2009 Lake Manitou Aquatic Vegetation Management Plan Update
Fulton County, IN
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Prepared for:
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Executive Summary

SePRO Corporation was contracted by the Indiana Department of Natural Resources (IDNR) to update the 2005 Lake Manitou long-term integrated aquatic vegetation management plan. Funding for development of this update was provided by IDNR. SePRO completed an update in 2007 following the first season of whole lake Sonar treatments for control of hydrilla (*Hydrilla verticillata*) and again in 2008 following a second season of treatments (SePRO 2008 & 2009). Items covered in this update include the 2009 sampling results and discussion, a review of the 2009 vegetation management effort, and updates to the budget and action plans.

The focus of the Lake Manitou vegetation management plan has shifted due to the discovery of hydrilla in 2006. Eradication of hydrilla is now the primary aquatic plant management goal for Lake Manitou. Hydrilla is an exotic invasive species that can form dense populations that disrupt ecosystems, displace native species, and impair fish and wildlife habitat. This was the first confirmed case of hydrilla in the Midwest. IDNR took quick action by closing all ramps, public and private, on the lake, and contracted the application of a fast-acting contact herbicide (i.e. Komeen; a.i. chelated copper) to reduce the potential for spread of vegetative fragments.

The Indiana Department of Administration and IDNR issued a Request for Proposal for hydrilla eradication on Lake Manitou on January 26, 2007. SePRO was awarded a three year contract for the hydrilla eradication project, and quickly teamed with ReMetrix LLC (Carmel, IN), Aquatic Control, Inc. (Seymour, IN) and Aquatic Weed Control, Inc (Syracuse, IN) to complete the project. Fluridone treatments were initiated in 2007 with the objective of maintaining > 6 ppb for 180 days. Applications were completed with a combination of Sonar AS and Sonar Q. No hydrilla was detected during the August 27 Tier II survey. Hydrilla tuber sampling was completed just prior to and 5 months after initial treatment and revealed hydrilla tuber numbers were significantly reduced (86% total reduction) from pretreatment densities, however, as expected viable tubers remained.

Modifications were made to the 2008 treatment prescription in an attempt to increase selectivity. Sonar pellet formulations were switched from Sonar Q, which was applied throughout the littoral zone in 2007, to Sonar PR, which was only applied to areas where hydrilla was previously documented and in a small inflow area. In addition, the whole lake concentration was to be maintained above 3 ppb instead of 6 ppb, with more frequent bump applications to minimize exposure of native species to relatively high concentrations. An initial treatment was completed in mid-May and followed by three bump applications in order to maintain fluridone levels. No hydrilla was detected during the 2008 Tier II surveys, but fragments were observed during FasTEST sample collection. The public boat ramp was opened in late June 2008. Tuber sampling indicated a 43% reduction had occurred in the tuber bank.

The same fluridone prescription used in 2008 was to be applied to the 2009 treatment program. Initial application was completed on May 14th with a combination of Sonar AS and PR. Thirty six gallons of Sonar AS and 1,010 pounds of Sonar PR were strategically applied to different areas of

the lake. Sonar PR was applied to 19 different locations where hydrilla had been documented in previous surveys and one location at the inflow. Sonar AS (6 ppb) was spread evenly over the entire lake. Bump applications were completed on June 17th, July 29th, and September 9th. A combination of Sonar AS and PR were applied during the June and July bumps while only Sonar AS was applied during the September bump. Tier II vegetation surveys were completed on June 16th and August 31st. No hydrilla was detected during either survey. One damaged hydrilla fragment was discovered during the June 22nd vegetation monitoring. This was the only documented observation of vegetative hydrilla during the 2009 season. The six permanent tuber sampling sites were sampled on October 5th. Sampling indicated that a further 19% reduction in the tuber bank occurred in 2009.

The hydrilla control efforts on Lake Manitou have continued to be successful in taking steps towards the stated goal of eradication. Three years of management have significantly reduced hydrilla tuber densities, prevented new hydrilla tuber production, and restricted the potential for hydrilla to spread to other waters in the region.

A Manitou Summit meeting to review and discuss the hydrilla eradication program with outside personnel as recommended in the 2008 AVMP update was held December 8, 2009. Attendees included; IDNR employees (Doug Keller, Aquatic Invasive species Coordinator; Tom Flatt, Habitat Coordinator; Jeremy Price, District Fisheries Biologist; Chip Long, Assistant Fisheries Biologist; Angela Studervant, Biologist, LARE Program), SePRO personnel (Dr. Tyler Koschnick, Director Research & Regulatory Affairs, Bob Johnson, Midwest Aquatic Specialist), ReMetrix LLC personnel (Richard Dirks, Geospatial Data Analyst), Aquatic Control Inc. personnel (David Isaacs, President; Nathan Long, Vice President), Aquatic Weed Control personnel (Jim Donahoe, President; David Keister, Biologist), Dr. Michael Netherland, US ACOE; Dr. Patrick Akers, CA hydrilla program manager; Dr. Lars Anderson (via conference call). Presentations were made by Doug Keller, Dr. Koschnick, Dr. Anderson, Dr. Netherland, and Richard Dirks. Review of historical information and details of the Manitou project and research updates were presented. Discussion of the information resulted in a general consensus that the Manitou project was progressing as would be expected and should be extended until the tuber monitoring program indicated eradication had been accomplished. Consensus of the group was that the current eradication program using a combination Sonar AS and Sonar PR protocol was working well and should be continued if funding was available. An optional treatment program using Sonar pellets only was discussed and recommended for consideration if budget limitations required a reduction in cost of the program. Modifications of the current program and an optional pellet only program were developed for consideration by the IDNR to continue the eradication program. These are presented in the Action Plan Update section.

The following is a list of recommended actions specifically designed to continue toward the goal of hydrilla eradication in Lake Manitou:

1. Continue the modified Sonar AS and Sonar PR treatment protocol or adopt the optional pellet-only treatment protocol should the IDNR choose that option.
2. Complete two Tier II surveys and regularly scheduled reconnaissance surveys in order to monitor the treatment effectiveness and impacts on native vegetation, as well as increased survey efforts for hydrilla if the pellet-only option is chosen.
3. Continue to focus tuber sampling efforts to the permanent monitoring stations in the fall. IDNR-approved modifications to the tuber sampling stations, exampled by the deletion of Station 1 which has not yielded any tubers in two consecutive sample years, are recommended. Increased sampling is expected as tuber densities decrease. Modifications to existing plans will take into consideration tuber densities, distribution, and attrition level in relation to control methods. Additionally, a goal for consecutive sampling events without finding tubers at the monitoring stations will be considered before aborting the active control phase of the eradication program.
4. Maintain ramp closures and inspections until sampling can be completed that indicates there is no vegetative hydrilla present in Lake Manitou. The actions to eradicate and isolate hydrilla to Lake Manitou have, without question, reduced the potential for spread to other waters in Indiana and the Midwest.
5. IDNR should continue with public education efforts in an attempt to prevent additional hydrilla introductions to Lake Manitou and other lakes in the region.

Acknowledgements

Funding for vegetation sampling, herbicide treatment, and preparation of the aquatic vegetation management plan was provided by the IDNR. Aquatic Control, Inc., Aquatic Weed Control, Inc., ReMetrix LLC, and SePRO Corporation completed the fieldwork, data processing, and map generation. Special thanks to Mr. Doug Keller, Aquatic Invasive Species Coordinator from the IDNR, for his assistance on this plan. In addition, special thanks are given to the Lake Manitou Association for their efforts. Authors of this report are Dr. Mark Heilman, Dr. Tyler Koschnick, and Mr. Bob Johnson of SePRO, Mr. Nathan Long of Aquatic Control, Inc., and Mr. Richard Dirks of ReMetrix LLC. The authors would like to acknowledge the valuable input from the staff of SePRO Corp., Aquatic Control, Inc., Aquatic Weed Control, Inc., and ReMetrix LLC.

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1.0 INTRODUCTION

This report was created in order to update the Lake Manitou Aquatic Vegetation Management Plan. In 2004, the Lake Manitou Association was awarded a grant through the Lake and River Enhancement (LARE) program to complete the original Lake Manitou Aquatic Vegetation Management Plan. Aquatic Weed Control completed the original plan in March of 2005 (Donahoe & Keister 2005). The Association was awarded grants again in 2005 and 2006 to update the plan and these updates were also completed by Aquatic Weed Control (Donahoe & Keister 2006 & 2007). The Indiana Department of Natural Resources (IDNR) took over funding vegetation management on Lake Manitou in 2007 following the discovery of hydrilla. SePRO completed updates to the plan in 2008 and 2009 (SePRO 2008 & 2009). The following management goals were established by the original plan:

1. Develop or maintain a stable diverse aquatic plant community that supports a good balance of predator and prey fish and wildlife species, good water quality, and is resistant to minor habitat disturbances and invasive species.
2. Direct efforts to preventing and/or controlling the negative impacts of aquatic invasive species.
3. Provide reasonable public access while minimizing the negative impacts on plant and wildlife species (Donahoe & Keister 2005).

Lake Manitou is an 809-acre lake located in Fulton County, Indiana. The primary purpose of the 2009 vegetation sampling and plan update is to document recent hydrilla eradication activities and to adjust the management plan as needed following the introduction of hydrilla into Lake Manitou in 2006. Items covered include the 2009 sampling results, a review of the 2009 vegetation management activities, and updates to the action plan. Once reviewed and approved, the update should be included in the original vegetation management plan, following the 2008 update but prior to the Appendix.

The original Lake Manitou Aquatic Vegetation Management Plan was created in 2004 and updates were completed in 2005, 2006, 2007, and 2008. The control of Eurasian watermilfoil was the primary objective of the original plan. This changed in August of 2006 when IDNR discovered hydrilla during a routine Tier II survey. This discovery precipitated a rapid response by IDNR Aquatic Invasive Species Coordinator, Doug Keller.

Upon confirmation of species, access to the lake was immediately closed to the public to prevent the potential for spread through boats and boat trailers (Figure 1.0.1). Due to a lack of viable hydrilla fragments following treatment, the public ramp was re-opened in June of 2008 but closed on April 27, 2009. The IDNR public ramp was opened again on July 1st and was still open at the time of the creation of this update.

Figure 1.01. Public notices posted at Lake Manitou public launches.

Hydrilla is an exotic invasive species that can form dense populations that disrupt ecosystems, displace native species, and impair fish and wildlife habitat. It has unique physiological and biological characteristics that can create a competitive advantage over many native submersed plant species, and has been termed "The Perfect Aquatic Weed" (Langeland 1996). Hydrilla has a low light and CO_2 compensation point compared to some native submersed plant species (Van et al. 1976); can switch between C_3 and C_4 carbon utilization under limiting conditions (Rao et al. 2002); forms dense canopies at the water surface which limits light penetration (Haller and Sutton 1975); and can have up to 85% of its biomass in the top 2 feet of water. Hydrilla can create an environment that is difficult for other plant species to effectively grow and compete (Figure 1.01). If hydrilla was not eradicated or its spread contained, it likely would rapidly spread to other waters, form monocultures of vegetation, impede recreation, reduce biodiversity, and result in biological pollution in many shallow lakes of Indiana. <u>Eradication of hydrilla is now the primary goal of vegetation management in Lake Manitou.</u>

Figure 1.02. Once established, hydrilla can quickly colonize available habitat with monospecific stands, out-competing exsiting native or endemic species.

Lake Manitou was the first confirmed location of hydrilla in the Midwest. Hydrilla is the number one aquatic plant problem in the U.S. with more money expended on management than for any other aquatic plant species. Other states have taken aggressive approaches against hydrilla recognizing the potential impact this species can have on recreation, water conveyance, biodiversity, and water use. California legislatively mandated an eradication program after the plant was identified in the State in 1976; Washington and Maine enacted eradication programs shortly after identifying hydrilla; hydrilla was discovered in Wisconsin in 2007 with eradication efforts underway; recently hydrilla was identified in New York, Idaho, and Kansas with aggressive control program being initiated. Many of these programs have, at a minimum, minimized the potential for further spread of hydrilla within the state by keeping the population at the lowest possible level and decreasing vegetative production.

Hydrilla can be easily spread through fragmentation, so control of this species took precedence over all other aquatic vegetation control efforts on Lake Manitou. Shortly after discovery, IDNR personnel mapped the hydrilla population in Lake Manitou and contracted Aquatic Weed Control, Inc., to treat approximately 20 acres of hydrilla in the lake with Komeen (the Poet's Point area in the northern section of the lake, and near the City ramp). The treatment was effective in controlling extant hydrilla biomass in the treatment areas to reduce potential for vegetation spread in Lake Manitou and downstream. Further surveys conducted independently

by IDNR personnel and SePRO personnel (Figure 1.03) confirmed additional sites in the lake with hydrilla. This led to a Request for Proposal (RFP) for a comprehensive hydrilla eradication program for Lake Manitou.

Figure 1.03. Lake Manitou hydrilla sightings 2006-2009. (Includes all sightings recorded by the project team and IDNR.)

SePRO Corporation was awarded a three-year contract and assembled a team focused on the management of vegetation in Lake Manitou, with the objective of hydrilla eradication. The team consisted of personnel from Aquatic Control, Inc., Aquatic Weed Control, Inc., ReMetrix LLC, and SePRO. Fluridone treatments were initiated in 2007 with the objective of maintaining greater than 6 ppb for 180 days. Applications were on May 18 with a bump application on June 26. Applications were completed with a combination of Sonar AS and Sonar Q. A Tier II aquatic vegetation survey was completed on May 31 and indicated that hydrilla was severely damaged by the initial treatment. No hydrilla was detected during the August 27th Tier II survey. Hydrilla tuber sampling was completed just prior to and 5 months after initial treatment and revealed hydrilla tuber numbers were significantly reduced (86% total reduction) from pretreatment densities, however, as expected viable tubers remained. In addition to the tuber reduction, the treatment program also provided successful control of hydrilla biomass throughout the 2007 season.

Modifications were made to the 2008 treatment prescription in an attempt to increase selectivity. Sonar pellet formulations were switched from Sonar Q, which was applied throughout the littoral zone in 2007, to Sonar PR, which was only applied to areas where hydrilla was previously documented and in a small inflow area. In addition, the whole lake concentration was to be maintained above 3 ppb instead of 6 ppb, with more frequent bump applications to minimize exposure of native species to relatively high concentrations.

In 2008, Sonar treatments were initiated on May 14th. Sonar PR (2.2 ppb) was applied to 18 different locations where hydrilla had been documented in previous surveys and one location at the inflow. Sonar AS (6 ppb) was spread evenly over the entire lake. Bump applications were completed on June 30th, August 19th, and October 8th. A combination of Sonar AS and PR were applied during the June and August bumps while only Sonar AS was applied during the October bump. Tier II vegetation surveys were completed on June 16th and August 27th. No hydrilla was detected during either survey, and Chara (*Chara spp.)* was dominant in both surveys. Following the June Tier II survey, IDNR opened the public boat launch. However, during the June 26th reconnaissance survey four hydrilla plants and fragments were detected floating along the north shore. This was the only confirmed observation of hydrilla during the 2008 season, with the exception of sprouting tubers. The six permanent tuber sampling sites were sampled on September 19th. Sampling indicated that a 43% reduction in the tuber bank occurred in 2008. Recent Lake Manitou invasive species treatment history is summarized below in Table 1.0.1.

Table 1.0.1. Lake Manitou Invasive Species Control History 2005-2009.

Year	Invasive Species Treated	Acres Treated	Product(s) Applied
2005	Eurasian watermilfoil	45	2,4-D
2006	Eurasian watermilfoil & Hydrilla	95 milfoil & 20 hydrilla	2,4-D & Copper (Komeen)
2007	Hydrilla	809 (whole Lake)	Fluridone (Sonar AS & Sonar Q)
2008	Hydrilla	809 (whole Lake)	Fluridone (Sonar AS & Sonar PR)
2009	Hydrilla	809 (whole Lake)	Fluridone (Sonar AS & Sonar PR)

In 2009 the hydrilla eradication team remained the same and a program similar to 2008 was initiated. The following sections will detail the progress of the 2009 hydrilla eradication program along with future Lake Manitou plant management plans.

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2.0 VEGETATION SAMPLING

Vegetation sampling activities varied little from 2008 with the exception of the removal of the spring tuber sampling event. Standard Tier II surveys (IDNR 2006) were completed on June 16th and August 31st to monitor the hydrilla population and quantify native species abundance. In addition, visual observations of the plant community were recorded throughout the season during FasTEST sampling. These observations aided in the timing of initial Sonar application, surveyed for potential hydrilla biomass, and provided insight into the progress of the treatments. Hydrilla tuber sampling was completed on October 5th to monitor depletion of the tuber bank. Table 2.0.1 is a summary of 2009 plant survey activities on Lake Manitou.

Table 2.0.1. Summary of 2009 Plant Surveys on Lake Manitou. 2009 herbicide treatment dates: May 14 (initial Sonar); June 17, July 29, and September 9 (Sonar bumps).

Date (2009)	Type of Survey
May 18	Reconnaissance Survey
June 8	Reconnaissance Survey
June 16	Tier II Survey
June 22	Reconnaissance Survey
July 9	Reconnaissance Survey
July 20	Reconnaissance Survey
August 3	Reconnaissance Survey
August 17	Reconnaissance Survey
August 31	Tier II Survey
September 21	Reconnaissance Survey
October 5	Reconnaissance Survey
October 5 & 6	Tuber sampling
October 19	Reconnaissance Survey
November 2	Reconnaissance Survey
November 16	Reconnaissance Survey

2.1 Reconnaissance Surveys

For reference: the initial Sonar treatment was conducted on May 14, 2009; bump treatments were conducted on June 17, July 29, and September 9, 2009. Details of the treatments can be found in Section 4.0.

Reconnaissance surveys were completed during FasTEST collections, and were the most frequent type of survey completed (Table 2.0.1). Surveyors followed a pre-established route designed to maneuver over known areas of hydrilla (Figure 2.1.1) Along with collecting FasTEST samples, personnel recorded information at each of the eight sample sites on plant species presence, injury, cover, and growth ratings, Secchi depth, and surface temperature. Dissolved oxygen/temperature profiles were also taken at the predetermined FasTEST site 2. Water samples were collected on three separate occasions at FasTEST site 2 to monitor orthophosphate, total phosphorus, and chlorophyll α (water quality monitoring will be discussed further in Section 3.0). Individual monitoring data sheets are included in the Appendix.

Figure 2.1.1. FasTEST monitoring/vegetation reconnaissance survey route

Surveying, in conjunction with water sampling, provided a rapid and cost effective means of assessing the effectiveness of the treatment program. This information, combined with the FasTEST results, helped determine the timing and necessity of bump applications. This survey

was responsible for the only observation and collection of hydrilla during the 2009 season (with the exception of tuber sampling). Four hydrilla plants and fragments were found along the north shore between the city access and Poet's Point during the June 22nd survey (Figures 2.1.2 and 2.1.3). A summary of the reconnaissance survey results for 2009 is provided below in Table 2.1.1

Figure 2.1.2. Hydrilla found on Lake Manitou during semimonthly vegetation monitoring and FasTEST sampling on June 22, 2009. Note fluridone activity evidenced by bleaching of vegetative structures.

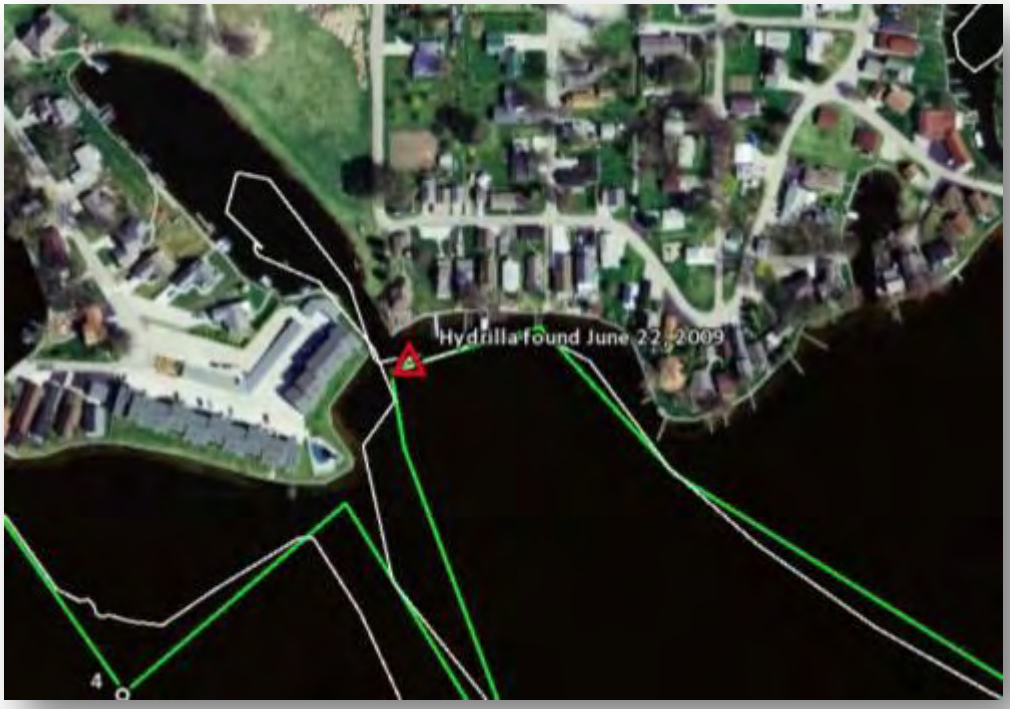

Figure 2.1.3. Location of hydrilla discovery, June 22, 2009

Table 2.1.1. Lake Manitou, FasTEST collection plant monitoring summary

Collection Date	Surface-T range (˚F)	Secchi depth (ft)	Species Observed and Injury Rating[a]
May 18	60.0-65.3	2.4-5.1	Chara (5)
June 8	70.3-72.6	2.3-4.5	Chara (2)
June 22	79.3-81.9	2.5-3.4	Chara (2) [Note: hydrilla observed along survey route; not found on rake]
July 9	75.2-77.8	2.9-4.3	Chara x2 (2)
July 20	75.3-79.7	2.4-4.8	n/a
Aug 3	74.3-75.7	2.8-4.2	n/a
Aug 17	79.2-80.8	2.8-4.8	coontail (3)
Aug 31	71.0-74.9	3.1-4.2	Sago (3), Chara (3)
Sept 21	70.9-71.9	4.1-5.3	Chara (3)
Oct 5	57.9-60.9	4.5-5.5	n/a
Oct 19	49.9-53.3	4.8-6.2	n/a

[a] Injury rating from 1-6 (1-healthy, 2-slight injury, 3-moderate injury, 4-severe injury, 5- dead plant, 6 – not present). Chara = *Chara* sp.; Sago = Sago pondweed; n/a = no plants found.

2.2 Tuber Sampling

2.2.1 Fall Tuber Sampling

Since the initiation of whole-lake hydrilla eradication efforts on Lake Manitou in 2007, the attrition of subterranean hydrilla turions (hereinafter referred to as tubers) has been monitored to confirm impacts of the multiple-year Sonar treatment program. On October 5-6, 2009, near the completion of the 3rd year of consecutive whole-lake eradication treatment, tubers were monitored at each of six permanent stations established in 2007 – 2008 (Figure 2.2.1). Stations 1 - 5 were established at the start of the hydrilla eradication project in May 2007. Station 6 was added during sampling in May 2008. All six stations were monitored in September 2008 and October 2009. Due to decreasing tuber densities in all permanent stations, at discretion of IDNR and management team, tuber density monitoring at the six permanent stations in 2009 was limited to a fall collection event. The 2009 collection protocol called for an initial collection of 100 sediment cores at each station. At stations where the initial 100 cores did not yield collection of a tuber, an additional 50 cores were collected to boost sampling intensity. A description of the sediment sampling methods and objectives were previously described in the *Lake Manitou Aquatic Vegetation Management Plan Update, Fulton County, IN, March 14, 2008*.

In fall 2009 sampling, a total of 25 tubers were collected from 700 total core samples: 24 in core samples and one floating (likely dislodged by the core sampler or anchor) (Table 2.2.1). Only tubers found in sediment cores were included in subsequent tables, figures, and analysis. Tubers found sprouting had no obvious above ground stem tissue, but during sampling, 4 detached sprouts (tissue detached from tubers) were also collected. The detached sprouts likely were broken off from other tubers during collection. Unsprouted tubers collected in the October 2009 survey were not assayed for viability, but based on 2007 (100% viable) and 2008 (83% viable) tests, it is likely that the vast majority remain viable.

Table 2.2.1. Summary data for six permanent hydrilla tuber monitoring stations sampled October 5-6, 2009. 100 4-inch diameter (0.0876 $ft^2 = \pi \times 0.167' \times 0.167'$) core samples were taken from Stations 2, 4, 5 and 6, and 150 cores were taken from Stations 1 and 3. No aboveground turions were found.

Site	GPS Waypoint	Sprouting hydrilla tubers	Non-sprouting hydrilla tubers	Number of core samples
Lighthouse Bay Station 1	083 T1	0	0	150
Dollar Store Bay Station 2	084 T1	0	1	100
White Dock Station 3	085 T1	0[a]	0	150
Poet's Point Station 4	086 T1	0	3	100
Poet's Bay Station 5	087 T1	3[b]	13	100
Lighthouse North Station 6	057 T1	3	1	100
TOTAL		**6**	**18**	**700**

[a] One detached hydrilla sprout and one curly-leaf pondweed turion also collected.
[b] Three detached sprouts and one floating tuber also collected.

Figure 2.2.1. Location of the six permanent tuber sampling stations. Sites 1 through 5 were established May 2007. Site 6 was established May 2008.

2.2.2 Tuber Sampling Summary (2007-2009 data)

The hydrilla management plan on Lake Manitou and associated control methods have been highly successful at reducing hydrilla tuber densities. Following three consecutive Sonar treatments, overall measured tuber abundance (sprouted and non-sprouting with corrections for sampling area) has decreased by 94% at the permanent sampling stations between May 2007 (pre-treatment) and October 2009 (Table 2.2.2 and Chart 2.2.1). Over the three season period, sprouting tuber density has decreased 98% and non-sprouting tuber density has decreased 84%. Looking at annual trends in attrition rate, the total tuber density (sprouting and non-sprouting) was reduced by 88% following the 1st year of Sonar treatment, with an additional 42% reduction after the second year, and an additional 19% reduction after the third year. Annuals reductions in sprouted tuber density were 95%, 41%, and 31% respectively over the three years of collection, while non-sprouted tubers declined by 68%, 42%, and 14% respectively over the same period of time. (Note: any minor differences in percent reductions from 2008 report due to differences in rounding associated with data correction for core sampling area).

Analysis of these three-year results indicates a decreasing tuber attrition rate at the six permanent monitoring stations on the lake (Charts 2.2.1, 2.2.2, and 2.2.3). Measured attrition rate has declined by approximately half with each annual cycle of management. This decline in attrition rate with each management cycle may be the result of reduced tuber sprouting rates over the course of the entire growing season. While late season survey results do not detect much annual difference in the proportion of sprouted versus unsprouted tubers collected (sprouted tubers were 29%, 29%, and 25% of total tubers collected in 2007, 2008, 2009, respectively), reduced sprouting for some portion of the growth season, most likely in the spring, could result in a growing proportion of the remaining tuber bank not being affected by an annual cycle of treatment. Complete monitoring of year-to-year, within-season trends in tuber sprouting is beyond the scope of the current tuber monitoring program, which has been narrowed to a single collection event in the fall to confirm full-season progress towards the ultimate management objective: hydrilla tuber bank eradication.

These latest data suggesting greater dormancy for remaining hydrilla tubers in Lake Manitou have implications for the long-term planning of management towards a goal of full hydrilla eradication. At the end of 2008, projections of decline in tuber abundance based on non-linear regression as well as constant attrition rate based on the last two collection results (42%) indicated that total attrition of the tuber bank (described as >99.5% of original May 2007 total numbers) would take between 2.6 – 4.5 years (Chart 2.2.2). Fall 2009 results document a greater persistence of tubers than predicted from either 2008 projection. If the first season's results (Year 0 to Year 1) are dropped (which also removes potential seasonal artifact), non-linear regression on remaining Year 1 – Year 3 results produces a model for attrition with improved agreement with actual measured reductions (Chart 2.2.3). Projection of tuber bank decline based solely on 2008-2009 attrition rate (19%) produces a flatter response curve than the regression model. Therefore, the revised non-linear model may still overestimate the rate of future hydrilla tuber attrition. Comparing both 2009 revised models for projected future

attrition, 99.5% attrition of the initial 2007 tuber bank would be projected to take between 8.6 and 14.7 years.

The notable increase in the number of projected annual cycles of whole-lake treatment to reach eradication of the lake's hydrilla tuber bank suggests that the overall multiple-year effort and cost to achieve true eradication may be 3-4X greater than indicated by the previous year's update report. Although the current data and models may still not be considered definitive without further assessment over perhaps another annual cycle or two, current information suggests that IDNR, SePRO, and their project partners should continue to examine and optimize future management strategy to gain long-term improvements and efficiencies. Functionally today, after multiple years of management, hydrilla on Lake Manitou has been suppressed to levels that pose a minimal short-term risk of inter-lake spread and ecological impairment. However, the natural aggressiveness of hydrilla that promoted a quick early infestation and necessitated a rapid response to management must still be considered when determining the long-term management approach. Intensive management will be required for Lake Manitou to prevent future hydrilla expansion. Future analysis will determine the functional outcome of this long-term management towards a full eradication goal or some other optimal, sustainable solution for maintenance and containment.

Table 2.2.2. Sprouted, Unsprouted, and Total Hydrilla Tubers Corrected For Sampled Area: A – Per Square Foot; B – Per Acre. Also presented are Annual Percent Reductions and Percent Reductions since 2007 Start of Manitou Hydrilla Management Program

A. Tubers Per Square Foot	Sprouted Tubers Per Square Foot					Unsprouted Tubers Per Square Foot					Total Tubers Per Square Foot (Sprouted and Unsprouted)				
	May 14-17 2007	Sept. 17 2007	May 12-14 2008	Sept. 15 2008	Oct. 5-6 2009	May 14-17 2007	Sept. 17 2007	May 12-14 2008	Sept. 15 2008	Oct. 5-6 2009	May 14-17 2007	Sept. 17 2007	May 12-14 2008	Sept. 15 2008	Oct. 5-6 2009
Station 1 WPT83	1.83	0.22	nd[a]	0.00	0.00	0.00	0.00	nd[a]	0.00	0.00	1.83	0.22	nd[a]	0.00	0.00
Station 2 WPT84	3.65	0.00	nd[a]	0.91	0.00	4.79	0.46	nd[a]	1.37	0.11	8.45	0.46	nd[a]	2.28	0.11
Station 3 WPT85	7.76	0.46	nd[a]	0.00	0.00	3.20	0.46	nd[a]	0.23	0.00	10.96	0.91	nd[a]	0.23	0.00
Station 4 WPT86	9.13	0.43	nd[a]	0.00	0.00	0.46	1.72	nd[a]	0.46	0.34	9.59	2.15	nd[a]	0.46	0.34
Station 5 WPT87	2.51	0.15	nd[a]	0.23	0.34	0.68	0.76	nd[a]	0.23	1.48	3.20	0.91	nd[a]	0.46	1.83
Station 6 WPT57	nd[a]	nd[a]	0.91	0.00	0.34	nd	nd	0.46	0.23	0.11	nd	nd	1.37	0.23	0.46
ALL SITES	**4.98**	**0.24**	**0.91**	**0.14**	**0.10**	**1.83**	**0.59**	**0.46**	**0.34**	**0.29**	**6.80**	**0.83**	**1.37**	**0.49**	**0.39**

B. Tubers Per Acre	Sprouted Tubers Per Acre					Unsprouted Tubers Per Acre					Total Tubers Per Acre (Sprouted and Unsprouted)				
	May 14-17 2007	Sept. 17 2007	May 12-14 2008	Sept. 15 2008	Oct. 5-6 2009	May 14-17 2007	Sept. 17 2007	May 12-14 2008	Sept. 15 2008	Oct. 5-6 2009	May 14-17 2007	Sept. 17 2007	May 12-14 2008	Sept. 15 2008	Oct. 5-6 2009
Station 1 WPT83	79,562	9,750	nd[a]	0	0	0	0	nd[a]	0	0	79,562	9,750	nd[a]	0	0
Station 2 WPT84	159,123	0	nd[a]	39,781	0	208,849	19,890	nd[a]	59,671	4,973	367,973	19,890	nd[a]	99,452	4,973
Station 3 WPT85	338,137	19,890	nd[a]	0	0	139,233	19,890	nd[a]	9,945	0	477,370	39,781	nd[a]	9,945	0
Station 4 WPT86	397,808	18,765	nd[a]	0	0	19,890	75,058	nd[a]	19,890	14,918	417,699	93,823	nd[a]	19,890	14,918
Station 5 WPT87	109,397	6,630	nd[a]	9,945	14,918	29,836	33,151	nd[a]	9,945	64,644	139,233	39,781	nd[a]	19,890	79,562
Station 6 WPT57	nd[a]	nd[a]	39,781	0	14,918	nd[a]	nd[a]	19,890	9,945	4,973	nd[a]	nd[a]	59,671	9,945	19,890
ALL SITES	**216,805**	**10,548**	**39,781**	**6,216**	**4,262**	**79,562**	**25,616**	**19,890**	**14,918**	**12,787**	**296,367**	**36,164**	**59,671**	**21,134**	**17,049**
Percent Reduction Year to Year	**n/a**	**95**	**n/a**	**41**	**31**	**n/a**	**68**	**n/a**	**42**	**14**	**n/a**	**88**	**n/a**	**42**	**19**
Percent Reduction Since May 2007	**n/a**	**95**	**n/a**	**97**	**98**	**n/a**	**68**	**n/a**	**81**	**84**	**n/a**	**88**	**n/a**	**93**	**94**

[a] nd indicates none detected

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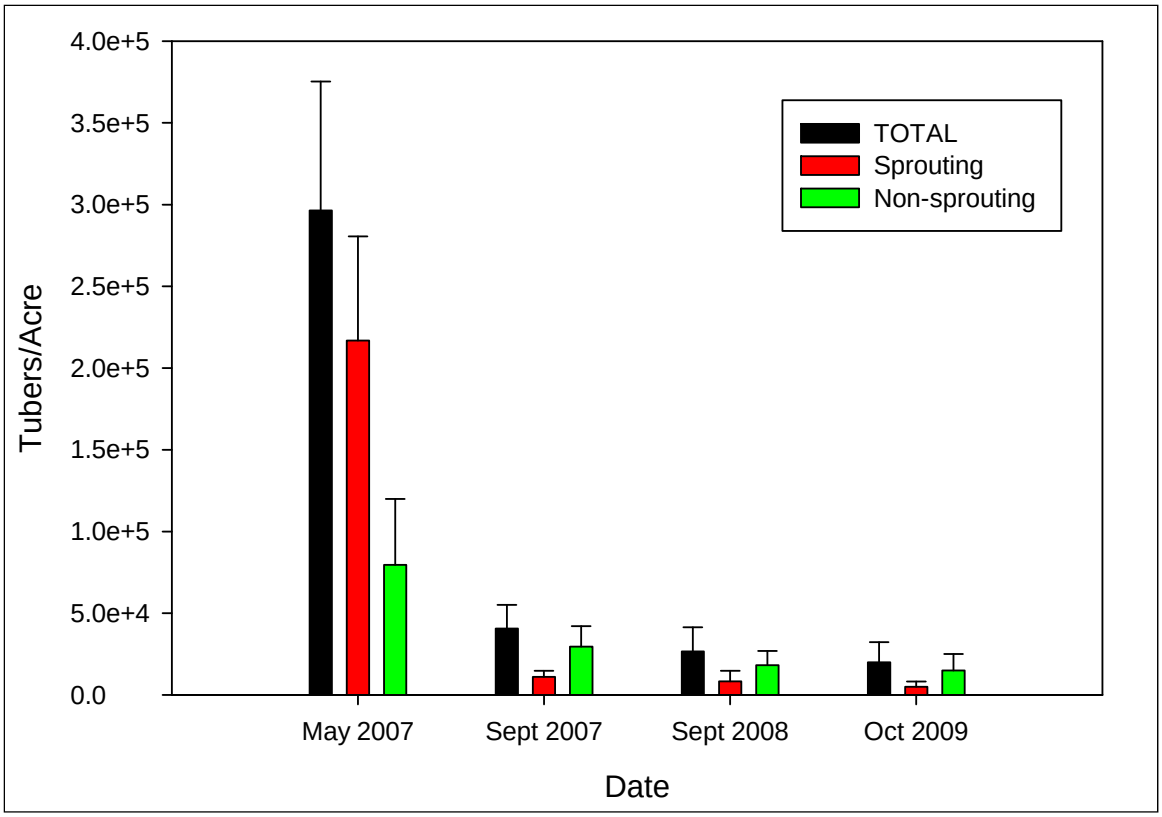

Chart 2.2.1. Overall changes in tuber abundance following three consecutive years of Sonar treatments (spouting + non-sprouting = total).

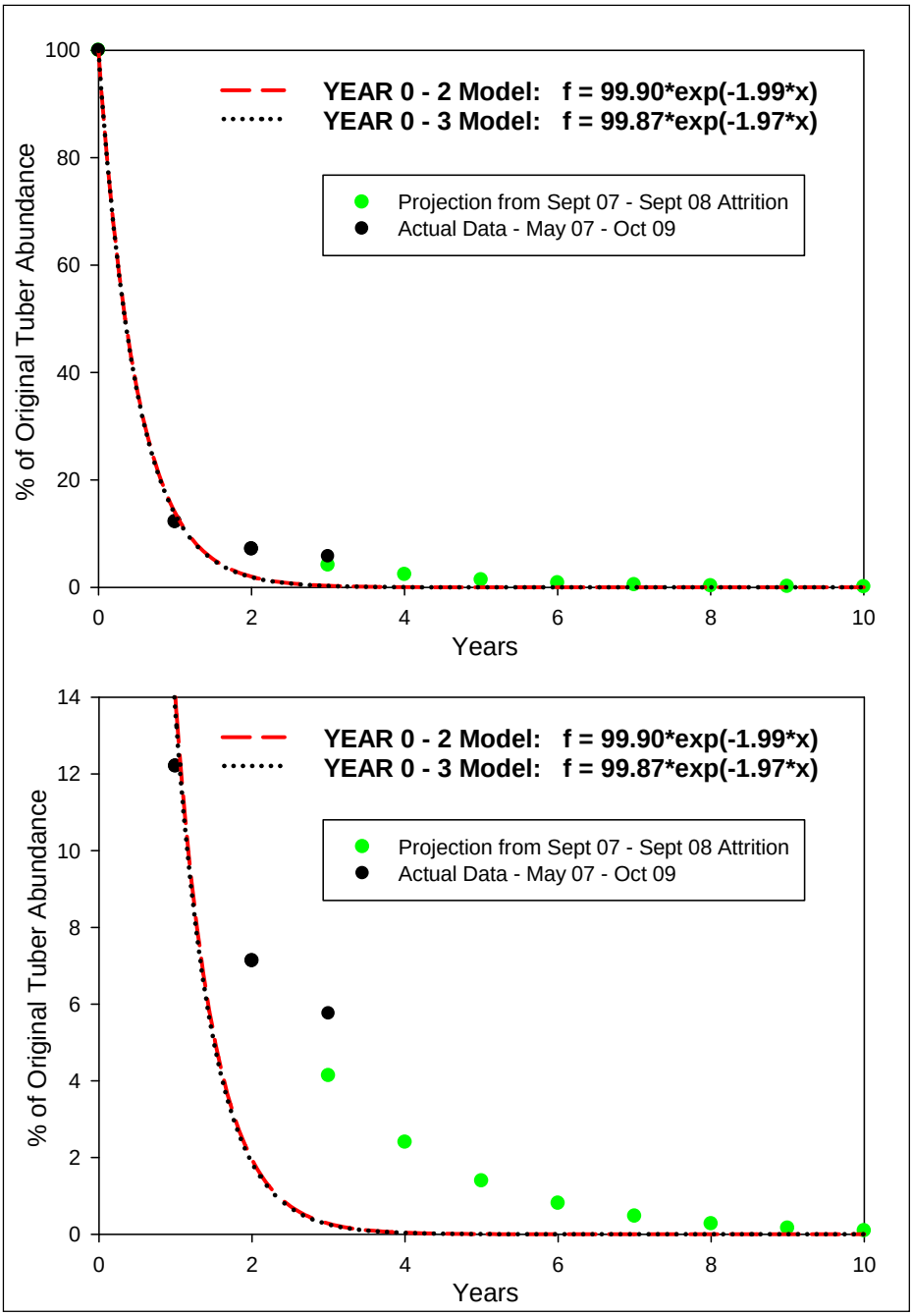

Chart 2.2.2. The attrition rate of hydrilla tubers on Lake Manitou based on 2008 Results and Projections. Year 1 (88%), Year 2 (42%), and Year 3 (19%) reductions (black dots) are from actual data and include both sprouted and unsprouted tubers; all subsequent reductions (years three through 10 – green dots) were based on reductions observed during year two (Sept 07 – 08: 42%). Graph lines represent predicted attrition rate based on non-linear regression analysis incorporating Year 0 – 2 data (red dashed line) or Year 0 – 3 data (black dotted line). Minimal differences exist between the two regressions. The top graph shows full 100% vertical axis while the bottom graph zooms in upon lower section of vertical axis for improved resolution of projected long-term annual trends.

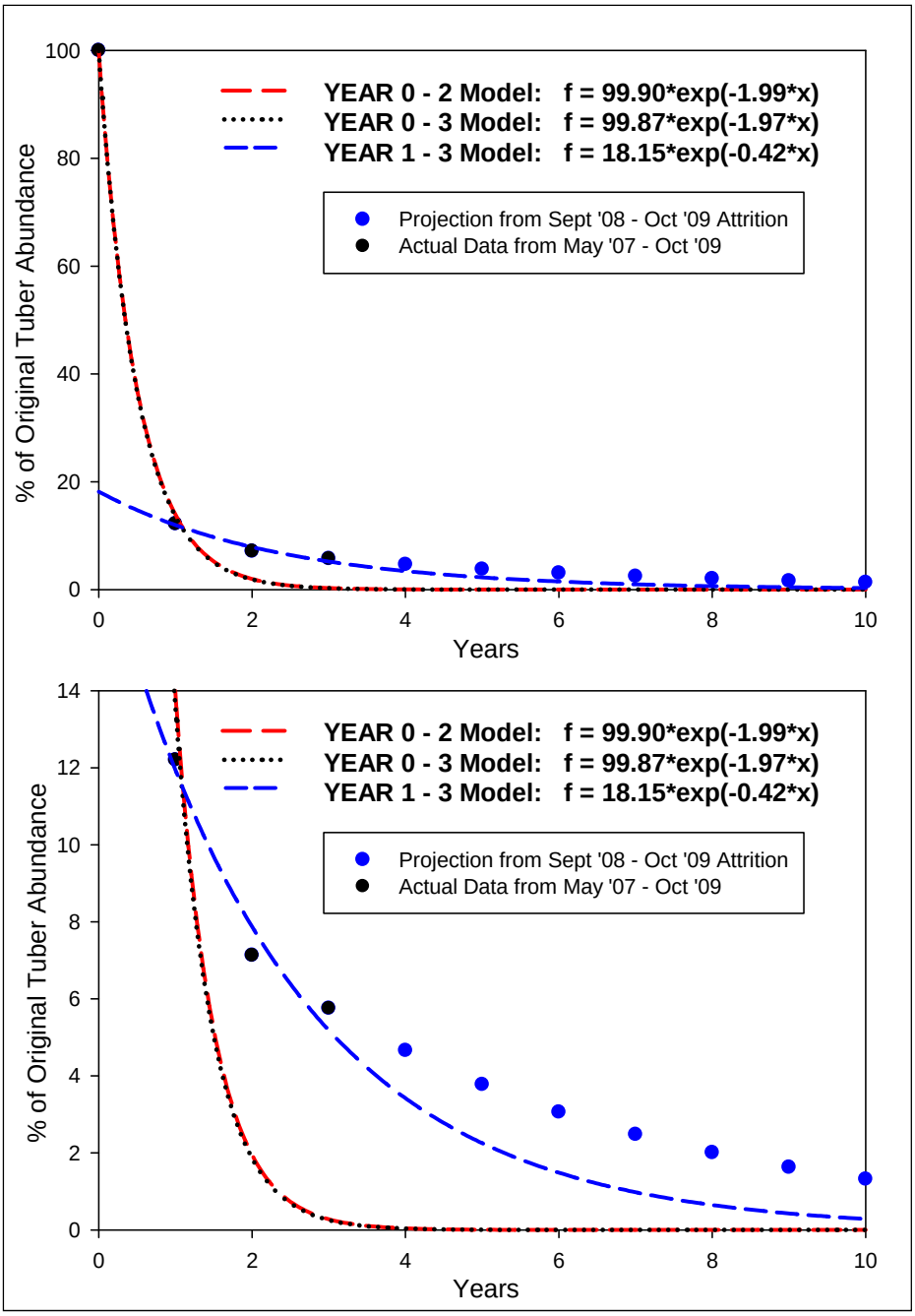

Chart 2.2.3. The attrition rate of hydrilla tubers on Lake Manitou based on 2009 Results and Projections. Year 1 (88%), Year 2 (42%), and Year 3 (19%) reductions (black dots) are from actual data and include both sprouted and unsprouted tubers; all subsequent reductions (years four through 10 – blue dots) were based on reductions observed during year three (Sept 08 – Oct 09: 19%). Graph lines represent predicted attrition rate based on non-linear regression analysis incorporating Year 0 – 2 data (red dashed line), Year 0 – 3 data (black dotted line), and Year 1 – 3 data (blue dashed line). Omission of Year 0 data did markedly improve regression fit of Year 1 – 3 results. The top graph shows full 100% vertical axis while the bottom graph zooms in upon lower section of vertical axis for improved resolution of projected long-term annual trends.

The notable increase in projected annual cycles of whole-lake treatment to reach formal eradication of the lake's hydrilla tuber bank suggests that the overall multiple-year effort and cost to achieve true eradication may be 3-4X greater than indicated by the previous year's update report. Although the current data and models may still not be considered definitive without further assessment over perhaps another annual cycle or two, current information suggests that IDNR, SePRO, and their project partners should continue to examine and optimize future management strategy to gain long-term improvements and efficiencies. Functionally today after multiple years of management, hydrilla on Lake Manitou has been suppressed to levels that pose a minimal short-term risk of inter-lake spread and ecological impairment. However, the natural aggressiveness of hydrilla that promoted a quick early infestation and necessitated a rapid response to management must still be considered when determining the long-term management approach. Intensive management will be required for Lake Manitou to prevent future hydrilla expansion. Future analysis will determine the functional outcome of this long-term management towards a full eradication goal or some other optimal, sustainable solution for maintenance and containment.

2.3 Tier II Surveys

For reference: the initial Sonar treatment was conducted on May 14, 2009; bump treatments were conducted on June 17, July 29, and September 9, 2009. Details of the treatments can be found in Section 4.0.

Tier II surveys were completed on June 16th and August 31st. Tier II surveys were included in the vegetation monitoring program to quantify species diversity and abundance, allow for pre- and post-treatment comparisons of the plant community, and locate additional areas of hydrilla. The design of the Lake Manitou point-intercept survey was based on the LARE protocol (IDNR 2006). A total of 122 sites were sampled in the spring and 119 sites were sampled in the late summer (Figure 2.3.1).

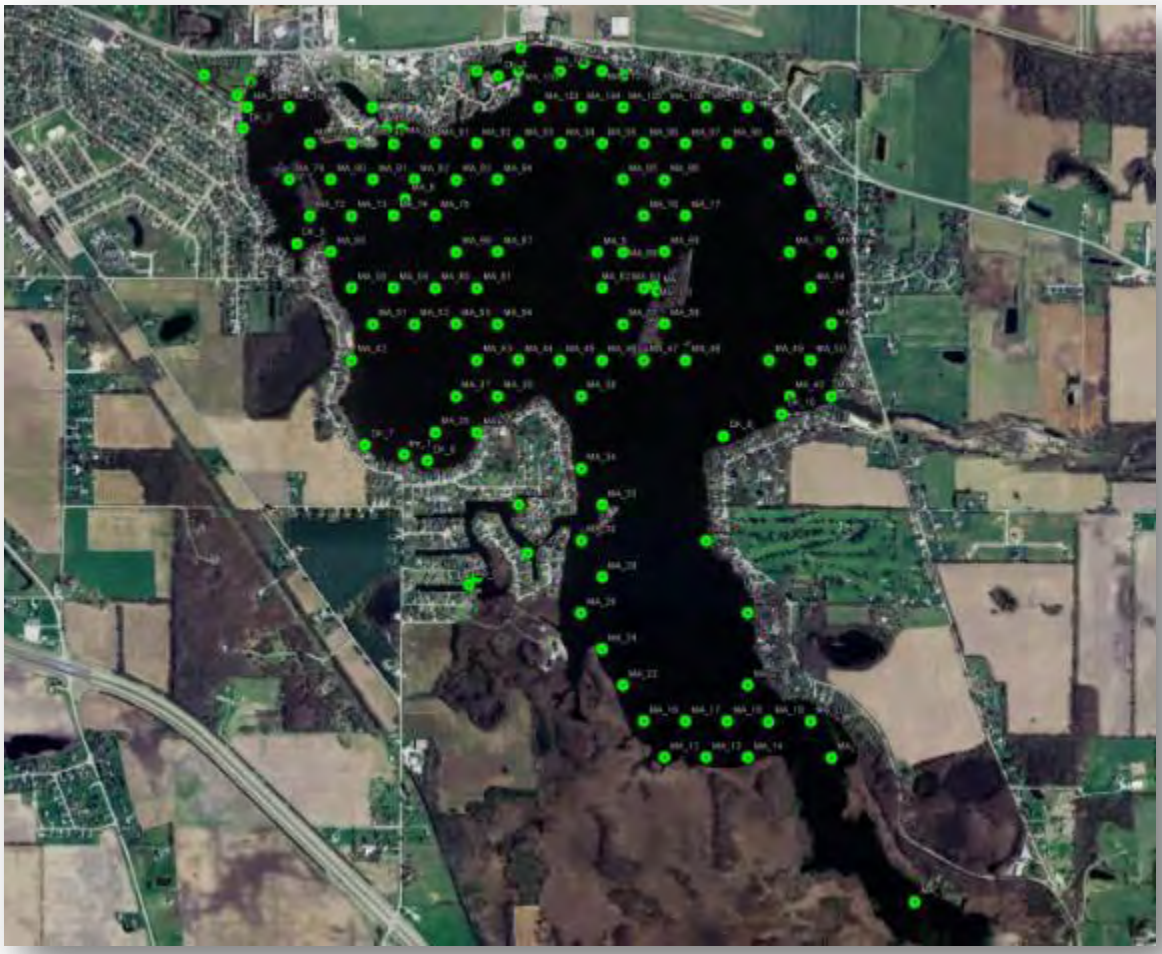

Figure 2.3.1. Tier II vegetation sample sites visited in 2009.

2.3.1 Spring Tier II Survey Results

The spring survey was conducted on June 16th. One rake drag was completed at each survey location. Plant density and injuring ratings were recorded for individual species (Table 2.3.1).

Vegetation was collected to a maximum depth of six feet. Aquatic vegetation was present at 28.7% of the sites. Six native submersed plant species were collected along with one non-native species. The maximum number of species per site was five; the mean species collected per site was 0.34. The species diversity index was 0.59 (Table 2.3.2).

Table 2.3.1. Plant rating scales used during the Tier II surveys.

Density Ratings	Injury Ratings
0: No plants retrieved	1: Healthy
1: 1-20% of rake teeth filled	2: Slight Injury
3: 20-99% of rake teeth filled	3: Moderate Injury
5: 100%+ of rake teeth filled	4: Severe Injury
8: Plant present but unranked	5: Dead Plant

Table 2.3.2. Occurrence and Abundance of Submersed Aquatic Plants in Lake Manitou. All depths: June 16, 2009.

Occurrence and Abundance of Submersed Aquatic Plants in Lake Manitou (all depths).

County:	Fulton	Total Sites:	122	Mean species/site:	0.34
Date:	6/16/09	Sites with plants:	35	SE Mean species/site:	0.06
Secchi (ft):	2	Sites with native plants:	34	Mean native species/site:	0.32
Max Plant Depth (ft):	6	Number of species:	7	SE Mean natives/site:	0.06
Trophic Status:	Meso	# of native species:	6	Species diversity:	0.59
		Maximum species/site:	5	Native species diversity:	0.55

All Depths (0 to 14 ft)	Frequency of Occurrence	Rake score frequency per sp.				Plant Dominance
Species		**0**	**1**	**3**	**5**	
Chara	18.9	81.1	18.9	0.0	0.0	3.8
Sago pondweed	9.8	90.2	9.0	0.8	0.0	2.3
Curlyleaf pondweed	1.6	98.4	1.6	0.0	0.0	0.3
Bladderwort	0.8	99.2	0.8	0.0	0.0	0.2
Coontail	0.8	99.2	0.8	0.0	0.0	0.2
Eel grass	0.8	99.2	0.8	0.0	0.0	0.2
Largeleaf pondweed	0.8	99.2	0.8	0.0	0.0	0.2
Filamentous Algae	47.5					

Other species observed: Water willow, duckweed, cattail, spatterdock, chara,

Chara (*Chara sp*.) was present at the highest percentage of sample sites (18.9%) and had the highest dominance rating (Figure 2.3.2). Sago pondweed (*Potamogeton pectinatus*) ranked second in percent occurrence and dominance (Figure 2.3.3). Curlyleaf pondweed, an invasive species, was collected at two sites (Figures 2.3.4 & 2.3.5), while eelgrass (*Vallisneria americana*), common coontail (*Ceratophyllum demersum*), bladderwort (*Utricularia sp.)* and largeleaf pondweed (*Potamogeton amplfolius)* were each collected at only a single site (Figures 2.3.5, 2.3.6, & 2.3.7). Water willow (*Justicia americana),* duckweed (*Lemna sp.),* cattail (*Typha sp*.), and spatterdock (*Nuphar sp.)* were observed but not collected with the rake. Filamentous algae were present at 47.5% of sites.

Figure 2.3.2. Lake Manitou, Chara distribution, June 16, 2009.

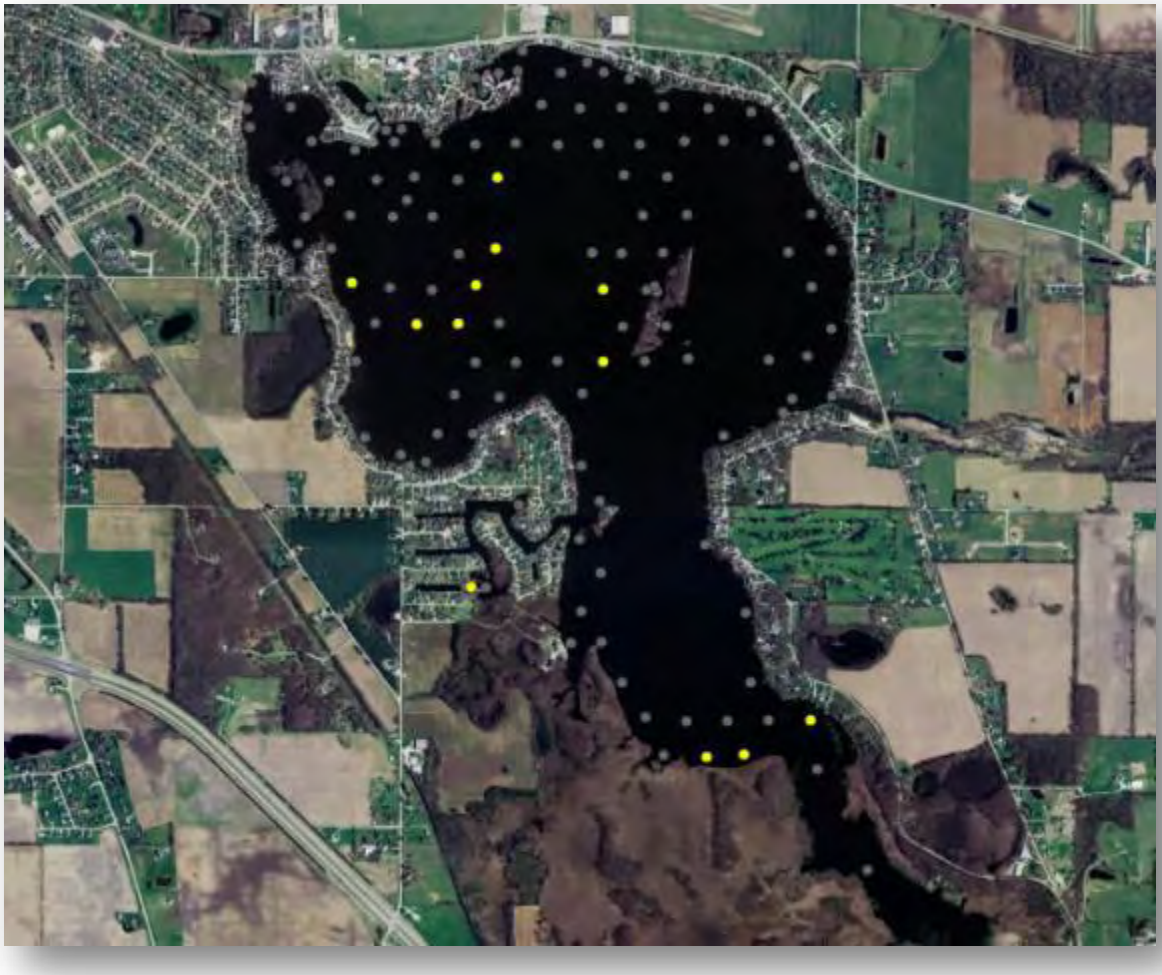

Figure 2.3.3. Lake Manitou, sago pondweed distribution, June 16, 2009.

It is also important to look at the species distribution throughout different depth ranges. Most of the plant growth was limited to shallow water. Ninety-nine sites were sampled in the 0-5 foot depth range. Aquatic vegetation was present at 34.3% of the shallow sites. A total of seven species were collected and the average number of species collected per site was 0.40. Chara occurred at the highest percentage of shallow sites (23.2%) and also had the highest dominance rating. Filamentous algae were present at 52.5% of the shallow sites (Table 2.3.3).

Table 2.3.3. Occurrence and Abundance of Submersed Aquatic Plants in Lake Manitou. 0-5 feet: June 16, 2009.

Occurrence and Abundance of Submersed Aquatic Plants in Lake Manitou (0-5 ft).								
County:	Fulton	Total Sites:	99				Mean species/site:	0.40
Date:	6/16/09	Sites with plants:	34				SE Mean species/site:	0.07
Secchi (ft):	2	Sites with native plants:	34				Mean native species/site:	0.39
Max Plant Depth (ft):	6	Number of species:	7				SE Mean natives/site:	0.07
Trophic Status:	Meso	# of native species:	6				Species diversity:	0.58
		Maximum species/site:	5				Native diversity:	0.55
Depth: 0 to 5 ft		Frequency of Occurrence	Rake score frequency per sp.				Plant Dominance	
Species			**0**	**1**	**3**	**5**		
Chara		23.2	76.8	23.2	0.0	0.0	4.6	
Sago pondweed		12.1	87.9	11.1	1.0	0.0	2.8	
Bladderwort		1.0	99.0	1.0	0.0	0.0	0.2	
Coontail		1.0	99.0	1.0	0.0	0.0	0.2	
Curlyleaf pondweed		1.0	99.0	1.0	0.0	0.0	0.2	
Eel grass		1.0	99.0	1.0	0.0	0.0	0.2	
Largeleaf pondweed		1.0	99.0	1.0	0.0	0.0	0.2	
Filamentous Algae		52.5						

The 5-10 foot depth range also contained vegetation, but at a very low level. Twenty-one sites were sampled within this range. Curlyleaf pondweed was the only species collected and it was present at only a single location. Filamentous algae were present at 23.8% of the sample sites within the 5-10 foot range (Table 2.3.4).

Table 2.3.4. Occurrence and Abundance of Submersed Aquatic Plants in Lake Manitou. 5-10 feet: June 16, 2009.

Occurrence and Abundance of Submersed Aquatic Plants in Lake Manitou (5-10 ft).								
County:	Fulton	Total Sites:	21				Mean species/site:	0.05
Date:	6/16/09	Sites with plants:	1				SE Mean species/site:	0.05
Secchi (ft):	2	Sites with native plants:	0				Mean native species/site:	0.00
Max Plant Depth (ft):	6	Number of species:	1				SE Mean natives/site:	0.00
Trophic Status:	Meso	# of native species:	0				Species diversity:	0.00
		Maximum species/site:	1				Native diversity:	0.00
Depth: 5 to 10 ft		Frequency of Occurrence	Rake score frequency per sp.				Plant Dominance	
Species			**0**	**1**	**3**	**5**		
Curlyleaf pondweed		4.8	95.2	4.8	0.0	0.0	1.0	
Filamentous Algae		23.8						

2.3.2 Summer Tier II Survey Results

The methods described in Section 2.3.1 were utilized again on August 31, 2009 (summer survey). Results of the sampling are listed in Table 2.3.5. Plants were growing to a maximum depth of five feet. Aquatic vegetation was present at 8.4% of the sites. A total of five species were collected. The maximum number of species per site was two, the mean species collected per site was 0.09, and the species diversity index was 0.69.

Table 2.3.5. Occurrence and Abundance of Submersed Aquatic Plants in Lake Manitou. All depths: August 31, 2009.

Occurrence and Abundance of Submersed Aquatic Plants in Lake Manitou (all depths).					
County:	Fulton	Total Sites:	119	Mean species/site:	0.09
Date:	8/31/09	Sites with plants:	10	SE Mean species/site:	0.03
Secchi (ft):	4.5	Sites with native plants:	10	Mean native species/site:	0.09
Max Plant Depth (ft):	5	Number of species:	5	SE Mean natives/site:	0.03
Trophic Status:	Meso	# of native species:	5	Species diversity:	0.69
		Maximum species/site:	2	Native species diversity:	0.69

All Depths	Frequency of Occurrence	Rake score frequency per sp.				Plant Dominance
Species		**0**	**1**	**3**	**5**	
Sago pondweed	4.2	95.8	3.4	0.8	0.0	1.2
Chara	2.5	97.5	2.5	0.0	0.0	0.5
Common bladderwort	0.8	99.2	0.8	0.0	0.0	0.2
Common coontail	0.8	99.2	0.8	0.0	0.0	0.2
Water stargrass	0.8	99.2	0.8	0.0	0.0	0.2
Filamentous Algae	21.0					

Other species observed: Cattail, spatterdock, Hibiscus, purple loosestrife, swamp loosestrife, Illinois pondweed

Sago pondweed was present at the highest percentage of sample sites and also had the highest dominance rating (Figure and Table 2.3.4). Chara ranked second in percent occurrence (2.5%) (Figure 2.3.5). Common bladderwort, common coontail, and water stargrass (*Heteranthera dubia*) were each present at single sample sites. Filamentous algae were collected at 21.0% of sites. Cattail, spatterdock, Hibiscus (*Hibiscus sp.)*, purple loosestrife (*Lythrum salicaria*), swamp loosestrife (*Decodon verticillatus*), and Illinois pondweed (*Potamogeton illinoensis*) were observed but not collected in a rake sample.

Table 2.3.6. Occurrence and Abundance of Submersed Aquatic Plants in Lake Manitou. 0-5 feet: August 30, 2009.

Occurrence and Abundance of Submersed Aquatic Plants in Lake Manitou (0-5 ft).					
County:	Fulton	Total Sites:	77	Mean species/site:	0.12
Date:	8/31/09	Sites with plants:	10	SE Mean species/site:	0.04
Secchi (ft):	4.5	Sites with native plants:	10	Mean native species/site:	0.12
Max Plant Depth (ft):	5	Number of species:	5	SE Mean natives/site:	0.04
Trophic Status:	Meso	# of native species:	5	Species diversity:	0.69
		Maximum species/site:	2	Native diversity:	0.69

Depth: 0 to 5 ft	Frequency of Occurrence	Rake score frequency per sp.				Plant Dominance
Species		**0**	**1**	**3**	**5**	
Sago pondweed	6.5	93.5	5.2	1.3	0.0	1.8
Chara	3.9	96.1	3.9	0.0	0.0	0.8
Bladderwort	1.3	98.7	1.3	0.0	0.0	0.3
Coontail	1.3	98.7	1.3	0.0	0.0	0.3
Water stargrass	1.3	98.7	1.3	0.0	0.0	0.3
Filamentous Algae	32.5					

Figure 2.3.4. Lake Manitou, sago pondweed distribution, August 31, 2009.

Figure 2.3.5. Lake Manitou, Chara distribution, August 31, 2009.

2.3.3 Tier II Survey Discussion

For reference: the initial Sonar treatment was conducted on May 14, 2009; bump treatments were conducted on June 17, July 29, and September 9, 2009. Details of the treatments can be found in Section 4.0.

Annual Tier II surveys have been completed on Lake Manitou since 2004. Aquatic Weed Control, Inc. completed surveys in 2004, 2005 and 2006 and Aquatic Control and ReMetrix completed Tier II surveys in 2007, 2008, and 2009. The primary objective of this vegetation management plan is the eradication of hydrilla. Hydrilla was detected shortly after the initial Sonar application. No hydrilla was observed or collected during the 2008 or 2009 Tier II surveys. Before the introduction of hydrilla, Eurasian watermilfoil control was the primary objective of

vegetation management. Milfoil is highly susceptible to low doses of Sonar, and has not been collected since the 2006 survey.

The hydrilla eradication treatment with Sonar was expected to temporarily alter the makeup of the submersed native plant community. Prior to the whole lake treatments, eelgrass occurred at the highest percentage of sample sites, but was either not collected or collected at low levels since treatment. Chara and sago pondweed are now the most frequently occurring species, however, Chara appears to have decreased in abundance when compared to last season. The reason for the decrease is unclear, as fluridone typically has little impact on this species. Water stargrass, which is typically tolerant to low rates of fluridone, was collected for this first time since Tier II survey began. This species may continue to increase due to its high fluridone tolerance and the lack of competition from other species. The changes in percent occurrence in the last nine Tier II surveys are illustrated in Table 2.3.7 and Chart 2.3.1.

Table 2.3.7. Percent occurrence of species in Lake Manitou in the last nine Tier II surveys.

Species	% of survey sites identified								
	Aug 2004	Aug 2005	Aug 2006	May 2007	Aug 2007	June 2008	Aug 2008	June 2009	Aug 2009
hydrilla (Hydrilla verticillata)				3.3%					
Eurasian watermilfoil (Myriophyllum spicatum)	27.5%	30.0%	2.9%	5.0%					
curlyleaf pondweed (Potamogeton crispus)				3.3%				1.6%	
common coontail (Ceratophyllum demersum)	26.4%	11.0%	24.3%	36.4%	7.4%		0.8%	0.8%	0.8%
Chara (Chara spp.)	12.1%	10.0%	10.0%	24.0%	38.8%	50.0%	33.9%	18.9%	2.5%
naiad species (Najas spp.)	11.0%	23.0%							
slender naiad (Najas flexillis)			8.6%				0.8%		
sago pondweed (Potamogeton pectinatus)	14.3%	16.0%	10.0%	20.7%	0.8%	6.5%	3.2%	9.8%	4.2%
eelgrass (Vallisneria americana)	50.5%	61.0%	42.9%	60.3%	6.6%			0.8%	
flatstem pondweed (Potamogeton zosteriformis)				4.1%					
largeleaf pondweed Potamogeton amplifolius)				2.5%				0.8%	
variable pondweed (Potamogeton gramineus)				0.8%					
common bladderwort (Utricularia vulgaris)					0.8%		0.8%	0.8%	0.8%
Illinois pondweed (Potamogeton illinoensis)	1.1%	2.0%	5.7%						
water stargrass (Heteranthera dubia)									0.8%

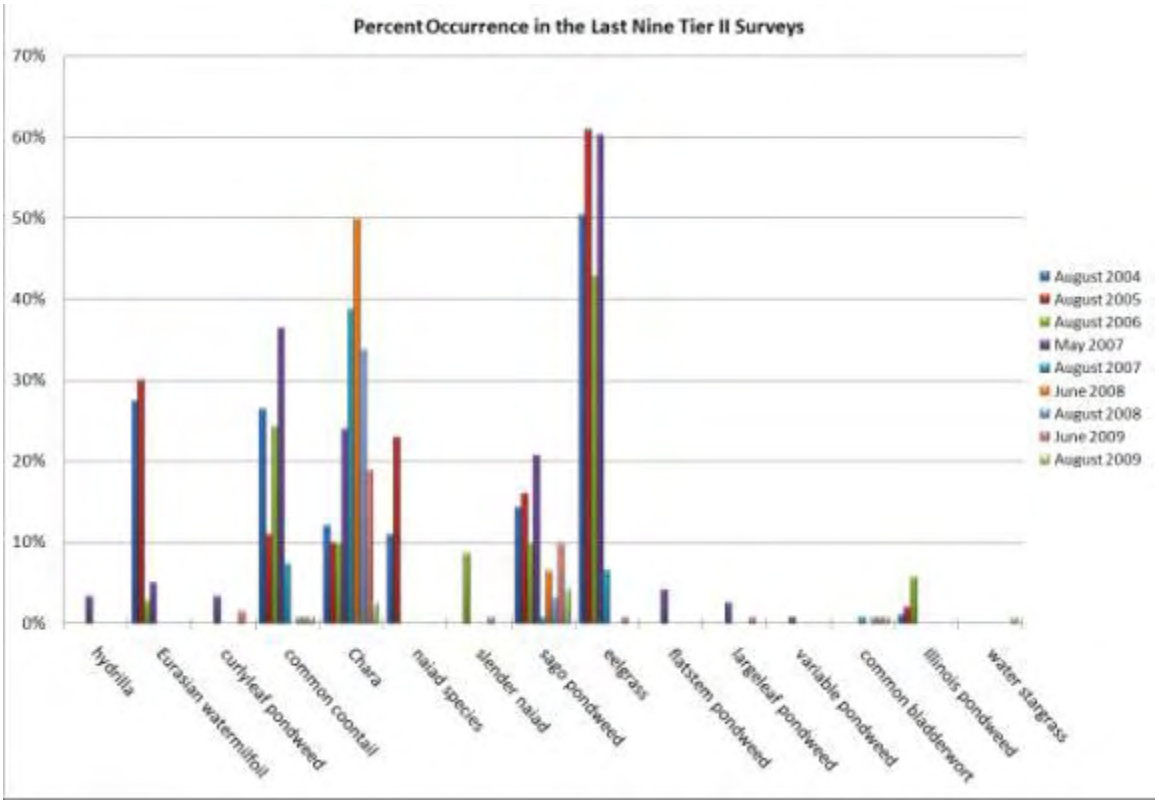

Chart 2.3.1. Percent occurrence of species in Lake Manitou in the last nine Tier II surveys (data from Table 2.3.6). (As discussed elsewhere in this report, hydrilla was found on Lake Manitou June 26, 2008 and June 22, 2009. However these discoveries were not made as a result of a Tier II survey and therefore are not represented within these data).

Tier II surveys not only provide information on individual species changes, they also provide data on lake-wide changes of submersed aquatic plant diversity and abundance. Table 2.3.8 and Chart 2.3.2 compares the percentage of sample sites with vegetation, native diversity index, and the number of native species collected in the last nine surveys. All post-whole lake treatment metrics have declined when compared to pre-treatment data. These metrics should continue to be monitored over time. Submersed vegetation metrics are expected to increase once the hydrilla eradication project is completed. Changes are being made to the application rates in an attempt to increase selectivity without jeopardizing the primary objective of hydrilla eradication.

Table 2.3.8. Lake Manitou, comparison of number of sample sites, % of sites with vegetation, native diversity index, and number of native species collected in the last seven Tier II surveys.

Survey Date	Number of Sample Sites	% of sites with vegetation	Native Diversity Index	Number of Native Species Collected
Aug 2004[1]	95	83.5%	0.72	6
Aug 2005[2]	100	79.0%	0.72	6
Aug 2006[3]	70	56.0%	0.74	7
May 2007	119	92.0%	0.73	7
Aug 2007	111	47.0%	0.46	5
June 2008	121	56.2%	0.20	2
Aug 2008	121	39.7%	0.26	5
June 2009	122	28.7%	0.55	6
Aug 2009	119	8.4%	0.69	5

[1]Donahoe & Keister 2005. [2]Donahoe & Keister 2006. [3]Donahoe & Keister 2007.

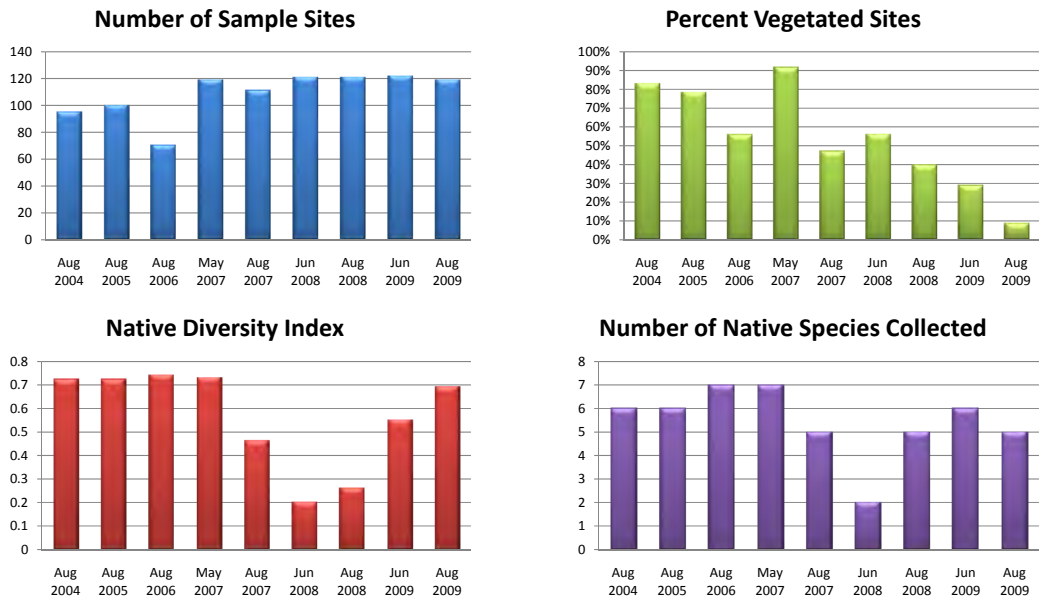

Chart 2.3.2. Comparison of number of sample sites, % of sites with vegetation, native diversity index, and number of native species collected in the last nine Tier II surveys. (Data are from Table 2.3.7)

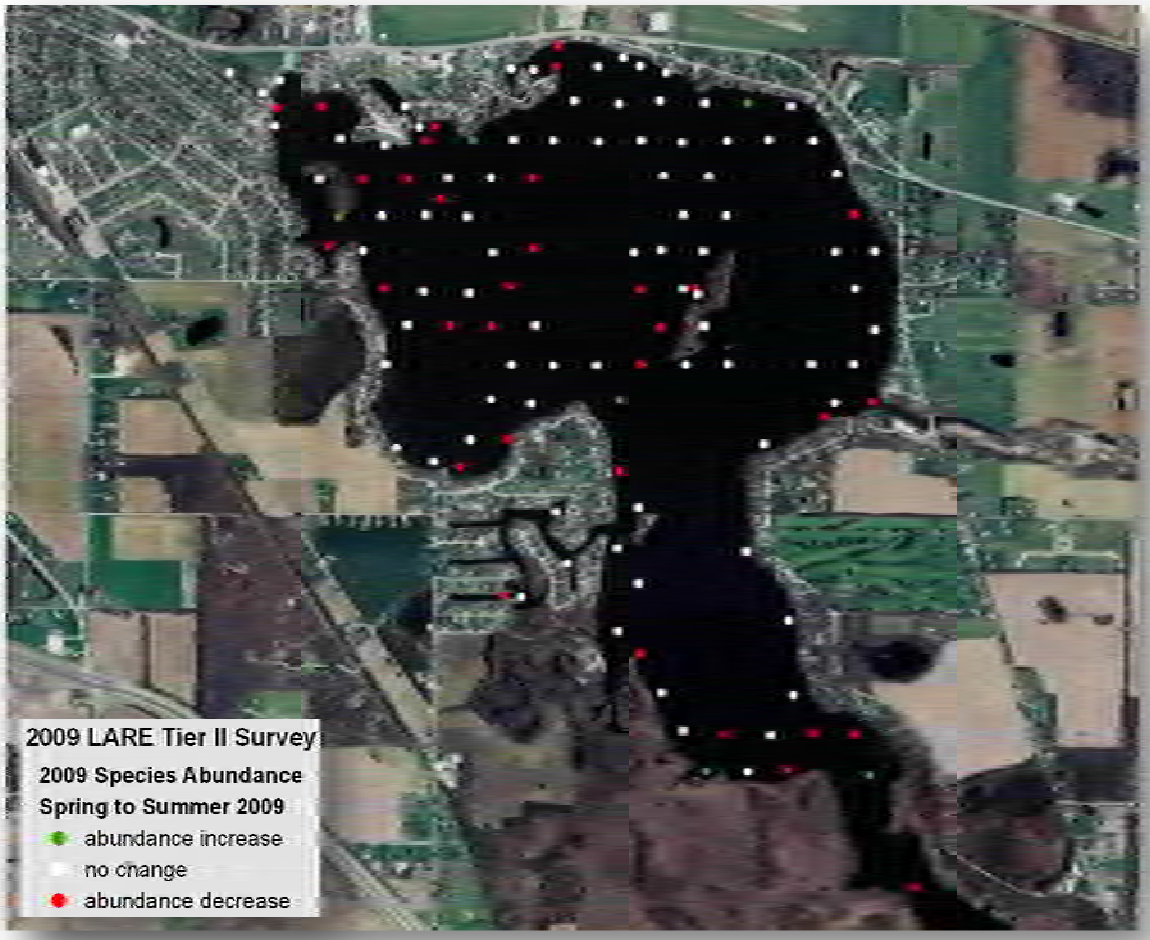

Figure 2.3.6. Lake-wide change in total species abundance, June 16, 2009 to August 31, 2009. Green markers indicate an increase in species present, white markers indicate no change, and red markers indicate a decrease in species present from June to August.

2.4 Additional Surveys

2.4.1 Hydroacoustic Survey for Precision Sonar Application

ReMetrix completed a bathymetric analysis of Lake Manitou based on hydroacoustic data collected October 5, 2006. A grid of single-beam hydroacoustic depth points were collected across the lake, and data between transects were modeled to create contours and a bathymetric surface for the entire lake. The results of the bathymetric analysis have been used to help plan every Sonar application. An accurate determination of water volume at the time of treatment is calculated based on measured thermocline depth (Table 2.4.1, paired with Table 4.1.1) to ensure accurate Sonar treatments. The data have enabled treatments to achieve more consistent, evenly distributed lake-wide Sonar concentrations than would otherwise have been achieved using regular application techniques.

Table 2.4.1. Water volume estimation calculations for Lake Manitou.

Water volume calculations for Lake Manitou based on hydroacoustic data collected 10/5/2006.							
Mean Depth = 10.67 Feet				Total Volume = 8,631 Acre Feet			
Interval (ft)	Surface Acres	Acre Feet	Cumulative Acre Feet	Interval (ft)	Surface Acres	Acre Feet	Cumulative Acre Feet
Surface – 1’	808	768	8,631	23’- 24’	129	124	1,234
1’-2’	740	719	7,863	24’- 25’	121	117	1,110
2’-3’	697	673	7,144	25’- 26’	114	111	993
3’-4’	644	609	6,471	26’- 27’	108	105	882
4’-5’	565	496	5,862	27’- 28’	102	98	777
5’-6’	432	391	5,366	28’- 29’	95	91	679
6’-7’	357	334	4,975	29’- 30’	88	85	588
7’- 8’	318	307	4,641	30’- 31’	82	79	503
8’- 9’	297	288	4,334	31’- 32’	76	73	424
9’- 10’	280	273	4,046	32’- 33’	69	66	351
10’- 11’	266	260	3,773	33’-34’	62	58	285
11’- 12’	254	248	3,513	34’-35’	54	51	227
12’- 13’	242	236	3,265	35’-36’	47	43	176
13’- 14’	231	225	3,029	36’-37’	39	37	133
14’- 15’	220	215	2,804	37’-38’	34	31	96
15’- 16’	209	204	2,589	38’-39’	28	24	65
16’- 17’	199	194	2,385	39’-40’	21	18	41
17’- 18’	189	184	2,191	40’-41’	15	11	23
18’- 19’	179	174	2,007	41’-42’	8	7	12
19’- 20’	169	164	1,833	42’-43’	5	3	5
20’- 21’	159	155	1,669	43’-44’	2	1	2
21’- 22’	150	145	1,514	44’-45’	<1	<1	1
22’- 23’	140	135	1,369				

ReMetrix

2.4.2. Other vegetation Surveys

According to Doug Keller, Aquatic Invasive Species Coordinator for IDNR, The Nature Conservancy performed surveys on nearly every natural lake 30 acres or larger in the natural lakes region this summer and no hydrilla was found. Since the Nature Conservancy was doing their surveys, IDNR did not conduct their traditional rake surveys of water bodies surrounding Lake Manitou this year (Personal communication, 9 Dec 2009).

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3.0 WATER QUALITY MONITORING

Basic water quality monitoring was included in the management plan to document these parameters throughout the treatment season. Sampling was conducted May, July and September at one-foot depths from FasTEST Site 2. Laboratory analysis included phosphorous (total and ortho) and chlorophyll *a*. Water samples were collected by Aquatic Weed Control, Inc and shipped to GEI Consultants Laboratory in Littleton, Colorado for analysis. This laboratory was utilized because of their low detection limits on phosphorous and nitrogen nutrients (2 µg/L - parts per billion). Chlorophyll detection limits were 0.0001 mg/L (0.1 mg/cubic meter).

In addition to the periodic water quality sampling, Aquatic Weed Control biologist recorded dissolved oxygen and temperature profiles at FasTEST sample Site 2 on May 18, June 8 & 22, July 7 & 20, August 3, 17 & 31, September 21, October 5 & 19, and November 2 & 16 (Table 3.0.1). These data were used to monitor thermocline depths for calculating Sonar bump treatments. The thermocline depth is important in calculating Sonar application rates and placement of Sonar pellets. Sonar generally does not mix below the thermocline, and slight thermal stratification can inhibit mixing into deeper waters. A thermocline defines a narrow, horizontal stratification boundary between cooler, deeper water and warmer, shallow water.

A thermocline is defined as a 1˚C temperature change over a depth of 1 meter. Each stratification zone has a discrete water volume that can be calculated and used to more precisely calibrate treatment rates (Table 2.4.1), often reducing the amount of Sonar applied. However, the thermocline depth changes throughout the season and must continually be monitored.

Secchi transparency readings were taken throughout the 2009 season (Table 3.0.2). Secchi measurements ranged from a maximum of 6.2 feet on October 19 to a low of 2.3 feet on June 8 (Table 3.0.3). Overall, minimum Secchi depths in 2009 seemed to average about 0.2 feet shallower than historical average while maximum Secchi depths averaged about 0.9 ft shallower when compared with the historical data. The July-August mean was consistent with the deeper end of recent July-August means at the lake (1999-2004 and 2007-2008).

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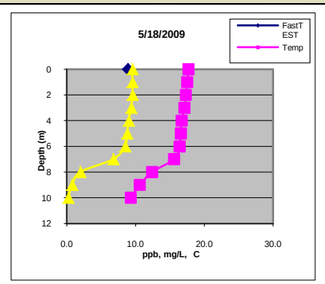
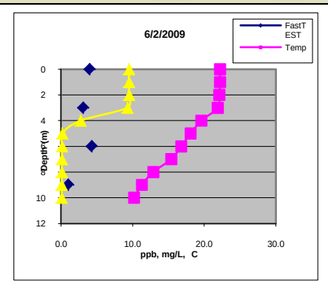
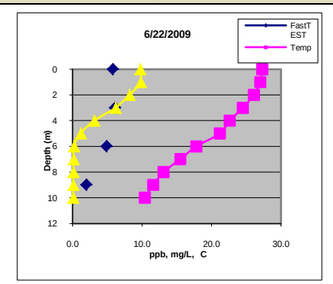
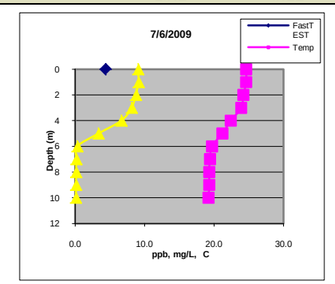
Table 3.0.1. 2009 Temperature and Dissolved Oxygen Profiles (FasTEST also included).

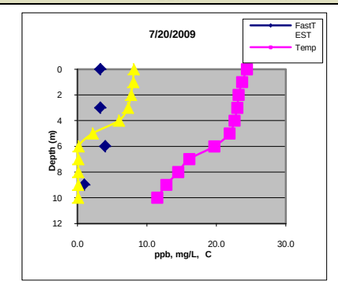
		5/18/2009			6/8/2009			6/22/2009			7/7/2009			7/20/2009			8/3/2009		
	DAT -->	4			25			5			20			33			5		
	Depth (m)	FasTEST	Temp	D O_2	FasTEST	Temp	D O_2	FasTEST	Temp	D O_2	FasTEST	Temp	D O_2	FasTEST	Temp	D O_2	FasTEST	Temp	D O_2
Site 2	0	8.9	17.7	9.53	4.0	22.2	9.46	5.8	27.3	9.69	4.4	24.6	9.06	3.3	24.4	8.09	4.9	23.9	7.62
	1		17.5	9.52		22.2	9.47		27.0	9.77		24.6	9.12		23.7	8.02		23.9	7.54
	2		17.3	9.54		22.1	9.47		26.1	8.16		24.2	8.74		23.2	7.70		23.9	7.50
	3		17.1	9.35	3.1	21.9	9.25	6.1	24.5	6.15		23.9	8.13	3.3	23.0	7.26		23.9	7.55
	4		16.7	8.99		19.6	2.71		22.6	3.09		22.4	6.65		22.6	5.96		23.8	7.42
	5		16.6	8.75		18.1	0.16		21.2	1.15		21.2	3.36		21.9	2.18		22.3	1.75
	6		16.4	8.47	4.3	16.8	0.13	4.9	17.8	0.17		19.7	0.33	4.0	19.7	0.15		19.9	0.26
	7		15.6	6.75		15.4	0.10		15.5	0.11		19.4	0.18		16.1	0.11		17.1	0.15
	8		12.4	1.95		12.9	0.09		13.1	0.08		19.3	0.15		14.5	0.10		16.1	0.11
	9		10.6	0.75	1.0	11.3	0.07	2.0	11.6	0.07		19.3	0.14	1.0	12.8	0.09		14.7	0.10
	10		9.3	0.20		10.2	0.07		10.4	0.06		19.2	0.12		11.5	0.08		13.4	0.09

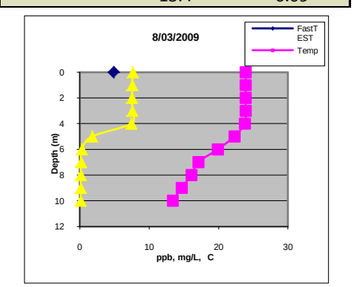




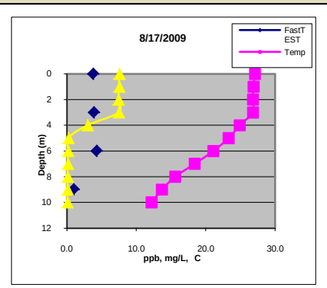


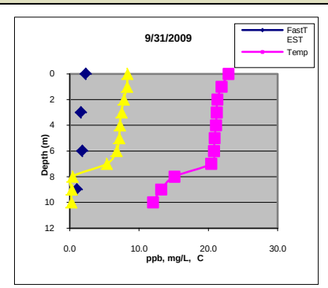


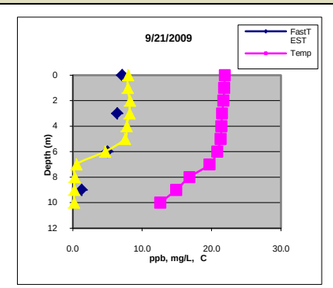


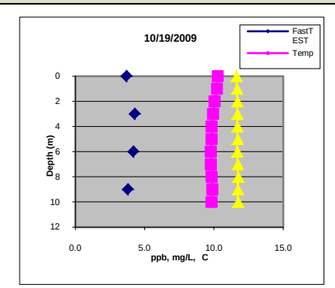


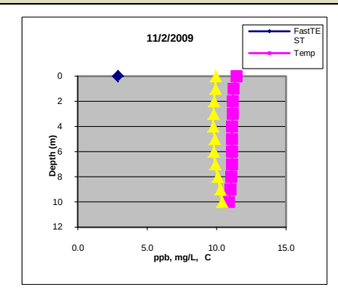
		8/17/2009			8/31/2009			9/21/2009			10/19/2009			11/2/2009			11/16/2009		
	DAT -->	19			33			12			40			54			68		
	Depth (m)	FasTEST	Temp	D O_2	FasTEST	Temp	D O_2	FasTEST	Temp	D O_2	FasTEST	Temp	D O_2	FasTEST	Temp	D O_2	FasTEST	Temp	D O_2
Site 2	0	3.8	27.1	7.54	2.3	22.9	8.29	7.1	21.9	7.95	3.7	10.3	11.62	2.9	11.4	9.93	3.1	9.4	10.74
	1		26.9	7.52		21.9	8.24		21.8	7.90		10.2	11.66		11.2	9.91		9.4	10.71
	2		26.8	7.41		21.3	7.77		21.7	8.21		10.1	11.68		11.2	9.80		9.5	10.64
	3	3.9	26.8	7.46	1.6	21.2	7.45	6.4	21.5	8.16	4.3	9.9	11.68		11.2	9.77		9.5	10.62
	4		24.9	2.97		21.1	7.21		21.4	7.74		9.8	11.68		11.1	9.75		9.5	10.60
	5		23.3	0.21		20.9	7.11		21.3	7.49		9.8	11.70		11.1	9.86		9.6	10.60
	6	4.3	21.1	0.16	1.8	20.8	6.73	5.0	20.8	4.64	4.2	9.8	11.67		11.1	9.79		9.6	10.58
	7		18.4	0.12		20.4	5.31		19.7	0.50		9.8	11.71		11.1	9.89		9.6	10.57
	8		15.6	0.09		15.1	0.35		16.8	0.23		9.8	11.74		11.1	10.07		9.6	10.55
	9	1.0	13.7	0.08	1.0	13.2	0.24	1.3	14.9	0.17	3.8	9.9	11.72		11.0	10.26		9.6	10.55
	10		12.2	0.07		12.0	0.19		12.6	0.14		9.8	11.73		10.9	10.39		9.6	10.53











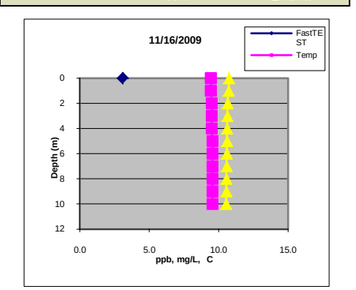


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Table 3.0.2. 2009 Secchi depths recorded on Lake Manitou (May to November, 2009).

Site	5/18	6/8	6/22	7/7	7/20	8/3	8/17	8/31	9/21	10/5	10/19	11/2	11/16
1	4.1	3.6	3.0	3.6	4.0	3.8	3.8	3.9	4.3	5.5	6.2	4.2	5.1
2	5.1	3.9	3.0	3.3	4.1	4.1	4.3	4.2	4.5	5.3	6.1	5.3	5.8
3	3.5	3.5	2.5	5.3*	3.3	3.0	4.1	3.9	4.5	5.2	5.3*	5.3*	5.3*
4	3.8	4.5	2.9	2.9	3.9	3.6	3.2	3.1	4.1	4.5	5.0*	4.2	4.1
5	3.1	4.1	3.1	4.3	4.6	4.2	4.2	4.3	5.3	5.0	5.3	5.8	5.1
6	2.8	3.9	3.2	3.4	3.8	3.9	4.7	4.2	4.9*	4.9*	4.8	4.4	4.9*
7	2.4	4.0	3.4	4.1	4.8	4.0	4.8	4.2	5.0	5.5	6.2	5.0	5.5
9	3.1	2.3	3.1	5.0*	2.4	2.8	2.8	5.0*	5.0*	5.0*	5.0*	5.0*	4.8
mean	**3.5**	**3.7**	**3.0**	**4.0**	**3.9**	**3.7**	**4.0**	**4.1**	**4.7**	**5.1**	**5.5**	**4.9**	**5.1**

* indicates the lake bottom was visible at the water depth listed.
Site locations can be seen in Figures 2.1.1 or 4.2.1.

Table 3.0.3. Summary of Secchi depths recorded on Lake Manitou 1999-2009. (1999 to 2004 data from Fascher & Jones 2006.)

Year	Minimum	Maximum	Jul-Aug Mean	Observations
1999	2.8	5.4	3.1	10
2000	2.6	6.3	3.2	11
2001	2.5	5.5	3.7	13
2002	2.5	7.2	3.8	15
2003	2.5	10.4	3.3	14
2004	2.7	4.1	3.3	12
2007*	2.6	9.0	3.9	80
2008*	2.1	8.6	3.3	95
2009*	2.3	6.2	3.8	104

*2007 - 2009 data are by authors of this report and are added for comparison with historical data.

Table 3.0.4. Water quality data collected from Lake Manitou in 2009.

Sample Date	Total P (µg/L)	Ortho P (µg/L)	Chlorophyll *a* (mg/L)
5/18/2009	47	16	0.0092
7/20/2009	26	3	0.0077
9/21/2009	23	3	0.0100

No historical ortho-phosphorus measurements were found to compare these results to, but historical data for total phosphorous and chlorophyll α readings were collected from 1999-2004 by the Indiana Volunteer Lake Monitors (summarized in Table 3.0.5). Comparison of the data indicates little change in these metrics following the past three years of Sonar treatment. Chlorophyll α concentration was highest in September 2009 at 0.0100 and lowest in July at 0.0077 for an average of 0.0090 over the three samples. These are comparable to data recorded for 2008 samples. Total P ranged from 23 to 47 ppb compared to 17 to 38 ppb during 2008. Ortho P was at a new maximum high of 16 ppb in June, but fell to a more normal level of 3 ppb in July and September samples.

Table 3.0.5. Total phosphorus, ortho-phosphorus, and chlorophyll *a* measurements collected from Lake Manitou, 1999-2009. (Data from 1999 to 2004 from Fascher & Jones 2006.)

	Minimum Total P (µg/L)	Maximum Total P (µg/L)	Minimum Ortho P (µg/L)	Maximum Ortho P (µg/L)	Minimum Chl *a* (mg/L)	Maximum Chl *a* (mg/L)
1999	47.0	63.0	n.a.	n.a.	0.0048	0.0174
2000	58.0	71.0	n.a.	n.a.	0.0097	0.0189
2001	1.8	10.3	n.a.	n.a.	0.0350	0.0660
2002	0.0	7.1	n.a.	n.a.	0.0240	0.0770
2003	2.5	10.4	n.a.	n.a.	0.0200	0.0370
2004	12.3	15.9	n.a.	n.a.	0.0310	0.0660
2007*	15	37	<2	5	0.0038	0.0127
2008*	17	38	1	3	0.0071	0.0124
2009	23	47	3	16	0.0077	0.0100

Chl *a* units originally expressed as µg/L in Fascher & Jones, 2006.
"n.a." means "not available"
*2007 - 2009 data are by authors of this report and are added for comparison with historical data.

The 2009 water quality data continues to show negligible effect on the water quality parameters monitored, even though vegetation surveys showed minimal submersed aquatic vegetation present. A similar water quality sampling program would be beneficial as the hydrilla eradication and re-vegetation by native plants progresses.

4.0 2009 VEGETATION CONTROL

The eradication of hydrilla was the primary objective of this Lake Manitou Aquatic Vegetation Management Plan. Due to the extensive reproductive capability of monoecious hydrilla through fragmentation, turions, and tubers, an aggressive prescription using the systemic herbicide Sonar was selected for the eradication project. Similar approaches have been taken in the States of Washington, Massachusetts, Maine, California and Kansas.

The initial lack of flow data for Lake Manitou resulted in the preparation of a treatment protocol based on static water conditions, with inclusion of additional "bump" treatments to sustain a Sonar residual in the lake for a period of 180 days at a lethal dose for hydrilla. Subsequent water flow data provided by the Indiana Department of Water indicated relatively long retention times, with a long-term (18-year) average of ~50% volume turnover from the period of April to September. This period would coincide with chemical control operations. However, large rain events cause the retention time to be much shorter (<30 days). Therefore, maintenance of an effective dose of Sonar for hydrilla required regularly scheduled monitoring of Sonar residue and periodic "bump" treatments as necessary.

SePRO collected hydrilla samples from Lake Manitou and conducted a PlanTEST at the SePRO Research and Technology Campus (SRTC) in Whitakers N.C. The PlanTEST is a proprietary test developed by SePRO Corporation that uses key biochemical parameters (Sprecher et al. 1998) to determine the plants inherent susceptibility to Sonar. The test was used to direct Sonar treatment recommendations by providing an indication of concentrations necessary for control. Plants were collected from Lake Manitou in September 2006 to conduct preliminary PlanTEST. The hydrilla in Lake Manitou responded favorably to Sonar under laboratory conditions (Figure 4.0.1). SePRO's recommended treatment protocol was based on results of the initial/preliminary PlanTEST, extensive experience in hydrilla control throughout the U.S., and proprietary modeling of Sonar dissipation from various formulations.

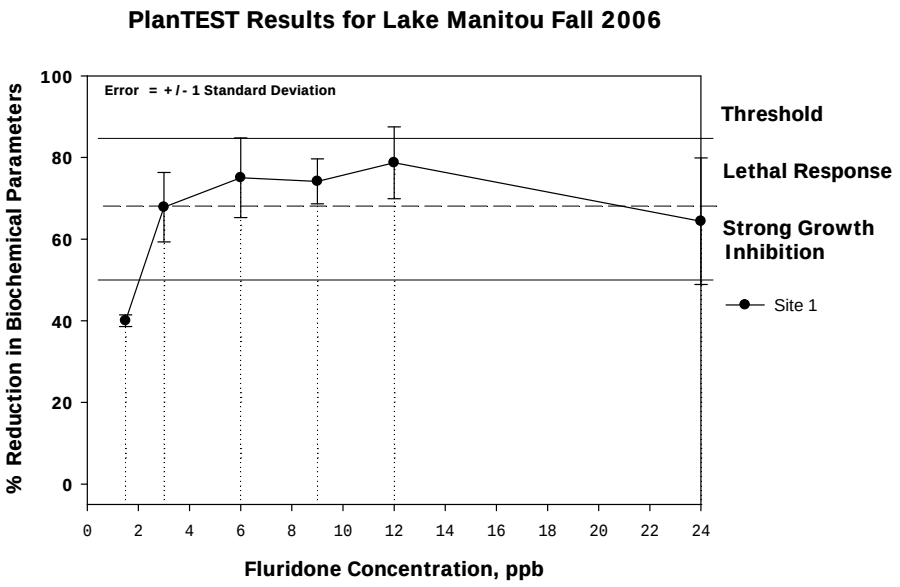


Chart 4.0.1 PlanTEST Results for Lake Manitou.

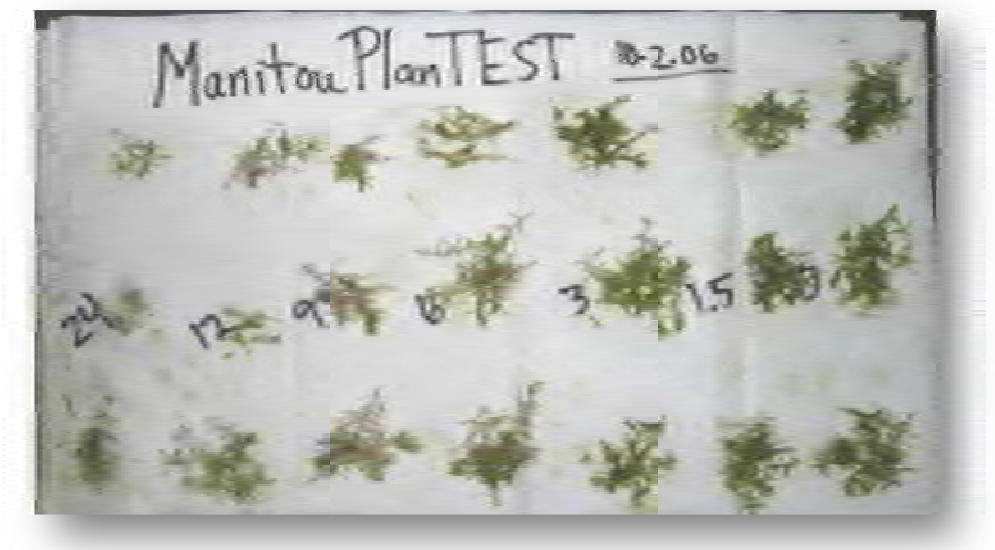


Figure 4.0.1. Lake Manitou hydrilla susceptibility to Sonar (PlanTEST).

Initially, the treatment prescription recommended for Lake Manitou was a minimum three year program, followed by comprehensive analysis of collected data and recommendations for either extension of this program or alternative management procedures to achieve eradication of hydrilla. Each year, relatively long exposure time to Sonar will be necessary to control the standing crop of hydrilla, prevent production of new tubers, and to control biomass sprouting from existing tubers.

The 2007 application maintained targeted levels of fluridone throughout the growing season and no hydrilla was observed that year. Modifications were made to the 2008 treatment prescription in an attempt to increase selectivity. Sonar pellet formulations were switched from Sonar Q, which was applied throughout the littoral zone in 2007, to Sonar PR, which was only applied to areas where hydrilla was previously documented and in a small inflow area. In addition, the whole lake concentration was to be maintained above 3 ppb instead of 6 ppb, with more frequent bump applications to minimize exposure of native species to relatively high concentrations. This same treatment strategy used in 2008 was used again in 2009.

4.1 Sonar Application

For reference: the initial Sonar treatment was conducted on May 14, 2009; bump treatments were conducted on June 17, July 29, and September 9, 2009. Details of the treatments can be found in Section 4.0.

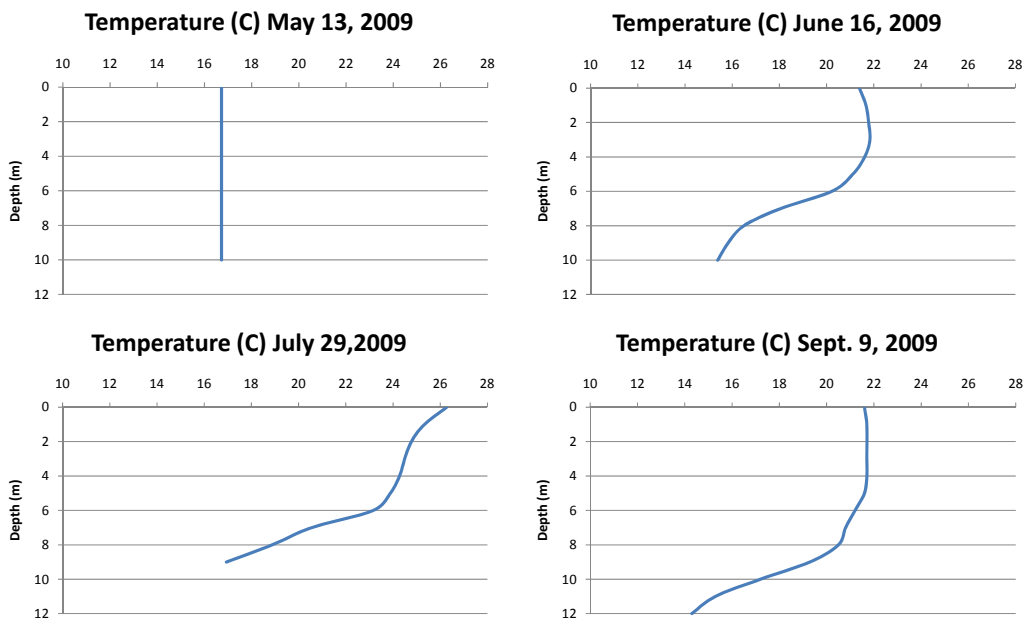
The initial Sonar application was completed on May 14, 2009 by Aquatic Control, Inc., with SePRO Corporation and ReMetrix personnel on site for technical assistance. The lake was posted with signage for public notification prior to application. Sonar AS was applied at a concentration of 6.0 ppb along with pelletized Sonar PR to 19 zones (Figure 4.1.2) at concentrations ranging from 40-100 ppb (total of 2.2 ppb). No consistent thermocline was identified prior to the May 14 treatment (Table 4.1.1). The whole lake volume of 8,361 acre feet was used in the Sonar AS calculation due to the lack of a thermocline.

Sonar AS was applied with a custom built Carolina Skiff, 19-foot fiberglass boat equipped with a 90hp engine. The boat was equipped with accustom built herbicide application unit designed for accurate application of low dose Sonar AS. Travel routes and rates were pre-determined using information generated by the one-foot bathymetric contour survey and water volume table provided by ReMetrix. The actual Sonar AS and Sonar PR application travel routes are illustrated in Figure 4.1.1. Sonar PR was applied to 19 different locations (18 previous hydrilla locations and one inflow location) (Figure 4.1.2). A custom built herbicide blower on a 19-foot Carolina Skiff was used for application of the pellets.

Table 4.1.1. Water Temperature and dissolved oxygen profiles associated with Sonar application dates. (Thermocline depths are indicated by a thicker line between rows).

	May 13 (Trtmt 5/14)	June 16 (Trtmt (6/17)		July 29 (Trtmt 7/29)		September 9 (Trtmt 9/9)	
Depth (m)	**Temp (C)**	**Temp (C)**	**D.O. (mg/L)**	**Temp (C)**	**D.O. (mg/L)**	**Temp (C)**	**D.O. (mg/L)**
Subsurface	16.7	21.4	8.73	26.3	6.70	21.6	8.70
1	16.7	21.7	8.73	25.3	5.50	21.7	8.50
2	16.7	21.8	8.60	24.8	5.00	21.7	8.10
3	16.7	21.8	7.21	24.5	5.00	21.7	7.50
4	16.7	21.6	4.95	24.3	4.70	21.7	7.10
5	16.7	21.1	3.10	23.9	2.80	21.6	5.80
6	16.7	20.2	2.77	23.2	1.20	21.2	3.60
7	16.7	18.1	0.27	20.6	0.30	20.8	2.40
8	16.7	16.5	0.19	18.9	0.20	20.5	1.10
9	16.7	15.8	0.17	16.9	0.20	19.3	0.50
10	16.7	15.4	0.15			17.2	0.40
11						15.3	0.30
12						14.3	0.20

Chart 4.1.1. Water Temperature profiles associated with Sonar application dates.



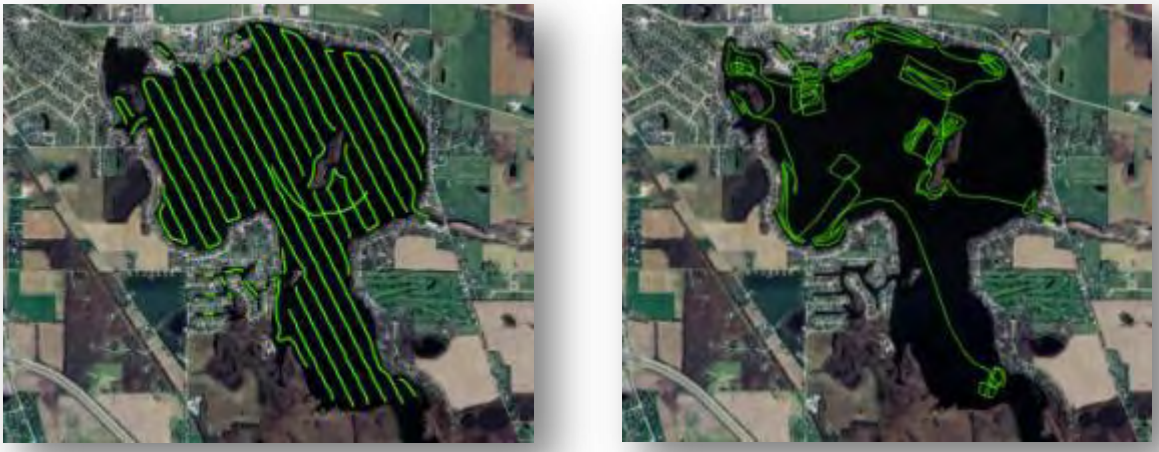


Figure 4.1.1. Initial application tracks for Sonar AS (*left map*) and Sonar PR (*right map*), May 14, 2009.

Figure 4.1.2. Sonar PR application prescription map, May 14, 2009.

The first bump treatment was completed on June 17 (34 days after initial treatment) with a combination of Sonar AS and PR. The bump treatment was conducted when residues had dropped to 3.7 ppb on June 8. Sonar AS was applied at concentration of 3.0 ppb and Sonar PR was applied at a concentration of 1.1 ppb. Sonar AS was applied evenly over the entire lake while Sonar PR was applied to the 19 previously selected locations. A thermocline had formed at 21 feet (Table 4.1.1). Figure 4.1.3 displays the actual application routes from the first bump treatment.

Figure 4.1.3. First "bump application" tracks for Sonar AS (*left map*) and Sonar PR (*right map*), June 17, 2009.

Sonar concentration had dropped to a mean of 3.0 ppb by July 20th. A second bump treatment was completed on July 29th (75 days after initial treatment) with a combination of Sonar AS and PR. Sonar AS was once again applied at concentration of 3.0 ppb and Sonar PR was applied at a concentration of 1.1 ppb. The thermocline remained at approximately 21.0 feet (Table 4.1.1). Figure 4.1.4 displays the actual application routes from the second bump treatment.

Figure 4.1.4. Second "bump application" tracks for Sonar AS (*left map*) and Sonar PR (*right map*), July 29, 2009.

Sonar concentration had dropped to a mean of 1.8 ppb by August 31st. A final bump treatment was completed on September 9th (119 days after initial treatment) with Sonar AS. Sonar AS was applied at concentration of 4.2 ppb with the thermocline at approximately 27 feet (Table 4.1.1). Figure 4.1.5 displays the actual application route from the final treatment.

Figure 4.1.5. Final "bump application" tracks for Sonar, September 9, 2009.

4.2 Herbicide Residue Monitoring

The FasTEST was used to monitor fluridone concentration 4, 25, 39, 54, 67, 81, 95, 109, 130, 144, 158, and 172 days following initial treatment. The FasTEST ensured the target concentrations were achieved and maintained through October 15th. FasTEST samples were collected from eight permanent stations located throughout Lake Manitou (Figure 4.2.1 & Table 4.2.1). Thirteen sets of subsurface samples were collected and results are summarized in Table 4.2.2, Chart 4.2.1, and Figure 4.2.3. Results indicate the concentration was maintained above 3 ppb for the majority of the 2009 growing season. The objective was to maintain >3 ppb until October 15th as it was determined that hydrilla would unlikely be able to sprout from a tuber and form a new tuber after that period.

Figure 4.2.1. Permanent FasTEST sample locations during 2009.

Table 4.2.1. Latitude and longitude coordinates for the eight FasTEST monitoring stations.

Site	Latitude	Longitude
1	N 41˚ 03' 26.0"	W 86˚ 10' 44.9"
2	N 41˚ 03' 05.9"	W 86˚ 11' 15.3"
3	N 41˚ 03' 35.3"	W 86˚ 10' 29.6"
4	N 41˚ 03' 31.5"	W 86˚ 11' 26.1"
5	N 41˚ 03' 05.0"	W 86˚ 10' 20.4"
6	N 41˚ 02' 23.3"	W 86˚ 10' 32.1"
7	N 41˚ 02' 43.5"	W 86˚ 10' 34.7"
9*	N 41˚ 02' 48.8"	W 86˚ 11' 01.4"

*Station 8 was removed after 2007; Station 9 was added in 2008.

Table 4.2.2. Concentration of 2009 FasTEST results from surface water samples. Vertical black lines indicate when "bump" treatments were made.

	5/18	6/8	6/22	7/7	7/20	8/3	8/17	8/31	9/21	10/5	10/19	11/2	11/16	Season
DAT[a] -->	**4**	**25**	**5**	**20**	**33**	**5**	**19**	**33**	**12**	**26**	**40**	**54**	**68**	**186**
Sites	---------- Sonar Concentration (ppb) ----------													
1	6.3	3.3	6.1	4.0	3.1	4.8	3.8	2.0	6.0	4.0	2.2	2.9	2.3	3.9
2	8.9	4.0	5.8	4.4	3.3	4.9	3.8	2.3	7.1	3.7	3.7	2.9	3.1	4.5
3	6.0	3.9	5.2	3.8	2.7	4.8	3.8	1.9	10.7	4.7	4.0	2.6	2.8	4.4
4	6.3	4.6	5.9	3.7	2.4	5.2	3.8	1.4	7.0	4.2	3.6	2.0	2.6	4.1
5	6.6	3.6	5.5	4.0	2.9	4.6	3.4	1.8	6.3	4.2	4.2	3.0	2.6	4.1
6	9.6	3.3	4.9	3.7	2.8	3.6	3.7	1.6	6.0	4.4	3.8	2.8	2.7	4.1
7	5.8	1.9	5.0	3.7	3.1	4.7	3.6	1.8	6.1	4.2	4.0	2.8	3.0	3.8
9	6.9	4.6	6.7	4.5	3.5	5.3	4.2	1.4	8.1	4.4	3.9	3.1	2.7	4.6
Lake Avg	**7.1**	**3.7**	**5.6**	**4.0**	**3.0**	**4.7**	**3.8**	**1.8**	**7.2**	**4.2**	**3.7**	**2.8**	**2.7**	**4.2**

[a] DAT represents the number of days after the last treatment.

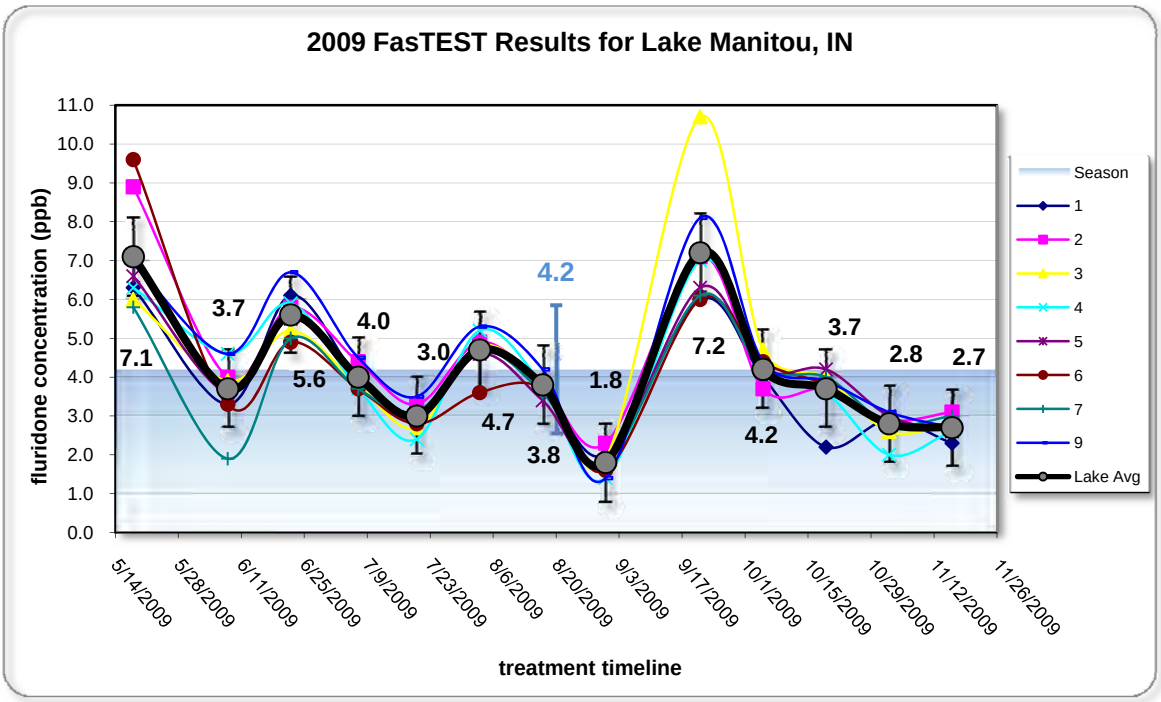


Chart 4.2.1. Sonar concentration by FasTEST site during 2009. The heavy black line, error bars and data labels represent the whole lake average at each sampling. The blue background and corresponding blue error bar and data label represents the season-long average concentration from mid-May through November 2009.

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5.0 ACTION PLAN UPDATE

As recommended in 2008, a Manitou Summit Conference was held December 8 with IDNR, SePRO, and invited researchers and professionals sharing experiences on hydrilla eradication projects around the U.S. Attendees included Doug Keller, IDNR Aquatic Invasive Species Coordinator; Tom Flatt, IDNR, Habitat Coordinator ; Jeremy Price, IDNR, District Fisheries Biologist; Chip Long, IDNR, Assistant Fisheries Biologist; Angela Studervant, Biologist, LARE Program; Dr. Mike Netherland, US ACOE; Dr. Patrick Akers, Chief, CA Hydrilla Program; Dr. Lars Anderson, USDA, (via Conference Call); David Isaacs, President, Aquatic Control Inc.; Nathan Long, Vice President, Aquatic Control Inc.; Jim Donahoe, President Aquatic Weed Control, Inc.; David Keister, Biologist, Aquatic Weed Control; Richard Dirks, Geospatial Data Analyst, ReMetrix, LLC; Dr. Tyler Koschnick, Director Research & Regulatory Affairs, SePRO Corp; Bob Johnson, Midwest Aquatic Specialist, SePRO Corp.

Presentations were given by Doug Keller, Dr. Anderson, Dr. Netherland, Dr. Akers, Richard Dirks and Dr. Koschnick. Research updates and historical information on hydrilla eradication and management were presented. Discussion of the information and details of the Manitou project resulted in a general consensus that the Manitou project was progressing as would be expected and should be extended until the tuber monitoring program indicated has been accomplished. It was also recommended that an ongoing vegetation monitoring program should be included in the future.

5.1 Diagnostic Data for Precision Sonar Application

Hydrilla produces large numbers of tubers that can remain dormant in the sediment for several years. This fact makes eradication difficult but not impossible. Based on current tuber attrition rates observed on Lake Manitou to date as part of a growing nationwide dataset on monoecious hydrilla population response to management, projected number of consecutive annual treatments with Sonar to reach tuber bank eradication in Manitou has increased. The slowing rate of tuber attrition observed over the three annual cycles of management projects to a 9 to 15-year horizon for complete eradication As presented at the December 2009 summit on status of the Manitou hydrilla program, eradications efforts like Pickerel Pond in Maine (7 consecutive cycles of Sonar with tubers still being found) and Pipe/Lucerne Lakes in Washington (11 cycles of Sonar between 1995 – 2007) confirm that complete eradication of hydrilla tubers requires a sustained long-term commitment. Recent data from NC State University monitoring of tuber populations on Lake Gaston in NC/VA indicates that the hydrilla tuber bank can double in a single year without Sonar treatment (Nawrocki, et al. 2009). If treatments end starting in 2010, tuber densities may return to pre-treatment levels rapidly within a few years. The first three years of Sonar application have resulted in successful control of hydrilla with subsequent reductions in tubers and apparent prevention of hydrilla spread to other waters of Indiana. The timing of treatments coincided with hydrilla tuber sprouting, which is expected to be similar in 2010. The treatments resulted in impact to the native submersed plant community, which was expected due to the importance placed on successful hydrilla control and the overall low species

richness. In 2008, modifications were made to the Sonar formulation, concentration, and application frequency and distribution to maintain emphasis on hydrilla control and attempt to improve selectivity. These methods modifications were continued in 2009 with no major adjustment. After multiple reviews of past Sonar dissipation and performance in Manitou, two potential management options are described for 2010 program. Both options are presented in an effort to seek further project efficiency based on past management experiences and current project status.

Option 1 – Multiple Formulation Protocol

Continue with similar multiple-formulation protocol utilized in 2008-2009 to maintain a whole lake Sonar concentration between 2.5 - 5 ppb. The whole lake (above the thermocline) would be treated with Sonar A.S. at an initial rate of 6 ppb and maintained above 2.5 ppb with subsequent bump treatments. This lake-wide treatment should control any hydrilla not accounted for in surveys or previously detected. In addition, Sonar PR would be applied to the 19 areas where hydrilla was previously identified (and one area at the inflow)—similar to the areas treated in 2009, shown in Figure 4.1.2 above. These areas range in size from 4.1 to 17.7 acres and total 161 acres (average depth approximately four feet). The concentration applied to these areas will remain similar to ’08-’09 rates and will range from 40 to 100 ppb in the treated areas. In-water concentrations will only be a fraction of that applied due to the sustained release of the pellets and rapid dilution from these areas. The total Sonar PR applied will be split into three treatments: 50% on day 1, and 25% each on day 45 and 90. This protocol allows for higher concentrations applied to areas with known hydrilla while minimizing concentrations on the whole lake and minimizing pellet application to the entire littoral zone. The overall rate of Sonar used compared to previous years with this integrated approach has been adjusted down slightly based on management experience on the lake. However, a further analysis of historic precipitation records during the May-Sept period over the last 20 years (Table 5.1.1) indicates that 2007-2009 were years with slightly lower than mean or median seasonal rainfall. Above or even average rainfall during the 2010 treatment cycle could still require similar or greater Sonar quantities as 2008-2009 to achieve slightly reduced target Sonar dose range.

Table 5.1.1. May through September monthly precipitation records from 1990-2009 for the Fulton County Airport just north of Lake Manitou in Rochester, Indiana. 2007 – 2009 records are compared to 20-year mean and median seasonal precipitation.

Monthly Precipitation (inches)

	May	Jun	Jul	Aug	Sept	TOTAL
1990	5.81	4.50	8.72	12.39	1.74	33.16
1991	3.28	2.14	2.81	3.25	1.70	13.18
1992	2.04	2.50	5.74	2.39	5.66	18.33
1993	4.44	5.42	4.48	3.17	7.10	24.61
1994	2.21	3.91	4.27	2.59	1.41	14.39
1995	5.10	5.87	1.83	4.50	0.49	17.79
1996	7.03	3.85	9.34	1.50	3.39	25.11
1997	5.65	3.58	6.37	4.20	5.90	25.70
1998	4.71	7.29	9.54	3.34	1.19	26.07
1999	3.16	4.16	1.42	3.18	2.51	14.43
2000	4.97	6.30	3.46	5.03	4.37	24.13
2001	4.19	4.13	8.49	5.64	3.15	25.60
2002	6.38	2.11	3.29	3.26	1.86	16.90
2003	6.28	2.00	9.33	1.97	5.26	24.84
2004	6.28	4.64	4.04	9.56	0.97	25.49
2005	2.31	3.52	3.95	2.65	4.43	16.86
2006	6.02	2.55	6.09	5.35	2.69	
2007	2.33	2.47	5.06	6.58	1.12	17.56
2008	4.12	5.64	1.57	2.60	3.59	17.52
2009	5.23	2.91	2.71	5.25	1.52	17.62
MEAN	**4.58**	**3.97**	**5.13**	**4.42**	**3.00**	**21.10**
MEDIAN	**4.84**	**3.88**	**4.38**	**3.30**	**2.60**	**20.52**

Difference from 20-Year Mean Precipitation

	May	Jun	Jul	Aug	Sept	TOTAL	% Diff
2007	-2.25	-1.50	-0.07	2.16	-1.88	-3.54	-16.8
2008	-0.46	1.67	-3.56	-1.82	0.59	-3.58	-17.0
2009	0.65	-1.06	-2.42	0.83	-1.48	-3.48	-16.5

Difference from 20-Year Median Precipitation

	May	Jun	Jul	Aug	Sept	TOTAL	% Diff
2007	-2.51	-1.41	0.69	3.28	-1.48	-2.96	-14.4
2008	-0.72	1.76	-2.81	-0.70	0.99	-3.00	-14.6
2009	0.39	-0.97	-1.67	1.95	-1.08	-2.90	-14.1

Option 2 – Pellet Formulation Protocol

Use a pellet-only protocol as discussed at the Manitou Summit meeting which uses high rates of Sonar pellets within designated zones where hydrilla plants or tubers have previously been reported. This would include the 19 zones established in 2008. These zones would be treated with a total of 140 ppb Sonar PR applied in three split treatments of 70 ppb in May, 35 ppb in June and 35 ppb in July.

This treatment model does introduce a slightly increased risk of the occurrence of areas of hydrilla biomass in some areas of Lake Manitou with no previously documented hydrilla plants or tubers. Due to this increased risk, an increase in sampling and observations is recommended. A modification of the 2009 monitoring protocol should include a biweekly sampling rotation of approximately 40 selected sites from the existing LARE Tier II survey locations such that all 122 accessible sites would be sampled after a six-week sampling cycle. The sole focus of this sampling should be hydrilla presence or absence. A quick response plan and budget for immediate treatment of hydrilla biomass with contact herbicide is included in this program. In addition a cost per gallon of Sonar AS is quoted in the event that it is needed to bring hydrilla growth under control.

Tuber sampling was reduced to a single fall survey of the six permanent stations at the request of IDNR in 2009. It is recommended that the modified sampling effort be continued in 2010 with exception of the deletion of Station 1. Deletion of Station 1 is in accordance with the established plan to abort any station where no tubers were collected in three consecutive sample collections. Future tuber sampling effort may have to be adjusted as the tuber bank becomes depleted, as previously mentioned. Tuber sampling can increase to a point as tuber density decreases, but “zero” tubers at the sampling sites should not be extrapolated to the whole lake or sampling area once zero is achieved. Stations should be monitored for three consecutive years with no hydrilla tubers before they are aborted.

It is also important to continue monitoring the submersed vegetation community with two Tier II surveys in 2010 (one late spring and one late summer). This will allow plant managers the ability to quantify changes in the native plant community and assist in potential detection of vegetative hydrilla. Similar surveys should be continued after the Sonar treatments are complete in order to detect any reintroductions of invasive species and monitor native vegetation recovery.

Finally, both Eurasian watermilfoil and curlyleaf pondweed (low abundance) were also present in Lake Manitou prior to the eradication effort on hydrilla. Both these species are susceptible to the Sonar concentrations being applied to control hydrilla, and were controlled by the Sonar treatments. Therefore, unless the seed bank of Eurasian watermilfoil and turion/seed bank of curlyleaf pondweed are long-lived, eradication of these two invasive species may also be attainable in Lake Manitou with repeated Sonar treatments. In 2009, limited finds were made of curlyleaf pondweed in June Tier II survey but Eurasian watermilfoil was not detected in either late spring or late summer assessments.

The original AMVP established three management goals:

1) Develop or maintain a stable diverse aquatic plant community that supports a good balance of predator and prey fish and wildlife species, good water quality, and is resistant to minor habitat disturbances and invasive species.
2) Direct efforts to preventing and/or controlling the negative impacts of aquatic invasive species.
3) Provide reasonable public access while minimizing the negative impacts on plant and wildlife species

Even after the introduction of hydrilla to Lake Manitou, the overall aquatic plant management objectives remain relatively the same: establish a diverse aquatic plant community, control aquatic invasive species, and provide reasonable public access. Currently, controlling hydrilla and eradicating this invasive species is paramount to the other objectives outlined in this plan. It is not unreasonable and should remain a goal to implement the other objectives long-term. Some of these objectives are realistic while hydrilla control is ongoing, and minor changes to the hydrilla control program were implemented to balance eradication efforts vs. other lake management objectives. Although the native species richness in Lake Manitou has historically been low, these species should recover to some extent during and/or following eradication efforts. Some minor introduction of additional native species may be justified long-term, as the plant community was historically dominated by a single species (i.e. eelgrass).

5.2 Budget Update

Budget review and updated cost projections are based on contract parameters.

The 2009 project cost was up 10% over 2008 due to a significant rain event late in the season which required a significant bump treatment to bring concentration back to 6 ppb to finish out the treatment season. In spite of this unusual event the project cost remained below the anticipated budget cap for the project.

Table 5.2.1. Budget update for 2009.

Year	Actual expenditures
2007	$349,920
2008	$317,549
2009	$351,949

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6.0 PUBLIC INVOLVEMENT

Public involvement is an important aspect of any vegetation management plan, but it takes on a whole new level of importance when dealing with an invasive species like hydrilla. IDNR Aquatic Invasive Species Coordinator, Doug Keller has headed up the public involvement aspect of the vegetation management plan (Personal communication, 9 Dec 2009).

Recent actions which Mr. Keller has undertaken in order to educate and inform the public concerning hydrilla are summarized below:

AIS (aquatic invasive species) presentation at joint meeting of Indiana Lake Management Society and Indiana Chapter of the American Fisheries Society January 2009
Presentation at Purdue AFS Student Chapter on AIS threats in Indiana March 2009
Hoosier Riverwatch program focusing on AIS plants and animals July 2009
Presentation on AIS plants in Indiana at Aquatic Control workshop
Presentation on AIS plants and animals at Steuben County Lakes Council meeting
Presentation on AIS plants at Cygnet workshop
News release: Manitou access closure in late April
News release: Manitou access opening in June

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7.0 REFERENCES CITED

Donahoe, J., and Keister, D, 2005. Lake Manitou Aquatic Vegetation Management Plan. Report to Lake Manitou Association, Rochester, IN.

Donahoe, J., and Keister, D, 2006. Lake Manitou Aquatic Vegetation Management Plan Update. Report to Lake Manitou Association, Rochester, IN.

Donahoe, J., and Keister, D, 2007. Lake Manitou Aquatic Vegetation Management Plan Update. Report to Lake Manitou Association, Rochester, IN.

Fascher, L. and Jones, W.W. 2006. Indiana Volunteer Lake Monitoring Report 1999 Report to IDEM Office of Water Quality, Indianapolis, IN.

Haller, W.T. and D.L. Sutton. 1975. Community structure and competition between hydrilla and Vallisneria. J. Aquat. Plant Manage. 13: 48-50.

Indiana Department of Natural Resources, Division of Fish and Wildlife. 2006. Tier II Aquatic Vegetation Survey Protocol. 26 pp.

Keller, Doug. Personal Communication. 9 December, 2009.

Langeland, K.A. 1996. *Hydrilla verticillata* (L.F.) Royle (Hydrocharitaceae), "The Perfect Aquatic Weed". Castanea 61:293-304.

J. J. Nawrocki, R. J. Richardson, S. Hoyle, A. P. Gardner, R. L. Roten. 2009. Monoecious hydrilla phenology and tuber dynamics in North Carolina. Presentation at the 2009 Annual Meeting of the Weed Science Society of America. February 9-13, 2009. Orlando, Florida.

Rao, S. K., N.C. Magnin, J.B. Reiskind and G. Bowes. 2002. Photosynthetic and other phosphoenolpyruvate carboxylase iosforms in the single-cell, facultative C4 system of *Hydrilla verticillata*. Plant Physiology. 130: 876-886.

SePRO, 2008. Lake Manitou Aquatic Vegetation Management Plan Update, March 14, 2008 Report to Indiana Department of Natural Resources. Indianapolis, IN.

SePRO, 2009. 2008 Lake Manitou Aquatic Vegetation Management Plan Update. Report to Indiana Department of Natural Resources. Indianapolis, IN.

Sprecher, S.L., M.D. Netherland and A.B. Stewart. 1998. Phytoene and carotene response of aquatic plants to fluridone under laboratory conditions. J. Aquat. Plant Manage. 36(2): 111-121.

Van T.K., Haller WT, Bowes G. 1976. Comparison of the photosynthetic characteristics of three submersed aquatic plants. Plant Physiol. 58:761-768.

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Appendix

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Lake Manitou Hydrilla Eradication Program – YEAR 3

Initial Sonar Application Summary – May 14, 2009 (Thursday).

Contractor (SePRO) and sub-contractors (Aquatic Control and ReMetrix, LLC) made the initial Sonar (fluridone) treatment for year three, targeting hydrilla eradication in Lake Manitou, IN.

Prescription Planning

No modifications were made to the treatment prescription this year. Similar to last year, it is assumed this methodology might require more bump treatments due to the tighter range of targeted concentrations and smaller distribution of Sonar slow-release pellets. The strategy employed the use of initial Sonar liquid and pellet application to start the season, followed by at least two subsequent "bump" treatments to maintain lake-wide concentrations.

A temperature and DO_2 profile completed May 13, 2009 indicated no thermal stratification. Assuming isothermal conditions, herbicide prescription maps were calibrated to apply Sonar liquid to the entire water volume. Sonar granular product was prescribed for littoral areas only; no adjustments to calculated doses were thus necessary. Like 2007 and 2008, Sonar liquid was applied using variable rate technology. Output varied according to depth of the water and speed of the vessel. Sonar PR (Precision Release) was applied to 19 zones that historically contained hydrilla. Target ppb rates were prescribed based upon potential for dilution, lake morphometry, and tuber presence. No pellet applications were planned to water deeper than 12 feet.

Application Equipment

Sonar A.S. (liquid) was applied using a GPS-coupled precision-application injection pump that adjusted rate based upon speed and water depth. A feedback log was saved to produce an "as applied" map. Northwest-southeast transect lines on 100 meter spacing were used to guide the liquid application. Sonar PR (pellet) was applied at varied ppb rates with a hopper-fed blower. GPS positioning was used to insure applications were kept within prescription boundaries.

Application notes

Prescription maps were derived from hydroacoustic depth data taken on October 5, 2006. Not all areas displayed within the Web Atlas as "shoreline" were accessible to the Sonar AS application vessel. GPS tracks and the "as-applied" log record the precise spatial positioning of the application. The equipment was triple-rinsed according to standard procedures and rinsate applied over the deepest areas in the lake. A total of 36 gallons of Sonar AS was applied. Sonar PR was applied to all areas as prescribed. A GPS record was kept to track the position of the vessel. The tracks do not necessarily represent the exact locations where granular applications were made, but rather a record of the granular vessel's position throughout the day's activities. A total of 1010 lbs of Sonar PR was applied to the 19 zones.

See the ReMetrix Web Atlas for an interactive map display of the aforementioned data.

http://ims.remetrix.com

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LARE Tier II Survey Raw Data 6/16/2009

WPT	Lat	Long	Depth	Rake score	Curlyleaf pondweed	Fil. Algae	Chara	Sago pondweed	Coontail	Bladder wort	Largeleaf pondweed	Eel grass
1	41.06090	-86.17843	4	0								
2	41.06142	-86.18021	4	0		P						
3	41.05924	-86.18810	3	1		P	1					
4	41.05921	-86.18875	4	1		P	1					
5	41.05530	-86.17996	5	0								
6	41.05695	-86.18784	4	1			1					
7	41.05406	-86.17718	3	0		P						
8	41.04456	-86.18524	4	1		P	1	1		1	1	1
9	41.06030	-86.19520	1	0								
10	41.06090	-86.19662	2	0		P						
11	41.03551	-86.16812	2	1		P	1					
12	41.03916	-86.17678	3	0		P						
13	41.03912	-86.17497	2	1		P		1				
14	41.03920	-86.17338	3	3	1			3				
15	41.03875	-86.17026	3	0		P						
16	41.04039	-86.17759	4	0		P						
17	41.04025	-86.17583	6	1	1							
18	41.04029	-86.17409	5	0		P						
19	41.04030	-86.17235	3	0		P						
20	41.04031	-86.17057	4	1		P	1	1				
22	41.04149	-86.17858	4	0		P						
23	41.04152	-86.17311	3	0		P						
24	41.04280	-86.17948	4	1		P			1			
26	41.04377	-86.18035	7	0		P						
27	41.04377	-86.17334	11	0								
28	41.04453	-86.18439	2	0		P						
29	41.04501	-86.17950	3	0		P						
30	41.04610	-86.18044	2	0		P						
31	41.04595	-86.17508	7	0								
32	41.04719	-86.18302	8	0								
33	41.04733	-86.17958	4	0								
34	41.04847	-86.18036	4	1		P	1					
35	41.04945	-86.18648	4	0								
36	41.04946	-86.18499	3	1		P	1					
37	41.05072	-86.18577	6	0								
38	41.05066	-86.18387	4	0		P						
39	41.05078	-86.18034	6	0		P						
40	41.05064	-86.17142	8	0								
41	41.05074	-86.16973	4	1		P	1					
42	41.05179	-86.18995	4	0		P						
43	41.05177	-86.18490	7	0								
44	41.05178	-86.18318	4	0								
45	41.05181	-86.18140	4	0								
46	41.05181	-86.17945	5	1				1				
47	41.05184	-86.17769	4	0		P						
48	41.05192	-86.17586	6	0		P						
49	41.05190	-86.17243	6	0								
50	41.05202	-86.17079	6	0		P						
51	41.05301	-86.18918	5	0								
52	41.05298	-86.18740	4	1				1				
53	41.05300	-86.18563	4	1				1				
54	41.05302	-86.18388	5	0								
55	41.05293	-86.17865	4	1		P	1					
56	41.05296	-86.17679	3	0		P						
57	41.05291	-86.16979	5	0		P						
58	41.05430	-86.19016	5	1				1				
59	41.05415	-86.18856	10	0								
60	41.05407	-86.18675	4	0								
61	41.05424	-86.18489	4	1				1				
62	41.05413	-86.17949	5	1				1				

LARE Tier II Survey Raw Data 6/16/2009 cont.

63	41.05412	-86.17764	4	0		P						
64	41.05425	-86.17063	6	0								
65	41.05540	-86.19107	4	0		P						
66	41.05523	-86.18561	4	0								
67	41.05542	-86.18407	4	1				1				
68	41.05529	-86.17871	5	0								
69	41.05532	-86.17694	4	0		P						
70	41.05537	-86.17161	6	0								
71	41.05542	-86.16978	5	0								
72	41.05641	-86.19216	3	0		P						
73	41.05646	-86.19026	4	0		P						
74	41.05643	-86.18845	5	0								
75	41.05644	-86.18676	6	0								
76	41.05652	-86.17782	6	0								
77	41.05655	-86.17593	5	0								
78	41.05659	-86.17067	4	1		P	1					
79	41.05756	-86.19298	3	0								
80	41.05757	-86.19115	4	1			1					
81	41.05761	-86.18916	4	1		P	1					
82	41.05770	-86.18755	4	0		P						
83	41.05762	-86.18570	4	0								
84	41.05771	-86.18401	4	1				1				
85	41.05782	-86.17862	6	0								
86	41.05776	-86.17679	6	0								
87	41.05813	-86.17139	5	0								
88	41.05883	-86.19191	3	0								
89	41.05858	-86.19007	4	0								
90	41.05882	-86.18841	3	1		P	1					
91	41.05880	-86.18665	4	0		P						
92	41.05877	-86.18495	4	0		P						
93	41.05881	-86.18324	4	0								
94	41.05876	-86.18144	5	0								
95	41.05882	-86.17971	6	0								
96	41.05880	-86.17796	5	0								
97	41.05890	-86.17607	5	0								
98	41.05893	-86.17439	7	0								
99	41.05894	-86.17246	5	0								
100	41.05986	-86.19466	3	1			1					
101	41.05994	-86.19282	3	1			1					
102	41.05995	-86.18944	8	0		P						
103	41.06005	-86.18215	4	0								
104	41.05995	-86.18052	5	0								
105	41.05998	-86.17874	5	0								
106	41.06002	-86.17694	4	0		P						
107	41.05997	-86.17505	5	0		P						
108	41.05986	-86.17323	4	0		P						
109	41.06092	-86.18498	3	0								
110	41.06113	-86.18318	3	1		P	1					
111	41.06108	-86.18132	4	0		P						
112	41.06111	-86.17951	4	0		P						
113	41.05424	-86.1773	4	1			1					
DK 1	41.06071	-86.19449	3	1			1					
DK 2	41.05927	-86.19456	14	0		P						
DK 3	41.06106	-86.18397	4	0		P						
DK 4	41.06179	-86.18296	3	1		P	1					
DK 5	41.05555	-86.19245	4	1		P	1					
DK 6	41.04855	-86.18697	4	1		P	1					
DK 7	41.04933	-86.18957	5	0		P						
DK 8	41.04548	-86.18241	5	0								
DK 9	41.04945	-86.17431	3	0								
DK 10	41.0502	-86.17181	2	1			1					
DNR 1	41.04877	-86.18804	3	0		P						

LARE Tier II Survey Raw Data 8/30/2009

WPT	Lat	Long	Depth	Rake score	Curlyleaf pondweed	Fil. Algae	Chara	Sago pondweed	Coontail	Bladderwort	Largeleaf pondweed	Eel grass	Water stargrass
1	41.06090	-86.17843	3	0									
2	41.06142	-86.18021	4	0		P							
3	41.05924	-86.18810	3	0									
4	41.05921	-86.18875	4	1		P	1						
5	41.05530	-86.17996	6	0									
6	41.05695	-86.18784	4	0									
7	41.05406	-86.17718	3	0									
8	41.04456	-86.18524	4	1		P				1			
9	41.06030	-86.19520	1	0									
10	41.06090	-86.19662	2	0									
11	41.03551	-86.16812											
12	41.03916	-86.17678	3	1				1					
13	41.03912	-86.17497	3	1									1
14	41.03920	-86.17338	3	3				3					
15	41.03875	-86.17026	2	1				1	1				
16	41.04039	-86.17759	3	0		P							
17	41.04025	-86.17583	6	0									
18	41.04029	-86.17409	5	0									
19	41.04030	-86.17235	4	0		P							
20	41.04031	-86.17057	3	0									
22	41.04149	-86.17858	3	0		P							
23	41.04152	-86.17311	3	0		P							
24	41.04280	-86.17948	2	0									
26	41.04377	-86.18035	4	0		P							
27	41.04377	-86.17334	7	0									
28	41.04453	-86.18439											
29	41.04501	-86.17950	3	0									
30	41.04610	-86.18044	2	0		P							
31	41.04595	-86.17508	3	0									
32	41.04719	-86.18302	12	0									
33	41.04733	-86.17958	4	0									
34	41.04847	-86.18036	4	0									
35	41.04945	-86.18648	5	0									
36	41.04946	-86.18499	3	0									
37	41.05072	-86.18577	5	0									
38	41.05066	-86.18387	4	0		P							
39	41.05078	-86.18034	5	1				1					
40	41.05064	-86.17142	15	0									
41	41.05074	-86.16973	4	0		P							
42	41.05179	-86.18995	2	0									
43	41.05177	-86.18490	6	0									
44	41.05178	-86.18318	3	0									
45	41.05181	-86.18140	4	0									
46	41.05181	-86.17945	6	0									
47	41.05184	-86.17769	4	0									
48	41.05192	-86.17586	7	0									
49	41.05190	-86.17243	7	0									
50	41.05202	-86.17079	5	0									
51	41.05301	-86.18918	5	0									
52	41.05298	-86.18740	4	0									
53	41.05300	-86.18563	4	0									
54	41.05302	-86.18388	5	0									
55	41.05293	-86.17865	4	0									
56	41.05296	-86.17679	3	0		P							
57	41.05291	-86.16979	6	0									
58	41.05430	-86.19016	5	0									
59	41.05415	-86.18856	7	0									
60	41.05407	-86.18675	4	0									
61	41.05424	-86.18489	4	0									
62	41.05413	-86.17949	5	0									
63	41.05412	-86.17764	4	0		P							

LARE Tier II Survey Raw Data 8/30/2009 cont.

64	41.05425	-86.17063	5	0									
65	41.05540	-86.19107	4	0									
66	41.05523	-86.18561	4	0									
67	41.05542	-86.18407	6	0									
68	41.05529	-86.17871	5	0									
69	41.05532	-86.17694	5	0									
70	41.05537	-86.17161	5	0									
71	41.05542	-86.16978	5	0									
72	41.05641	-86.19216	3	0									
73	41.05646	-86.19026	4	0									
74	41.05643	-86.18845	5	0									
75	41.05644	-86.18676	7	0									
76	41.05652	-86.17782	6	0									
77	41.05655	-86.17593	6	0									
78	41.05659	-86.17067	4	0									
79	41.05756	-86.19298	3	0									
80	41.05757	-86.19115	4	0									
81	41.05761	-86.18916	4	0									
82	41.05770	-86.18755	4	0									
83	41.05762	-86.18570	4	0									
84	41.05771	-86.18401	4	0									
85	41.05782	-86.17862	7	0									
86	41.05776	-86.17679	6	0									
87	41.05813	-86.17139	5	0									
88	41.05883	-86.19191	3	0									
89	41.05858	-86.19007	4	0									
90	41.05882	-86.18841	4	0									
91	41.05880	-86.18665	4	1			1						
92	41.05877	-86.18495	4	0		P							
93	41.05881	-86.18324	4	0									
94	41.05876	-86.18144	5	0									
95	41.05882	-86.17971	6	0									
96	41.05880	-86.17796	5	0		P							
97	41.05890	-86.17607	5	0									
98	41.05893	-86.17439	8	0									
99	41.05894	-86.17246	5	0									
100	41.05986	-86.19466	5	0									
101	41.05994	-86.19282	3	0									
102	41.05995	-86.18944	6	0									
103	41.06005	-86.18215	4	0		P							
104	41.05995	-86.18052	4	0									
105	41.05998	-86.17874	5	0		P							
106	41.06002	-86.17694	4	0									
107	41.05997	-86.17505	4	1		P		1					
108	41.05986	-86.17323	3	0		P							
109	41.06092	-86.18498	3	0									
110	41.06113	-86.18318	3	0		P							
111	41.06108	-86.18132	4	0									
112	41.06111	-86.17951	4	0		P							
113	41.05424	-86.1773	4	0		P							
DK 1	41.06071	-86.19449	4	1			1						
DK 2	41.05927	-86.19456	4	0									
DK 3	41.06106	-86.18397	2	0		P							
DK 4	41.06179	-86.18296	3	0		P							
DK 5	41.05555	-86.19245	3	0									
DK 6	41.04855	-86.18697	4	0		P							
DK 7	41.04933	-86.18957	7	0									
DK 8	41.04548	-86.18241	14	0									
DK 9	41.04945	-86.17431	20	0									
DK 10	41 0502	-86.17181	6	0									

FasTEST Collection Vegetation Monitoring Data Sheets

May 18 – November 16, 2009

Lake Manitou Sample Collection

Injury:		Cover:		Growth:		Other Indicators:		
1	Healthy	1	80-100	1	From Apical Tips or Nodes	T	Topped out Vegetation	Biologist Name:
2	Slight injury	2	60-79	2	From Seeds	I	Suspected Insect Damage	
3	Moderate injury	3	40-59	3	From Root Crown or Rhizomes	P	Suspected Pathogen Damage	David Keister
4	Severe Injury	4	20-39	4	From Turions or Tubers	M	Mechanical Damage	Aquatic Weed Control
5	Dead plant	5	<19	5	From Perennial - shrub, tree, etc.	W	Water Fluctuation Damage	
6	Not present	6	Not present	6	No growth	E	End of Life Cycle	

Survey Date: 18-May-09

Date of Treatment: 14-May-08

Gauge Reading: gauge not there

Site	Species	Injury	Cover	Growth	Other	Photos	Secchi	Depth	H2OTemp	D O2	Notes
1	no plants	6					4.1		63.0	-	depth 6.5 feet
2	no plants	6					5.1	surface	63.8	9.53	depth 30 feet
								1m	63.5	9.52	
								2m	63.1	9.54	
								3m	62.8	9.35	
								4m	62.0	8.99	
								5m	61.8	8.75	
								6m	61.5	8.47	
								7m	60.1	6.75	
								8m	54.3	1.95	
								9m	51.1	0.75	
								10m	48.8	0.20	
3	algae present						3.5		64.2	-	depth 5 feet
	Chara	5									
4	algae present	6					3.8		62.5	-	depth 5 feet
	Chara										
5	no plants	6					3.1		60.0	-	depth 18 feet
6	algae present	6					2.8		61.6	-	depth 4 feet
7	no plants	6					2.4	surface	64.6	8.52	depth 39 feet
								1m	63.8	8.46	
								2m	63.5	8.46	
								3m	62.6	8.16	
								4m	62.2	7.90	
								5m	61.8	7.47	
								6m	61.2	6.74	
								7m	60.8	6.90	
								8m	60.1	6.16	
								9m	60.0	6.09	
								10m	58.6	4.31	
								11m	57.0	2.66	
9	algae present						3.1		65.3	-	depth 5 feet
	Chara	5									**Summary**
											water level maybe 8 inches high. Lake losing a lot of water over the dam
											water temp 60.0 - 65.3 F
											Secchi 2.4 - 5.1 feet
											sunny, Temp 60's
											rake samples taken at each shallow fastest point
											coontail, curly leaf, and duckweed all observed floating
											Chara was the only plant collected on rake
											gauge for lake level was gone-may have been washed away
											no hydrilla found

Lake Manitou Sample Collection

Injury:		Cover:		Growth:		Other Indicators:		
1	Healthy	1	80-100	1	From Apical Tips or Nodes	T	Topped out Vegetation	Biologist Name:
2	Slight injury	2	60-79	2	From Seeds	I	Suspected Insect Damage	
3	Moderate injury	3	40-59	3	From Root Crown or Rhizomes	P	Suspected Pathogen Damage	David Keister
4	Severe Injury	4	20-39	4	From Turions or Tubers	M	Mechanical Damage	Aquatic Weed Control
5	Dead plant	5	<19	5	From Perennial - shrub, tree, etc.	W	Water Fluctuation Damage	
6	Not present	6	Not present	6	No growth	E	End of Life Cycle	

Survey Date: 8-Jun-09

Date of Treatment: 14-May-08

Gauge Reading: gauge not there

Site	Species	Injury	Cover	Growth	Other	Photos	Secchi	Depth	H2OTemp	D O2	Notes
1	no plants		6				3.6		70.9	-	depth 6.5 feet
2	no plants		6				3.9	surface	71.9	9.46	depth 30 feet
								1m	71.9	9.47	
								2m	71.7	9.47	
								3m	71.5	9.25	
								4m	67.3	2.71	
								5m	64.6	0.16	
								6m	62.3	0.13	
								7m	59.8	0.10	
								8m	55.2	0.09	
								9m	52.4	0.07	
								10m	50.4	0.07	
3	no plants		6				3.5		72.0	-	depth 5 feet
4	algae present						4.5		70.3	-	depth 5 feet
	Chara	2	5	3							
5	no plants		6				4.1		72.6	-	depth 18 feet
6	algae present		6				3.9		71.0	-	depth 4 feet
7	no plants		6				4.0	surface	72.0	10.4	depth 39 feet
								1m	71.7	10.5	
								2m	71.5	10.5	
								3m	71.4	10.4	
								4m	69.8	7.3	
								5m	66.0	1.9	
								6m	65.3	1.2	
								7m	62.8	0.2	
								8m	61.7	0.1	
								9m	60.3	0.1	
								10m	58.9	0.1	
								11m	56.9	0.1	
9	algae present						2.3		72.6	-	depth 5 feet
											Summary
											water level still appears high - no gauge
											water temp 70.3 - 72.6 F
											Secchi 2.3 - 4.5 feet
											windy, rainy, temp in 60's
											rake samples taken at each shallow fastest point
											sago pondweed observed at south end of lake
											Chara was the only plant collected on rake
											no hydrilla found

Lake Manitou Sample Collection

Injury:		Cover:		Growth:		Other Indicators:		
1	Healthy	1	80-100	1	From Apical Tips or Nodes	T	Topped out Vegetation	Biologist Name:
2	Slight injury	2	60-79	2	From Seeds	I	Suspected Insect Damage	
3	Moderate injury	3	40-59	3	From Root Crown or Rhizomes	P	Suspected Pathogen Damage	David Keister
4	Severe Injury	4	20-39	4	From Turions or Tubers	M	Mechanical Damage	Aquatic Weed Control
5	Dead plant	5	<19	5	From Perennial - shrub, tree, etc.	W	Water Fluctuation Damage	
6	Not present	6	Not present	6	No growth	E	End of Life Cycle	

Survey Date: 22-Jun-09

Date of Treatment: 14-May-09

Gauge Reading: gauge not there

Site	Species	Injury	Cover	Growth	Other	Photos	Secchi	Depth	H2OTemp	D O2	Notes
1	no plants		6				3.0		79.3	-	depth 6.5 feet
2	no plants		6				3.0	surface	81.1	9.69	depth 30 feet
								1m	80.6	9.77	
								2m	78.9	8.16	
								3m	76.1	6.15	
								4m	72.6	3.09	
								5m	70.2	1.15	
								6m	64.1	0.17	
								7m	59.9	0.11	
								8m	55.6	0.08	
								9m	52.9	0.07	
								10m	50.8	0.06	
3	no plants		6				2.5		80.0	-	depth 5 feet
	algae present										
4	algae present						2.9		79.3	-	depth 5 feet
	Chara	2	5	3							
5	no plants		6				3.1		80.2	-	depth 18 feet
6	algae present		6				3.2		80.7	-	depth 4 feet
7	no plants		6				3.4	surface	81.9	11.43	depth 39 feet
								1m	81.2	11.60	
								2m	79.9	10.29	
								3m	76.0	6.06	
								4m	74.0	4.16	
								5m	70.9	1.47	
								6m	69.2	0.26	
								7m	65.5	0.14	
								8m	63.3	0.11	
								9m	60.1	0.09	
								10m	58.1	0.08	
								11m	56.8	0.08	
9	algae present						3.1		79.1	-	depth 5 feet
											Summary
											water level slightly high - no gauge
											water temp 79.3 - 81.9 F Secchi 2.5 - 3.4 feet
											sunny, warm temp in upper 80's
											rake samples taken at each shallow fastest point
											sago, coontail, curlyleaf, elodea and duckweed observed floating
											Chara was the only plant collected on rake
											Severely damaged hydrilla found along north shore between city access and poets point

Lake Manitou Sample Collection

Injury:		Cover:		Growth:		Other Indicators:		
1	Healthy	1	80-100	1	From Apical Tips or Nodes	T	Topped out Vegetation	Biologist Name:
2	Slight injury	2	60-79	2	From Seeds	I	Suspected Insect Damage	
3	Moderate injury	3	40-59	3	From Root Crown or Rhizomes	P	Suspected Pathogen Damage	David Keister
4	Severe Injury	4	20-39	4	From Turions or Tubers	M	Mechanical Damage	Aquatic Weed Control
5	Dead plant	5	<19	5	From Perennial - shrub, tree, etc.	W	Water Fluctuation Damage	
6	Not present	6	Not present	6	No growth	E	End of Life Cycle	

Survey Date: 7-Jul-09

Date of Treatment: 14-May-09

Gauge Reading: gauge not there

Site	Species	Injury	Cover	Growth	Other	Photos	Secchi	Depth	H2OTemp	D O2	Notes
1	Algae Present		6				3.6		75.4	-	depth 6.5 feet
2	no plants		6				3.3	surface	76.3	9.06	depth 30 feet
								1m	76.2	9.12	
								2m	75.6	8.74	
								3m	75.1	8.13	
								4m	72.3	6.65	
								5m	70.2	3.36	
								6m	67.5	0.33	
								7m	66.9	0.18	
								8m	66.8	0.15	
								9m	66.7	0.14	
								10m	66.5	0.12	
3	no plants		6				bottom visible		76.4		depth 5 feet
	algae present										
4	algae present						2.9		75.6	-	depth 5 feet
	Chara	2	5	3							
5	no plants		6				4.3		76.8	-	depth 18 feet
6	algae present		6				3.4		76.6	-	depth 4 feet
	Chara	2	5	3							
	sago pondweed	2	5	2							
7	no plants		6				4.1	surface	77.8	10.04	depth 39 feet
								1m	77.0	10.16	
								2m	76.4	10.00	
								3m	75.8	9.21	
								4m	75.1	8.33	
								5m	72.8	6.16	
								6m	71.2	3.33	
								7m	67.4	0.24	
								8m	63.6	0.18	
								9m	60.7	0.15	
								10m	58.4	0.13	
								11m	56.7	0.12	
9	algae present						bottom visible		75.2	-	depth 5 feet
											Summary
											water level about average - no gauge
											water temp 75.2 - 77.8 F
											Secchi 2.9 - 4.3 feet
											sunny, warm temp in upper 70s
											rake samples taken at each shallow fastest point
											sago, coontail, curlyleaf, elodea and duckweed observed floating
											Chara and sago pondweed were collected on rake; no hydrilla found

Lake Manitou Sample Collection

Injury:		Cover:		Growth:		Other Indicators:		
1	Healthy	1	80-100	1	From Apical Tips or Nodes	T	Topped out Vegetation	Biologist Name:
2	Slight injury	2	60-79	2	From Seeds	I	Suspected Insect Damage	
3	Moderate injury	3	40-59	3	From Root Crown or Rhizomes	P	Suspected Pathogen Damage	David Keister
4	Severe Injury	4	20-39	4	From Turions or Tubers	M	Mechanical Damage	Aquatic Weed Control
5	Dead plant	5	<19	5	From Perennial - shrub, tree, etc.	W	Water Fluctuation Damage	
6	Not present	6	Not present	6	No growth	E	End of Life Cycle	

Survey Date: 20-Jul-09

Date of Treatment: 14-May-09

Gauge Reading: gauge not there

Site	Species	Injury	Cover	Growth	Other	Photos	Secchi	Depth	H2OTemp	D O2	Notes
1	no plants		6				4.0		75.3	-	depth 6.5 feet
2	no plants		6				4.1	surface	75.9	8.09	depth 30 feet
								1m	74.7	8.02	
								2m	73.8	7.70	
								3m	73.4	7.26	
								4m	72.7	5.96	
								5m	71.4	2.18	
								6m	67.5	0.15	
								7m	61.0	0.11	
								8m	58.1	0.10	
								9m	55.0	0.09	
								10m	52.7	0.08	
3	no plants		6				3.3		75.5	-	depth 5 feet
	algae present										
4	algae present						3.9		75.4	-	depth 5 feet
5	no plants		6				4.6		79.5	-	depth 18 feet
6	no plants		6				3.8		76.7	-	depth 4 feet
7	no plants		6				4.8	surface	76.0	8.70	depth 39 feet
								1m	75.2	8.64	
								2m	74.6	8.31	
								3m	73.7	6.79	
								4m	73.4	5.72	
								5m	73.0	4.68	
								6m	72.0	2.23	
								7m	68.4	0.21	
								8m	63.5	0.14	
								9m	60.3	0.12	
								10m	58.6	0.11	
								11m	57.2	0.10	
9	algae present						2.4		75.3	-	depth 5 feet
											Summary
											water level about average - no gauge
											water temp 75.3 - 79.7 F
											Secchi 2.4 - 4.8 feet
											sunny, warm temp in mid 70s
											rake samples taken at each shallow fastest point
											sago, coontail, and duckweed observed floating
											sago pondweed appears to be increasing rapidly at the south end of the lake
											no hydrilla found

Lake Manitou Sample Collection

Injury:		Cover:		Growth:		Other Indicators:		
1	Healthy	1	80-100	1	From Apical Tips or Nodes	T	Topped out Vegetation	Biologist Name:
2	Slight injury	2	60-79	2	From Seeds	I	Suspected Insect Damage	David Keister
3	Moderate injury	3	40-59	3	From Root Crown or Rhizomes	P	Suspected Pathogen Damage	
4	Severe Injury	4	20-39	4	From Turions or Tubers	M	Mechanical Damage	Aquatic Weed Control
5	Dead plant	5	<19	5	From Perennial - shrub, tree, etc.	W	Water Fluctuation Damage	
6	Not present	6	Not present	6	No growth	E	End of Life Cycle	

Survey Date: 3-Aug-09

Date of Treatment: 14-May-08

Gauge Reading: gauge not there

Site	Species	Injury	Cover	Growth	Other	Photos	Secchi	Depth	H2OTemp	D O2	Notes
1	no plants		6				3.8		74.9	-	depth 6.5 feet
2	no plants		6				4.1	surface	75.1	7.62	depth 30 feet
								1m	75.1	7.54	
								2m	75.1	7.50	
								3m	75.0	7.55	
								4m	74.9	7.42	
								5m	72.2	1.75	
								6m	67.9	0.26	
								7m	62.8	0.15	
								8m	60.9	0.11	
								9m	58.4	0.10	
								10m	56.1	0.09	
3	no plants		6				3.0		75.4		depth 5 feet
	algae present										
4	algae present						3.6		74.7	-	depth 5 feet
5	no plants		6				4.2		75.7	-	depth 18 feet
6	no plants		6				3.9		75.4	-	depth 4 feet
	algae present										
7	no plants		6				4.0	surface	75.2	8.56	depth 39 feet
								1m	75.3	8.53	
								2m	75.3	8.47	
								3m	75.2	8.39	
								4m	75.2	8.30	
								5m	75.1	7.84	
								6m	74.5	5.94	
								7m	70.0	0.24	
								8m	64.1	0.18	
								9m	61.5	0.14	
								10m	58.2	0.12	
								11m	56.6	0.11	
9	algae present						2.8		74.3	-	depth 5 feet
											Summary
											water level about average - no gauge
											water temp 74.3 - 75.7 F
											Secchi 2.8 - 4.2 feet
											sunny, windy, warm temp in mid 70s
											rake samples taken at each shallow fastest point
											sago, and duckweed observed floating
											took pictures of sago at south end of lake
											no hydrilla found

Lake Manitou Sample Collection

Injury:		Cover:		Growth:		Other Indicators:		
1	Healthy	1	80-100	1	From Apical Tips or Nodes	T	Topped out Vegetation	Biologist Name:
2	Slight injury	2	60-79	2	From Seeds	I	Suspected Insect Damage	
3	Moderate injury	3	40-59	3	From Root Crown or Rhizomes	P	Suspected Pathogen Damage	David Keister
4	Severe Injury	4	20-39	4	From Turions or Tubers	M	Mechanical Damage	Aquatic Weed Control
5	Dead plant	5	<19	5	From Perennial - shrub, tree, etc.	W	Water Fluctuation Damage	
6	Not present	6	Not present	6	No growth	E	End of Life Cycle	

Survey Date: 17-Aug-09

Date of Treatment: 14-May-08

Gauge Reading: gauge not there

Site	Species	Injury	Cover	Growth	Other	Photos	Secchi	Depth	H2OTemp	D O2	Notes
1	no plants		6				3.8		79.6	-	depth 6.5 feet
2	no plants		6				4.3	surface	80.8	7.54	depth 30 feet
								1m	80.5	7.52	
								2m	80.3	7.41	
								3m	80.2	7.46	
								4m	76.9	2.97	
								5m	74.0	0.21	
								6m	70.0	0.16	
								7m	65.1	0.12	
								8m	60.0	0.09	
								9m	56.7	0.08	
								10m	54.0	0.07	
3	algae present						4.1		79.2	-	depth 5 feet
4	algae present						3.2		79.7	-	depth 5 feet
5	no plants		6				4.2		79.3	-	depth 18 feet
6	no plants		6				4.7		80.4	-	depth 4 feet
7	no plants		6				4.8	surface	80.6	7.73	depth 39 feet
								1m	80.4	7.68	
								2m	80.2	7.54	
								3m	80.0	7.45	
								4m	79.9	7.02	
								5m	77.7	2.78	
								6m	76.9	1.85	
								7m	75.2	0.20	
								8m	71.1	0.14	
								9m	68.6	0.11	
								10m	63.6	0.08	
								11m	60.1	0.07	
9	algae present						2.8		79.4	-	depth 5 feet
	coontail		3	1							**Summary**
											water level slightly high - no gauge
											water temp 79.2 - 80.8 F
											Secchi 2.8 - 4.8 feet
											cloudy, windy, rainy
											rake samples taken at each shallow fastest point
											coontail and sago observed at south end of lake- coontail collected on rake
											no hydrilla found

Lake Manitou Sample Collection

Injury:		Cover:		Growth:		Other Indicators:		
1	Healthy	1	80-100	1	From Apical Tips or Nodes	T	Topped out Vegetation	Biologist Name:
2	Slight injury	2	60-79	2	From Seeds	I	Suspected Insect Damage	
3	Moderate injury	3	40-59	3	From Root Crown or Rhizomes	P	Suspected Pathogen Damage	David Keister
4	Severe Injury	4	20-39	4	From Turions or Tubers	M	Mechanical Damage	Aquatic Weed Control
5	Dead plant	5	<19	5	From Perennial - shrub, tree, etc.	W	Water Fluctuation Damage	
6	Not present	6	Not present	6	No growth	E	End of Life Cycle	

Survey Date: 31-Aug-09

Date of Treatment: 14-May-08

Gauge Reading: gauge not there

Site	Species	Injury	Cover	Growth	Other	Photos	Secchi	Depth	H2OTemp	D O2	Notes
1	no plants		6				3.9		71.7	-	depth 6.5 feet
2	no plants		6				4.2	surface	73.2	8.29	depth 30 feet
								1m	71.5	8.24	
								2m	70.4	7.77	
								3m	70.1	7.45	
								4m	69.9	7.21	
								5m	69.7	7.11	
								6m	69.4	6.73	
								7m	68.8	5.31	
								8m	59.1	0.35	
								9m	55.7	0.24	
								10m	53.6	0.19	
3	algae present						3.9		72.3	-	depth 5 feet
	Chara	3	5	3							
4	algae present						3.1		72.8	-	depth 5 feet
5	no plants		6				4.3		73.9	-	depth 18 feet
6	Sago	3	5	2			4.2		74.9	-	depth 4 feet
7	no plants		6				4.2	surface	74.1	9.21	depth 39 feet
								1m	71.8	8.70	
								2m	71.3	8.01	
								3m	71.0	7.83	
								4m	70.9	7.65	
								5m	70.8	6.83	
								6m	70.5	6.56	
								7m	70.0	4.42	
								8m	68.3	2.00	
								9m	68.0	0.25	
								10m	62.1	0.18	
								11m	58.5	0.14	
9	algae present						bottom visible		71	-	depth 5 feet
											Summary
											water level slightly high - no gauge
											water temp 71.0 - 74.9 F
											Secchi 3.1 - 4.2 feet
											sunny, calm, temp in upper 70's
											rake samples taken at each shallow fastest point
											coontail and Chara collected on rake
											no hydrilla found

Lake Manitou Sample Collection

Injury:		Cover:		Growth:		Other Indicators:		
1	Healthy	1	80-100	1	From Apical Tips or Nodes	T	Topped out Vegetation	Biologist Name:
2	Slight injury	2	60-79	2	From Seeds	I	Suspected Insect Damage	
3	Moderate injury	3	40-59	3	From Root Crown or Rhizomes	P	Suspected Pathogen Damage	David Keister
4	Severe Injury	4	20-39	4	From Turions or Tubers	M	Mechanical Damage	Aquatic Weed Control
5	Dead plant	5	<19	5	From Perennial - shrub, tree, etc.	W	Water Fluctuation Damage	
6	Not present	6	Not present	6	No growth	E	End of Life Cycle	

Survey Date: 21-Sep-09

Date of Treatment: 14-May-09

Gauge Reading: gauge not there

Site	Species	Injury	Cover	Growth	Other	Photos	Secchi	Depth	H2OTemp	D O2	Notes
1	no plants		6				4.3		71.0	-	depth 6.5 feet
2	no plants		6				4.5	surface	71.5	7.95	depth 30 feet
								1m	71.3	7.90	
								2m	71.0	8.21	
								3m	70.7	8.16	
								4m	70.5	7.74	
								5m	70.3	7.49	
								6m	69.4	4.64	
								7m	67.5	0.50	
								8m	62.3	0.23	
								9m	58.9	0.17	
								10m	54.7	0.14	
3	algae present						4.5		71.3	-	depth 5 feet
4	algae present						4.1		71.0	-	depth 5 feet
5	no plants		6				5.3		71.9	-	depth 18 feet
6	algae present						bottom visible		71.2	-	depth 4 feet
7	no plants		6				5.0	surface	71.0	7.49	depth 39 feet
								1m	71.0	7.43	
								2m	71.0	7.37	
								3m	71.0	7.30	
								4m	70.8	6.77	
								5m	70.7	6.30	
								6m	70.2	4.04	
								7m	69.9	3.21	
								8m	68.8	0.23	
								9m	66.7	0.18	
								10m	62.6	0.14	
								11m	59.5	0.12	
9	algae present						bottom visible		70.9	-	depth 5 feet
	Chara	3	5	3							**Summary**
											water level might be low-not much water going over dam
											water temp 70.9 - 71.9 F
											Secchi 4.1 - 5.3 feet
											cloudy, breezy, temp in upper 70's
											rake samples taken at each shallow fastest point
											Chara collected on rake
											no hydrilla found

Lake Manitou Sample Collection

Injury:		Cover:		Growth:		Other Indicators:		
1	Healthy	1	80-100	1	From Apical Tips or Nodes	T	Topped out Vegetation	Biologist Name:
2	Slight injury	2	60-79	2	From Seeds	I	Suspected Insect Damage	
3	Moderate injury	3	40-59	3	From Root Crown or Rhizomes	P	Suspected Pathogen Damage	David Keister
4	Severe Injury	4	20-39	4	From Turions or Tubers	M	Mechanical Damage	Aquatic Weed Control
5	Dead plant	5	<19	5	From Perennial - shrub, tree, etc.	W	Water Fluctuation Damage	
6	Not present	6	Not present	6	No growth	E	End of Life Cycle	

Survey Date: 5-Oct-09

Date of Treatment: 14-May-09

Gauge Reading: gauge not there

Site	Species	Injury	Cover	Growth	Other	Photos	Secchi	Depth	H2OTemp	D O2	Notes
1	no plants		6				5.5		59.3	-	depth 6.5 feet
2	no plants		6				5.3	surface	59.7	8.37	depth 30 feet
								1m	59.2	8.19	
								2m	58.6	7.87	
								3m	58.5	7.73	
								4m	58.4	7.64	
								5m	58.4	7.56	
								6m	58.3	7.58	
								7m	58.3	7.10	
								8m	58.2	7.48	
								9m	58.1	7.45	
								10m	58.0	7.41	
3	algae present						5.2		59.3	-	depth 5 feet
4	no plants		6				4.5		59.0	-	depth 5 feet
5	no plants		6				5.0		60.6	-	depth 18 feet
6	algae present						bottom visible		60.9	-	depth 4 feet
7	no plants		6				5.5	surface	60.4	7.66	depth 39 feet
								1m	59.5	7.39	
								2m	59.1	7.12	
								3m	59.0	6.93	
								4m	58.9	6.81	
								5m	58.9	7.00	
								6m	58.8	6.92	
								7m	58.8	6.80	
								8m	58.8	6.77	
								9m	58.7	6.49	
								10m	58.6	6.38	
								11m	58.6	6.46	
9	algae present						bottom visible		57.9	-	depth 5 feet
											Summary
											water level might be low-not much water going over dam
											water temp 57.9 - 60.9 F
											Secchi 4.5 - 5.5 feet
											sunny, temp in low 60's
											rake samples taken at each shallow fastest point
											no plants collected on rake
											no hydrilla found

Lake Manitou Sample Collection

Injury:		Cover:		Growth:		Other Indicators:		
1	Healthy	1	80-100	1	From Apical Tips or Nodes	T	Topped out Vegetation	Biologist Name:
2	Slight injury	2	60-79	2	From Seeds	I	Suspected Insect Damage	
3	Moderate injury	3	40-59	3	From Root Crown or Rhizomes	P	Suspected Pathogen Damage	David Keister
4	Severe Injury	4	20-39	4	From Turions or Tubers	M	Mechanical Damage	Aquatic Weed Control
5	Dead plant	5	<19	5	From Perennial - shrub, tree, etc.	W	Water Fluctuation Damage	
6	Not present	6	Not present	6	No growth	E	End of Life Cycle	

Survey Date: 19-Oct-09

Date of Treatment: 14-May-09

Gauge Reading: gauge not there

Site	Species	Injury	Cover	Growth	Other	Photos	Secchi	Depth	H2OTemp	D O2	Notes
1	algae present						6.2		49.9	-	depth 6.5 feet
2	no plants		6				6.1	surface	50.5	11.62	depth 30 feet
								1m	50.4	11.66	
								2m	50.1	11.68	
								3m	49.9	11.68	
								4m	49.7	11.68	
								5m	49.7	11.70	
								6m	49.6	11.67	
								7m	49.6	11.71	
								8m	49.7	11.74	
								9m	49.8	11.72	
								10m	49.7	11.73	
3	algae present						bottom visible		53.3	-	depth 5 feet
4	algae present						bottom visible		49.5	-	depth 5 feet
5	no plants		6				5.3		49.9	-	depth 18 feet
6	algae present						4.8		50.7	-	depth 4 feet
7	no plants		6				6.2	surface	50.8	11.51	depth 39 feet
								1m	50.7	11.52	
								2m	50.8	11.51	
								3m	50.8	11.50	
								4m	50.6	11.48	
								5m	50.6	11.42	
								6m	50.5	11.42	
								7m	50.5	11.36	
								8m	50.5	11.34	
								9m	50.5	11.30	
								10m	50.5	11.28	
								11m	50.5	11.25	
9	algae present						bottom visible		50.7	-	depth 5 feet
											Summary
											water level probably average-little water going over dam
											water temp 49.9 - 53.3 F
											Secchi 4.8 - 6.2 feet
											cloudy, windy, temp in mid 50's
											rake samples taken at each shallow fastest point
											no plants collected on rake
											Lake completely de-stratified
											no hydrilla found

Lake Manitou Sample Collection

Injury:		Cover:		Growth:		Other Indicators:		
1	Healthy	1	80-100	1	From Apical Tips or Nodes	T	Topped out Vegetation	Biologist Name:
2	Slight injury	2	60-79	2	From Seeds	I	Suspected Insect Damage	
3	Moderate injury	3	40-59	3	From Root Crown or Rhizomes	P	Suspected Pathogen Damage	David Keister
4	Severe Injury	4	20-39	4	From Turions or Tubers	M	Mechanical Damage	Aquatic Weed Control
5	Dead plant	5	<19	5	From Perennial - shrub, tree, etc.	W	Water Fluctuation Damage	
6	Not present	6	Not present	6	No growth	E	End of Life Cycle	

Survey Date: 2-Nov-09

Date of Treatment: 14-May-09

Gauge Reading: gauge not there

Site	Species	Injury	Cover	Growth	Other	Photos	Secchi	Depth	H2OTemp	D O2	Notes
1	no plants		6				4.2		51.6	-	depth 6.5 feet
2	no plants		6				5.3	surface	52.6	9.93	depth 30 feet
								1m	52.2	9.91	
								2m	52.1	9.80	
								3m	52.1	9.77	
								4m	52.0	9.75	
								5m	52.0	9.86	
								6m	52.0	9.79	
								7m	52.0	9.89	
								8m	51.9	10.07	
								9m	51.8	10.26	
								10m	51.6	10.39	
3	algae present						bottom visible		51.7	-	depth 5 feet
4	no plants		6				4.2		51.5	-	depth 5 feet
5	no plants		6				5.8		53.0	-	depth 18 feet
6	no plants						4.4		52.6	-	depth 4 feet
7	no plants		6				5.0	surface	52.6	10.45	depth 39 feet
								1m	52.4	10.41	
								2m	52.3	10.40	
								3m	50.2	10.35	
								4m	52.1	10.25	
								5m	52.1	10.18	
								6m	52.0	9.92	
								7m	52.0	9.76	
								8m	52.0	9.76	
								9m	51.9	9.81	
								10m	51.9	9.76	
								11m	51.8	9.57	
9	algae present						bottom visible		51.2	-	depth 5 feet
											Summary
											water level probably a little high
											water temp 51.2 - 53.0 F
											Secchi 4.2 - 5.8 feet
											cloudy, windy, temp in mid 50's
											rake samples taken at each shallow fastest point
											no plants collected on rake
											Lake completely de-stratified
											no hydrilla found

Lake Manitou Sample Collection

Injury:		Cover:		Growth:		Other Indicators:		
1	Healthy	1	80-100	1	From Apical Tips or Nodes	T	Topped out Vegetation	Biologist Name:
2	Slight injury	2	60-79	2	From Seeds	I	Suspected Insect Damage	
3	Moderate injury	3	40-59	3	From Root Crown or Rhizomes	P	Suspected Pathogen Damage	David Keister
4	Severe Injury	4	20-39	4	From Turions or Tubers	M	Mechanical Damage	Aquatic Weed Control
5	Dead plant	5	<19	5	From Perennial - shrub, tree, etc.	W	Water Fluctuation Damage	
6	Not present	6	Not present	6	No growth	E	End of Life Cycle	

Survey Date: 16-Nov-09

Date of Treatment: 14-May-09

Gauge Reading: gauge not there

Site	Species	Injury	Cover	Growth	Other	Photos	Secchi	Depth	H2OTemp	D O2	Notes
1	algae present						5.1		49.2	-	depth 6.5 feet
2	no plants		6				5.8	surface	49.0	10.74	depth 30 feet
								1m	49.0	10.71	
								2m	49.1	10.64	
								3m	49.1	10.62	
								4m	49.1	10.60	
								5m	49.2	10.60	
								6m	49.2	10.58	
								7m	49.2	10.57	
								8m	49.2	10.55	
								9m	49.2	10.55	
								10m	49.2	10.53	
3	algae present						bottom visible		48.2	-	depth 5 feet
4	no plants		6				4.1		49.1	-	depth 5 feet
5	no plants		6				5.1		48.9	-	depth 18 feet
6	no plants						bottom visible		49.8	-	depth 4 feet
7	no plants		6				5.5	surface	49.2	10.76	depth 39 feet
								1m	49.7	10.60	
								2m	49.7	10.56	
								3m	49.7	10.54	
								4m	49.7	10.51	
								5m	49.7	10.44	
								6m	49.7	10.41	
								7m	49.7	10.36	
								8m	49.7	10.33	
								9m	49.7	10.31	
								10m	49.7	10.26	
								11m	49.6	10.22	
9	Chara	4	5	3			4.8		48.6	-	depth 5 feet
											Summary
											water level looks high - no gauge
											water temp 48.2 - 50.1 F
											Secchi 4.1 - 5.8 feet
											cloudy, windy, temp in mid 40's
											rake samples taken at each shallow fastest point
											Chara collected on rake
											Lake completely de-stratified
											no hydrilla found