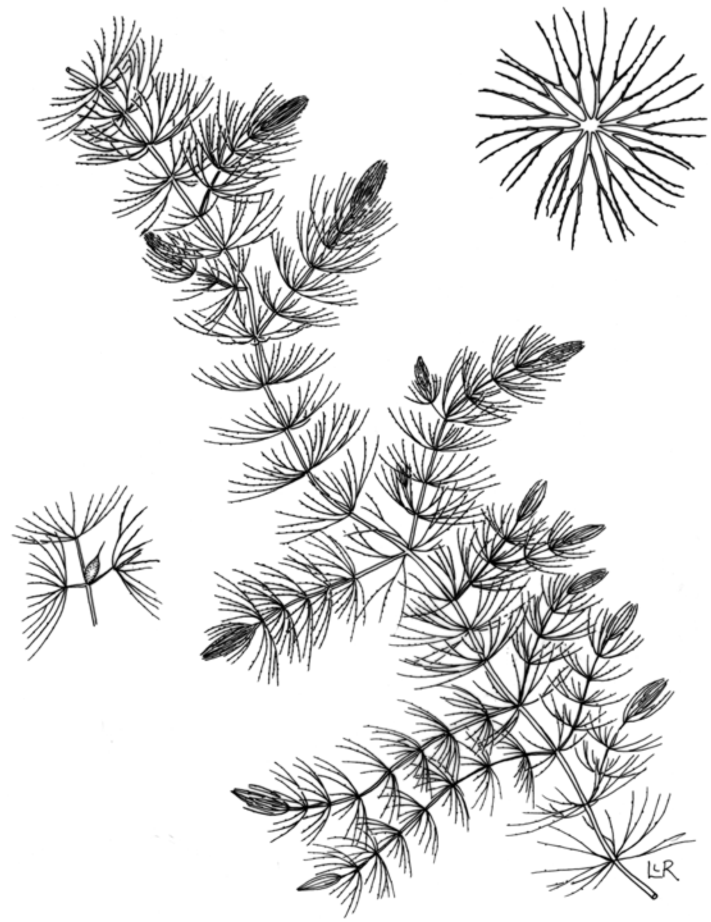
# A Comparison of the Distribution of Aquatic Plants in Holcombe Flowage, Chippewa County, Wisconsin between 1994/95 and 2006



*Ceratophyllum demersum*
Coontail

Beaver Creek Reserve
connecting people with nature


Citizen Science Center
Fall Creek, Wisconsin

January 2007

# A Comparison of the Distribution of Aquatic Plants in Holcombe Flowage, Chippewa County, Wisconsin between 1994/95 and 2006

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Beaver Creek Reserve, Citizen Science Center
January, 2007

## Contents

# Contents cont.

# Figures and Tables

## Figures



## Tables

# Abstract

In 2001 the Lower Chippewa River Settlement Agreement was reached in an effort to balance the energy needs of the community and the health of the Chippewa River biological and economic resources. A comparison of the distribution of aquatic plants in Holcombe Flowage between 1994/95 and 2006 was conducted to determine if the aquatic plant community has changed since the elimination of late-winter drawdowns.

US Army Corps of Engineers staff surveyed Holcombe Flowage in 1994/95. Using similar sampling techniques and sampling sites, a survey was conducted in 2006 by Beaver Creek Citizen Science researchers to be compared with the 1994/95 study. A baseline of information for density was created for use at a later date.

The Holcombe Flowage plant community has significantly changed in the 10-year time span between the surveys, and other minor changes in the community indicate that the community may be moving away from a more natural and diverse state.

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# I. INTRODUCTION

Holcombe Flowage was created in 1950 as a hydroelectric reservoir owned and operated by Xcel Energy. The reservoir, with an area of 1,640 ha (3,670 acres), is located on the Chippewa River in Chippewa County, Wisconsin (T32N, R6W), with additional inflows from the Flambeau and Jump Rivers. Holcombe Flowage has a maximum depth of 62 feet with the most acreage of the lake having a depth under 20ft (Appendix A).

The public heavily uses Holcombe Flowage. Multiple campgrounds and public parks are located along the lakeshore and the lake is used for fishing, boating, and other types of water recreation throughout the year. Holcombe provides critical habitat for fish and wildlife, stabilizes sediments flowing down the Chippewa River, and buffers nutrient inputs from watersheds. Xcel Energy, formally Northern States Power (NSP), owns a large amount of shoreline property along the flowage.

Due to these aspects of Holcombe Flowage and other impoundments created by Xcel Energy, the Wisconsin Department of Natural Resources (WDNR) in conjunction with environmental groups and Xcel Energy implemented the Chippewa Settlement Agreement in 2001 as part of a multiple dam re-licensing program. This agreement was reached to reduce or eliminate late winter drawdowns (Chippewa River Settlement Team, 2001). The last late winter drawn down performed on Holcombe Flowage was during the winter of 1994.

During the summers of 1994 and 1995 the US Army Corp of Engineers in cooperation with Northern States Power Company and WDNR conducted a pre-drawdown aquatic macrophyte study. Approximately 10 years later (2006) another aquatic macrophyte study was conducted and compared to the first to determine if any changes in the macrophyte community occurred due to the elimination of late winter draw downs.

The specific goals of this study are to: 1) provide a detailed description of the vegetative change to the community between the 1994/95 and 2006 studies, 2) evaluate any changes, 3) note location and abundance of any species of concern both native and invasive, and 4) identify any possible sensitive areas that may require management and/or protection.

# II. METHODS

## Field Methods

The Wisconsin Department of Natural Resources, and Xcel Energy identified 16 areas on Holcombe Flowage for aquatic plant sampling in 1994/95 (Appendix B). Aquatic plant sampling consisted of 1) biomass sampling, 2) point sampling of plant presence or absence, 3) species list of all plants observed, 4) location of species of concern, and 5) voucher specimen collection. Sampling was conducted in mid-summer of both 1994 and 1995, so seasonal trends or seasonally sensitive species may have been under-represented. The survey spanned over two growing seasons due to the size of the flowage. (Madsen and Barko, 1999)

The 2006 aquatic plant sampling used the same sampling sites determined for the 1994/95 study. The data collected in 2006 differed in that, 1) biomass was not measured, and 2) point sampling for density occurred, while similarly collected were 1) point sampling of plant presence or absence, 2) species list of all plants observed, 3) location of species of concern, and 4) voucher specimen collection.

Sample point grids varied in size between 5m and 300m squares (Appendix B). A total of 724 points were visited over various areas on Holcombe Flowage (Appendix C). At each grid point all species present were recorded and densities were taken using Jessen and Lound's (1962) raking method. Four raked samples were taken, using steel-thatching rakes, with one sample raked in each quarter of the 6-foot square, circular point. The aquatic plant species present on each rake sample were recorded. Each species was given an occurrence rating (0-5) based on the number of rake samples on which it was present at each quadrat (Deppe & Lathrop, 1992).

A rating of 1 indicated the species was present on 1 rake sample.
A rating of 2 indicated the species was present on 2 rake samples.
A rating of 3 indicated the species was present on 3 rake samples.
A rating of 4 indicated the species was present on 4 rake samples.
A rating of 5 indicated the species was abundantly present on all 4 rakes samples at the quadrat.

The actual depth and sediment type were recorded; sediment type was classified visually. An underwater camera was used to verify sediment type and deep-water plant occurrence.

If actual depth was greater than 15 feet, the point was deemed outside the littoral zone and not sampled. Additional points were added if the grid did not sample close enough to the shoreline to ensure collection of species in very shallow water.

Visual inspection and periodic samples were taken between grid points in order to record the presence of any species that did not occur at the sampled points for use in the species list only. Specimens of all plant species present were collected and preserved as voucher specimens. Nomenclature was according to Crow and Hellquist (2000) and Gleason and Cronquist (1991).

Secchi disk readings in 1994/95 were taken only when an area (bay) was sampled. Secchi disk measurements for the 2006 study were recorded once a week during July and August at five locations around the flowage: three locations on the main flowage, one on Cranberry Lake, and one on Pine Lake. GPS coordinates were taken of each location and translated to maps using the ARCView GIS 9 program (ESRI, USA) (Appendix A).

Shoreline development was assessed by comparison of 1992 and 2005 aerial photos in ARCView GIS 9 program.

Data Analysis

The data for each year was analyzed separately and compared. For both the 1994/95 and 2006 studies the percent frequency (number of quadrats at which species occurred / total number of quadrats), and relative frequency (number of quadrats at which species occurred / sum of all species occurrences) were calculated for each species. Additionally, the mean density (sum of species' occurrence ratings / number of quadrats), relative density (sum of species' occurrence ratings/ sum of all plant densities), and mean density where present (sum of species' occurrence ratings / number of quadrats at which the species occurred) were calculated for each species in 2006.

Due to the differences in frequency and location of Secchi disk measurements in 1994/95 and 2006, a direct comparison cannot be made between these two studies. The 2006 Secchi disk readings were averaged for a seasonal 1% light penetration reading, and used to calculate a maximum rooting depth (3 x Secchi reading) as per Dunst (1982).

The diversity of the plant populations was measured using Simpson's Diversity Index. The 1994/95 and 2006 studies were compared using Sorensen's Coefficient of Community Similarity to indicate similarities and differences between pre- and post-drawdown communities.

An Aquatic Macrophyte Community Index (AMCI), developed for Wisconsin Lakes, was applied to Holcombe Flowage. Data in seven categories that characterize the aquatic plant community was converted to values 0 – 10 and combined as outlined by Nichols et al. (2000).

Coefficients of Conservatism (Ĉ) and Floristic Quality Index (*I*) were used to evaluate the closeness of Holcombe Flowage aquatic plant community to an undisturbed condition (Nichols, 1999). A Coefficient of Conservatism is an assigned value, 0 – 10, based on the probability that a species will occur in a relatively undisturbed habitat. The Average Coefficient of Conservation (Ĉ) is the mean of the coefficients of conservatism for all species found in a lake; the Floristic Quality Index was calculated from the average coefficients, and represents a measure of a plant community's closeness to an undisturbed condition.

III. RESULTS:

Water Quality

Secchi disk readings were the only water quality measurement collected during this study. Aquatic plants can survive with a minimum of 1 - 2% of original surface illumination. Plants vary in their tolerance to low light levels, so changes in water clarity could cause shifts in species composition of an aquatic plant community. Water clarity is reduced by turbidity (suspended materials such as algae and silt) and dissolved organic chemicals that discolor the water. Secchi disk readings measure both turbidity and the degree in which color affects light penetration.

Comparisons of Secchi disk reading taken during the growing seasons of 1994/95 and 2006 indicated the calculated maximum rooting depth in Holcombe Flowage changed (Table 1 & 2). Actual maximum rooting depths were greater than calculated during 2006 in all instances, except Cranberry Lake indicating that more light was reaching the bottom of the lake then being measured were as in 1994/95 the calculated depth was always greater than the actual rooting depth. (Note that 1994/95 values were only taken once at each location). During 2006, the Jump River, North of Hwy. 27, had the deepest Secchi disk readings, while Cranberry Lake had the shallowest readings (Table 2). All Secchi disk readings fluctuated during the summer depending on whether there was an algae bloom present.

Algae, nutrients and water clarity are measured and combined to determine the trophic status of a lake (Table 3). Based solely on the Secchi disk readings, Holcombe Flowage would be considered eutrophic. Based on independent data from WDNR, Holcombe Flowage is a mesotrophic lake (Table 3). Eutrophic lakes are high in nutrients and support a large biomass. Oligotrophic lakes are low in nutrients and support limited plant growth and smaller populations of fish. Mesotrophic lakes have intermediate levels of nutrients and biomass.

**Table 1. Calculated and actual rooting depths for four areas in Holcombe Flowage.**
*****1994 calculated values were based on a single reading whereas the 2006 numbers were seasonal averages.

| | 1994* | | 2006 | |
|---|---|---|---|---|
| | Calculated Rooting Depth (ft) | Actual Rooting Depth (ft) | Calculated Rooting Depth (ft) | Actual Rooting Depth (ft) |
| Jump River | 10.32 | 7.5 | 8.35 | 9.5 |
| Pine Lake | 8.85 | 7.3 | 8.22 | 10.75 |
| Cranberry Lake | 8.37 | 4.2 | 6.47 | 4.5 |
| Pine Island | 15.25 | 10 | - | 10.75 |

**Table 2. Seasonal average Secchi disk readings in feet and 1% light availability for 2006.**

| | Jump River | Pine Point Park | Pine Lake | Dam | Cranberry Lake | Flowage Average |
|---|---|---|---|---|---|---|
| Secchi Disk Average (ft) | 2.78 | 2.80 | 2.74 | 3.18 | 2.16 | 2.73 |
| 1% Light (ft) | 8.35 | 8.40 | 8.22 | 9.53 | 6.47 | 8.19 |

**Table 3. Trophic status.** All data from table was collected by an independent source during 2006 (Wisc. DNR volunteer database).

| | Quality Index | Phosphorus ug/l | Chlorophyll ug/l | Secchi Disk ft. |
|---|---|---|---|---|
| Oligotrophic | Excellent | <1 | <1 | >19 |
| | Very Good | 1-10 | 1-5 | 8-19 |
| Mesotrophic | Good | **10-30** | **5-10** | 6-8 |
| | Fair | 30-50 | 10-15 | **5-6** |
| Eutrophic | Poor | 50-150 | 15-30 | **3-4** |
| Hypereutrophic | Very Poor | >150 | >30 | >3 |
| Pike Lake, 2006 Summer Mean | Good | 25.3ug/l | 9.62ug/l | 4.5 feet |

After Lillie & Mason (1983) & Shaw et. al. (1993)

Lake Morphometry

The morphometry of a lake has an impact on aquatic macrophyte distribution. The slope of the littoral zone, the zone where at least 1% of sunlight can reach the bottom of the lake, accounts for approximately 72% of the observed variability in growth of submerged plants (Duarte and Kalff, 1986). Gentle slopes support more plant growth than steep slopes (Engel, 1985).

Holcombe Flowage's main basin has gently sloped littoral zone offering many opportunities for aquatic plant colonization. Many inlets and bays are shallow which is likely an effect of sedimentation, while the Main Channel is relatively deep.

Shoreline Land Use

Practices on shore can directly impact the aquatic plant community through increased sedimentation from erosion, and increased nutrient levels from fertilizer run-off, soil erosion and toxins from farmland and urban run-off (Jennings et al., 2003; Meyer et al., 1997; Konkel et al., 1997).

Most properties along Holcombe Flowage with permanent structures, i.e. homes, parks, campgrounds, were mowed as close to the shoreline as the slope to the lake would allow. The majority of land owned by Northern States Power (NSP) had natural shorelines a minimum of 30 feet from the waterline, the recommended distance by the Wisconsin Department of Natural Resources for a buffer zone.

All areas with the exception of Bays 3, 15, and 16 had an increase in the amount of development along the shoreline between 1992 and 2005. Bays 3 and 15 stayed at the same level of development, while Bay 16's amount of developed shoreline decreased

(Table 4). The most common type of shoreline development visible from aerial photos was lawn.

**Table 4. Percentage of shoreline developed verses undeveloped for 1992 and 2005.**

| | 1992 | | 2006 | |
|---|---|---|---|---|
| | Developed | Undeveloped | Developed | Undeveloped |
| Main Channel | 40% | 60% | 41% | 59% |
| Pine Lake | 16% | 84% | 29% | 71% |
| Cranberry Lake | 24% | 76% | 28% | 72% |
| Poverty Bay | 29% | 71% | 47% | 53% |
| Pine Island | 43% | 57% | 57% | 43% |
| Blank Bay | 37% | 63% | 62% | 38% |
| Bay 3 | - | 100% | - | 100% |
| Bay 8 | 67% | 33% | 75% | 25% |
| Bay 11 | 24% | 76% | 49% | 51% |
| Bay 13 | 25% | 75% | - | 100% |
| Bay 14 | - | 100% | 43% | 57% |
| Bay 15 | 47% | 53% | 47% | 53% |
| Bay 16 | 76% | 24% | 58% | 49% |
| Bay 18 | 31% | 69% | 51% | 49% |
| Bay 22 | 20% | 80% | 40% | 60% |
| Bay 32 | 64% | 36% | 85% | 15% |
| Bay 33 | 4% | 96% | 83% | 17% |

Sediment Composition

The 1994/95 survey indicated that silt, sand, and organic material were the most common substrates found in Holcombe Flowage. Approximately three percent of the sampling sites were rock or gravel, both of which are inhospitable to plant growth.

Silt, sand, and muck were the most common substrates found during the 2006 survey (Appendix D). Peat was found in 2006, but not in 1995; peat was possibly lumped with muck in the 1994/95 study to form the organic substrate category.

Over the past 10 years Holcombe Flowage increased in softer sediments (silt, muck/peat) that are more conducive to plant growth than harder substrates (i.e. rock or gravel) (Tables 5 & 6).

**Table 5. Sediment occurrence in Holcombe Flowage, 1994/95.**

| | | Zone 1 0-1.5Ft Depth | Zone 2 1.5-5ft Depth | Zone 3 5-10ft Depth | Zone 4 10-15ft Depth | Overall |
|---|---|---|---|---|---|---|
| **Soft Sediments** | **Organic** | 14.8% | 17.8% | 12.5% | 11.0% | 15.1% |
| | **Silt** | 48.1% | 36.5% | 47.5% | 54.9% | 43.2% |
| | **Clay** | - | 0.3% | 6.3% | 8.8% | 3.1% |
| **Hard Sediments** | **Sand** | 31.5% | 41.8% | 31.3% | 7.7% | 33.0% |
| | **Gravel** | 1.9% | 2.6% | - | 2.2% | 1.8% |
| | **Rock** | 3.7% | 1.0% | 2.5% | - | 1.5% |
| | **No Data** | - | - | - | 15.4% | 2.3% |

**Table 6. Sediment occurrence in Holcombe Flowage, 2006.** * Muck and peat possibly were lumped into one category in 1994/95 called "organic".

| | | Zone 1 0-1.5Ft Depth | Zone 2 1.5-5ft Depth | Zone 3 5-10ft Depth | Zone 4 10-15ft Depth | Overall |
|---|---|---|---|---|---|---|
| **Soft Sediment** | **Muck*** | 12.9% | 21.7% | 9.8% | 7.8% | 14.8% |
| | **Peat*** | 0.9% | 2.7% | 6.9% | 3.9% | 3.7% |
| | **Silt** | 31.0% | 44.9% | 68.4% | 74.8% | 53.4% |
| | **Clay** | - | - | - | - | - |
| **Hard Sediment** | **Sand** | 45.7% | 29.3% | 12.6% | 12.6% | 25.2% |
| | **Sand/Silt** | 2.6% | 0.8% | 1.7% | 1.0% | 1.4% |
| | **Rock** | 6.0% | 3.4% | 0.6% | - | 2.6% |
| | **Gravel** | 1.7% | 1.1% | - | - | 0.8% |

<u>Sediment Influence</u>

Many aquatic plants rely on soft to intermediate substrates for rooting stability and nutrients (Engel, 1985). The richness or sterility of the sediment can influence which plant species survive and how abundantly they grow. High-density sediments such as sand and rock are lower in nutrients and support less overall plant growth. Because of the intermediate density of silt, it is the most favorable for plant growth. Nutrient availability is greatest in sediments of intermediate density (Barko, 1988).

Silt was the dominant sediment for Holcombe Flowage in both 1994/95 and 2006.

Currently, sediment does not appear to be a limiting factor for aquatic plant growth in Holcombe Flowage with over 60% of the sediment being conducive to quality plant growth (Table 7).

**Table 7. Sediment vegetation influence.** ***** Muck and peat possibly were lumped into one category in 1994/95 called "organic".

**1994/95**

| Sediment | % Occurrence | % Vegetated |
|---|---|---|
| Organic | 15.1% | 72.8% |
| Silt | 43.2% | 57.8% |
| Clay | 3.1% | 5.3% |
| Sand | 33.0% | 74.1% |
| Gravel | 1.8% | 81.8% |
| Rock | 1.5% | 33.3% |
| No Data | 2.3% | - |

**2006**

| Sediment | % Occurrence | % Vegetated |
|---|---|---|
| Peat | 3.7% | 25.0% |
| Muck | 14.8% | 85.6% |
| Silt | 53.4% | 56.4% |
| Sand | 25.2% | 50.0% |
| Silt/Sand | 1.4% | 33.7% |
| Gravel | 0.8% | 40.0% |
| Rock | 2.6% | 18.2% |

Species Present

There were five more plant species found in 2006 than in 1994/95; the number increase was not considered statistically significant, but when the changes in the species' composition were taken into an account there was a statistical difference.

In 1994/95, 47 aquatic plant species were documented in Holcombe Flowage: 15 emergents, 5 floating leaf, and 27 submersed species. None of these species were listed as endangered, threatened or species of special concern. Two non-native species were found: *Potamogeton crispus* and *Lythrum salicaria* (Appendix E & G).

The plant community increased to 52 aquatic plant species documented in 2006: 19 emergents, 5 floating leaf, and 28 submersed species. None of these species were listed as endangered, or threatened, but three of the submersed species found are classified as species of special concern: *Ceratophyllum echinatum, Potamogeton diversifolius,* and *Utricularia geminiscapa.* These species of special concern are at risk of state extirpation due to lack of abundance. Four non-native species were present in 2006: *Eichhornia crassipes*, *Potamogeton crispus, Lythrum salicaria,* and *Myriophyllum spicatum* (Appendix E ,G, & H).

Water hyacinth (*Eichhornia crassipes)*, a tropical aquatic plant, most likely escaped an ornamental pond adjacent to the flowage during a storm surge. Scientists are uncertain if plants or viable seeds can survive midwestern winters, but *Eichhornia crassipes* is known to aggressively reproduce vegetatively in northern portions of the Midwest (Czarapata, 2005). Due to the question of viability, water hyacinth was not included in the flowage species list, but still noteworthy to include in the list of exotic species.

The number of drawdown intolerant species increased from nine species in 1994/95 to 11 species in 2006, but was not statistically significant (Appendix F).

Depth Zones

Due to sampling methods used, an equal sampling of different depth zones was not possible; equal area coverage of the lake basin was the main concern. Lake depths in 1994/95 and 2006 were similar due to little sedimentation and minimal dredging; therefore the majority of data points fell within the same depth zones for both studies.

Most of the sampling points were located in the second depth zone (1.5- 5ft), followed in quantity by the third depth zone (5-10ft). The first depth zone (0-1.5ft) was underrepresented in the study. This depth zone contains most of the emergent vegetation and the shallow sand dwelling rosette species; as a result those species are underrepresented in this study (Table 8).

The first and second depth zones changed markedly. The first zone doubled in its size while the second depth zone reduced in size between 1994/95 and 2006. The percent of those sites vegetated were also reduced in the second depth zone. All other depth zones retained approximately the same percentage of sites vegetated (Table 7).

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**Table 8. Percent depth of zones in Holcombe Flowage with corresponding percent of vegetation.**

| | 1994/95 | | 2006 | |
|---|---|---|---|---|
| | % of sites in Flowage | % Vegetated | % of sites in Flowage | % Vegetated |
| Zone 1 (0 – 1.5ft) | 8.8% | 92.6% | 17.3% | 91.4% |
| Zone 2 (1.5 – 5ft) | 50.1% | 92.5% | 40.9% | 85.8% |
| Zone 3 (5 – 10ft) | 26.5% | 35.2% | 26.1% | 35.4% |
| Zone 4 (10 – 15ft) | 14.6% | 1.1% | 15.7% | 4.8% |

Frequency of Occurrence

In 1994/95, 70.79% of the littoral zone in Holcombe Flowage was vegetated. The percent of the littoral zone vegetated increased by 4% by 2006 (74.55%), while the littoral zone area in Holcombe Flowage increased by1%.

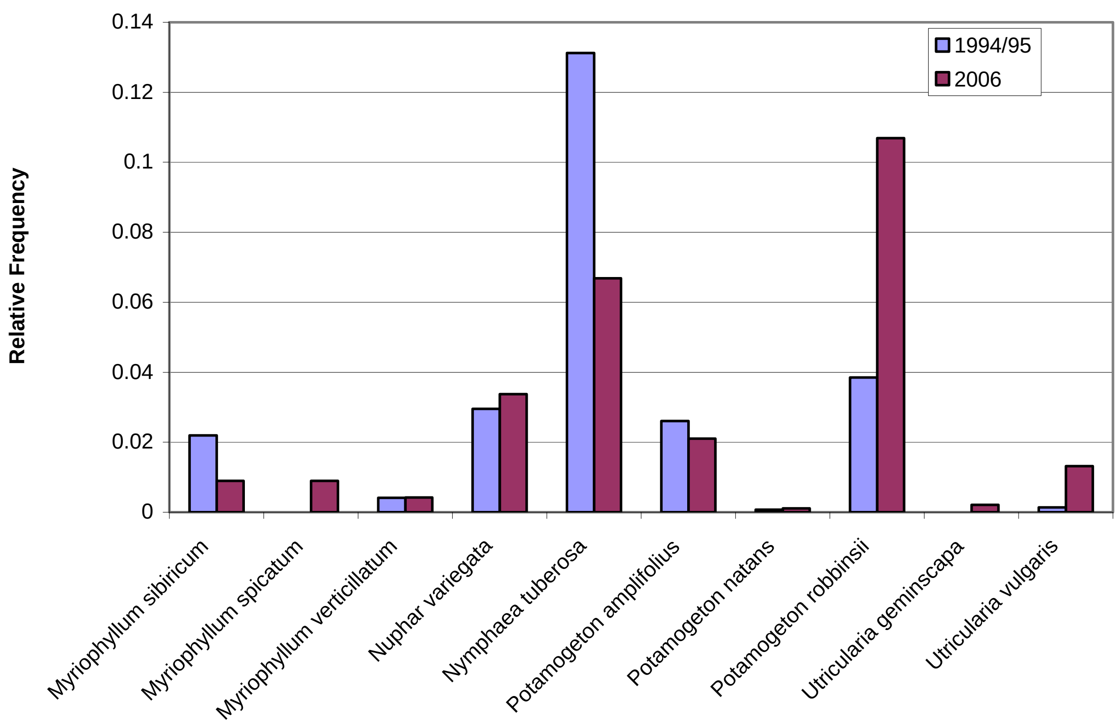
*Elodea canadensis* (46.21%) and *Nymphaea tuberosa* (35.30%) were the species most frequently found at sites in the littoral zone in 1994. In 2006, *Elodea canadensis* (54.33%) and *Ceratophyllum demersum* (56.32%) occupied the highest percentage of littoral zone sites (Table 9) & (Appendix I).

**Table 9. Frequency of prevalent aquatic plant species in Holcombe Flowage.** Only the top seven species are listed. Others species can be found in Appendix I.

| Species | 1994/95 | 2006 |
|---|---|---|
| *Ceratophyllum demersum* | 28.1% | 56.3% |
| *Elodea canadensis* | 46.2% | 54.3% |
| *Megalodonta beckii* | 5.0% | 17.5% |
| *Nymphaea tuberosa* | 35.3% | 22.9% |
| *Potamogeton robbinsii* | 5.9% | 36.6% |
| *Potamogeton spirillus* | 17.0% | 2.2% |
| *Vallisneria americana* | 18.9% | 22.9% |

The overall frequency of drawdown sensitive species in 2006 study was higher than that shown by the 1994/95 study, but not significantly (25% to 27%) (Figure1).

**Figure 1. Relative frequency of drawdown sensitive species found in 1994/95 and 2006.**



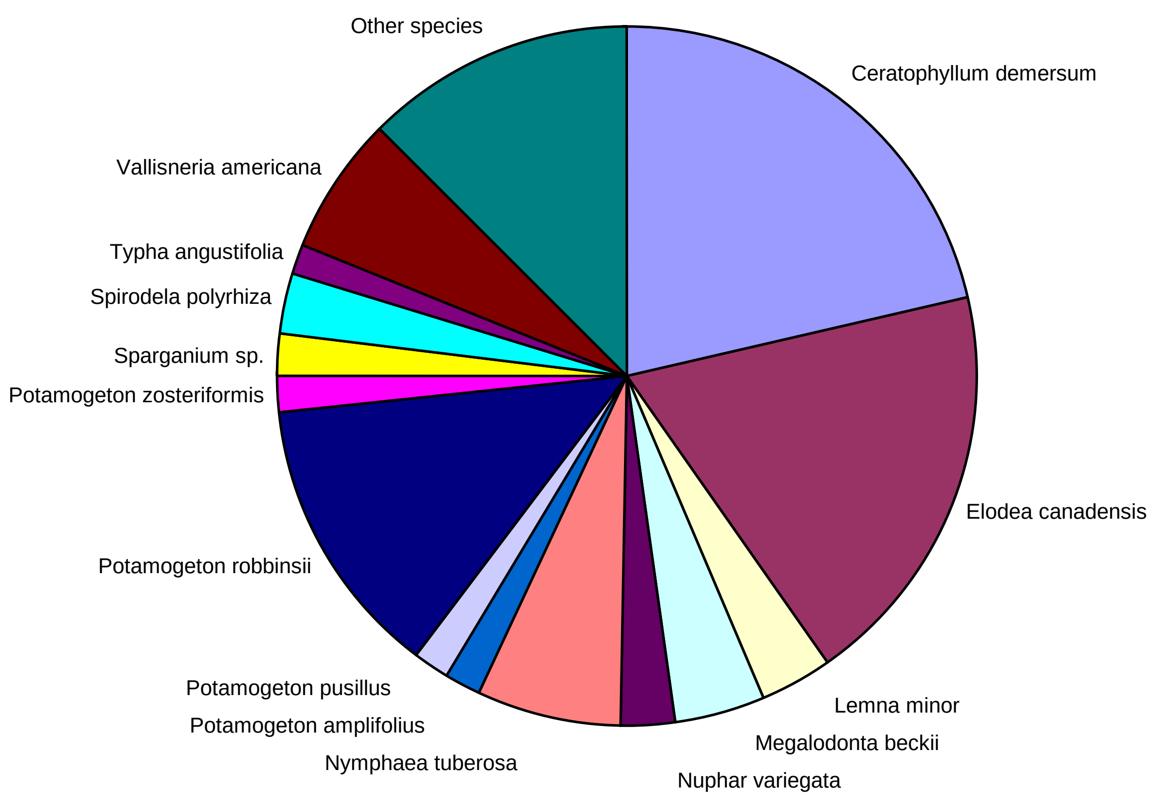

Aquatic plant growth in both studies was affected by depth. Plants were less common in the deepest zone (10 – 15ft) than in the rest of the littoral zone. The next area with minimal growth was the third depth zone (5 - 10ft) (Table 7). The ranking of depth zones did not change in the ten years between the two studies, but the percentages of vegetated area in the shallower depth zones did decrease by 2006.

Density

The "mean density where present" indicates the density or aggregation of a species' growth form in Holcombe Flowage when the species was found. For 2006, even though some species may not have occurred frequently within the lake, where they did occur, they were dense. *Ceratophyllum demersum* (248.25), *Megalodonta beckii* (198.00), and *Elodea canadensis* (98.33) had the highest mean densities when present (Appendix I).

The overall density of the littoral zone of the flowage was dominated by *Ceratophyllum demersum* (1.79), *Elodea canadensis* (1.60), and *Potamogeton robbinsii* (1.10) (Figure 2).

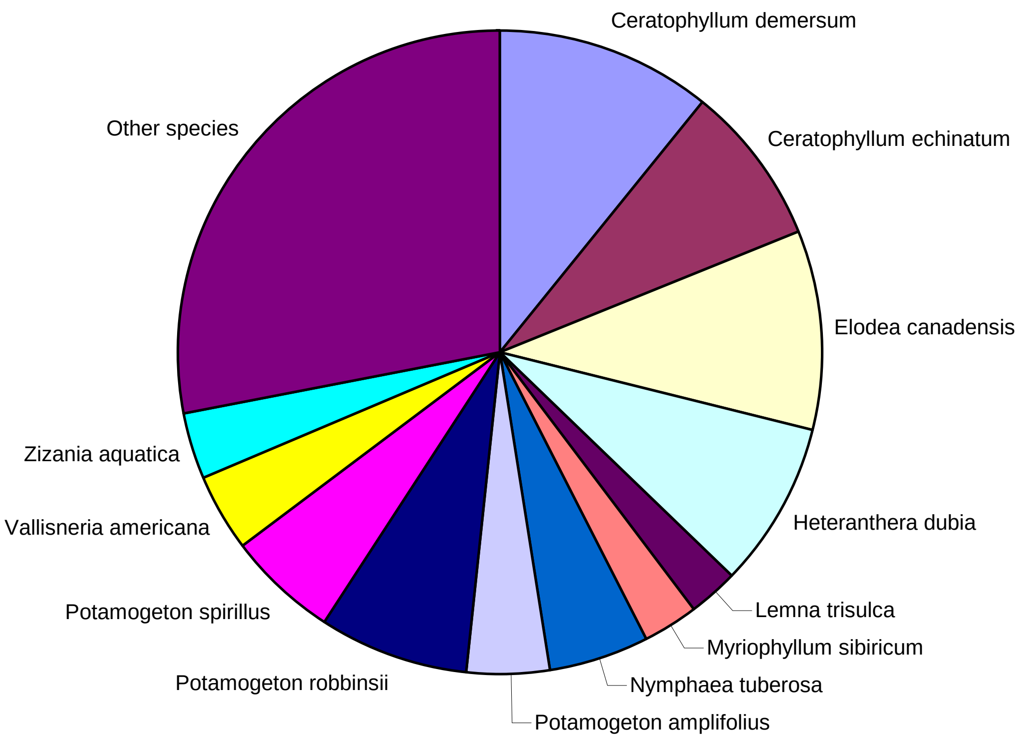
**Figure 2. Relative density of aquatic plants found in 2006 in Holcombe Flowage with values greater than 1.5%.**



Dominance

Based on the dominance value, *Ceratophyllum demersum* was the predominant species in 2006; it occurred most frequently and with the highest density. *Elodea canadensis*, *Ceratophyllum echinatum,* and *Heteranthera dubia* were sub-dominants in 2006 (Figure 3).

**Figure 3. Dominance values for prominent species in 2006.**




Distribution

Seventeen distinct areas of Holcombe Flowage were identified in 1994/95 and 2006 for possible differing aquatic plant growth patterns: Main Channel, Cranberry Lake, Pine Lake, Poverty Bay, Pine Island, two bays adjacent to Main Channel, three bays adjacent to Pine Lake, and seven bays near Poverty Bay.

1) Main Channel (150 points) (300m x 300m) – The Main Channel included points starting at the Chippewa/Rusk county line of the Chippewa and Jump Rivers to the Holcombe dam downstream. Nearly all shoreline not belonging to Northern States Power (NSP) is dominated by lawns mowed to the waters edge or nearly so. The proportion of the channel area vegetated increased from 18% to 30%.

   There were 17 species present in 2006 at the sampling points including 1 emergent (*Eleocharis palustris*), 2 floating leaf (*Nuphar variegata, Nymphaea tuberosa*), and

14 submersed species (*Ceratophyllum demersum, Elodea canadensis, Heteranthera dubia, Najas flexilis, Nitella, Potamogeton amplifolius, Potamogeton crispus, Potamogeton nodosus, Potamogeton pusillus, Potamogeton richardsonii, Potamogeton robbinsii, Potamogeton spirillus, Potamogeton zosteriformis, Vallisneria americana*).

In addition to plants found at the sampling points, 4 emergents (*Berula erecta*, *Carex sp., Iris versicolor, Sagittaria rigida*) were present in the Main Channel.

2) Cranberry Lake (42 points) (100m x 100m) – Cranberry Lake is located in the southwest region of Holcombe Flowage. This area is attached to the flowage via a narrow channel, which flows underneath Hwy M. The lake is relatively shallow (max. depth 15 ft); the water is darkly stained from the organic substrate, mainly peat, and therefore has a low calculated maximum rooting depth. Floating mats of vegetation are present and vary in location depending on prevailing winds. The majority of the submersed macrophytes were located at the mouth of the creek flowing into Cranberry Lake. The proportion of area vegetated increased by 0.5 % between 1994/95 and 2006 (34.3% to 34.8%).

   There were 15 species present in 2006 at the sampling points including 1 emergent (*Carex pseudo-cyperus*), 3 floating leaf (*Nuphar variegata, Nymphaea tuberosa, Spirodela polyrhiza*) and 11 submersed species (*Ceratophyllum demersum, Ceratophyllum echinatum, Elodea canadensis, Megalodonta beckii, Potamogeton foliosus, Potamogeton natans, Potamogeton pusillus, Potamogeton richardsonii, Potamogeton robbinsii, Potamogeton spirillus, Potamogeton zosteriformis*).

   In addition to plants found at the sampling points, 6 emergents (*Comarum palustre, Dulichium arundinaceum, Iris versicolor, Sagittaria latifolia, Schoenoplectus tabernaemontani, Typha angustifolia*) and 2 submersed species (*Myriophyllum sibiricum, Potamogeton crispus*) were present in Cranberry Lake.

3) Pine Lake (55 points) (100m x 100m) – Pine Lake is located in the southeast region of Holcombe Flowage. This lake is separated from the flowage by a low bridge and contains three bays that were sampled separately (11, 18, and Blank Bay). This body of water does not have a public boat launch and the whole lake is a no-wake zone. A large wetland owned by NSP is located at the east end of lake. The proportion of area vegetated increased from 50% to 69% between 1994/95 and 2006.

   There were 28 species present in 2006 at the sampling points including 6 emergent (*Carex pseudo-cyperus, Carex*, *Eleocharis palustris, Sparganium sp. Typha angustifolia, Typha latifolia*), 3 floating leaf (*Lemna minor, Nuphar variegata, Nymphaea tuberosa*), and 19 submersed species (*Ceratophyllum demersum, Ceratophyllum echinatum, Elodea canadensis, Megalodonta beckii, Myriophyllum sibiricum, Myriophyllum spicatum, Najas flexilis, Nitella, Potamogeton crispus, Potamogeton diversifolius, Potamogeton foliosus, Potamogeton nodosus, Potamogeton pusillus, Potamogeton richardsonii, Potamogeton robbinsii,* *Potamogeton spirillus, Potamogeton zosteriformis, Utricularia vulgaris, Vallisneria americana*).

In addition to plants found at the sampling points, 2 emergent (*Scirpus cyperinus, Sagittaria rigida*) and 2 submergent (*Heteranthera dubia, Potamogeton epihydrus*) species were present in Pine Lake.

4) Blank Bay (19 points) (5m x 5m) – Blank Bay is the center bay on the north shore of Pine Lake. This bay is very shallow with a maximum depth of four feet. Lawns mowed to the waters edge border 2/3rds of the shoreline surrounding the bay and there are two private cement boat launches. The proportion of area vegetated did not change between 1994/95 and 2006; during both studies the bay was 100% vegetated.

   There were 26 species present in 2006 at the sampling points including 3 emergent (*Sparganium sp., Typha angustifolia, Zizania aquatica)* 4 floating leaf (*Lemna minor, Nuphar variegata, Nymphaea tuberosa, Spirodela polyrhiza*), and 19 submersed species (*Ceratophyllum demersum, Elodea canadensis, Megalodonta beckii, Heteranthera dubia, Myriophyllum sibiricum, Myriophyllum spicatum, Najas flexilis, Nitella, Potamogeton amplifolius, Potamogeton crispus, Potamogeton epihydrus, Potamogeton foliosus, Potamogeton nodosus, Potamogeton pusillus, Potamogeton richardsonii, Potamogeton robbinsii, Potamogeton zosteriformis, Utricularia vulgaris, Vallisneria americana*).

   In addition to plants found at the sampling points, 2 emergent (*Scirpus cyperinus, Iris versicolor*) species were present in Blank Bay.

5) Bay 18 (20 points) (5m x 5m) – Bay 18 is located on the west side of the north shore of Pine Lake. This bay is very shallow with a maximum depth of four feet. The proportion of area vegetated in the bay did not change between 1994/95 and 2006; both years it was 100% vegetated.

   There were 26 species present in 2006 at the sampling points including 6 emergent (*Carex pseudo-cyperus, Eleocharis palustris, Sagittaria latifolia, Schoenoplectus tabernaemontani, Sparganium sp., Typha angustifolia)* 5 floating leaf (*Lemna minor, Lemna trisulca, Nuphar variegata, Nymphaea tuberosa, Spirodela polyrhiza*), and 15 submersed species (*Ceratophyllum demersum, Elodea canadensis, Megalodonta beckii, Myriophyllum sibiricum, Myriophyllum spicatum, Najas flexilis, Nitella, Potamogeton foliosus, Potamogeton pusillus, Potamogeton robbinsii, Potamogeton zosteriformis, Stuckenia pectinatus, Utricularia geminiscapa, Utricularia vulgaris, Vallisneria americana*).

   In addition to plants found at the sampling points, 1 emergent (*Zizania aquatica*) species was present in Bay 18.

6) Bay 11 (20 points) (5m x 5m) – Bay 11 is the east bay on the north shore of Pine Lake. The majority of the bay is shallow with an eight-foot deep hole, at points #4

and #11. Approximately 2/3rds of the shoreline is lawn to the waters edge. The proportion of area vegetated increased between 1994/95 and 2006 from 95% to 100%.

There were 12 species present in 2006 at the sampling points including 4 emergent (*Sparganium sp., Typha angustifolia, Typha latifolia, Zizania aquatica)* 2 floating leaf (*Nuphar variegata*, *Nymphaea tuberosa*), and 6 submersed species (*Ceratophyllum demersum, Elodea canadensis, Najas flexilis, Nitella, Potamogeton zosteriformis, Utricularia vulgaris*).

No additional plants were found between sampling points.

7) Bay 22 (63 points) (20m x 20m) – Bay 22 is located in the northwest corner of the flowage adjacent to a long narrow bay south of two islands in the mouth of the Jump River. This bay is shallow with a deep hole in the near the center of the bay. Also, a beaver dam blocked off 10 points on the northwest end of the bay. There was a distinct visual difference in the water clarity on each side of the dam with the greatest plant diversity found in the section dammed from the Main Channel. The southern, eastern, and part of the western shores are part of a campground with permanent mobile homes and trailers. The shore around the bay is mowed to the waters edge where slope allows. The proportion of area vegetated in the bay decreased between 1994/95 and 2006 from 70% to 49%.

   There were 23 species present in 2006 at the sampling points including 1 emergent *(Sagittaria rigida)* 5 floating leaf (*Lemna minor, Lemna trisulca, Nuphar variegata, Nymphaea tuberosa, Spirodela polyrhiza*), and 17 submersed species (*Ceratophyllum demersum, Chara, Elodea canadensis, Megalodonta beckii, Myriophyllum sibiricum, Myriophyllum verticillatum, Najas flexilis, Nitella, Potamogeton amplifolius, Potamogeton diversifolius, Potamogeton epihydrus, Potamogeton foliosus, Potamogeton pusillus, Potamogeton richardsonii, Potamogeton robbinsii, Potamogeton zosteriformis, Vallisneria americana*).

   In addition to plants found at the sampling points, 4 emergent (*Carex pseudo-cyperus, Iris versicolor, Schoenoplectus tabernaemontani, Sparganium sp.*) species were present in Bay 22 along the beaver dam.

8) Bay 8 (69 points) (20m x 20m) – Bay 8 is at the end of a long narrow bay located at the north end of Holcombe Flowage, south of two islands in the mouth of the Jump River. There is a strip of deep water in the center of the bay, which becomes anoxic (zero dissolved oxygen) in the winter. The bay is completely surrounded by homes with lawns that are mowed to the shoreline where slope allows. The proportion of area vegetated in the bay decreased from 54% in 1995 to 24% in 2006.

   There were 5 species present in 2006 at the sampling points including 1 floating leaf (*Nymphaea tuberosa*), and 4 submersed species (*Ceratophyllum demersum, Elodea canadensis, Potamogeton zosteriformis, Vallisneria americana*).

No additional plants were found outside the sampling points in Bay 8.

9) Pine Island (84 points) (50m x 50m) – Pine Island is located on the north end of the Main Channel. This bay has many inlets and the majority of the shoreline has native vegetation up to 30 feet from the shoreline. The proportion of area vegetated in the bay increased from 73% to 96%.

   There were 25 species present in 2006 at the sampling points including 6 emergent (*Lythrum salicaria, Sagittaria rigida, Sagittaria latifolia, Sparganium sp., Typha angustifolia, Zizania aquatica)* 5 floating leaf (*Lemna minor, Lemna trisulca, Nuphar variegata, Nymphaea tuberosa, Spirodela polyrhiza*), and 14 submersed species (*Ceratophyllum demersum, Elodea canadensis, Heteranthera dubia, Myriophyllum verticillatum, Najas flexilis, Nitella, Potamogeton crispus, Potamogeton foliosus, Potamogeton natans, Potamogeton pusillus, Potamogeton richardsonii, Potamogeton robbinsii, Potamogeton zosteriformis, Vallisneria americana*).

   No additional plants were found outside the sampling points in the Pine Island area.

10) Bay 3 (20 points) (5m x 5m) – Bay 3 is located east of the Pine Point County Park with the access to the bay from the Main Channel. Bay 3 is completely surrounded by Pine Point County Park and while there are campsites on the bay, there is at least 30 feet of natural vegetation between the waters edge and the campsites. The proportion of area vegetated in the bay has increased between 1994/95 and 2006 from 40% to 50%.

   There were 9 species present in 2006 at the sampling points including 2 floating leaf (*Lemna minor, Nymphaea tuberosa*), and 7 submersed species (*Ceratophyllum demersum, Ceratophyllum echinatum, Elodea canadensis, Najas flexilis, Potamogeton amplifolius, Potamogeton richardsonii, Vallisneria americana*).

   In addition to plants found at the sampling points, 1 emergent (*Eleocharis acicularis*) 1 floating leaf (*Nuphar variegata*) and 1 submergent (*Heteranthera dubia*) species were also present in Bay 3.

11) Bay 14 (20 points) (5m x 5m) – Bay 14 is located south of Pine Point County Park with access through a chain of bays to the Main Channel (Appendix C). The bay's west shore has a minimum of 30 feet of natural vegetation to the waters edge. The east end of the bay has homes with lawns mowed to the waterline. The proportion of area vegetated in the bay has increased between 1994/95 and 2006 from 80% in 1995 to 90%.

   There were 11 species present in 2006 at the sampling points including 2 floating leaf (*Nuphar variegata, Nymphaea tuberosa*), and 9 submersed species (*Ceratophyllum demersum, Elodea canadensis, Heteranthera dubia, Megalodonta beckii, Nitella,* *Potamogeton pusillus, Potamogeton robbinsii, Utricularia vulgaris, Vallisneria americana*).

In addition to plants found at the sampling points, 6 emergent (*Iris versicolor, Lythrum salicaria, Sagittaria latifolia, Schoenoplectus tabernaemontani, Scirpus cyperinus, Sparganium sp.*) and 2 submergent (*Potamogeton amplifolius, Potamogeton richardsonii)* species were present in Bay 14.

12) Bay 15 (35 points) (10m x 10m) – Bay 15 is located south of Pine Point County Park. The western shore has at least 30ft of buffer zone at the waters edge. The rest of the bay is surrounded by homes with lawns mowed to the waterline. The proportion of area vegetated in the bay increased between 1994/95 and 2006 from 52% in 1995 to 94% in 2006.

    There were 19 species present in 2006 at the sampling points including 1 emergent (*Sparganium sp.)* 4 floating leaf (*Lemna minor, Nuphar variegata, Nymphaea tuberosa, Spirodela polyrhiza*), and 14 submersed species (*Ceratophyllum demersum, Elodea canadensis, Heteranthera dubia, Megalodonta beckii, Myriophyllum verticillatum, Nitella, Potamogeton amplifolius, Potamogeton epihydrus, Potamogeton foliosus, Potamogeton pusillus, Potamogeton richardsonii, Potamogeton robbinsii, Potamogeton zosteriformis, Vallisneria americana*).

    In addition to plants found at the sampling points, 2 emergent (*Iris versicolor, Sagittaria latifolia*) species were present in Bay 15.

13) Bay 13 (45 points) (10m x 10m) – Bay 13 is located west of Pine Point County Park. The bay is completely surrounded by the park with no motorboat access. A man-made dam separates the bay from the mouth of Cranberry Creek. There are visual differences in water clarity between the bay and the flowage at the small dam. The proportion of area vegetated in the bay increased between 1994/95 and 2006 from 76% to 90%.

    There were 20 species present in 2006 at the sampling points including 2 emergent (*Sagittaria latifolia, Sparganium sp.)* 5 floating leaf (*Lemna minor, Lemna trisulca, Nuphar variegata, Nymphaea tuberosa, Spirodela polyrhiza*), and 13 submersed species (*Ceratophyllum demersum, Elodea canadensis, Heteranthera dubia, Megalodonta beckii, Najas flexilis, Nitella, Potamogeton amplifolius, Potamogeton crispus, Potamogeton foliosus, Potamogeton pusillus, Potamogeton robbinsii, Potamogeton zosteriformis, Vallisneria americana*).

    No additional plants were found between sampling points.

14) Bay 32 (20 points) (5m x 5m) – Bay 32 is located off the Main Channel just south of Pine Point County Park. This small bay is relatively shallow except for a 10-foot deep hole in the center of the bay. The bay is surrounded by lawns; either boathouses or natural shoreline extending one foot or less from the waters edge separate water

from lawn. The proportion of area vegetated in the bay decreased from 90% in 1994 to 80% in 2006.

There were 15 species present in 2006 at the sampling points including 3 emergent (*Sagittaria latifolia, Sparganium sp., Typha angustifolia)* 2 floating leaf (*Nuphar variegata, Nymphaea tuberosa*), and 10 submersed species (*Ceratophyllum demersum, Elodea canadensis, Megalodonta beckii, Myriophyllum sibiricum, Najas flexilis, Nitella, Potamogeton epihydrus, Potamogeton pusillus, Potamogeton robbinsii, Vallisneria americana*).

In addition to plants found at the sampling points, 2 emergent (*Eleocharis palustris, Iris versicolor*) species were present in Bay 32.

15) Bay 33 (19 points) (10m x 10m) – Bay 33 is located off the Main Channel just south of Pine Point County Park. This bay has a maximum depth of eight feet with the majority of the western and southern shoreline covered in native vegetation, while the eastern shore has lawn to the waters edge. The proportion of area vegetated in the bay increased between 1994/95 and 2006 from 65% to 90%.

There were 15 species present in 2006 at the sampling points including 1 emergent (*Sparganium sp.)* 2 floating leaf (*Nuphar variegata, Nymphaea tuberosa) an*d 12 submersed species (*Ceratophyllum demersum, Elodea canadensis, Megalodonta beckii, Najas flexilis, Potamogeton amplifolius, Potamogeton epihydrus, Potamogeton foliosus, Potamogeton pusillus, Potamogeton richardsonii, Potamogeton robbinsii, Potamogeton zosteriformis, Vallisneria americana*).

In addition to plants found at the sampling points, 1 emergent (*Eichhornia crassipes*) species was present in Bay 33. Three individual colonies of *Eichhornia crassipes* (water hyacinth) were found widely spaced from each other, but not included in the total species list (See "Species Present" section).

16) Bay 16 (20 points) (5m x 5m) – Bay 16 is located south of Pine Point County Park. This bay is accessible from Cranberry Creek via a narrow, hidden, shallow channel. Homes surround the bay with lawns mowed to the waters edge where slope allows. The amount of aquatic plants in the bay increased between 1994/95 and 2006 from 50% to 65% vegetation.

There were 15 species present in 2006 at the sampling points including 2 floating leaf (*Nuphar variegata*, *Nymphaea tuberosa*), and 13 submersed species (*Ceratophyllum demersum, Elodea canadensis, Heteranthera dubia, Megalodonta beckii, Najas flexilis, Nitella, Potamogeton amplifolius, Potamogeton crispus, Potamogeton richardsonii, Potamogeton robbinsii, Potamogeton spirillus, Potamogeton zosteriformis, Vallisneria americana*).

No additional plants were found between sampling points.

17) Poverty Bay (44 points) (50m x50m) – Poverty Bay is in the southeast end of the flowage near Cranberry Creek. This bay, a large shallow inlet, has a maximum depth of six feet near the eastern shore. The amount of aquatic plants in the bay increased from 92% to 95% between 1994/95 and 2006.

There were 24 species present in 2006 at the sampling points including 3 emergent *(Schoenoplectus tabernaemontani, Sparganium sp., Typha angustifolia)* 4 floating leaf (*Lemna trisulca, Nuphar variegata, Nymphaea tuberosa, Spirodela polyrhiza*), and 17 submersed species (*Ceratophyllum demersum, Elodea canadensis, Heteranthera dubia, Megalodonta beckii, Myriophyllum sibiricum, Najas flexilis, Nitella, Potamogeton amplifolius, Potamogeton diversifolius, Potamogeton foliosus, Potamogeton pusillus, Potamogeton richardsonii, Potamogeton robbinsii, Potamogeton spirillus, Potamogeton zosteriformis, Utricularia vulgaris, Vallisneria americana*).

In addition to plants found at the sampling points, 1 emergent (*Sagittaria latifolia*) and 1 submersed (*Potamogeton crispus*) species were present in Poverty Bay.

Aquatic Plant Community

The Coefficient of Community Similarity, a measurement of the degree to which the two communities resemble one another, indicates the 1994/95 and the 2006 communities are statistically different (Ss = 0.73). Coefficients less than Ss =0.75 or 75% indicate that two communities are considered to be significantly different.

Other various parameters can indicate small changes in the composition of the community and directional trends in the aquatic plant community. Examples of changes in these parameters from 1994/95 to 2006 (Table 9) include:

1) an increase in number of species
2) an increase in maximum rooting depth
3) an increase in percentage of the littoral zone vegetated
4) a change in the coverage of the three types of plants structure (emergent, submergent, and floating-leaf)
5) a decrease in Simpson's Diversity Index. Simpson's Diversity Index rates the diversity in an aquatic community. A value of 1.0 would mean that each individual plant in the community is a different species (the most diversity achievable).
6) a decrease in Floristic Quality (see below), the community's closeness to an undisturbed condition
7) an increase in the overall quality of the aquatic plant community (AMCI) (see below)

**Table 10. Changes in Holcombe Flowage aquatic plant community between 1994/95 and 2006. *** The change in the percent of floating leaf species found is based on the actual number and not the rounded sum.

| | 1994/95 | 2006 | Change 1994/95-2006 | % Change 1994/95-2006 |
|---|---|---|---|---|
| Number of Species | 45 | 51 | 6 | 13% |
| Maximum Rooting Depth | 10 | 10.75 | 0.75 | 8% |
| % Littoral Zone Vegetated | 73% | 75% | 0.019 | 3% |
| % Emergents | 7% | 5% | -2% | -30% |
| % Submergents | 67% | 78% | 11% | 17% |
| % Floating-Leaf | 17% | 17% | 0% | 2%* |
| % Exotic Species | 0.82% | 1.37% | 0.54% | 66% |
| % Sensitive Species | 11% | 19% | 8% | 71% |
| % Drawdown Intolerant Species | 25% | 27% | 2% | 7% |
| Simpson's Diversity Index | 0.921 | 0.918 | -0.003 | 0% |
| Average Coefficient of Conservatism | 5.49 | 5.28 | -0.21 | -4% |
| AMCI | 54 | 59 | 5 | 9% |
| FQI | 35.99 | 35.83 | -0.16 | 0% |

The greatest percentage change to Holcombe Flowage aquatic plant community was the increase of sensitive species. Many sensitive species are drawdown intolerant. The second greatest percentage change was exotic species found, followed by a reduction of emergent species.

The Aquatic Macrophyte Community Index (AMCI) developed by Nichols et al. (2000) was applied to Holcombe Flowage. Values between 0 and 10 are given for each of seven measures of quality of an aquatic plant community (i.e. rooting depth, % vegetated, number of submersed, exotic, and sensitive species, number of taxa, and Simpson's Diversity Index). The greatest value for the index is 70. The AMCI in Holcombe Flowage was calculated at 59 in 2006, versus 54 in 1995, which indicates a positive shift in the aquatic plant community. Lakes in the region range from 52 to 62; in both years Holcombe Flowage fell within the regional averages.

One method for evaluating the closeness of an aquatic plant community to an undisturbed condition is the Coefficient of Conservatism ($\hat{C}$). The $\hat{C}$-value is the probability that a specific species of aquatic plant will be located in an undisturbed area (Nichols, 1999). Applied to Holcombe Flowage, the Coefficient of Conservatism in 2006 decreased from the 1995 numbers by 4%. During both years, Holcombe Flowage's conservatism values were below state (5.5-6.9) and regional (6.1-7.7) averages (Nichols, 1999).

Another method of evaluating the closeness of an aquatic plant community to an undisturbed condition is the Floristic Quality Index ($I$); the $I$-value is derived with the use of the Ĉ-value. Holcombe Flowage's *I*-value (35.83) is greater than state (16.9-27.5) and regional (17.8-30.2) averages for both years.

## IV. DISCUSSION

The Chippewa Valley Settlement Agreement's removal of late winter drawdowns did not have a significant impact on Holcombe Flowage. Holcombe Flowage rarely had a significant winter draw down in the history of the flowage; the last drawdown of 10ft or greater was conducted in 1979 (Appendix J). Lake Wissota, another reservoir of the Chippewa River, had late winter drawdowns removed by the same agreement. Although certain plant community trends are similar between Lake Wissota and Holcombe Flowage, the shift in the aquatic plant community and overall improvement in water clarity for Lake Wissota was more dramatic (Heuschele, 2005). It is likely that significant changes in the overall quality of Holcombe's aquatic plant community are not due to cessation of late winter drawdowns.

### Water Clarity

The increase in water clarity can be inferred based on the increase in maximum rooting depth. The lake is naturally dark due to tannins in the water, and may explain why the increase in clarity was not greater. The increase in maximum rooting depth could be linked to the halt of late winter drawdowns. Elimination of late winter drawdowns may have contributed to the reduction of excess nitrogen and phosphorus as these nutrients settle and become trapped within the sediment layer. The natural recharging of lakes after late winter drawdowns stirs up settled sediments causing nutrients and fine particles to be released into the water column, reducing water clarity (Scheffer, 1990).

Improved water clarity may also be linked to the overall increase in aquatic plants inhabiting the littoral zone. An increase in aquatic vascular plants in lakes reduces the amount of excess phosphorus and nitrogen available to algae (Lombardo & Cooke, 2003). This reduction in turn lowers the amount of algae growth and increases light infiltration at greater depths.

### Sediments

There was an increase in the occurrence of soft sediments and sand between 1995 and 2006 (17%). Small particle sediment deposition could be caused by the removal of winter drawdowns, which stirs up lighter sediments and carries them downriver. Another cause of the increased sediment deposition could be the possible increase in upstream erosion.

The lake currently has a high level of aquatic plant species diversity (51 species) for the state of Wisconsin. In 2006, 62% of sites containing sand, silt, and/or muck sediment, the preferred sediment types for aquatic plants, were vegetated. Sediment type is currently not a limiting factor based on 2006 data, because 97% of the sites contained sediment conducive to aquatic plant growth, but only 62% of the sites were vegetated.

Aquatic Plant Community

Based on the Coefficient of Community Similarity, Holcombe Flowage aquatic plant community of 1994/95 was different from Holcombe Flowage aquatic plant community of 2006 (Ss = 0.73). This statistical test assesses the species present during one study versus not present in the comparative study. For additional comparison four other indices were applied.

The change in the community based on the Simpson's Diversity Index is negligible (0.003).

The average Coefficient of Conservatism ($\hat{C}$) decreased by four percent, dropping below the state (5.5-6.9) and regional (6.1-7.7) averages for lakes in Wisconsin. The $\hat{C}$-value does not include exotics, aquatic mosses, or species found in wetland communities not exclusively found in lakes (Nichols, 1999).

The Floristic Quality Index (*I*), Holcombe Flowage's closeness to an undisturbed condition, decreased by a negligible amount (Table 8). The *I*-value, which is derived from the average Coefficient of Conservation, is considered subjective. Floristic Quality Index has been used to successfully describe terrestrial plant communities in Wisconsin (Nichols, 1999). Unfortunately, the Floristic Quality in lakes appears to be so heavily related to water quality and number of species found that it is not considered a valuable measurement on its own (Nichols, 1999).

The Aquatic Macrophyte Community Index (AMCI) value increased by nine percent. This index uses seven parameters to reduce subjectivity (rooting depth, % vegetated, number of submersed, exotic, and sensitive species, number of taxa, and Simpson's Diversity Index). Therefore, this index seems a more reliable measure for comparison between the two studies.

An aquatic plant community changes when species within the community change (Appendix E). Values of the Floristic Quality Index, Coefficient of Conservatism, and the Aquatic Macrophyte Community Index could change if the location of the sampling points were shifted slightly. There were six species, all emergents, found in 2006 that were not included in the afore-mentioned calculations because they were located between sampling points, while the total number of species in the lake was collected from the sampling points and periodic observations between points, hence including the whole lake and not predetermined parts. Emergents were underrepresented in this study due to the under representation of sampling points in the 0-1.5ft. depth zone.

While the aquatic plant communities of 1994/95 and 2006 were significantly different, there were other significant changes in the community. The species composition shifted during the intervening 10 years. Holcombe Flowage has an increase in new species sensitive to water level fluctuations and an increased frequency of water fluctuation sensitive species than in 1994/95. The elimination or reduction of water fluctuations (i.e. late winter drawdowns) is likely the cause for this change in community dynamics.

The number of species found in Holcombe Flowage has increased from 45 to 51 species. The quantity of emergents was reduced by 30%; these plants are tolerant to water fluctuations and without the yearly water fluctuation the emergents may not be able to compete with submersed and floating leaf species. The number of floating-leaf plants found did not change. The frequency of two floating-leaf plants sensitive to water fluctuations, *Nymphaea odorata* and *Nuphar variegata,* decreased between 1994/95 and 2006. Submergents increased by 17%; while some species are annuals and tolerant to water fluctuations others are perennials that are more sensitive. These sensitive species have increased in frequency since 1994/95 including one exotic aquatic plant, *Myriophyllum spicatum*.

During the 1994/95 survey, all calculated maximum rooting depths were greater than actual values, and greater than the calculated maximum values of 2006. Calculated maximum values for 2006 were less than actual plant rooting depths in all cases except Cranberry Lake, where likely another factor, either sediment or pH, is affecting plant growth. Only annuals and perennials with large seed producing abilities could survive frozen sediment conditions caused by ice being directly dropped onto the sediment and freezing it through the transfer of energy. A majority of adult plants die during winter when ice crystals form in the root systems and break the roots apart; only the seeds are hearty enough to survive and perpetuate a given species (Engel, 1985 & 1990). During the 2006 survey not only was calculated maximum rooting depth greater than 1994/95, but the actual maximum rooting depth (10.75 ft) was greater than the calculated rooting depth (8.22 ft). The species found at depths greater than 7 ft were *Ceratophyllum demersum*, and *Elodea canadensis*, both of which have adaptations to tolerate low light levels.

Holcombe Flowage's aquatic plant density ranged from 0.21 (*Elodea canadensis*) to 0.0002 (*Acorus calamus*). Plants with the highest density in Holcombe Flowage are plants that are also the most tolerant of low light levels found in the flowage (*Elodea canadensis, and Ceratophyllum demersum*). The flowage contains a mix of pioneer species and competitive species. Pioneer species produce many offspring in high densities to ensure species survival (i.e. annuals), whereas competitor species produce fewer offspring to prevent competition with the parent plant during the next growing season. Hence, a less dense stand of diverse plants would be found in an area where competitor plants exist (Grime, 2002).

The percent change of vegetation in the littoral zone between 1994/95 and 2006 depended on where in the flowage was being measured. Bay 8 (-56%), Bay 22 (-30%) and Bay 32 (-11%) had fewer plants in 2006 than in 1994/95. The greatest commonalities among the bays were each bay had the majority of its shoreline vegetated by lawn or hard structures (i.e. boat houses and decks) and were heavily trafficked by boats. Areas that had a large increase in vegetation over the 10 year period, Bay 15 (81%), Main Channel (67%), Bay 33 (38%) and Pine Island (32%), were buffered by natural vegetation on a large percentage of the shoreline and had relatively light boat traffic relative to a bay's size. Note boat traffic is based on a visual assessment during the weekdays throughout the summer of 2006.

## V. CONCLUSION

Based on the calculated Aquatic Macrophyte Community Index, Holcombe Flowage is an overall average impoundment for in the North Lakes and Forest region of Wisconsin.

Holcombe Flowage is characterized by a very large and diverse aquatic plant community for the North Lakes and Forest region of Wisconsin. This community has 75% of its littoral zone vegetated compared to the regional average of 85%, and has a higher than average number of species located in the lake. The community resembles more of an undisturbed condition more than most lakes in the North Lakes and Forest region. The 1.5 – 5ft depth zone supports most of the plant growth in the lake.

*Ceratophyllum demersum* was the dominant aquatic plant species with *Elodea canadensis* and *Heteranthera dubia* as the sub-dominant species. Seventy-five percent of the littoral sites were vegetated making Holcombe Flowage an average vegetated lake.

There was a significant change in the aquatic plant community between 1994/95 and 2006, as well as other small changes that affect lake health. The positive changes are:

1) An increase in the percentage of littoral zone vegetated.
2) An increase in actual maximum rooting depth.
3) An increase in sensitive species present.
4) An increase in drawdown intolerant species.
5) An increase in the number of plant species present.
6) A decrease in the frequency of the exotic species *Potamogeton crispus,* and *Lythrum salicaria*.

Some changes occurred that are of concern and should be monitored to ensure that they are not the beginning of a negative trend:

1) A decrease in Average Coefficient of Conservatism (Ĉ).
2) A decrease in Simpson's Diversity Index
3) A decrease in Floristic Quality Index
4) The appearance of exotic species *Eichhornia crassipes,* and *Myriophyllum spicatum.*
5) An increase in shoreline development.

Healthy aquatic plant communities play a vital role in lakes. Plants provide improved water quality by removing nutrients that would otherwise be available for algae blooms (Engel, 1985). Plants also provide cover and food for fish and invertebrates (Engel, 1985 & 1990). Lakes with a healthy and diverse community of native aquatic plants are more resistant to invasions of non-native species and excessive growth of more competitive species.

## VI. MANAGEMENT RECOMMENDATIONS

Protecting the aquatic plant community is beneficial for the overall health of Holcombe Flowage. With the removal of late winter drawdowns, the chief threats to the health of this aquatic plant community are invasive species and decline of riparian buffers.

*Myriophyllum spicatum* found in Pine Lake adjacent to the Main Channel of Holcombe Flowage should be managed for reduction and possible eradication.

1) A biological control method with the use of weevils (*Eurhychiopsis lecontei)* does not appear economically feasible at this time. No native populations of weevils were found during a survey of invertebrates in Holcombe Flowage during 2006. Also, the wintering habitat for weevils is lacking on the north shore (windward side) of the lake and therefore would not support a viable population of weevils if introduced for biological control.

2) Manual removal of adult plants is possible and recommended in shallow areas of Pine Lake

3) Chemical control is an option, but proper permits are required and herbicide can be disruptive to native plants. Due to the large area of infestation, herbicide treatment would be expensive and may require multiple treatments.

*Lythrum salicaria* is present, but infestations are spotty and small compared to previous years. The current management plan appears to be affective and should be continued.

*Potamogeton crispus* has not reached invasive proportions in Holcombe Flowage. The native aquatic plant community seems to have absorbed the added stress of competition with *Potamogeton crispus* without detriment to the community as a whole. Based on this interaction *Potamogeton crispus* eradication is not a priority.

The removal of additional riparian buffer zone (up to30ft from shoreline) on municipal, county, and state land should be avoided. Restoration of riparian buffer zones on these lands is recommended. Also riparian zones on property owned by NSP, but leased to a second party should also be restored. Education to private landowners about the importance of riparian buffer zones on their own property should be encouraged.

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# Appendix A

Holcombe Flowage map containing Secchi disk locations

1) Entire Flowage

# Appendix B

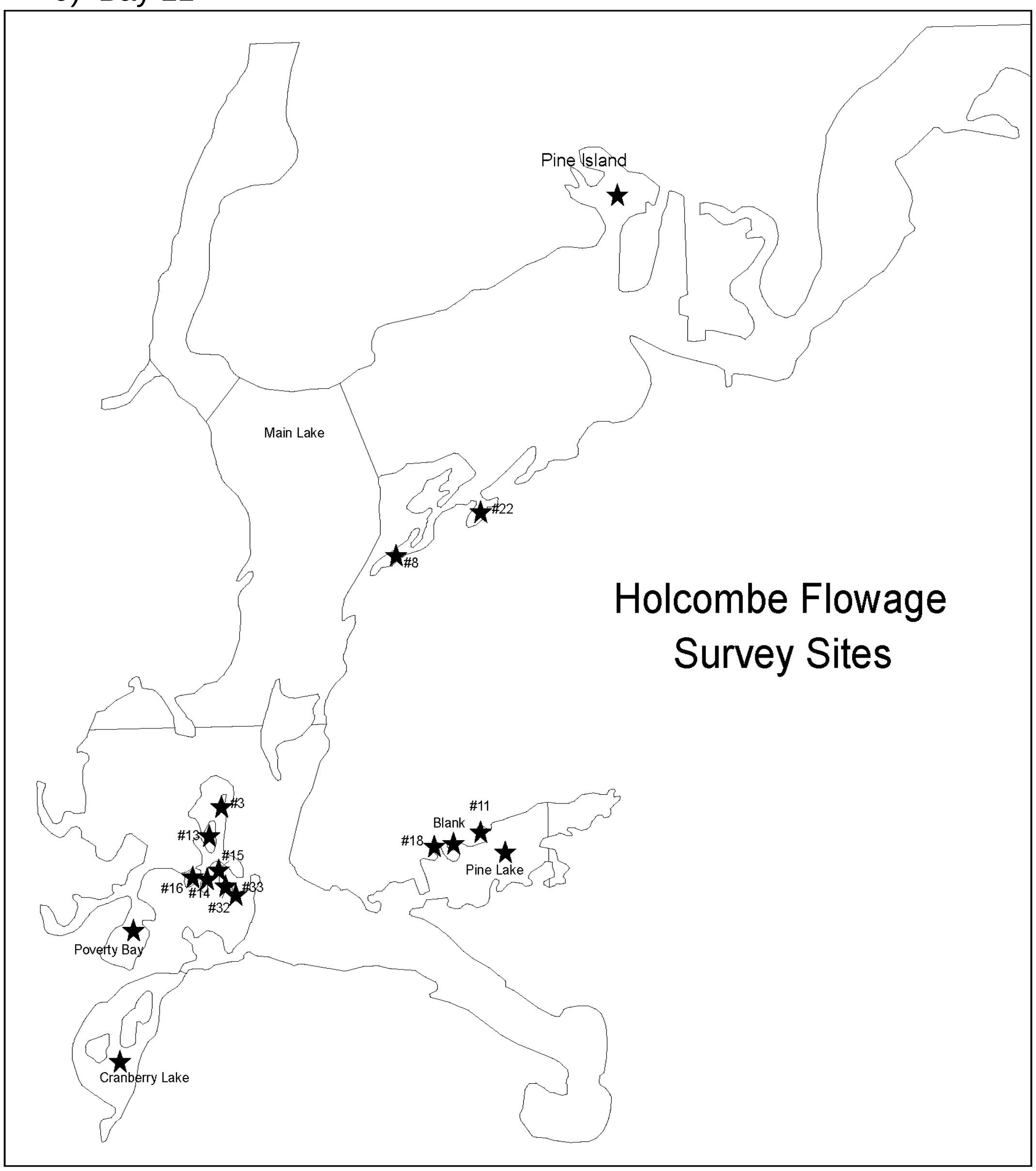
Sample site grid sizes and the number of points for each site sampled in Holcombe Flowage 1994/95 and 2006.

| Site | Grid Size (m) | Number of Data Points |
|---|---|---|
| Main Channel | 300 x 300 | 150 |
| Pine Lake | 100 x100 | 55 |
| Cranberry Lake | 100 x 100 | 42 |
| Poverty Bay | 50 x 50 | 44 |
| Pine Island | 50 x 50 | 82 |
| Blank Bay | 5 x 5 | 20 |
| Bay 3 | 5 x 5 | 20 |
| Bay 8 | 20 x 20 | 70 |
| Bay 11 | 5 x 5 | 20 |
| Bay 13 | 10 x 10 | 45 |
| Bay 14 | 5 x 5 | 20 |
| Bay 15 | 10 x 10 | 35 |
| Bay 16 | 5 x 5 | 20 |
| Bay 18 | 5 x 5 | 20 |
| Bay 22 | 20 x 20 | 56 |
| Bay 32 | 5 x 5 | 20 |
| Bay 33 | 10 x 10 | 19 |
| TOTAL | | 738 |

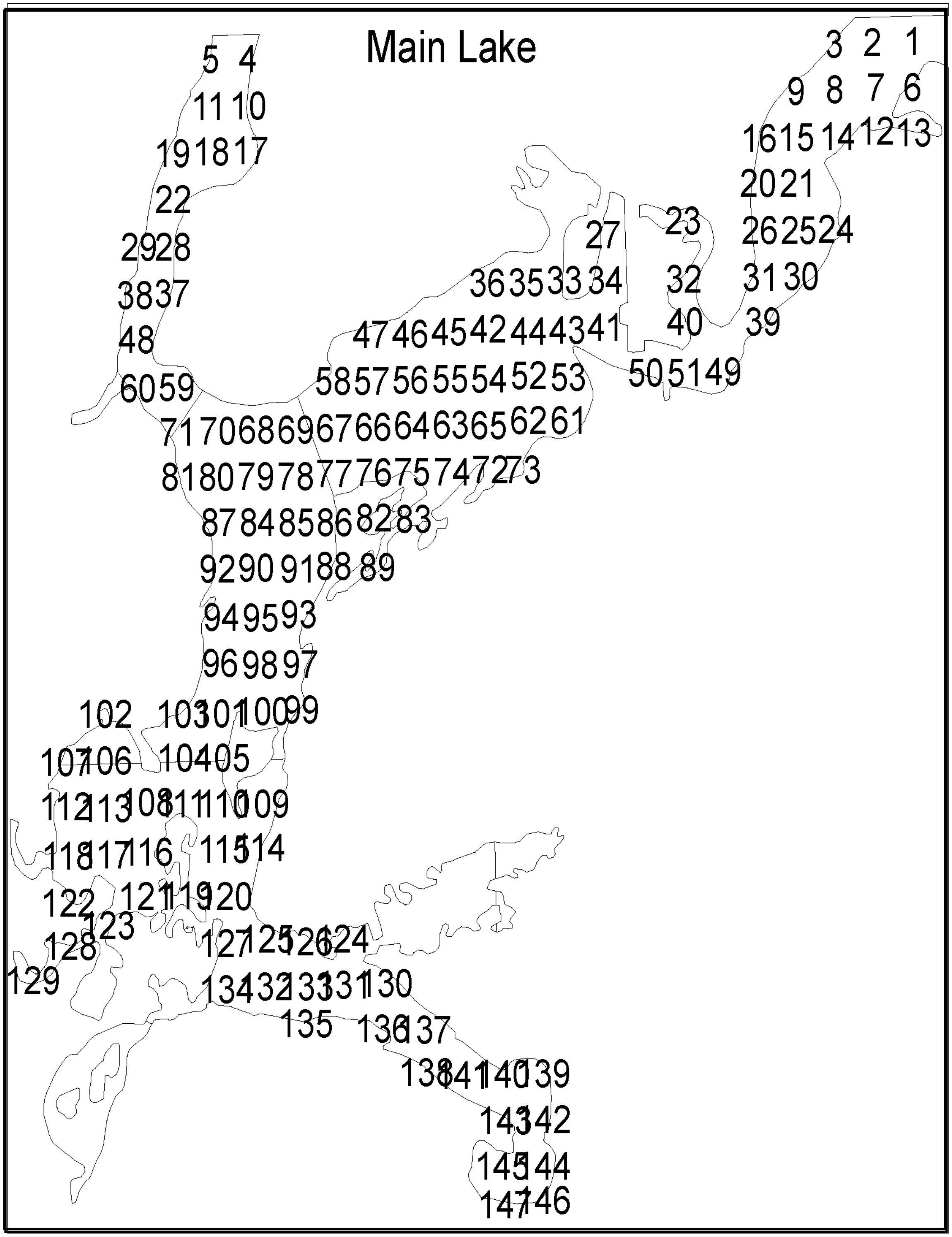
# Appendix C

Locations of sample points in 17 different areas of the Holcombe Flowage.

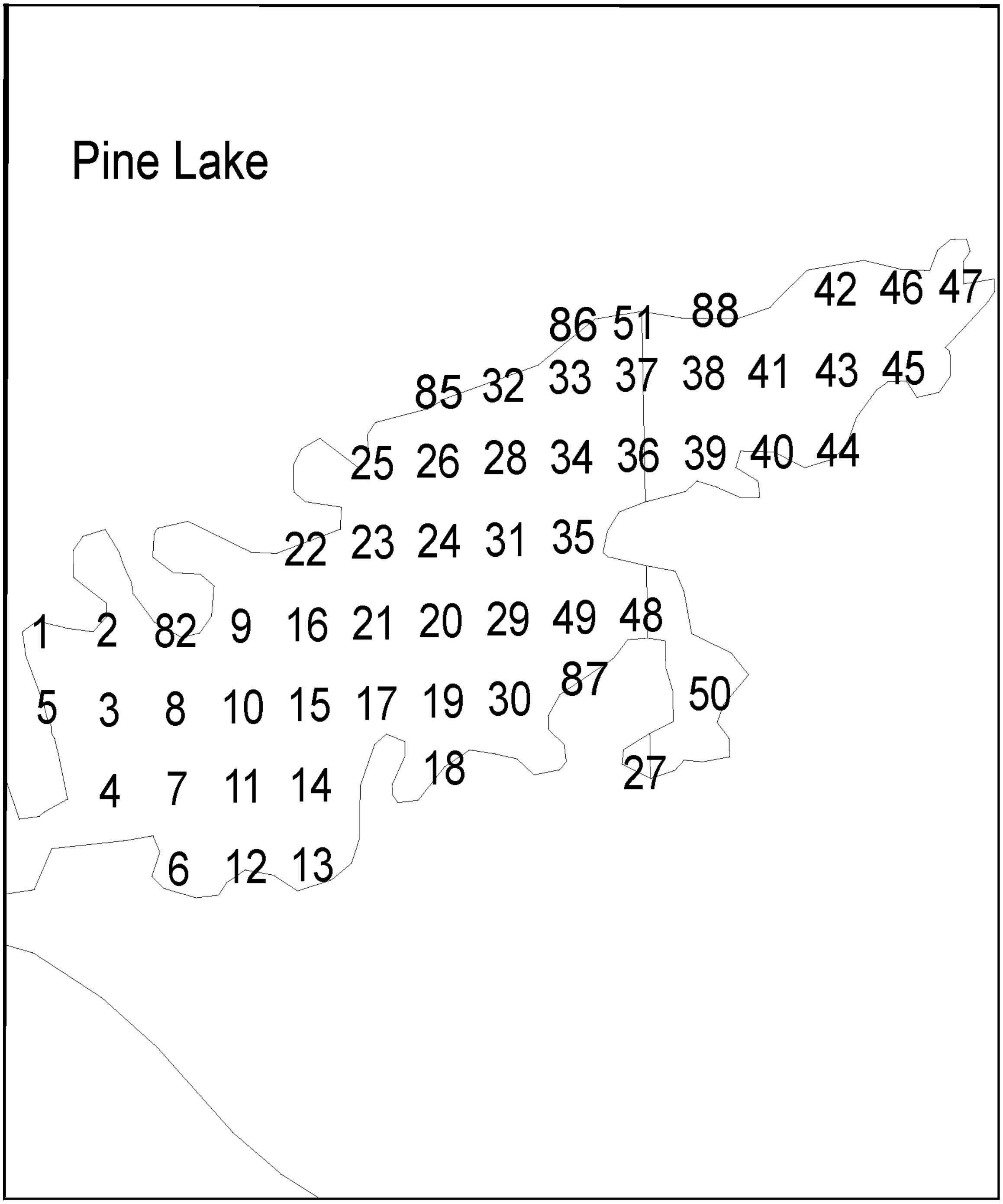
1) Main Channel
2) Pine Lake
3) Cranberry Lake
4) Poverty Bay
5) Pine Island
6) Blank Bay
7) Bay 3
8) Bay 8
9) Bay 11
10) Bay 13
11) Bay 14
12) Bay 15
13) Bay 16
14) Bay 18
15) Bay 22
16) Bay 32
17) Bay 33



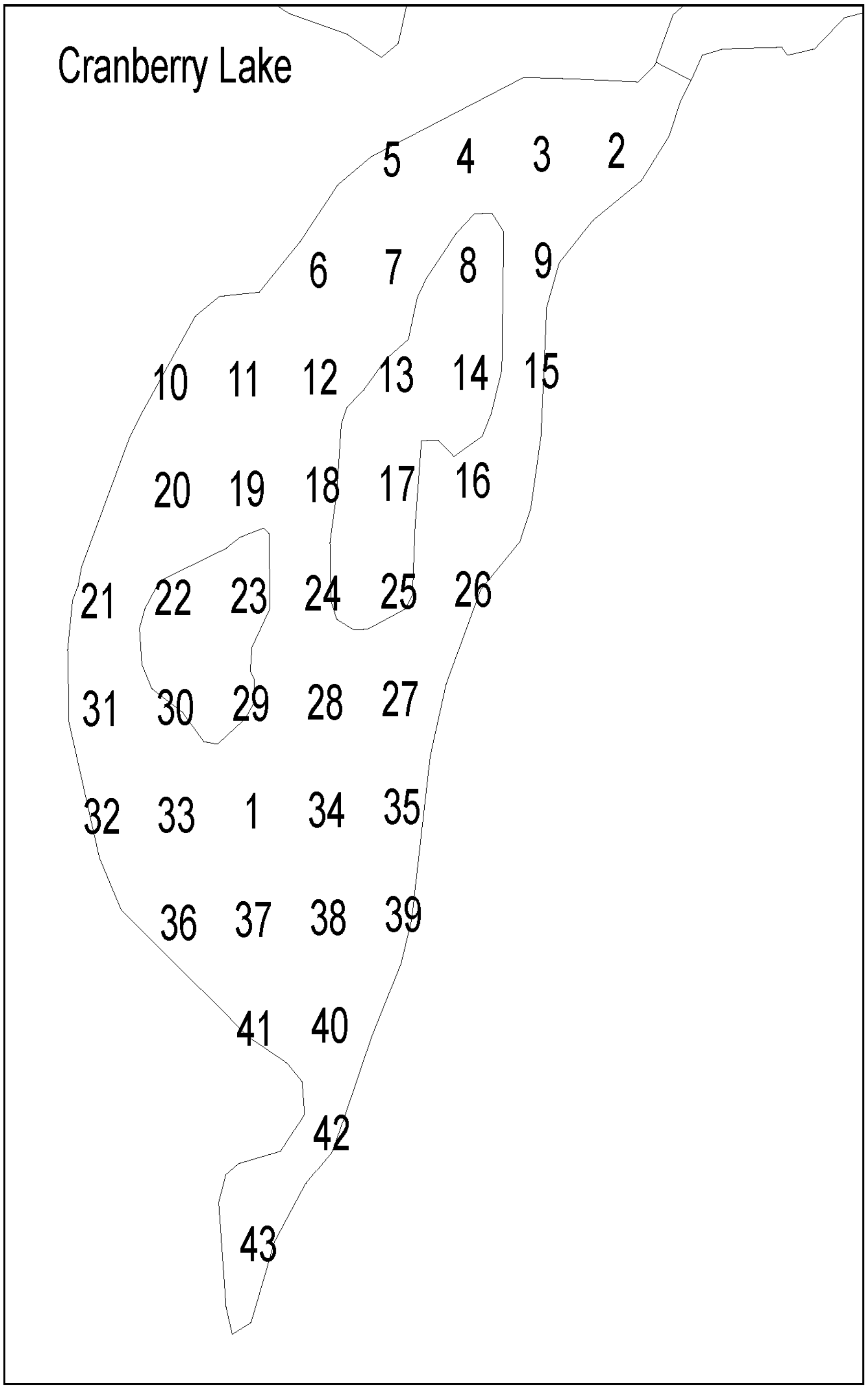
1) Main Channel - 150 survey sites at 300m X 300m.



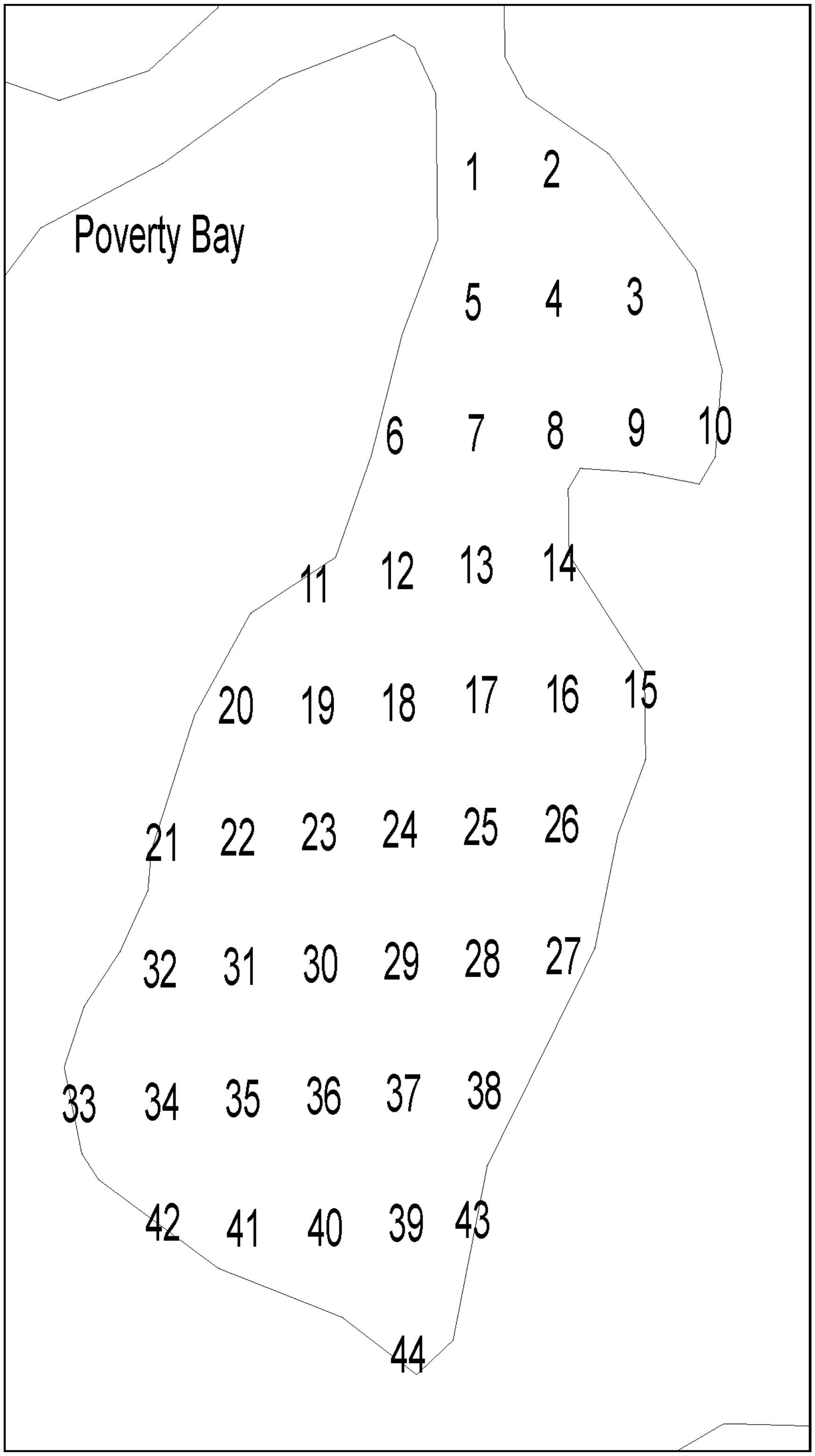
2) Pine Lake – 55 survey locations at 100m x 100m.



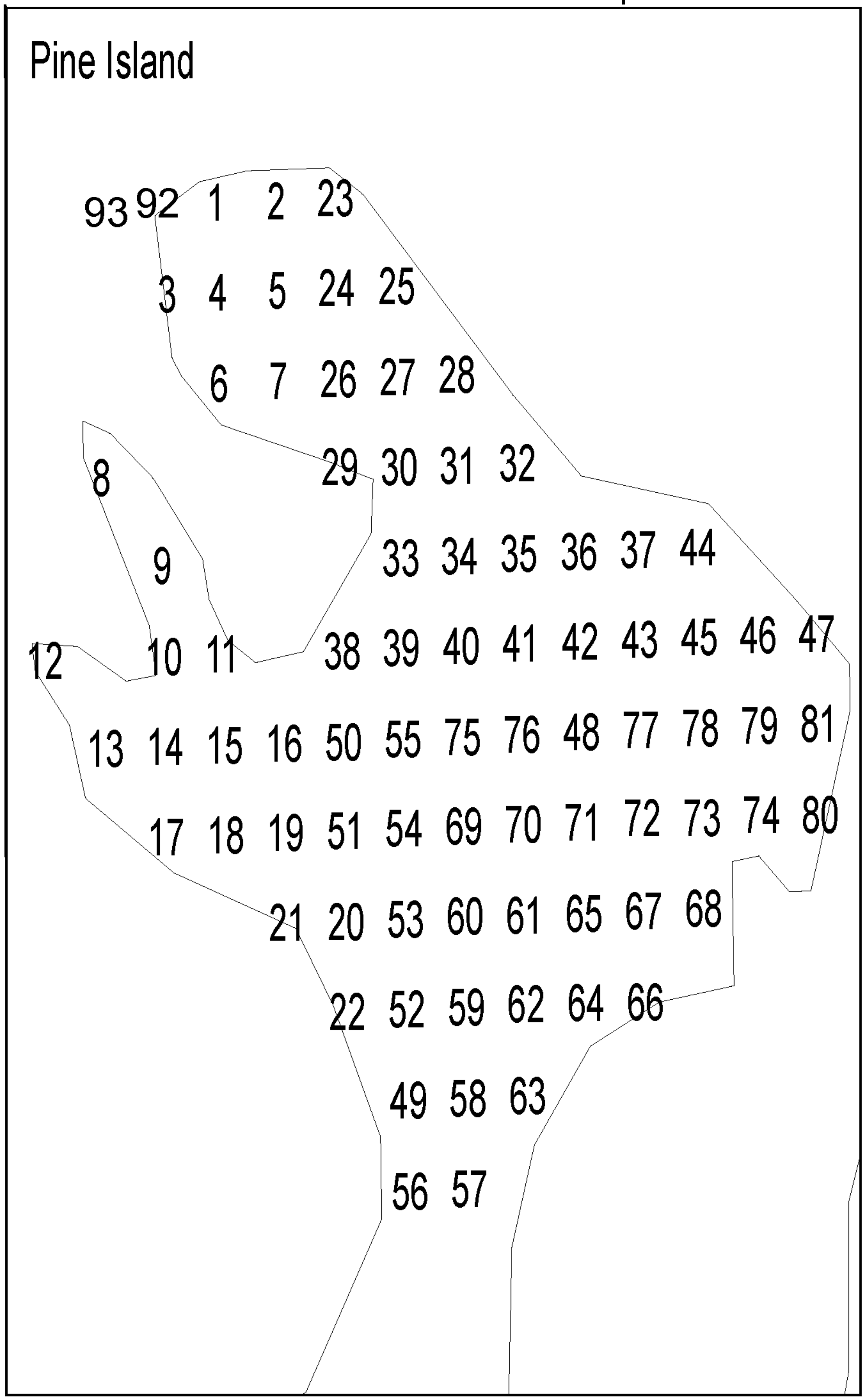
3) Cranberry Lake - 42 survey locations at 100m x 100m



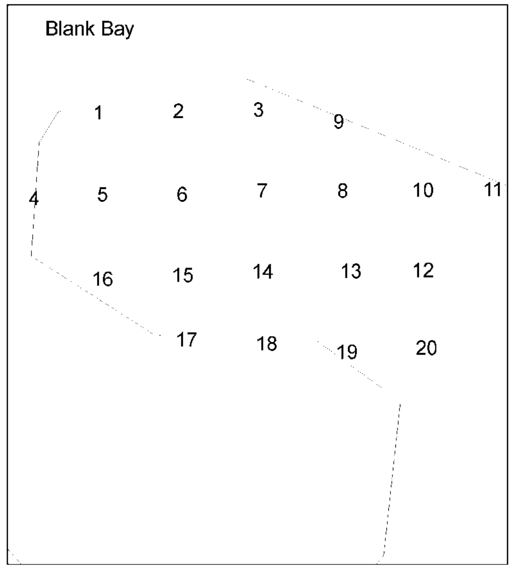
4) Poverty Bay – 44 site locations at 50m x 50m



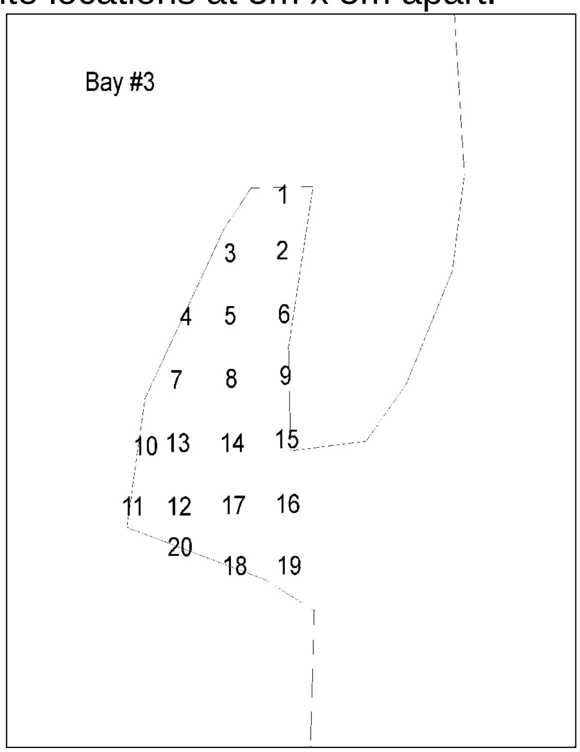
5) Pine Island – 82 site locations at 50m x 50m apart.



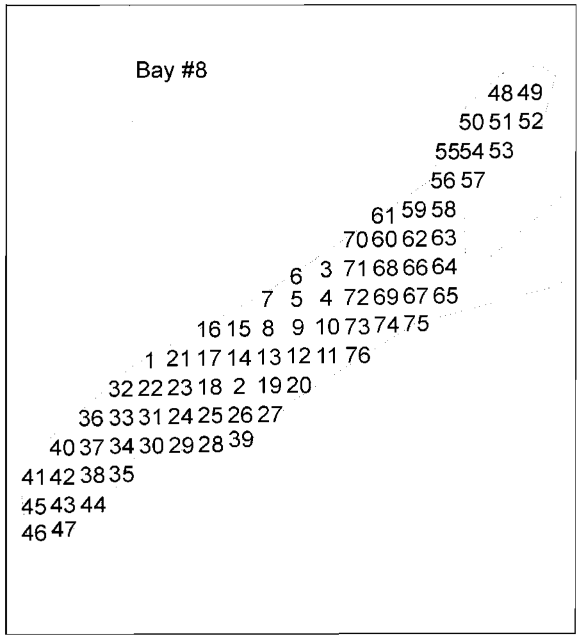
6) Blank Bay – 20 site locations at 5m x 5m apart.



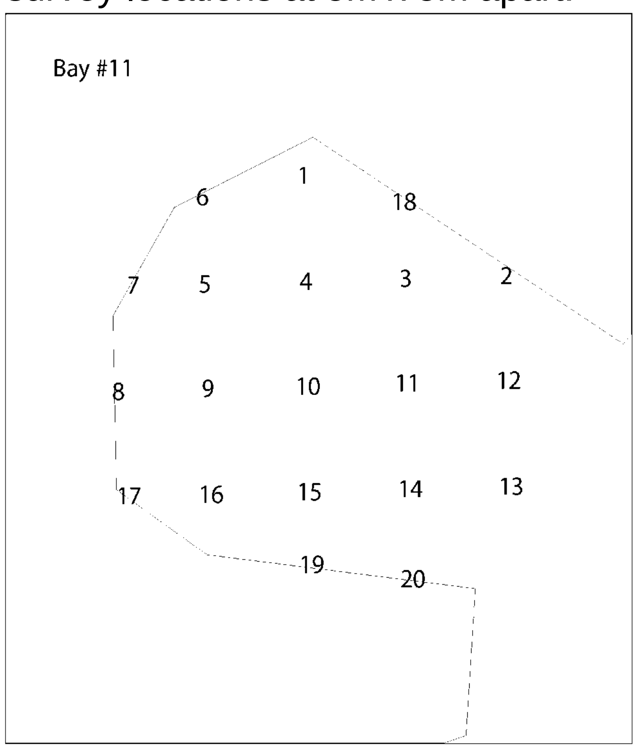

7) Bay 3 – 20 site locations at 5m x 5m apart.



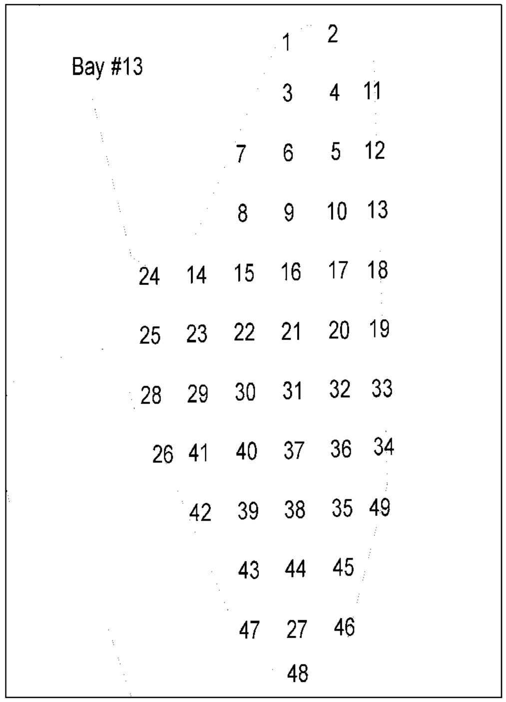
8) Bay 8 – 70 survey locations at 20m x 20m apart.



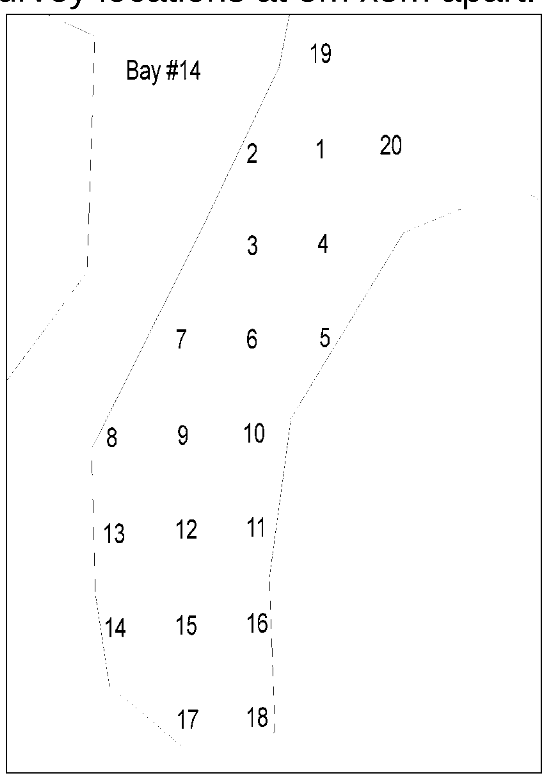

9) Bay 11 – 20 survey locations at 5m x 5m apart.



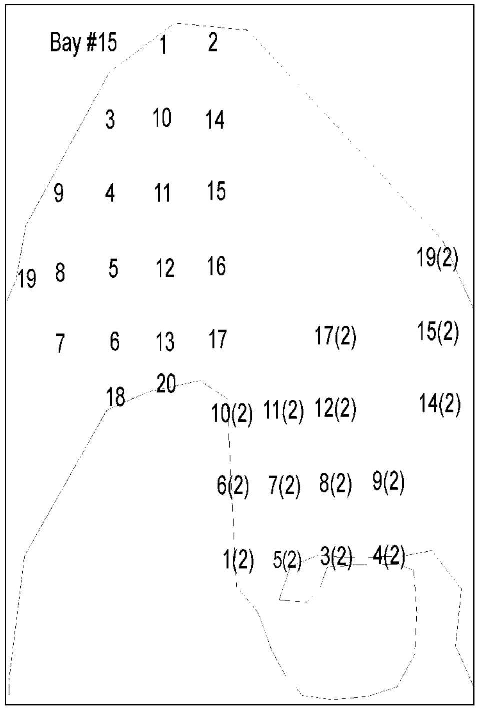
10) Bay 13 – 45 survey locations at 10m x 10m apart.



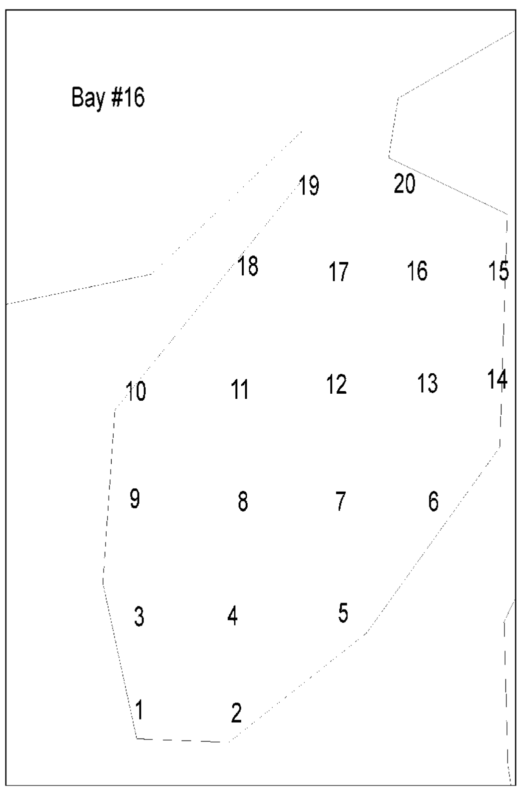

11) Bay 14 - 20 survey locations at 5m x5m apart.



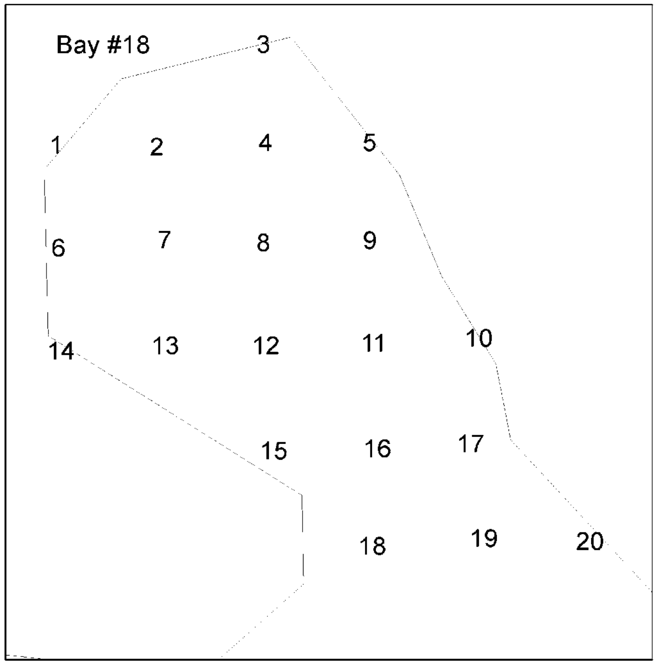
12) Bay 15 – 35 survey locations at 10m x 10m apart.



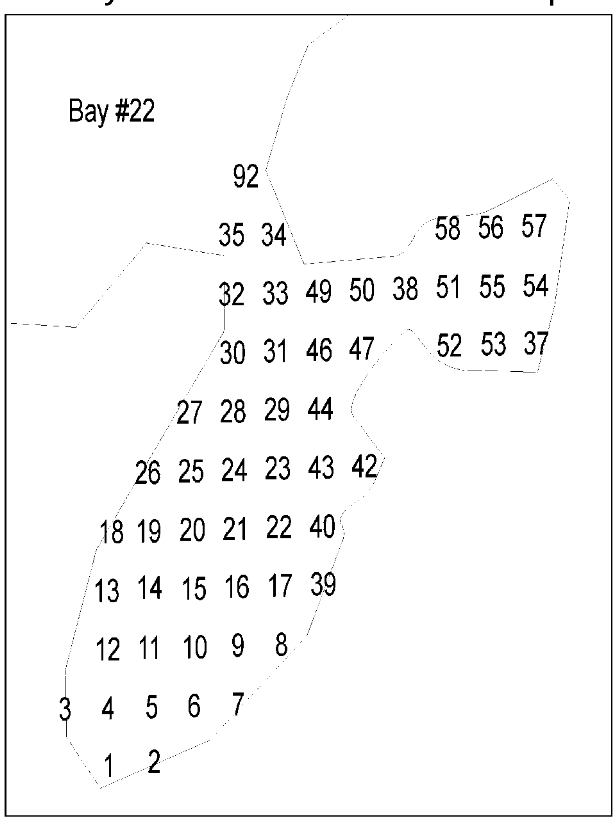

13) Bay 16 – 20 survey locations at 5m x 5m apart.



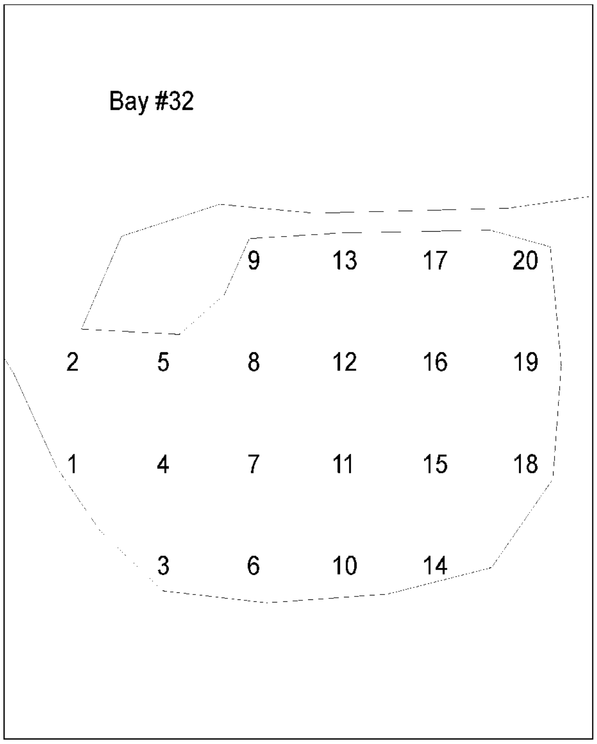
14) Bay 18 – 20 survey locations at 5m x 5m apart.



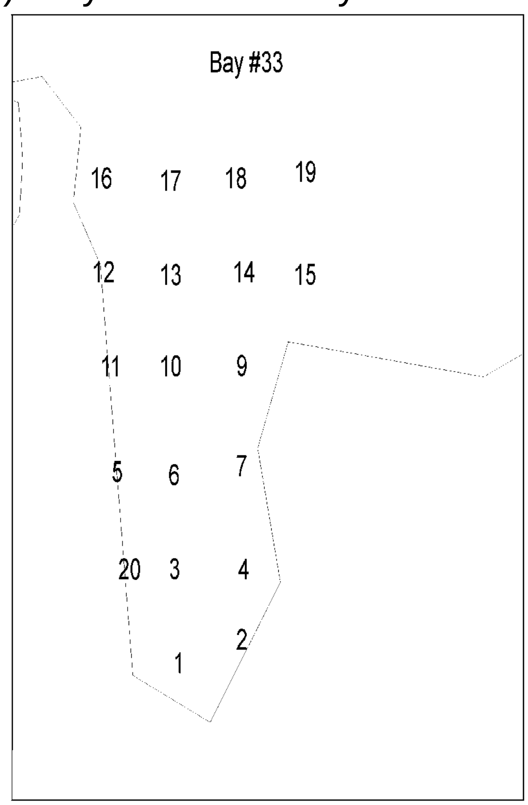

15) Bay 22 – 56 survey locations at 20m x 20m apart.



16) Bay 32 – 20 survey locations at 5m x 5m apart.




17) Bay 33 – 19 survey locations at 10m x 10m apart.



# Appendix D

Sediment distribution of Holcombe Flowage.

1) Main Channel
2) Pine Lake, Bay 11, Bay 18, & Blank Bay
3) Cranberry Lake
4) Poverty Bay
5) Pine Island
6) Bay 3 & Bay 13
7) Bay 8 & Bay 22
8) Bay 14, Bay 15, Bay 16, Bay 32 & Bay 33

# Appendix E

Species List for 1994/95 and 2006. * Species were counted from the hard data furnished by the US Army Corp. of Engineers

## 1994/95 Species Lists (47)*

Emergents

*Carex spp.*
*Carex pseudo-cyperus*
*Dulichium arundinaceum*
*Eleocharis sp.*
*Iris versicolor*
*Lythrum salicaria*
*Sagittaria latifolia*
*Sagittaria rigida*
*Schoenoplectus tabernaemontani*
*Scirpus cyperinus*
*Sium suave*
*Sparganium spp.*
*Typha angustifolia*
*Typha latifolia*
*Zizania aquatica*

Floating-Leaf

*Lemna minor*
*Lemna trisulca*
*Nuphar advena*
*Nymphaea tuberosa*
*Spirodela polyrhiza*

Submersed

*Ceratophyllum demersum*
*Chara spp*
*Elodea canadensis*
*Heteranthera dubia*
*Megalodonta beckii*
*Myriophyllum sibiricum*
*Myriophyllum verticillatum*
*Najas flexilis*
*Nitella spp*
*Polygonum natans*
*Potamogeton amplifolius*
*Potamogeton crispus*

## 2006 Species List (52)

Emergents

*Acorus calamus*
*Berula erecta*
*Carex*
*Carex pseudo-cyperus*
*Comarum palustre*
*Dulichium arundinaceum*
*Eleocharis acicularis.*
*Eleocharis palustris*
*Iris versicolor*
*Lythrum salicaria*
*Sagittaria latifolia*
*Sagittaria rigida*
*Schoenoplectus tabernaemontani*
*Scirpus cyperinus*
*Sium suave*
*Sparganium spp.*
*Typha angustifolia*
*Typha latifolia*
*Zizania aquatica*

Floating-Leaf

*Lemna minor*
*Lemna trisulca*
*Nuphar variegata*
*Nymphaea tuberosa*
*Spirodela polyrhiza*

Submersed

*Ceratophyllum demersum*
*Ceratophyllum echinatum*
*Chara spp*
*Elodea canadensis*
*Heteranthera dubia*
*Megalodonta beckii*
*Myriophyllum sibiricum*
*Myriophyllum spicatum*

# Appendix E cont.

1994/95 Submersed Cont.

*Potamogeton diversifolius*
*Potamogeton epihydrus*
*Potamogeton natans*
*Potamogeton nodosus*
*Potamogeton obtusifolius*
*Potamogeton pusillus*
*Potamogeton richardsonii*
*Potamogeton robbinsii*
*Potamogeton spirillus*
*Potamogeton zosteriformis*
*Ranuculus spp.*
*Stuckenia pectinatus*
*Utricularia minor*
*Utricularia vulgaris*
*Vallisneria americana*

2006 Submersed Cont.

*Myriophyllum verticillatum*
*Najas flexilis*
*Nitella spp*
*Potamogeton amplifolius*
*Potamogeton crispus*
*Potamogeton diversifolius*
*Potamogeton epihydrus*
*Potamogeton foliosus*
*Potamogeton natans*
*Potamogeton nodosus*
*Potamogeton obtusifolius*
*Potamogeton pusillus*
*Potamogeton richardsonii*
*Potamogeton robbinsii*
*Potamogeton spirillus*
*Potamogeton zosteriformis*
*Stuckenia pectinatus*
*Utricularia geminiscapa*
*Utricularia vulgaris*
*Vallisneria americana*

# Appendix F

Drawdown intolerant species present in 1994/95 and 2006.

**1994/1995**

*Nuphar advena*
*Nymphaea tuberosa*
*Myriophyllum sibiricum*
*Myriophyllum verticillatum*
*Potamogeton amplifolius*
*Potamogeton natans*
*Potamogeton robbinsii*
*Utricularia minor*
*Utricularia vulgaris*

**2006**

*Eleocharis acicularis*
*Nuphar variegata*
*Nymphaea tuberosa*
*Myriophyllum sibiricum*
*Myriophyllum verticillatum*
*Myriophyllum spicatum*
*Potamogeton amplifolius*
*Potamogeton natans*
*Potamogeton robbinsii*
*Utricularia geminiscapa*
*Utricularia vulgaris*

# Appendix G

Locations of exotic species Purple Loosestrife (*Lythrum salicaria*), Curly-leaf Pondweed (*Potamogeton crispus*), and Eurasian Water-Milfoil (*Myriophyllum spicatum*) throughout the Holcombe Flowage.

1) Purple Loosestrife
2) Curly-leaf Pondweed
3) Eurasian Water-milfoil

# Appendix H

Plant species locations on Holcombe Flowage separated by vegetation type (i.e. emergent, floating-leaf, or submergent).

1) Main Channel
2) Pine Lake, Bay 11, Bay 18, & Blank Bay
3) Cranberry Lake
4) Poverty Bay
5) Pine Island
6) Bay 3 & Bay 13
7) Bay 8 & Bay 22
8) Bay 14, Bay 15, Bay 16, Bay 32 & Bay 33

# Appendix I

Individual plant data analysis for 1994/1995.

| Species | . %Freq | % Freq. w/ Veg. | %Freq. Littoral zone | Relative Freq. |
|---|---|---|---|---|
| *Carex sp.* | 4.4% | 7.3% | 5.2% | 0.02 |
| *Carex pseudo-cyperus* | - | - | - | - |
| *Ceratophyllum demersum* | 23.8% | 39.7% | 28.1% | 0.10 |
| *Chara* | 1.1% | 1.8% | 1.3% | - |
| *Dulichium arundinaceum* | - | - | - | - |
| *Eleocharis* | 2.2% | 3.7% | 2.6% | 0.01 |
| *Elodea canadensis* | 39.1% | 65.3% | 46.2% | 0.17 |
| *Heteranthera dubia* | 1.9% | 3.1% | 2.2% | 0.01 |
| *Iris versicolor* | 0.2% | 0.3% | 0.2% | - |
| *Lemna minor* | 2.2% | 3.7% | 2.6% | 0.01 |
| *Lemna trisulca* | - | - | - | - |
| *Lythrum salicaria* | 0.9% | 1.6% | 1.1% | - |
| *Megalodonta beckii* | 4.2% | 7.0% | 5.0% | 0.02 |
| *Myriophyllum sibiricum* | 5.0% | 8.4% | 5.9% | 0.02 |
| *Myriophyllum verticillatum* | 0.9% | 1.6% | 1.1% | - |
| *Najas flexilis* | 9.9% | 16.4% | 11.6% | 0.04 |
| *Nitella sp.* | 1.4% | 2.3% | 1.7% | 0.01 |
| *Nuphar variegata* | 6.7% | 11.2% | 7.9% | 0.03 |
| *Nymphaea tuberosa* | 29.9% | 49.9% | 35.3% | 0.13 |
| *Polygonum natans* | - | - | - | - |
| *Potamogeton amplifolius* | 5.9% | 9.9% | 7.0% | 0.03 |
| *Potamogeton crispus* | 1.9% | 3.1% | 2.2% | 0.01 |
| *Potamogeton diversifolius* | 3.0% | 5.0% | 3.5% | 0.01 |
| *Potamogeton epihydrus* | 12.5% | 20.9% | 14.8% | 0.05 |
| *Potamogeton natans* | 0.2% | 0.3% | 0.2% | - |
| *Potamogeton nodosus* | 0.8% | 1.3% | 0.9% | - |
| *Potamogeton obtusifolius* | 0.3% | 0.5% | 0.4% | - |
| *Potamogeton pusillus* | 7.0% | 11.7% | 8.3% | 0.03 |
| *Potamogeton richardsonii* | 5.0% | 8.4% | 5.9% | 0.02 |
| *Potamogeton robbinsii* | 8.8% | 14.6% | 10.4% | 0.04 |
| *Potamogeton spirillus* | 14.4% | 24.0% | 17.0% | 0.06 |
| *Potamogeton zosteriformis* | 9.7% | 16.2% | 11.5% | 0.04 |
| *Ranunculs aquatilis* | 0.2% | 0.3% | 0.2% | - |
| *Sagittaria latifolia* | 2.5% | 4.2% | 3.0% | 0.01 |
| *Sagittaria rigida* | - | - | - | - |
| *Schoenoplectus tabernaemontani* | - | - | - | - |
| *Scirpus cyperinus* | - | - | - | - |
| *Sium suave* | 0.8% | 1.3% | 0.9% | - |
| *Sparganium sp.* | 2.2% | 3.7% | 2.6% | 0.01 |
| *Spirodela polyrhiza* | - | - | - | - |
| *Stuckenia pectinatus* | 0.2% | 0.3% | 0.2% | - |

| | | | | |
|---|---|---|---|---|
| *Typha angustifolia* | 2.5% | 4.2% | 3.0% | 0.01 |
| *Typha latifolia* | - | - | - | - |
| *Utricularia minor* | - | - | - | - |
| *Utricularia vulgaris* | 0.3% | 0.5% | 0.4% | - |
| *Vallisneria americana* | 16.0% | 26.6% | 18.9% | 0.07 |
| *Zizania aquatica* | 2.5% | 4.2% | 3.0% | 0.01 |
| Totals | 227.9% | | | 1.00 |

# Appendix I cont.

Individual plant data analysis for 2006

| Species | %Freq. | %Freq. w/ Veg. | %Freq. Littoral zone | Relative Freq. | Mean Density | Mean Density Present | Relative Density |
|---|---|---|---|---|---|---|---|
| *Acorus calamus* | 0.1% | 0.2% | 0.2% | - | - | 1.00 | - |
| *Berula erecta* | - | - | - | - | - | - | - |
| *Carex pseudo-cyperus* | 0.3% | 0.5% | 0.4% | - | 0.01 | 1.50 | - |
| *Carex sp.* | 0.1% | 0.2% | 0.2% | - | - | 1.00 | - |
| *Ceratophyllum demersum* | 46.5% | 76.0% | 56.7% | 0.17 | 1.79 | 3.16 | 0.21 |
| *Ceratophyllum echinatum* | 0.4% | 0.7% | 0.5% | - | 0.01 | 1.33 | - |
| *Chara* | 0.3% | 0.5% | 0.4% | - | 0.01 | 1.50 | - |
| *Comarum palustre* | - | - | - | - | - | - | - |
| *Dulichium arundinaceum* | - | - | - | - | - | - | - |
| *Eleocharis acicularis* | - | - | - | - | - | - | - |
| *Eleocharis palustris* | 0.6% | 1.0% | 0.7% | - | 0.02 | 2.25 | - |
| *Elodea canadensis* | 45.3% | 74.1% | 55.2% | 0.16 | 1.60 | 2.89 | 0.19 |
| *Heteranthera dubia* | 5.6% | 9.2% | 6.9% | 0.02 | 0.09 | 1.37 | 0.01 |
| *Iris versicolor* | - | - | - | - | - | - | - |
| *Lemna minor* | 8.6% | 14.0% | 10.5% | 0.03 | 0.27 | 2.55 | 0.03 |
| *Lemna trisulca* | 6.1% | 9.9% | 7.4% | 0.02 | 0.17 | 2.29 | 0.02 |
| *Lythrum salicaria* | 0.1% | 0.2% | 0.2% | - | - | 1.00 | - |
| *Megalodonta beckii* | 14.4% | 23.5% | 17.5% | 0.05 | 0.36 | 2.04 | 0.04 |
| *Myriophyllum sibiricum* | 2.5% | 4.1% | 3.1% | 0.01 | 0.03 | 1.12 | - |
| *Myriophyllum spicatum* | 2.5% | 4.1% | 3.1% | 0.01 | 0.06 | 2.00 | 0.01 |
| *Myriophyllum verticillatum* | 0.9% | 1.5% | 1.1% | - | 0.01 | 1.33 | - |
| *Najas flexilis* | 5.6% | 9.2% | 6.9% | 0.02 | 0.09 | 1.37 | 0.01 |
| *Nitella sp.* | 4.4% | 7.3% | 5.4% | 0.02 | 0.07 | 1.27 | 0.01 |
| *Nuphar variegata* | 8.6% | 14.0% | 10.5% | 0.03 | 0.21 | 1.98 | 0.02 |
| *Nymphaea tuberosa* | 19.6% | 32.0% | 23.8% | 0.07 | 0.56 | 2.36 | 0.07 |
| *Potamogeton amplifolius* | 6.1% | 9.9% | 7.4% | 0.02 | 0.14 | 1.93 | 0.02 |
| *Potamogeton crispus* | 1.2% | 1.9% | 1.4% | - | 0.01 | 1.00 | - |
| *Potamogeton diversifolius* | 0.9% | 1.5% | 1.1% | - | 0.01 | 1.33 | - |
| *Potamogeton epihydrus* | 1.5% | 2.4% | 1.8% | 0.01 | 0.03 | 1.50 | - |
| *Potamogeton foliosus* | 4.7% | 7.7% | 5.8% | 0.02 | 0.09 | 1.63 | 0.01 |
| *Potamogeton natans* | 0.3% | 0.5% | 0.4% | - | 0.01 | 3.00 | - |
| *Potamogeton nodosus* | 0.4% | 0.7% | 0.5% | - | 0.01 | 1.67 | - |
| *Potamogeton pusillus* | 7.6% | 12.3% | 9.2% | 0.03 | 0.14 | 1.55 | 0.02 |
| *Potamogeton richardsonii* | 5.0% | 8.2% | 6.1% | 0.02 | 0.09 | 1.41 | 0.01 |
| *Potamogeton robbinsii* | 30.1% | 49.2% | 36.6% | 0.11 | 1.10 | 3.00 | 0.13 |
| *Potamogeton spirillus* | 1.8% | 2.9% | 2.2% | 0.01 | 0.04 | 1.83 | 0.00 |
| *Potamogeton zosteriformis* | 7.6% | 12.3% | 9.2% | 0.03 | 0.14 | 1.47 | 0.02 |
| *Sagittaria latifolia* | 1.2% | 1.9% | 1.4% | - | 0.03 | 2.00 | - |
| *Sagittaria rigida* | 0.7% | 1.2% | 0.9% | - | 0.02 | 2.20 | - |
| *Schoenoplectus tabernaemontani* | 0.3% | 0.5% | 0.4% | - | 0.01 | 4.00 | - |
| *Scirpus cyperinus* | - | - | - | - | - | - | - |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Sium suave* | - | - | - | - | - | - | - |
| *Sparganium sp.* | 4.4% | 7.3% | 5.4% | 0.02 | 0.18 | 3.23 | 0.02 |
| *Spirodela polyrhiza* | 6.5% | 10.7% | 7.9% | 0.02 | 0.21 | 2.68 | 0.03 |
| *Stuckenia pectinatus* | 0.1% | 0.2% | 0.2% | - | - | 2.00 | - |
| *Typha angustifolia* | 3.1% | 5.1% | 3.8% | 0.01 | 0.13 | 3.52 | 0.02 |
| *Typha latifolia* | 0.9% | 1.5% | 1.1% | - | 0.01 | 1.33 | - |
| *Utricularia geminiscapa* | 0.6% | 1.0% | 0.7% | - | 0.01 | 1.00 | - |
| *Utricularia vulgaris* | 3.1% | 5.1% | 3.8% | 0.01 | 0.06 | 1.62 | 0.01 |
| *Vallisneria americana* | 19.4% | 31.7% | 23.6% | 0.07 | 0.53 | 2.25 | 0.06 |
| *Zizania aquatica* | 1.0% | 1.7% | 1.3% | - | 0.03 | 2.43 | - |
| Totals | 281.3% | | | 1.00 | 8.41 | | 1.00 |

# Appendix J

Holcombe Flowage dam winter drawdown levels for 1950 thru 2004.

| YEAR | START DATE | END DATE | TOTAL # OF DAYS | MAXIMUM DEPTH (Ft.) |
|---|---|---|---|---|
| 1950 | Lake Holcombe was filled for the first time. | | | |
| 1951 | 3/5 | 4/8 | 34 | 10 |
| 1952 | 2/11 | 4/8 | 56 | 9.5 |
| 1953 | 2/21 | 3/21 | 28 | 8.6 |
| 1954 | 2/15 | 3/19 | 32 | 10 |
| 1955-58 | Drawdown information is not available. | | | |
| 1959 | 3/2 | 3/28 | 26 | 7 |
| 1960 | 2/22 | 3/19 | 25 | 4 |
| 1961 | 3/7 | 4/1 | 26 | 5 |
| 1962 | 2/26 | 4/16 | 50 | 10 |
| 1963 | 3/6 | 4/2 | 27 | 3 |
| 1964 | A winter drawdown did not take place. | | | |
| 1965 | 2/23 | 4/13 | 50 | 10 |
| 1966 | 3/29 | 4/7 | 10 | 3 |
| 1967 | 2/24 | 3/31 | 27 | 10 |
| 1968 | A winter drawdown did not take place. | | | |
| 1969 | 3/4 | 4/8 | 35 | 10 |
| 1970 | 3/12 | 4/13 | 32 | 5 |
| 1971 | 2/24 | 4/10 | 47 | 10 |
| 1972 | 2/23 | 4/15 | 52 | 10 |
| 1973 | 2/28 | 3/13 | 14 | 4 |
| 1974 | 3/1 | 4/15 | 46 | 6 |
| 1975 | 2/25 | 4/18 | 53 | 10 |
| 1976 | 2/23 | 3/30 | 36 | 10 |
| 1977 | A winter drawdown did not take place. | | | |
| 1978 | 3/1 | 3/30 | 30 | 5 |
| 1979 | 2/27 | 4/6 | 39 | 10 |
| 1980* | 3/11 | 4/7 | 27 | 9 |
| 1981 | A winter drawdown did not take place. | | | |
| 1982 | 3/22 | 4/1 | 10 | 7 |
| 1983 | A winter drawdown did not take place. | | | |
| 1984 | A winter drawdown did not take place. | | | |
| 1985 | A winter drawdown did not take place. | | | |

| | | | | |
|---|---|---|---|---|
| 1986 | 3/21 | 3/29 | 8 | 8 |
| 1987 | | A winter drawdown did not take place. | | |
| 1988 | | A winter drawdown did not take place. | | |
| 1989 | 3/27 | 3/29 | 2 | 5 |
| 1990 | | A winter drawdown did not take place. | | |
| 1991 | | A winter drawdown did not take place. | | |
| 1992 | 3/7 | 3/27 | 20 | 5.2 |
| 1993 | 3/16 | 3/31 | 15 | 5.7 |
| 1994 | 3/1 | 3/28 | 27 | 5.6 |
| 1995 | | A winter drawdown did not take place. | | |
| 1996 | | A winter drawdown did not take place. | | |
| 1997 | | A winter drawdown did not take place. | | |
| 1998 | | A winter drawdown did not take place. | | |
| 1999 | | A winter drawdown did not take place. | | |
| 2000 | | A winter drawdown did not take place. | | |
| 2001 | | A winter drawdown did not take place. | | |
| 2002 | | A winter drawdown did not take place. | | |
| 2003 | | A winter drawdown did not take place. | | |
| 2004 | | A winter drawdown did not take place. | | |

* Winter operating regime changed from a one-foot fluctuation to a three-foot fluctuation.