2011North Dakota Lake Water Quality Assessment Reports

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INTRODUCTION

Project Description and Purpose

The Lake Water Quality Assessment Project (LWQA) is part of the ongoing efforts of the North Dakota Department of Health's Division of Water Quality Surface Water Quality Management Program (SWQMP) to track the health and wellbeing of the States waters. Lakes monitored in 2011 had either never previously been monitored or had no recent water quality data and were in the western region of North Dakota with emphasis in the energy producing regions.

The monitoring plan calls for collecting water quality data on fifteen lakes in 2011. Water quality samples were collected three times with each sampling visit appropriately spaced to represent the spring, summer and fall seasons.

The core purpose of the LWQA is to describe the general chemical, physical and biological characteristic of each water body by: 1) determining spatial differences among lakes and reservoirs and region; 2) identifying the limiting nutrient; 3) estimating the trophic status; and when applicable 4) determine temporal trends in lake water quality by comparing 2011 LWQA data to previous LWQA other historic water quality data.

The water quality information generated from the project is reduced into a report format useful to the general public, lake associations, North Dakota Game and Fish Department and the North Dakota Department of Health's Division of Water Quality to prioritize lakes, reservoirs and their watersheds for lake maintenance and improvement projects (i.e., Save Our Lakes, Total Maximum Daily Loads, Section 319 Non-point Source Management Program). The report will be accessible on the North Dakota Department of Health's webpage or by request.

The water quality report is not intended to be a comprehensive evaluation of the individual lake or reservoir but rather a simple and functional characterization of the major water quality parameters, limiting nutrients, and current trophic status. If sufficient historic data are available for a lake or reservoir, trends (improving, declining, or stable) in water quality are also assessed.

Lakes and Reservoirs Assessed in 2011

A total of fifteen (15) lakes and reservoirs were monitored in the open water period 2011 (Figure 1, Table 1). Assessed lakes and reservoirs were selected by the North Dakota Department of Health Surface Water Quality Management Program. All water quality samples are collected utilizing a 2-meter depth integrated water column tube sampler. A complete monitoring plan and sampling procedures may be obtained by contacting the North Dakota Department of Health's Surface Water Management Program (NDDoH 2011).

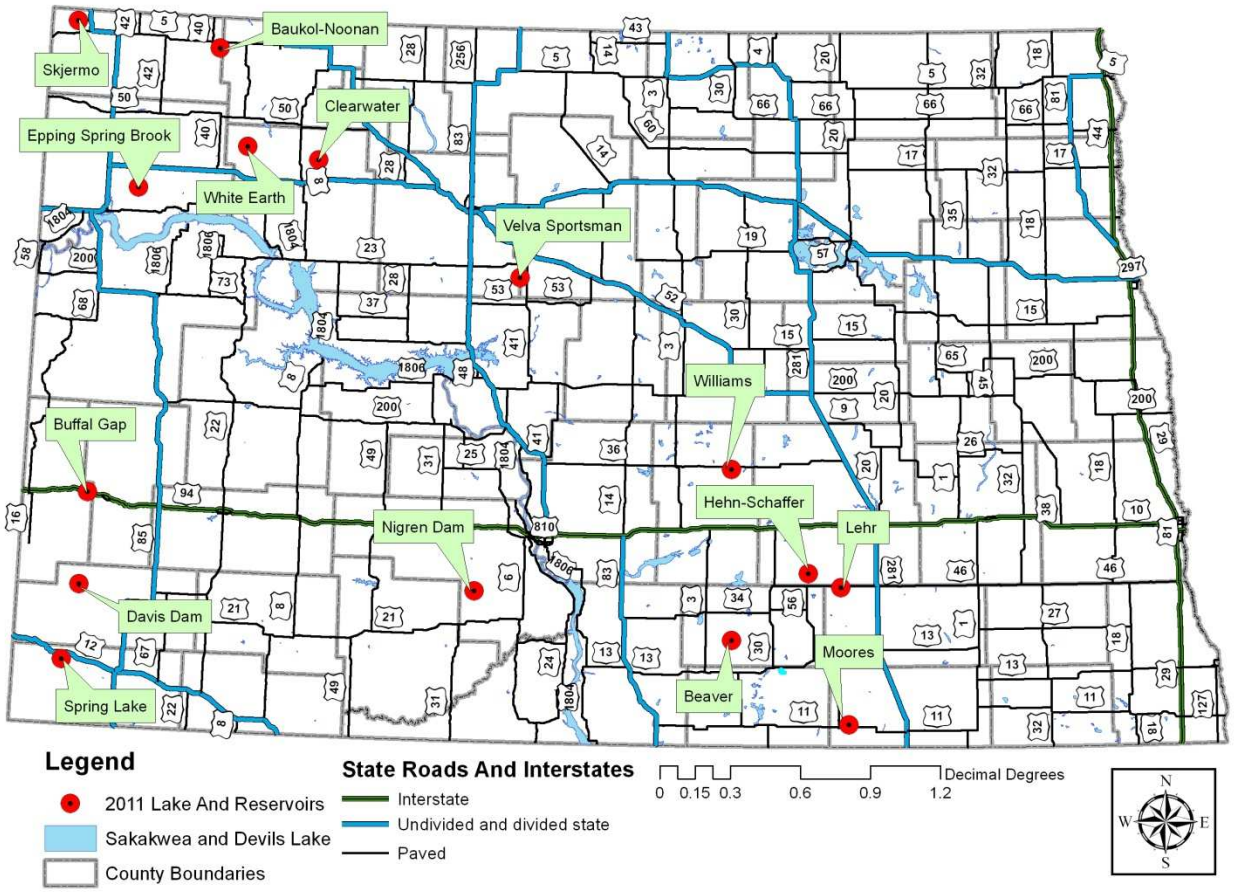

Figure 1. Location of 2011 LWQA Lakes and Reservoirs in North Dakota

Sample Frequency

Sampling frequency is three times during the open water period. The first sampling date represents spring and occurs in May or June, the second represents summer and is collected in July or August, and the third represents fall and is collected in September or October. Note: The reservoir South Buffalo Gap was not sampled in the fall due to inaccessibility.

Water Quality Variables

Water Quality data collected for each lake or reservoir includes field measurements of secchi disk transparency and weather conditions and a water column profile with specific conductance, temperature, dissolved oxygen and pH. Water quality samples are analyzed for a suite of chemical analytes (Table 2). All water quality samples collected are analyzed by the North Dakota Department of Health's Division of Laboratory Services for general chemistry.

Table 1. Lakes and Reservoirs Included in 2011 Lake Water Quality Assessment Project (by County)

Lake Name	County	Lake Name	County
Spring Lake	Bowman	Nygren Dam	Morton
Moores Lake	Dickey	Clear Water Lake	Mountrail
Baukol-Noonan Dam	Divide	White Earth Dam	Mountrail
Skjermo Lake	Divide	Davis Dam	Slope
South Buffalo Gap	Golden Valley	Hehn-Schaffer Lake	Stutsman
Lake Williams	Kidder	Velva Sportsman Dam	Ward
Lehr (Schlenker) Dam	LaMoure	Epping Springbrook Dam	Williams
Beaver Lake	Logan		

Table 2. Summary of Lake Water Quality Assessment Water Quality Variables

Field Measurements	General	Nutrients	Biological
Secchi Disk Transparency	Sodium	Total Nitrogen	Chlorophyll-a
Dissolved Oxygen	Potassium	Total Phosphorus	
Temperature	Magnesium	Total Kjeldahl Nitrogen	
	Calcium	Nitrate + Nitrite	
	Iron	Total Ammonia	
	Hardness		
	Alkalinity		
	Bicarbonate		
	Carbonate		
	Hydroxide		
	Chloride		
	Sulfate		
	Conductivity		
	pH		

Historical Water Quality and Trends Analysis

When available, historical water quality data was compared to the 2011 data in an attempt to determine water quality trends. Since most of the historical water quality data was collected at multiple depths, only water samples collected between one and two meters of depth are used in the comparison analysis. Historical water quality data for trend assessment was further restricted to data collected by the SWQMP between 1991 and 2011. Trends assessments were conducted for each lake or reservoir by comparing historical descriptive statistics (e.g., mean, minimum, maximum and standard deviation) and graphical comparisons of Carlson's Trophic Status Index (TSI) scores over time.

Temperature and Dissolved Oxygen Profiles

Temperature and dissolved oxygen (DO) play an important role in a lake or reservoir's overall health and ability to sustain appropriately diverse populations of aquatic life. In general, cooler

water temperatures and the higher oxygen concentrations will result in increased diversity and populations of aquatic species.

During periods of summer stratification, the majority of the cool water in a lake or reservoir is in a region referred to as the hypolimnion. The hypolimnion is defined as the water below the thermocline. The depth of the thermocline is defined by a 1 degree shift in temperature occurring within a 1-meter change in depth. The thermocline results in two layers of water; a warmer upper layer (epilimnion) and a cooler bottom layer (hypolimnion). While the epilimnion is exposed to wind action and the photosynthetic activity of algae, the hypolimnion is often isolated.

The water in the hypolimnion is typically an area of increased oxygen consumption, where accumulated organic matter (e.g., settling algae) is decomposed. The decomposition processes require oxygen which is obtained from the water column in the hypolimnion. The rate at which oxygen is consumed in the hypolimnion, termed the hypolimnetic oxygen depletion rate, is directly related to the amount of organic matter deposited in the hypolimnion which is directly related to the lake or reservoir's trophic status. This relationship makes the tracking of temperature and dissolved oxygen profiles an excellent measure of increasing or decreasing eutrophication.

Trophic Status Assessment

Trophic status is the primary indicator used to assess whether a lake or reservoir is meeting or likely to meet its intended beneficial uses (e.g., fishery class, recreation use). Trophic status is a measure of the primary productivity of a lake or reservoir and is directly related to the level of nutrients (i.e., phosphorus and nitrogen) entering the lake or reservoir from its watershed and/or from the internal recycling and the amount discharged. Highly productive lakes, termed "hypereutrophic," contain excessive nutrients (usually phosphorus) and are characterized by large growths of macrophytes, blue-green algal blooms, low transparency, and low dissolved oxygen concentrations. These lakes typically experience frequent fish kills that can result in excessive rough fish populations (carp and bullhead) and poor sport fisheries. Additionally, due to frequent algal blooms and excessive weed growth these lakes are also undesirable for contact recreational uses such as swimming and boating.

Mesotrophic and eutrophic lakes, on the other hand, have lower phosphorus concentrations, low to moderate levels of algae and aquatic plant growth, high transparency and adequate dissolve oxygen concentrations throughout the year. Mesotrophic lakes do not regularly experience algal blooms, while eutrophic lakes experience occasional moderate to severe algal blooms for durations of a few days to a few weeks.

Due to the relationship between trophic status indicators and the aquatic community or between trophic status indicators and the frequency of algal blooms, trophic status becomes an effective indicator of aquatic life and recreation use support in lakes and reservoirs. For purposes of this assessment it is assumed that hypereutrophic lakes are either at risk of not supporting or do not fully support a sustainable sport fishery and are limited in recreational uses, whereas mesotrophic lakes fully support both aquatic life and recreation use. Eutrophic lakes may be assessed as fully

supporting, fully supporting but threatened, or not supporting their uses for aquatic life or recreation.

Since trophic status indicators specific to North Dakota waters have not been developed, Carlson's trophic status index (TSI) (Carlson, 1977) has been chosen to assess the trophic status of lakes or reservoirs. To develop a numerical TSI value, Carlson's TSI uses a mathematical relationship based on three indicators: 1) Secchi Disk Transparency in meters (m); 2) surface total phosphorus as P concentration expressed as µg/ L; and 3) chlorophyll-a concentration expressed as µg/L.

This numerical value, ranging from 0-100, corresponds to a trophic condition with increasing values indicating a more eutrophic (degraded) condition. Carlson's TSI estimates are calculated using the following equations and is also depicted graphically in Figure 2.

- Trophic status based on Secchi Disk Transparency (TSIS):
  TSIS = 60 - 14.41 ln (SD)
  Where SD = Secchi disk transparency in meters.

- Trophic status based on total phosphorus (TSIP):
  TSIP = 14.20 ln (TP) + 4.15
  Where TP = Total phosphorus concentration in µg L^{-1}.

- Trophic status based on chlorophyll-a (TSIC):
  TSIC = 9.81 ln (TC) + 30.60
  Where TC = Chlorophyll-a concentrations in µg L^{-1}.

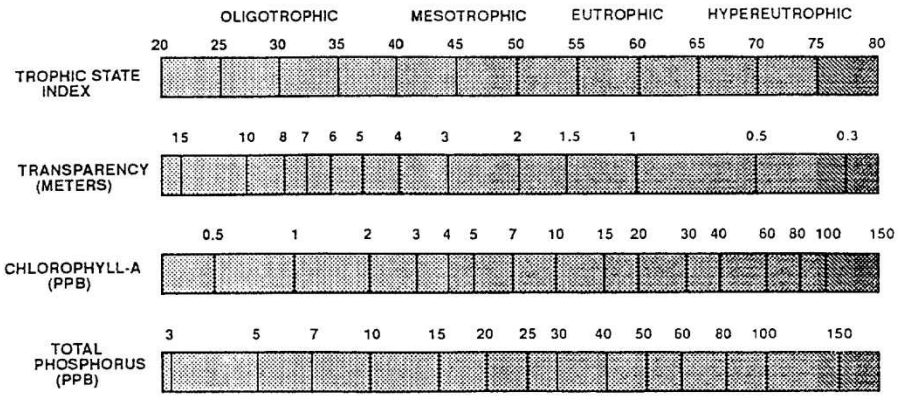

Figure 2. A Graphic Representation of Carlson's TSI

Of the three indicators chlorophyll-a is the best indicator of trophic status as it is a direct measure of lake productivity. Secchi disk transparency should be considered the next most reliable indicator and phosphorus concentration least. In theory, for a given lake or reservoir, the measures of chlorophyll-a, secchi disk transparency, and phosphorus concentration are all interrelated and should yield similar trophic status index values, however this is often not the case. Many lakes and reservoirs in North Dakota are shallow, nitrogen limited and windswept causing non-algal turbidity to limit light penetration resulting in low Secchi disk transparency and low chlorophyll-a concentration even though there is abundant phosphorus. In other instances some species of micronutrients may be limiting algal growth even though excessive phosphorus is present.

Comparison Results

In an attempt to better understand the significance of the water quality results, each waterbody is compared to similar waterbodies within the same region. For purposes of this comparison the waterbody types are limited to natural lakes and reservoirs.

The lake types were chosen as natural lakes are older, usually do not have a control structure, and generally have longer residence times. Reservoirs by contrast are manmade, usually have a control structure and have shorter hydraulic residence times. These factors have significant impact on the water quality which should be considered when making regional comparisons.

Regionality was selected as geology, landscape, and climatic can have a dramatic influence on water quality. For example, lakes and reservoirs in the eastern part of the state will naturally have different water quality than lakes or reservoirs in the west as a result of the variations in soils, natural vegetation, land use patterns, and precipitation. One way to group or classify broad regional area based factors is to use ecorgions that have similar land forms, geological history, soils and ecological function. There are four different Level III Ecoregions in North Dakota. From east to west they are the Lake Agassiz Plain (48), Northern Glaciated Plains (46), Northwestern Glaciated Plains (42), and the Northwestern Great Plains (43) (Figure 2).

While it is most helpful to compare each lake or reservoir in relationship to as specific an ecological region as possible, it is also necessary to have an adequate sample size of lakes and reservoirs to compare. Therefore, to ensure an adequate sample size of lakes and reservoirs the four level III ecoregions in the state were combine into two broader ecoregions. The Lake Agassiz Plain (48) and Northern Glaciaed Plains (46) ecoregions were combined to form the Cultivated Plains region and the Northwestern Glaciated Plains (42) and Northwestern Great Plains (43) ecoregions were combined to form the Rangeland Plains region (Figure 3).

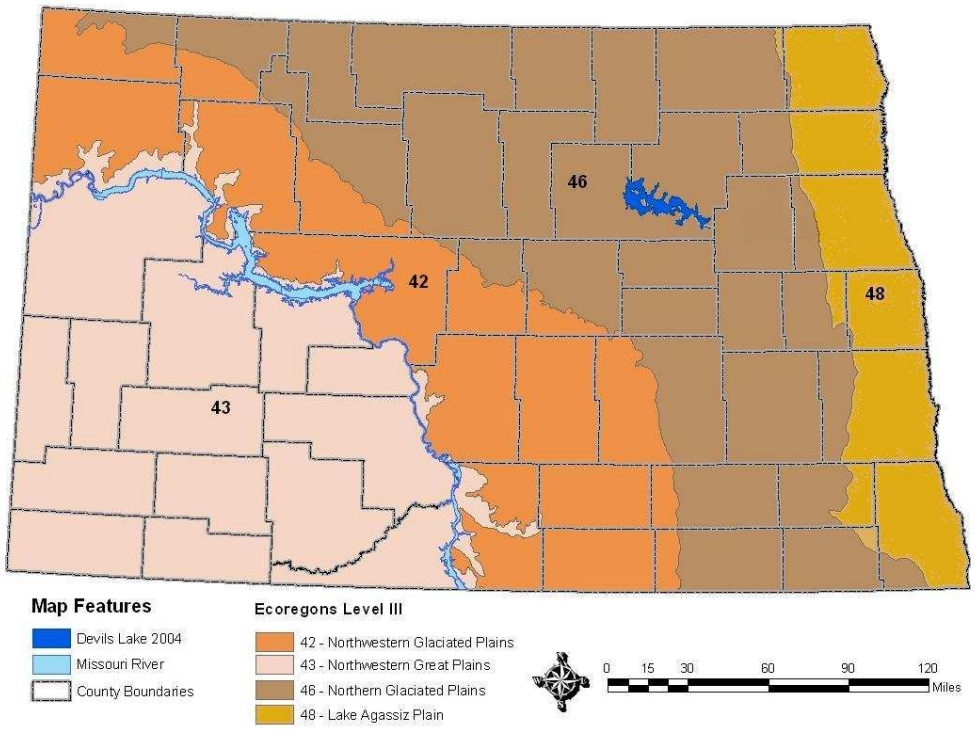

Figure 2. Level III Ecological Region in North Dakota

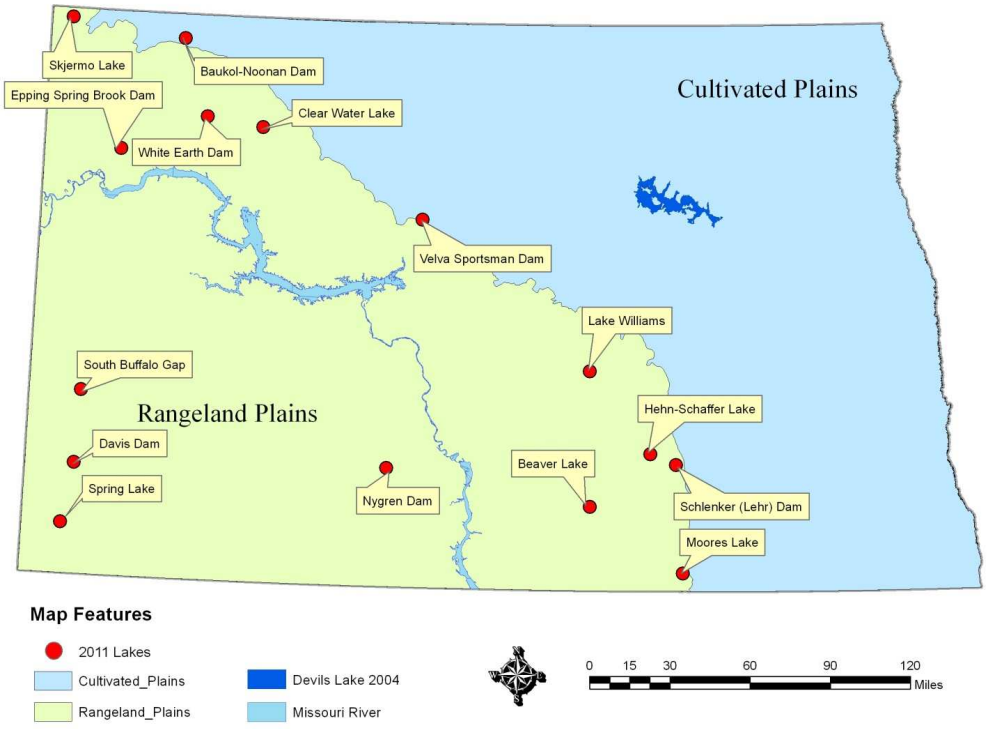

Figure 3. Cultivated Plains and Rangeland Plains Regions in North Dakota

Spring Lake, Bowman County

BACKGROUND

Spring Lake is a small prairie reservoir on the Lower Coyote Creek just 4 miles west of Rhame North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish Department. Fish species managed for are northern pike and yellow perch.

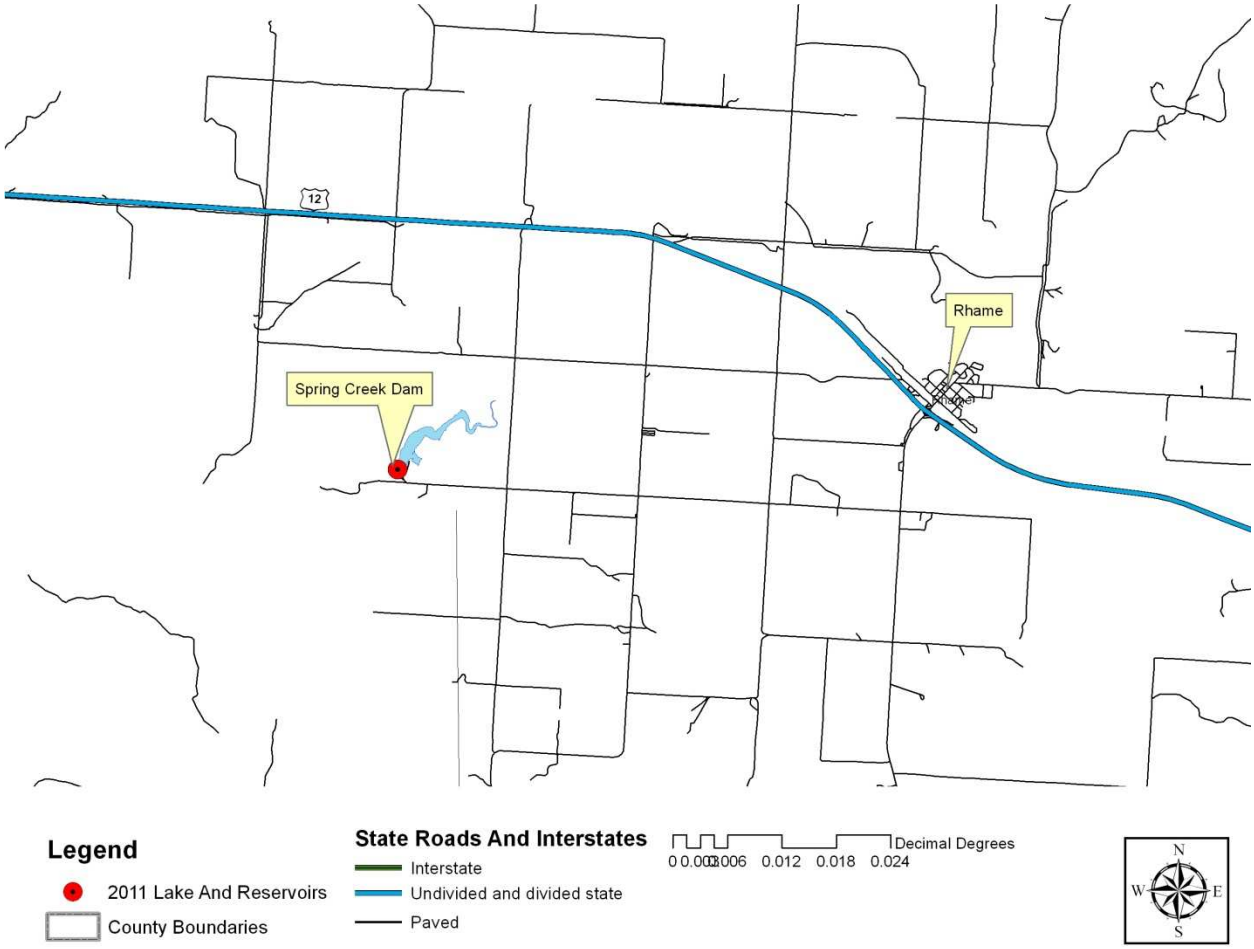

Figure 1. Location of Spring Lake

Physiographic/Ecological Setting: Spring Lake has a surface area of 41 acres, a mean depth of 4.9 and a maximum depth of 15 ft. It is a windswept reservoir with little or no shelter from the ever present prairie wind and sun (Figure 2). The reservoir is located in the Northwestern Great Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figure 3).

Recreational Facilities: Recreational facilities at Spring Lake are an access road, parking and a small gravel ramp.

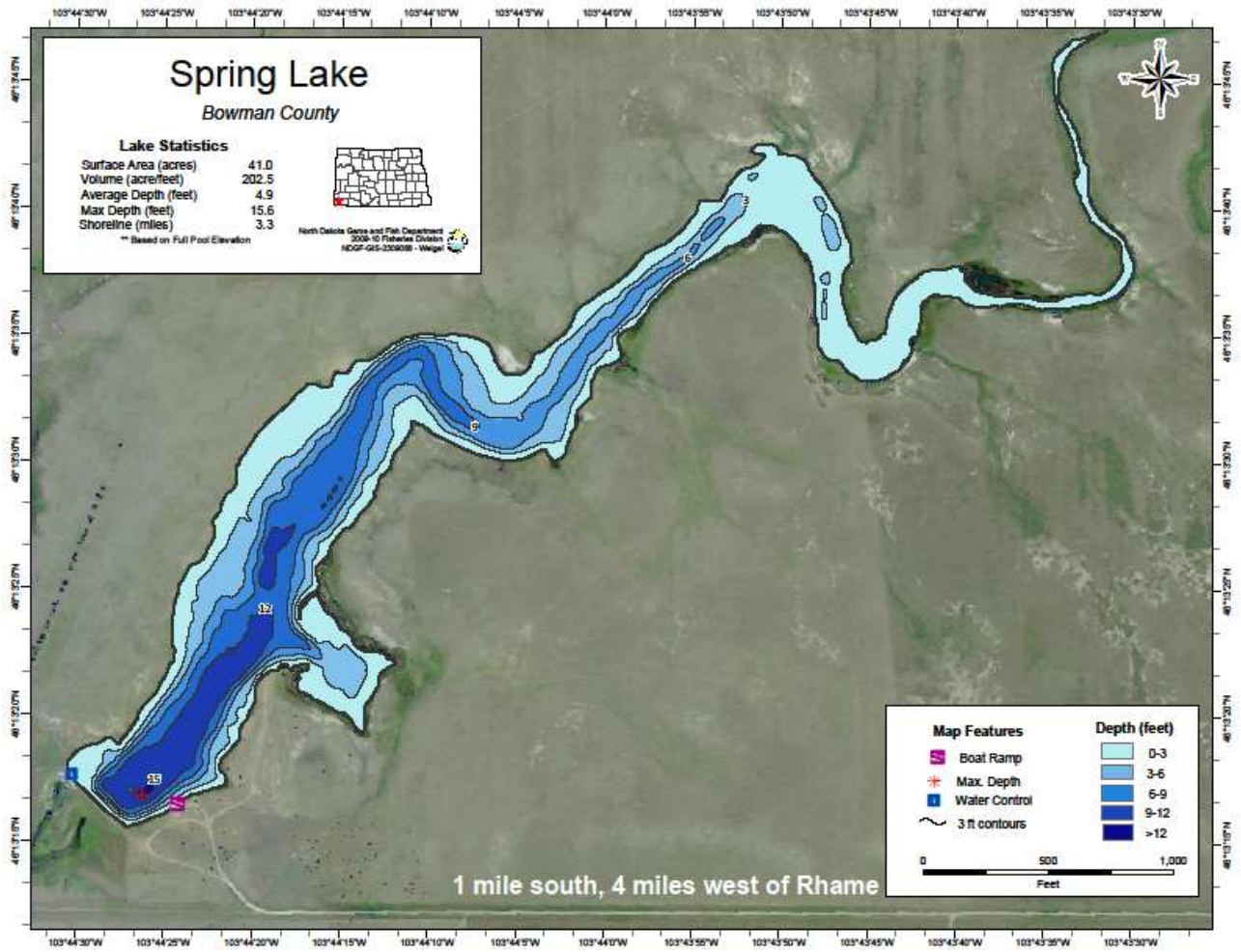

Figure 2. Contour Map of Spring Lake (Map Courtesy of North Dakota Game and Fish Department)

Water Quality Standards Classification: Spring Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 reservoir. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: Historical water quality data include 3 samples collected in 1994-1995.

WATER QUALITY MONITORING RESULTS

The water quality assessment for Spring Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional data for reservoirs in the Rangeland Plains Region.

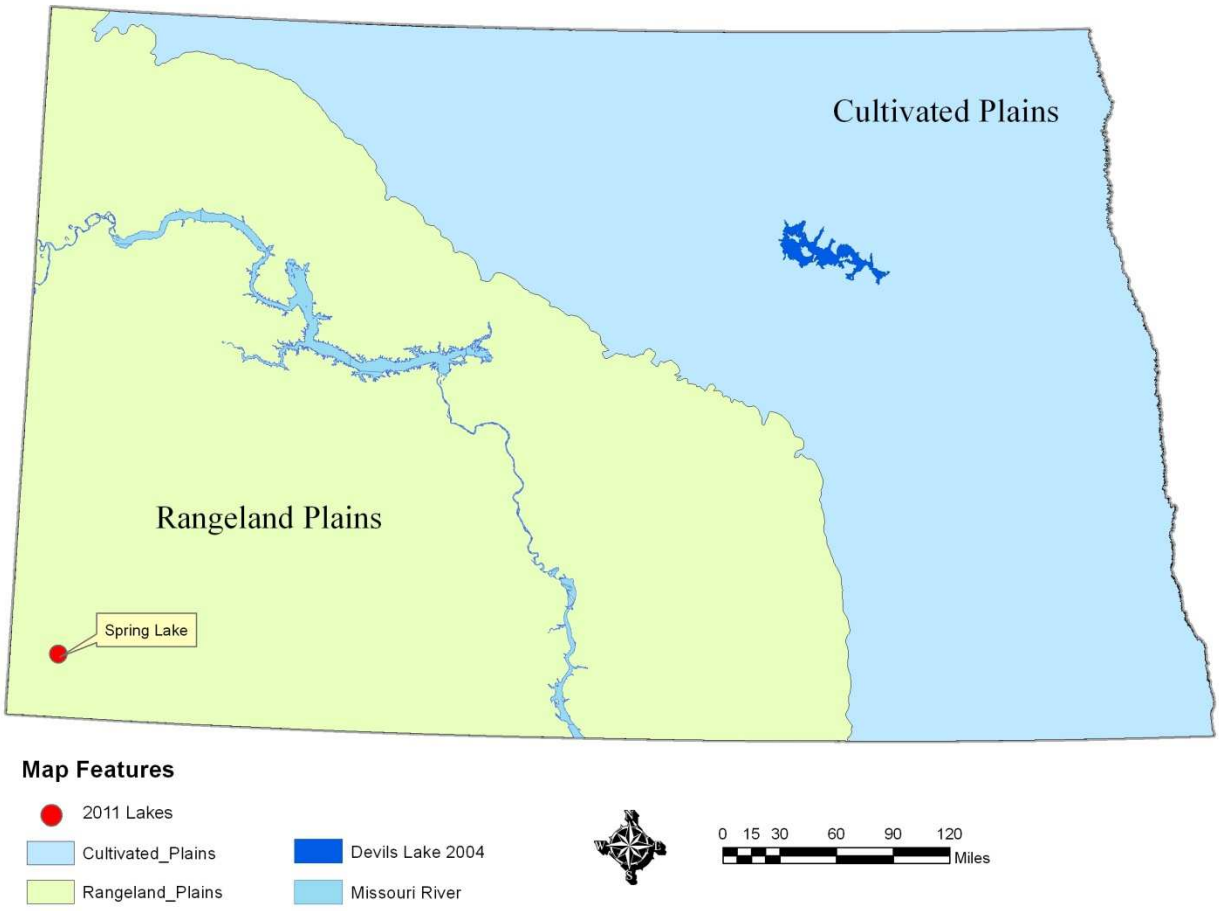

Figure 3. Spring Lake Location and the Cultivated and Rangeland Plans Regions

Temperature and Dissolved Oxygen Profile Results: There are six temperature and dissolved oxygen profiles for Spring Lake collected in 1994-95 and 2011 (Figures 4 and 5). The profile data indicates that Spring Lake does not thermally stratification during the open water period, which is to be expected in a shallow exposed reservoir. The profiles also indicate that during the open water period the reservoir remains well enough oxygenated to support aquatic life but the aquatic community might experience stress or partial winter kills during years with normal or above normal snow cover.

General Water Quality: Data collected in 2011 indicates that Spring Lake is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 223 to 274 mg/L (Table 1) and that the reservoir is sodium bicarbonate dominated with an average sodium concentration of 229 mg/L and an average bicarbonate concentration of 761 mg/L. The average total dissolved solids concentration and specific conductance measurements for the 2011 sampling period were 1350 mg/L and 1800 µmhos/cm, respectively. The average total nitrogen and total phosphorus concentrations were 1.03 mg/L and 0.04 mg/L respectively.

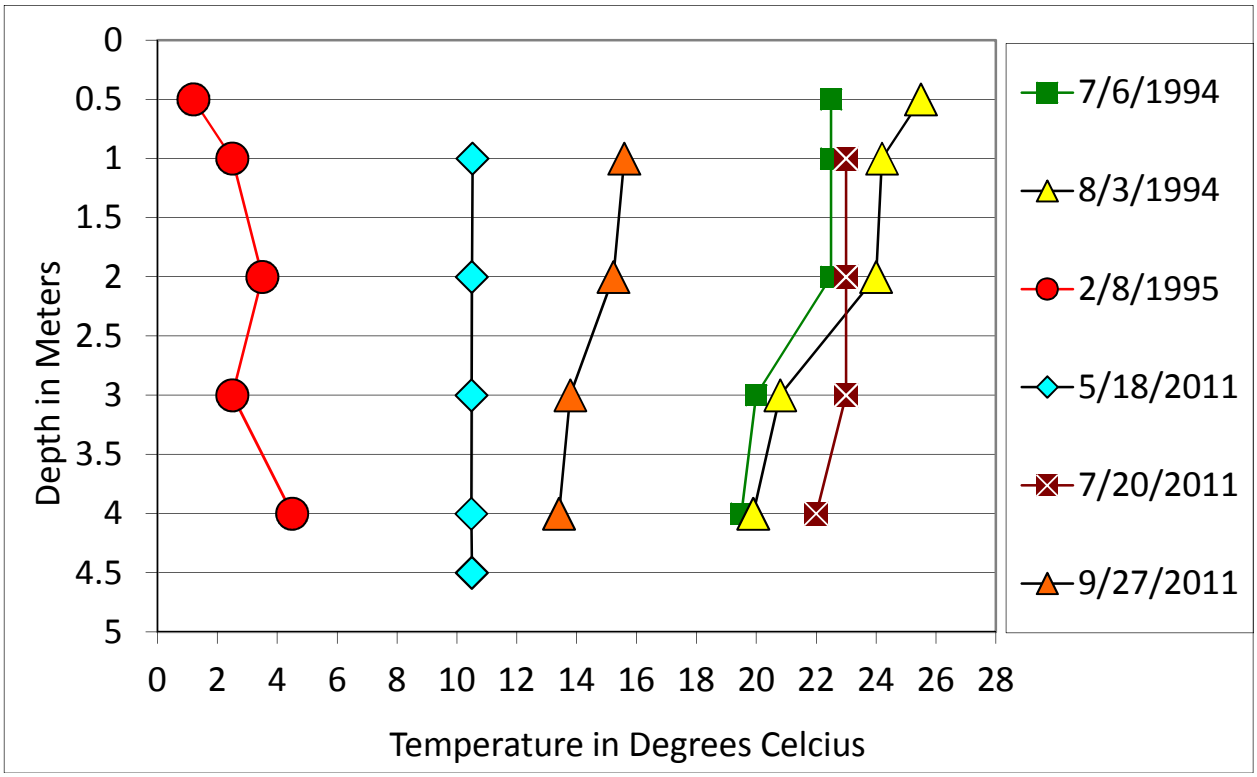

Figure 4. Temperature Profiles for Spring Lake

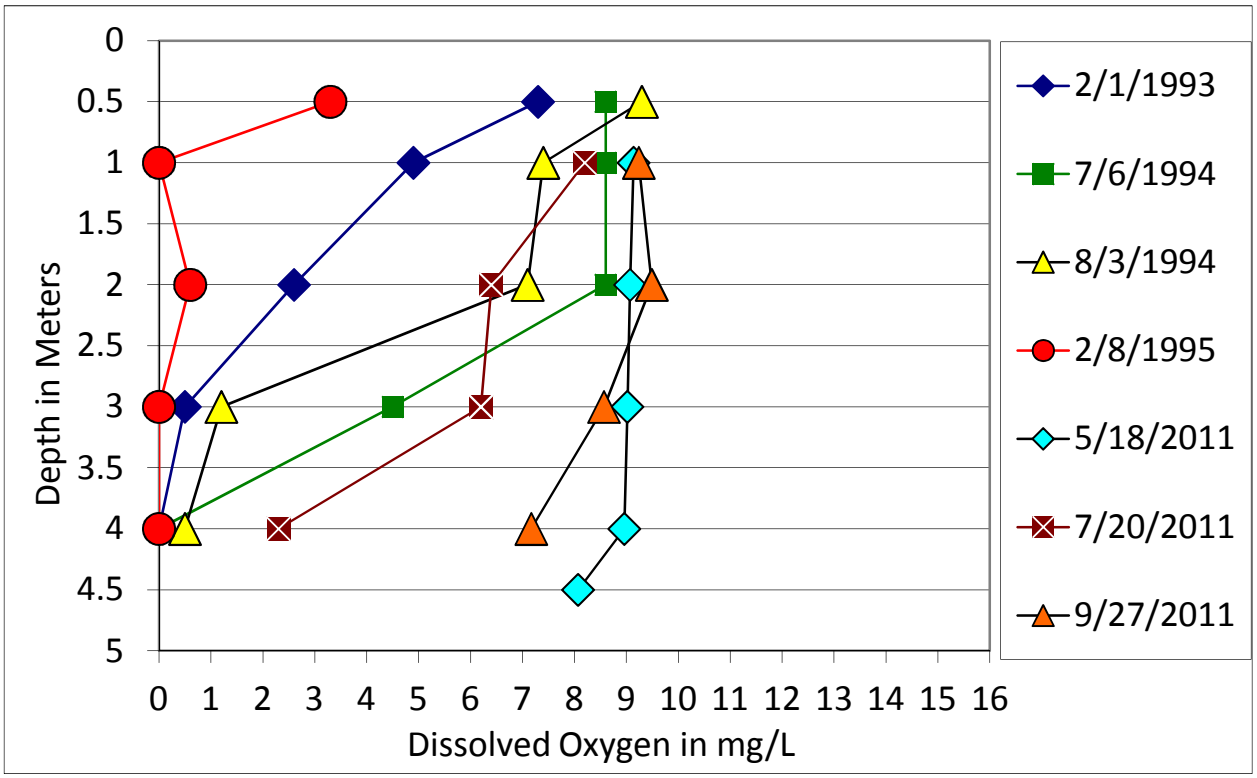

Figure 5. Dissolved Oxygen Profiles for Spring Lake

Table 1. Statistical Summary of Spring Lake's (Bowman Co) 2011 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	247	223	274	26
Total Ammonia as N	mg/L	3	0.05	0.03[1]	0.09	0.04
Bicarbonate (HCO_3)	mg/L	3	276	250	322	40
Calcium (Ca)	mg/L	3	75.9	68.1	80.4	6.8
Carbonate (CO_3)	mg/L	3	13	6	24	10
Chloride (Cl)	mg/L	3	18.1	15	24.3	5.4
Chlorophyll-a	µg/L	3	8	6	12	3.5
Specific Conductance	µmhos	3	1800	1700	1910	105
Total Dissolved Solids	mg/L	3	1350	1260	1460	101
Total Hardness as ($CaCO_3$)	mg/L	3	581	534	658	67
Hydroxide (OH)	mg/L	3	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	3	0.12	0.11	0.15	0.02
Magnesium (Mg)	mg/L	3	95	81.5	111	14.9
Nitrate + Nitrite as N	mg/L	3	0.03[1]	0.03[1]	0.03[1]	0
Total Kjeldahl Nitrogen as N	mg/L	3	1	0.72	1.25	0.26
Total Nitrogen as N	mg/L	3	1.03	0.75	1.28	0.26
pH		3	8.52	8.35	8.65	0.15
Total Phosphorus as P	mg/L	3	0.04	0.03[1]	0.05	0.01
Potassium (K)	mg/L	3	21.4	19.3	22.8	1.8
Sodium (Na)	mg/L	3	229	222	240	9.9
Sulfate (SO4)	mg/L	3	761	646	859	108

[1]Equal to the lower reporting limit

When compared to water quality for reservoirs in the Rangeland Plans Region, Spring Lake is slightly less fresh but also less nutrient rich than average (Tables 1 and 2). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 1113 mg/L, 1.32 mg/L, and 0.128 mg/L respectively, compared to Spring Lake's average TDS, total nitrogen, and total phosphorus concentrations of 292 mg/L, 1.043 mg/L and 0.126 mg/L respectively.

When comparing historical water quality data (1994-1995) to current (2011), there is a slight but recognizable improvement in nutrient concentrations. For example, the historical average total nitrogen and total phosphorus concentrations were 2.127 mg/L and 0.212 mg/L, respectively, compared to the 2011 averages of 1.03 mg/L and 0.040 mg/L (Tables 1 and 2). Unlike the nutrients dissolved solids have remained constant or increased. Examples are the bicarbonate, sulfate and sodium average concentrations of 276 mg/L, 761 mg/L and 279 mg/L in 2011 compared to the 1994-1995 average concentrations of 241 mg/L, 536 mg/L and 273 mg/L, respectively (Tables 1 and 3).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	571	282	3	982	130
Total Ammonia as N	mg/L	651	0.092	0.001	2.44	0.178
Bicarbonate (HCO_3)	mg/L	571	296	4	1040	143
Calcium (Ca)	mg/L	571	55	2	206	30
Carbonate (CO_3)	mg/L	569	24	1	197	28
Chloride (Cl)	mg/L	571	14	1	75	10
Chlorophyll-a	µg/L	456	19.6	1.5	218	26.1
Specific Conductance	µmhos	591	1618	4	5880	973
Total Dissolved Solids	mg/L	572	1113	17	5110	773
Total Hardness as ($CaCO_3$)	mg/L	571	410	9	2100	288
Hydroxide (OH)	mg/L	514	1	1	1	0
Iron (Fe)	mg/L	572	0.2	0.01	4.11	0.35
Magnesium (Mg)	mg/L	571	66.4	1	412	54.9
Nitrate + Nitrite as N	mg/L	650	0.064	0.003	1.49	0.127
-Total Kjeldahl Nitrogen as N	mg/L	541	1.36	0.08	7.72	0.78
Total Nitrogen as N	mg/L	484	1.32	0.02	4.84	0.63
pH		591	8.54	5.74	9.87	0.55
Total Phosphorus as P	mg/L	657	0.126	0.04	3.16	0.185
Potassium (K)	mg/L	571	13.9	1	52.5	6.9
Sodium (Na)	mg/L	571	214	3	932	168
Sulfate (SO4)	mg/L	569	578	1	3210	512

[1]Equal to the lower reporting limit
[2]Data collected from 76 reservoirs between 1991 and 2011

Limiting Nutrients: The water quality samples collected in 1994-95 and 2011 indicate that Spring Lake is phosphorus limited (Figure 6). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen to total phosphorus (N:P) of 15 to 1 is nutrient equilibrium. Using this assumption when the N:P ratio is less than 15:1, nitrogen is limiting and when it exceeds 15:1 phosphorus is. The ratios ranged wildly in 1994-95 with a low of 6 and a high of 266, however in 2011 the range was very consistent falling between 26 and 29 indicating phosphorus limitation at least during the open water period.

Table 3. Statistical Summary of Spring Lake's 1994-1995 Water Quality Data.

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	282	102	375	156
Total Ammonia as N	mg/L	3	0.229	0.005	0.668	38
Bicarbonate (HCO_3)	mg/L	3	241	124	308	102
Calcium (Ca)	mg/L	3	23.3	19.7	26.7	3.5
Carbonate (CO_3)	mg/L	3	50.5	0.5	81	43.6
Chloride (Cl)	mg/L	3	6.3	4.1	7.5	1.9
Chlorophyll-a	µg/L	3	8	7	9	1.4
Specific Conductance	µmhos	3	1556	518	2180	905
Total Dissolved Solids	mg/L	3	1061	382	1450	590
Total Hardness as ($CaCO_3$)	mg/L	3	200	118	247	71
Hydroxide (OH)	mg/L	3	1	1	1	0
Iron (Fe)	mg/L	3	0.304	0.043	0.773	0.41
Magnesium (Mg)	mg/L	3	34	16.7	45.8	15.5
Nitrate + Nitrite as N	mg/L	3	0.267	0.003	0.765	0.44
Total Kjeldahl Nitrogen as N	mg/L	3	1.86	1.06	2.83	0.89
Total Nitrogen as N	mg/L	3	2.127	1.063	3.595	0.89
pH		3	8.42	6.73	9.33	1.46
Total Phosphorus as P	mg/L	3	0.212	0.002	0.603	0.34
Potassium (K)	mg/L	3	15.9	13.7	17.5	1.9
Sodium (Na)	mg/L	3	273	76	408	175
Sulfate (SO4)	mg/L	3	536	185	725	305

[1]Equal to the lower reporting limit

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 1004-95 and 2011, Spring Lake's trophic status is estimated as eutrophic with no recognizable trend (Figure 7). The Trophic Status Index (TSI) scores based on chlorophyll-a were consistent ranging only 7 points (48 to 55), as was secchi disk with a range of just 19 points (46-65). Total phosphorus scores had a much larger range of 70 points (26 to 96) using the entire data set but if the highest and lowest are discarded the range was just 10 points (51-61) right in the heart of the eutrophic range.

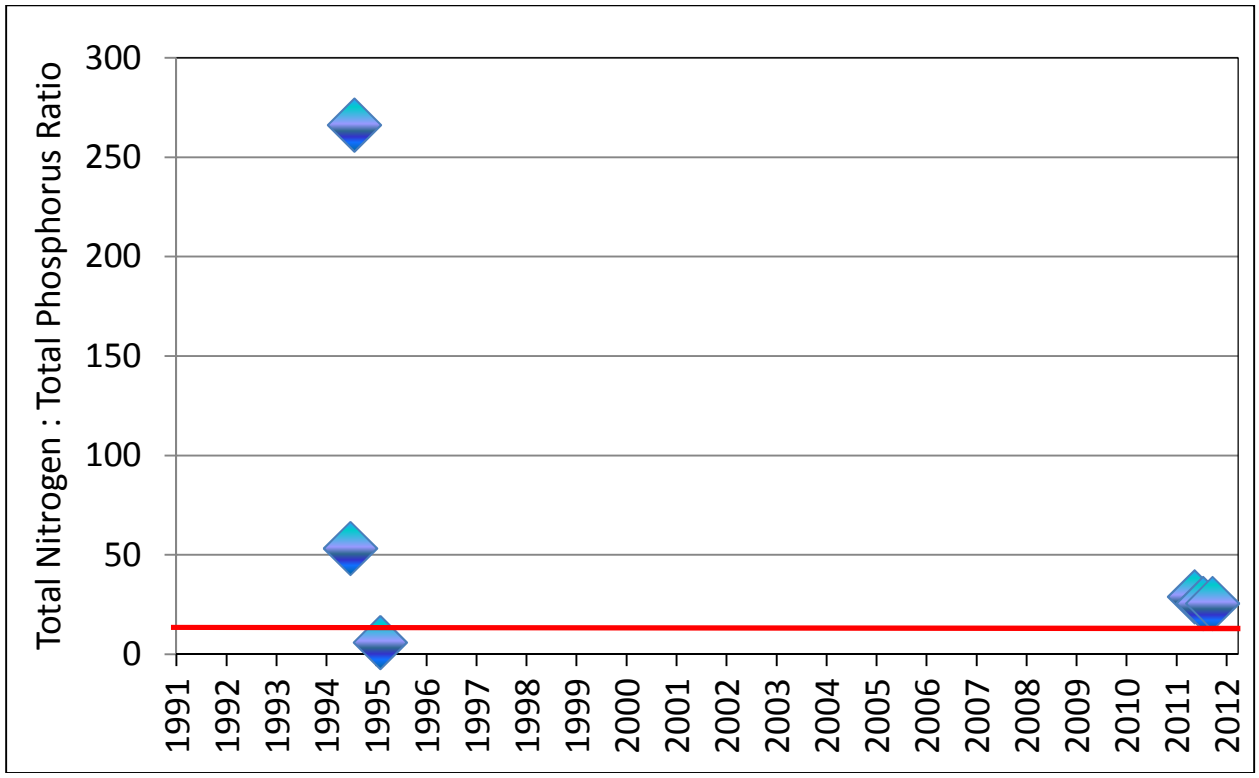

Figure 6. Spring Lake's Total Nitrogen to Total Phosphorus Ratio

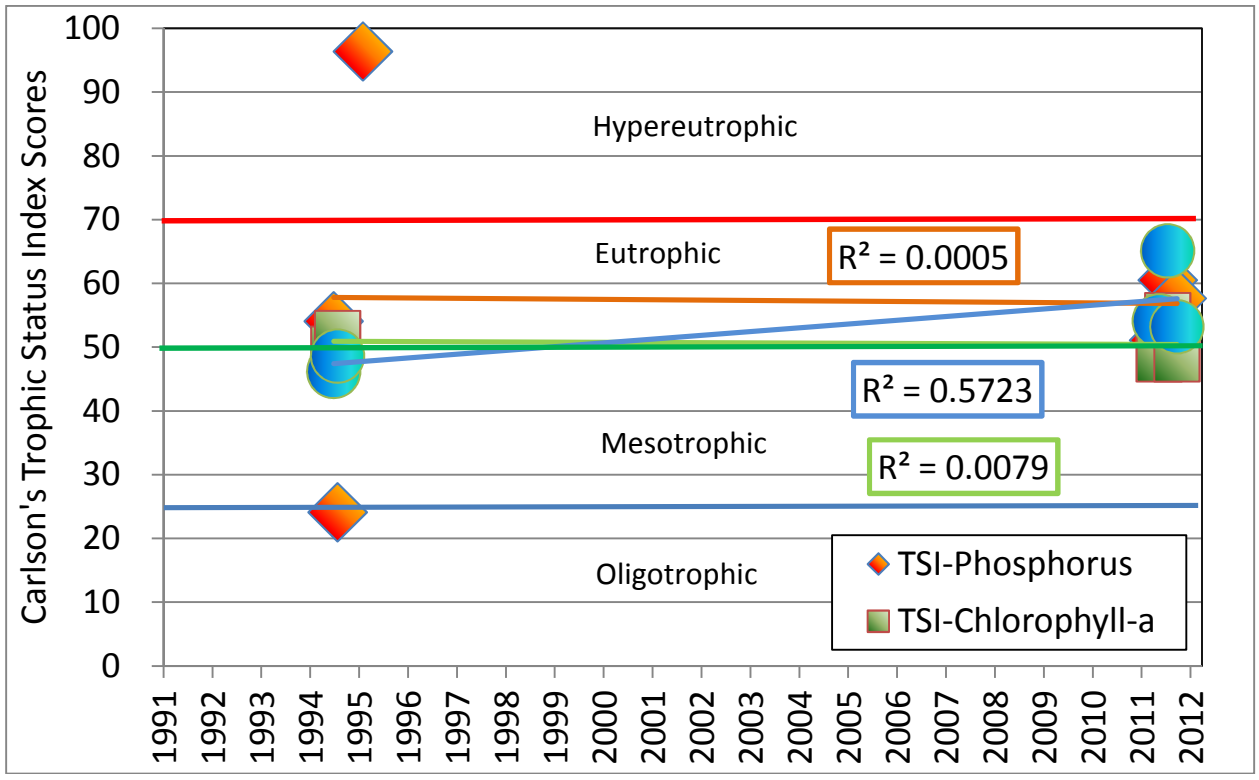

Figure 7. Spring Lake's TSI Scores

Moores Lake, Dickey County

BACKGROUND

Moores Lake is a beautiful little prairie lake on the eastern edge of the Missouri Coteau approximately 16 miles west and 2 miles north of Ellendale, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish Department. Fish species managed for are northern pike, yellow perch, and largemouth bass.

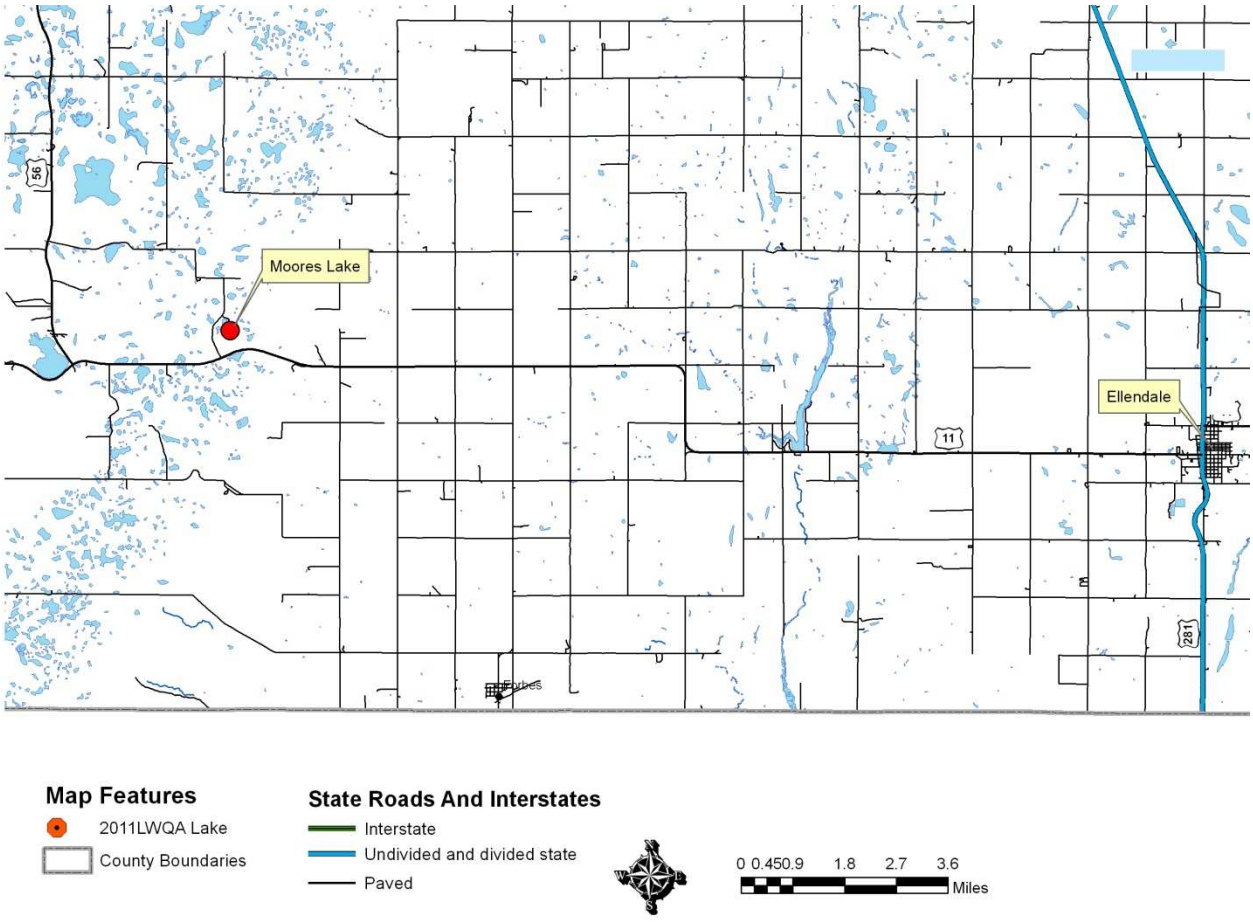

Figure 1. Location of Moores Lake

Physiographic/Ecological Setting: Moores Lake has a surface area of 23.3 acres, a mean depth of 7.1 feet and a maximum depth of 12 feet (Figure 2). Moores is a perched lake nested in a series of high hills with fair protection from the prevailing northwest wind. The reservoir is located in the Northwestern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figure 3).

Recreational Facilities: Recreational facilities at Moores Lake are a few primitive two track trails with no designated parking or picnic area. There is no boat ramp.

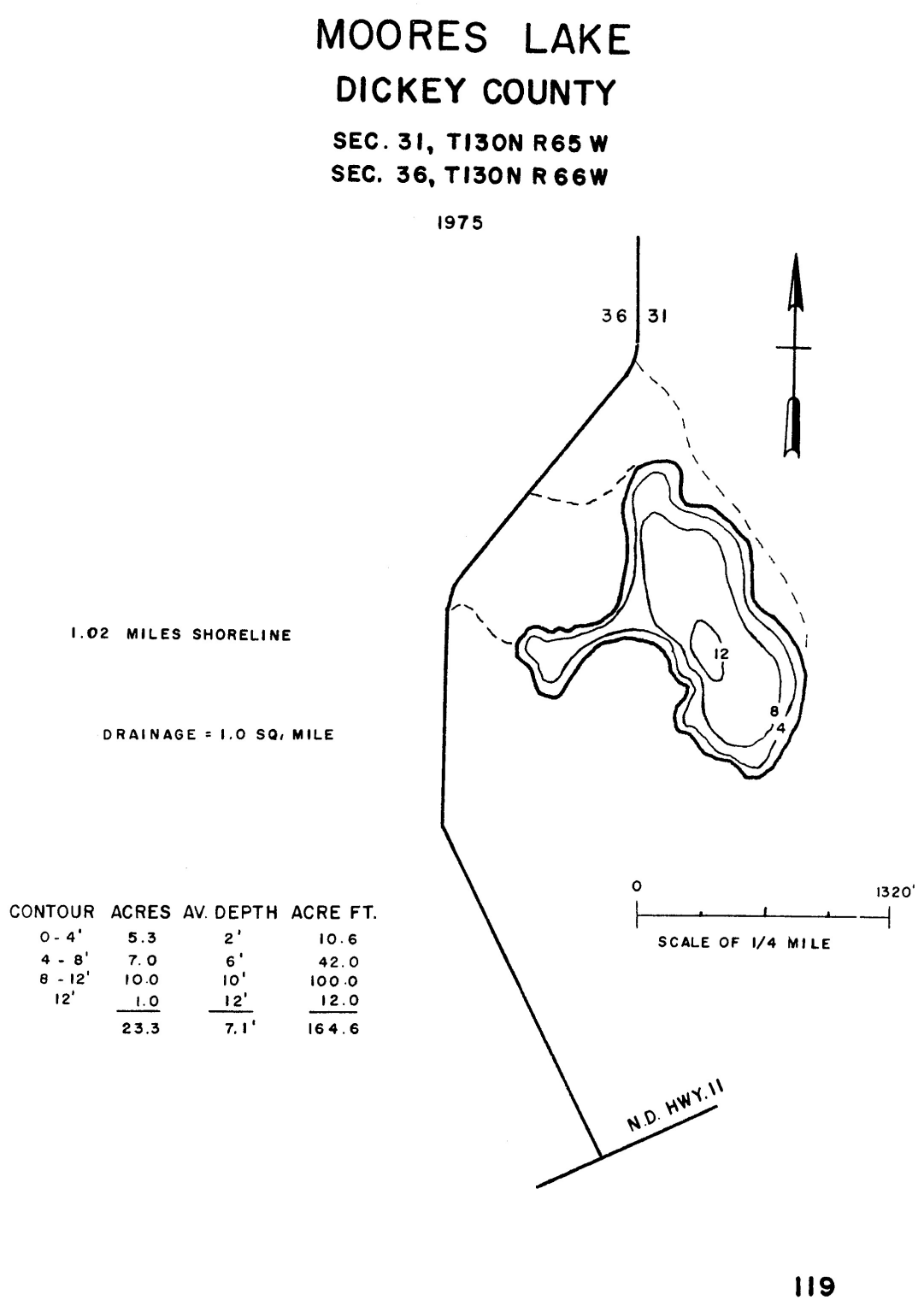

Figure 2. Contour Map of Moores Lake (Map Courtesy of North Dakota Game and Fish Department)

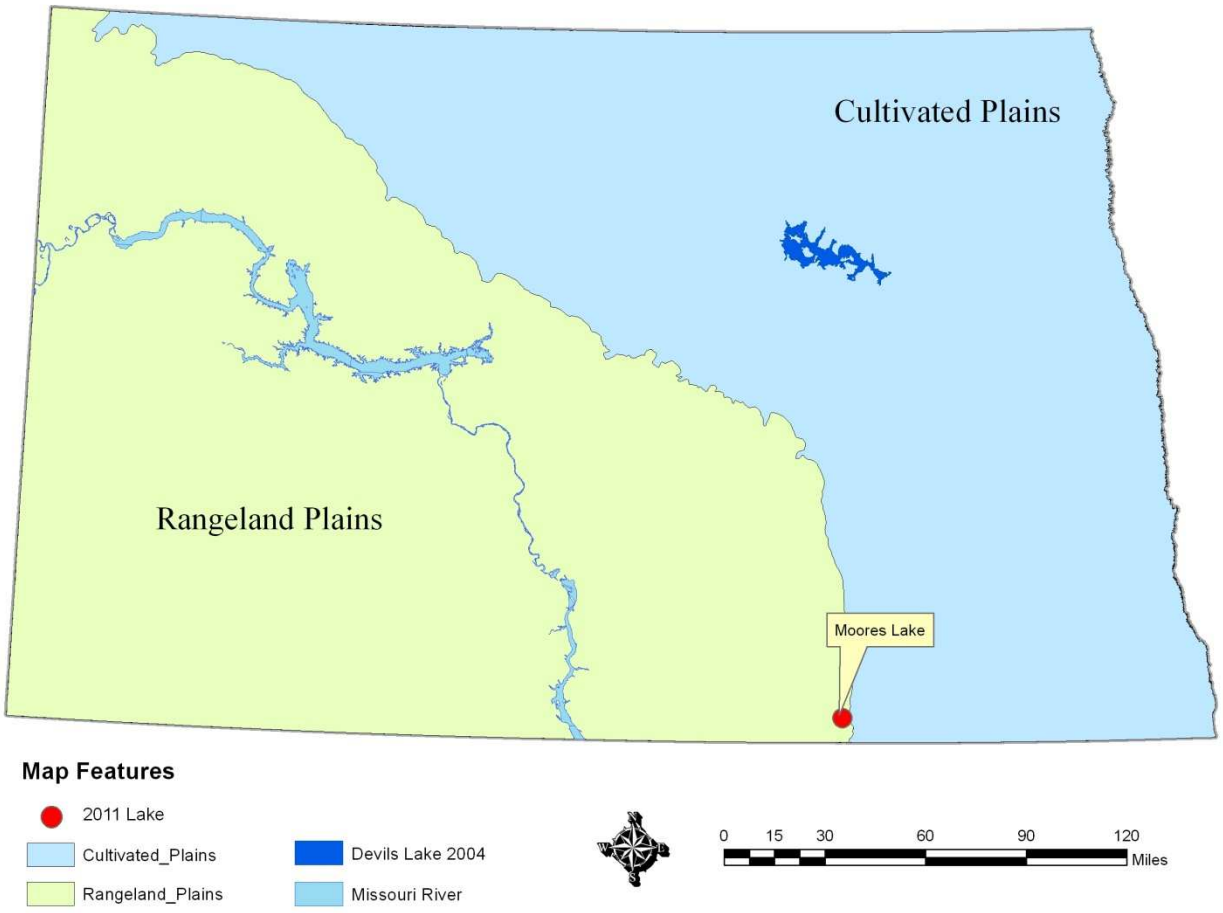

Figure 3. Moores Lake Location and the Cultivated and Rangeland Plans Regions

Water Quality Standards Classification: Moores Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: There is no historical water quality available for Moores Lake.

WATER QUALITY MONITORING RESULTS

The water quality assessment for Moores Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional data for natural lakes in the Rangeland Plains Region.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Moores Lake collected in 2011 (Figures 4 and 5). The profile data indicates that Moores Lake does not thermally stratification during the open water period. Data also indicates that during the open water period the lake remains well enough oxygenated to support aquatic life.

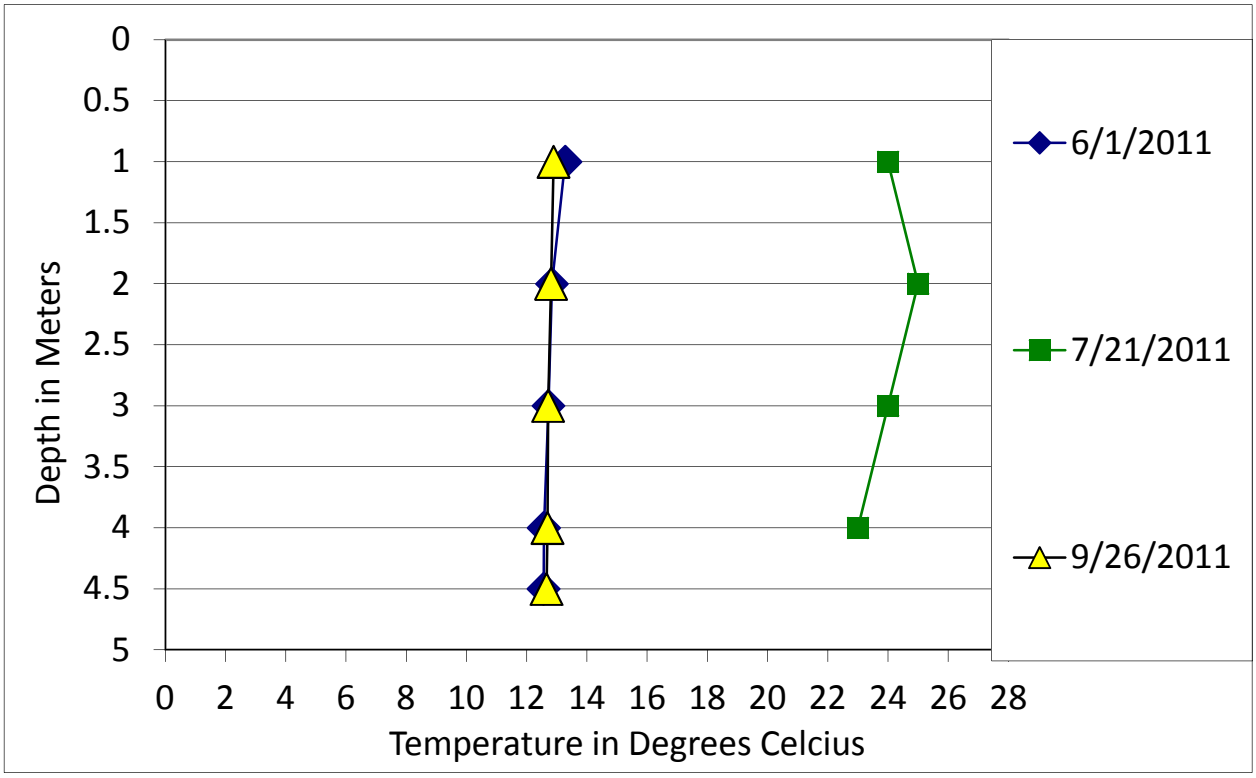

Figure 4. Temperature Profiles for Moores Lake

General Water Quality: Data collected in 2011 indicates that Moores Lake is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 209 to 231 mg/L (Table 1) and that the lake is sodium sulfate dominated with an average sodium concentration of 40.2 mg/L and an average sulfate concentration of 407 mg/L. The average total dissolved solids concentration and specific conductance measurements for the 2011 sampling period were 613 mg/L and 1090 µmhos/cm, respectively. The average total nitrogen and total phosphorus concentrations were 0.85 mg/L and 0.03 mg/L respectively.

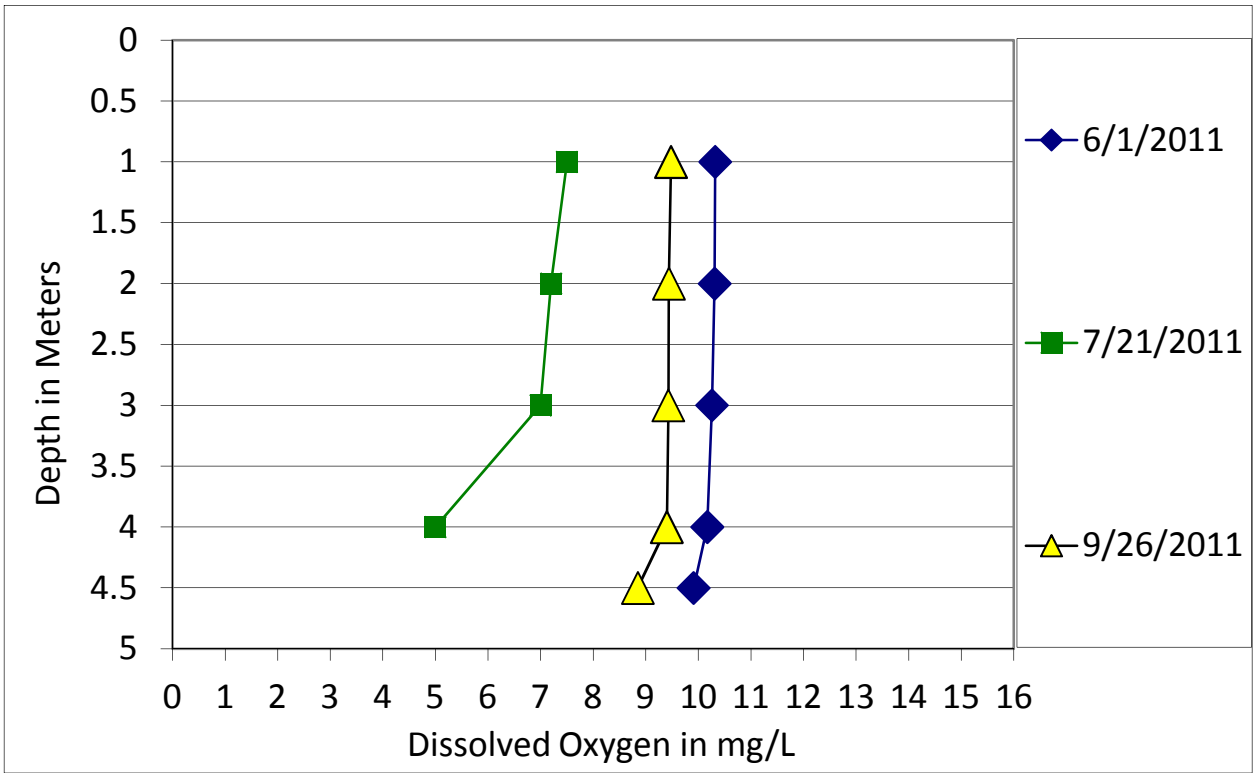

Figure 5. Dissolved Oxygen Profiles for Moores Lake

When compared to water quality for lakes in the Rangeland Plans Region, Moores Lake is fresher and less eutrophic than most (Tables 1 and 2). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 1398 mg/L, 1.75 mg/L, and 0.22 mg/L respectively, compared to Moores Lake's average TDS, total nitrogen, and total phosphorus concentrations of 613 mg/L, 0.85 mg/L and 0.04 mg/L respectively.

Limiting Nutrients: The water quality samples collected in 2011 indicate that Moores Lake is phosphorus limited (Figure 6). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen to total phosphorus (N:P) of 15 to 1 is nutrient equilibrium. Using this assumption when the N:P ratio is less than 15:1, nitrogen is limiting and when it exceeds 15:1 phosphorus is. Moores Lake total nitrogen to total phosphorus ratios ranged between a low of 23 and 93 in 2011 consistently indicating it is phosphorus limited.

Table 1. Statistical Summary of Moores Lake's 2011 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	223	209	231	12
Total Ammonia as N	mg/L	3	0.03[1]	0.03[1]	0.03[1]	0
Bicarbonate (HCO_3)	mg/L	3	260	251	268	9
Calcium (Ca)	mg/L	3	82.9	76	87	6
Carbonate (CO_3)	mg/L	3	6	2	10	4
Chloride (Cl)	mg/L	3	10.1	6.9	15	4.3
Chlorophyll-a	µg/L	3	6	6	6	0
Specific Conductance	µmhos	3	1090	1080	1100	10
Total Dissolved Solids	mg/L	3	786	778	795	9
Total Hardness as ($CaCO_3$)	mg/L	3	613	605	622	9
Hydroxide (OH)	mg/L	3	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	3	0.1	0.08	0.15	0.04
Magnesium (Mg)	mg/L	3	98.7	94.2	105	5.6
Nitrate + Nitrite as N	mg/L	3	0.05	0.03[1]	0.08	0.03
Total Kjeldahl Nitrogen as N	mg/L	3	0.8	0.71	0.87	0.08
Total Nitrogen as N	mg/L	3	0.85	0.74	0.95	0.11
pH		3	8.41	8.32	8.51	0.1
Total Phosphorus as P	mg/L	3	0.03	0.01[1]	0.04	0.02
Potassium (K)	mg/L	3	11.9	11.2	12.5	0.7
Sodium (Na)	mg/L	3	40.2	38.5	42.5	2.1
Sulfate (SO4)	mg/L	3	407	400	417	9

[1]Equal to the lower reporting limit

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2011, Moores Lake's trophic status is estimated as mesotrophic bordering on eutrophic with no recognizable trend (Figure 7). The Trophic Status Index (TSI) scores based on chlorophyll-a was consistently at 48 at all three sample dates and based on secchi disk and total phosphorus the range was 34 to 58 supports a mesotrophic estimation.

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Lakes in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	430	499	111	4770	466
Total Ammonia as N	mg/L	554	0.105	0.001	2.23	0.223
Bicarbonate (HCO_3)	mg/L	430	461	60	2990	308
Calcium (Ca)	mg/L	431	42.9	0.5	294	38.9
Carbonate (CO_3)	mg/L	424	74	1	1420	141
Chloride (Cl)	mg/L	430	41.6	1.7	1070	97.8
Chlorophyll-a	µg/L	383	22	2	292	36
Specific Conductance	µmhos	430	1939	424	20100	1890
Total Dissolved Solids	mg/L	430	1398	227	18200	1640
Total Hardness as ($CaCO_3$)	mg/L	431	530	74	2370	299
Hydroxide (OH)	mg/L	369	1	1	1	0
Iron (Fe)	mg/L	432	0.23	0.01	7.07	0.52
Magnesium (Mg)	mg/L	431	102.8	8.5	567	69.5
Nitrate + Nitrite as N	mg/L	551	0.042	0.001	0.54	0.055
Total Kjeldahl Nitrogen as N	mg/L	523	1.82	0.08	8.5	1.04
Total Nitrogen as N	mg/L	461	1.75	0.24	5.52	0.87
pH		430	8.78	7.4	9.87	0.36
Total Phosphorus as P	mg/L	561	0.22	0.01	1.94	0.33
Potassium (K)	mg/L	431	32.8	3.1	356	35.7
Sodium (Na)	mg/L	431	278	16.9	4680	490.1
Sulfate (SO4)	mg/L	430	590.9	34	10500	847.6

[1]Equal to the lower reporting limit
[2]Data collected from 66 natural and enhanced Lakes between 1991 and 2011

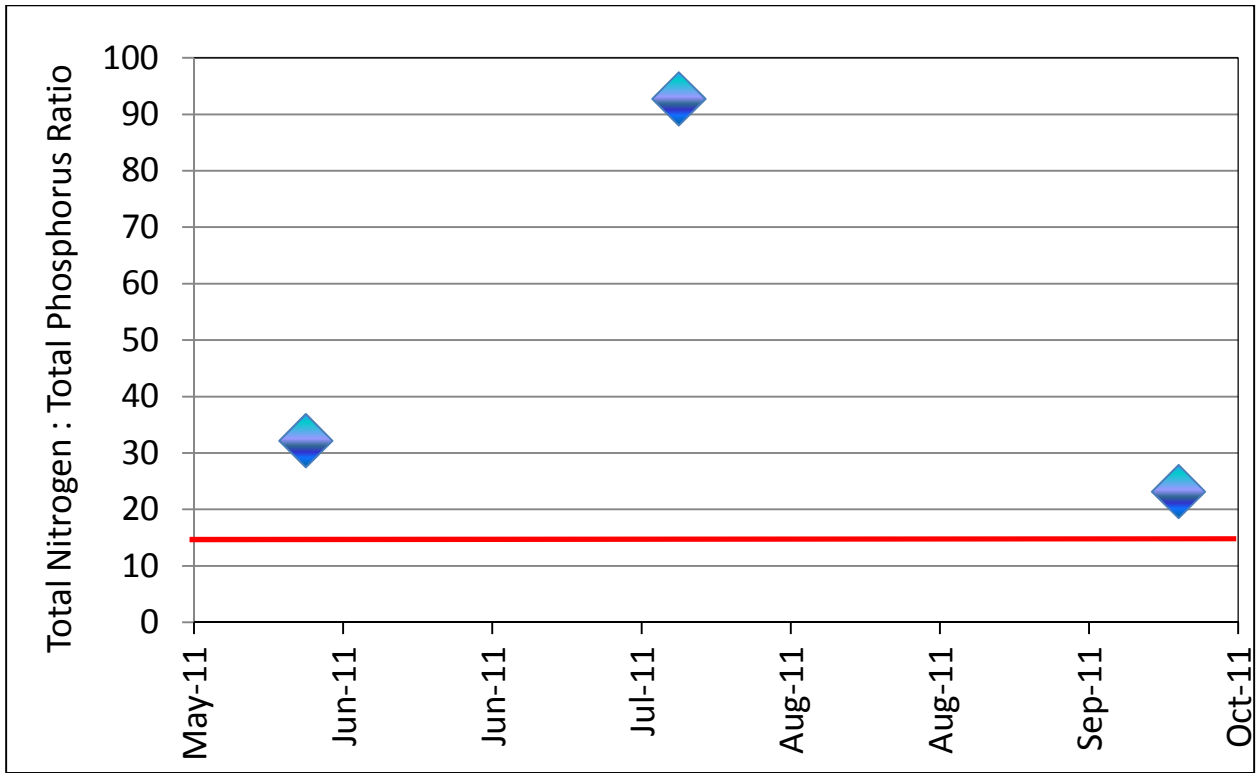

Figure 6. Moores Lake's Total Nitrogen to Total Phosphorus Ratio

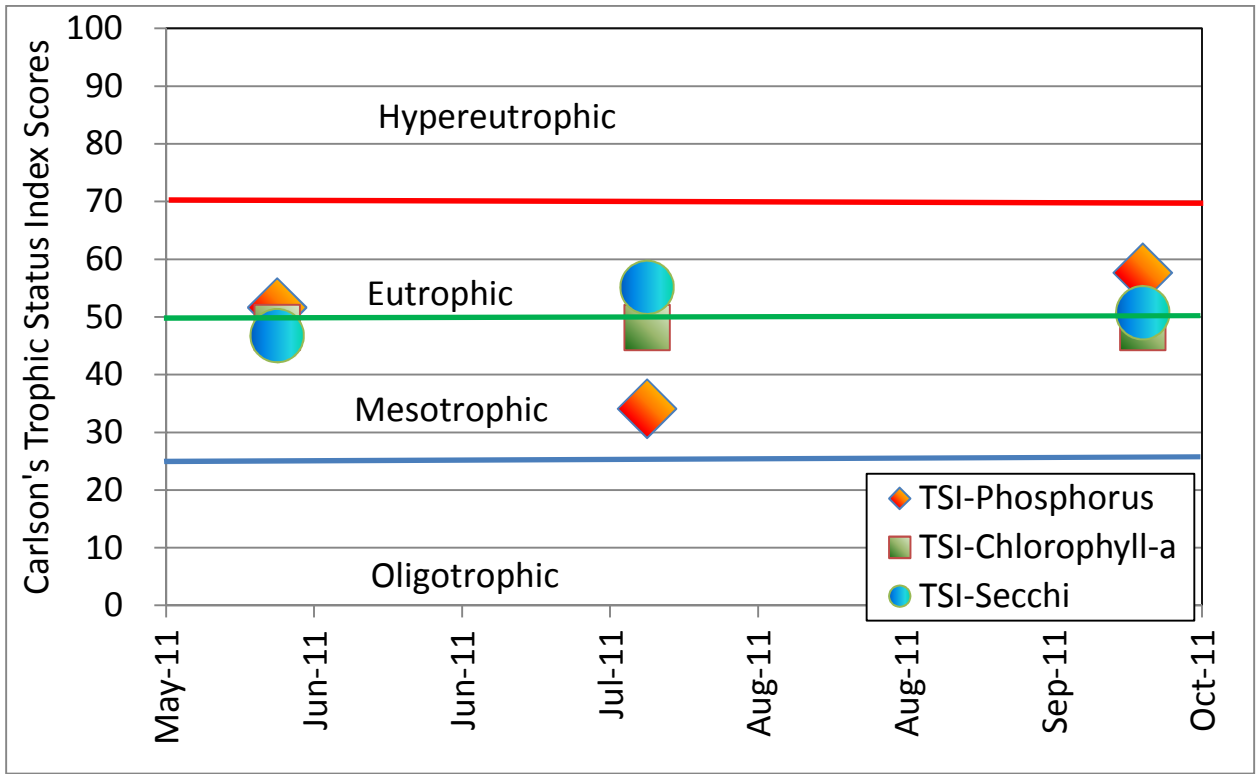

Figure 7. Moores Lake's TSI Scores

Baukol-Noonan Dam, Divide County

BACKGROUND

Baukol-Noonan Dam is an abandoned strip mine pit on the West Branch of Short Creek 2.5 miles east and 1 mile south of Noonan, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish Department. Fish species managed for are trout, largemouth bass and bluegill.

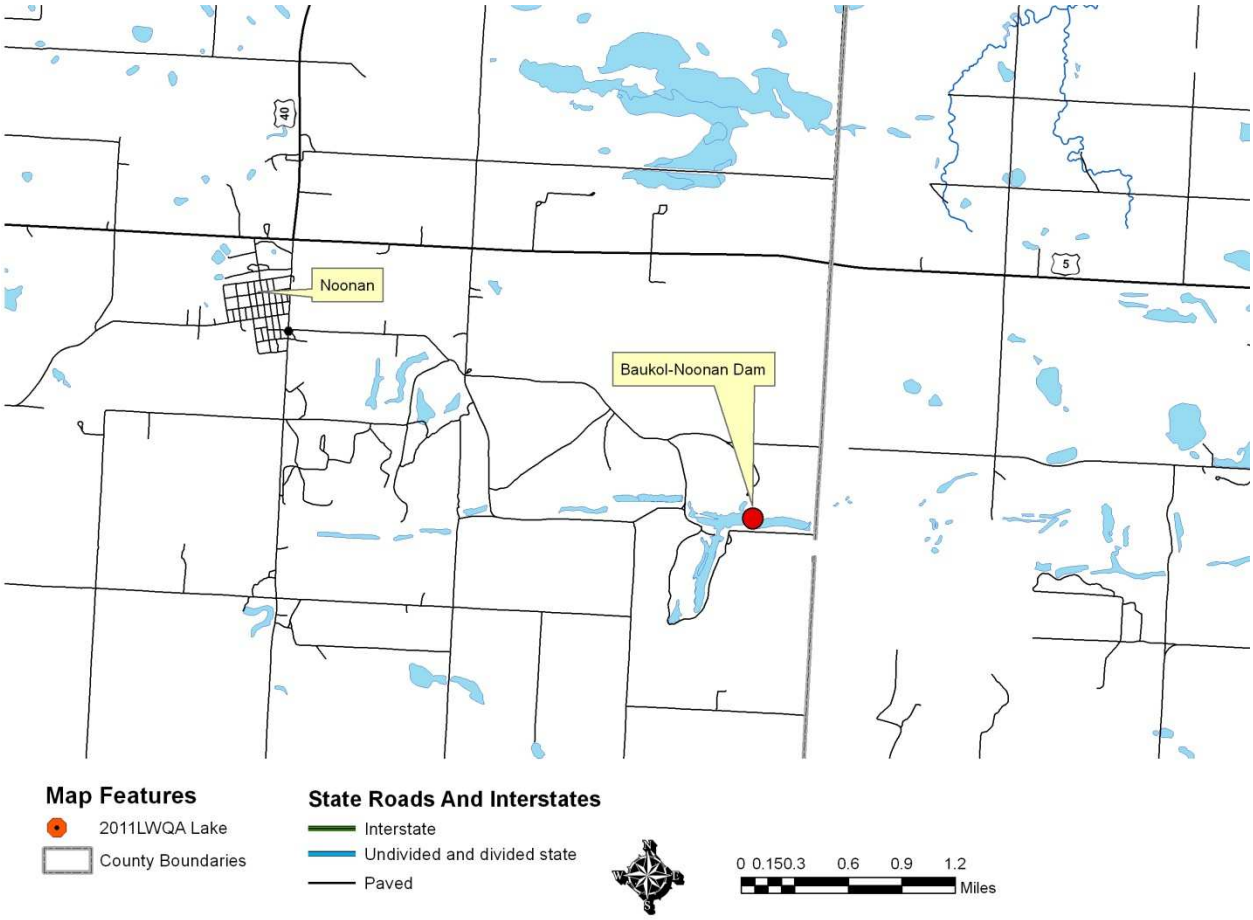

Figure 1. Location of Baukol-Noonan Dam

Physiographic/Ecological Setting: Baukol-Noonan Dam has 3 distinct sections. In total it has a surface area of 45.4 acres and a maximum depth of 28.5ft. It is an isolated, narrow and fragmented reservoir (Figure 2). The reservoir is located in the Northern Glaciated Plains Level III Ecoregion, which is part of the broader Cultivated Plains Region (Figures 3).

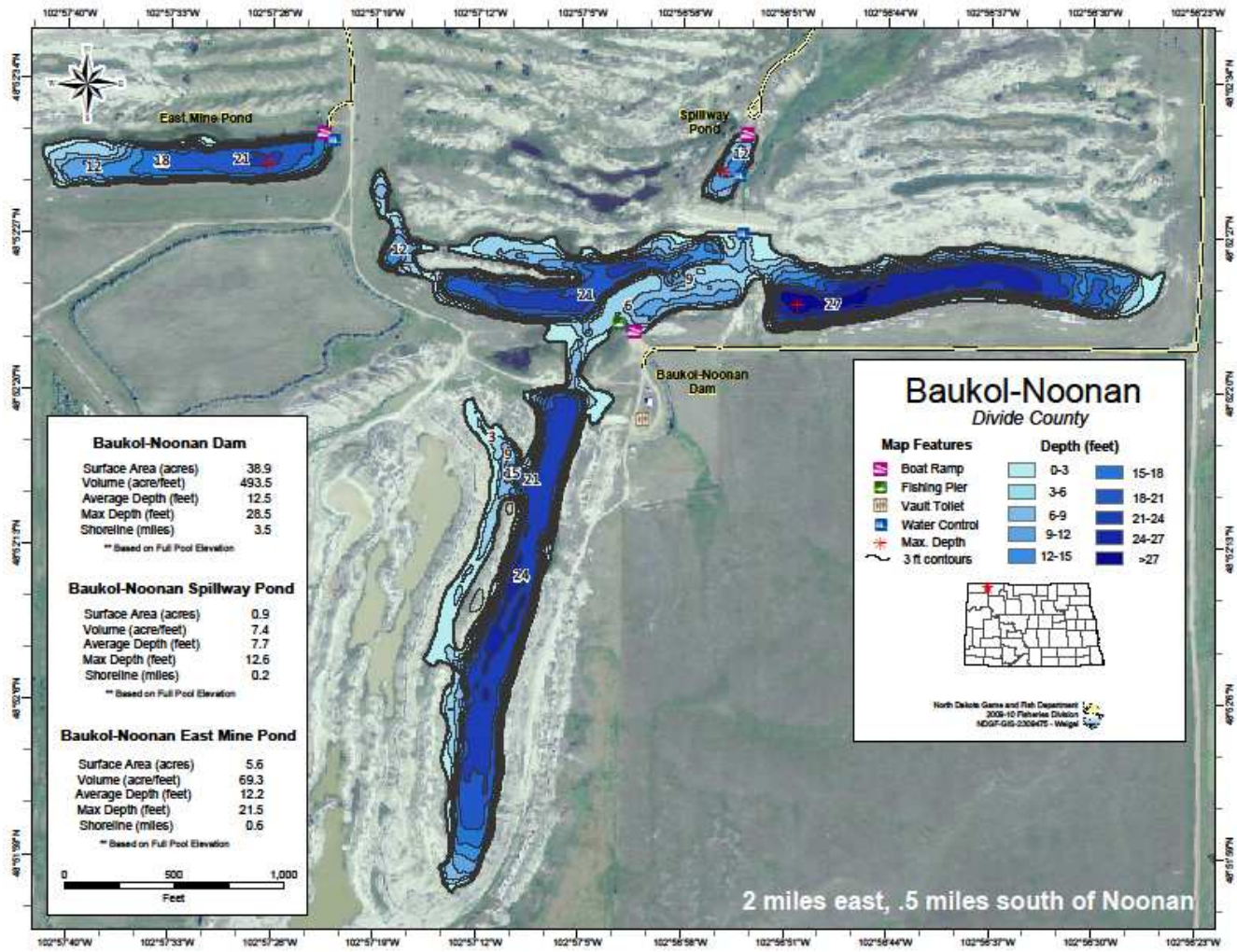

Figure 2. Contour Map of Baukol-Noonan Dam (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Baukol-Noonan Dam are excellent and include camping and picnic areas with vault toilets and covered shelter and multiple boat ramps.

Water Quality Standards Classification: Baukol-Noonan Dam is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 2 waterbody. Class 2 lakes and reservoirs are defined as a "cool water fishery" or "waters capable of supporting natural reproduction and growth of cool water fishes (e.g., northern pike and walleye) and associated aquatic biota. These waters are also capable of supporting growth and marginal survival of cold water species and associated biota."

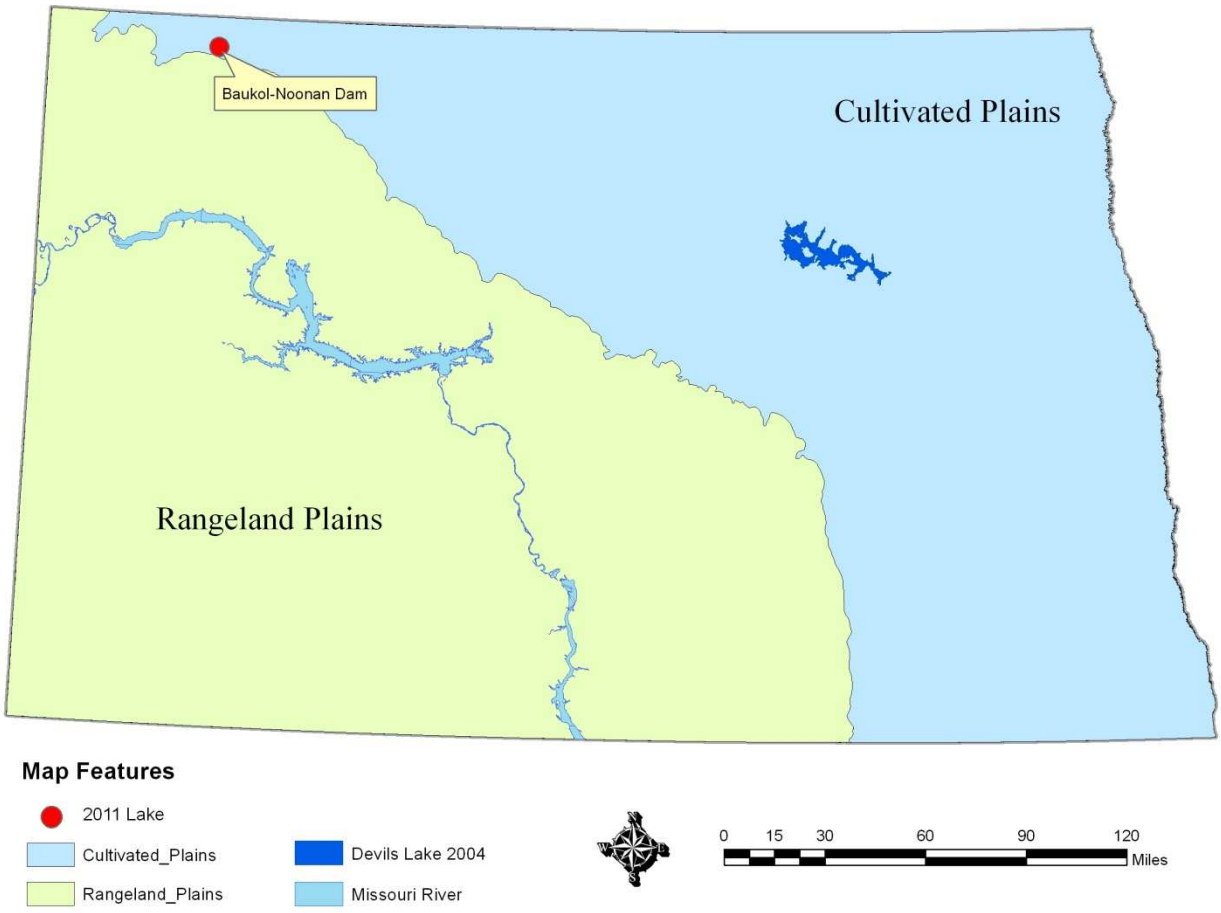

Figure 3. Baukol-Noonan Dam Location and the Cultivated and Rangeland Plans Regions

Historical Water Quality Sampling: Historical water quality data include 3 samples collected in 1992-1993.

WATER QUALITY MONITORING RESULTS

The water quality assessment for Baukol-Noonan Dam is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional data for reservoirs in the Cultivated Plains Region.

Temperature and Dissolved Oxygen Profile Results: There are six temperature and dissolved oxygen profiles for Baukol-Noonan Dam collected in 1992-93 and 2011 (Figures 4 and 5). The temperature profiles indicate that Baukol-Noonan Dam occasionally thermally stratifies and de-stratifies which would be expected in this narrow protected body of water (Figure 4). The oxygen profiles indicate that the reservoir experiences moderate oxygen decay in the hypolimnion while the majority of the reservoir remains well enough oxygenated to support aquatic life (Figure 5).

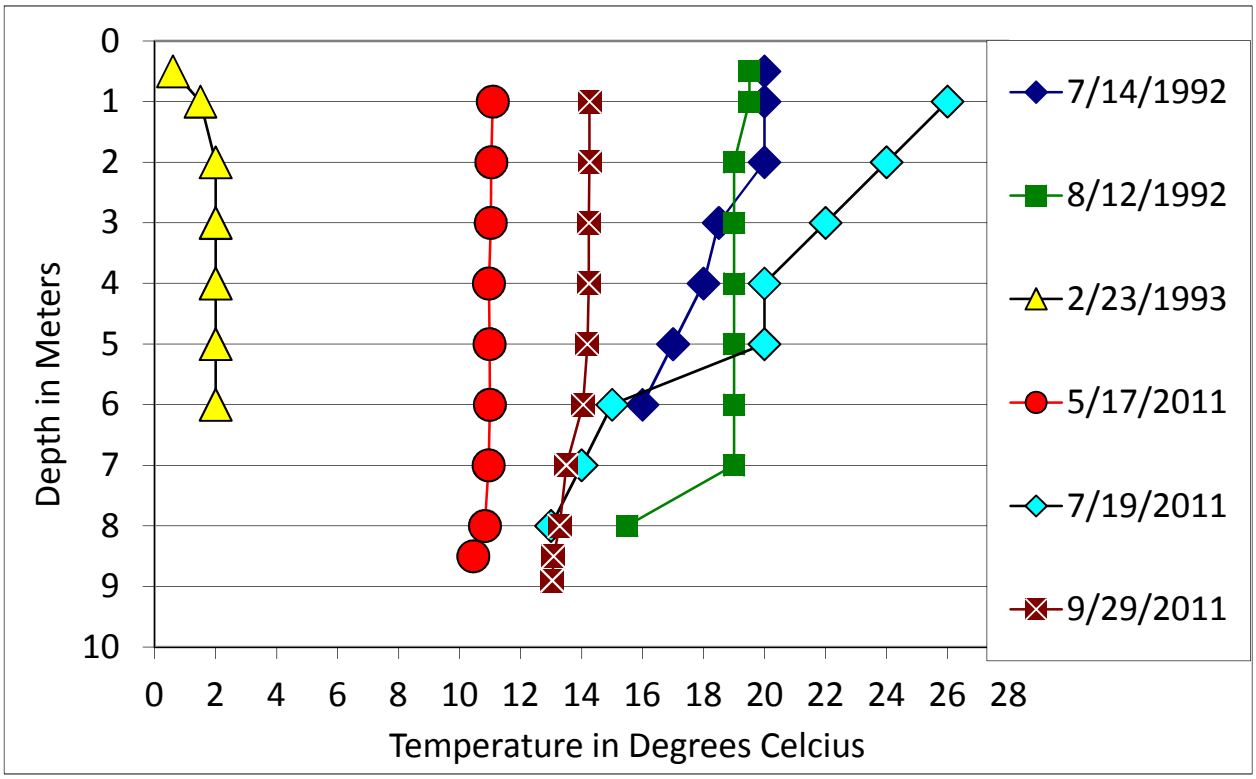

Figure 4. Temperature Profiles for Baukol-Noonan Dam

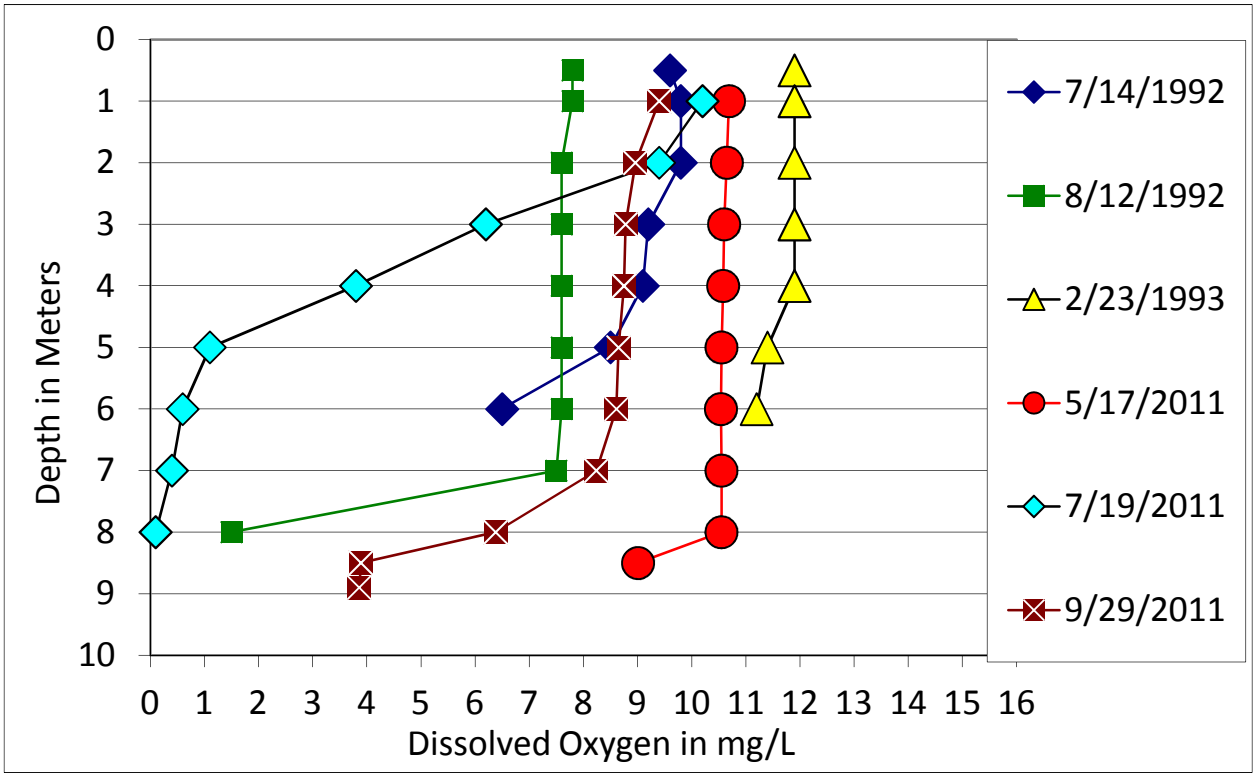

Figure 5. Dissolved Oxygen Profiles for Baukol-Noonan Dam

General Water Quality: Data collected in 2011 indicates that Baukol-Noonan Dam is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 192 to 286 mg/L (Table 1) and that the reservoir is sodium sulfate dominated with an average sodium concentration of 259 mg/L and an average sulfate concentration of 624 mg/L. The average total dissolved solids concentration and specific conductance measurements for the 2011 sampling period were 1189 mg/L and 1677 µmhos/cm, respectively. The average total nitrogen and total phosphorus concentrations were 0.907 mg/L and 0.012 mg/L respectively.

Table 1. Statistical Summary of Baukol-Noonan Dam's 2011 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	238	192	286	47
Total Ammonia as N	mg/L	3	0.048	0.03[1]	0.085	0.032
Bicarbonate (HCO_3)	mg/L	3	270	192	338	74
Calcium (Ca)	mg/L	3	74	59	96.5	19.8
Carbonate (CO_3)	mg/L	3	10	3[1]	21	9.6
Chloride (Cl)	mg/L	3	23.9	17.3	35.5	10.1
Chlorophyll-a	µg/L	3	9.7	5.3	12	3.8
Specific Conductance	µmhos	3	1677	1310	2070	381
Total Dissolved Solids	mg/L	3	1189	897	1430	270
Total Hardness as ($CaCO_3$)	mg/L	3	403	346	501	85
Hydroxide (OH)	mg/L	3	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	3	0.22	0.05[1]	0.45	0.21
Magnesium (Mg)	mg/L	3	53	43.6	63.1	9.8
Nitrate + Nitrite as N	mg/L	3	0.03[1]	0.03[1]	0.03[1]	0
Total Kjeldahl Nitrogen as N	mg/L	3	0.877	0.639	1.06	0.216
Total Nitrogen as N	mg/L	3	0.907	0.669	1.09	0.216
pH		3	8.5	8.4	8.8	0.3
Total Phosphorus as P	mg/L	3	0.016	0.012	0.021	0.005
Potassium (K)	mg/L	3	11	10.5	11.9	0.8
Sodium (Na)	mg/L	3	259.3	170	377	106.4
Sulfate (SO4)	mg/L	3	624	472	720	133

[1]Equal to the lower reporting limit

When compared to water quality for reservoirs in the Cultivated Plans Region, Baukol-Noonan Dam is substantially less fresh and nutrient poorer than average (Tables 1 and 2). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 352 mg/L, 1.51 mg/L, and 0.324 mg/L respectively, compared to Baukol-Noonan Dam's average TDS, total nitrogen, and total phosphorus concentrations of 1189 mg/L, 0.907 mg/L and 0.016 mg/L respectively.

Table 2. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Cultivated Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	429	262	88	891	97
Total Ammonia as N	mg/L	609	0.141	0.001	2.07	0.203
Bicarbonate (HCO_3)	mg/L	429	296	91	951	108
Calcium (Ca)	mg/L	432	69	19	169	25
Carbonate (CO_3)	mg/L	411	13	1	93	15
Chloride (Cl)	mg/L	430	21	1	113	17
Chlorophyll-a	µg/L	476	19.8	1.5	388	29.5
Specific Conductance	µmhos	429	1049	217	3140	501
Total Dissolved Solids	mg/L	421	692	127	2300	377
Total Hardness as ($CaCO_3$)	mg/L	432	352	95	1090	126
Hydroxide (OH)	mg/L	368	1	1	1	0
Iron (Fe)	mg/L	430	0.15	0.01	3.19	0.22
Magnesium (Mg)	mg/L	432	43.6	11.2	161	19.8
Nitrate + Nitrite as N	mg/L	602	0.119	0.003	2.06	0.224
Total Kjeldahl Nitrogen as N	mg/L	522	1.45	0.21	4.41	0.64
Total Nitrogen as N	mg/L	461	1.51	0.42	3.95	0.61
pH		430	8.34	1.76	9.4	0.52
Total Phosphorus as P	mg/L	611	0.324	0	2.27	0.29
Potassium (K)	mg/L	432	11.5	2.7	34.5	5.3
Sodium (Na)	mg/L	432	100	2	582	103
Sulfate (SO4)	mg/L	430	285	1	1350	212

[1]Equal to the lower reporting limit
[2]Data collected from 45 reservoirs between 1991 and 2011

When comparing historical water quality data (1992-1993) to 2011 there has been a notable decrease in the concentrations of dissolved solids. For example, the historical average total for total dissolved solids, sulfate, and alkalinity and bicarbonates 2070 mg/L, 1172 mg/L, 353 mg/L, and 329 mg/L compared to 2011 concentrations of 1189 mg/L, 624 mg/L, 270 mg/L, and 238 mg/L.

Unlike dissolved solids, nutrient concentrations have remain virtually unchanged. For example the historical total nitrogen and total phosphorus concentration are 0.764 mg/L and 0.011 mg/L compared to the 2011 concentrations of 0.907 mg/L and 0.016 mg/L, respectively (Tables 1 and 3).

Table 3. Statistical Summary of Baukol-Noonan Dam's 1992-1993 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	329	308	368	34
Total Ammonia as N	mg/L	2	0.04	0.01[1]	0.07	0.04
Bicarbonate (HCO_3)	mg/L	3	353	323	409	49
Calcium (Ca)	mg/L	3	50.6	49.6	51.2	0.9
Carbonate (CO_3)	mg/L	3	24	20	27	4
Chloride (Cl)	mg/L	3	35.9	34.1	39.2	2.8
Chlorophyll-a	µg/L	2	3[1]	3[1]	3[1]	0
Specific Conductance	µmhos	3	2834	2637	3140	268
Total Dissolved Solids	mg/L	3	2070	1840	2300	230
Total Hardness as ($CaCO_3$)	mg/L	3	315	308	324	8
Hydroxide (OH)	mg/L	1	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	3	0.128	0.073	0.215	0.076
Magnesium (Mg)	mg/L	3	45.7	44.6	47.8	1.8
Nitrate + Nitrite as N	mg/L	3	0.024	0.007	0.033	0.014
Total Kjeldahl Nitrogen as N	mg/L	2	0.74	0.6	0.88	0.198
Total Nitrogen as N	mg/L	2	0.764	0.61	0.913	0.212
pH		3	8.703	8.54	8.84	0.152
Total Phosphorus as P	mg/L	2	0.011	0.010[1]	0.021	0.015
Potassium (K)	mg/L	3	11.6	11.6	11.7	0.1
Sodium (Na)	mg/L	3	559	540	582	21
Sulfate (SO4)	mg/L	3	1172	976	1350	188

[1]Equal to the lower reporting limit

Limiting Nutrients: The water quality samples collected in 1992-93 and 2011 indicate that Baukol-Noonan Dam is phosphorus limited (Figure 6). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen to total phosphorus (N:P) of 15 to 1 is nutrient equilibrium. Using this assumption when the N:P ratio is less than 15:1, nitrogen is limiting and when it exceeds 15:1 phosphorus is.

The historical (1992-1993) N:P ratios ranged between 30 and 78 with one outlier of 5 in February of 1992. In 2011 the range of N:P ratios were more consistent falling between 46 and 78 indicating that phosphorus is the limiting nutrient for primary production in Baukol-Noonan Dam.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 1992-93 and 2011, Baukol-Noonan Dam's trophic status is estimated as mesotrophic in 1992-93 trending towards eutrophic in 2011 (Figure 7). The trophic status index (TSI) scores based on all estimators were consistent with chlorophyll-a ranging only 13 points (41 to 55), secchi disk ranging 20 points (47-67) and total phosphorus ranging 6 points (42-48) if the winter sample in 1993 is not included.

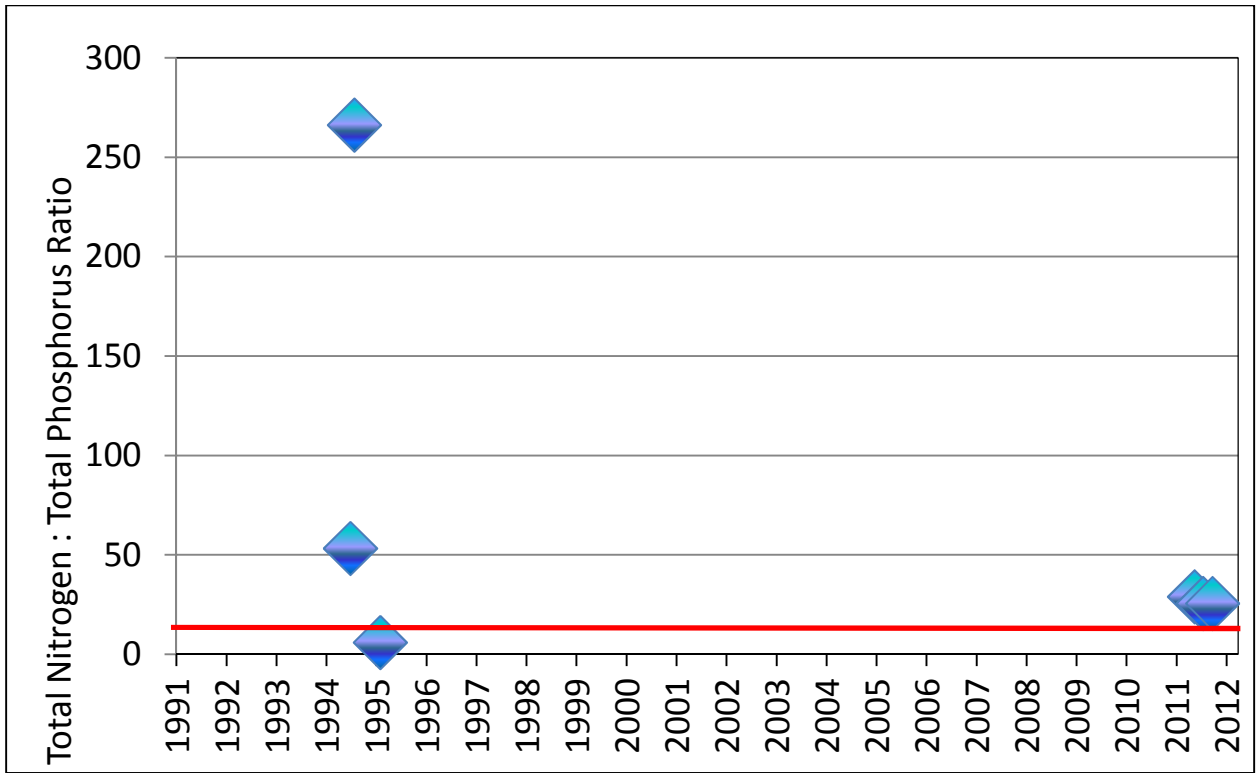

Figure 6. Baukol-Noonan Dam's Total Nitrogen to Total Phosphorus Ratio

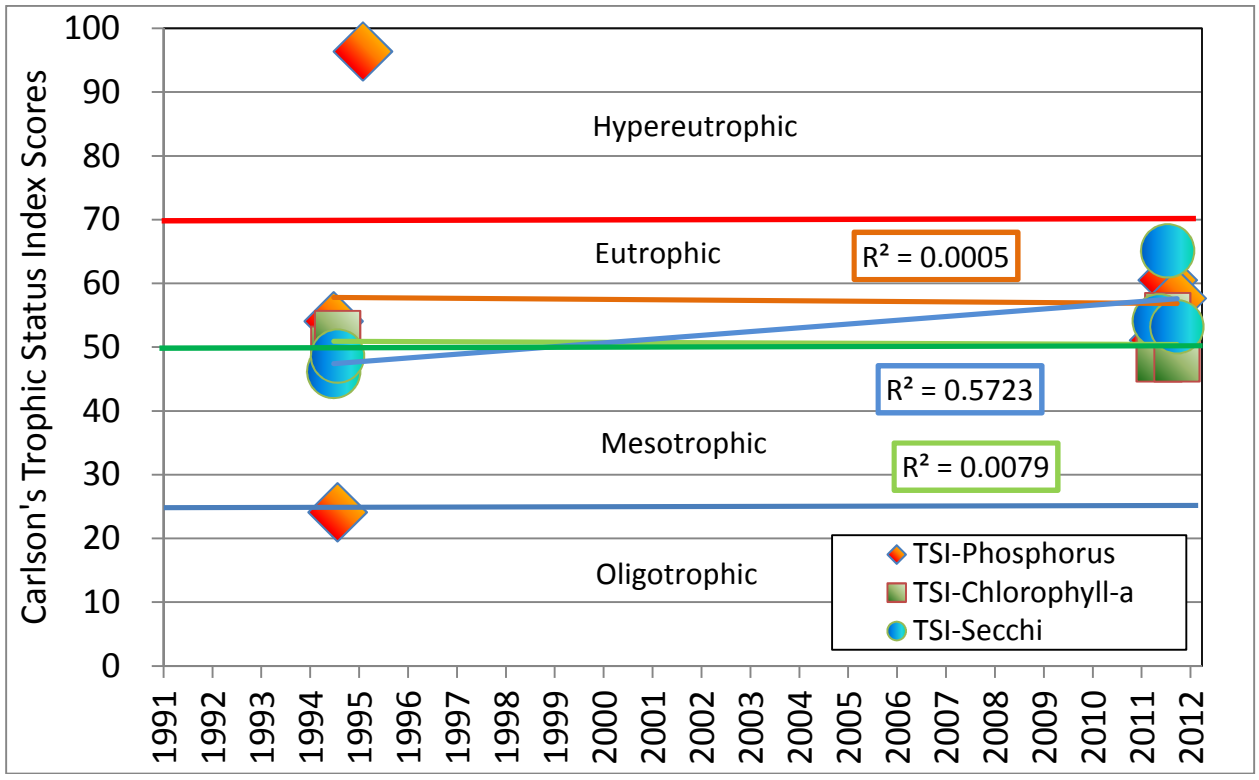

Figure 7. Baukol-Noonan Dam's TSI Scores

Skjermo Lake, Divide County

BACKGROUND

Skjermo Lake is an example of a nice prairie lake located just a few miles south of the Canadian border in the very northwest corner of the state. The nearest town to Skjermo Lake is Fortuna which lies 3 miles to the south and 4 miles east (Figure 1). The fishery is managed by the North Dakota Game and Fish Department. Fish species managed for are northern pike and yellow perch.

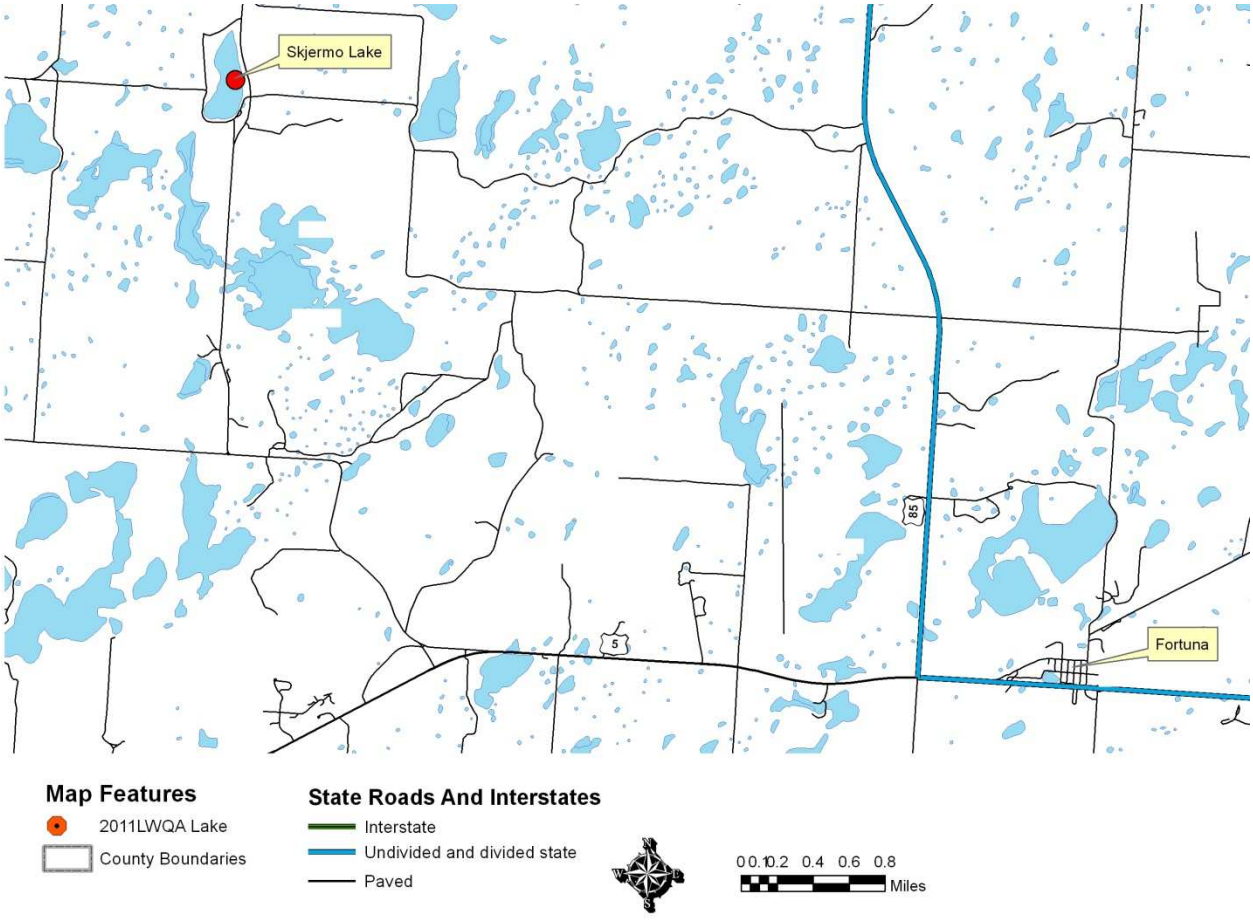

Figure 1. Location of Skjermo Lake

Physiographic/Ecological Setting: Skjermo Lake has a surface area of 42.6 acres, a mean depth of 9.6 feet and a maximum depth of 19.5 feet. Skjermo Lake is nested in a natural pocket within the end moraine of the last ice age known as the Missouri Coteau (Figure 2). The lake is located in the Northwestern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figures 3).

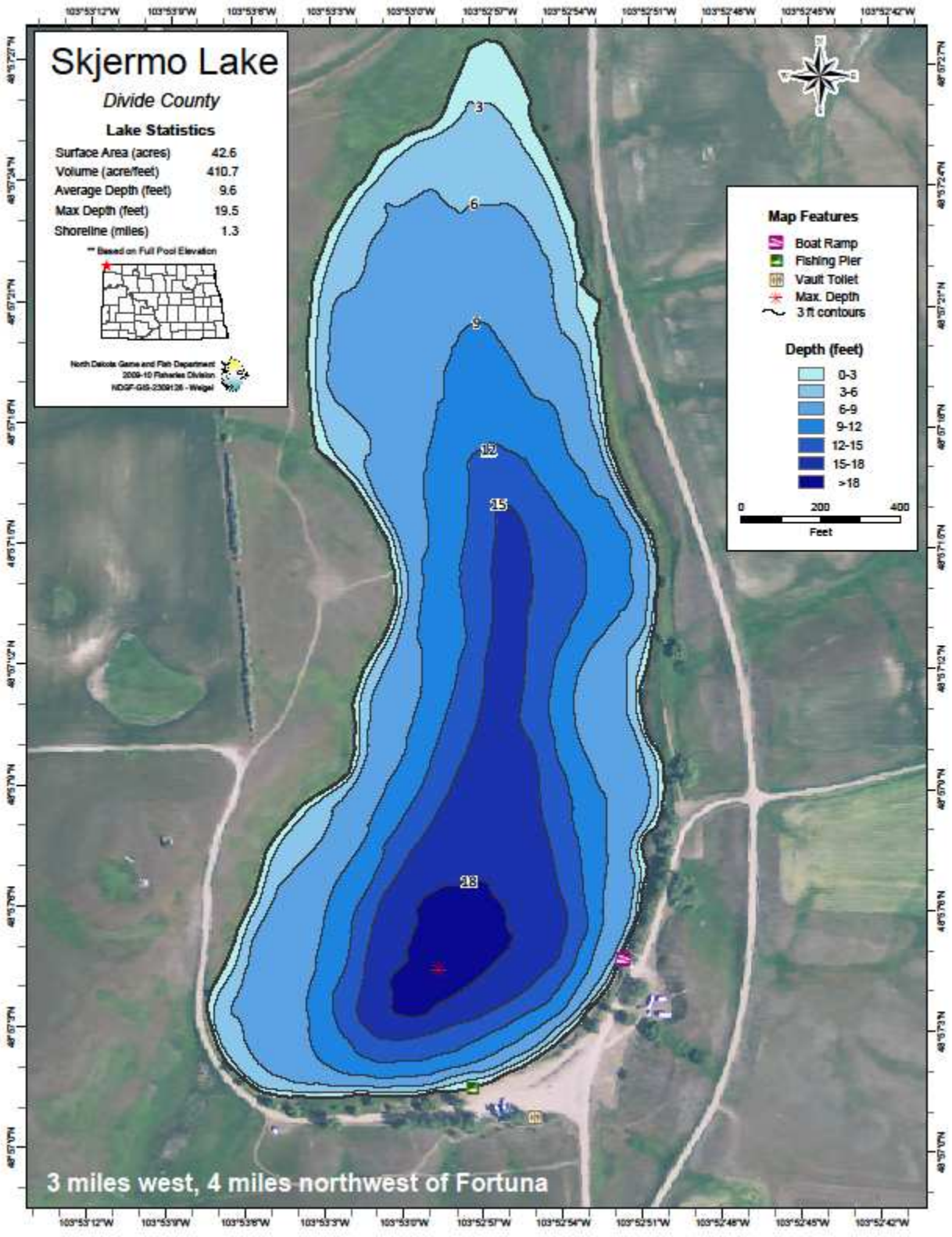

Figure 2. Contour Map of Skjermo Lake (Map Courtesy of North Dakota Game and Fish Department)

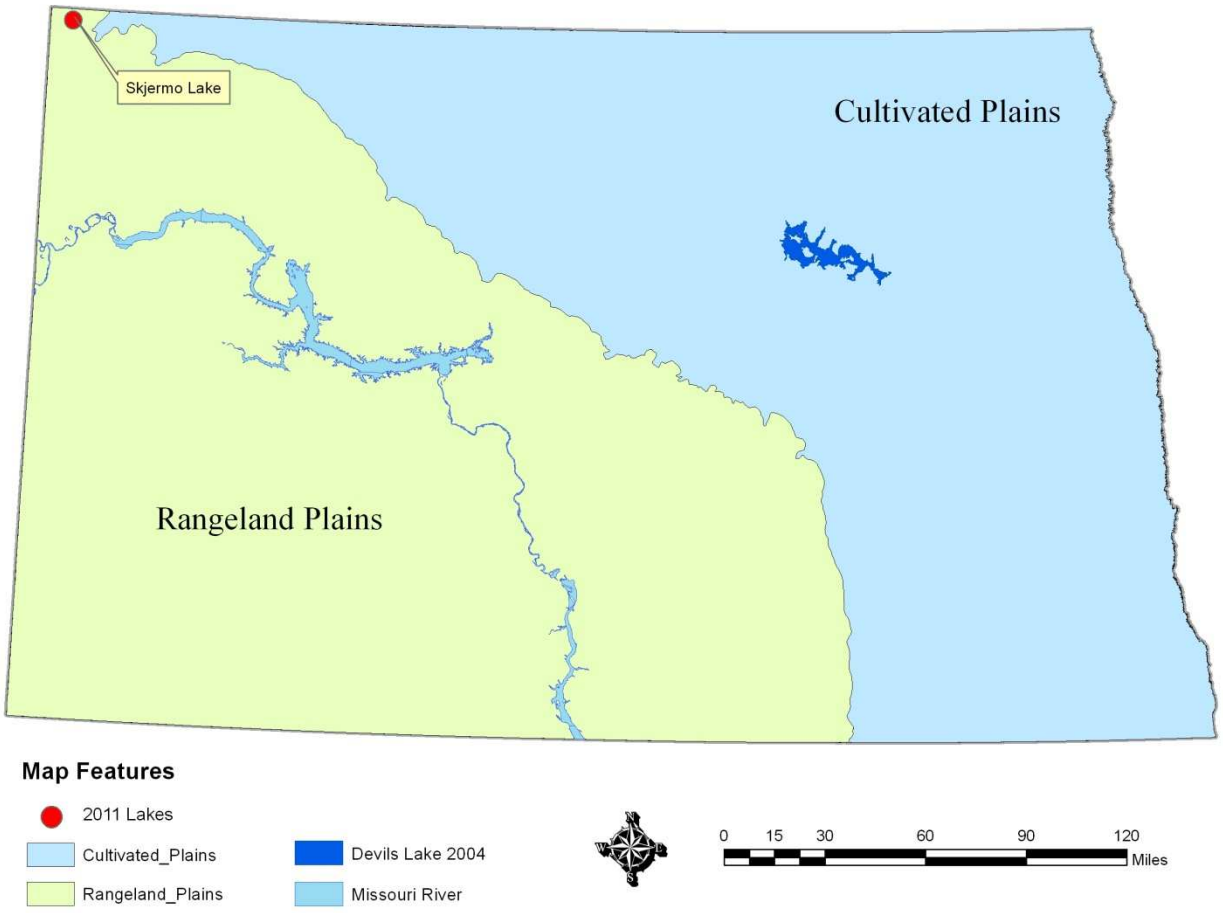

Figure 3. Skjermo Lake Location and the Cultivated and Rangeland Plans Regions

Recreational Facilities: Recreational facilities at Skjermo Lake are an access road, parking, camping and picnic area, a pavilion, small cement boat ramp and outdoor toilets.

Water Quality Standards Classification: Skjermo Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 2 lake. Class 2 lakes or reservoirs are defined as a "cool water fishery" or "waters capable of supporting natural reproduction and growth of cool water fishes (e.g., northern pike and walleye) and associated aquatic biota. These waters are also capable of supporting the growth and marginal survival of cold water species and associated biota."

Historical Water Quality Sampling: Historical water quality data include 3 samples collected in 1992-1993.

WATER QUALITY MONITORING RESULTS

The water quality assessment for Skjermo Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional data for lakes in the Rangeland Plains Region.

Temperature and Dissolved Oxygen Profile Results: There are six temperature and dissolved oxygen profiles for Skjermo Lake collected in 1992-1993 and 2011 (Figures 4 and 5). The temperature profiles indicate that Skjermo Lake weakly thermally stratification for short durations during the open water period (Figure 4). The dissolved oxygen profiles indicates that during the open water period the lake remains well enough oxygenated to support aquatic life but there is at risk of partial winter kills during years with normal or above normal ice and snow cover (Figure 5).

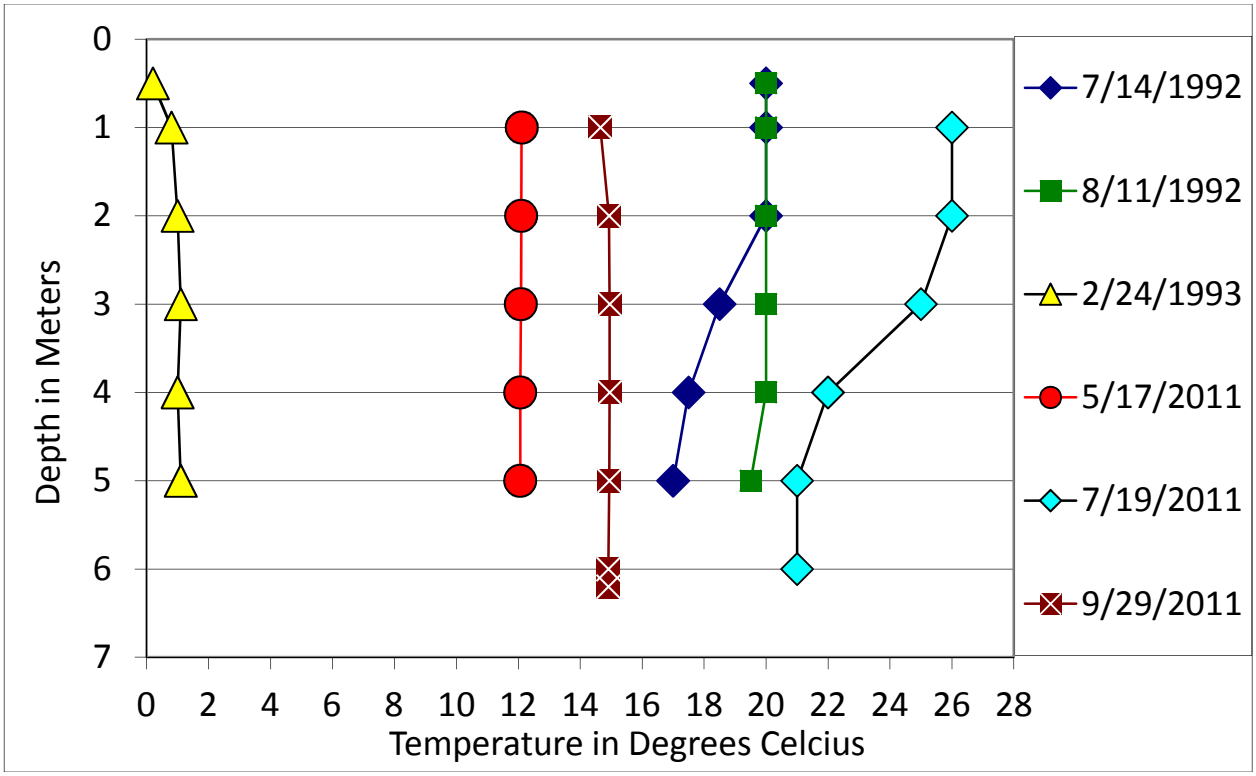

Figure 4. Temperature Profiles for Skjermo Lake

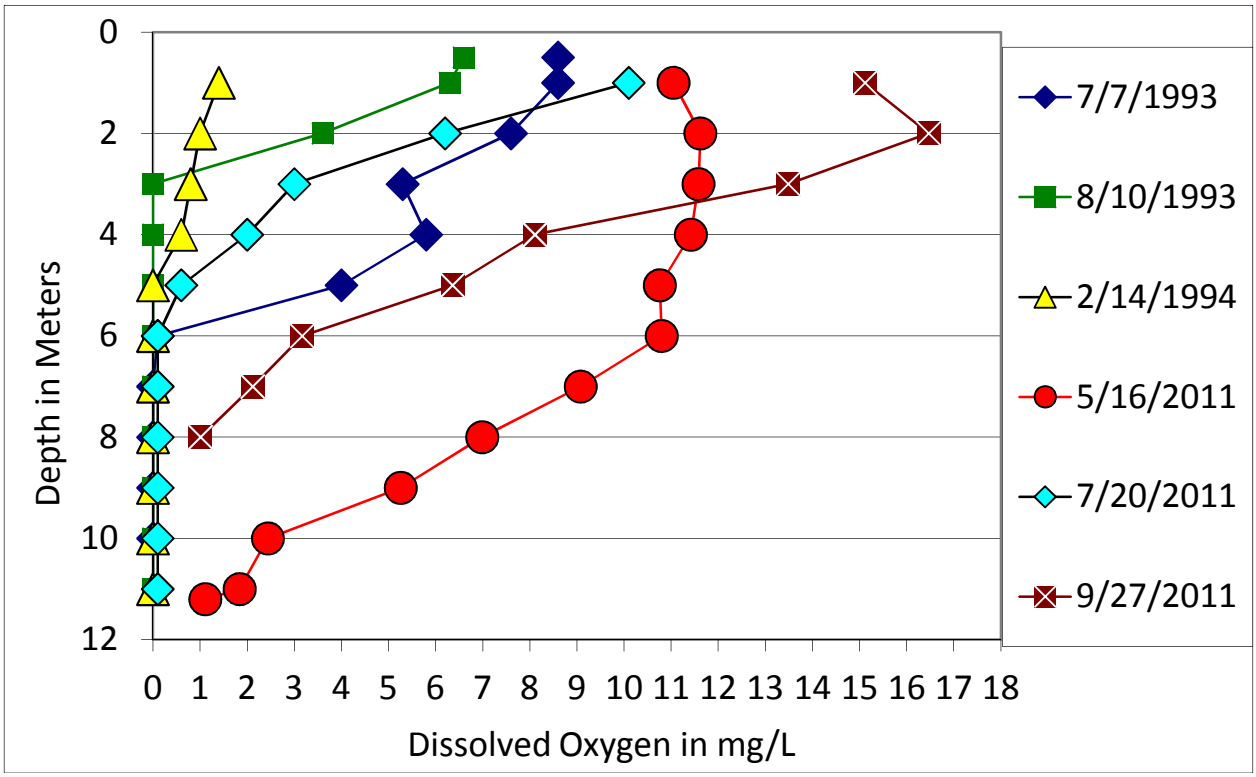

Figure 5. Dissolved Oxygen Profiles for Skjermo Lake

General Water Quality: Data collected in 2011 indicates that Skjermo Lake is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 146 to 160 mg/L (Table 1) and that the lake is sodium sulfate dominated with an average sodium concentration of 94 mg/L and an average sulfate concentration of 1447 mg/L. The average total dissolved solids concentration and specific conductance measurements for the 2011 sampling period were 2230 mg/L and 2533 µmhos/cm, respectively. The average total nitrogen and total phosphorus concentrations were 1.69 mg/L and 0.01 mg/L respectively.

When compared to the water quality for natural lakes in the Rangeland Plans region, Skjermo Lake is more mineralized but less eutrophic than average (Tables 1 and 2). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 1398 mg/L, 1.75 mg/L, and 0.220 mg/L compared to Skjermo Lake's 2011 average TDS, total nitrogen, and total phosphorus concentrations of 2230 mg/L, 1.69 mg/L and 0.01 mg/L, respectively.

Table 1. Statistical Summary of Skjermo Lake's 2011 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	155	146	160	8
Total Ammonia as N	mg/L	3	0.41	0.06	1.05	0.55
Bicarbonate (HCO_3)	mg/L	3	190	178	196	10
Calcium (Ca)	mg/L	3	285	275	294	9.5
Carbonate (CO_3)	mg/L	3	1[1]	1[1]	1[1]	0
Chloride (Cl)	mg/L	3	71.5	68.3	77	4.8
Chlorophyll-a	µg/L	3	4	3[1]	6	1.7
Specific Conductance	µmhos	3	2533	2480	2610	68
Total Dissolved Solids	mg/L	3	2230	2150	2290	72
Total Hardness as ($CaCO_3$)	mg/L	3	1603	1550	1660	55
Hydroxide (OH)	mg/L	3	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	3	0.08	0.05	0.12	0.03
Magnesium (Mg)	mg/L	3	216	210	224	7.1
Nitrate + Nitrite as N	mg/L	3	0.17	0.09	0.27	0.09
Total Kjeldahl Nitrogen as N	mg/L	3	1.52	1	2.38	0.75
Total Nitrogen as N	mg/L	3	1.69	1.09	2.65	0.84
pH		3	8.03	7.71	8.21	0.28
Total Phosphorus as P	mg/L	3	0.01[1]	0.01[1]	0.01[1]	0
Potassium (K)	mg/L	3	24.2	23.4	24.9	0.8
Sodium (Na)	mg/L	3	94	92.2	95.7	1.8
Sulfate (SO4)	mg/L	3	1447	1370	1490	67

[1]Equal to the lower reporting limit

When comparing historical water quality data collected in 1992-1993 to the 2011 data, there appears to be an improvement in nutrient concentrations particularly in the ratio of total nitrogen to total phosphorus. For example, the historical average total nitrogen and total phosphorus concentrations were 1.44 mg/L and 0.032 mg/L, respectively, compared to the 2011 averages of 1.69 mg/L and 0.01 mg/L (Tables 1 and 3).

While the ratios of nutrients seem to have improved, the concentrations of dissolved solids have moved up and down but do not show a clear trend. Examples are the bicarbonate, sulfate and sodium average concentrations of 190 mg/L, 1447 mg/L and 94 mg/L in 2011 compared to the 1992-1993 average concentrations of 101 mg/L, 1583 mg/L and 167 mg/L, respectively.

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Lakes in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	430	499	111	4770	466
Total Ammonia as N	mg/L	554	0.105	0.001	2.23	0.223
Bicarbonate (HCO_3)	mg/L	430	461	60	2990	308
Calcium (Ca)	mg/L	431	42.9	0.5	294	38.9
Carbonate (CO_3)	mg/L	424	74	1	1420	141
Chloride (Cl)	mg/L	430	41.6	1.7	1070	97.8
Chlorophyll-a	µg/L	383	22	2	292	36
Specific Conductance	µmhos	430	1939	424	20100	1890
Total Dissolved Solids	mg/L	430	1398	227	18200	1640
Total Hardness as ($CaCO_3$)	mg/L	431	530	74	2370	299
Hydroxide (OH)	mg/L	369	1	1	1	0
Iron (Fe)	mg/L	432	0.23	0.01	7.07	0.52
Magnesium (Mg)	mg/L	431	102.8	8.5	567	69.5
Nitrate + Nitrite as N	mg/L	551	0.042	0.001	0.54	0.055
Total Kjeldahl Nitrogen as N	mg/L	523	1.82	0.08	8.5	1.04
Total Nitrogen as N	mg/L	461	1.75	0.24	5.52	0.87
pH		430	8.78	7.4	9.87	0.36
Total Phosphorus as P	mg/L	561	0.22	0.01	1.94	0.33
Potassium (K)	mg/L	431	32.8	3.1	356	35.7
Sodium (Na)	mg/L	431	278	16.9	4680	490.1
Sulfate (SO4)	mg/L	430	590.9	34	10500	847.6

[1]Equal to the lower reporting limit
[2]Data collected from 66 natural and enhanced Lakes between 1991 and 2011

Limiting Nutrients: The water quality samples collected in 1992-93 and 2011 indicate that Skjermo Lake is phosphorus limited (Figure 6). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen to total phosphorus (N:P) of 15 to 1 is nutrient equilibrium. Using this assumption when the N:P ratio is less than 15:1, nitrogen is limiting and when it exceeds 15:1 phosphorus is.

The N:P ratio ranged from a low of 48 to a high of 65 in 1992-93 but increased to 84 and 189 in 2011. Note that phosphorus limitation is preferred to nitrogen limitation as phosphorus is finite in its ability to be available for primary production while free nitrogen may be affix by certain undesirable primary producers like blue-green algae.

Trophic Status Assessment: Based on the historical and current chlorophyll-a, secchi disk transparency, and total phosphorus data, Skjermo Lake's trophic status is estimated as eutrophic in 1992-1993, but has improved to mesotrophic in 2011 (Figure 7). This assessment is supported by an increase in the total nitrogen to total phosphorus ratios with all total phosphorus concentration in 2011 being at or below the laboratory reporting concentration of 0.01 mg/L..

Table 3. Statistical Summary of Skjermo Lake's 1992-1993 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	137	119	165	25
Total Ammonia as N	mg/L	2	0.04	0.03[1]	0.04	0
Bicarbonate (HCO_3)	mg/L	3	167	145	201	30
Calcium (Ca)	mg/L	3	253	233	282	25.7
Carbonate (CO_3)	mg/L	1	1[1]	1[1]	1[1]	0
Chloride (Cl)	mg/L	3	83.2	72.6	101	15.5
Chlorophyll-a	µg/L	2	3.6	3.2	4	0.6
Specific Conductance	µmhos	3	2815	2497	3380	491
Total Dissolved Solids	mg/L	3	2380	2000	2900	466
Total Hardness as ($CaCO_3$)	mg/L	3	1663	1510	1920	224
Hydroxide (OH)	mg/L	1	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	3	0.047	0.042	0.051	0.005
Magnesium (Mg)	mg/L	3	251	226	295	38.2
Nitrate + Nitrite as N	mg/L	2	0.146	0.031	0.261	0.163
Total Kjeldahl Nitrogen as N	mg/L	2	1.385	1.35	1.42	0.049
Total Nitrogen as N	mg/L	2	1.44	1.38	1.66	0.212
pH		3	7.983	7.62	8.19	0.316
Total Phosphorus as P	mg/L	3	0.032	0.022	0.047	0.013
Potassium (K)	mg/L	3	28.1	26.1	31.5	2.9
Sodium (Na)	mg/L	3	101	94	114	11
Sulfate (SO4)	mg/L	3	1583	1260	1980	366

[1]Equal to the lower reporting limit.

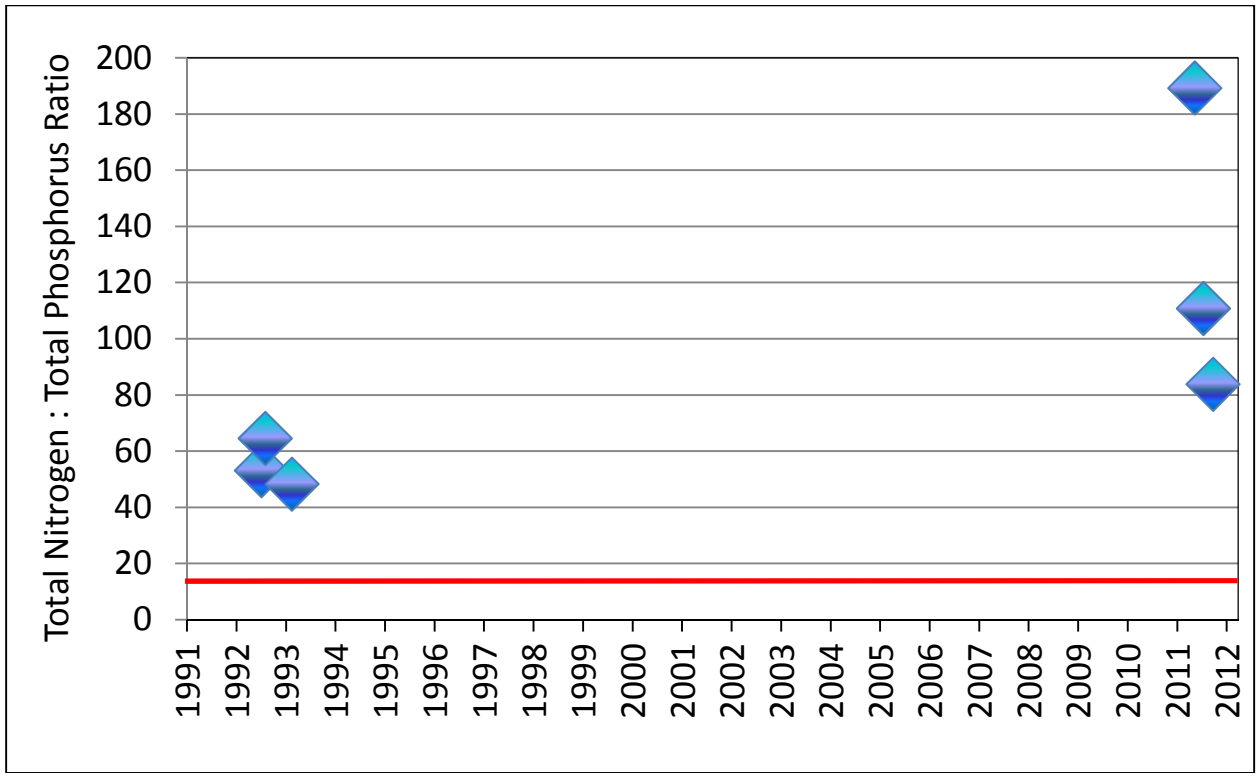

Figure 6. Skjermo Lake's Total Nitrogen to Total Phosphorus Ratio

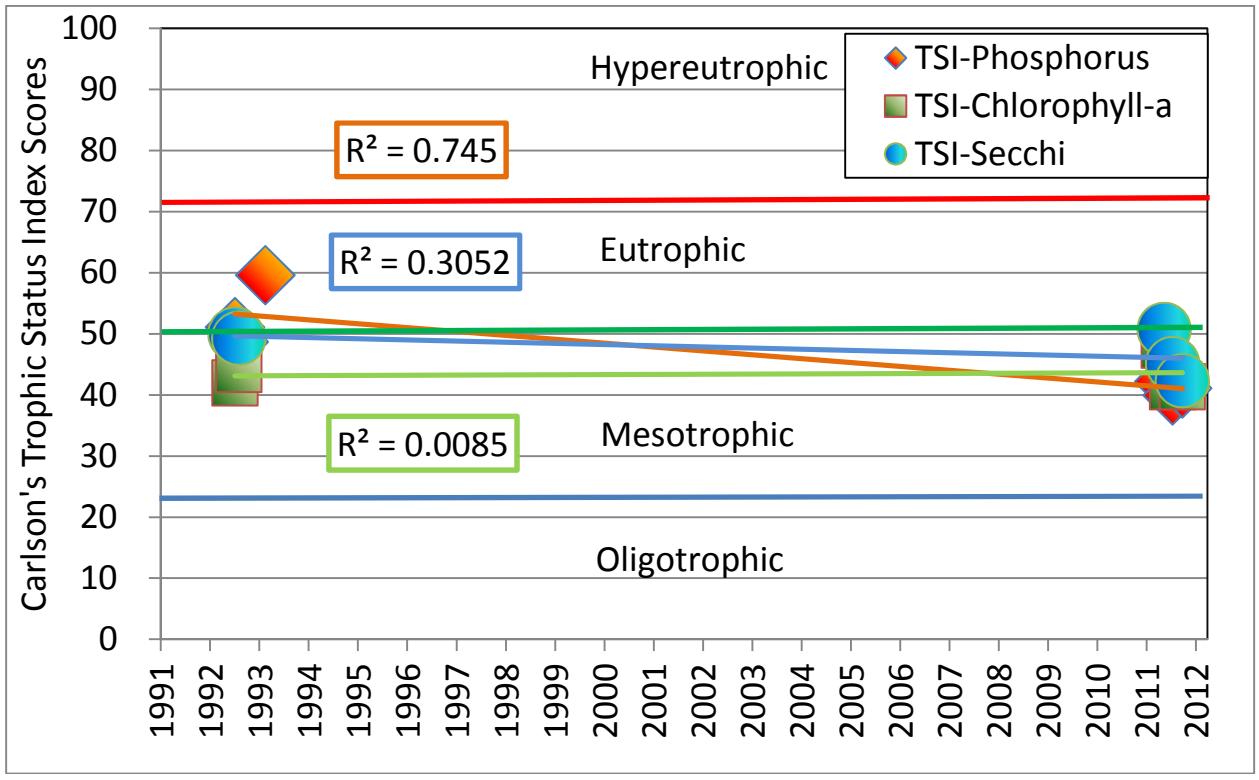

Figure 7. Skjermo Lake's TSI Scores

South Buffalo Gap, Golden Valley County

BACKGROUND

South Buffalo Gap is a small reservoir in the North Dakota badlands. The dam is located within the boundaries of the Little Missouri National Grasslands on the upper end of a small tributary to Andrews Creek two miles south of Buffalo Gap (Figure 1). The fishery is managed by the North Dakota Game and Fish Department. Fish species managed for are trout, bluegill and largemouth bass.

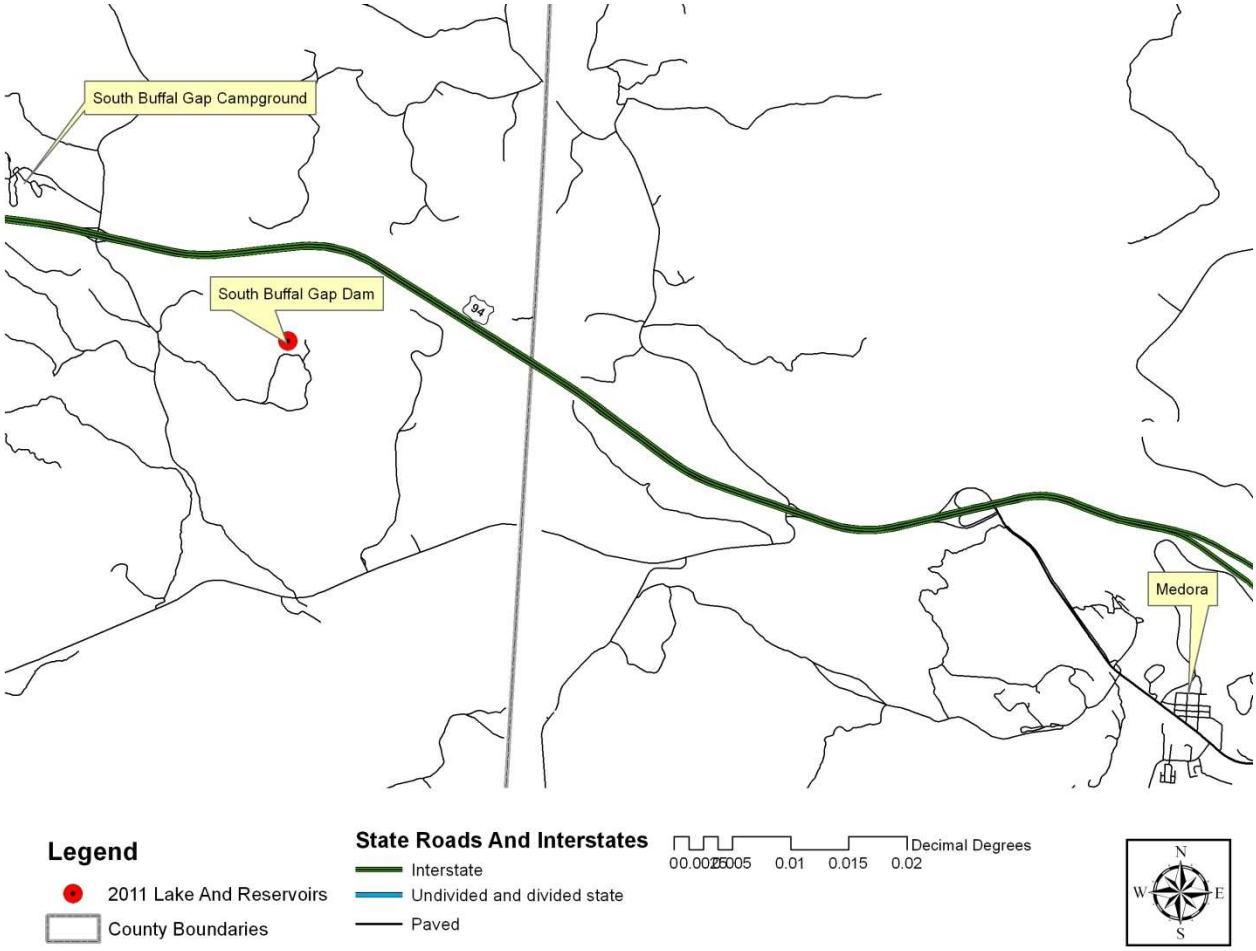

Figure 1. Location of South Buffalo Gap

Physiographic/Ecological Setting: South Buffalo Gap has a surface area of approximately 4.3 acres, a mean depth of 5.8 feet and a maximum depth of 12. It is an isolated little reservoir in a beautiful valley leading into steep buttes and Juniper draws (Figure 2). The reservoir is located in the Northwestern Great Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figures 3).

Recreational Facilities: Recreational facilities at South Buffalo Gap are primitive and include an access road and small trail along its southern shore. The lake lacks a boat ramp or any other facilities. The access road is deeply rutted with a gumbo foundation that is slippery and difficult to travel at times and 4 wheel drives are recommended unless the weather has been dry.

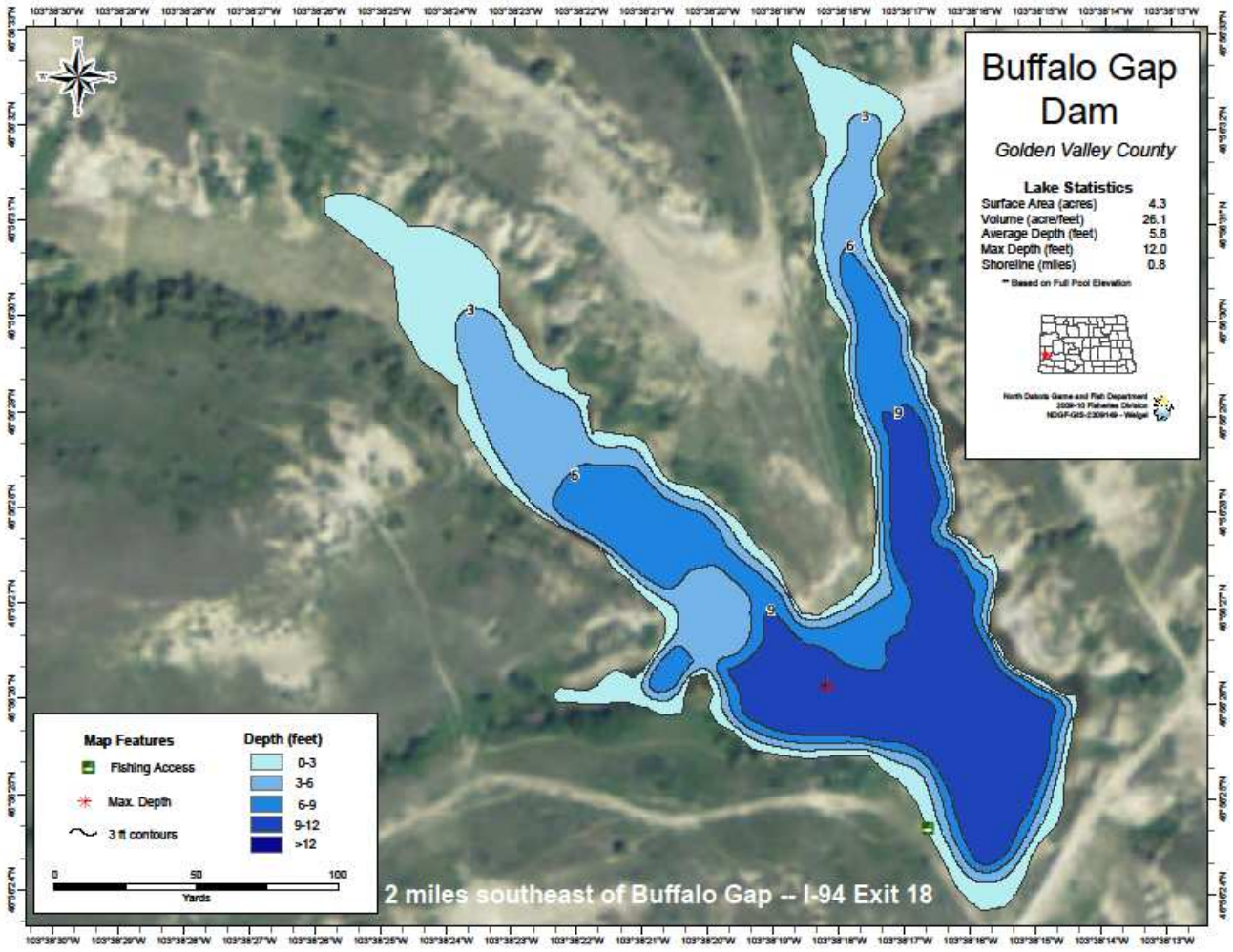

Figure 2. Contour Map of South Buffalo Gap (Map Courtesy of North Dakota Game and Fish Department)

Water Quality Standards Classification: South Buffalo Gap is not classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011). If classified, it would most likely be assigned a class 3. A class 3 reservoir, is defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: Historical water quality data include 3 samples collected in 1992-1993.

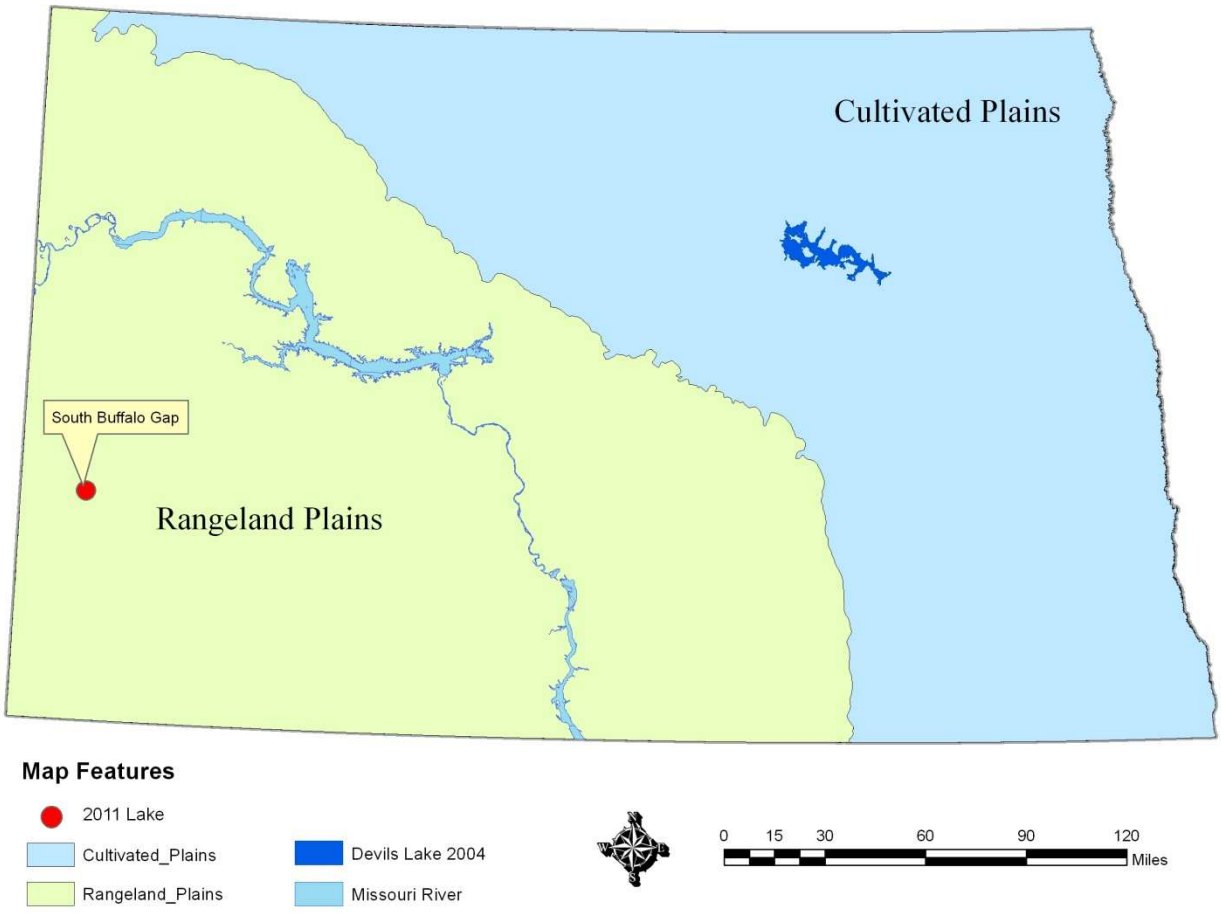

Figure 3. South Buffalo Gap Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for South Buffalo Gap is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional data for reservoirs in the Rangeland Plains Region.

Note that South Buffalo Gap was the only water body sampled only twice in 2011. The lack of a third sample was due to the fluctuating water levels leaving an extensive mud ring around the lake preventing access by boat.

Temperature and Dissolved Oxygen Profile Results: There are five temperature and dissolved oxygen profiles for South Buffalo Gap collected in 1994-95 and 2011 (Figures 4 and 5). The profile data indicates that South Buffalo Gap does not thermally stratification during the open or iced water period. Data also indicates that the reservoir remains well enough oxygenated to support aquatic life.

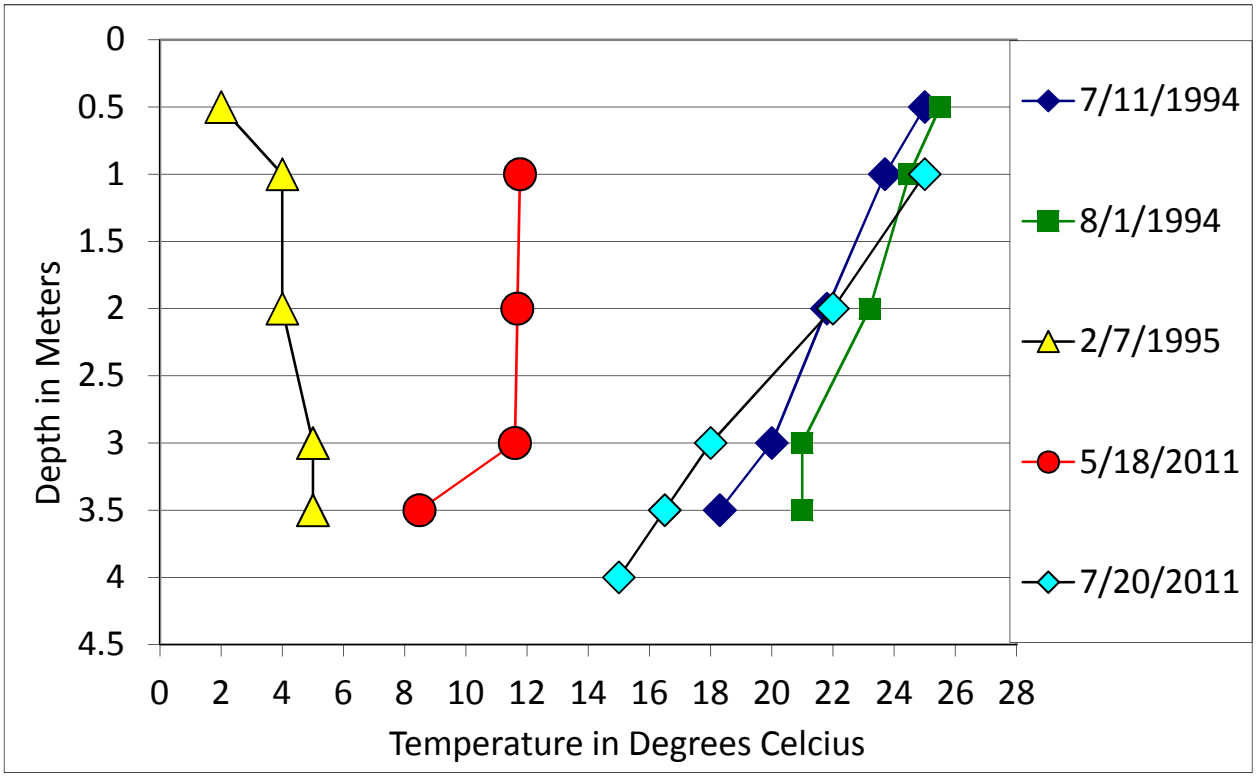

Figure 4. Temperature Profiles for South Buffalo Gap

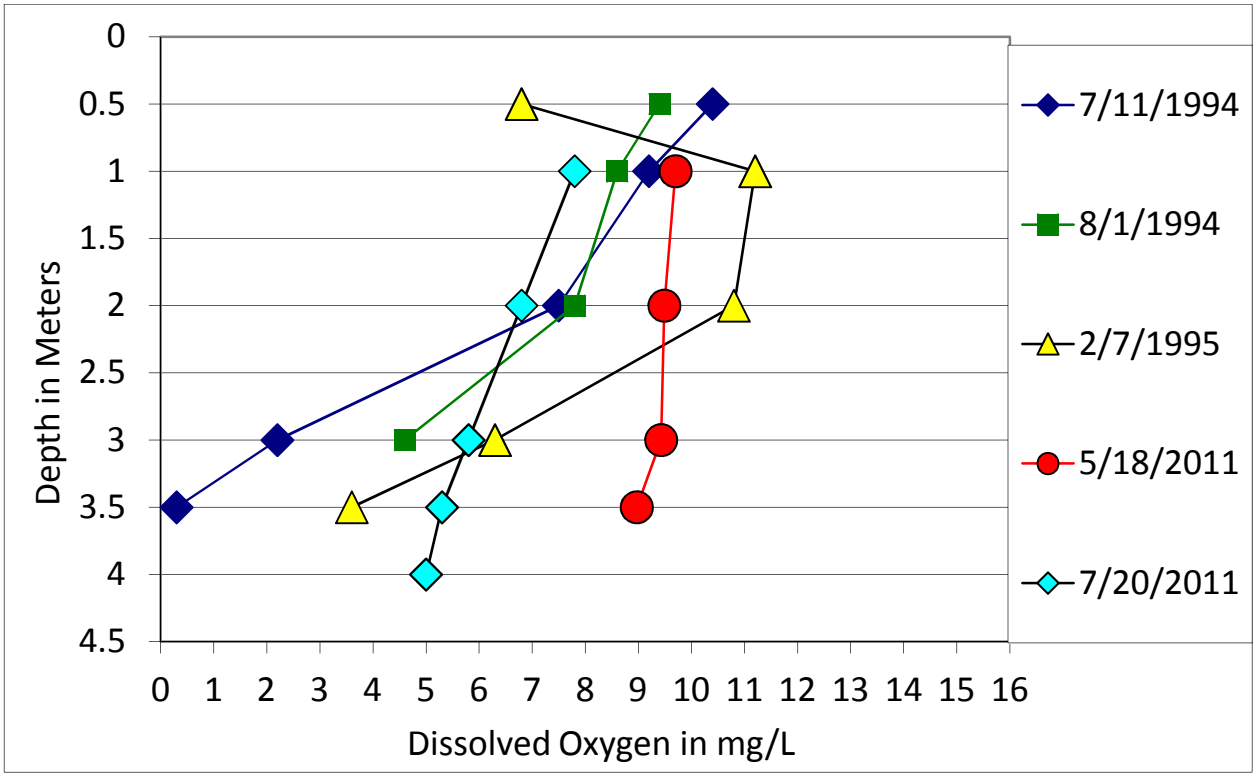

Figure 5. Dissolved Oxygen Profiles for South Buffalo Gap

General Water Quality: Water quality data collected in 2011 indicates that South Buffalo Gap is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 174 to 192 mg/L (Table 1) and that the reservoir is sodium sulfate dominated with an average sodium concentration of 498 mg/L and an average sulfate concentration of 1290 mg/L. The average total dissolved solids concentration and specific conductance measurements for the 2011 sampling period were 2075 mg/L and 2780 µmhos/cm, respectively. While rich in minerals the reservoir is relatively nutrient poor for North Dakota with average total nitrogen and total phosphorus concentrations of 0.82 mg/L and 0.02 mg/L respectively.

Table 1. Statistical Summary of South Buffalo Gap's 2011 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	2	183	174	192	13
Total Ammonia as N	mg/L	2	0.03[1]	0.03[1]	0.03[1]	0
Bicarbonate (HCO_3)	mg/L	2	210	185	234	35
Calcium (Ca)	mg/L	2	79	73.5	84.5	7.8
Carbonate (CO_3)	mg/L	2	7	1[1]	13	8
Chloride (Cl)	mg/L	2	24.8	19.6	30	7.4
Chlorophyll-a	µg/L	2	16	12	20	5.7
Specific Conductance	µmhos	2	2780	2470	3090	438
Total Dissolved Solids	mg/L	2	2075	1730	2420	488
Total Hardness as ($CaCO_3$)	mg/L	2	441	373	509	96
Hydroxide (OH)	mg/L	2	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	2	0.5	0.3	0.69	0.27
Magnesium (Mg)	mg/L	2	59.2	46	72.4	18.7
Nitrate + Nitrite as N	mg/L	2	0.04	0.03[1]	0.05	0.01
Total Kjeldahl Nitrogen as N	mg/L	2	0.78	0.73	0.82	0.07
Total Nitrogen as N	mg/L	2	0.82	0.78	0.85	0.05
pH		2	8.32	8.03	8.6	0.4
Total Phosphorus as P	mg/L	2	0.02	0.01[1]	0.03	0.01
Potassium (K)	mg/L	2	10.4	9.8	10.9	0.8
Sodium (Na)	mg/L	2	498	429	566	96.9
Sulfate (SO4)	mg/L	2	1290	1030	1550	368

[1]Equal to the lower reporting limit

When compared to water quality for reservoirs in the Rangeland Plans Region, South Buffalo Gap is an anomaly with much higher mineral concentrations but lower nutrient concentrations (Tables 1 and 2). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 1113 mg/L, 1.32 mg/L, and 0.128 mg/L respectively, compared to South Buffalo Gap's average TDS, total nitrogen, and total phosphorus concentrations of 2075 mg/L, 0.82 mg/L and 0.02 mg/L respectively.

Table 2. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	571	282	3	982	130
Total Ammonia as N	mg/L	651	0.092	0.001	2.44	0.178
Bicarbonate (HCO_3)	mg/L	571	296	4	1040	143
Calcium (Ca)	mg/L	571	55	2	206	30
Carbonate (CO_3)	mg/L	569	24	1	197	28
Chloride (Cl)	mg/L	571	14	1	75	10
Chlorophyll-a	µg/L	456	19.6	1.5	218	26.1
Specific Conductance	µmhos	591	1618	4	5880	973
Total Dissolved Solids	mg/L	572	1113	17	5110	773
Total Hardness as ($CaCO_3$)	mg/L	571	410	9	2100	288
Hydroxide (OH)	mg/L	514	1	1	1	0
Iron (Fe)	mg/L	572	0.2	0.01	4.11	0.35
Magnesium (Mg)	mg/L	571	66.4	1	412	54.9
Nitrate + Nitrite as N	mg/L	650	0.064	0.003	1.49	0.127
Total Kjeldahl Nitrogen as N	mg/L	541	1.36	0.08	7.72	0.78
Total Nitrogen as N	mg/L	484	1.32	0.02	4.84	0.63
pH		591	8.54	5.74	9.87	0.55
Total Phosphorus as P	mg/L	657	0.126	0.04	3.16	0.185
Potassium (K)	mg/L	571	13.9	1	52.5	6.9
Sodium (Na)	mg/L	571	214	3	932	168
Sulfate (SO4)	mg/L	569	578	1	3210	512

[1]Equal to the lower reporting limit
[2]Data collected from 76 reservoirs between 1991 and 2011

When comparing historical water quality data (1994-1995) to current (2011), there is an increase in the dissolved solid and associated parameters and nitrogen and a drop in phosphorus. Examples are the bicarbonate, sulfate and sodium average concentrations of 210 mg/L, 1290 mg/L and 489 mg/L in 2011 compared to the 1994-1995 average concentrations of 195 mg/L, 636 mg/L and 288 mg/L, respectively.

The historical average total nitrogen and total phosphorus concentrations were 0.63 mg/L and 0.058 mg/L, respectively, compared to the 2011 averages of 0.82 mg/L and 0.02 mg/L (Tables 1 and 2). The nutrients total nitrogen and total phosphorus are responsible for most of the primary production within a water body and when one increases the other usually decreases. While not conclusive an increase in nitrogen concentration and a decrease in phosphorus concentration usually indicate an improving nutrient condition.

Table 3. Statistical Summary of South Buffalo Gap's 1994-1995 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	4	179	171	202	15
Total Ammonia as N	mg/L	4	0.01[1]	0.01[1]	0.02	0.01
Bicarbonate (HCO_3)	mg/L	4	195	174	247	35
Calcium (Ca)	mg/L	4	37.8	36.8	39.3	1.1
Carbonate (CO_3)	mg/L	4	12	1[1]	17	7
Chloride (Cl)	mg/L	4	3.8	3.5	4.4	0.4
Chlorophyll-a	µg/L	2	3[1]	3[1]	3[1]	0
Specific Conductance	µmhos	4	1650	1560	1690	61
Total Dissolved Solids	mg/L	4	1108	981	1150	85
Total Hardness as ($CaCO_3$)	mg/L	4	199	188	206	8
Hydroxide (OH)	mg/L	4	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	4	0.098	0.078	0.132	0.024
Magnesium (Mg)	mg/L	4	25.3	21.7	27.6	2.6
Nitrate + Nitrite as N	mg/L	4	0.022	0.005	0.073	0.034
Total Kjeldahl Nitrogen as N	mg/L	4	0.61	0.89	1.28	0.399
Total Nitrogen as N	mg/L	4	0.63	0.9	1.35	0.433
pH		4	8.583	7.95	8.84	0.423
Total Phosphorus as P	mg/L	4	0.058	0.018	0.088	0.029
Potassium (K)	mg/L	4	8.1	7.1	8.6	0.7
Sodium (Na)	mg/L	4	288	243	317	35
Sulfate (SO4)	mg/L	4	636	562	671	50

[1]Equal to the lower reporting limit

Limiting Nutrients: The water quality samples collected in 1992-93 and 2011 indicate that South Buffalo Gap is phosphorus limited (Figure 6). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen to total phosphorus (N:P) of 15 to 1 is nutrient equilibrium. Using this assumption when the N:P ratio is less than 15:1, nitrogen is limiting and when it exceeds 15:1 phosphorus is.

The ratio of total nitrogen to total phosphorus ranged substantially in both 1994-1995and 2011 with a low of 10 and a high of 62 in 1994-1995 and a low of 30 and a high of 71 in 2011. However the results are all above 15 with one exception indicating that while the reservoir might experience some instances when it is nitrogen is limiting.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 1994-95 and 2011, South Buffalo Gap's trophic status is estimated as eutrophic with no recognizable trend (Figure 7). The Trophic Status Index (TSI) scores for South Buffalo Gap, based on chlorophyll-a, ranged from 41 to 60 with the majority being in the eutrophic range. An estimate of eutrophic was supported by both the secchi disk measurements and total phosphorus concentrations with TSI scores ranging between 44 and 70.

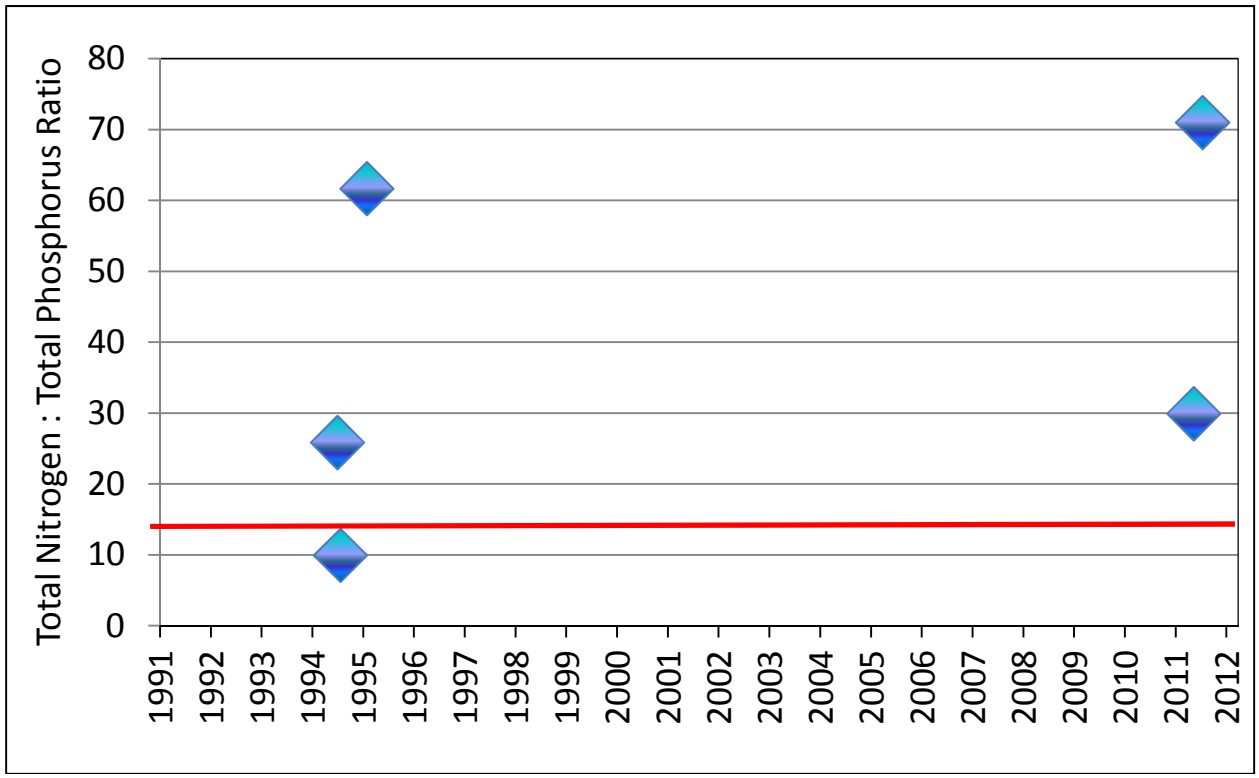

Figure 6. South Buffalo Gap's Total Nitrogen to Total Phosphorus Ratio

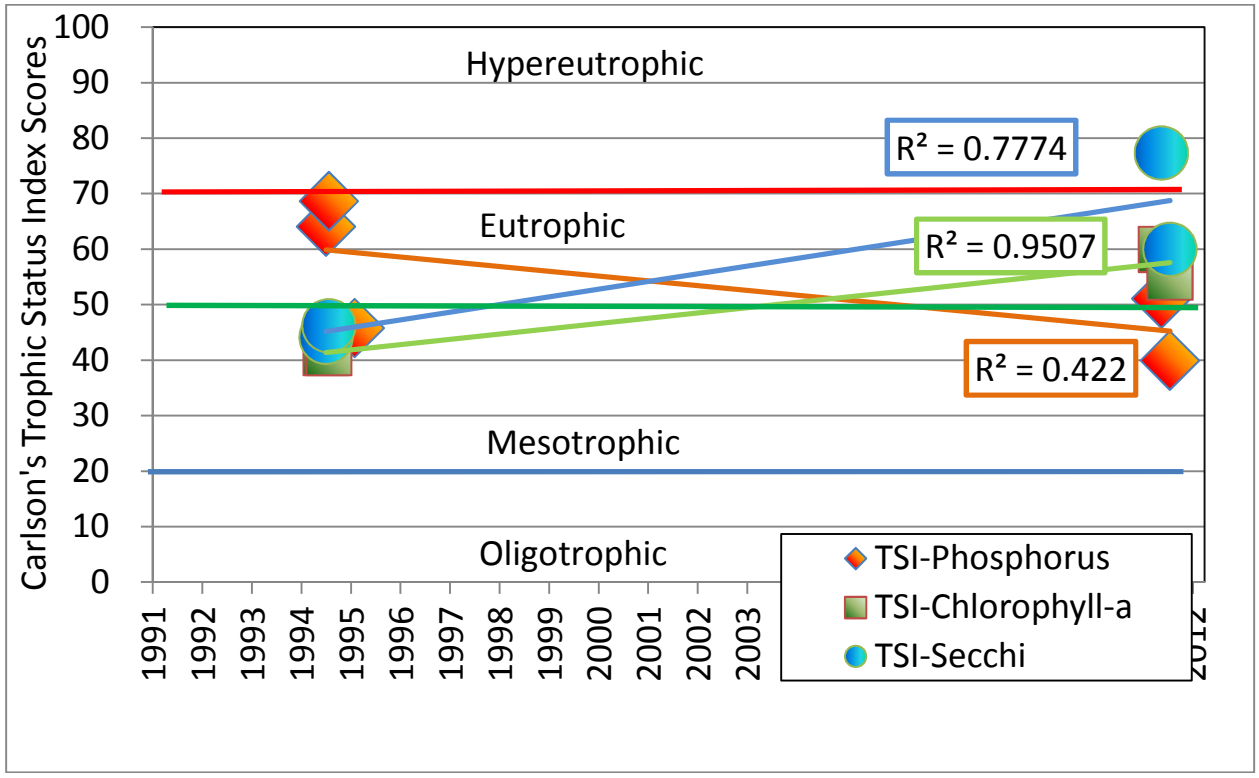

Figure 7. South Buffalo Gap's TSI Scores

Lake Williams, Kidder County

BACKGROUND

Lake Williams is a pothole lake on the southern edge of the town Lake Williams in Kidder County, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish Department. Fish species managed for are northern pike, walleye and yellow perch.

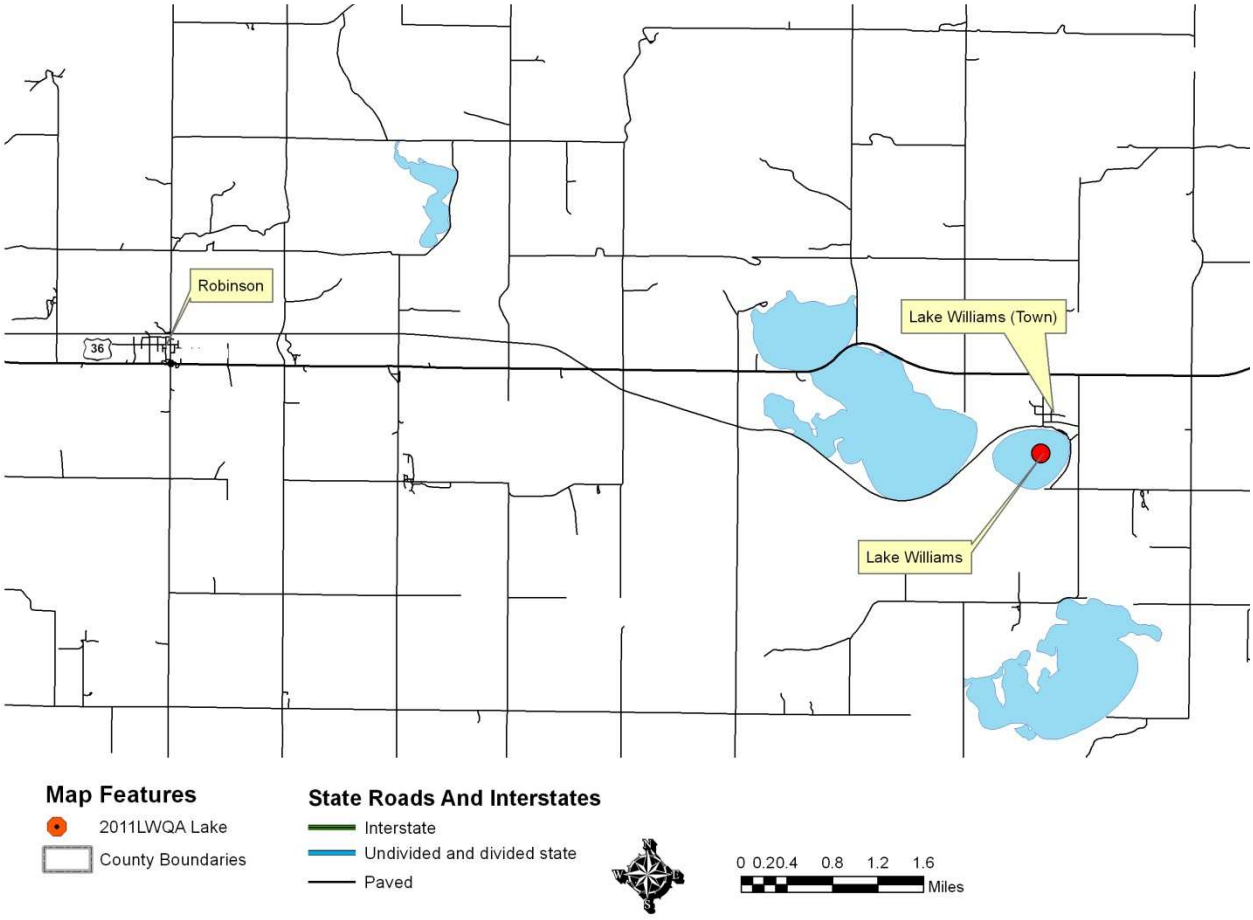

Figure 1. Location of Lake Williams

Physiographic/Ecological Setting: Lake Williams is a good example of a 171 acre natural North Dakota prairie lake with a maximum depth of 26.3 feet (Figure 2). The lake is glacial in origin with a fine sand and gravel shoreline. The lake is located in the Northwestern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figures 3 and 4).

Recreational Facilities: Recreational facilities at Lake Williams are an access road, parking, camping and picnic area, a small cement boat ramp and outdoor toilets. It is a beautiful under-utilized recreational resource.

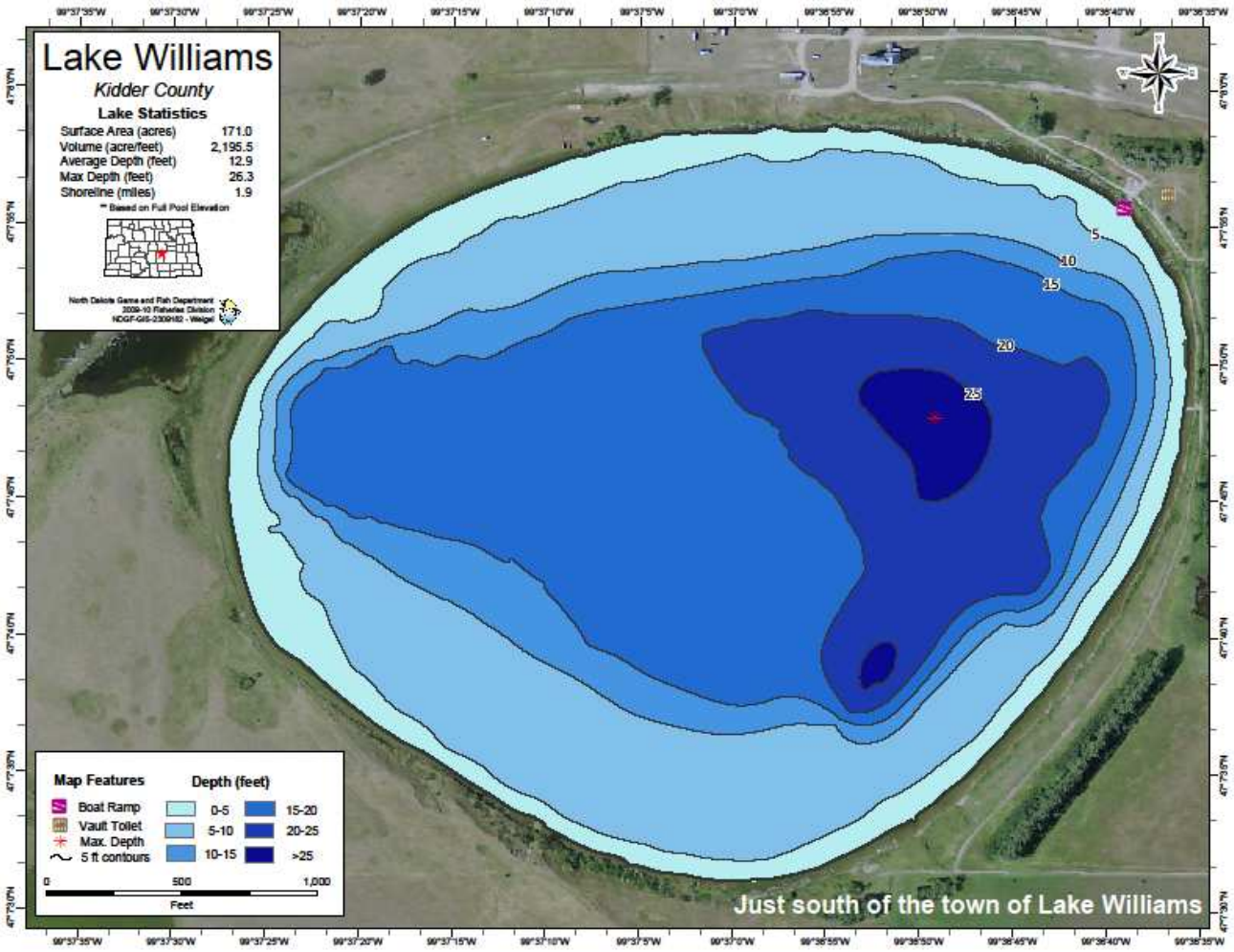

Figure 2. Contour Map of Lake Williams (Map Courtesy of North Dakota Game and Fish Department)

Water Quality Standards Classification: Lake Williams is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species might also be present.

Historical Water Quality Sampling: Historical water quality data include 3 samples collected in 1992-1993.

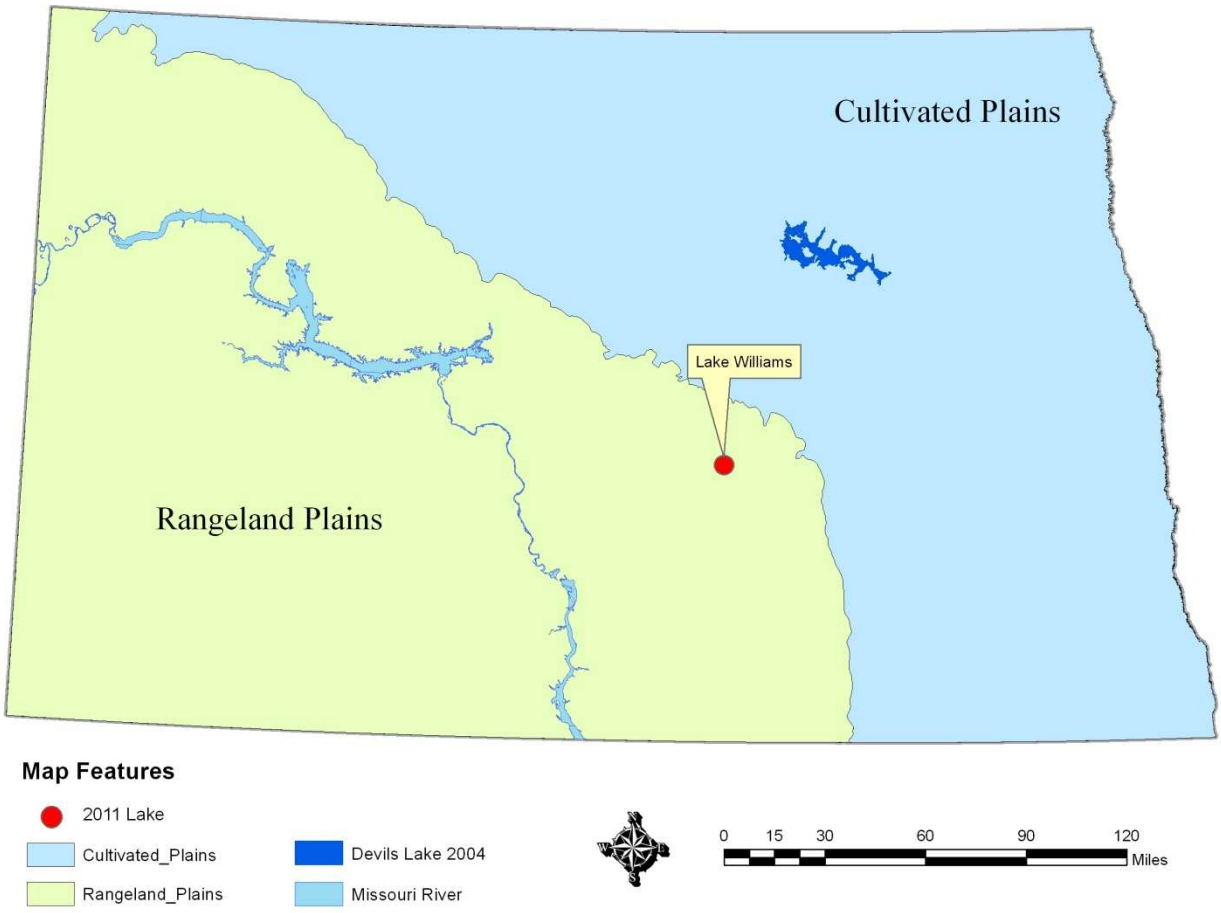

Figure 3. Lake Williams Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Lake Williams is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional data for lakes in the Rangeland Plains Region.

Temperature and Dissolved Oxygen Profile Results: There are six temperature and dissolved oxygen profiles for Lake Williams collected in 1992-93 and 2011 (Figures 4 and 5). The profile data indicates that Lake Williams does not thermally stratify. The profiles results also indicate that the lake remains well enough oxygenated to support aquatic life year round with only a gradual sag in the oxygen concentrations nears the water-sediment interface.

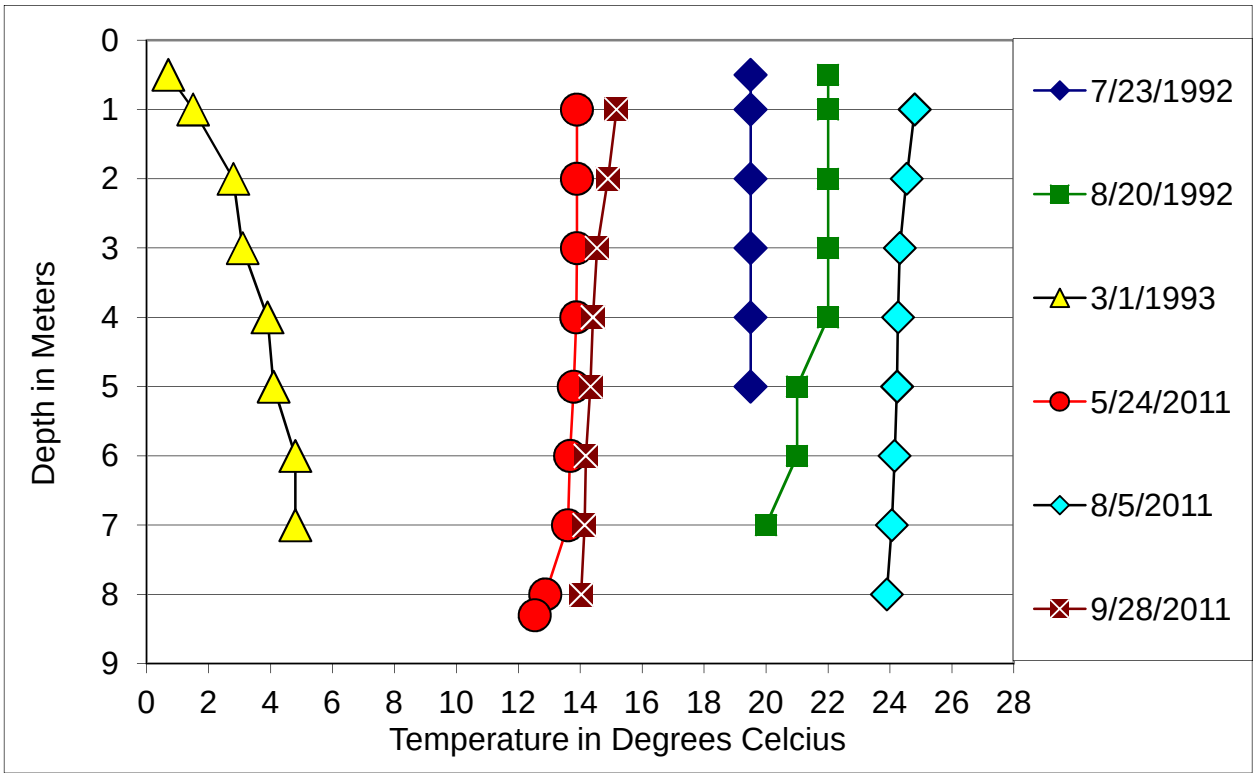

Figure 4. Temperature Profiles for Lake Williams

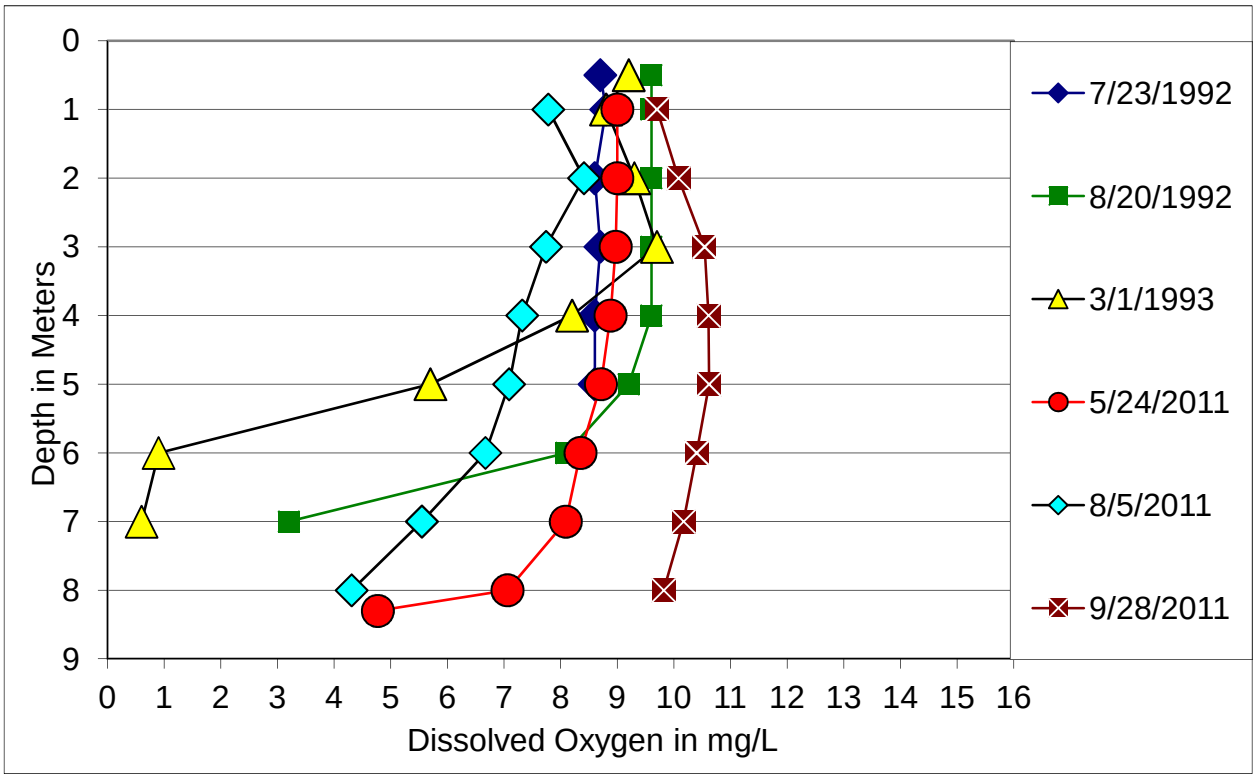

Figure 5. Dissolved Oxygen Profiles for Lake Williams

General Water Quality: Data collected in 2011 indicates that Lake Williams is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 317 to 338 mg/L, sodium bicarbonate dominated with average sodium concentrations of 28.9 mg/L and average bicarbonate concentration of 358 mg/L. Total dissolved solids concentration and specific conductance measurements for the 2011 sampling period averaged 428 mg/L and 700 µmhos/cm, respectively and total nitrogen and total phosphorus concentrations were 0.68 mg/L and 0.03 mg/L respectively.

Table 1. Statistical Summary of Lake William's 2011 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	328	317	338	11
Total Ammonia as N	mg/L	3	0.03[1]	0.03[1]	0.03[1]	0
Bicarbonate (HCO_3)	mg/L	3	358	331	386	28
Calcium (Ca)	mg/L	3	27.3	23.8	32	4.2
Carbonate (CO_3)	mg/L	3	21	13	27	7
Chloride (Cl)	mg/L	3	8.6	8.2	9	0.4
Chlorophyll-a	µg/L	3	9.1	6	14.4	4.6
Specific Conductance	µmhos	3	700	665	752	46
Total Dissolved Solids	mg/L	3	428	420	442	12
Total Hardness as ($CaCO_3$)	mg/L	3	382	352	398	26
Hydroxide (OH)	mg/L	3	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	3	0.05	0.05	0.05	0
Magnesium (Mg)	mg/L	3	76.2	69.7	81.6	6
Nitrate + Nitrite as N	mg/L	3	0.03[1]	0.03[1]	0.03[1]	0
Total Kjeldahl Nitrogen as N	mg/L	3	0.65	0.63	0.67	0.03
Total Nitrogen as N	mg/L	3	0.68	0.66	0.7	0.03
pH		3	8.73	8.51	8.87	0.19
Total Phosphorus as P	mg/L	3	0.03	0.01[1]	0.03	0.01
Potassium (K)	mg/L	3	12.3	11.9	12.5	0.3
Sodium (Na)	mg/L	3	28.9	28.3	29.9	0.9
Sulfate (SO4)	mg/L	3	77	74	80	3

[1]Equal to the lower reporting limit

In comparison to the water quality for all natural lakes in the Rangeland Plans Region, Lake Williams, is fresher and less eutrophic than most (Tables 1 and 2). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 1398 mg/L, 1.75 mg/L, and 0.220 mg/L compared to Lake Williams' 2011 average TDS, total nitrogen, and total phosphorus concentrations of 428 mg/L, 0.68 mg/L and 0.03 mg/L, respectively.

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Lakes in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	430	499	111	4770	466
Total Ammonia as N	mg/L	554	0.105	0.001	2.23	0.223
Bicarbonate (HCO_3)	mg/L	430	461	60	2990	308
Calcium (Ca)	mg/L	431	42.9	0.5	294	38.9
Carbonate (CO_3)	mg/L	424	74	1	1420	141
Chloride (Cl)	mg/L	430	41.6	1.7	1070	97.8
Chlorophyll-a	µg/L	383	22	2	292	36
Specific Conductance	µmhos	430	1939	424	20100	1890
Total Dissolved Solids	mg/L	430	1398	227	18200	1640
Total Hardness as ($CaCO_3$)	mg/L	431	530	74	2370	299
Hydroxide (OH)	mg/L	369	1	1	1	0
Iron (Fe)	mg/L	432	0.23	0.01	7.07	0.52
Magnesium (Mg)	mg/L	431	102.8	8.5	567	69.5
Nitrate + Nitrite as N	mg/L	551	0.042	0.001	0.54	0.055
Total Kjeldahl Nitrogen as N	mg/L	523	1.82	0.08	8.5	1.04
Total Nitrogen as N	mg/L	461	1.75	0.24	5.52	0.87
pH		430	8.78	7.4	9.87	0.36
Total Phosphorus as P	mg/L	561	0.22	0.01	1.94	0.33
Potassium (K)	mg/L	431	32.8	3.1	356	35.7
Sodium (Na)	mg/L	431	278	16.9	4680	490.1
Sulfate (SO4)	mg/L	430	590.9	34	10500	847.6

[1]Equal to the lower reporting limit
[2]Data collected from 66 natural and enhanced Lakes between 1991 and 2011

When comparing historical water quality data collected in 1992-1993 to the 2011 data, the mineral concentrations appear fairly constant with a slight decrease in the sulfates. For example, the historical average concentrations for total dissolved solids, sulfates and bicarbonates are 427 mg/L, 103 mg/L and 333 mg/L and the 2011 averages are 428 mg/L, 77 mg/L and 358 mg/L, respectively.

Unlike dissolved solids concentrations total phosphorus and total nitrogen concentrations appear to be trending downward resulting in a decrease in the over productivity of the lake. For example the average total nitrogen and total phosphorus concentrations in 1992 and 1993 were 1.20 mg/L and 0.04 mg/L, and the 2011 averages are 0.68 mg/L and 0.03 mg/L, respectively (Tables 1 and 3).

Table 3. Statistical Summary of Lake William's 1992-1993 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	347	318	397	43
Total Ammonia as N	mg/L	2	0.06	0.01[1]	0.13	0.09
Bicarbonate (HCO_3)	mg/L	3	333	290	416	72
Calcium (Ca)	mg/L	3	16.7	13.2	22.3	4.9
Carbonate (CO_3)	mg/L	3	45	34	52	9
Chloride (Cl)	mg/L	3	10.4	9.3	12.3	1.7
Chlorophyll-a	µg/L	2	6	4	8	2.8
Specific Conductance	µmhos	3	778	714	895	102
Total Dissolved Solids	mg/L	3	472	435	527	49
Total Hardness as ($CaCO_3$)	mg/L	3	398	375	414	20
Hydroxide (OH)	mg/L	1	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	3	0.392	0.017	1.14	0.648
Magnesium (Mg)	mg/L	3	86.6	83.1	89.5	3.2
Nitrate + Nitrite as N	mg/L	2	0.034	0.007	0.06	0.037
Total Kjeldahl Nitrogen as N	mg/L	2	1.07	1.02	1.12	0.071
Total Nitrogen as N	mg/L	2	1.2	1.03	1.18	0.108
pH		3	8.93	8.65	9.12	0.248
Total Phosphorus as P	mg/L	3	0.042	0.019	0.065	0.023
Potassium (K)	mg/L	3	14.4	13.6	14.8	0.7
Sodium (Na)	mg/L	3	31	31	32	1
Sulfate (SO4)	mg/L	3	103	94	120	14

[1]Equal to the lower reporting limit

Limiting Nutrients: The water quality samples collected in 1992, 1993 and 2011 indicate that Lake Williams is phosphorus limited (Figure 6). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth; and that the nitrogen to phosphorus ratio of 15 is nutrient equilibrium, a ratio greater than 15 indicates phosphorus limited and a ratio of less than 15 being nitrogen limited.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 1992, 1993 and 2011, Lake Williams' trophic status is estimated as eutrophic with a stable to improving trend (Figure 7). The Trophic Status Index (TSI) scores based on chlorophyll-a were consistently in the upper mesotrophic to lower eutrophic range at 44 to 50 for both sampling periods and are well supported by the trophic status indicators secchi disk and total phosphorus.

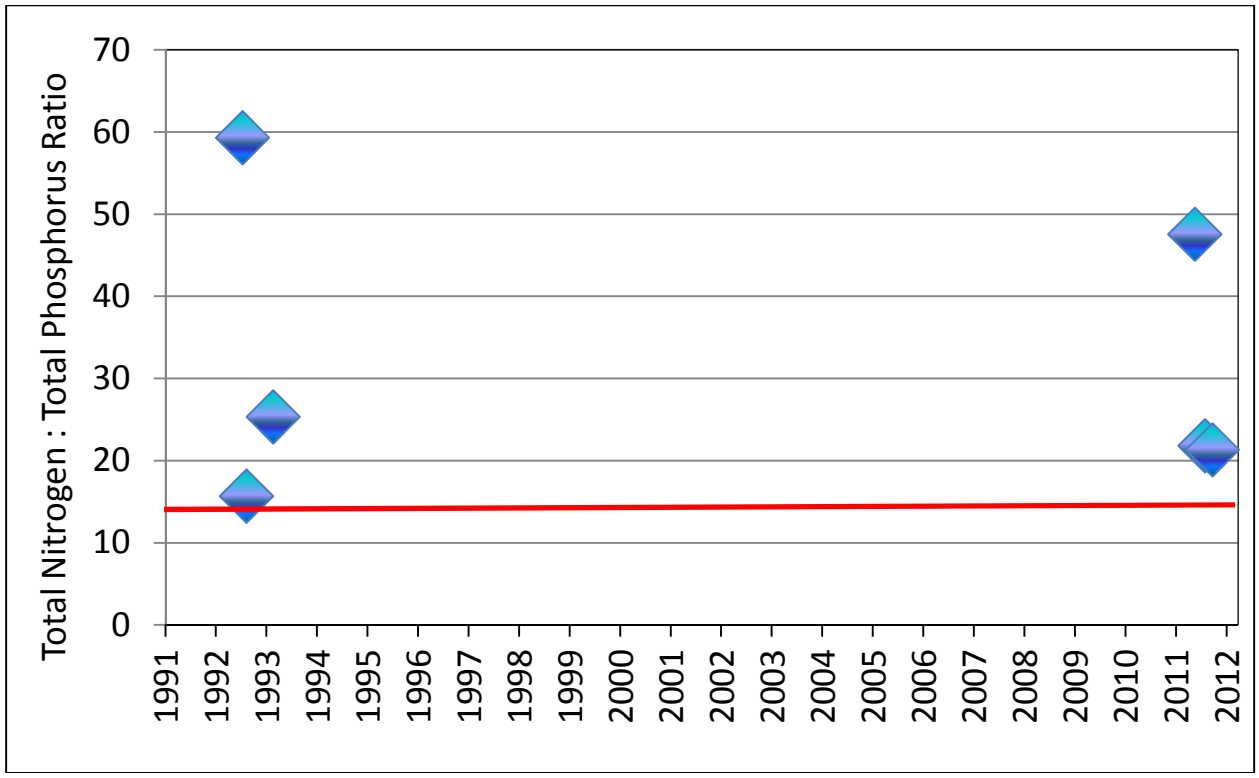

Figure 6. Lake Williams' Total Nitrogen to Total Phosphorus Ratio

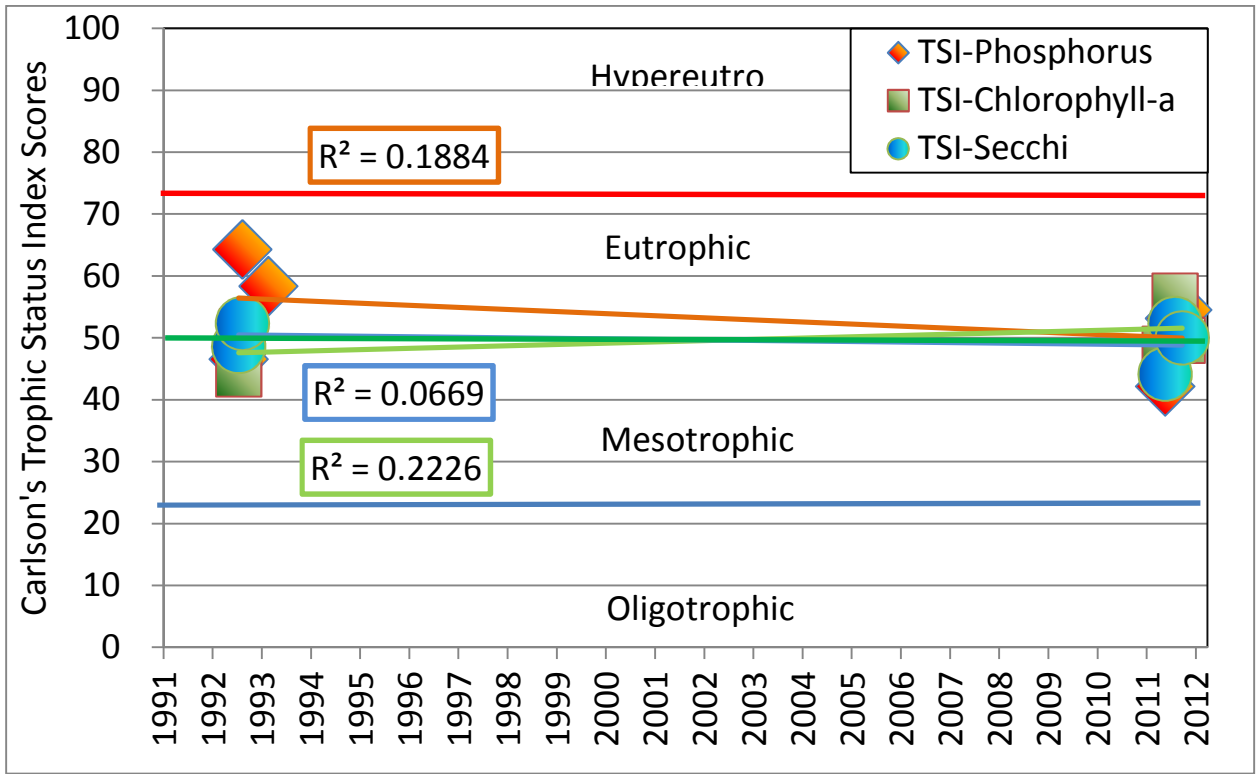

Figure 7. Lake Williams' TSI Scores

Lehr Dam (Schlenker), LaMoure County

BACKGROUND

Lehr Dam is a small impoundment on the head waters of Bone Hill Creek 10 miles east and ½ mile east of Gackle in LaMoure County, ND (Figure 1). The fishery is managed by the North Dakota Game and Fish Department. Fish species managed for are largemouth bass, yellow perch and bluegill.

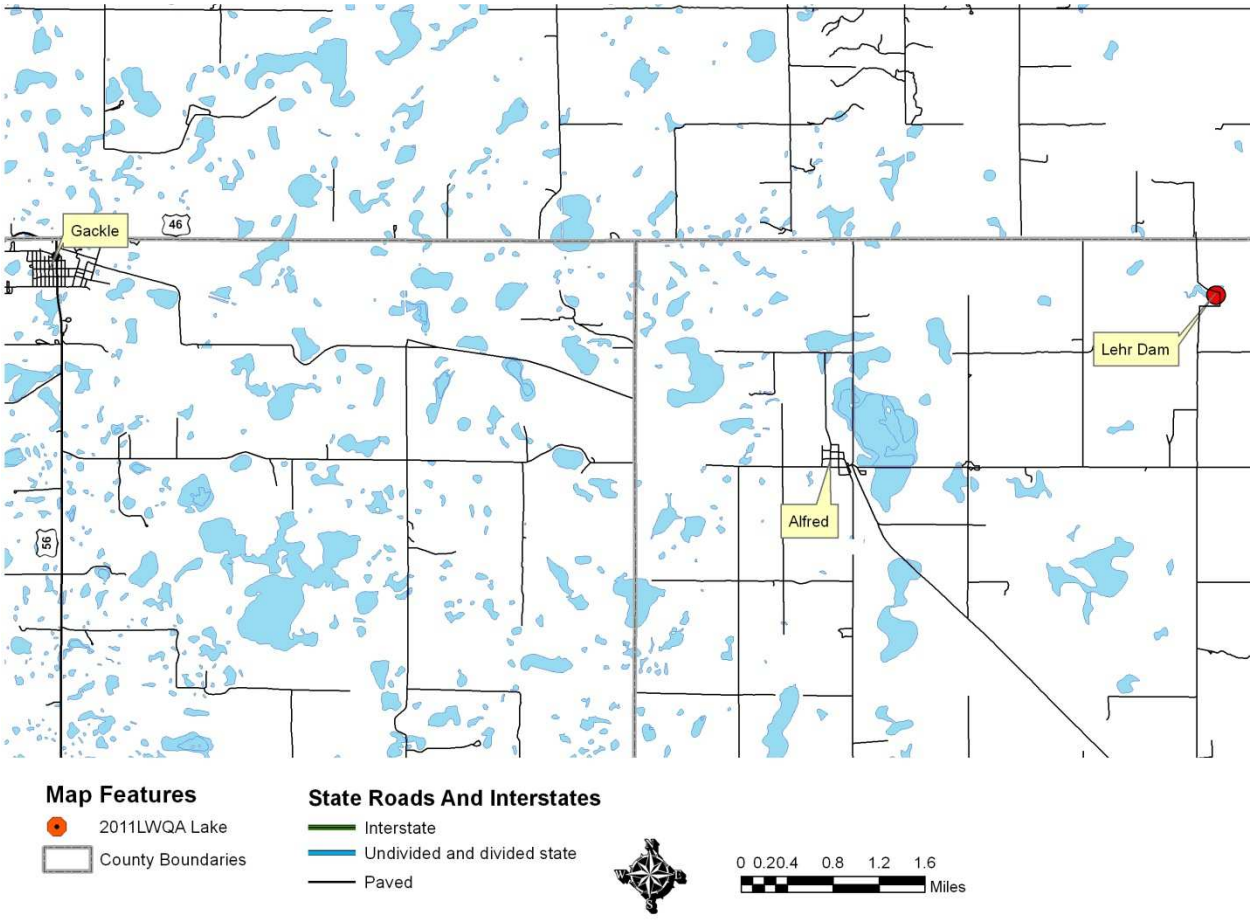

Figure 1. Location of Lehr Dam

Physiographic/Ecological Setting: Lehr Dam has a surface area of 11.3 acres and a maximum depth of 24 ft (Figure 2). The reservoir is located in the Northern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figures 3).

Recreational Facilities: Recreational facilities at Lehr Dam are an access road, parking, and a small cement boat ramp.

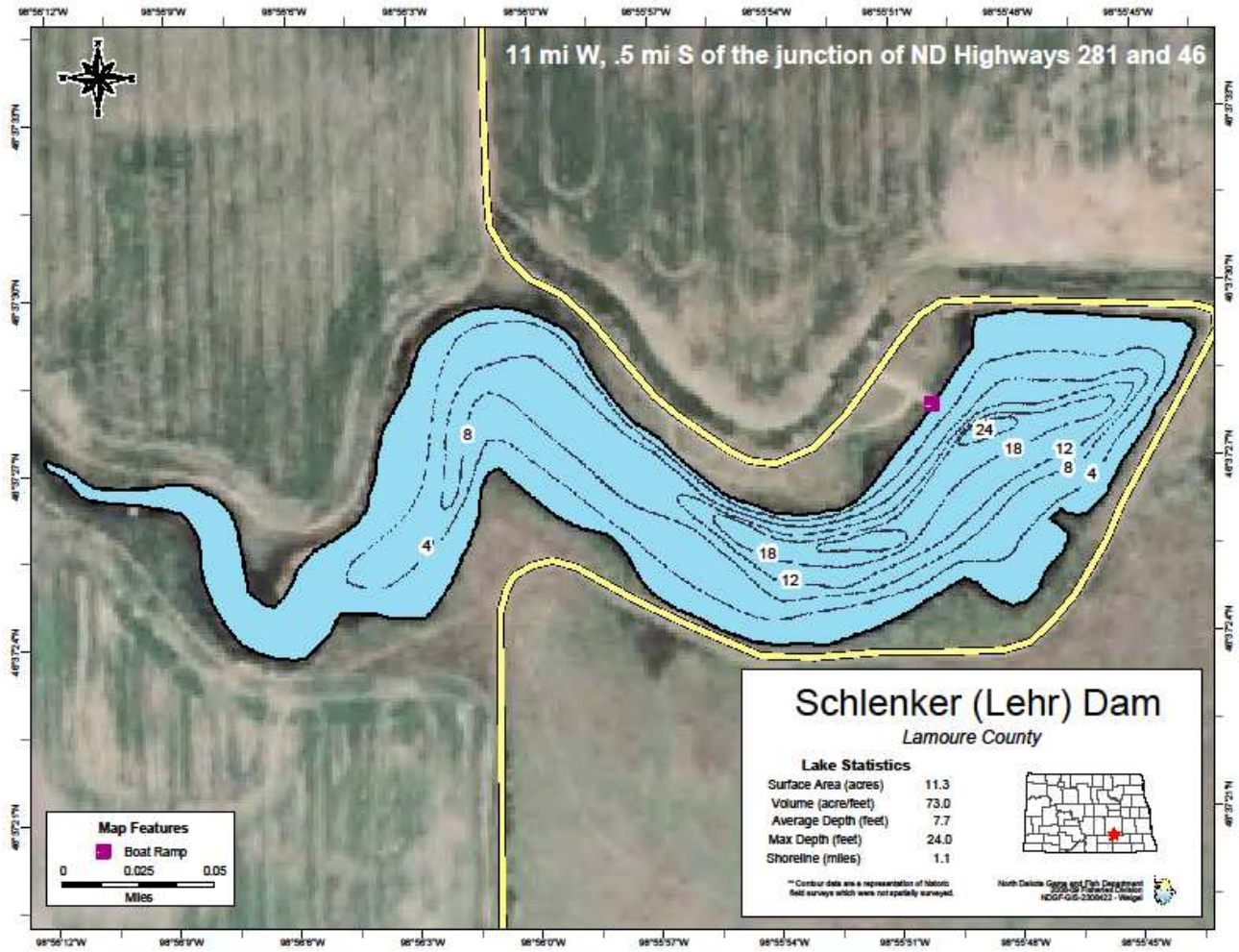

Figure 2. Contour Map of Lehr Dam (Map Courtesy of North Dakota Game and Fish Department)

Water Quality Standards Classification: Lehr Dam is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 2 lake. Class 2 lakes or reservoirs are defined as a "cool water fishery" or "waters capable of supporting natural reproduction and growth of cool water fishes (e.g., northern pike and walleye) and associated aquatic biota. These waters are also capable of supporting the growth and marginal survival of cold water species and associated biota."

Historical Water Quality Sampling: Historical water quality data include 3 samples collected in 1993 and 1994.

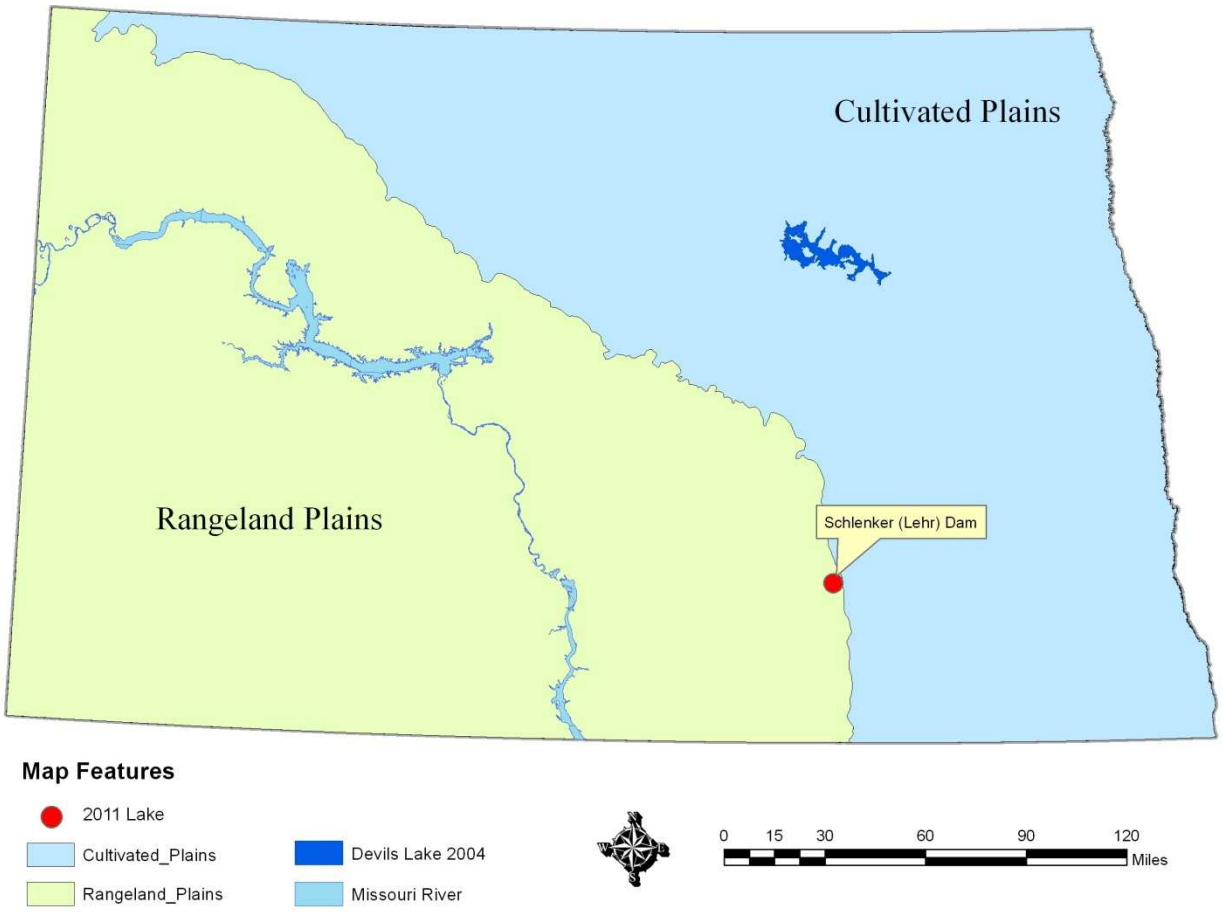

Figure 3. Lehr Dam Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Lehr Dam is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional data for reservoirs in the Rangeland Plains Region.

Temperature and Dissolved Oxygen Profile Results: There are eight temperature and dissolved oxygen profiles for Lehr Dam collected in 1993, 1994 and 2011 (Figures 4 and 5). The profile data indicates that Lehr Dam weakly thermally stratification for short durations during the open water period. The results indicate that when thermally stratified Lehr Dams dissolved oxygen rapidly decays often to levels below which many aquatic species can survive. Additionally both ice cover profiles (2/3/1993 and 3/1/1994) indicate that partial fish kills are likely if not common due to low dissolved oxygen.

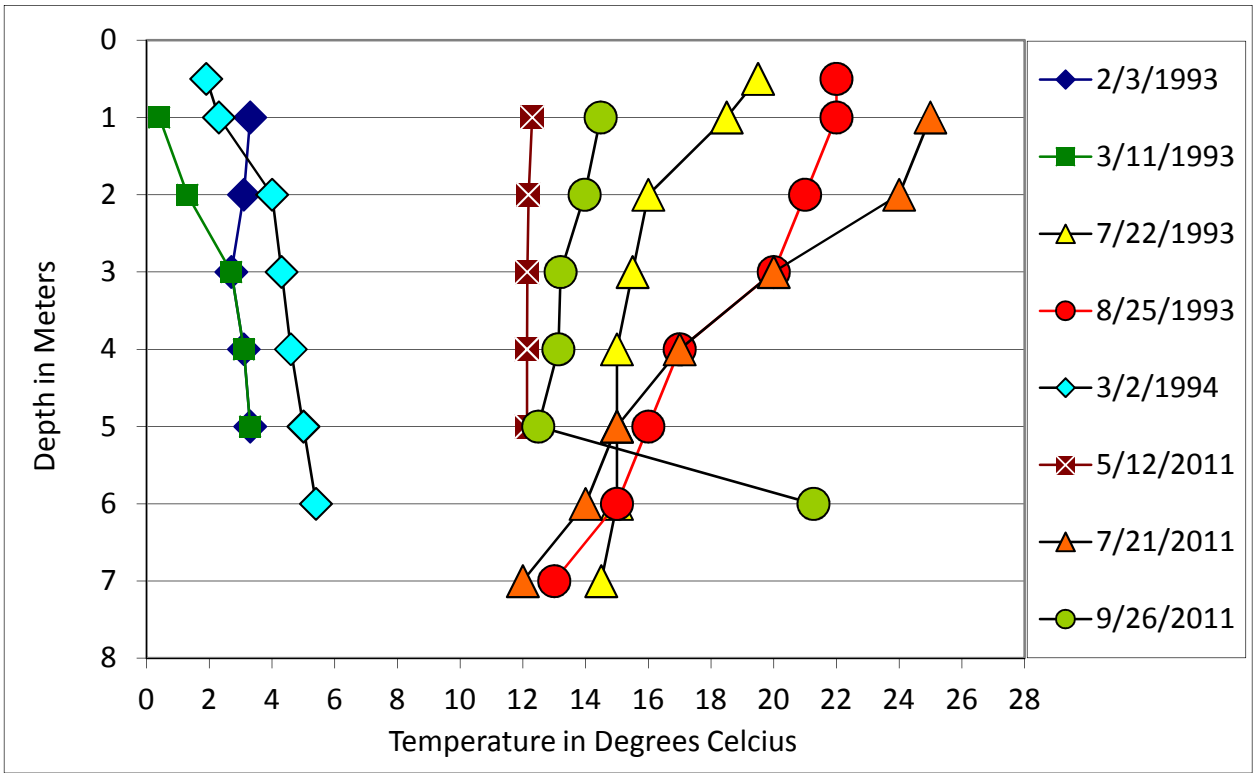

Figure 4. Temperature Profiles for Lehr Dam

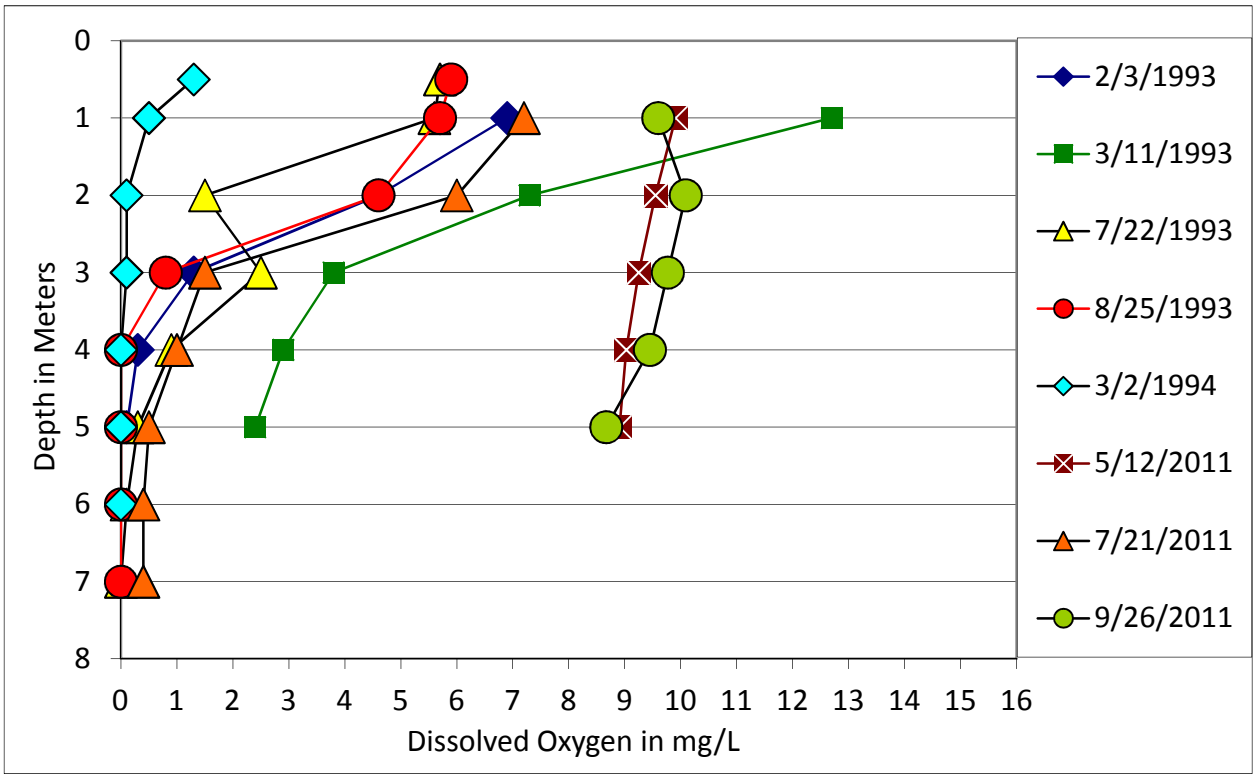

Figure 5. Dissolved Oxygen Profiles for Lehr Dam

General Water Quality: Water quality data collected in 2011 indicates that Lehr Dam is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 400 to 415 mg/L (Table 1) and that the lake is sodium sulfate dominated with an average sodium concentration of 257 mg/L and an average sulfate concentration of 1008 mg/L.

The average total dissolved solids concentration and specific conductance measurements for the 2011 sampling period were 1900 mg/L and 2437 µmhos/cm, respectively. The 2011 nutrient concentrations are quite high with average total nitrogen and total phosphorus concentrations of 1.95 mg/L and 0.51 mg/L respectively.

Table 1. Statistical Summary of Lehr Dam's 2011 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	410	400	415	8
Total Ammonia as N	mg/L	3	0.03[1]	0.03[1]	0.03[1]	0
Bicarbonate (HCO_3)	mg/L	3	485	461	507	23
Calcium (Ca)	mg/L	3	111	105	120	8.1
Carbonate (CO_3)	mg/L	3	8	1[1]	22	12
Chloride (Cl)	mg/L	3	53.6	50.6	58.3	4.1
Chlorophyll-a	µg/L	3	11.5	10.7	12	0.7
Specific Conductance	µmhos	3	2437	2390	2470	42
Total Dissolved Solids	mg/L	3	1900	1810	1980	85
Total Hardness as ($CaCO_3$)	mg/L	3	1076	999	1160	81
Hydroxide (OH)	mg/L	3	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	3	0.1	0.07	0.12	0.03
Magnesium (Mg)	mg/L	3	195	179	210	15.5
Nitrate + Nitrite as N	mg/L	3	0.03[1]	0.03[1]	0.03[1]	0
Total Kjeldahl Nitrogen as N	mg/L	3	1.92	1.89	1.97	0.04
Total Nitrogen as N	mg/L	3	1.95	1.92	2	0.04
pH		3	8.38	8.27	8.59	0.18
Total Phosphorus as P	mg/L	3	0.51	0.21	0.72	0.27
Potassium (K)	mg/L	3	28.8	27.7	29.9	1.1
Sodium (Na)	mg/L	3	257	253	262	4.7
Sulfate (SO4)	mg/L	3	1008	945	1060	58

[1]Equal to the lower reporting limit

When compared to the water quality for all reservoirs in the Rangeland Plans Region, Lehr Dam is more mineralized and more nutrient rich than most (Tables 1 and 2). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 1113 mg/L, 1.32 mg/L, and 0.126 mg/L respectively, compared to Lehr Dam's 2011 average TDS, total nitrogen, and total phosphorus concentrations of 1900 mg/L, 1.95 mg/L and 0.51 mg/L respectively.

Table 2. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	571	282	3	982	130
Total Ammonia as N	mg/L	651	0.092	0.001	2.44	0.178
Bicarbonate (HCO_3)	mg/L	571	296	4	1040	143
Calcium (Ca)	mg/L	571	55	2	206	30
Carbonate (CO_3)	mg/L	569	24	1	197	28
Chloride (Cl)	mg/L	571	14	1	75	10
Chlorophyll-a	µg/L	456	19.6	1.5	218	26.1
Specific Conductance	µmhos	591	1618	4	5880	973
Total Dissolved Solids	mg/L	572	1113	17	5110	773
Total Hardness as ($CaCO_3$)	mg/L	571	410	9	2100	288
Hydroxide (OH)	mg/L	514	1	1	1	0
Iron (Fe)	mg/L	572	0.2	0.01	4.11	0.35
Magnesium (Mg)	mg/L	571	66.4	1	412	54.9
Nitrate + Nitrite as N	mg/L	650	0.064	0.003	1.49	0.127
Total Kjeldahl Nitrogen as N	mg/L	541	1.36	0.08	7.72	0.78
Total Nitrogen as N	mg/L	484	1.32	0.02	4.84	0.63
pH		591	8.54	5.74	9.87	0.55
Total Phosphorus as P	mg/L	657	0.126	0.004	3.16	0.185
Potassium (K)	mg/L	571	13.9	1	52.5	6.9
Sodium (Na)	mg/L	571	214	3	932	168
Sulfate (SO4)	mg/L	569	578	1	3210	512

[1]Equal to the lower reporting limit
[2]Data collected from 76 reservoirs between 1991 and 2011

When comparing historical water quality data collected in 1993 and 1994 to the 2011 data the results appears to describe two completely different waterbodies. Nearly every parameter has increased, but none so dramatically as the dissolved solids. For example, the average concentrations in 1993-94 for alkalinity, sulfates, bicarbonates and dissolved solids are 132 mg/L, 68 mg/L, 162 mg/L, and 232 mg/L compared to the 2011 averages of 410 mg/L, 1008 mg/L, 485 mg/L, and 1900 mg/l, respectively.

Like the basic chemistry of the reservoir nutrient concentration and overall condition of the reservoir has changed. For example, the historical average total nitrogen and total phosphorus concentrations were 1.06 mg/L and 0.339 mg/L, compared to the 2011 averages of 1.95 mg/L and 0.51 mg/L (Tables 1 and 3).

This dramatic change is interesting limnologically as no major industry has entered the watershed. The only substantial change in land use is the near complete transition from small grains to row crops.

Table 3. Statistical Summary of Lehr Dam's 1992-1993 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	2	132	116	148	23
Total Ammonia as N	mg/L	2	0.07	0.06	0.08	0.02
Bicarbonate (HCO_3)	mg/L	2	162	142	181	28
Calcium (Ca)	mg/L	2	34.7	29.6	39.8	7.2
Carbonate (CO_3)	mg/L	2	1[1]	1[1]	1[1]	0
Chloride (Cl)	mg/L	2	3.6	3.2	4	0.6
Chlorophyll-a	µg/L	2	11.3	6	16.5	7.4
Specific Conductance	µmhos	2	384	372	396	17
Total Dissolved Solids	mg/L	2	232	215	249	24
Total Hardness as ($CaCO_3$)	mg/L	2	160	139	181	30
Hydroxide (OH)	mg/L	2	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	2	0.386	0.069	0.703	0.448
Magnesium (Mg)	mg/L	2	17.8	15.7	19.9	3
Nitrate + Nitrite as N	mg/L	2	0.045	0.035	0.055	0.014
Total Kjeldahl Nitrogen as N	mg/L	2	1.01	0.837	1.18	0.243
Total Nitrogen as N	mg/L	2	1.06	0.922	1.24	0.257
pH		2	7.715	7.64	7.79	0.106
Total Phosphorus as P	mg/L	2	0.339	0.334	0.343	0.006
Potassium (K)	mg/L	2	9.6	9.4	9.7	0.2
Sodium (Na)	mg/L	2	17	16	17	1
Sulfate (SO4)	mg/L	2	68	68	68	0

[1]Equal to the lower reporting limit

Limiting Nutrients: The water quality samples collected in 1992, 1993 and 2011 indicate that Lehr Dam is nitrogen limited (Figure 6). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen to total phosphorus is at equilibrium at 15 to 1. When the N:P ratio is less than 15 nitrogen is assumed to be the limiting nutrient and when it exceeds 15 the limiting nutrient is assumed to be phosphorus. The total nitrogen to total phosphorus ratio for Lehr Dam was between 3 and 9 clearly identifying within the nitrogen limited range.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 1993, 1994 and 2011 Lehr Dam's trophic status is estimated is eutrophic and declining (Figure 7). The trophic status index (TSI) scores based on chlorophyll-a range is 48 to 58, for secchi disk 42 to 63 and for phosphorus 81 to 99 clearly indicating a reservoir that is over fertilized.

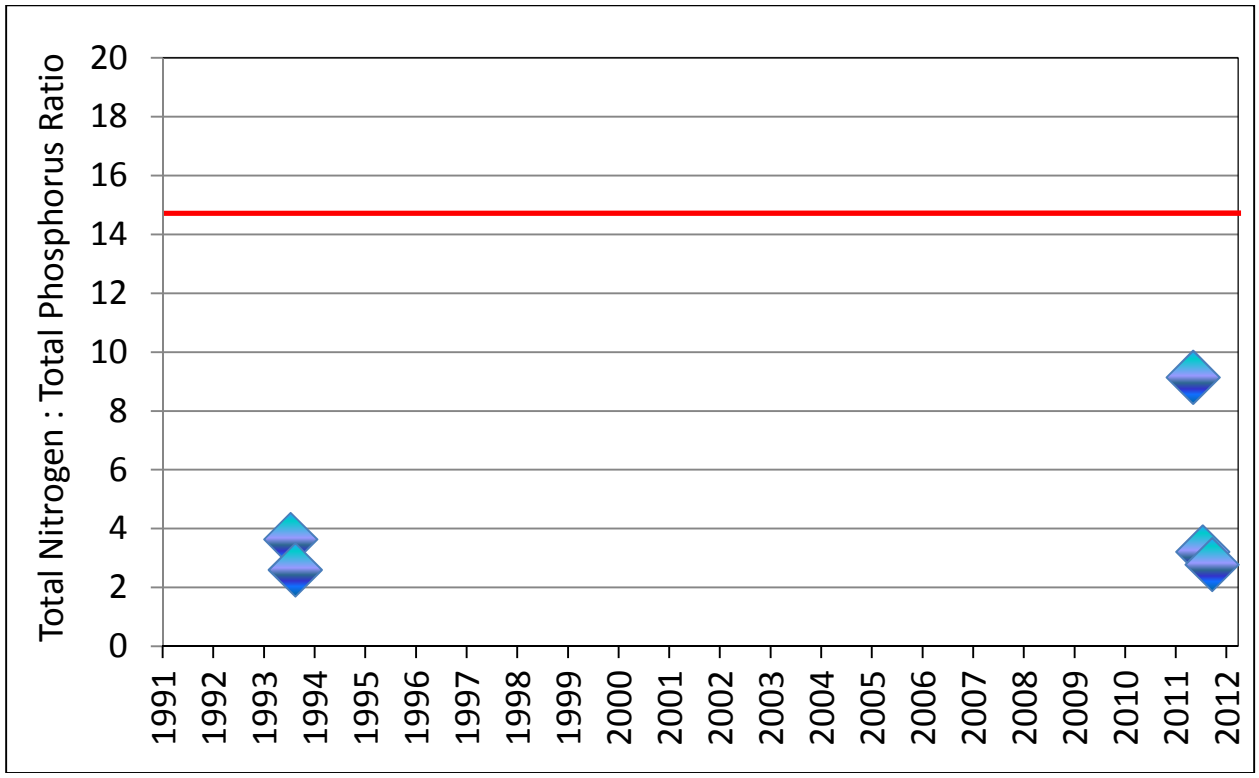

Figure 6. Lehr Dam's Total Nitrogen to Total Phosphorus Ratio

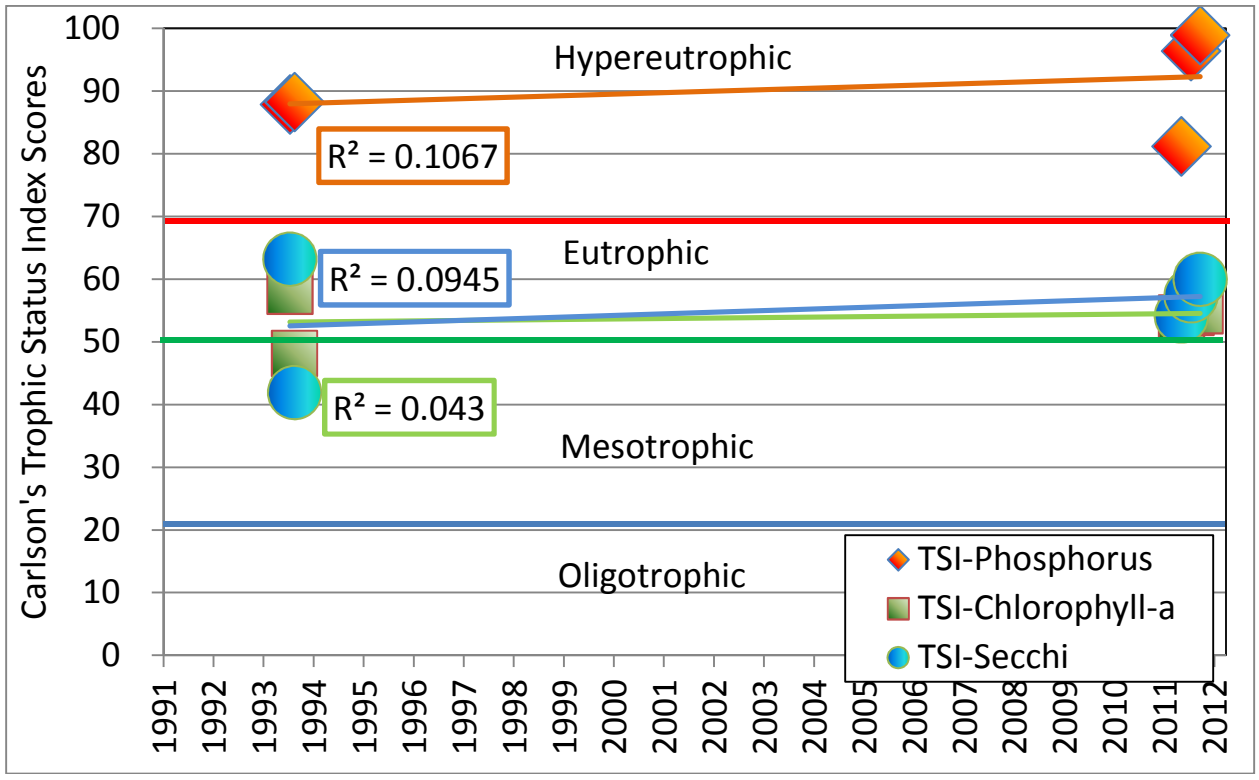

Figure 7. Lehr Dam's TSI Scores

Beaver Lake, Logan County

BACKGROUND

Beaver Lake is a large wetland enhanced to a shallow prairie lake. It lies on the Missouri Coteau 7 miles south and 7 miles east of town of Napoleon in Logan County, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish Department. Fish species managed for are northern pike and yellow perch.

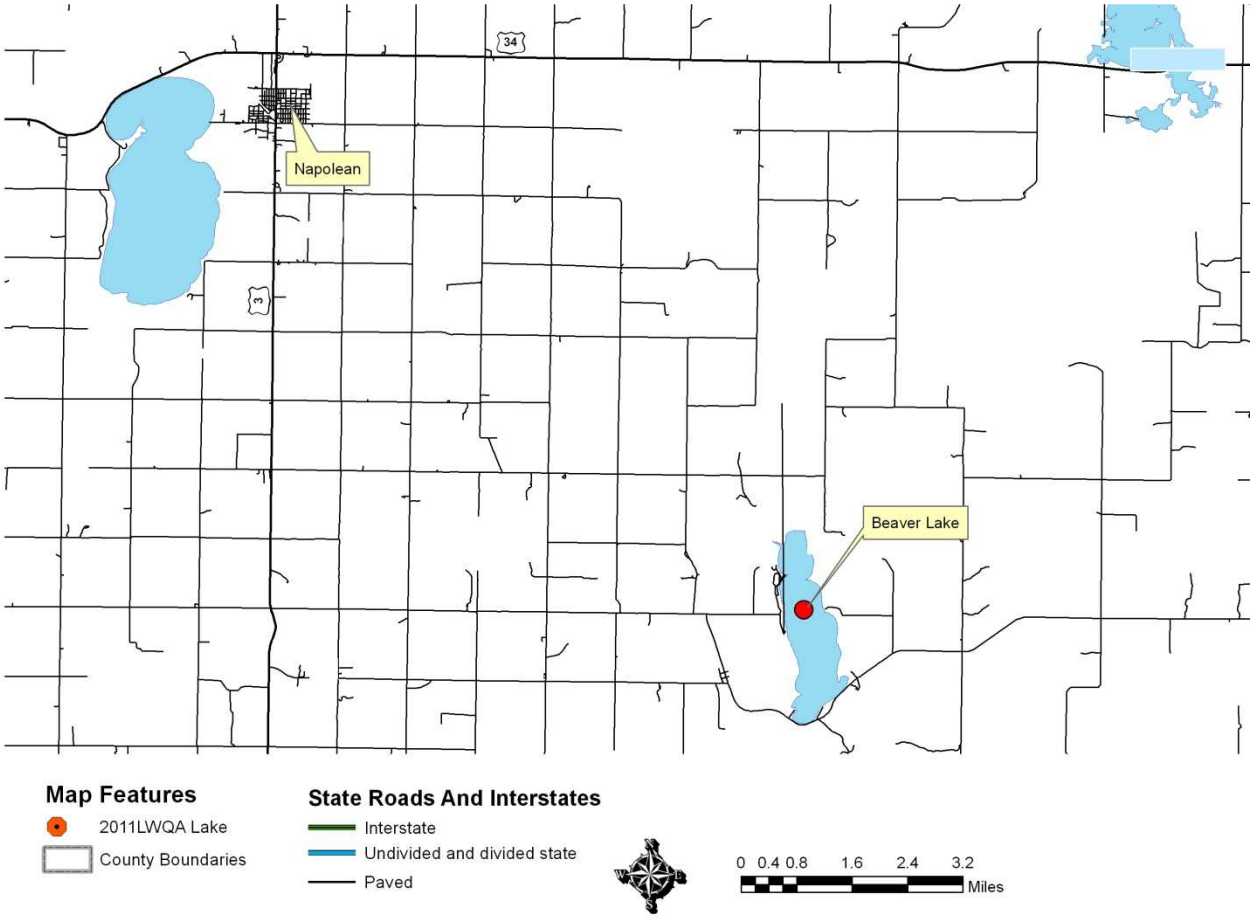

Figure 1. Location of Beaver Lake

Physiographic/Ecological Setting: Beaver Lake has 982.3 windswept surface acres with a maximum depth of 7 feet (Figure 2). The lake is glacial in origin, an outwash pothole with a rock, gravel and fine sand mixed shoreline. The lake is located in the Northwestern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figures 3).

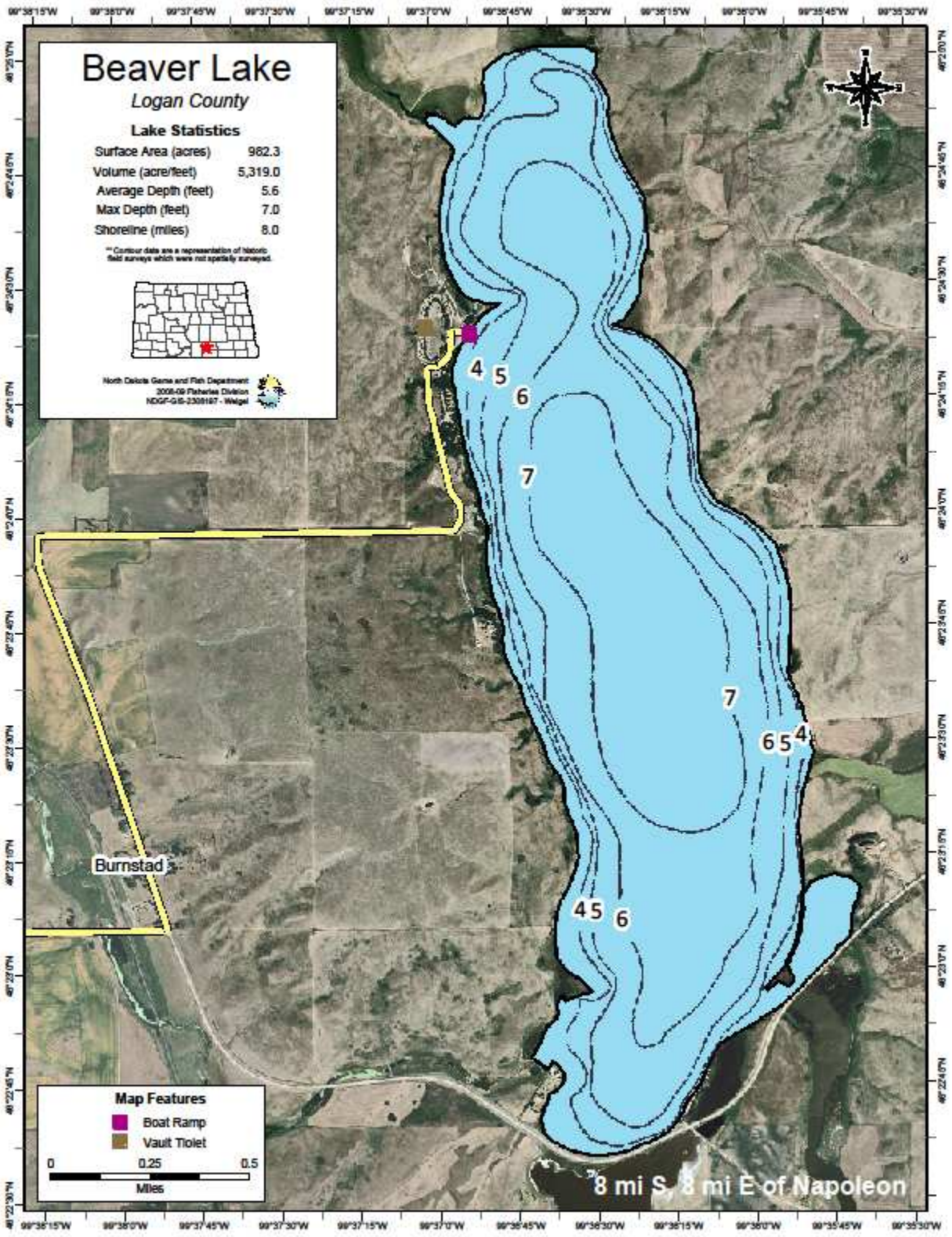

Figure 2. Contour Map of Beaver Lake (Map Courtesy of North Dakota Game and Fish Department)

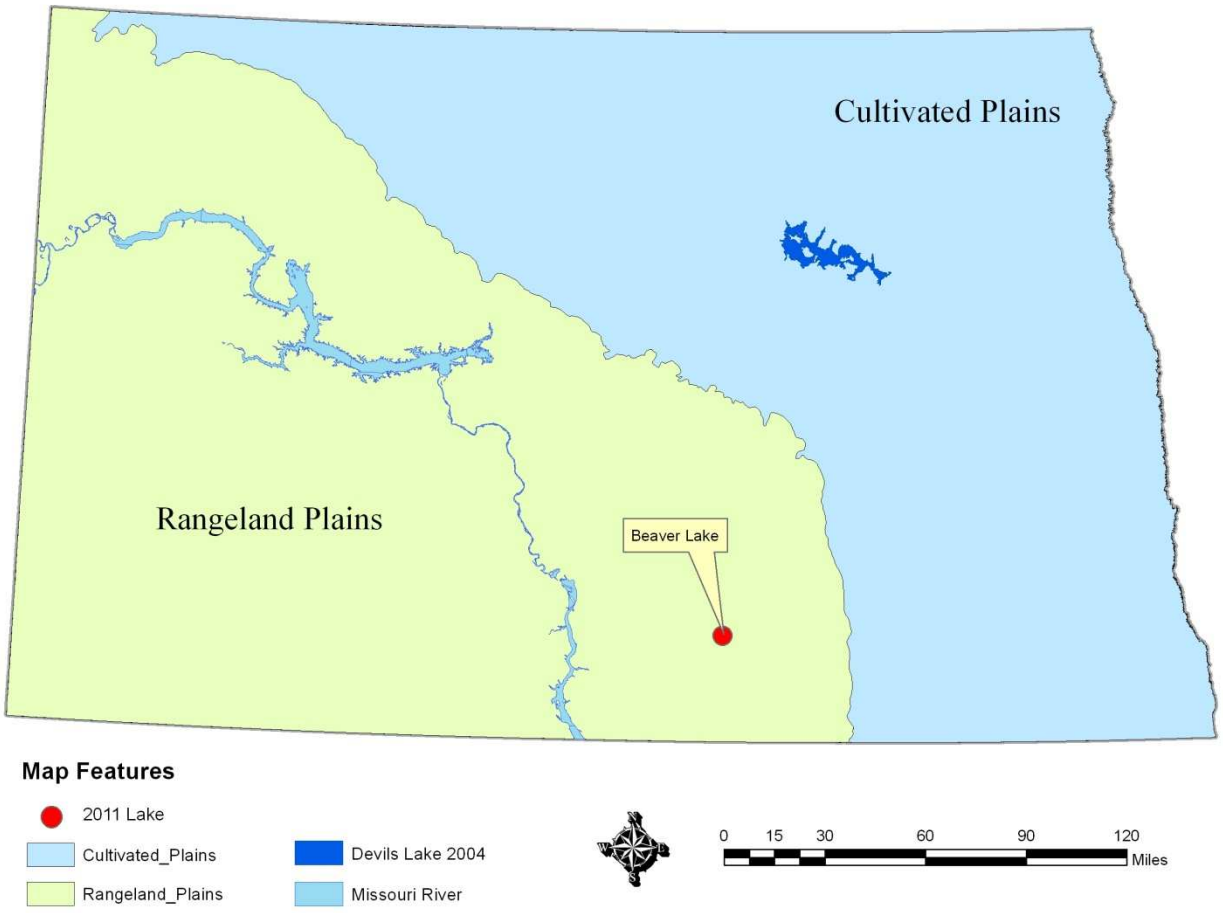

Figure 3. Beaver Lake Location and the Cultivated and Rangeland Plans Regions

Recreational Facilities: Recreational facilities at Beaver Lake are excellent with a beautifully treed State Park on its west shore. Beaver Lake State Park has year round access and permanent staff on site. Facilities include primitive and electric camp sites, showers, RV dump, playground, swim beach, boat ramp, picnic area, and law enforcement on site. It is a clean well maintained park within a stone-throw of many historical and interesting sites.

Water Quality Standards Classification: Beaver Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species might also be present.

Historical Water Quality Sampling: Historical water chemistry data include 3 samples in 1990 and 3 samples collected in 1992-1993. Historical temperature and dissolved oxygen data includes 3 profiles from 1992-93.

WATER QUALITY MONITORING RESULTS

The water quality assessment for Beaver Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional data for lakes in the Rangeland Plains Region.

Temperature and Dissolved Oxygen Profile Results: There are seven temperature and dissolved oxygen profiles for Beaver Lake collected in 1990, 1992-93 and 2011 (Figures 4 and 5). The temperature profile data indicates that Beaver Lake does not thermally stratify which is expected in a large shallow lake and North Dakota prevailing winds (Figure 4). The results indicates that during the open water period the lake remains well enough oxygenated to support all manner aquatic life but under ice it may experience a substantial sag in dissolved oxygen concentrations (Figure 5).

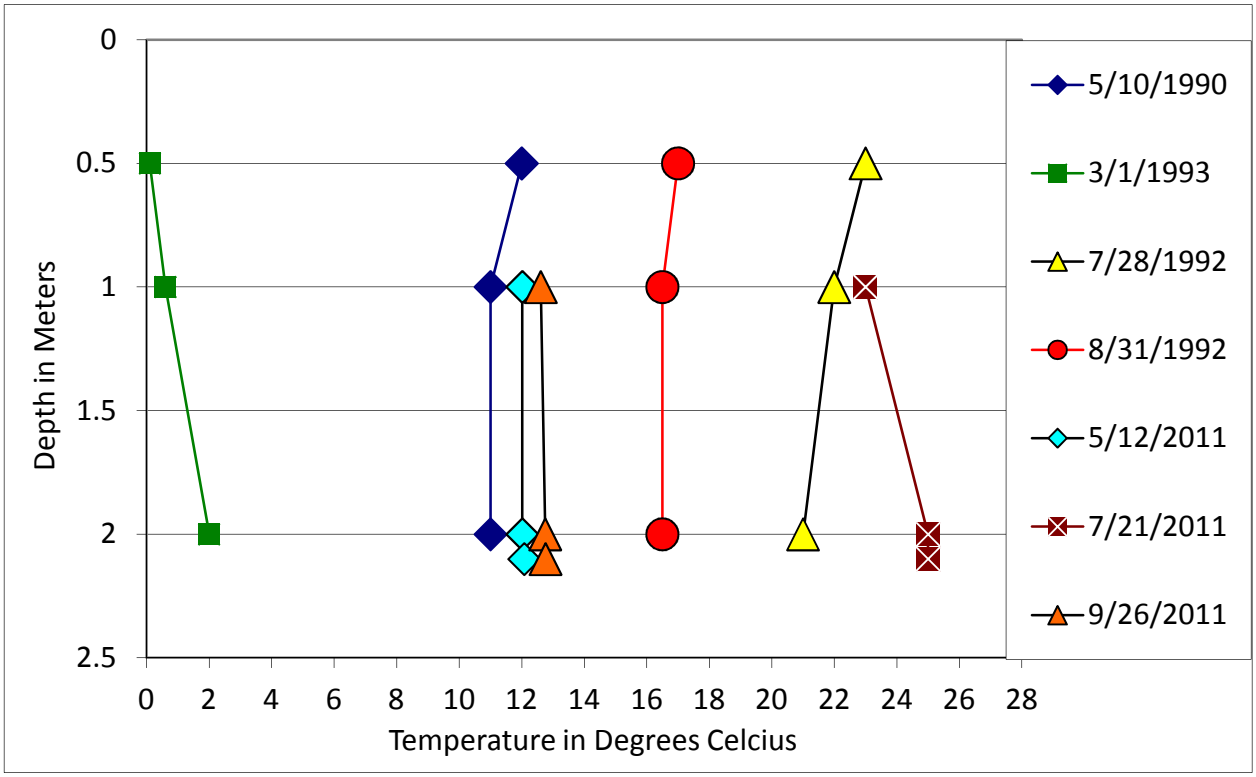

Figure 4. Temperature Profiles for Beaver Lake

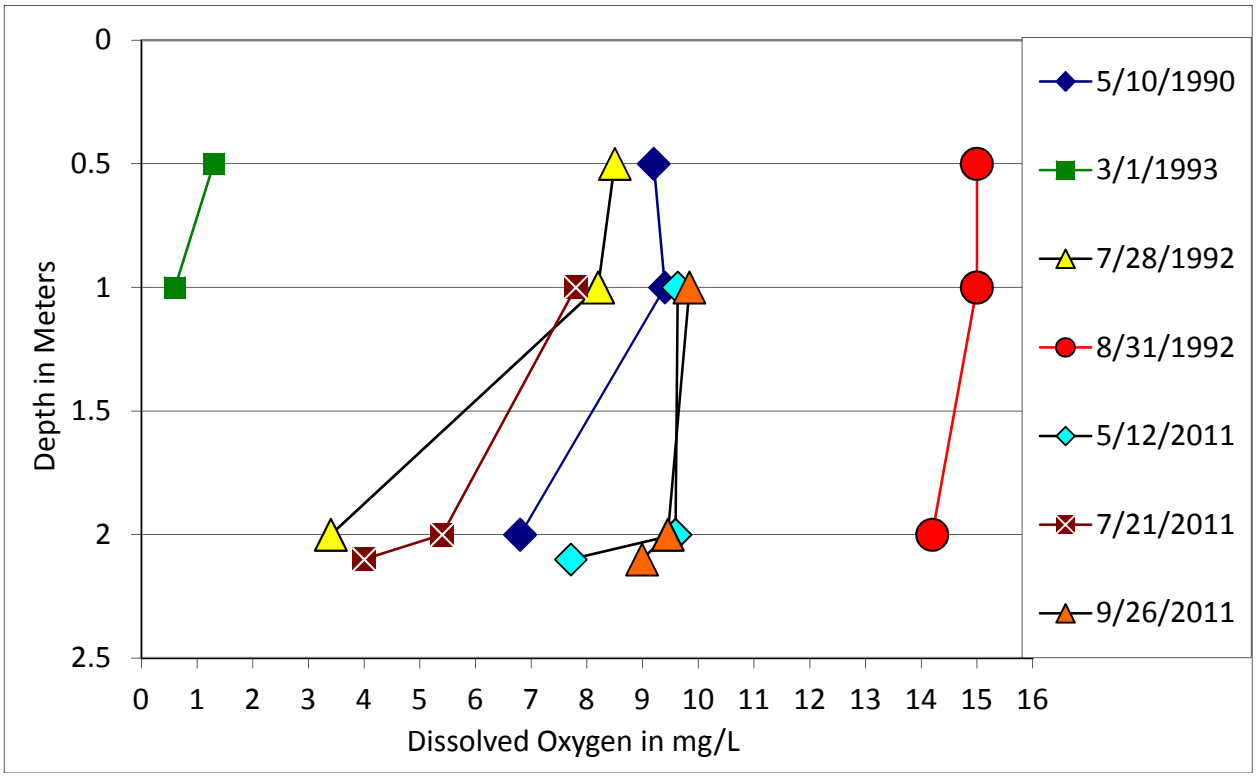

Figure 5. Dissolved Oxygen Profiles for Beaver Lake

Historically Beaver Lake rarely experiences a winter die off. The ability to be only 7 feet deep and maintain a fishery is most like due to its large surface area that utilizes the faintest light for photosynthesis. Additionally, it is most likely nested into the shallow glacial aquifer giving it twelve months of minimal flow from receiving and discharging ground water.

General Water Quality: Water quality data collected in 2011 indicates that Beaver Lake is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 228 to 277 mg/L (Table 1) and that the lake is sodium bicarbonate dominated with an average sodium concentration of 69.8 mg/L and an average bicarbonate concentration of 286 mg/L. The average total dissolved solids concentration and specific conductance measurements for the 2011 sampling period were 509 mg/L and 783µmhos/cm, respectively.

Nutrient concentrations indicate that Beaver Lake, while not short of ingredients for primary production, it is not overly fertilized with total nitrogen and total phosphorus concentrations of 0.852 mg/L and 0.128 mg/L respectively.

Table 1. Statistical Summary of Beaver Lake's 2011 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	254	228	277	25
Total Ammonia as N	mg/L	3	0.03[1]	0.03[1]	0.03[1]	0
Bicarbonate (HCO_3)	mg/L	3	286	233	328	48
Calcium (Ca)	mg/L	3	54.7	48.3	60.3	6
Carbonate (CO_3)	mg/L	3	11.3	5[1]	22	9.3
Chloride (Cl)	mg/L	3	11.6	9.8	12.8	1.6
Chlorophyll-a	µg/L	3	20.7	15	23.5	4.9
Specific Conductance	µmhos	3	783	688	834	82
Total Dissolved Solids	mg/L	3	509	435	554	65
Total Hardness as ($CaCO_3$)	mg/L	3	318	273	343	39
Hydroxide (OH)	mg/L	3	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	3	0.52	0.37	0.8	0.25
Magnesium (Mg)	mg/L	3	44.1	37.1	48.6	6.2
Nitrate + Nitrite as N	mg/L	3	0.03[1]	0.03[1]	0.03[1]	0
Total Kjeldahl Nitrogen as N	mg/L	3	0.829	0.783	0.87	0.044
Total Nitrogen as N	mg/L	3	0.859	0.813	0.9	0.044
pH		3	8.5	8.4	8.8	0.2
Total Phosphorus as P	mg/L	3	0.128	0.064	0.216	0.079
Potassium (K)	mg/L	3	13.1	12.7	13.6	0.5
Sodium (Na)	mg/L	3	69.8	58.2	79.9	10.9
Sulfate (SO4)	mg/L	3	162	131	189	29

[1]Equal to the lower reporting limit

In comparison to the water quality for all natural lakes in the Rangeland Plans Region, Beaver Lake is fresher and lower in nutrients than most (Tables 1 and 2). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 1398 mg/L, 1.75 mg/L, and 0.220 mg/L compared to Beaver Lake's 2011 average TDS, total nitrogen, and total phosphorus concentrations of 509 mg/L, 0.859 mg/L and 0.128 mg/L, respectively.

When comparing historical water quality data (1990, 1992-1993) to 2011 data, the mineral concentrations have declined noticeably. For example, the historical average concentrations for total dissolved solids, sulfates and bicarbonates are 787 mg/L, 199 mg/L and 538 mg/L and the 2011 averages are 509 mg/L, 162 mg/L and 286 mg/L, respectively.

Total phosphorus and total nitrogen concentrations are also trending downward resulting in a decrease in the over availability for primary production. For example the average total nitrogen and total phosphorus concentrations in 1990, 1992-93 were 3.26 mg/L and 0.435 mg/L and the 2011 averages had fallen to 0.859 mg/L and 0.128 mg/L, respectively (Tables 1 and 3).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	571	282	3	982	130
Total Ammonia as N	mg/L	651	0.092	0.001	2.44	0.178
Bicarbonate (HCO_3)	mg/L	571	296	4	1040	143
Calcium (Ca)	mg/L	571	55	2	206	30
Carbonate (CO_3)	mg/L	569	24	1	197	28
Chloride (Cl)	mg/L	571	14	1	75	10
Chlorophyll-a	µg/L	456	19.6	1.5	218	26.1
Specific Conductance	µmhos	591	1618	4	5880	973
Total Dissolved Solids	mg/L	572	1113	17	5110	773
Total Hardness as ($CaCO_3$)	mg/L	571	410	9	2100	288
Hydroxide (OH)	mg/L	514	1	1	1	0
Iron (Fe)	mg/L	572	0.2	0.01	4.11	0.35
Magnesium (Mg)	mg/L	571	66.4	1	412	54.9
Nitrate + Nitrite as N	mg/L	650	0.064	0.003	1.49	0.127
Total Kjeldahl Nitrogen as N	mg/L	541	1.36	0.08	7.72	0.78
Total Nitrogen as N	mg/L	484	1.32	0.02	4.84	0.63
pH		591	8.54	5.74	9.87	0.55
Total Phosphorus as P	mg/L	657	0.126	0.004	3.16	0.185
Potassium (K)	mg/L	571	13.9	1	52.5	6.9
Sodium (Na)	mg/L	571	214	3	932	168
Sulfate (SO4)	mg/L	569	578	1	3210	512

[1]Equal to the lower reporting limit
[2]Data collected from 76 reservoirs between 1991 and 2011

Limiting Nutrients: The water quality samples collected in 1992-93 and 2011 indicate that Beaver Lake is phosphorus limited (Figure 6). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen to total phosphorus 15 to 1 is nutrient equilibrium; and that a ratio greater represents phosphorus limitation and less than 15 nitrogen limitation.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 1992-93 and 2011, Beaver Lake's trophic status is estimated as borderline eutrophic with a marked improving trend (Figure 7). The Trophic Status Index (TSI) scores based on chlorophyll-a in 2011 are consistently in the upper eutrophic to hypereutrophic range at 57 to 62.

Table 3. Statistical Summary of Beaver Lake's 1992-1993 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	6	488	396	667	133
Total Ammonia as N	mg/L	6	0.35	0.01[1]	0.73	0.35
Bicarbonate (HCO_3)	mg/L	6	538	392	814	206
Calcium (Ca)	mg/L	6	37.1	29.6	49.7	8.9
Carbonate (CO_3)	mg/L	6	28	1[1]	45	22
Chloride (Cl)	mg/L	6	26.6	21.4	36.8	7.6
Chlorophyll-a	µg/L	2	49.5	44	55	7.8
Specific Conductance	µmhos	6	1192	918	1680	379
Total Dissolved Solids	mg/L	6	787	627	1080	223
Total Hardness as ($CaCO_3$)	mg/L	6	330	261	451	86
Hydroxide (OH)	mg/L	2	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	6	0.371	0.146	0.5	0.148
Magnesium (Mg)	mg/L	6	57.6	45.5	79.5	15.4
Nitrate + Nitrite as N	mg/L	4	0.009	0.006	0.013	0.003
Total Kjeldahl Nitrogen as N	mg/L	4	3.248	1.68	4.82	1.737
Total Nitrogen as N	mg/L	4	3.26	1.69	4.83	1.738
pH		6	8.63	7.88	9.11	0.566
Total Phosphorus as P	mg/L	6	0.435	0.282	0.574	0.129
Potassium (K)	mg/L	6	25.8	22.6	30.2	2.8
Sodium (Na)	mg/L	6	147	118	200	37
Sulfate (SO4)	mg/L	6	199	137	303	73

[1]Equal to the lower reporting limit.

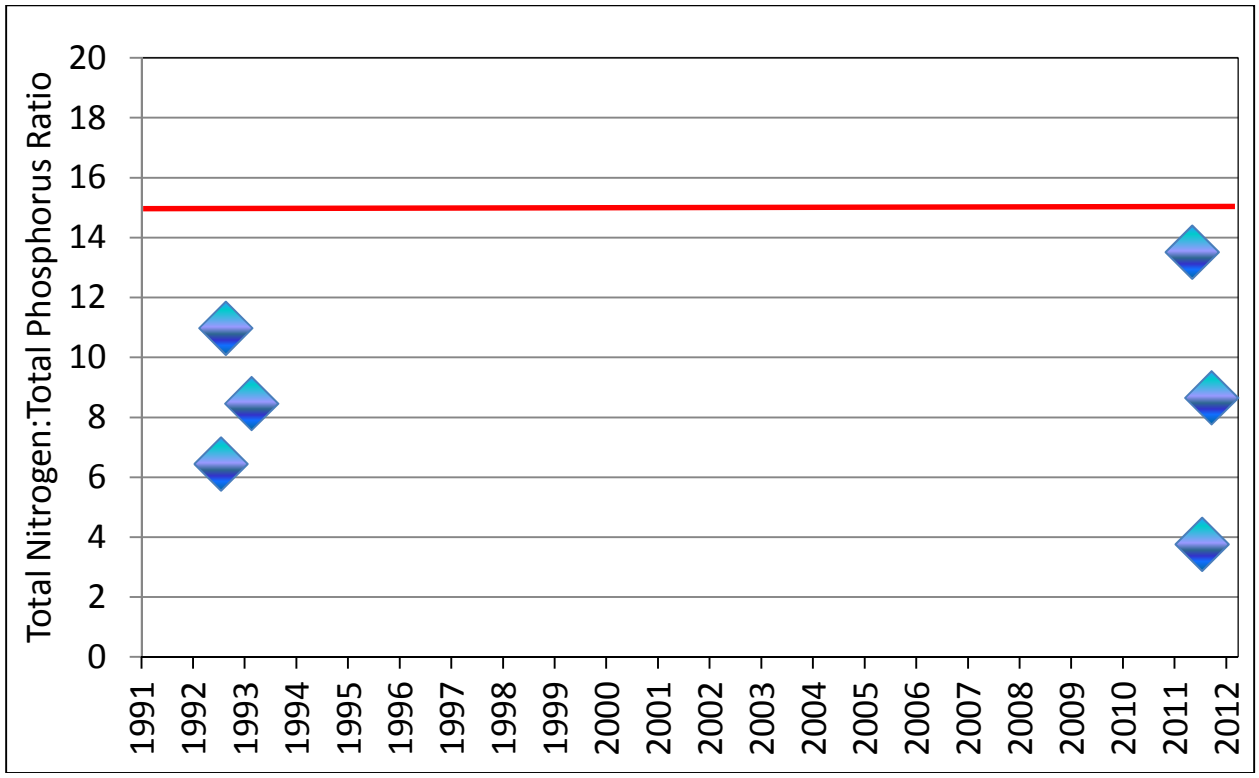

Figure 6. Beaver Lake's Total Nitrogen to Total Phosphorus Ratio

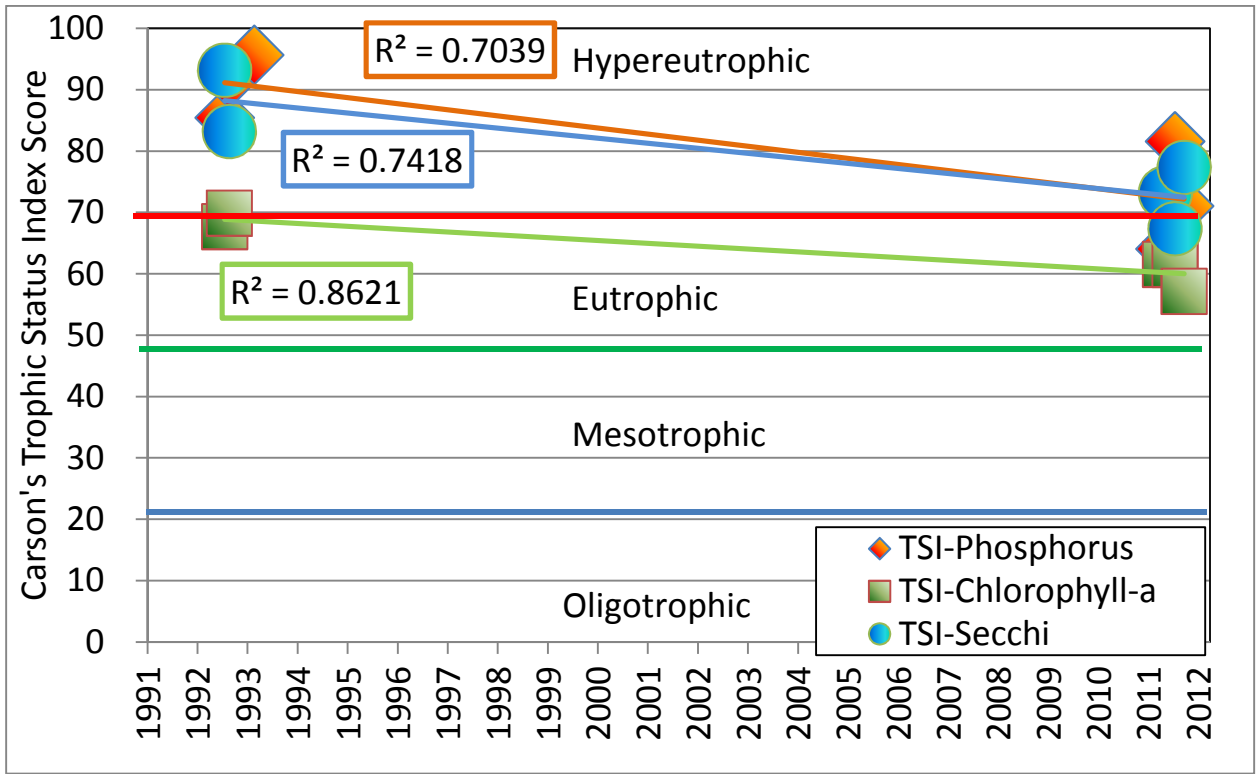

Figure 7. Beaver Lake's TSI Scores

Nygren Dam, Morton County

BACKGROUND

Nygren Dam is a small rural reservoir in Morton County, North Dakota. The dam is located 9.5 miles north and 2 miles east of Flasher on a tertiary drainage to the Heart River (Figure 1). The fishery is managed by the North Dakota Game and Fish Department. Fish species managed for are trout, bluegill and largemouth bass.

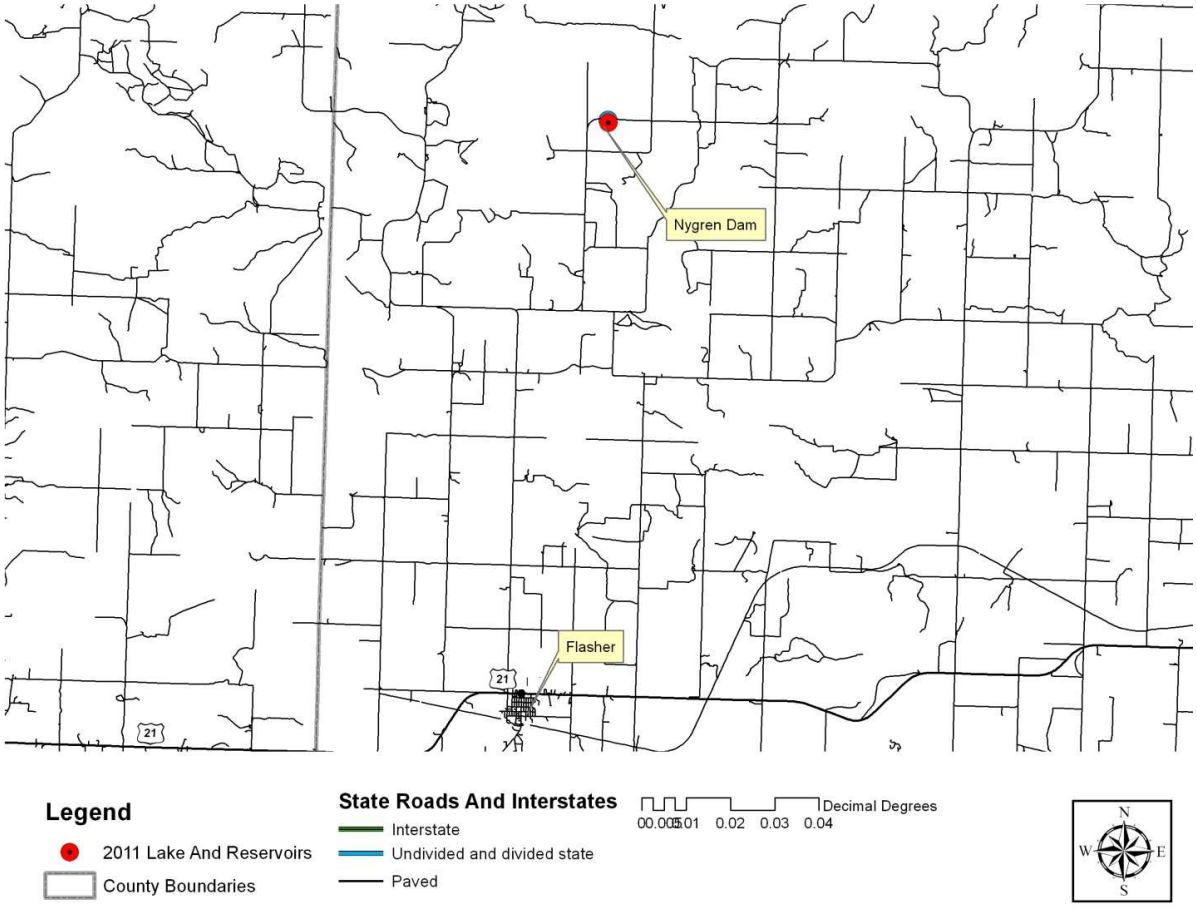

Figure 1. Location of Nygren Dam

Physiographic/Ecological Setting: Nygren Dam has a surface area of 6.7 acres, an average depth of 14.5 feet and a maximum depth of 37.6 feet. It is an isolated little reservoir perched at the top of the breaks to the Heart River (Figure 2). The reservoir is located in the Northwestern Great Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figure 3).

Recreational Facilities: Recreational facilities at Nygren Dam are a boat ramp, vault toilet, fishing pier, picnic area and parking.

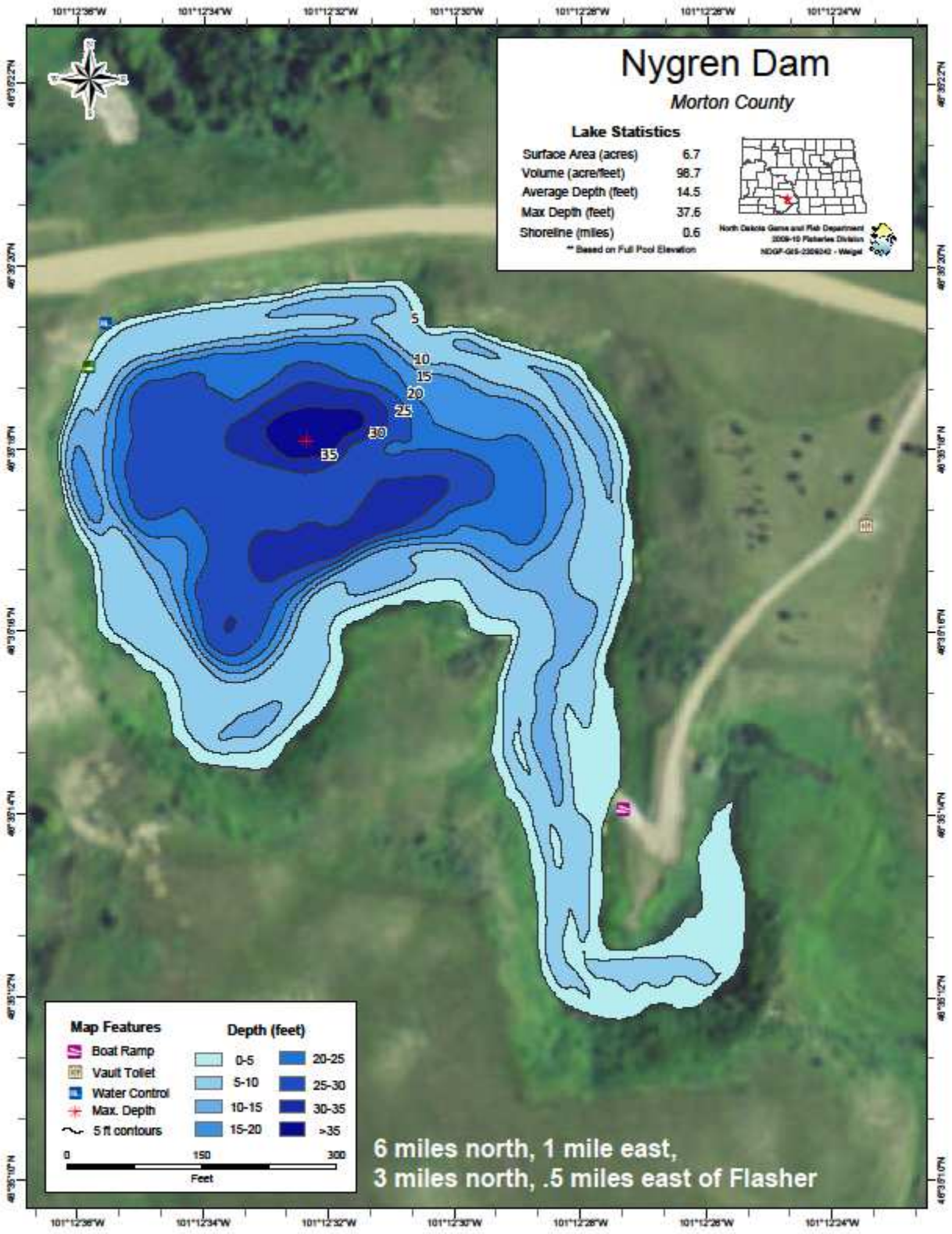

Figure 2. Contour Map of Nygren Dam (Map Courtesy of North Dakota Game and Fish Department)

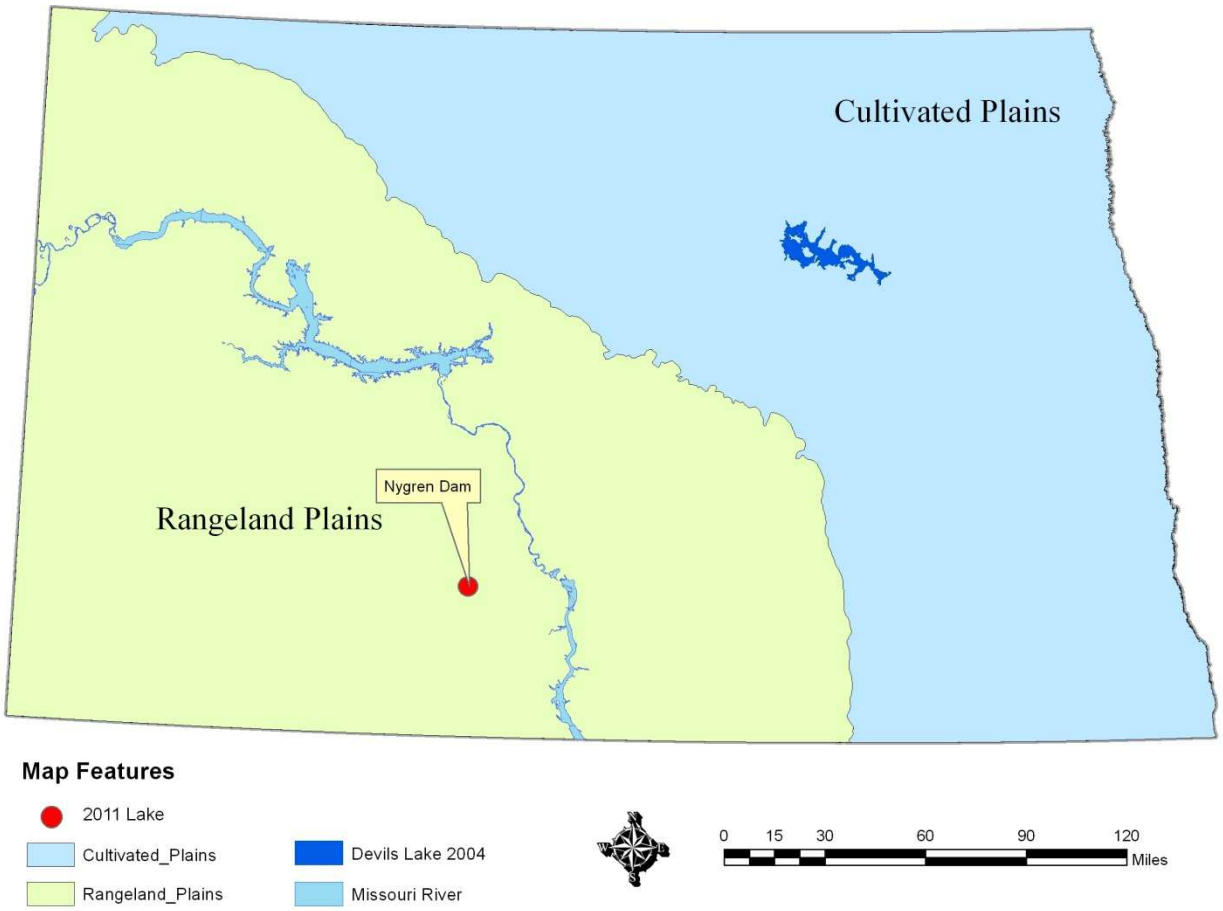

Figure 3. Nygren Dam Location and the Cultivated and Rangeland Plans Regions

Water Quality Standards Classification: Nygren Dam is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a Class 2 waterbody. A class 3 lakes and reservoirs are defined as "cool water fisheries" or "waters capable of supporting natural reproduction and growth of cool water fishes (e.g., northern pike and walleye) and associated aquatic biota. Some cold water species may also be present."

Historical Water Quality Sampling: Historical water quality data include 4 water quality samples collected in 1993 and 1994.

WATER QUALITY MONITORING RESULTS

The water quality assessment for Nygren Dam is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional data for reservoirs in the Rangeland Plains Region.

Temperature and Dissolved Oxygen Profile Results: There are six temperature and dissolved oxygen profiles for Nygren Dam collected in 1993, 1994 and 2011 (Figures 4 and 5). The temperature profile data indicates that Nygren Dam is usually thermally stratification during both the open and iced water periods (Figure 4).

The dissolved oxygen profiles indicate that the reservoir experiences rapid and often complete oxygen decay below the thermal-cline during these periods. Fortunately the reservoir is uncommonly deep for its size (Figure 2) preventing major die offs during de-stratification events.

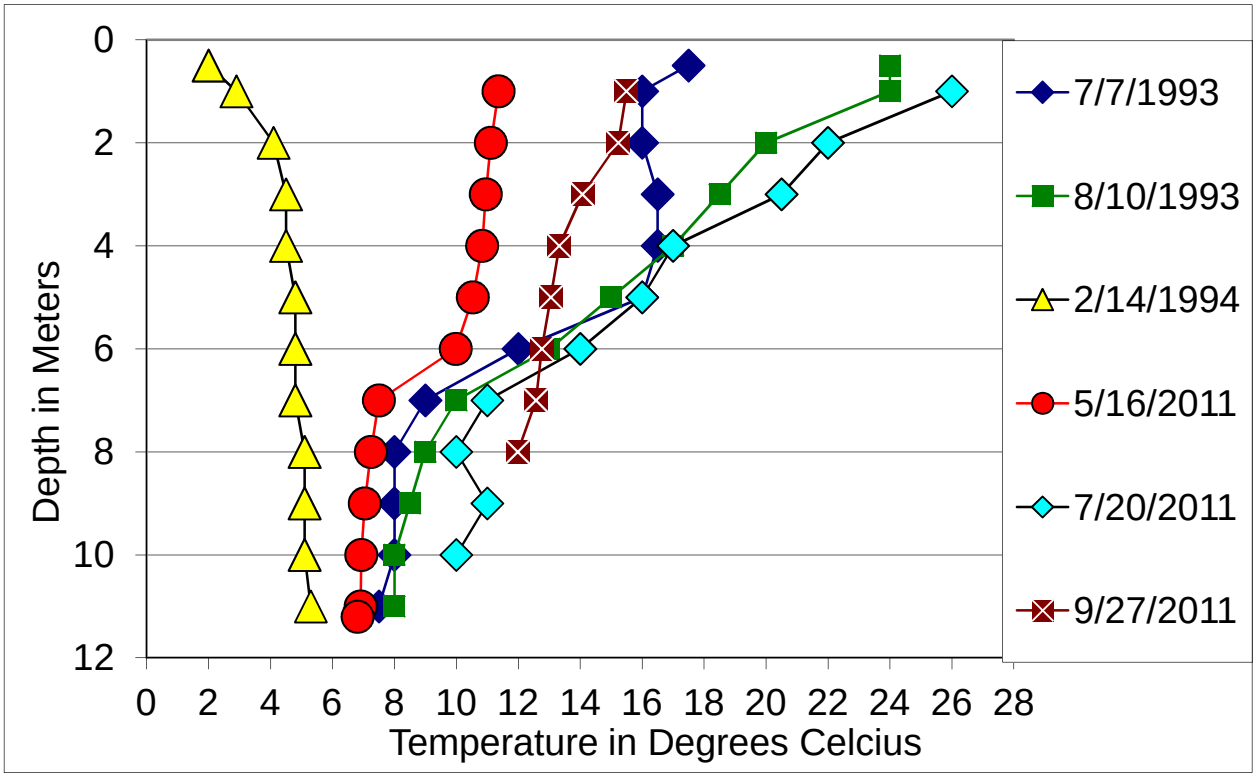

Figure 4. Temperature Profiles for Nygren Dam

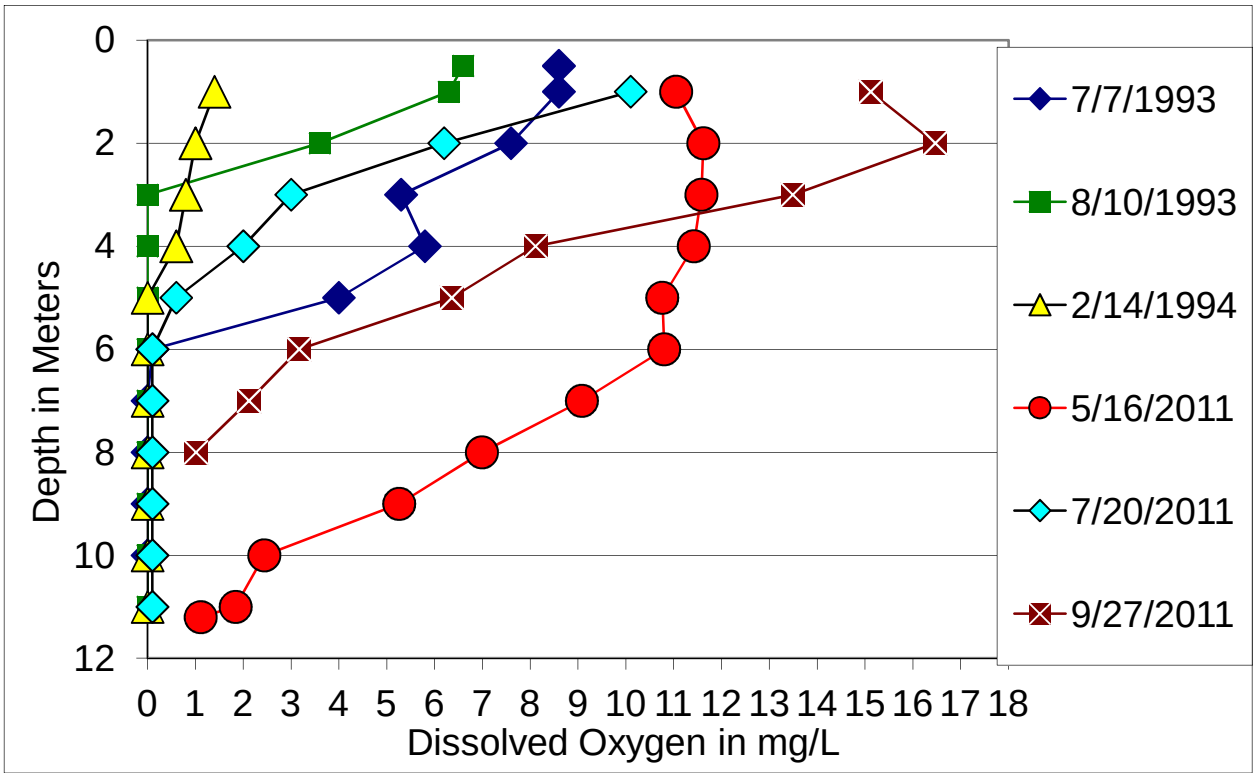

Figure 5. Dissolved Oxygen Profiles for Nygren Dam

General Water Quality: Data collected in 2011 indicates that Nygren Dam is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 229 to 250 mg/L (Table 1) and that the reservoir is sodium bicarbonate dominated with an average sodium concentration of 62.7 mg/L and an average bicarbonate concentration of 262 mg/L. The average total dissolved solids concentration and specific conductance measurements for the 2011 sampling period were 310 mg/L and 527µmhos/cm, and the average total nitrogen and total phosphorus concentrations were of 1.23 mg/L and 0.07 mg/L respectively.

When compared to water quality for reservoirs in the Rangeland Plans Region, Nygren Dam has lower concentrations of dissolved minerals and phosphorus but about average concentrations of nitrogen (Tables 1 and 2). For example, the regional average TDS, total phosphorus, and total nitrogen concentrations are 1113 mg/L, 1.32 mg/L, and 0.128 mg/L respectively, compared to Nygren Dam's average total dissolved solids, total nitrogen, and total phosphorus concentrations of 310 mg/L, 1.23 mg/L and 0.07 mg/L respectively.

When comparing historical water quality data collected in 1993 and 1994 to current 2011, there is an increase in the dissolved solid and associated parameters but nutrients remained fairly stable. For example, the historical and 2011 averages in pairs for total dissolved solids, sulfates, bicarbonates are 223 and 310 mg/L, 15 and 40 mg/L, 227 and 267 mg/L, respectively, and the historical and 2001 concentrations in pairs for total nitrogen and total phosphorus concentrations are 1.55 and 1.23 mg/L and 0.10 and 0.07 mg/L (Tables 1 and 2).

Table 1. Statistical Summary of Nygren Dam's 2011 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	241	229	250	11
Total Ammonia as N	mg/L	3	0.08	0.03[1]	0.18	0.09
Bicarbonate (HCO_3)	mg/L	3	262	197	296	56
Calcium (Ca)	mg/L	3	23	17	28.5	5.8
Carbonate (CO_3)	mg/L	3	16	1[1]	40	21
Chloride (Cl)	mg/L	3	4.1	4	4.2	0.1
Chlorophyll-a	µg/L	3	54.1	25.6	80.6	27.6
Specific Conductance	µmhos	3	527	500	556	28
Total Dissolved Solids	mg/L	3	310	299	318	10
Total Hardness as ($CaCO_3$)	mg/L	3	162	151	168	9
Hydroxide (OH)	mg/L	3	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	3	0.09	0.05[1]	0.17	0.07
Magnesium (Mg)	mg/L	3	25.4	23.6	26.3	1.5
Nitrate + Nitrite as N	mg/L	3	0.03[1]	0.03[1]	0.03[1]	0
Total Kjeldahl Nitrogen as N	mg/L	3	1.2	1.04	1.51	0.27
Total Nitrogen as N	mg/L	3	1.23	1.07	1.54	0.27
pH		3	8.63	8.17	9.3	0.59
Total Phosphorus as P	mg/L	3	0.07	0.02[1]	0.1	0.05
Potassium (K)	mg/L	3	9.3	8.7	9.9	0.6
Sodium (Na)	mg/L	3	62.7	61.5	63.9	1.2
Sulfate (SO4)	mg/L	3	40	38	41	1

[1]Equal to the lower reporting limit

Table 2. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Rangeland Plains Ecological Region of North Dakota.

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	571	282	3	982	130
Total Ammonia as N	mg/L	651	0.092	0.001	2.44	0.178
Bicarbonate (HCO_3)	mg/L	571	296	4	1040	143
Calcium (Ca)	mg/L	571	55	2	206	30
Carbonate (CO_3)	mg/L	569	24	1	197	28
Chloride (Cl)	mg/L	571	14	1	75	10
Chlorophyll-a	µg/L	456	19.6	1.5	218	26.1
Specific Conductance	µmhos	591	1618	4	5880	973
Total Dissolved Solids	mg/L	572	1113	17	5110	773
Total Hardness as ($CaCO_3$)	mg/L	571	410	9	2100	288
Hydroxide (OH)	mg/L	514	1	1	1	0
Iron (Fe)	mg/L	572	0.2	0.01	4.11	0.35
Magnesium (Mg)	mg/L	571	66.4	1	412	54.9
Nitrate + Nitrite as N	mg/L	650	0.064	0.003	1.49	0.127
-Total Kjeldahl Nitrogen as N	mg/L	541	1.36	0.08	7.72	0.78
Total Nitrogen as N	mg/L	484	1.32	0.02	4.84	0.63
pH		591	8.54	5.74	9.87	0.55
Total Phosphorus as P	mg/L	657	0.126	0.04	3.16	0.185
Potassium (K)	mg/L	571	13.9	1	52.5	6.9
Sodium (Na)	mg/L	571	214	3	932	168
Sulfate (SO4)	mg/L	569	578	1	3210	512

[1]Equal to the lower reporting limit
[2]Data collected from 76 reservoirs between 1991 and 2011.

Table 3. Statistical Summary of Nygren Dam's 1993-1994 Water Quality Data.

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	4	197	163	236	39
Total Ammonia as N	mg/L	4	0.36	0.14	0.94	0.39
Bicarbonate (HCO_3)	mg/L	4	227	199	288	42
Calcium (Ca)	mg/L	4	18.7	15.7	26.9	5.5
Carbonate (CO_3)	mg/L	4	8	1[1]	28	14
Chloride (Cl)	mg/L	4	1	0.3	3	1.4
Chlorophyll-a	µg/L	2	21.5	3	40	26.2
Specific Conductance	µmhos	4	394	339	464	64
Total Dissolved Solids	mg/L	4	223	190	266	37
Total Hardness as ($CaCO_3$)	mg/L	4	108	90	140	23
Hydroxide (OH)	mg/L	4	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	4	0.496	0.17	0.699	0.244
Magnesium (Mg)	mg/L	4	14.9	12.4	17.6	2.9
Nitrate + Nitrite as N	mg/L	4	0.082	0.006	0.128	0.055
Total Kjeldahl Nitrogen as N	mg/L	4	1.47	1.23	1.63	0.363
Total Nitrogen as N	mg/L	4	1.55	1.24	1.76	0.414
pH		4	8.163	7.52	9.04	0.641
Total Phosphorus as P	mg/L	4	0.1	0.079	0.12	0.017
Potassium (K)	mg/L	4	10.1	9.2	10.9	0.9
Sodium (Na)	mg/L	4	41	34	49	8
Sulfate (SO4)	mg/L	4	15	8	19	5

[1]Equal to the lower reporting limit

Limiting Nutrients: The water quality samples collected in 1993, 1994 and 2011 indicate that Nygren Dam is phosphorus limited with periods of equilibrium (Figure 6). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen to total phosphorus is at equilibrium at 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus. Nygren Dam's ratio ranged between a low of 11 and a high of 67.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 1993, 1994 and 2011, Nygren Dam's trophic status is estimated as eutrophic with no recognizable trend (Figure 7). The Trophic Status Index (TSI) scores based on chlorophyll-a ranged between 41to 74, with the majority being in the eutrophic range. The estimate of eutrophic was supported by the secchi disk measurements with a TSI range of 49 and 57 and closely by total phosphorus concentrations with a range of TSI scores of 44 and 71.

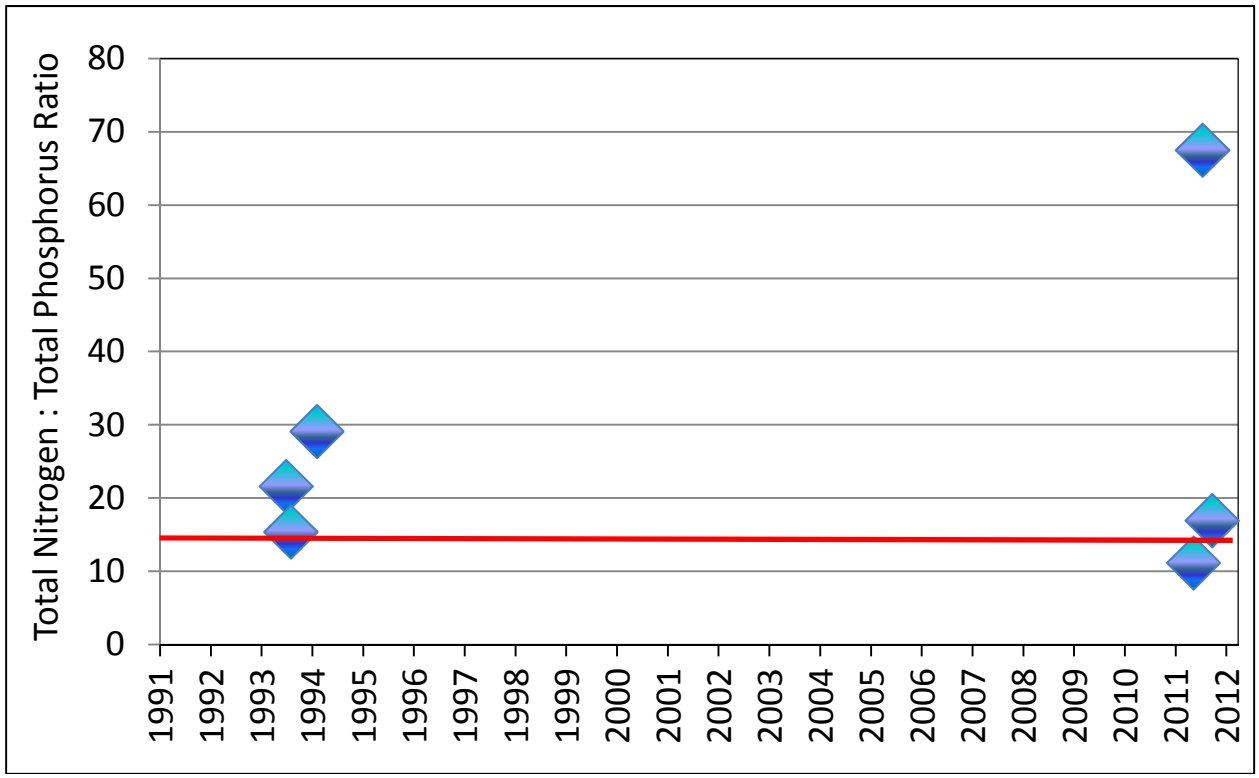

Figure 6. Nygren Dam's Total Nitrogen to Total Phosphorus Ratio

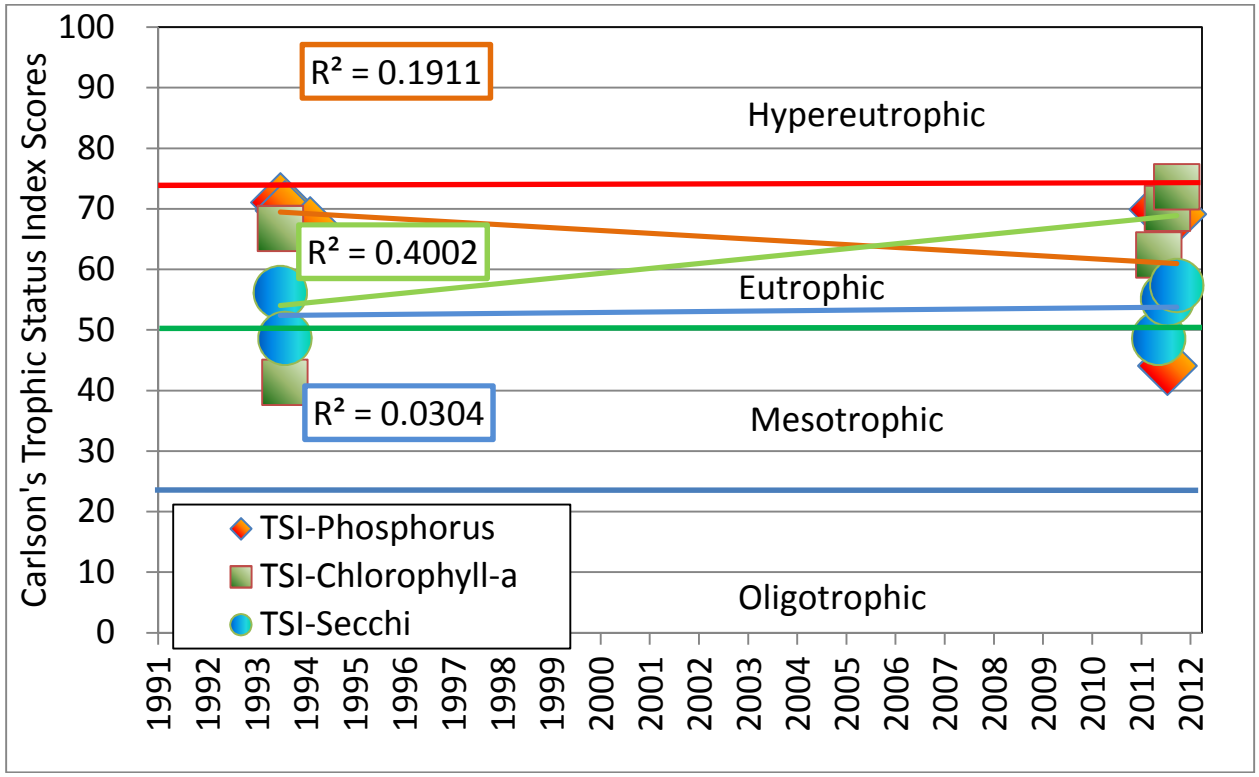

Figure 7. Nygren Dam's TSI Scores

Clear Water Lake, Mountrail County

BACKGROUND

Clear Water Lake is a nice prairie lake located 2 miles west and 4.5 miles north of Palermo, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish Department. Fish species managed for are northern pike and yellow perch.

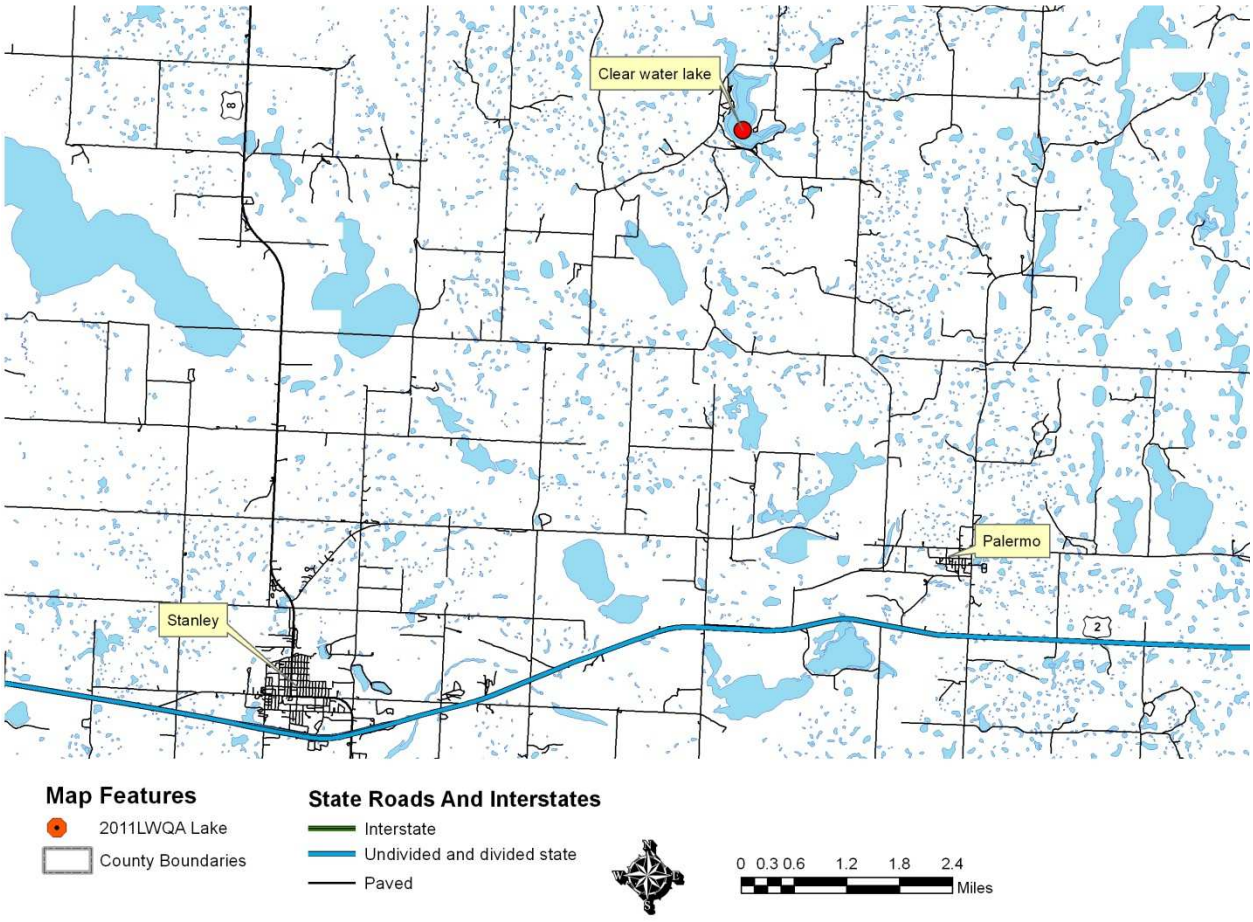

Figure 1. Location of Clear Water Lake

Physiographic/Ecological Setting: Clear Water Lake has a surface area of 32.3 acres, a mean depth of 8.1 feet and a maximum depth of 13 feet (Figure 2). The lake is glacial in origin and nested in a scenic depression within one of the most pristine grassland ecosystems in the continental United Sates known as the Missouri Coteau. The Missouri Coteau is part of the Northwestern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figures 3).

Recreational Facilities: Recreational facilities at Clear Water Lake are an access road, parking, camping and picnic area, swim beach and a small cement boat ramp. There is some low density urban development on the lakes western and north shores.

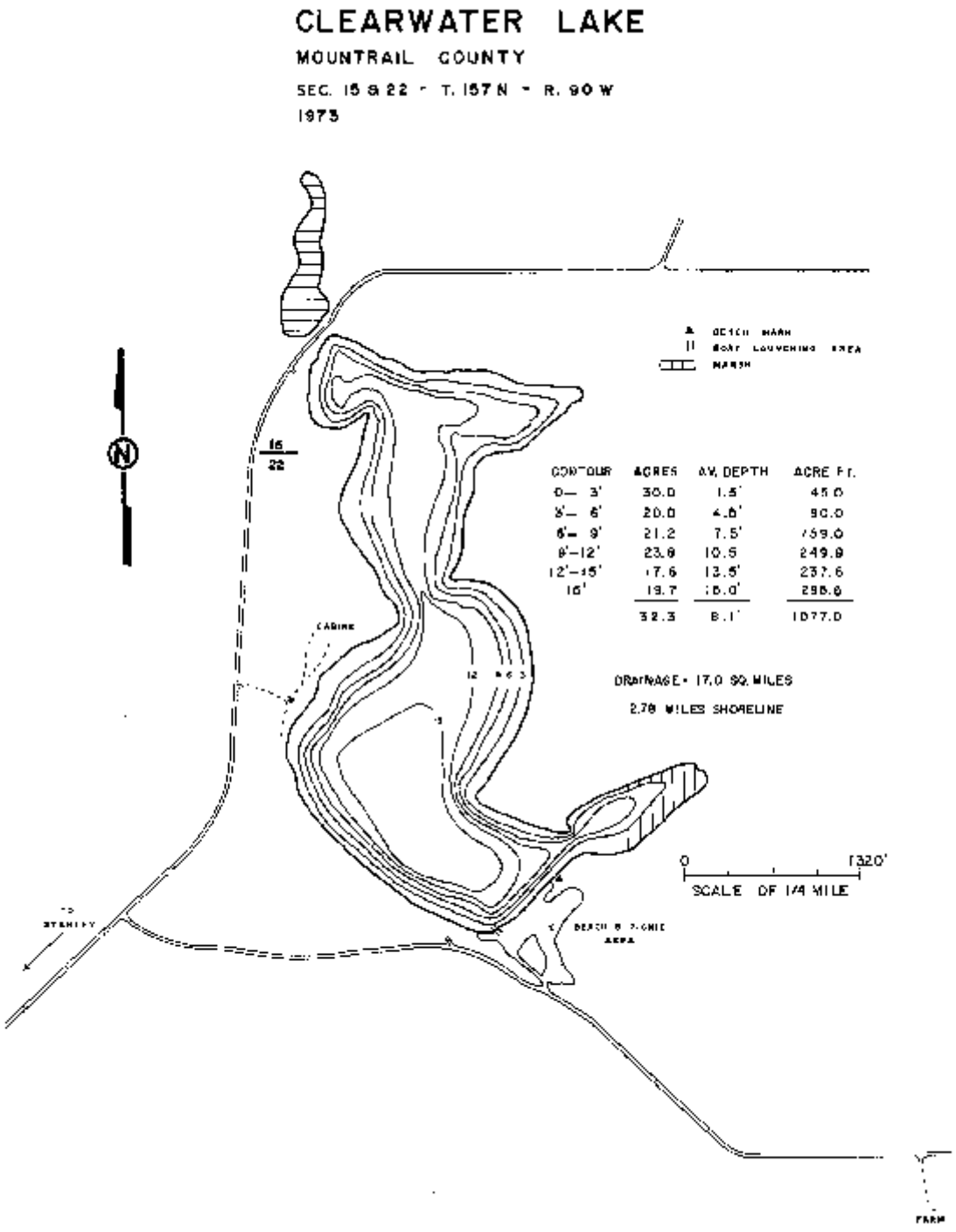

Figure 2. Contour Map of Clear Water Lake (Map Courtesy of North Dakota Game and Fish Department)

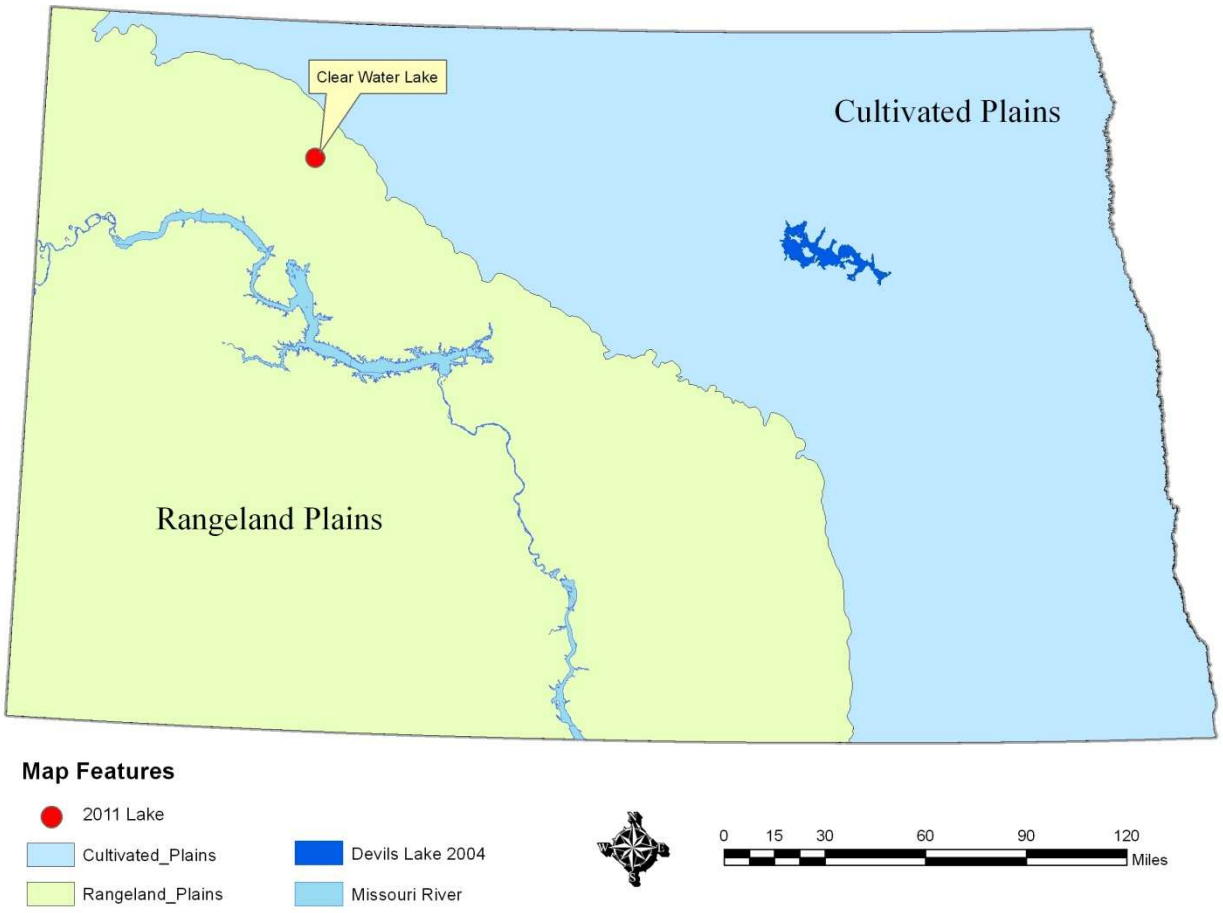

Figure 3. Clear Water Lake Location and the Cultivated and Rangeland Plans Regions

Water Quality Standards Classification: Clear Water Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species might also be present."

Historical Water Quality Sampling: Historical water quality data include 3 samples collected in 1992 and 1993.

WATER QUALITY MONITORING RESULTS

The water quality assessment for Clear Water Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional data for lakes in the Rangeland Plains Region.

Temperature and Dissolved Oxygen Profile Results: There are six temperature and dissolved oxygen profiles for Clear Water Lake collected in 1992, 1993 and 2011 (Figures 4 and 5). The temperature profile data indicates that Clear Water Lake does not regularly thermally stratify (Figure 4).

The dissolved oxygen profile results indicates that during the open water period the lake remains well enough oxygenated to support the aquatic life associated with a class 3 lake but the profile collected in February of 1993 shows concentrations at levels stressful if not lethal to all but the most tolerant of fish species (Figure 5). These results would predict that Clear Water Lake occasionally suffers partial winter die offs of aquatic species.

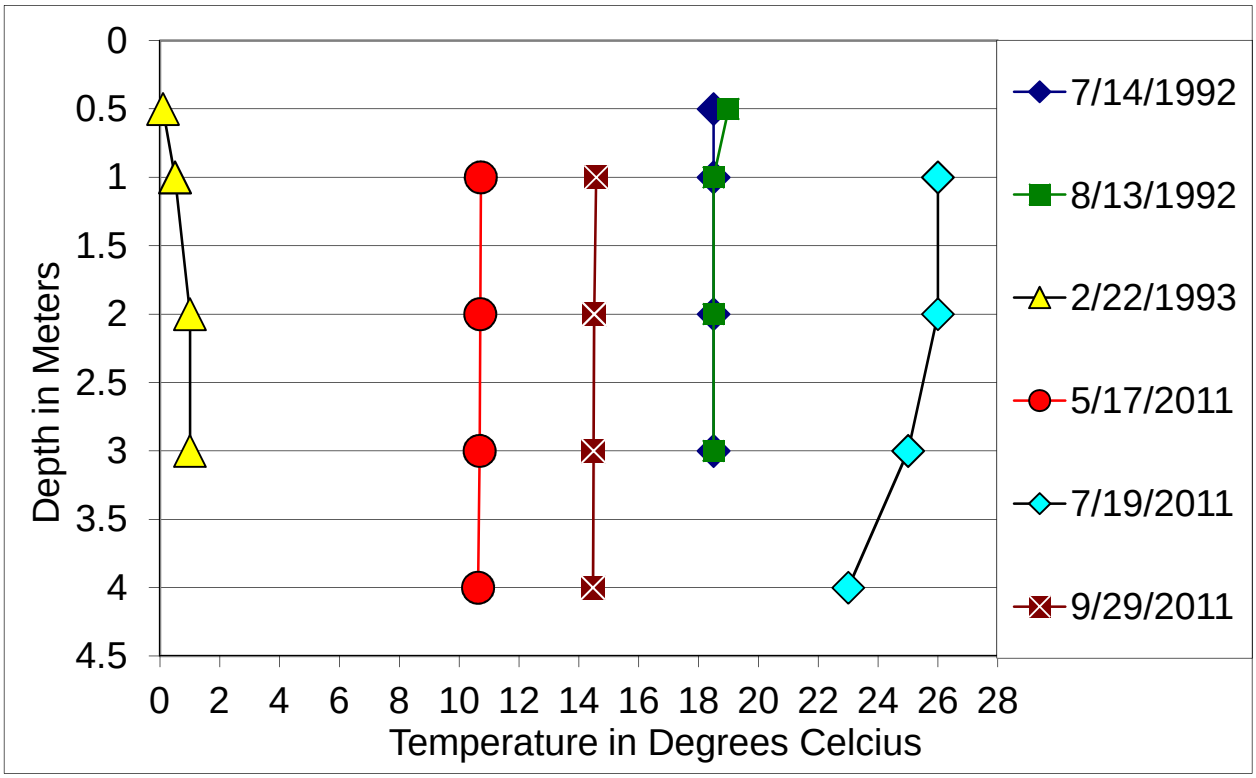

Figure 4. Temperature Profiles for Clear Water Lake

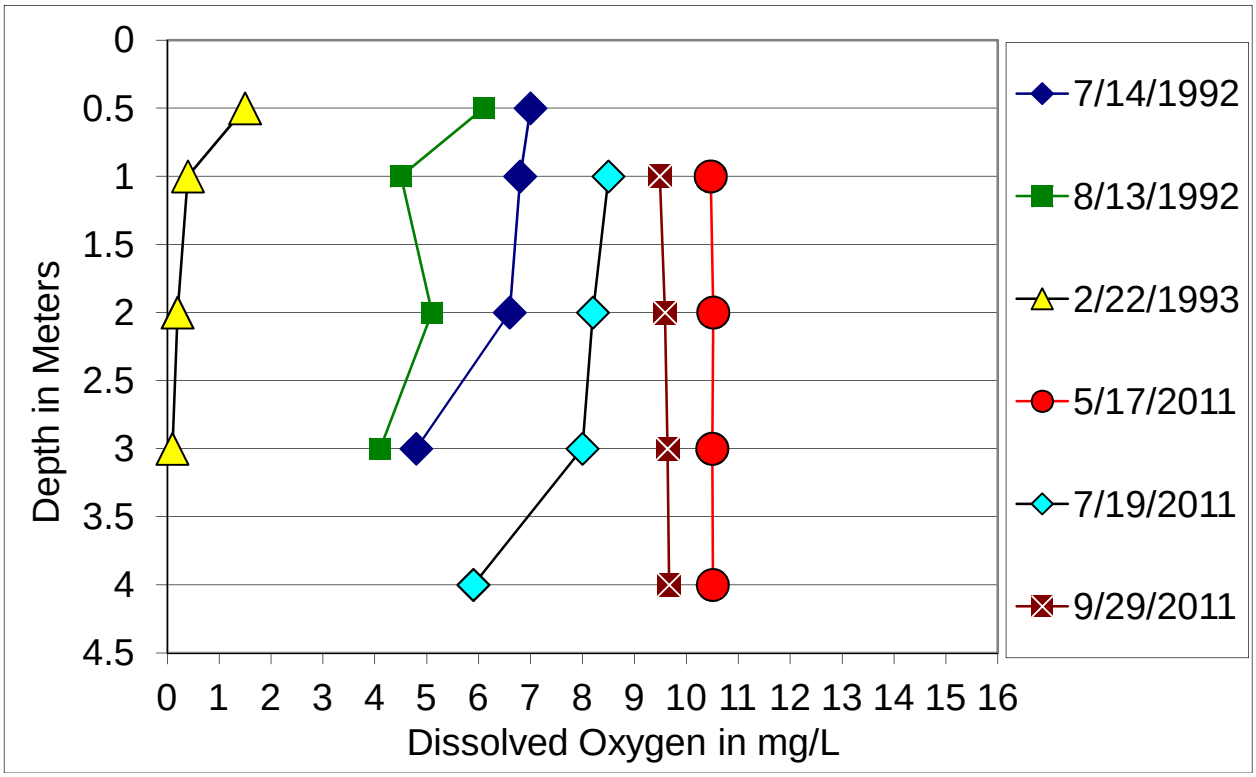

Figure 5. Dissolved Oxygen Profiles for Clear Water Lake

General Water Quality: Data collected in 2011 indicates that Clear Water Lake is quite well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 1060 to 1130 mg/L (Table 1). The lake is sodium bicarbonate dominated with an average sodium concentration of 265 mg/L and an average bicarbonate concentration of 867 mg/L. The lake is relatively saline and well mineralized with average total dissolved solids concentration and specific conductance measurements for the 2011 sampling period of 1733 mg/L and 2333 µmhos/cm, respectively.

The lake has an abundant concentration of nitrogen but is relatively phosphorus poor. The average total nitrogen and total phosphorus concentrations in 2011 are 2.94 mg/L and 0.02 mg/L respectively.

When compared to the water quality for all lakes in the Rangeland Plans region, Clear Water Lake has higher concentrations of minerals and nitrogen than most but less phosphorus (Tables 1 and 2). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 1398 mg/L, 1.75 mg/L, and 0.22 mg/L respectively, compared to Clear Water Lake's 2011 average TDS, total nitrogen, and total phosphorus concentrations of 1733 mg/L, 2.94 mg/L and 0.02 mg/L respectively.

Table 1. Statistical Summary of Clear Water Lake's 2011Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	1083	1060	1130	40
Total Ammonia as N	mg/L	3	0.1	0.03[1]	0.19	0.09
Bicarbonate (HCO_3)	mg/L	3	867	818	955	76
Calcium (Ca)	mg/L	3	7.9	6.8	9.3	1.3
Carbonate (CO_3)	mg/L	3	225	168	277	55
Chloride (Cl)	mg/L	3	44.7	41.3	50.8	5.3
Chlorophyll-a	µg/L	3	6.3	3[1]	10	3.5
Specific Conductance	µmhos	3	2333	2280	2430	84
Total Dissolved Solids	mg/L	3	1733	1670	1780	57
Total Hardness as ($CaCO_3$)	mg/L	3	1063	1040	1100	32
Hydroxide (OH)	mg/L	3	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	3	0.09	0.05[1]	0.15	0.05
Magnesium (Mg)	mg/L	3	253	247	262	7.8
Nitrate + Nitrite as N	mg/L	3	0.03[1]	0.03[1]	0.04	0.01
Total Kjeldahl Nitrogen as N	mg/L	3	2.9	2.77	3.03	0.13
Total Nitrogen as N	mg/L	3	2.94	2.8	3.06	0.13
pH		3	9.19	9.14	9.23	0.05
Total Phosphorus as P	mg/L	3	0.02[1]	0.02[1]	0.03	0.01
Potassium (K)	mg/L	3	97.4	89.8	106	8.1
Sodium (Na)	mg/L	3	265	251	283	16.5
Sulfate (SO4)	mg/L	3	414	376	488	64

[1]Equal to the lower reporting limit

When comparing historical water quality data collected in 1992-1993 to 2011 data, there appears to be a slight improvement in the nutrient concentrations. For example, the historical average total nitrogen and total phosphorus concentrations were 4.21 mg/L and 0.056 mg/L, respectively, compared to the 2011 averages of 2.94 mg/L and 0.02 mg/L (Tables 1 and 3).

Like the nutrients, the concentrations of dissolved solids have also decreased. The decrease is actually fairly substantial possible indicating a trend. Examples are the bicarbonate, sulfate and sodium average concentrations of 867 mg/L, 414 mg/L and 265 mg/L in 2011 compared to the 1992-1993 average concentrations of 1697 mg/L, 532 mg/L and 401 mg/L, respectively.

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Lakes in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	430	499	111	4770	466
Total Ammonia as N	mg/L	554	0.105	0.001	2.23	0.223
Bicarbonate (HCO_3)	mg/L	430	461	60	2990	308
Calcium (Ca)	mg/L	431	42.9	0.5	294	38.9
Carbonate (CO_3)	mg/L	424	74	1	1420	141
Chloride (Cl)	mg/L	430	41.6	1.7	1070	97.8
Chlorophyll-a	µg/L	383	22	2	292	36
Specific Conductance	µmhos	430	1939	424	20100	1890
Total Dissolved Solids	mg/L	430	1398	227	18200	1640
Total Hardness as ($CaCO_3$)	mg/L	431	530	74	2370	299
Hydroxide (OH)	mg/L	369	1	1	1	0
Iron (Fe)	mg/L	432	0.23	0.01	7.07	0.52
Magnesium (Mg)	mg/L	431	102.8	8.5	567	69.5
Nitrate + Nitrite as N	mg/L	551	0.042	0.001	0.54	0.055
Total Kjeldahl Nitrogen as N	mg/L	523	1.82	0.08	8.5	1.04
Total Nitrogen as N	mg/L	461	1.75	0.24	5.52	0.87
pH		430	8.78	7.4	9.87	0.36
Total Phosphorus as P	mg/L	561	0.22	0.01	1.94	0.33
Potassium (K)	mg/L	431	32.8	3.1	356	35.7
Sodium (Na)	mg/L	431	278	16.9	4680	490.1
Sulfate (SO4)	mg/L	430	590.9	34	10500	847.6

[1]Equal to the lower reporting limit
[2]Data collected from 66 natural and enhanced Lakes between 1991 and 2011

Limiting Nutrients: The water quality samples collected in 1992, 1993 and 2011 indicate that Clear Water Lake is phosphorus limited (Figure 6). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen to total phosphorus is in equilibrium at 15 to 1. When the total nitrogen to total phosphorus ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

The ratio of nitrogen to phosphorus ranged from a low of 41 in July of 1992 to a high of 170 in September of 2011. A phosphorus limited aquatic ecosystem is customarily preferred to nitrogen limited one as phosphorus is finite in its availability for primary production while some species of primary producers are able to affix free nitrogen.

Table 3. Statistical Summary of Clear Water Lake's 1992-1993 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	1883	1570	2440	483
Total Ammonia as N	mg/L	3	0.66	0.52	0.85	0.17
Bicarbonate (HCO_3)	mg/L	3	1697	1420	2170	412
Calcium (Ca)	mg/L	3	5.2	4.9	5.6	0.4
Carbonate (CO_3)	mg/L	3	297	244	399	88
Chloride (Cl)	mg/L	3	70	56.9	91.5	18.8
Chlorophyll-a	µg/L	2	3[1]	3[1]	3[1]	0
Specific Conductance	µmhos	3	3558	3056	4450	774
Total Dissolved Solids	mg/L	3	2633	2210	3340	616
Total Hardness as ($CaCO_3$)	mg/L	3	1420	1250	1680	229
Hydroxide (OH)	mg/L	1	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	3	0.106	0.038	0.223	0.102
Magnesium (Mg)	mg/L	3	341.7	301	405	55.6
Nitrate + Nitrite as N	mg/L	3	0.071	0.016	0.179	0.094
Total Kjeldahl Nitrogen as N	mg/L	2	4.135	3.28	4.99	1.209
Total Nitrogen as N	mg/L	2	4.21	3.3	5.17	1.33
pH		3	8.947	8.88	9.01	0.065
Total Phosphorus as P	mg/L	3	0.056	0.025	0.081	0.028
Potassium (K)	mg/L	3	151	131	182	27.2
Sodium (Na)	mg/L	3	401	347	487	75
Sulfate (SO4)	mg/L	3	532	423	703	150

[1]Equal to the lower reporting limit

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 1992, 1993 and 2011, Clear Water Lake's trophic status is estimated was mesotrophic, and stable to slightly improved (Figure 7). The Trophic Status Index (TSI) scores based on chlorophyll-a are quite consistent for a biological measurement ranging between 41 and 53. This mesotrophic assessment is supported by the trophic status indicators secchi disk and total phosphorus particularly in 2011 with a range of 45 to 54.

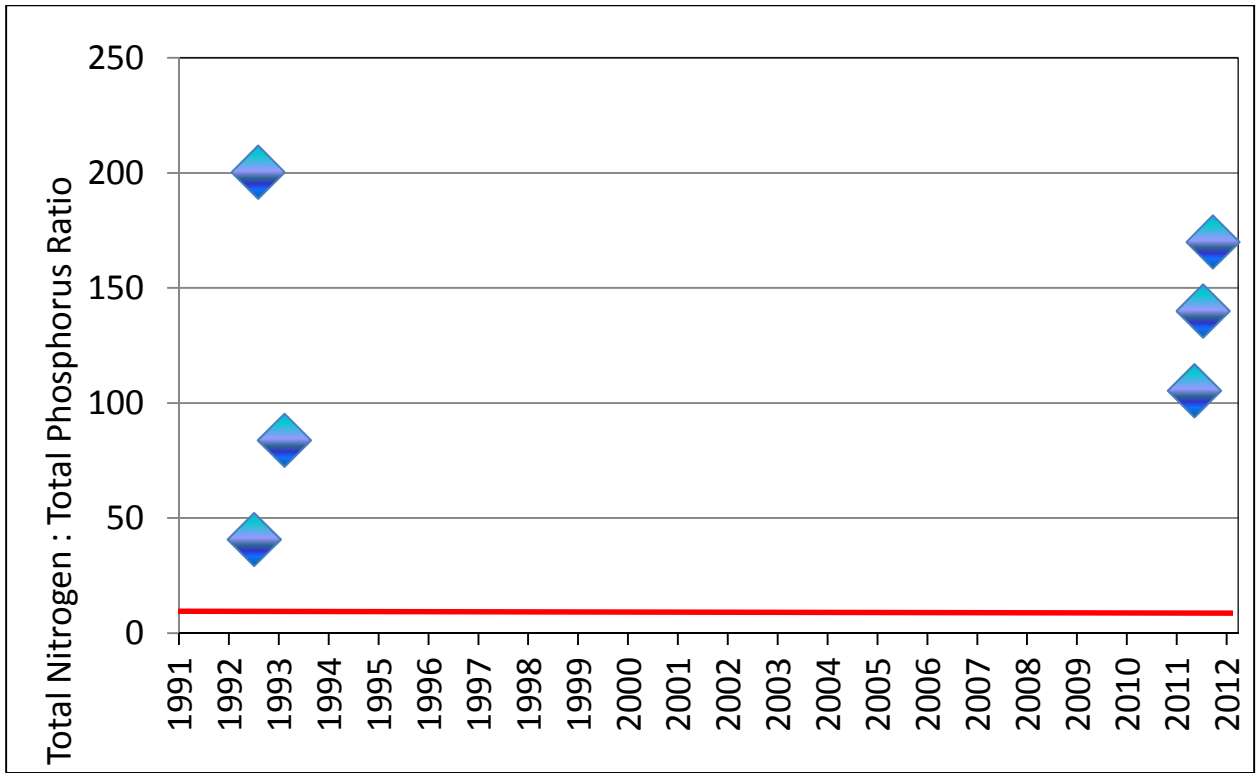

Figure 6. Clear Water Lake's Total Nitrogen to Total Phosphorus Ratio

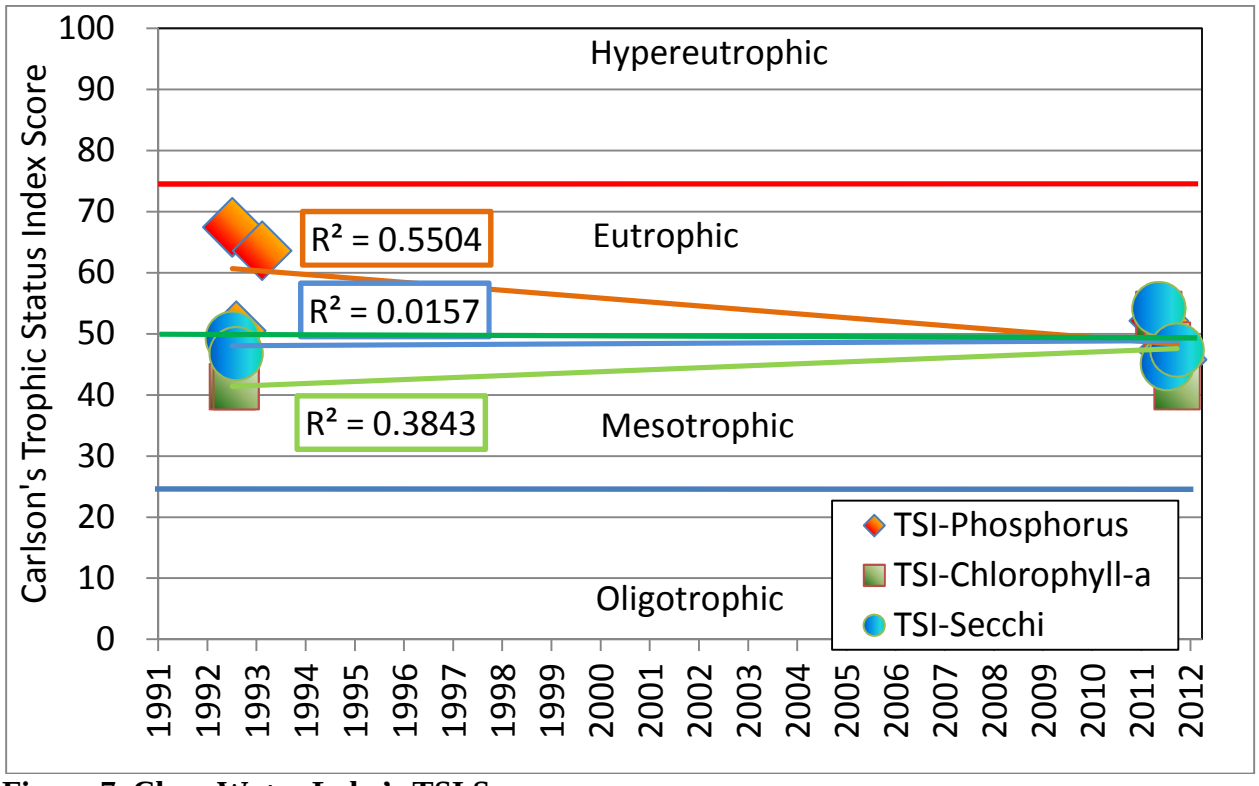

Figure 7. Clear Water Lake's TSI Scores

White Earth Dam, Mountrail County

BACKGROUND

White Earth Dam is a small reservoir situated in the scenic White Earth valley five miles north and eight miles east of Tioga, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish Department. Fish species managed for are northern pike, walleye and yellow perch.

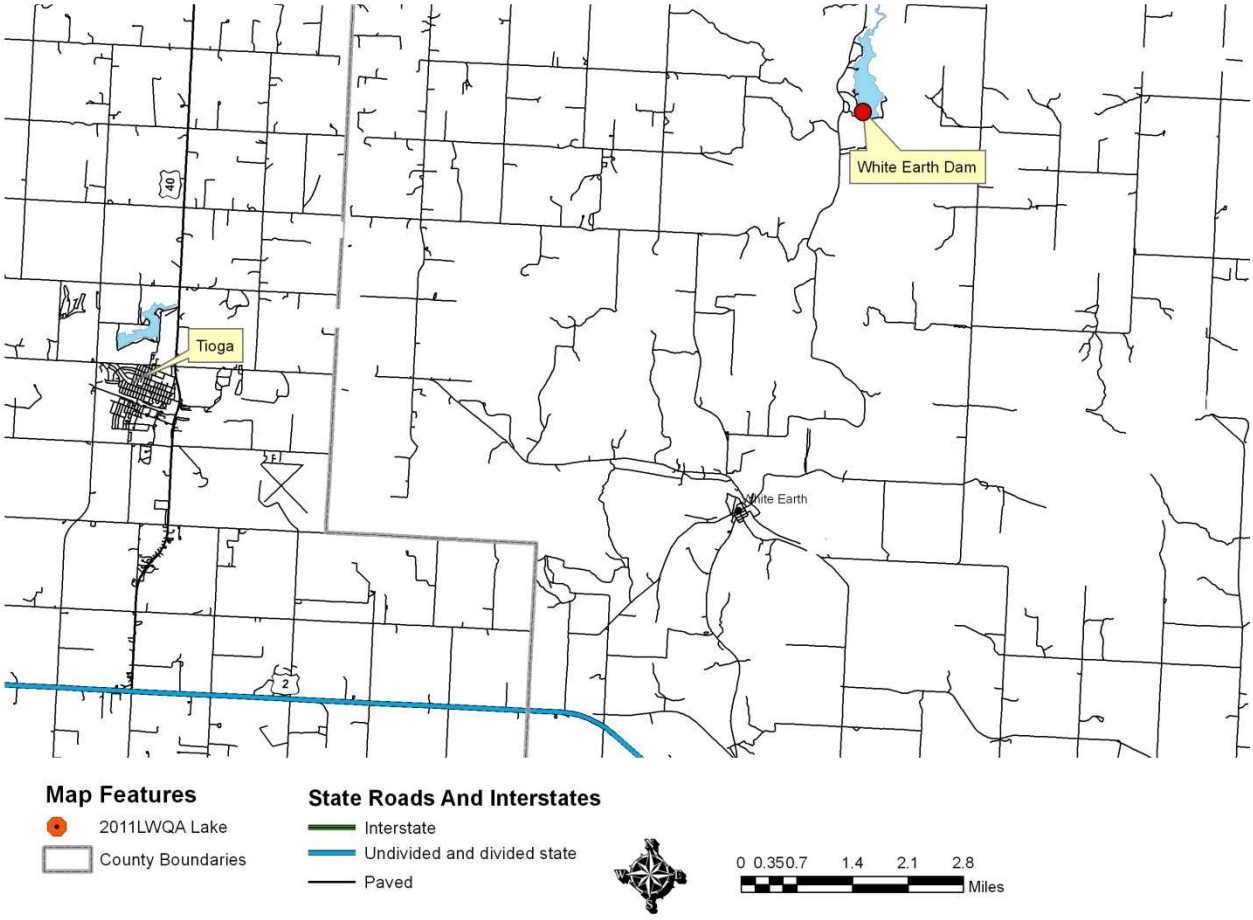

Figure 1. Location of White Earth Dam

Physiographic/Ecological Setting: White Earth Dam has a surface area of 141.7 acres, an average depth of 7.9 feet and a maximum depth of 20.5 feet (Figure 2). The reservoir lies in a very picturesque valley surrounded by brightly colored buttes and cedar draws. The White Earth valley lies in a finger of the Northwestern Great Plains Level III Region, which is part of the broader Rangeland Plains Region (Figure 3).

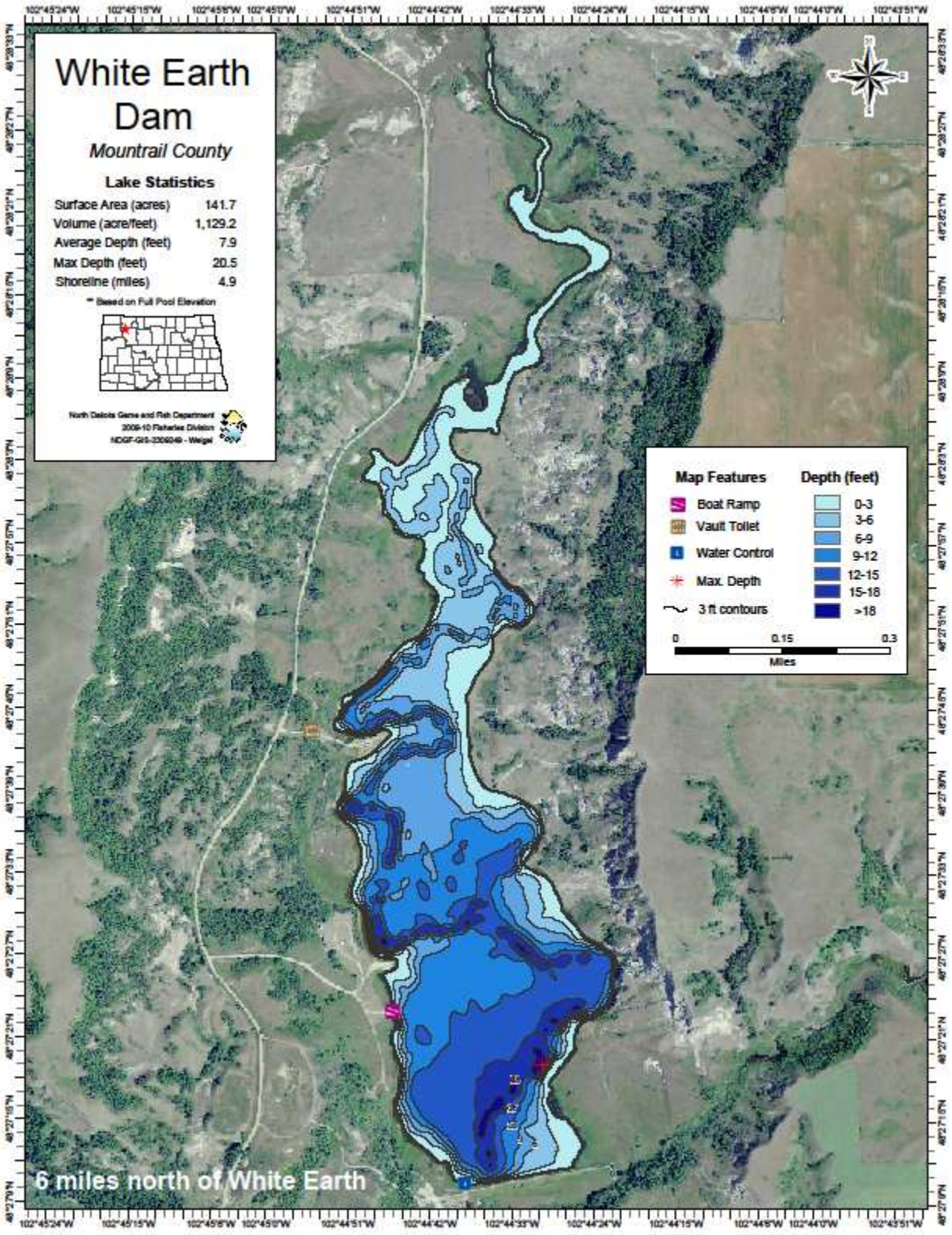

Figure 2. Contour Map of White Earth Dam (Map Courtesy of North Dakota Game and Fish Department)

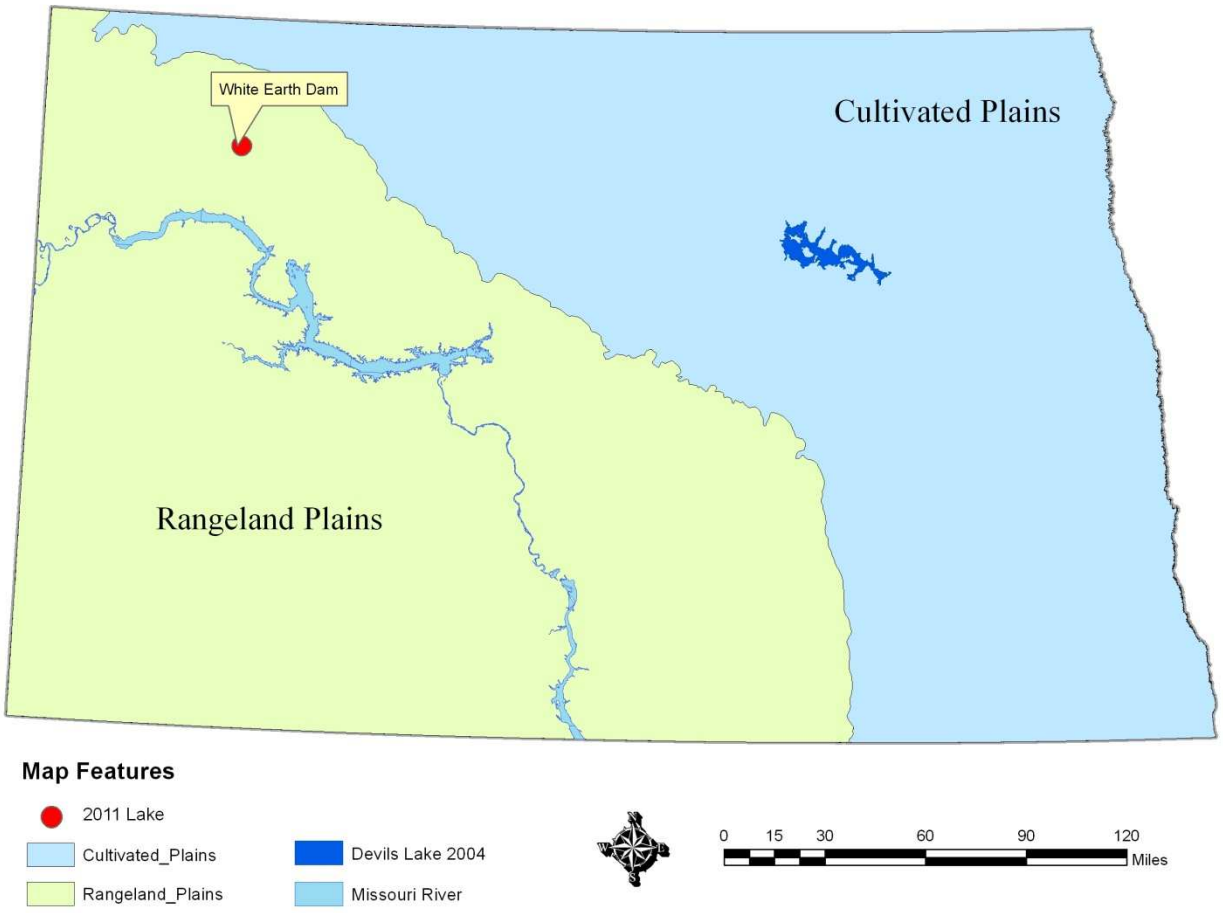

Figure 3. White Earth Dam Location and the Cultivated and Rangeland Plans Regions

Recreational Facilities: Recreational facilities at White Earth Dam are excellent and include two access roads, parking to camping and picnic areas with tables, vault toilets and a nice cement ramp.

Water Quality Standards Classification: White Earth Dam is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 waterbody. Class 3 lakes and reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: Historical water quality data include 3 samples collected in 1992 and 1993.

WATER QUALITY MONITORING RESULTS

The water quality assessment for White Earth Dam is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional data for reservoirs in the Rangeland Plains Region.

Temperature and Dissolved Oxygen Profile Results: There are six temperature and dissolved oxygen profiles for White Earth Dam collected in 1992, 1993 and 2011 (Figures 4 and 5). The temperature profiles indicate that White Earth Dam rarely or only weakly thermally stratifies and only at the sediment-water interface. The lack of thermal stratification is most likely due to White Earth Dam lying prone to the prevailing northwest wind and the perennial nature of the white earth River (Figure 4).

Dissolved oxygen profiles indicates that the reservoir remains well enough oxygenated, even during ice cover, to support warm and cool water species and associated aquatic biota. However, the profile also indicates that during ice cover oxygen concentrations do decline below 5 mg/L which is enough to cause stress to both cool and warm species (Figure 5).

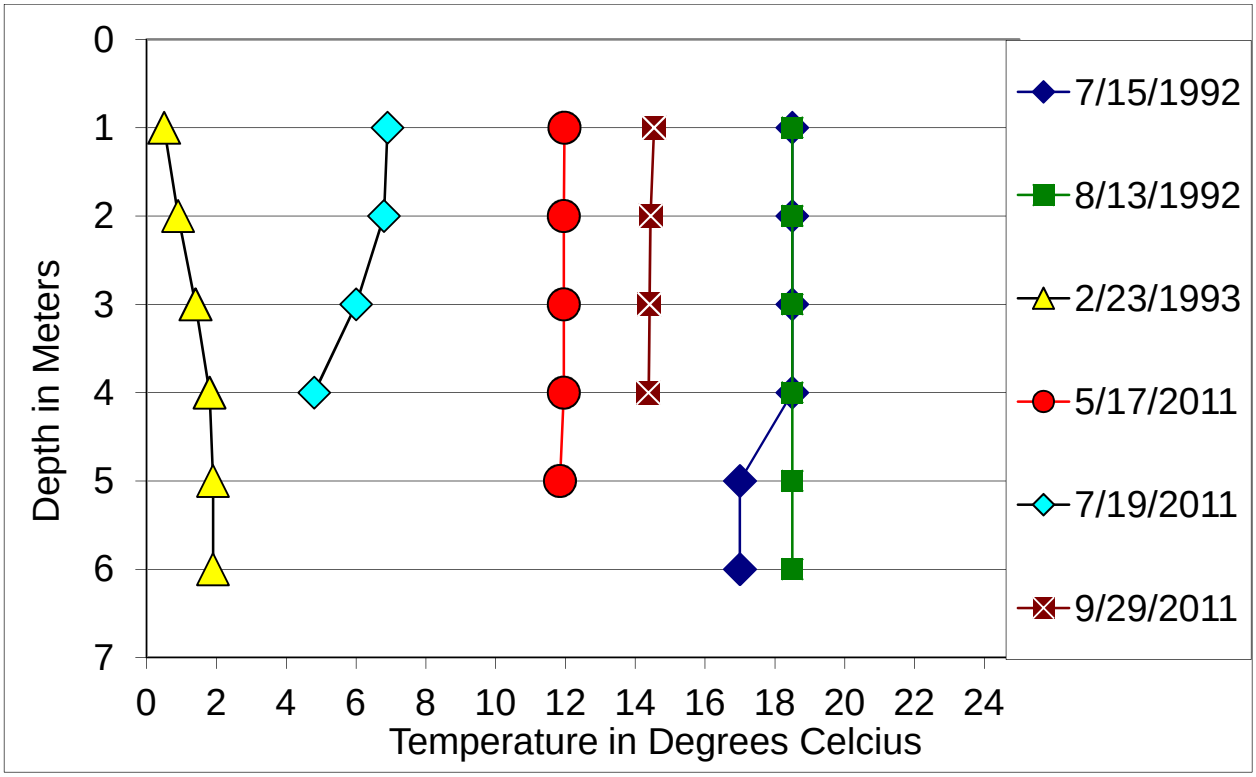

Figure 4. Temperature Profiles for White Earth Dam

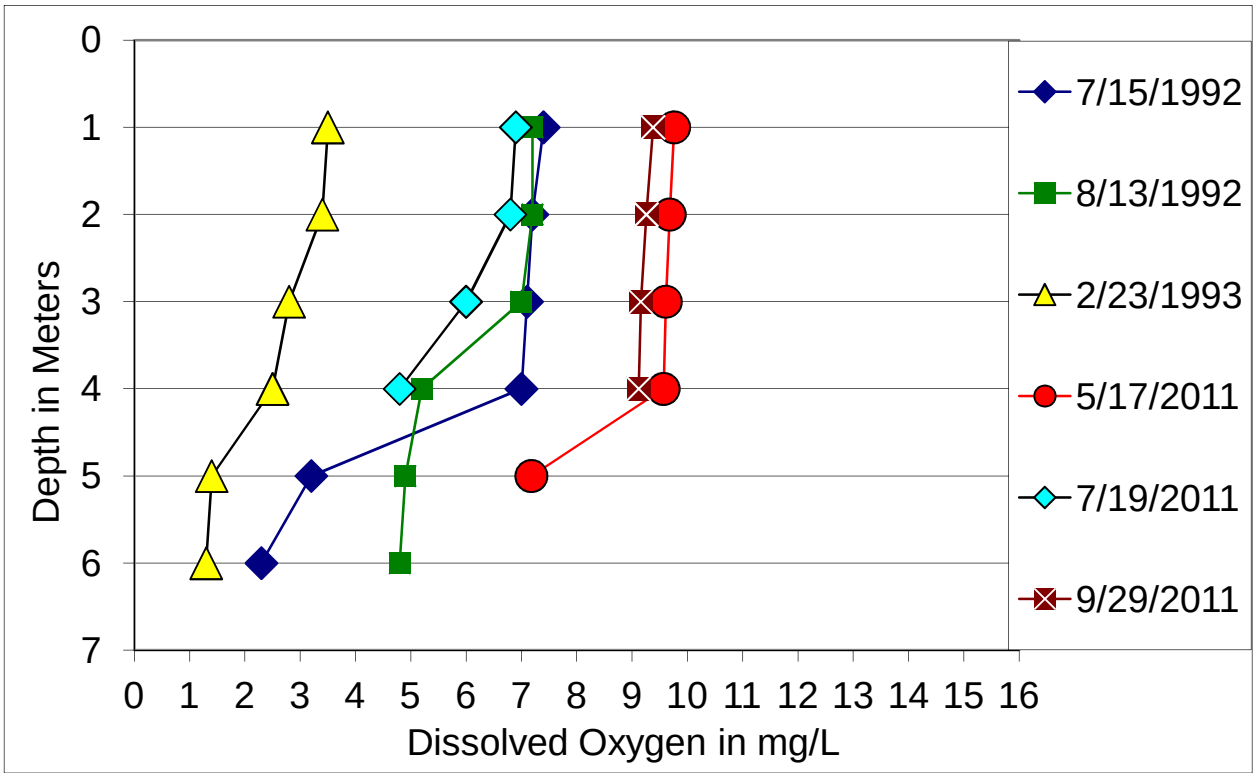

Figure 5. Dissolved Oxygen Profiles for White Earth Dam

General Water Quality: Data collected in 2011 indicates that White Earth Dam is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 291 to 502 mg/L (Table 1) and that the reservoir is sodium bicarbonate dominated with an average sodium concentration of 181 mg/L and an average bicarbonate concentration of 466 mg/L. The average total dissolved solids concentration and specific conductance measurements for the 2011 sampling period are 1045 mg/L and 1520 µmhos/cm, respectively. The average total nitrogen and total phosphorus concentrations are 1.50 mg/L and 0.16 mg/L respectively.

Table 1. Statistical Summary of White Earth Dam's 2011 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	409	291	502	108
Total Ammonia as N	mg/L	3	0.03[1]	0.03[1]	0.03[1]	0
Bicarbonate (HCO_3)	mg/L	3	466	342	544	108
Calcium (Ca)	mg/L	3	66.8	65.5	69	1.9
Carbonate (CO_3)	mg/L	3	17	6	34	15
Chloride (Cl)	mg/L	3	37.6	33.3	41.2	4
Chlorophyll-a	µg/L	3	8	6	12	3.5
Specific Conductance	µmhos	3	1520	1270	1740	236
Total Dissolved Solids	mg/L	3	1045	845	1250	203
Total Hardness as ($CaCO_3$)	mg/L	3	520	453	563	59
Hydroxide (OH)	mg/L	3	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	3	0.32	0.1	0.55	0.22
Magnesium (Mg)	mg/L	3	85.7	70.4	96.8	13.7
Nitrate + Nitrite as N	mg/L	3	0.03	0.03	0.03	0
Total Kjeldahl Nitrogen as N	mg/L	3	1.47	1.06	1.72	0.36
Total Nitrogen as N	mg/L	3	1.5	1.09	1.75	0.36
pH		3	8.51	8.37	8.75	0.21
Total Phosphorus as P	mg/L	3	0.16	0.08	0.24	0.08
Potassium (K)	mg/L	3	16.8	15.7	18.2	1.3
Sodium (Na)	mg/L	3	181	126	240	57.1
Sulfate (SO4)	mg/L	3	410	358	481	64

[1]Equal to the lower reporting limit

When compared to water quality for reservoirs in the Rangeland Plans Region, White Earth Dam is fairly average with concentrations close to the mean. For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 1113 mg/L, 1.32 mg/L, and 0.126 mg/L respectively, compared to White Earth Dam's average TDS, total nitrogen, and total phosphorus concentrations of 1045 mg/L, 1.50 mg/L and 0.16 mg/L (Tables 1 and 2).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	571	282	3	982	130
Total Ammonia as N	mg/L	651	0.092	0.001	2.44	0.178
Bicarbonate (HCO_3)	mg/L	571	296	4	1040	143
Calcium (Ca)	mg/L	571	55	2	206	30
Carbonate (CO_3)	mg/L	569	24	1	197	28
Chloride (Cl)	mg/L	571	14	1	75	10
Chlorophyll-a	µg/L	456	19.6	1.5	218	26.1
Specific Conductance	µmhos	591	1618	4	5880	973
Total Dissolved Solids	mg/L	572	1113	17	5110	773
Total Hardness as ($CaCO_3$)	mg/L	571	410	9	2100	288
Hydroxide (OH)	mg/L	514	1	1	1	0
Iron (Fe)	mg/L	572	0.2	0.01	4.11	0.35
Magnesium (Mg)	mg/L	571	66.4	1	412	54.9
Nitrate + Nitrite as N	mg/L	650	0.064	0.003	1.49	0.127
Total Kjeldahl Nitrogen as N	mg/L	541	1.36	0.08	7.72	0.78
Total Nitrogen as N	mg/L	484	1.32	0.02	4.84	0.63
pH		591	8.54	5.74	9.87	0.55
Total Phosphorus as P	mg/L	657	0.126	0.004	3.16	0.185
Potassium (K)	mg/L	571	13.9	1	52.5	6.9
Sodium (Na)	mg/L	571	214	3	932	168
Sulfate (SO4)	mg/L	569	578	1	3210	512

[1]Equal to the lower reporting limit
[2]Data collected from 76 reservoirs between 1991 and 2011

When comparing historical water quality data collected in 1992-1993 to data collected in 2011, there has been a notable decrease in the concentrations of dissolved minerals. For example, the historical average total for total dissolved solids, sulfate, and alkalinity and bicarbonates are 2280 mg/L, 1019 mg/L, 814 mg/L, and 854 mg/L compared to the 2011 concentrations of 1045 mg/L, 410 mg/L, 409 mg/L, and 466 mg/L (Tables 1 and 3).

Like dissolved solids the concentrations of nutrients, total nitrogen and total phosphorus, have also declined from 1992-93 to 2011. The total nitrogen average concentration in 1992 and 1993 was 2.0 mg/L compare to the 2011 average of 1.50 mg/L, and the total phosphorus concentration has declined was 0.244 mg/L in 1992-93 to 0.16 mg/L in 2011 (Tables 1 and 3).

Table 3. Statistical Summary of White Earth Dam's 1992-1993 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	814	720	982	146
Total Ammonia as N	mg/L	3	0.11	0.09	0.15	0.03
Bicarbonate (HCO_3)	mg/L	3	854	747	1040	162
Calcium (Ca)	mg/L	3	49.8	48.2	50.8	1.4
Carbonate (CO_3)	mg/L	3	69	63	78	8
Chloride (Cl)	mg/L	3	20.9	18.5	24.9	3.5
Chlorophyll-a	µg/L	2	3.2	3[1]	3.4	0.3
Specific Conductance	µmhos	3	3126	2837	3680	480
Total Dissolved Solids	mg/L	3	2280	1990	2640	331
Total Hardness as ($CaCO_3$)	mg/L	3	557	536	587	27
Hydroxide (OH)	mg/L	1	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	3	0.121	0.086	0.15	0.032
Magnesium (Mg)	mg/L	3	105	101	112	6.1
Nitrate + Nitrite as N	mg/L	3	0.07	0.015	0.173	0.09
Total Kjeldahl Nitrogen as N	mg/L	2	1.93	1.75	2.11	0.255
Total Nitrogen as N	mg/L	2	2	1.76	2.12	0.264
pH		3	8.747	8.65	8.86	0.106
Total Phosphorus as P	mg/L	3	0.244	0.216	0.289	0.039
Potassium (K)	mg/L	3	16.1	15.5	16.8	0.7
Sodium (Na)	mg/L	3	581	542	653	63
Sulfate (SO4)	mg/L	3	1019	828	1190	182

[1]Equal to the lower reporting limit

Limiting Nutrients: The water quality samples collected in 1992, 1993 and 2011 indicate that White Earth Dam is nitrogen limited (Figure 6). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen to total phosphorus is at equilibrium at 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus. The historical water quality data collected in 1992 and 1993) has a N:P ratio ranging from 8 to 9 and the 2011 ratio ranged from 7 to 14 indicating that there is a luxurious supply of phosphorus for primary production in White Earth Dam.

Trophic Status Assessment: Based on the chlorophyll-a data collected in 1992, 1993 and 2011, White Earth Dam's trophic status is estimated as eutrophic with no identifiable trend (Figure 7). The Trophic Status Index (TSI) score based on chlorophyll-a is fairly consistent between the years ranging from a low of 41 in 1992 and a high of 55 in 2011. Trophic Status Scores for secchi disk a support a eutrophic assessment with a range of 52 to 67 and total phosphorus indicate a hypereutrophic assessment with a range of 67 to 86.

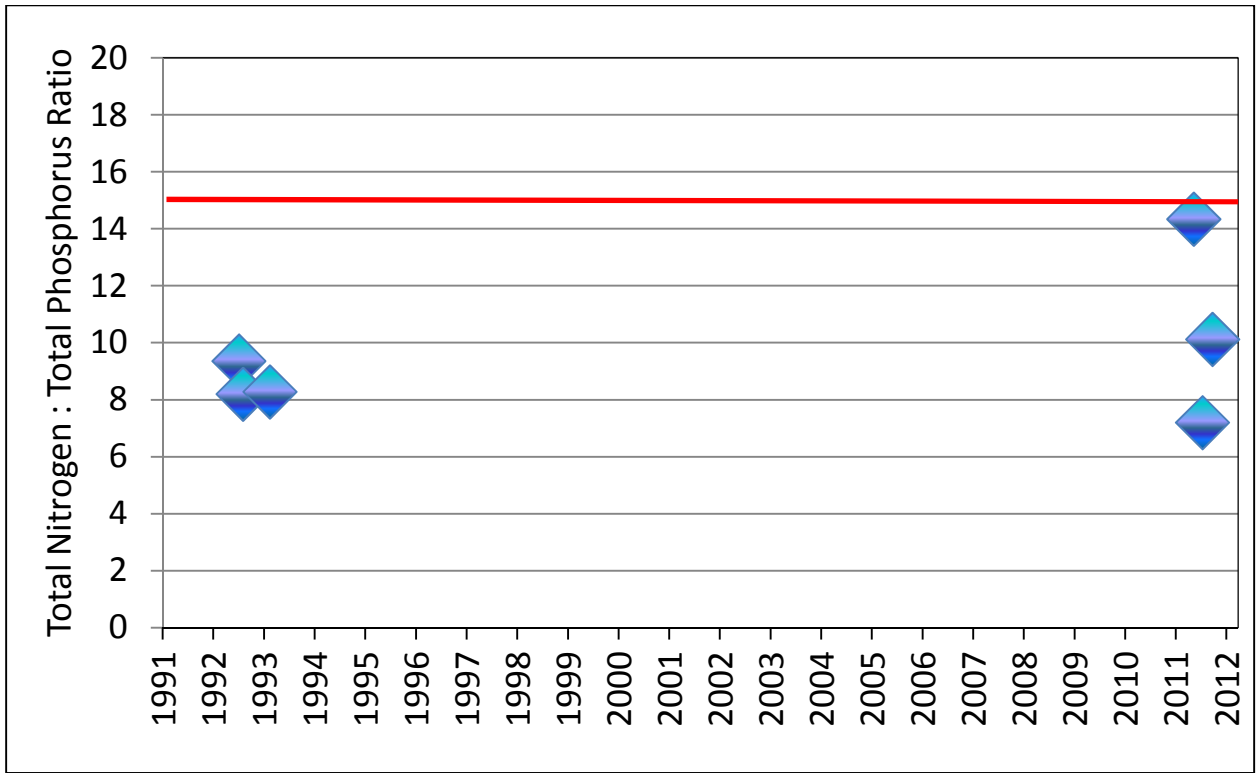

Figure 6. White Earth Dam's Total Nitrogen to Total Phosphorus Ratio

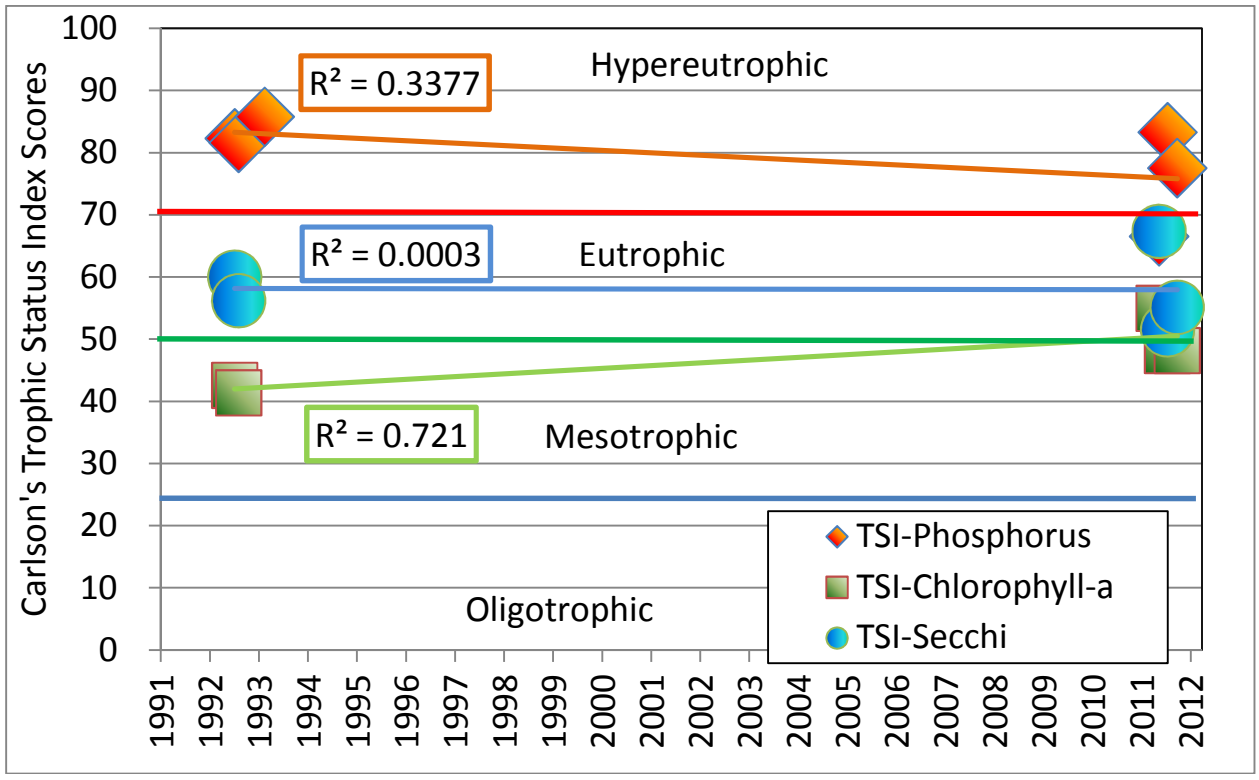

Figure 7. White Earth Dam's TSI Scores

Davis Dam, Slope County

BACKGROUND

Davis Dam is a small reservoir on situated in the scenic Little Missouri Grasslands on Spring Creek 16 miles west and 4 miles north of Amidon, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish Department. Fish species managed for are trout, largemouth bass and bluegill.

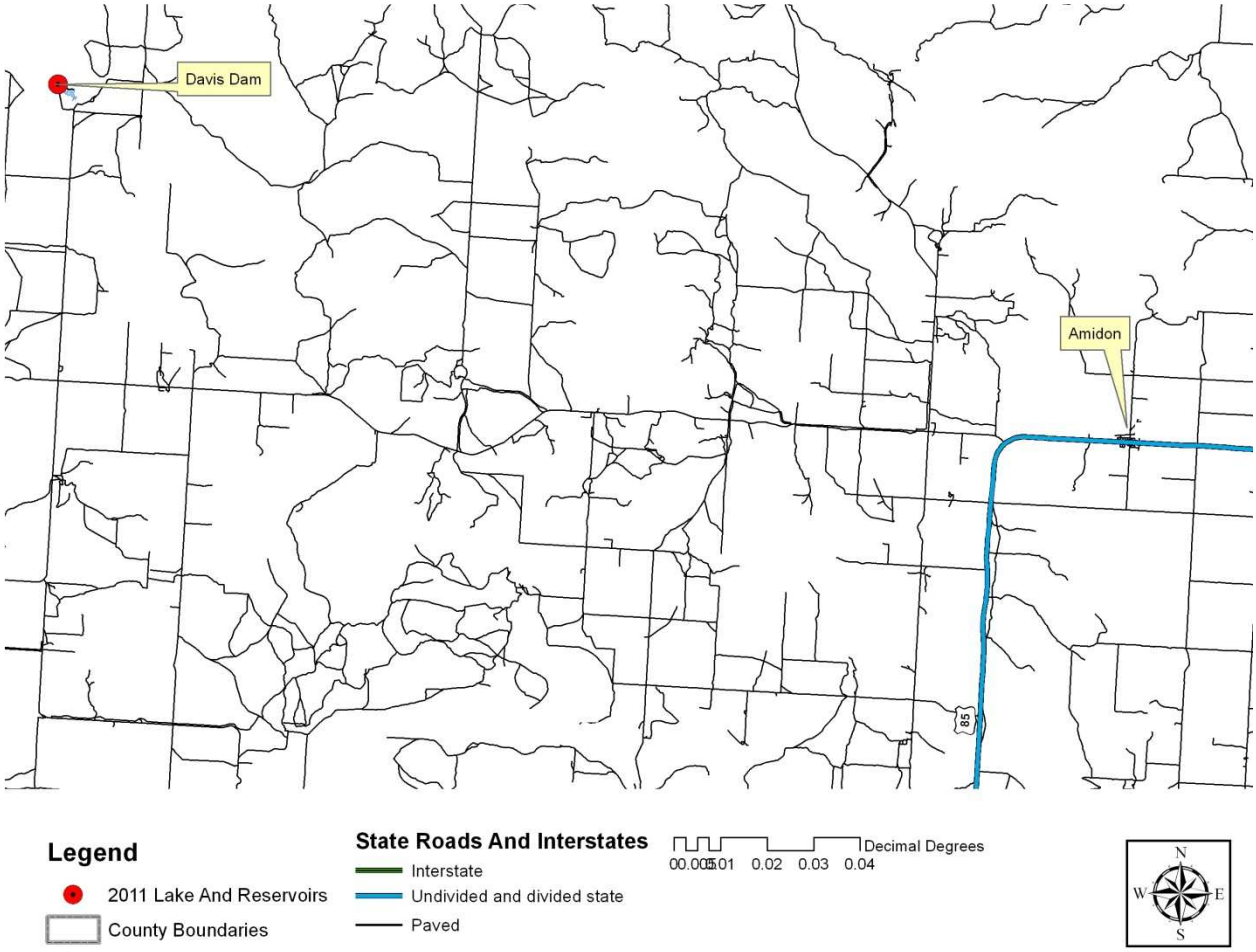

Figure 1. Location of Davis Dam

Physiographic/Ecological Setting: Davis Dam has a surface area of 13.1 acres, an average depth of 10.3 feet and a maximum depth of 24.5 feet (Figure 2). The reservoir lies in a very picturesque badlands valley surrounded by brightly colored buttes, hardwood bottoms and cedar draws. The entire drainage is in the Northwestern Great Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figure 3).

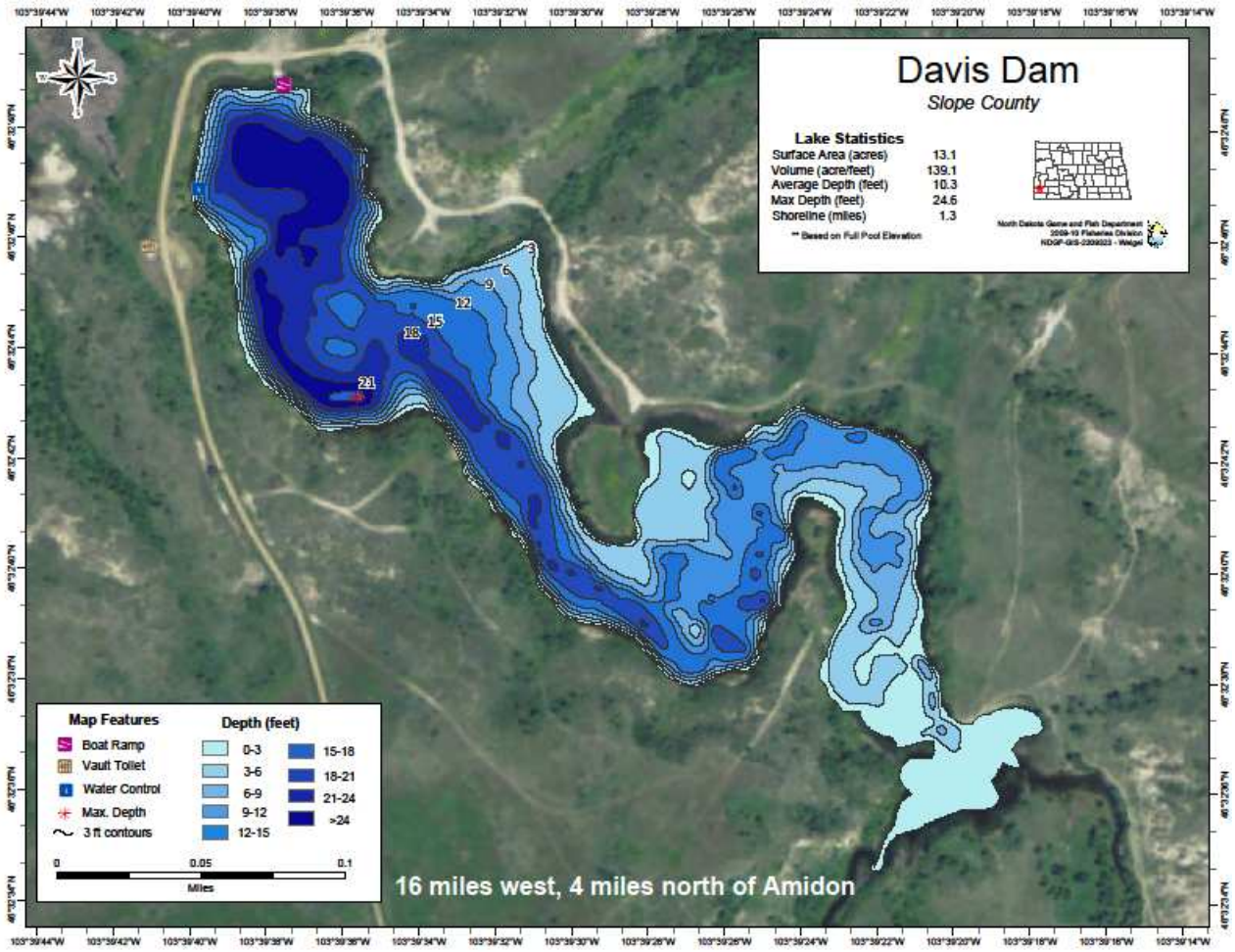

Figure 2. Contour Map of Davis Dam (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Davis Dam are primitive camping and picnic areas, a vault toilet and cement ramp. In recent years the NDG&F Save Our Lakes Program has hollowed out and rocked numerous areas along the shore to provide improved access for shore fishing.

Water Quality Standards Classification: Davis Dam is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 2 waterbody. Class 2 lakes and reservoirs are defined as a "cool water fishery" or "waters capable of supporting natural reproduction and growth of cool water fishes (e.g., northern pike and walleye) and associated aquatic biota. Some cold water species may also be present."

Historical Water Quality Sampling: Historical water quality data include three water quality samples collected in 1994 and 1995, and six temperature/dissolved oxygen profiles collected between 1990 and 1994.

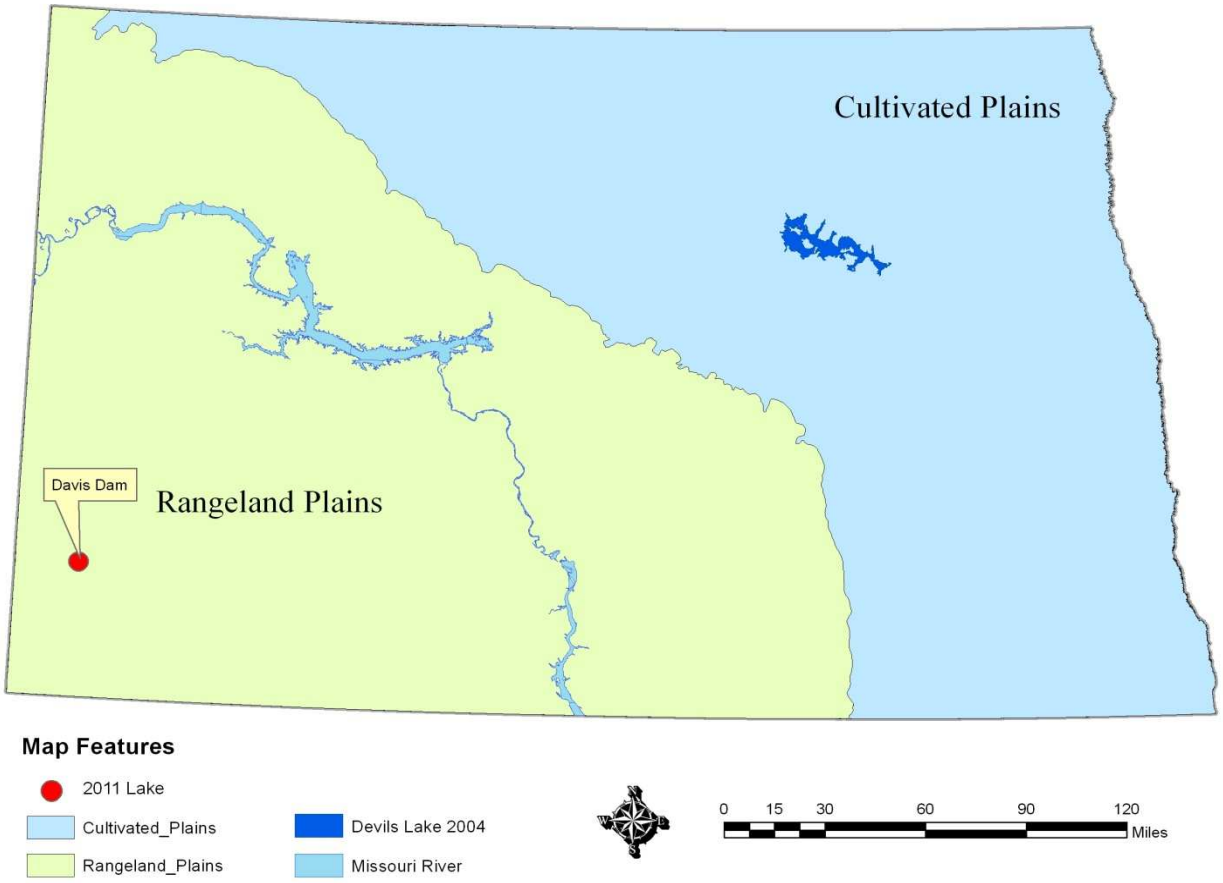

Figure 3. Davis Dam Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Davis Dam is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional data for reservoirs in the Rangeland Plains Region.

Temperature and Dissolved Oxygen Profile Results: There are nine temperature and dissolved oxygen profiles for Davis Dam collected in 1990, 1992, 1994, 1995 and 2011 (Figures 4 and 5). The temperature profiles indicate that Davis Dam commonly thermally stratifies and de-stratifies sometimes to depths as shallow as 2 meters (Figure 4). The process of stratification is assisted by Davis Dam physical setting where it lies tightly into a protected drainage reducing the opportunity for wind induced remixing.

The dissolved oxygen profiles show that during periods of thermal stratification, Davis Dam sometime experiences rapid decay of dissolved oxygen with little oxygen available below 3 meters of depth (Figure 5). If during these periods of thermal stratification, the water temperature is also above 15 degrees Celsius, a partial fish die-off of predominately trout can and does periodically occur.

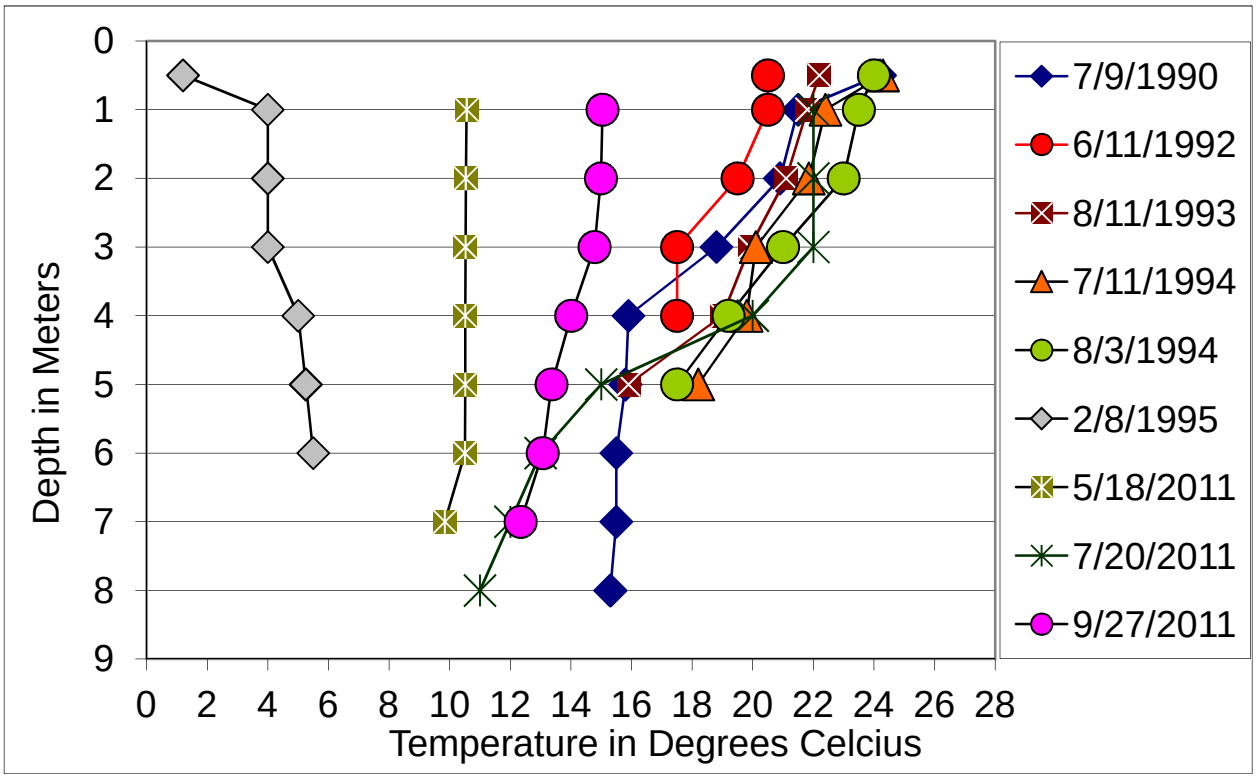

Figure 4. Temperature Profiles for Davis Dam

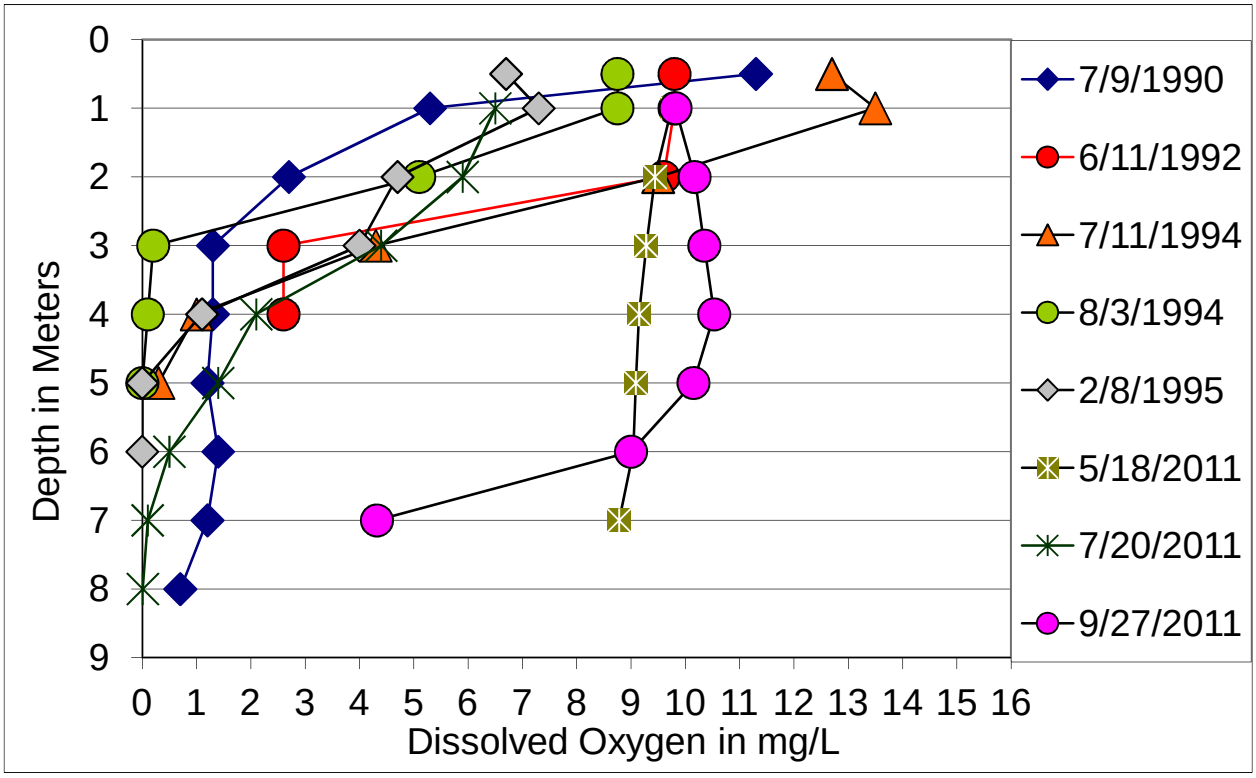

Figure 5. Dissolved Oxygen Profiles for Davis Dam

General Water Quality: Data collected in 2011 indicates that Davis Dam is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 227 to 276 mg/L (Table 1) and that the reservoir is sodium sulfate dominated with an average sodium concentration of 163.3 mg/L and an average sulfate concentration of 878 mg/L. The reservoir has an average total dissolved solids concentration and specific conductance measurements for the 2011 sampling period of 1483 mg/L and 1830 µmhos/cm, respectively and an average total nitrogen and total phosphorus concentrations of 0.874 mg/L and 0.018 mg/L respectively.

Table 1. Statistical Summary of Davis Dam's 2011 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	258	227	276	27
Total Ammonia as N	mg/L	3	0.03[1]	0.03[1]	0.03[1]	0
Bicarbonate (HCO_3)	mg/L	3	311	277	336	31
Calcium (Ca)	mg/L	3	135.7	102	157	29.5
Carbonate (CO_3)	mg/L	3	2.7	1[1]	6	2.9
Chloride (Cl)	mg/L	3	12.2	6.6	15	4.9
Chlorophyll-a	µg/L	3	7.1	3[1]	10	3.6
Specific Conductance	µmhos	3	1830	1410	2140	377
Total Dissolved Solids	mg/L	3	1483	1040	1840	407
Total Hardness as ($CaCO_3$)	mg/L	3	856	595	1060	238
Hydroxide (OH)	mg/L	3	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	3	0.11	0.05[1]	0.17	0.06
Magnesium (Mg)	mg/L	3	125.6	82.7	162	40
Nitrate + Nitrite as N	mg/L	3	0.03[1]	0.03[1]	0.03[1]	0
Total Kjeldahl Nitrogen as N	mg/L	3	0.844	0.761	0.89	0.072
Total Nitrogen as N	mg/L	3	0.874	0.791	0.92	0.072
pH		3	8.2	8.1	8.4	0.1
Total Phosphorus as P	mg/L	3	0.018	0.014	0.024	0.006
Potassium (K)	mg/L	3	10.4	9.8	10.9	0.6
Sodium (Na)	mg/L	3	163.3	129	198	34.5
Sulfate (SO4)	mg/L	3	878	570	1130	284

[1]Equal to the lower reporting limit

When compared to water quality for reservoirs in the Rangeland Plans Region, Davis Dam is more mineralized but has fewer nutrients for primary production than most reservoirs. For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 1113 mg/L, 1.32 mg/L, and 0.126 mg/L respectively, compared to Davis Dam's average TDS, total nitrogen, and total phosphorus concentrations of 1483 mg/L, 0.874 mg/L and 0.018 mg/L (Tables 1 and 2).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	571	282	3	982	130
Total Ammonia as N	mg/L	651	0.092	0.001	2.44	0.178
Bicarbonate (HCO_3)	mg/L	571	296	4	1040	143
Calcium (Ca)	mg/L	571	55	2	206	30
Carbonate (CO_3)	mg/L	569	24	1	197	28
Chloride (Cl)	mg/L	571	14	1	75	10
Chlorophyll-a	µg/L	456	19.6	1.5	218	26.1
Specific Conductance	µmhos	591	1618	4	5880	973
Total Dissolved Solids	mg/L	572	1113	17	5110	773
Total Hardness as ($CaCO_3$)	mg/L	571	410	9	2100	288
Hydroxide (OH)	mg/L	514	1	1	1	0
Iron (Fe)	mg/L	572	0.2	0.01	4.11	0.35
Magnesium (Mg)	mg/L	571	66.4	1	412	54.9
Nitrate + Nitrite as N	mg/L	650	0.064	0.003	1.49	0.127
Total Kjeldahl Nitrogen as N	mg/L	541	1.36	0.08	7.72	0.78
Total Nitrogen as N	mg/L	484	1.32	0.02	4.84	0.63
pH		591	8.54	5.74	9.87	0.55
Total Phosphorus as P	mg/L	657	0.126	0.004	3.16	0.185
Potassium (K)	mg/L	571	13.9	1	52.5	6.9
Sodium (Na)	mg/L	571	214	3	932	168
Sulfate (SO4)	mg/L	569	578	1	3210	512

[1]Equal to the lower reporting limit
[2]Data collected from 76 reservoirs between 1991 and 2011

When comparing historical water quality data collected in 1994 and 1995 to data collected in 2011, there has been a notable increase in the concentrations of dissolved minerals. For example, the historical average total for total dissolved solids, sulfate, and alkalinity and bicarbonates are 553 mg/L, 303 mg/L, 135 mg/L, and 137 mg/L compared to the current (2011) concentrations of 1483 mg/L, 878 mg/L, 258 mg/L and 311 mg/L (Tables 1 and 3).

Unlike the dissolved solid concentrations the concentrations of nitrogen and phosphorus have declined in 2011 from the 1994-1995 averages. The total nitrogen average in 1994-1995 was 1.61 mg/L compare to the 2011 average of 0.874 mg/L and total phosphorus was 0.065 mg/L in 1994-1995 compared to 0.018 mg/L in 2011 (Tables 1 and 3).

Table 3. Statistical Summary of Davis Dam's 1994-1995 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	135	122	152	15
Total Ammonia as N	mg/L	3	0.01[1]	0.01[1]	0.01[1]	0
Bicarbonate (HCO_3)	mg/L	3	137	116	149	19
Calcium (Ca)	mg/L	3	44.5	38.3	51.7	6.8
Carbonate (CO_3)	mg/L	3	14	1[1]	22	11
Chloride (Cl)	mg/L	3	3.8	3.4	4	0.3
Chlorophyll-a	µg/L	2	40.5	15	66	36.1
Specific Conductance	µmhos	3	909	720	1020	165
Total Dissolved Solids	mg/L	3	553	427	653	115
Total Hardness as ($CaCO_3$)	mg/L	3	278	218	317	53
Hydroxide (OH)	mg/L	3	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	3	0.177	0.038	0.451	0.237
Magnesium (Mg)	mg/L	3	40.6	29.7	46.5	9.5
Nitrate + Nitrite as N	mg/L	3	0.083	0.005[1]	0.24	0.136
Total Kjeldahl Nitrogen as N	mg/L	3	1.53	1.16	1.94	0.395
Total Nitrogen as N	mg/L	3	1.61	1.4	1.95	0.531
pH		3	8.33	7.15	8.93	1.022
Total Phosphorus as P	mg/L	3	0.065	0.05[1]	0.08	0.015
Potassium (K)	mg/L	3	11	10.6	11.7	0.6
Sodium (Na)	mg/L	3	67	45	78	19
Sulfate (SO4)	mg/L	3	303	224	372	75

[1]Equal to the lower reporting limit

Limiting Nutrients: The water quality samples collected in 1994, 1995 and 2011 indicate that Davis Dam is phosphorus limited (Figure 6). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen to total phosphorus is at equilibrium at 15 to 1. When the ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus. The historical 1994-1995 ratios showed a reservoir on the edge of being nitrogen limited with a range between 15 and 30 but in 2011 that ranged has moved upward towards a healthier ratio that ranged between 33 and 65.

Trophic Status Assessment: Based on the chlorophyll-a data collected in 1994, 1995 and 2011 Davis Dam's trophic condition is eutrophic bordering on mesotrophic with a substantial improving trend (Figure 7). In 1994-1995 the Trophic Status Index scores for chlorophyll-a ranged between 57 and 72 or the mid-eutrophic to hypereutrophic range but in 2011 the scores have fallen to between 41 and 55 indicating a near mesotrophic condition. This change is supported by a drop in TSI scores for phosphorus and secchi disk transparency as well (Figure 7).

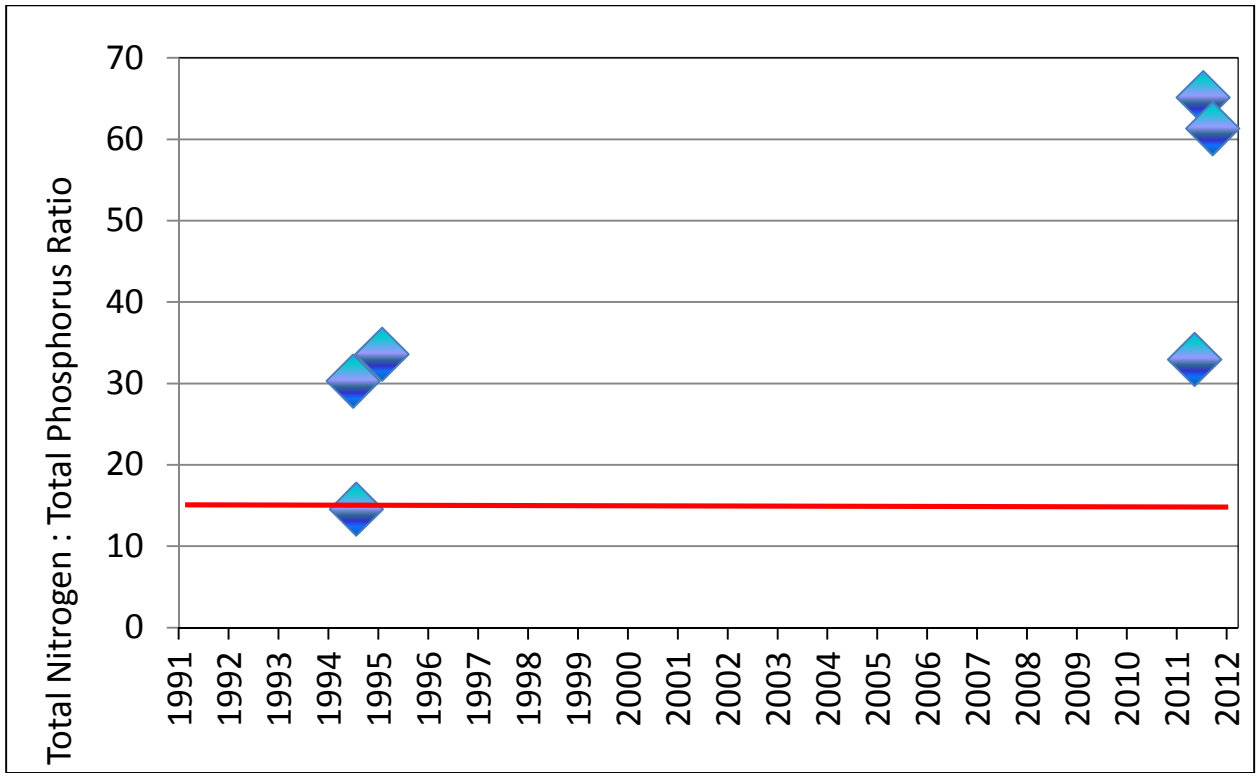

Figure 6. Davis Dam's Total Nitrogen to Total Phosphorus Ratio

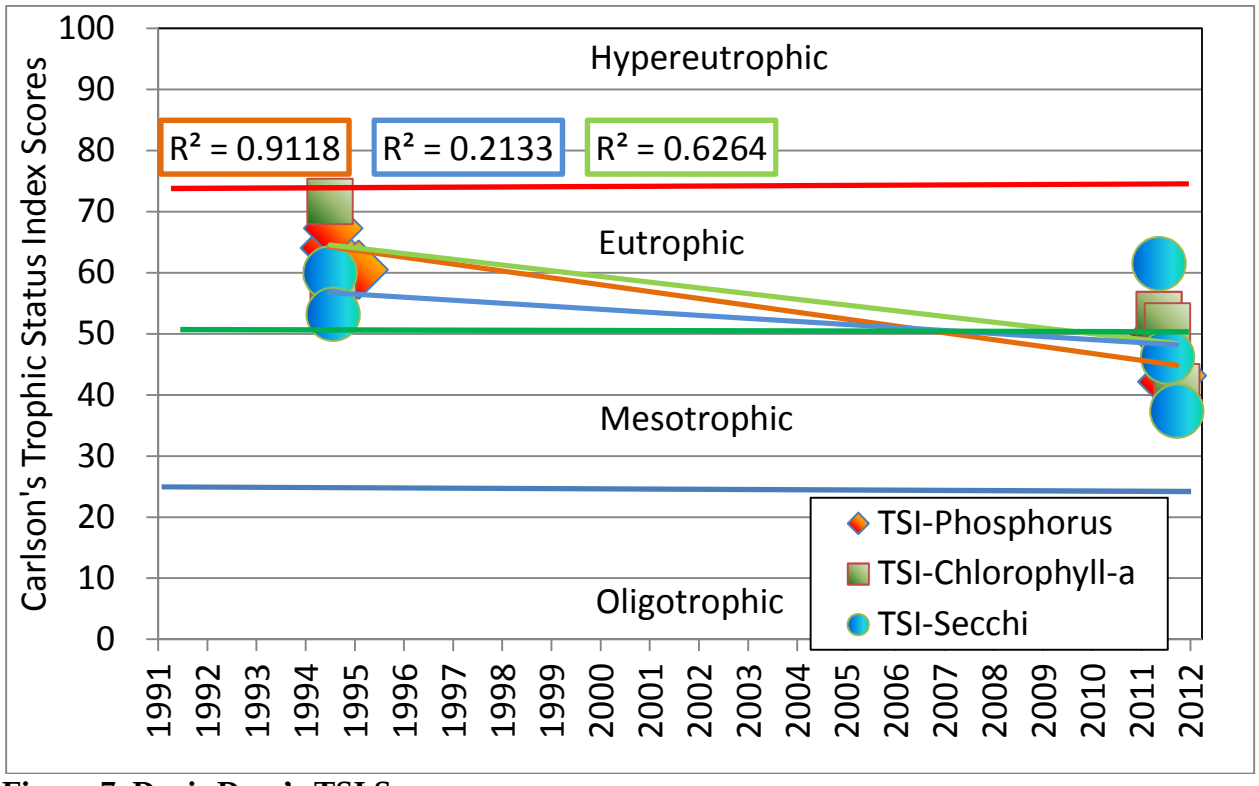

Figure 7. Davis Dam's TSI Scores

Hehn-Schaffer Lake, Stutsman County

BACKGROUND

Hehn-Schaffer Lake is a prairie lake located 4 miles north of Gackle, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish Department. Fish species managed for are northern pike, walleye and yellow perch.

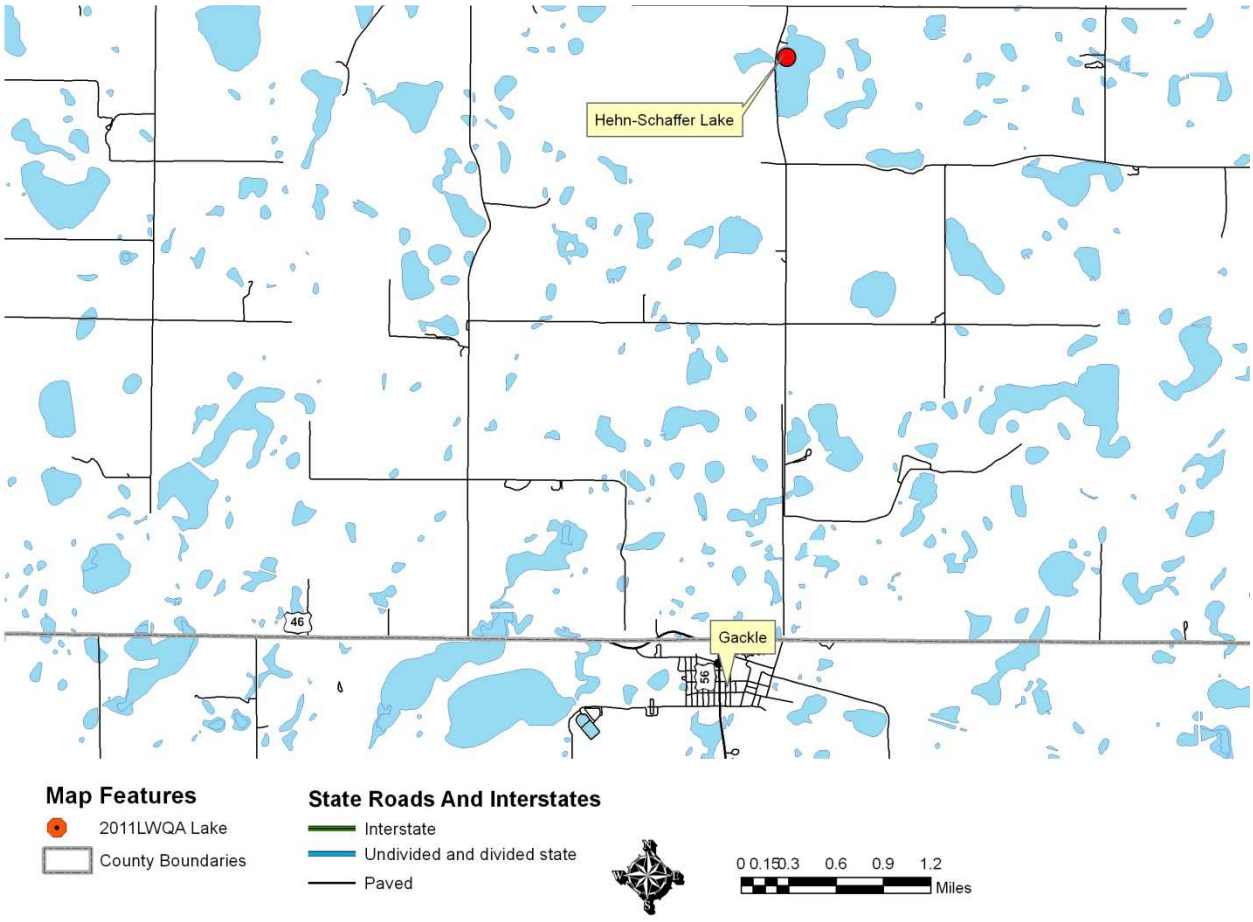

Figure 1. Location of Hehn-Schaffer Lake

Physiographic/Ecological Setting: Hehn-Schaffer Lake has a surface area of 72.7 acres, a mean depth of 12.1 feet and a maximum depth of 16.2 feet (Figure 2). The lake is glacial in origin and nested in a natural depression of the Missouri Coteau. The Missouri Coteau is part of the Northwestern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figures 3).

Recreational Facilities: Recreational facilities at Hehn-Schaffer Lake are an access road, parking, vault toilet, covered picnic shelter and a small cement boat ramp.

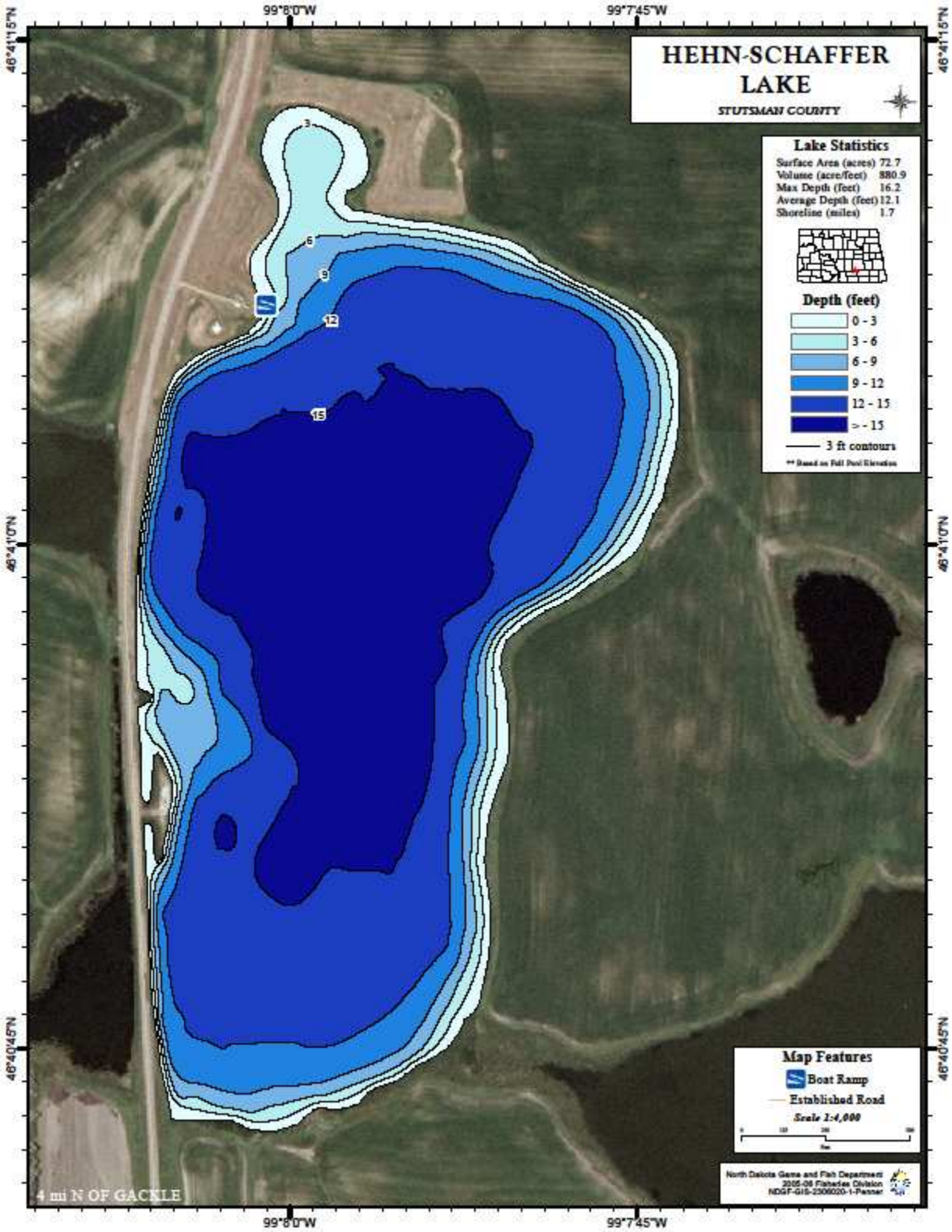

Figure 2. Contour Map of Hehn-Schaffer Lake (Map Courtesy of North Dakota Game and Fish Department)

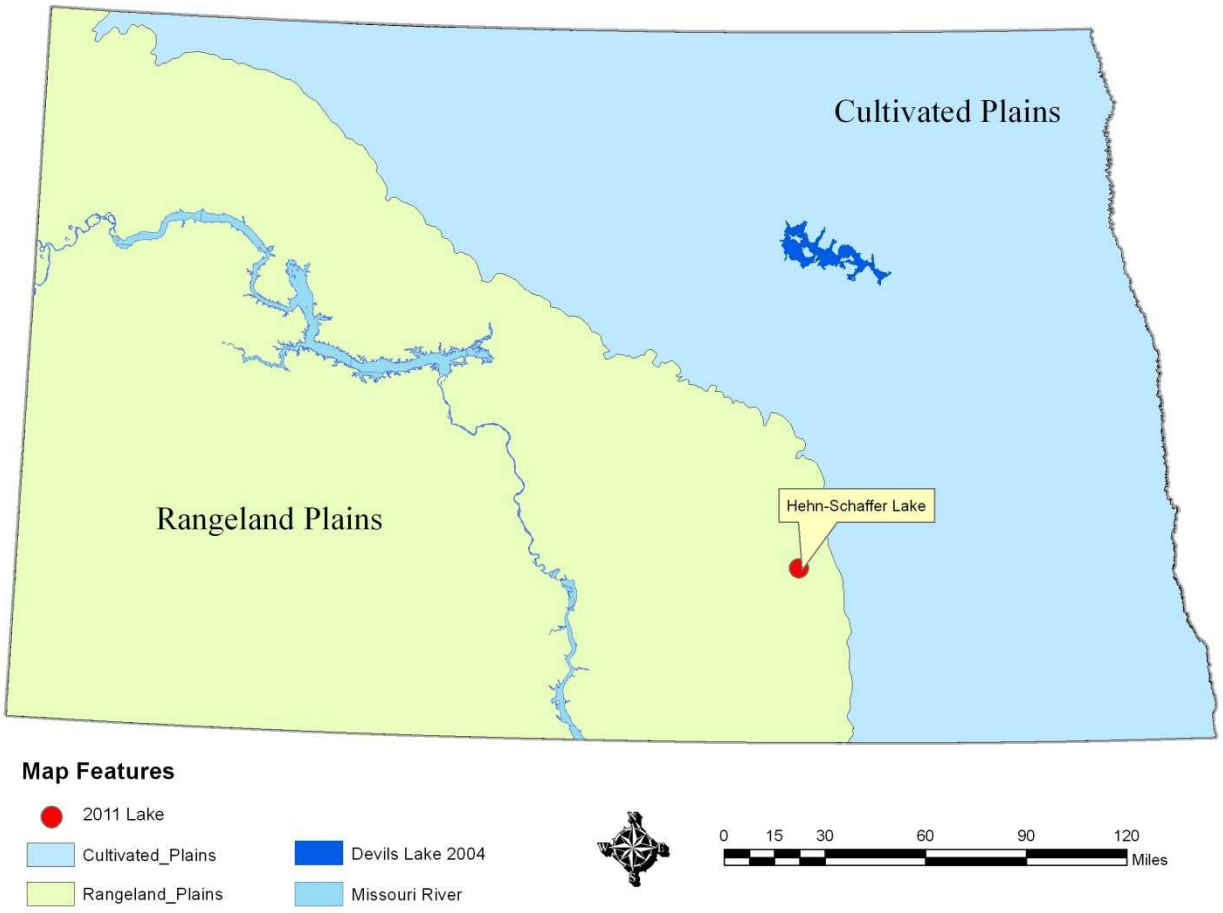

Figure 3. Hehn-Schaffer Lake Location and the Cultivated and Rangeland Plans Regions

Water Quality Standards Classification: Hehn-Schaffer Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species might also be present."

Historical Water Quality Sampling: There is no historical water quality data available.

WATER QUALITY MONITORING RESULTS

The water quality assessment for Hehn-Schaffer Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional data for lakes in the Rangeland Plains Region.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Hehn-Schaffer Lake collected in 2011 (Figures 4 and 5). The temperature profile data indicates that Hehn-Schaffer Lake is normally not stratified during the open water period, but can experience a deep stratification near the sediment water interface (Figure 4).

The dissolved oxygen profiles indicates that during the open water period the lake remains well enough oxygenated to support the aquatic life associated with a class 3 lake. They also show that there is rapid dissolved oxygen decay below the thermal-cline during periods (Figure 5).

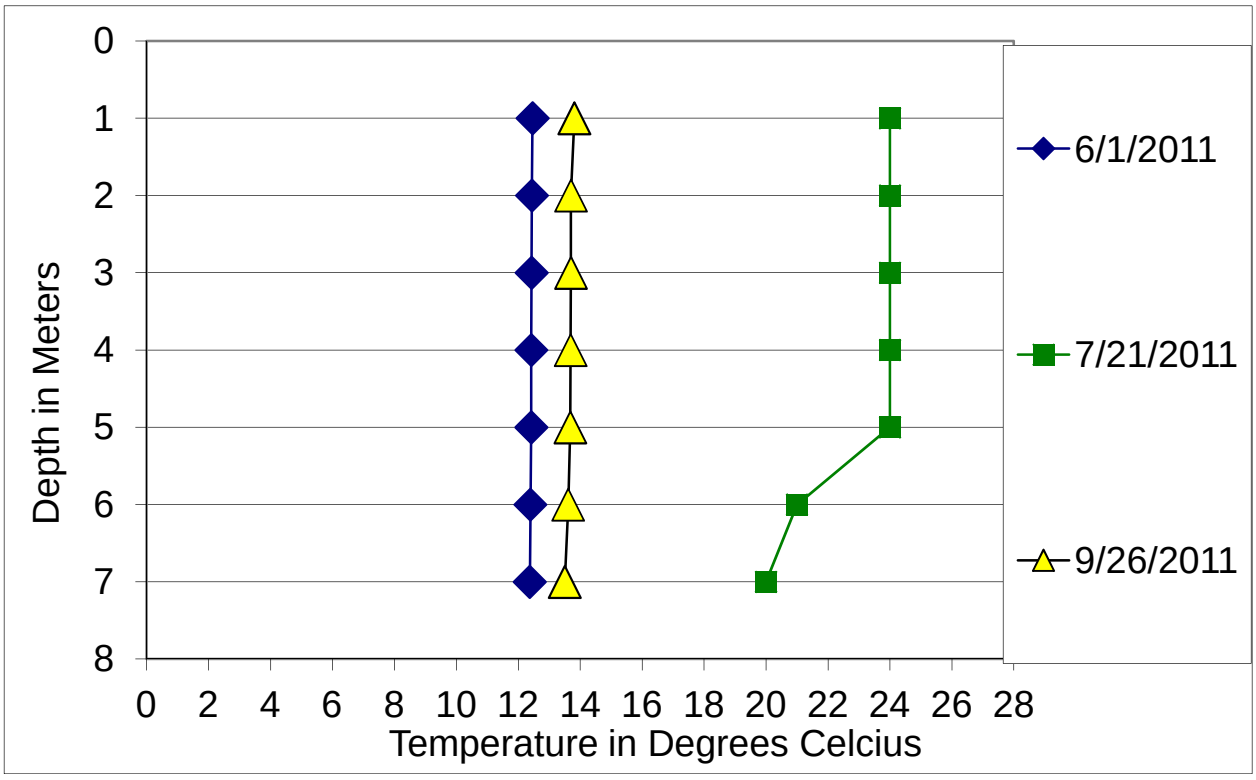

Figure 4. Temperature Profiles for Hehn-Schaffer Lake

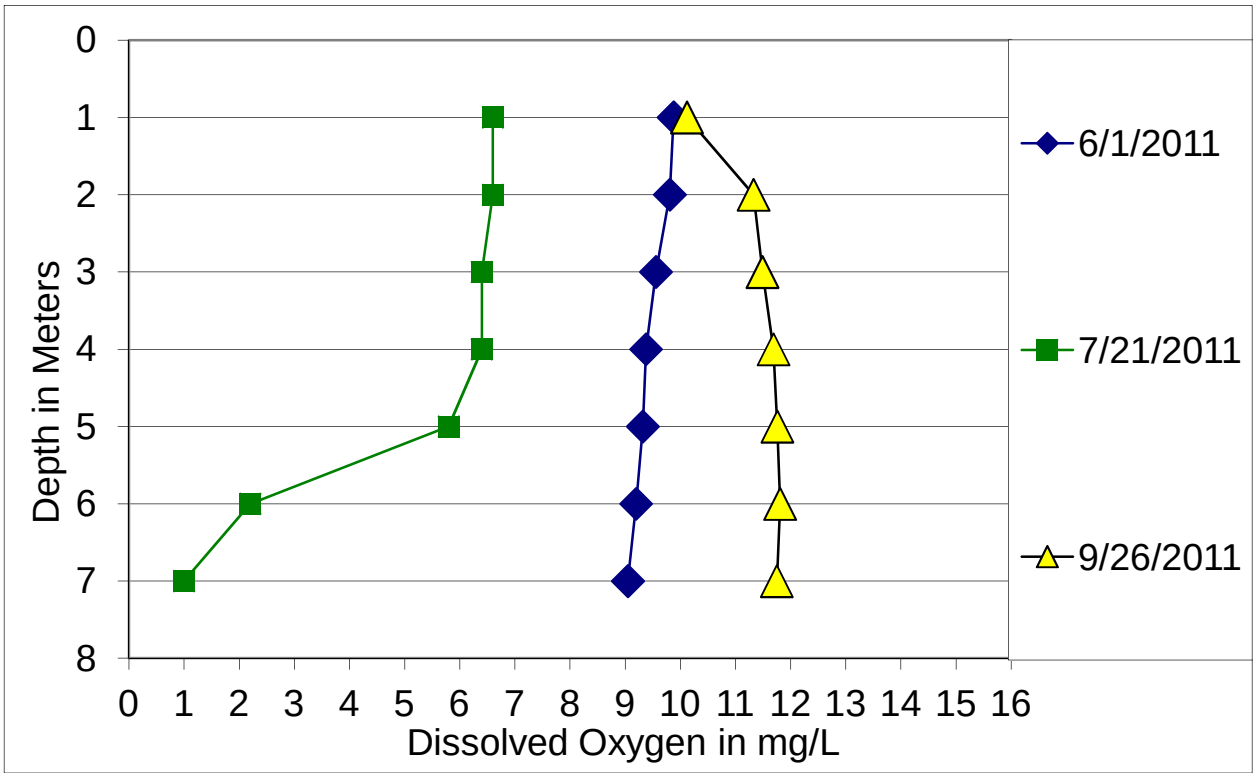

Figure 5. Dissolved Oxygen Profiles for Hehn-Schaffer Lake

General Water Quality: Water quality data collected in 2011 indicates that Hehn-Schaffer Lake is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 325 to 342 mg/L (Table 1). The lake is sodium bicarbonate dominated with an average sodium concentration of 88.5 mg/L and an average bicarbonate concentration of 365 mg/L. The lake is relatively saline and well mineralized with average total dissolved solids concentration and specific conductance measurements for the 2011 sampling period of 620 mg/L and 953µmhos/cm, respectively.

The lake has an abundant concentration of nitrogen and phosphorus. The average total nitrogen and total phosphorus concentrations in 2011 are 1.64 mg/L and 0.185 mg/L respectively.

Compared to the water quality for all lakes in the Rangeland Plans Region, Hehn-Schaffer Lake has fewer dissolved solids than most but about average concentrations of nutrients (Tables 1 and 2). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 1398 mg/L, 1.75 mg/L, and 0.22 mg/L respectively, compared to Hehn-Schaffer Lake's 2011 average TDS, total nitrogen, and total phosphorus concentrations of 620 mg/L, 1.64 mg/L and 0.185 mg/L respectively.

Table 1. Statistical Summary of Hehn-Schaffer Lake's 2011 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	331	325	342	9
Total Ammonia as N	mg/L	3	0.098	0.03[1]	0.139	0.06
Bicarbonate (HCO_3)	mg/L	3	365	342	379	20
Calcium (Ca)	mg/L	3	56.4	54.8	57.5	1.4
Carbonate (CO_3)	mg/L	3	19.3	9	28	9.6
Chloride (Cl)	mg/L	3	14.5	12.8	17.3	2.4
Chlorophyll-a	µg/L	3	30.3	6	57.7	26
Specific Conductance	µmhos	3	953	944	963	10
Total Dissolved Solids	mg/L	3	620	609	637	15
Total Hardness as ($CaCO_3$)	mg/L	3	386	372	403	16
Hydroxide (OH)	mg/L	3	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	3	0.25	0.07	0.42	0.17
Magnesium (Mg)	mg/L	3	59.4	57	63	3.2
Nitrate + Nitrite as N	mg/L	3	0.06	0.03[1]	0.13	0.06
Total Kjeldahl Nitrogen as N	mg/L	3	1.577	1.35	1.7	0.197
Total Nitrogen as N	mg/L	3	1.64	1.38	1.83	0.233
pH		3	8.6	8.4	8.8	0.2
Total Phosphorus as P	mg/L	3	0.185	0.182	0.19	0.004
Potassium (K)	mg/L	3	20.8	20	21.3	0.7
Sodium (Na)	mg/L	3	88.5	85.3	90.3	2.8
Sulfate (SO4)	mg/L	3	180	178	181	2

[1]Equal to the lower reporting limit

Limiting Nutrients: The water quality samples collected in 2011 indicate that Hehn-Schaffer Lake is nitrogen limited (Figure 6). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that a lake is at nutrient equilibrium with a ratio of 15 to 1. When the ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Hehn-Schafer Lake's ratio of nitrogen to phosphorus ranged from a low of 7 to a high of 10 in 2011. It is important to recognize that a nitrogen limited lake is never really limited from primary production as some species of primary producers are able to affix free nitrogen.

Trophic Status Assessment: Based on the chlorophyll-a and supported by the secchi disk transparency measurements and total phosphorus concentrations in 2011 Hehn-Schaffer Lake's trophic status is estimated was eutrophic (Figure 7). The Trophic Status Index (TSI) scores based on chlorophyll-a ranged between 48 and 70, secchi disk scores range of 45 to 54 and total phosphorus between 79 and 80.

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Lakes in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	430	499	111	4770	466
Total Ammonia as N	mg/L	554	0.105	0.001	2.23	0.223
Bicarbonate (HCO_3)	mg/L	430	461	60	2990	308
Calcium (Ca)	mg/L	431	42.9	0.5	294	38.9
Carbonate (CO_3)	mg/L	424	74	1	1420	141
Chloride (Cl)	mg/L	430	41.6	1.7	1070	97.8
Chlorophyll-a	µg/L	383	22	2	292	36
Specific Conductance	µmhos	430	1939	424	20100	1890
Total Dissolved Solids	mg/L	430	1398	227	18200	1640
Total Hardness as ($CaCO_3$)	mg/L	431	530	74	2370	299
Hydroxide (OH)	mg/L	369	1	1	1	0
Iron (Fe)	mg/L	432	0.23	0.01	7.07	0.52
Magnesium (Mg)	mg/L	431	102.8	8.5	567	69.5
Nitrate + Nitrite as N	mg/L	551	0.042	0.001	0.54	0.055
Total Kjeldahl Nitrogen as N	mg/L	523	1.82	0.08	8.5	1.04
Total Nitrogen as N	mg/L	461	1.75	0.24	5.52	0.87
pH		430	8.78	7.4	9.87	0.36
Total Phosphorus as P	mg/L	561	0.22	0.01	1.94	0.33
Potassium (K)	mg/L	431	32.8	3.1	356	35.7
Sodium (Na)	mg/L	431	278	16.9	4680	490.1
Sulfate (SO4)	mg/L	430	590.9	34	10500	847.6

[1]Equal to the lower reporting limit
[2]Data collected from 66 natural and enhanced Lakes between 1991 and 2011

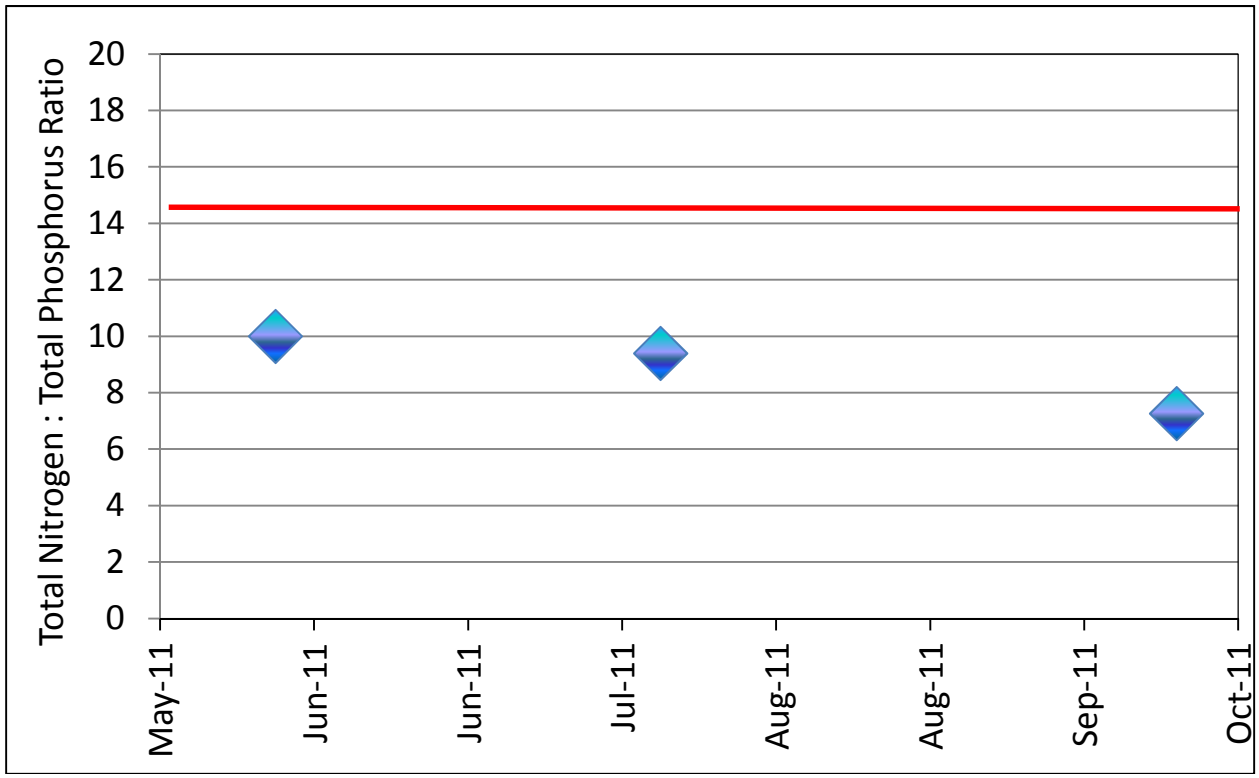

Figure 6. Hehn-Schaffer Lake's Total Nitrogen to Total Phosphorus Ratio

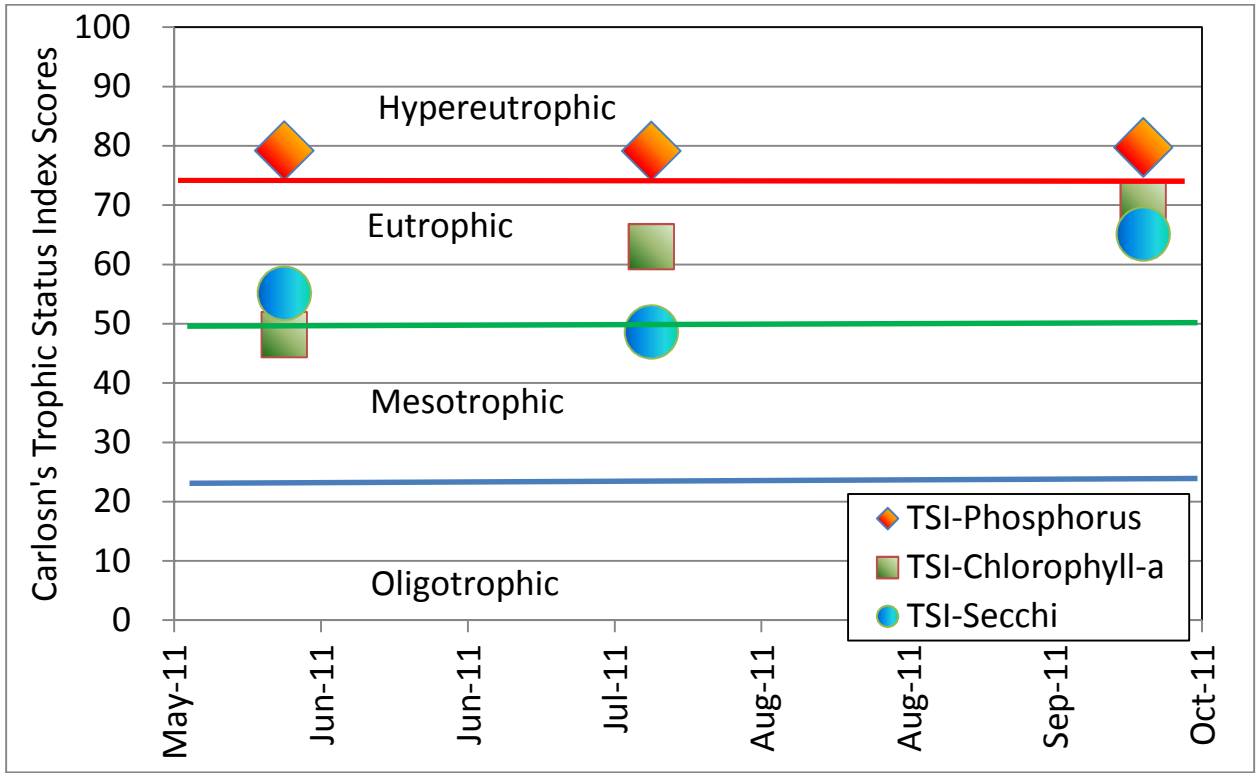

Figure 7. Hehn-Schaffer Lake's TSI Scores

Velva Sportsmans Pond, Ward County

BACKGROUND

Velva Sportsmans Pond is a little reservoir on Spring Creek, a small perennial tributary of the Souris River 8 miles south and 2 miles west of Velva, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish Department. Fish species managed for are trout with seasonal and no live bait restrictions.

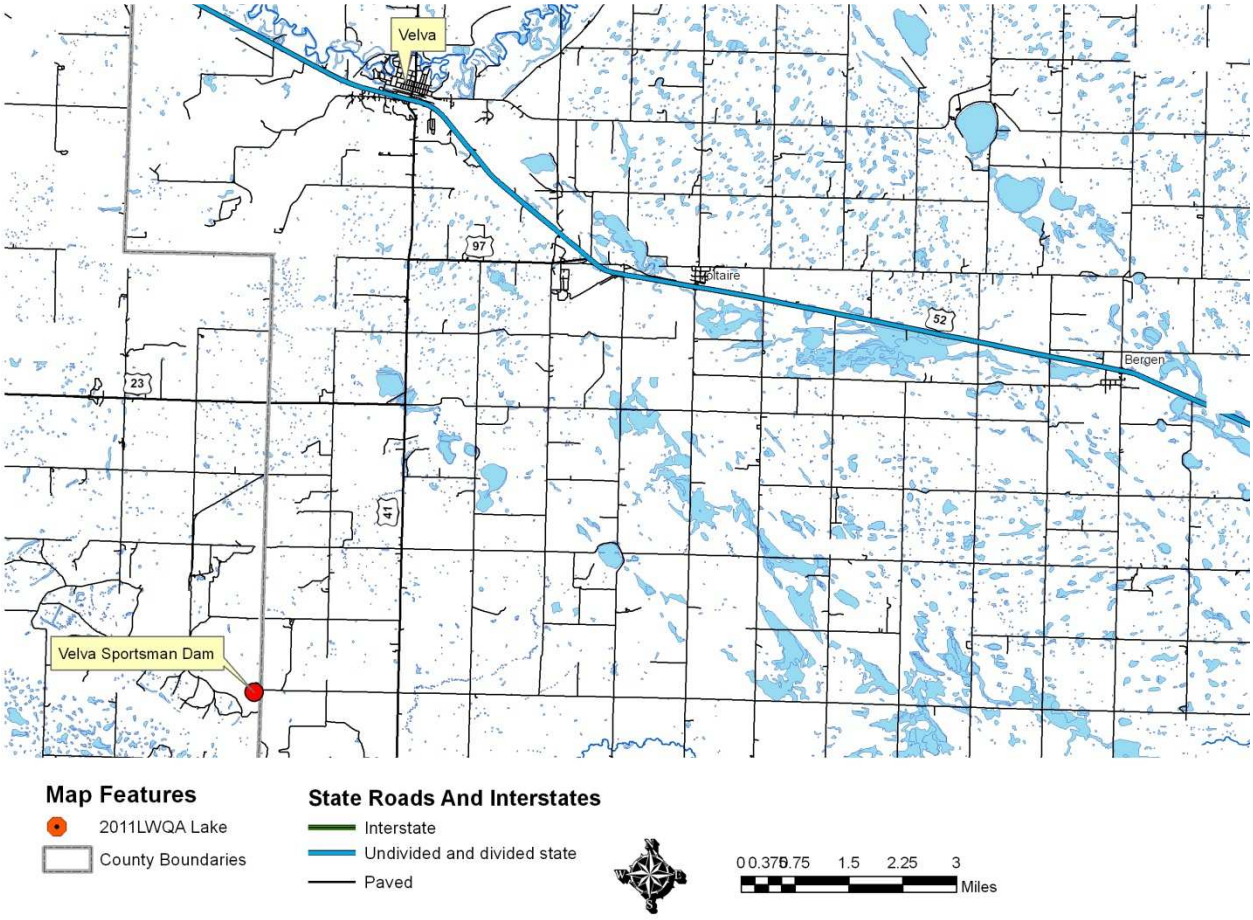

Figure 1. Location of Velva Sportsmans Pond

Physiographic/Ecological Setting: Velva Sportsmans Pond has a surface area of 5.3 acres, an average depth of 12.3 feet and a maximum depth of 26.5 ft (Figure 2). The reservoir lies just below the spoils of a pre-reclamation coal mine. The entire drainage is in the Northern Glaciated Plains Level III Ecoregion, which is part of the broader Cultivated Plains Region (Figure 3).

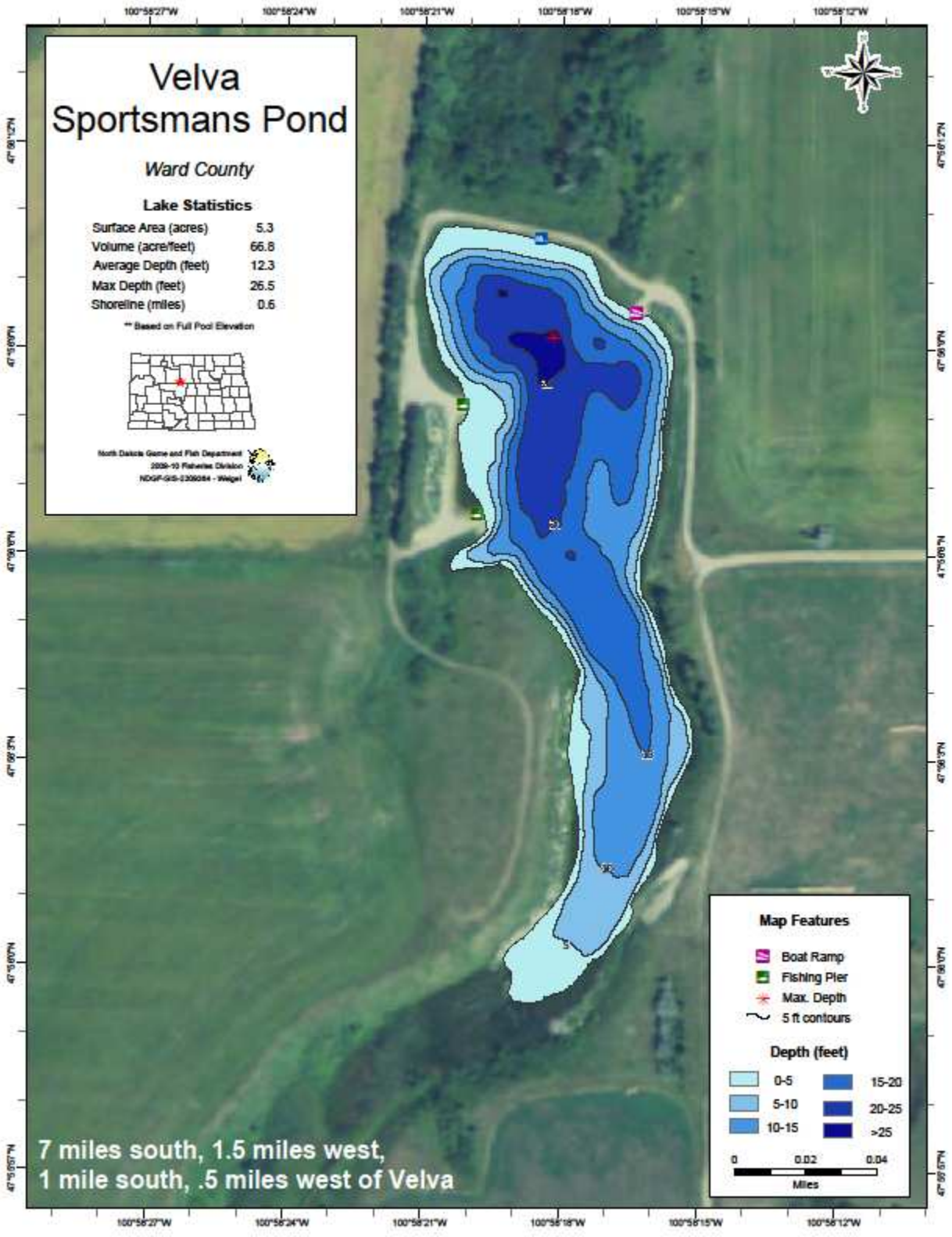

Figure 2. Contour Map of Velva Sportsmans Pond (Map Courtesy of North Dakota Game and Fish Department)

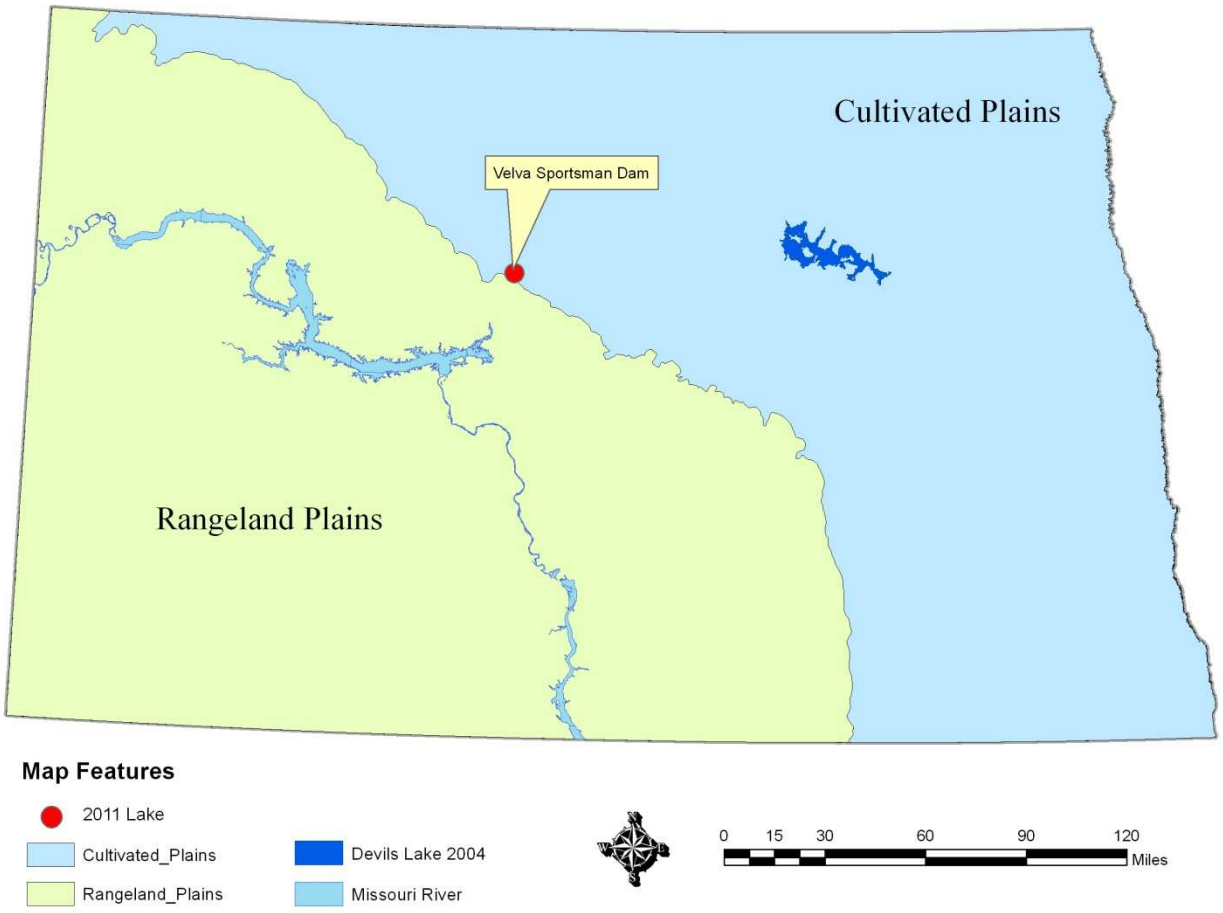

Figure 3. Velva Sportsmans Pond Location and the Cultivated and Rangeland Plans Regions

Recreational Facilities: Recreational facilities at Velva Sportsmans Pond are primitive camping, a picnic area, and a cement ramp. In recent years the NDG&F Save Our lakes Program has hollowed out and rocked areas along the shore to provide improved access for shore fishing.

Water Quality Standards Classification: Velva Sportsmans Pond is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 1 waterbody. Class 1 lakes and reservoirs are defined as a "cold water fishery" or "waters capable of supporting growth of cold water fish species (e.g., salmonids) and associated aquatic biota."

Historical Water Quality Sampling: Historical water quality data include seven total nitrogen and total phosphorus samples, five chlorophyll-a samples, and eight temperature and dissolved oxygen profiles collected between 1991 and 1994.

WATER QUALITY MONITORING RESULTS

The water quality assessment for Velva Sportsmans Pond is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional data for reservoirs in the Cultivated Plains Region.

Temperature and Dissolved Oxygen Profile Results: There are eleven temperature and dissolved oxygen profiles for Velva Sportsmans Pond collected in 1991 - 1994 and in 2011 (Figures 4 and 5). The temperature profiles indicate that Velva Sportsmans Pond weakly thermally stratifies at depths of 2 to 4 meters (Figure 4).

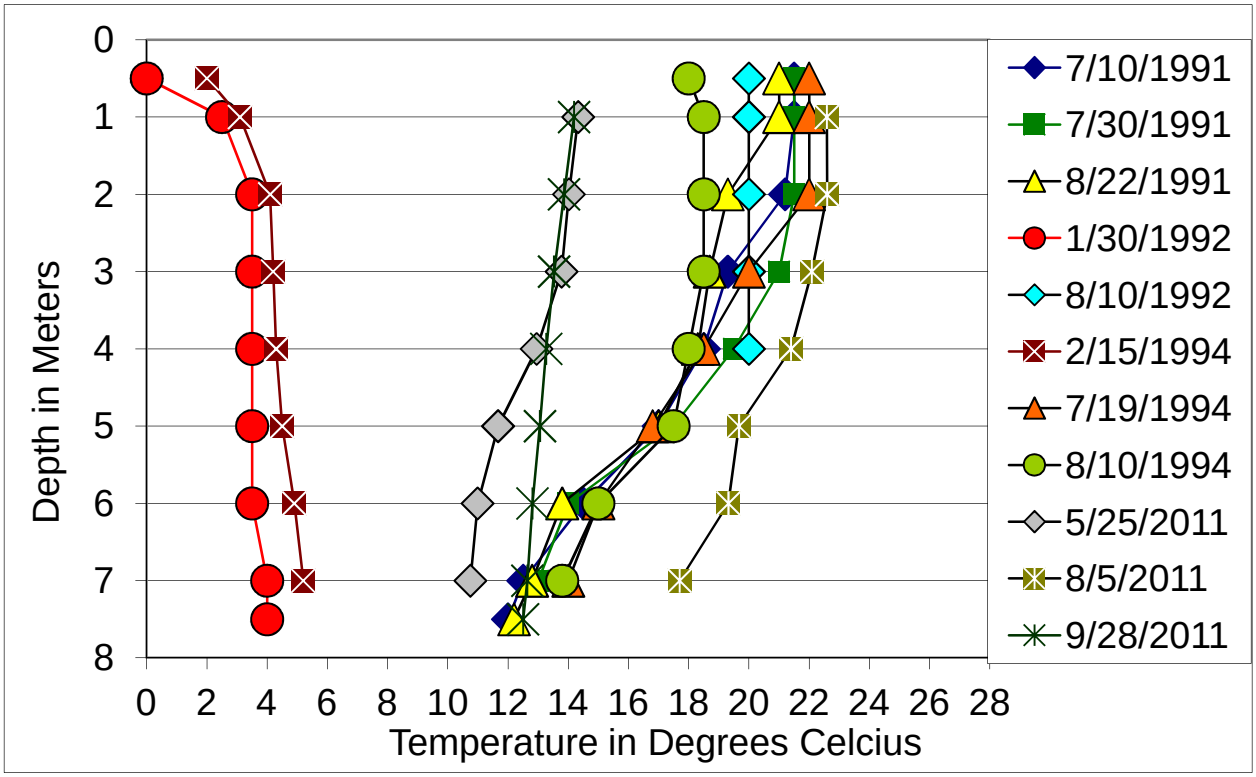

Figure 4. Temperature Profiles for Velva Sportsmans Pond

The dissolved oxygen profiles show that during periods of thermal stratification, Velva Sportsmans Pond experiences rapid decay of dissolved oxygen with little oxygen available below 4 or 5 meters depth (Figure 5). However the temperature profiles indicate that the temperature rarely exceeds 18 degrees above these depths providing areas for fish survival.

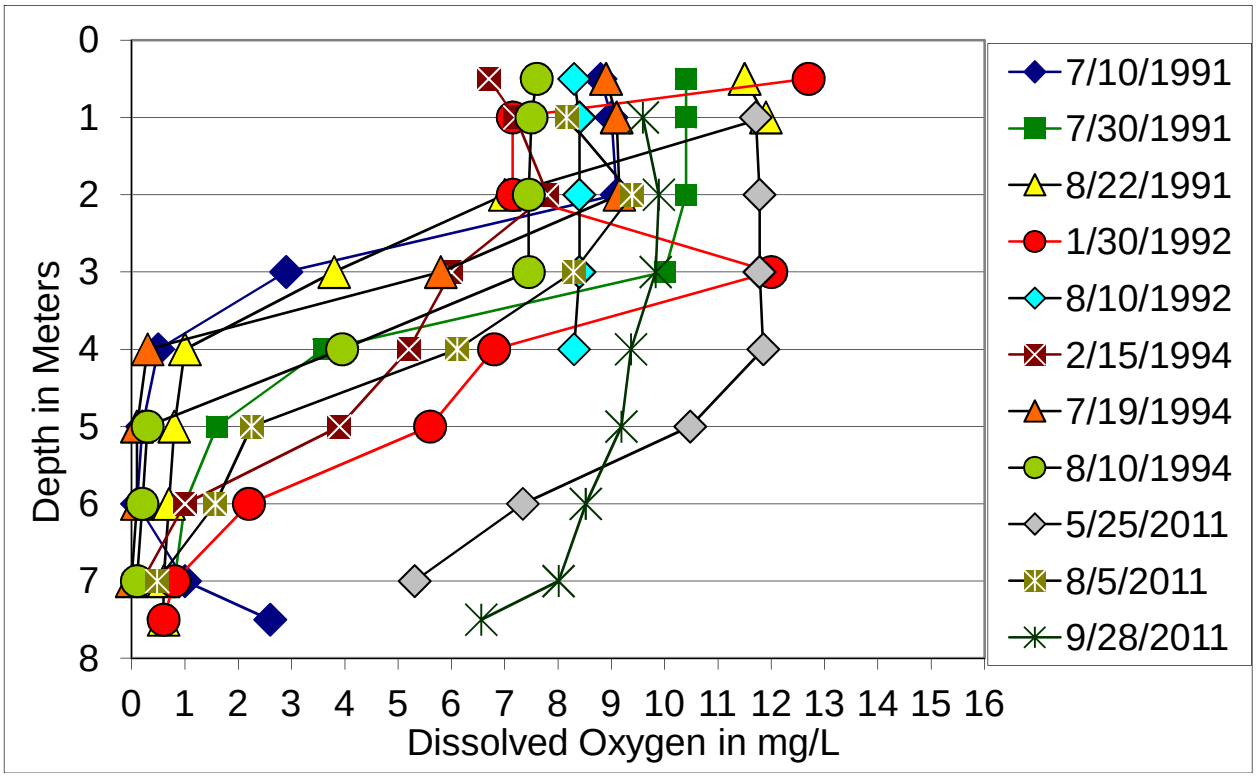

Figure 5. Dissolved Oxygen Profiles for Velva Sportsmans Pond

General Water Quality: Data collected in 2011 indicates that Velva Sportsmans Pond is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 302to 309 mg/L (Table 1) and that the reservoir is sodium sulfate dominated with an average sodium concentration of 92.9 mg/L and an average sulfate concentration of 470 mg/L. The reservoir has an average total dissolved solids concentration and specific conductance measurements for the 2011 sampling period of 972 mg/L and 1830 µmhos/cm, respectively and an average total nitrogen and total phosphorus concentrations of 0.72 mg/L and 0.03 mg/L respectively.

When compared to water quality for reservoirs in the Cultivated Plans Region, Velva Sportsmans Pond is slightly more mineralized then most but is substantially poorer in nutrients for primary production. For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 352 mg/L, 1.51 mg/L, and 0.324 mg/L respectively, compared to Velva Sportsmans Pond's average TDS, total nitrogen, and total phosphorus concentrations of 972 mg/L, 0.72 mg/L and 0.03 mg/L (Tables 1 and 2).

Table 1. Statistical Summary of Velva Sportsman Dam's 2011 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	306	302	309	4
Total Ammonia as N	mg/L	3	0.03[1]	0.03[1]	0.03[1]	0
Bicarbonate (HCO_3)	mg/L	3	365	362	371	5
Calcium (Ca)	mg/L	3	119	114	128	8.1
Carbonate (CO_3)	mg/L	3	4	3	6	2
Chloride (Cl)	mg/L	3	15.8	15	17.4	1.4
Chlorophyll-a	µg/L	3	20	10.2	36.3	14.2
Specific Conductance	µmhos	3	1307	1260	1360	50
Total Dissolved Solids	mg/L	3	972	857	1040	100
Total Hardness as ($CaCO_3$)	mg/L	3	638	601	696	51
Hydroxide (OH)	mg/L	3	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	3	0.08	0.05	0.15	0.06
Magnesium (Mg)	mg/L	3	83	76.7	91.4	7.6
Nitrate + Nitrite as N	mg/L	3	0.17	0.03	0.37	0.18
Total Kjeldahl Nitrogen as N	mg/L	3	0.54	0.5	0.58	0.04
Total Nitrogen as N	mg/L	3	0.72	0.61	0.87	0.14
pH		3	8.35	8.34	8.36	0.01
Total Phosphorus as P	mg/L	3	0.03	0.02	0.03	0.01
Potassium (K)	mg/L	3	9.2	8.2	9.8	0.9
Sodium (Na)	mg/L	3	92.9	77.8	101	13.1
Sulfate (SO4)	mg/L	3	470	377	523	81

[1]Equal to the lower reporting limit

When comparing historical water quality data collected in 1992-1994 to the 2011 data the quality has remained remarkably consistent with the exception of nitrogen. For example, the historical average concentration for total phosphorus, total dissolved solids, sulfate, and alkalinity and bicarbonates are 0.03 mg/L, 955 mg/L, 455 mg/L, 359 mg/L, and 439 mg/L compared to the current (2011) concentrations of0.03 mg/L, 972 mg/L, 470 mg/L, 306 mg/L and 365 mg/L (Tables 1 and 3).

Unlike the other water quality parameters the concentrations of total nitrogen has declined from the 1992 - 1994 average of 1.28 to 0.072 mg/L. While no statistical analysis has been performed to test the significance of this reduction it is obviously substantial (Tables 1 and 3).

Limiting Nutrients: The water quality samples collected in 1991 - 1994 and 2011 indicate that Velva Sportsmans Pond is phosphorus limited (Figure 6). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the lake is at nutrient equilibrium with a ratio of total nitrogen to total phosphorus of 15 to 1. When the ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus. Velva sportsman Dams ratios in 1991 through 2011 a ranged between a low of 18 to a high of 76.

Trophic Status Assessment: Based on the chlorophyll-a data collected in 1991 - 1994 and 2011 Velva Sportsmans Pond's trophic condition is eutrophic bordering on mesotrophic with no recognizable trend (Figure 7). In 1991 - 1994 the Trophic Status Index Scores, for chlorophyll-a ranged between 41 and 56 and in 2011 between 53 and 66. A eutrophic assessment is supported by the Trophic Status Scores associated with secchi dick measurements and total phosphorus concentrations with ranges of 36 to 59 and 46 to 64, respectively.

Table 2. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	571	282	3	982	130
Total Ammonia as N	mg/L	651	0.092	0.001	2.44	0.178
Bicarbonate (HCO_3)	mg/L	571	296	4	1040	143
Calcium (Ca)	mg/L	571	55	2	206	30
Carbonate (CO_3)	mg/L	569	24	1	197	28
Chloride (Cl)	mg/L	571	14	1	75	10
Chlorophyll-a	µg/L	456	19.6	1.5	218	26.1
Specific Conductance	µmhos	591	1618	4	5880	973
Total Dissolved Solids	mg/L	572	1113	17	5110	773
Total Hardness as ($CaCO_3$)	mg/L	571	410	9	2100	288
Hydroxide (OH)	mg/L	514	1	1	1	0
Iron (Fe)	mg/L	572	0.2	0.01	4.11	0.35
Magnesium (Mg)	mg/L	571	66.4	1	412	54.9
Nitrate + Nitrite as N	mg/L	650	0.064	0.003	1.49	0.127
Total Kjeldahl Nitrogen as N	mg/L	541	1.36	0.08	7.72	0.78
Total Nitrogen as N	mg/L	484	1.32	0.02	4.84	0.63
pH		591	8.54	5.74	9.87	0.55
Total Phosphorus as P	mg/L	657	0.126	0.004	3.16	0.185
Potassium (K)	mg/L	571	13.9	1	52.5	6.9
Sodium (Na)	mg/L	571	214	3	932	168
Sulfate (SO4)	mg/L	569	578	1	3210	512

[1]Equal to the lower reporting limit
[2]Data collected from 76 reservoirs between 1991 and 2011

Table 3. Statistical Summary of Velva Sportsman Dam's 1991-1995 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	4	359	328	390	33
Total Ammonia as N	mg/L	4	0.02	0.01[1]	0.03	0.01
Bicarbonate (HCO_3)	mg/L	4	439	401	476	40
Calcium (Ca)	mg/L	4	103.6	87.4	118	14.4
Carbonate (CO_3)	mg/L	3	1[1]	1[1]	1[1]	0
Chloride (Cl)	mg/L	4	1.9	0.3	3.5	1.8
Chlorophyll-a	µg/L	5	8.2	3[1]	13	3.9
Specific Conductance	µmhos	4	1365	1280	1440	68
Total Dissolved Solids	mg/L	4	955	870	1090	94
Total Hardness as ($CaCO_3$)	mg/L	4	570	509	619	48
Hydroxide (OH)	mg/L	3	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	4	0.049	0.021	0.093	0.031
Magnesium (Mg)	mg/L	4	75.5	70.7	78.7	3.4
Nitrate + Nitrite as N	mg/L	4	0.653	0.005[1]	1.3	0.748
Total Kjeldahl Nitrogen as N	mg/L	4	0.628	0.33	1	0.34
Total Nitrogen as N	mg/L	4	1.28	0.35	1.4	0.43
pH		4	7.88	7.36	8.23	0.392
Total Phosphorus as P	mg/L	4	0.03	0.018	0.039	0.009
Potassium (K)	mg/L	4	8.3	7.4	9.2	0.8
Sodium (Na)	mg/L	4	92	84	97	6
Sulfate (SO4)	mg/L	4	455	398	546	66

[1]Equal to the lower reporting limit

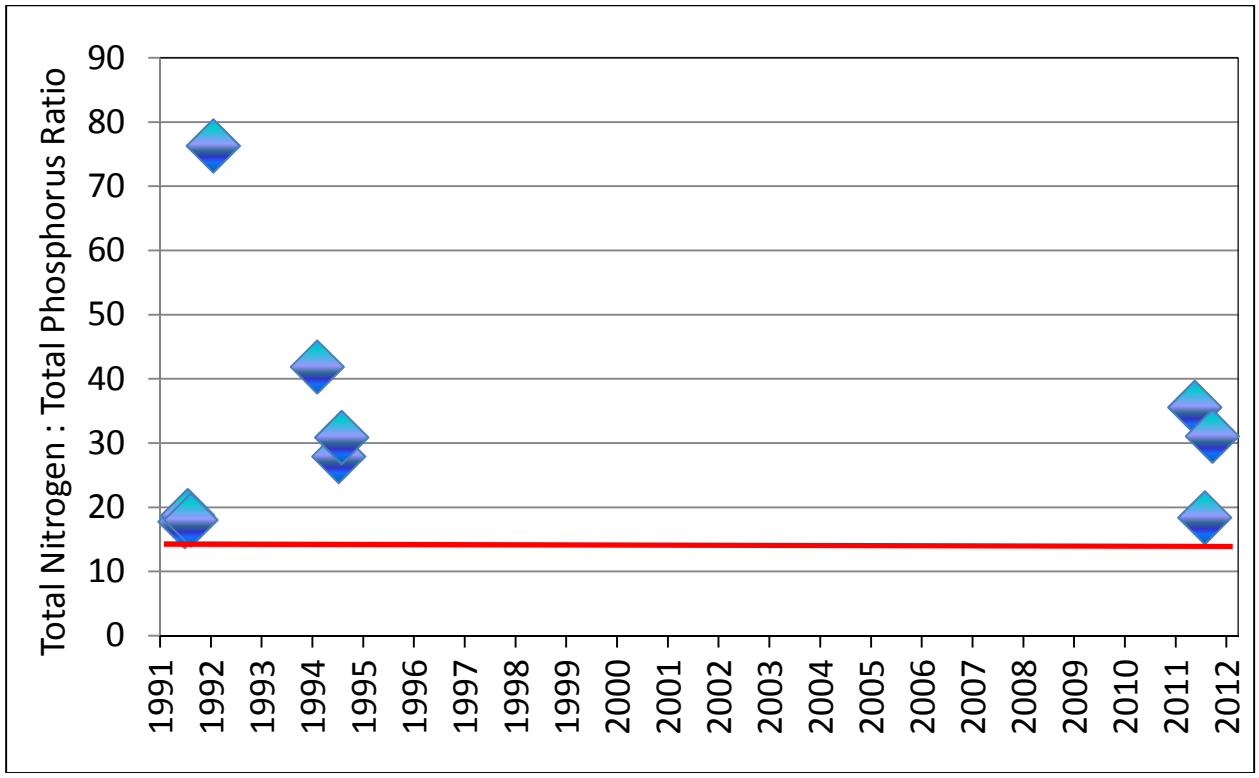

Figure 6. Velva Sportsmans Pond's Total Nitrogen to Total Phosphorus Ratio

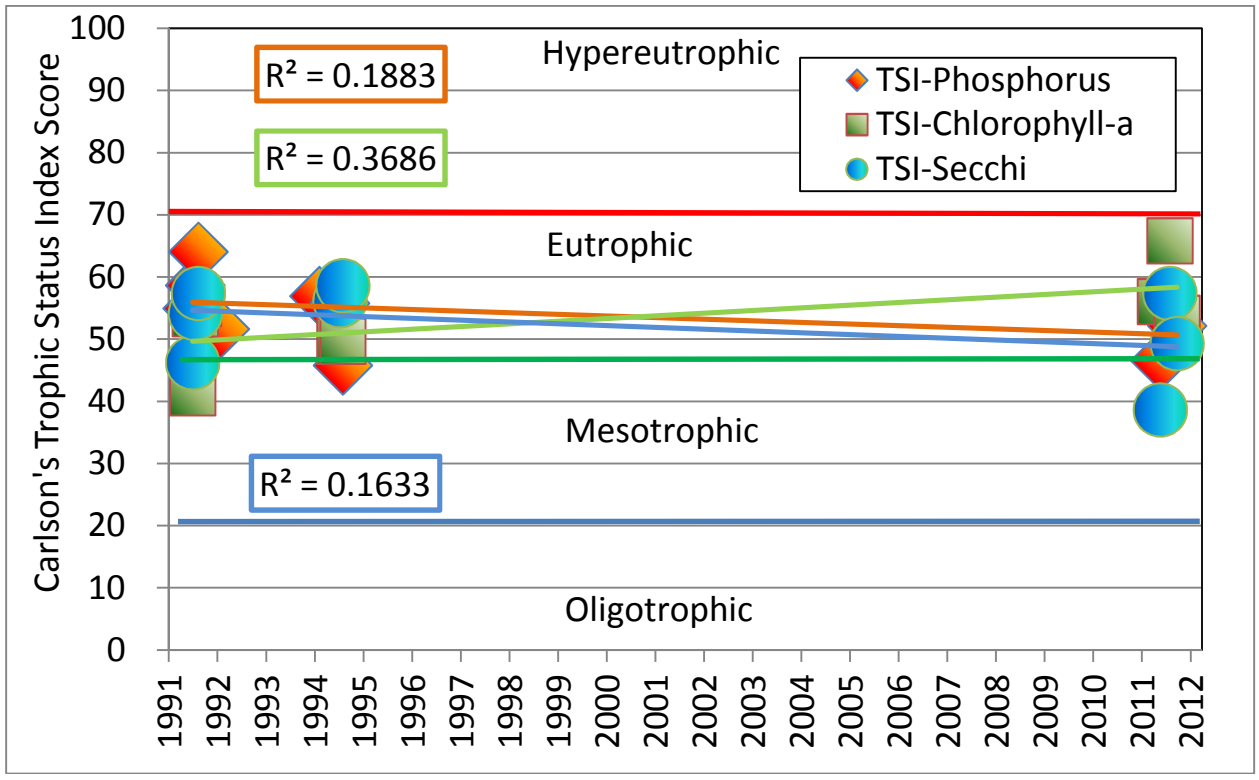

Figure 7. Velva Sportsmans Pond's TSI Scores

Epping-Spring Brook Dam, Williams County

BACKGROUND

Epping-Spring Brook Dam is a small prairie reservoir on Stony Creek 5 miles north and 9 miles east of Williston, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish Department. Fish species managed for are northern pike, walleye and yellow perch.

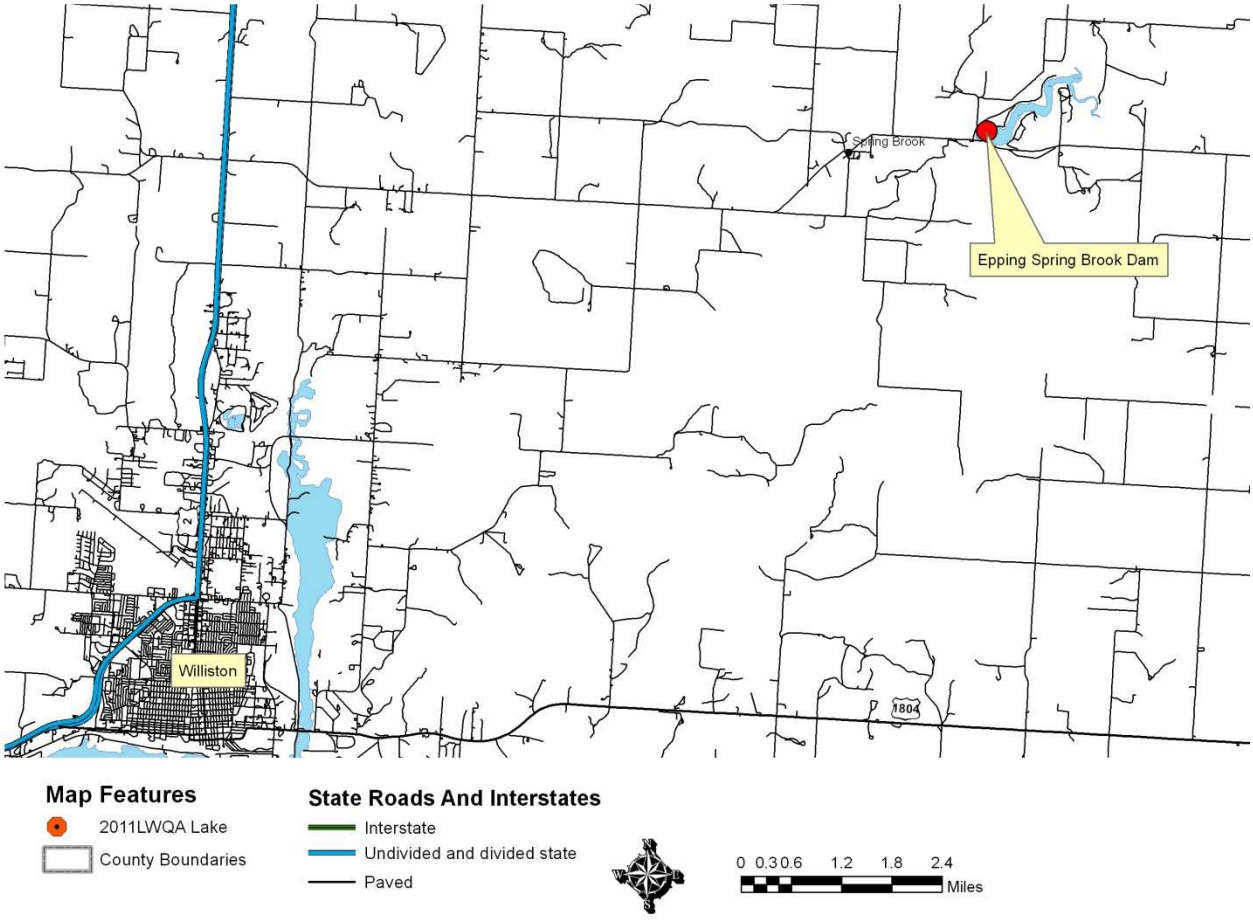

Figure 1. Location of Epping-Spring Brook Dam

Physiographic/Ecological Setting: Epping-Spring Brook Dam has a surface area of 128.3 acres, a mean dept of 11.5 and a maximum depth of 29.8 ft. It is a windswept reservoir with little or no shelter from the ever present North Dakota wind and sun (Figure 2). The reservoir is located in the Northern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figure 3).

Recreational Facilities: Recreational facilities at Epping-Spring Brook Dam are an access road, parking spots, camping and picnic area with a cement ramp and courtesy dock.

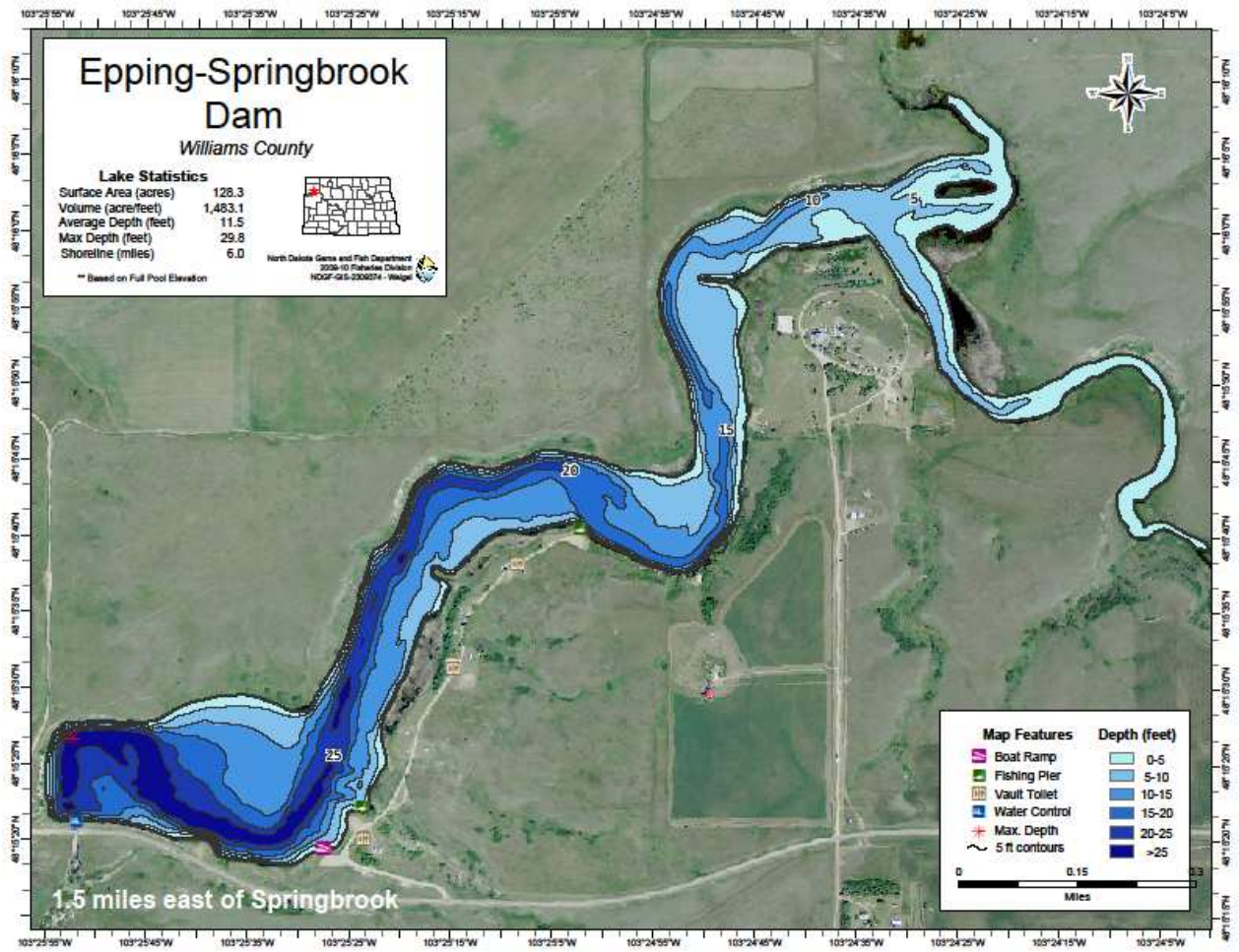

Figure 2. Contour Map of Epping-Spring Brook Dam (Map Courtesy of North Dakota Game and Fish Department)

Water Quality Standards Classification: Epping-Spring Brook Dam is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 waterbody. Class 3 lakes and reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth Bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: Historical water quality data include 3 samples collected in 1992-1993.

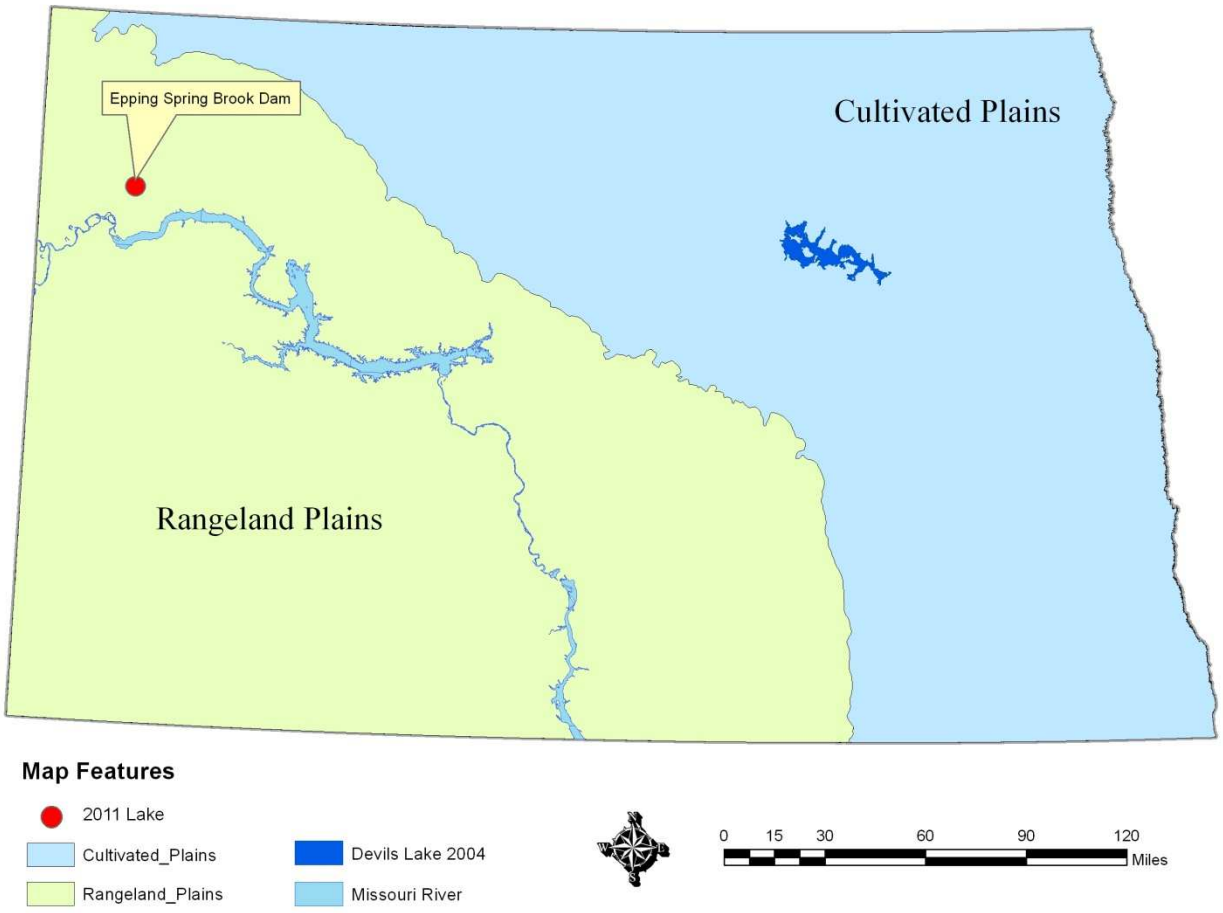

Figure 3. Epping-Spring Brook Dam Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Epping-Spring Brook Dam is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional data for reservoirs in the Rangeland Plains Region.

Temperature and Dissolved Oxygen Profile Results: There are six temperature and dissolved oxygen profiles for Epping-Spring Brook Dam collected in 1991, 1992 and 2011 (Figures 4 and 5). The temperature profile data indicates that Epping-Spring Brook Dam either does not thermally stratified or only weakly stratified (Figure 4)

During periods of weak thermal stratification Epping Spring Brook Dam experiences moderate decay in the dissolved oxygen concentrations. On the positive side the decay is gradual and the reservoirs maintains enough oxygen to support a warm water fishery and associated aquatic biota (Figure 5).

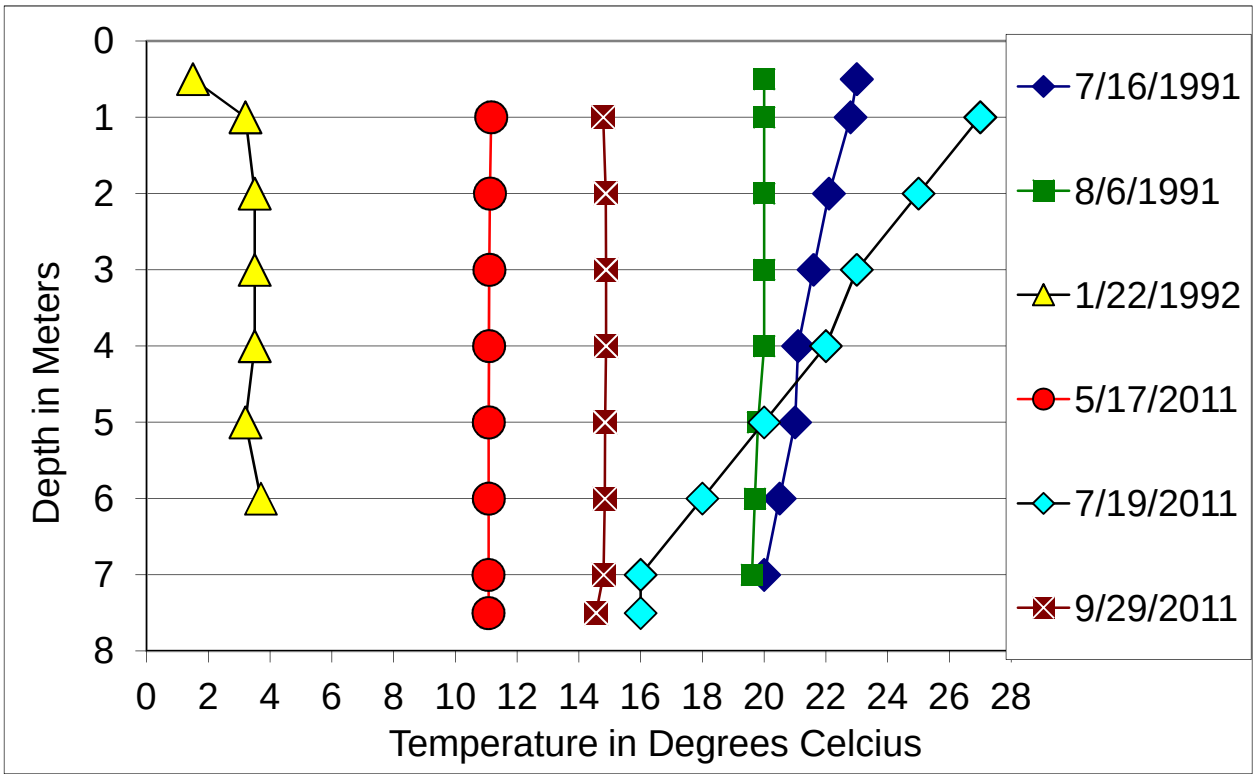

Figure 4. Temperature Profiles for Epping-Spring Brook Dam

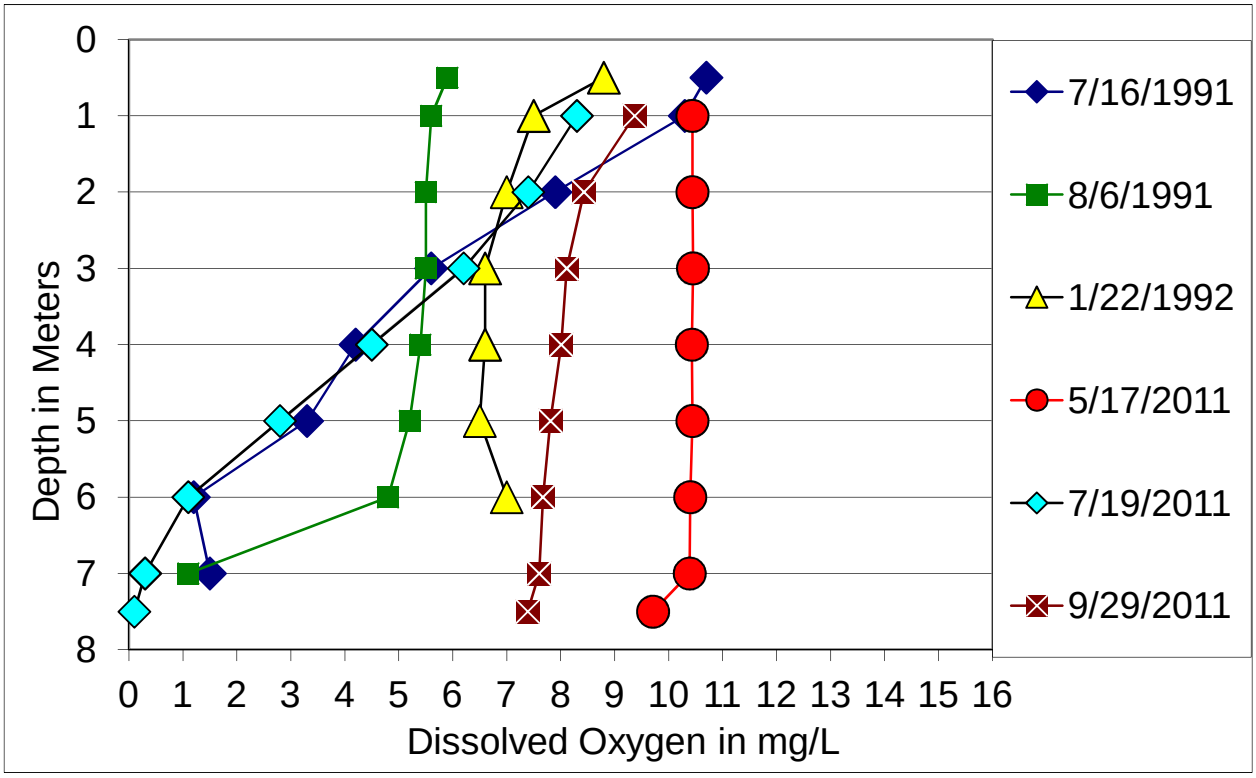

Figure 5. Dissolved Oxygen Profiles for Epping-Spring Brook Dam

General Water Quality: Water quality data collected in 2011 indicates that Epping-Spring Brook Dam is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 177 to 247 mg/L (Table 1) and that the reservoir is sodium sulfate dominated with an average sodium concentration of 64.5 mg/L and an average bicarbonate concentration of 245 mg/L. The average total dissolved solids concentration and specific conductance measurements for the 2011 sampling period were 735 mg/L and 1037 µmhos/cm, respectively and the average total nitrogen and total phosphorus concentrations are 1.031 mg/L and 0.262 mg/L respectively.

Table 1. Statistical Summary of Epping-Spring Brook Dam's 2011 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	205	177	247	37
Total Ammonia as N	mg/L	3	0.047	0.03[1]	0.082	0.03
Bicarbonate (HCO_3)	mg/L	3	245	216	288	38
Calcium (Ca)	mg/L	3	88.3	79.1	101	11.3
Carbonate (CO_3)	mg/L	3	3	1[1]	7	3.5
Chloride (Cl)	mg/L	3	10.4	7.1	15	4.1
Chlorophyll-a	µg/L	3	7	3[1]	12	4.6
Specific Conductance	µmhos	3	1037	932	1120	96
Total Dissolved Solids	mg/L	3	735	635	832	99
Total Hardness as ($CaCO_3$)	mg/L	3	496	438	574	70
Hydroxide (OH)	mg/L	3	1[1]	1[1]	1[1]	0
Iron (Fe)	mg/L	3	0.19	0.1	0.31	0.11
Magnesium (Mg)	mg/L	3	67	58.4	78.2	10.2
Nitrate + Nitrite as N	mg/L	3	0.06	0.03[1]	0.12	0.05
Total Kjeldahl Nitrogen as N	mg/L	3	0.971	0.814	1.14	0.163
Total Nitrogen as N	mg/L	3	1.031	0.844	1.26	0.211
pH		3	8.3	8.1	8.5	0.2
Total Phosphorus as P	mg/L	3	0.262	0.096	0.348	0.144
Potassium (K)	mg/L	3	11.9	10.9	12.4	0.8
Sodium (Na)	mg/L	3	64.5	52.4	72.2	10.6
Sulfate (SO4)	mg/L	3	368	311	403	50

[1]Equal to the lower reporting limit

When compared to water quality for other reservoirs in the Rangeland Plans Region, Epping-Spring Brook Dam is similar with the exception of phosphorus which is substantially higher than the average (Tables 1 and 2). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 1113 mg/L, 1.32 mg/L, and 0.126 mg/L respectively, compared to Epping-Spring Brook Dam's average TDS, total nitrogen, and total phosphorus concentrations of 1037 mg/L, 1.031 mg/L and 0.262 mg/L, respectively.

Table 2. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Cultivated Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	429	262	88	891	97
Total Ammonia as N	mg/L	609	0.141	0.001	2.07	0.203
Bicarbonate (HCO_3)	mg/L	429	296	91	951	108
Calcium (Ca)	mg/L	432	69	19	169	25
Carbonate (CO_3)	mg/L	411	13	1	93	15
Chloride (Cl)	mg/L	430	21	1	113	17
Chlorophyll-a	µg/L	476	19.8	1.5	388	29.5
Specific Conductance	µmhos	429	1049	217	3140	501
Total Dissolved Solids	mg/L	421	692	127	2300	377
Total Hardness as ($CaCO_3$)	mg/L	432	352	95	1090	126
Hydroxide (OH)	mg/L	368	1	1	1	0
Iron (Fe)	mg/L	430	0.15	0.01	3.19	0.22
Magnesium (Mg)	mg/L	432	43.6	11.2	161	19.8
Nitrate + Nitrite as N	mg/L	602	0.119	0.003	2.06	0.224
Total Kjeldahl Nitrogen as N	mg/L	522	1.45	0.21	4.41	0.64
Total Nitrogen as N	mg/L	461	1.51	0.42	3.95	0.61
pH		430	8.34	1.76	9.4	0.52
Total Phosphorus as P	mg/L	611	0.324	0	2.27	0.29
Potassium (K)	mg/L	432	11.5	2.7	34.5	5.3
Sodium (Na)	mg/L	432	100	2	582	103
Sulfate (SO4)	mg/L	430	285	1	1350	212

[1]Equal to the lower reporting limit
[2]Data collected from 45 reservoirs between 1991 and 2011

When comparing historical water quality data from 1991 and 1992 to the 2011 data there has been some improvement. The improvements are a decrease in most dissolved solids and the principle nutrients responsible for primary production nitrogen and phosphorus. For example, the historical averages for alkalinity, sodium, and bicarbonates are 345 mg/L, 115 mg/L and 315 mg/L compared to the 2011 average concentrations of 205 mg/L, 64.5 mg/L and 245 mg/L. Like the dissolved solids the average concentration of the nutrients nitrogen and total phosphorus concentrations have decreased. The 1991-1992 average for total nitrogen and total phosphorus is 2.88 mg/L and 0.700 mg/L compared to the 2011 averages of 1.031 mg/L and 0.262 mg/L, respectively (Tables 1 and 3).

Table 3. Statistical Summary of Epping-Spring Brook Dam's 1991-1992 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	345	329	374	25
Total Ammonia as N	mg/L	3	0.33	0.01	0.66	0.33
Bicarbonate (HCO_3)	mg/L	3	315	274	383	59
Calcium (Ca)	mg/L	3	62.3	54.7	66.7	6.6
Carbonate (CO_3)	mg/L	3	52	36	63	14
Chloride (Cl)	mg/L	3	11	10	11.7	0.9
Chlorophyll-a	µg/L	2	14	3	25	15.6
Specific Conductance	µmhos	3	1181	1090	1340	138
Total Dissolved Solids	mg/L	3	795	745	896	87
Total Hardness as ($CaCO_3$)	mg/L	3	407	354	463	55
Hydroxide (OH)	mg/L	0				
Iron (Fe)	mg/L	3	0.109	0.054	0.206	0.085
Magnesium (Mg)	mg/L	3	61.2	52.8	72.1	9.9
Nitrate + Nitrite as N	mg/L	3	0.013	0.003	0.026	0.012
Total Kjeldahl Nitrogen as N	mg/L	3	2.873	2.51	3.52	0.561
Total Nitrogen as N	mg/L	3	2.88	2.52	3.55	0.573
pH		3	9.033	8.8	9.2	0.208
Total Phosphorus as P	mg/L	3	0.7	0.615	0.805	0.097
Potassium (K)	mg/L	3	14.6	13.1	15.4	1.3
Sodium (Na)	mg/L	3	115	100	138	20
Sulfate (SO4)	mg/L	3	324	288	368	41

[1]Equal to the lower reporting limit

Limiting Nutrients: The water quality samples collected in 1991, 1992 and 2011 indicate that Epping-Spring Brook Dam is nitrogen limited (Figure 6). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen to total phosphorus is at nutrient equilibrium at a ratio of 15 to 1. When the ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

The historical 1991-1992 total nitrogen to total phosphorus ratio for Epping-Spring Brook Dam is a flat 4 and in 2011 the ratio ranged between 3 and 9 clearly indicating nitrogen limitation using the LWQA criteria.

Trophic Status Assessment: Based on the chlorophyll-a data collected in 1991, 1992 and 2011, Epping-Spring Brook Dam's trophic status is estimated as eutrophic with no recognizable trend. This assessment is supported by the Secchi Disk measurements but not the total phosphorus concentrations. Total phosphorus concentrations indicate a hypereutrophic condition with an improving trend towards eutrophic (Figure 7). The ranges of Trophic Status Index (TSI) scores are 41 to 62 for chlorophyll-a, 47 to 63 for secchi disk, and 70 to 100 for total phosphorus.

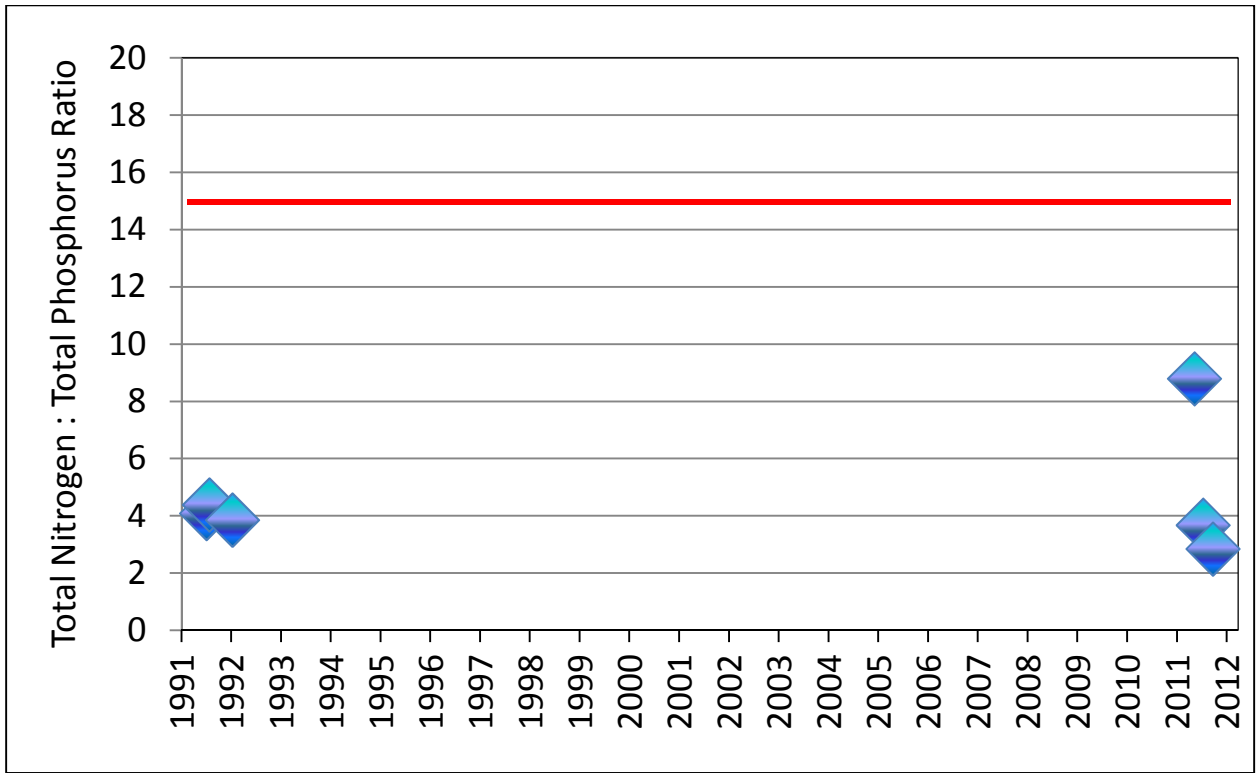

Figure 6. Epping-Spring Brook Dam's Total Nitrogen to Total Phosphorus Ratio

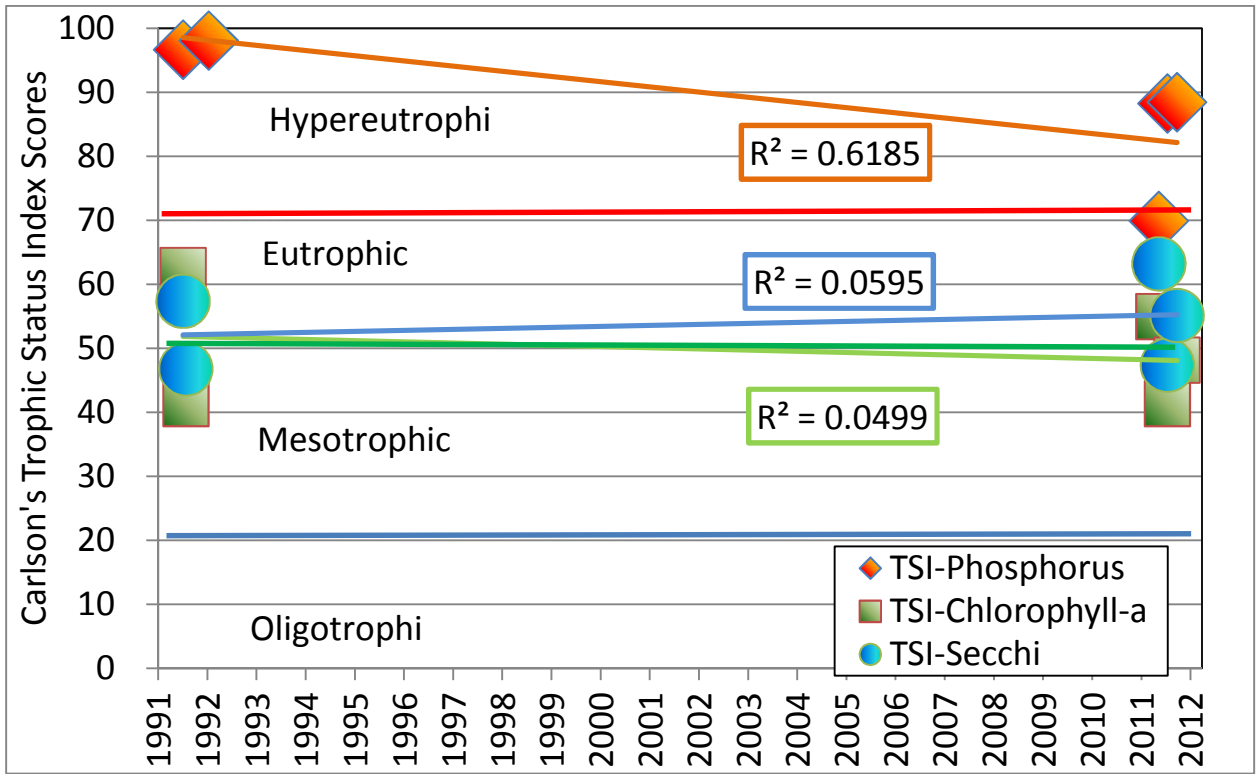

Figure 7. Epping-Spring Brook Dam's TSI Scores

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