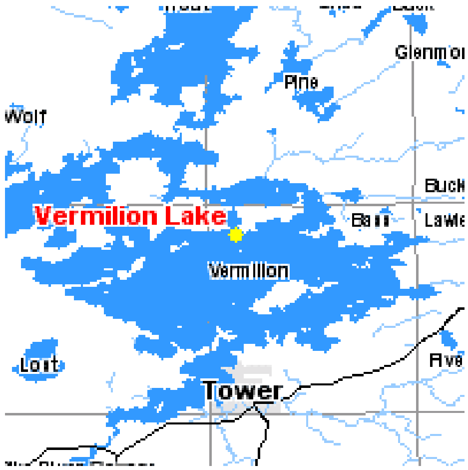
Lake Vermilion

(ID #69-0378)
St. Louis County, Minnesota

LAKE ASSESSMENT PROGRAM
2000



Minnesota Pollution Control Agency
Environmental Outcomes Division

in cooperation with
Minnesota Department of Natural Resources
Boise Fort Band of Chippewa
University of Minnesota-Duluth
Natural Resources Research Institute
Sportsman's Club of Lake Vermilion
St. Louis County

May 2001

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SUMMARY AND RECOMMENDATIONS

Lake Vermilion is the 7th largest lake in Minnesota (40,557 acres) located in St. Louis County, near Tower Minnesota (Figure 1). Land use in the watershed is characterized by forested and wetland uses which is typical for lakes in this region of the state - the Northern Lakes and Forests ecoregion.

Lake Vermilion was sampled during the summer of 2000 by Minnesota Pollution Control Agency (MPCA) and University of Minnesota staff, after consultation with the Minnesota Department of Natural Resources (DNR), St. Louis County, and the Sportsman's Club of Lake Vermilion (Club). The primary focus of this assessment was to evaluate trophic status and nutrient-related trends. Four sites, consistent with historical studies on the lake, were sampled: Pike Bay, Big Bay, Wakemup Bay, and the outlet of the lake. These sites allowed us to begin to look at spatial differences in the quality of the lake and derive meaningful estimates of "mean" condition for the overall lake. Water quality data collected during the study reveal an area-weighted summer mean phosphorus concentration of 23 µg/L, mean chlorophyll-a of 6.3 µg/L, and Secchi transparency of 7 feet (2.5 meters). The phosphorus, chlorophyll-a, and Secchi values are on the upper range of values exhibited by reference lakes in this ecoregion. Total phosphorus, chlorophyll-a, and Secchi transparency help to characterize the trophic status of a lake and in general we see good correspondence between these variables as compared to empirical models (Carlson's Trophic State Index). For Lake Vermilion, these measures indicate *mesotrophic* conditions.

Historical Citizen Lake-Monitoring Program (CLMP) Secchi transparency data, which date back to 1976, reveal a significant improvement in transparency based on 21 summers of data. During this period, the summer mean Secchi ranged from 5 feet to 9 feet (1.5 – 2.7 m). Transparency varies from year to year, with values near 5 feet in the late 1970's to 8 feet in the late 1990's. DNR monitoring (Large Lakes Program) of several sites in August of each year, since the mid 1980's, did not reveal any significant temporal trends but indicated that TP typically ranges between 20 - 40 µg/L and chlorophyll-a typically ranges between 10 - 20 µg/L during late summer.

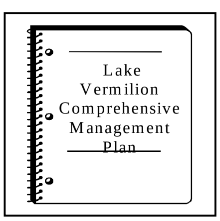
Two eutrophication models were used to estimate the water quality of Lake Vermillion based on lake and watershed characteristics. These models provided an opportunity to: compare observed measures with predicted, estimate water and phosphorus (P) budgets for the lake, and a further basis for evaluating the quality of the lake. The first model, MINLEAP, provides estimates of in-lake P based on the volume of the lake, size of watershed , and ecoregion characteristics. For Pike Bay, the model predicted an in-lake P of 33 ± 7 µg/L which compared favorably with the observed value (29 µg/L); while for the lake as whole, the model estimated a concentration of 17 ± 5 µg/L which is slightly lower, but not significantly different, than the observed values. This implies that the P concentration in Pike Bay and the overall lake is in the range expected based on the noted characteristics. Other comparisons of predicted and observed chlorophyll-a and Secchi transparency also exhibited reasonable agreement.

The second model, BATHTUB, allowed us to "route" water and P-loads through the main basins and estimate water and nutrient budgets for the lake. Pike Bay, which accounts for about one percent of the volume of the lake, has 56 percent of total watershed area of the entire lake draining to it via the Pike and East and West Twin Rivers. This results in high nutrient loading to the Bay, and combined with its shallowness, results in higher TP (29 µg/L) and higher chlorophyll-a (9.5 µg/L) as compared to sites in the main basin of the lake. Internal recycling of TP from the sediments may contribute to the nutrient loading of the Bay as well. Crude estimates of on-site septic system leaching to the lake suggest that this source-category may contribute on the order of five percent of the lake's P budget. The City of Tower's wastewater treatment facility was estimated to contribute about three percent of the P loading to Pike Bay. Because of the lakes' large surface area, atmospheric deposition on the surface of the lake could account for on the order of 15 percent of the P-loading to the lake. Other sources of P loading include direct runoff from the immediate watershed and processes in the lake which encourage re-circulation of phosphorus. Water residence time ranges from about 0.1 year in Pike Bay to about 10.5 years in Wakemup Bay and averages about 4.4 years overall.

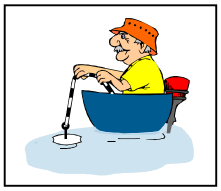
The combination of observed data and model predictions provide a basis for some initial goal setting for the lake. It is clear that Pike Bay cannot attain the same water quality as that of the main lake because of its shallowness and the large watershed that drains to it. Based on observed and predicted data, a phosphorus goal on the order of 20 to 25 µg/L may be appropriate for the Bay. A slightly lower goal of 15 to 20 µg/L may be appropriate for the main basin of the lake. Further monitoring and more detail modeling of this system will allow for refinement of these goals and to determine the steps needed to achieve the goals.

The following recommendations are based on the Lake Assessment Program (LAP) study of Lake Vermilion. The recommendations are typically directed to a lake association, however, these recommendations are directed toward the Sportsman's Club of Lake Vermilion (Club) because it is the largest organization that speaks for Lake Vermilion and therefore most capable of promoting these recommendations. It is understood that many of these recommendations must be implemented with cooperation from many local, state, and federal agencies or organizations, under overall guidance and leadership from the Club.

1. Lake Vermilion, because of its moderate phosphorus and chlorophyll-a concentrations, would be sensitive to change in trophic status with increases in the nutrient loading from watershed or in-lake sources. These sources would increase the in-lake phosphorus concentration that can increase algae concentrations, and subsequently reduce transparency. It is essential, therefore, that all local government convey the lake protection efforts groups with land use/zoning authorities for St. Louis County. The Club should be commended for their efforts to date, which include interacting with local and state governments, and historical participation in the CLMP. To complement these efforts, the Club should lead the development of a plan for protecting the water quality of the lake. This plan, referred to as a *lake management plan*, should incorporate a series of activities in a prioritized fashion that will aid in the long-term protection and improvement of the lakes. The plan should be developed cooperatively by a committee consisting of representatives from state agencies (e.g., the Minnesota Department of Natural Resources [MDNR], Minnesota Board Water and Soil Resources, MPCA), local units of government, and Lake Association members. The following activities could be included in the plan:



a. **The Club should continue to participate in the CLMP and related monitoring programs**.

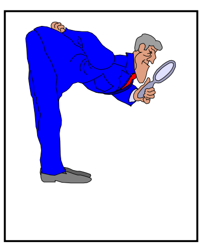


Data from this program provides an excellent basis for assessing long-term and year-to-year variations in algal productivity, i.e., trophic status of the lakes (this study has shown there is good agreement between the Secchi, TP and chlorophyll-a TSI's). Whenever possible *consistent* sites should be used each year -- this enhances our ability to assess trends over time.

b. **Further development or land use change in the lake's watershed should occur in a manner that minimizes water quality impacts on the lake**. In the shoreland areas, setback and

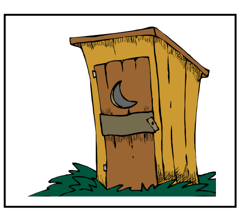
stormwater provisions should be strictly followed and the amount of impervious area (roads, rooftops, and parking lots) should be minimized. DNR, MPCA and county shoreland regulations will be important in this regard. This would especially apply to any new development in or near the shoreline area. Properly designed sedimentation basins should be employed to minimize P and sediment loading to the lake, which results from construction and increased establishment of impervious areas. Also, activities in the immediate watershed that change drainage patterns, such as wetland removal or major alterations in lake use, should be discouraged unless they are carefully planned and adequately controlled. Shoreland property owners should be encouraged to maintain buffer areas of natural vegetation between their lawns and the lakeshore and minimize removal of aquatic vegetation. The Club should seek representation on boards or commissions that address land management activities so that their impact can be minimized. The booklet, Protecting Minnesota's Waters: The Land-Use Connection, may be a useful educational tool in this area.

c. **A more detailed examination of land use practices in the watershed and identification of the possible nutrient sources such as lawn fertilizer, and the effects of ditching and**



draining of wetlands, etc., may aid the Club in determining areas where best management practices may be needed. The Club should also work, closely with St. Louis County and the Natural Resource Conservation Service (NRCS) as needed. Thus, the Club should be vigilant of significant changes in land use in the watershed, and work with the aforementioned county offices and landowners to ensure that BMPs are implemented and excess runoff is minimized. The most likely scenarios for change in land use could be increased silvacultural, road building, and/or continued development on or near the lake.

d. **Poorly maintained onsite septic systems could be an important source of P to the near-shore waters of Lake Vermillion**. While it is difficult to assess the contribution of this source to the overall nutrient budget of the lake, steps should be taken to improve information on the



number and status of systems around the lake. An inventory that could include the location (where on lake), usage (year-round or seasonal), type of system, age of system, and frequency of maintenance (pumping schedule) combined with a strong education effort might be a good place to start. This could provide a basis for determining where improved treatment or alternative systems may be needed and gain a sense of the overall knowledge of systems around the lake. This information would allow for improved modeling estimation, but more importantly, would help educate homeowners on proper maintenance and their responsibilities regarding their systems.

2. **The 2000 water quality (trophic status) of Lake Vermilion was slightly below average (median) when compared to other lakes in the NLF ecoregion.** However, the lake could exhibit declines in transparency and increases in the amount of algae with increases in in-lake total phosphorus. Degraded water quality could shift the balance in this productive lake from desirable to less desirable species of fish. Because changes in species composition are difficult to reverse, they should be avoided whenever possible. Watershed land use practices, poor management of shorelands, increased development in the shoreland areas and/or draining of wetlands in the watershed provide the greatest likelihood for increases in phosphorus loading.

   Conversely, a reduction of the amount of nutrients that enter the lake may result in improved transparency and a reduction in algal concentrations. One means of reducing nutrient input is by implementing best management practices (BMPs) in the watershed (land management activities used to control non-point source pollution). Technical assistance in BMP implementation may be available through local resources management agencies. The Club should continue to work with the St. Louis County SWCD to examine land use practices in the watershed and develop strategies for reducing the transport of nutrients to the lake. It may be wise to first focus efforts on the immediate watershed of the lake.

   a. Lake Vermilion has a healthy fish community, characteristic of a mesotrophic lake, based on current fisheries data. Sustaining this fishery requires maintaining good water quality and habitat. A significant aspect of the habitat is the rooted (emergent and submergent) plants. These plants serve as a nursery area for many fish species and for zooplankton (which feed on algae). The near-shore emergent plants, such as bulrush and cattails, are essential to the overall ecology of the lake and serve to stabilize shorelines as well. *Lakeshore property owners should be encouraged to minimize the removal of these plants.* The Club can play a major role in educating members about the value of these plants and encourage property owners to remove only the minimum amount needed to gain access to the lake, rather than the maximum allowed by permit. The MDNR Ely Area Fisheries office and St. Louis County offices can provide educational information on the value of the rooted vegetation.

   b. The MPCA's Clean Water Partnership Program (CWP) is also an option for further assessing and dealing with non-point sources of nutrients in the watershed. However, since there is extensive competition for CWP funding, it may be in the best interest of the Club and Lake Vermilion to continue to work with the St. Louis County SWCD, the local water planner and the local townships to do as much as possible to protect the condition of the lake by means of local ordinances and education of shoreland residents. If these steps prove to be inadequate or lake conditions worsen (as evidenced by significant declines in Secchi transparency measurements), application to CWP may then be appropriate. *One indication of a declining trend in water quality would be if summer-mean transparency remained consistently below the recent (1990's) long-term mean of 8 feet (2.4 m) (for the main lake) or if summer-mean TP increased above the ranges observed in 2000.*

c. Should a CWP or other natural resources grant program application be deemed necessary, this study serves as a foundation upon which further studies and assessments may be based. The water and nutrient income-outgo summaries were estimated based on limited amounts of monitoring data and should be considered best approximations. The next step would be to define water and nutrient sources to the lake in a much more detailed fashion. At a minimum the following should be included:

- The former USGS gages on the Pike River and the outlet of the lake should be re-established. This would lay the foundation for a more accurate water and nutrient budget when combined with a sampling program at each site.
- Other pertinent sites for flow estimation and sampling would include the two next largest tributaries to Pike Bay -- East and West Two Rivers.
- Additional in-lake monitoring sites may be needed to more accurately characterize the numerous bays of Lake Vermillion and allowed for improved modeling by creating more segments (bays) in the model framework.
- The planimetry (measurement of the area of the depth contours) of the bathymetric map should be completed so that more accurate estimates of the volume of individual bays can be determined. More accurate estimation of lake volume can reduce potential errors in modeling the lake.
- An accurate count of on-site septic systems around the lake, noting location (bay) and whether the residence is seasonal or year round would be useful. Noting whether the system is up-to-code would be helpful also; this would allow for an improved estimate of the contribution of on-site septic systems to the P budget. Example survey forms for this purpose are available from the MPCA.

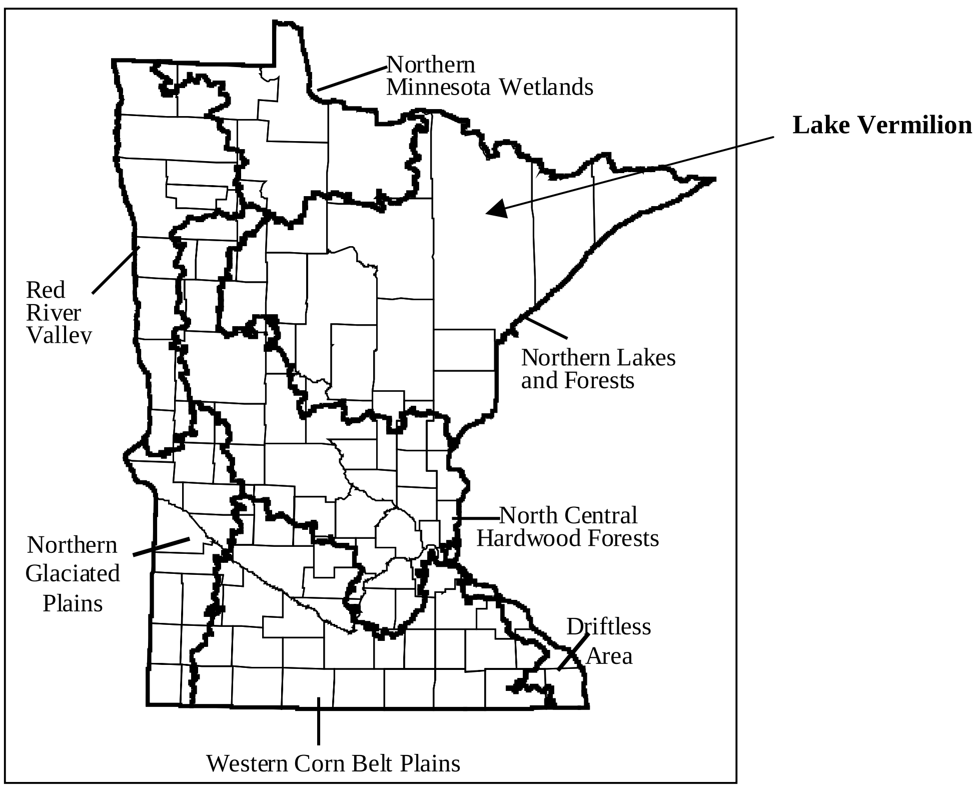
BACKGROUND

Description of the Lake Vermilion Watershed

Lake Vermilion is located between the towns of Tower and Cook in northeastern Minnesota (Figure 1). It is the seventh largest lake in Minnesota, with an area of 40,557 acres. The lake is on the southern edge of the Canadian Shield, and was formed during the last glaciation (~ 10,000 years ago). The thin soils and surficial bedrock common throughout the lake and its watershed are a result of the retreating glaciers.

Since land use affects water quality, it has proven helpful to divide the state into regions where land use and water resources are similar. Minnesota is divided into seven regions, referred to as ecoregions, as defined by soils, land surface form, natural vegetation and current land use. Data gathered from representative, minimally-impacted (reference) lakes within each ecoregion serve as a basis for comparing the water quality and characteristics of other lakes. Lake Vermillion is located in the Northern Lakes and Forests (NLF) ecoregion (Figure 1).

Figure 1. Location and Ecoregion Map for Lake Vermilion



Lake Vermilion has a diverse basin comprised of numerous bay, and distinct basins (Figure 2). The mean depth of the lake is approximately 19.1 feet, and the maximum depth is 76 feet. For the purposes of our study and this report, we have divided the lake into three relatively distinct basins: Pike Bay, Big Bay and Wakemup Bay. Individual areas and mean depth were estimated based on DNR bathymetric maps (Table 1). The areas for the basins should be relatively accurate as we were able to take them directly from the maps and the overall area agrees with DNR records. Mean depths were estimated for each basin by inspection of the bathymetric maps and best professional judgment. Future efforts to improve on modeling in the report should include planimetry of the maps to allow for more accurate definition of mean depth. Watershed areas were estimated based on USGS Web-based maps of the subwatersheds of Lake Vermillion and the boundaries used correspond to the DNR watershed map included in this report (Figure 2). A brief summary follows:

- **Pike Bay** is the southern most bay and is located at the mouth of the Pike River. It is very shallow with a mean depth of about 5 feet (1.5 m) and has a surface area of about 3.5 mi^2 (9.2 km^2). This bay accounts for about one percent of the volume of the lake but receives runoff from about 56 percent of the lake's watershed via the Pike, East Two and West Two Rivers. The city of Tower is located in this watershed and the municipal wastewater treatment facility discharges to the Bay via East Twin River.

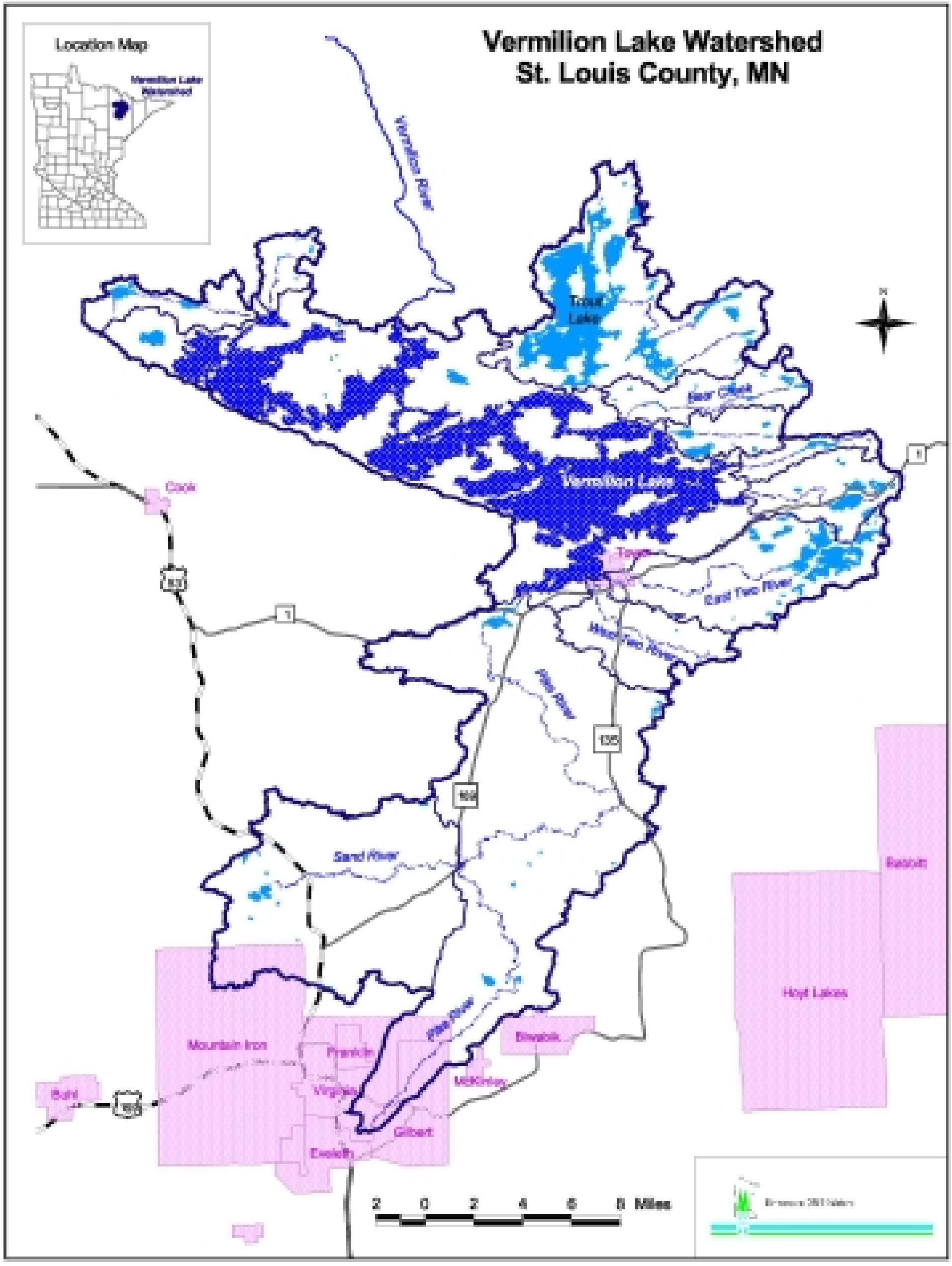
- **Big Bay** is the largest of the bays at 41.5 mi^2 (108 km^2), accounts for about 65 percent by volume, and is immediately to the north of Pike Bay. It is much deeper than Pike Bay with a maximum depth of 76 ft (23 m) and a mean depth of 19 ft (5.8 m). It also has an extremely large fetch (distance over which the wind can blow unimpeded by land) of about 5 - 6 miles (8 – 9.6 km) which contributes to the well-mixed conditions throughout most of the open water season. It has a relatively small immediate watershed relative to its size (Table 1). Trout Lake is a prominent feature to the north and much of that portion of the watershed drains through it before entering Big Bay.

- **Wakemup Bay** is located to the northwest and is about 16. 9 mi2 (43.9 km) in size. This bay is moderately deep with a maximum depth of 57 ft (17.3 m) and mean depth of 22.9 ft. (7 m). this portion of the lake has a relatively small watershed (Table 1). Water from this bay and Big Bay flow northward to Wolf Bay, which represents the outlet of the lake and the beginning of the Vermilion River.

Table 1. Lake Vermillion morphometric and watershed summary

Bay	Area mi^2	km^2	Mean Depth ft	Volume acre-ft	Watershed mi^2
Pike	3.6	9.2	5.0	11,410	241
Big	41.5	107.4	19.0	504,089	128
Wakemup	16.9	43.9	23.0	248,328	52
Wolf	1.4	3.6	12.0	10,800	10
Whole Lake	63.4	164.1	19.1	774,627	431

Figure 2. The Lake Vermilion Watershed



The total watershed area of Lake Vermilion at its outlet is about 495 mi^2 (1,282 km^2). Of this, the lake accounts for 63.3 mi^2 or about 13 percent of the watershed, leaving a watershed area of about 432 mi^2. The Pike River is the single largest subwatershed at about 192 mi^2 (497 km^2), and it accounts for 44 percent of the lake's watershed. It has a flow on the order of 100 cubic feet per second (cfs) based on USGS records at the former gage location. The Pike River drains predominantly forested and lowland areas, and flows northward entering the lake at Pike Bay where a dam regulates the flow. Direct drainage (which does not flow through any significant lakes prior to entering Vermilion) comprises about 16 percent (67 mi^2 / 173 km^2) and basically consists of the land which rings the lakeshore. This direct drainage area also contains most of the development in the watershed. The remaining 173 mi^2 (40 percent) of the watershed drains to the lake via small tributaries which flow from lakes and wetlands, primarily to the northeast and east of the lake into Big Bay. These numerous lakes and wetlands serve to filter the runoff and typically yield water which is very low in nutrients. Trout Lake, for example, has a subwatershed of about 50 mi^2 (including the lake) and all water from that portion of Vermilion's watershed will pass through Trout Lake, which results in substantial reduction in nutrient loading to the lake from that subwatershed. Other named tributaries include East Two River, which has its headwaters in the Eagles Nest Lakes, and flows into Pike Bay just outside the city limits of Tower. West Two River, has a smaller drainage area, but also flows into Pike Bay West of Tower.

Land Use and Development

Land use in the Lake Vermilion watershed is primarily forest and wetland. With the exception of the cities of Tower and Soudan, most of the development occurs along the shoreline, with high densities clustered along the south shore of the lake along Big and Pike bays. There are, however, some clusters of development on Wakemup and Wolf Bays to the west. St. Louis County has estimated there are about 2,330 homes/cabins around the lake. In addition, there are about 30 resorts, 5 marinas, and 3 campgrounds on the lake.

This diverse watershed, with land uses ranging from pristine wildness to cities and towns has many agencies and organizations that own or manage land in the watershed, including the Minnesota DNR, Nett Lake Indian Reservation (Boise Forte Band of Chippewa), and the Superior National Forest. Tower and Soudan, the only towns in the watershed, are located in the SE corner of the watershed, with a combined population of about 700. Tower-Soudan State Park is located on the lake, near Swedetown and Stuntz Bays. The Boise Fort Band of Chippewa own land on the peninsula between Pike Bay and Everetts/Big Bays. Superior National Forest (including the Boundary Water Canoe Area) land extends east of the Vermilion River to Trout Lake.

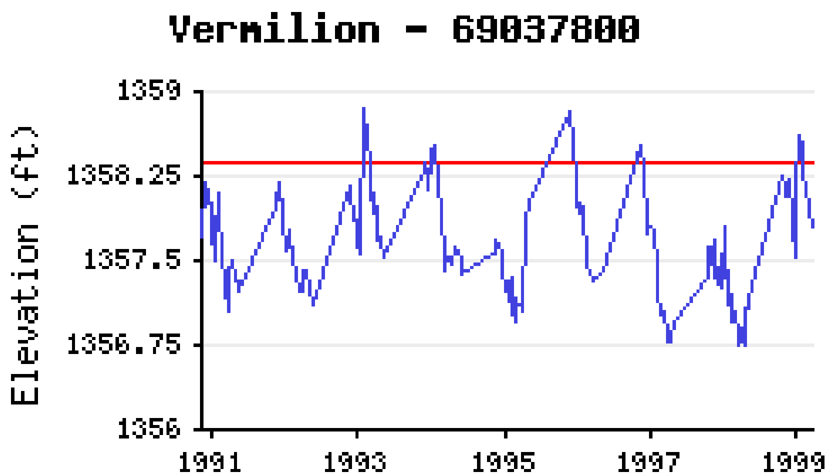
Hydrology: Precipitation, Runoff and Lake Levels

Based on State climatology records, precipitation averages about 24 - 26 inches annually in the vicinity of Lake Vermilion. 2000 water-year precipitation in the Lake Vermilion watershed ranged from 23.5 inches at Eveleth to 27.2 inches at Cook and averaged about 24 - 25 inches based on State Climatology Office records. Evaporation averages about 26 inches (0.66 m) in this portion of the state. Based on isopleth maps compiled from USGS flow records, runoff in this portion of the state averages 9.8 inches (0.25 m) and ranges from 5.1 inches (0.13 m) to 12.1 inches (0.31 m), which represent one-in-ten year low and high flow. Based on long-term records compiled for the USGS gage on the Vermillion River at Crane Lake, runoff for the Vermillion River averages 9.6 inches (0.25 m).

Lake level is regulated by a control structure at the lake's outlet - the Vermilion River. The average elevation over the period of record is 1357.38 feet, and the Ordinary High Water Level (OHW) is

1358.35 feet (Figure 3). The ordinary high water level (OHW) is a reference point that defines the DNR's regulatory authority over development projects that are proposed to alter the course, current, or cross section of public waters and public waters wetlands. For lakes and wetlands, the OHW is the highest water level that has been maintained for a sufficient period of time to leave evidence upon the landscape (see http://www.dnr.state.mn.us/waters/lakes/answers.html#OHW). Historical streamflow rates at the outlet of the lake average 319 cfs, based on a U.S. Geological Survey streamflow gage that operated from 1912 - 1980. The Vermilion River then flows to Crane Lake in Voyageurs National Park.

Figure 3. Elevation of Lake Vermilion (1991-99) with Ordinary High Water Level Noted. Courtesy of Minnesota DNR



Permitted wastewater facilities in Lake Vermilion Watershed

The Lake Vermilion watershed includes several facilities covered by MPCA water quality permits -- National Pollutant Discharge Elimination System (NPDES)/State Disposal System (SDS) permits, which regulate the management and disposal of wastewater. Some of the NPDES/SDS permits in the Vermilion watershed primarily cover the management of stormwater at relatively small industrial operations, such as gravel pits and asphalt plants. The MPCA also covers four larger wastewater dischargers in the watershed under NPDES/SDS permits: the Tower/Breitung municipal wastewater treatment plant, Tower Soudan State Park, and the USX Minntac and Ispat-Inland taconite tailings basin areas. The Tower/Breitung sewage treatment plant discharges to the East Two River, and limits and monitors for typical sewage wastewater pollutants like phosphorus, solids, biochemical oxygen demand, fecal coliform and pH. The DNR state park de-waters its mine workings to a series of small wetlands flowing into the East Two River; pollutants such as cobalt, copper, solids, sulfate and pH are tested in this discharge. The two taconite facilities discharge substantial seepage from their tailings basins to wetlands and small streams in the upper Pike River watershed. The Ispat-Inland tailings basin also periodically discharges through a siphon pipe, and USX may seek authorization for a similar pipe discharge from their tailings basin. Suspended sediment, metals (for example, cobalt, mercury and molybdenum) and various dissolved solids related pollutants such as chloride, fluoride, sulfate, conductivity and hardness are the focus of testing in the tailings basin discharges.

Historical Studies Conducted on Lake Vermilion

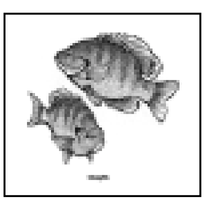
There have been several historical studies and some long-term monitoring of the water quality of Lake Vermillion. Some of those studies are summarized here. Pertinent data from the studies will be addressed in the Trend section of this report.

Minnesota Department of Natural Resources Studies

Minnesota's ten largest natural walleye lakes have a combined surface area of more than 825,000 acres and account for approximately 40% of the entire statewide walleye harvest (DNR, 1997). These lakes include: Cass, Kabetogama, Lake of the Woods, Leech, Mille Lacs, Pepin, Rainy, Upper Red, Vermilion, and Winnibigoshish. In 1983, the MN DNR Section of Fisheries increased its commitment to managing these waters by establishing the Large Lakes Monitoring Program (LLP). The primary responsibility of the LLP includes annual collection, analysis, and reporting of fish population data, monitoring long-term population trends, development of management recommendations, and public outreach. Three primary types of data are collected on all large lakes: 1. Fish population information- through annual assessments; 2. Fish harvest information- through creel surveys usually two of every six years; and 3. Water quality information- collected during the annual assessments (in Lake Vermilion water quality samples are collected in the first week of August).

Samples are analyzed for phosphorus, chlorophyll *a*, pH, conductivity, total dissolved solids, and alkalinity. The five sampling sites are: Big Bay near Spider Island, North Pine Island near the Trout Lake portage, Frazier Bay west of Breezy Point, Niles Bay, and Wakemup Bay east of Center Island (Figure 4). One sample is collected annually and while the data are useful for describing late summer water quality at these sites and inter-site variability on that date, they do not describe summer-mean conditions for the period of record. They do, however, represent a valuable record for trend assessment purposes.

Description of the Lake Vermilion Fishery



The following is an excerpt from the DNR Fisheries Special Publication No. 151 (1997):

"Lake Vermilion has a diverse fish community that is dominated by cisco, northern pike, white sucker, bluegill, smallmouth bass, yellow perch, and walleye. Other species that are present in lesser numbers include whitefish, muskellunge, brown bullhead, burbot, rock bass, largemouth bass, and black crappie. Fishing pressure has increased on Lake Vermilion, from a mean of 9.1 angler hours/acre in 1984-85 to 13.4 angler hours/acre in 1990-91.

Walleye are the primary component of the sport fishery, comprising 54% of the total yield for the four years creel surveys were conducted. The estimated annual harvest of walleye is 69,000 pounds. Most of the walleye harvest occurs in the summer, as winter angling on Lake Vermilion is usually insignificant. The median gill net catch for walleye from 1983 -1996 was 12.4 fish/net and the population was relatively stable. The walleye age structure is relatively young and the size structure is relatively small. The historical median of annual mean lengths from gill nets was 13.0 inches and the historical median PSD value was 27. Walleye recruitment is moderately variable with occasional strong and poor year classes produced. Exceptionally strong year classes were produced in 1983 and 1988, while poor year classes were produced in 1985 and 1992. Recruitment appears to be related to first year growth.

Northern pike are a major component of the sport fishery, comprising 20% of the total yield. The estimated annual harvest of northern pike is 26,000 pounds. The median gill net catch from 1983-96 was 1.0 fish/net and the population was stable. The historical median of annual mean lengths from gill nets was 25.5 inches and the historical median PSD value was 85.

Bluegill and smallmouth bass are also important components of the fishery, comprising 9% and 8% of the total yield respectfully. The estimated annual harvest of these species is 12,000 pounds of bluegill and 10,000 pounds of smallmouth bass. Bluegill were not historically abundant in Lake Vermilion. The population increased during the 1980's, peaked in 1987, and has since declined and stabilized at a moderate level of abundance (median trap net catch = 23.9 fish/net). The historical median of annual mean lengths for bluegill from trap nets was 6.1 inches and the historical median PSD value was 23. The smallmouth bass population appears to be stable with a median electrofishing catch rate of 26.6 fish/hour. The historical median of annual mean lengths was 9.6 inches and the historical median PSD value was 30.

Yellow perch are a minor component of the sport fishery, although they are abundant in the lake. Most perch are not large enough to be acceptable to anglers and there is a high rate of yellow grub infestation. The estimated annual harvest of yellow perch is 2000 pounds, 2% of the total yield. The median gill net catch from 1983-96 was 25.8 fish/net. The perch population fluctuated widely during this period, peaking in 1991. A recent increase in the average size of perch in Big Bay has the potential to increase fishing pressure directed at perch.

Black crappie and largemouth bass are also minor components of the fishery, comprising 4% and 1% of the total yield respectively. The estimated annual harvest of these species is 5,000 pounds for black crappie and 2,000 pounds for largemouth bass. Population data for largemouth bass is minimal as this species is not readily collected in standard assessment gear. Creel survey data suggests that bass numbers increased from 1984 -1991. The median trap net catch of black crappie was 1.4 fish/net. The black crappie population is characterized by highly variable recruitment.

Muskellunge were first introduced in the lake in 1968 and a major stocking program was started in 1987. Spring trap net assessments and angler reports indicate the population is doing well with the larger fish approaching 50 inches."

A detailed summary of the 2000 fishery population assessment is found in the Appendix.

Minnesota Department of Health

For information on the Minnesota Department of Health's fish consumption advisory on Lake Vermilion, please see the following web page:

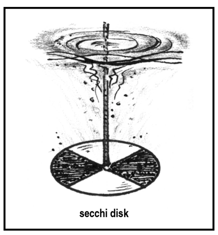
www.dnr.state.mn.us/perl/lk_advisory.pl?downum=69037800

Lake Vermilion Sportsman's Club

The Lake Vermilion Sportsman's Club has been instrumental as well in the collection of data for the lake. In their efforts, they have collaborated with the Bois Forte Band who are interested in the quality of the lake as well. Most of their studies have dealt with near-shore impacts of development and have focused on bacteria and related monitoring.

Minnesota Pollution Control Agency Studies

Citizen Lake-Monitoring Program



The MPCA has administered a volunteer lake-monitoring program, called the Citizen Lake-Monitoring Program (CLMP), since the 1970's. The CLMP involves voluntary participation of citizens residing on or near lakes or those who are frequent lake users. Participants are asked to take weekly transparency measurements on their lake during the summer using a Secchi disk. As of 1999, Lake Vermilion had 5 volunteers monitoring 10 sites. These data are particularly useful for assessing trends in the water quality of the lake over time and for estimating trophic status.

Tower - Soudan Wastewater Study

MPCA staff sampled Pike Bay in 1971 and 1983 to study the impact of the wastewater treatment discharges from the cities of Tower and Soudan (MPCA, 1985). Both phosphorus and chlorophyll-a concentrations exceeded ecoregion expectations. It was determined that, at that time, the wastewater treatment plants could not meet their limitations. The plants have since been combined, upgraded, and meet effluent limits, which include a phosphorus limit of 1 mg/L.

MPCA's 2000 Water Quality Assessment

In 1999, the Lake Vermilion Sportsman's Club approached both the MPCA and St. Louis County regarding the possibility of conducting a lake water quality assessment. The Club was interested in developing a baseline assessment to be used to track the lake's response to increasing development pressure, and to use the data to help develop a watershed and lake management plan. The results from this monitoring effort will be the primary focus of this report.

The MPCA developed the Lake Assessment Program (LAP) to assist lake associations or municipalities in the collection and analysis of baseline water quality data in order to assess the trophic status of their lakes. The general work plan for LAP includes Association participation in the Citizen Lake-Monitoring Program (CLMP), cooperative examination of land use and drainage patterns in the watershed of the lake, and an assessment of the data by MPCA staff. Because of the size and complexity of the Lake Vermilion Watershed, the general work plan had to be altered. After consultation with the DNR and the Sportsman's Club, MPCA staff selected 4 monitoring sites (Figure 4).

1. Pike Bay near the Hoodoo Point Public Access
2. Big Bay near Spider Island at the lake's maximum depth
3. Wakemup Bay East of Center Island
4. Vermilion River at the lake's outlet, and the historical USGS flow station

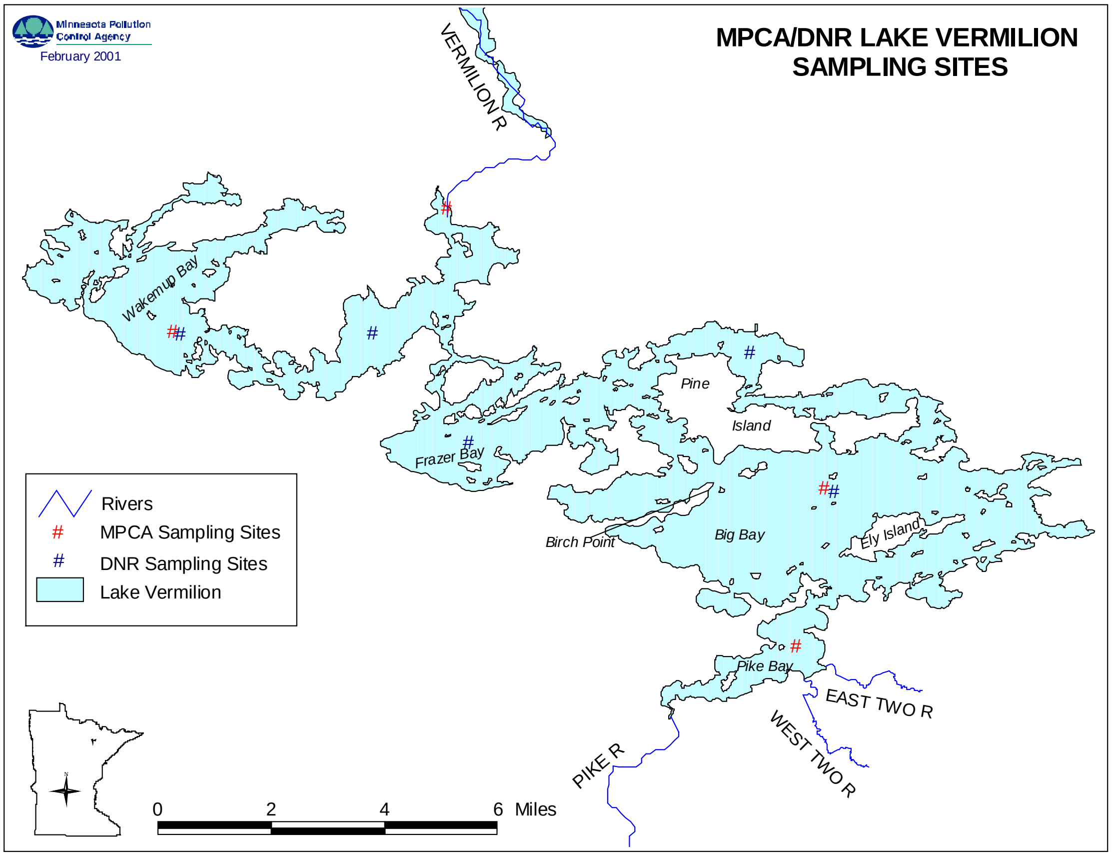
The intent was to select sites that included the major tributary (Pike River/Bay), the lake's outlet (Vermilion River), and both the East (Big Bay) and West (Wakemup) Basins. Sites 2 and 3 are currently being sampled by the DNR, as part of their Large Lake Monitoring Program (Figure 4).

Lake surface samples were collected with an integrated sampler, which is a PVC tube 6.6 feet (2 meters) in length with an inside diameter of 1.24 inches (3.2 centimeters). Near-bottom samples were collected with a two-liter PVC Kemmerer sampler. In addition, phytoplankton (algae) samples were taken with an integrated sampler.

Sampling procedures were employed as described in the MPCA Quality Control Manual. Laboratory analyses were performed by the laboratory of the Minnesota Department of Health using U.S. Environmental Protection Agency (EPA)-approved methods. Samples were analyzed for nutrients, color, solids, pH, alkalinity, turbidity, conductivity, chloride and chlorophyll-a. Temperature and dissolved oxygen profiles and Secchi transparency measurements were also taken. All data were stored in STORET, the EPA's national water quality data bank.

Samples were collected on May 9, June 13, July 18, August 9, and September 12, 2000. High winds prevented sample collection from Big Bay on September 12, 2000.

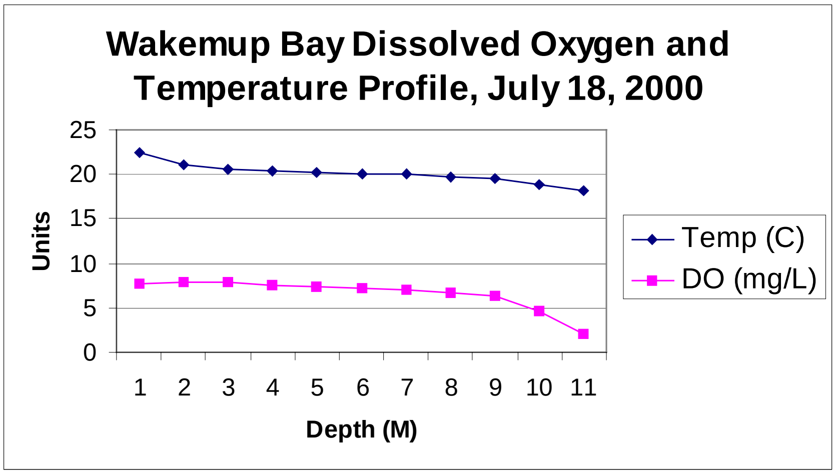
Figure 4. Lake Vermilion sampling sites.

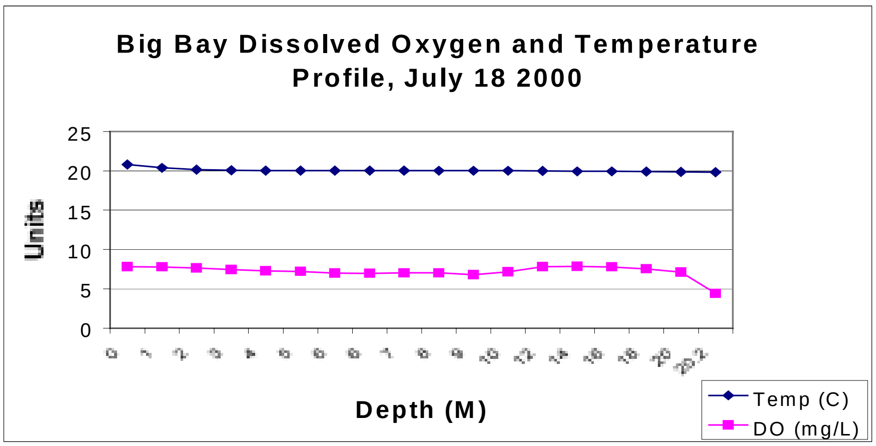


In-Lake Conditions- 2000

Dissolved oxygen (DO) and temperature profiles were taken at all sites except Vermilion River. Readings were collected at one-meter intervals from the surface to the lake bottom. Pike Bay did not thermally stratify (form distinct layers) because of its shallow depth and current and wind mixing. Oxygen concentrations were consistent from the surface to the bottom on all sample dates as well. Well-mixed conditions were also evident in Wakemup and Big Bays (Figure 5). A slight decline in temperature and DO were noted near the bottom of the lake. DO remained above 5 mg/L, a level necessary for long-term survival of game-fish, throughout most of the water column. Temperatures were at or above 20 C (68 F) from the surface to the bottom on most dates. The frequent high winds and large fetch prevent stratification of these sites under most circumstances. These findings are consistent with what the DNR has found in their routine monitoring of these sites.

Figure 5. Dissolved oxygen and temperature profiles.





Total phosphorus (TP) and chlorophyll-a (along with Secchi transparency) are commonly used to describe the trophic status, or productivity, of lakes. Phosphorus is the nutrient that limits algal growth in most Minnesota lakes. Chlorophyll-a concentrations provide an estimation of algal productivity. In turn, the amount of algae in the water typically limits the transparency of the water as measured by a Secchi disk. For most Minnesota lakes, these three measurements are related and provide an estimate of the trophic status (i.e. productivity) of a lake.

Phosphorus concentrations were fairly consistent between sampling sites in 2000 (Figure 6). The highest concentrations were found in Pike Bay, as expected because it has the smallest volume yet receives runoff from a major portion of the lakes' watershed. Concentrations in the other bays and the outlet were relatively stable from June through August. All bays exhibited an increase on the September sampling which may have been the result of extensive wind mixing of these sites. Overall, there was no difference in summer-means between these sites, with the exception of Pike Bay (Table 2). Phosphorus concentrations were much higher in near-bottom samples later in the year from Wakemup bay (Figure 6b). This most likely occurred because the water column was stratified in Wakemup Bay; the low oxygen environment was conducive to the release of TP from the lake sediments to the water column.

Figure 6a. Lake Vermilion 2000 Surface Total Phosphorus Concentrations

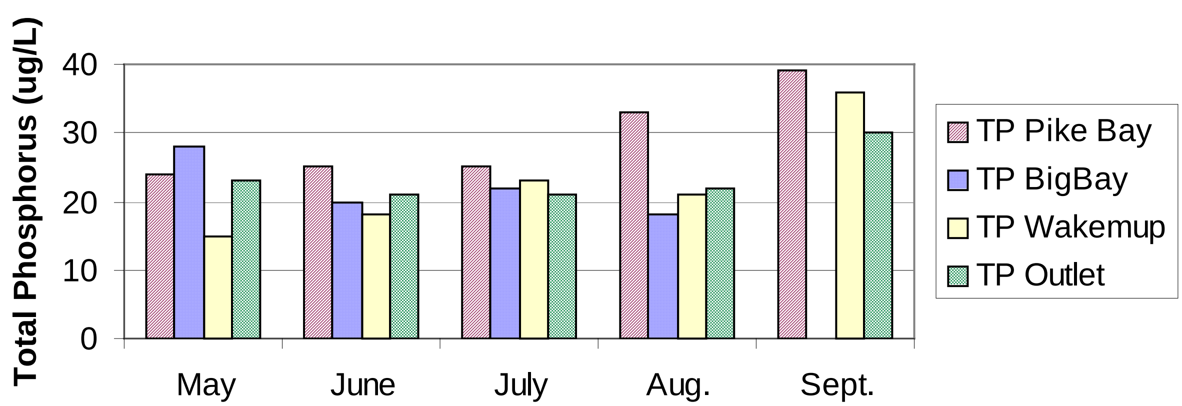
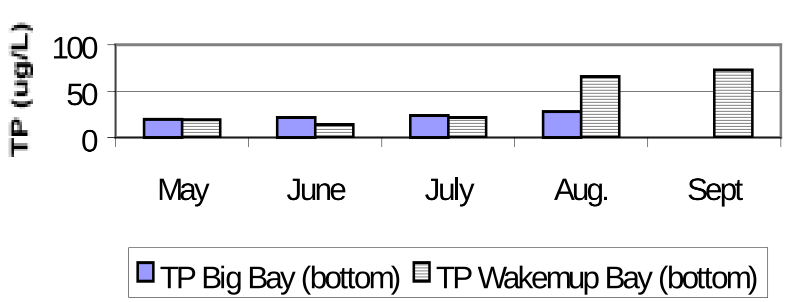
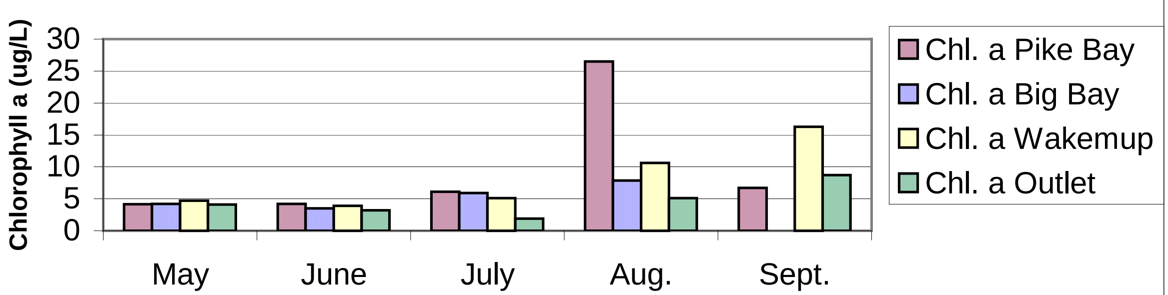


Figure 6b. Lake Vermilion 2000 Hypolimnetic TP



Based on previous work on Minnesota lakes, we typically characterize chlorophyll-a concentrations greater than 10 µg/L as "mild blooms," greater than 20 µg/L as "nuisance blooms," and concentrations greater than 30 µg/L as "severe nuisance blooms" (Heiskary and Walker, 1987). Based on the monthly monitoring of Vermilion blooms were not evident over the May through July timeframe at these sites (Figure 7), however, in August nuisance bloom conditions were evident on Pike Bay and concentrations increased at the other sites as well. This was likely the result of increased TP combined with peak temperatures – both of which contribute to the growth of algae. Late summer rains would have contributed additional P loads to the Bay over this time period. There was minimal difference between summer-mean chlorophyll-a at these sites (Table 2).

Figure 7. Lake Vermilion 2000 Surface Chlorophyll a



Algal analysis

MPCA staff (Dr. Howard Markus) conducted a rapid assessment of the algal community to determine dominant algal forms. Abundance was calculated for each sample based on numerical quantity, and not by volume. The percentages of the total sample within each of the following four groups were calculated: green algae, diatoms, blue-green algae (cyanobacteria), and other taxa (including yellow, brown, and red algae, and dinoflagellates). Diatoms and blue-green algae were the most common forms at all sites (Figure 8). Diatoms were most abundant at the two riverine sites, Pike Bay and the Outlet, while blue-green algae were the most abundant in the main lake sites (Big and Wakemup bays). Diatoms frequently originate on a substrate (Bronmark, and Hanson, 1998), such as the surface of aquatic vegetation or stream / lake substrates. This may account for the greater abundance of diatoms in the more riverine and shallower Pike Bay and Outlet samples. Big and Wakemup Bays are deeper and truly lake-like which may allow diatoms to sediment out more rapidly and where conditions may favor the growth of blue-green algae. A seasonal transition from diatoms to greens to blue-green algae is typical for most eutrophic or mesotrophic lakes in Minnesota. This is driven by competition for nutrients, predation by zooplankton, temperature, light and other factors.

Figure 8. Dominant Algal Communities in Lake Vermilion, 2000

Site	Pike Bay				Big Bay				Wakemup Bay				Outlet			
	Percent Of Sample				Percent Of Sample				Percent Of Sample				Percent Of Sample			
	Green	Other	Diatom	Blue/Green	Green	Other	Diatom	Blue/Green	Green	Other	Diatom	Blue/Green	Green	Other	Diatom	Blue/Green
June		15	80	5		20	55	25			35	65		5	90	5
July	10	15	60	15	10	5	55	30			30	70	5	10	45	40
August			85	15		5	20	75			20	80	5		50	45
September						5	35	60			60	40	5		45	50

Lake Vermilion Diatom Survey (contributed by Dr. John Kingston, University of Minnesota, Duluth)

Diatoms (Division Bacillariophyta) are the protistan algae used most often as bioindicators of water quality (Stoermer & Smol 1999). Diatom samples were collected during the May fieldwork and analyzed at the Natural Resources Research Division's Ely Field Station. Surface sediments (0-1cm) were collected at Big Bay and Wakemup Bay using a Glew gravity corer. Sediments were not retrievable at the Pike Bay site, because sediments are not deposited uniformly due to wind fetch and shallow depth. Sediments were also not collected at the outlet of Lake Vermilion, because we did not launch a boat in the Vermilion River. At all four sites, qualitative phytoplankton net tows were collected using a 20µm mesh size.

(Appendix IB) shows the relative abundance of various diatom species in these samples. Also included are columns giving the apparent total phosphorus optima of these taxa from two published regional data sets, one for southeastern Ontario (Reavie & Smol 2001) and another for British Columbia (Reavie, Hall & Smol 1995).

If one scans the apparent TP optima in the table (see Appendix IB), it is evident that the common diatoms in Lake Vermilion indicate a TP range consistent with the water chemistry sampling done throughout the season. The plankton collection from Pike Bay includes many benthic forms which were less common in the plankton at deeper stations in Big Bay and Wakemup Bay. Examination of the living collections showed that large motile benthic diatoms such as *Entomoneis ornata* were particularly common in Pike Bay. The plankton from the Outlet at Vermilion River also contains many benthic species, a reflection of our sampling methods using a plankton net in a shallow riffle area that contains much periphyton.

The plankton collections in May have common spring species such as the euplanktonic *Asterionella formosa*, *Fragilaria capucina*, and the meroplanktonic *Aulacoseira ambigua*. In contrast, surface sediment collections from Big Bay and Wakemup Bay integrate common diatom species both spatially and temporally, and we see higher representation of common summer and autumn plankton species such as the *Stephanodiscus* species in Big Bay and

Fragilaria crotonensis in Wakemup Bay. The high *Stephanodiscus hantzschii* abundance in Big Bay indicates more eutrophic conditions at that site compared to Wakemup Bay.

As we develop regional diatom/nutrient data sets for northern Minnesota lakes, we will be in a much stronger position to quantitatively reconstruct baselines and trends in sediment cores from Minnesota lakes and from the various basins of large lakes such as Lake Vermilion.

A detailed list of the diatom species found in Lake Vermilion is listed in the Appendix.

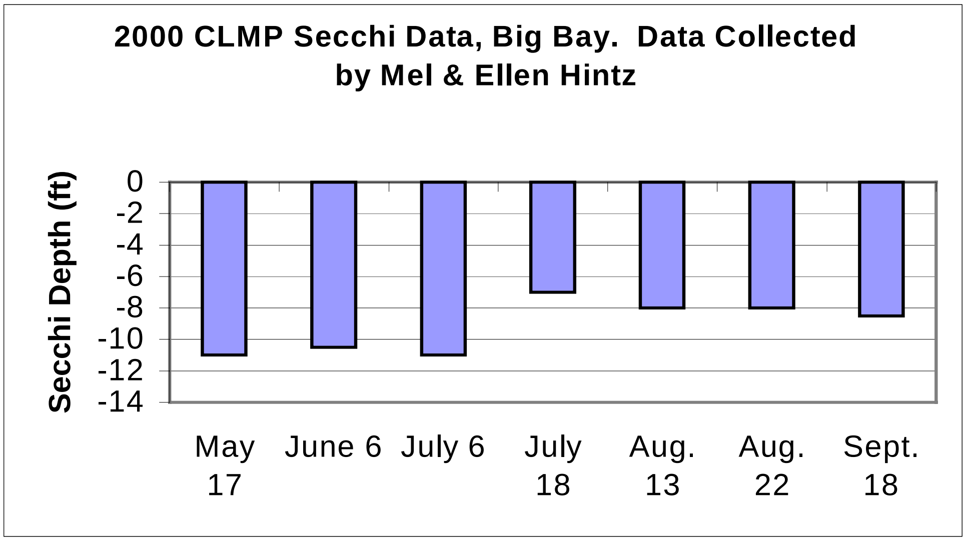
Spatial variation in water quality

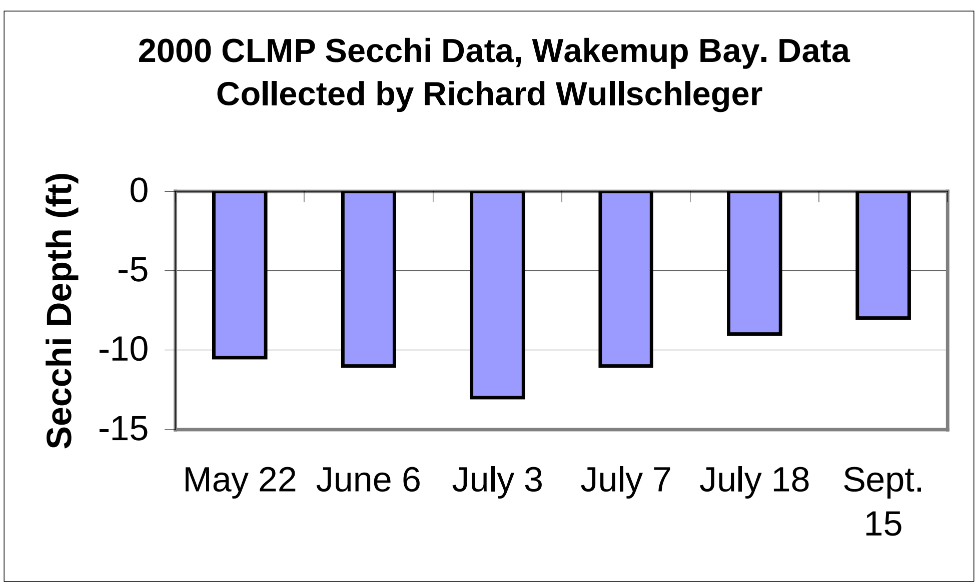
Between-site variability was evident in several of the water quality parameters. In most cases, this variability is related to the size and landuse characteristics of the watershed draining to the site and the volume/depth of the site. As noted previously, TP was similar in Big and Wakemup Bay, while Pike Bay was higher than both, and subsequently, chlorophyll-a was higher in Pike as well. Chlorophyll-a was similar between Big and Wakemup Bay on the four dates when both were sampled (Figure 7). Color was higher in Pike as compared to the other bays and was a direct result of the wetland/forest landuse that characterizes the Pike River watershed. Wetlands, in particular, contribute incompletely dissolved plant matter that yields the coffee coloration of the water. Pike Bay would be considered dark based on its value of 120 Pt-Co units. This level of coloration will limit light to some degree. In contrast, Big Bay had moderate coloration and Wakemup was relatively clear.

The dissolved mineral chemistry varied among the basins. The major dissolved ions in inland surface water are: calcium, magnesium, sodium, potassium, sulfate, chloride, and bicarbonate and carbonate (i.e. alkalinity) (Wetzel, 1982). Conductivity measurements provide an indication of the amount of these ions dissolved in the water column. Conductivity readings averaged 136 µmhos/cm in Big Bay and only 55 in Wakemup Bay. Some of the individual ions listed above were tested, and the pattern of higher values in the eastern basins (Big and Pike) as compared to the western basin (Wakemup) was evident. Alkalinity was 37 mg/L in Big Bay and 27 mg/L in Wakemup; chloride was 7.3 mg/L in Big Bay and 3.0 mg/L in Wakemup; and sulfate was 16 mg/L in Big Bay and < 5 mg/L in Wakemup. The higher concentrations of these dissolved ions in the eastern basins results from runoff from the watershed as compared to Wakemup Bay which has a very small watershed and is more dependent on precipitation. The chloride concentrations were considerably (up to 7 times) higher than the typical range (Table 2) and are most likely due to human influence such as road salt runoff, wastewater from Tower/ Soudan, Soudan State Park mine dewatering and mine drainage from upstream tailings basins which drain to the Pike River.

CLMP data from volunteers in Big and Wakemup Bays are shown in Figure 9. Transparencies averaged 9.1 feet in Big Bay, and 10.4 feet in Wakemup Bay. At both sites, transparencies declined throughout the summer, concurrent with increases in algal growth. These data provide additional indications that water quality varies among Lake Vermilion's basins.

Figure 9. 2000 CLMP Secchi for Selected Sites





Trophic Status and Summary

One means to evaluate the trophic status of a lake and to interpret the relationship between total phosphorus, chlorophyll-a a and Secchi transparency is Carlson's Trophic State Index (TSI, Carlson 1977). This index was developed from the interrelationships of summer Secchi transparency and the concentrations of surface water chlorophyll-a a and total phosphorus. TSI values are calculated as follows:

Total phosphorus TSI (TSIP) = 14.42 1n (TP) + 4.15
Chlorophyll-a a TSI (TSIC) = 9.91 1n (Chl a) + 30.6
Secchi disk TSI (TSIS) = 60 - 14.41 1n (SD)

TP and chlorophyll-a are in µg/L and Secchi transparency is in meters. TSI values range from 0 (ultra-oligotrophic) to 100 (hypereutrophic). In this index, each increase of 10 units represents a doubling of algal biomass.

Average values for the trophic variables in Lake Vermilion and respective TSI's are presented in Figures 10 a-c. TSI's from three sites (Pike, Big, and Wakemup Bays) are presented to demonstrate the relationship between these three variables. Based on these values, Lake Vermilion is considered *mesotrophic* in condition. The mean TSI of 50 ranks Lake Vermilion at the 27^{th} percentile relative to about 1,075 other lakes in the Northern Lakes and Forest ecoregion. In other words, its TSI value is lower (less eutrophic) than 27 percent of the lakes assessed in this region. The individual TSI values and percentiles agree fairly well at all sites. One exception is Pike Bay where the Secchi disk reading is lower than expected based on the TP and chlorophyll-a concentrations. The high color of Pike Bay may contribute to the lower transparency. Overall, these relationships imply that Secchi transparency would be a good indicator of trophic status for Lake Vermillion, though some between-site variability in the interrelationships may occur.

Table 2. Lake Vermilion Water Quality Summary, Summer 2000.
Compared to typical range for minimally-impacted lakes in NLF Ecoregion

Parameter	Pike Bay	Big Bay	Wakemup Bay	Lake Outlet	Lake-Wide Average[2]	NLF Ecoregion Range [1]
Total Phosphorus (µg/L)	29	22	23	23.4	22.7	**14 – 27**
Chlorophyll-a mean (ugh/L)	9.5	5.3	8.1	4.6	6.3	**4 – 10**
Chlorophyll-a max (µg/L)	26.5	7.8	16.3	8.7	14.8	< **15**
Secchi Disk (meters)	1.0	2.4	2.9	-	2.5	**2.4 – 4.6**
Total Kjeldahl Nitrogen (mg/L)	0.75	0.59	0.53	0.53	0.60	**0.40 - 0.75**
Alkalinity (mg/L)	35	37	27	31	32	**40 – 140**
Color (Pt-Co Units)	120	47	20	24	53	**10 – 35**
pH (SU)	7.5	7.5	7.5	7.3	7.5	**7.2 – 8.3**
Chloride (mg/L)	8.5	7.3	3.0	5.4	6.0	**.6 – 1.2**
Sulfate (mg/L)	15.2	16.0	< 5.0	10.6	11.7	**-**
Total Suspended Solids (mg/L)	5.6	2.4	3.1	2.5	3.4	< **1 – 2**
Total Suspended Inorganic Solids (mg/L)	3.2	0.9	0.9	.0.9	1.5	< **1 – 2**
Conductivity (umhos/cm)	139	136	55	104	107	**50 – 250**
TN:TP ratio	26:1	27:1	24:1	23:1	25:1	**25:1 – 35:1**

[1] Derived from Heiskary and Wilson (1989)
[2] Area-weighted for TP, chlorophyll-a and Secchi

Figure 10a. Carlson's Trophic State Index for Lake Vermilion- Pike Bay
R.E. Carlson

TSI < 30 Classical Oligotrophy: Clear water, oxygen throughout the year in the hypolimnion, salmonid fisheries in deep lakes.

TSI 30 - 40 Deeper lakes still exhibit classical oligotrophy, but some shallower lakes will become anoxic in the hypolimnion during the summer.

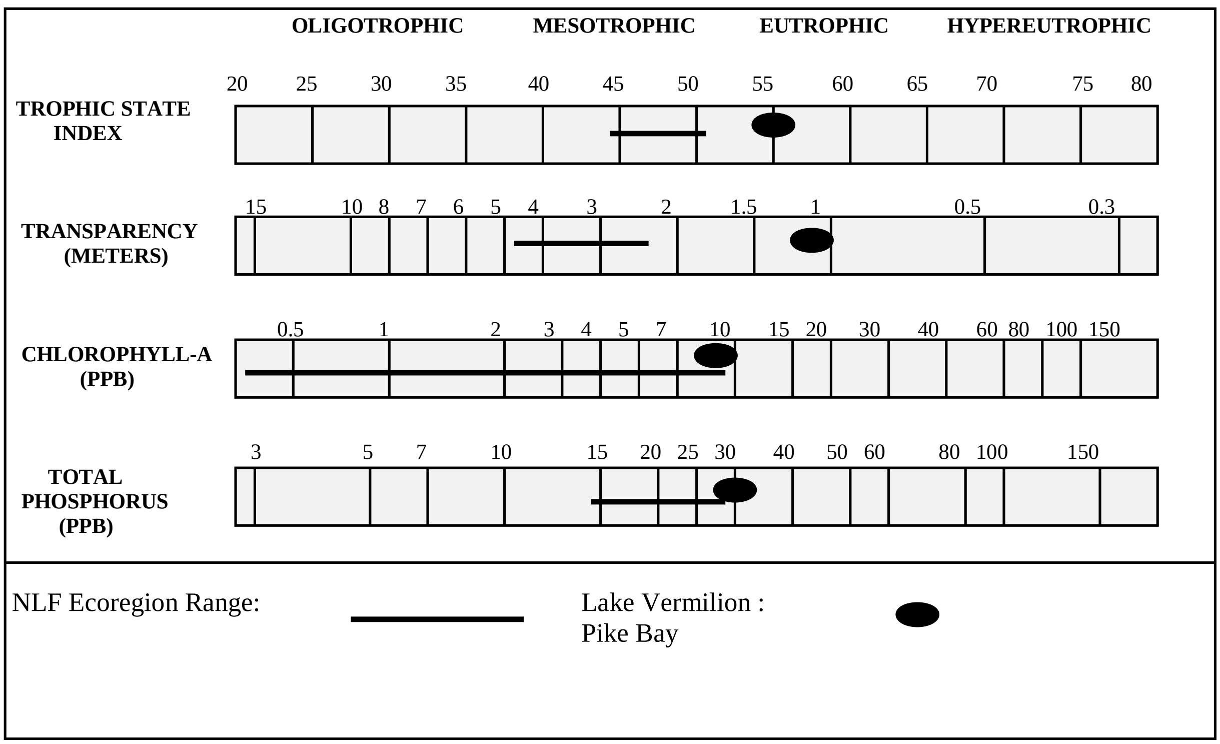
TSI 40 - 50 Water moderately clear, but increasing probability of anoxia in hypolimnion during summer.

TSI 50 - 60 Lower boundary of classical eutrophy: Decreased transparency, anoxic hypolimnia during the summer, macrophyte problems evident, warm-water fisheries only.

TSI 60 - 70 Dominance of blue-green algae, algal scums probable, extensive macrophyte problems.

TSI 70 - 80 Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited by light penetration. Often would be classified as hypereutrophic.

TSI > 80 Algal scums, summer fish kills, few macrophytes, dominance of rough fish.



After Moore, l. and K. Thornton, [Ed.]1988. Lake and Reservoir Restoration Guidance Manual. USEPA>EPA 440/5-88-002.

Figure 10b. Carlson's Trophic State Index for Lake Vermilion- Big Bay
R.E. Carlson

TSI < 30 Classical Oligotrophy: Clear water, oxygen throughout the year in the hypolimnion, salmonid fisheries in deep lakes.

TSI 30 - 40 Deeper lakes still exhibit classical oligotrophy, but some shallower lakes will become anoxic in the hypolimnion during the summer.

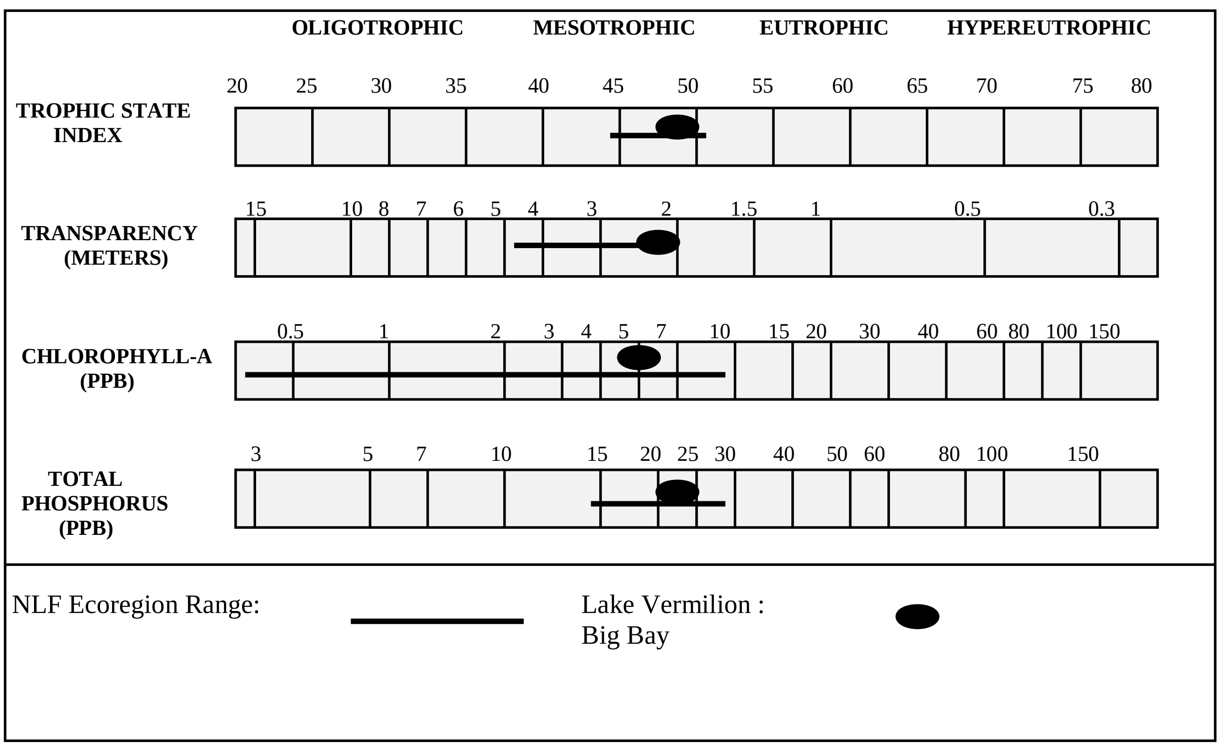
TSI 40 - 50 Water moderately clear, but increasing probability of anoxia in hypolimnion during summer.

TSI 50 - 60 Lower boundary of classical eutrophy: Decreased transparency, anoxic hypolimnia during the summer, macrophyte problems evident, warm-water fisheries only.

TSI 60 - 70 Dominance of blue-green algae, algal scums probable, extensive macrophyte problems.

TSI 70 - 80 Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited by light penetration. Often would be classified as hypereutrophic.

TSI > 80 Algal scums, summer fish kills, few macrophytes, dominance of rough fish.



<u>After</u> Moore, l. and K. Thornton, [Ed.]1988. Lake and Reservoir Restoration Guidance Manual. USEPA>EPA 440/5-88-002.

Figure 10c. Carlson's Trophic State Index for Lake Vermilion- Wakemup Bay
R.E. Carlson

TSI < 30 Classical Oligotrophy: Clear water, oxygen throughout the year in the hypolimnion, salmonid fisheries in deep lakes.

TSI 30 - 40 Deeper lakes still exhibit classical oligotrophy, but some shallower lakes will become anoxic in the hypolimnion during the summer.

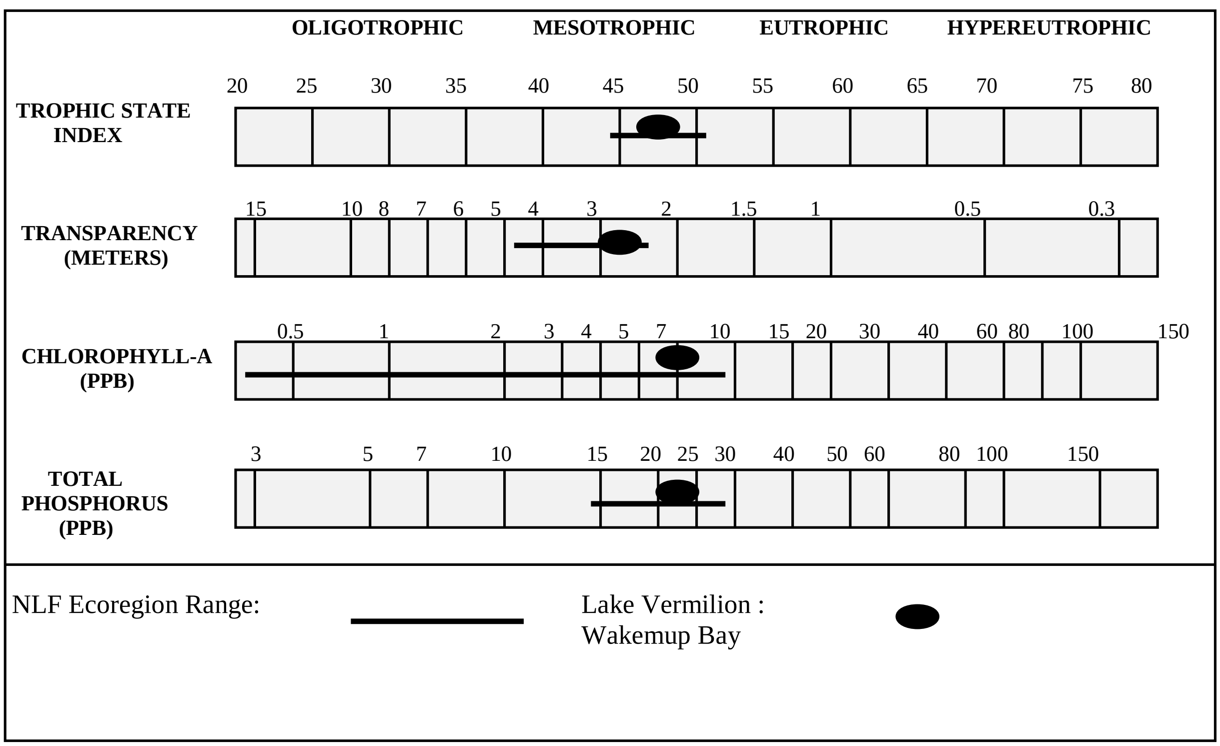
TSI 40 - 50 Water moderately clear, but increasing probability of anoxia in hypolimnion during summer.

TSI 50 - 60 Lower boundary of classical eutrophy: Decreased transparency, anoxic hypolimnia during the summer, macrophyte problems evident, warm-water fisheries only.

TSI 60 - 70 Dominance of blue-green algae, algal scums probable, extensive macrophyte problems.

TSI 70 - 80 Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited by light penetration. Often would be classified as hypereutrophic.

TSI > 80 Algal scums, summer fish kills, few macrophytes, dominance of rough fish.



After Moore, l. and K. Thornton, [Ed.]1988. Lake and Reservoir Restoration Guidance Manual. USEPA>EPA 440/5-88-002.

Water Quality Trends, Historical Data Summary

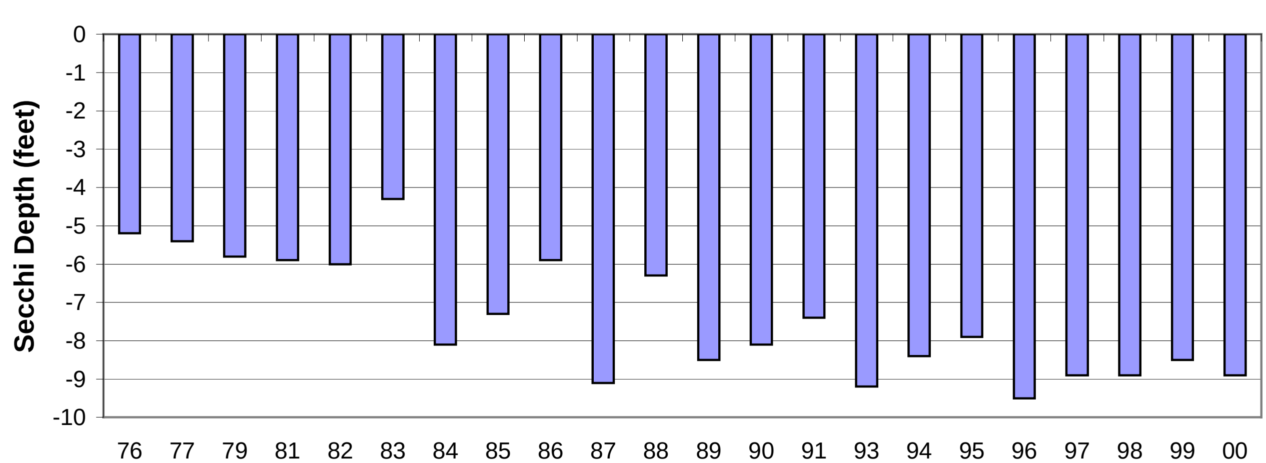
For purely illustrative purposes, historical data has been summarized in Table 3. Nitrogen, phosphorus, and chlorophyll-a are shown because they are the most important chemical parameters in determining primary productivity and trophic status. The earliest data that could be found in the historical record was collected by the DNR in September of 1943. Other data include: a special DNR chlorophyll-a study in 1997 and 1999, the DNR Large Lakes Monitoring Program data, historical data in the STORET database, and the 2000 MPCA water quality assessment. These data sets are not directly comparable because the data were collected for different purposes at varying sites over different time frames. Nonetheless, they help place the most recent data into perspective.

Table 3. Lake Vermilion Historical Data Summary

Monitoring Program / Data set	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll-a (µg/L)
DNR - 1943	48	0.32	-
EPA / MPCA STORET – 1976-93	38	0.92	6.7
DNR Large Lakes 1984-2000	30		13.0
DNR Chlorophyll-a Study - 1997			8.6
DNR Chlorophyll-a Study - 1999			9.9
MPCA Lake Assessment - 2000	24	0.6	6.9

The long-term average summer-mean Secchi transparency for Lake Vermilion is 7.4 feet (2.2 m) based on 22 summers of monitoring (Figure 11). A distinct improvement in transparency is evident if we compare data from the late 1970's through the mid 1980's, which ranged from 4 to 8 feet; with measures from the late 1980's through the 1990's, which ranged from about 6 to 9 feet. Viewing this data in conjunction with Table 3 suggests there may have been some reductions in nutrient concentrations in recent years that could have contributed to improved transparency in the lake. One reduction in nutrient loading to the lake (and Pike Bay in particular) would have been the wastewater treatment facilities at Tower and Breitung that did not treat for phosphorus until they were combined in the 1980s.

Figure 11. Long Term CLMP Secchi Data for Lake Vermilion



The DNR data from the Large Lake Monitoring Program provide a valuable data set for comparing late summer TP and chlorophyll-a at several sites on the lake. No significant temporal trend in TP or chlorophyll-a are evident from these data for the period from 1984 to 2000 (Figure 12a and b). August TP concentrations vary from about 20 to 30 µg/L in most years and sites. There is a slight upward trend from 1996 to 1998 but a decline as well from 1998 to 2000. No consistent between-site pattern is evident over this period of record; and, with the exception of the 1998 TP outlier at Big Bay, concentrations were fairly similar between sites.

The chlorophyll-a data (Figure 12b) suggest a slight decline from the late 1980's through 1996. As was the case with TP, 1997 and 1998 were marked by increased chlorophyll-a, followed by declines in 1999 and 2000. In most years, concentrations were similar between sites and typically ranged from 10 – 15 µg/L. Elevated chlorophyll-a was noted in 1998, consistent with elevated TP, however the peak chlorophyll-a was at the Trout Lake site rather than in Big Bay site which exhibited the elevated TP. It is unclear whether the elevated 1998 TP and chlorophyll-a data are simply outliers or if they are a reflection of actual variability in Lake Vermillion. At any rate, no long-term trend was evident from this data.

Modeling Summary

Numerous complex mathematical models are available for estimating nutrient and water budgets for lakes. These models can be used to relate the flow of water and nutrients from a lake's watershed to observed conditions in the lake. Alternatively, they may be used for estimating changes in the quality of the lake as a result of altering nutrient inputs to the lake (e.g., changing land uses in the watershed) or altering the flow of amount of water that enters the lake. To analyze the in-lake water quality of Lake Vermilion, the models MINLEAP (Wilson 1988) and BATHTUB (Walker, 1987) were used. The "Minnesota Lake Eutrophication Analysis Procedures" (MINLEAP), was developed by MPCA staff based on an analysis of data collected from the ecoregion reference lakes. It is used as a screening tool for estimating lake condition with minimal input data and is described in greater detail in Wilson and Walker (1989). BATHTUB was developed by Dr. William Walker for the US Army Corps of Engineers for use on their reservoir systems. It is widely used in Minnesota for eutrophication modeling for lakes and reservoirs in Clean Lakes and Clean Water Partnership studies.

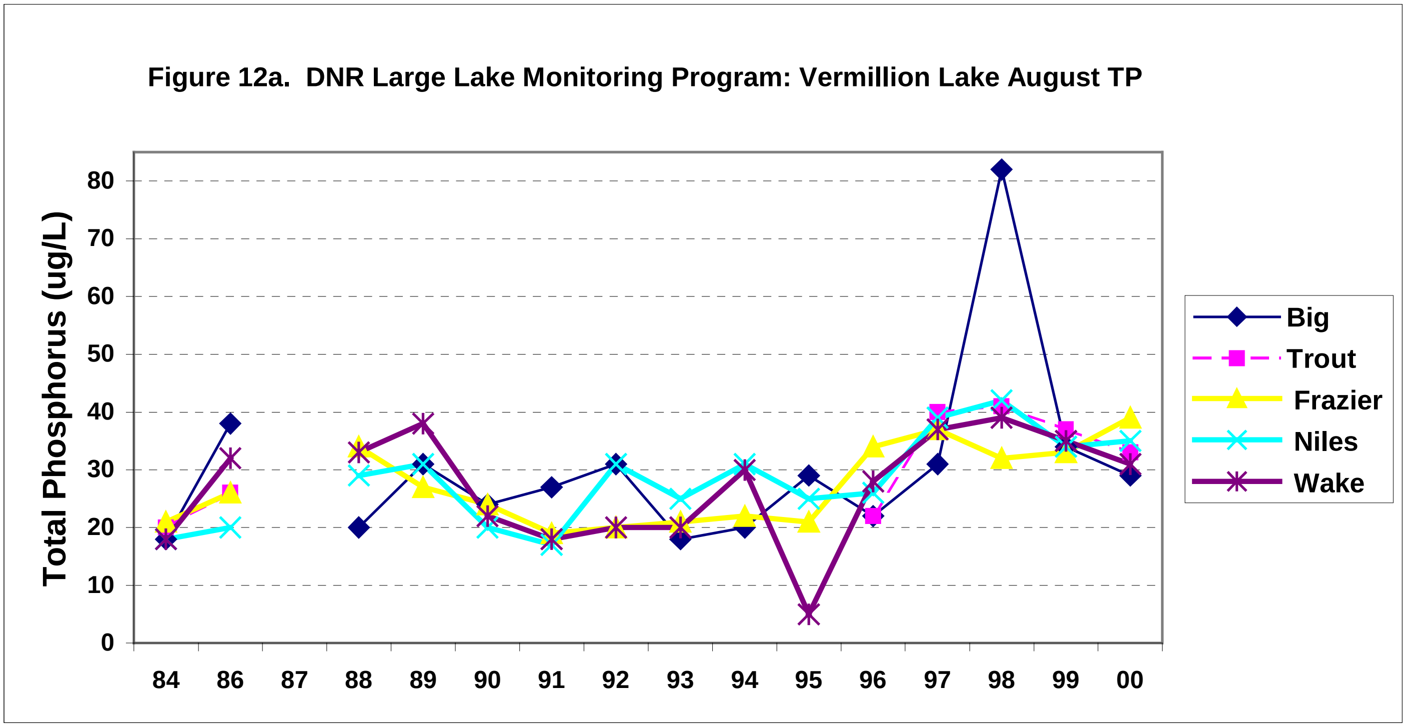


Figure 12a. DNR Large Lake Monitoring Program: Vermillion Lake August TP
Total Phosphorus (ug/L)
0
10
20
30
40
50
60
70
80
84
86
87
88
89
90
91
92
93
94
95
96
97
98
99
00
Big
Trout
Frazier
Niles
Wake

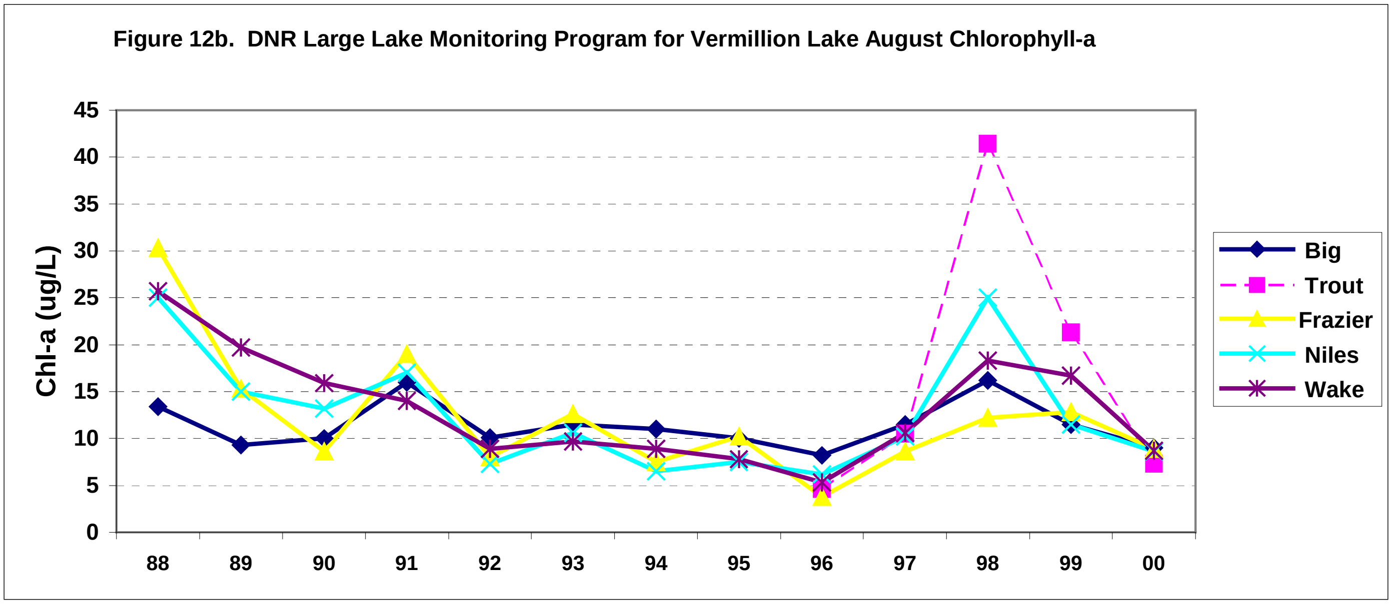


Figure 12b. DNR Large Lake Monitoring Program for Vermillion Lake August Chlorophyll-a
Chl-a (ug/L)
0
5
10
15
20
25
30
35
40
45
88
89
90
91
92
93
94
95
96
97
98
99
00
Big
Trout
Frazier
Niles
Wake

The **MINLEAP model** was run individually for Pike Bay and the whole lake. MINLEAP is used to provide a gross estimate of in-lake P based simply on the volume of the lake (bay), size of watershed, and basic inputs for the NLF ecoregion. In this case, the model was calibrated for measured precipitation in 2000 and stream inflow P was set at 40 µg/L for Pike Bay and 30 µg/L for the entire lake. These values were thought to be more representative of the Pike River (40 µg/L) and overall runoff from the entire watershed (30 µg/L) than the default value of 50 µg/L.

Observed and predicted P for Pike Bay were not significantly different (29 and 33 µg/L). The predicted chlorophyll-a concentration (based upon predicted TP) is 10.8 µg/L, which is not significantly different than the measured value for 2000. However the predicted transparency is slightly higher than observed (Table 4). The model also estimates the frequency of occurrence of *nuisance* (> 20 µg/L chl-a) and *severe nuisance* (> 30 µg/L chl-a) algal blooms. Based on an observed summer-mean chlorophyll-a of 9.5 µg/L nuisance blooms likely occurred about 4 percent of the summer. In contrast, at a predicted concentration of 10.8 µg/L, nuisance blooms could occur from 6-15 percent of the summer.

The Pike River is the single largest tributary to Lake Vermilion and would be the primary contributor of the water and P loading to Pike Bay (Table 4). Because of its small volume and large water loading from the Pike River, the water residence time (time it would take to fill the lake if it were empty) for Pike Bay is very short – on the order of 0.1 years. The areal water load (water load from runoff and precipitation divided by lake surface area) is about 15.6 m/yr and outflow from the lake is estimated at 143.8 HM^3/yr (~ 161cfs) based on the inputs used in MINLEAP.

Similar estimates were made for the lake as a whole as presented in Table 4. Predicted P is slightly lower (but not significantly different) than observed, and as a result, predicted chlorophyll-a and Secchi are not significantly different as well. Because of the much larger volume relative to the watershed (Table 5), the residence time of the lake is much longer and is on the order of 1.4 years. The Lake retains about 49 percent of the P load based on MINLEAP.

A regression model (Vighi and Chiaudani, 1985), based on the morphoedaphic index commonly used in fishery science, was used to estimate “background” TP for Pike Bay and Lake Vermilion. This model predicts TP based on mean depth and alkalinity. Based on this equation, background TP for Pike Bay and Lake Vermilion was estimated at 21 and 13 µg/L respectively. While alkalinity is similar between Pike Bay and Lake Vermilion, Pike Bay is substantially shallower, which contributes to the higher background concentration and makes sense that is background P would be higher given the large watershed that drains to it.

TABLE 4. MINLEAP Model Results for Pike Bay and Entire Lake Vermilion. Comparison of observed and predicted values.

	Pike		Whole Lake	
Parameter	**Obs 2000**	**Pred**	**Obs 2000**	**Pred**
TP (μg/L)	29 ± 2.9	33 ± 7	23 ± 1.4	17 ± 5
chl-a (μg/L)	9.5 ± 4.3	10.8	6.3 ± 1.3	4.1
% chl-a >20 μg/L		6 - 15%		0 - 1%
% chl-a >30 μg/L		1 - 5%		0%
Secchi (meters)	1.0	1.9	2.5	3.4
P loading rate (kg P/yr)		5,878		8,657
P retention (%)		20		49
P inflow conc. (ug/L)		40		30
water load (m/yr)		15.6		4.1
outflow volume (hm^3/yr)		144		259
"background P" (μg/L)		21.4		13.3
residence time (years)		0.1		1.4

Note cfs * 0.8931=hm3/yr

The BATHTUB model provides a further basis for estimating water and nutrient budgets for the Lake Vermilion watershed using a combination of runoff , P export coefficients based on land use in the watershed, and data from similar systems in this ecoregion. This model allows for the "routing" of water and nutrient loads between the basins. In this fashion improved estimates of nutrient and water exchange can be obtained and improved estimates of in-lake condition should be possible. For this effort, we divided the lake into four fairly distinct basins that corresponded to our monitoring sites: Pike Bay, Big Bay, Wakemup Bay and Wolf Bay. Individual areas and mean depth were estimated based on MDNR bathymetric maps (Table 1). Reference to "direct or immediate" drainage is meant to imply that portion of the watershed that drains directly to the lake via small tributaries without passing through a major lake. This would include much of the land around Wakemup Bay and subwatersheds to the east of Big Bay. In other instances, runoff may flow through significant lakes such as Trout Lake to the north of Big Bay. These lakes will retain much of the P generated from the subwatershed and as such are addressed differently in the modeling effort. Additional estimates and inputs to the model are as follows:

1. *Septic loading* was based on a total of 2,330 residences around the lake as supplied by the St. Louis County (based on 911 records, or "fire numbers"). Of the 2,330 residences, we estimated about 80 percent were seasonal and the remainder year round residences. This allowed for P loading estimates from septics based on: 2.2 capita per residence, estimated days of use (seasonal vs. year round), standard P loading per capita, and P retention by septic systems and soils ranging from "high retention" of 90 % to a "low retention" of 60 %. High retention is anticipated for well maintained systems in good soils and poor retention is anticipated for poorly maintained systems in poor (e.g. water-logged soils). For this model run we selected 70 percent retention which translates to a loading rate of 800 kg P/yr reaching the lake. A reasonable bracket might be 80 percent (534 kg P/yr.) to 60 percent

(1,068 kg P/yr). This estimate was then subdivided among the basins based on the estimated intensity of development (septics) around the lake: Pike Bay (10 percent), Big Bay (60 percent) and Wakemup Bay (30 percent).

2. *P export coefficients* - standard coefficients based on the literature and past experience were used. These were applied to lands in the "immediate" watershed of Lake Vermilion.
3. *Precipitation* was based on data from the surrounding area in 2000. Runoff was estimated from USGS records for the Vermilion River as measured at Crane Lake.
4. *Atmospheric deposition rate* of 15 kg P/km^2/yr was used.
5. *P concentrations* for runoff from Trout Lake, Pike River, and Two Rivers were estimated from available data and/or ecoregion-based data summaries (McCollor and Heiskary, 1993).
6. *Point sources* – Measured discharge and concentration data were used for the Tower wastewater treatment facility. Values for Soudan State Park were estimated (0.09 mgd).
7. *Internal loading* was used as an input for Pike Bay as a means to balance the "observed" in-lake P with "estimated." This was deemed reasonable based the shallowness of the Bay and the likelihood of wind resuspension of P from bottom sediments.

Good agreement was obtained between observed and predicted P for all segments (Table 5). In the case of Pike Bay, this was achieved by including a term for "internal loading" of P. This seemed reasonable based on the shallowness, susceptibility to wind mixing, and the limited exchange with the main basin of the lake. Internal loading was not used for Big Bay or Wakemup Bay – though it could account for a portion of the underestimate of P in these basins as well. In general we see good agreement between observed and predicted chlorophyll-a and Secchi values for each basin. This suggests Lake Vermilion is generating the amount of algae we would expect based on measured P and standard regression equations.

Pike Bay represents about one percent of the volume of Lake Vermilion (Table 1) but receives runoff from about 55 percent of the watershed via the Pike River and East and West Two Rivers (Table 6). These three rivers account for the vast majority of the external loading to Pike Bay and about 62 percent of the total loading (external plus internal). In comparison on-site septic systems and the Tower WWTF discharge contributed on the order of five percent or less of the P loading.

Table 5. Comparison of observed mean (± standard error) versus predicted values from BATHTUB model

	Total Phosphorus (µg/L)		**Chlorophyll-a (µg/L)**		**Secchi (m)**	
Basin	**Observed**	**Predicted**	**Observed**	**Predicted**	**Observed**	**Predicted**
Pike	29.0 ± 2.9	29.0	9.5 ± 4.3	11.3	1.0 ± .1	1.0
Big	22.0 ± 2.1	20.4	5.3 ± 1.0	6.6	2.2 ± .05	2.4
Wakemup	23.0 ± 3.6	19.7	8.1 ± 2.4	6.3	2.9 ± .27	3.3
Wolf (outlet)	23.4 ± 1.7	19.9	4.6 ± 1.2	6.4		2.0
Lakewide	22.7 ± 1.4	20.7	6.3 ± 1.3	6.8	2.5 ± .2	2.4

Table 6. BATHTUB estimated phosphorus loading to Lake Vermilion.

Pike Bay	Loading kg P/yr	Percent
Pike River	3,560	44 %
Two Rivers	1,450	18 %
Precipitation	138	2 %
Tower WWTF	247	3 %
Septics	80	1 %
Soudan State Park	3	0 %
Internal (unaccounted for)	2,697	32 %
Sum	8,125	
Retained	230	3 %
Big Bay		
Pike Bay outflow & diffusive	6,458	58 %
Immediate watershed	1,849	17 %
Trout Lake watershed	530	5 %
Precipitation	1,611	15 %
Septics	480	5 %
Sum	11,027	
Retained	7,206	65 %
Wakemup		
Immediate	1,530	40 %
Diffusive	1,578	39 %
Precipitation	658	17 %
Septics	240	6 %
Sum	4,006	
Retained	3,259	85 %
Wolf (outlet)		
Inflow	4,397	96 %
Precipitation	55	1 %
Immediate	153	3 %
Sum	4,052	
Retained	151	4 %
Outflow to Vermilion River	4,453	

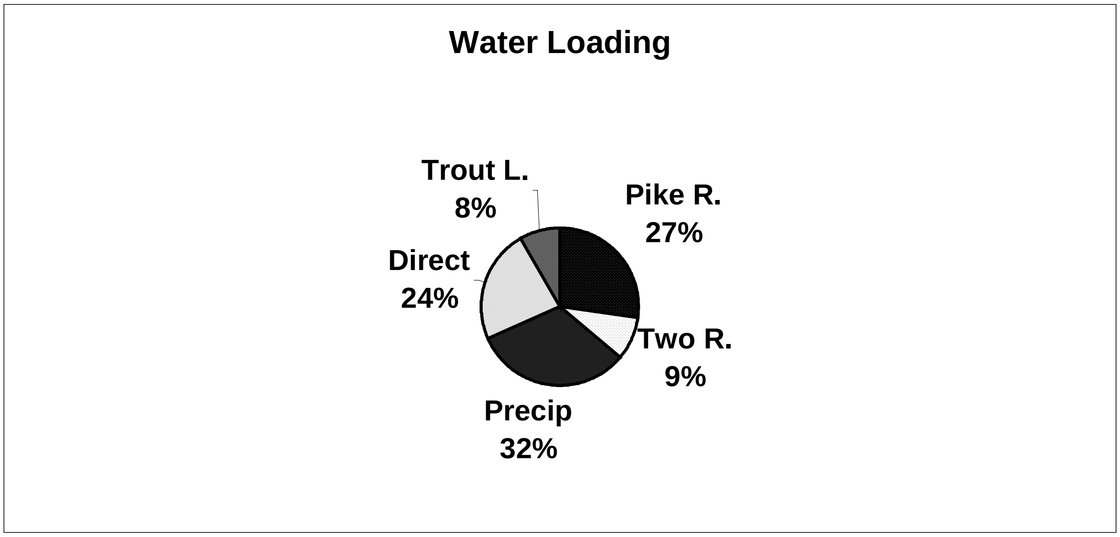
Internal loading, which represents P recycled from the sediments, is common in both shallow, well-mixed lakes as well as deep, thermally-stratified lakes. In deep lakes, internal recycling is typically associated with oxygen-poor conditions that allow P to be released as iron-bearing compounds in the sediment lose their ability to adsorb P. In most cases, this "internal" source of P is retained in the deep hypolimnetic waters until fall mixing. In shallow lakes, internal P release is often caused by several processes including: wind resuspension of sediments and bacterial decomposition of organic matter in the sediments. This release is enhanced by warm temperatures and release rates are often greatest as temperatures rise above 17 degrees C at the sediment surface – as was the case for Pike Bay throughout the summer of 2000 (Appendix). In shallow lakes this P is rapidly recycled into the system. An aerobic release rate of 0.8 $mg/m^2/da$ was used to balance the P budget for Pike Bay. This value is on the low end based on the literature and is much lower than release rates measured for highly eutrophic Lake Pepin (2.7 – 7.8 $mg/ m^2/da$). For Pike Bay it was estimated that this "internal" source could account for almost a third of the P loaded to the Bay (based on the measured P concentration for the Bay). As we noted, this was done to balance the P budget for the Bay and, as such, we cannot ascertain the accuracy of this estimate. By improving the estimate of external loading to Pike Bay we will be able to improve on this in the future. Water residence time for Pike Bay is on the order of .012 years (44 days) based on the water loading estimates we made.

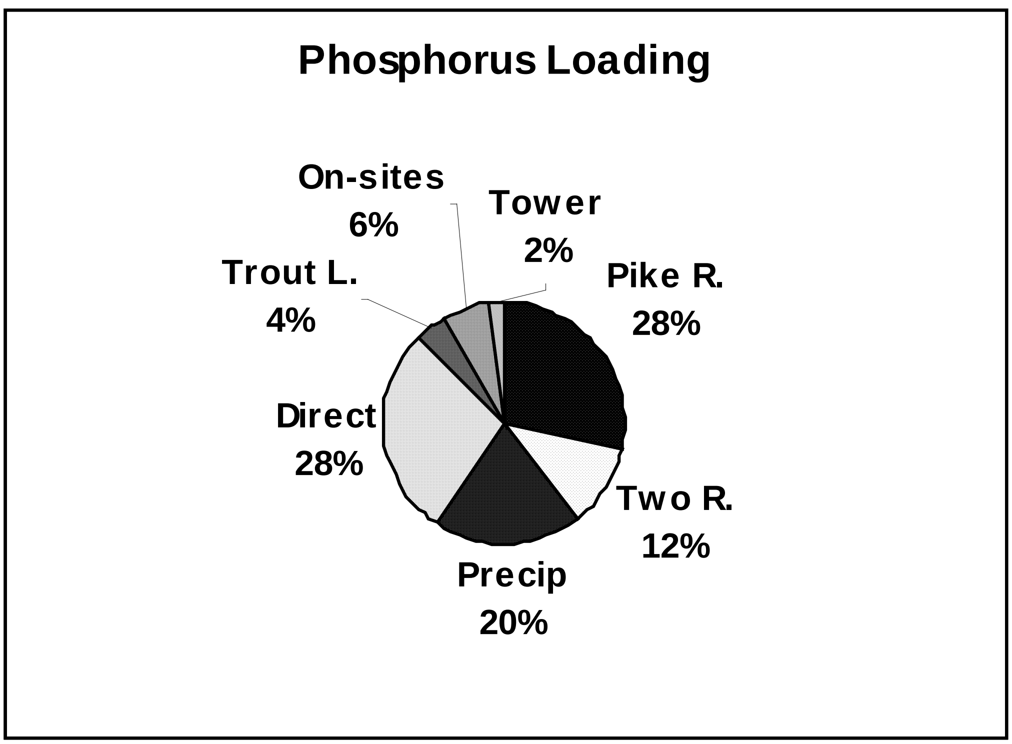
Big Bay accounts for about 65 percent of the volume of Lake Vermilion (Table 1). The largest source of P to Big Bay is the outflow (advective flow) from Pike Bay, combined with "diffusive mixing" within Big Bay (Table 6). Diffusive mixing represents mixing within the bay caused by wind or currents and becomes important in systems where there may be incomplete mixing between the segments (bays), in contrast to systems where water flows directly from one segment to another. Precipitation on the surface of Big Bay is significant to both the water and P budget for the Bay (27% and 15% respectively). Runoff from the watershed accounts for about 22 percent of the P budget. Trout Lake is a prominent feature in the watershed to the north of the bay and it serves to "process" all runoff from this portion of the watershed. Large and deep lakes like Trout might retain on the order of 80 to 90 percent of the P that enters the lake and this substantially reduces the amount of P delivered to Vermilion. On-site septic systems were estimated to contribute about of five percent of the P budget. Water residence time for Big Bay is on the order of 3.3 years.

Wakemup Bay accounts for about 32 percent of the Lake by volume, but has a very small immediate watershed (Table 1). As such, precipitation on the surface of Wakemup Bay is a large contributor to the water budget (48 %) and an important portion of the P budget (16 %) as well. Runoff from the immediate watershed and diffusive mixing within the Bay account for about 79 percent of the P budget. On-site septic systems were estimated to contribute about six percent of the P budget. Water residence time was estimated at 10.5 years for this Bay.

Wakemup and Big Bays flow northeast and northwest respectively and come together near Wolf Bay. This small segment was added to the model to represent the mixing of these two bays and in-lake data for Wolf Bay was collected at the outlet of the lake. The collective flow and P loads from Wakemup and Big Bays account for over 97 percent of the water budget and about 95 percent of the P budget at this point. The overall residence time for the entire lake was estimated at about 4.4 years.

Figure 13. Estimated water and phosphorus budget for Lake Vermilion. Relative contributions from external sources (excludes groundwater).





Model Review and Goal Setting

While numerous assumptions were made in the modeling of Lake Vermilion the results provide some general themes that can be useful as we think about next steps in the management of the lake. The Pike River and East and West Two Rivers are the largest tributaries (drain about 56 % of the total watershed) and most likely are the largest external source of P to Lake Vermilion (Figure 13). Since these rivers drain to Pike Bay, which contains about one percent of the lakes' volume, they will dominate the water quality of Pike Bay. In contrast, other subwatersheds like Trout Lake, which drains about 12 % of total watershed, contribute a rather small percentage of the P load. Precipitation on the lake is a significant portion of the water and P budget because of Lake Vemillion's large surface area and relatively small watershed (Figure 12). The wastewater discharge from the City of Tower, while an important source, contributes a small portion of the P load to the lake.

On-site septic system loading to the lake may be a small portion of the P load (about 5 percent) based on the information we had available and the techniques we used to make our estimates. Should systems or soils around the lake retain less P (70 %) than we used in our assumptions the relative contribution from this source could be greater (and likewise if the systems retain more it would contribute less).

Of the source-categories we have noted, some might be considered controllable (subject to management) while others are not. Sources which would generally be considered not controllable would include: atmospheric deposition of P on the lake, background runoff from forest and wetland areas (typical of this landscape), and diffusive sources (mixing within the lake). Those sources that can be viewed as controllable would include: a portion of the septic system effluent that leaches to the lake, wastewater discharges, a portion of the urban runoff (stormwater) that drains to the lake from driveways, parking lots, rooftops, lawns and other surfaces which contribute runoff and P to the lake. While septic systems appeared to be a small contributor (on a lake-wide basis) it may be among the most "controllable" portion of the P loading to the lake considering that atmospheric and natural background loads cannot be reduced. Also any P which leaches to the sub-surface waters from improperly maintained systems will most likely reach the lake and contribute to the overall growth of algae in the lake and/r near-shore growths of attached algae or excessive rooted plant growth.

It is very hard to calculate the portion that might be subject to management at this point, but some initial estimates can be made based on our data and diatom-reconstructed P. The Vighi and Chiaudani regression estimated background P concentrations for Pike Bay (21 µg/L) and the whole lake (13 µg/L). For Pike Bay, this represents about 72 percent of the measured P (29 µg/L) and for the main basin of the lake this represents about 56 percent of the 22.7 µg/L lakewide average. This suggests that current day values are above background and there may be some opportunity for reduction in P load to the lake.

The current phosphorus criteria value for support of swimmable use in the Northern Lakes and Forests ecoregion is less than 30 µg/L (Heiskary and Wilson, 1990). At or below 30 µg P/L, "nuisance algal blooms" (chlorophyll-a >20 µg/L) should occur less than 5 percent of the summer and transparency should remain above 2 meters over 70 percent of the summer. Based on 2000 data, Lake Vermilion had an area-weighted summer-mean P of 22.7 µg/L, summer-mean chlorophyll-a of 6.3 µg/L and Secchi of 2.5 m. Nuisance algal blooms were not apparent on Big or Wakemup Bays based on the summer-mean chlorophyll-a and monitoring data (Figure 7). Mild blooms (chlorophyll-a > 10 µg/L) may have occurred about 10 percent of the summer. Pike Bay, with a mean P concentration of 29 µg/L and a chlorophyll-a of 9.5 µg/L, was estimated to have mild blooms about 30 - 40 percent of the summer and "nuisance blooms" about five percent or less of the summer. Based on 2000 monitoring, nuisance blooms were observed on one of five dates.

Based on observed data and model estimates, a reasonable P goal for Pike Bay may be in the 20 to 25 µg/L range. At 25 µg/L nuisance blooms should not occur and mild blooms should occur less than about 10 percent of the summer. For the remainder of the lake, a P goal of 20 µg/L or less should be reasonable. At 20 µg/L, nuisance blooms should not occur and mild blooms should occur less than five percent of the summer. Secchi should average on the order 2.5 – 3.0 m over the summer. At this point it is difficult to refine these goals any further or to determine the long-term achievability of the goals. More monitoring is needed to refine the water and nutrient budget for the lake and reduce the uncertainty in our model estimates. Our data and model estimates do, however, provide some general direction on which subwatersheds should be priorities for future monitoring and what might constitute "manageable" sources of P to the lake.

Table 7. Lake Vermilion Summer-Mean Phosphorus and Model Estimates in µg/L.

Lake or Bay	2000 Mean	MINLEAP	Vighi –P (background)	BATHTUB
Pike	**29.0 ± 2.9**	**33 ± 7**	**21**	**29.0**
Big	**22.0 ± 2.2**			**20.4**
Wakemup	**23.0 ± 3.6**			**19.7**
Area-weighted	**22.7 ± 1.4**	**17 ± 5**	**13**	**20.7**

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Appendices

Appendix IA. Water Quality Data

Lake Vermilion Water Quality Data- 2000

Big Bay- off Spider Island,in 70 foot hole

Wakemup Bay- near Stove Top Reef in 50 foot hole

Pike Bay- East of Whiskey Island, and South of Hoodoo Point

Outlet- Vermilion River at lake outlet near Vermilion Dam Resort

units			M		umhos	M	mg/L		PtCo	mg/L			ug/L	mg/L	ug/L	
Date	**Time**	**Site**	**Depth**	**pH**	**Cond.**	**Sec**	**TSS**	**SVS**	**Color**	**Alk.**	**Cl**	**SO4**	**TP**	**TKN**	**Chl. a**	**Pheo**
5/9/00	1200	**Big Bay**	0-2	7.7	107	2.4	1.6	1.2	50	34	7.4	17.0	28	0.570	4.2	2.8
5/9/00	1200	**Big Bay**	15										20			
5/9/00	1700	**Outlet**	0-2	7.0	77		2.4	1.6	20	25	5.3	11.0	23	0.490	4.1	2.8
5/9/00	1115	**Pike Bay**	0-2	7.6	122	1.3	4.4	2.4	80	25	9.5	26.0	24	0.600	4.2	3.2
5/9/00	1530	**Wakemup**	0-2	7.4	42	3.7	2.0	<1	20	22	2.9	5.5	15	0.470	4.7	1.0
5/9/00	1530	**Wakemup**	9										19			
6/13/00	1020	**Big Bay**	0-2	7.7	143	2.4	2.4	1.2	50	34	7.4	19.0	20	0.560	3.5	1.4
6/13/00	1020	**Big Bay**	13										22			
6/13/00	1600	**Outlet**	0-2	7.4	107		2.0	1.6	30	26	5.6	10.0	21	0.470	3.2	1.6
6/13/00	1100	**Pike Bay**	0-2	7.7	168	B	6.8	3.2	120	38	11.0	23.0	25	0.700	4.2	1.1
6/13/00	1330	**Wakemup**	0-2	7.4	57	3.4	1.2	1.2	20	18	3.1	<5	18	0.460	3.9	1.4
6/13/00	1330	**Wakemup**	10										14			
7/18/00	1145	**Big Bay**	0-2	7.6	146	2.4	3.6	2.0	50	38	7.3	16.0	22	0.630	5.9	2.9
7/18/00	1145	**Big Bay**	19										24			
7/18/00	1630	**Outlet**	0-2	7.5	114		2.0	1.2	20	30	5.5	12.0	21	0.520	1.9	1.6
7/18/00	1045	**Pike Bay**	0-2	7.3	130	0.8	5.2	2.4	140	34	7.3	10.0	25	0.820	6.1	3.9
7/18/00	1445	**Wakemup**	0-2	7.8	58	2.9	3.6	2.8	20	30	3.1	5.3	23	0.560	5.1	2.3
7/18/00	1445	**Wakemup**	10										22			
8/8/00	1700	**Outlet**	0-2	7.5	115		2.4	1.6	30	42	5.5	10.0	22	0.520	5.1	1.9
8/8/00	1130	**Pike Bay**	0-2	7.5	138	1.0	5.6	2.0	140	42	7.3	7.9	33	0.810	26.5	30.0
8/8/00	1500	**Wakemup**	0-2	7.3	60	2.3	3.2	2.8	20	42	3.2	<5	21	0.550	10.6	2.9
8/8/00	1500	**Wakemup**	10										66			
8/8/00	1215	**Big Bay**	0-2	7.4	149	2.2	2.0	1.6	40	42	7.4	12.0	18	0.620	7.9	2.4
8/8/00	1215	**Big Bay**	15										28			
9/12/00	1030	**Pike Bay**	0-2	7.6	141	1.0	6.0	2.0	120	38	7.4	9.1	39	0.830	6.7	1.8
9/12/00	1400	**Outlet**	0-2	7.5	110		4.0	2.4	20	33	5.4	10.0	30	0.660	8.7	1.9
9/12/00	1230	**Wakemup**	0-2	7.7	59	2.4	5.6	3.2	20	23	3.1	<5	36	0.650	16.3	8.0
9/12/00	1230	**Wakemup**	10										73			

Cond= Specific Conductivity

Secchi= Secchi Depth (meters)

TSS= Total Suspended Solids

SVS= Suspended Volatile Solids

Alk= Alkalinity as CaCO3

Chl. a= Chlorophyll a

Phaeo= Phaephytin a

TKN= Total Kjeldahl Nitrogen

TP= Total Phosphorus

Cl= Chloride

SO4= Sulfate

Temperature, Dissolved Oxygen, Conductivity, pH, and Redox (ORP) Profiles for Summer 2000

Pike Bay Site 116

Pike	Site 116							
Date	Time	Depth	Temp	DO	SpCond	pH	ORP	DO%
MMDDYY	HHMMSS	meters	øC	mg/l	æS/cm	Units	mV	Sat
50900	110429	0.0	16.3	7.4	122	7.6	380	77
50900	110455	1.0	16.3	7.4	122	7.6	381	77
61300	105623	0.1	16.8	8.2	169	7.7	313	87
61300	105729	1.0	16.9	8.2	172	7.8	313	87
61300	105804	1.3	16.9	8.3	172	7.9	313	87
71800	105248	0.2	20.1	7.8	131	7.3	363	85
71800	105355	1.0	19.6	7.8	131	7.4	362	85
71800	105422	1.7	19.3	7.7	131	7.3	364	83
80800	112904	0.0	20.9	7.5	139	7.5	378	85
80800	113018	1.0	20.8	7.5	138	7.5	378	85
80800	113119	0.5	20.8	7.5	139	7.5	377	85
91200	103458	0.3	15.7	8.7	141	7.6	510	88
91200	103549	1.9	15.7	8.7	141	7.6	512	88

Big Bay Site 130

Big	Site 130							
Date	Time	Depth	Temp	DO	SpCond	pH	ORP	DO%
MMDDY Y	HHMMSS	meters	øC	mg/l	æS/cm	Units	mV	Sat
50900	114751	0.0	11.9	8.8	107	7.7	410	84
50900	114819	1.0	11.8	8.9	107	7.7	409	85
50900	114846	1.9	11.8	8.9	107	7.7	409	84
50900	114913	3.1	11.8	9.0	107	7.7	409	85
50900	114941	4.0	11.8	9.0	107	7.7	408	85
50900	115001	5.1	11.8	8.8	107	7.7	408	84
50900	115039	6.0	11.7	8.8	107	7.7	407	83
50900	115103	6.8	11.5	8.7	107	7.7	407	82
50900	115141	7.9	11.4	8.7	107	7.7	407	81
50900	115212	8.9	10.8	8.6	107	7.6	408	80
50900	115247	10.1	10.5	8.5	107	7.5	409	79
50900	115322	10.9	10.5	8.5	107	7.5	408	78
50900	115338	12.1	10.5	8.5	107	7.5	408	78
50900	115401	12.9	10.4	8.5	107	7.5	408	78
50900	115417	13.9	10.4	8.5	107	7.5	408	78
50900	115446	15.1	10.3	8.4	107	7.5	408	77
50900	115509	16.4	10.3	8.1	107	7.4	335	75
50900	115637	16.2	10.3	7.4	107	7.3	260	68
61300	101741	0.3	16.1	9.3	143	7.7	309	97
61300	101831	1.1	16.1	9.0	143	7.7	311	93

61300	101852	2.1	16.1	8.8	143	7.7	311	91
61300	101922	3.1	16.1	8.6	144	7.7	311	89
61300	101947	4.2	16.1	8.5	144	7.7	311	89
61300	102021	4.8	16.1	8.5	145	7.7	312	89
61300	102059	6.2	16.1	8.6	145	7.7	312	89
61300	102141	6.5	16.1	8.6	145	7.7	313	89
61300	102219	7.1	16.1	8.5	145	7.7	312	89
61300	102253	8.1	16.1	8.5	145	7.7	312	88
61300	102315	9.0	16.1	8.5	145	7.7	312	88
61300	102338	10.0	16.1	8.4	145	7.7	312	88
61300	102359	10.0	16.1	8.4	145	7.7	312	87
61300	102446	11.2	16.1	8.4	145	7.7	312	87
61300	102515	11.9	16.1	8.4	146	7.7	312	87
61300	102540	12.9	16.1	8.4	146	7.7	313	88
71800	113503	0.0	20.8	7.8	146	7.6	364	87
71800	113544	1.0	20.4	7.8	146	7.6	365	86
71800	113638	2.0	20.2	7.7	146	7.6	365	84
71800	113739	3.0	20.1	7.4	146	7.6	367	82
71800	113842	4.0	20.1	7.3	146	7.5	367	80
71800	113937	5.0	20.0	7.2	146	7.5	368	79
71800	114035	6.0	20.0	7.0	147	7.6	366	77
71800	114048	6.0	20.0	7.0	147	7.6	366	77
71800	114204	7.0	20.0	7.0	147	7.6	366	77
71800	114255	8.0	20.0	7.0	147	7.6	366	77
71800	114410	9.0	20.0	6.8	147	7.6	365	75
71800	114752	10.0	20.0	7.2	148	7.6	367	79
71800	115440	12.0	20.0	7.8	148	7.3	367	86
71800	115524	14.0	20.0	7.9	148	7.4	366	86
71800	115616	16.0	19.9	7.8	148	7.4	366	85
71800	115710	18.0	19.9	7.5	148	7.5	366	83
71800	115752	20.0	19.9	7.1	148	7.4	313	78
71800	115938	20.2	19.9	4.4	150	7.2	207	47
80800	120041	0.0	21.3	7.5	148	7.5	376	86
80800	120640	16.1	19.7	2.8	154	7.0	366	31

Wakemup Bay Site 131

Wakemup	Site 131							
Date	Time	Depth	Temp	DO	SpCond	pH	ORP	DO%
MMDDYY	HHMMSS	meters	øC	mg/l	æS/cm	Units	mV	Sat
50900	152228	0.0	12.7	8.7	42	7.4	375	84
50900	152254	1.0	12.6	8.7	42	7.5	377	84
50900	152319	1.9	12.6	8.7	42	7.5	377	84
50900	152343	3.3	12.5	8.7	42	7.5	378	84
50900	152359	4.1	12.5	8.7	42	7.5	379	84
50900	152411	4.9	12.5	8.7	42	7.5	379	84
50900	152432	5.9	12.5	8.7	42	7.5	378	84
50900	152458	7.0	12.5	8.7	42	7.5	379	84
50900	152517	8.0	12.4	8.7	42	7.5	378	84
50900	152538	9.2	12.2	8.7	42	7.4	379	83
50900	152601	9.9	12.2	8.6	42	7.4	378	83

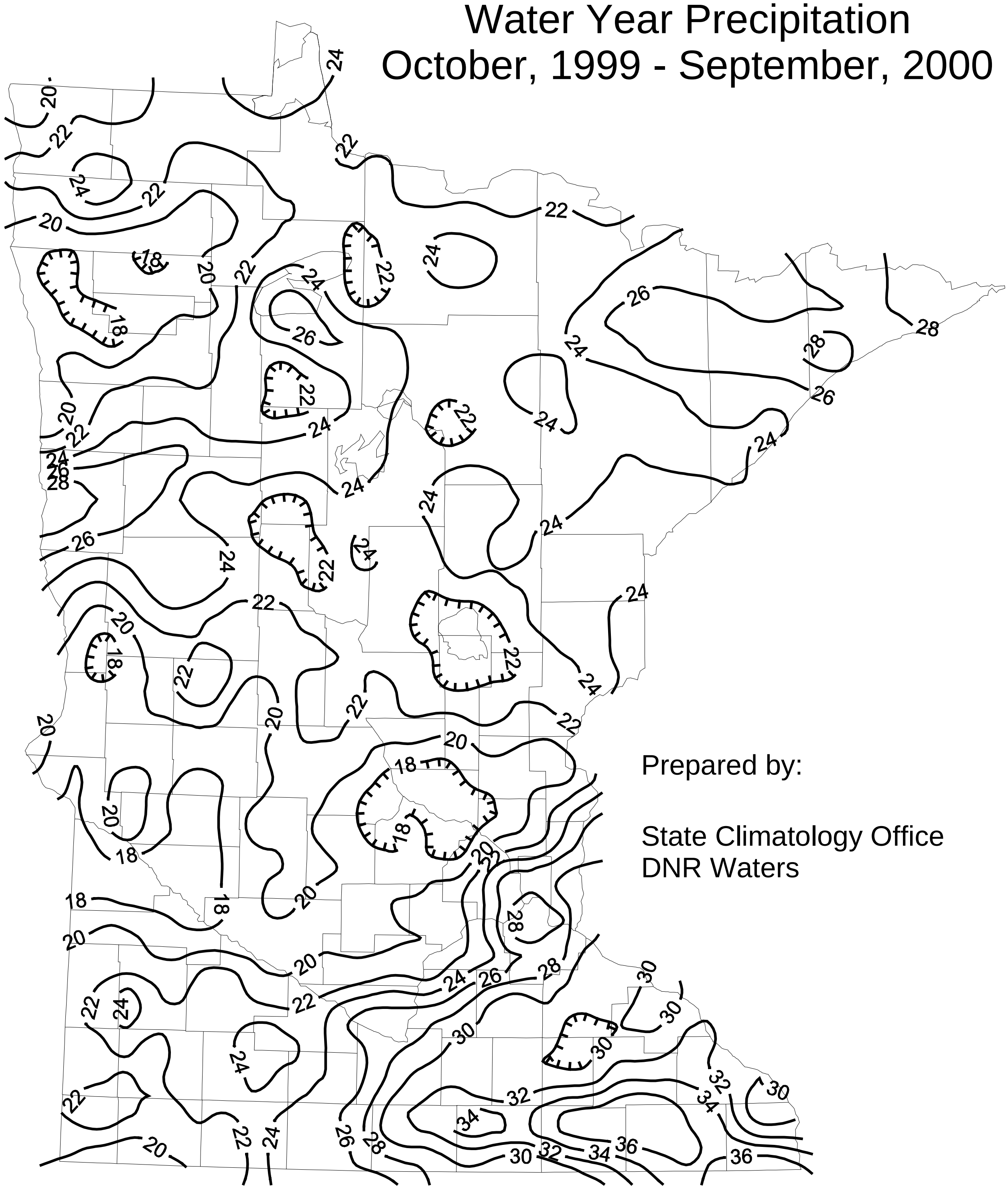
61300	132226	0.2	16.0	8.9	57	7.4	328	92
61300	132331	1.0	16.0	8.6	57	7.4	329	89
61300	132405	2.0	16.0	8.5	57	7.4	328	88
61300	132439	3.0	16.0	8.5	58	7.4	329	88
61300	132513	4.0	16.0	8.5	58	7.4	329	88
61300	132547	5.0	15.9	8.5	58	7.4	329	88
61300	132621	6.1	15.9	8.5	58	7.4	328	88
61300	132723	7.0	15.9	8.5	58	7.4	328	88
61300	132809	8.0	15.9	8.4	58	7.4	328	87
61300	132909	9.0	15.9	8.4	58	7.4	328	87
61300	133012	10.0	15.9	8.4	58	7.4	328	86
61300	133053	11.1	15.5	2.9	82	6.9	234	26
71800	144631	0.2	22.4	7.7	59	7.7	333	89
71800	144716	1.1	21.1	7.8	58	8.0	331	88
71800	144743	2.0	20.6	7.9	58	8.0	332	87
71800	144833	2.9	20.3	7.6	58	7.8	336	84
71800	144859	4.0	20.2	7.4	58	7.7	339	81
71800	145112	6.0	20.1	7.2	59	7.3	345	79
71800	145145	7.0	20.0	7.0	59	7.3	347	77
71800	145228	8.0	19.7	6.6	59	7.2	348	72
71800	145323	9.0	19.6	6.3	59	7.0	350	69
71800	145406	10.0	18.8	4.7	60	6.9	353	50
71800	145439	11.2	18.2	2.1	73	6.6	332	22
80800	150423	0.2	21.5	7.7	60	7.6	358	88
80800	150500	1.0	21.5	7.7	60	7.6	357	88
80800	150546	2.1	21.5	7.7	60	7.7	357	88
80800	150620	3.1	21.5	7.7	60	7.7	357	88
80800	150654	4.1	21.5	7.7	60	7.7	357	88
80800	150725	5.0	21.5	7.7	60	7.7	358	88
80800	150801	6.1	21.5	7.6	60	7.7	359	87
80800	150838	7.0	21.2	6.6	61	7.5	362	75
80800	150907	8.0	19.9	4.1	63	7.3	366	45
80800	150932	9.0	19.6	3.0	66	7.1	372	33
80800	151009	10.1	19.4	1.9	69	6.9	376	20
80800	151044	11.1	19.2	0.4	83	6.7	275	4
91200	121340	0.3	17.1	9.0	59	7.7	480	94
91200	121631	1.0	17.1	9.1	60	7.8	488	95
91200	121753	2.0	17.1	9.1	59	7.8	491	95
91200	121908	2.9	17.1	9.1	60	7.7	493	94
91200	122011	4.0	17.0	9.0	60	7.7	493	94
91200	122041	5.2	17.0	9.0	60	7.7	494	94
91200	122121	5.9	17.0	9.0	60	7.7	495	94
91200	122157	7.2	17.0	9.0	59	7.7	496	94
91200	122210	7.9	16.9	8.9	60	7.6	496	93
91200	122248	9.1	16.9	8.8	60	7.6	497	92
91200	122350	10.2	16.9	8.8	60	7.6	497	91
91200	122442	10.9	17.0	5.3	91	7.1	380	55

Appendix IB. Diatoms Found in Lake Vermilion May 2000, Data from John Kingston, University of Minnesota, Duluth

	total P optimum	total P optimum	Pike Bay	Big Bay	Big Bay	Wakemup Bay	Wakemup Bay	Outlet
	(ug/L) Ontario	(ug/L) British Columbia	plankton	surface sediments	plankton	surface sediments	plankton	plankton
Diatom Taxon	Reavie & Smol (2001)	Reavie et al. (1995)	20um	0-1cm	20um	0-1cm	20um	20um
Achnanthidium minutissimum (Kutzing) Czarnecki	16	14						3.6%
Asterionella formosa Hassall	14	15	21.0%	5.8%	51.6 %	2.1%	35.7%	25.5 %
Aulacoseira ambigua (Grunow) Simonsen	16	22.6	14.5%	10.1%	1.3%	19.1%	17.2%	14.6 %
Aulacoseira distans (Ehrenberg) Simonsen		15		1.4%				
Aulacosira granulata (Ehrenberg) Simonsen	19	36	8.1%	20.9%	1.3%	16.3%	9.6%	1.5%
Aulacoseira subarctica (O. Muller) Haworth	14	17	3.2%	7.2%	3.8%		0.6%	
Cyclotella bodanica var. *affinis* (Grunow) A. Cleve	11	10	3.2%	2.9%	2.5%	2.1%	0.6%	5.1%
Cyclotella michiganiana Skvortzow	14	26		0.7%				
Cyclotella kuetzingiana Thwaites		13						0.7%
Cyclotella stelligera Cleve & Grunow in Van Heurck	11	14				1.4%		
Encyonema minutum (Hilse in Rabenhorst) Mann in Round *et al.*		10						1.5%
Entomoneis ornata (Bailey) Reimer in Patrick & Reimer			1.6%		0.6%			
Eucocconeis lapponica var. *ninckei* (Reimer) Stoermer & Yang						0.7%		
Fragilaria capucina Desmazieres	17	23	19.4%	6.5%	8.9%	27.0%	13.4%	2.9%
Fragilaria capucina var. *mesolepta* (Rabenhorst) Rabenhorst	27	16	2.4%					
Fragilaria crotonensis Kitton	14	18	5.6%	2.9%	25.5 %	17.0%	3.8%	18.2 %
Fragilaria vaucheria (Kutzing) Petersen	17	17					2.5%	
Gomphonema olivaceoides Hustedt								0.7%
Gomphonema parvulum (Kutzing) Kutzing	21	19	0.8%					
Gyrosigma acuminatum (Kutzing) Rabenhorst		22	0.8%					
Hantzschia amphioxys (Ehrenberg) Grunow							0.6%	
Hippodonta capitata (Ehrenberg) Lange-Bertalot, Metzeltin & Witkowski								0.7%
Karayevia laterostrata (Hustedt) Kingston	17		0.8%					
Navicula cryptocephala Kutzing	16	10	2.4%					
Navicula schadei Krasske	19							1.5%
Sellaphora seminulum (Grunow) Mann	16							1.5%
Sellaphora cf. *seminulum* (Grunow) Mann						0.7%		
Navicula subrotundata Hustedt	17							1.5%
Navicula tripunctata var. *schizonemoides* (Van Heurck) Patrick								0.7%
Nitzschia dissipata var. *media* (Hantzsch) Grunow	15		0.8%					
Nitzschia paleacea Grunow in Van Heurck	16		0.8%					
Staurosira construens var. *venter* (Ehrenberg) Hamilton in Hamilton et al.	18	13						1.5%
Staurosirella ansata (Hohn & Hellerman) Kingston								0.7%
Stephanodiscus hantzschii Grunow in Cleve & Grunow	24	14		20.1%	3.2%	1.4%	2.5%	
Stephanodiscus minutulus (Kutzing) Cleve & Moller	15	14		2.2%		2.8%	0.6%	1.5%
Stephanodiscus niagarae Ehrenberg	17	19	4.0%	14.4%				
Stephanodiscus vestibulus Hakansson, Theriot & Stoermer		16		1.4%				
Synedra filiformis var. *exilis* Cleve-Euler				0.7%				
Synedra ostenfeldii (Krieger) A. Cleve				1.4%				
Synedra rumpens var. *familiaris* (Kutzing) Hustedt					0.6%	4.3%		
Synedra ulna (Nitzsch) Ehrenberg	18		0.8%					
Synedra ulna var. *chaseana* Thomas		13			0.6%			
Tabellaria fenestrata (Lyngbye) Kutzing		11	6.5%					
Tabellaria flocculosa (Roth) Kutzing strain 3 of Koppen	12	23		1.4%		5.0%	12.7%	16.1 %
Tabellaria flocculosa (Roth) Kutzing strain 4 of Koppen			3.2%					

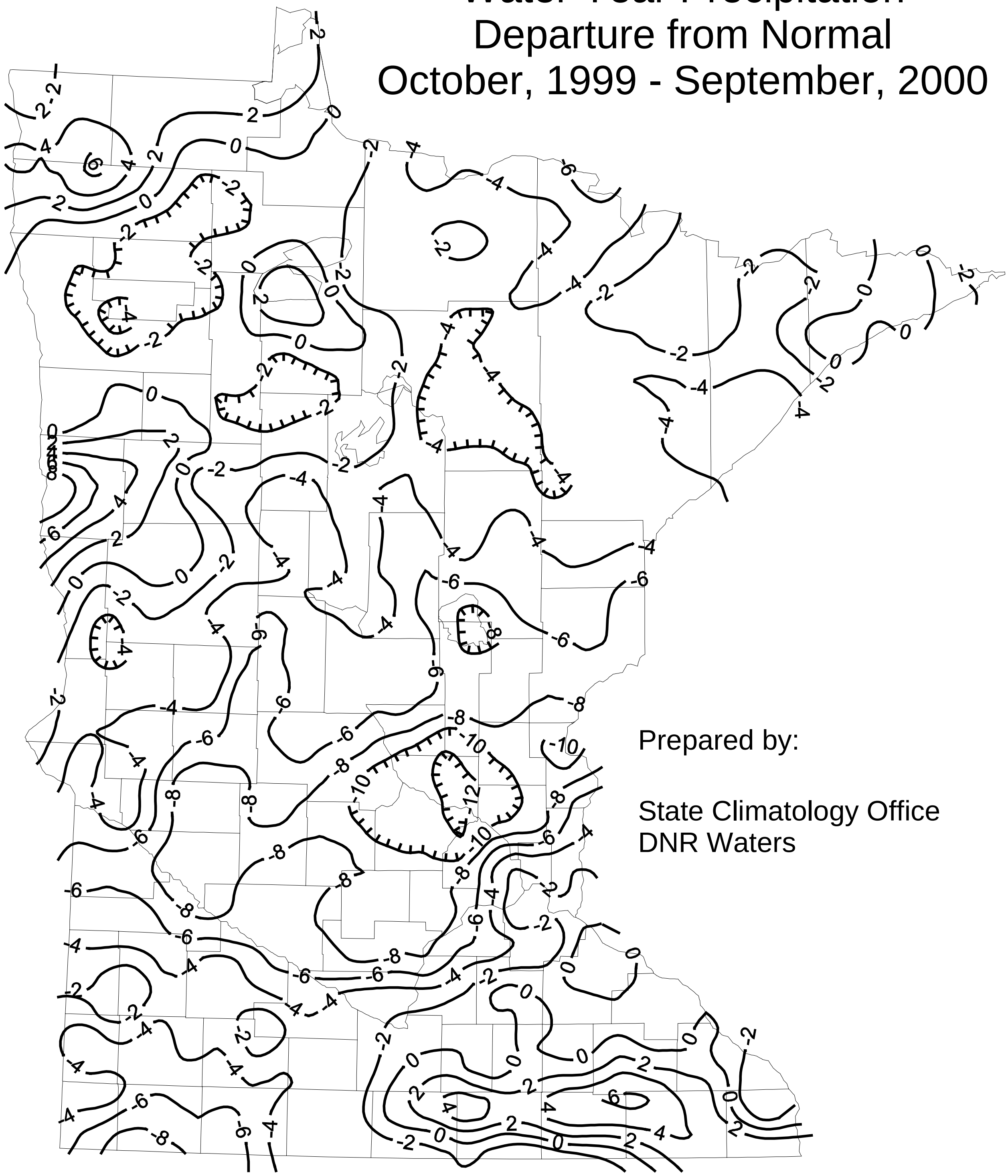
Appendix II. Climatic Data

Water Year Precipitation
October, 1999 - September, 2000



values are in inches

Water Year Precipitation
Departure from Normal
October, 1999 - September, 2000



Prepared by:

State Climatology Office
DNR Waters

values are in inches

Appendix III DNR Fisheries Data, 2000

Minnesota Department of Natural Resources, Division of Fisheries
2000 Lake Vermilion Fish Population Assessment

Lake Name:............................Vermilion
DOW Number:...........................69-0378
Location:.............................St. Louis Co., T 61-63, R 14-16
Nearest Town:.........................Tower MN and Cook MN
Major Watershed Unit:.................73 (Vermilion River)
Minor Watershed Unit:.................50
Lake Class (Schupp 1992):.............2
Management Classification.............Walleye
Surface Acres:........................40,557
Littoral Acres:.......................15,039 (37%)
Maximum Depth:........................76 ft.
Greatest Length:......................27.0 mi.
Length Of Shoreline:..................201.8 mi. (excluding island shoreline)
Maximum Fetch:........................8.4 mi.
Map ID:...............................B0272
Special Regulations:..................None
Resorts:..............................30
Marinas:..............................5
Campgrounds:..........................3
Private homes and cabins:.............2,300 (1995)
Current Stocking:.....................Walleye egg take site at Pike River
15,000,000 walleye fry annually
5,000 muskie biennially
Managed northern pike spawning area
Other Jurisdiction:...................U.S. Forest Service (Superior Forest)
Bureau of Land Management (70 islands)
Bois Forte Indian Reservation
1854 Treaty Authority

Table 1. Gillnet catch expressed as number/lift and pounds/lift, Lake Vermilion, 2000.

Gillnet Catch In Number/Lift (20 gillnet sets)

Historical Quartiles 1984-2000

Species	Total Number	Number Per Net	25% Quartile	50% Quartile	75% Quartile
Northern Cisco	378	18.9	9.3	11.8	14.5
Lake whitefish	11	0.6	0	0	0.1
Northern pike	12	0.6	0.6	1.0	1.2
White sucker	67	3.4	2.4	2.8	3.4
Brown bullhead	13	0.6	0.1	0.2	0.5
Rock bass	9	0.4	0.2	0.4	0.5
Pumpkinseed	1	0.1	0	0	0.1
Bluegill	13	0.6	0.4	0.6	1.0
Smallmouth bass	3	0.2	0.2	0.2	0.2
Black crappie	20	1.0	0.2	0.3	1.0
Yellow perch	733	36.6	20.9	28.8	35.0
Walleye	363	18.2	10.9	13.2	15.4

Gillnet Catch In Pounds/Lift (20 gillnet sets)

Historical Quartiles 1984-2000

Species	Total Pounds	Pounds Per Net	25% Quartile	50% Quartile	75% Quartile
Northern Cisco	300.8	15.0	6.4	8.4	10.8
Lake whitefish	26.3	1.3	0	0	0.2
Northern pike	80.9	4.0	2.8	3.8	5.6
White sucker	132.7	6.6	4.8	5.0	6.4
Brown bullhead	9.5	0.5	0.06	0.2	0.3
Rock bass	3.1	0.2	0.1	0.1	0.2
Pumpkinseed	0.1	0.01	0	0	0.01
Bluegill	3.7	0.2	0.1	0.1	0.2
Smallmouth bass	5.9	0.3	0.1	0.2	0.3
Black crappie	6.3	0.3	0.1	0.1	0.2
Yellow perch	200.4	10.0	4.6	6.2	7.9
Walleye	362.8	18.1	8.9	11.7	12.5

Gillnetting was conducted from 8/29/00 to 9/13/00.

Table 2. Length-frequency distribution of gillnetted fish, Lake Vermilion, 2000.

LENGTHS	TLC	LKW	NOP	WTS	BRB	RKB	BLG	BLC	YEP	WAE
04.0-4.4										
04.5-4.9							1	1		
05.0-5.4									26	
05.5-5.9						1			125	
06.0-6.4						1			86	
06.5-6.9							4	3	58	
07.0-7.4						5	6	4	61	2
07.5-7.9						1	1		56	8
08.0-8.4	1						1	3	44	2
08.5-8.9	7				1			2	82	8
09.0-9.4	24				1	1		6	57	10
09.5-9.9	36								52	16
10.0-10.4	4				2			1	44	7
10.5-10.9	4			2	2				24	7
11.0-11.4	16			2	2				15	21
11.5-11.9	30			4	4				3	30
12.0-12.9	116			4						42
13.0-13.9	105			1	1					55
14.0-14.9	32			5						52
15.0-15.9	3	2		7						36
16.0-16.9		5		12						15
17.0-17.9		1	1	13						8
18.0-18.9				11						16
19.0-19.9				5						9
20.0-20.9		1								9
21.0-21.9		2		1						4
22.0-22.9			1							1
23.0-23.9										1
24.0-24.9			1							2
25.0-25.9										
26.0-26.9			2							1
27.0-27.9										1
28.0-28.9			1							
29.0-29.9			2							
30.0+			4							
Total	378	11	12	67	13	9	13	20	733	363
Mean Length	12.2	17.7	28.9	16.2	11.0	7.3	7.0	8.1	7.8	13.8

Additional fish caught: 1 PMK - 5.4"
3 SMB - 13.7", 17.3", & 12.8"

Table 3. Trapnet catch expressed as number/lift and pounds/lift, Lake Vermilion, 2000.

Trapnet Catch In Number/Lift (29 trapnet sets)

Historical Quartiles 1987-2000

Species	Total Number	Number Per Net	25% Quartile	50% Quartile	75% Quartile
Northern pike	32	1.1	0.5	0.6	1.0
White sucker	3	0.1	0.1	0.2	0.2
Golden shiner	2	0.1	0	0.03	0.1
Brown bullhead	57	2.0	1.2	1.5	1.9
Rock bass	42	1.4	0.6	1.0	1.4
Pumpkinseed	48	1.7	1.0	1.8	2.9
Bluegill	783	27.0	17.8	24.9	34.3
Smallmouth bass	1	0.03	0.03	0.03	0.1
Largemouth bass	11	0.4	0.03	0.2	0.5
Black crappie	40	1.4	0.7	1.4	2.1
Yellow perch	284	9.8	7.8	8.8	12.4
Walleye	60	2.1	0.8	1.4	1.7

Trapnet Catch In Pounds/Lift (29 trapnet sets)

Historical Quartiles 1987-2000

Species	Total Pounds	Pounds Per Net	25% Quartile	50% Quartile	75% Quartile
Northern pike	66.9	2.3	1.3	1.6	2.2
White sucker	5.0	0.2	0.2	0.2	0.4
Golden shiner	0.2	0.01	0	0.003	0.01
Brown bullhead	52.6	1.8	0.9	1.2	1.7
Rock bass	11.1	0.4	0.1	0.2	0.3
Pumpkinseed	5.2	0.2	0.2	0.2	0.3
Bluegill	108.1	3.7	3.6	4.6	5.7
Smallmouth bass	0.8	0.03	0.003	0.01	0.03
Largemouth bass	3.8	0.1	0.02	0.1	0.1
Black crappie	16.6	0.6	0.4	0.6	1.0
Yellow perch	73.2	2.5	1.2	1.6	2.0
Walleye	67.1	2.3	0.8	1.4	1.7

Trapnetting was conducted from 8/1/00 to 8/8/00.

Table 4. Length-frequency distribution of trapnetted fish, Lake Vermilion, 2000.

LENGTHS	NOP	WTS	BRB	RKB	PMK	BLG	LMB	BLC	YEP	WAE
00.1-2.9						1				
03.0-3.4					3	10				

LENGTHS	NOP	WTS	BRB	RKB	PMK	BLG	LMB	BLC	YEP	WAE
03.5-3.9				1	6	85		3		
04.0-4.4				3	10	141		1	1	
04.5-4.9				2	4	88	2		12	
05.0-5.4				3	12	72			22	
05.5-5.9					7	108			19	
06.0-6.4				5	5	100		2	23	
06.5-6.9				10	1	88		2	29	2
07.0-7.4				8		46	3	2	35	1
07.5-7.9			1	6		27	1	3	32	2
08.0-8.4				1		12	2	3	18	1
08.5-8.9				3		4	1	7	27	
09.0-9.4			5			1		7	21	1
09.5-9.9			4					2	19	4
10.0-10.4			2						12	4
10.5-10.9			7					3	11	5
11.0-11.4			12					1	3	5
11.5-11.9			2					3		3
12.0-12.9			7				2	1		3
13.0-13.9			11							4
14.0-14.9	1		6							3
15.0-15.9		2								7
16.0-16.9	2	1								1
17.0-17.9										4
18.0-18.9	2									3
19.0-19.9	7									
20.0-20.9	6									3
21.0-21.9	3									2
22.0-22.9	2									
23.0-23.9	4									
24.0-24.9	1									
25.0-25.9	2									1
26.0-26.9	2									1
27.0-27.9										
Total	32	3	57	42	48	783	11	40	284	60
Mean Length	21.1	15.7	11.7	6.7	4.9	5.5	8.1	8.5	7.6	13.7

Additional fish caught: 2 GOS - 5.2" & 5.7"
1 SMB - 11.5"

Table 5. Shoreline seine catch and growth of young-of-the-year gamefish, Lake Vermilion, 2000.

Seine Catch In Number/Haul (60 hauls)

Historical Quartiles 1984-2000

Species	Total Number	Number Per Haul	25% Quartile	50% Quartile	75% Quartile
YOY Bluegill	0	0	0	0.05	2.8
YOY Smallmouth bass	125	2.1	1.0	2.3	4.2
YOY Largemouth bass	1	0.02	0.2	0.9	3.8
YOY Black crappie	66	1.1	0.9	5.0	7.1
YOY Yellow perch	4,532	75.5	72.9	261.9	488.1
YOY Walleye	358	6.0	1.6	2.7	12.4

Mean Length Of Selected Species Sampled The Fourth Week Of July

			Historical Quartiles 1984-2000		
Species	Number Sampled	Mean Length	25% Quartile	50% Quartile	75% Quartile
YOY Yellow perch	277	1.59	1.55	1.61	1.76
YOY Walleye	3	2.99	2.83	3.42	4.00

Seining was conducted at 15 standard sampling stations once a week during the month of July, for a total of 60 seine hauls.

Seining the first week was done July 3 and 5.
Seining the second week was done July 10 and 11.
Seining the third week was done July 18 and 20.
Seining the fourth week was done July 24 and 25.

Table 6. Electrofishing catch and growth of young-of-the-year walleye, Lake Vermilion, 2000.

Electrofishing Catch Of YOY Walleye In Number/Hour (9 Stations)

			Historical Quartiles 1988-2000		
	Total Number	Number Per Hour	25% Quartile	50% Quartile	75% Quartile

YOY Walleye Catch	256	85.3	71.6	118.3	163.9

Mean Length Of YOY Walleye Sampled By Electrofishing

			Historical Quartiles 1988-2000		
	Total Number	Mean Length	25% Quartile	50% Quartile	75% Quartile
YOY Walleye Mean Length	256	4.71	4.82	5.36	5.60

The electrofishing assessment for YOY walleye was conducted from 9/21/00 to 9/26/00.

Electrofishing effort consisted of a 20 minute run at each of 9 standard sampling stations, for a total effort of 180 minutes or 3 hours.

Summary of 2000 Lake Vermilion Assessment

Fall Gillnetting

The 2000 walleye gillnet catch was 18.2 fish/net, the highest catch ever observed on Lake Vermilion. Walleye gillnet catches have been higher than the long term mean for the last five years. High walleye catches in recent years were due to strong year classes produced in 1994, 1995 and 1997. The 1998 year class also appears to be stronger than average. Poor year classes were produced in 1992 and 1993. Angling prospects for walleye in the year 2000 are good. Above average numbers of walleye were sampled in the 12.0-15.9 inch length increments, the size range that dominates the walleye harvest on Lake Vermilion. The mean length of gillnetted walleye was 13.8 inches, the largest average size ever observed on Lake Vermilion.

The gillnet catch of northern pike was 0.6 fish/net, slightly below the historical median. Northern pike reproduction has been relatively consistent from year to year. Yellow perch had a gillnet catch of 36.6 fish/net, well above the historical median. Strong year classes of perch were produced in 1994, 1995, and 1997. The cisco catch was 18.9 fish/net, well above the historical median.

Summer Trapnetting

The trapnet catch of bluegill was 27.0 fish/net, slightly above the historical median. Bluegill catches have been relatively stable since 1998. Strong year classes were produced in 1995 and 1997. Trapnetted bluegill had a mean length of 5.5 inches, well below the historical median.

The trapnet catch of black crappie was 1.4 fish/net, which was also the historical median. Crappie numbers on Lake Vermilion are generally low with occasional population spikes in response to strong year classes. Moderately strong year classes were produced in 1994, 1995, and 1997. The mean length of trapnetted crappie was 8.5 inches, slightly above the historical median.

Seining

The seine catch of YOY walleye was of 6.0 fish/haul. The catch was well above the historical median, however CPUE has not proven to be a reliable indicator of year class strength. The mean length of YOY walleye sampled the last week of July was 2.99 inches, well below the historical median. Mean length of YOY walleye has shown strong correlation to eventual year class strength on Lake Vermilion, indicating the 2000 year class may be below average in strength. The sample size of YOY walleye for the fourth week of July was only three fish.

The seine catch of yellow perch was 75.5 fish/haul, well below the historical median. The mean length of YOY yellow perch sampled the last week of July was 1.59 inches, which is near the historical median.

Fall Electrofishing (YOY Walleye)

The fall electrofishing catch of YOY walleye was 85.3 fish/hour, well below the historical median. It was the second straight year of low YOY walleye catches. YOY walleye had a mean length of 4.71 inches, well below the historical median. Both CPUE and mean length indicate the 2000 year class may be below average in strength.

Spring Electrofishing (Smallmouth Bass)

Spring elctrofishing for smallmouth bass was not done in 2000, due to poor weather and overtime constraints.