Buffalo Lake

Buffalo Lake Enhancement Project Summary Report

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2025

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Buffalo Lake Enhancement Project
Hydrologic Study

(Conducted by Emmons & Olivier Resources, Inc.)

Prepared by: EOR

For the Buffalo Lake Protection and Rehabilitation District and Cason Land & Water Management, LLC

Buffalo Lake Enhancement Project Hydrologic Study

August 22, 2025

Cover Images

Buffalo Lake Dam (November 20, 2025)

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1. BACKGROUND

1.1. Purpose and Scope

The Buffalo Lake District is evaluating a potential change in operation of the Buffalo Lake Dam (also known locally as the "Montello Dam") to raise the water level of the lake during parts of the year to improve conditions for lake users. The dam is owned and operated by the Wisconsin Department of Natural Resource (WDNR). The DNR awarded the District with a Surface Water Grant to study potential benefits and impacts of the proposed changes to the environment and landowners near the lake.

The dam has 4 operable gates plus an overflow spillway. Before 2019, they were not operated, and the lake level fluctuated based on inflows and the capacity of the overflow spillway. Starting in 2019, the DNR began to operate the gates to maintain the level of Buffalo Lake consistent with the water levels specified in the 1976 operating order. The operating order specifies a winter maximum lake level corresponding to 8.0 ft on the staff gage mounted on the dam and a summer maximum of 8.5 ft. The order specifies that the summer maximum applies to the period from May 20 through October 1.

No change in either the summer or winter maximum stages is currently proposed. Rather, the District proposes to increase the duration of the summer maximum to May 1 – October 15, an additional 20 days in May and an additional 14 days in October.

This study evaluated potential impacts that the proposed dam operation change could have on the following issues:

- Peak flood elevations on the lake
- Groundwater levels around the lake
- Water temperature in the Fox River downstream of the dam
- Lakeshore erosion
- Wetland community composition and quality

2. DAM OPERATION AND LAKE LEVEL DATA

2.1. Lake Level Records

The WDNR provided a spreadsheet with data on the lake stage and dam gate operation for the period of June 3, 2019 through July 2, 2024 (Uriah Monday, written communication, 2024). WDNR photographs the staff gage on each visit and records the lake level in the spreadsheet. A staff gage reading of 8.0 ft corresponds to elevation 769.0 ft in the National Geodetic Vertical Datum of 1929 (NGVD29) according to WDNR records. The Flood Insurance Study (FIS) lists a vertical datum conversion between NGVD29 and the more recent North American Vertical Datum of 1988 (NAVD88) of NGVD29 – 0.1 ft = NAVD88. Therefore, a gage reading of 8.0 ft equals 768.9 ft NAVD88 (**Table 1**). Unless otherwise noted, this report describes elevations in NAVD88.

Table 1. Conversion of staff gage measurements and NAVD88 elevations.

Gage Reading (ft)	NAVD88 Elevation (ft)
8.0	768.9
8.5	769.4
9.0	769.9

Add 760.9 ft to gage readings to calculate NAVD88 elevations.

2.2. Dam Operation

The dam has 3 sluice gates and one split leaf gate, all with a sill elevation of 761.5 ft. The dam's auxiliary spillway is a weir with a 168-ft-long crest at elevation 768.65 ft (7.75 ft on the local gage datum). There is additionally a fish passage with an invert of 768.2 ft (7.3 ft on the local gage datum) and a flow width of 20'.

The gates have typically been checked on weekly visits by WDNR staff and adjusted as needed to comply with the water level order. It appears that the gate operation is based on professional judgement of the operator and not a written operation plan. The gates have been partially open by variable amounts most of the time during the winter water level period and closed most of the time during the summer season, with the gates open occasionally to pass high flows.

Spring operation records for 2020 – 2024 indicate that, after the gate settings are adjusted on May 20, it takes about a week for the water level to approximately reach the summer maximum. In 2020, the lake was already above the summer maximum at 8.8 ft on May 20, so gates were opened to lower the water level. Conditions in 2023 were very dry, and the lake could not be raised all the way to 8.5 ft for most of the summer.

In late summer, dry conditions typically have made it difficult to maintain the lake at 8.5 ft, so that little or no gate adjustment has been needed on October 1 to drop the lake to the winter maximum of 8.0 ft.

2.3. Lake Outflows

The WDNR also provided outflows from the lake at the dam estimated by two methods. The first method estimated daily flows for October 1st, 1991 through July 9th, 2024, based on flows at the USGS gage on the Fox River downstream of the lake at Berlin prorated by drainage area. The second method uses hydraulic calculations of the discharge through the dam based on the gate settings and overflow spillway capacity to estimate discharge at approximately weekly intervals from June 3rd 2019 through July 2nd 2024. Outflows estimated by the gage transfer method and lake those estimated by hydraulic calculations for the dam gates are similar for low flows. However, high flow estimates based on the hydraulic calculations for the dam gates are much higher (**Figure 1**). The short-term spikes in discharge from the dam reflect sudden opening of the gates to release water before the lake level drops and outflow is reduced. The difference with the gage transfer method likely reflects streamflow routing between Montello and Berlin that attenuates peak discharge by the time flow reaches Berlin. This comparison provides confidence in the estimates of discharge at the dam for low flows. It also illustrates that, while the timing of high flows matches well for the two methods, the magnitude of high flow estimates based on analysis of the downstream gaging station are likely to be inaccurate due to routing between Buffalo Lake and Berlin.

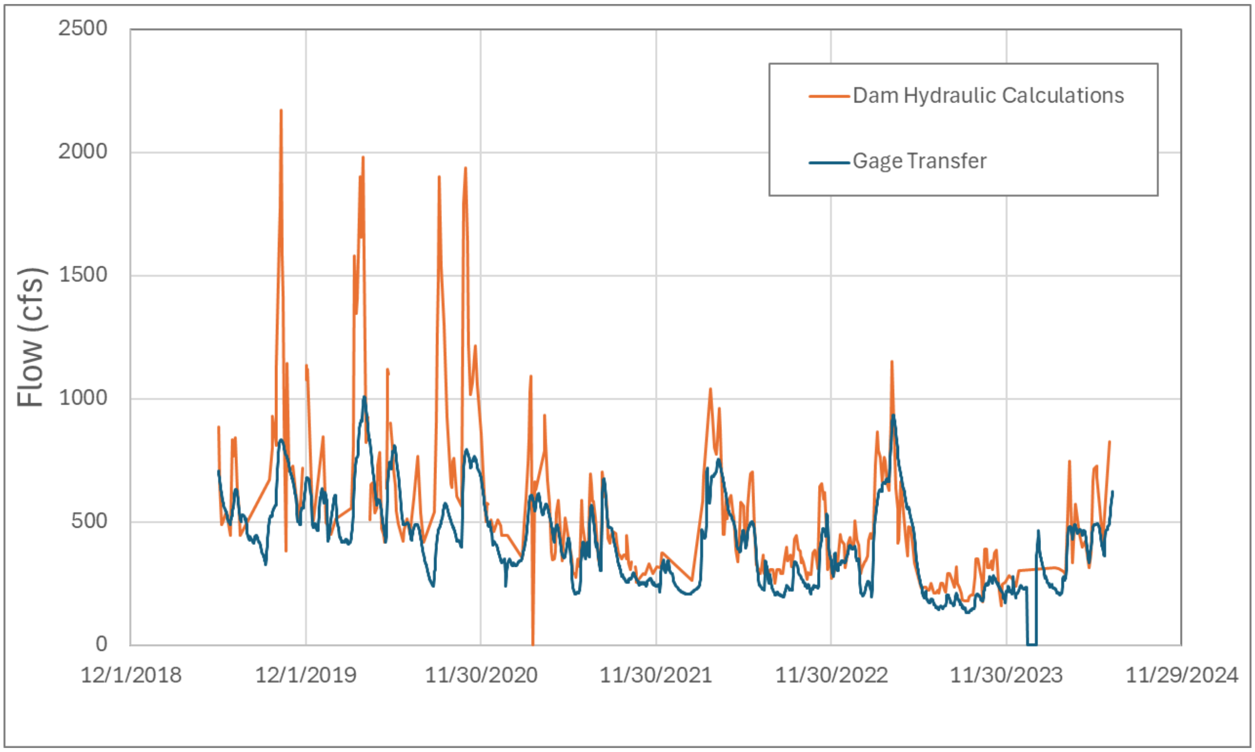

Figure 1. WDNR estimates of Buffalo Lake outflows.

2.4. Shoreline Changes

No elevation data is available to precisely define the lake's shoreline position at the ordered levels of 8.0 ft or 8.5 ft. The most recent topographic data for Buffalo Lake and its shoreline is the Marquette County LiDAR survey from 2018. At that time, the lake stage was 770.36 ft (9.46 ft on the gage), which is above both the summer and winter maximum. A bathymetric map from WDNR for 1967 (**Figure 2)** illustrates the shoreline at a stage of 8.0 ft and depth contours below the water level. However, this map obviously does not use modern terrain data, and its scale is too small for precise comparisons with other data sources.

Information on how the extent of inundation differs from lake stages in the range of 8.0 ft to 8.5 ft to a stage of 9.5 ft (the lowest stage represented in the LiDAR) can be inferred by a visual comparison of aerial photographs from recent years, when the lake was near 8.0 ft to 8.5 ft, with the position of the lidar contour representing a stage of 9.5 ft. The 9.5 ft contour was developed in GIS from the LiDAR dataset, creating a surface model in the local datum and delineating the 9.5 ft elevation with a contour line. Aerial photographs are available from Google for March 11, 2021, June 30, 2021, and May 4, 2024. WDNR measured lake stage within 1 – 4 days before and after these dates, making it possible to estimate a range of stages represented by these aerial photographs (**Table 2**).

Aerial images from these dates with the 9.5 ft contour overlaid on them are included in **Appendix A**. These images include an overview of the entire lake, at which scale differences are indiscernible, and larger-scale images for selected locations. In addition, digital data transmitted with this report includes a .kml file of the 9.5 ft contour that can be imported into Google Earth to allow comparison of this contour location with these and other historical aerial images at any location around the lake. Note that the precise location of the shoreline can be difficult to determine in some locations due to the presence of aquatic macrophytes. This comparison of available data illustrates that there is little difference in lake inundation extents for stages in the range of the dam's operating orders.

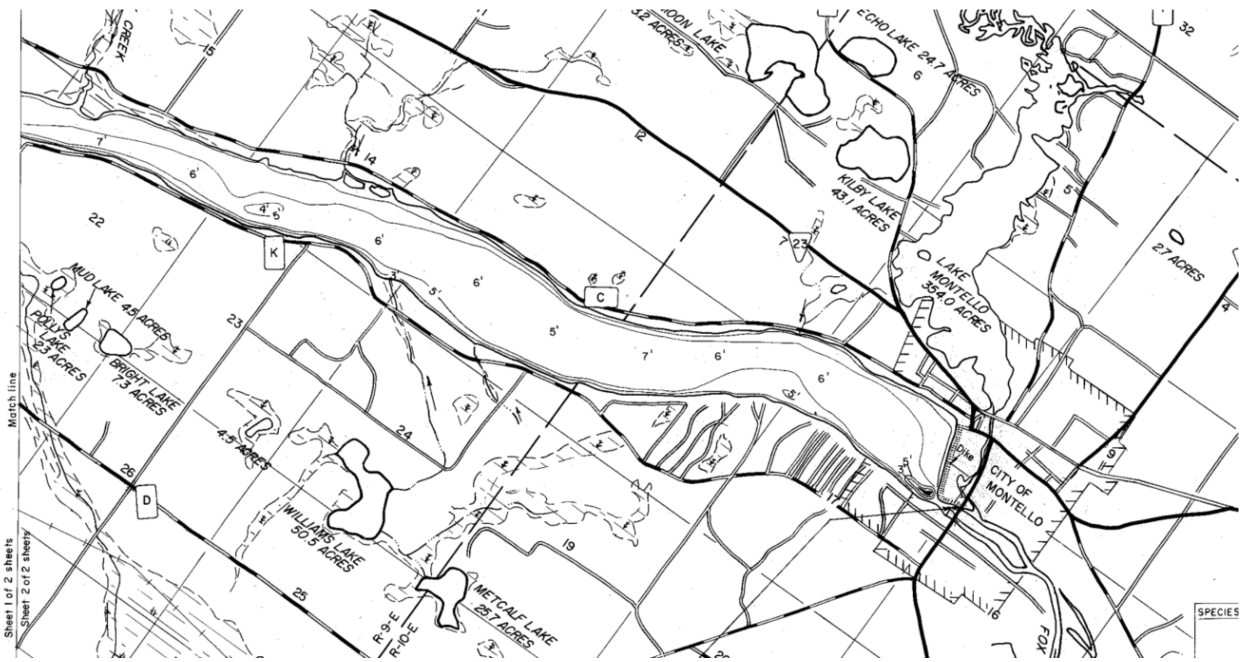

Figure 2. A portion of the 1967 WDNR bathymetric map.

Table 2. Estimated lake stage on dates of recent aerial photographs.

Aerial Photograph Date	Preceding Stage Measurement	Following Stage Measurement
March 11, 2021	8.14 ft March 10, 2021	8.22 ft March 12, 2021
June 30, 2021	8.64 ft June 28, 2021	8.50 ft July 1, 2021
May 4, 2024	8.03 ft April 30, 2024	7.93 ft May 7, 2024

3. LAKE FLOOD LEVELS

Two related but distinct issues were evaluated in this analysis of flood levels on Buffalo Lake. One is whether the proposed change to the dam operation would affect the effective regulatory Base Flood Elevation (BFE) for the 100-year event listed in the Flood Insurance Study (FIS) for Marquette County. This depends on how the flood elevation was calculated in the FIS. The second issue is whether and by how much flood levels would actually change if a flood occurred during the periods in May or October when the lake is proposed to be raised from 8.0 ft to 8.5 ft.

3.1. Flood Insurance Study Review

Flood floods into Buffalo Lake used in the Flood Insurance Study (FIS) are based on the hydrologic analysis in the Columbia County FIS, because flood flows in the Fox River upstream of the lake are affected by overflow from the Wisconsin River into the Fox River at Portage, Wisconsin. The FIS used a coincident frequency analysis of the Wisconsin and Fox Rivers and an estimate of overflows between the watersheds.

Hydrologic and hydraulic flood calculations for Buffalo Lake were performed by the U.S. Army Corps of Engineers (USACE) in 1999 using a UNET model for the Fox River, the results of which were then used to initialize a HEC-2 model of flood elevations. EOR spoke with the USACE modeler, Terry Zien, for insights into that analysis and received written records from the USACE. The UNET model uses a lake stage of 769.37 ft NGVD 1929 at the dam as the initial condition before routing the upstream hydrograph through the lake. This corresponds to a gage reading of 8.37 ft, which is between the summer and winter maximum water levels. Documentation from the USACE states that this starting elevation was selected using a rating curve for the dam developed in 1980 by Owen Ayers Associates. Presumably, the USACE selected a representative low flow in Buffalo Lake to calculate this elevation, but those details are not available. The UNET model calculated a peak 100-year discharge of 3829 cfs and a 100-year stage of 771.99 ft (NGVD 1929) at the Montello dam. This peak discharge is considerably lower than the flow of 4652 cfs the Fox River at Endeavor upstream of the dam, indicating a substantial routing effect through the lake.

Because the UNET flood elevation at the Montello Dam was used as the downstream boundary condition for the HEC-2 model, either model could reasonably be said to be the source of the elevations at the Dam. Moreover, the downstream boundary for the UNET model is a rating curve referenced to the 1980 National Dam Safety Program Inspection Report, Fox River, Montello Dam (Inventory No 01015). We were unable to locate a copy of this document, however the rating curve was obtained from the UNET input files.

Comparing the rating curve in the UNET model to model results at the same discharges for a hydrologic model developed by EOR using the HEC-HMS software (described below in Section 3.2.3) shows a near-identical stage-discharge relationship when the dam gates are fully closed; for this reason, we conclude that the FIS flood elevations were developed with the assumption that the dam gates were fully closed.

3.2. Analysis

The proposed dam operation change could theoretically affect the lake flood stage if the flood occurred during the period when the lake level would be at 8.5 ft instead of 8.0 ft. EOR evaluated the impact of the proposed water level change on lake flood stage by 3 methods: evaluating the seasonality of historical floods, a comparison of flood hydrograph volume with lake storage, and performing hydrologic modeling.

3.2.1. Seasonality of Flood Flows

Stream flows and flood risk are non-uniform during the year, and so the timing of the proposed changes must be examined in the context of the seasonal variation of high flows.

EOR analyzed the series of estimated stream flows provided by Uriah Monday of the WDNR described above that were developed with the gage transfer analysis for the Berlin stream gaging station. According to this record, flows in the Fox River peak in the spring, roughly between mid-March and early June (**Figure 3**). Median flows during this period range from 500 to 600 cfs, well up from the 250-300 cfs median values for much of the remainder of the year. This suggests that the marginal risk of increased water levels is significantly concentrated during the spring period of interest, rather than the fall period.

Peak annual flows do not always coincide with periods of generally high flow. For the period 1992 – 2021 there were 8 recorded years with annual peaks higher than 1000 cfs; of these, half took place during the summer and early fall, and only one took place during the periods of proposed change (1271 cfs on May 8, 2012), with the remainder occurring in March and April.

We conclude that the antecedent conditions that create increased vulnerability are likely concentrated during the spring period of interest, while the individual high flows that would be likely to trigger an extreme flood event are more broadly distributed throughout the summer months.

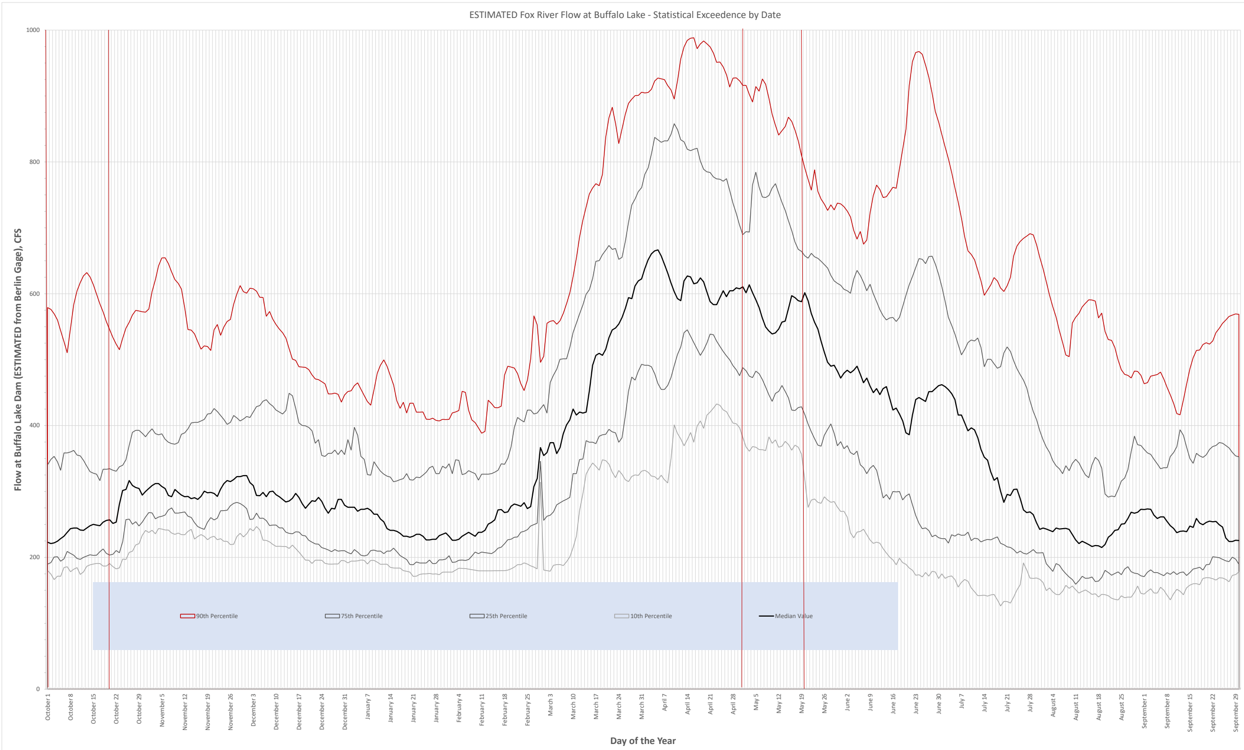

Figure 3. Exceedance probability flows for WY 1992 – 2022 (from WDNR with annotation of proposed spring and fall extension of summer maximum lake stage added by EOR).

3.2.2. Volumetric Comparison

The 100-year flood hydrograph calculated for Buffalo Lake from the UNET model output has a full volume of 33,708 ac-ft. This includes a 1-day "warm up" period with a constant discharge of 300 cfs. The flood discharge peaks at the end of day 5 and is still falling after day 9 (the end of the modeled hydrograph). Considering only the rising limb of the hydrograph, from its start on model day 2 to its peak at the end of day 5 yields a volume of 13,737 ac-ft.

The incremental storage volume between the starting stage of 8.37 ft assumed in the FIS and the 8.5 ft maximum summer level can be calculated by multiplying the lake area (2179 ac per the WDNR) by the water level difference of 0.13 ft. This yields a storage difference of 283 ac-ft. This is 2% of the volume of the rising limb of the 100-year flood hydrograph, a small enough difference that the peak lake stage should be essentially the same for a 100-year event with the lake starting at either the elevation assumed in the FIS or the 8.5 ft summer maximum stage.

3.2.3. Hydrologic Modeling

Hydrologic modeling was used to evaluate the difference in flood stage on the lake if a 100-year event were to occur during one of the periods when the lake stage is proposed to be raised from 8.0 ft to 8.5 ft. The USACE no longer supports the UNET model used in the FIS, and the FIS analysis did not simulate the dam gates in a way that is conducive to testing the impact of gate operation on water levels. Therefore, EOR built a hydrologic model using the HEC-HMS software to evaluate lake inflows, outflows and stage. This model was used to evaluate the effects of antecedent lake stage and gate operation on flood peak elevations.

HEC-HMS model construction details include the following.

- *Reservoir* – Limited bathymetry data were available, however over the very limited elevation range with active storage there is little variation in the marginal storage per unit of elevation change. The stage-area relationship is shown in **Table 3**.

Table 3. Buffalo Lake stage-area relationship used in HEC-HMS model.

Stage (ft)	Area (ac)	Source
0	0	Per the 1967 WDNR map, the lake stage is defined from the lake invert
8	2179	Normal stage lake area published by WDNR
11.2	2900	100-year flood elevation, area measured from 100-year floodplain maps.
12	2900	Conservative assumption of straight sided storage; not active in this model.

- *Dam* – The model includes a single sluice gate representing the 4 gates with elevations dimensions taken from the dam plans and an opening width equal to the opening width of the 4 gates together. In reality, one gate is a split-leaf type, and the gates are operated independently; however the goal of this modeling was to represent the aggregate capacity of the gates accurately enough to evaluate impacts of the proposed water level change, not to simulate individual gate operation. The model also includes the fish ladder and auxiliary spillway weir.

- *Historical Flows* – The model uses WDNR's lake inflows estimated based on drainage area ratio with the USGS gage at Berlin. For modeling efficiency, we simulated slightly more than 1-year period using the annual flow series including the 2008 water year, with an additional 3 months at the end (October 1, 2007 – December 31, 2008). This period contained the largest event during the period of record, which had an estimated peak inflow to Buffalo Lake of 1776 cfs plus an apparent snowmelt event of 1135 cfs.

- *FIS flows* – We used the 9-day hydrograph from the UNET model developed by the USACE and used in the FIS (**Figure 4**). The peak discharge is 3829 cfs.

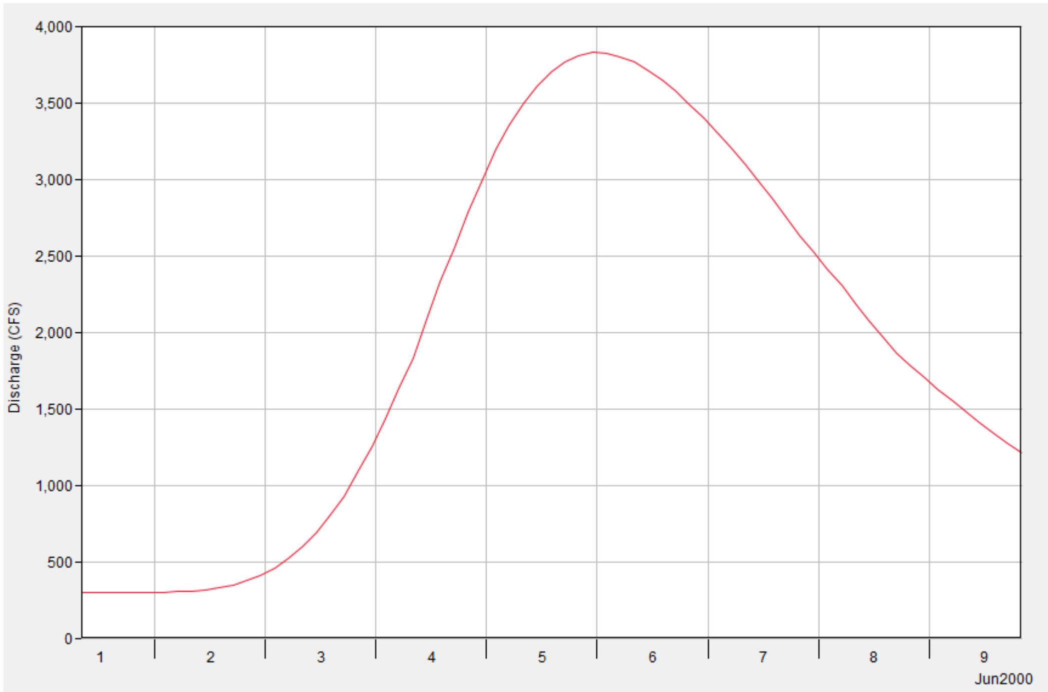

Figure 4. UNET discharge hydrograph. Horizontal axis units are days.

Historical Flow Data Simulation

A continuous simulation of historical flows was performed to evaluate the impact that gate settings have on the flood level of the lake. As noted above, we simulated a little over 1 year using 2007 and 2008 data for modeling efficiency. The model does not attempt to simulate actual weekly adjustments of the gates. Rather, a range of constant gate openings was modeled and compared to ascertain the difference that makes for lake flood stage. **Figure 5** shows model runs for the 4 gates being closed, and for openings of 0.5 ft, 1 ft, and 2 ft (all gates open the same amount). The runs most closely representing actual historical operation of the dam are the scenarios with the gates closed and gates open 0.5 ft. The lake stage during low flows for these scenarios is generally between 8.0 ft - 8.5 ft for the gates closed and between 7.5 ft - 8.0 ft for the 0.5-ft-opening scenario.

Also note that these simulations illustrate that gate operation can make a substantial difference in the lake flood elevation. For the largest event simulated in 2008, the peak lake stage is approximately 0.7 ft lower for the scenario with the gates open 2 ft vs. the gates-closed scenario. These means there is an opportunity to mitigate flood impacts through gate operation during high flow events.

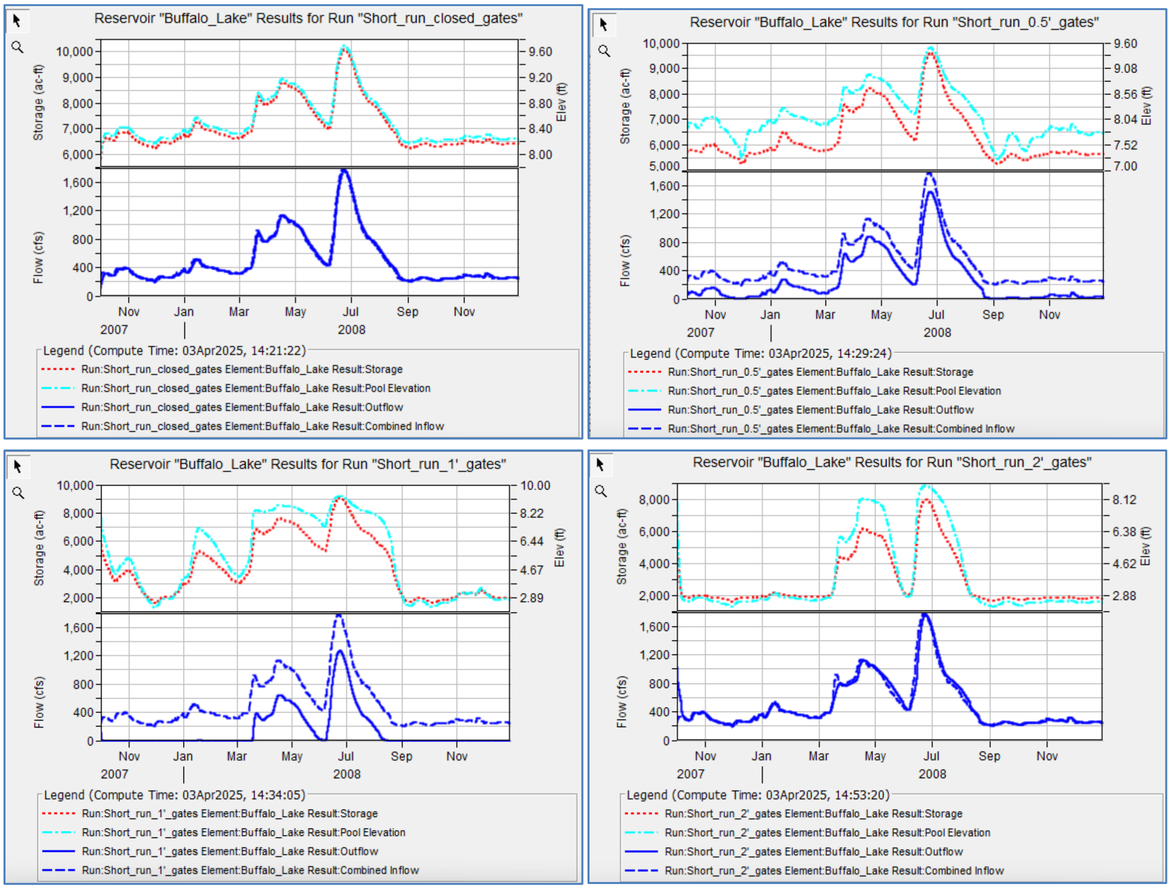

Figure 5. HEC-HMS simulation of 2007-2008 flows for gates closed (upper left), gates open 0.5 ft (upper right), gates open 1.0 ft (lower left) and gates open 2.0 ft (lower right). Lake stage shown in light blue.

<u>Impact on the Flood Insurance Study Elevations</u>

The HEC-HMS model developed for this project was used to establish a rating curve based on the reconstructed dam geometry with the modeled gates fully closed, and this was compared to the published FIS values. Through the range of flows up to the 100-year flow (3829 cfs) the calculated water surface elevations at the dam match within 0.02 ft, with the exception of the highest tested flow of 4150 cfs where the two figures deviated by 0.07 ft (**Table 4**). Based on this near match, we conclude that the FIS elevations were developed assuming the dam gates were fully closed, representing the worst-case scenario from a flood perspective.

Table 4. Comparison of dam rating curve from the Flood Insurance Study UNET model and the HEC-HMS model with all dam gates closed.

Flow	UNET elevation	HEC-HMS with gates closed	Difference
(cfs)	(ft)	(ft)	(ft)
1120	770.06	770.07	-0.01
1870	770.69	770.67	0.02
2290	770.96	770.97	-0.01
2550	771.15	771.15	0
3250	771.6	771.6	0
3500	771.77	771.75	0.02
4150	772.2	772.13	0.07

To evaluate whether the proposed change in the target stage during the period of interest would require a change in the BFE, we used the newly developed HEC-HMS model to evaluate the effect of reduced antecedent storage on the flood stage elevation, assuming in both cases that the dam gates are fully closed.

The antecedent flows in the UNET model output were adjusted to ensure a stable elevation in the impoundment prior to the onset of the flood peak; for the 8.37' lake elevation this required a steady inflow of 351 CFS, while for the 8.5' lake elevation the antecedent flows were increased to 456 cfs. Flows above these values were not changed and were identical in both simulations. The initial lake elevation was set to the target elevation in each model to ensure rapid equilibration.

Under these conditions the HEC-HMS model shows a peak flood stage of 10.82 ft for both scenarios, confirming that the loss of storage from the higher initial stage does not impact the 100-year flood elevation to 0.01 ft, using the conditions represented in the effective Flood Insurance Study model.

<u>Actual Impact on Flood Elevations</u>

While the above analysis evaluated the proposed conditions compared with the conditions modeled in the FIS (with a starting lake stage of 8.37 ft), it is also relevant to compare flood elevations for lake stages starting at 8.0 ft vs. 8.5 ft. This comparison applies to the proposed extension of the summer maximum level, from May 1 – May 20 and October 1 – October 15.

With this in mind, we repeated the above analysis, comparing the 100-year flood elevation for starting stages at the winter and summer maxima (8.0 ft and 8.5 ft, respectively). Simulating the 8.5 ft stage requires a 456 cfs antecedent flow (as before), while the 8.0 ft stage is initialized with a flow of 110 cfs. Running the same 100-year hydrograph in each simulation results in a slightly lower peak flood stage of 10.81 ft for the winter level scenario vs 10.82 ft for the summer level scenario.

While this shows an increase in the modeled 100-year flood stage of 0.01 ft, it must be noted that this increase in risk would occur only over the 19 days in May and 14 days in October during which the increase in stage is requested, or less than 10% of the year. It also assumes that the gates are fully closed and are not opened in anticipation of or in reaction to the flood event, which is highly conservative.

We therefore concluded that the proposed operation change would have minimal impact on flood elevations of Buffalo Lake.

4. GROUNDWATER IMPACTS

4.1. Issues Addressed

This analysis evaluated how the proposed increased duration of the summer maximum lake stage would affect groundwater near the lake. In particular, impacts to agricultural lands were considered, including tile drainage systems and depth to water table changes. The proposed dam operation changes affect the timing of groundwater fluctuations but not the magnitude of variations. We evaluated the distance from Buffalo Lake at which the seasonal lake level fluctuation has an impact on groundwater elevations, and evaluated the time it takes groundwater to respond to the seasonal change in lake level.

4.2. Areas Evaluated for Risk

4.2.1. Agricultural Areas

Potential risks to agriculture stem from the longer period that is proposed for the summer maximum, which could coincide with spring planting or fall harvest activities. Impacts in fall appear less likely than in spring, because the WDNR’s water level records indicate that the lake is commonly below its summer maximum at the end of the summer (before the date when the winter maximum takes effect) due to dry conditions and low lake inflows, however during and after the spring snowmelt it is likely the lake could be brought to the proposed higher target elevation in many years. Low-lying agricultural fields near the lake with the potential to be impacted by increased groundwater elevations were identified based on information from the District and aerial photograph review. Specific areas evaluated are shown in **Figure 6** and described below.

<u>Agricultural Area 1</u>

These fields are upstream of Buffalo Lake along the west side of the Fox River near the CTH O crossing. Marquette County LiDAR elevation data indicate that the Fox River elevation here was approximately 2 ft higher than the level of Buffalo Lake during that 2018 survey date, with a river elevation of 772.2 ft. The lowest elevation of crop fields in this area is approximately 780 ft.

Agricultural Area 2

These fields east of Endeavor on the east side of Buffalo Lake south and north of Gem Avenue. A ditch network drains these fields to the Fox River upstream of Buffalo Lake. Field elevations range from 772 ft in the southern part of this area to over 780 ft in the northern portion near and to the north of Gem Avenue.

Agricultural Area 3

This area is south of Packwaukee on the east side of Buffalo Lake, with fields primarily south of the railroad tracks. Ditches drain these fields southward to the Fox River near the upstream end of Buffalo Lake. Fields in this area are primarily above elevation 775 ft.

Agricultural Area 4

This muck farm is located at Endeavor west of Buffalo Lake and Interstate 39. This is a former wetland basin that drained to the Fox River via Chapman Creek. A ditch network is visible throughout the farm, but fields are generally lower than the level of Buffalo Lake and Chapman Creek, with elevations of 763 – 767 ft throughout much of the farm and 769 – 771 at southern fields near the creek. The fields are presumably dewatered by a pumping system because there is no route for gravity drainage, and pumps have been observed by a District representative (Dustin Esselman, written communication, 2025).

Agricultural Area 5

Fields north of Buffalo Lake at Packwaukee are drained by the Mad River and tributary ditches. Most of the fields in this area are above elevation 780 ft, but the southern portion of this area has fields at 774 – 775 ft.

4.2.2. Residential Areas

Potential residential impacts include groundwater interference with septic systems and basement seepage. Because the proposal only extends the duration of the summer maximum but does not increase that level, the change would only be expected to prolong existing problems with high groundwater, if they are currently occurring.

Residential areas are present along most of the shoreline of the lake, in Packwaukee and Montello, Buffalo Shore Estates on the east side of the lake between Packwaukee and Endeavor, and on the west side of the lake at Endeavor. These areas include some low-lying properties near the lake where high groundwater could have an impact on septic systems or other features.

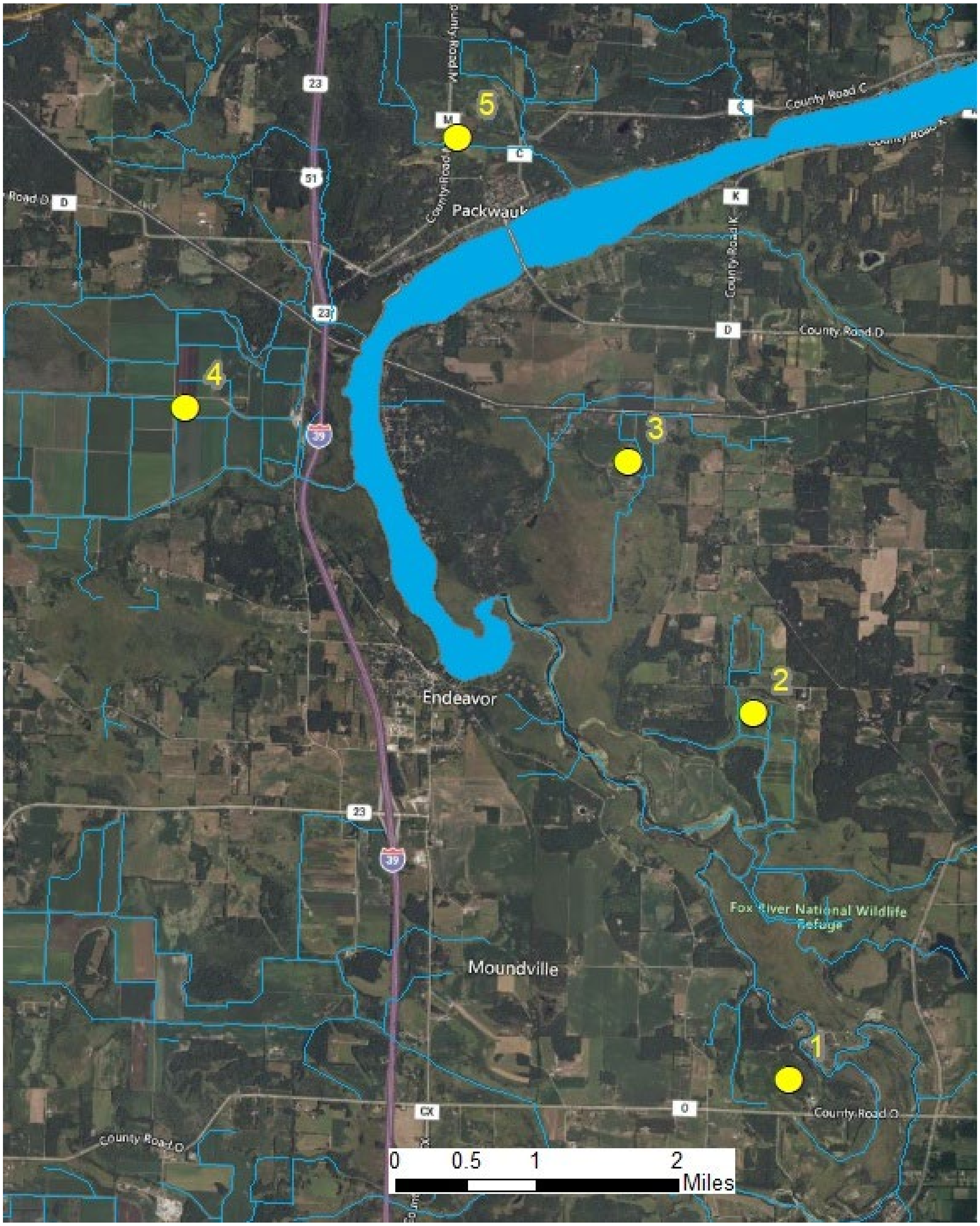

Figure 6. Agricultural areas evaluated for groundwater impacts.

4.3. Aquifer Properties

Properties of the groundwater flow system around Buffalo Lake were reviewed to provide insights into potential impacts of the proposed dam operation change and to develop input parameters for groundwater modeling techniques used to quantify groundwater response to lake level changes.

The Buffalo Lake area has not been subject to a detailed hydrogeologic study, however it is at the boundary of the WDNR's Central Sands Lakes Study[1], and the geology has been mapped by the Wisconsin Geological and Natural History Survey. Additional information is provided by Well Construction Reports available from the WDNR.

Buffalo Lake and the Fox River occupy an area once flooded by Glacial Lake Oshkosh[2]. Up to 80m of clay were deposited in offshore areas of the glacial lake, and sandier deposits formed closer to the lake's shoreline. Sandy glacial till deposits and sandstone bedrock are present below the lake deposits. The geologic map of the area indicates the presence of peat over sandy and silty wetland and stream deposits at the west end of Buffalo Lake (map units po and ps on **Figure 7**). This suggests the possible presence of high-transmissivity sandy materials in that area.

EOR's review of Well Construction Reports for 25 wells near Buffalo Lake found that most wells near the western part of Buffalo Lake (**Figure 8**), where low lying farms are located, were drilled through sand overlying clay and sandy till and/or sandstone bedrock. The shallow sand is typically tens of feet thick at these wells, with a mid-range value of about 50 ft. Many of them have little water level drawdown reported during drillers' pumping tests, indicating high hydraulic conductivity. It therefore appears that the water table around Buffalo Lake is in a sandy aquifer that is likely to be well connected to the lake.

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[1] Wisconsin Geological and Natural History Survey, 2020. Appendix a – Central Sands Lakes Study Technical Report: Data Collection and Hydrostratigraphy.

[2] Hooyer, TS, Mode WN and Clayton, L 2021. Quaternary geology of Columbia, Green Lake, and Marquette Counties, Wisconsin, with contributions to the map by JW Attig: Wisconsin Geological and Natural History Survey Bulletin 114, 38p, 1 pale, scale 1:100,000.

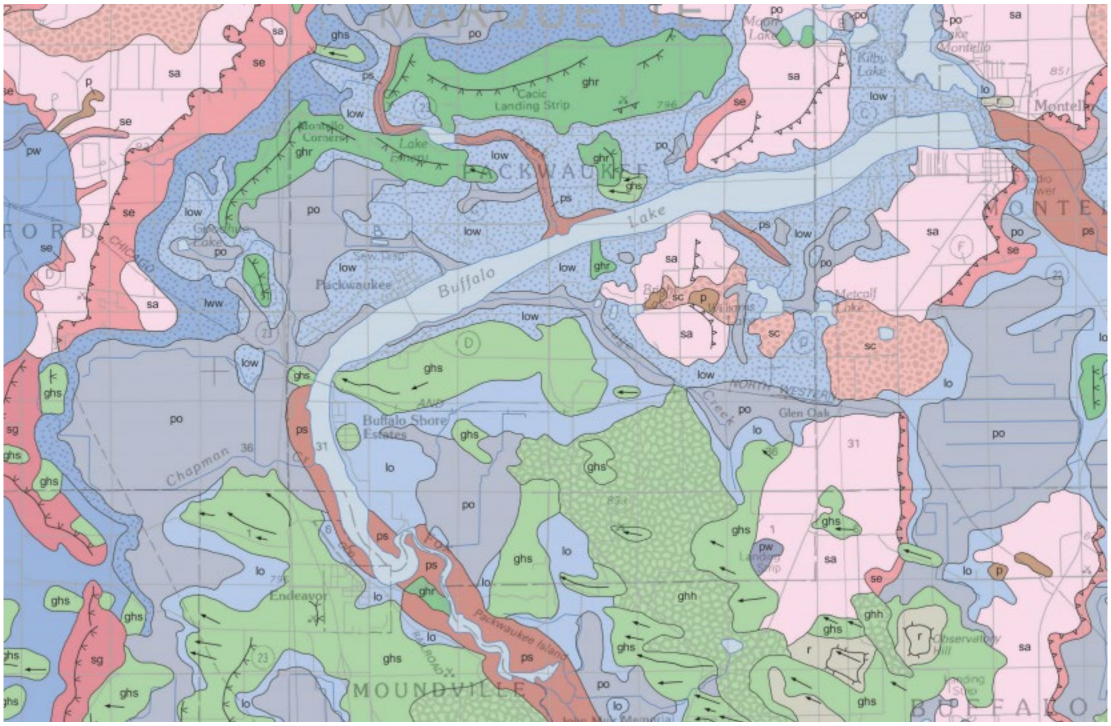

Figure 7. Quaternary geology map of the Buffalo Lake area (from WGNHS).

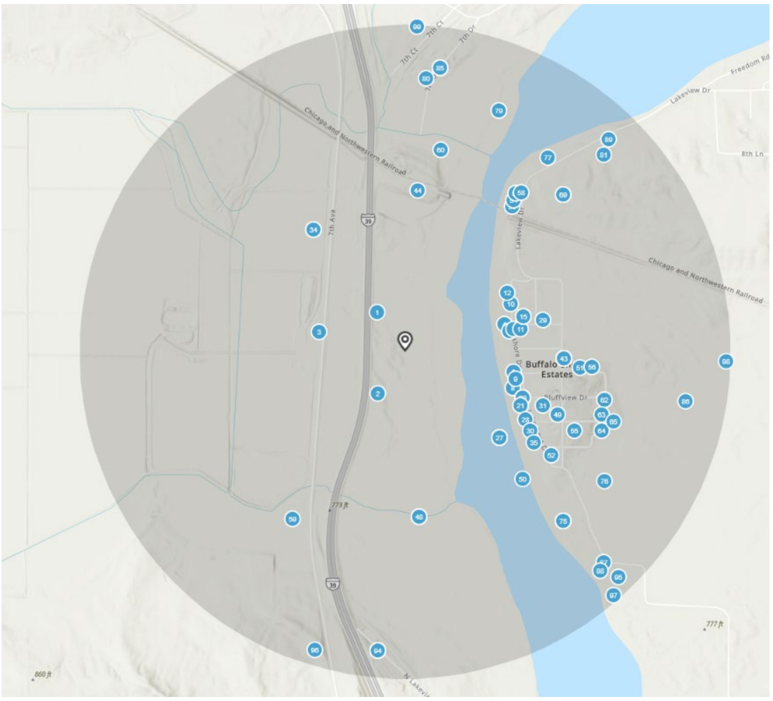

Figure 8. Locations of Well Construction Reports near west end of Buffalo Lake. Records for 25 of these wells were reviewed for geologic and groundwater information.

The WDNR's Central Sands Lakes Study included 46 aquifer tests for wells in the region, albeit farther north than Buffalo Lake. The mean hydraulic conductivity and specific yield for these tests were 106 ft/d and 0.17, respectively. The WDNR study also used water supply well drillers' specific capacity tests for approximately 23,000 wells in the unconsolidated aquifer. The average hydraulic conductivity for wells east of the terminal glacial moraine, where Buffalo Lake is located, was 112 ft/d (**Figure 9**).

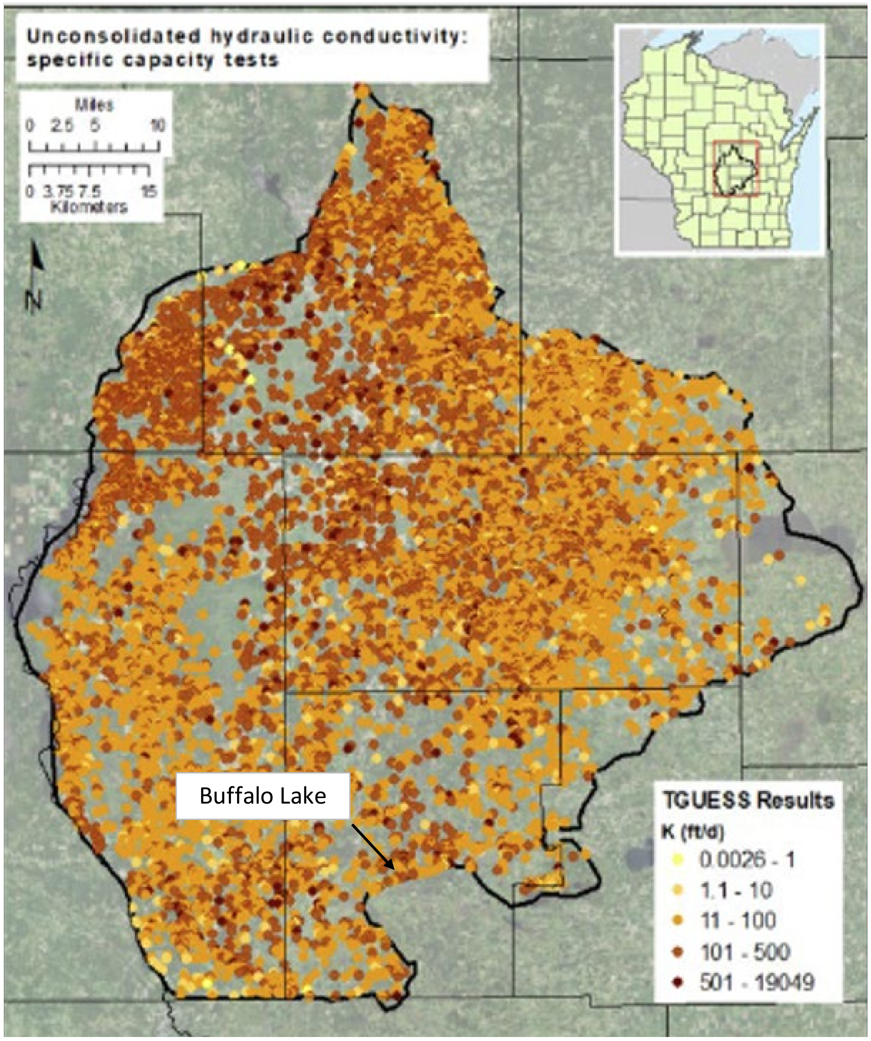

Figure 9. Hydraulic conductivity of the unconsolidated aquifer from well drillers' specific capacity tests (Figure 31b from the WDNR Central Sands Lakes Study)

4.4. Impact Analysis

This analysis evaluated groundwater impacts related to the proposed extension of the summer maximum lake stage period. We used the groundwater GFLOW to evaluate the extent of the area around the lake where groundwater elevation is affected by changes between lake stages 8.0 ft and 8.5 ft. The length of time it takes for groundwater to respond to a change in lake level was evaluated using transient analytical equations.

4.4.1. Extent of Groundwater Affected by Lake Level Change

A groundwater model was constructed using the computer program GFLOW to evaluate differences in the groundwater elevation for lake stages 8.0 ft and 8.5 ft. GFLOW is a steady-state, 2-dimensional analytic element model distributed by the U.S. Environmental Protection Agency that is well-suited to simulate groundwater-surface water interactions. The model simulates the regional flow system using Buffalo Lake, the Fox River and tributary streams as head boundary conditions, a regional recharge rate of 11.5 in/yr estimated by the U.S. Geological Survey[3], and the properties of the shallow sand aquifer described above (hydraulic conductivity of 112 ft/d; aquifer thickness of approximately 50 ft, and porosity of 0.2).

The groundwater model simulates flow toward Buffalo Lake and tributary streams, as expected. Water table elevation contours for the lake at 8.0 ft and 8.5 ft show similar patterns with little difference visible at a scale that includes the extent of the lake (**Figure 10**). Because the model is steady state, it simulates the maximum impact of the lake level change and does not provide information on how rapidly water table fluctuations occur. The water table also fluctuates with climatic conditions (i.e. wet and dry seasons), which are not simulated by this GFLOW model. The simulations here illustrate the difference that lake stage makes for groundwater levels.

The extent of the area around Buffalo Lake where groundwater elevations differ for the lake at 8.0 ft versus 8.5 ft is shown in **Figure 11**. This distance varies around the lake but is on the order of one mile in many locations. More rise generally occurs where streams drain into the lake, because the water level in streams is affected by the increase in lake level, and this contributes to groundwater rise near the streams. The seasonal water table rise at the agricultural fields described above ranges from less than 0.1 ft to 0.3 ft (**Table 5**), with the exception of Area 4 where pumping is used for dewatering. The GFLOW model does not represent impacts on that area, which are discussed below in Section 4.4.3.

The seasonal water table rise also occurs in residential areas, including the northern shoreline of the lake, Packwaukee, Buffalo Shore Estates, and at Endeavor. We are unaware of high groundwater impacts to septic systems or other uses of residential properties around the lake. Additional impacts due to the proposed changes to the dates for the summer maximum are unlikely because (1) the lake is already managed at the

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[3] Gebert, WA, JF Walker, and RJ Hunt, 2011. Groundwater Recharge in Wisconsin - Annual Estimates for 1970-99 using Streamflow Data. USGS Fact Sheet 2009-3092.

8.5 ft stage for more than 4 months of the year, and (2) historical information suggests the lake was typically higher than 8.5 ft before the WDNR began to more actively manage the water level in 2019.

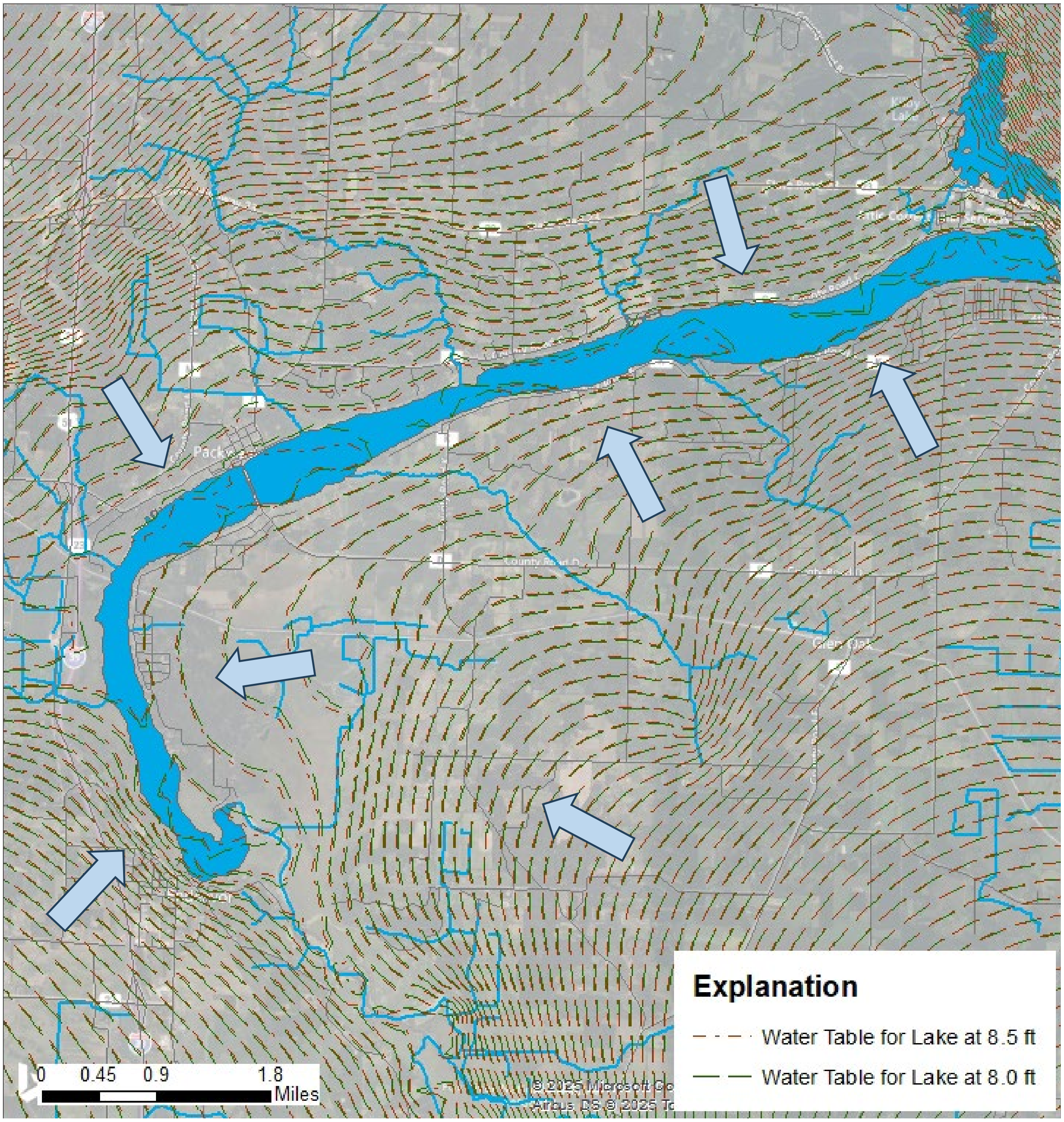

Figure 10. Simulated water table elevation contours for lake stages 8.0 ft and 8.5 ft. Contour interval is 2 ft.

Table 5. Seasonal water table rise for lake stage increase from 8.0 ft to 8.5 ft for selected agricultural areas.

Agricultural Area	Simulated rise in water table for lake stage increase from 8.0 ft to 8.5 ft
Area 1	<0.1 ft
Area 2	0.2 ft
Area 3	0.1 – 0.2 ft
Area 4	N/A [1]
Area 5	0.1 – 0.3 ft

[1] Model simulation of water table change does not apply to Area 4.

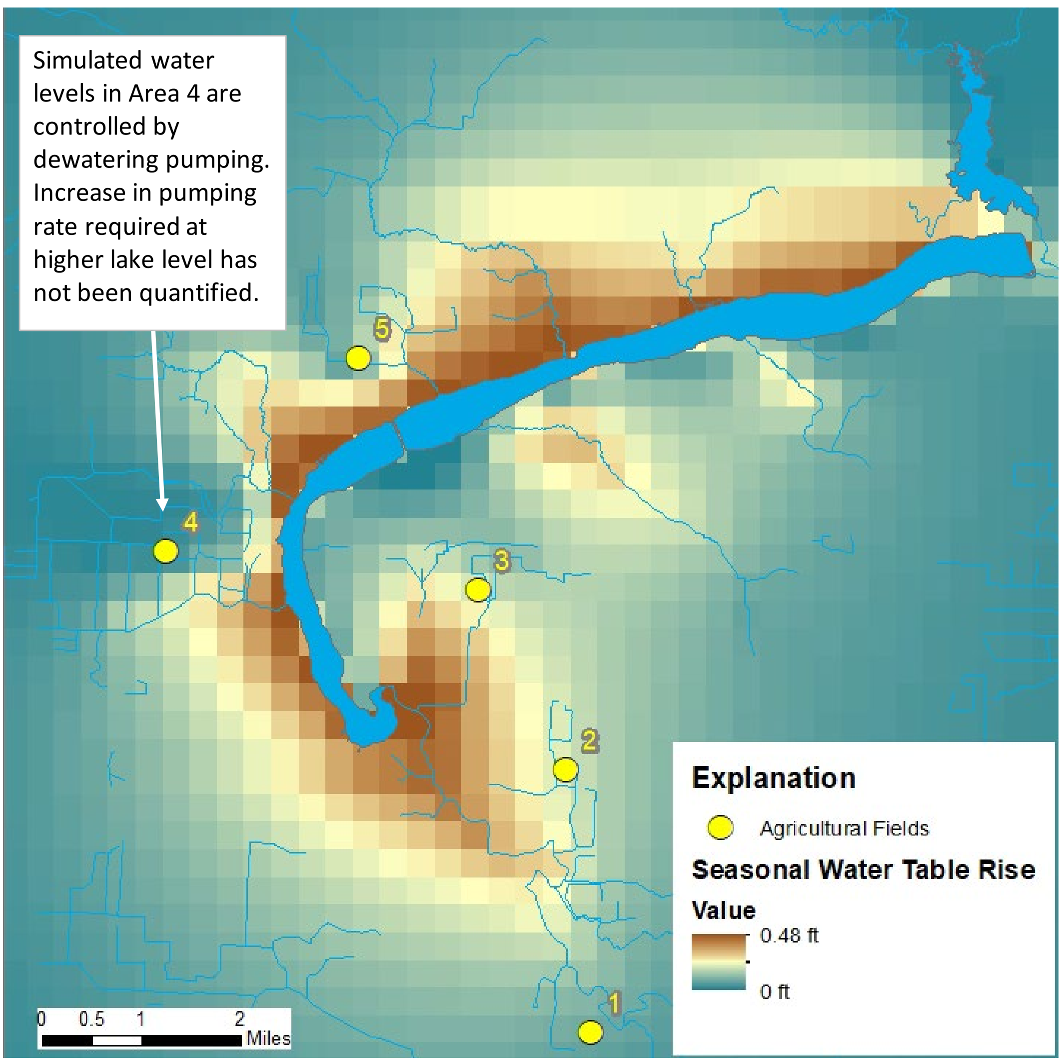

Figure 11. GFLOW model simulation of rise in water table for lake stage increase from 8.0 ft to 8.5 ft.

4.4.2. Transient Response Time

The purpose of this analysis was to understand how the change in timing of the rise in lake level in spring and drop in lake level in fall would affect properties near the lake with shallow groundwater. This timing is particularly relevant for agricultural fields where spring planting and fall harvest activities could be affected. We used the analytic method described by Kresic[4] (**Figure 12**) to estimate how long it takes the groundwater near the lake to rise or fall in response to a change in lake level. This technique uses the aquifer properties described above to calculate the rate at which groundwater rises in response to the seasonal 0.5 ft lake level increase at different distances from the lake. This method assumes that the change in lake level is rapid compared to changes in the groundwater level, which is reasonable because lake level data from the WDNR indicate that the spring rise in lake level from 8.0 ft to 8.5 ft typically takes about a week.

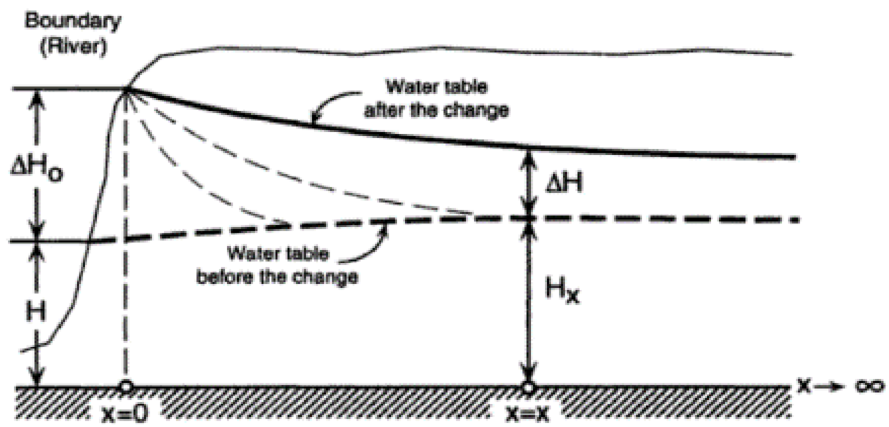

Figure 12. Boundary conditions for transient 1-dimensional flow with a sudden change at a boundary, such as a lake (from Kresic, 1997)

This analysis simulates the water table response in the shallow sand aquifer connected to the lake, using the same aquifer hydraulic conductivity (112 ft/d) and thickness (50 ft) as the GFLOW model, plus the specific yield value of 0.17 determined by the WDNR Central Sands Lakes Study. The analytical equation was used to compute water table change over time at different distances from the lake that fall within the zone of influence around the lake determined by the GFLOW model.

The calculated water table change rates (**Table 6, Figures 13 - 15**) illustrate that the shallow sandy aquifer is transmissive enough that the water table would rise quickly after the lake is elevated 6 inches in May. At a distance of 100 ft, most of the groundwater rise would occur within about a week. At 500 ft, the groundwater would rise 4 inches after 20 days (the proposed number of days to change the start of the summer maximum). At distances of 1000 ft and greater, the water table rise would occur more slowly, taking more than a month to rise 3 inches. This analysis illustrates that near the lake, groundwater response is

[4] Kresic, N, 1997. Quantitative Solutions in Hydrogeology and Groundwater Modeling. Lewis Publishers.

likely to be fast enough to make a measurable difference in groundwater levels in May if the lake is raised to the summer maximum level on May 1. Farther from the lake, most of the groundwater rise would occur during the summer, presumably after spring planting activities have been completed.

Table 6. Analytical calculations of time for water table elevation change at different distances from Buffalo Lake following a 6 inch increase in lake level, rounded to the nearest inch.

	Water Table Change (inches)		
Distance from Lake (ft)	**5 days**	**20 days**	**45 days**
100	5 in	6 in	6 in
500	2 in	4 in	5 in
1000	0 in	2 in	3 in
1500	0 in	1 in	2 in

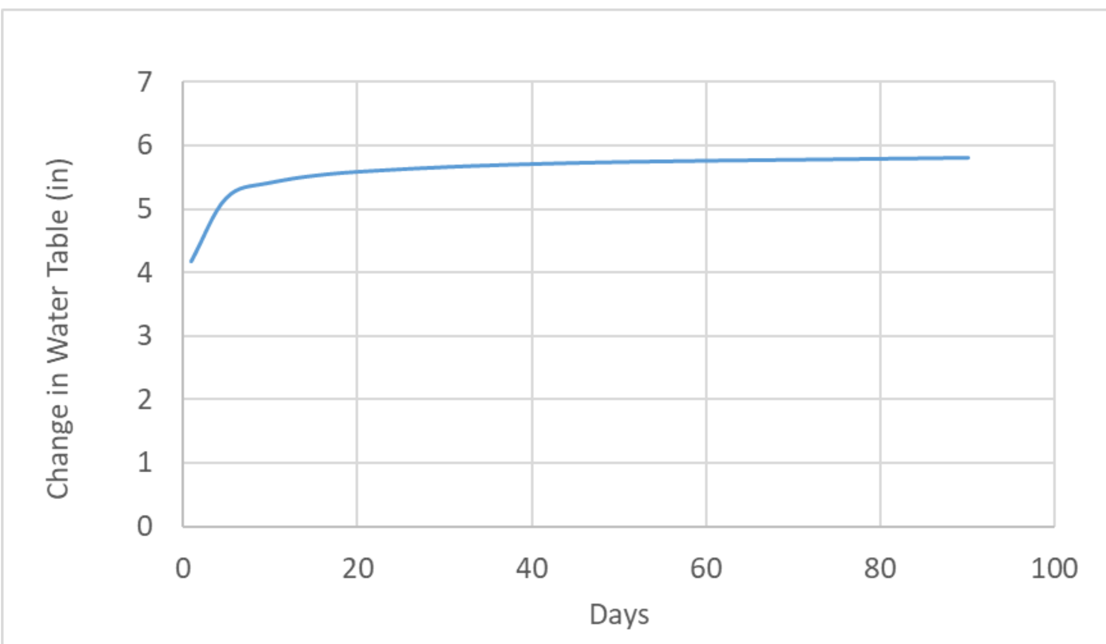

Figure 13. Predicted water table rise after the lake is raised from 8.0 ft to 8.5 ft at 100 ft from the shoreline.

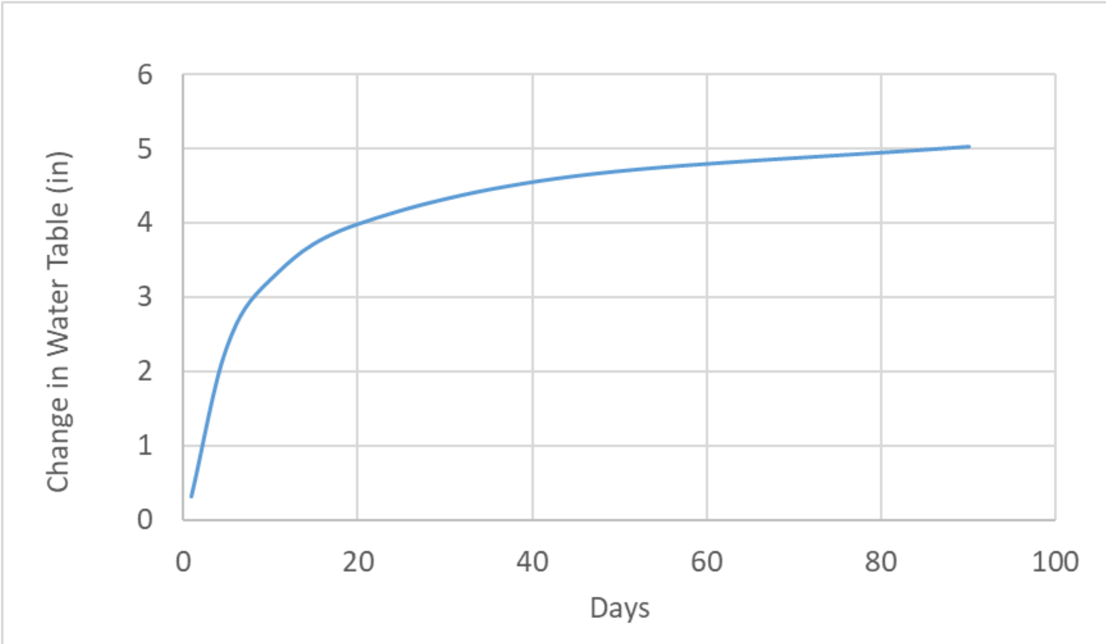

Figure 14. Predicted water table rise after the lake is raised from 8.0 ft to 8.5 ft at 500 ft from the shoreline.

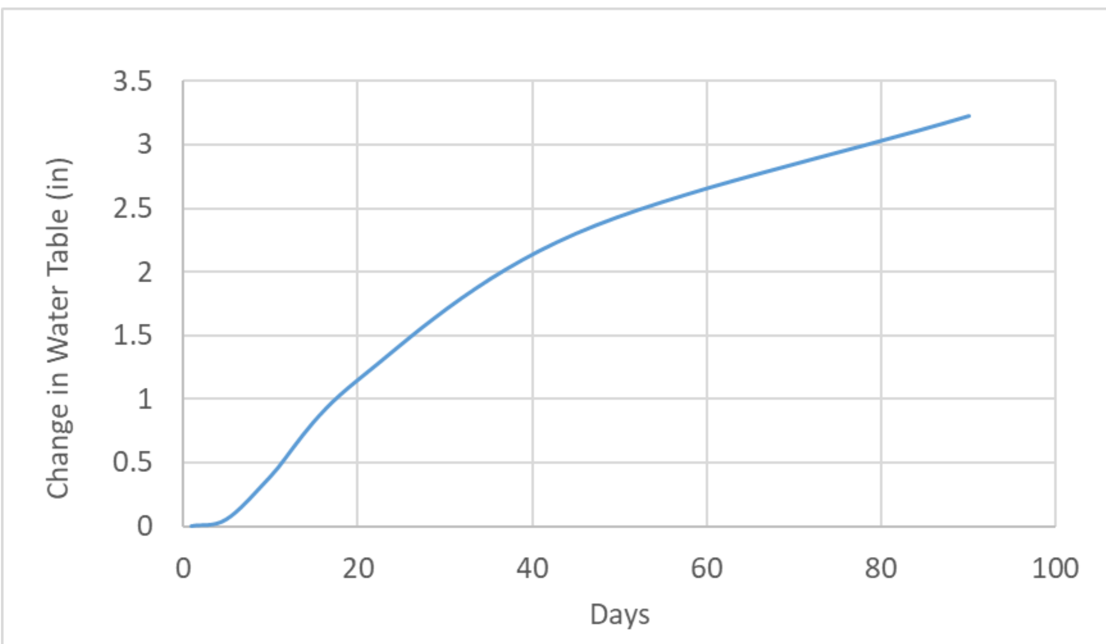

Figure 15. Predicted water table rise after the lake is raised from 8.0 ft to 8.5 ft at 1500 ft from the shoreline.

4.4.3. Muck Farm at Endeavor (Area 4)

As noted above, this farm is unlike other areas evaluated because its fields are below the water level of Buffalo Lake and must be dewatered by pumping. At higher the lake levels, there is a greater head difference between the lake and the field drainage system, so that a higher pumping would be needed to maintain the same water level in the fields. The proposed operation change does not increase the summer maximum lake stage, but it would increase the time period when a higher dewatering rate could be necessary. Without site-specific calibration data, the groundwater model can not estimate the increased pumping rate with confidence.

The eastern edge of the fields at CTH CX is approximately 1500 - 2000 ft from Buffalo Lake, and the southern edge of the fields is immediately adjacent to Chapman Creek, which could experience some water level rise with the change in lake level. The analysis above indicates that some difference in groundwater levels at the farm could be experienced in May if the lake is raised to 8.5 ft on May 1.

More information from this farmer would be helpful in determining the magnitude of impact on their operations. For example, does the existing dewatering system have the capacity to get the fields dry enough when the lake is at the 8.5 ft summer maximum? How much does additional dewatering at the higher lake stage cost in terms of additional energy usage? When are the critical periods that fields need to be sufficiently dewatered?

5. THERMAL IMPACTS

5.1. Data Collection

Cason Land & Water Management collected water temperature data at two locations in 2024. The 2024 monitoring began on May 30, 2024 below the dam gates (**Figure 16**) and upstream of the lake at CTH O bridge (**Figure 17**). The logger below the dam gates was removed on September 6, 2024 because no flow was passing through the gates. The logger upstream of the lake was removed on October 15, 2024. Monitoring for 2025 began with deployment of data loggers on April 4; results are not available at the time of this writing. Cason provided EOR with draft temperature data for a preliminary review in this report; Cason will provide the full dataset and final analysis after the monitoring has been completed in a subsequent document.

Figure 16. Temperature monitoring location downstream of the dam in 2024.

Figure 17. Temperature monitoring location upstream of Buffalo Lake in 2024.

5.2. Analysis

Water temperature in the Fox River downstream of the Buffalo Lake dam could be affected by a change in discharge related to the proposed water level change. Discharge downstream of the dam is reduced in the spring during the time that the dam gates are adjusted to hold back more water and raise the lake level from 8.0 ft to 8.5 ft, and flow is increased in the fall if it is necessary to open gates to release more water to lower the lake level. The proposed operation change would shift the spring period of reduced discharge 20 days earlier (starting on May 1 instead of May 20), and the period of increased fall discharge would occur two weeks later (starting on October 15 instead of October 1).

As noted above, the time for the lake to adjust between the winter and summer maxima is approximately 1 week. This means that the Fox River discharge downstream of the dam would be lower than for current operation from about May 1 – 7, and discharge downstream would be greater than for current operation from about May 20 – 27 (the current adjustment period). The magnitude of discharge reduction in the spring has historically been about 150 – 250 cfs, based on WDNR's calculated outflows at the dam before and after gate adjustments.

In fall, release of water from the dam is not always needed to reach the winter maximum stage of 8.0 ft due to low flows and lake levels, as noted above. If a release is necessary, the increase in downstream discharge would be shifted from October 1 to October 15.

Temperature monitoring data do not capture the period when the water level was increased from 8.0 ft to 8.5 ft in 2024, and data loggers near the dam were removed due to lack of flow before the October 1 transition to the winter maximum stage. Data currently being collected in 2025 should capture the period when the lake is raise to the summer maximum. Data from 2024 (**Figure 18)** illustrate that the temperature difference from upstream of the lake to downstream of the lake varied a few degrees around zero from the end of May to mid-June, indicating little difference in the daily average temperature upstream and downstream of the lake. From mid-June through mid-August, the temperature downstream of the lake was about 2 degrees warmer than the upstream temperature, indicating the warming effect of the lake. After mid-August, the data show substantial scatter, likely due to low-flow conditions at both sites.

2025 monitoring data will provide more information, but available data show that the period in early May when discharge in the river downstream of the dam would be lower for the proposed operation change is before the lake began to have a warming effect in 2024. *This observation, the short duration of reduced downstream flows (approximately 1 week), and the fact that early May is not typically a critically cold or hot part of the year suggests that downstream temperature changes will be minimal for the proposed operation change.*

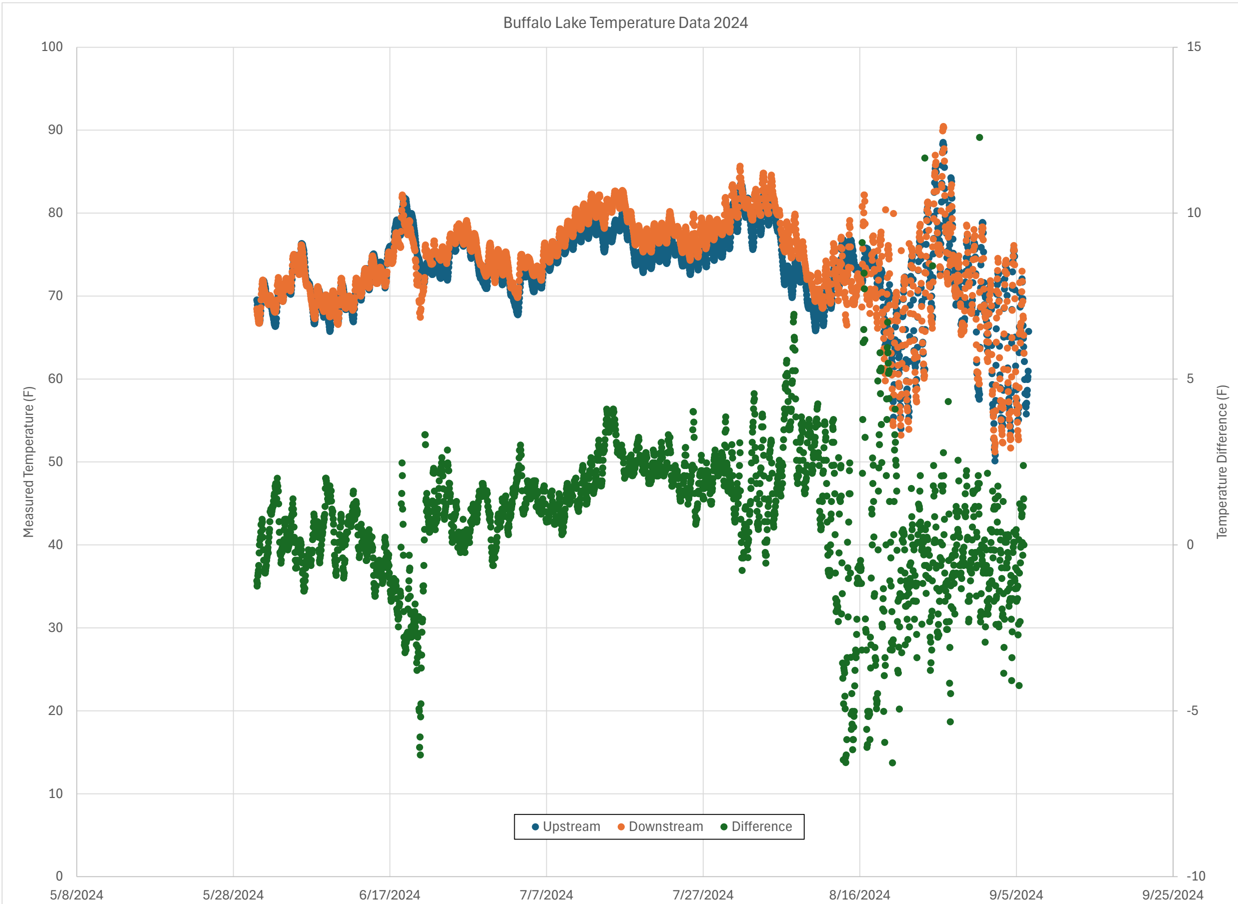

Figure 18. 2024 temperature data and upstream-downstream difference. (Data from Cason Land & Water Management)

6. SHORELINE EROSION RISK

6.1. Methods & Data

Increased water depth is a potential risk factor for shoreline erosion, and this risk was evaluated using the WDNR Erosion Intensity Score Worksheet. This is a semi-quantitative tool that considers: fetch; water depth; bank height, composition, stability, vegetation, orientation and geometry; adjacent structures; aquatic vegetation; and boat wakes.

The WDNR tool was applied for the east end of Buffalo Lake where wave erosion risk is highest, because it has the longest fetch relative to prevailing west winds, the deepest water, and least aquatic vegetation cover to dissipate energy. May and October could be sensitive periods; differences in aquatic vegetation growth from early to late May and potential senescence in early-mid-October could result in different aquatic plant cover during the period when the summer maximum lake stage is proposed to be extended.

Erosion Intensity Scores were calculated for existing conditions, representing the lake at 8.0 ft, and for an increase in lake level to 8.5 ft. To be conservative, worst-case rankings were used for the 8.5 ft scenario, increasing water depth at 20 ft and 100 ft offshore by one category and reducing aquatic vegetation cover by 1 category.

Data sources included maps of the lake shoreline, the 1967 bathymetric map, soil survey data, LiDAR topographic data for the shoreline, and observations of aquatic vegetation and shoreline condition visible on aerial photographs.

We calculated "high" Erosion Intensity Scores for both scenarios, with numeric scores of 55 for the 8.0 ft stage and 60 for the 8.5 ft stage.

Because this potential change in erosion potential only applies from May 1 –20 and October 1 – 15 and even conservative representations of the changing conditions results in the same Erosion Intensity Score category, we conclude that the risk of increased shoreline erosion for the proposed operation change is small. The small expected change in shoreline erosion would have a minimal impact on nutrient loading from lakeshore sediment. In fact, a higher water level would be expected to slightly increase sediment and nutrient trapping by particle settling and reduce potential resuspension of lakebed sediments and the nutrients they contain.

7. WETLAND IMPACTS

The purpose of this analysis was to evaluate potential effects from proposed water level manipulations on the reservoir, with proposed changes extending high water levels on Buffalo Lake 3 weeks earlier in spring and 2 weeks later in fall. The scope of this analysis was based on reviewing available information on wetlands near the lake and wetland literature. In addition, EOR conducted a reconnaissance field visit to gain more insights into selected wetlands after reviewing available data.

7.1. Desktop Data Analysis

7.1.1. Wetland Communities Near Buffalo Lake

According to Natural Heritage Inventory Data, upland natural communities occurring within five miles of Buffalo Lake include Oak Barrens, Southern Dry Forest, Dry Prairie, Northern Dry Forest, Northern Dry-Mesic Forest, Mesic Prairie, Oak Woodland, and Eastern Red Cedar Thicket.

Wetland natural communities within five miles include Northern Wet Forest, Southern Sedge Meadow, Floodplain Forest, Calcareous Fen, Southern Tamarack Swamp, Emergent Marsh, Northern Sedge Meadow, Wet-Mesic Prairie, Shrub-Carr, Spring Pond, Open Bog, Lake (shallow, hard, seepage), Lake (deep, hard, drainage), Lake (shallow, soft seepage), and Springs and Spring Runs—Hard.

The WDNR provided results of FQA surveys from 2025 for several sites at Page Creek and Summerton Bog. At Page Creek, this includes a Southern Sedge Meadow with high floristic quality and an alder thicket with low floristic quality at the Buffalo Lake shoreline, The Summerton Bog area includes calcareous fen and sedge meadow sites with high floristic quality, an alder thicket with medium floristic quality, sedge meadow on ditch fill with medium floristic quality, a wet-mesic prairie site with medium floristic quality, and ruderal wet meadow and ruderal shrub swamp sites with low floristic quality.

7.1.2. Aerial Imagery Review/Offsite Analysis

Three areas were the focus of historic aerial imagery analysis, including a hay field southeast of County Highway K, Page Creek Marsh State Natural Area, and Summerton Bog State Natural and the surrounding muck farms. Twelve photos were obtained from the 1990's to 2022.

The hay field southeast of County Highway K, or Page Creek Southeast, appears to be a hay field as late as 2010, with about half the field harvested for hay and the other half left fallow. By 2013, the area was row-cropped, with minimal crop stress but some slight saturation signatures. Overall, changes in this area of interest appear to be linked to general climatic trends and broad land use changes, rather than lake level manipulation.

Page Creek Marsh State Natural Area shows a shift from open fields in upland areas to dominance by scrubby oaks and invasive brush. By 2022, small clumps of dogwood and willow are visible in the wetland and along its edges. Off-color areas within the wetland indicate invasion of phragmites and cattails, a symptom of invasive species spreading throughout the landscape. Changes here do not appear linked to any apparent water level manipulation.

Summerton Bog shows muck farms in a historic wetland basin, as well as the tamarack swamp present within the State Natural Area. The muck farms appear to have significant dikes and drainageway infrastructure and likely pump water out of the fields. Tamaracks within the State Natural Area appear healthy as late as 2015, but by 2020 there is a significant die-off of tamarack.

7.2. Field Observations

A site visit was conducted in the area surrounding Buffalo Lake near Montello, Wisconsin on November 19, 2024. EOR staff visited the Page Creek State Natural Area and the Summerton Bog State Natural Area to look for signs of stress on woody species that may have included adventitious roots on tamarack, needle drop (needles were still visible on November 19), die-off of wetland trees, or community composition change in calcareous fens.

Soil pits were sampled to a depth of at least 24 inches at Page Creek Marsh State Natural Area and Summerton Bog State Natural Area. Saturation and water table depth were observed. A species list of all vascular plants was taken at Page Creek Marsh. Other qualitative data observed included natural communities present, current water levels, geomorphology of the reservoir, and stress to woody plants including adventitious roots or needle-drop on coniferous trees.

Water table depth, where reached, ranged from 0-16 inches, with the water typically at or very near the surface in wetlands (**Table 7**). Antecedent precipitation conditions were normal for the preceding three months, with the last month receiving above average precipitation (**Figure 20**). At Page Creek Marsh, the water table corresponded tightly with elevation. At Summerton Bog, the water table occurred at 4-6 inches along a seepage slope, with springs and spring runs emanating along this slope. Below the seepage slope, topography leveled off into a tamarack swamp, and the water table occurred at 12 inches.

Table 7. Water table observed at soil pits.

Elevation	Water Table Depth	Site
794 ft	4-6 in	Summerton Bog
783 ft	12 in	Summerton Bog
772 ft	1 in	Page Creek
771 ft	+1 in (standing water)	Page Creek
771 ft	+2 in (standing water)	Page Creek
773 ft	11 in	Page Creek
773.5 ft	15 in	Page Creek

Groundwater influences both the Sedge Meadow (Page Creek) and Tamarack Swamp (Summerton Bog), with fen species such as *Muhlenbergia glomerata*, *Rumex Britannica*, and *Sium suave*, indicating contact with calcium-rich groundwater. Uplands in topographically higher positions contained classic Oak Barrens species like *Quercus ellipsoidalis*, *Schizachyrium scoparium*, and *Asclepias verticillata*. More disturbed areas were dominated by non-native shrubs and *Bromus inermis*. A full species list from Page Creek Marsh is located in **Appendix B**.

At Page Creek Marsh, shrub species are not common in the wetland, although *Cornus racemosa* is located on the toeslope of the wetland with a mix of Facultative species. Aerial imagery analysis indicates that this shrub invasion is more recent, occurring within the last ten years, although this is likely the result of fire suppression rather than impacts from lake levels. The WDNR's Prescribed Burn Dashboard indicates that no fires have occurred at Page Creek Marsh since at least 2019.

Numerous dead tamarack trees were observed at Summerton Bog and along Lakeview Drive, though no adventitious roots were observed, indicating a lack of stress from flooding.[5] The dozens of dead tamaracks

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[5] Veverica, Timothy J., Kane, Evan S., and Kasischke, Eric S.. 2012. Tamarack and black spruce adventitious root patterns are similar in their ability to estimate organic layer depths in northern temperate forests. Canadian Journal of Soil Science. 92(5): 799-802. https://doi.org/10.4141/cjss2011-111.

observed on site near the soil pits did not show adventitious roots, but there is considerably more die off to the south. Die off could be resulting from larch beetle or larch sawfly, from high water levels and flooding in 2018, or from lower water levels due to active operation of the dam gates since 2019. Evidence collected onsite is inconclusive regarding the cause of tamarack die off.

A potential White Pine Swamp was observed along Highway K, south of Buffalo Lake (see location in **Appendix A**), although this community has little apparent connection to Buffalo Lake, and drainage in this area directed southwest to Williams Lake.

Figure 19. Bordering Page Creek

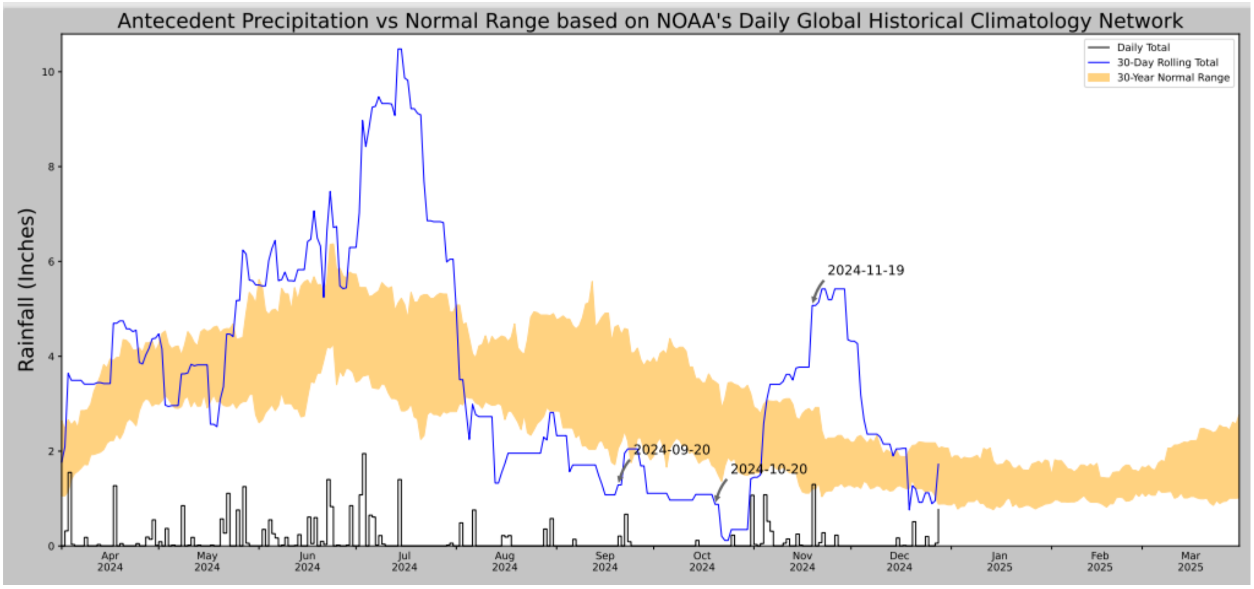


Figure 20. Antecedent precipitation for the Buffalo Lake area

7.3. Interpretation and Conclusions

Within preserved natural areas, groundwater resources appear to be intact, with observations from the site visit showing evidence of groundwater at or near the surface of both Page Creek and Summerton Bog. Emergent, floating-leaved, or submergent marsh along Buffalo Lake are unlikely to be impacted since most of the lake is shallow enough to support aquatic macrophytes. Maintaining higher water levels may impact plant germination, though this is unlikely to have any significant effect since drawdowns will still occur in winter, allowing for seed contact with nearshore habitat.

Based on data gathered during the site visit, wetland natural communities are intact, with healthy hydrologic profiles. There is no evidence of impacts from either flooding or drawdowns. Minor indications of degradation include invasions of shrubs and invasive species. Based on aerial imagery review, these invasions had occurred since at least 2005, with shrub invasion occurring in the last ten years. Both symptoms are indicative of widespread changes occurring elsewhere in the watershed such as habitat fragmentation, sprawling home developments, and spreading invasive species. A comparison of Mean Coefficient of Conservatism values shows that the Page Creek Sedge Meadow retains a high conservation value (**Table 8**). The Mean C value was lower on the November 19 site visit due to the senescence of most plant species. *Carex* species dominate the Sedge Meadow, and since most Carex were unidentifiable on the November site visit, the 2024 Mean C value is an underestimate.

Table 8. Cover-weighted Mean C values at Page Creek Marsh State Natural Area

Survey	Cover-weighted Mean C
WDNR Timed Meander (7/7/2015)	5.828
EOR Meander (11/19/2024)	4.780

The cause of apparent tamarack die off along the Interstate on the west side of the Buffalo Lake is unknown. The amount of dead trees rapidly increased after 2018, rather than dying all at once. If sudden water level shifts were the cause, a sudden die off would also be expected. Rather, aerial imagery suggests this is a gradual die off which might be consistent with larch beetle or larch sawfly infestations. If cause and effect are desired, a more focused study of tamaracks should be investigated.

Wetlands immediately adjacent to the lake have potential to be impacted by the increased duration of higher lake levels. However, the comparison of the extent of lake inundation at different stages in **Appendix A** illustrates very limited changes for stages in the range of 8.0 ft – 9.5 ft. This suggests that potential wetland impacts related to direct inundation by the lake would have a very limited extent for the proposed change from 8.0 ft to 8.5 ft.

Insight into the effect of the proposed higher water levels in May is provided by the U.S. Army Corps of Engineers hydrology performance standards for wetland mitigation.[6] For calcareous fens, the target hydrology is a water table 12 inches or less below the soil surface throughout the growing season with the exception of drought conditions. For sedge meadows, the target is a water table within 12 inches of the soil surface to at least July 1 (for organic soils). In our opinion, these are the most sensitive wetland communities near the lake, and raising the lake to the summer level on May 1 instead of May 20 is likely to either help or do no harm to these wetlands.

In areas of steep slopes that occur around much of Buffalo Lake, the extent of groundwater level changes and resulting effects on groundwater-dependent wetlands is expected to be minor. This includes the potential White Pine Swamp, which occurs high above lake levels.

Wetlands not included in this investigation could be affected by manipulated lake levels, but Page Creek Marsh and Summerton Bog are some of the closest and highest quality wetlands near Buffalo Lake. The most sensitive systems are expected to be groundwater dependent, and both communities analyzed showed healthy groundwater profiles. It is expected that this is the case in other wetlands surrounding Buffalo Lake, but further monitoring could take place to confirm this assumption.

Overall, extending higher water levels six weeks into spring and fall is unlikely to significantly affect wetlands, except perhaps immediately adjacent to Buffalo Lake, as noted above. While hydrologic alteration from dams and other artificial controls is typically detrimental to wetland quality, both the existing and proposed scenarios entail altered water levels. It is notable that operation of the dam for many years before 2019 caused higher water levels at low flows than have occurred since then, so that hydrologically connected wetlands experienced higher water levels prior to the last 6 years.

[6] U.S. Army Corps of Engineers, St. Paul District, 2019. Target Hydrology and Performance Standards for Compensatory Mitigation Sites. Regulatory Branch Guidance, Version 6.0.

8. OVERALL CONCLUSIONS

Shoreline fluctuation

- No detailed elevation data is available to precisely delineate the shoreline of the lake at stages of 8.0 ft and 8.5 ft, or even 9.0 ft; however, historic aerial photographs from periods when the lake stage was measured show that lake inundation extent and surface area do not vary much in the range of the winter and summer maxima.

Lake Flood Levels

- The dam gates have the capacity to substantially lower lake flood stage.
- The proposed operation change will not impact the Base Flood Elevation of Buffalo Lake defined in the Marquette County Flood Insurance Study.
- The difference in 100-year lake stage elevation is minimal for a flood that occurs when the lake starts at 8.0 ft vs. 8.5 ft.

Groundwater

- Groundwater levels around Buffalo Lake rise and fall depending on the lake stage. The zone near the lake affected by changes between the winter and summer maxima is variable and extends up to about 1 mile in some locations.
- The change in groundwater level in this zone of influence is rapid enough to create measurable changes in groundwater levels during the proposed extension of the summer maximum stage in spring and fall.
- Additional risk to residential properties appears minimal, but existing problems with high groundwater (if they are occurring) could be extended with an increased duration of the summer maximum lake stage.
- The predicted rise in groundwater level due to increasing the lake stage from 8.0 ft to 8.5 ft evaluated at 4 farms to the south, east and north of Buffalo Lake ranges from less than 0.1 ft to 0.3 ft.
- The muck farm west of the lake at Endeavor appears to have a dewatering pumping system that would be affected by an extended duration of the summer maximum lake level. A higher lake level would require a higher dewatering rate; the high stage is already occurring each summer, but the duration requiring more pumping would be extended by 20 days in May.
- We recommend that the District engages with this muck farmer to discuss the proposed operation change, potential impacts on farm operations, and options for mitigation, if necessary.

Fox River Temperature

- Observations regarding water temperature in this report are preliminary, based on initial data from part of the total monitoring period provided to EOR by Cason Land & Water Management. The full dataset and analysis will be provided in a subsequent document.
- The time to raise the lake from the winter level to the summer level has historically been about one week, and during this period, flows downstream in the Fox River are affected.
- This period of approximately 1 week of reduced spring flows would shift from late May 20 to early May with the proposed operational change.
- Lake level data are insufficient to demonstrate the historical time to draw the lake down in the fall, because fall water levels have commonly started below the summer maximum due to dry weather. However, the capacity of the gates suggests a similar duration for this lake level adjustment as for spring.
- In May of 2024, Buffalo Lake appeared to have little impact on water temperature downstream.
- The proposed operation change is expected to have minimal impact on the temperature of the Fox River downstream of the lake, given the short duration of flow reduction and typical lack of thermal stress (extreme hot or cold) in May. In fact, the shift in discharge reduction from late May to early May could reduce warm weather thermal stress in the river.

Shoreline Erosion

- The shoreline Erosion Intensity Score is high for the lake at both the winter and summer maxima. Changes in shoreline erosion potential due to the proposed operation change are minimal.
- This implies e minimal change in nutrient loading to the lake from shoreline erosion.
- At the higher lake level, a slight increase sediment and nutrient trapping by particle settling and reduced resuspension of lakebed sediments and the nutrients they contain is expected.

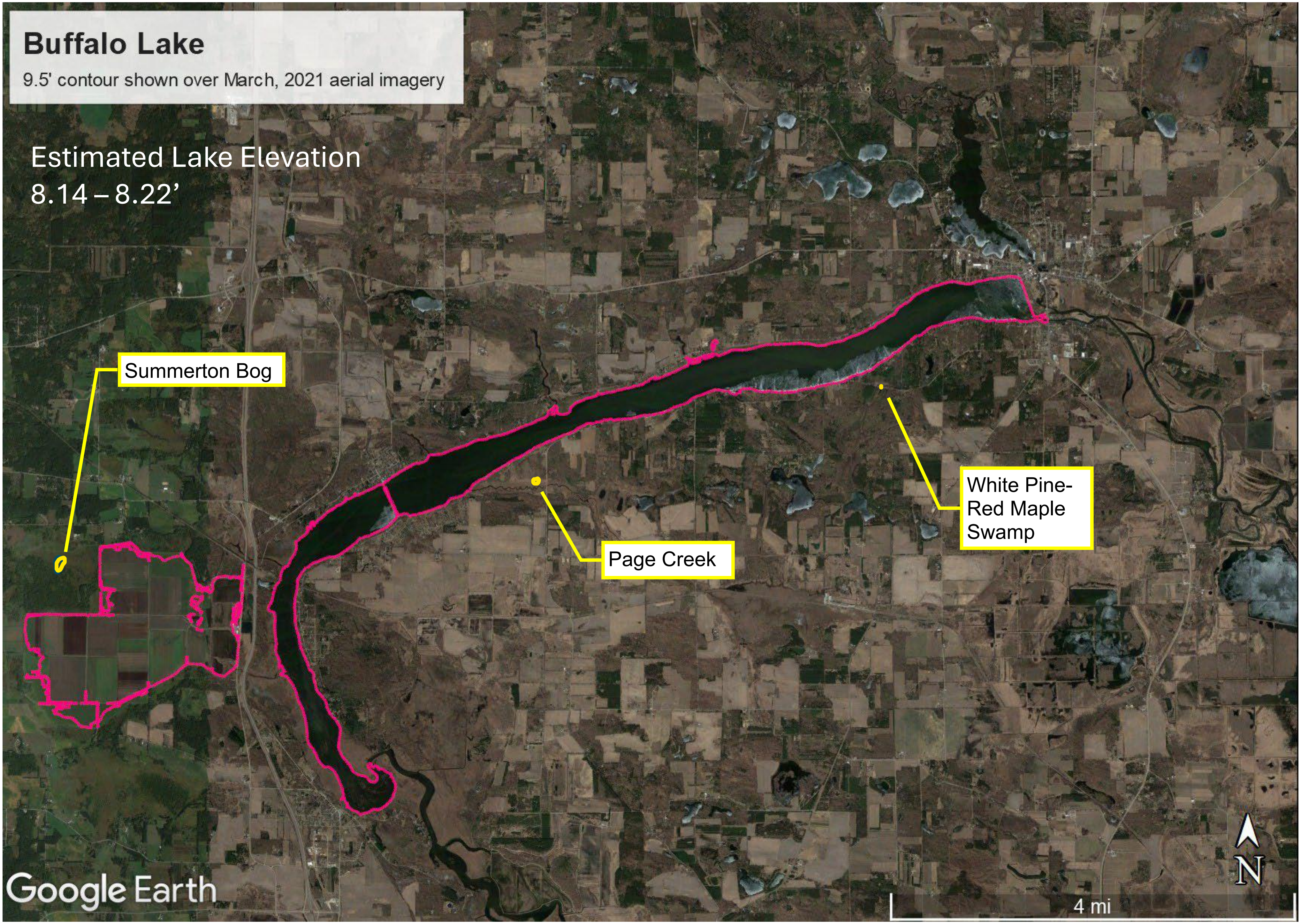
Wetlands

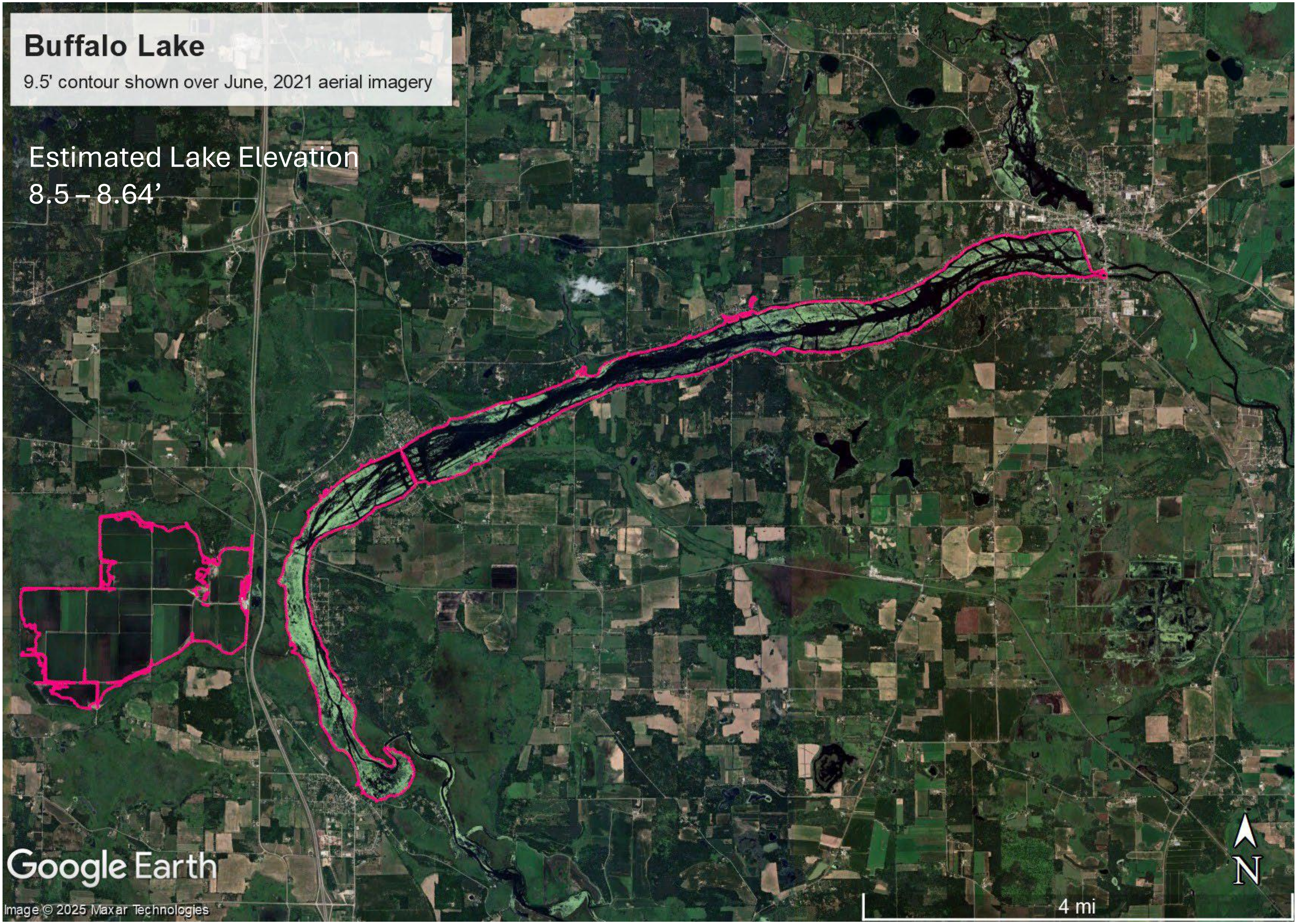
- Wetlands evaluated with desktop data and field visits do not show indications of stress related to lake level fluctuations.
- Extending the duration of the summer maximum lake level is not expected to negatively affect wetlands and is more likely to benefit them through higher groundwater levels during more of the growing season.

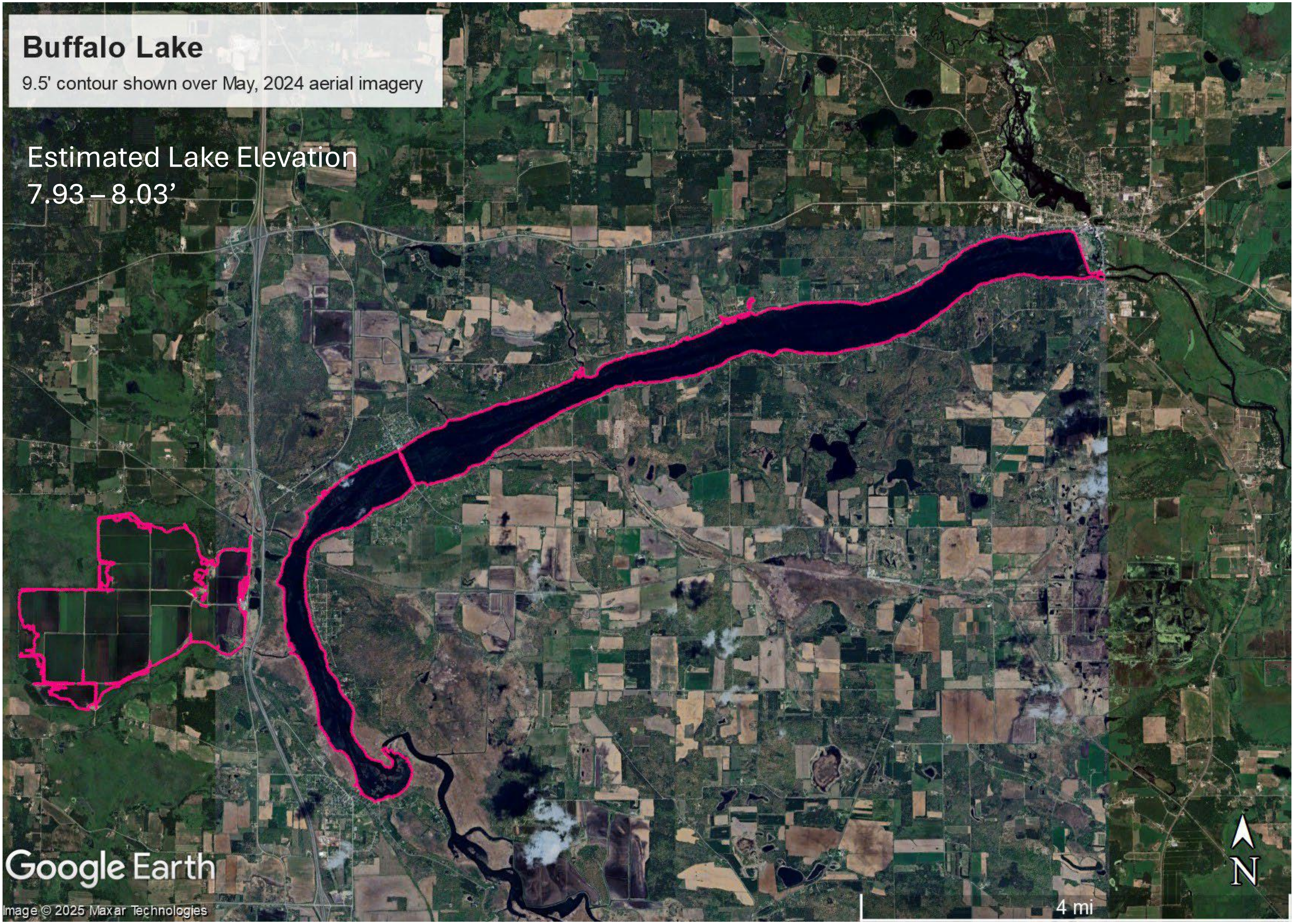
APPENDIX A. COMPARISON OF AERIAL PHOTOGRAPHS AND LIDAR ELEVATIONS

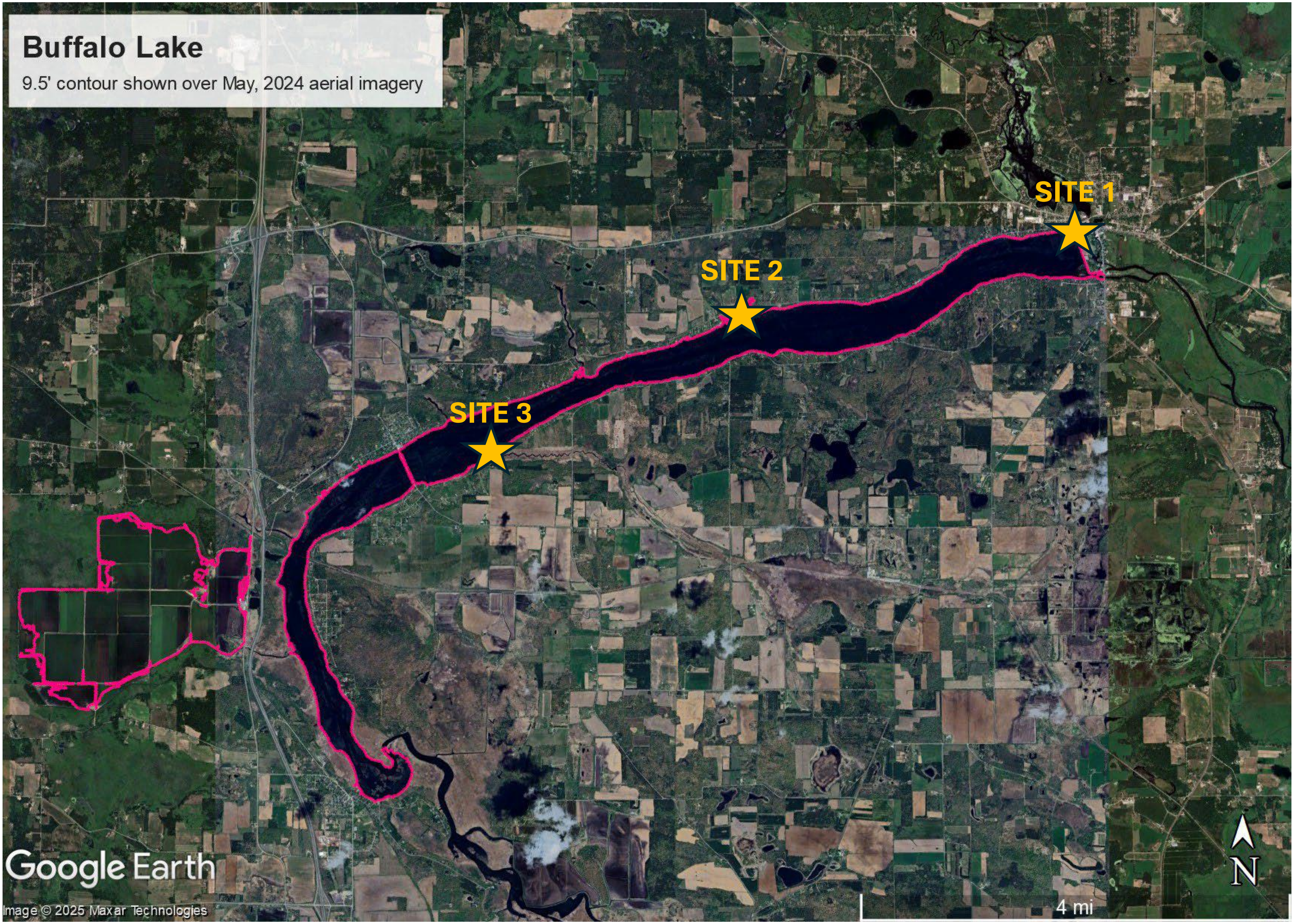
This print report includes the following static maps comparing the elevation contour for lake stage 9.5 ft with aerial photographs on three dates for which the lake stage can be estimated from DNR stage measurements.

The electronic transmittal of this report also includes a .kml file of the 9.5 ft contour that can be imported into Google Earth. This allows comparison with aerial photographs for the dates shown here plus additional photographs available from Google at any location and scale.


Buffalo Lake
9.5' contour shown over March, 2021 aerial imagery
Estimated Lake Elevation
8.14 – 8.22’
Summerton Bog
Page Creek
White Pine-
Red Maple
Swamp
Google Earth
4 mi
N


Buffalo Lake
9.5' contour shown over June, 2021 aerial imagery
Estimated Lake Elevation
8.5 – 8.64’
Google Earth
Image © 2025 Maxar Technologies
N
4 mi


Buffalo Lake
9.5' contour shown over May, 2024 aerial imagery
Estimated Lake Elevation
7.93 – 8.03'
Google Earth
Image © 2025 Maxar Technologies
4 mi
N


Buffalo Lake
9.5' contour shown over May, 2024 aerial imagery
SITE 1
SITE 2
SITE 3
Google Earth
Image © 2025 Maxar Technologies
4 mi
N


Buffalo Lake
9.5' contour shown over March, 2021 aerial imagery
Estimated Lake Elevation
8.14 – 8.22’
Google Earth
1000 ft
N


Buffalo Lake
9.5' contour shown over June, 2021 aerial imagery
Estimated Lake Elevation
8.5 – 8.64’
Google Earth
Image © 2025 Maxar Technologies
1000 ft
N


Buffalo Lake
9.5' contour shown over May, 2024 aerial imagery
Estimated Lake Elevation
7.93 – 8.03’
Google Earth
Image © 2025 Maxar Technologies
Image © 2025 Airbus
N
1000 ft


Buffalo Lake
9.5' contour shown over March, 2021 aerial imagery
Estimated Lake Elevation
8.14 – 8.22'
Google Earth
N
1000 ft

Buffalo Lake
9.5' contour shown over June, 2021 aerial imagery
Estimated Lake Elevation
8.5 – 8.64’
Google Earth
N
1000 ft


Buffalo Lake
9.5' contour shown over May, 2024 aerial imagery
Estimated Lake Elevation
7.93 – 8.03'
Google Earth
N
1000 ft


Buffalo Lake
9.5' contour shown over June, 2021 aerial imagery
Estimated Lake Elevation
8.14 – 8.22’
Google Earth
N
1000 ft

Buffalo Lake
9.5' contour shown over June, 2021 aerial imagery
Estimated Lake Elevation
8.5 – 8.64’
Google Earth
Image © 2025 Maxar Technologies
N
1000 ft


Buffalo Lake
9.5' contour shown over May, 2024 aerial imagery
Estimated Lake Elevation
7.93 – 8.03’
Google Earth
Image © 2025 Airbus
N
1000 ft

APPENDIX B. OBSERVED SPECIES LIST, PAGE CREEK MARSH

Scientific Name	Family	Native?	C	W	Physiognomy	Common Name
Alnus incana	Betulaceae	native	4	-3	shrub	mountain alder
Asclepias incarnata	Apocynaceae	native	5	-5	forb	swamp milkweed
Bidens tripartita	Asteraceae	native	5	-3	forb	straw-stem beggar-ticks
Bromus kalmii	Poaceae	native	8	0	grass	arctic brome
Calamagrostis canadensis	Poaceae	native	5	-5	grass	blue-joint grass
Carex hystericina	Cyperaceae	native	3	-5	sedge	bottlebrush sedge
Carex lacustris	Cyperaceae	native	6	-5	sedge	common lake sedge
Cornus sericea	Cornaceae	native	3	-3	shrub	red osier dogwood
Dulichium arundinaceum	Cyperaceae	native	9	-5	sedge	pond sedge
Euthamia graminifolia	Asteraceae	native	4	0	forb	common flat-topped goldenrod
Eutrochium maculatum	Asteraceae	native	4	-5	forb	spotted joe-pye-weed
Geum macrophyllum	Rosaceae	native	6	-3	forb	big-leaved avens
Juncus tenuis	Juncaceae	native	1	0	forb	path rush
Lathyrus palustris	Fabaceae	native	5	-3	forb	marsh pea
Lycopus americanus	Lamiaceae	native	4	-5	forb	american water-horehound
Lysimachia thyrsiflora	Primulaceae	native	7	-5	forb	swamp loosestrife
Muhlenbergia glomerata	Poaceae	native	9	-5	grass	marsh muhly
Muhlenbergia mexicana	Poaceae	native	4	-3	grass	leafy satin grass
Onoclea sensibilis	Dryopteridaceae	native	5	-3	fern	sensitive fern

Rumex britannica	Polygonaceae	native	8	-5	forb	greater water dock
Schoenoplectus tabernaemontani	Cyperaceae	native	4	-5	sedge	great bulrush
Scirpus atrovirens	Cyperaceae	native	3	-5	sedge	black bulrush
Scirpus cyperinus	Cyperaceae	native	4	-5	sedge	wool-grass
Sium suave	Apiaceae	native	5	-5	forb	hemlock water-parsnip
Solidago canadensis	Asteraceae	native	1	3	forb	canadian goldenrod
Spartina pectinata	Poaceae	native	5	-3	grass	prairie cord grass
Spiraea tomentosa	Rosaceae	native	6	-3	shrub	hard-hack
Stachys palustris	Lamiaceae	native	5	-5	forb	hedge-nettle
Symphyotrichum puniceum	Asteraceae	native	5	-5	forb	swamp aster
Thelypteris palustris	Thelypteridaceae	native	7	-3	fern	eastern marsh fern
Typha latifolia	Typhaceae	native	1	-5	forb	broad-leaved cat-tail
Verbena hastata	Verbenaceae	native	3	-3	forb	blue vervain
Zanthoxylum americanum	Rutaceae	native	3	3	shrub	common prickly-ash

SECTION II

Buffalo Lake Enhancement Project
Point-Intercept Survey

(Conducted by Cason Land & Water Management, LLC.)

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Buffalo Lake

2024 Point-Intercept Survey Summary Report with Statistical Analysis

Submergent Aquatic Plant Survey

Cason Land & Water Management, LLC conducted a Point Intercept Aquatic plant survey of the Buffalo Lake on July 3rd – 26th, 2024. At 828 of the 907 grid points (**Figure 1**) plotted across the lake aquatic plant samples were collected from a boat with a single rake pull or throw. At depths of 15 feet or less, a double rake head attached to a pole was used to collect a sample; a double rake head on a rope was used for depths greater than 15 feet. Plants were observed up to a depth of 8 feet (**Figure 2**). All plant samples collected were identified to genus and species whenever possible, and the information was recorded. Twenty-three different aquatic plant species were observed on the rake during the survey and a total of forty-two plant species were observed in total during the survey (**Table 1**). The aquatic invasive species Eurasian watermilfoil and Curly-leaf pondweed were observed during the survey as well as several wetland invasive species which are denoted in red text (**Table 1**). An abundance rating was also given for each species collected using criteria established by the WDNR. In addition to the plant data, water depths were also recorded for each location. Data collected was used to determine species composition, percent frequency and relative abundance.

Simpson Diversity Index

To estimate the diversity of the aquatic plant community, the Simpson Diversity Index takes into account both the number of species identified (richness) and the distribution or relative abundance of each species. With the Simpson Diversity Index (D), 1 represents infinite diversity and 0 represents no diversity. That is, the bigger the value of D, the higher the diversity. Buffalo Lake was calculated to have a Simpson Diversity Index of 0.88.

Assessment of Floristic Quality Resources

The plant data collected for Buffalo Lake was used to assess the *floristic quality* of the lake. The method used, assigns a value to each native plant species called a *Coefficient of Conservatism*. Coefficient values range from 0-10 and reflect a particular species' likelihood of occurring in a relatively undisturbed landscape. Species with low coefficient values, such as sago pondweed (*Stuckenia pectinata*) (C=3), are likely to be found in a variety of habitat types and can tolerate high levels of human disturbance. On the other hand, species with higher coefficient values, such as white-stem pondweed (*Potamogeton praelongus*) (C=8), are much more likely to be restricted to high quality natural areas. By averaging the coefficient values available for the submergent and emergent species found in the lake, a value was assigned to the lake. The average *Coefficient of Conservatism* value for lakes in Wisconsin is 6.0, Buffalo Lake's average was also found to be exactly 6.0 during the 2024 survey.

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By utilizing the Coefficients of Conservatism for the plant species of Buffalo Lake, further assessment of floristic quality was made. By multiplying the average coefficient values for Buffalo Lake by the square root of the number of plant species found, a Floristic Quality Index (FQI) was calculated. The average for Wisconsin lakes is 22.2; Buffalo Lake has a FQI of 26.83. According to the U.S. Fish and Wildlife Service "The FQI is an indication of native vegetative quality for an area: generally, 1-19 indicates low vegetative quality; 20-35 indicates high vegetative quality and above 35 indicates "Natural Area" quality. Wetlands with a FQI of 20 or greater are considered high quality aquatic resources."

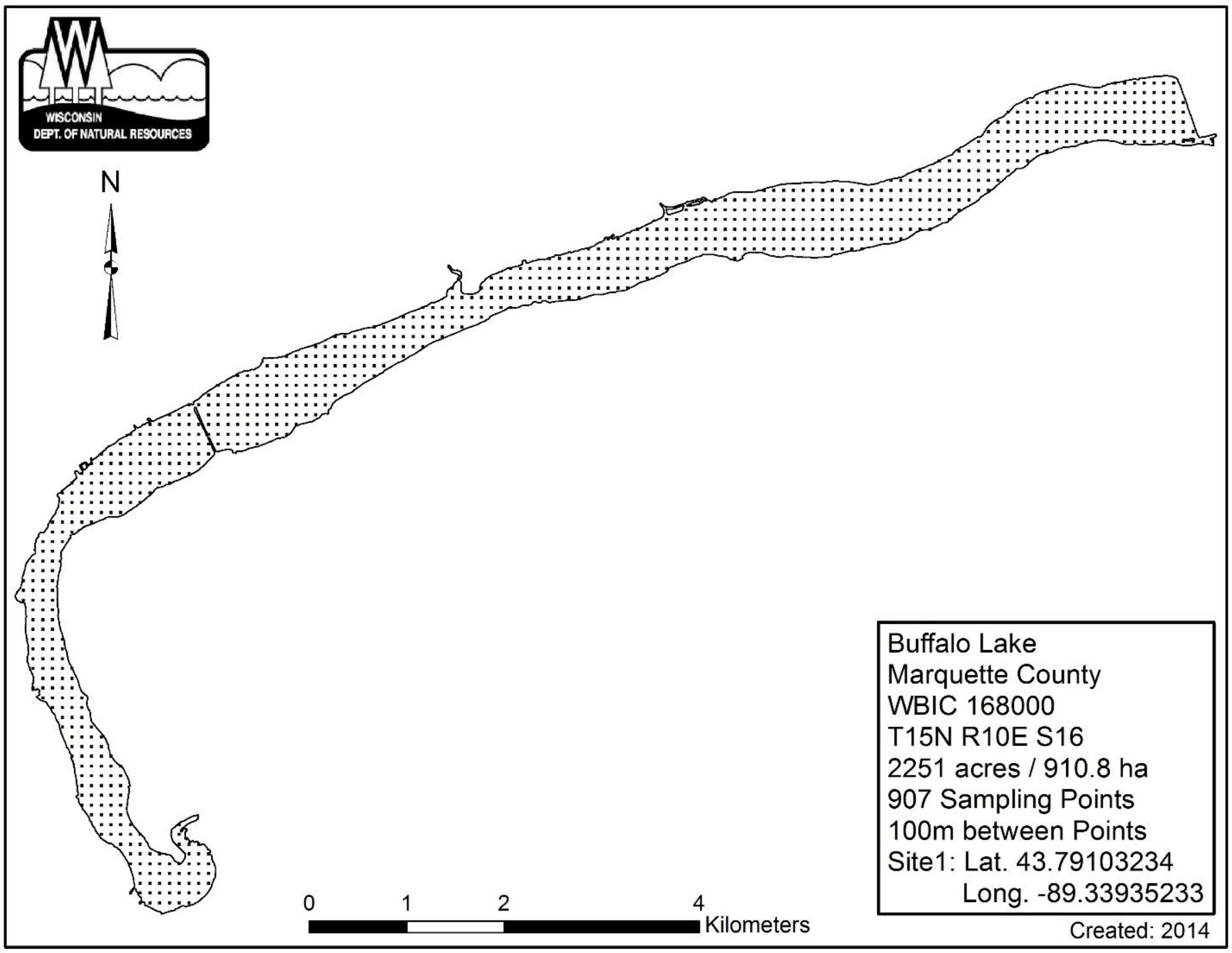

Figure 1. Point-Intercept survey grid provided by WDNR.

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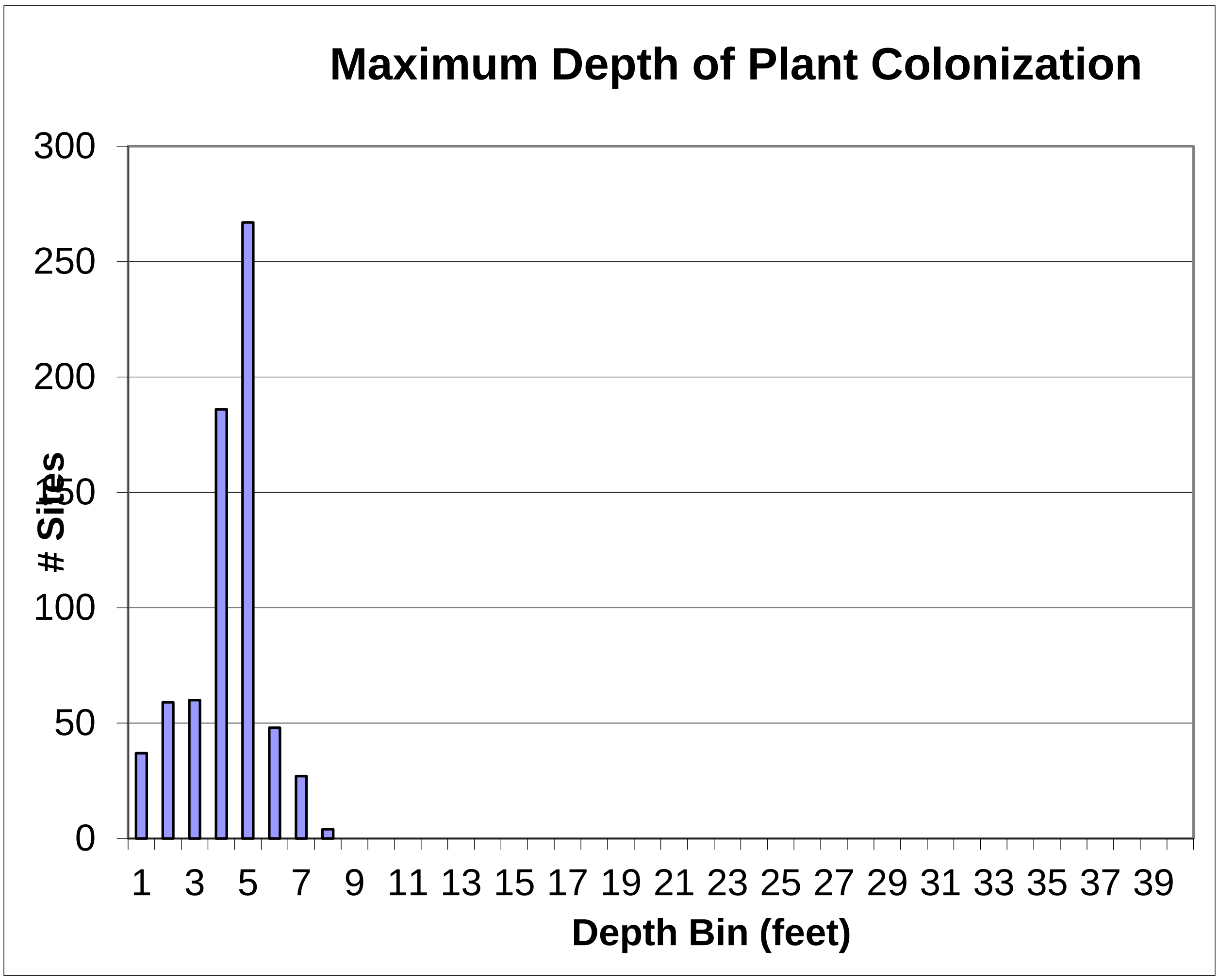

Figure 2. Maximum Depth of Plant Colonization observed during the 2024 survey.

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Table 1. Buffalo Lake Aquatic Species present during the 2024 survey.

Species	Scientific Name	Plant type: floating leaf, free floating, submergent, emergent	% Relative Frequency of Occurence	Sites Found
Coontail	*Ceratophyllum demersum*	Submergent	17.2	453
Common watermeal	*Common watermeal*	Free Floating	13.9	367
Small duckweed	*Lemna minor*	Free Floating	13.8	364
Flat-stem pondweed	*Potamogeton zosteriformis*	Submergent	12.9	340
Forked duckweed	*Lamna triscula*	Free Floating	10.3	270
Common waterweed	*Elodea canadensis*	Submergent	9.8	259
Large duckweed	*Spirodela polyrhiza*	Free Floating	7.9	208
Eurasian water milfoil	*Myriophyllum spicatum*	Submergent	5.2	137
White water lily	*Nymphaea odorata*	Floating leaf	2.4	63
White water crowfoot	*Ranunculus aquatilis*	Submergent	2	53
Wild celery	*Vallisneria americana*	Submergent	1.4	36
Southern naiad	*Najas guadalupensis*	Submergent	0.9	25
Spiny hornwort	*Ceratophyllum echinatum*	Submergent	0.5	13
Sago pondweed	*Stuckenia pectinata*	Submergent	0.4	11
Nitella	*Nitella sp.*	Submergent	0.3	8
Slender waterweed	*Elodea nutalli*	Submergent	0.2	4
Water star-grass	*Heteranthera dubia*	Submergent	0.2	5
Curly-leaf pondweed	*Potamogeton crispus*	Submergent	0.2	6
Leafy pondweed	*Potamogeton foliosus*	Submergent	0.2	4
Small pondweed	*Potamogeton pusillus*	Submergent	0.2	5
Muskgrasses	*Chara sp.*	Submergent	0	1
Northern blue flag	*Iris versicolor*	Emergent	0	1
Long-leaf pondweed	*Potamogeton nodosus*	Submergent	0	1
Swamp Milkweed	*Asclepias incarnata*	Emergent	Visual	1
Wild calla	*Calla palustris*	Emergent	Visual	1
Bulbet-Bearing Water Hemlocl	*Cicuta bilbifera*	Emergent	Visual	1
Water Hemlock	*Cicuta douglasii*	Emergent	Visual	1
Red-osier Dogwood	*Cornus sericea*	Shrub	Visual	1
Orange jewelweed	*Impatiens capensis*	Emergent	Visual	2
Purple Loosestrife	*Lythrum salicaria*	Emergent	Visual	6
American Lotus	*Nelumbo lutea*	Floating leaf	Visual	11
Ditch Stonecrop	*Penthorum sedoides*	Forb	Visual	1
Reed canary grass	*Phalaris arundinacea*	Emergent	Visual	2
Common reed	*Phragmites australis*	Emergent	Visual	5
Water smartweed	*Polygonum amphibium*	Emergent/Floating leaf	Visual	3
Great Water Dock	*Rumex britannica*	Emergent	Visual	1
Common arrowhead	*Sagittaria latifolia*	Emergent	Visual	1
Willow	*Salex sp.*	Woody plant	Visual	1
Softstem bulrush	*Schoenoplectus tabernaemontani*	Emergent	Visual	2
Common bur-reed	*Sparganium eurycarpum*	Emergent	Visual	9
Cattail	*Typha sp.*	Emergent	Visual	77
Wild rice	*Zizania sp.*	Emergent	Visual	18
Filamentous algae	*various*	Free floating	N/A	63

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Species Richness: 23
Species Richness (with visuals): 42
Simpson Diversity Index (D): 0.88
Floristic Quality Index (FQI): 26.83
Avg. Coefficient of Conservatism (C): 6

The following maps illustrate the distribution of aquatic invasive species (**Figures 3 & 4**), overall rake fullness (**Figure 5),** the seven most abundant (non-free-floating) plant species in Buffalo Lake (**Figures 6-12**), and lastly four floating-leaf species that would have otherwise made the top seven native species list (**Figures 13-16**).

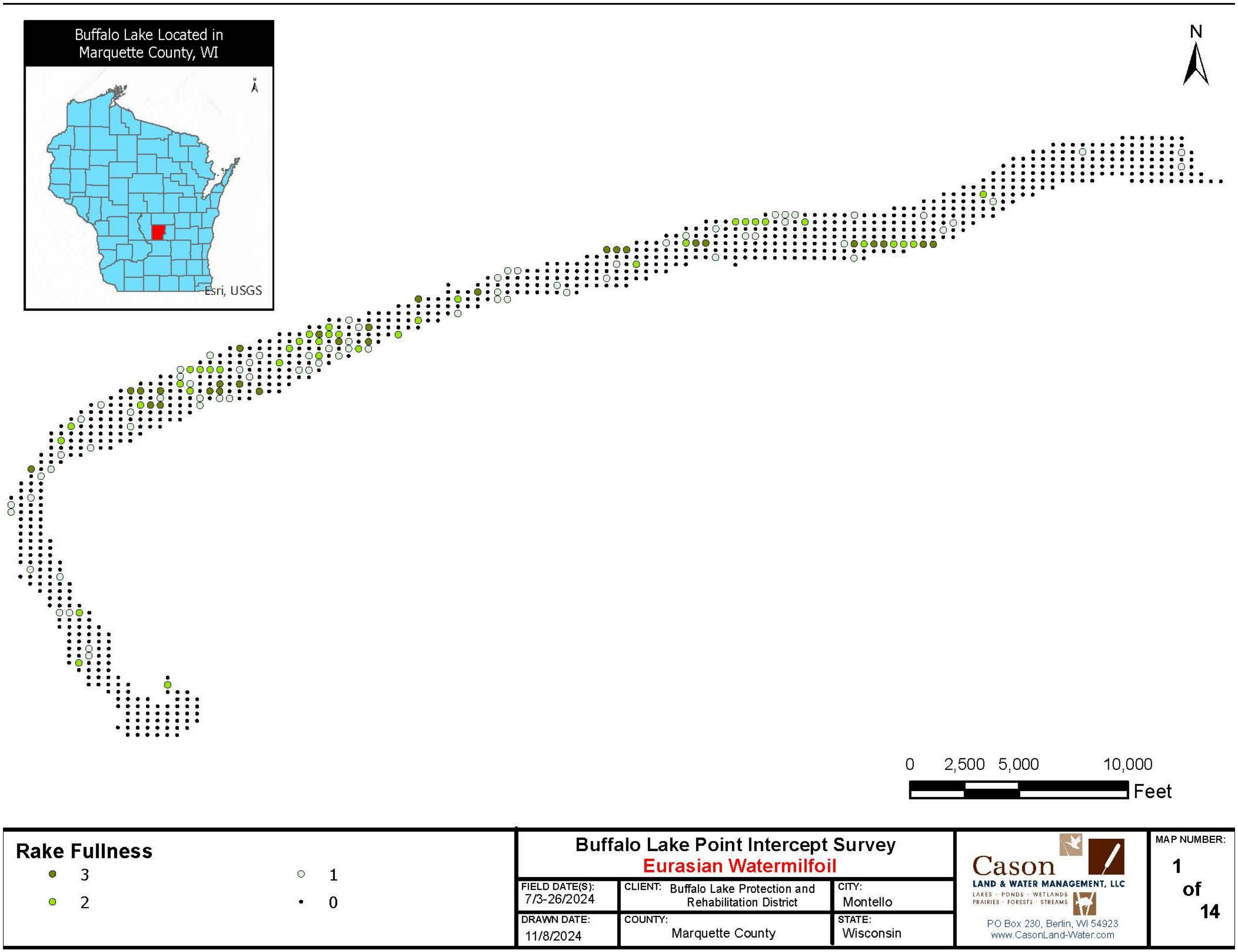

Figure 3. Distribution of Eurasian Watermilfoil in Buffalo Lake.

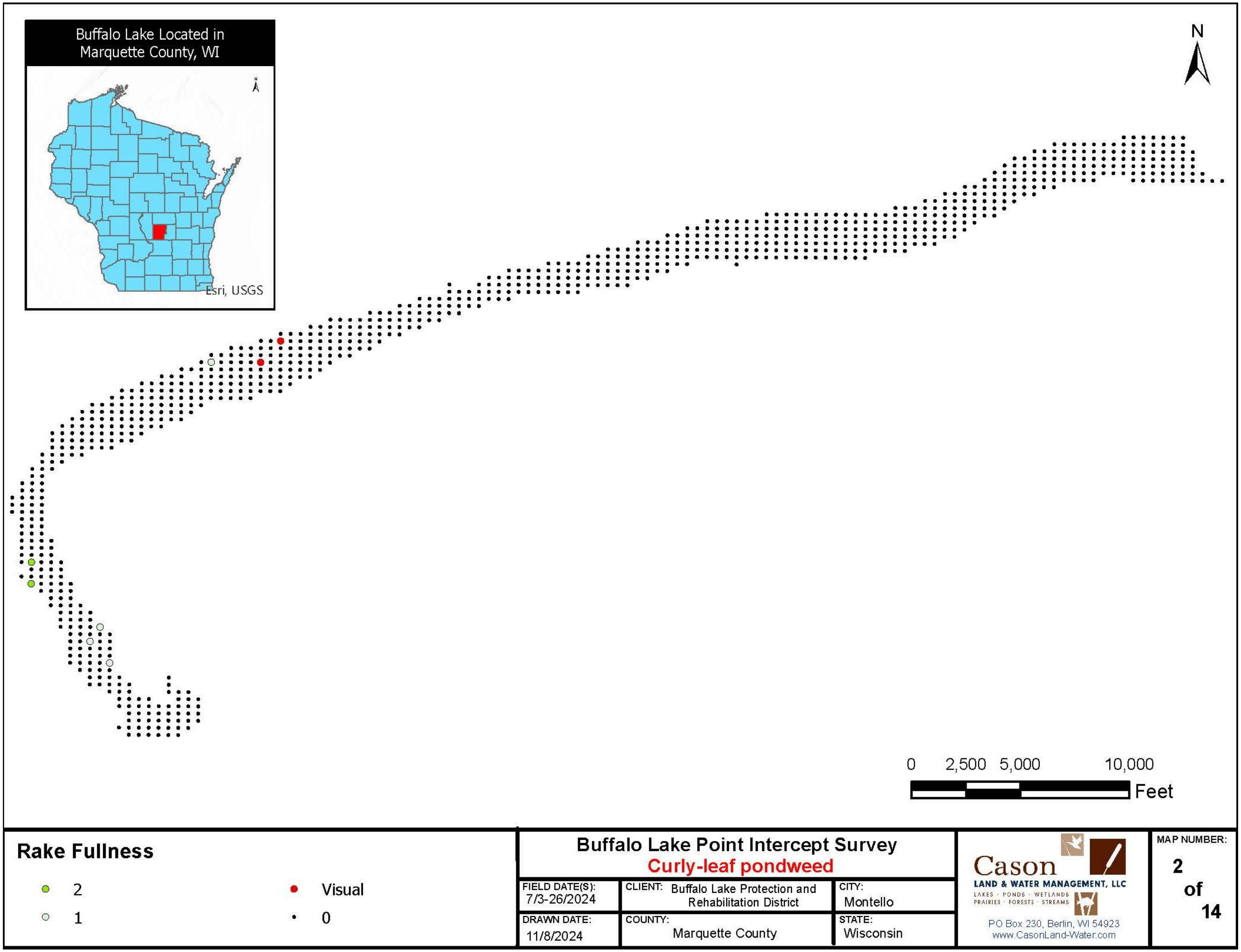

Figure 4. Distribution of Curly-leaf pondweed in Buffalo Lake.

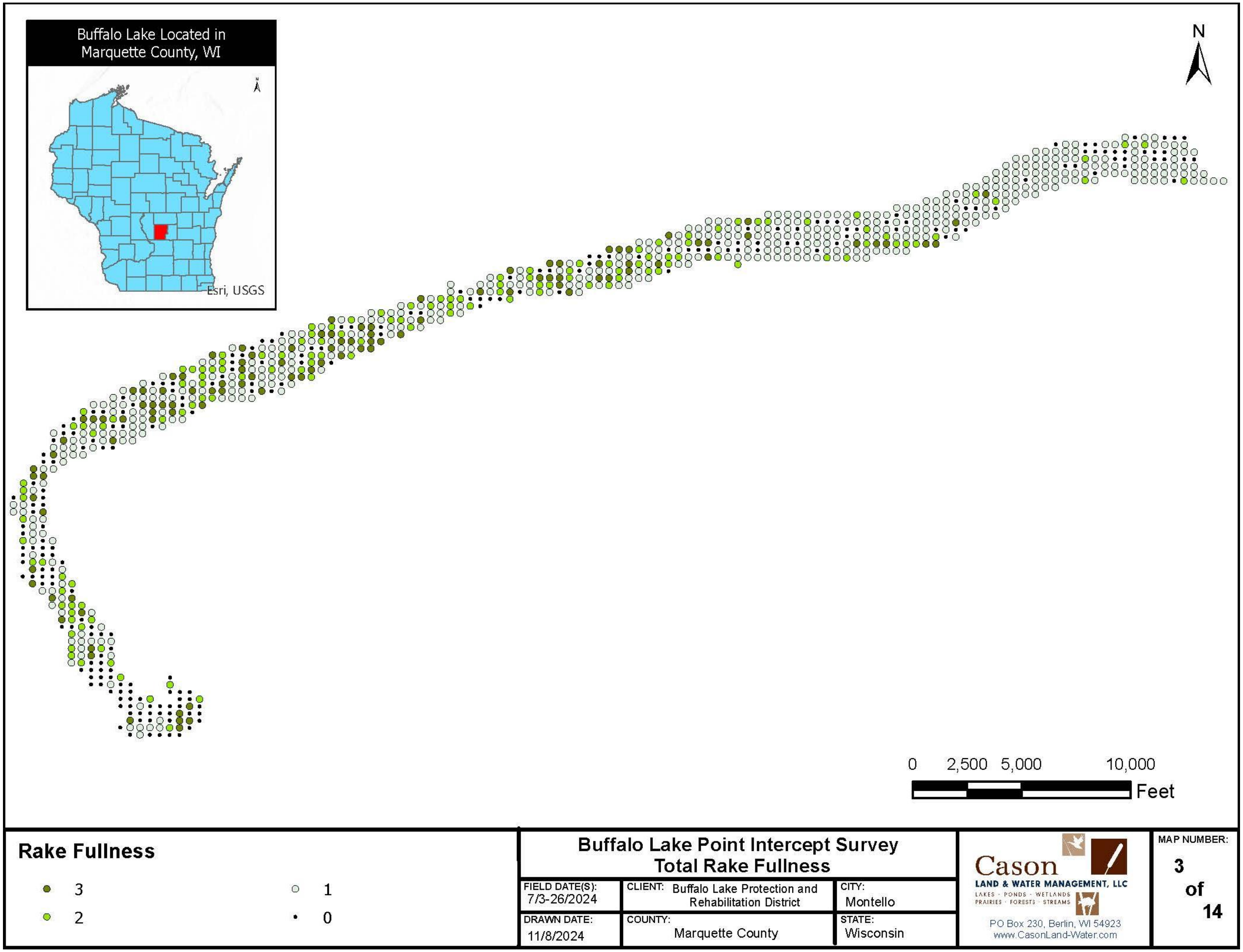

Figure 5. Distribution of Total Rake Fullness in Buffalo Lake.

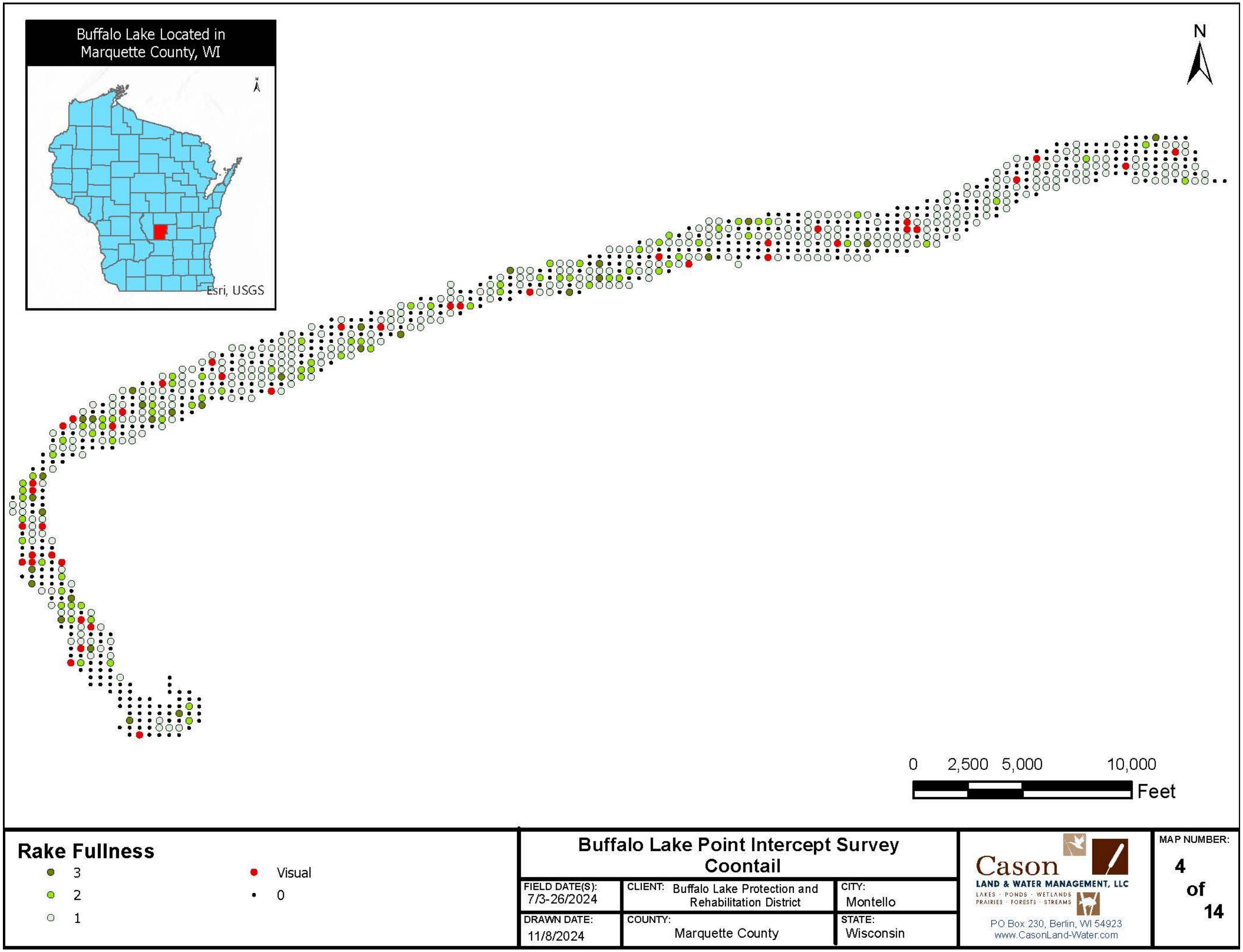

Figure 6. Distribution of Coontail in Buffalo Lake.

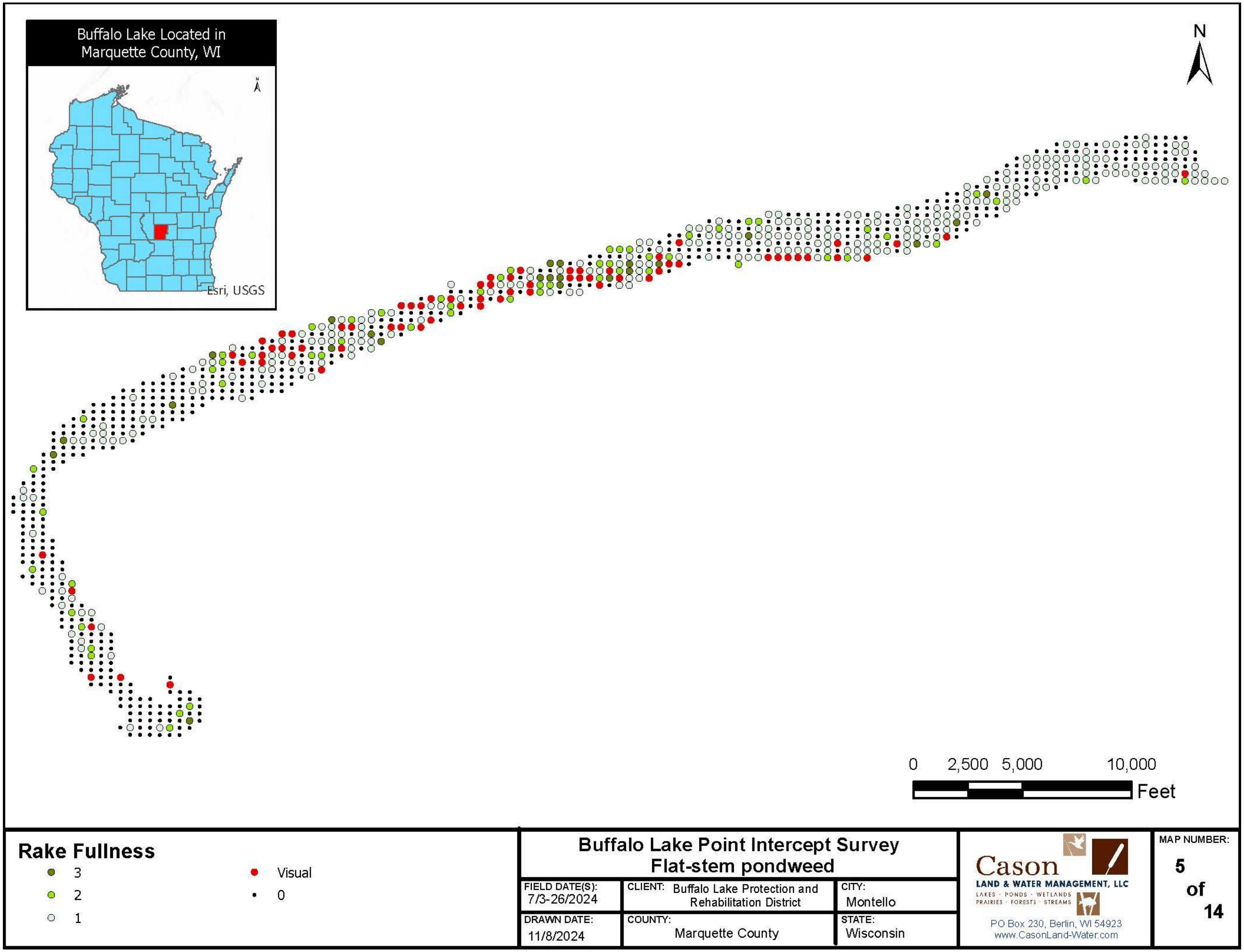

Figure 7. Distribution of Flat-stem pondweed in Buffalo Lake.

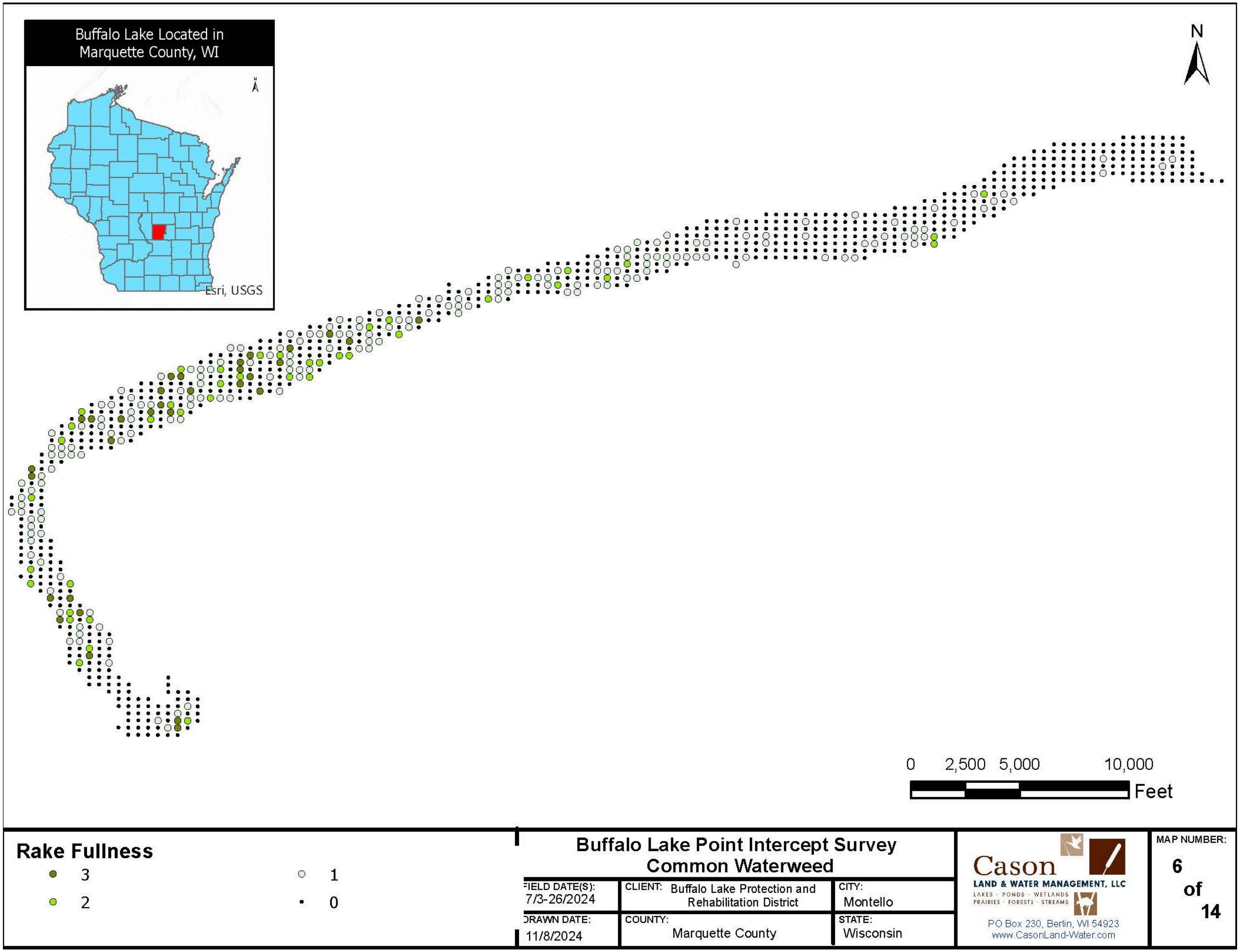

Figure 8. Distribution of Common waterweed in Buffalo Lake.

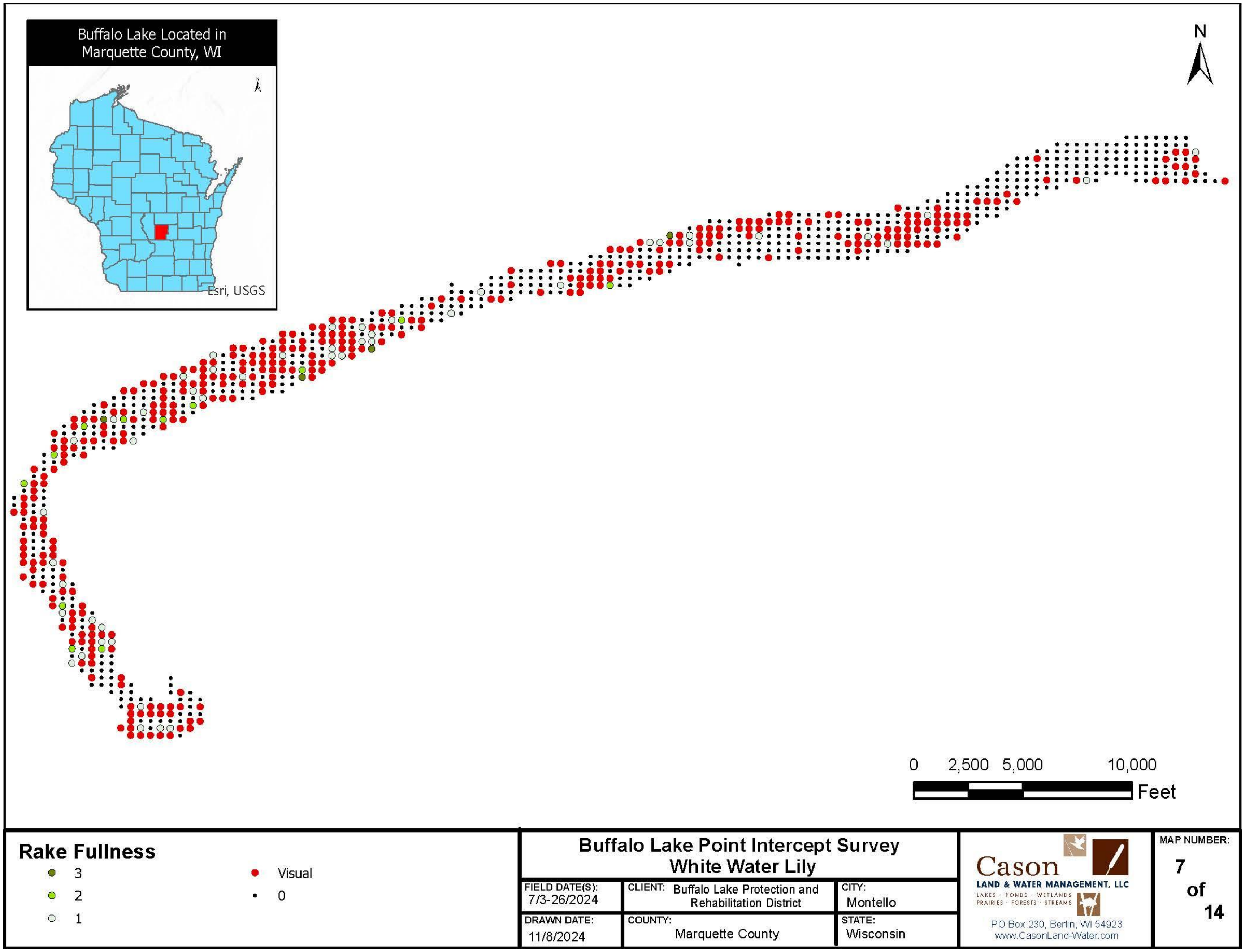

Figure 9. Distribution of White water lily in Buffalo Lake.

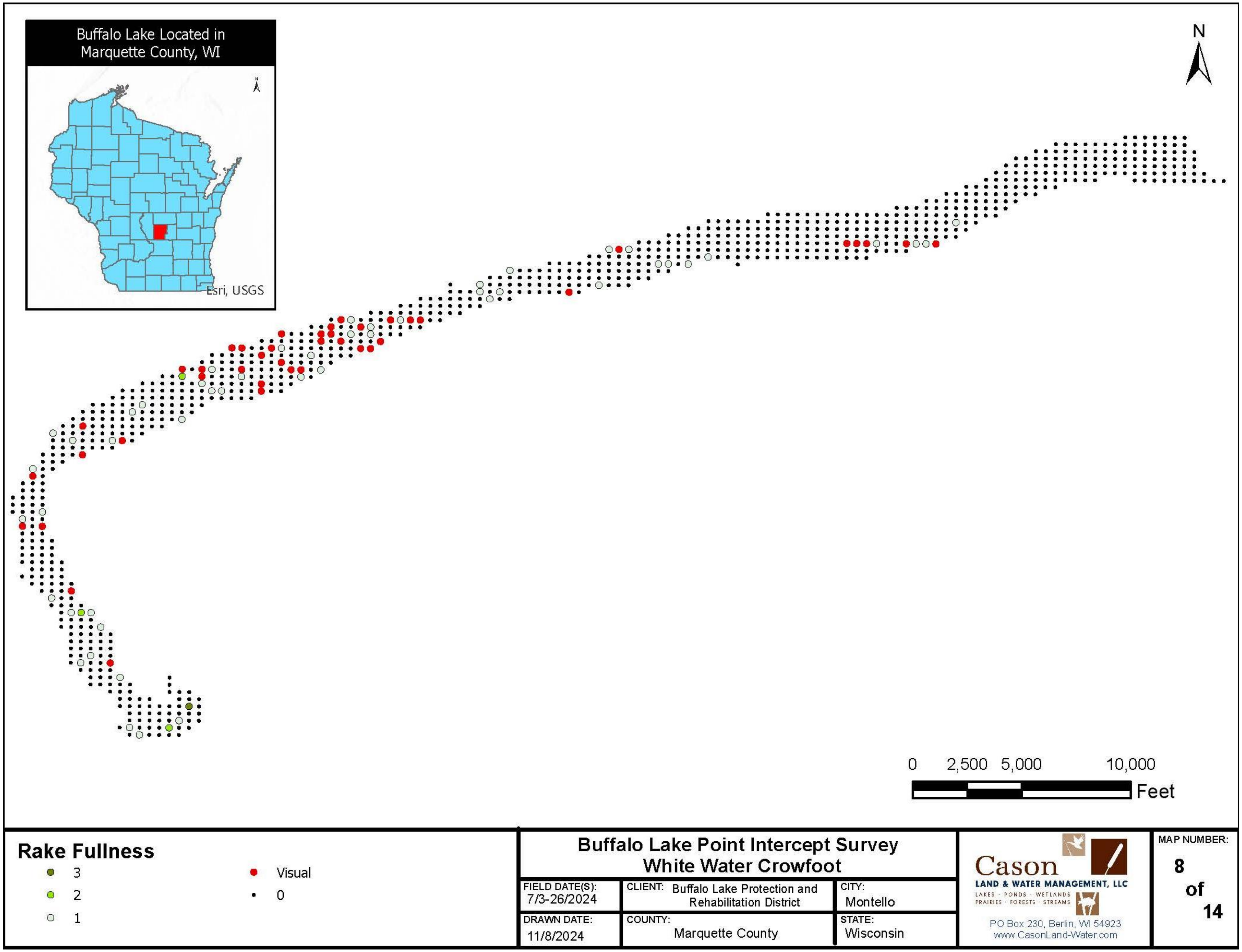

Figure 10. Distribution of White water crowfoot in Buffalo Lake.

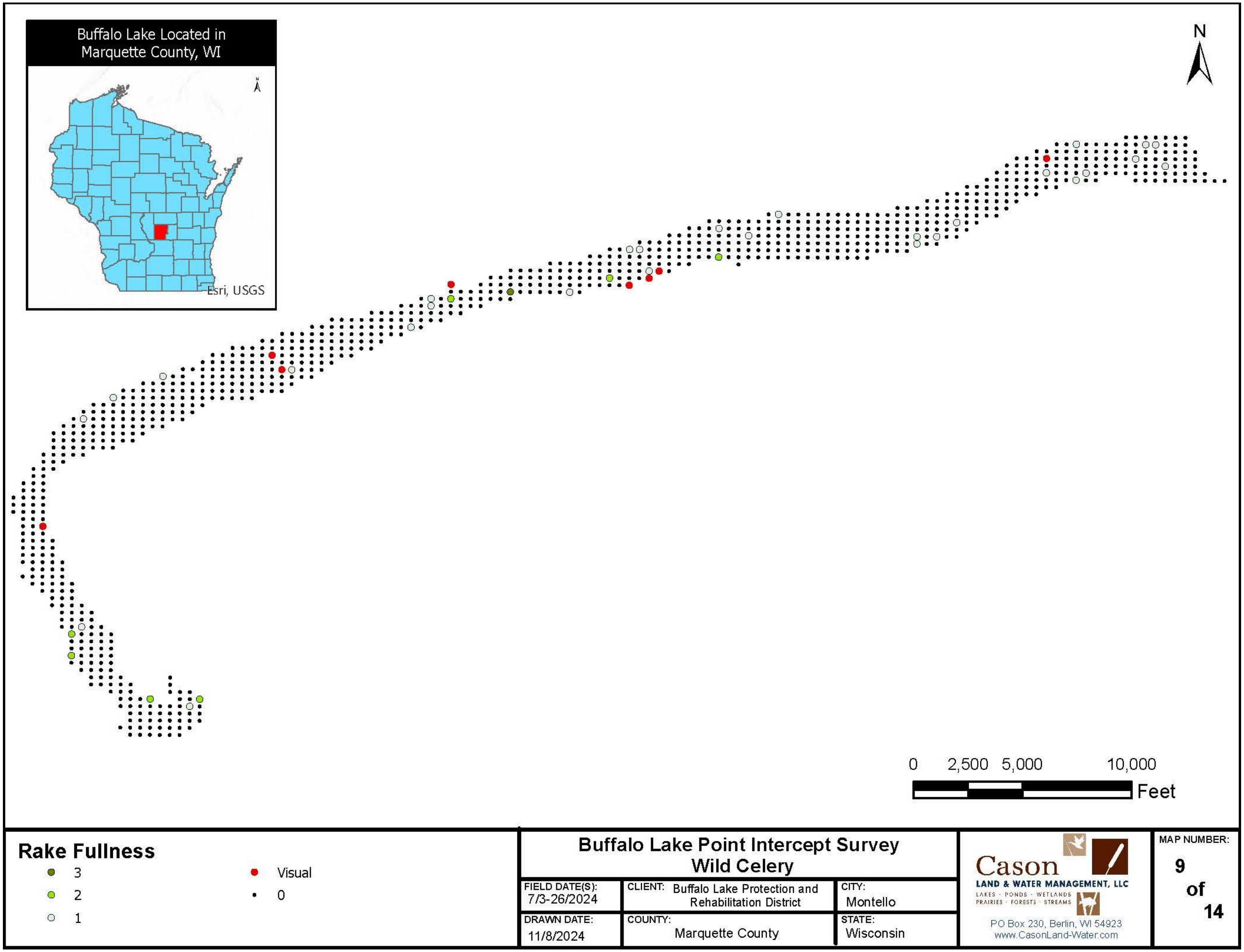

Figure 11. Distribution of Wild celery in Buffalo Lake.

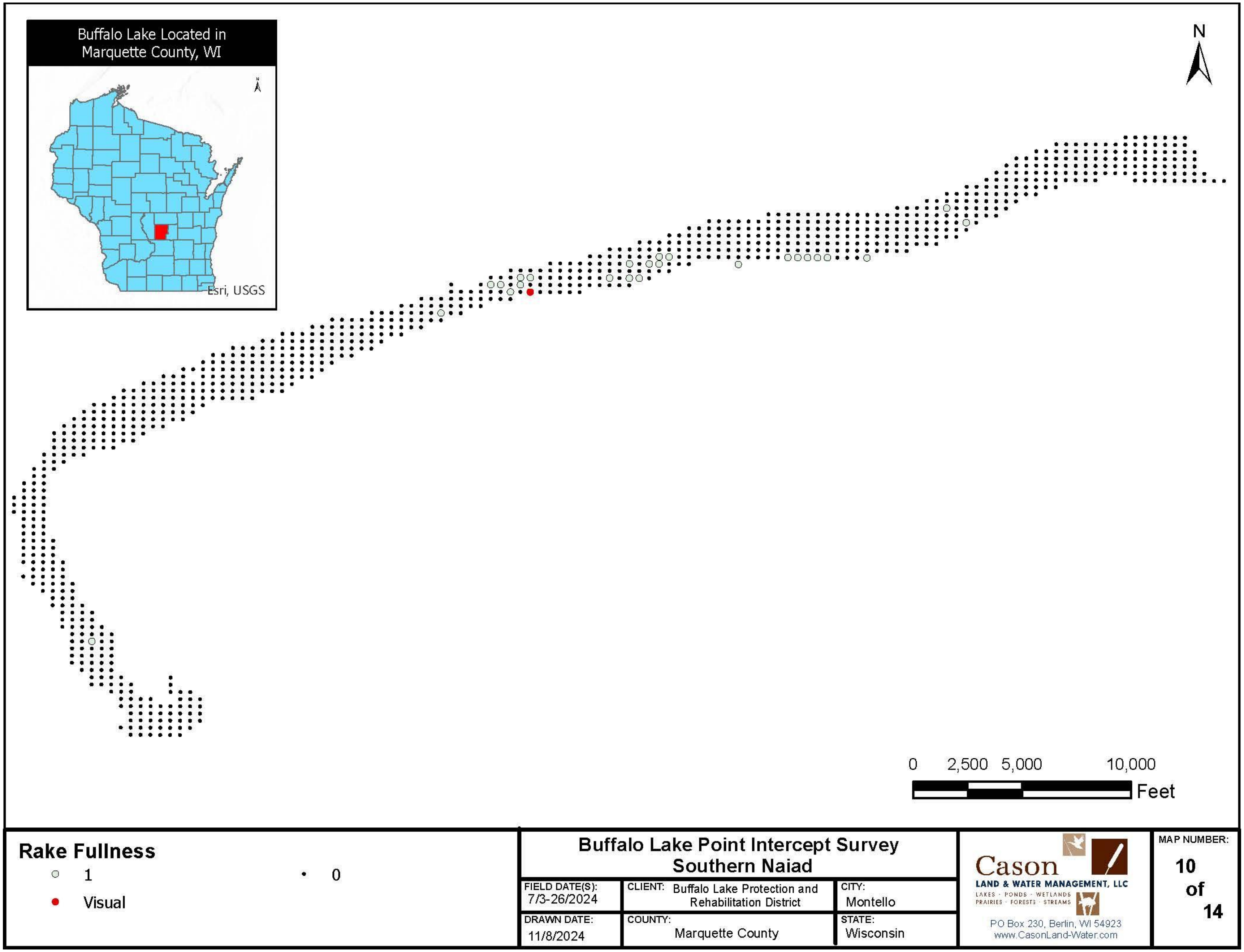

Figure 12. Distribution of Southern Naiad in Buffalo Lake.

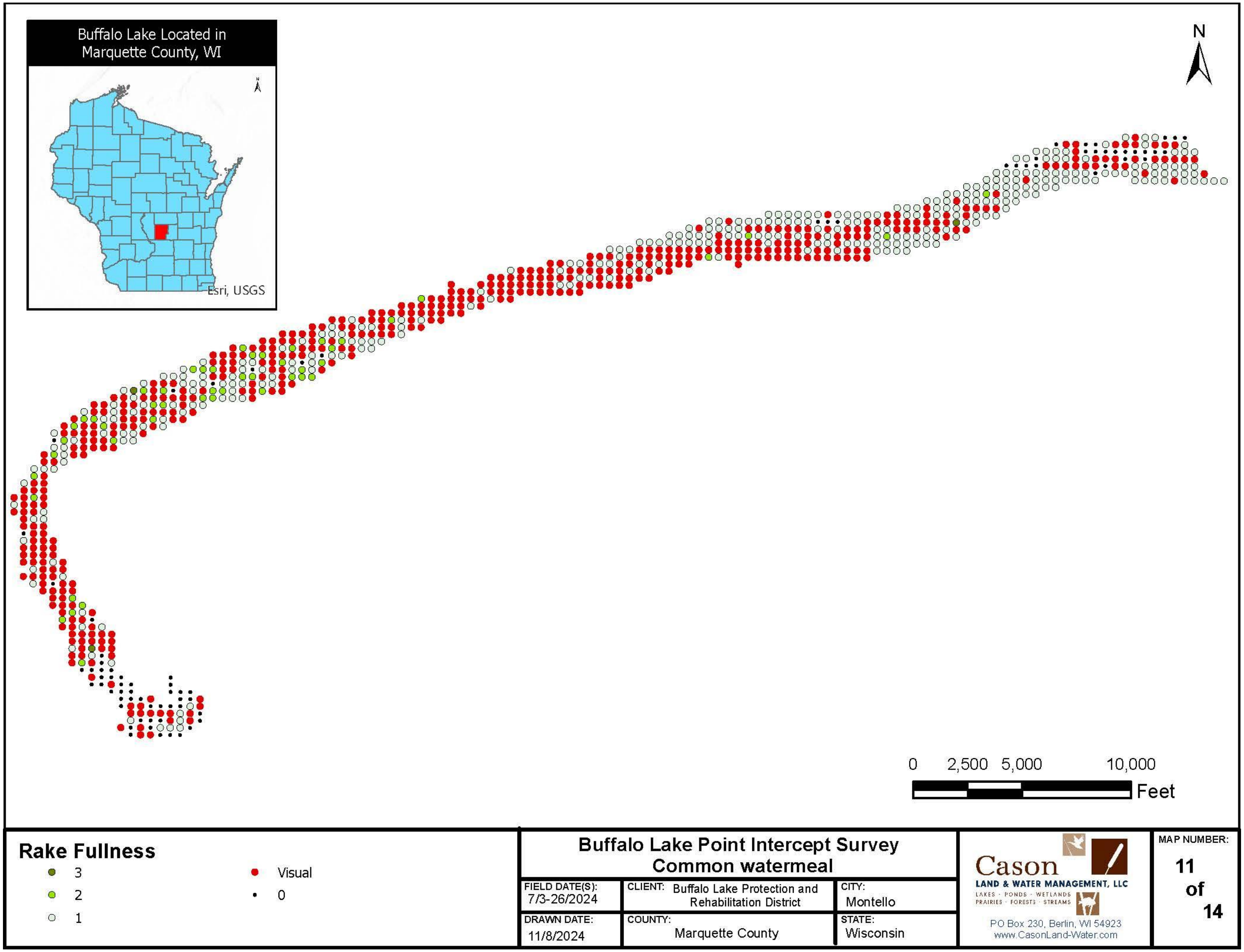

Figure 13. Distribution of Common watermeal in Buffalo Lake.

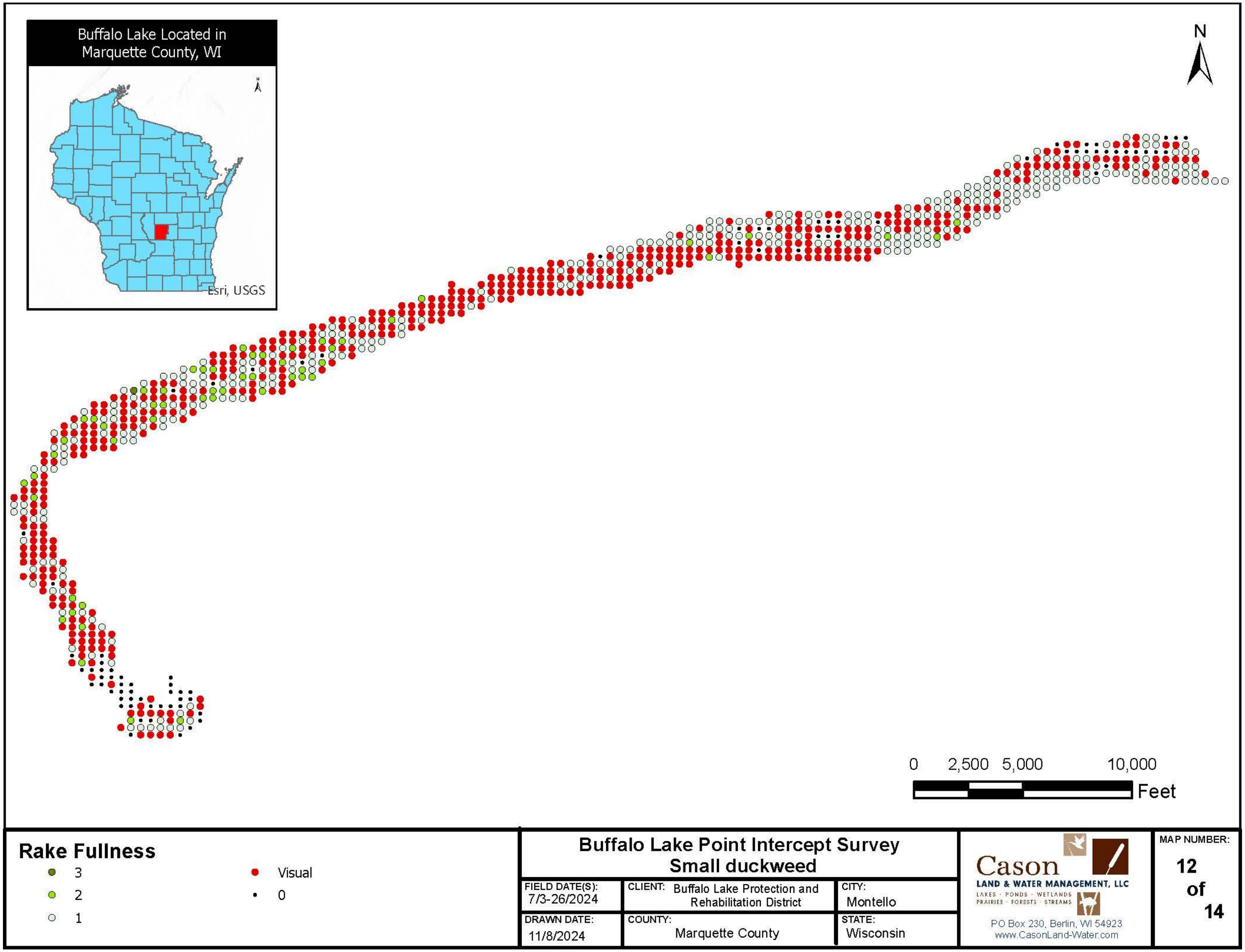

Figure 14. Distribution of Small duckweed in Buffalo Lake.

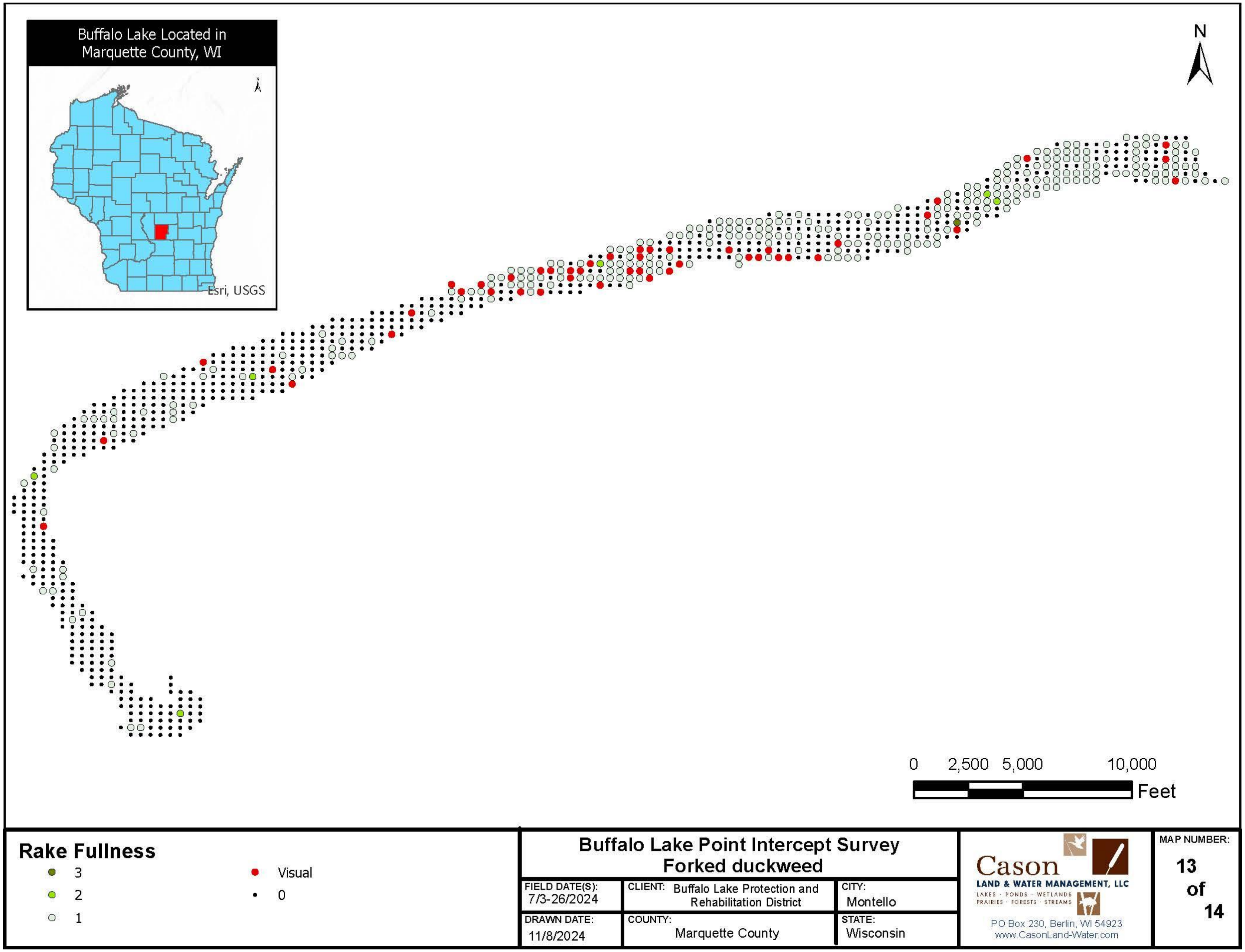

Figure 15. Distribution of Forked duckweed in Buffalo Lake.

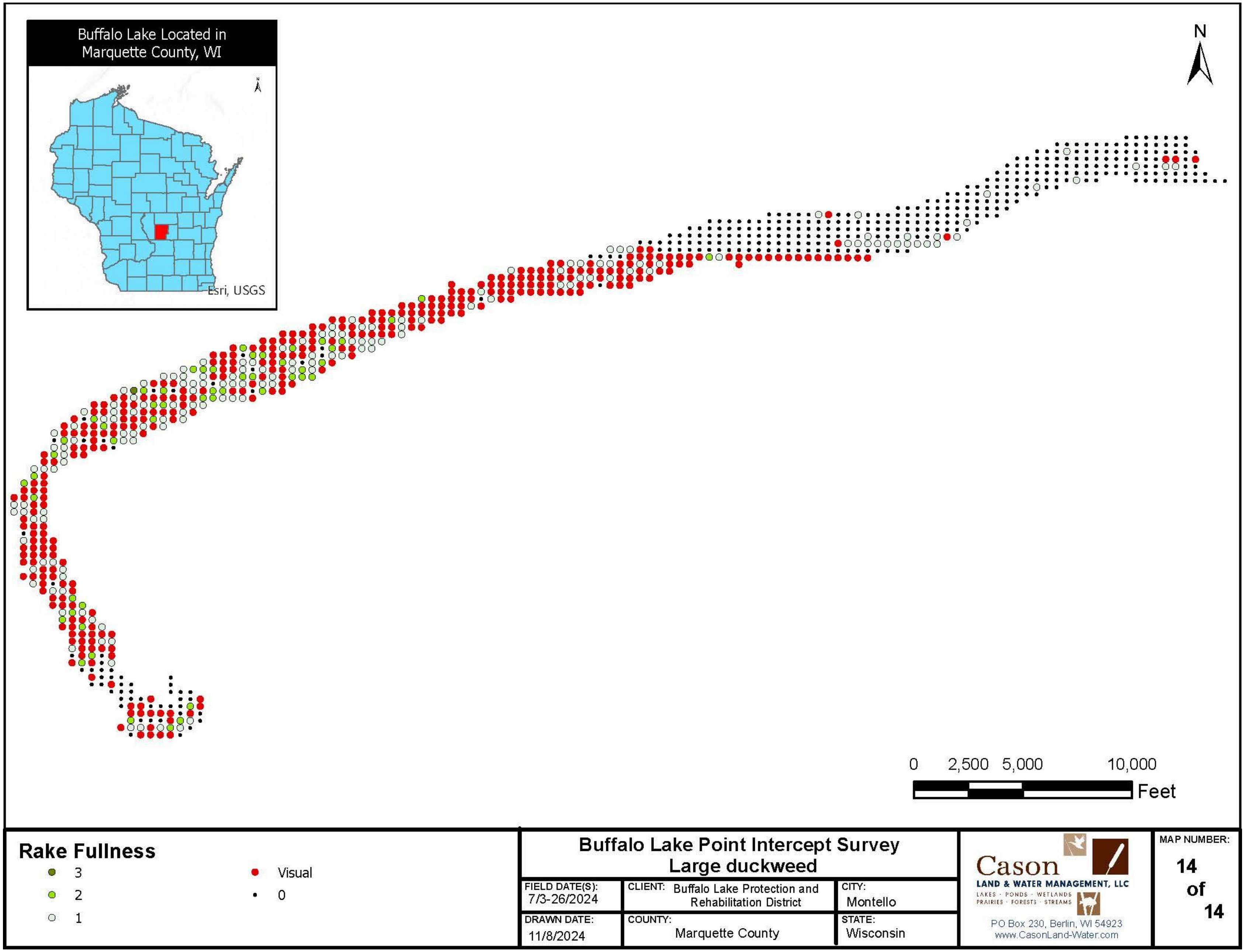

Figure 16. Distribution of Large duckweed in Buffalo Lake.

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Trends in the Aquatic Plant Community

The relative frequency of occurrence of each species found on Buffalo Lake are listed for each year that Point-Intercept surveys were conducted (2015, 2024, **Table 2**). Differences in species richness from year to year are likely due to variable observer biases and accessibility barriers to certain portions of the lake. A year-by-year summary is provided for the number of PI points which were sampled, the species richness observed via rake pulls, species richness including visual observations, the Simpson Diversity index (D) value, the Floristic Quality Index value (FQI), as well as the average coefficient of conservatism (C) value (**Table 3**). However, the FQI and C values were not available from the 2015 survey data.

Statistical analyses were performed on the relative frequency of occurrence data from 2015 to 2024. A chi-square analysis was used to identify statistically significant differences among species and indicate both significant increases and decreases (**Table 4**). As for aquatic invasive species, Eurasian watermilfoil has significantly increased in relative frequency of occurrence whereas Curly-leaf pondweed has significantly decreased in Buffalo Lake (**Table 4**). Additionally for AIS, Brittle Naiad was not observed during the 2024 survey resulting in a significant decrease of that species as well (**Table 4**). Native aquatic plant species that experienced an increase in relative frequency of occurrence during the last nine years include:Common watermeal, Small duckweed, Flat-stem pondweed, Forked duckweed, Large duckweed, Southern naiad, Spiny hornwort, Nitella, American Lotus, Common bur-reed, Cattail, and Wild rice (**Table 4**). Native species that experienced a decrease in relative frequency of occurrence during the last nine years include: Coontail, Common waterweed, White water crowfoot, Wild celery, Sago pondweed, Water star-grass, Small pondweed, Northern watermilfoil, Slender naiad (**Table 4**). Also, three new wetland invasive species were observed during the 2024 survey which were not observed during the 2025 survey, those species include: Purple loosestrife, Reed canary grass, and Common reed.

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Table 2. Buffalo Lake aquatic plant species present by year and relative frequency of occurrence.

Species	Scientific Name	% Relative Frequency of Occurence 2024	% Relative Frequency of Occurence 2015
Coontail	*Ceratophyllum demersum*	17.2	26.4
Common watermeal	*Wolffia columbiana*	13.9	2.8
Small duckweed	*Lemna minor*	13.8	3.2
Flat-stem pondweed	*Potamogeton zosteriformis*	12.9	5.2
Forked duckweed	*Lemna triscula*	10.3	0.9
Common waterweed	*Elodea canadensis*	9.8	19.1
Large duckweed	*Spirodela polyrhiza*	7.9	0.7
Eurasian water milfoil	*Myriophyllum spicatum*	5.2	5.1
White water lily	*Nymphaea odorata*	2.4	2.8
White water crowfoot	*Ranunculus aquatilis*	2	5
Wild celery	*Vallisneria americana*	1.4	8
Southern naiad	*Najas guadalupensis*	0.9	0.2
Spiny hornwort	*Ceratophyllum echinatum*	0.5	Absent
Sago pondweed	*Stuckenia pectinata*	0.4	2.1
Nitella	*Nitella sp.*	0.3	Absent
Slender waterweed	*Elodea nutalli*	0.2	0.1
Water star-grass	*Heteranthera dubia*	0.2	3.1
Curly-leaf pondweed	*Potamogeton crispus*	0.2	2.4
Leafy pondweed	*Potamogeton foliosus*	0.2	Absent
Small pondweed	*Potamogeton pusillus*	0.2	8.1
Muskgrasses	*Chara sp.*	0	0.3
Northern blue flag	*Iris versicolor*	0	Absent
Long-leaf pondweed	*Potamogeton nodosus*	0	0.2
Swamp Milkweed	*Asclepias incarnata*	Visual	Absent
Wild calla	*Calla palustris*	Visual	Absent
Bulbet-Bearing Water Her	*Cicuta bilbifera*	Visual	Absent
Water Hemlock	*Cicuta douglasii*	Visual	Absent
Red-osier Dogwood	*Cornus sericea*	Visual	Absent
Orange jewelweed	*Impatiens capensis*	Visual	Absent
Purple Loosestrife	*Lythrum salicaria*	Visual	Absent
American Lotus	*Nelumbo lutea*	Visual	0.1
Ditch Stonecrop	*Penthorum sedoides*	Visual	Absent
Reed canary grass	*Phalaris arundinacea*	Visual	Absent
Common reed	*Phragmites australis*	Visual	Absent

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Table 2 (cont.). Buffalo Lake aquatic plant species present by year and relative frequency of occurrence.

Species	Scientific Name	% Relative Frequency of Occurence 2024	% Relative Frequency of Occurence 2015
Water smartweed	*Polygonum amphibium*	Visual	Absent
Great Water Dock	*Rumex britannica*	Visual	Absent
Common arrowhead	*Sagittaria latifolia*	Visual	Absent
Willow	*Salex sp.*	Visual	Absent
Softstem bulrush	*Schoenoplectus tabernaemo*	Visual	Absent
Common bur-reed	*Sparganium eurycarpum*	Visual	Absent
Cattail	*Typha sp.*	Visual	0.1
Wild rice	*Zizania sp.*	Visual	0.1
Filamentous algae	*various*	N/A	2.7
Northern watermilfoil	*Myriophyllum sibiricum*	Absent	0.3
Slender naiad	*Najas flexilis*	Absent	2.8
White-stem pondweed	*Potamogeton praelongus*	Absent	0.1
Fern pondweed	*Potamogeton robbinsii*	Absent	0.1
Hardstem bulrush	*Schoenoplectus acutus*	Absent	0.1
Brittle Naiad	*Najas minor*	Absent	0.7

Table 3: A year-by-year summary of the number of PI points which were sampled, the species richness observed via rake pulls, species richness including visual observations, the Simpson Diversity index (D) value, the Floristic Quality Index value (FQI), as well as the average coefficient of conservatism (C) value.

	2024	2015
Number of sampled points:	828	675
Species Richness:	23	23
Species Richness (with visuals):	42	23
Simpson Diversity Index (D):	0.88	0.87
Floristic Quality Index (FQI):	26.83	29.40
Avg. Coefficient of Conservatism (C):	6.00	6.00

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Table 4: Results of chi-square analysis of percent frequency of occurrence survey data from the 2015 and 2024 Point-Intercept surveys of Buffalo Lake. Species are organized by 2024 percent frequency, with the highest frequency first. Green rows indicate significant increase and red rows indicate significant decrease in plant occurrence from 2015-2024. Invasive species are indicated with red text.

Species	Scientific Name	Percent Frequency		Significant Change	Increase (I) or Decrease (D)
		2015	2024		
Coontail	*Ceratophyllum demersum*	26.4	17.2	**	D
Common watermeal	*Wolffia columbiana*	2.8	13.9	***	I
Small duckweed	*Lemna minor*	3.2	13.8	***	I
Flat-stem pondweed	*Potamogeton zosteriformis*	5.2	12.9	***	I
Forked duckweed	*Lemna triscula*	0.9	10.3	***	I
Common waterweed	*Elodea canadensis*	19.1	9.8	***	D
Large duckweed	*Spirodela polyrhiza*	0.7	7.9	***	I
Eurasian water milfoil	*Myriophyllum spicatum*	5.1	5.2	*	I
White water lily	*Nymphaea odorata*	2.8	2.4	n.s.	I
White water crowfoot	*Ranunculus aquatilis*	5	2	***	D
Wild celery	*Vallisneria americana*	8	1.4	***	D
Southern naiad	*Najas guadalupensis*	0.2	0.9	***	I
Spiny hornwort	*Ceratophyllum echinatum*	0	0.5	**	I
Sago pondweed	*Stuckenia pectinata*	2.1	0.4	***	D
Nitella	*Nitella sp.*	0	0.3	*	I
Slender waterweed	*Elodea nutalli*	0.1	0.2	n.s.	I
Water star-grass	*Heteranthera dubia*	3.1	0.2	***	D
Curly-leaf pondweed	*Potamogeton crispus*	2.4	0.2	***	D
Leafy pondweed	*Potamogeton foliosus*	0	0.2	n.s.	I
Small pondweed	*Potamogeton pusillus*	8.1	0.2	***	D
Muskgrasses	*Chara sp.*	0.3	0	n.s.	D
Northern blue flag	*Iris versicolor*	0	0	n.s.	I
Long-leaf pondweed	*Potamogeton nodosus*	0.2	0	n.s.	D
Swamp Milkweed	*Asclepias incarnata*	0	0	n.s.	I
Wild calla	*Calla palustris*	0	0	n.s.	I
Bulbet-Bearing Water Hemlock	*Cicuta bilbifera*	0	0	n.s.	I
Water Hemlock	*Cicuta douglasii*	0	0	n.s.	I
Red-osier Dogwood	*Cornus sericea*	0	0	n.s.	I
Orange jewelweed	*Impatiens capensis*	0	0	n.s.	I
Purple Loosestrife	*Lythrum salicaria*	0	0	*	I
American Lotus	*Nelumbo lutea*	0.1	0	*	I
Ditch Stonecrop	*Penthorum sedoides*	0	0	n.s.	I
* significant change (α=0.05), ** more significant change (α=0.01), *** most significant change (α=0.001)					

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Table 4 (cont.): Results of chi-square analysis of percent frequency of occurrence survey data from the 2015 and 2024 Point-Intercept surveys of Buffalo Lake. Species are organized by 2024 percent frequency, with the highest frequency first. Green rows indicate significant increase and red rows indicate significant decrease in plant occurrence from 2015-2024. Invasive species are indicated with red text.

Species	Scientific Name	Percent Frequency		Significant Change	Increase (I) or Decrease (D)
		2015	2024		
Reed canary grass	*Phalaris arundinacea*	0	0	n.s.	I
Common reed	*Phragmites australis*	0	0	*	I
Water smartweed	*Polygonum amphibium*	0	0	n.s.	I
Great Water Dock	*Rumex britannica*	0	0	n.s.	I
Common arrowhead	*Sagittaria latifolia*	0	0	n.s.	I
Willow	*Salex sp.*	0	0	n.s.	I
Softstem bulrush	*Schoenoplectus tabernaemon*	0	0	n.s.	I
Common bur-reed	*Sparganium eurycarpum*	0	0	**	I
Cattail	*Typha sp.*	0.1	0	***	I
Wild rice	*Zizania sp.*	0.1	0	**	I
Filamentous algae	*various*	2.7	N/A	n.s.	I
Northern watermilfoil	*Myriophyllum sibiricum*	0.3	0	*	D
Slender naiad	*Najas flexilis*	2.8	0	***	D
White-stem pondweed	*Potamogeton praelongus*	0.1	0	n.s.	D
Fern pondweed	*Potamogeton robbinsii*	0.1	0	n.s.	D
Hardstem bulrush	*Schoenoplectus acutus*	0.1	0	n.s.	D
Brittle Naiad	*Najas minor*	0.7	0	***	D
* significant change (α=0.05), ** more significant change (α=0.01), *** most significant change (α=0.001)					

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Resources

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SECTION III

Buffalo Lake Enhancement Project
Floating Leaf & Emergent Plant Survey

(Conducted by Cason Land & Water Management, LLC.)

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Buffalo Lake

2024 Floating leaf & Emergent Plant Survey Summary

On August 29, 2024, Cason Land & Water Management, LLC conducted a floating leaf and emergent plant survey on Buffalo Lake which followed a full point-intercept survey.

This survey was conducted by navigating through all navigable waters on Buffalo Lake to plot the diversity and distribution of various floating-leaf, emergent, and riparian plant species in the system. This survey is conducted by trained biologists with experience in plant identification. Locations of plants were transferred to mapping software known as ArcGIS Pro to create the detailed maps provided.

Buffalo Lake, as a lotic system, naturally undergoes regular fluctuations in water levels. During the 2024 survey, water levels were estimated to be 12–18 inches higher than in recent years. A comparison of aerial imagery from 2023 to field observations in 2024 suggests a reduction in the abundance of floating-leaf plants between those two years. However, when 2024 survey results for emergent and floating-leaf vegetation are compared to the 2015 survey, an overall increase in plant abundance is observed over the longer timeframe. The table below provides the estimated acres between surveys.

Aquatic Plant Community	2015 Acres	2024 Acres
Emergent	373.0	498.5
Floating leaf	505.6	720.4
Mixed Emergent & Floating Leaf	43.8	38.1
Total	**922.5**	**1,257.0**

The table below provides a comparison of which species were noted to be present during the 2015 and 2024 emergent plant surveys.

Floating leaf & Emergent Plant Species	2024	2015
American Lotus (*Nelumbo lutea*)	**Present**	**Present**
Arrowhead (*Sagittaria sp.*)	**Present**	**Present**
Cattail (*Typha sp.*)	**Present**	**Present**
Blue flag Iris (*Iris versicolor*)	**Present**	**Present**
Bristly Sedge (*Carex comosa*)	**Present**	**Absent**
Bur Reed (*Sparganium sp.*)	**Present**	**Present**
Japanese Knotweed (*Reynoutria japonica*)	**Present**	**Absent**
Long-leaf Pondweed (*Potamogeton nodosus*)	**Present**	**Absent**
Orange Jewelweed (*Impatiens capensis*)	**Present**	**Absent**
Phragmites (*Phragmites australis*)	**Present**	**Present**
Purple Loosestrife (*Lythrum salicaria*)	**Present**	**Absent**
River Bulrush (*Bolboschoenus fluviatilis*)	**Absent**	**Present**
Softstem Bulrush (*Schoenoplectus tabernaemontani*)	**Present**	**Present**
White Water-Lily (*Nymphaea alba*)	**Present**	**Present**
Wild Rice (*Zizania palustris*)	**Present**	**Present**
Yellow Iris (*Iris pseudacorus*)	**Present**	**Absent**

Legend

- White Water Lily
- Catail sp
- American Lotus
- White water lily & Wild Rice
- Phragmites
- Bristly Sedge
- Yellow Iris
- Bur reed
- Soft-stem Bulrush
- Purple Loosestrife

Buffalo Lake
Floating Leaf & Emergent Plant Survey

FIELD DATE(S): 08/29/2024	CLIENT: Buffalo Lake Protection and Rehabilitation District	CITY: Montello
DRAWN DATE: 9/10/2025	COUNTY: Marquette County	STATE: Wisconsin

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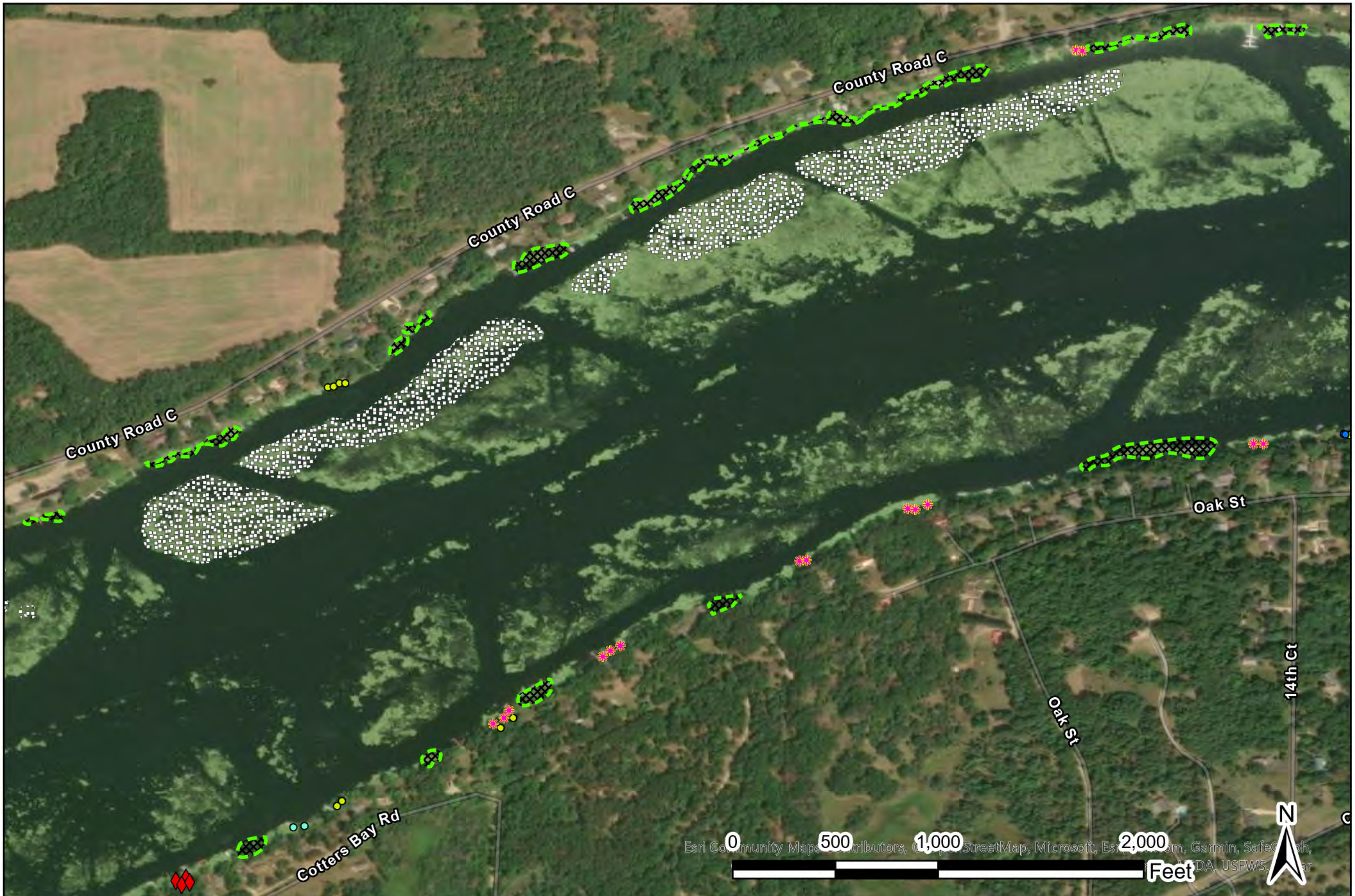

Legend

- White Water Lily
- Catail sp
- Bristly Sedge
- Yellow Iris
- Bur reed
- Soft-stem Bulrush
- Japanese Knotweed

Buffalo Lake
Floating Leaf & Emergent Plant Survey

FIELD DATE(S):	CLIENT:	CITY:
08/29/2024	Buffalo Lake Protection and Rehabilitation District	Montello
DRAWN DATE:	**COUNTY:**	**STATE:**
11/21/2024	Marquette County	Wisconsin

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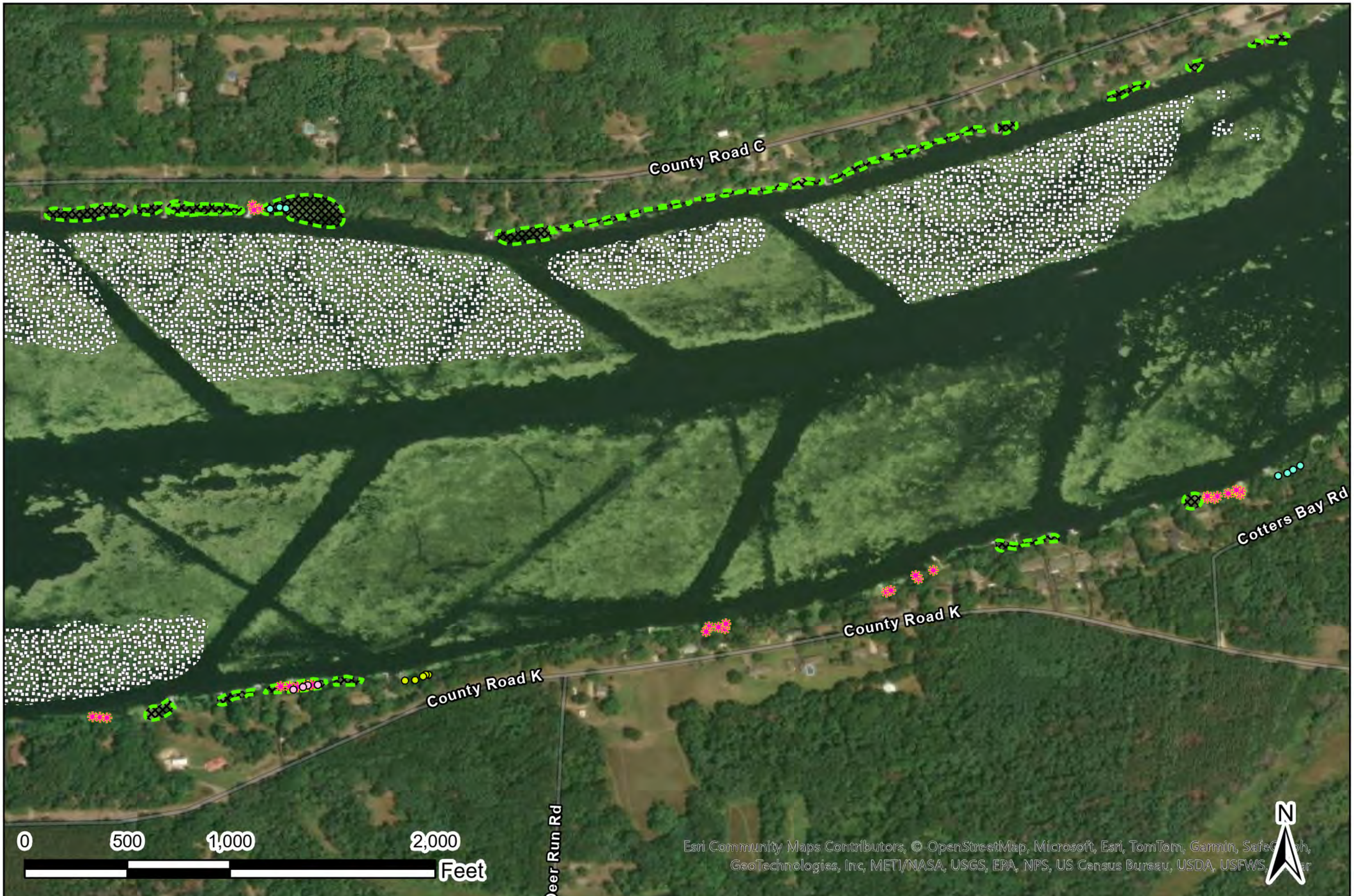

Legend

- White Water Lily
- Catail sp
- Bristly Sedge
- Bur reed
- Soft-stem Bulrush

Buffalo Lake
Floating Leaf & Emergent Plant Survey

FIELD DATE(S):	CLIENT: Buffalo Lake Protection and Rehabilitation District	CITY: Montello
08/29/2024		
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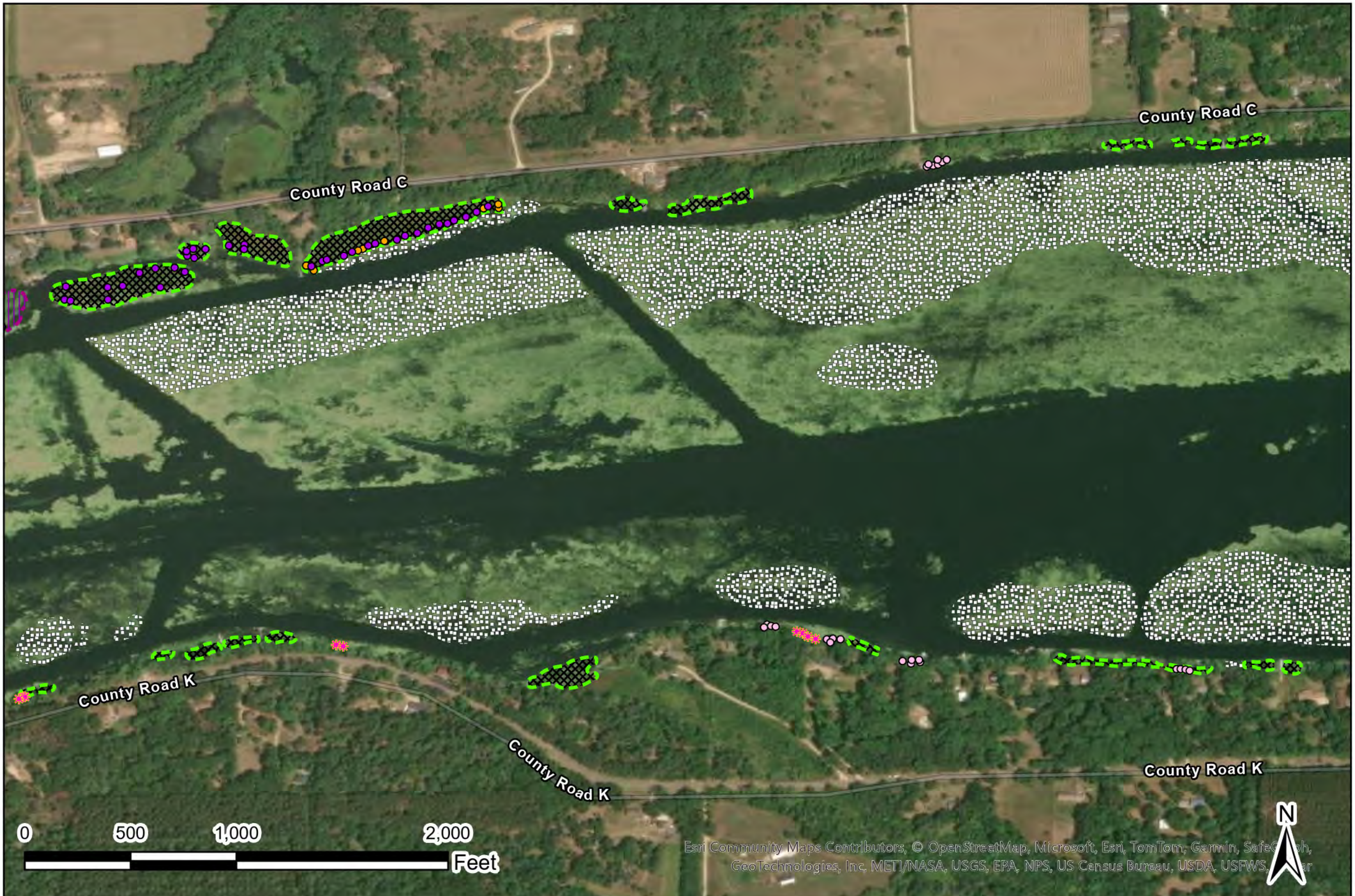

Legend

- White Water Lily
- Catail sp
- Various Emergent Plants
- Bur reed
- Soft-stem Bulrush
- Orange Jewelweed
- Purple Loosestrife

Buffalo Lake
Floating Leaf & Emergent Plant Survey

FIELD DATE(S): 08/29/2024	CLIENT: Buffalo Lake Protection and Rehabilitation District	CITY: Montello
DRAWN DATE: 11/21/2024	COUNTY: Marquette County	STATE: Wisconsin

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Legend

- White Water Lily
- Catail sp
- Cattail & Wild Rice
- Phragmites
- Various Emergent Plants
- Bristly Sedge
- Yellow Iris
- Bur reed
- Soft-stem Bulrush
- Purple Loosestrife

Buffalo Lake
Floating Leaf & Emergent Plant Survey

FIELD DATE(S): 08/29/2024	CLIENT: Buffalo Lake Protection and Rehabilitation District	CITY: Montello
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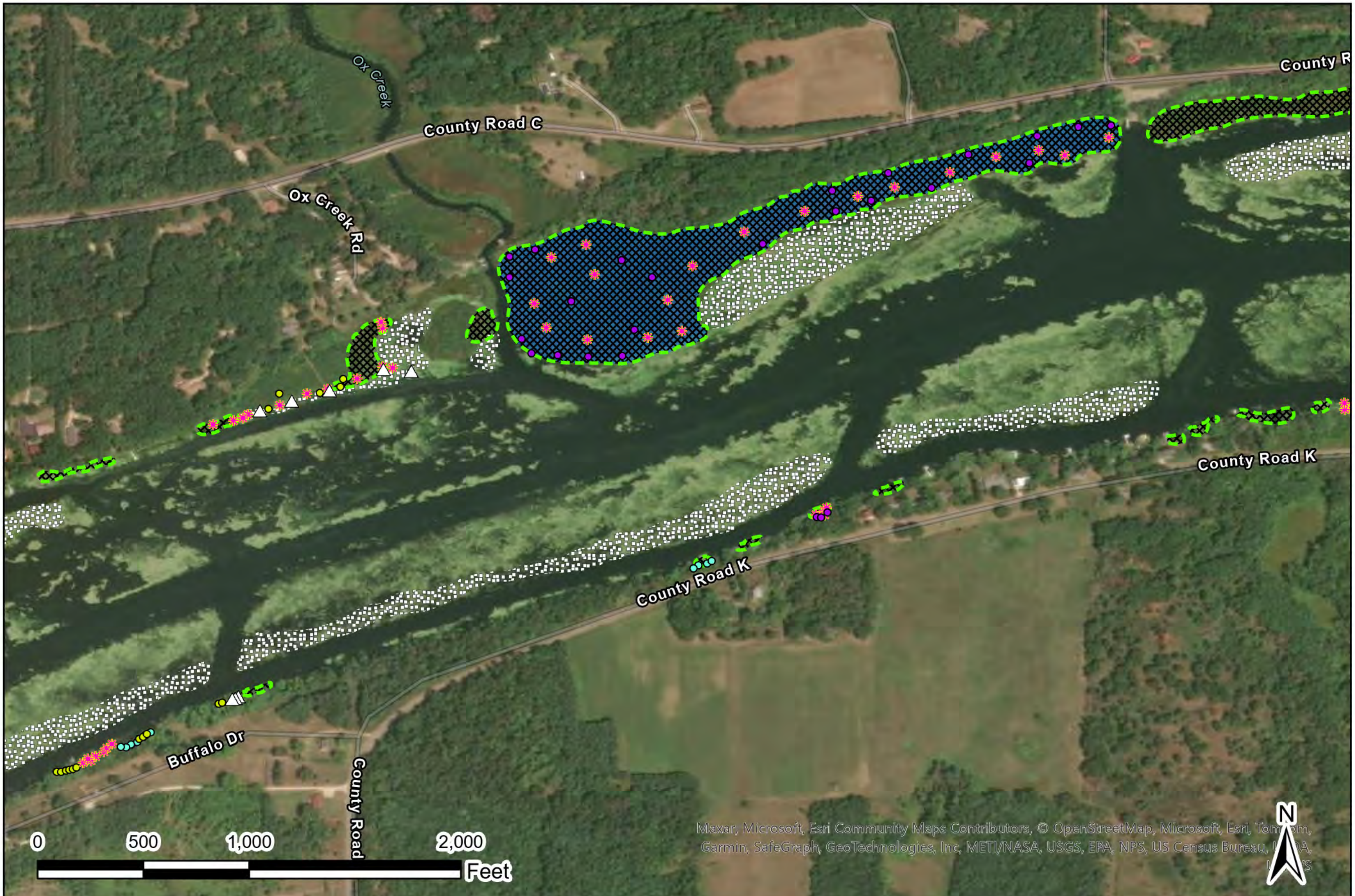

Legend

- White Water Lily
- Catail sp
- Cattail & Wild Rice
- Bristly Sedge
- Yellow Iris
- Bur reed
- Soft-stem Bulrush
- Purple Loosestrife
- Arrowhead

Buffalo Lake
Floating Leaf & Emergent Plant Survey

FIELD DATE(S): 08/29/2024	CLIENT: Buffalo Lake Protection and Rehabilitation District	CITY: Montello
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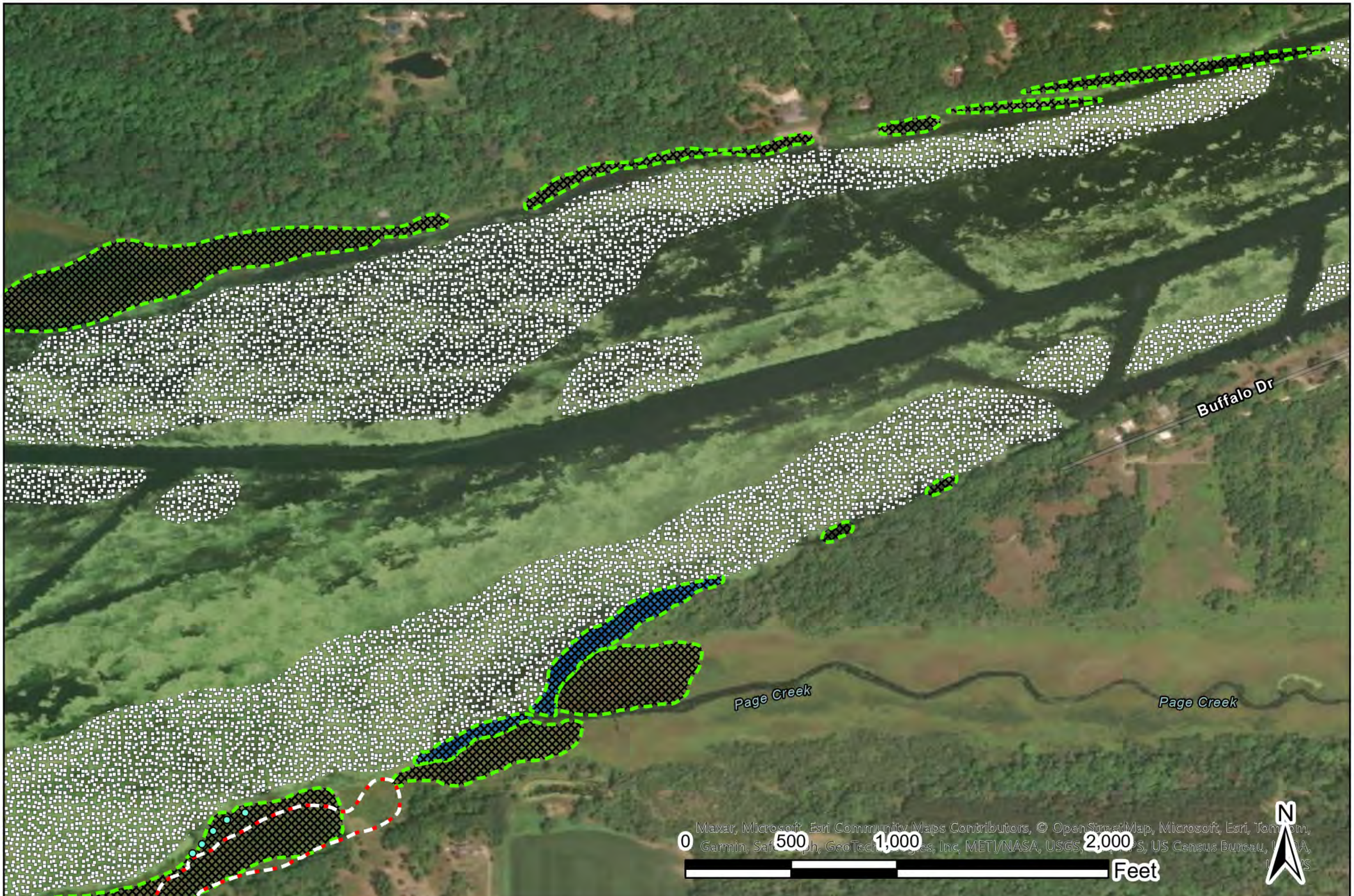

Legend

- White Water Lily
- Catail sp
- Cattail & Wild Rice
- Phragmites
- Bristly Sedge

Buffalo Lake
Floating Leaf & Emergent Plant Survey

FIELD DATE(S): 08/29/2024	CLIENT: Buffalo Lake Protection and Rehabilitation District	CITY: Montello
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Legend

White Water Lily
Catail sp
Phragmites
Bur reed
Soft-stem Bulrush
Purple Loosestrife

Buffalo Lake
Floating Leaf & Emergent Plant Survey

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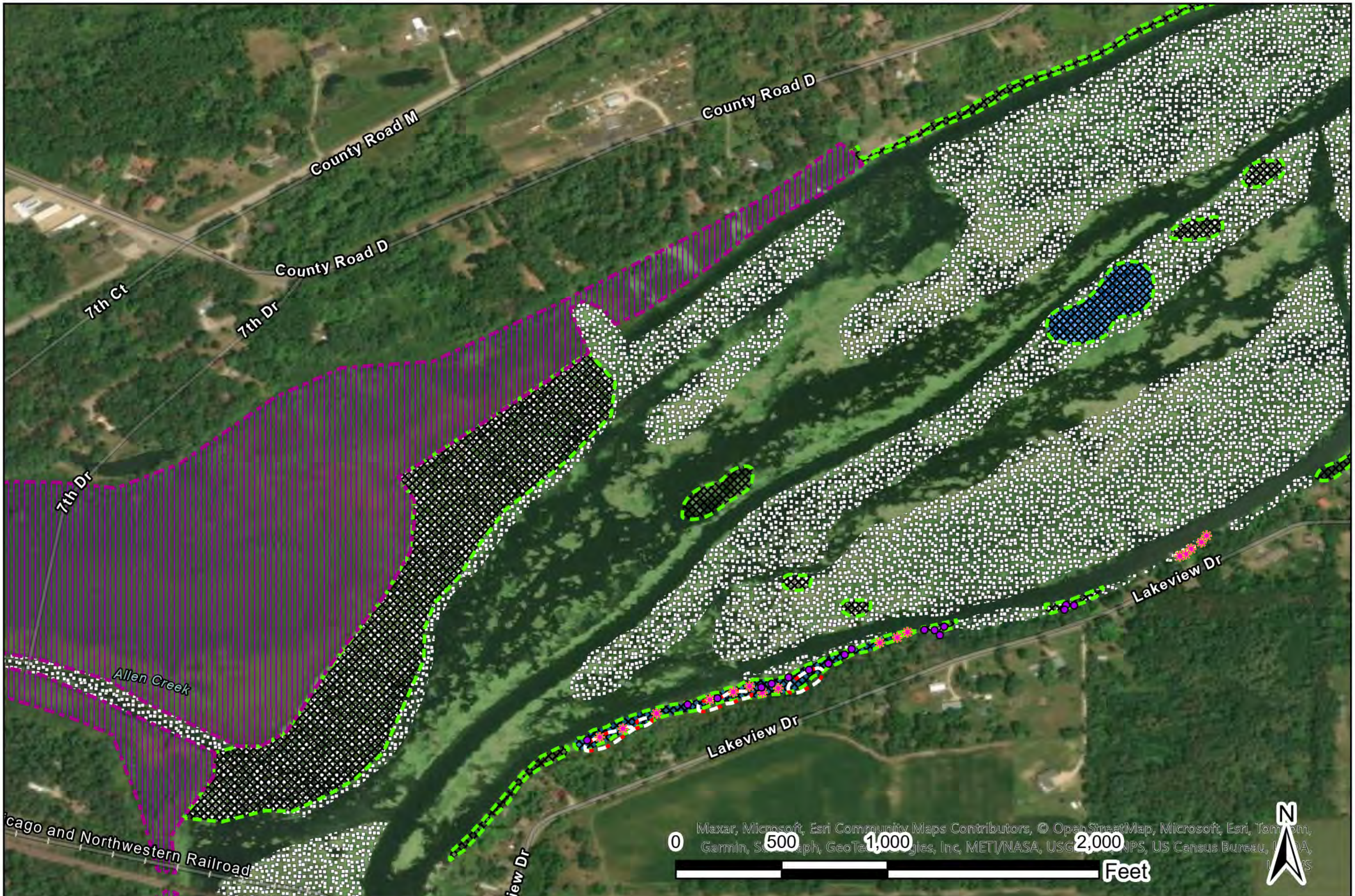

Legend

- White Water Lily
- Catail sp
- Cattail & Wild Rice
- Phragmites
- Various Emergent Plants
- Bur reed
- Purple Loosestrife

Buffalo Lake
Floating Leaf & Emergent Plant Survey

FIELD DATE(S): 08/29/2024	CLIENT: Buffalo Lake Protection and Rehabilitation District	CITY: Montello
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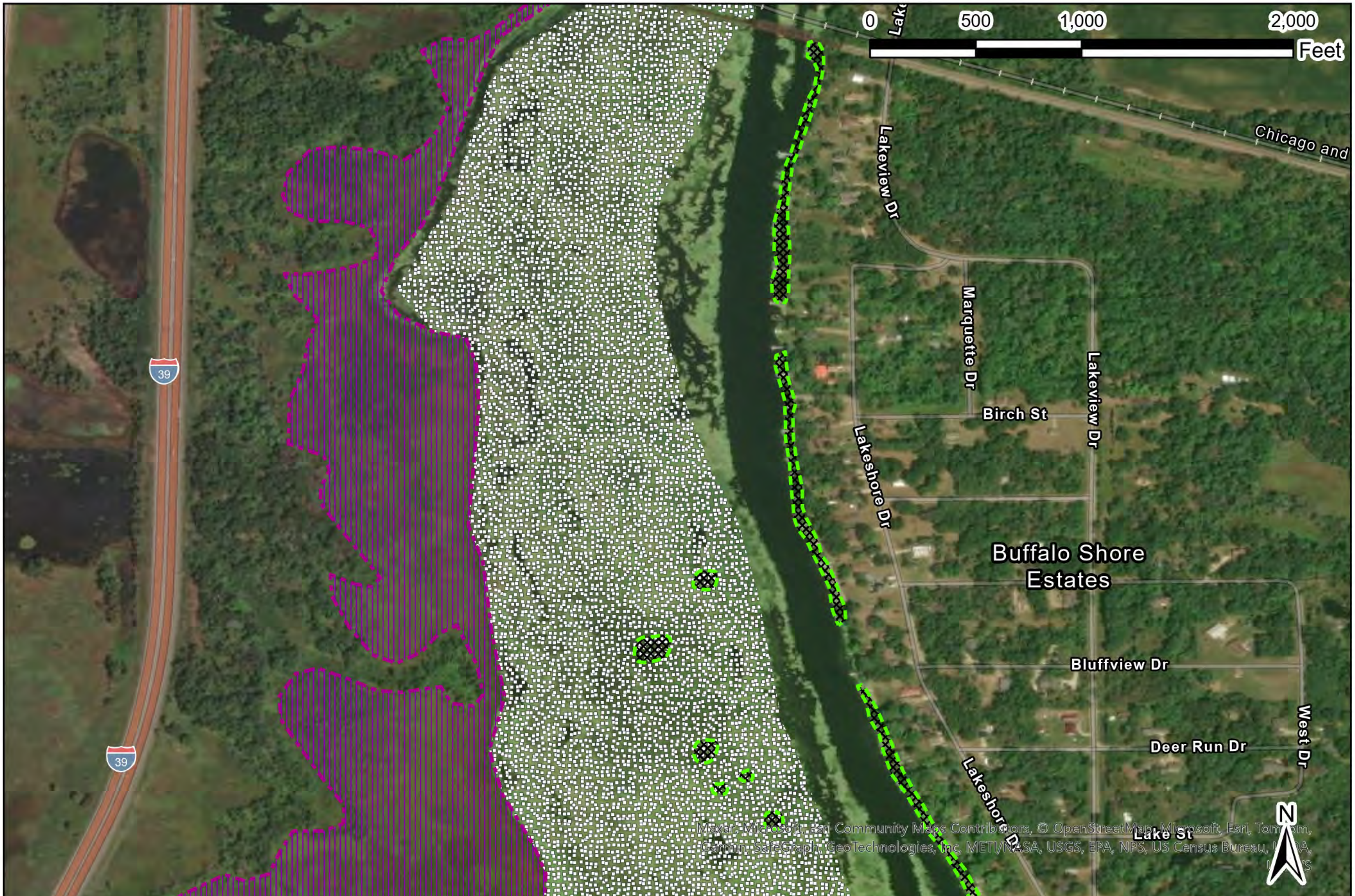

Legend

- White Water Lily
- Catail sp
- Various Emergent Plants

Buffalo Lake
Floating Leaf & Emergent Plant Survey

FIELD DATE(S): 08/29/2024	CLIENT: Buffalo Lake Protection and Rehabilitation District	CITY: Montello
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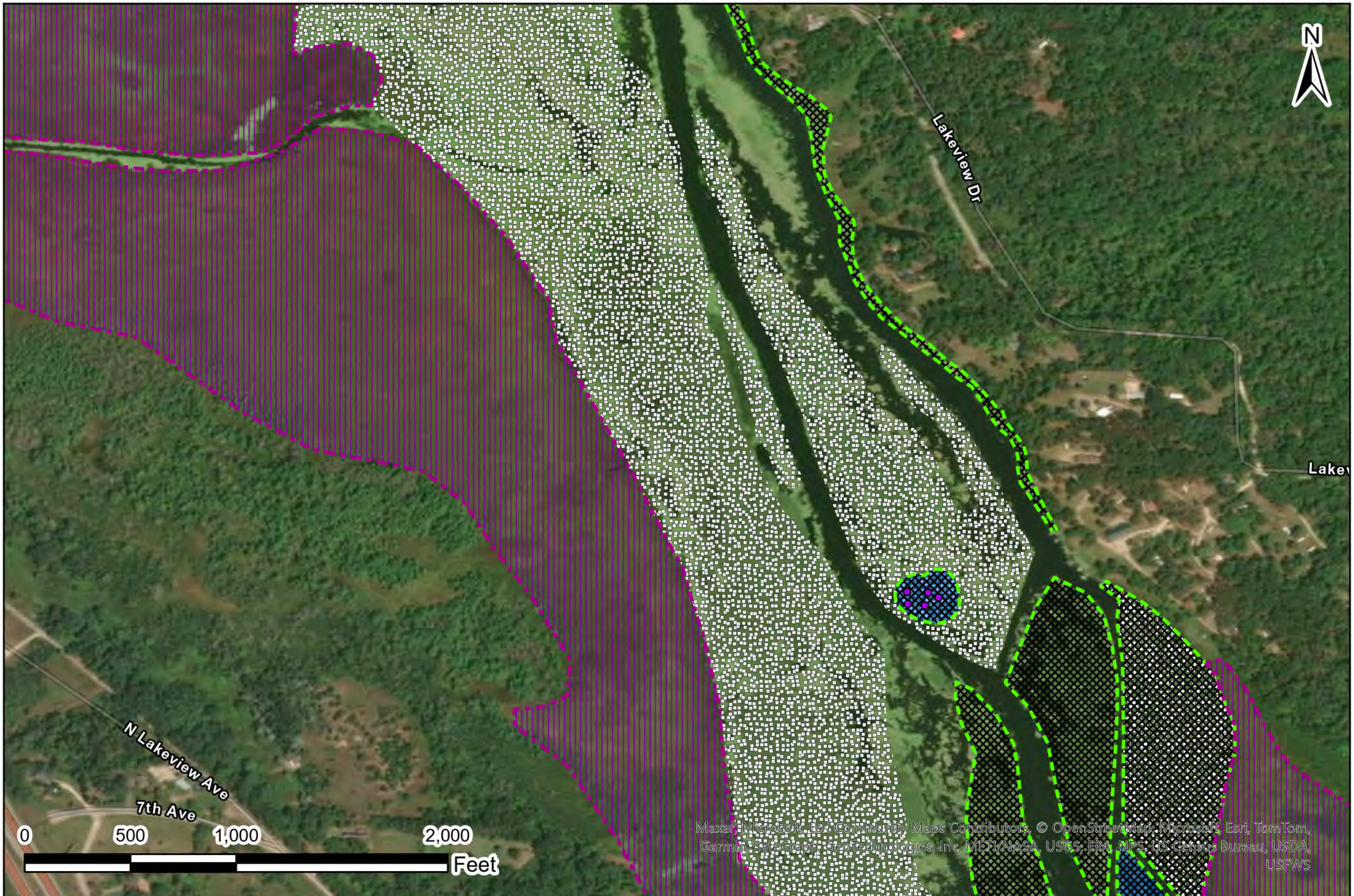

Legend

- White Water Lily
- Catail sp
- Cattail & Wild Rice
- Various Emergent Plants
- Purple Loosestrife

Buffalo Lake
Floating Leaf & Emergent Plant Survey

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11/21/2024	Marquette County	Wisconsin

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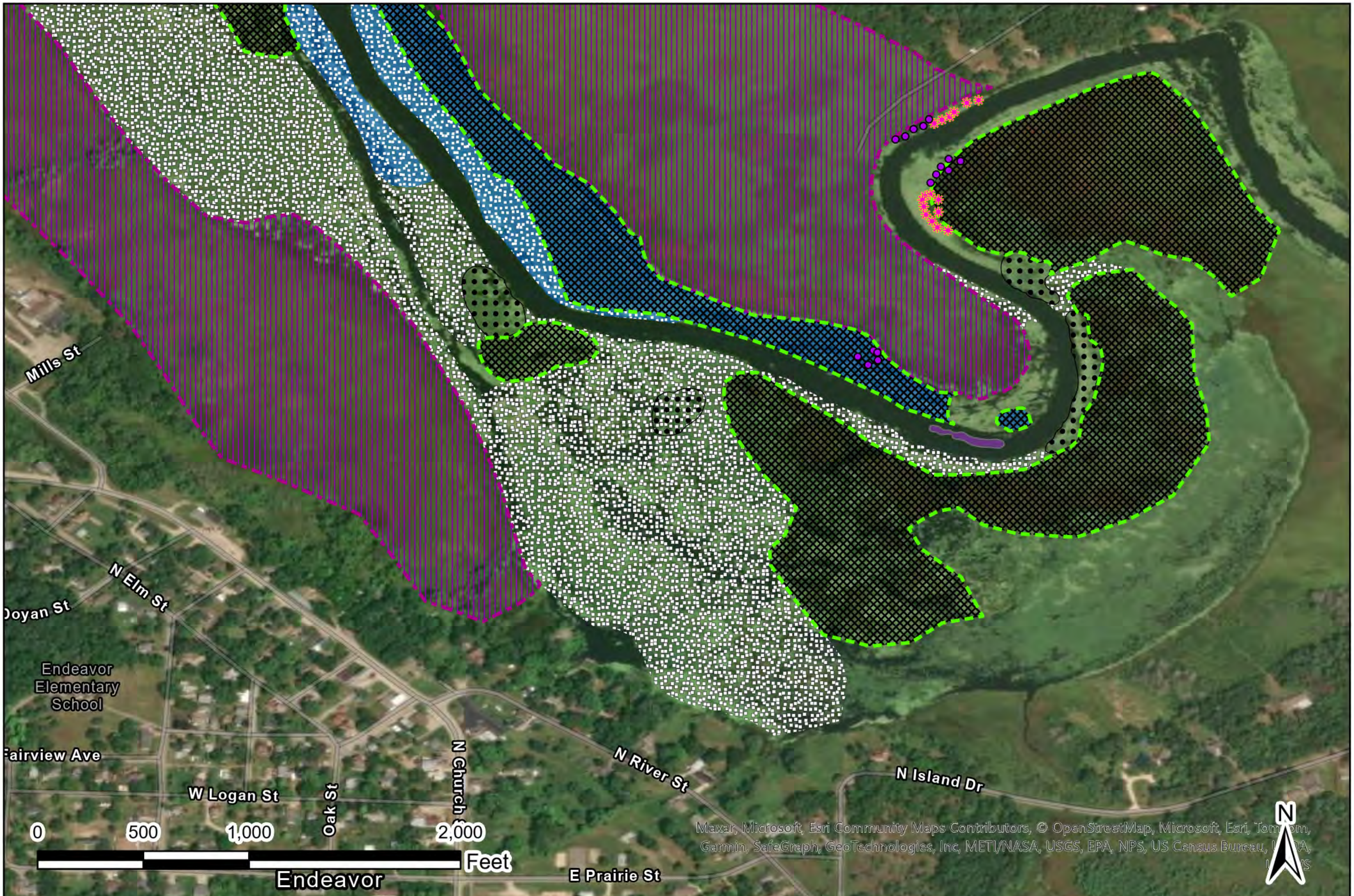

Legend

- White Water Lily
- White water lily & Wild Rice
- Catail sp
- Cattail & Wild Rice
- American Lotus
- Long-leaf Pondweed
- Various Emergent Plants
- Bur reed
- Purple Loosestrife

Buffalo Lake
Floating Leaf & Emergent Plant Survey

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