Lake Water Quality Assessment for Lake Tschida Grant County, North Dakota

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SUMMARY

Lake Tschida is a Bureau of Reclamation project built in 1948-1994 as an irrigation storage reservoir. The reservoir is located approximately 17 miles south of Glen Ullin on the Heart River in northwestern Grant County. The reservoir and contributing watershed lie within the Missouri Slope Uplands physiographic region of North Dakota. The Missouri Slope Uplands are composed primarily of rolling hills and uplands. At full pool, Lake Tschida covers approximately 5,018 acres, with a maximum depth of 64 feet and an average depth of 27.9 feet (Figure 1).

Land use in the watershed surrounding Lake Tschida is primarily small grain and livestock production. Soils in the watershed are moderately fertile to fertile, well-drained and susceptible to wind and water erosion. Annual precipitation ranges from 14 to 16 inches with between 80 and 90 percent of the precipitation occurring between April and September. Other industries within the Heart River drainage include coal and oil extraction/exploration.

Lake Tschida is classified as a cool water fishery, i.e., "waters capable of supporting growth and propagation of nonsalmonoid fishes and marginal growth of salmonoid fishes and associated aquatic biota." (NDDoH, 2001) The North Dakota Game and Fish Department (NDGF) manages Lake Tschida's fishery by annually assessing the fish community through test netting and stocking/restocking appropriately.

In recent years, the stocking regimen has included northern pike, walleye, yellow perch, bluegill and smallmouth bass. Test-netting operations capture an assortment of species including black crappie, yellow perch, bluegill, bullhead, smallmouth bass, river carp sucker, walleye, spottail shiner, white sucker, common carp, orange spotted sunfish, white bass, channel catfish, fathead minnow, greater red ears, largemouth bass and goldeye. As evidenced by the number of species captured, Lake Tschida is a highly diverse sport fishery.

Lake Tschida receives heavy recreational use during the ice-free period and moderate use during the winter months. Recreational facilities include five public use areas containing boat ramps, rest rooms and drinking water sources. Private developments along Lake Tschida include more than 116 cabins and 122 trailers located on the north and south shores. Also adjacent to Lake Tschida are hundreds of acres of public lands management by the NDGF for outdoor recreation.

WATER QUALITY

Water quality samples were collected from Lake Tschida during the summers of 1992 and 2000 and winters of 1993 and 2001 as part of the Lake Water Quality Assessment project (LWQA). Samples were collected at one sample site located near the dam over the deepest area of the lake in 1992-1993 due to low-water conditions resulting from an extended drought. In 2000-2001, two additional sites were added representing the mid-point and inlet areas of the reservoir. Sampling locations are graphically displayed in Figure 160.

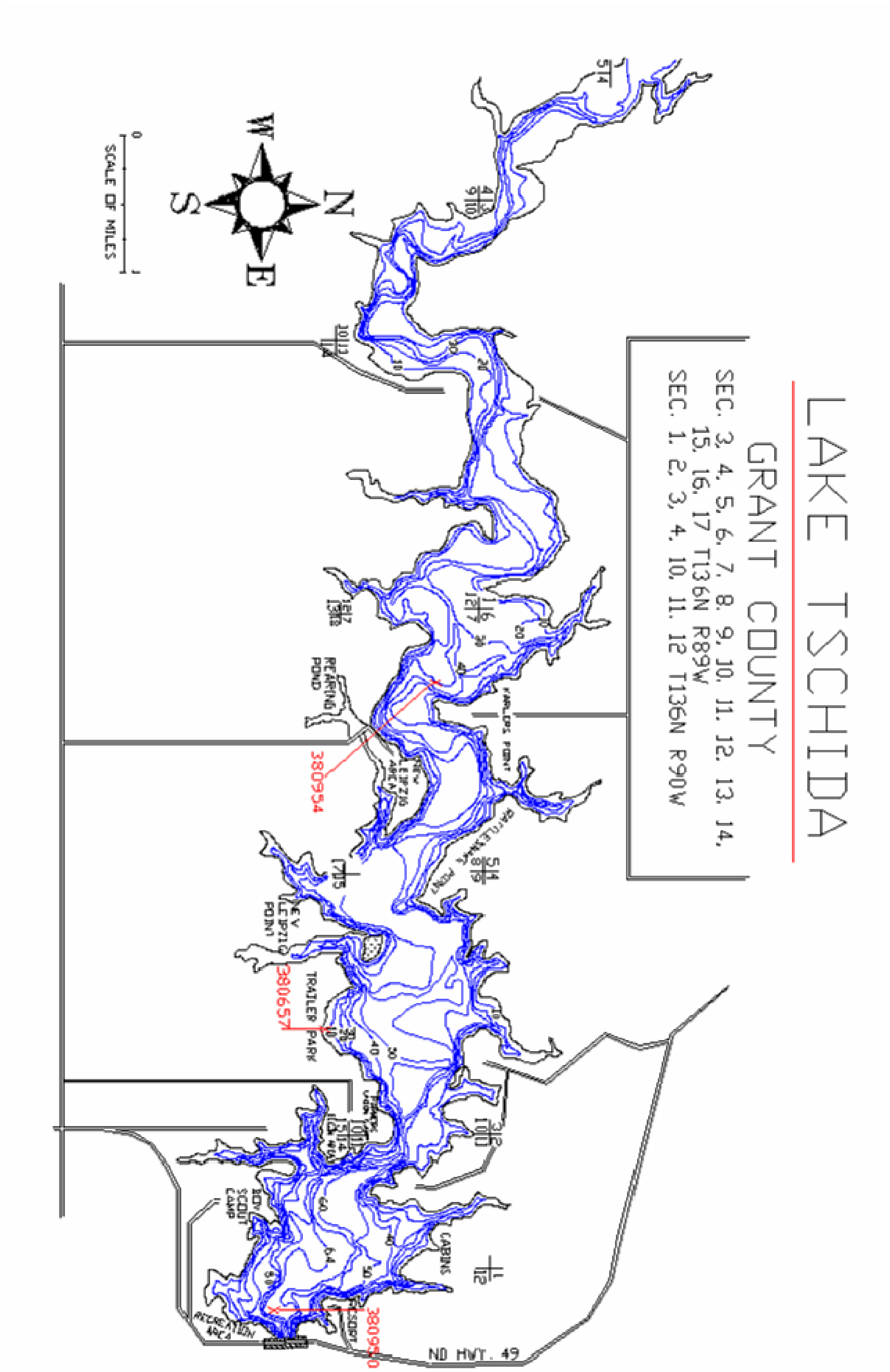

Figure 1. Map of Lake Tschida

Water quality water column samples were collected at three depths at the dam and mid-lake sites (representing the epilimnion, metalimnion and hypolimnion) and at the one-meter depth at the inlet site. Samples were collected twice during the summer of 1992, once during the winter of 1992-1993, four times during the summer of 2000 and once during the winter in 2000-2001. During the winter of 2001, samples were only collected at the dam and mid-lake sites due to unsafe ice conditions in the inlet area.

The chemical and physical data collected during the 2000-2001 LWQA project defined Lake Tschida as a mesoptrophic, well-buffered water body that rarely thermally stratifies. This is different than the 1992-1993 assessment which classified Lake Tschida as a well-buffered eutrophic water body. The variations in water chemistry and improvement in biological response and nutrient availability is most likely due to the increase in lake volume and decrease in lake residence time between the water years of 1992-1993 and 2000-2001.

Comparable total dissolved solids concentrations were higher in 2000-2001 than in 1992-1993, but the phosphorus on average was lower (Tables 1, 2 and 3). Concentrations of total alkalinity as $CaCO_3$ in 2000-2001 ranged from 271 milligrams per liter (mg/L) to 355 mg/L with volume-weighted means of 288 mg/L in the deepest area, 285 mg/L at mid-lake and 304 mg/L in the inlet area, representing a slight drop in the alkalinity concentrations range from 1992-1993.

Sulfates and bicarbonates were the dominant anions in the water column in both 1992-1993 and 2000-2001. Sulfate concentrations were approximately 11 percent higher in 2000-2001 than 1992-1993, while bicarbonate concentrations were very similar. In 1992-1993, sulfate concentrations ranged between 446 mg/L and 649 mg/L, and bicarbonates ranged between 307 mg/L and 496 mg/L. In 2000-2001, sulfate concentrations ranged between 660 mg/L and 839 mg/L, while bicarbonates ranged between 305 mg/L and 433 mg/L.

The total phosphate as phosphate concentrations ranged between 0.024 mg/L and 0.063 mg/L in 2000-2001and 0.038 mg/L and 0.155 mg/L in 1992-1993, representing a significant reduction in available phosphorus. In both 1992-1993 and 2000-20001, the reported concentrations of total phosphorus as phosphate exceeded the state's target concentrations of 0.02 mg/L in all samples analyzed but stayed under the 1995-2001 long-term average of 0.152 mg/L.

Overall concentrations of nitrate plus nitrite as nitrogen concentrations increased in 2000-2001 from 1992-1993. Nitrate plus nitrite as nitrogen concentrations increased from 0.012 mg/L to 0.470 mg/L in 1992-1993 and from 0.01 mg/L to 0.290 mg/L exceeding the state's target concentration of 0.25 mg/L only once on July 19, 2000. The increase in concentrations of nitrate plus nitrite as nitrogen is due to the reduction in total phosphorus concentrations and a return to a more balanced nutrient ratio.

Table 1. Lake Tschida Near Dam - Volume-Weighted Mean Water Chemistry Concentrations for Selected Parameters Reported During the 1992-1993 and 2000-2001 LWQA Projects and the Arithmetic Mean for all North Dakota Lakes Sampled Between 1995 and 2001

Parameter	1992-1993 Volume-Weighted Mean	2000-2001 Volume-Weighted Mean	1995-2001 North Dakota Mean
Total Dissolved Solids	1100 mg/L	1273 mg/L	1545 mg/L
Hardness as Calcium	325 mg/L	454 mg/L	474 mg/L
Sulfates as SO_4	513 mg/L	694 mg/L	785 mg/L
Chlorides	18 mg/L	12.4 mg/L	64 mg/L
Total Alkalinity as $CaCO_3$	324 mg/L	288 mg/L	229 mg/L
Bicarbonate	359 mg/L	327 mg/L	274 mg/L
Conductivity	1652 umhos/cm	1794 umhos/cm	1984 umhos/cm
Total Phosphorus as PO_4	0.074 mg/L	0.042 mg/L	0.152 mg/L
Nitrate + Nitrite as N	0.076 mg/L	0.113 mg/L	0.117 mg/L
Total Ammonia as N	0.164 mg/L	0.047 mg/L	0.272 mg/L
Total Kjeldahl Nitrogen	1.870 mg/L	0.717 mg/L	1.775 mg/L

Table 2. Lake Tschida Mid-Lake - Volume-Weighted Mean Water Chemistry Concentrations for Selected Parameters Reported During the 2000-2001 LWQA Projects and the Arithmetic Mean for all North Dakota Lakes Sampled Between 1995 and 2001

Parameter	2000-2001 Volume-Weighted Mean	1995-2001 North Dakota Mean
Total Dissolved Solids	1285 mg/L	1545 mg/L
Hardness as Calcium	462 mg/L	474 mg/L
Sulfates as SO_4	702 mg/L	785 mg/L
Chlorides	12.4 mg/L	64 mg/L
Total Alkalinity as $CaCO_3$	285 mg/L	229 mg/L
Bicarbonate	319 mg/L	274 mg/L
Conductivity	1797 umhos/cm	1984 umhos/cm
Total Phosphorus as PO_4	0.030 mg/L	0.152 mg/L
Nitrate + Nitrite as N	0.094 mg/L	0.117 mg/L
Total Ammonia as N	0.042 mg/L	0.272 mg/L
Total Kjeldahl Nitrogen	0.682 mg/L	1.775 mg/L

Table 3. Lake Tschida Inlet Area - Mean Water Chemistry Concentrations for Selected Parameters Reported During the 2000-2001 LWQA Projects and the Arithmetic Mean for all North Dakota Lakes Sampled Between 1995 and 2001

Parameter	2000-2001 Mean	1995-2001 North Dakota Mean
Total Dissolved Solids	1393 mg/L	1545 mg/L
Hardness as Calcium	469 mg/L	474 mg/L
Sulfates as SO_4	768 mg/L	785 mg/L
Chlorides	13.9 mg/L	64 mg/L
Total Alkalinity as $CaCO_3$	304 mg/L	229 mg/L
Bicarbonate	325 mg/L	274 mg/L
Conductivity	1933 umhos/cm	1984 umhos/cm
Total Phosphorus as PO_4	0.060 mg/L	0.152 mg/L
Nitrate + Nitrite as N	0.020 mg/L	0.117 mg/L
Total Ammonia as N	0.090 mg/L	0.272 mg/L
Total Kjeldahl Nitrogen	0.880 mg/L	1.775 mg/L

LIMITING NUTRIENT

The primary nutrients driving the trophic response within Lake Tschida are nitrogen and phosphorus. For purposes of this assessment, nutrient limitation is identified by comparing the ratio of total nitrogen to total phosphorus (N:P). When the N:P ratio is 15, the nutrients are considered in equilibrium. A ratio greater than 15 indicates that phosphorus is limiting, and a ratio of less than 15 indicates that nitrogen is limiting. Of note, when nitrogen becomes the conservative nutrient, primary production is rarely limited. Instead, this is a state that favors primary producers that are able to affix nitrogen or are tolerant of low-nitrogen conditions.

The 1992-1993 N:P ratios ranged from 7 to 27 with an average of 14.5, indicating that during major periods of time there was an abundant supply of phosphorus for primary production. This situation improved dramatically in 2000-2001 when the range increased to 10 to 33 with average ratios of 17 at the inlet, 26 at mid-lake and 21 near the dam (Figures 2 and 3).

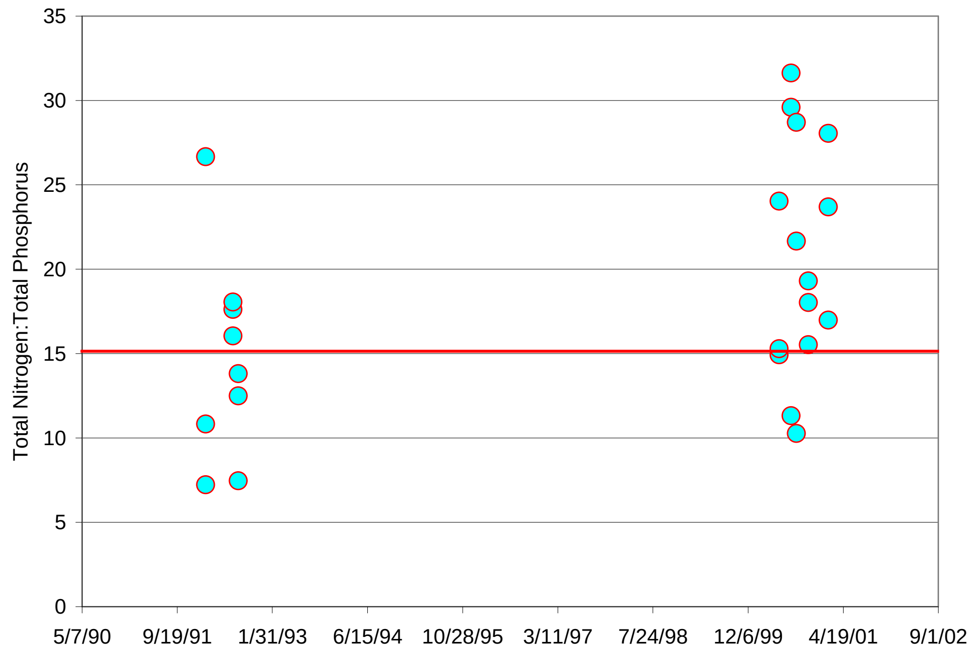

Figure 2. Lake Tschida Near Dam Total Nitrogen to Total Phosphorus Ratios 1992-1993 and 2000-2001

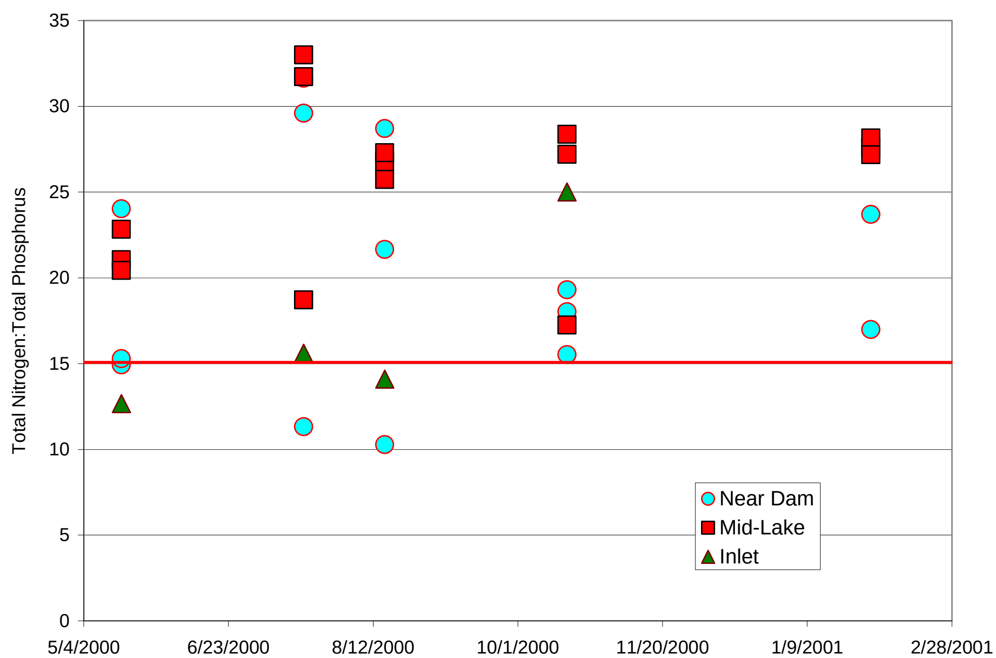

Figure 3. Lake Tschida Near Dam, Mid-Lake and Inlet Area Total Nitrogen to Total Phosphorus Ratios 2000-2001

TEMPERATURE AND OXYGEN

Temperature profiles collected during the 2000-2001 LWQA Project (Figures 4, 8 and 10) indicate Lake Tschida rarely thermally stratifies. This assumption is supported by the 1992-1993 LWQA data as well (Figure 6). Of the three temperature profiles collected in 1992-1993 and five sets in 2000-2001, only once during July 2001 was Lake Tschida thermally stratified (Figure 4). Oxygen profiles collected during the 2000-2001 LWQA indicate that Lake Tschida is well-oxygenated above the metalimnion with rapid oxygen depletions below the metalimnion (Figures 5, 7, 9, and 11).

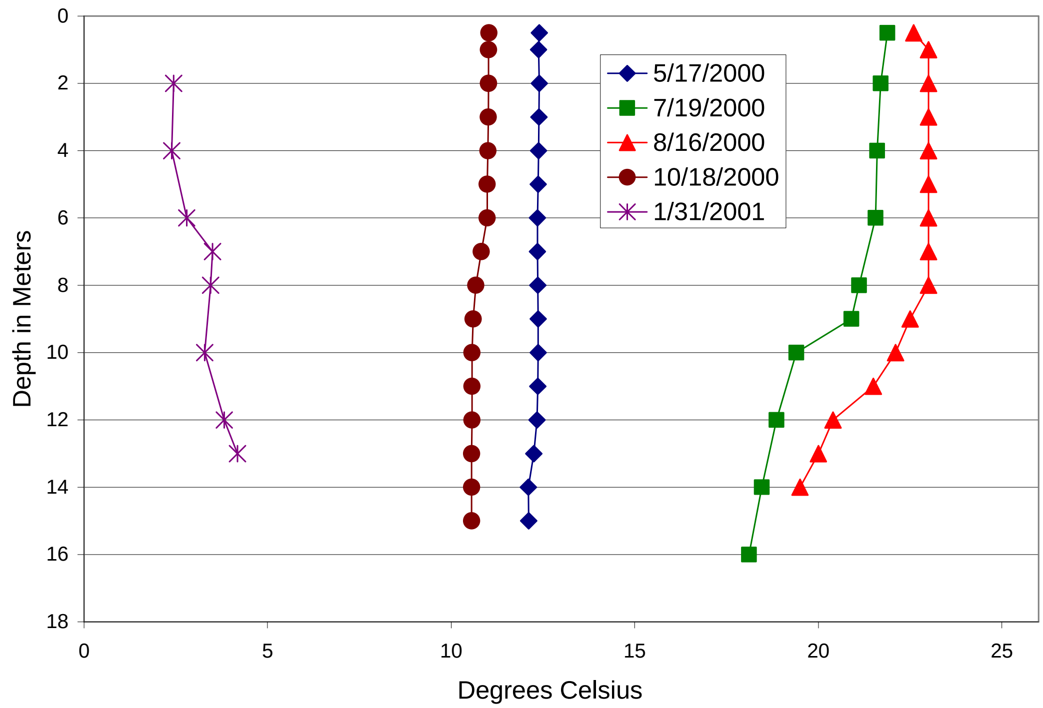

Figure 4. Lake Tschida Near Dam Temperature Profiles 2000-2001

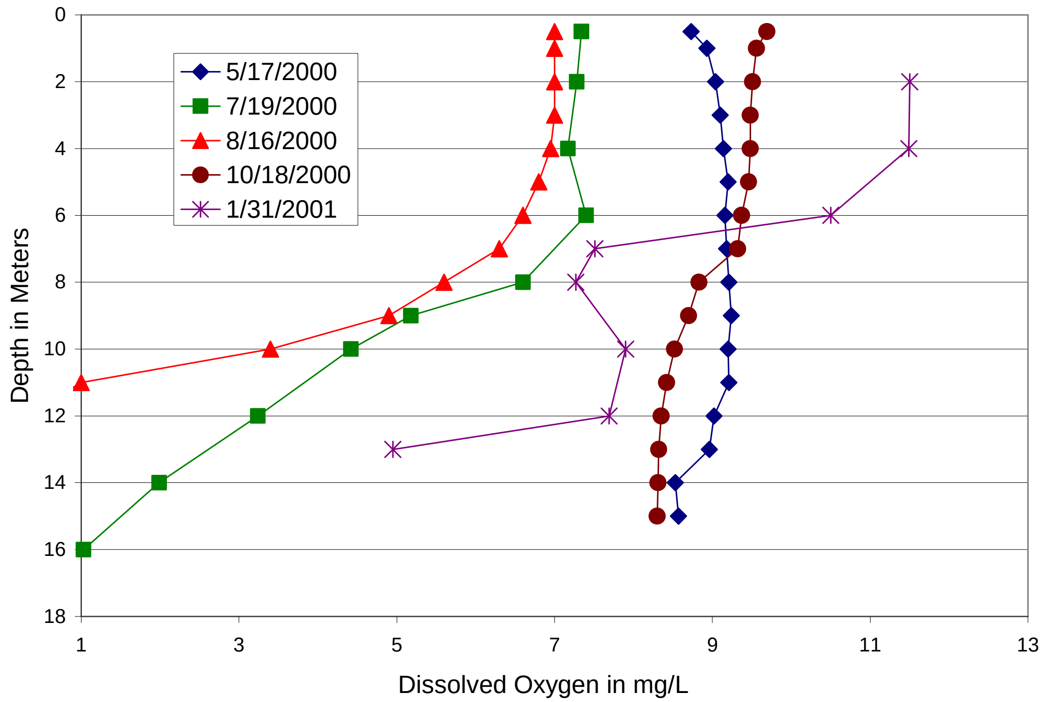

Figure 5. Lake Tschida Near Dam Dissolved Oxygen Profiles 2000-2001

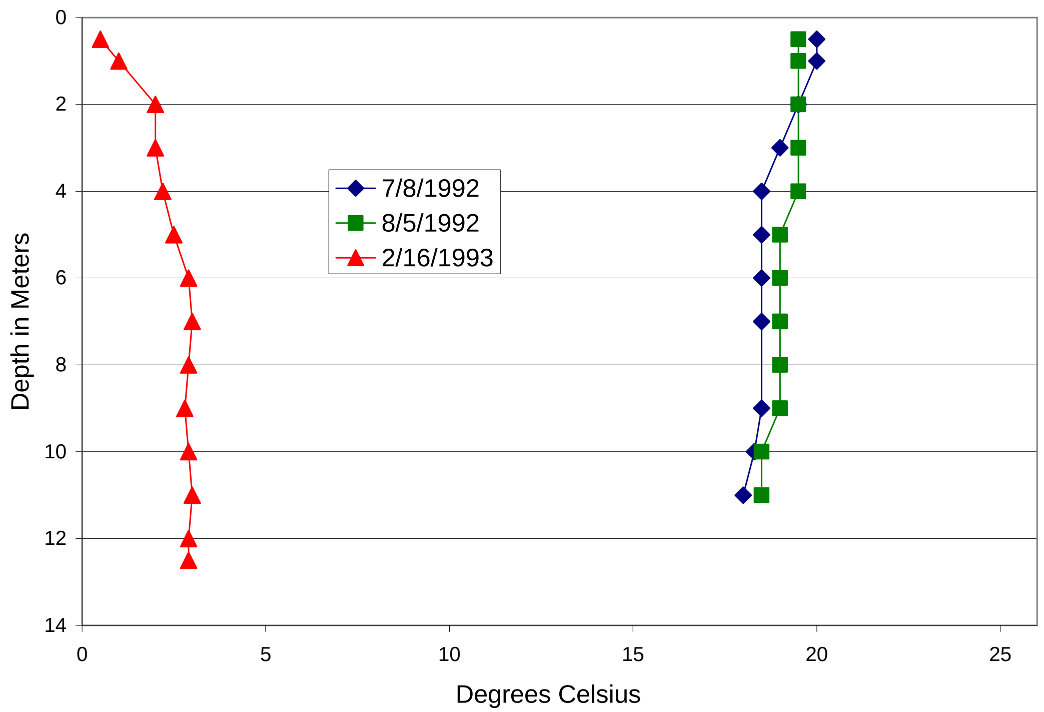

Figure 6. Lake Tschida Near Dam Temperature Profiles 1992-1993

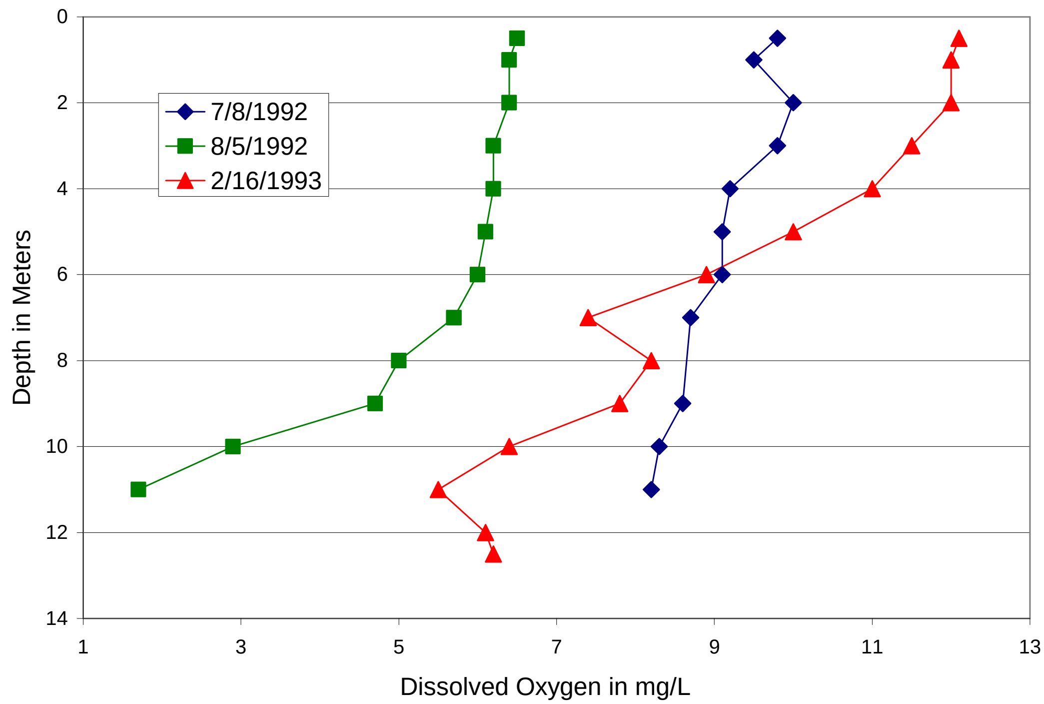

Figure 7. Lake Tschida Near Dam Dissolved Oxygen Profiles 1992-1993

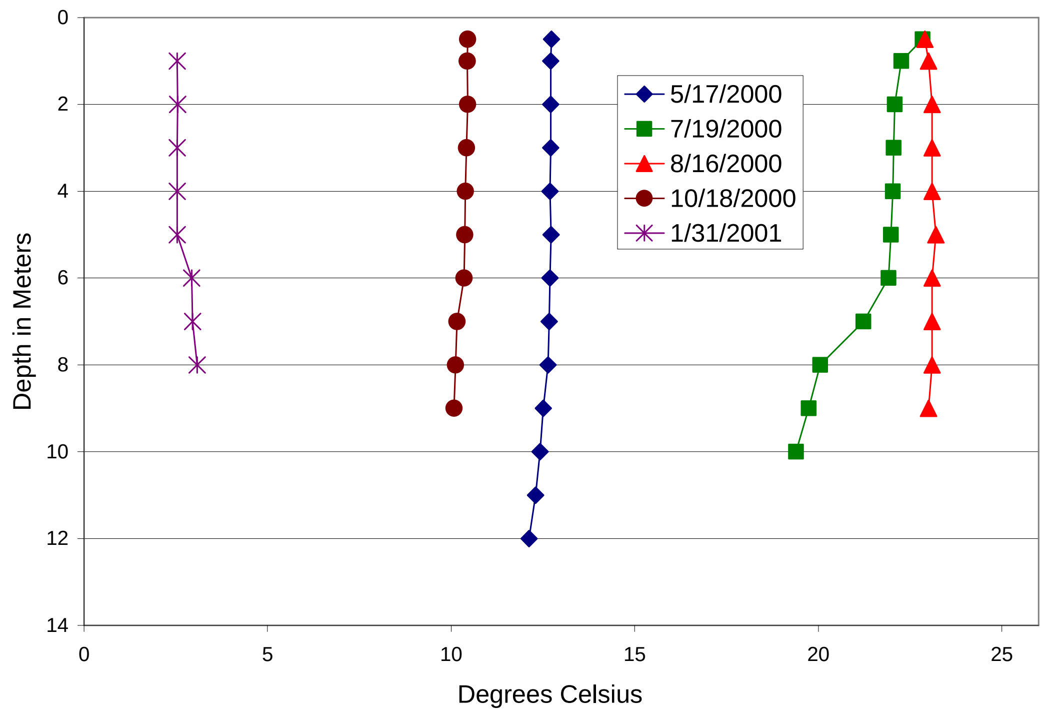

Figure 8. Lake Tschida Mid-Lake Temperature Profiles 2000-2001

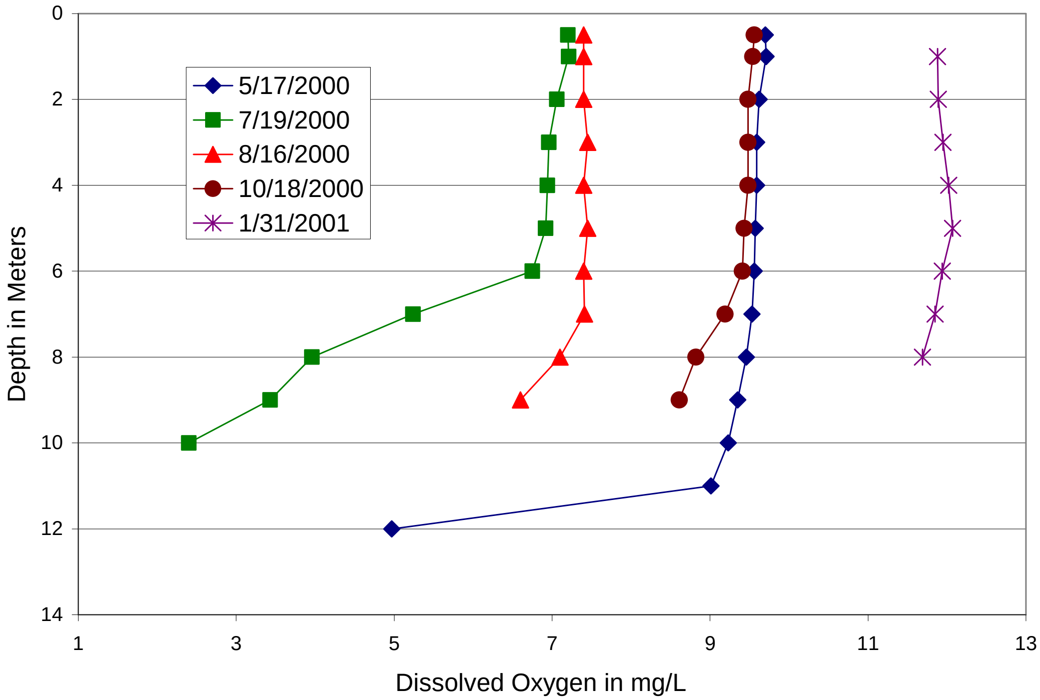

Figure 9. Lake Tschida Mid-Lake Dissolved Oxygen Profiles 2000-2001

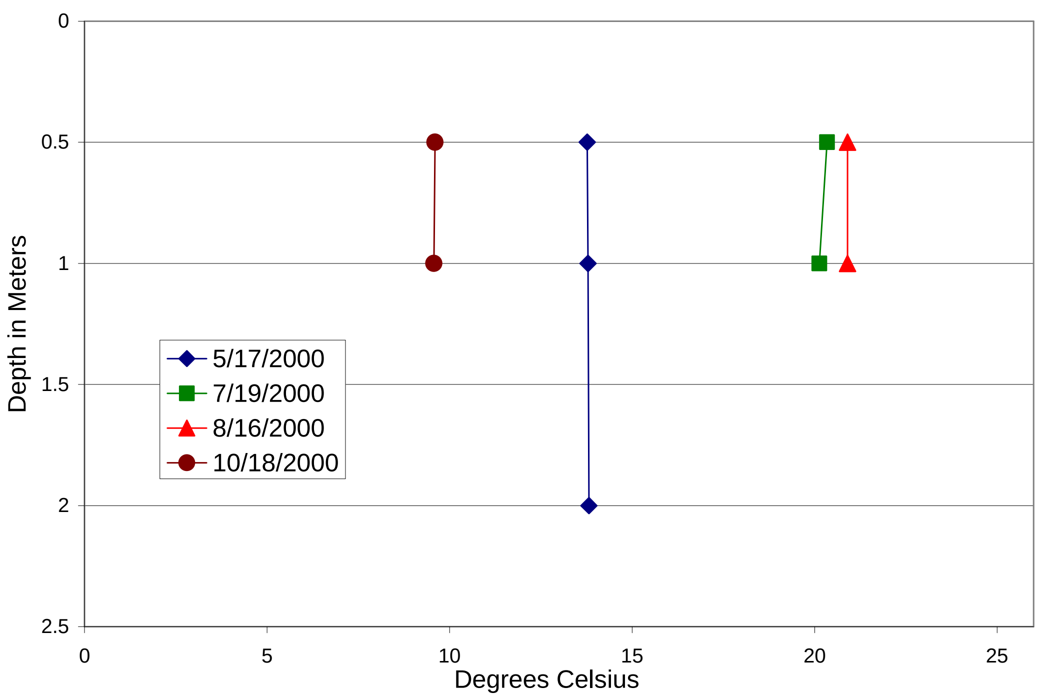

Figure 10. Lake Tschida Inlet Area Temperature Profiles 2000

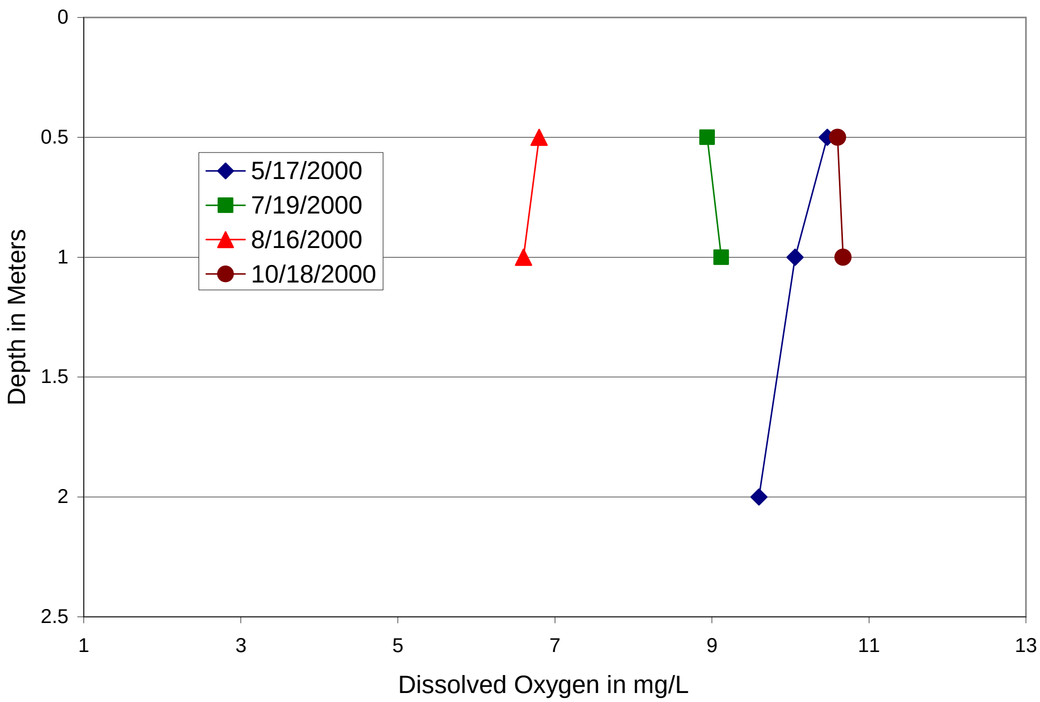

Figure 11. Lake Tschida Inlet Area Dissolved Oxygen Profiles 2000

TROPHIC STATUS

Water quality data collected during the 1992-1993 LWQA Project indicated that Lake Tschida at the near-dam site was eutrophic. The 2000-2001 assessment indicated a much improved trophic status of mesotrophic. Both assessments are based on three primary indicators: secchi disk transparency, chlorophyll-a and summer surface total phosphate concentrations. In 2000-2001, these same indicators identified Lake Tschida as mesotrophic in the mid-lake areas and hypereutrophic in the inlet area.

This project estimated trophic status using Carlson's Trophic Status Index (TSI) (Carlson 1977). Carlson's TSI was selected because of its common use among limnologists and because it was developed for lakes in Minnesota, a state close to North Dakota geographically. Carlson's TSI uses a mathematical relationship based on secchi disk transparency, concentrations of total phosphorus at the surface and chlorophyll-a concentrations. This numerical value then corresponds to a trophic condition ranging from 0 to 100 with increasing values indicating a more eutrophic condition (Figure 12).

Supporting ancillary information of a eutrophic assessment in 1992-1993 included frequent nuisance algal blooms and a phytoplankton community dominated by blue-green algal species. In 2000-2001, data supporting a mesotrophic condition for the near-dam and mid-lake areas was a reduction in the frequency and severity of algal blooms and low macrophyte biomass. Ancillary data supporting a hypereutrophic condition in the inlet area in 2000-2001 was the constant presence of algae as well as suspended organic matter and an unpleasant smell.

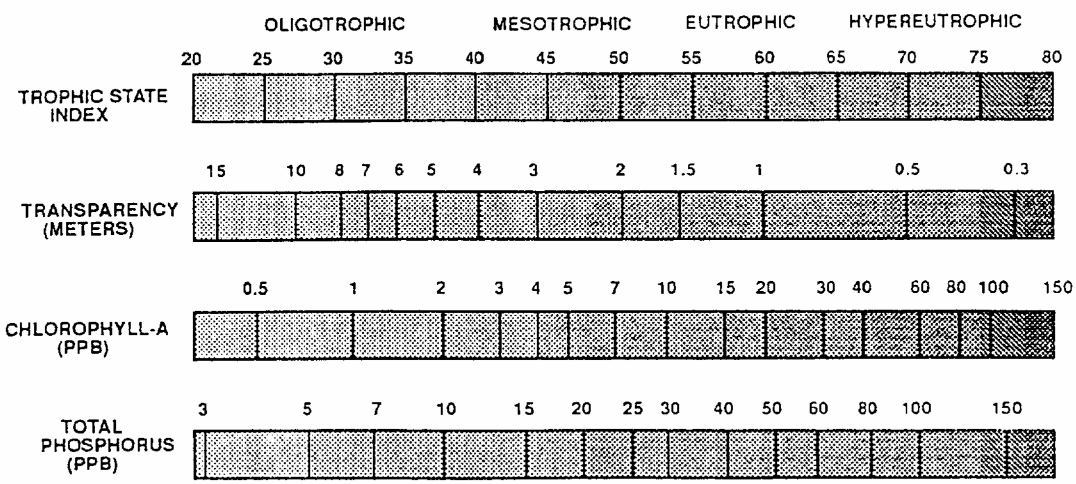

Figure 12. Graphic Depiction of Carlson's Trophic Status Index.

PHYTOPLANKTON

Lake Tschida's phytoplankton community was sampled twice during the summer of 1992. The two samples collected contained representation from four divisions and nine genera. The largest contributors to the phytoplankton community by numerical density were the blue-green algae, Cyanophyta, with four genera present.

Mean numerical density of blue-green algae for the two samples collected during the summer of 1992 was 137,473 cells per milliliter, representing a dominance of 76-fold over all other divisions combined. Other divisions represented in the phytoplankton community in descending order of numerical dominance were Chlorophyta, Cryptophyta and Bacillariophyta.

The phytoplankton community by volume was also dominated by blue-green algae. Blue-green algae occupied more than 99 percent of the phytoplankton community by volume, representing a 145-fold dominance over all other divisions combined.

SEDIMENTS

Sediments were collected from Lake Tschida and analyzed for trace elements, PCBs and selected pesticides (Table 4). Sediments were collected at the deepest area of lake, a littoral area and as far upstream as was possible to travel by boat. Sediment sampling sites are represented by the identification numbers 380950, 380657 and 380954 in Figure 1.

Table 4. List of Analytes Completed for Sediment and Whole Fish Samples Collected from Lake Tschida in 1992

Analyte	Analyte	Analyte
Aluminum (Al)	Manganese (Mn)	Iron (Fe)
Copper (Cu)	Zinc (Zn)	Barium (Ba)
Chromium (Cr)	Lead (Pb)	Mercury (Hg)
Hoelon	2-4-D	Dicamba
Dinoseb	MCPA	Tordon
2-4-5-T	Silvex	Pentachlorobenzoic Acid
Bromoxynil	Dichloprop	Bentazon

Sediment samples collected from Lake Tschida contained detectable levels of all trace elements tested for with the exceptions of (1) mercury in the deepest and littoral area sediments and (2) selenium in the inlet area sediments. Reported trace element concentrations in the sediment samples collected from Lake Tschida were compared to the reported concentrations for all lakes assessed in the LWQA Project to that time.

In general, trace element concentrations were near or above the 75th percentile for all lakes sampled but below the maximum reported. The exceptions were (1) mercury, selenium and chromium in the inlet area sediments and (2) chromium and selenium in the deepest area sediments which were near or below the median. Reported concentrations of selected pesticides and PCBs were below detectable limits for all samples collected from Lake Tschida.

WHOLE FISH

Fish were collected from Lake Tschida in 1991-1992, composited by species, ground whole and analyzed for a suite of trace elements, PCBs and organic compounds (Table 4). Species captured were white bass, channel catfish, common carp, white sucker, yellow perch and walleye.

In general, reported trace element concentrations in the whole fish samples from Lake Tschida were near or below the 25th percentile when compared to concentrations reported for whole fish analyzed in the LWQA Project. The exceptions were the selenium and mercury concentrations which were above the median and close to the 75th percentile.

Detectable pesticide residues found in the fish collected from Lake Tschida were DDD and DDE. DDD and DDE are breakdown derivatives of the agricultural insecticide DDT. DDT was banned in 1973 because of its harmful effects on the environment. Concentrations of DDE and DDD were found in only about half of the samples analyzed and were near the detection level closely approximating the median concentration of all whole fish analyzed during the LWQA Project.

WATERSHED

Lake Tschida and its contributing watershed have a surface area of 995,102 acres located on the Missouri Slope Uplands in portions of Grant, Hettinger, Morton and Stark Counties, North Dakota. The watershed is composed primarily of rolling to hilly uplands except in badland areas and near prominent buttes. Slopes are generally gentle and reliefs range from 50 to 300 feet with few exceeding 100 feet. Drainages are generally well defined in the form of intermittent and perennial streams. Few shallow aquifers exist in the Lake Tschida watershed other than along stream drainages.

Soils in the watershed are moderately deep to shallow, formed from weathered, loamy glacial till or soft bedrock. In general, soils are moderately fertile to fertile, well drained and susceptible to wind and water erosion. Average precipitation in the Lake Tschida watershed ranges from 14 to 16 inches, with between 80 and 90 percent of the annual precipitation occurring between April and September.

A small percentage of the Lake Tschida watershed is composed of badlands. Badlands are eroded formations composed of buttes and steeply eroded drainages. Badland soils are generally thin and formed from sandy and clayey materials. Badland areas are highly susceptible to wind and water erosion.

Land use within the Lake Tschida watershed is approximately 95 percent agricultural, with 47 percent actively cultivated. The remaining 38 percent of agricultural lands are either in pastures, haylands or concentrated feeding areas. The 5 percent of the watershed that is not in agricultural use is in wetland and wildlife management, roads and small urban developments (Table 5).

Within the Lake Tschida watershed, there are three small rural municipalities, one point source discharge at the city of Gladstone, 886 farms and 791 concentrated livestock feeding areas. The city of Gladstone has a North Dakota Department of Health wastewater discharge permit. Due to the regulations imposed upon this release site and the distance the discharge location is from the reservoir, it poses only a minimal threat to the water quality of Lake Tschida. However, the concentrated livestock feeding areas, construction and other activities within the watershed do pose a significant risk due to their ability to deliver a large combined load of nutrients and sediments.

According to the information provided by the Grant, Hettinger and Stark County Soil Conservation Districts, between 45 and 70 percent of the cultivated lands and between 60 and 90 percent of all the remaining agricultural lands within the Lake Tschida watershed are "adequately treated" against soil loss. It should be noted that "adequately treated" still allows erosion or soil loss to occur. "Adequately treated" is defined as the amount of land treatment necessary to achieve the soil loss tolerance (T).

Table 5. Land Use in the Lake Tschida Watershed

Land Use	Percent of Total Landuse	Percent Adequately Treated
Cropland	47.0	45-70
Rangeland	28.2	60-95
Hayland	12.8	65-97
CRP	6.4	100
Wet/Wild[1]	1.1	N/A
Other	2.9	N/A
Farmstead	886[3]	N/A
Feedlots[2]	791[3]	42-50

[1]Wet/Wild are wildlife management areas, wetlands and lakes.
[2]Feedlots are areas where livestock are concentrated to be fed.
[3]Represents the number of farms and concentrated livestock feeding areas within the contributing watershed.

It is estimated that within the Lake Tschida watershed, the average "T" value is three to five tons per acre depending on land use. Based on an average soil loss of just over four tons per acre, approximately 4,078,158 tons of soil are lost annually from within the watershed. Assuming a delivery rate of 10 to 15 percent, between 407,816 and 611,723 tons of soil are delivered to Lake Tschida annually.