Nutrient Budget and Management Data Analysis Report

Getting Rid of the Green – Phase Three

Big Chetec Lake, Sawyer County, Wisconsin

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Getting Rid of the Green – Phase Three
Big Chetec Lake, Sawyer County, Wisconsin

Prepared for:
Big Chetek Chain Lake Association and Wisconsin Department of Natural Resources

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April 1, 2009

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Date

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Nutrient Budget and Management Data Analysis Report

Getting Rid of the Green – Phase Three

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1.0 Introduction

During the 2007 open water season data necessary to complete water and nutrient budget analyses for Big Chetac Lake was collected. Tributary monitoring, precipitation and evaporation data, groundwater data, internal phosphorous releases rates, curly-leaf pondweed (CLP) phosphorous release rates, and watershed and near shore phosphorous contributions were assessed in 2008. Additional information was added including a septic system analysis, atmospheric contributions of phosphorous, and a more accurate assessment of the total mass of CLP in the lake. The following is a report summarizing the findings of this exercise. Point and non-point sources of nutrient loading to the lake are identified and quantified. Total seasonal loading is compared to the overall increase of in-lake phosphorous mass for the 2007 open water season. Possible management alternatives are mentioned, but will be more completely defined in the final recognized Comprehensive Lake Management Plan for Big Chetac Lake, scheduled for completion in 2010.

2.0 In-Lake Water Budget

Determining a budget for a lake, be it a water budget or a nutrient budget, involves determining how much is coming into the lake and how much is going out. Water inputs to Big Chetac Lake include local tributaries, precipitation, and groundwater inflow. Water going out includes that which goes out through Birch Lake and over the dam, groundwater outflow, and evaporation. Since reliable flow data from the Birch lake dam could not be obtained, and the fact that the flow over the dam includes the water contributed by the Birch Lake watershed, an alternative water budget approach was used to assess outflow. Surface outflow from Big Chetac Lake was estimated as the residual term in the water budget.

Figure 1 shows the rain fall and lake stage for the 2007 season. Precipitation for May through September 2007 was 13.6 inches based on data from a nearby monitoring station. Lake Stage was recorded daily by volunteers on a Staff Gauge installed in the lake by this consulting agency. Evaporation from the lake's surface was estimated at 21.2 inches based on average annual evaporation rates reported by the USGS for the area (27 inches) and a percent of annual evaporation of 78.5% for the time period from May to September which was determined in USGS Studies of Silver and Whitefish Lakes in 2006. Precipitation minus evaporation over Big Chetac Lake would have resulted in a lake level drop of 7.6 inches. The actual drop in lake level during this time frame was 6.5 inches according to daily lake staff gauge readings recorded by volunteers.

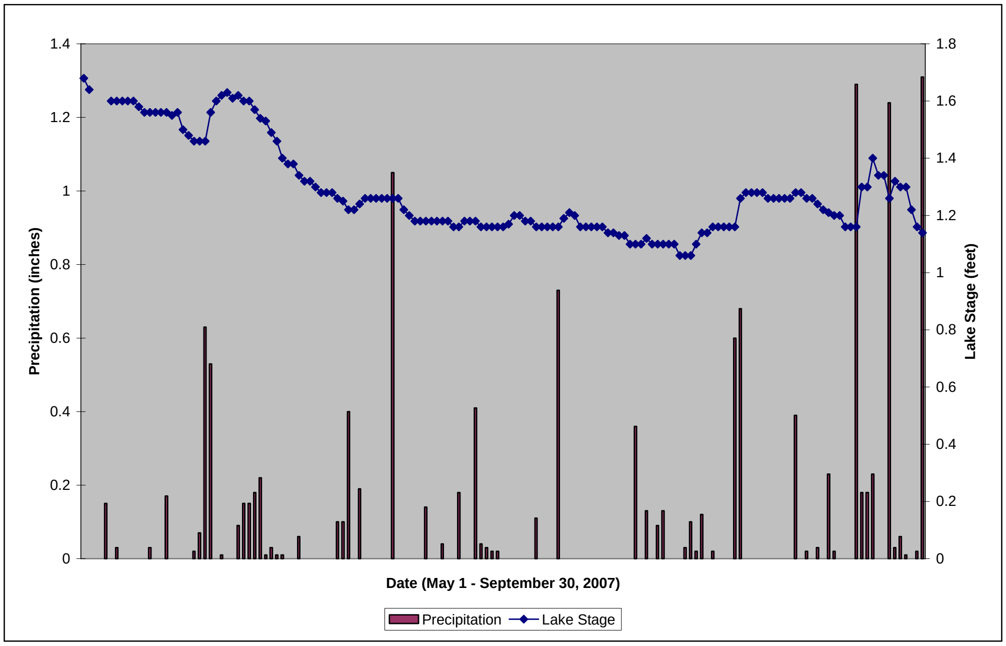


Figure 1 – Big Chetac Lake Stage and Precipitation

The average rate of stream inflow from May to September for four monitored sub-watersheds (Benson, Heron, Knuteson, and Red Cedar Springs) was 11.6 cfs. Assuming inflow from unmonitored watersheds is areal proportional, the average inflow from the entire watershed is 15.2 cfs. Net groundwater inflow (inflow minus outflow) is estimated at only 0.6 cfs. Since the areal proportional approach to estimating inflow from unmonitored watersheds has essentially already accounted for groundwater inflow, a separate groundwater inflow value was not added. Surface outflow into Birch Lake and over the dam is calculated as 10.9 cfs. Table 1 summarizes the water budget data for Big Chetac Lake.

Table 1
May - September 2007 Water Budget for Big Chetac Lake

Budget Component	inches or ft^3/sec	Volume (m^3)
Precipitation	13.6 in.	+3,367,734
Evaporation	21.2 in.	-5,249,703
Inflow	15.2 ft3/sec	+5,689,864
Storage change	1.1 in.	+272,390
Surface outflow	10.9 ft3/sec	-4,080,285

3.0 In-Lake Monitoring of Total Phosphorous, Chlorophyll *a,* and Secchi Depth

Nutrient sampling of water in Big Chetac was completed on fifteen different dates starting on April 25, 2007 and ending on October 7, 2007 at three different lake sites: North Basin, Central Basin, and South Basin. Total phosphorous, total nitrogen and chlorophyll *a* concentrations were measured at the following depths: 0-2m, 2.5m, 3.5m, 4.5m, 5.5m, 6.5m, and 7.5m if the depth of the basin permitted it. North was sampled at all of these depths, Central was sampled through 5.5m, and South was sampled through 4.5m. Secchi disk readings and temperature and dissolved oxygen profiles, and pH measurements were also taken. The goal of this sampling was to determine seasonal changes in phosphorus mass, algal abundance and pH; to determine the time period for which each basin became anoxic or oxygen depleted in the bottom waters; and to determine if Big Chetac Lake was nitrogen or phosphorous limited.

Excess phosphorous in a lake system often leads to an increase in algal growth, and a decline in Secchi Disk readings of water clarity particularly in the summer months. This is the case in Big Chetac Lake. Figure 2 shows the average sampling results for all three basins for each of these parameters over the 5 month sampling period in 2007. Trend lines are added to show the relationship between increases in phosphorous concentration leading to increases in chlorophyll *a* (a measurement of algal concentrations) and decreasing Secchi readings.

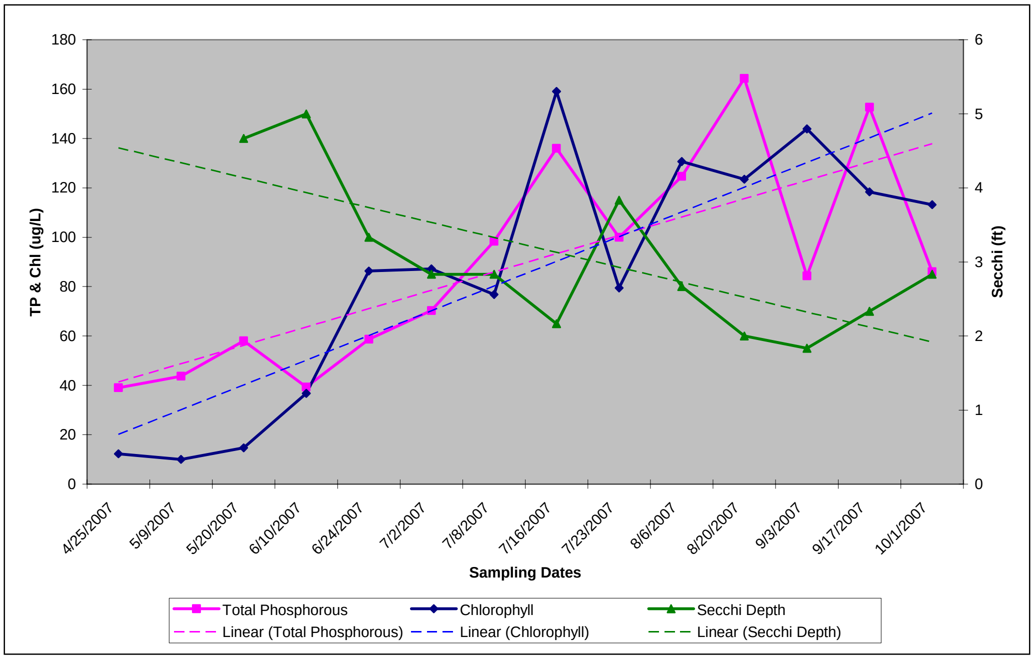


Figure 2 – Total P and Chlorophyll Concentrations (0-2m) and Secchi Disk Averages for Big Chetac Lake

The total in-lake phosphorous mass is determined by multiplying the phosphorous concentration in the lake at the time of sampling by the total volume of the lake. If phosphorous readings are taken at different depths and the volume of lake water at each of those depths can be determined, a relatively accurate determination of the total lbs of phosphorous in the lake on any given sampling date can be estimated. The difference between the minimum phosphorous mass during the year and the maximum phosphorous mass during the year shows the lake's response to inputs of phosphorus. For this study, Big Chetac Lake was divided into three separate basins (North, Central, and South) and the phosphorous mass was determined for each basin based on measured phosphorous concentrations at each depth and the corresponding volume at that depth. Adjustments were made in the volume of the top two meters of the lake based on daily fluctuations in lake level as recorded on a Lake Staff Gauge. For Big Chetac Lake, the 2007 seasonal increase in phosphorous mass was determined to be 9,624 lbs. Figure 3 shows the total calculated phosphorous mass for each basin and the lake as a whole. Individual basin mass is determined by phosphorous concentration and volume at separate depths in each basin. Figure 4 shows the proportion of this total mass that comes from each basin.

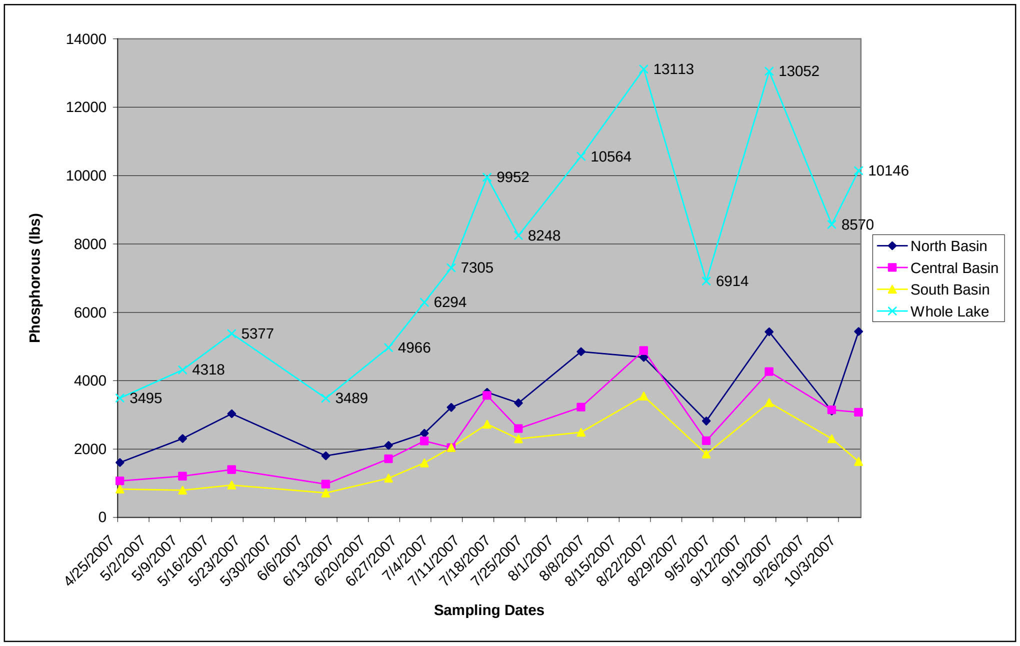


Figure 3 – 2007 In-Lake Phosphorous Mass

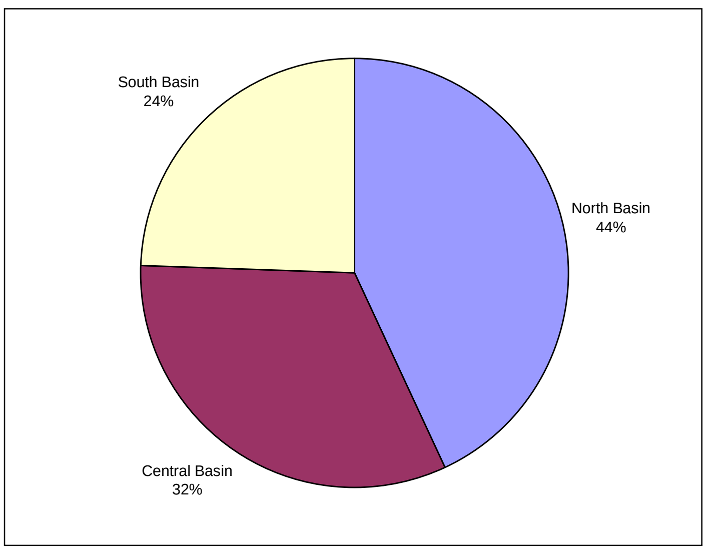


Figure 4 – Percent In-lake Phosphorous Mass by Basin

4.0 In-Lake Nitrogen to Phosphorous Ratios

The nitrogen to phosphorous ratio in the lake is an important indicator as to which nutrient controls the abundance of algae found every year in Big Chetac Lake. If the nitrogen to phosphorous ratio in the lake is less than 10 to 1, then nitrogen is likely to be the limiting nutrient leading to algal growth. Ratios between 10 to 1 and 15 to 1 are considered transitional between nitrogen and phosphorus limitation. For ratios greater than 15 to 1, phosphorus is likely to be the limiting nutrient. A limiting nutrient means that the algal growth is dependent on the amount of that nutrient freely available in the water column. Most nitrogen to phosphorous ratios for Big Chetac Lake indicate phosphorus limitation or transitional nitrogen and phosphorus limitation (Figure 5). On only 3 of the 15 sampling dates was nitrogen limitation indicated.

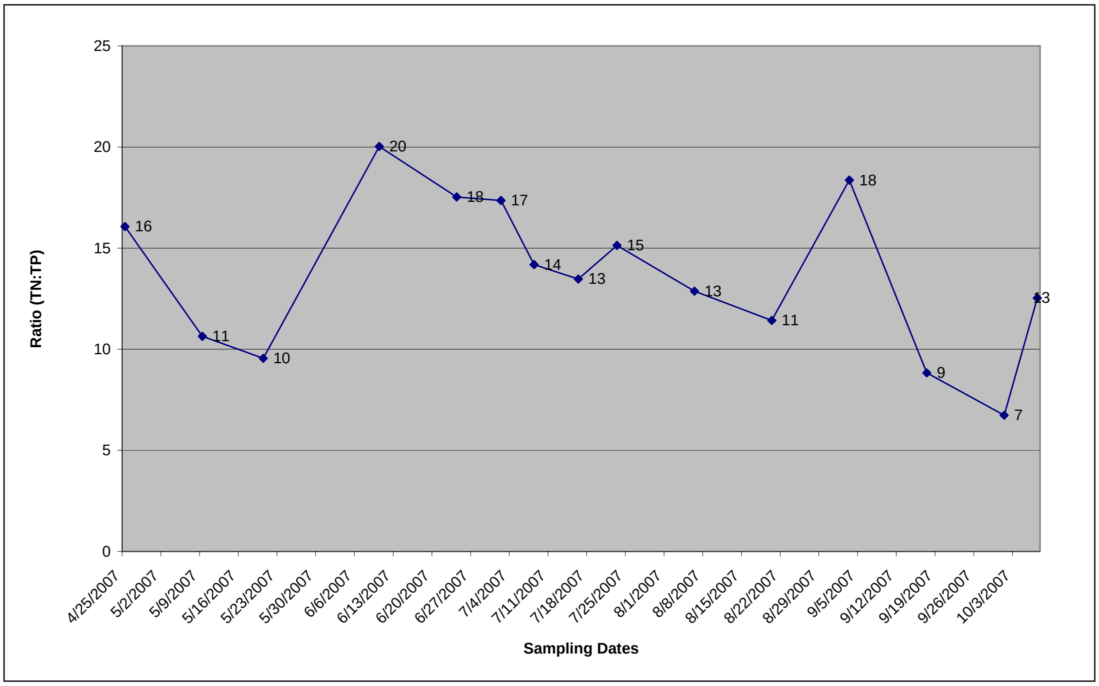


Figure 5 – 2007 Seasonal TN:TP Ratios (Whole Lake)

Algal growth in Big Chetac Lake is mostly dependent on the amount of phosphorous available in the water column. If the amount of phosphorous goes up the algal growth is likely to go up as well. If it goes down, algal growth will likely go down. There are a couple of times during the open water season where nitrogen may be limiting. In mid May and late September the nitrogen to phosphorous ratio dips below 10 to 1 particularly in the Central and South basins. The role of nitrogen limitation when ratios are transitional (10-15 to 1) is not well understood.

5.0 Phosphorous Loading Sources to Big Chetac Lake

The estimated total phosphorous mass increase for the lake in 2007 is 9,624 lbs. The next step is to determine what the sources are for phosphorous loading to the system. The following sources were looked at: atmospheric deposition, groundwater flow, tributary loading, near shore contributions, that portion of the unmonitored watershed not already accounted for with tributary loading, septic system contributions, internal loading (recycling of nutrients already in the lake from sediment release) and curly-leaf pondweed decay.

As phosphorous enters a water body it immediately begins to be used. Plants and algae take in some of the available phosphorous. Some of it settles out to the bottom of the lake and is trapped in the sediment. Out flow from the lake removes still more. The total amount of phosphorous that is used up by plants and that settles out of the water column is difficult to determine. The amount removed by outflow from the lake can be quantified by comparing outflow to the in-lake phosphorous concentration in the surface waters. An average outflow of 10.9 cfs from Big Chetac Lake coupled with an average 0-2 meter total phosphorous concentration of 0.104 mg/L in the South Basin over the time period from May through September 2007 indicates approximately 940 lbs of phosphorous is removed by outflow.

The estimated loading from the various sources of phosphorous should be somewhat comparable to the estimated phosphorous mass increase in the lake based on actual water sampling. Figure 6 shows the estimated phosphorous loading from the sources indicated. Total loading from these sources over a 5 month period from May through September is estimated at 11,749 lbs. Assuming that phosphorous is removed from the lake via outflow (940 lbs), plant use (unknown), and settling (unknown), a higher loading value than the measured mass in the lake is reasonable. Some of these sources of phosphorous can be controlled, while others can not.

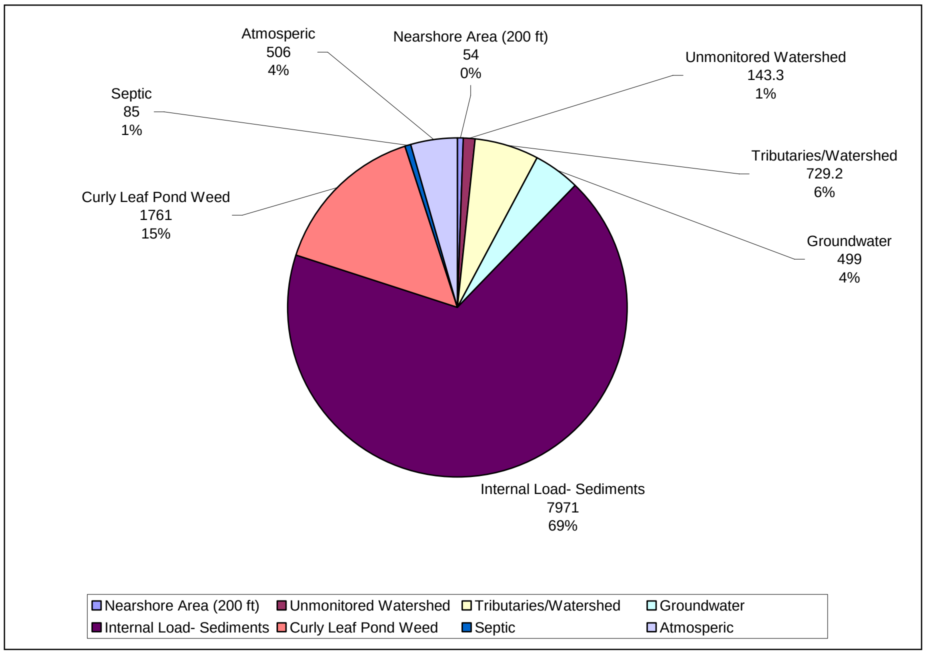


Figure 6 – May through September 2007 Phosphorous Loading in Lbs to Big Chetac Lake

6.0 Atmospheric Contribution

Atmospheric deposition of phosphorous comes from the phosphorous found in the dust and other particulate matter that is blown over and settles into the lake or is cleansed from the air when it rains. This particulate matter could be carried to the lake from a great distance away by a weather system or be blown off the land immediately adjacent to the lake. As such, it can not be controlled except to implement best management practices aimed at fixing the dust to the ground. Grass cover crops and dampening of exposed sediment/sand/gravel areas to prevent wind erosion are several examples of best management practices that could be implemented. A default value taken from the Wisconsin Lake Modeling Suite (WiLMS) of 0.3 kg/hectare/year is used with a Big Chetac Lake surface area of 976 hectares to generate a value of approximately 644 lbs of phosphorous per year. To get the percent loading from May through September the total annual load (644 lbs) is multiplied by the value used in calculating evaporation rates (78.5%) making it approximately 506 lbs or 4%.

7.0 Groundwater Contribution

Groundwater flow into the lake also contributes phosphorous. The type of substrate groundwater flows through, the areas of inflow and outflow, and the volume of groundwater that is moving influences the amount of phosphorous it carries into the lake. The amount and direction of groundwater flow for Big Chetac Lake was estimated by installing 12 mini-piezometers around the perimeter of the lake. Areas of inflow and outflow are determined by the difference in head height or hydraulic gradient within each piezometer from the lake level. If the head is greater than the lake level then groundwater is flowing into the lake and if it is less than the lake level it is flowing out of the lake. Furthermore, groundwater flow must be characterized by a certain area that it flows through before getting to the lake in order to be quantified. For this project groundwater flow was connected to an area extending 20 ft into the lake from the perimeter. Groundwater would flow into and out of the lake through this area of the lake bed. Different soil types have different permeability rates. This means that groundwater flows through the different soils of the lake bed at different rates. The soil type and flow rate (hydraulic conductivity) were determined for each of the 12 piezometers installed around the lake. Based on the results recorded, groundwater flows into the lake primarily from the north and west with some inflow from the east, and flows out primarily to the south and east (Appendix A). The daily flow of groundwater into the lake is estimated at just over 2 gallons (2.01) per square feet of lake bed.

An analysis of the nutrient concentrations present in water samples taken from inside the piezometers provides an estimate of how much phosphorous is carried with the groundwater. The average phosphorous concentration inside the piezometers was 0.0785 mg/L. Daily groundwater flow into the lake was calculated at approximately 4,990,670 gallons per day. Flow rate multiplied by phosphorous concentration multiplied by 153 days (May through September) equates to approximately 499 lbs of phosphorous or 4% of the total seasonal load. This is a natural source of phosphorous to the lake therefore control is not possible. The amount of phosphorous carried into the lake by groundwater however, can be influenced by the number of household septic systems around the lake. Groundwater that flows through an area where a septic system is not functioning properly or is all together failing, likely carries significantly more phosphorous than normal groundwater.

8.0 Septic System Contribution

Most people assume that septic systems (also known as On-site Wastewater Systems [OWS]), particularly those that do not operate properly, contribute a significant amount of phosphorous to a lake. For this reason, Sawyer County was asked by the Big Chetac Lake Association to complete an OWS Survey around the lake. In order for this to occur, the lake association was required to get at least 51% of the lake front property owners to approve the survey. A letter was sent to all lake residents requesting approval for the septic survey on September 1, 2006. Eventually 62% of all lake shore property owners supported the survey. Only 22% did not approve, the rest did not respond. The purpose of the survey was to identify compliant, non-compliant, and failing OWS. The survey was started in May of 2008, and continued through August 2008. It included on-site interviews with property owners when present, location and type of OWS, and a determination through a variety of factors of whether the system was compliant and working, non-compliant and working, failing, or inconclusive. Sawyer County attempted to survey 378 systems. Their results are shown in Figure 7.

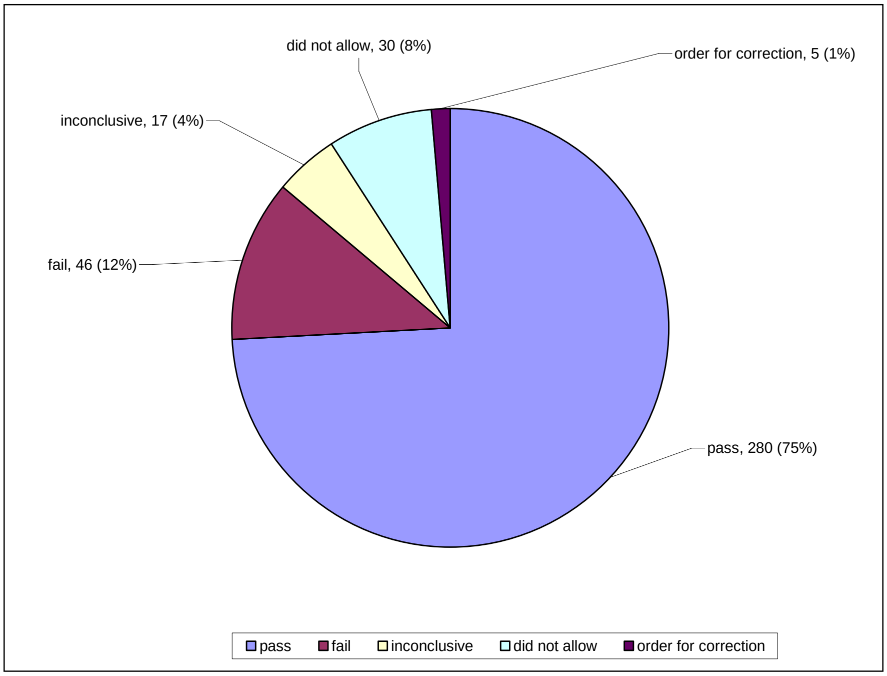


Figure 7 – Big Chetac Lake OWS Survey Results

For Big Chetac Lake, Sawyer County completed a septic system analysis of passing and failing systems. They recorded 378 systems of which 280 were passing, 46 were failing, 17 were inconclusive, and 30 households did not allow an inspection (Maki et al. 2008). Orders for correction were issued at 5 locations. Orders of correction are for the worst systems requiring immediate attention. It is believed that 90% of the systems that did not allow inspection are likely failing. Also, 50% of the inconclusive systems were listed as failing. The total number of passing OWS is 292; the total number of failing systems is 81.

In order to determine the potential phosphorous load contributed by OWS around the lake, several bits of information are needed. The total number of failing or passing systems is just one factor. In addition, the number of per-capita years (people years) the system is in use, an export coefficient based on an average household phosphorous discharge of wastewater to septic systems, and a soil retention coefficient based on the type of soil around the lake and slope of the lake shore is required.

8.2 Export Coefficient

An accepted value for the average amount of phosphorus discharged with household wastewater is 1.5 kg/capita/year, where capita is the number of people in the household, except in states where a phosphorus detergent ban is in place. Wisconsin currently has a phosphorus ban in affect for detergents, but not for fertilizers. The Wisconsin Lake Modeling Suite (WiLMS) estimates that the export coefficient is between 0.3 and 0.8 with the most likely value being 0.5.

8.3 Soil Retention Coefficient

The soil retention factor for phosphorus discharged into conventional on-site wastewater systems is based on many different soil characteristics within the lake impacting zone including phosphorus adsorption capacity, natural drainage, permeability, and slope. This coefficient can range from 0 to 1.0. A value of 0 suggests that all phosphorous transported to the septic system eventually reaches the surface water. A value of 1.0 suggests no phosphorous reaches the surface water. Soils around Big Chetac Lake are generally a sandy loam with moderate to good permeability and good drainage on relatively steep slopes of 5 to 45%. These conditions indicate that a soil retention value around 0.90 be used, suggesting that little of the total phosphorous transported into OWS reaches the surface water (assuming the OWS is functioning properly). If an OWS is not functioning properly or failing then a much smaller soil retention value, around 0.15, is used. Because of steep slopes, disturbed shoreline cover, and a high groundwater table around the lake, most of the phosphorous transported into these systems will likely reach the surface water.

8.4 Capita Years

Capita years is determined by multiplying the number of people in a household by the total time they use the OWS, essentially the number of days per year that the household is lived in. At the time of the Septic Survey, those residents that were home were asked to provide information related to the number of people living in the household and the numbers of days they lived there. There are both permanent and seasonal residents living on Big Chetac Lake. 30% are permanent residents with an average number of people per household of 1.98 based on 51% of all permanent households surveyed. 70% are seasonal residents with an average number of people per household of 2.67 based on 19% of all seasonal households surveyed. Based on the same percentages of households surveyed permanent residents spend 365 days a year at their homes and seasonal residents spend 94.33 days a year.

8.5 Analysis

An analysis of this data suggests that phosphorous contributed by septic systems on Big Chetac Lake is in the 1/3 of 1% to 1.2% range. Table 2 shows the data used to calculate the total mass of phosphorous contributed to the lake by all of the septic systems around the lake. Results suggest that 49.08 kg or approximately 108 lbs of phosphorous (about 1.2 %) would be contributed to Big Chetac Lake in one year by all septic systems on the lake, passing and failing. Phosphorous loading from May through September would be the highest as the majority of households are in greater use in the summer. Again the value established for evaporation rates from May to September is reasonable to calculate the total phosphorous load from septic systems during this time frame. Summer phosphorous loading from septic systems on Big Chetac Lake is approximately 85 lbs.

Table 2
Septic System Loading of Phosphorous - All OWS

Type	# of People	Days in Residence	# of Households	Export Coefficient	Soil Retention Coefficient	(1-SR)	Total kg of Phosphorous per year
Seasonal							
Passing	2.67	94.33/365	197	0.5	0.90	.10	6.84
Failing	2.67	94.33/365	66	0.5	0.15	.85	19.47
Permanent							
Passing	1.98	365/365	94	0.5	0.90	.1	9.31
Failing	1.98	365/365	16	0.5	0.15	.85	13.46
			373 OWS			49.08 kg (108.2 lbs)	

However, not all OWS are contributing phosphorous to the lake. If the system is operating the way it should, and is in an area of shoreline where groundwater flows away from the lake, little to no phosphorous is likely reaching the lake. If the system is non-compliant or failing, it may be contributing phosphorous overland via surface runoff. Table 3 reflects the changes that occur in the calculations when those OWS in areas where groundwater flows away from the lake are accounted for. Of the 373 systems checked by Sawyer County, approximately 108 are in areas where ground water is likely entering the lake verses exiting the lake. If only the systems on the side of the lake where groundwater flows into the lake are included, then the total phosphorous contribution from septic systems is 14.5 kg or approximately 32 lbs a year, or less than one percent of the total loading. Any contribution is significant but other phosphorous contributors are much more substantial.

Table 3
Septic System Loading of Phosphorous - OWS w/Groundwater into the Lake

Type	# of People	Days in Residence	# of Households	Export Coefficient	Soil Retention Coefficient	(1-SR)	Total kg of Phosphorous per year
Seasonal							
Passing	2.67	94.33/365	58	0.5	0.90	.1	2.01
Failing	2.67	94.33/365	19	0.5	0.15	.85	5.61
Permanent							
Passing	1.98	365/365	27	0.5	0.90	.1	2.67
Failing	1.98	365/365	5	0.5	0.15	.85	4.21
			108 OWS			14.5 kg (32.0 lbs)	

A more accurate estimation of the contributions made by septic systems could be done but it would require a more comprehensive evaluation of the number capita (people) years each system is in use. A relatively small percentage of residents were home when Sawyer County completed this survey. Several questions could be added to the Lake User Survey being completed in 2009 to get a better estimation of per capita use. The values for soil coefficients and the export coefficient for phosphorous contributed by the average person or household are default values included in lake modeling programs designated for use in Wisconsin. Conversations with Craig Roesler, WDNR suggest that these are probably adequate for this calculation.

9.0 Curly-leaf Pondweed Contributions

Curly-leaf pondweed (CLP) is an early season, non-native, aquatic, invasive plant species. There is a great deal of it present in Big Chetac Lake. In the spring and early summer 2008 CLP was present across more than 35% of the lake's total surface and more than 66% of the littoral zone (Berg, 2008). CLP grows early and quickly often being well-established even before the winter ice goes out of the lake. It has dense growth patterns that create large masses of vegetation that can interfere with lake recreational uses and shade out other plant growth. However, the life cycle of this plant typically concludes in late June or early July. The large masses of vegetation die and senesce quickly and then often disappear from the water column in a very short period of time.

Decaying CLP and other vegetation releases phosphorous into the lake water. However, just how much is still unclear. The reported phosphorous content of CLP varies widely and is likely dependent on a variety of existing conditions in any given lake. The phosphorous content of the CLP from Big Chetac Lake in 2007 was measured at 0.26% by the WDNR (Roesler, 2008) based on plant samples from 10 different sites. The median CLP biomass was calculated to be 245 g/m^2. Based on an area of CLP covering 621 acres (Berg 2008) the total phosphorous mass potentially released from CLP in Big Chetac Lake is estimated at 3,522 lbs or 30 % of the total phosphorous load.

The total phosphorous mass value contributed by CLP from the previous paragraph assumes that 100% of the phosphorous contained in the CLP will go directly into the water column. This is probably not the case. Naturally senescing CLP generally settles to the lake bottom where a substantial portion of the decomposition occurs. This would likely result in some of the phosphorous released by CLP being immediately captured in the sediment. Filamentous algae present in the area where CLP is decaying and periphyton on the remaining plant community would likely use up some of the phosphorous released from the CLP as well (Roesler, 2008). Conditions in Big Chetac Lake would seem to support this assumption. The 2008 Big Chetac Lake CLP Survey completed in June and late July of 2008 (Berg 2008) indicated that a large amount of living CLP was still visible in late July, and that rake samples taken from the bottom still contained a lot of CLP detritus. A better value to consider for Big Chetac Lake might be 50% of the potential phosphorous released from the CLP making it to the water column. If this is the case, then CLP contributed around 1761 lbs or 15% of the total phosphorous load based on 2008 CLP coverage in the lake.

A review of research conducted by Roesler (2008), related to how much and how quickly phosphorous from decaying CLP is available in the water column suggests that the majority of phosphorous released is done so in the first few days to a couple of weeks after CLP senesces. After release, phosphorous levels often return to pre-release levels within 2 to 4 weeks, unless some other phosphorus source kicks in, like oxygen depletion and sediment phosphorus release in the bottom waters. In 2007, most CLP disappeared from the surface waters of Big Chetac Lake prior to June 20th. A spike in phosphorous concentration should be identifiable somewhere around late June or early July, particularly in the zero to three meter water depth where CLP is most prevalent. Figure 8 shows the average top and bottom phosphorous concentrations in the lake as a whole. Phosphorus concentrations in the surface water are increasing at that time. However, deep sediment phosphorus release due to anoxia begins at about the same time, making it difficult to further separate the impacts from CLP phosphorus release and from sediment phosphorus release.

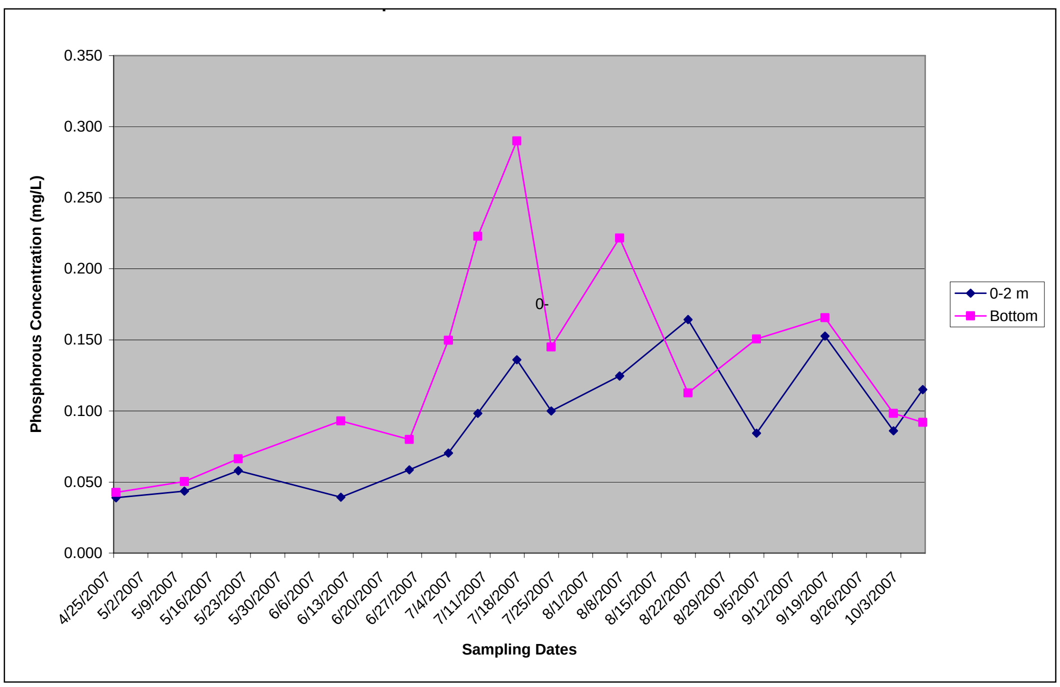


Figure 8 – Lake Wide Phosphorous Concentrations at the Surface and Bottom

There is some concern over the impacts decaying CLP has on dissolved oxygen levels in a lake where large amounts of the plant exists. While decaying CLP may slightly reduce dissolved oxygen levels near the deep water edges of the littoral zone, in general decay occurs in that area of the littoral zone that receives oxygen recharge. In Big Chetac Lake, anoxia occurred below the 4 meter depth. Depletion at this depth is likely the result of sediment oxygen demand fueled mostly by algal decomposition. A more likely impact of curly-leaf pondweed, other than the phosphorous released from the plant itself, is the increase in pH in the surrounding waters that usually accompanies extensive plant and algal growth which removes carbon dioxide changing the overall alkalinity of the lake water. Additional phosphorous release can occur from sediments in contact with high pH waters even though dissolved oxygen levels are stable.

10.0 Sediment Phosphorous Release

Internal loading of phosphorous from the sediments was determined at three stations located in three separate basins in Big Chetac Lake. Sediment cores were taken and sent to the ERDC Eau Galle Aquatic Ecology Laboratory, an Army Corp of Engineers work station, for analysis. These sediment cores where placed in incubation chambers and water taken from Big Chetac Lake was added. Three conditions were tested and the amount of phosphorous released from the sediment was recorded. Table 4 shows the sediment phosphorous release rates determined under oxic, anoxic, and oxic with a high pH conditions.

Table 4
Rates ($mg/m^2/day$) of Phosphorous Release in Sediments from Big Chetac Lake (James, 2007)

Station	Oxic	Oxic High pH	Anoxic
North Basin	0.8	1.0	19.1
Central Basin	ND	0.4	12.9
South Basin	ND	0.8	11.8

Lake water pH values were considered to be normal if they were less than 8.5 and high if they were greater than 8.5. Temperature, dissolved oxygen, and pH monitoring was completed in all three basins on 14 different dates from April 25, 2007 to October 7, 2007. Data was recorded at the following depths: 0-2m, 2.5m, 3.5 m, 4.5m, 5.5m, 6.5m, and 7.5m when the depth of the basin allowed. The North Basin was sampled at all of these depths, the Central Basin was sampled down to 5.5m, and the South Basin was sampled to 4.5m. From this monitoring the number of days each basin was anoxic and the number of days each basin had high pH values was determined. The depth at which the each basin became anoxic was also recorded. The North Basin became anoxic on June 18 and remained so for 90 consecutive days. The Central Basin also became anoxic on June 18 but only remained so for 23 consecutive days. The South Basin became anoxic on July 5 and remained so for only 5 days. Figure 9 shows the dissolved oxygen levels in all three basins through the season. Levels less than 2 mg/L is considered to be anoxic.

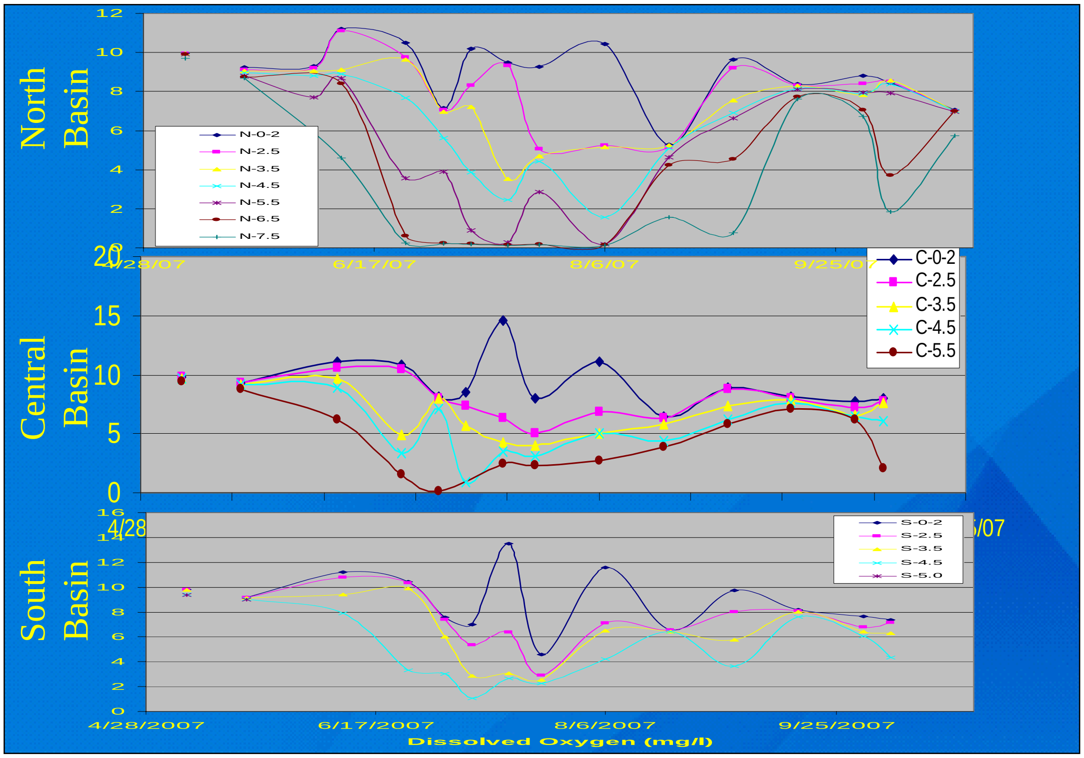


Figure 9 – Internal Loading - DO Concentration

High pH in the North Basin became apparent on June 4 and lasted through the end of this study (considered September 30). High pH in the Central and the South Basins became apparent on June 10 and lasted through the end of this study period. Using the sediment release rates determined by the Army Corp of Engineers, a daily and a cumulative phosphorous mass was calculated. Figure 10 shows the internal phosphorous load released from the sediments for each basin and the lake as a whole. Figure 11 shows the cumulative phosphorous load from lake sediments from May through September 2007.

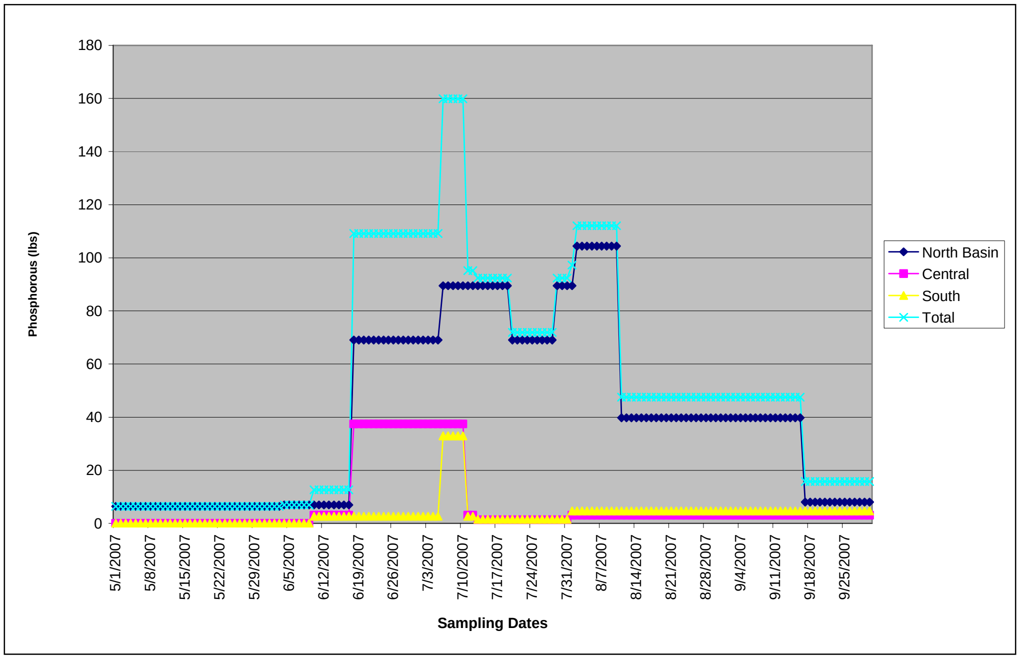


Figure 10 – Daily Internal Phosphorous Load for Each Basin and the Lake as a Whole

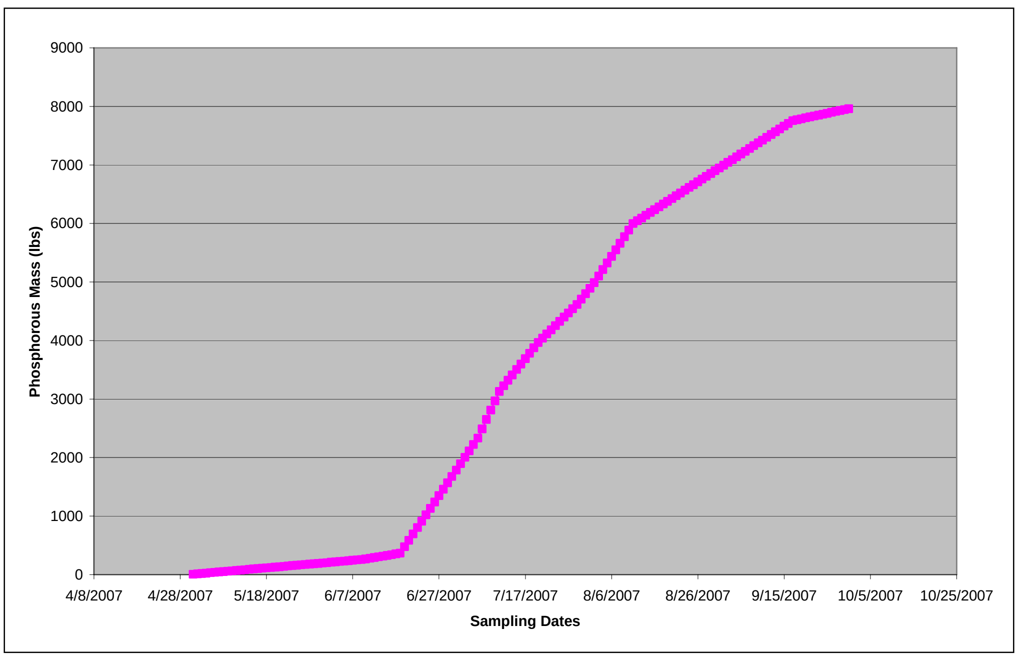


Figure 11 – Cumulative Phosphorous Released by the Sediments into Big Chetac Lake

The total mass of phosphorous that comes from internal recycling of phosphorous (released form the sediment) is approximately 7,971 lbs or 69% of the total load. Recycling of existing phosphorous in Big Chetac Lake is by far the largest factor determining how much algae growth occurs in the lake. Unfortunately, internal release of phosphorous on this scale is one of the hardest and most expensive sources to manage.

11.0 Tributary Loading

There are several main tributaries to Big Chetac Lake. Heron (Squaw) Creek on the west side of the lake, Benson Creek from the north, and Knuteson Creek from the east. In addition, stream flow comes into the lake from Red Cedar Springs and Turtle Pond. An unnamed tributary coming in from the southeast under Hwy 48 was also sampled, but after the first spring sampling period it was dry. Water quality samples (provided there was water flowing) were taken from these tributaries near their outlets into Big Chetac Lake on four different sampling dates during the 2007 open water season. Stream flow was also measured on these dates. Comparisons between flows in the tributaries and the flows at the nearby USGS Chippewa River Gauging Station were made to estimate tributary flows over the course of the season.

Phosphorus loads contributed by the tributaries can be determined by multiplying the phosphorous concentration in the stream water by the daily flow rate. It was assumed that phosphorus loads from unmonitored watersheds were areal proportional to loads from the monitored watersheds. Figure 12 shows the lbs of phosphorous contributed from May 1 to September 30, 2007 by each of the streams and their associated sub-watersheds monitored in this study, the near shore area of the watershed, and the unmonitored portion of the watershed.

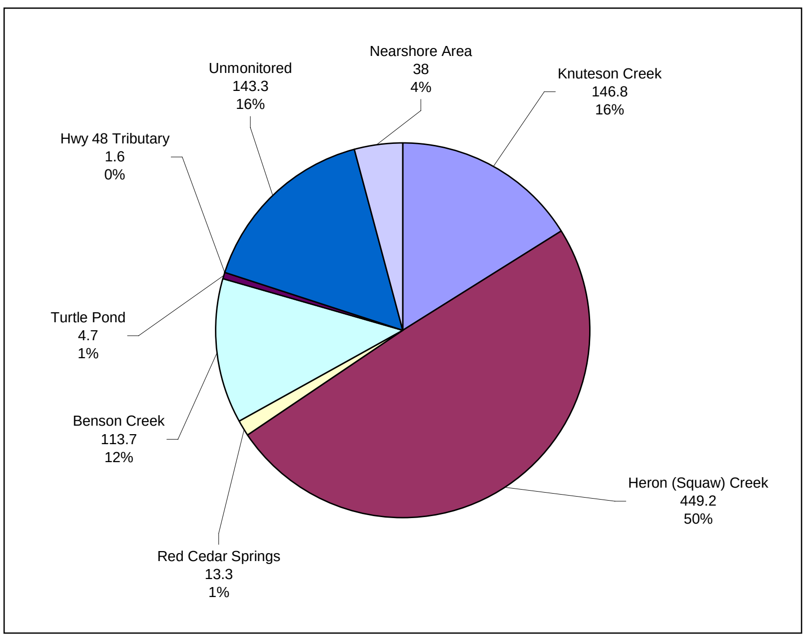


Figure 12 – Phosphorous Loading in Lbs From the Big Chetac Lake Watershed

Fifty percent of the phosphorous loading contributed by tributaries to Big Chetac Lake comes from the Heron Creek sub-watershed. There are extensive wetland ponds included in this watershed which may explain the higher phosphorous values recorded for this tributary. Groundwater with higher phosphorous concentrations discharging to the streams in this sub-watershed is also a possibility. The Knuteson Creek sub-watershed has the largest area (Figure 13), and the majority of agriculture and open area (Figure 14). The Knuteson Creek sub-watershed contributes 17% of the phosphorous load, as does that portion of the watershed that was not monitored in this study. Figure 15 shows the land coverage of the entire Big Chetac Lake watershed. Natural land cover occupies more than 93%. Agriculture and grasslands cover the remaining 7%. Residential area is primarily limited to the near shore area of the lake and is less than one percent of the total Big Chetac Lake watershed. While the majority of the Big Chetac Lake watershed is in a natural state, there may still be some opportunity to implement agricultural best management practices, to limit erosion from stream banks, or provide greater buffer strips along stream banks in more developed areas of the watershed.

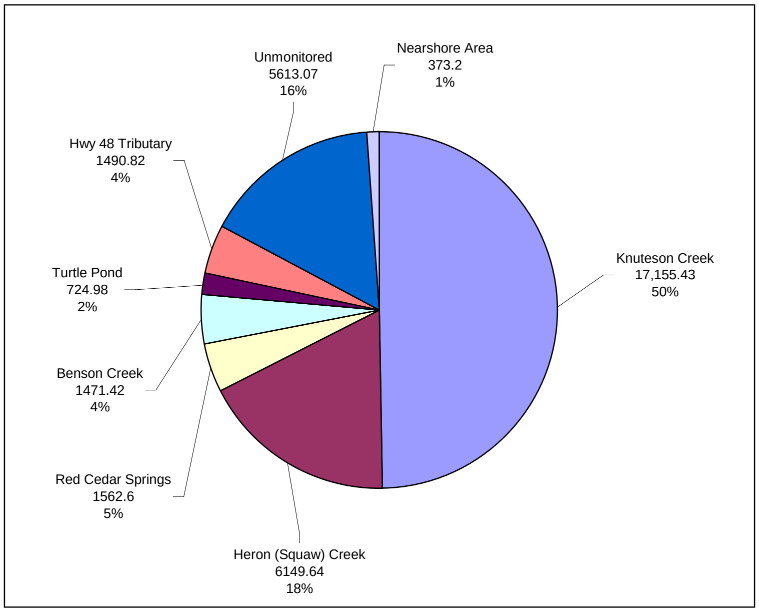


Figure 13 – Portion of the Total Watershed (Acres)

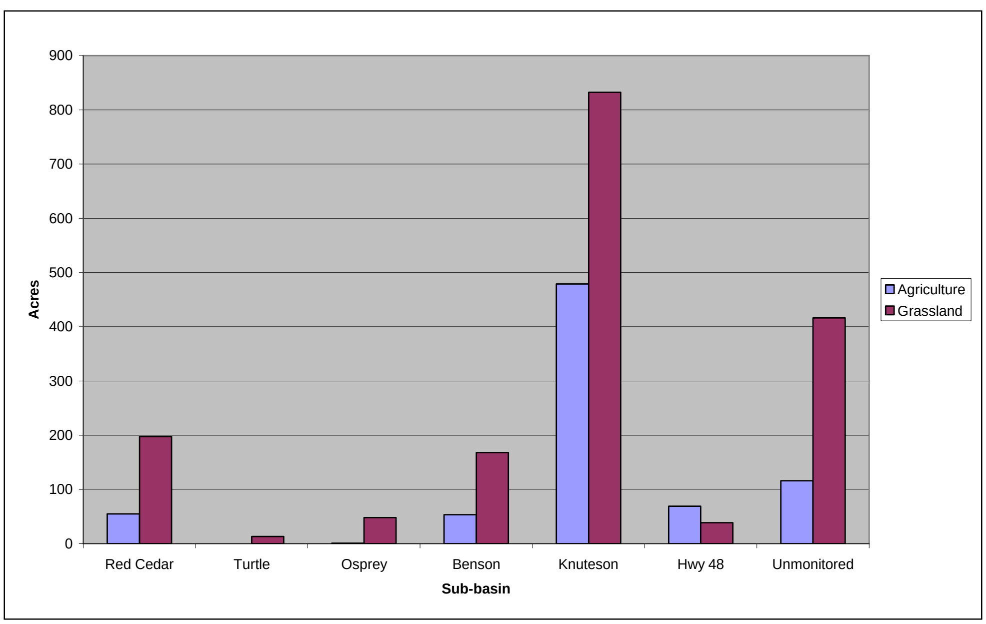


Figure 14 – Agriculture and Grasslands Within Each Monitored Sub-basin and the Unmonitored Portion of the Total Watershed

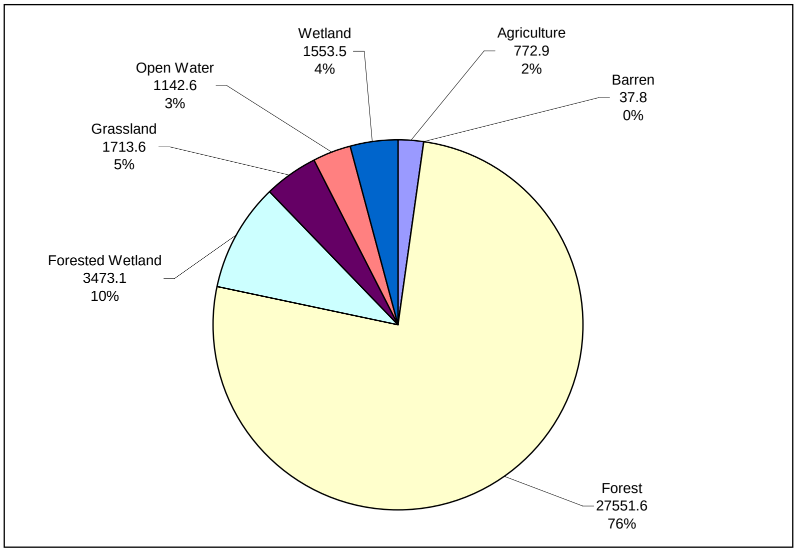


Figure 15 – Total Ground Cover in Acres for the Big Chetac Lake Watershed

12.0 Near Shore/Shoreline

The unmonitored portion of the watershed includes that area immediately adjacent to the lake shoreline known as the “near shore” area. In this study, the near shore area was considered to be that portion of the shore from the edge of the lake back 200 ft. Near shore land use was determined by looking at 6 inch pixel aerials of the lake and mapping it using GIS applications. It is in this area that the majority of development and disturbance to the natural shoreline occurs. Natural vs. disturbed ground cover; the amount of impervious surfaces including house and garage roofs, driveways, walk ways, and patios; the use of fertilizers, failing septic systems, and sites with high erosion all influence phosphorous loading from the near shore area. Figure 16 shows the land use recorded in the near shore area around Big Chetac Lake.

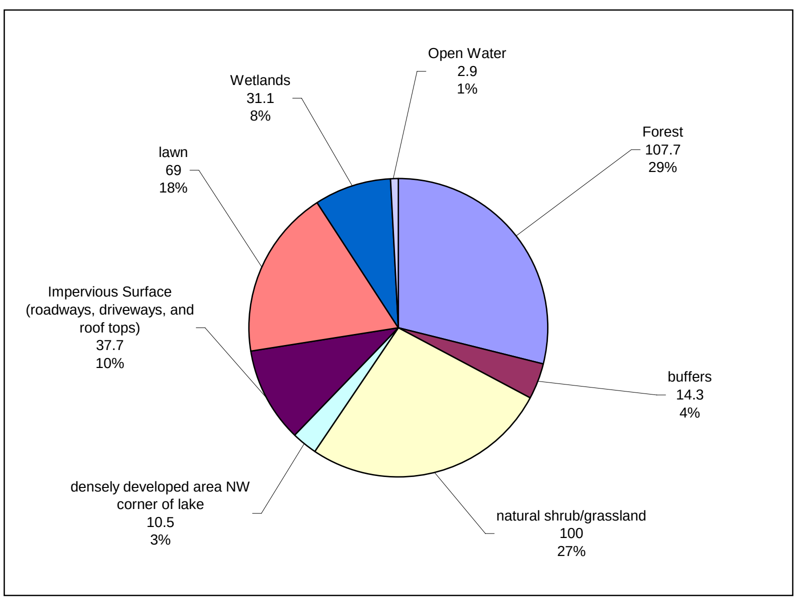


Figure 16 – Near Shore Lane Use in Acres Within 200 Feet of the Shoreline

Low, medium, and high export coefficients for phosphorous release for each of the land uses in Figure 16 were determined by combining peer-reviewed literature and lake models (WiLMS, Lin 2004, and Reckow et al. 1980). Several land uses were combined to accommodate for the land use coefficients that were found. Total phosphorous loading from the near shore area of Big Chetac Lake are shown in Figure 17. The total annual phosphorous loading to Big Chetac Lake from the near shore area ranges from 90 lbs using low export coefficients to 468 lbs when using high export coefficients. A portion of the phosphorous loading coming from the near shore area is already accounted for in the groundwater and tributary loading values so for the sake of this study, use of the phosphorous loading value using the low export coefficient (90 lbs/yr) is reasonable. Seasonal (May through September) loading from the near shore area is likely greater than at any other time of the year, except for spring snowmelt. For the sake of determining a seasonal loading value for the near shore area, 60% of the annual near shore load (54 lbs) was included.

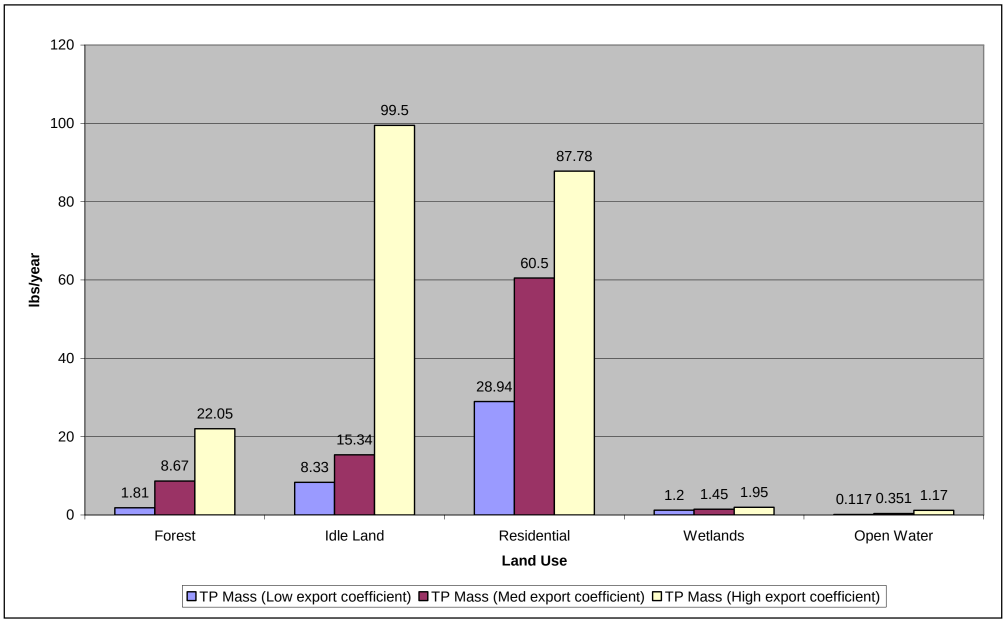


Figure 17 – Low, Medium, and High Phosphorous Loading to Big Chetac Lake from the Near Shore Area (200 Feet) in Lbs

Many improvements can be made in this area to limit the total amount of phosphorous that enters the lake. While other sources of phosphorous to the lake are much more significant, changes in the near shore area are probably the easiest to make and may provide improvement long-term.

13.0 Summary

Internal loading of existing phosphorous is by far the largest factor contributing to the degradation of the water quality in Big Chetac Lake. Methods for preventing this internal release of phosphorous do exist, but are likely either too expensive to implement at the scale of Big Chetac Lake, or not proven to be truly effective. The addition of aluminum sulfate to the lake could lock up a portion of the phosphorous available in the bottom sediments. Summer aeration of the hypolimnetic area of the lake (the area below the thermocline that becomes anoxic) could be accomplished but would likely not prove to be very effective. A better direction to move in would be to control the curly-leaf pondweed growth in the lake.

At somewhere around 15% of the estimated phosphorous loading, the decay of CLP is a significant source to the lake. Removing large amounts of CLP would lesson the total mass of plant material that senesces releasing phosphorous into the lake. It could potentially reduce high pH levels later in the season. Physical removal would also remove a portion of the CLP turions that become the next season's new growth. It may also allow native plants to rebound in the system. Complete eradication of CLP is not possible for Big Chetac Lake, but it may be possible to reduce its impact on water quality and native plant species by removing large amounts of it. Large-scale harvesting may be the best option, but early-season herbicide application may be effective in some areas. Keeping other aquatic invasive species like Eurasian water milfoil out of the lake by maintaining a watercraft inspection program will also be important for maintaining or improving the water quality in Big Chetac Lake.

Improving conditions related to septic systems and in the near shore area will also benefit the lake in the long run. Shoreland restoration or the establishment of buffer strips, septic system improvements, and no use of phosphorous containing fertilizers could help. Improvements within the watershed will also help in the long run. There may be opportunities for stream bank stabilization, implementation of best management practices in the limited agricultural areas, and opportunities to lesson the impact of roadway right-of-ways, timber harvesting, etc. It is important to note however, that there are no inexpensive quick fixes that will provide immediate improvement.

A more detailed management plan will be constructed in the next phase of this project. Recommendations for maintaining and improving water quality in the lake will be laid out.

A timetable and plan for implementation will be laid out. Recommendations for managing the CLP will be made. A management plan will incorporate all that has been learned about how Big Chetac Lake "works" and include substantial input from those that live on and use the lake.

14.0 References

Berg, Matt. 2008. Aquatic macrophyte Survey for Chetac Lake, Sawyer County, Wisconsin. Endangered Resources Services, LLC, St. Croix Falls, WI.

James, William F. 2007. Internal Loading and Phosphorous Water Chemistry Letter Report: Big Chetac Lake, Wisconsin. Sawyer County, Wisconsin. ERDC Eau Galle Aquatic Ecology Laboratory. Spring Valley, WI.

Lin, J. P. (2004). "Review of published export coefficient and event mean concentration (EMC) data," *WRAP Technical Notes Collection* (ERDC TN-WRAP-04-3), U.S. Army Engineer Research and Development Center, Vicksburg, MS. *www.wes.army.mil/el/wrap*

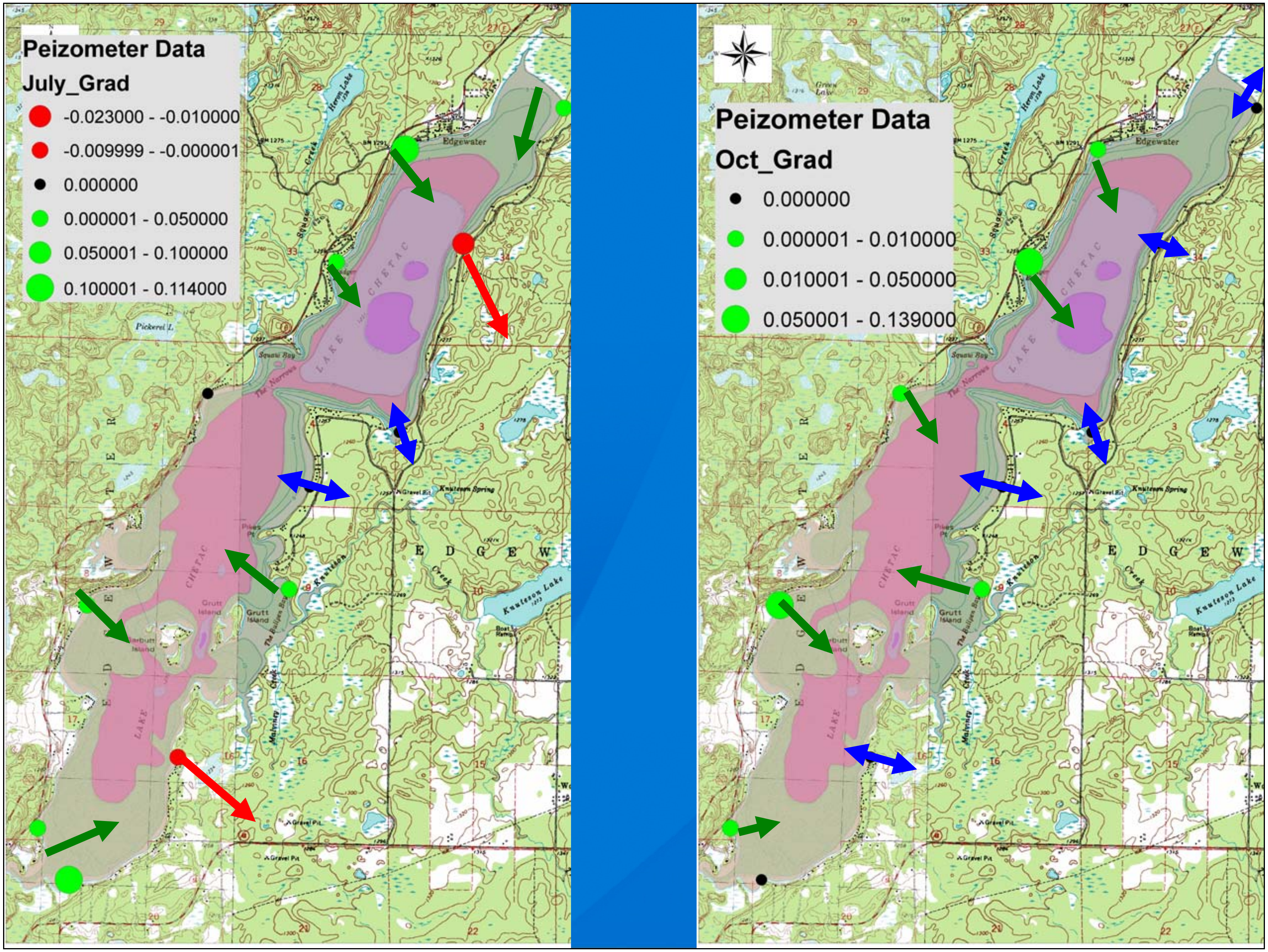
Maki, Mert, E. Wellauer, and J. Kozlowski. 2008. 2008 Lake Chetac Sewer Survey, Town of Edgewater, Sawyer County, Wisconsin. Sawyer County Zoning Administration, Hayward, WI.

Reckow, K. H., M. N. Beaulac, and J. T. Simpson. 1980. Modeling phosphorus loading and lake response under uncertainty: a manual and compilation of export coefficients. Department of Resource Development, Michigan State University. East Lansing, MI.

Roesler, Craig. 2008. Personal Communication. Wisconsin Department of Natural Resources, Water Resources Management Specialist. Hayward, WI.

Appendix A

Groundwater Flow


Peizometer Data
July_Grad
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-0.009999 - -0.000001
0.000000
0.000001 - 0.050000
0.050001 - 0.100000
0.100001 - 0.114000
Peizometer Data
Oct_Grad
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0.050001 - 0.139000