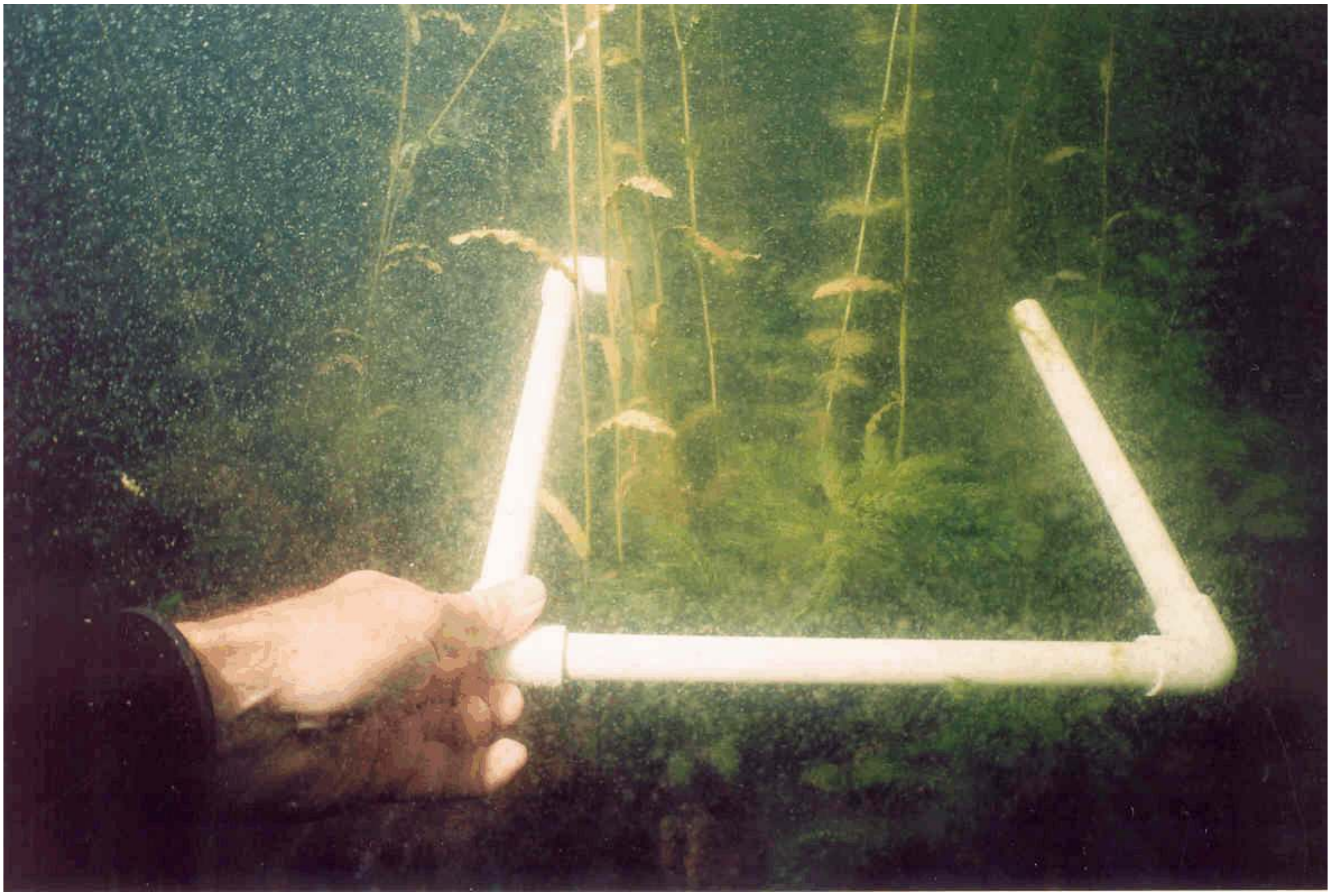

Curlyleaf Pondweed in Heine Pond, 2007

# Review of Curlyleaf Pondweed Responses to Sediment Iron Treatments


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# Review of Curlyleaf Pondweed Responses to Sediment Iron Treatments


## Summary

The one-time sediment iron treatments reduced curlyleaf pondweed to below nuisance densities (set at less than 150 stems/$m^2$) in five out of six treated lake areas (Table 1).

In Heine Pond, there has been curlyleaf control for nine years. In Lee Lake and Eagle Lake, there has been curlyleaf control for the last two years. In Orchard Lake, stem densities in the treated area have been less than the reference areas in three out of four years, but stem densities have been below nuisance levels in only one out of four years.

In general, curlyleaf control does not occur in the first growing season after an iron treatment, but control seems to occur in the second year (3 out of 6 sites) and curlyleaf control continues after that (except for Orchard Lake).

There is no other technique where a one-time application of a compound has been found to control curlyleaf for nine years. The key to long term curlyleaf control is to manipulate the lake sediments to create conditions that are not conducive to nuisance curlyleaf growth. Iron does not kill curlyleaf, but indirectly effects its growth characteristics by changing the sediment chemistry. Native aquatic plants are not effected by the sediment changes associated with iron additions (McComas, unpublished).


**Table 1. Summary of curlyleaf stem density results for four lakes after a single sediment iron treatment. Yes = indicates stem densities were below the nuisance benchmark of 150 stems/$m^2$ and the treatment met project objectives. No = indicates stem densities were not below the nuisance benchmark of 150 stems/$m^2$.**

| | Water Depth (ft) | Curlyleaf Control Years After Treatment | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Heine Pond | 4 | no | no | yes | yes | yes | yes | yes | yes | yes |
| Heine Pond | 7 | no | yes | yes | yes | yes | yes | yes | yes | yes |
| Lee Lake | 5.5 | ? | no | yes | yes | | | | | |
| Orchard Lake | 5.5 | no | no | yes | no | | | | | |
| Eagle Lake | 5 | no | yes | yes | | | | | | |
| Eagle Lake | 6 | yes | yes | yes | | | | | | |

# Introduction

A persistent problem on numerous lakes in Minnesota has been curlyleaf pondweed, a non-native aquatic plant, that can grow to heavy growth conditions and produce adverse impacts on water quality and impede navigation.

Previous research has found that mechanical harvesting and herbicides can alleviate heavy growth conditions for the season, but it takes an annual effort which also incurs an annual expense.

Recent studies have shown that curlyleaf growth seems to be naturally controlled with high levels of naturally occurring sediment iron and with a sediment pH less than 7.7.

The objective of adding iron filings to lake sediments, which would mimic conditions found in lakes with light or moderate curlyleaf growth, is to see if sediment iron additions can reduce the heavy growth of curlyleaf pondweed.

**Figure 1. Non-nuisance curlyleaf pondweed growing in an iron treated area in Orchard Lake in May 2006.**

# Methods

**Iron Application:** For lake applications, 4-inch diameter holes were drilled through the ice, thirty feet apart and approximately 60 pounds of iron filings were poured into each hole (Figure 2). The final sediment iron dose was equivalent to about 30 grams of elemental iron per square foot of lake bottom. Del Hogan and workers representing Clear Water Technologies, Inc. added the iron filings to all four lakes described in this report.

**Figure 2. [top] Iron addition into Orchard Lake on March 9, 2004.**
**[bottom] Pattern of holes drilled in the ice in Lee Lake through which iron filings were added.**

## Methods - continued

**Stem Density Determination:** Curlyleaf pondweed stem densities were quantified using a 0.1 $m^2$ quadrat (a square frame, with sides about 1-foot long). Curlyleaf stem counts were made with scuba diving efforts. Locations for stem counts were randomly selected within treatment and reference areas by swimming on a line for 5 strokes and then placing the quadrat on the lake bottom.

A curlyleaf density rating system was developed and is shown in Table 1. The objective of the iron additions was to lower stem densities to below heavy growth conditions.

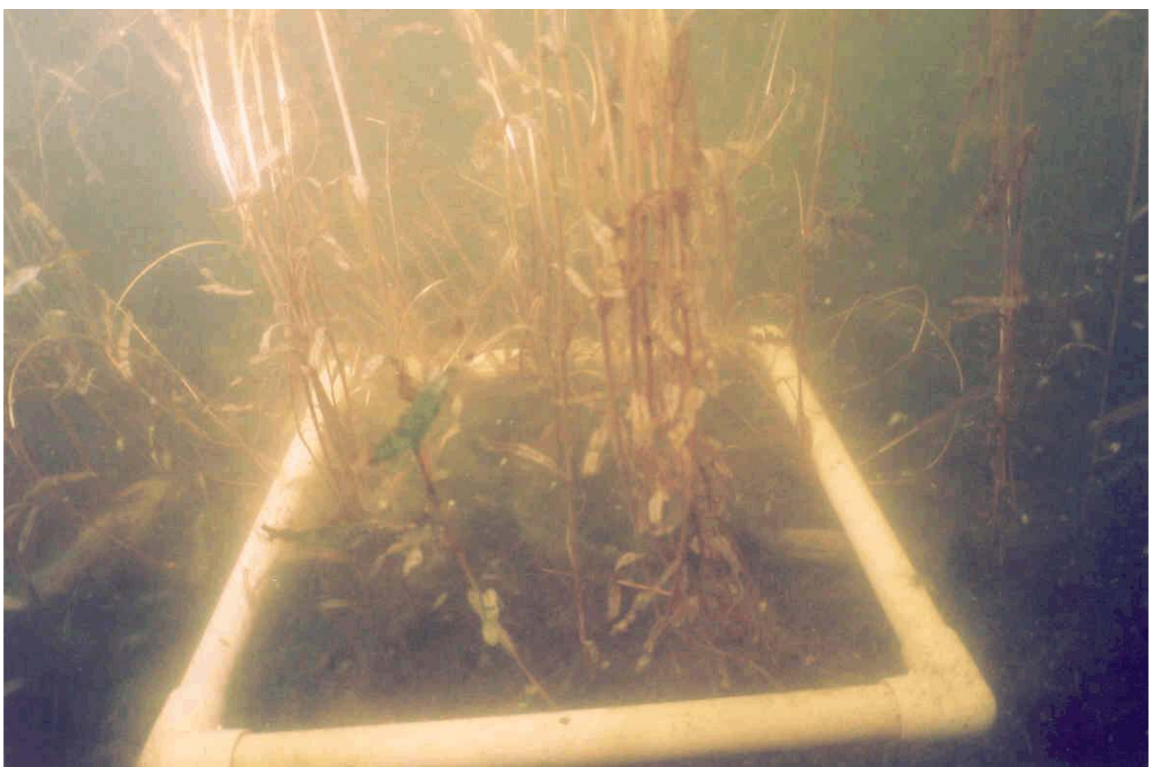


**Figure 3. The 0.1 $meter^2$ quadrat is in position on the lake bottom in Orchard Lake in May, 2006. All curlyleaf plants found within the square frame were counted.**

# Table 1. Curlyleaf Pondweed Growth Characteristics

## Light Growth Conditions

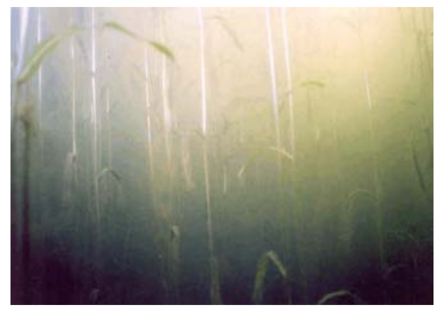
Plants rarely reach the surface.

Navigation and recreational activities are not generally hindered.

Stem density: 0 - 160 stems/$m^2$
Biomass: 0 - 50 g-dry wt/$m^2$
Estimated TP loading: <1.7 lbs/ac

*MnDNR rake sample density equivalent for non-nuisance conditions: 1, 2, or 3.*

## Moderate Growth Conditions



Broken surface canopy conditions.

Navigation and recreational activities may be hindered.

Lake users may opt for control.

Stem density: 100 - 280 stems/$m^2$
Biomass: 50 - 85 g-dry wt/$m^2$
Estimated TP loading: 2.2 - 3.8 lbs/ac

*MnDNR rake sample density equivalent for light nuisance conditions: 3 or 4.*

## Heavy Growth Conditions

Solid or near solid surface canopy conditions.

Navigation and recreational activities are severely limited.

Control is necessary for navigation and/or recreation.

Stem density: 400+ stems/$m^2$
Biomass: >300 g-dry wt/$m^2$
Estimated TP loading: >6.7 lbs/ac

*MnDNR rake sample density has a scale from 1 to 4. For heavy nuisance conditions where plants top out at the surface, the scale has been extended: 4.5 is equivalent to a near solid surface canopy and a 5 is equivalent to a solid surface canopy.*

## Heine Pond, Eagan, Minnesota

Heine Pond is a 7.4 acre pond in Eagan, Minnesota. Curlyleaf pondweed was first reported in Heine Pond in 1992 and an aquatic plant harvesting and cutting program was conducted in 1994 through 1997. In 1996, Heine Pond had a light alum treatment with an aluminum application of 6 g Al/m$^2$. However, curlyleaf continued to flourish.

Heine Pond was an experimental lake for sediment iron treatments applied to control curlyleaf pondweed. Iron was added in November, 1998 with an iron application of 323 g/m$^2$ (30 g/ft$^2$) in the littoral area and 75 g/m$^2$ (7 g/ft$^2$) in the profundal zone. A control area was not treated (Figure 4). Results are shown in Figure 5.

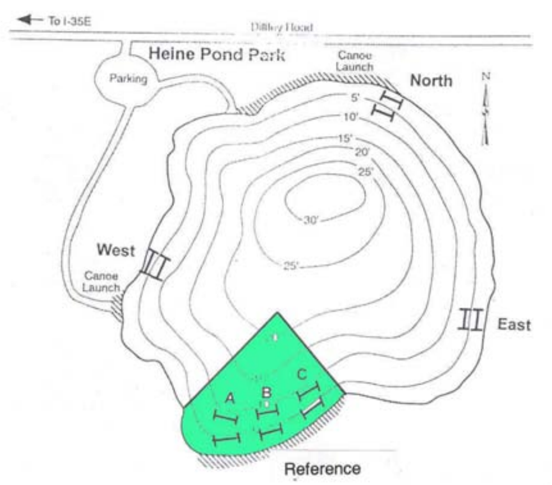



**Figure 4. Heine Pond iron treatment map. The shaded area represents the untreated reference area.**

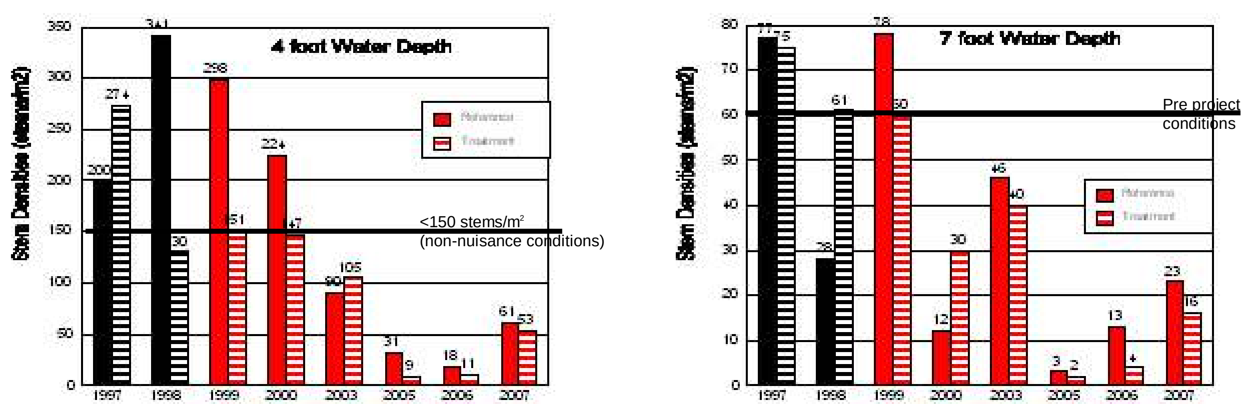



**Figure 5. Average of Heine Pond curlyleaf pondweed stem densities for reference and treatment sites for pre-treatment conditions in 1997 and 1999 (black bars) and for post treatment conditions (red bars).**

## Lee Lake, Lakeville, Minnesota

Lee Lake is a 25-acre lake in Lakeville, Minnesota. Iron filings were added to two ½-acre plots on March 10, 2004. In the treated area, sites were monitored within known heavy curlyleaf growth areas based on sampling from 2002 and 2003. Two reference areas were also delineated in known heavy growth areas (Figure 6). Results are shown in Figure 7.

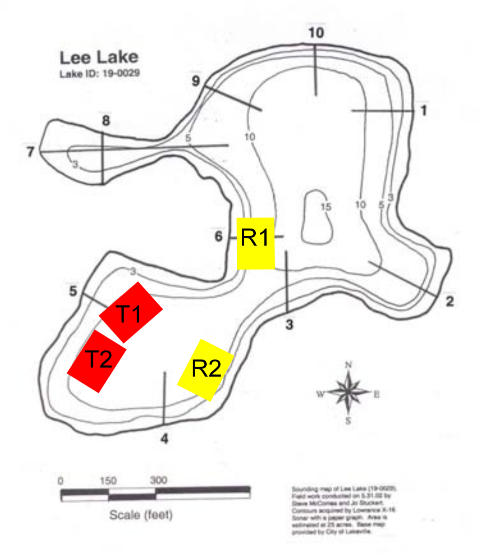



**Figure 6. Locations of treatment (T1 and T2) and reference (R1 and R2) sites.**

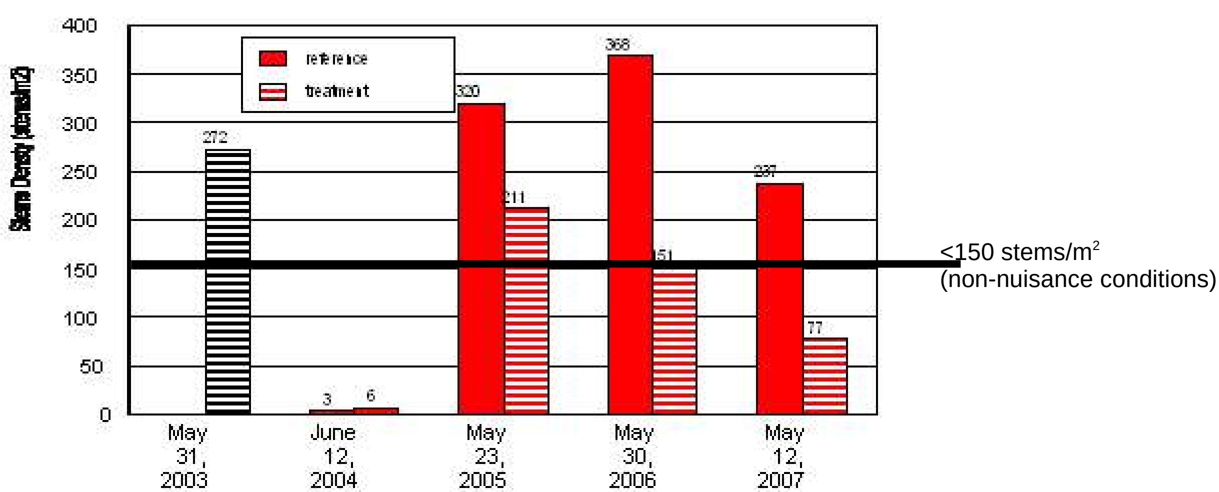



**Figure 7. Average of Lee Lake curlyleaf pondweed stem densities for reference and treatment sites for pre-treatment conditions in 2003 (black bar) and for post treatment conditions (red bars).**

## Orchard Lake, Lakeville, Minnesota

Orchard Lake is a 234-acre lake in Lakeville, Minnesota. Iron filings were added to two 1-acre plots on March 9, 2004. One site in each of the two treated plots was monitored within known heavy curlyleaf growth areas based on sampling from 2002 and 2003. In addition, two reference areas, located in known heavy growth areas, were also monitored (Figure 8). Results are shown in Figure 9.

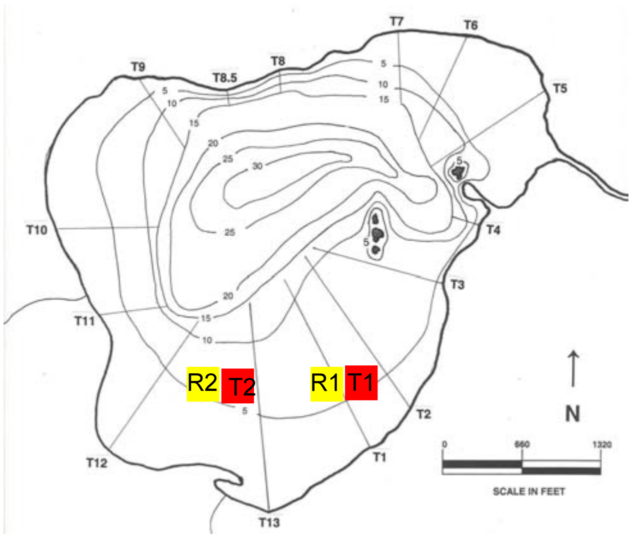



**Figure 2. Locations of treatment (T1 and T2) and reference (R1 and R2) sites.**

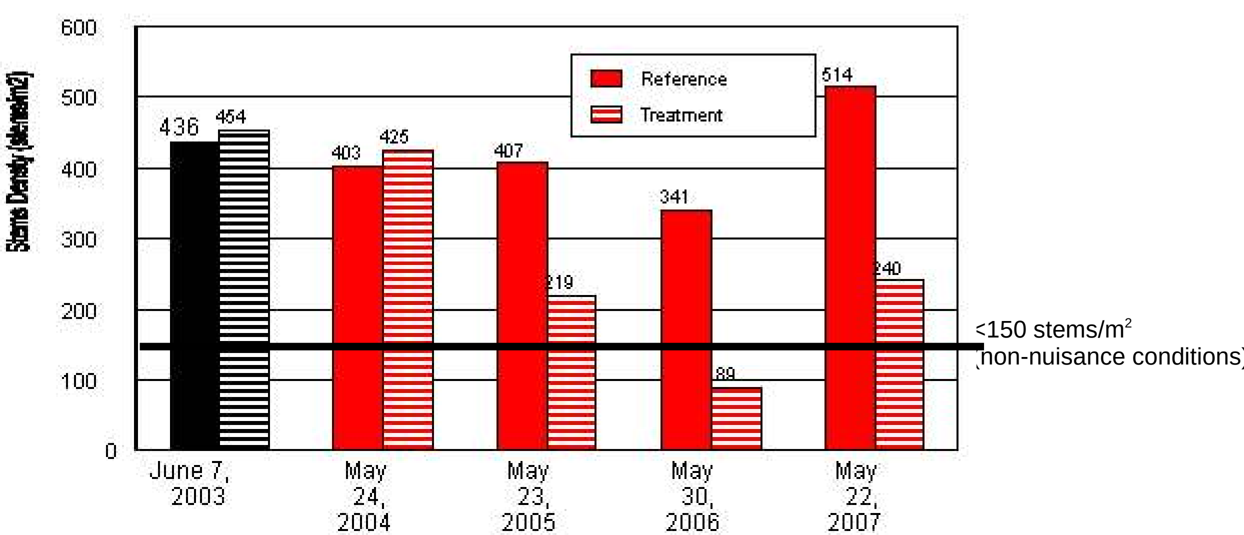



**Figure 9. Average of Orchard Lake curlyleaf pondweed stem densities for reference and treatment sites for pre-treatment conditions in 2003 (black bars) and for post treatment conditions (red bars).**

## Eagle Lake, Maple Grove, Minnesota

Eagle Lake is a 200-acre lake in Maple Grove, Minnesota. Iron filings were added to a two-acre plot in February 2005. Monitoring in the treatment site occurred within known nuisance curlyleaf growth areas based on previous monitoring by the Three Rivers Park District. An adjacent reference area with two sampling depths was also monitored and was located in known heavy growth areas (Figure 10). Results are shown in Figure 11.

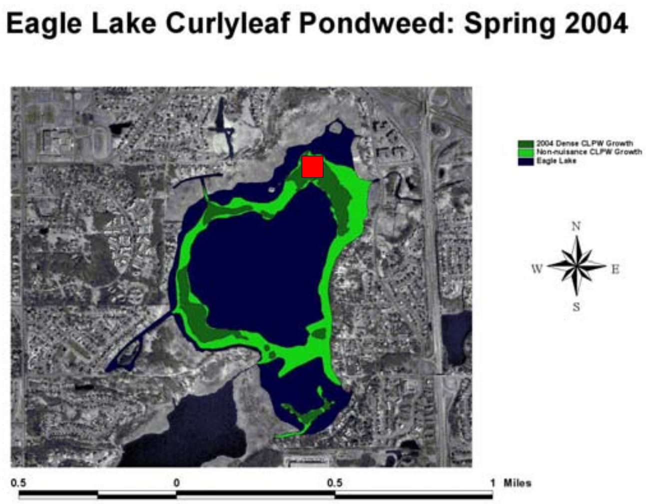



**Figure 10. Location of the iron treatment site in Eagle Lake, shown in red shading. Dark green areas indicate areas of heavy curlyleaf growth. Iron filings were added in an area of heavy curlyleaf growth. Plant survey and map was produced by Three Rivers Park District 2004.**

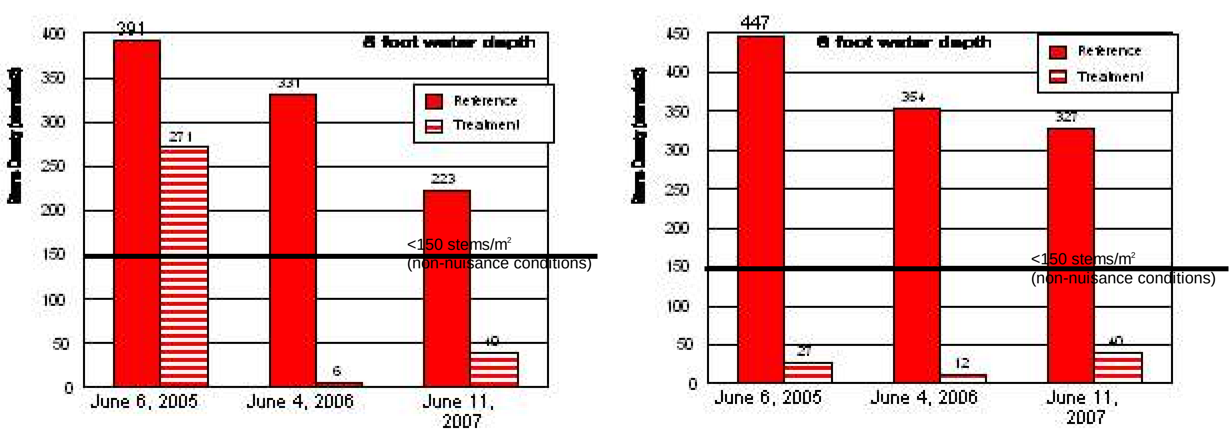



**Figure 11. Average of Eagle Lake curlyleaf pondweed stem densities for reference and treatment sites for post treatment conditions (red bars).**

# Discussion

The addition of iron filings to lake sediments increases the sediment iron content and seems to mimic what is found in natural lake sediments where light growth of curlyleaf pondweed is associated with a high iron concentration (Table 3). The role of iron may serve as a pH regulator. It appears that sediment pH is the master variable and sediment iron influences sediment pH. Lake sediment analyses in untreated lakes find that at high sediment iron concentrations, the sediment pH is low. At low iron concentrations, the pH is higher. Using these sediment characteristics, lake sediments can be tested and curlyleaf growth characteristics can be predicted. Examples of lake sediment sampling, predictions, and actual curlyleaf growth for Bald Eagle Lake (Figure 12) and for Rush Lake (Figure 13) are shown below.

**Table 3. Sediment characteristics related to curlyleaf pondweed growth for untreated lakes.**

| | Lake Sediments Supporting Light Growth (n=45) | Lake Sediments Supporting Heavy Growth (n=20) | t-Test (p<value) |
|---|---|---|---|
| pH | <6.8 | >7.7 | 0.00000000008 |
| Fe (ug/cm$^3$) | 150 | 48.8 | 0.000000000009 |
| Mn | 24.7 | 20.5 | 0.16 (ns) |
| Fe/MN | 5.3 | 1.6 | 0.00000004 |
| Bulk density (g/cm$^3$-dry) | 1.0 | 0.51 | 0.00002 |
| Organic matter (%) | 7.27 | 20.2 | 0.001 |
| Nitrogen ($NH_4$-N) (ug/cm$^3$) | 11.9 | 4.07 | 0.0000006 |

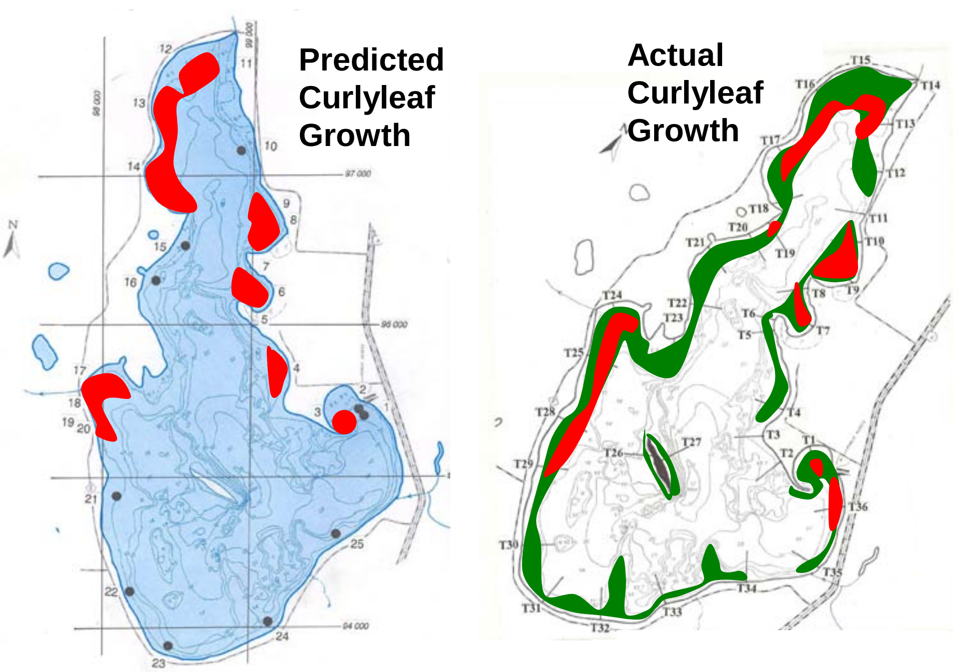
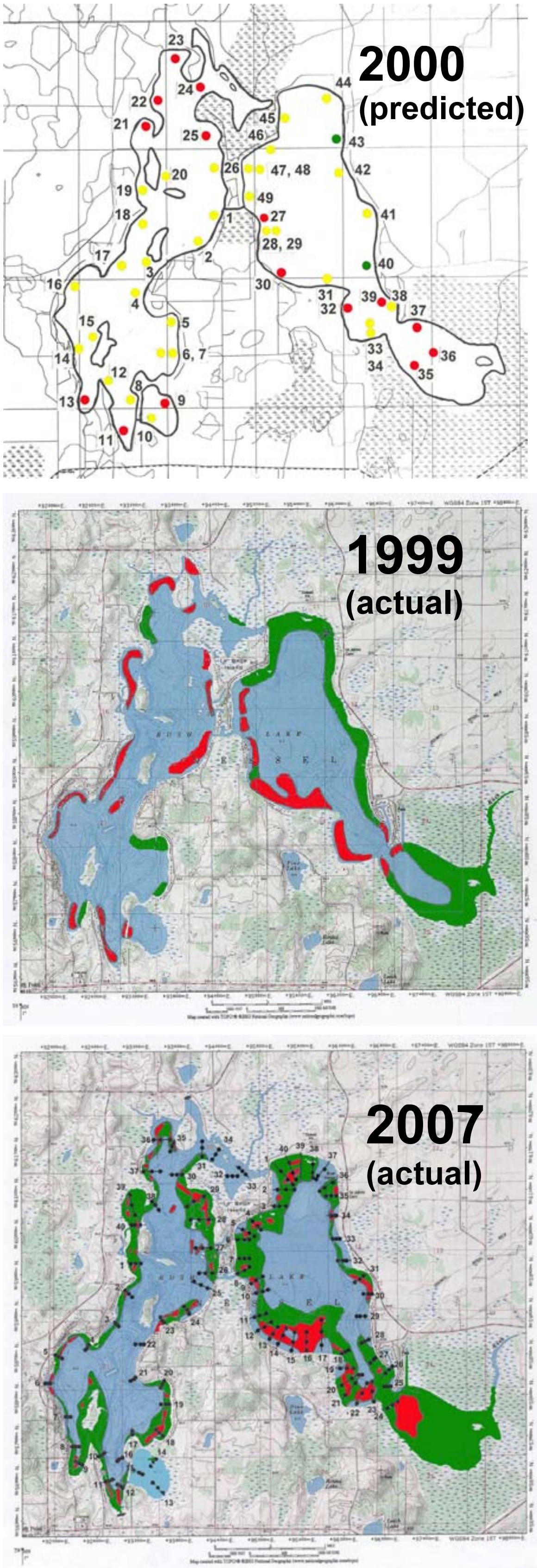



**Figure 12. Predicted heavy growth of curlyleaf pondweed based on sediment characteristics and actual growth for Bald Eagle Lake. Red shading indicates areas of heavy growth.**




**Predicted Curlyleaf Growth in Rush Lake**

| Legend | |
|---|---|
| ! (green) | Potential for non-nuisance growth. |
| ! (yellow) | Potential for light nuisance growth. |
| ! (red) | Potential for heavy nuisance growth. |

**Rush Lake:** Based on sediment characteristics collected in 2000 curlyleaf growth characteristics for Rush Lake were predicted and are shown in the top map. Actual curlyleaf growth characteristics are shown in the bottom maps. Sediment analysis has predicted heavy curlyleaf growth fairly accurately.

**Figure 13. Predicted heavy growth of curlyleaf pondweed based on sediment characteristics and actual growth for Rush Lake. Red shading indicates areas of heavy growth.**