invasive perennial aquatic emergent plant, Flowering Rush (*Butomus umbellatus;* Figure 24) which may grow up to 4 feet high in shallow water and also can grow in deeper water without producing flowers at the apical portion. The stems are triangular in cross section and the leaves are shaped like long swords. The plant reproduces via seeds and bulb-lets which are dispersed by water currents.

Figure 20. Eurasian Watermilfoil ©RLS

Figure 21. Starry Stonewort ©RLS

Figure 22. Purple Loosestrife ©RLS

Figure 23. Phragmites ©RLS

Figure 24. Flowering Rush

Exotic Aquatic Plant Species	*Common Name*	*Growth Habit*
Myriophyllum spicatum	Hybrid Eurasian Watermilfoil	Submersed; Rooted
Nitellopsis obtusa	Starry Stonewort	Submersed; Rooted
Lythrum salicaria	Purple Loosestrife	Emergent
Phragmites australis	Giant Common Reed	Emergent
Butomus umbellatus	Flowering Rush	Emergent

Table 15. PBWOA lakes exotic aquatic plant and macro algae species (August 6-7, 2015).

The surveys conducted on the PBWOA Lakes utilized the methods as defined by the Michigan Department of Environmental Quality (MDEQ). The Aquatic Vegetation Assessment Site (AVAS) Survey method was developed by the MDEQ to assess the presence and relative abundance of submersed, floating-leaved, and emergent aquatic vegetation within and around the littoral zones of Michigan lakes. With this survey method, the littoral zone areas of the lake are divided into lakeshore sections approximately 100 - 300 feet in length. The species of aquatic macrophytes present and relative abundance of each macrophyte are recorded and then the amount of cover in the littoral zone is calculated. **A full list of all species and their relative abundance for all lakes is listed in Appendix A. Table 16 below summarizes the acreage of invasive milfoil and starry stonewort found in each lake and the canals. Note: The quantity of emergent such as Purple loosestrife, Phragmites, and Flowering rush was difficult to estimate due to the sparse cover but maps showing geo-referenced locations of each invasive species were created and are shown in Figures 25-47 below.**

PBWOA Lake Name	Milfoil Acreage	Starry Stonewort Acreage
Zukey Lake	4.75	7.3
Strawberry Lake	16.5	8.75
Gallagher Lake	7.1	6.3
Little Portage Lake	9.5	9.5
Big Portage Lake	25	34.5
Baseline Lake	0	9.75
Whitewood Lake	2.5	6.75
Tamarack Lake	0.7	9.1

Table 16. PBWOA Lakes exotic aquatic plant and macro algae species coverage (August 6-7, 2015).

Zukey Lake Invasive Aquatic Plant Maps:

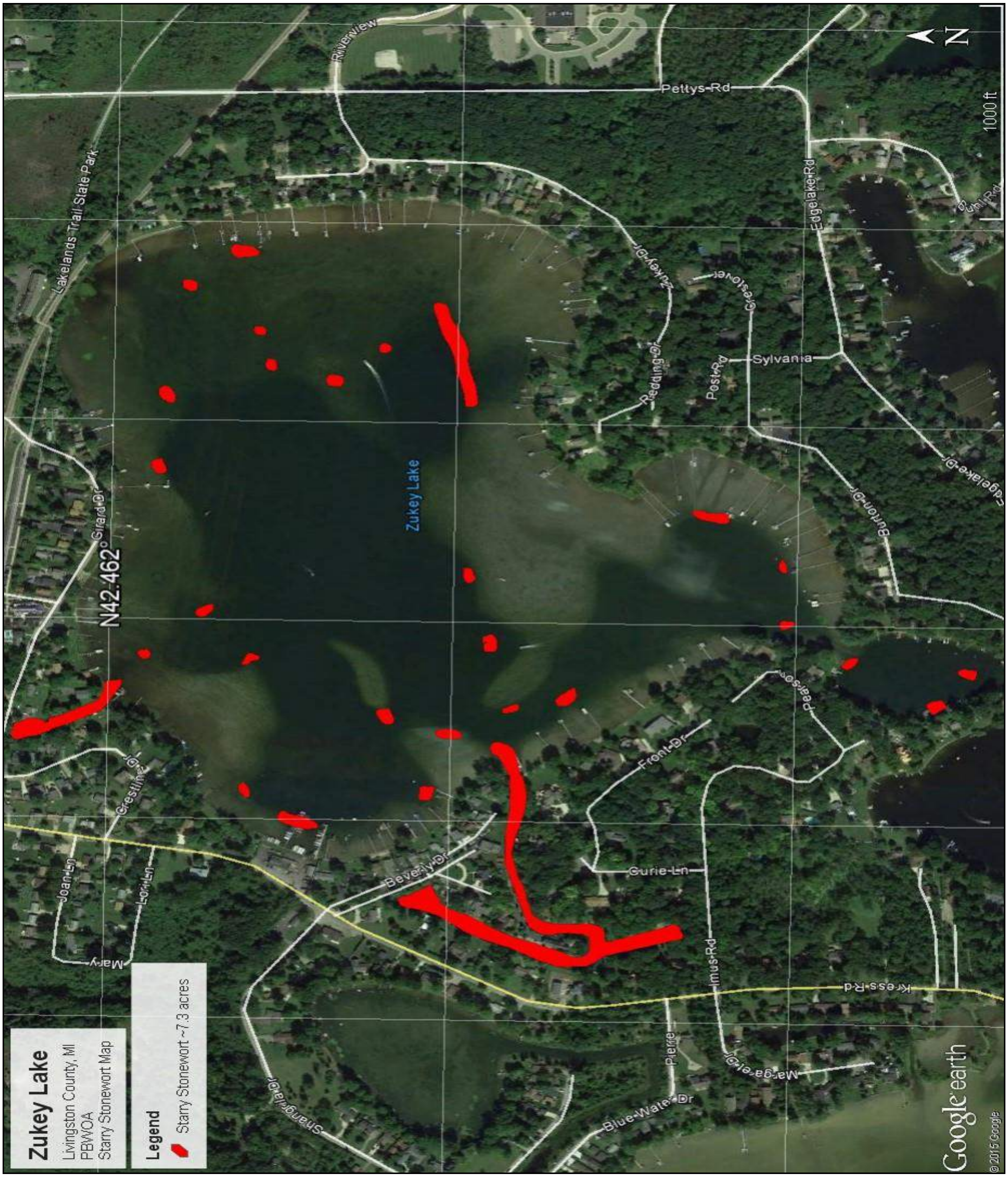

Figure 25. Zukey Lake Starry Stonewort locations (August, 2015).

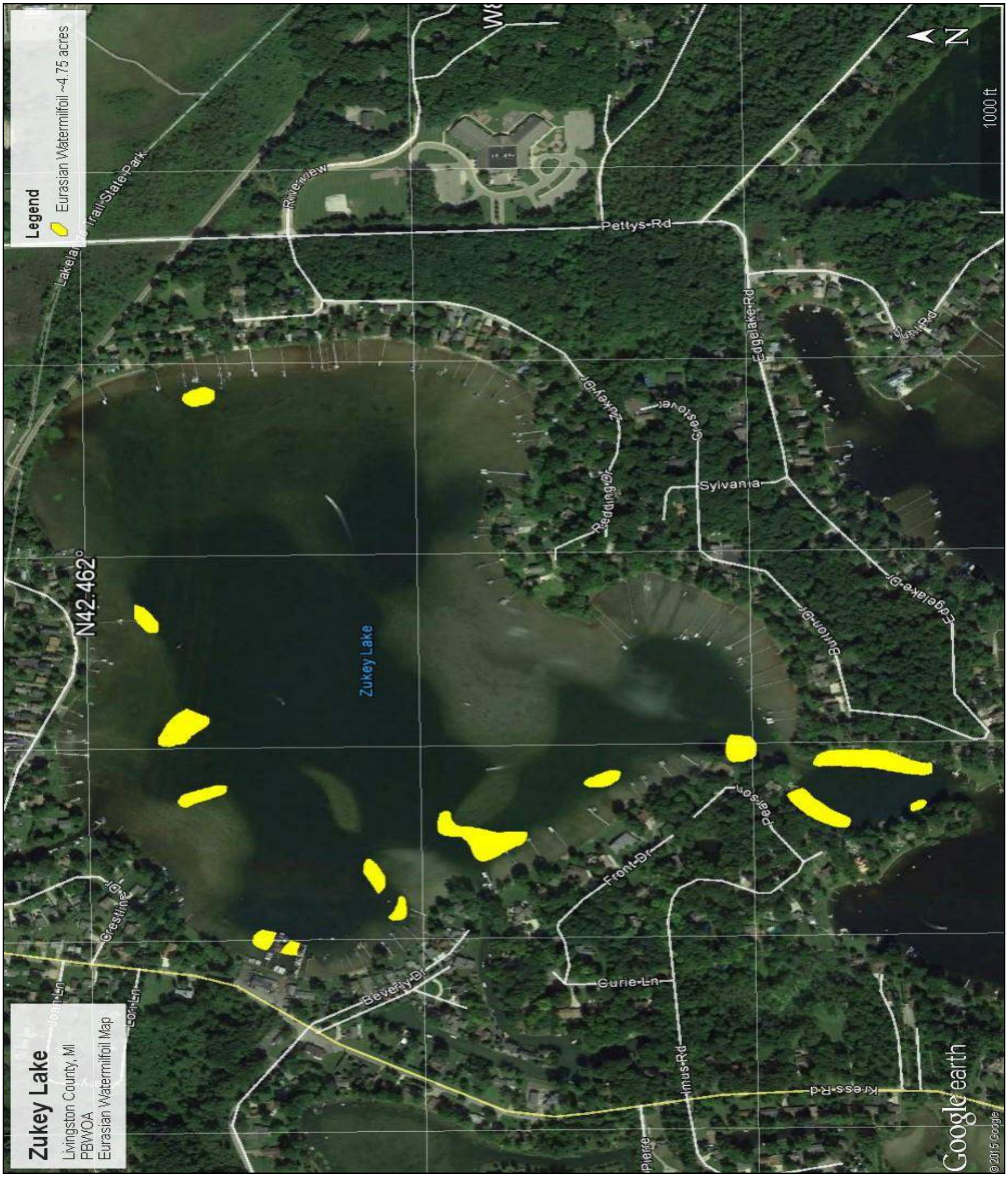

Figure 26. Zukey Lake Invasive Watermilfoil locations (August, 2015).

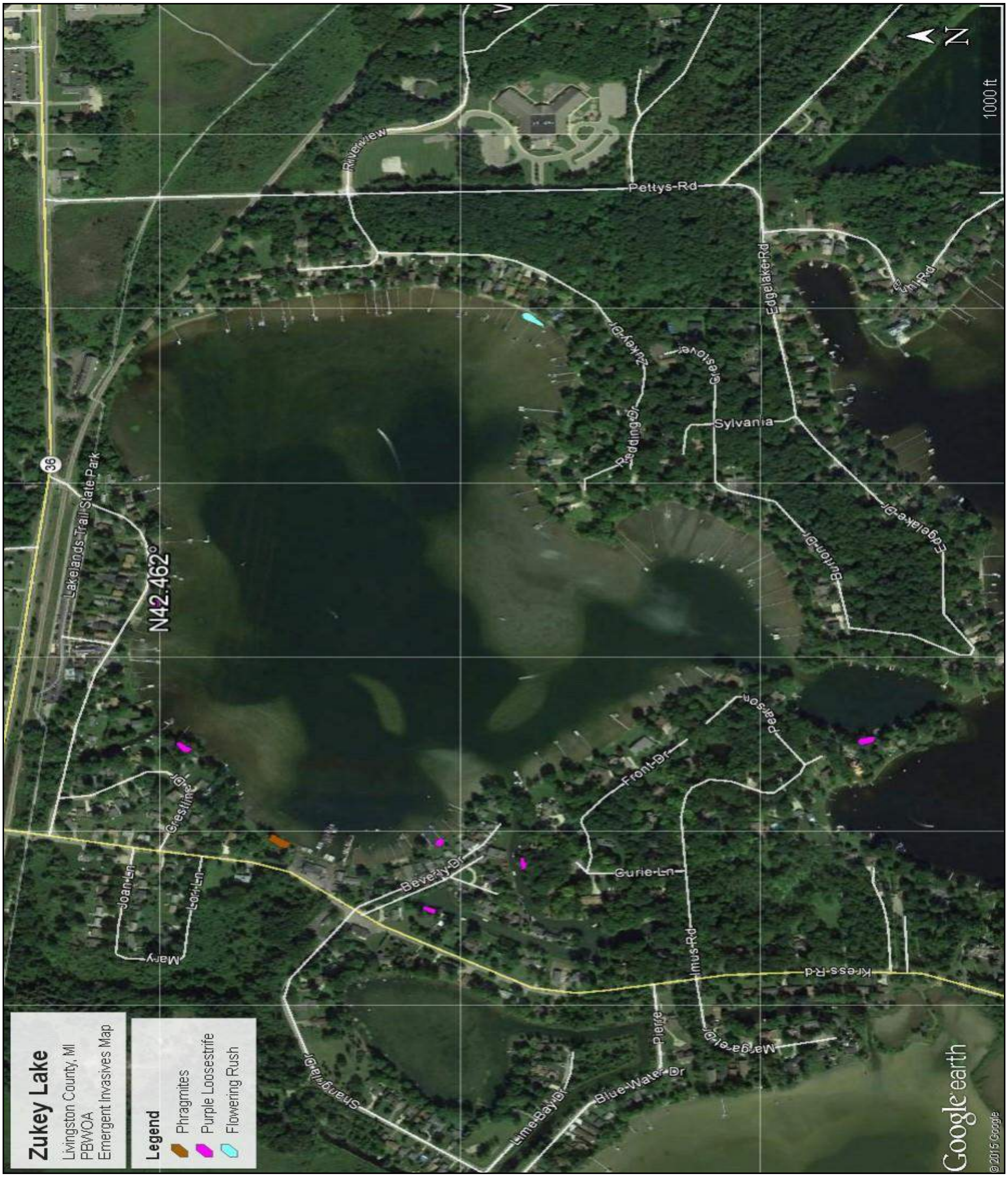

Figure 27. Zukey Lake Invasive Emergent locations (August, 2015).

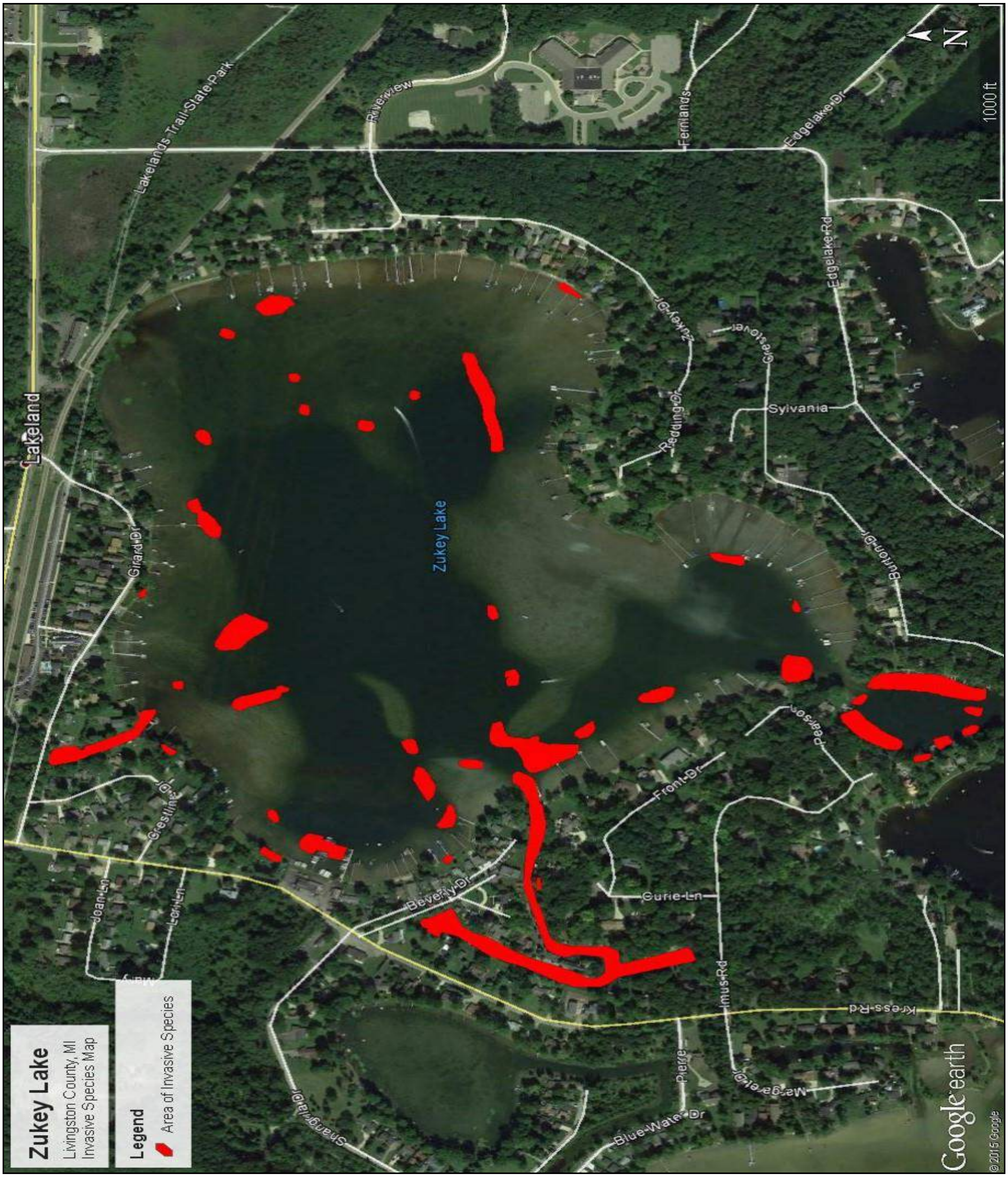

Figure 28. Zukey Lake Invasive Submersed and Emergents locations (August, 2015).

Strawberry Lake Invasive Aquatic Plant Maps:

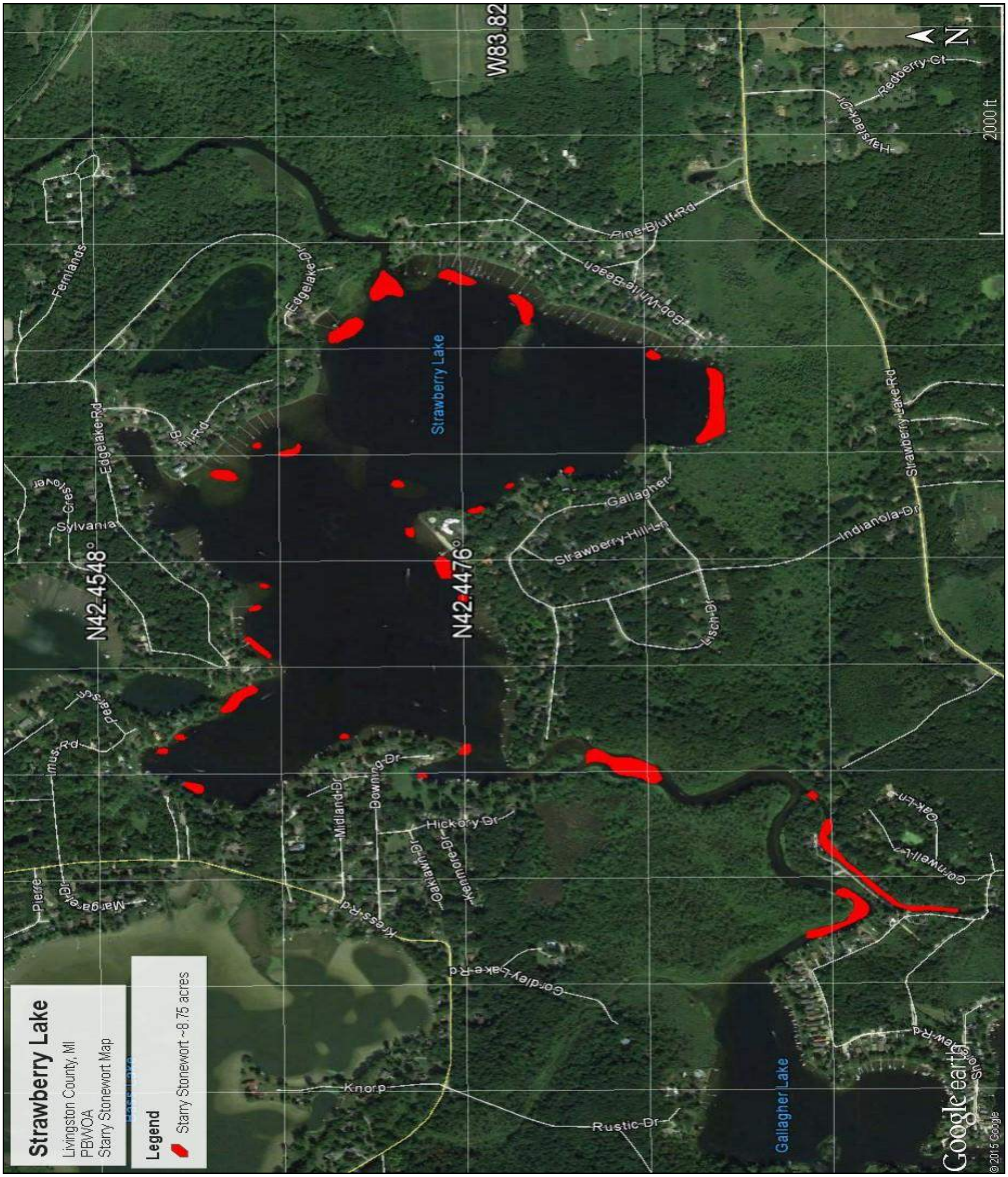

Figure 29. Strawberry Lake Starry Stonewort locations (August, 2015).

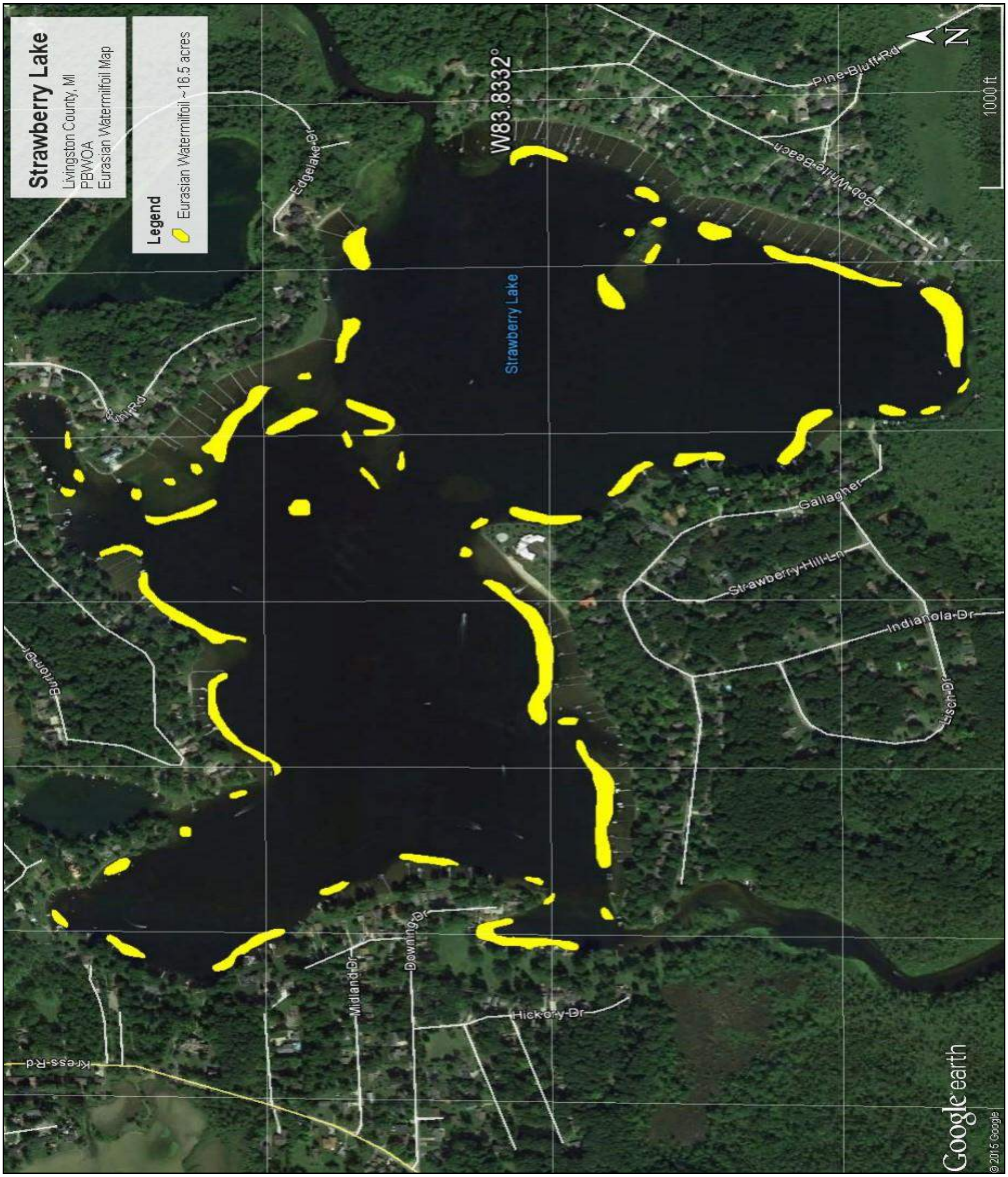

Figure 30. Strawberry Lake Invasive Watermilfoil locations (August, 2015).

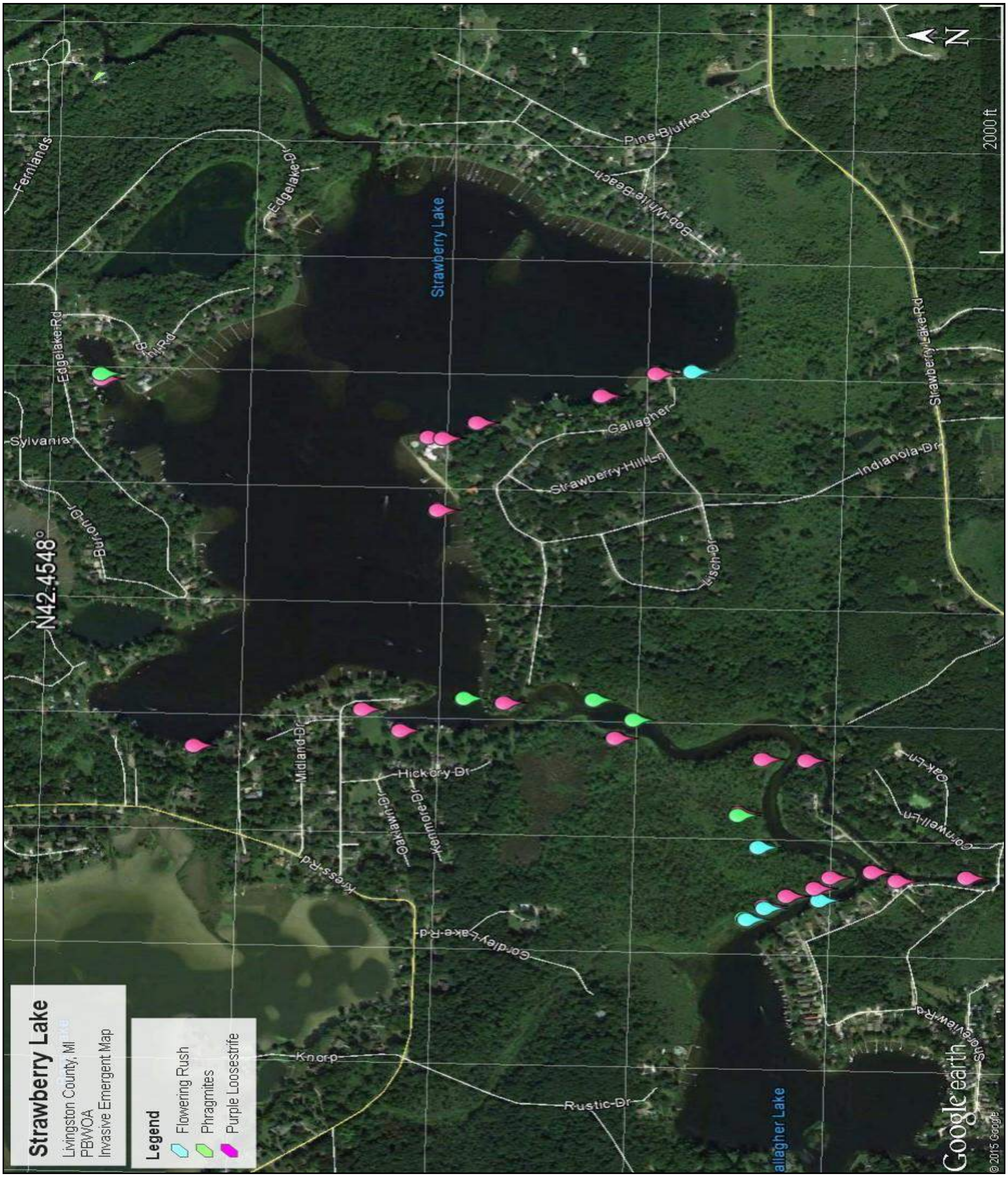

Figure 31. Strawberry Lake Invasive Emergent locations (August, 2015).

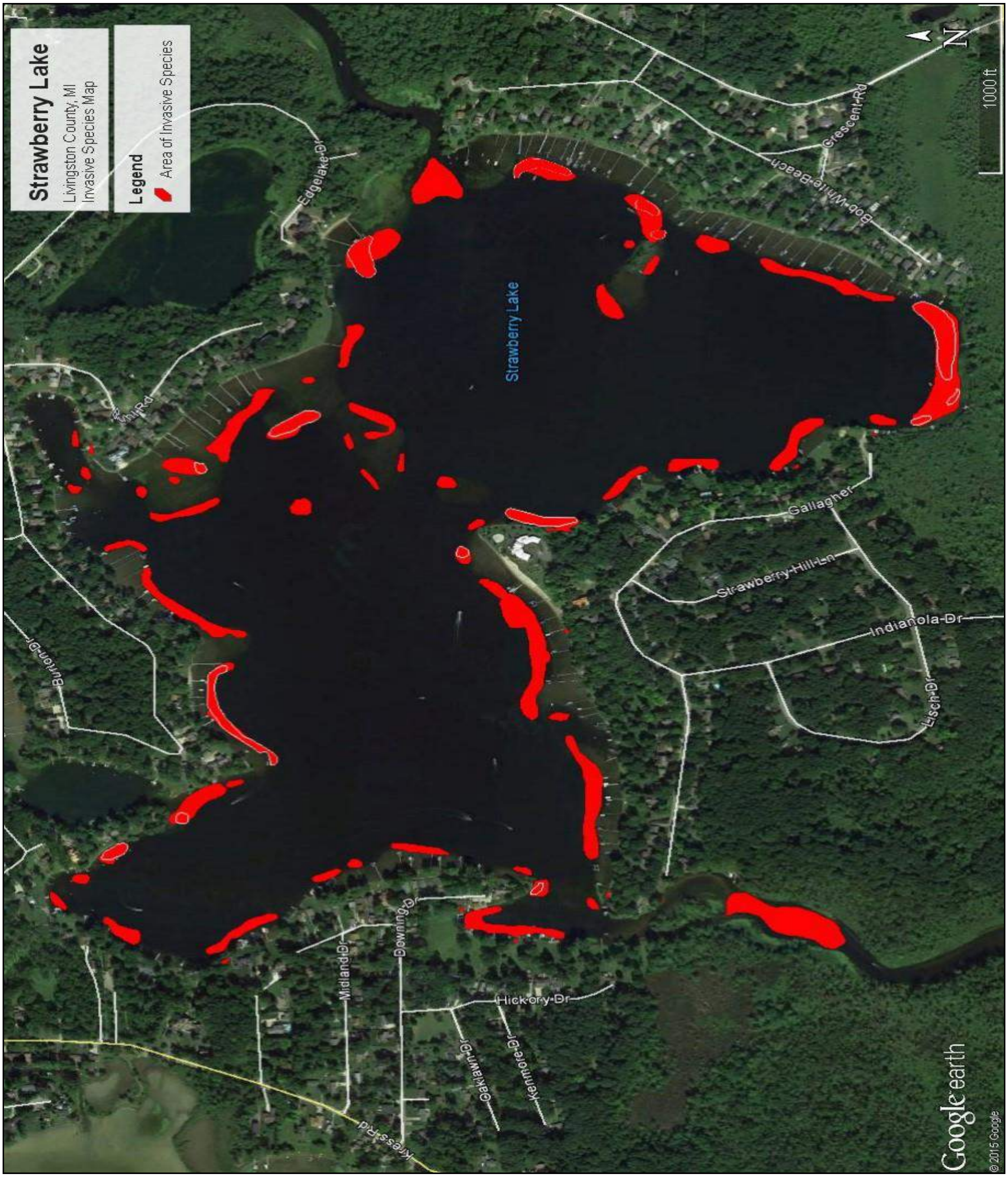

Figure 32. Strawberry Lake Invasive Submersed and Emergents locations (August, 2015).

Gallagher Lake Invasive Aquatic Plant Maps:

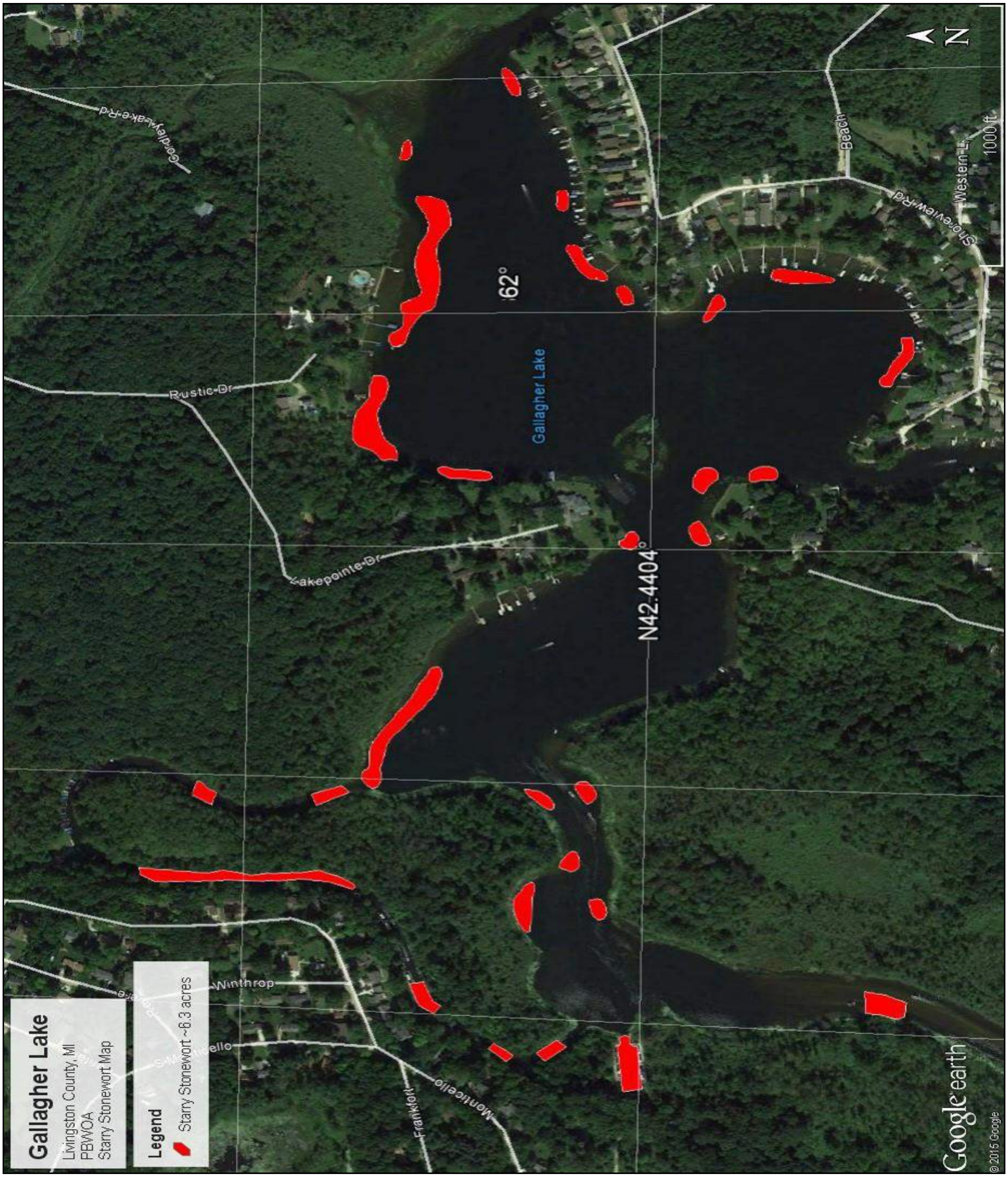

Figure 33. Gallagher Lake Invasive Starry Stonewort locations (August, 2015).

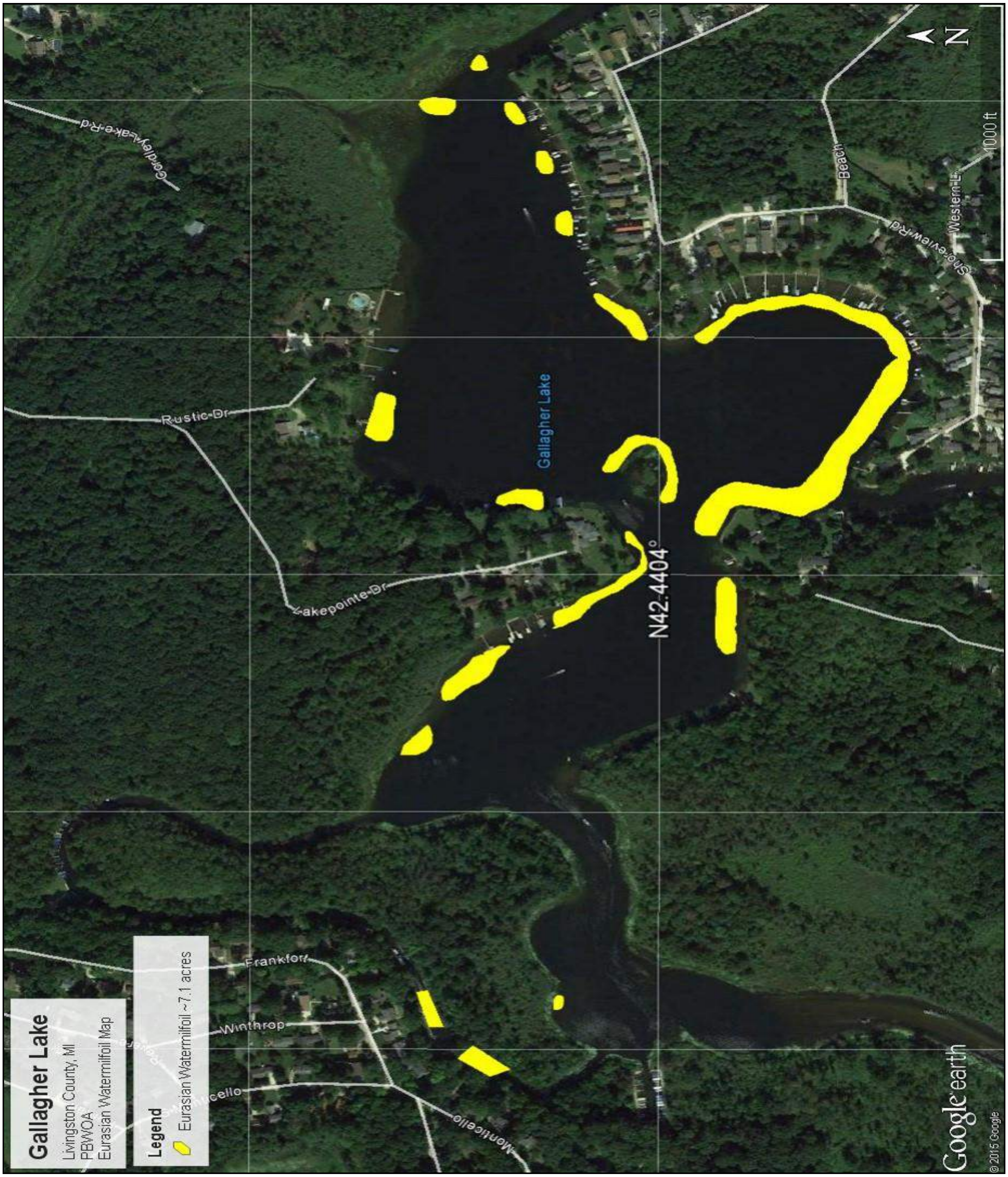

Figure 34. Gallagher Lake Invasive Watermilfoil locations (August, 2015).

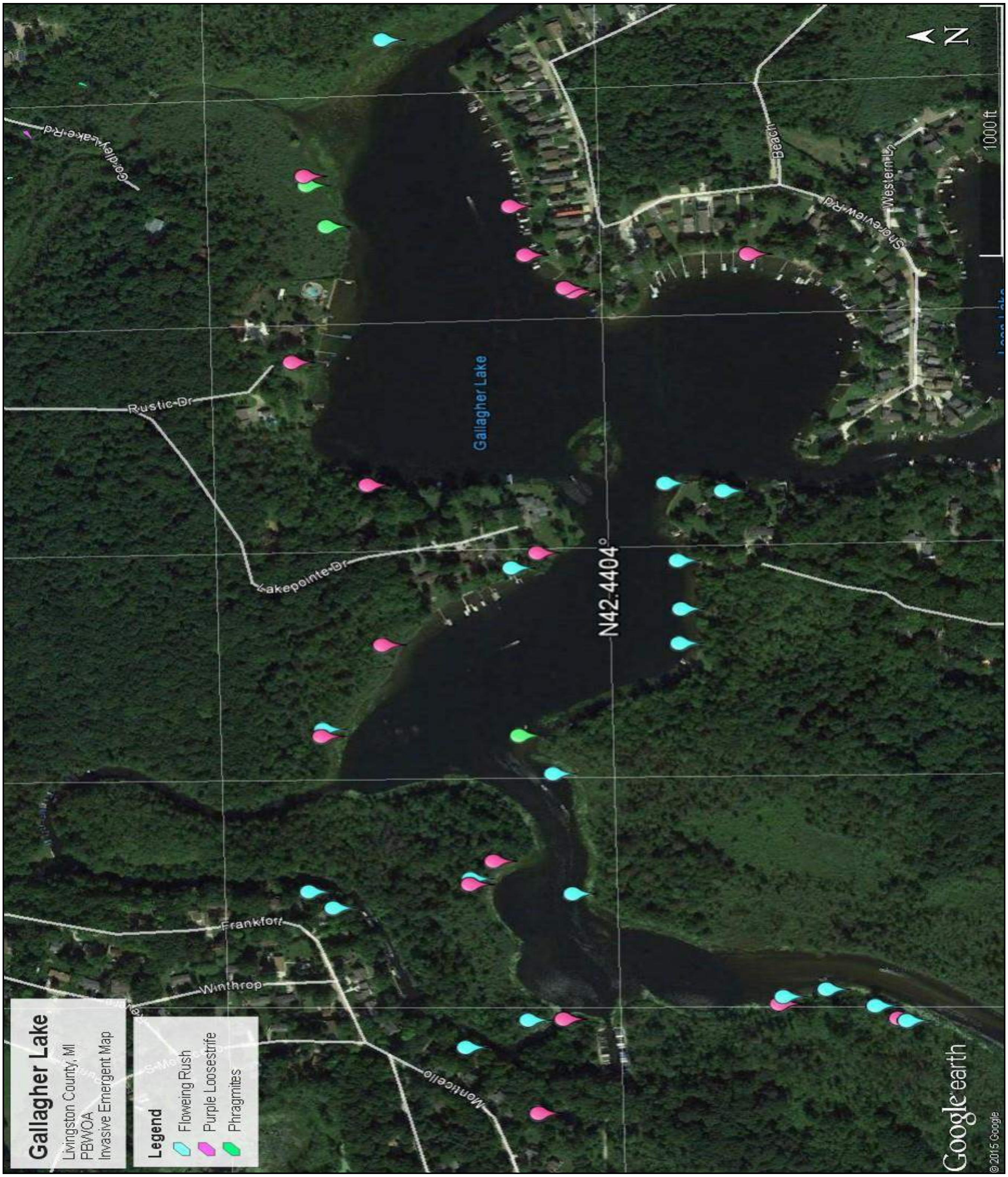

Figure 35. Gallagher Lake Invasive Emergent locations (August, 2015).

Figure 36. Gallagher Lake Invasive Submersed and Emergents locations (August, 2015).

Little Portage Lake Invasive Aquatic Plant Maps:

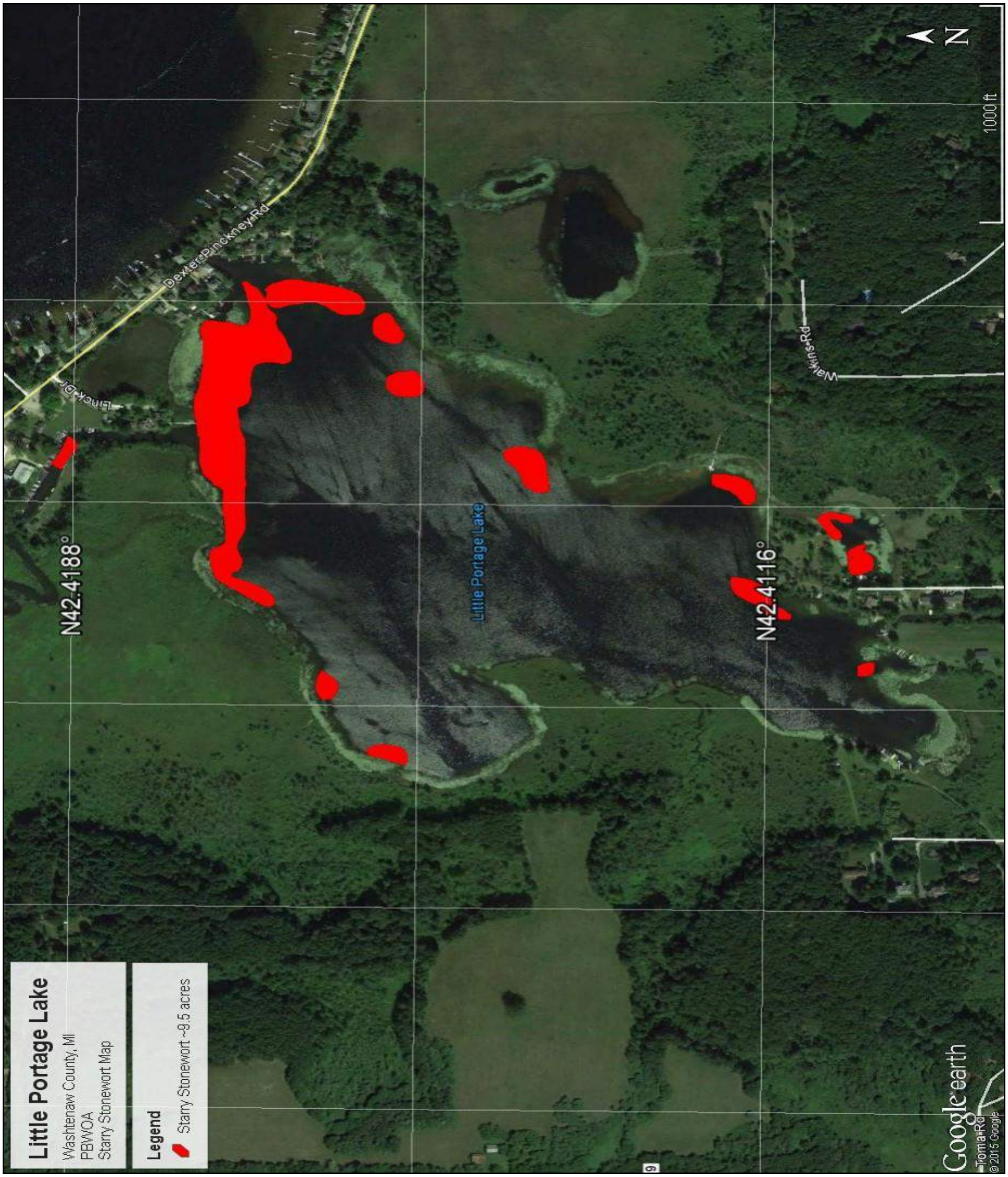

Figure 37. Little Portage Lake Invasive Starry Stonewort locations (August, 2015).

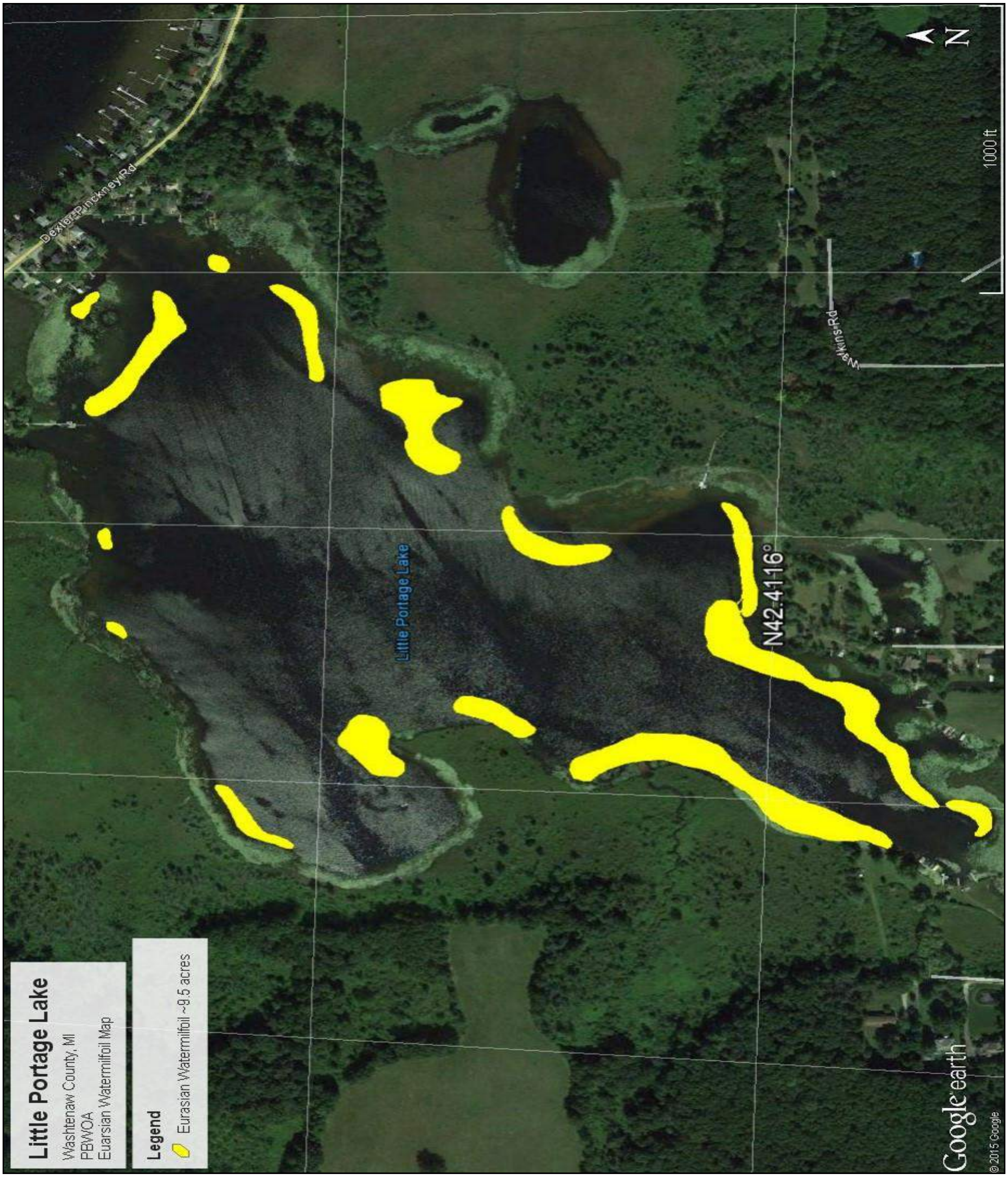

Figure 38. Little Portage Lake Invasive Watermilfoil locations (August, 2015).

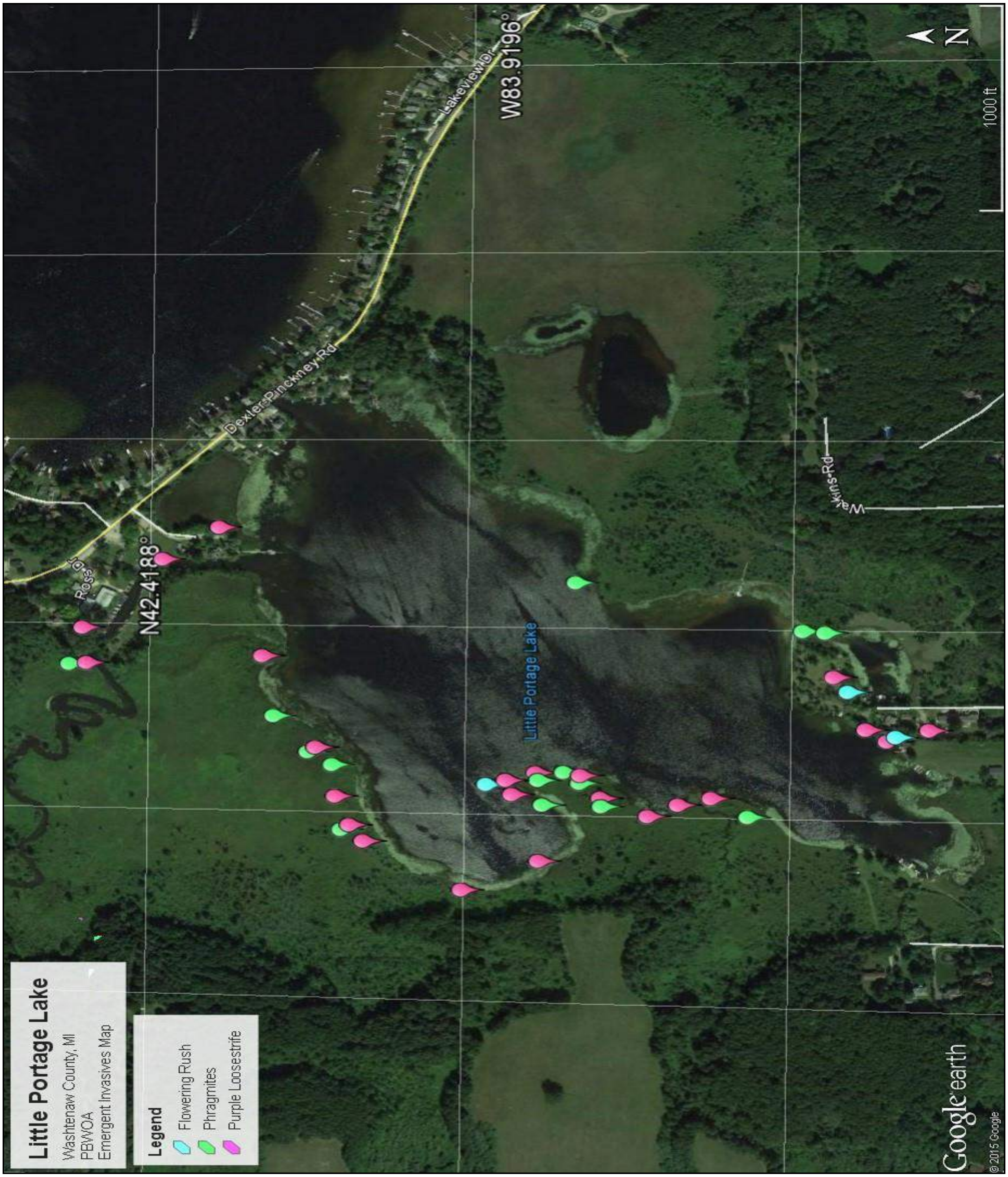

Figure 39. Little Portage Lake Emergent locations (August, 2015).

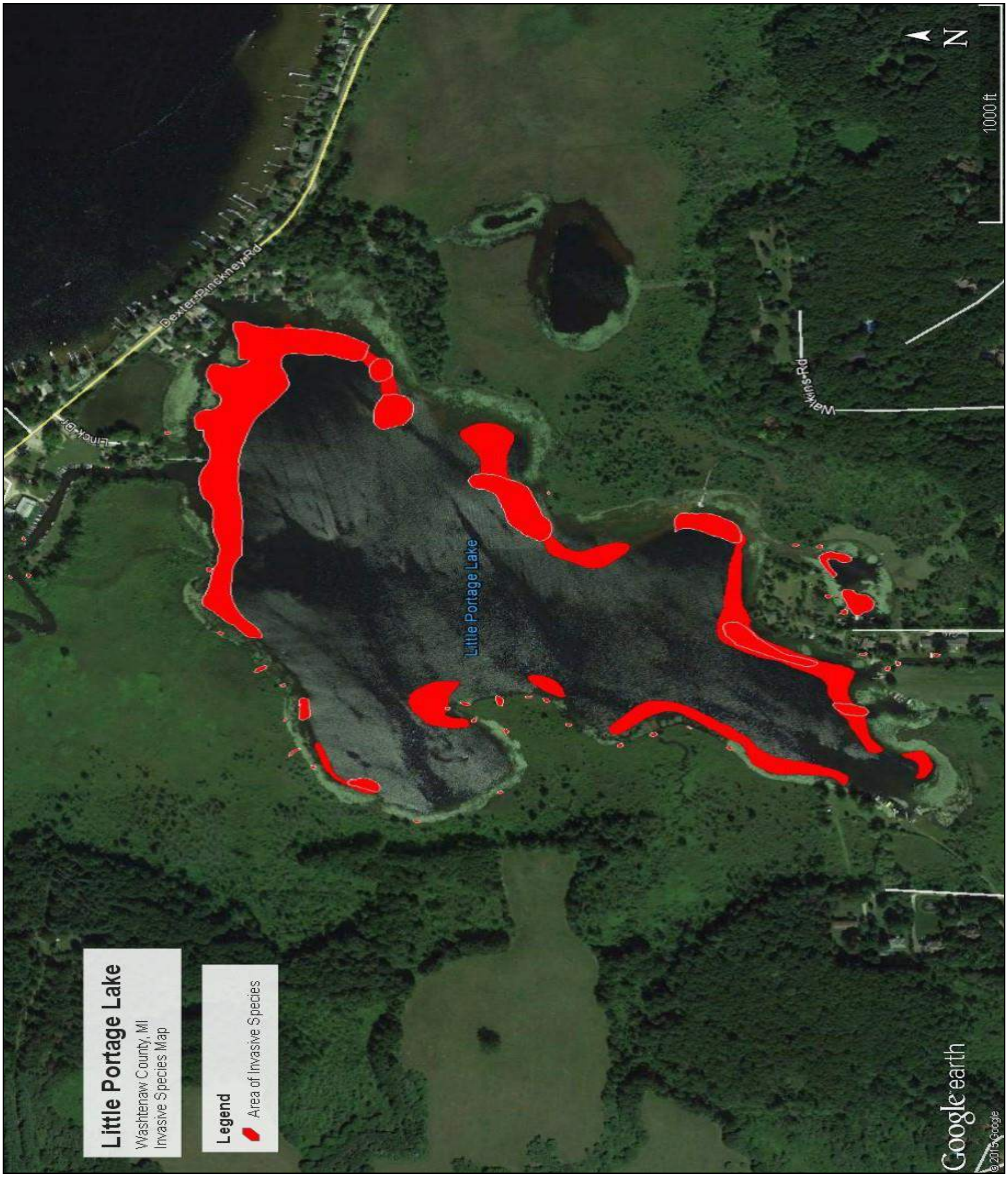

Figure 40. Little Portage Lake Invasive Submersed and Emergents locations (August, 2015).

Big Portage Lake Invasive Aquatic Plant Maps:

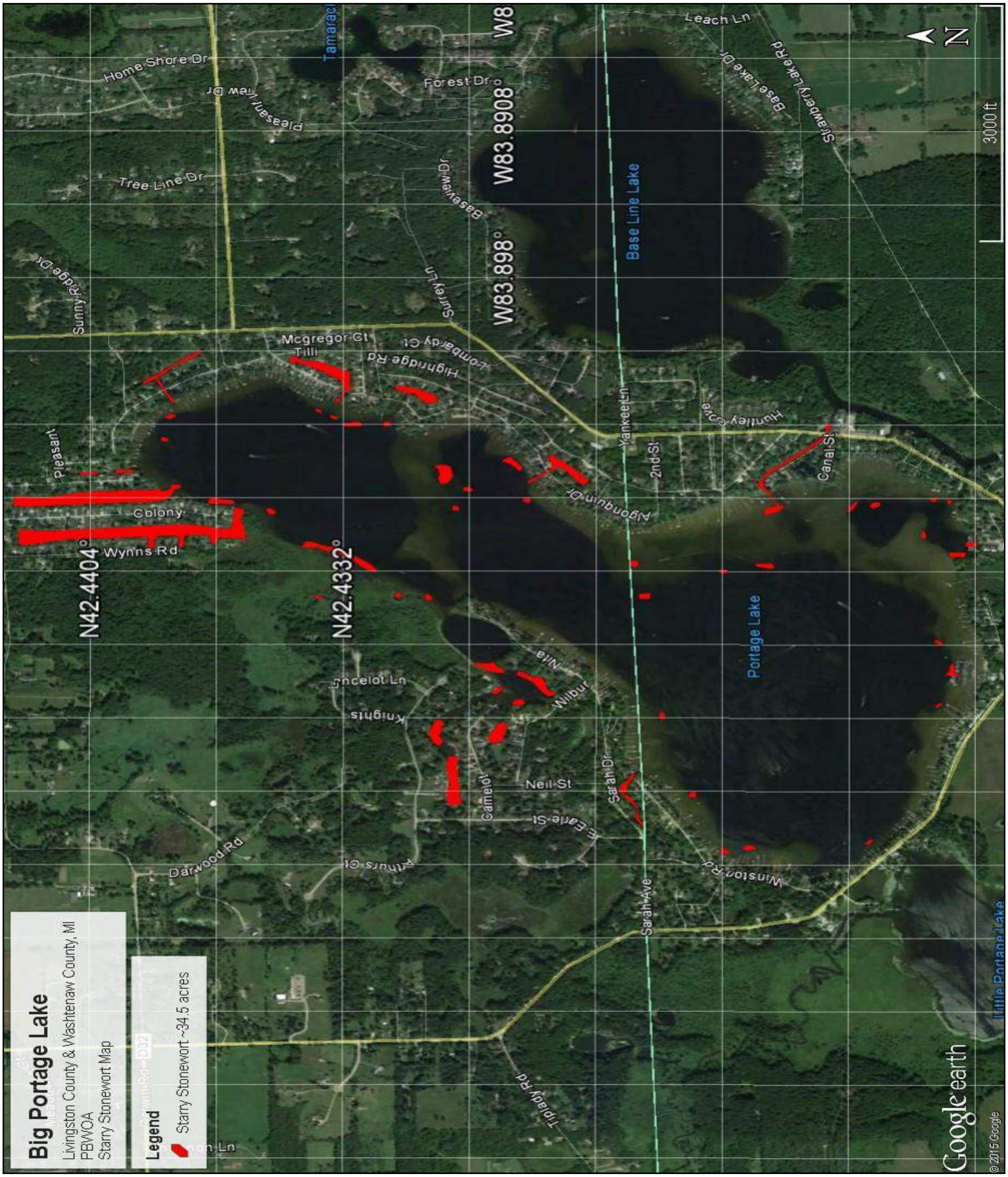

Figure 41. Big Portage Lake Starry Stonewort locations (August, 2015).

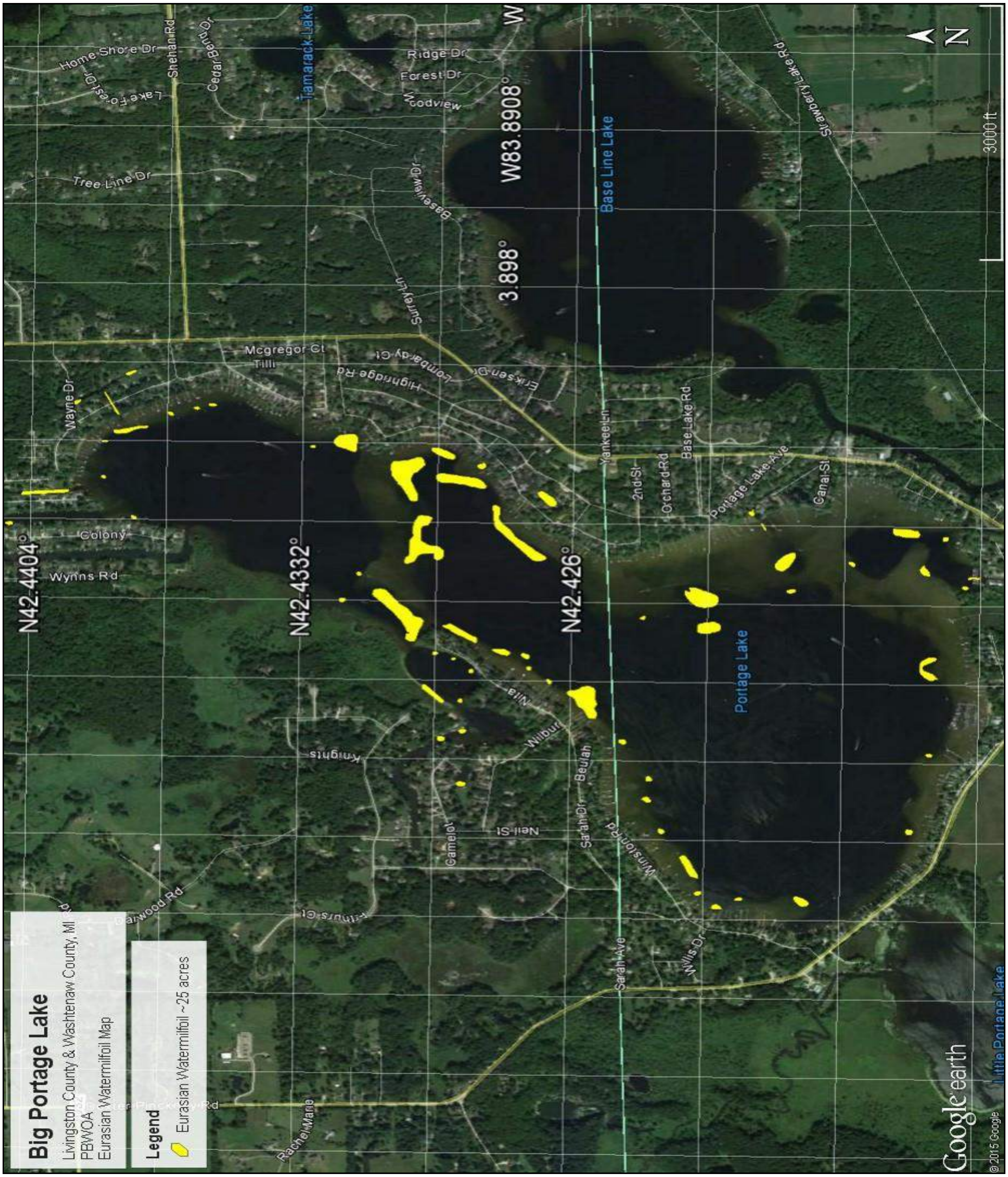

Figure 42. Big Portage Lake Invasive Watermilfoil locations (August, 2015).

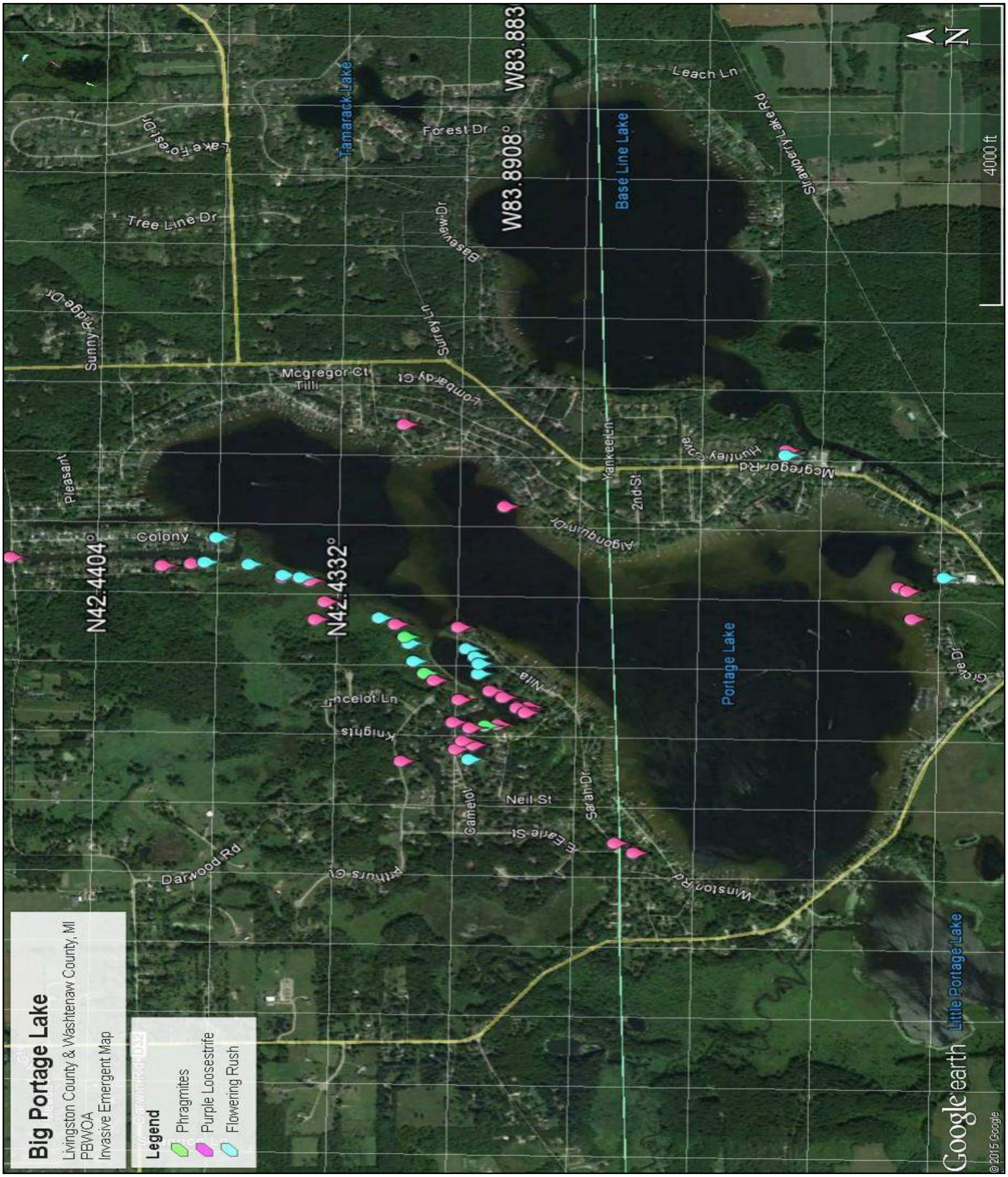

Figure 43. Big Portage Lake Invasive Emergent locations (August, 2015).

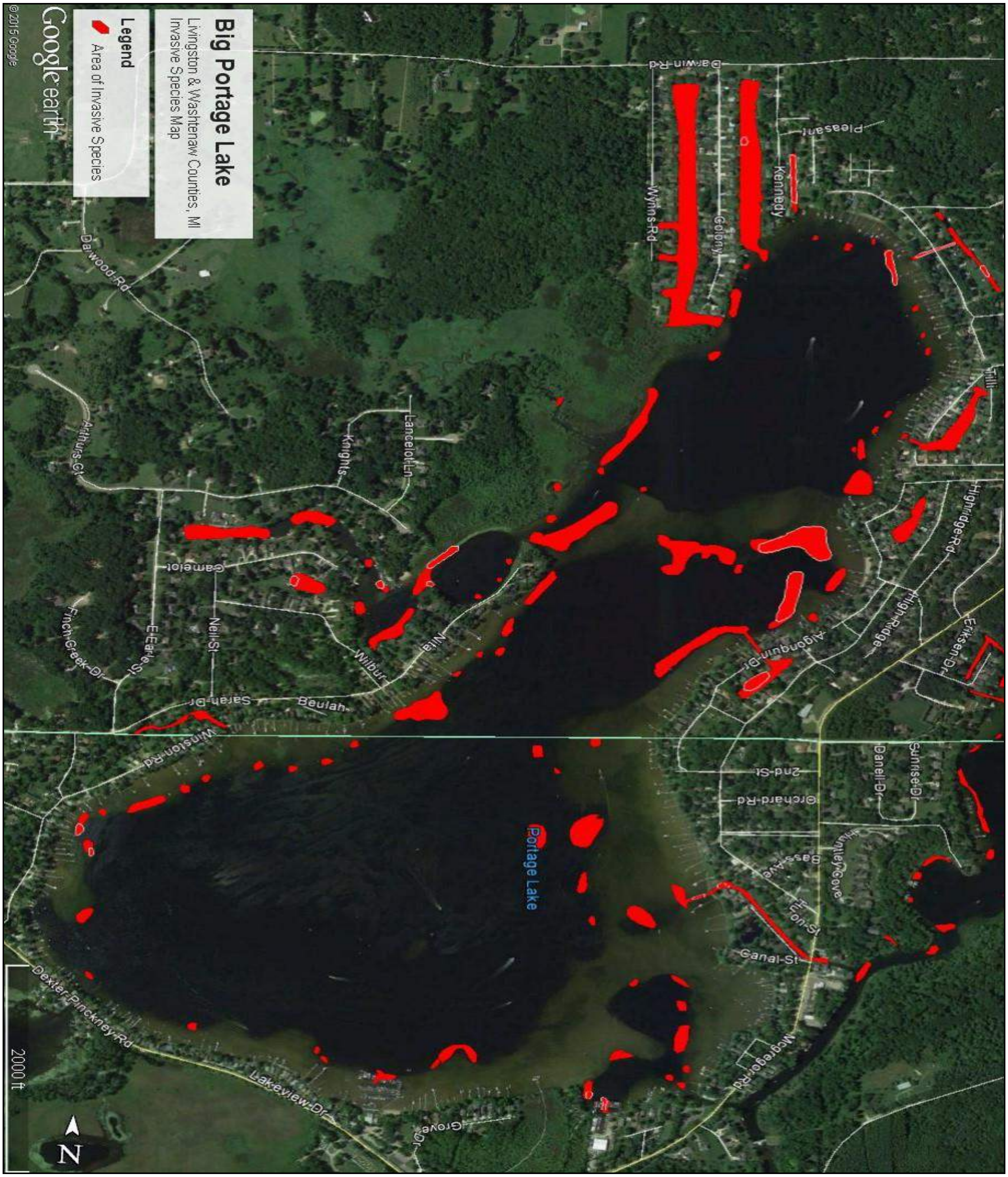

Figure 44. Big Portage Lake Invasive Submersed and Emergents locations (August, 2015).

Baseline Lake Invasive Aquatic Plant Maps:

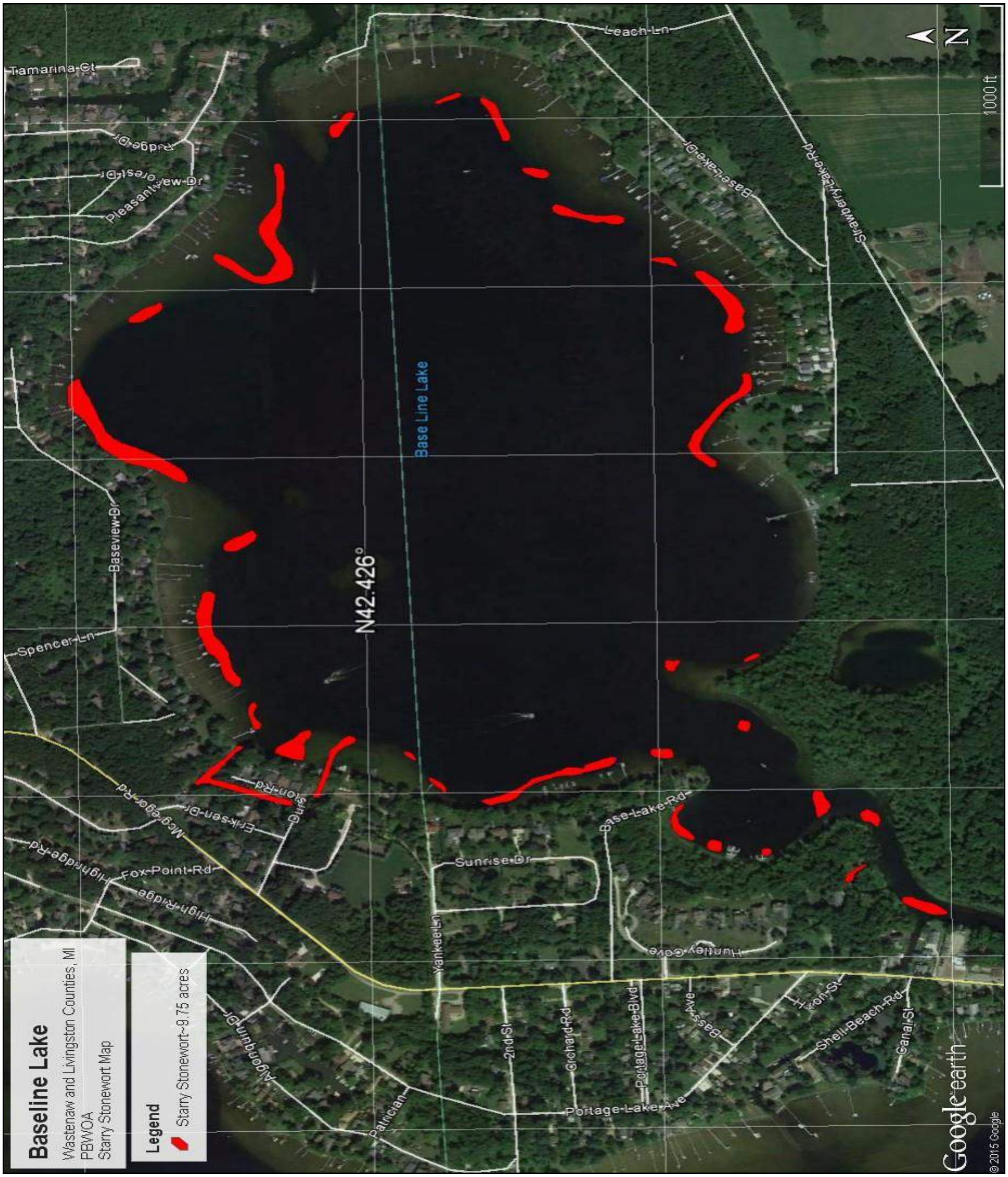

Figure 45. Baseline Lake Invasive Starry Stonewort locations (August, 2015).

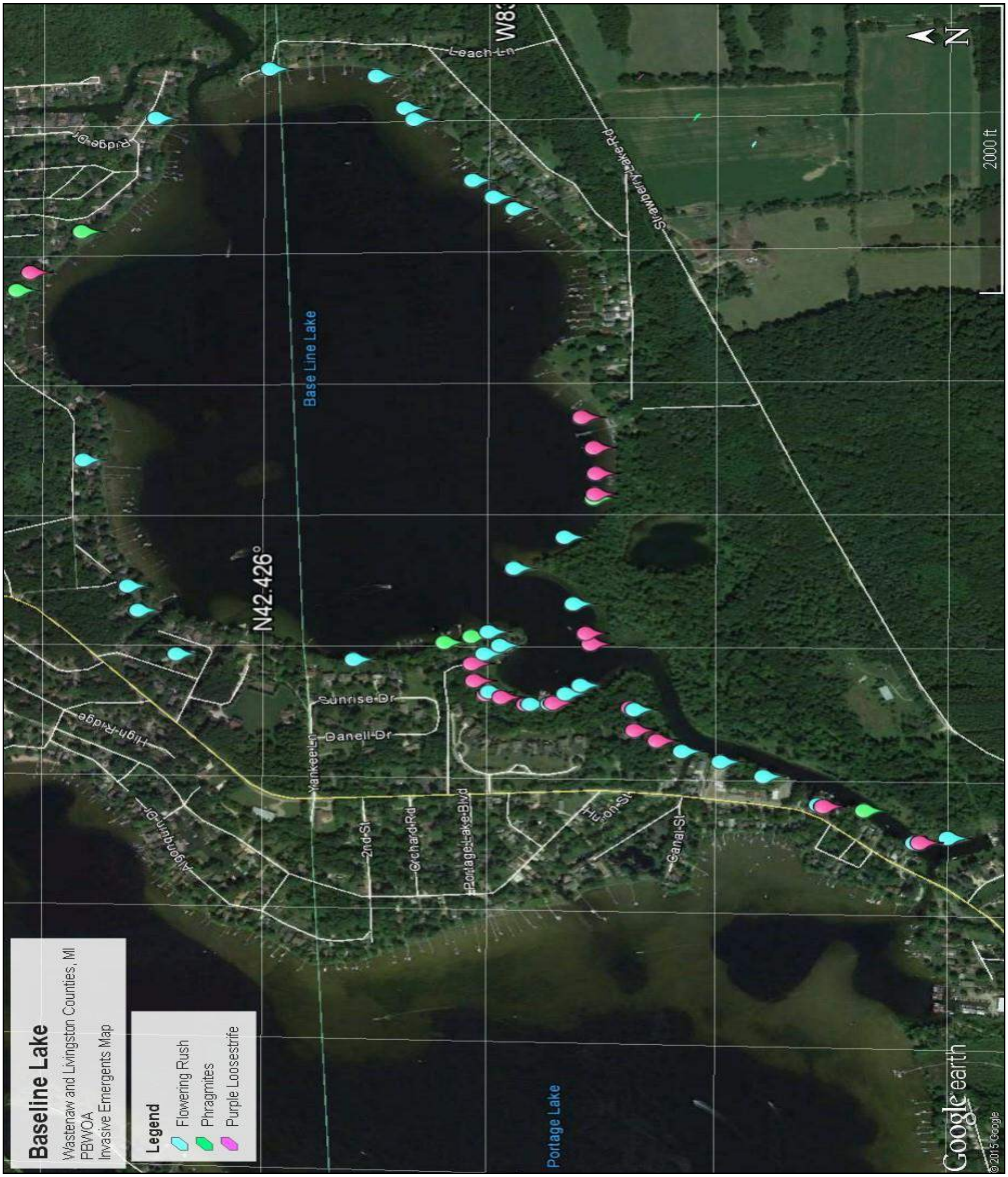

Figure 46. Baseline Lake Invasive Emergents locations (August, 2015).

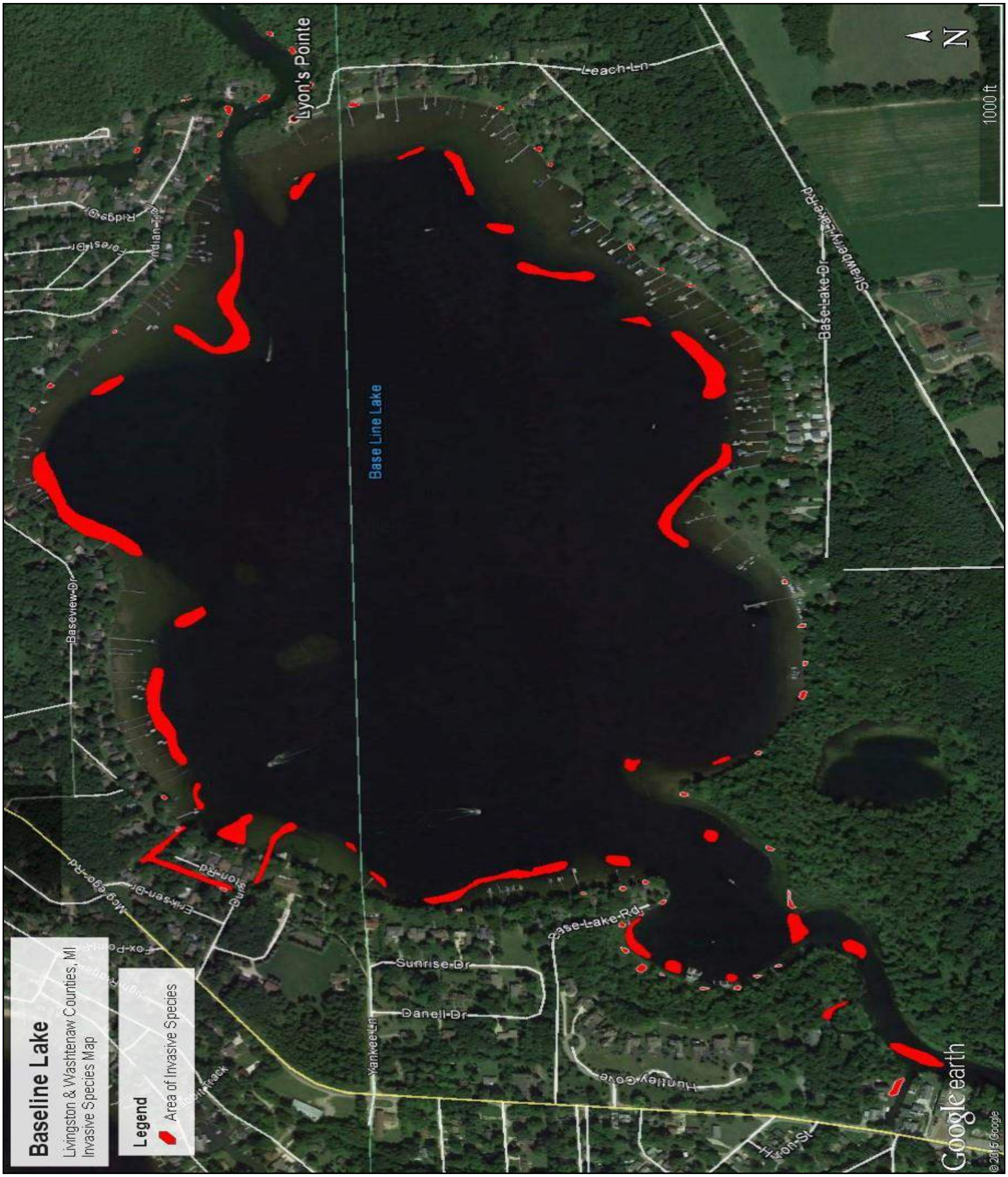

Figure 47. Baseline Lake Invasive Submersed and Emergents locations (August, 2015).

Whitewood Lakes Invasive Aquatic Plant Maps:

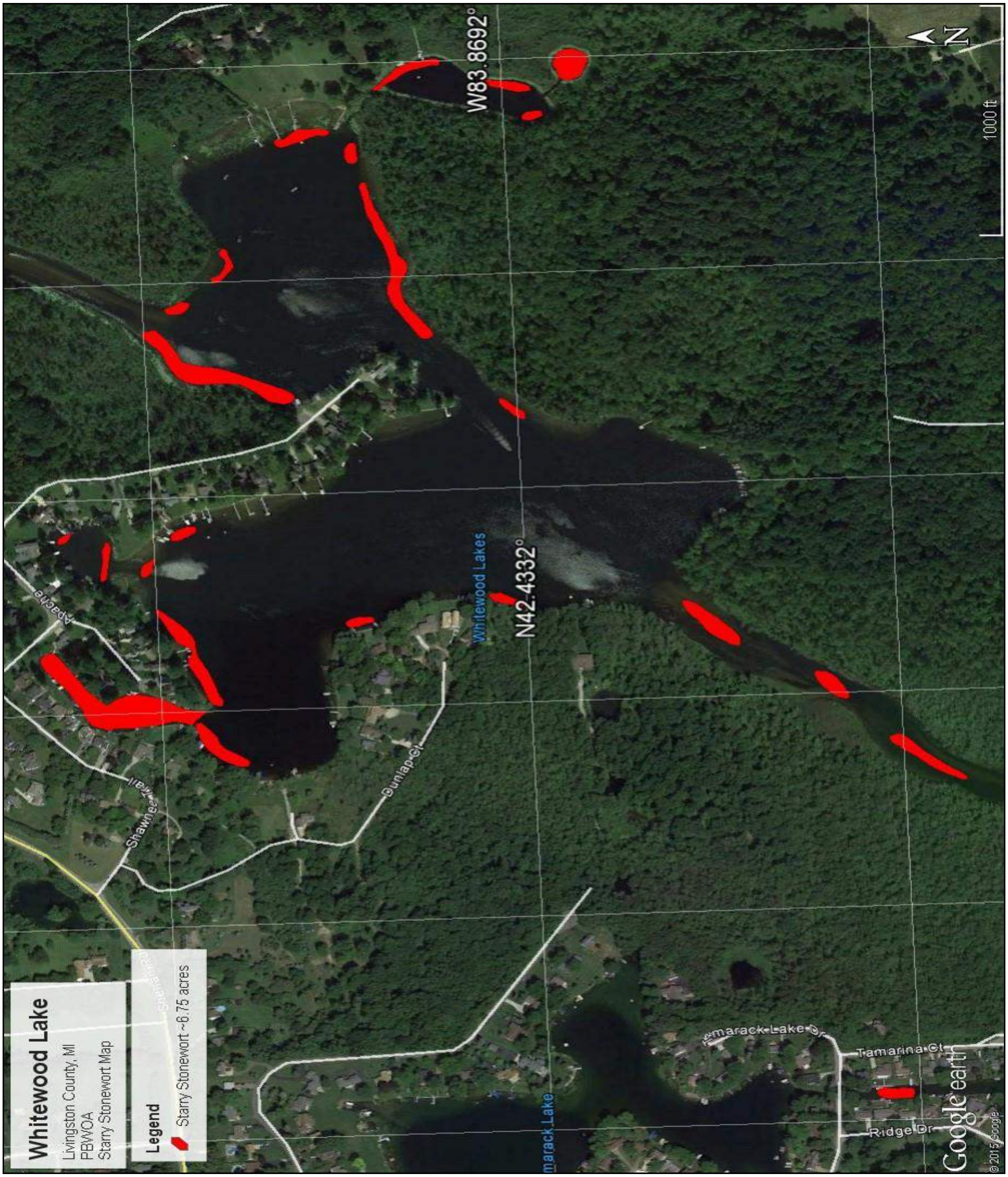

Figure 48. Whitewood Lake Invasive Starry Stonewort locations (August, 2015).

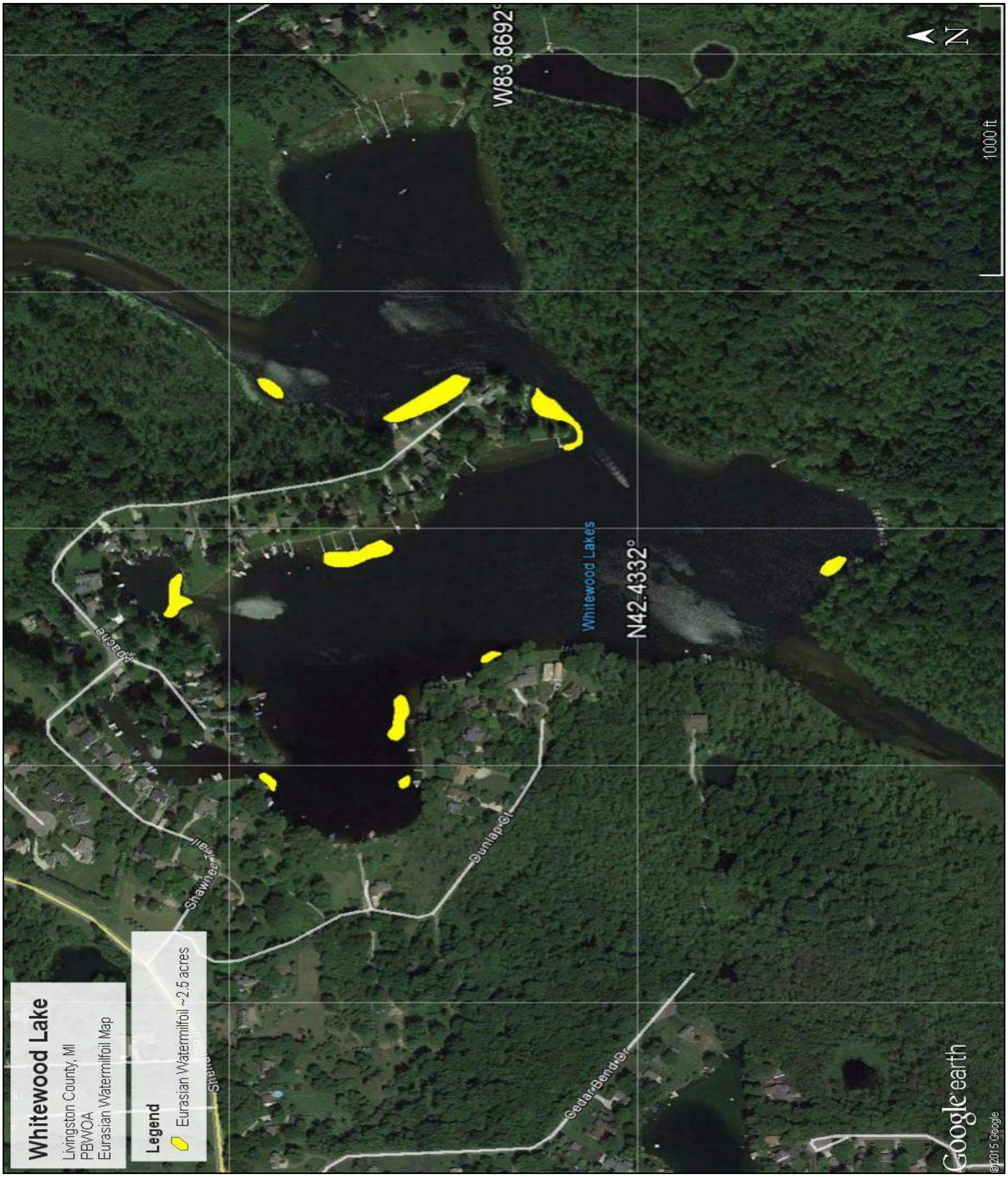

Figure 49. Whitewood Lake Invasive Watermilfoil locations (August, 2015).

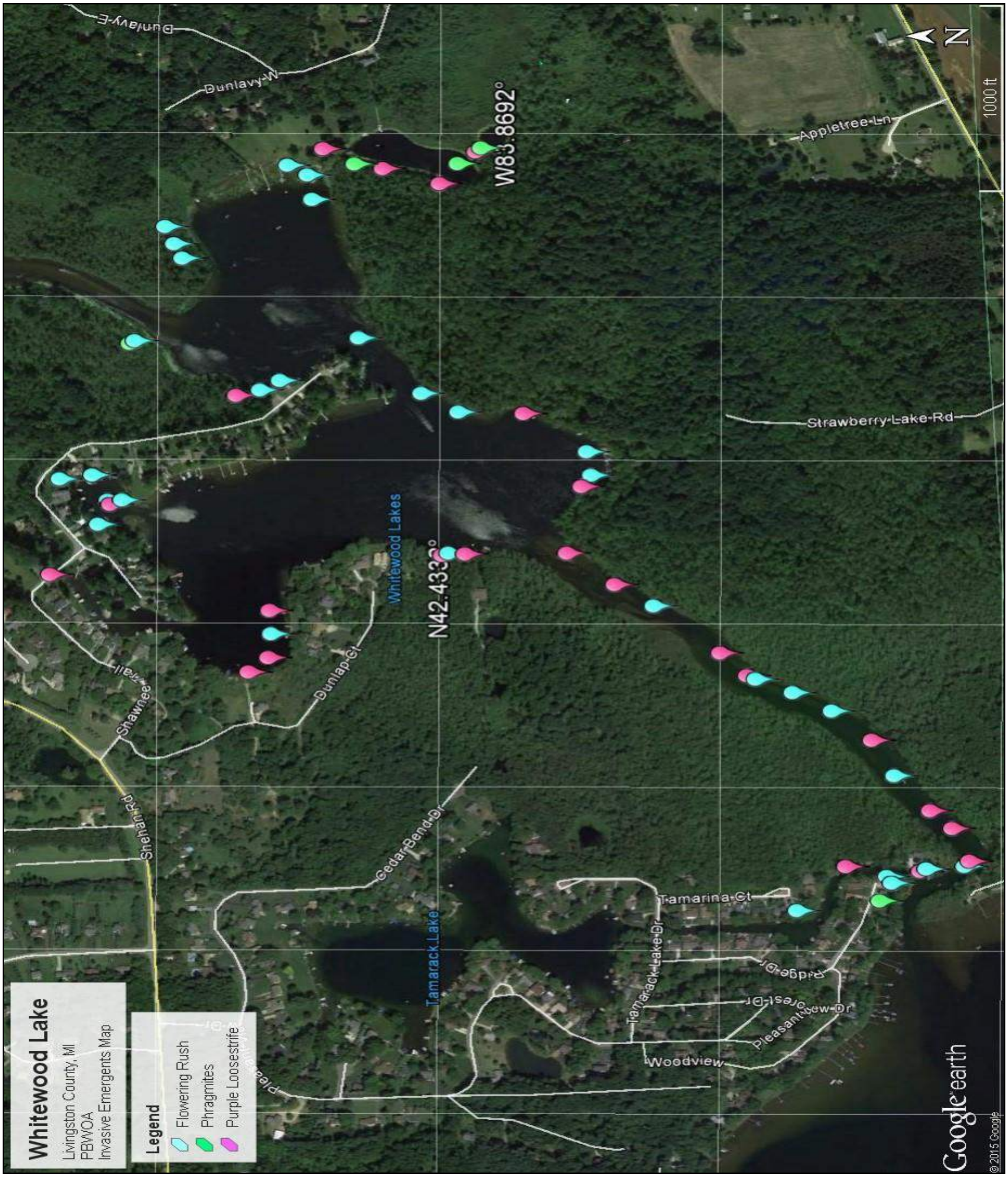

Figure 50. Whitewood Lake Invasive Emergents locations (August, 2015).

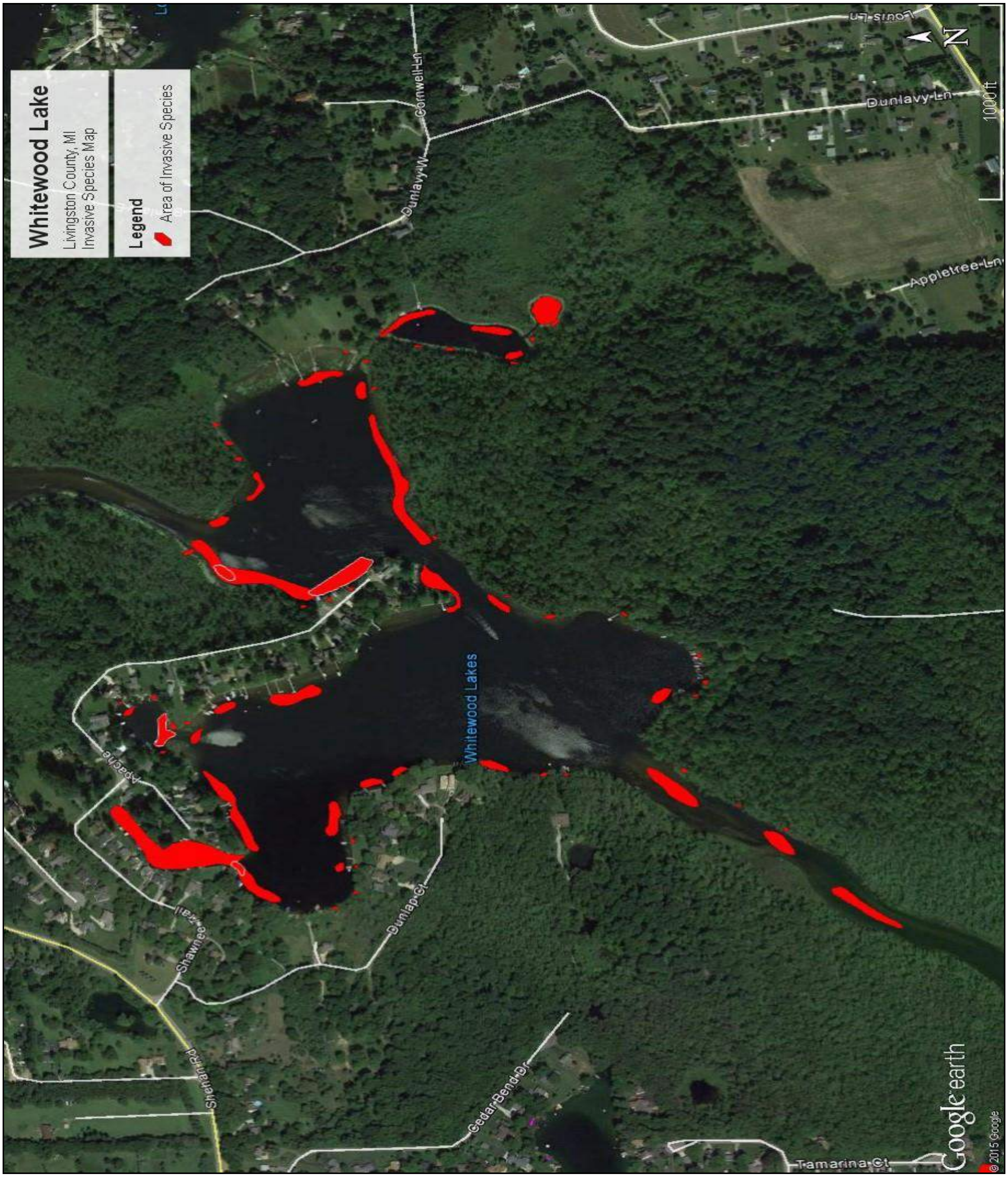

Figure 51. Whitewood Lake Invasive Submersed and Emergents locations (August, 2015).

Tamarack Lake Invasive Aquatic Plant Maps:

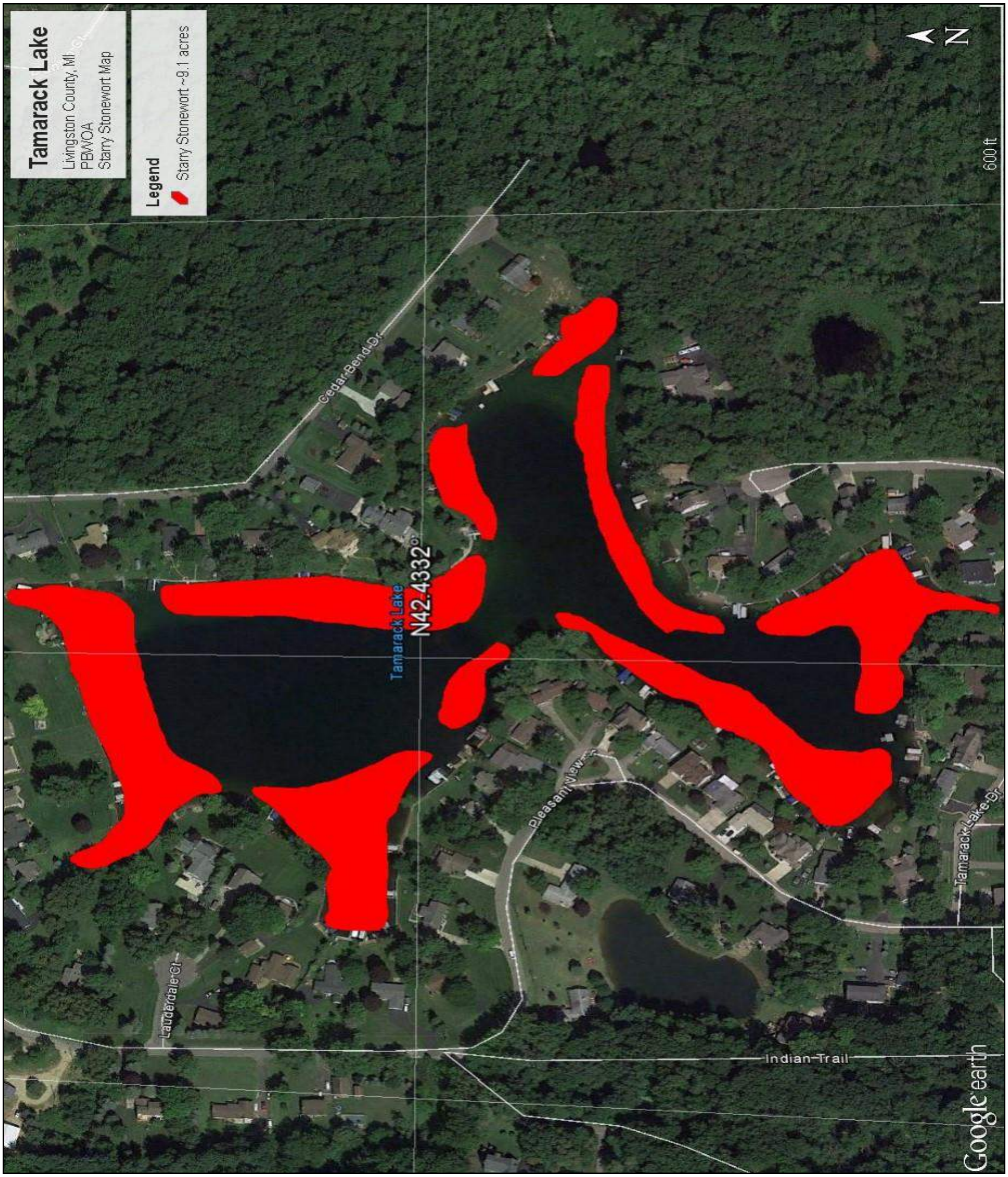

Figure 52. Tamarack Lake Invasive Starry Stonewort locations (August, 2015).

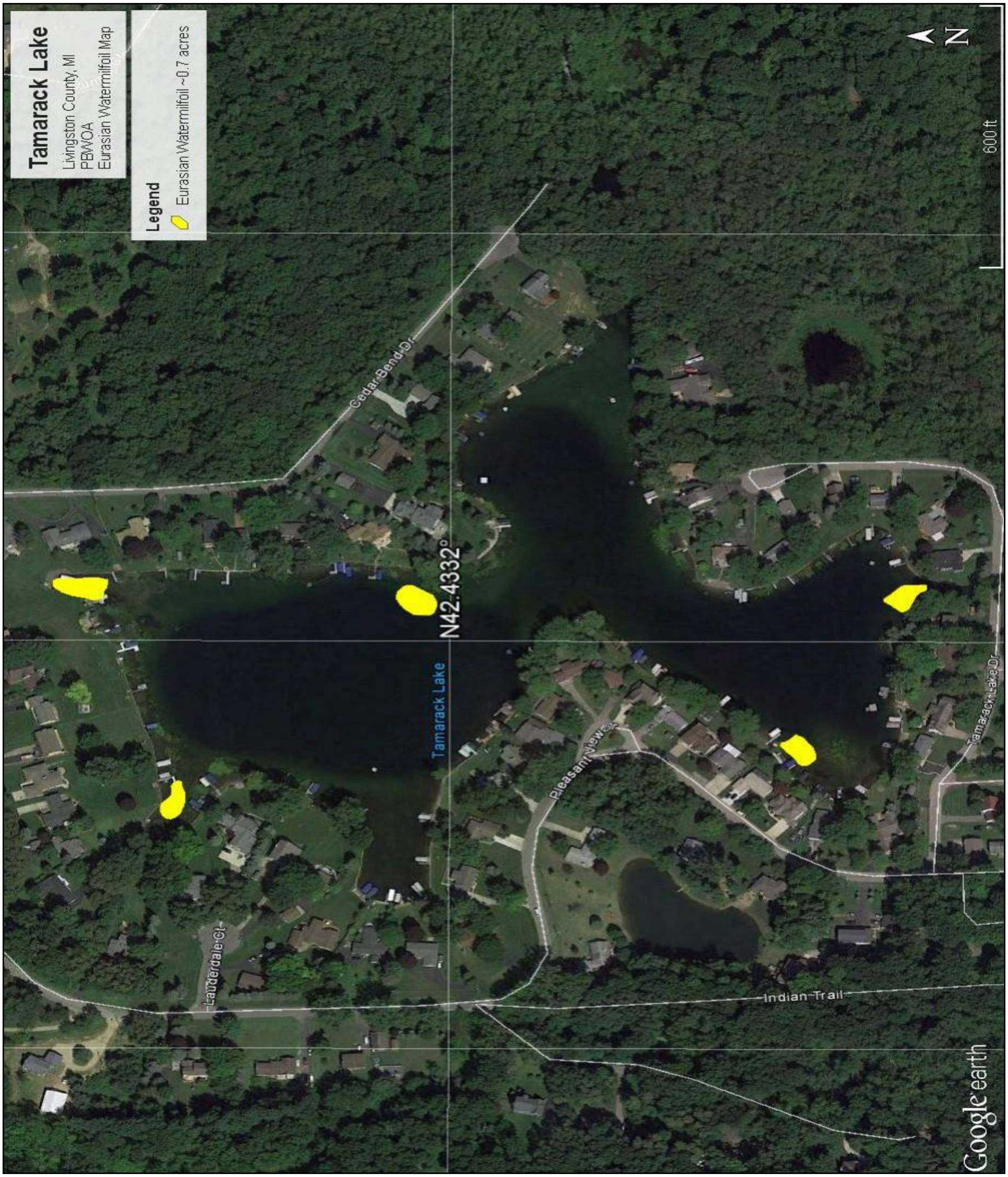

Figure 53. Tamarack Lake Invasive Watermilfoil locations (August, 2015).

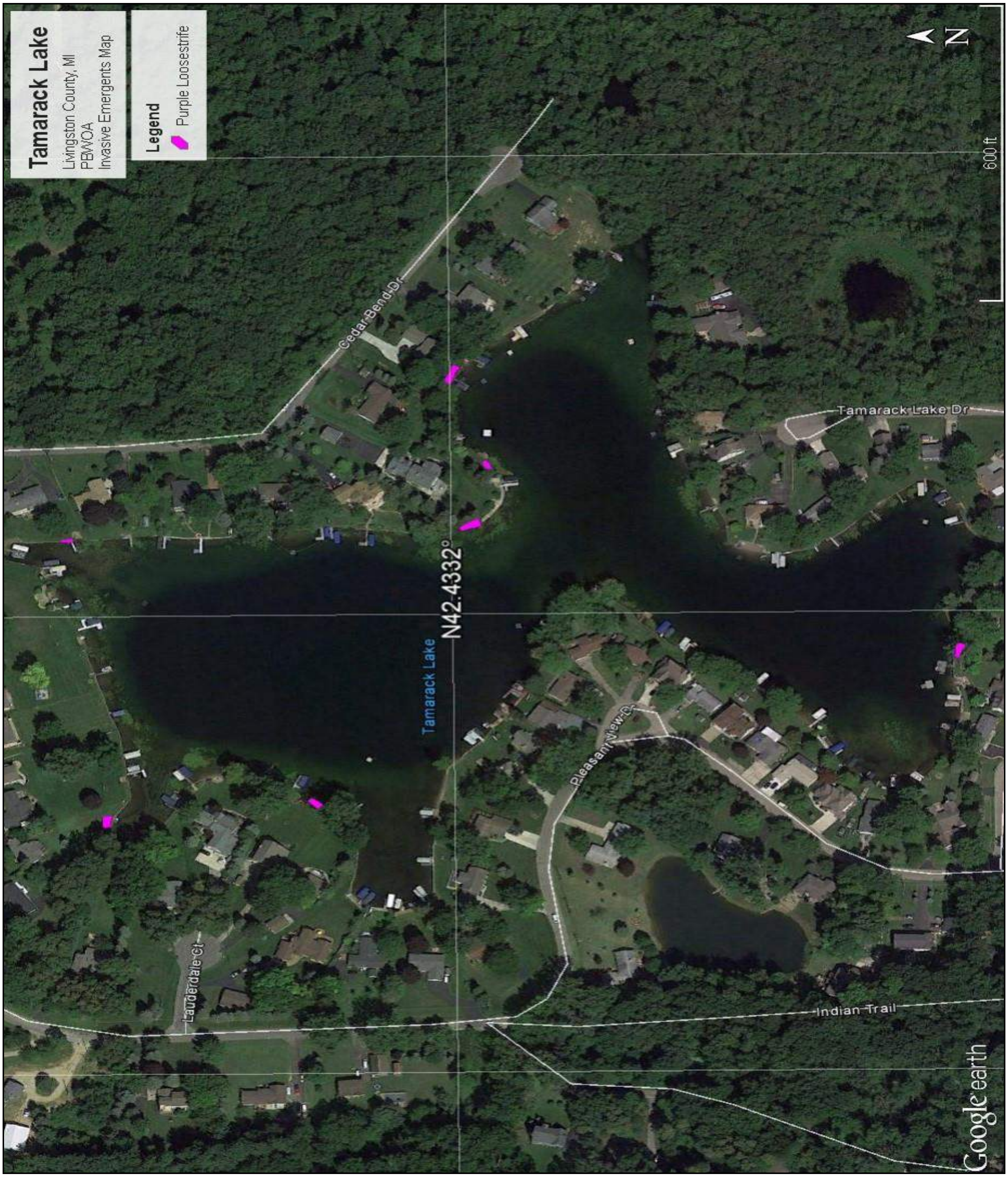

Figure 54. Tamarack Lake Invasive Emergents locations (August, 2015).

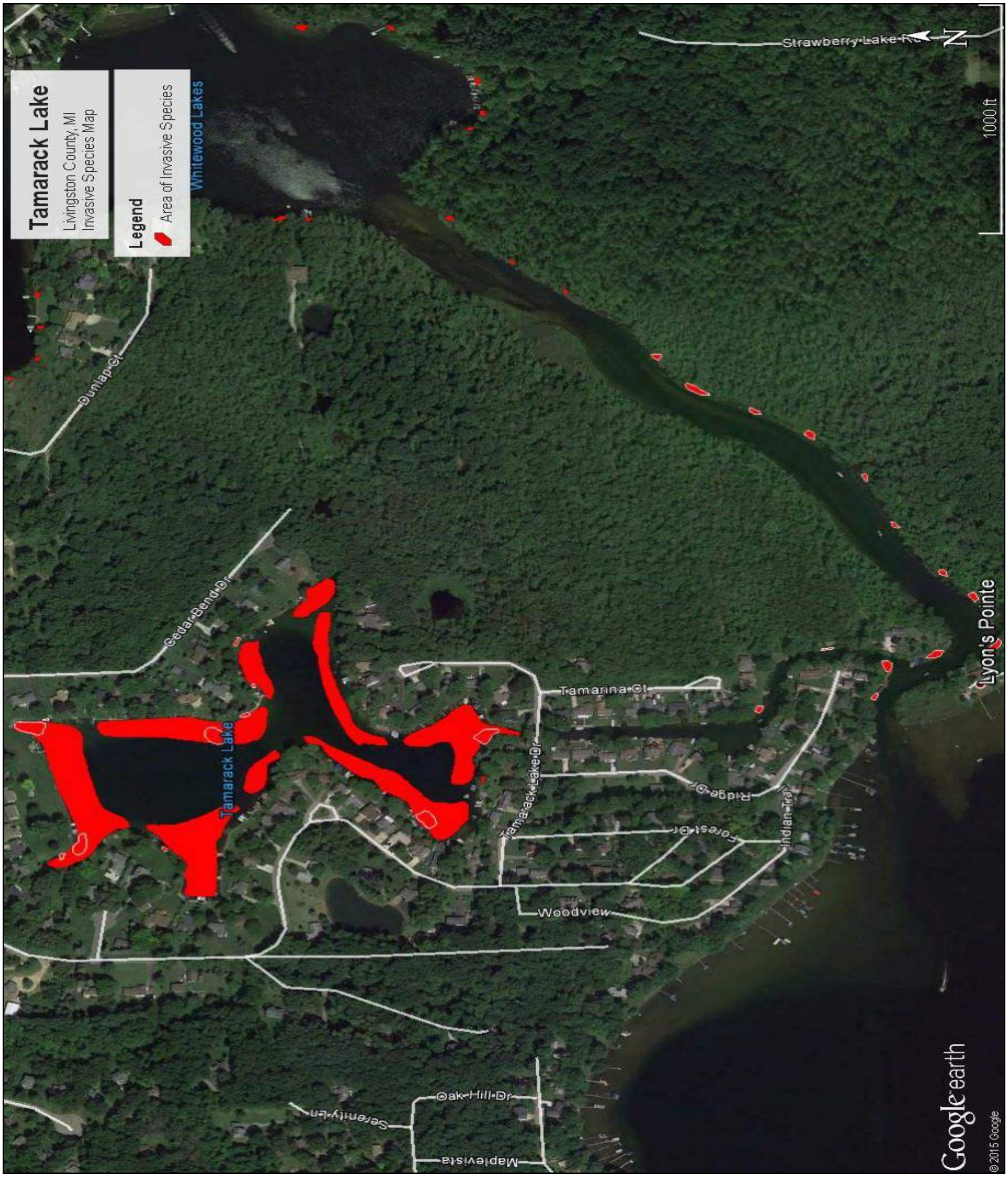

Figure 55. Tamarack Lake Invasive Submersed and Emergents locations (August, 2015).

4.2.2 PBWOA Lakes Native Aquatic Macrophytes

There are hundreds of native aquatic plant species in the waters of the United States. The most diverse native genera include the Potamogetonaceae (Pondweeds) and the Haloragaceae (Milfoils). Native aquatic plants may grow to nuisance levels in lakes with abundant nutrients (both water column and sediment) such as phosphorus, and in sites with high water transparency. **The diversity of native aquatic plants is essential for the balance of aquatic ecosystems, because each plant harbors different macroinvertebrate communities and varies in fish habitat structure.**

The PBWOA lakes are quite diverse containing between 18-26 native submersed, floating-leaved, and emergent aquatic plant species (Table 17). The majority of the emergent macrophytes may be found along the shoreline of the lake. Additionally, the majority of the floating-leaved macrophyte species can be found near the shoreline. This is likely due to enriched sediments and shallower water depth with reduced wave energy, which facilitates the growth of aquatic plants with various morphological forms**.** There was also **the floating-leaved macrophytes such as, *Nymphaea odorata* (White-Waterlily)**, which are critical for housing macroinvertebrates and should be protected and preserved in non-recreational areas to serve as food sources for the fishery and wildlife around the lake. The **emergent plants, such as (Cattails), and *Schoenoplectus acutus* (Bulrushes)** are critical for shoreline stabilization as well as for wildlife and fish spawning habitat. The presence of Purple Loosestrife and invasive Phragmites and Flowering Rush around the PBWOA lakes shorelines are an imminent threat to the emergent macrophyte populations, which could be displaced if left untreated or removed.

Whole lake scans using a Lowrance® HDS® 9 GPS unit with a 83-200 kHz transducer and GIS-based BIOBASE® software to produce aquatic vegetation biovolume maps were conducted between June 22-23, 2015 and August 6, 2015. Individual scanning dates are listed on the individual lake maps.

The maps in Figures 56-63 below show the overall aquatic vegetation biovolume for the individual lakes. The color red denotes high growing aquatic vegetation in the water column which can include floating-leaved lily pads and pondweeds. The colors orange and yellow also denote vegetation that grows moderately high in the water column. The color green denotes aquatic vegetation that grows low to the bottom. The color blue represents areas that lack aquatic vegetation.

Lake Name	# Native Submersed Species	# Native Floating-Leaf Species	# Native Emergent Species	TOTAL # Native Species
Zukey Lake	17	3	6	26
Strawberry Lake	15	3	5	23
Gallagher Lake	16	2	6	24
Little Portage Lake	15	3	7	25
Big Portage Lake	20	3	3	26
Baseline Lake	15	3	4	22
Whitewood Lake	13	2	5	20
Tamarack Lake	12	2	4	18

Table 17. PBWOA lakes native aquatic plant species coverage (August 6-7, 2015).

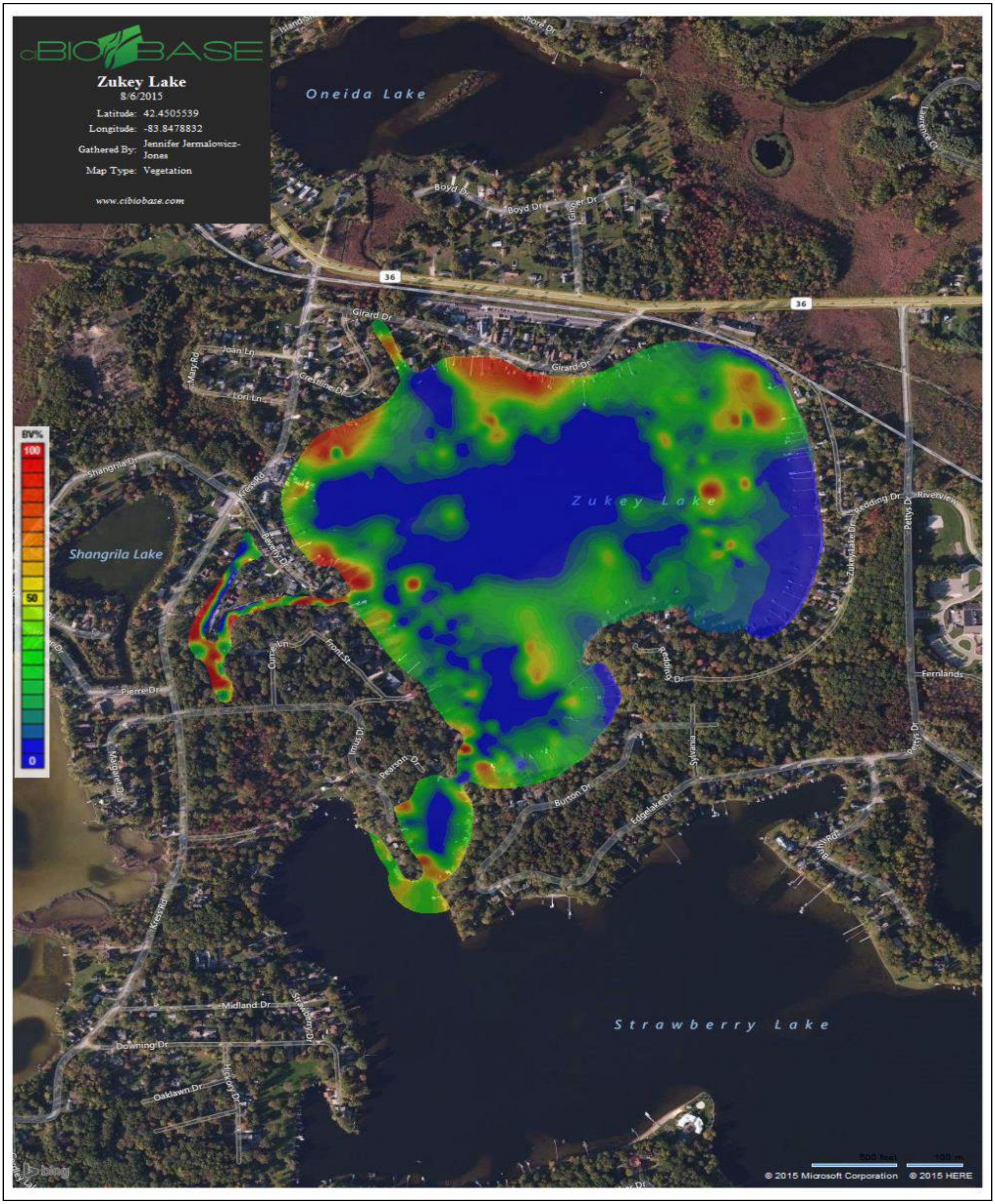

Figure 56. Zukey Lake aquatic vegetation biovolume map (August 6, 2015).

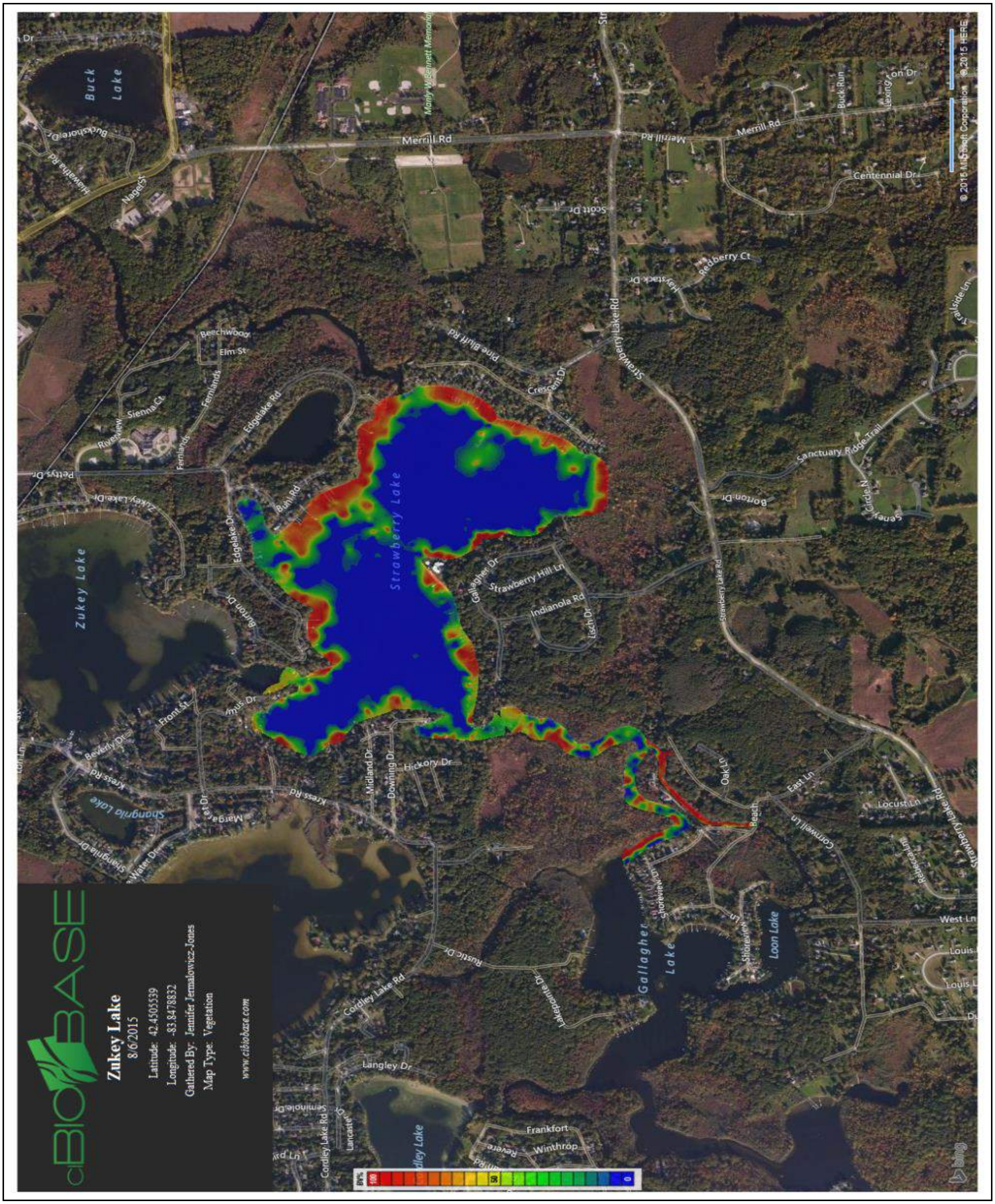

Figure 57. Strawberry Lake aquatic vegetation biovolume map (August 6, 2015).

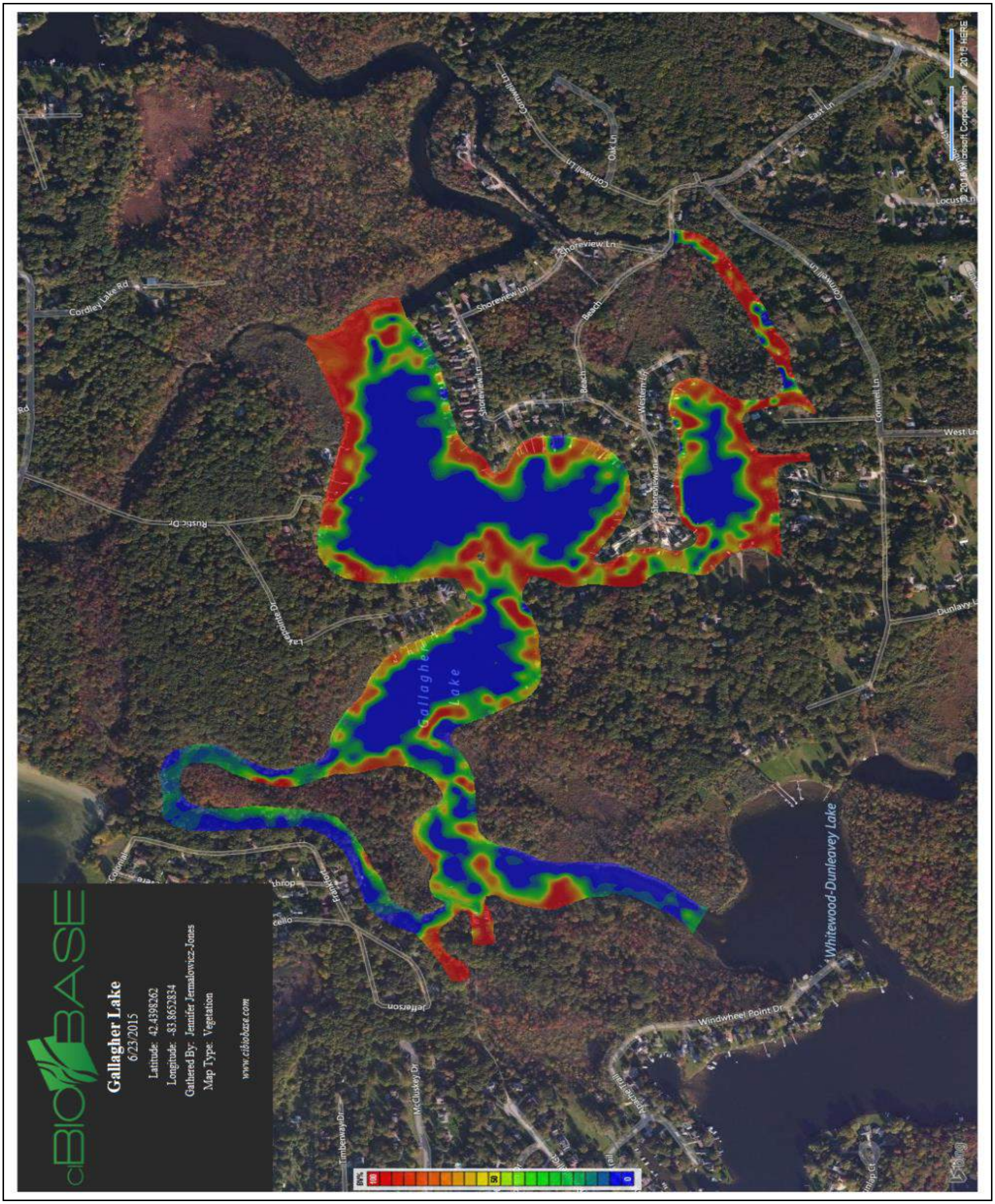

Figure 58. Gallagher and Loon Lakes aquatic vegetation biovolume map (June 23, 2015).

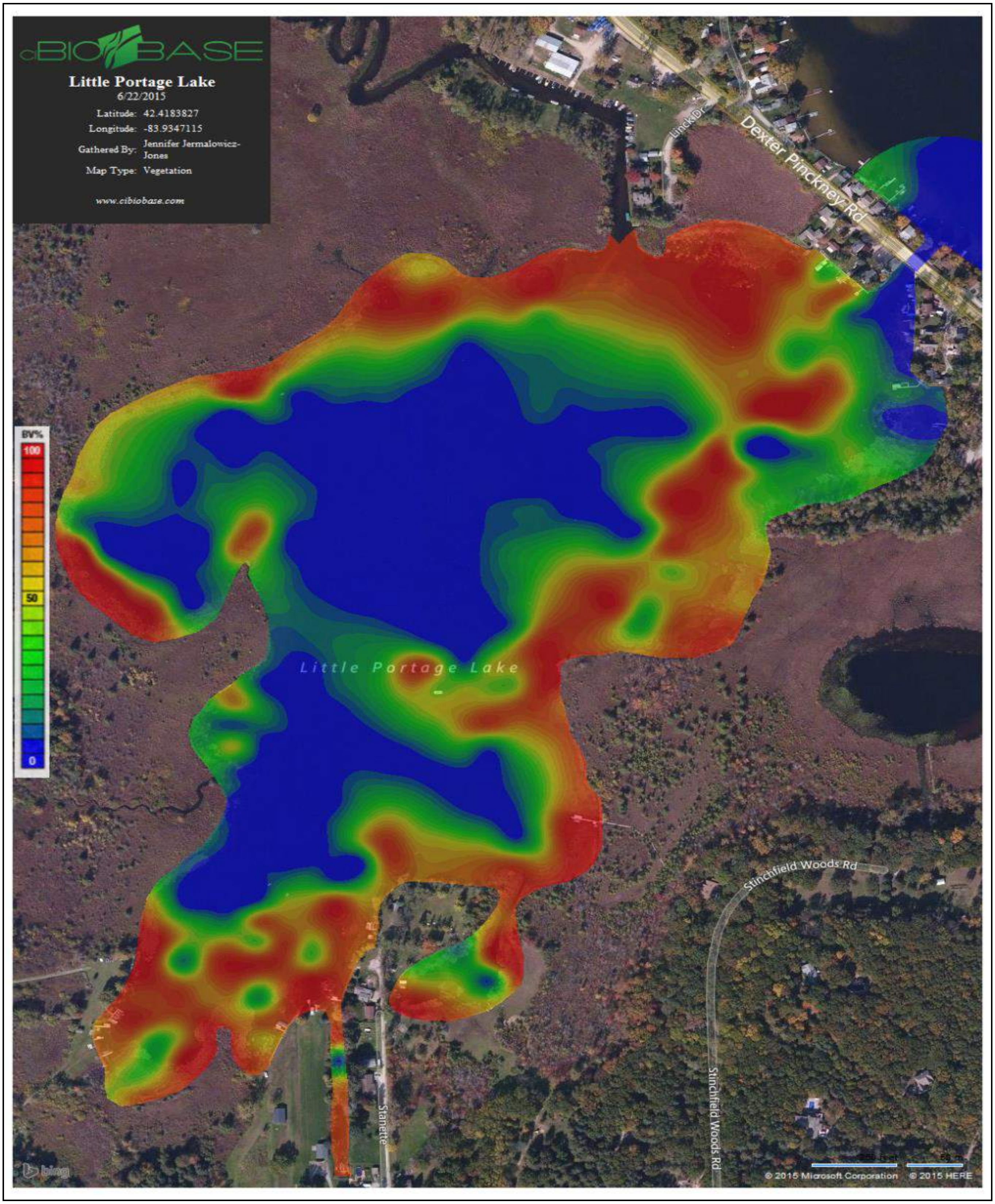

Figure 59. Little Portage Lake aquatic vegetation biovolume map (June 22, 2015).

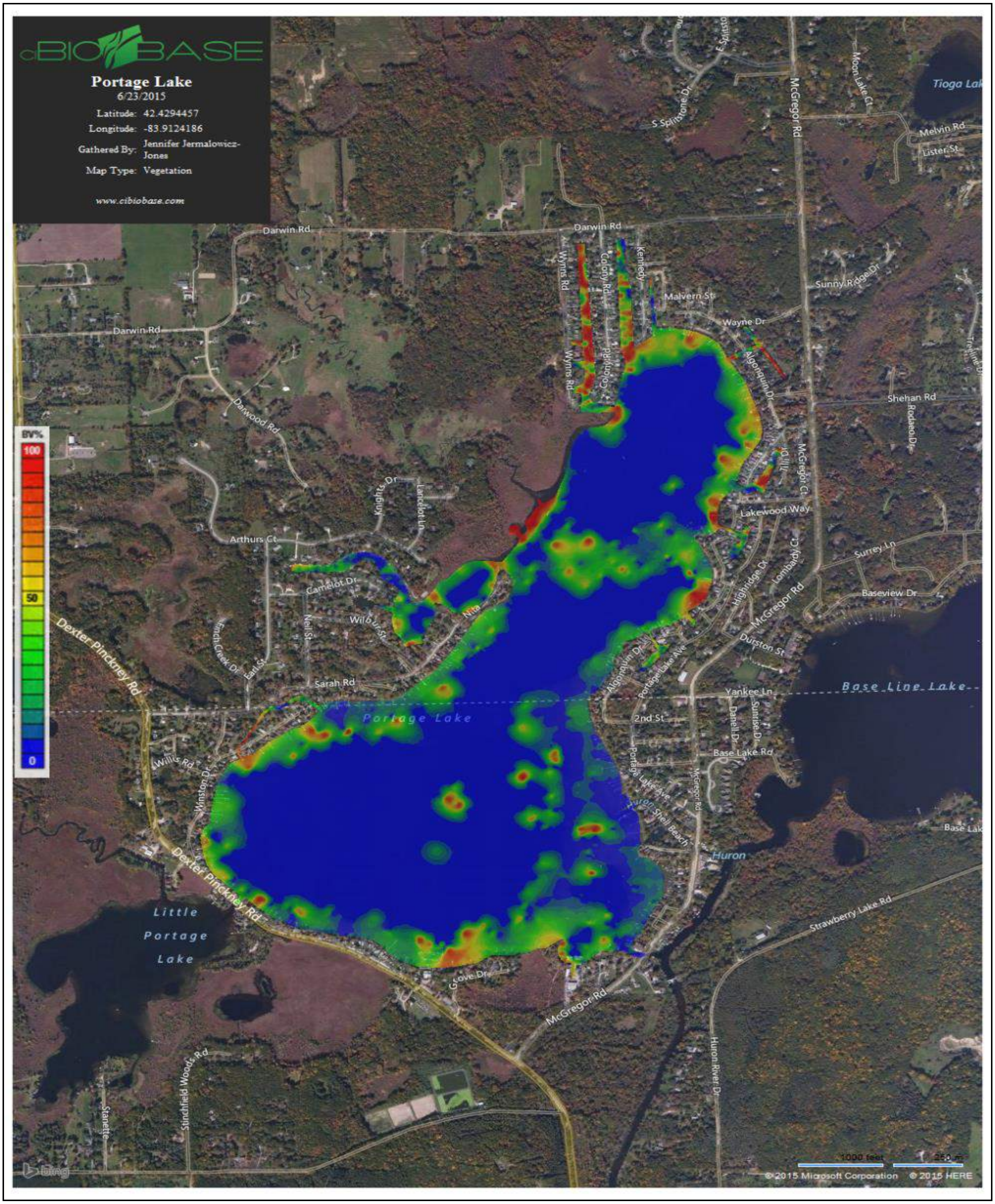

Figure 60. Big Portage Lake aquatic vegetation biovolume map (June 23, 2015).

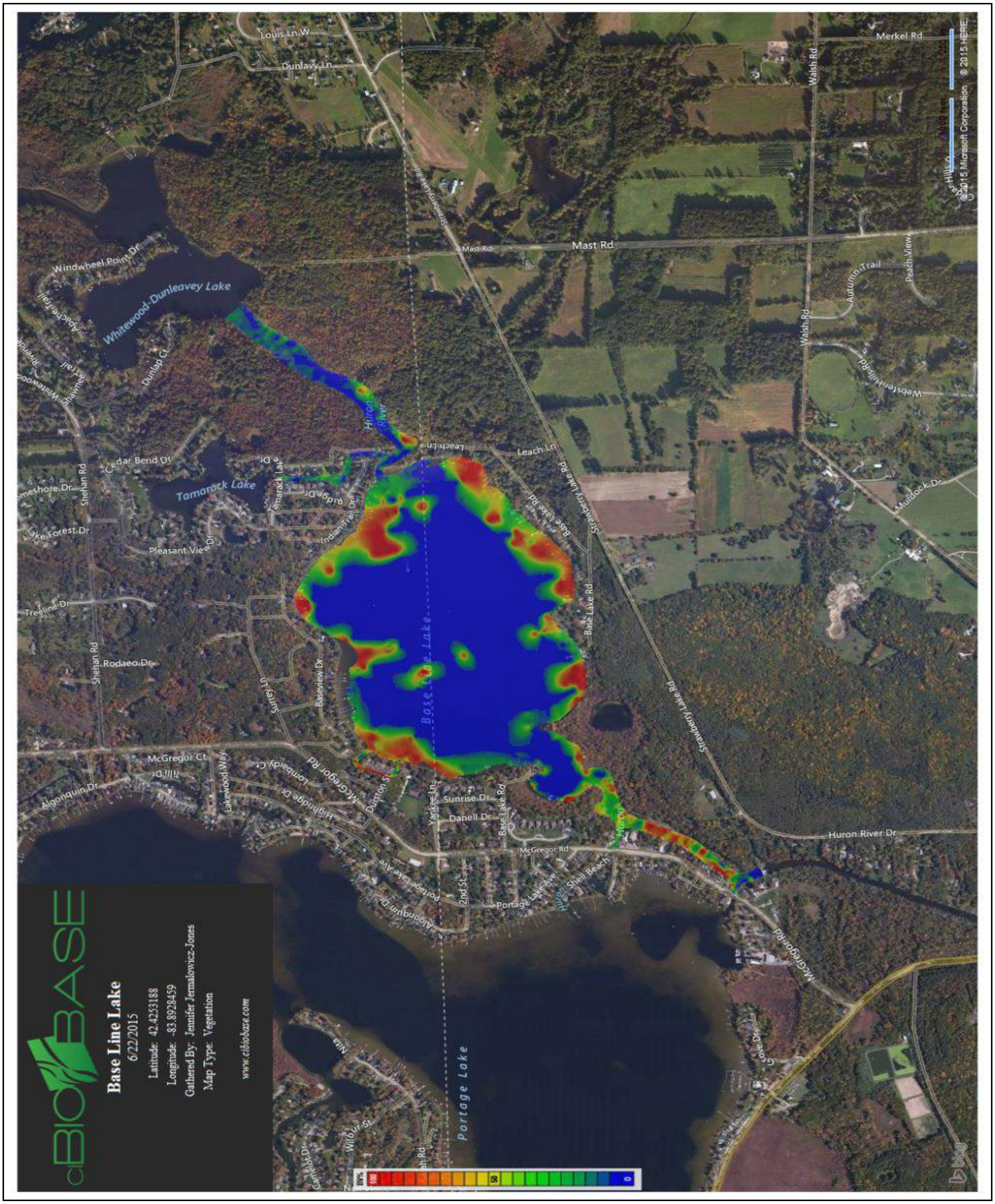

Figure 61. Baseline Lake aquatic vegetation biovolume map (June 22, 2015).

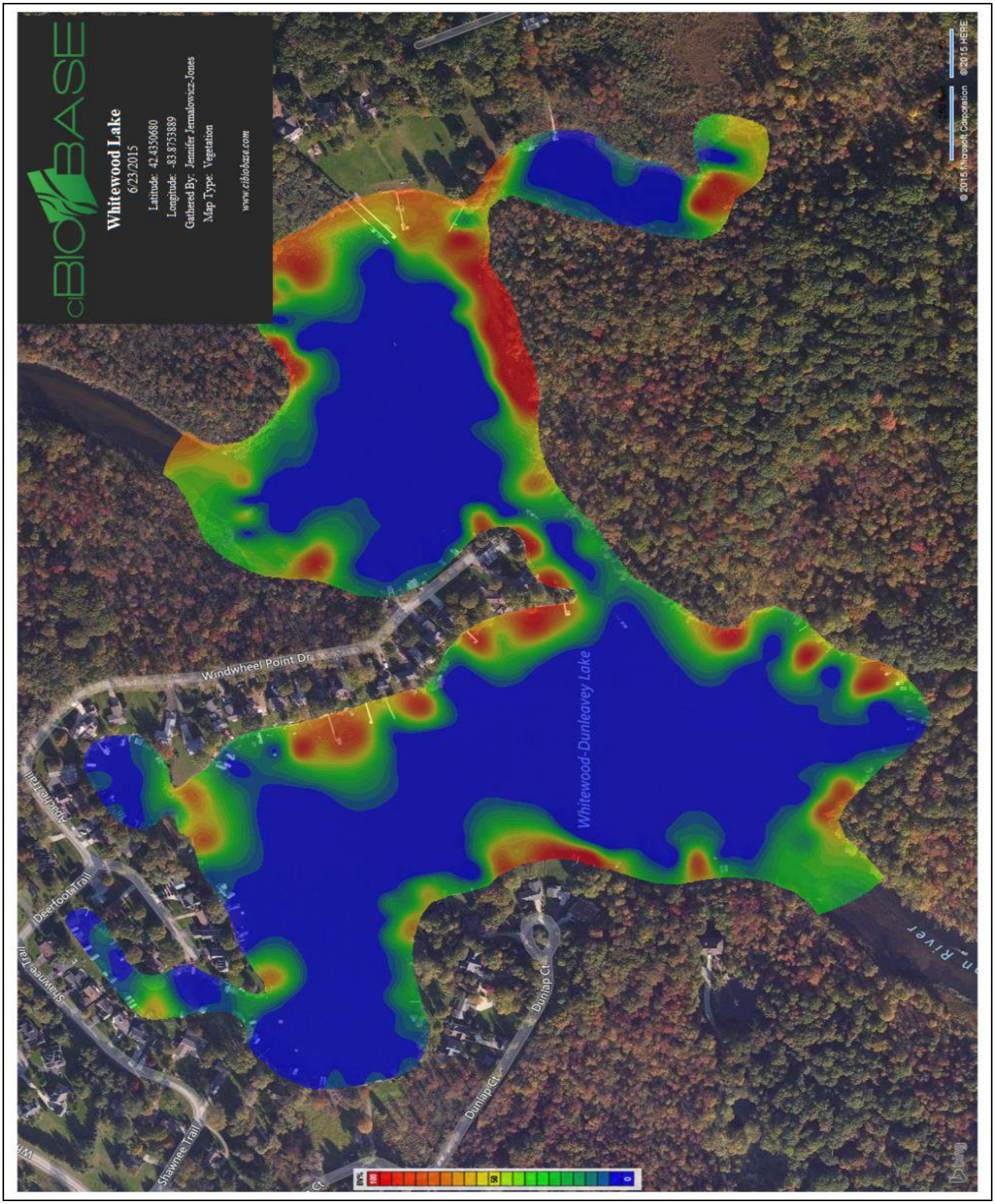

Figure 62. Whitewood Lakes aquatic vegetation biovolume map (June 23, 2015).

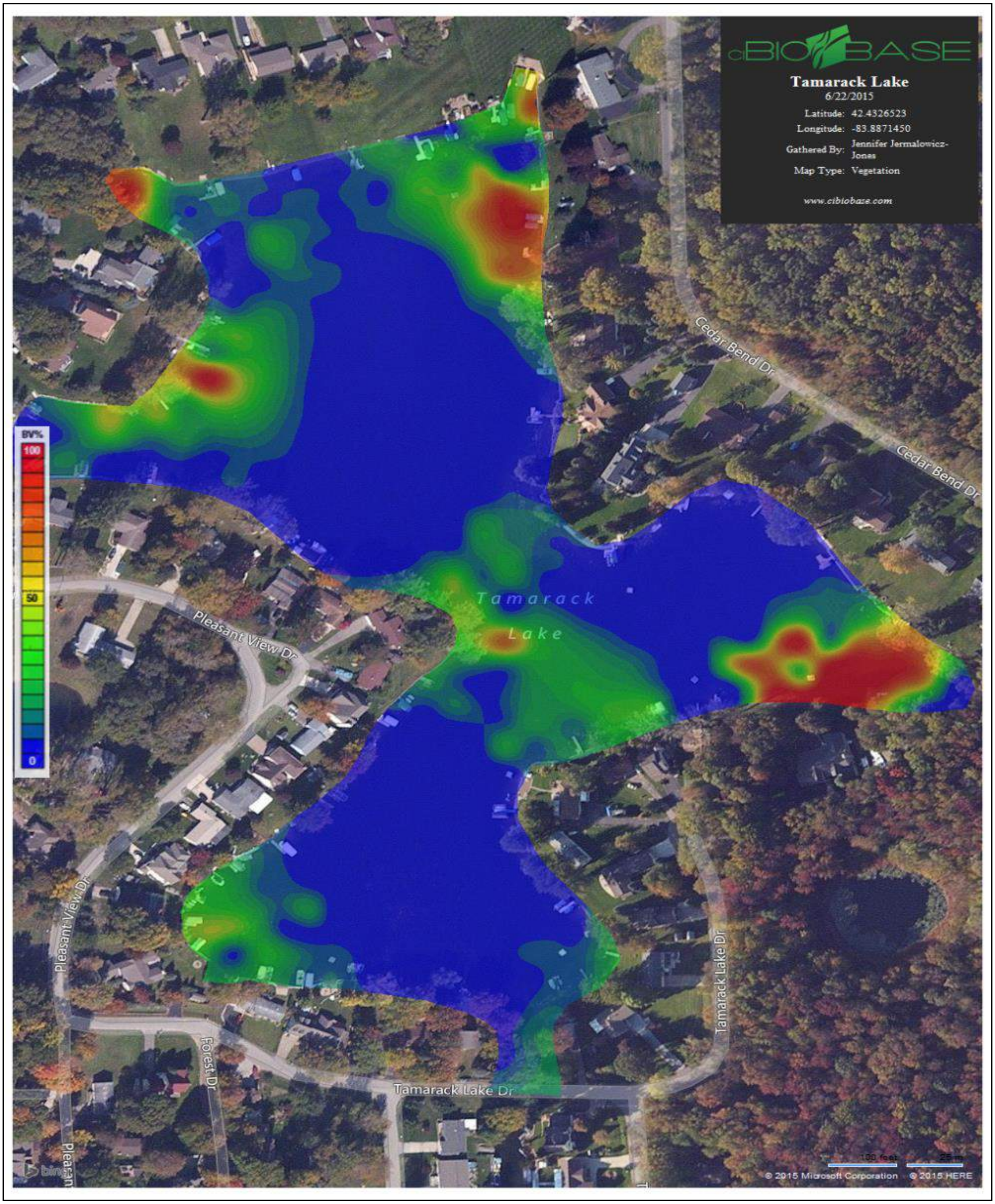

Figure 63. Tamarack Lake aquatic vegetation biovolume map (June 22, 2015).

5.0 PBWOA LAKES MANAGEMENT IMPROVEMENT METHODS

5.1 PBWOA Lakes Aquatic Plant Management

Lake management strategies, including the management of exotic aquatic plants and macro algae, best management practices on impaired or mucky soils and steep slopes, and nutrient reduction from external sources, are available for improving the water quality of the PBWOA lakes. The lake management components involve both within-lake (basin) and around-lake (watershed) solutions to protect and restore these unique aquatic ecosystems. **The goals of any Lake Management Plan (LMP) are to improve water quality, wildlife habitat, aquatic plant and animal biodiversity, recreational use, and protect property values.** Regardless of the management goals, all management decisions must be site-specific and should consider the socio-economic, scientific, and environmental components of the LMP (Madsen 1997).

The management of submersed and emergent invasive aquatic plants is necessary in and around the PBWOA lakes due to accelerated growth and distribution. **Management options** should be **environmentally and ecologically sound and financially feasible**. Options for control of these invasives are limited yet are capable of achieving strong results when used properly. The following management options are discussed with advantages and disadvantages relative to the PBWOA lakes.

5.1.1 Aquatic Herbicides and Applications

The use of aquatic chemical herbicides is regulated by the MDEQ under Part 33 (Aquatic Nuisance) of the Natural Resources and Environmental Protection Act, P.A. 451 of 1994, and requires a permit. The permit contains a list of approved herbicides for a particular body of water, as well as dosage rates, treatment areas, and water use restrictions. **Contact and systemic aquatic herbicides are the two primary categories used in aquatic systems.**

Contact herbicides such as diquat, flumioxazin, and hydrothol cause damage to leaf and stem structures; whereas systemic herbicides are assimilated by the plant roots and are lethal to the entire plant. Wherever possible, it is preferred to use a systemic herbicide for longer-lasting aquatic plant control. There are often restrictions with usage of some systemic herbicides around shoreline areas that contain shallow drinking wells. **In the PBWOA lakes, the use of contact herbicides (such as diquat and flumioxazin and chelated copper-based algaecides) would be recommended only for invasive starry stonewort or for the treatment of the emergent Phragmites (with the use of imazapyr). Hand-pulling removal of the dead emergent biomass can then proceed after the seeds of the emergent have been killed with herbicide.**

Systemic herbicides such as 2, 4-D and triclopyr are the two primary herbicides used to treat milfoil that occurs in a scattered distribution such as that noted in PBWOA lakes. Fluridone (trade name, SONAR®) is a systemic whole-lake herbicide treatment that is applied to the entire lake volume in the spring and is used for extensive infestations. The objective of a fluridone treatment is to selectively control the growth of milfoil in order to allow other native aquatic plants to germinate and create a more diverse
aquatic plant community**. Due to the overall low amount of milfoil in the PBWOA lakes and likely hybridization of milfoil, the use of fluridone is not recommended at this time in any of the lakes. Recommended herbicides for all of the lakes include liquid or granular triclopyr nearshore and possibly granular 2,4-D or triclopyr in**

offshore areas. 2, 4-D cannot be used in near shore areas with shallow well (< 30 feet deep) restrictions so knowledge of these well depths is important for future treatments if the use of 2, 4-D is desired.

5.1.2 Mechanical Harvesting

Mechanical harvesting involves the physical removal of nuisance aquatic vegetation with the use of a mechanical harvesting machine (Figure 64). The mechanical harvester collects numerous loads of aquatic plants as they are cut near the lake bottom. The plants are off-loaded onto a conveyor and then into a dump truck. Harvested plants are then taken to an offsite landfill or farm where they can be used as fertilizer. Mechanical harvesting is preferred over chemical herbicides when primarily native aquatic plants exist, or when excessive amounts of plant biomass need to be removed. Mechanical harvesting is usually not recommended for the removal of Eurasian Watermilfoil since the plant may fragment when cut and re-grow on the lake bottom. **Due to the threat of milfoil fragmentation, the use of mechanical harvesting for the removal of milfoil in the PBWOA lakes is not recommended. Once the milfoil has been successfully reduced with herbicides, then harvesting could be used to remove dense native aquatic vegetation if it becomes problematic in the future and herbicides are not desired.**

Mechanical harvesting does not require a permit from the Michigan Department of Environmental Quality (MDEQ); however, some counties require a launch site use permit from the Michigan Department of Natural Resources (MDNR) if a public access site is present.

Figure 64. A mechanical harvester

5.1.3 Benthic Barriers and Nearshore Management Methods

Benthic barrier mats (Figure 65) and Weed Rollers (Figure 66) have been used to reduce weed growth in small areas such as beach areas and around docks. The benthic mats are placed on the lake bottom in early spring prior to the germination of aquatic vegetation. They act to reduce germination of all aquatic plants and lead to a local area free of most aquatic vegetation. Benthic barriers are manufactured in various sizes between 100-400 feet in length.

Weed Rollers are electrical devices that utilize a rolling arm which rolls along the lake bottom in small areas (usually not more than 50 feet) and pulverizes the lake bottom to reduce germination of any aquatic vegetation within a particular area.

Both methods would be useful in recreational lakes such as the PBWOA lakes and work best in shallow beach areas and near docks to reduce nuisance native aquatic vegetation growth. They both may also reduce invasive species around docks and beaches if implemented prior to germination in early spring.

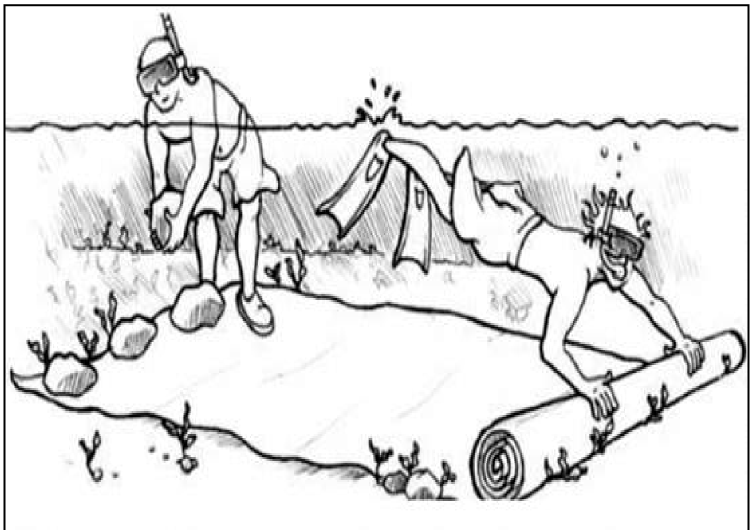

Figure 65. A benthic barrier. Photo courtesy of Cornell Cooperative Extension.

Figure 66. A weed roller.

5.1.4 Diver Assisted Suction Harvesting (DASH) and Dredging

Suction harvesting via a Diver Assisted Suction Harvesting (DASH) boat (Figure 67) involves hand removal of individual plants by a SCUBA diver in selected areas of lake bottom with the use of a hand-operated suction hose. Samples are dewatered on land or removed via fabric bags to an offsite location**. This method is generally recommended for small (less than 1 acre) spot removal of vegetation since it is costly on a large scale. It may be used in the future to remove small remaining areas of milfoil after large-scale initial treatments have been successful or may be useful for small areas of dense lily pad growth.**

However, this activity and dredging may cause re-suspension of sediments (Nayar et *al*., 2007) which may lead to increased turbidity and reduced clarity of the water. **These processes requires a permit from the MDEQ/Army Corps of Engineers and are very costly and may need to be repeated in the same areas. They are not recommended for widespread aquatic plant control.**

Figure 67. A DASH boat for hand-removal of milfoil or other nuisance vegetation. ©Restorative Lake Sciences

5.1.5 Laminar Flow Aeration and Bioaugmentation

Laminar flow aeration systems (Figure 68) are retrofitted to a particular site and account for variables such as water depth and volume, contours, water flow rates, and thickness and composition of lake sediment. The systems are designed to completely mix the surrounding waters and evenly distribute dissolved oxygen throughout the lake sediments for efficient microbial utilization.

A laminar flow aeration system utilizes diffusers which are powered by onshore air compressors. The diffusers are connected via extensive self-sinking airlines which help to purge the lake sediment pore water of gases such as benthic carbon dioxide (CO_2) and hydrogen sulfide (H_2S). In addition to the placement of the diffuser units, the concomitant use of bacteria and enzyme treatments to facilitate the microbial breakdown of organic sediments is also used.

Benefits and Limitations of Laminar Flow Aeration

A study by Turcotte et *al*. (1988) analyzed the impacts of bioaugmentation on the growth of Eurasian Watermilfoil and found that during two four-month studies, the growth and re-generation of this plant was reduced significantly with little change in external nutrient loading.

Beutel (2006) found that lake oxygenation eliminates release of NH_3+ from sediments through oxygenation of the sediment-water interface. Allen (2009) demonstrated that NH_3+ oxidation in aerated sediments was significantly higher than that of control mesocosms with a relative mean of 2.6 ± 0.80 mg N g dry wt day^{-1} for aerated mesocosms and 0.48 ± 0.20 mg N g dry wt day^{-1} in controls.

Although this is a relatively new area of research, recent case studies have shown promise on the positive impacts of laminar flow aeration systems on aquatic ecosystem management with respect to organic matter degradation and resultant increase in water depth, and rooted aquatic plant management in eutrophic ecosystems (Jermalowicz-Jones, 2010-present). Toetz (1981) found evidence of a decline in *Microcystis* algae (a toxin-producing blue-green algae) in Arbuckle Lake in Oklahoma. Other studies (Weiss and Breedlove, 1973; Malueg et *al.*, 1973) have also shown declines in overall algal biomass.

Conversely, a study by Engstrom and Wright (2002) found no significant differences between aerated and non-aerated lakes with respect to reduction in organic sediments. This study was however limited to one sediment core per lake and given the high degree of heterogeneous sediments in inland lakes may not have accurately represented the conditions present throughout much of the lake bottom.

The Laminar Flow Aeration system has some limitations including the inability to break down mineral sediments, the requirement of a constant Phase I electrical energy source to power the units. **Due to the high amount of sand and mineral sediments in the PBWOA lakes, the reduction of sediment muck or organics is unlikely. The deep basins of the PBWOA lakes could however benefit from increased dissolved oxygen from aeration in these basins if desired. Aeration and bio augmentation have also been successfully used to reduce nuisance algal blooms.**

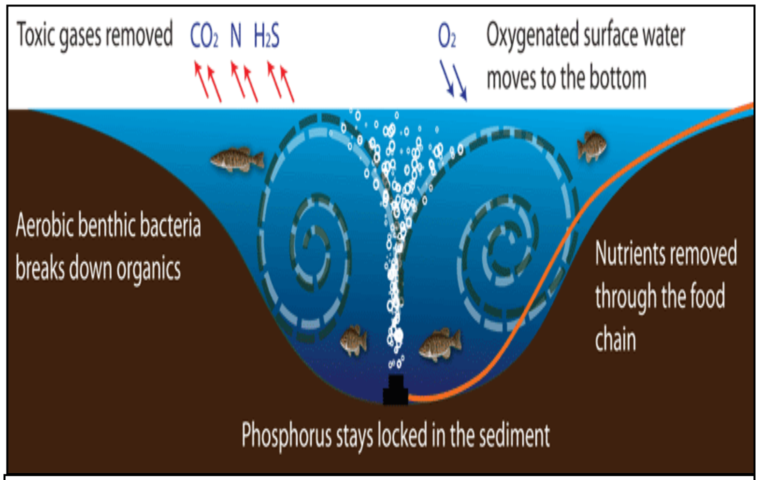

Figure 68. A diagram showing the laminar flow aeration mechanisms. ©RLS

5.2 PBWOA Lakes Watershed Management

In addition to the proposed treatment of invasive Watermilfoil and Starry Stonewort in the PBWOA lakes, it is recommended that Best Management Practices (BMP's) be implemented to protect and improve the water quality of the PBWOA lakes. The guidebook, Lakescaping for Wildlife and Water Quality (Henderson et *al*. 1998) provides the following guidelines:

1) Maintenance of brush cover on lands with steep slopes (those > 12%; see soil table earlier in report)
2) Development of a vegetation buffer zone 25-30 feet from the land-water interface with approximately 60-80% of the shoreline bordered with vegetation
3) Limiting boat traffic and boat size to reduce wave energy and thus erosion potential
4) Encouraging the growth of dense shrubs or emergent shoreline vegetation to control erosion
5) Using only <u>native</u> genotype plants (those native to the PBWOA lakes or the region) around the lake since they are most likely to establish and thrive than those not acclimated to growing in the area soils

The book may be ordered online at: http://web2.msue.msu.edu/bulletins/mainsearch.cfm.

5.2.1 PBWOA Lakes Erosion and Sediment Control

The construction of new impervious surfaces (i.e. paved roads and walkways, houses) should be minimized and kept at least 100 feet from the lakefront shoreline to reduce surface runoff potential. In addition, any wetland areas around the PBWOA lakes should be preserved to act as a filter of nutrients from the land and to provide valuable wildlife habitat. Construction practices near the lakeshore should minimize the chances for erosion and sedimentation by keeping land areas adjacent to the water stabilized with rock, vegetation, or wood retaining walls. This is especially critical in areas that contain land slopes greater than 12%. **Erosion of soils into the water may lead to increased turbidity and nutrient loading to the lake.** Seawalls should consist of rip-rap (stone, rock), rather than metal, due to the fact that rip-rap offers a more favorable habitat for lakeshore organisms, which are critical to the ecological balance of the lake ecosystems. Rip-rap should be installed in front of areas where metal seawalls are currently in use. The rip-rap should extend into the water to create a presence of microhabitats for enhanced biodiversity of the aquatic organisms within the PBWOA lakes. The emergent aquatic plant, *Schoenoplectus* sp. (Bulrushes) present around the PBWOA lakes offers satisfactory stabilization of shoreline sediments and assists in the minimization of sediment release into the lake.

5.2.2 PBWOA Lakes Nutrient Source Control

Based on the high ratio of nitrogen to phosphorus (i.e. N: P > 15) of many of the PBWOA lakes, any additional inputs of phosphorus to the lake are likely to create additional algal and aquatic plant growth. Accordingly, RLS recommends the following procedures to protect the water quality of the PBWOA lakes:

1) Avoid the use of lawn fertilizers that contain phosphorus (P). P is the main nutrient required for aquatic plant and algae growth, and plants grow in excess when P is abundant. When possible, water lawns with lake water that usually contains adequate P for successful lawn growth. If you must fertilize your lawn, assure that the middle number on the bag of fertilizer reads “0” to denote the absence of P. If possible, also use low N in the fertilizer or use lake water.

2) Preserve riparian vegetation buffers around the lakes (such as those that consist of cattails, bulrushes, and swamp loosestrife), since they act as a filter to catch nutrients and pollutants that occur on land and may run off into the lake. As an additional bonus, Canada geese (*Branta canadensis*) usually do not prefer lakefront lawns with dense riparian vegetation because they are concerned about the potential of hidden predators within the vegetation.

3) Do not burn leaves near the lake shoreline since the ash is a high source of P. The ash is lightweight and may become airborne and land in the water eventually becoming dissolved and utilized by aquatic vegetation and algae.

4) Assure all areas that drain into the lake from the surrounding land are vegetated and that no fertilizers are used in areas with saturated soils. (refer to PBWOA soils data earlier in report).

5.2.3 Prevention of Invasive Species

An exotic species is a non-native species that does not originate from a particular location. When international commerce and travel became prevalent, many of these species were transported to areas of the world where they did not originate. Due to their small size, insects, plants, animals, and aquatic organisms may escape detection and be unknowingly transferred to unintended habitats. The first ingredient to successful prevention of unwanted transfers of exotic species to the PBWOA lakes is awareness and education. **Many of the PBWOA lakes contained zebra mussels. In addition to invasive aquatic plants such as watermilfoil and Starry Stonewort which were plentiful in the PBWOA lakes, the PBWOA residents should be aware of other invasive aquatic species such as *Hydrilla* and Water Chestnut which could become problematic if not detected early through an "Early Detection Rapid Response" protocol. Fortunately, none of the PBWOA lakes contained *Hydrilla* or Water Chestnut during the August, 2015 surveys. However, regular surveys are needed to assure that these invasives do not enter the PBWOA lakes and grow in excess.**

Zebra Mussels

Zebra mussels (*Dreissena polymorpha*) were first discovered in Lake St. Clair in 1988 (Herbert et al. 1989) and likely arrived in ballast water or on shipping vessels from Europe (McMahon 1996). They are easily transferred to other lakes because they inherit a larval (nearly microscopic) stage where they can easily avoid detection. The mussels then grow into the adult (shelled) form and attach to substrates (i.e. boats, rafts, docks, pipes, aquatic plants, and lake bottom sediments) with the use of byssal threads. The fecundity (reproductive rate) of female zebra mussels is high, with as many as 40,000 eggs laid per reproductive cycle and up to 1,000,000 in a single spawning season (Mackie and Schlosser 1996). Although the mussels only live 2-3 years, they are capable of great harm to aquatic environments. In particular, they have shown selective grazing capabilities by feeding on the preferred zooplankton food source (green algae) and expulsion of the non-preferred blue green algae (cyanobacteria). Additionally, they may decrease the abundance of beneficial diatoms in aquatic ecosystems (Holland 1993). Such declines in favorable algae, can decrease zooplankton populations and ultimately the biomass of planktivorous fish populations. Zebra mussels are viewed by some as beneficial to lakes due to their filtration capabilities and subsequent contributions to increased water clarity. However, such water clarity may allow other photosynthetic aquatic plants to grow to nuisance levels (Skubinna et *al*. 1995).

The recommended prevention protocols for introduction of zebra mussels includes steam-washing all boats, boat trailers, jet-skis, and floaters prior to placing them into the PBWOA lakes. Fishing poles, lures, and other equipment used in other lakes (and especially the Great Lakes) should also be thoroughly steam-washed before use in the PBWOA lakes. Additionally, all solid construction materials (if recycled from other lakes) must also be steam-washed. **Boat transom wells must always be steam-washed and emptied prior to entry into the lakes.**

Invasive Aquatic Plants

In addition to Eurasian watermilfoil (*M. spicatum*), many other invasive aquatic plant species are being introduced into waters of the North Temperate Zone. The majority of exotic aquatic plants do not depend on high water column nutrients for growth, as they are well-adapted to using sunlight and minimal nutrients for successful growth. These species have similar detrimental impacts to lakes in that they decrease the quantity and abundance of native aquatic plants and associated macroinvertebrates and consequently alter the lake fishery. Such species include *Hydrilla verticillata* and *Trapa natans* (Water Chestnut). ***Hydrilla* was introduced**

to waters of the United States from Asia in 1960 (Blackburn et *al*. 1969) and is a highly problematic submersed, rooted, aquatic plant in tropical waters. *Hydrilla* had been found in Lake Manitou (Indiana, USA) and in other nearby states such as NY, PA, and OH. *Hydrilla* retains many physiologically distinct reproductive strategies which allow it to colonize vast areas of water and to considerable depths, including fragmentation, tuber and turion formation, and seed production. Currently, the methods of control for

Hydrilla include the use of chemical herbicides, rigorous mechanical harvesting, and Grass Carp (*Ctenopharyngodon idella* Val.), with some biological controls currently being researched. However, use of the Grass Carp in Michigan is currently not permitted by the Michigan Department of Natural Resources (MDNR).

Water Chestnut (*Trapa natans*) is a non-native, annual, submersed, rooted aquatic plant that was introduced into the United States in the 1870's yet may be found primarily in the northeastern states. The stems of this aquatic plant can reach lengths of 12-15 feet, while the floating leaves form a rosette on the lake surface. Seeds are produced in July and are extremely thick and hardy and may last for up to 12 years in the lake sediment. If stepped on, the seed pods may even cause deep puncture wounds to those who recreate on the lakes. Methods of control involve the use of mechanical removal and chemical herbicides. Biological controls are not yet available for the control of this aquatic plant.

6.0 PBWOA LAKES MANAGEMENT PROJECT CONCLUSIONS & RECOMMENDATIONS

The urgent control of the submersed invasive Watermilfoil and Starry Stonewort and the emergent Phragmites and Purple Loosestrife in and around the PBWOA lakes is essential for the long-term preservation of the favorable (non-nuisance) native aquatic plant communities in the lakes and for optimal recreation use of the lakes. The use of selective aquatic herbicides for species-specific control of these plants is preferred over other methods at this time for reasons described above with each method. Mechanical harvesting could be used in future years once the milfoil is controlled and not a threat to fragmentation. Additional improvements would include the assurance that all areas with steep slopes around the lake are vegetated at all times so that runoff is reduced. If the water becomes turbid during a rain event, all efforts to determine the entry point of the turbidity should be executed to reduce sediment loading to the lakes.

Furthermore, a professional limnologist/aquatic botanist should perform regular GPS-guided whole-lake surveys each spring and late summer/early fall to monitor the growth and distribution of all invasives and nuisance aquatic vegetation growth prior to and after treatments to determine treatment efficacy. Furthermore, continuous monitoring of the lake for potential influxes of other exotic aquatic plant genera (i.e. *Hydrilla*) that could also significantly disrupt the ecological stability of the PBWOA lakes is critical. The lake manager should oversee all management activities and would be responsible for the creation of aquatic plant management survey maps, direction of the herbicide applicator(s) to target-specific areas of aquatic vegetation for removal, implementation of watershed best management practices, administrative duties such as the processing of contractor invoices, and lake management education.

6.1 Cost Estimates for PBWOA Lakes Improvements

The proposed aquatic vegetation management program for the control of hybrid Eurasian Watermilfoil and nuisance native aquatic plant growth in the PBWOA lakes would begin during the 2016 season. **A breakdown of estimated costs associated with the various proposed treatments in and around the PBWOA lakes is presented in Table 18.** It should be noted that proposed costs are estimates and may change in response to changes in environmental conditions (i.e. increases in aquatic plant growth or distribution, or changes in herbicide costs).

Every aquatic vegetation management plan should offer solutions that are ecologically sound, practical, and economically feasible. Since funds for the suggested management improvements and oversight are limited, it was suggested that the Huron Chain of Lakes utilize a Special Assessment District (SAD) under either P.A. 188 of 1954 or P.A. 451 of 1994, as amended, to fund the suggested improvements.

The SAD should include all riparian properties around the PBWOA lakes which would derive benefit from the intended improvements mentioned in the management plan. It is critical that the properties within the SAD be equitable to properties within a particular category. Furthermore, it is suggested that the four municipalities and two counties work closely with the PBWOA lakes Association on this project as all are important stakeholders for this unique water resource assemblage. The Huron River Watershed Council may also serve as a valuable informational resource.

If aquatic herbicides to be used in PBWOA lakes, they must be registered by the United States Environmental Protection Agency (EPA) and also must be used according to the safety guidelines listed for that particular herbicide on the MSDS sheet. The aquatic herbicide registration process requires that intense studies on human exposure and health, effects on fisheries and wildlife, bio-persistence, and analysis of chemical breakdown products all be assessed to determine if these substances are safe to use in aquatic habitats for the control of nuisance aquatic vegetation.

Lake Name	Approx. Milfoil Treatment Cost	Approx. Starry Stonewort Treatment Cost	Approx. Emergent Treatment Cost
Zukey Lake	$3,325	$4,380	$500
Strawberry Lake	$11,550	$5,250	$3,000
Gallagher Lake	$4,970	$3,780	$3,000
Little Portage Lake	$6,650	$5,700	$3,000
Big Portage Lake	$17,500	$20,700	$3,000
Baseline Lake	$0	$5,850	$4,000
Whitewood Lake	$1,750	$4,050	$4,500
Tamarack Lake	$490	$5,460	$500
TOTAL	**$46,235**	**$55,170**	**$21,500**

Table 18. PBWOA lakes submersed exotic aquatic plant and macro algae treatment costs. Note: Costs are estimates based on average per acre product market product costs for systemic granular herbicides at 200 pounds per acre at $700 per acre for milfoil control and $600 per acre for Starry Stonewort treatment. Additional costs would include estimated project contingency (10% of total cost of treatments $122,905 + project implementation $25,000) = $14,791. Project implementation includes annual lake surveys, engineering, and oversight. **Total program costs would be approximately $162,696.**

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APPENDIX A

PBWOA LAKES AVAS DATA SHEETS

LAKE NAME-ZUKEY LAKE **COUNTY- Livingston** **SURVEY DATE: 6 August 2015**

Standard Aquatic Vegetation Summary Sheet SURVEY BY: NKG, GLJ

		Total number of AVAS's 142 for each Density Catagory				Calculations				Sum of Previous Four Columns	Total Number of AVAS's	Quotient of Column 9 divided by Column 10		
		A	B	C	D	Catagory A x 1	Catagory B x10	Catagory C x 40	Catagory D x 80					
Code No	Plant Name	1	2	3	4	5	6	7	8	9	10	11	Code No	Plant Name
1	Eurasian milfoil	23	3	1	0	23	30	40	0	93	142	0.7	1	Eurasian milfoil
2	Curly leaf pondweed	1	0	0	0	1	0	0	0	1	142	0.0	2	Curly leaf pondweed
3	Chara	22	37	11	4	22	370	440	320	1152	142	8.1	3	Chara
4	Thinleaf pondweed	3	0	0	0	3	0	0	0	3	142	0.0	4	Thinleaf pondweed
5	Flatstem pondweed	1	0	0	0	1	0	0	0	1	142	0.0	5	Flatstem pondweed
6	Robbins pondweed	0	0	0	0	0	0	0	0	0	142	0.0	6	Robbins pondweed
7	Variable pondweed	2	0	0	0	2	0	0	0	2	142	0.0	7	Variable pondweed
8	Whitestem pondweed	1	0	0	0	1	0	0	0	1	142	0.0	8	Whitestem pondweed
9	Richardsons pondweed	4	0	0	0	4	0	0	0	4	142	0.0	9	Richardsons pondweed
10	Illinois pondweed	26	12	0	0	26	120	0	0	146	142	1.0	10	Illinois pondweed
11	Large leaf pondweed	3	0	0	0	3	0	0	0	3	142	0.0	11	Large leaf pondweed
12	American pondweed	0	0	0	0	0	0	0	0	0	142	0.0	12	American pondweed
13	Floating leaf pondweed	3	0	0	0	3	0	0	0	3	142	0.0	13	Floating leaf pondweed
14	Water stargrass	0	0	0	0	0	0	0	0	0	142	0.0	14	Water stargrass
15	Wild Celery	16	7	0	0	16	70	0	0	86	142	0.6	15	Wild Celery
16	Sagittaria	0	0	0	0	0	0	0	0	0	142	0.0	16	Sagittaria
17	Northern milfoil	12	17	7	1	12	170	280	80	542	142	3.8	17	Northern milfoil
18	Whorled milfoil	0	0	0	0	0	0	0	0	0	142	0.0	18	Whorled milfoil
19	Variable milfoil	0	0	0	0	0	0	0	0	0	142	0.0	19	Variable milfoil
20	Coontail	2	0	0	0	2	0	0	0	2	142	0.0	20	Coontail
21	Common Elodea	1	0	0	0	1	0	0	0	1	142	0.0	21	Common Elodea
22	Bladderwort-Large	5	9	0	0	5	90	0	0	95	142	0.7	22	Bladderwort-Large
23	Bladderwort-mini	0	0	0	0	0	0	0	0	0	142	0.0	23	Bladderwort-mini
24	Buttercup	0	0	0	0	0	0	0	0	0	142	0.0	24	Buttercup
25	Southern Naiad	2	1	0	0	2	10	0	0	12	142	0.1	25	Southern Naiad
26	Slender naiad	0	0	0	0	0	0	0	0	0	142	0.0	26	Slender naiad
27	Sago Pondweed	6	4	0	0	6	40	0	0	46	142	0.3	27	Sago Pondweed
28	Starry Stonewort	23	15	10	3	23	150	400	240	813	142	5.7	28	Starry Stonewort
29	Flowering Rush	2	0	0	0	2	0	0	0	2	142	0.0	29	
30	White Waterlily	5	0	0	0	5	0	0	0	5	142	0.0	30	White Waterlily
31	Yellow Waterlily	6	3	0	0	6	30	0	0	36	142	0.3	31	Yellow Waterlily
32	Watershield	0	0	0	0	0	0	0	0	0	142	0.0	32	Watershield
33	Duckweed	1	0	0	0	1	0	0	0	1	142	0.0	33	Duckweed
34	Spirodella	0	0	0	0	0	0	0	0	0	142	0.0	34	
35	Watermeal	0	0	0	0	0	0	0	0	0	142	0.0	35	Watermeal
36	Arrowhead	3	0	0	0	3	0	0	0	3	142	0.0	36	Arrowhead
37	Pickerelweed	3	0	0	0	3	0	0	0	3	142	0.0	37	Pickerelweed
38	Arrow Arum	0	0	0	0	0	0	0	0	0	142	0.0	38	Arrow Arum
39	Cattails	3	0	0	0	3	0	0	0	3	142	0.0	39	Cattails
40	Bulrushes	5	0	0	0	5	0	0	0	5	142	0.0	40	Bulrushes
41	Iris	1	0	0	0	1	0	0	0	1	142	0.0	41	Iris
42	Swamp Loosestrife	0	0	0	0	0	0	0	0	0	142	0.0	42	Swamp Loosestrife
43	Purple Loosestrife	7	0	0	0	7	0	0	0	7	142	0.0	43	Purple Loosestrife
44	Water Smartweed	0	0	0	0	0	0	0	0	0	142	0.0	44	Water Smartweed
45	Phragmites	1	0	0	0	1	0	0	0	1	142	0.0	45	Phragmites
46	Submersed Bulrush	6	5	1	0	6	50	40	0	96	142	0.7	46	Submersed Bulrush
47	Burr Reed	1	0	0	0	1	0	0	0	1	142	0.0	47	Burr Reed
												22.3		

LAKE NAME-STRAWBERRY LAKE **COUNTY- Livingston** **SURVEY DATE: 6 August 2015**

Standard Aquatic Vegetation Summary Sheet SURVEY BY: NKG, GLJ

Code No	Plant Name	Total number of AVAS's 49 for each Density Catagory A	B	C	D	Calculations Catagory A x 1	Catagory B x10	Catagory C x 40	Catagory D x 80	Sum of Previous Four Columns	Total Number of AVAS's	Quotient of Column 9 divided by Column 10	Code No	Plant Name
		1	2	3	4	5	6	7	8	9	10	11		
1	Eurasian milfoil	56	59	23	2	56	590	920	160	1726	197	8.8	1	Eurasian milfoil
2	Curly leaf pondweed	0	0	0	0	0	0	0	0	0	197	0.0	2	Curly leaf pondweed
3	Chara	8	4	0	0	8	40	0	0	48	197	0.2	3	Chara
4	Thinleaf pondweed	0	0	0	0	0	0	0	0	0	197	0.0	4	Thinleaf pondweed
5	Flatstem pondweed	0	4	0	0	0	40	0	0	40	197	0.2	5	Flatstem pondweed
6	Robbins pondweed	0	0	0	0	0	0	0	0	0	197	0.0	6	Robbins pondweed
7	Variable pondweed	0	0	0	0	0	0	0	0	0	197	0.0	7	Variable pondweed
8	Whitestem pondweed	1	0	0	0	1	0	0	0	1	197	0.0	8	Whitestem pondweed
9	Richardsons pondweed	4	1	0	0	4	10	0	0	14	197	0.1	9	Richardsons pondweed
10	Illinois pondweed	2	0	1	0	2	0	40	0	42	197	0.2	10	Illinois pondweed
11	Large leaf pondweed	1	1	0	0	1	10	0	0	11	197	0.1	11	Large leaf pondweed
12	American pondweed	0	0	0	0	0	0	0	0	0	197	0.0	12	American pondweed
13	Floating leaf pondweed	5	2	1	0	5	20	40	0	65	197	0.3	13	Floating leaf pondweed
14	Water stargrass	0	0	0	0	0	0	0	0	0	197	0.0	14	Water stargrass
15	Wild Celery	22	32	10	3	22	320	400	240	982	197	5.0	15	Wild Celery
16	Sagittaria	0	0	0	0	0	0	0	0	0	197	0.0	16	Sagittaria
17	Northern milfoil	2	0	0	0	2	0	0	0	2	197	0.0	17	Northern milfoil
18	Whorled milfoil	0	0	0	0	0	0	0	0	0	197	0.0	18	Whorled milfoil
19	Variable milfoil	0	0	0	0	0	0	0	0	0	197	0.0	19	Variable milfoil
20	Coontail	7	3	1	0	7	30	40	0	77	197	0.4	20	Coontail
21	Common Elodea	3	0	0	0	3	0	0	0	3	197	0.0	21	Common Elodea
22	Bladderwort-Large	2	0	0	0	2	0	0	0	2	197	0.0	22	Bladderwort-Large
23	Bladderwort-mini	0	0	0	0	0	0	0	0	0	197	0.0	23	Bladderwort-mini
24	Buttercup	0	0	0	0	0	0	0	0	0	197	0.0	24	Buttercup
25	Southern Naiad	3	1	0	0	3	10	0	0	13	197	0.1	25	Southern Naiad
26	Slender naiad	0	0	0	0	0	0	0	0	0	197	0.0	26	Slender naiad
27	Sago Pondweed	5	0	0	0	5	0	0	0	5	197	0.0	27	Sago Pondweed
28	Flowering Rush	2	2	0	0	2	20	0	0	22	197	0.1	28	Flowering Rush
29	Starry Stonewort	18	18	15	15	18	180	600	1200	1998	197	10.1	29	Starry Stonewort
30	White Waterlily	2	0	0	0	2	0	0	0	2	197	0.0	30	White Waterlily
31	Yellow Waterlily	12	4	0	0	12	40	0	0	52	197	0.3	31	Yellow Waterlily
32	Watershield	0	0	0	0	0	0	0	0	0	197	0.0	32	Watershield
33	Duckweed	0	0	0	0	0	0	0	0	0	197	0.0	33	Duckweed
34	Spirodella	1	0	0	0	1	0	0	0	1	197	0.0	34	
35	Watermeal	0	0	0	0	0	0	0	0	0	197	0.0	35	Watermeal
36	Arrowhead	3	1	0	0	3	10	0	0	13	197	0.1	36	Arrowhead
37	Pickerelweed	3	0	0	0	3	0	0	0	3	197	0.0	37	Pickerelweed
38	Arrow Arum	0	0	0	0	0	0	0	0	0	197	0.0	38	Arrow Arum
39	Cattails	2	0	0	0	2	0	0	0	2	197	0.0	39	Cattails
40	Bulrushes	5	0	0	0	5	0	0	0	5	197	0.0	40	Bulrushes
41	Iris	0	0	0	0	0	0	0	0	0	197	0.0	41	Iris
42	Swamp Loosestrife	2	0	0	0	2	0	0	0	2	197	0.0	42	Swamp Loosestrife
43	Purple Loosestrife	26	3	1	0	26	30	40	0	96	197	0.5	43	Purple Loosestrife
44	Water Smartweed	0	0	0	0	0	0	0	0	0	197	0.0	44	Water Smartweed
45	Phragmites	2	6	1	0	2	60	40	0	102	197	0.5	45	Phragmites
46	Submersed Bulrush	1	0	0	0	1	0	0	0	1	197	0.0	46	Submersed Bulrush
47	Water Spikerush	0	0	0	0	0	0	0	0	0	197	0.0	47	Water Spikerush
												27.1		

LAKE NAME-GALLAGHER LAKE **COUNTY- Livingston** **SURVEY DATE: 6 August 2015**

Standard Aquatic Vegetation Summary Sheet SURVEY BY: NKG, GLJ

		Total number of AVAS's 117 for each Density Catagory				Calculations				Sum of Previous Four Columns	Total Number of AVAS's	Quotient of Column 9 divided by Column 10		
		A	B	C	D	Catagory A x 1	Catagory B x10	Catagory C x 40	Catagory D x 80					
Code No	Plant Name	1	2	3	4	5	6	7	8	9	10	11	Code No	Plant Name
1	Eurasian milfoil	30	14	1	0	30	140	40	0	210	117	1.8	1	Eurasian milfoil
2	Curly leaf pondweed	0	0	0	0	0	0	0	0	0	117	0.0	2	Curly leaf pondweed
3	Chara	2	0	0	0	2	0	0	0	2	117	0.0	3	Chara
4	Thinleaf pondweed	1	0	0	0	1	0	0	0	1	117	0.0	4	Thinleaf pondweed
5	Flatstem pondweed	3	0	0	0	3	0	0	0	3	117	0.0	5	Flatstem pondweed
6	Robbins pondweed	0	0	0	0	0	0	0	0	0	117	0.0	6	Robbins pondweed
7	Variable pondweed	0	0	0	0	0	0	0	0	0	117	0.0	7	Variable pondweed
8	Whitestem pondweed	0	0	0	0	0	0	0	0	0	117	0.0	8	Whitestem pondweed
9	Richardsons pondweed	4	1	0	0	4	10	0	0	14	117	0.1	9	Richardsons pondweed
10	Illinois pondweed	3	0	0	0	3	0	0	0	3	117	0.0	10	Illinois pondweed
11	Large leaf pondweed	4	0	0	0	4	0	0	0	4	117	0.0	11	Large leaf pondweed
12	American pondweed	0	0	0	0	0	0	0	0	0	117	0.0	12	American pondweed
13	Floating leaf pondweed	4	1	0	0	4	10	0	0	14	117	0.1	13	Floating leaf pondweed
14	Water stargrass	0	0	0	0	0	0	0	0	0	117	0.0	14	Water stargrass
15	Wild Celery	11	16	6	0	11	160	240	0	411	117	3.5	15	Wild Celery
16	Sagittaria	0	0	0	0	0	0	0	0	0	117	0.0	16	Sagittaria
17	Northern milfoil	14	5	1	0	14	50	40	0	104	117	0.9	17	Northern milfoil
18	Whorled milfoil	0	0	0	0	0	0	0	0	0	117	0.0	18	Whorled milfoil
19	Variable milfoil	0	0	0	0	0	0	0	0	0	117	0.0	19	Variable milfoil
20	Coontail	4	0	0	0	4	0	0	0	4	117	0.0	20	Coontail
21	Common Elodea	0	0	0	0	0	0	0	0	0	117	0.0	21	Common Elodea
22	Bladderwort-Large	2	1	0	0	2	10	0	0	12	117	0.1	22	Bladderwort-Large
23	Bladderwort-mini	0	0	0	0	0	0	0	0	0	117	0.0	23	Bladderwort-mini
24	Buttercup	0	0	0	0	0	0	0	0	0	117	0.0	24	Buttercup
25	Southern Naiad	2	1	0	0	2	10	0	0	12	117	0.1	25	Southern Naiad
26	Slender naiad	0	0	0	0	0	0	0	0	0	117	0.0	26	Slender naiad
27	Sago Pondweed	5	1	0	0	5	10	0	0	15	117	0.1	27	Sago Pondweed
28	Starry Stonewort	2	18	26	10	2	180	1040	800	2022	117	17.3	28	Starry Stonewort
29	Flowering Rush	19	1	0	0	19	10	0	0	29	117	0.2	29	
30	White Waterlily	0	0	0	0	0	0	0	0	0	117	0.0	30	White Waterlily
31	Yellow Waterlily	12	5	0	0	12	50	0	0	62	117	0.5	31	Yellow Waterlily
32	Watershield	0	0	0	0	0	0	0	0	0	117	0.0	32	Watershield
33	Duckweed	0	0	0	0	0	0	0	0	0	117	0.0	33	Duckweed
34	Spirodella	0	0	0	0	0	0	0	0	0	117	0.0	34	
35	Watermeal	0	0	0	0	0	0	0	0	0	117	0.0	35	Watermeal
36	Arrowhead	1	0	0	0	1	0	0	0	1	117	0.0	36	Arrowhead
37	Pickerelweed	10	3	0	0	10	30	0	0	40	117	0.3	37	Pickerelweed
38	Arrow Arum	0	0	0	0	0	0	0	0	0	117	0.0	38	Arrow Arum
39	Cattails	1	1	0	0	1	10	0	0	11	117	0.1	39	Cattails
40	Bulrushes	1	3	0	0	1	30	0	0	31	117	0.3	40	Bulrushes
41	Iris	0	0	0	0	0	0	0	0	0	117	0.0	41	Iris
42	Swamp Loosestrife	2	0	0	0	2	0	0	0	2	117	0.0	42	Swamp Loosestrife
43	Purple Loosestrife	14	2	1	0	14	20	40	0	74	117	0.6	43	Purple Loosestrife
44	Water Smartweed	0	0	0	0	0	0	0	0	0	117	0.0	44	Water Smartweed
45	Phragmites	3	0	0	0	3	0	0	0	3	117	0.0	45	Phragmites
46	Submersed Bulrush	0	0	0	0	0	0	0	0	0	117	0.0	46	Submersed Bulrush
47	Burr Reed	0	0	0	0	0	0	0	0	0	117	0.0	47	Burr Reed
												26.4		

LAKE NAME-LOON LAKE **COUNTY- Livingston** **SURVEY DATE: 6 August 2015**

Standard Aquatic Vegetation Summary Sheet SURVEY BY: NKG, GLJ

		Total number of AVAS's 47 for each Density Catagory				Calculations				Sum of Previous Four Columns	Total Number of AVAS's	Quotient of Column 9 divided by Column 10		
		A	B	C	D	Catagory A x 1	Catagory B x10	Catagory C x 40	Catagory D x 80					
Code No	Plant Name	1	2	3	4	5	6	7	8	9	10	11	Code No	Plant Name
1	Eurasian milfoil	11	1	0	0	11	10	0	0	21	47	0.4	1	Eurasian milfoil
2	Curly leaf pondweed	0	0	0	0	0	0	0	0	0	47	0.0	2	Curly leaf pondweed
3	Chara	1	0	0	0	1	0	0	0	1	47	0.0	3	Chara
4	Thinleaf pondweed	0	0	0	0	0	0	0	0	0	47	0.0	4	Thinleaf pondweed
5	Flatstem pondweed	2	2	0	0	2	20	0	0	22	47	0.5	5	Flatstem pondweed
6	Robbins pondweed	0	0	0	0	0	0	0	0	0	47	0.0	6	Robbins pondweed
7	Variable pondweed	1	0	0	0	1	0	0	0	1	47	0.0	7	Variable pondweed
8	Whitestem pondweed	1	0	0	0	1	0	0	0	1	47	0.0	8	Whitestem pondweed
9	Richardsons pondweed	2	0	0	0	2	0	0	0	2	47	0.0	9	Richardsons pondweed
10	Illinois pondweed	1	0	0	0	1	0	0	0	1	47	0.0	10	Illinois pondweed
11	Large leaf pondweed	2	0	0	0	2	0	0	0	2	47	0.0	11	Large leaf pondweed
12	American pondweed	0	0	0	0	0	0	0	0	0	47	0.0	12	American pondweed
13	Floating leaf pondweed	2	1	0	0	2	10	0	0	12	47	0.3	13	Floating leaf pondweed
14	Water stargrass	0	0	0	0	0	0	0	0	0	47	0.0	14	Water stargrass
15	Wild Celery	1	1	0	0	1	10	0	0	11	47	0.2	15	Wild Celery
16	Sagittaria	0	0	0	0	0	0	0	0	0	47	0.0	16	Sagittaria
17	Northern milfoil	4	6	3	0	4	60	120	0	184	47	3.9	17	Northern milfoil
18	Whorled milfoil	0	0	0	0	0	0	0	0	0	47	0.0	18	Whorled milfoil
19	Variable milfoil	0	0	0	0	0	0	0	0	0	47	0.0	19	Variable milfoil
20	Coontail	3	0	0	0	3	0	0	0	3	47	0.1	20	Coontail
21	Common Elodea	1	0	0	0	1	0	0	0	1	47	0.0	21	Common Elodea
22	Bladderwort-Large	6	1	0	0	6	10	0	0	16	47	0.3	22	Bladderwort-Large
23	Bladderwort-mini	0	0	0	0	0	0	0	0	0	47	0.0	23	Bladderwort-mini
24	Buttercup	0	0	0	0	0	0	0	0	0	47	0.0	24	Buttercup
25	Southern Naiad	1	0	0	0	1	0	0	0	1	47	0.0	25	Southern Naiad
26	Slender naiad	0	0	0	0	0	0	0	0	0	47	0.0	26	Slender naiad
27	Sago Pondweed	0	0	0	0	0	0	0	0	0	47	0.0	27	Sago Pondweed
28	Starry Stonewort	0	3	9	28	0	30	360	2240	2630	47	56.0	28	Starry Stonewort
29	Flowering Rush	9	4	0	0	9	40	0	0	49	47	1.0	29	
30	White Waterlily	2	0	0	0	2	0	0	0	2	47	0.0	30	White Waterlily
31	Yellow Waterlily	3	3	3	0	3	30	120	0	153	47	3.3	31	Yellow Waterlily
32	Watershield	0	0	0	0	0	0	0	0	0	47	0.0	32	Watershield
33	Duckweed	0	0	0	0	0	0	0	0	0	47	0.0	33	Duckweed
34	Spirodella	0	0	0	0	0	0	0	0	0	47	0.0	34	
35	Watermeal	0	0	0	0	0	0	0	0	0	47	0.0	35	Watermeal
36	Arrowhead	0	0	0	0	0	0	0	0	0	47	0.0	36	Arrowhead
37	Pickerelweed	3	1	0	0	3	10	0	0	13	47	0.3	37	Pickerelweed
38	Arrow Arum	1	0	0	0	1	0	0	0	1	47	0.0	38	Arrow Arum
39	Cattails	1	0	0	0	1	0	0	0	1	47	0.0	39	Cattails
40	Bulrushes	4	0	0	0	4	0	0	0	4	47	0.1	40	Bulrushes
41	Iris	0	0	0	0	0	0	0	0	0	47	0.0	41	Iris
42	Swamp Loosestrife	1	0	0	0	1	0	0	0	1	47	0.0	42	Swamp Loosestrife
43	Purple Loosestrife	2	0	0	0	2	0	0	0	2	47	0.0	43	Purple Loosestrife
44	Water Smartweed	0	0	0	0	0	0	0	0	0	47	0.0	44	Water Smartweed
45	Phragmites	0	0	0	0	0	0	0	0	0	47	0.0	45	Phragmites
46	Submersed Bulrush	0	0	0	0	0	0	0	0	0	47	0.0	46	Submersed Bulrush
47	Burr Reed	0	0	0	0	0	0	0	0	0	47	0.0	47	Burr Reed
												66.7		

LAKE NAME-LITTLE PORTAGE LAKE **COUNTY- Washtenaw** **SURVEY DATE: 7 August 2015**

Standard Aquatic Vegetation Summary Sheet SURVEY BY: NKG, GLJ

		Total number of AVAS's 121 for each Density Catagory				Calculations				Sum of Previous Four Columns	Total Number of AVAS's	Quotient of Column 9 divided by Column 10		
		A	B	C	D	A x 1	B x10	C x 40	D x 80					
Code No	Plant Name	1	2	3	4	5	6	7	8	9	10	11	Code No	Plant Name
1	Eurasian milfoil	34	16	5	0	34	160	200	0	394	121	3.3	1	Eurasian milfoil
2	Curly leaf pondweed	1	0	0	0	1	0	0	0	1	121	0.0	2	Curly leaf pondweed
3	Chara	5	8	18	3	5	80	720	240	1045	121	8.6	3	Chara
4	Thinleaf pondweed	1	0	0	0	1	0	0	0	1	121	0.0	4	Thinleaf pondweed
5	Flatstem pondweed	3	7	4	1	3	70	160	80	313	121	2.6	5	Flatstem pondweed
6	Robbins pondweed	0	0	0	0	0	0	0	0	0	121	0.0	6	Robbins pondweed
7	Variable pondweed	0	0	0	0	0	0	0	0	0	121	0.0	7	Variable pondweed
8	Whitestem pondweed	4	1	0	0	4	10	0	0	14	121	0.1	8	Whitestem pondweed
9	Richardsons pondweed	3	0	0	0	3	0	0	0	3	121	0.0	9	Richardsons pondweed
10	Illinois pondweed	1	3	0	0	1	30	0	0	31	121	0.3	10	Illinois pondweed
11	Large leaf pondweed	2	5	2	0	2	50	80	0	132	121	1.1	11	Large leaf pondweed
12	American pondweed	0	0	0	0	0	0	0	0	0	121	0.0	12	American pondweed
13	Floating leaf pondweed	2	0	1	0	2	0	40	0	42	121	0.3	13	Floating leaf pondweed
14	Water stargrass	0	0	0	0	0	0	0	0	0	121	0.0	14	Water stargrass
15	Wild Celery	1	1	1	0	1	10	40	0	51	121	0.4	15	Wild Celery
16	Sagittaria	0	0	0	0	0	0	0	0	0	121	0.0	16	Sagittaria
17	Northern milfoil	9	4	2	1	9	40	80	80	209	121	1.7	17	Northern milfoil
18	Whorled milfoil	3	0	0	0	3	0	0	0	3	121	0.0	18	Whorled milfoil
19	Variable milfoil	0	0	0	0	0	0	0	0	0	121	0.0	19	Variable milfoil
20	Coontail	2	0	1	0	2	0	40	0	42	121	0.3	20	Coontail
21	Common Elodea	0	0	0	0	0	0	0	0	0	121	0.0	21	Common Elodea
22	Bladderwort-Large	3	0	0	0	3	0	0	0	3	121	0.0	22	Bladderwort-Large
23	Bladderwort-mini	0	0	0	0	0	0	0	0	0	121	0.0	23	Bladderwort-mini
24	Buttercup	0	0	0	0	0	0	0	0	0	121	0.0	24	Buttercup
25	Southern Naiad	1	1	1	0	1	10	40	0	51	121	0.4	25	Southern Naiad
26	Slender naiad	0	0	0	0	0	0	0	0	0	121	0.0	26	Slender naiad
27	Sago Pondweed	4	2	1	0	4	20	40	0	64	121	0.5	27	Sago Pondweed
28	Starry Stonewort	10	13	10	10	10	130	400	800	1340	121	11.1	28	Starry Stonewort
29	Flowering Rush	6	0	0	0	6	0	0	0	6	121	0.0	29	
30	White Waterlily	5	0	0	0	5	0	0	0	5	121	0.0	30	White Waterlily
31	Yellow Waterlily	7	4	8	0	7	40	320	0	367	121	3.0	31	Yellow Waterlily
32	Watershield	0	0	0	0	0	0	0	0	0	121	0.0	32	Watershield
33	Duckweed	1	0	0	0	1	0	0	0	1	121	0.0	33	Duckweed
34	Spirodella	0	0	0	0	0	0	0	0	0	121	0.0	34	
35	Watermeal	0	0	0	0	0	0	0	0	0	121	0.0	35	Watermeal
36	Arrowhead	2	0	0	0	2	0	0	0	2	121	0.0	36	Arrowhead
37	Pickerelweed	3	0	0	0	3	0	0	0	3	121	0.0	37	Pickerelweed
38	Arrow Arum	1	0	0	0	1	0	0	0	1	121	0.0	38	Arrow Arum
39	Cattails	5	2	4	0	5	20	160	0	185	121	1.5	39	Cattails
40	Bulrushes	7	0	0	0	7	0	0	0	7	121	0.1	40	Bulrushes
41	Iris	0	0	0	0	0	0	0	0	0	121	0.0	41	Iris
42	Swamp Loosestrife	2	1	0	0	2	10	0	0	12	121	0.1	42	Swamp Loosestrife
43	Purple Loosestrife	22	2	0	0	22	20	0	0	42	121	0.3	43	Purple Loosestrife
44	Water Smartweed	0	0	0	0	0	0	0	0	0	121	0.0	44	Water Smartweed
45	Phragmites	7	4	3	0	7	40	120	0	167	121	1.4	45	Phragmites
46	Submersed Bulrush	0	0	0	0	0	0	0	0	0	121	0.0	46	Submersed Bulrush
47	Burr Reed	6	0	0	0	6	0	0	0	6	121	0.0	47	Burr Reed
												37.5		

LAKE NAME-BIG PORTAGE LAKE **COUNTY- Livingston and Washtenaw** **SURVEY DATE: 7 August 2015**

Standard Aquatic Vegetation Summary Sheet SURVEY BY: NKG, GLJ

		Total number of AVAS's 496 for each Density Catagory				Calculations				Sum of Previous Four Columns	Total Number of AVAS's	Quotient of Column 9 divided by Column 10		
		A	B	C	D	Catagory A x 1	Catagory B x10	Catagory C x 40	Catagory D x 80					
Code No	Plant Name	1	2	3	4	5	6	7	8	9	10	11	Code No	Plant Name
1	Eurasian milfoil	94	25	5	0	94	250	200	0	544	496	1.1	1	Eurasian milfoil
2	Curly leaf pondweed	1	0	0	0	1	0	0	0	1	496	0.0	2	Curly leaf pondweed
3	Chara	38	55	43	7	38	550	1720	560	2868	496	5.8	3	Chara
4	Thinleaf pondweed	5	0	0	0	5	0	0	0	5	496	0.0	4	Thinleaf pondweed
5	Flatstem pondweed	8	2	1	0	8	20	40	0	68	496	0.1	5	Flatstem pondweed
6	Robbins pondweed	1	0	0	0	1	0	0	0	1	496	0.0	6	Robbins pondweed
7	Variable pondweed	1	0	0	0	1	0	0	0	1	496	0.0	7	Variable pondweed
8	Whitestem pondweed	6	2	0	0	6	20	0	0	26	496	0.1	8	Whitestem pondweed
9	Richardsons pondweed	8	11	1	0	8	110	40	0	158	496	0.3	9	Richardsons pondweed
10	Illinois pondweed	49	53	5	0	49	530	200	0	779	496	1.6	10	Illinois pondweed
11	Large leaf pondweed	10	6	1	0	10	60	40	0	110	496	0.2	11	Large leaf pondweed
12	American pondweed	0	0	0	0	0	0	0	0	0	496	0.0	12	American pondweed
13	Floating leaf pondweed	2	1	1	0	2	10	40	0	52	496	0.1	13	Floating leaf pondweed
14	Water stargrass	0	0	0	0	0	0	0	0	0	496	0.0	14	Water stargrass
15	Wild Celery	14	56	31	6	14	560	1240	480	2294	496	4.6	15	Wild Celery
16	Sagittaria	0	0	0	0	0	0	0	0	0	496	0.0	16	Sagittaria
17	Northern milfoil	1	0	0	0	1	0	0	0	1	496	0.0	17	Northern milfoil
18	Whorled milfoil	33	32	29	0	33	320	1160	0	1513	496	3.1	18	Whorled milfoil
19	Variable milfoil	0	0	0	0	0	0	0	0	0	496	0.0	19	Variable milfoil
20	Coontail	5	4	4	0	5	40	160	0	205	496	0.4	20	Coontail
21	Common Elodea	1	0	0	0	1	0	0	0	1	496	0.0	21	Common Elodea
22	Bladderwort-Large	14	1	0	0	14	10	0	0	24	496	0.0	22	Bladderwort-Large
23	Bladderwort-mini	0	0	0	0	0	0	0	0	0	496	0.0	23	Bladderwort-mini
24	Buttercup	0	0	0	0	0	0	0	0	0	496	0.0	24	Buttercup
25	Southern Naiad	3	13	3	0	3	130	120	0	253	496	0.5	25	Southern Naiad
26	Slender naiad	0	0	0	0	0	0	0	0	0	496	0.0	26	Slender naiad
27	Sago Pondweed	10	3	0	0	10	30	0	0	40	496	0.1	27	Sago Pondweed
28	Starry Stonewort	46	35	20	51	46	350	800	4080	5276	496	10.6	28	Starry Stonewort
29	Flowering Rush	15	8	0	0	15	80	0	0	95	496	0.2	29	Flowering Rush
30	White Waterlily	1	0	0	0	1	0	0	0	1	496	0.0	30	White Waterlily
31	Yellow Waterlily	9	13	3	0	9	130	120	0	259	496	0.5	31	Yellow Waterlily
32	Watershield	0	0	0	0	0	0	0	0	0	496	0.0	32	Watershield
33	Duckweed	1	0	0	0	1	0	0	0	1	496	0.0	33	Duckweed
34	Spirodella	0	0	0	0	0	0	0	0	0	496	0.0	34	
35	Watermeal	0	0	0	0	0	0	0	0	0	496	0.0	35	Watermeal
36	Arrowhead	0	0	0	0	0	0	0	0	0	496	0.0	36	Arrowhead
37	Pickerelweed	2	1	0	0	2	10	0	0	12	496	0.0	37	Pickerelweed
38	Arrow Arum	0	0	0	0	0	0	0	0	0	496	0.0	38	Arrow Arum
39	Cattails	2	2	1	0	2	20	40	0	62	496	0.1	39	Cattails
40	Bulrushes	2	0	1	0	2	0	40	0	42	496	0.1	40	Bulrushes
41	Iris	0	0	0	0	0	0	0	0	0	496	0.0	41	Iris
42	Swamp Loosestrife	0	0	0	0	0	0	0	0	0	496	0.0	42	Swamp Loosestrife
43	Purple Loosestrife	29	6	1	0	29	60	40	0	129	496	0.3	43	Purple Loosestrife
44	Water Smartweed	0	0	0	0	0	0	0	0	0	496	0.0	44	Water Smartweed
45	Phragmites	1	2	0	0	1	20	0	0	21	496	0.0	45	Phragmites
46	Submersed Bulrush	0	0	0	0	0	0	0	0	0	496	0.0	46	Submersed Bulrush
47	Water Spikerush	0	0	0	0	0	0	0	0	0	496	0.0	47	Water Spikerush
												29.9		

LAKE NAME-BASELINE LAKE **COUNTY- Livingston and Washtenaw** **SURVEY DATE: 6 August 2015**

Standard Aquatic Vegetation Summary Sheet SURVEY BY: NKG, GLJ

Code No	Plant Name	Total number of AVAS's 148 for each Density Catagory A	B	C	D	Calculations Catagory A x 1	Catagory B x10	Catagory C x 40	Catagory D x 80	Sum of Previous Four Columns	Total Number of AVAS's	Quotient of Column 9 divided by Column 10	Code No	Plant Name
		1	2	3	4	5	6	7	8	9	10	11		
1	Eurasian milfoil	0	0	0	0	0	0	0	0	0	148	0.0	1	Eurasian milfoil
2	Curly leaf pondweed	0	0	0	0	0	0	0	0	0	148	0.0	2	Curly leaf pondweed
3	Chara	10	4	1	6	10	40	40	480	570	148	3.9	3	Chara
4	Thinleaf pondweed	1	0	0	0	1	0	0	0	1	148	0.0	4	Thinleaf pondweed
5	Flatstem pondweed	1	0	0	0	1	0	0	0	1	148	0.0	5	Flatstem pondweed
6	Robbins pondweed	1	0	0	0	1	0	0	0	1	148	0.0	6	Robbins pondweed
7	Variable pondweed	0	0	0	0	0	0	0	0	0	148	0.0	7	Variable pondweed
8	Whitestem pondweed	1	0	0	0	1	0	0	0	1	148	0.0	8	Whitestem pondweed
9	Richardsons pondweed	2	8	0	0	2	80	0	0	82	148	0.6	9	Richardsons pondweed
10	Illinois pondweed	2	4	1	0	2	40	40	0	82	148	0.6	10	Illinois pondweed
11	Large leaf pondweed	3	0	0	0	3	0	0	0	3	148	0.0	11	Large leaf pondweed
12	American pondweed	0	0	0	0	0	0	0	0	0	148	0.0	12	American pondweed
13	Floating leaf pondweed	8	3	0	0	8	30	0	0	38	148	0.3	13	Floating leaf pondweed
14	Water stargrass	0	0	0	0	0	0	0	0	0	148	0.0	14	Water stargrass
15	Wild Celery	11	25	24	5	11	250	960	400	1621	148	11.0	15	Wild Celery
16	Sagittaria	0	0	0	0	0	0	0	0	0	148	0.0	16	Sagittaria
17	Northern milfoil	5	3	0	0	5	30	0	0	35	148	0.2	17	Northern milfoil
18	Whorled milfoil	0	0	0	0	0	0	0	0	0	148	0.0	18	Whorled milfoil
19	Variable milfoil	0	0	0	0	0	0	0	0	0	148	0.0	19	Variable milfoil
20	Coontail	0	0	0	0	0	0	0	0	0	148	0.0	20	Coontail
21	Common Elodea	1	0	0	0	1	0	0	0	1	148	0.0	21	Common Elodea
22	Bladderwort-Large	1	0	0	0	1	0	0	0	1	148	0.0	22	Bladderwort-Large
23	Bladderwort-mini	0	0	0	0	0	0	0	0	0	148	0.0	23	Bladderwort-mini
24	Buttercup	0	0	0	0	0	0	0	0	0	148	0.0	24	Buttercup
25	Southern Naiad	4	0	1	0	4	0	40	0	44	148	0.3	25	Southern Naiad
26	Slender naiad	0	0	0	0	0	0	0	0	0	148	0.0	26	Slender naiad
27	Sago Pondweed	4	1	0	0	4	10	0	0	14	148	0.1	27	Sago Pondweed
28	Starry Stonewort	17	22	26	15	17	220	1040	1200	2477	148	16.7	28	Starry Stonewort
29	Flowering Rush	19	13	2	0	19	130	80	0	229	148	1.5	29	
30	White Waterlily	2	0	0	0	2	0	0	0	2	148	0.0	30	White Waterlily
31	Yellow Waterlily	2	1	0	0	2	10	0	0	12	148	0.1	31	Yellow Waterlily
32	Watershield	0	0	0	0	0	0	0	0	0	148	0.0	32	Watershield
33	Duckweed	1	0	0	0	1	0	0	0	1	148	0.0	33	Duckweed
34	Spirodella	0	0	0	0	0	0	0	0	0	148	0.0	34	
35	Watermeal	0	0	0	0	0	0	0	0	0	148	0.0	35	Watermeal
36	Arrowhead	1	0	0	0	1	0	0	0	1	148	0.0	36	Arrowhead
37	Pickerelweed	2	0	0	0	2	0	0	0	2	148	0.0	37	Pickerelweed
38	Arrow Arum	0	0	0	0	0	0	0	0	0	148	0.0	38	Arrow Arum
39	Cattails	0	0	1	0	0	0	40	0	40	148	0.3	39	Cattails
40	Bulrushes	4	0	0	0	4	0	0	0	4	148	0.0	40	Bulrushes
41	Iris	1	0	0	0	1	0	0	0	1	148	0.0	41	Iris
42	Swamp Loosestrife	0	0	0	0	0	0	0	0	0	148	0.0	42	Swamp Loosestrife
43	Purple Loosestrife	13	3	0	0	13	30	0	0	43	148	0.3	43	Purple Loosestrife
44	Water Smartweed	0	0	0	0	0	0	0	0	0	148	0.0	44	Water Smartweed
45	Phragmites	2	3	0	0	2	30	0	0	32	148	0.2	45	Phragmites
46	Submersed Bulrush	0	0	0	0	0	0	0	0	0	148	0.0	46	Submersed Bulrush
47	Water Spikerush	0	0	0	0	0	0	0	0	0	148	0.0	47	Water Spikerush
												36.1		

LAKE NAME-WHITEWOOD LAKES **COUNTY- Livingston** **SURVEY DATE: 6 August 2015**

Standard Aquatic Vegetation Summary Sheet SURVEY BY: NKG, GLJ

		Total number of AVAS's 127 for each Density Catagory				Calculations				Sum of Previous Four Columns	Total Number of AVAS's	Quotient of Column 9 divided by Column 10		
		A	B	C	D	Catagory A x I	Catagory B x10	Catagory C x 40	Catagory D x 80					
Code No	Plant Name	1	2	3	4	5	6	7	8	9	10	11	Code No	Plant Name
1	Eurasian milfoil	20	5	1	0	20	50	40	0	110	127	0.9	1	Eurasian milfoil
2	Curly leaf pondweed	0	0	0	0	0	0	0	0	0	127	0.0	2	Curly leaf pondweed
3	Chara	2	1	0	0	2	10	0	0	12	127	0.1	3	Chara
4	Thinleaf pondweed	2	1	0	0	2	10	0	0	12	127	0.1	4	Thinleaf pondweed
5	Flatstem pondweed	0	0	0	0	0	0	0	0	0	127	0.0	5	Flatstem pondweed
6	Robbins pondweed	0	0	0	0	0	0	0	0	0	127	0.0	6	Robbins pondweed
7	Variable pondweed	0	0	0	0	0	0	0	0	0	127	0.0	7	Variable pondweed
8	Whitestem pondweed	0	0	0	0	0	0	0	0	0	127	0.0	8	Whitestem pondweed
9	Richardsons pondweed	8	7	7	0	8	70	280	0	358	127	2.8	9	Richardsons pondweed
10	Illinois pondweed	1	1	0	0	1	10	0	0	11	127	0.1	10	Illinois pondweed
11	Large leaf pondweed	3	0	0	0	3	0	0	0	3	127	0.0	11	Large leaf pondweed
12	American pondweed	0	0	0	0	0	0	0	0	0	127	0.0	12	American pondweed
13	Floating leaf pondweed	6	3	0	0	6	30	0	0	36	127	0.3	13	Floating leaf pondweed
14	Water stargrass	0	0	0	0	0	0	0	0	0	127	0.0	14	Water stargrass
15	Wild Celery	9	13	15	0	9	130	600	0	739	127	5.8	15	Wild Celery
16	Sagittaria	0	0	0	0	0	0	0	0	0	127	0.0	16	Sagittaria
17	Northern milfoil	7	7	7	0	7	70	280	0	357	127	2.8	17	Northern milfoil
18	Whorled milfoil	0	0	0	0	0	0	0	0	0	127	0.0	18	Whorled milfoil
19	Variable milfoil	0	0	0	0	0	0	0	0	0	127	0.0	19	Variable milfoil
20	Coontail	1	0	0	0	1	0	0	0	1	127	0.0	20	Coontail
21	Common Elodea	1	0	0	0	1	0	0	0	1	127	0.0	21	Common Elodea
22	Bladderwort-Large	2	1	0	0	2	10	0	0	12	127	0.1	22	Bladderwort-Large
23	Bladderwort-mini	0	0	0	0	0	0	0	0	0	127	0.0	23	Bladderwort-mini
24	Buttercup	0	0	0	0	0	0	0	0	0	127	0.0	24	Buttercup
25	Southern Naiad	0	2	0	0	0	20	0	0	20	127	0.2	25	Southern Naiad
26	Slender naiad	0	0	0	0	0	0	0	0	0	127	0.0	26	Slender naiad
27	Small-leaf Pondweed	0	0	0	0	0	0	0	0	0	127	0.0	27	Small-leaf Pondweed
28	Starry Stonewort	12	11	14	14	12	110	560	1120	1802	127	14.2	28	Starry Stonewort
29	Flowering Rush	9	6	1	0	9	60	40	0	109	127	0.9	29	
30	White Waterlily	2	0	0	0	2	0	0	0	2	127	0.0	30	White Waterlily
31	Yellow Waterlily	8	4	1	0	8	40	40	0	88	127	0.7	31	Yellow Waterlily
32	Watershield	0	0	0	0	0	0	0	0	0	127	0.0	32	Watershield
33	Duckweed	0	0	0	0	0	0	0	0	0	127	0.0	33	Duckweed
34	Spirodella	0	0	0	0	0	0	0	0	0	127	0.0	34	
35	Watermeal	0	0	0	0	0	0	0	0	0	127	0.0	35	Watermeal
36	Arrowhead	2	0	0	0	2	0	0	0	2	127	0.0	36	Arrowhead
37	Pickerelweed	6	1	1	0	6	10	40	0	56	127	0.4	37	Pickerelweed
38	Arrow Arum	0	0	0	0	0	0	0	0	0	127	0.0	38	Arrow Arum
39	Cattails	3	0	0	0	3	0	0	0	3	127	0.0	39	Cattails
40	Bulrushes	3	3	0	1	3	30	0	80	113	127	0.9	40	Bulrushes
41	Iris	0	0	0	0	0	0	0	0	0	127	0.0	41	Iris
42	Swamp Loosestrife	7	2	0	0	7	20	0	0	27	127	0.2	42	Swamp Loosestrife
43	Purple Loosestrife	19	5	8	0	19	50	320	0	389	127	3.1	43	Purple Loosestrife
44	Water Smartweed	0	0	0	0	0	0	0	0	0	127	0.0	44	Water Smartweed
45	Phragmites	3	2	0	0	3	20	0	0	23	127	0.2	45	Phragmites
46	Submersed Bulrush	3	4	2	0	3	40	80	0	123	127	1.0	46	Submersed Bulrush
47	Water Spikerush	0	0	0	0	0	0	0	0	0	127	0.0	47	Water Spikerush
												34.7		

LAKE NAME-TAMARACK LAKE **COUNTY- Livingston** **SURVEY DATE: 7 August 2015**

Standard Aquatic Vegetation Summary Sheet SURVEY BY: NKG, GLJ

		Total number of AVAS's 49 for each Density Catagory				Calculations				Sum of Previous Four Columns	Total Number of AVAS's	Quotient of Column 9 divided by Column 10		
						Catagory	Catagory	Catagory	Catagory					
		A	B	C	D	A x 1	B x10	C x 40	D x 80					
Code No	Plant Name	1	2	3	4	5	6	7	8	9	10	11	Code No	Plant Name
1	Eurasian milfoil	7	0	0	0	7	0	0	0	7	49	0.1	1	Eurasian milfoil
2	Curly leaf pondweed	0	0	0	0	0	0	0	0	0	49	0.0	2	Curly leaf pondweed
3	Chara	2	0	0	0	2	0	0	0	2	49	0.0	3	Chara
4	Thinleaf pondweed	1	0	0	0	1	0	0	0	1	49	0.0	4	Thinleaf pondweed
5	Flatstem pondweed	0	0	0	0	0	0	0	0	0	49	0.0	5	Flatstem pondweed
6	Robbins pondweed	0	0	0	0	0	0	0	0	0	49	0.0	6	Robbins pondweed
7	Variable pondweed	0	0	0	0	0	0	0	0	0	49	0.0	7	Variable pondweed
8	Whitestem pondweed	0	0	0	0	0	0	0	0	0	49	0.0	8	Whitestem pondweed
9	Richardsons pondweed	1	0	0	0	1	0	0	0	1	49	0.0	9	Richardsons pondweed
10	Illinois pondweed	2	1	0	0	2	10	0	0	12	49	0.2	10	Illinois pondweed
11	Large leaf pondweed	3	1	0	0	3	10	0	0	13	49	0.3	11	Large leaf pondweed
12	American pondweed	0	0	0	0	0	0	0	0	0	49	0.0	12	American pondweed
13	Floating leaf pondweed	1	0	0	0	1	0	0	0	1	49	0.0	13	Floating leaf pondweed
14	Water stargrass	0	0	0	0	0	0	0	0	0	49	0.0	14	Water stargrass
15	Wild Celery	1	0	0	0	1	0	0	0	1	49	0.0	15	Wild Celery
16	Sagittaria	0	0	0	0	0	0	0	0	0	49	0.0	16	Sagittaria
17	Northern milfoil	1	0	0	0	1	0	0	0	1	49	0.0	17	Northern milfoil
18	Whorled milfoil	0	0	0	0	0	0	0	0	0	49	0.0	18	Whorled milfoil
19	Variable milfoil	0	0	0	0	0	0	0	0	0	49	0.0	19	Variable milfoil
20	Coontail	1	0	0	0	1	0	0	0	1	49	0.0	20	Coontail
21	Common Elodea	1	0	0	0	1	0	0	0	1	49	0.0	21	Common Elodea
22	Bladderwort-Large	4	1	0	0	4	10	0	0	14	49	0.3	22	Bladderwort-Large
23	Bladderwort-mini	0	0	0	0	0	0	0	0	0	49	0.0	23	Bladderwort-mini
24	Buttercup	0	0	0	0	0	0	0	0	0	49	0.0	24	Buttercup
25	Southern Naiad	1	1	0	0	1	10	0	0	11	49	0.2	25	Southern Naiad
26	Slender naiad	0	0	0	0	0	0	0	0	0	49	0.0	26	Slender naiad
27	Small-leaf Pondweed	0	0	0	0	0	0	0	0	0	49	0.0	27	Small-leaf Pondweed
28	Flowering Rush	1	1	0	0	1	10	0	0	11	49	0.2	28	Flowering Rush
29	Starry Stonewort	1	1	10	39	1	10	400	3120	3531	49	72.1	29	Starry Stonewort
30	White Waterlily	3	0	0	0	3	0	0	0	3	49	0.1	30	White Waterlily
31	Yellow Waterlily	7	8	0	0	7	80	0	0	87	49	1.8	31	Yellow Waterlily
32	Watershield	0	0	0	0	0	0	0	0	0	49	0.0	32	Watershield
33	Duckweed	0	0	0	0	0	0	0	0	0	49	0.0	33	Duckweed
34	Spirodella	0	0	0	0	0	0	0	0	0	49	0.0	34	
35	Watermeal	0	0	0	0	0	0	0	0	0	49	0.0	35	Watermeal
36	Arrowhead	0	0	0	0	0	0	0	0	0	49	0.0	36	Arrowhead
37	Pickerelweed	2	0	0	0	2	0	0	0	2	49	0.0	37	Pickerelweed
38	Arrow Arum	0	0	0	0	0	0	0	0	0	49	0.0	38	Arrow Arum
39	Cattails	1	1	0	0	1	10	0	0	11	49	0.2	39	Cattails
40	Bulrushes	3	0	0	0	3	0	0	0	3	49	0.1	40	Bulrushes
41	Iris	2	0	0	0	2	0	0	0	2	49	0.0	41	Iris
42	Swamp Loosestrife	0	0	0	0	0	0	0	0	0	49	0.0	42	Swamp Loosestrife
43	Purple Loosestrife	7	1	0	0	7	10	0	0	17	49	0.3	43	Purple Loosestrife
44	Water Smartweed	0	0	0	0	0	0	0	0	0	49	0.0	44	Water Smartweed
45	Phragmites	0	0	0	0	0	0	0	0	0	49	0.0	45	Phragmites
46	Submersed Bulrush	0	0	0	0	0	0	0	0	0	49	0.0	46	Submersed Bulrush
47	Water Spikerush	0	0	0	0	0	0	0	0	0	49	0.0	47	Water Spikerush
												76.2		