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# Limnology of Selected South Dakota Lakes

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# LIMNOLOGY OF SELECTED SOUTH DAKOTA LAKES

BY

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LIMNOLOGY OF SELECTED SOUTH DAKOTA LAKES

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser Date

Wildlife Management Department

LIMNOLOGY OF SELECTED SOUTH DAKOTA LAKES

Abstract

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Physical, chemical, and biological aspects of 45 lakes in South Dakota were studied from July 1965 to July 1967. Maximum water temperature at the surface reached 28 C. Most of the lakes studied exhibited continous circulation except when ice covered. Thermocline formation was observed in six of the lakes. Light transmission was influenced by turbidity, and varied greatly within individual lakes and among lakes. Dissolved oxygen concentrations ranged from near saturation to less than the recommended minimum for fish life. All lakes studied were basic ranging from a pH of 7.1 to 11.3. Specific conductance of lakes occupying open basins was lowest in the unglaciated area west of the Missouri River (70-590 micromhos at 25 C) and highest in Mankato drift of the Wisconsin ice age (330-1260 micromhos at 25 C). Concentrations of major anions and cations tended to follow patterns which were associated with major physical divisions of the state or various drift types of the Wisconsin ice age. Trace elements were found in most lakes studied. Those lakes which developed dense summer blooms of phytoplankton were usually dominated by the blue-green algae Aphanizomenon or Microcystis. The maximum concentration of Chlorophyll *a* observed was 19.1 mg/l. Chlorophyll concentrations were generally higher in lakes east of the Missouri River.

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TABLE OF CONTENTS

| | Page |
|---|---|
| INTRODUCTION | 1 |
| STUDY AREA | 2 |
| Physical Divisions | 6 |
| METHODS | 14 |
| RESULTS AND DISCUSSION | 16 |
| Physical Considerations | 16 |
| Temperature | 16 |
| Light Transmission and Turbidity | 18 |
| Chemical Considerations | 28 |
| Dissolved Oxygen | 28 |
| pH | 31 |
| Specific Conductance | 31 |
| Alkalinity | 39 |
| Sulfate | 43 |
| Chloride | 48 |
| Hardness Relationships | 51 |
| Calcium and Magnesium | 54 |
| Sodium and Potassium | 58 |
| Nitrogen and Phosphorous | 61 |
| Iron and Manganese | 66 |
| Silica | 66 |
| Aluminum, Barium, Boron, Copper | 71 |

| | Page |
|---|---|
| Biological Considerations . . . . . . . . . . . . . . | 74 |
| Chlorophyll Concentrations . . . . . . . . . . . | 74 |
| SUMMARY . . . . . . . . . . . . . . . . . . . . . . . . | 80 |
| LITERATURE CITED . . . . . . . . . . . . . . . . . . . . | 83 |
| APPENDIX . . . . . . . . . . . . . . . . . . . . . . . . | 87 |

LIST OF TABLES


| Table | | Page |
|---|---|---|
| 1 | Morphometry of lakes studied . . . . . . . . . . | 7 |
| 2 | Summary of data pertaining to turbidity and light transmission. Light transmission is expressed as relative intensity of surface radiation . . . . . . . . . . . . . . . . . . . . | 20 |
| 3 | Ranges of dissolved oxygen concentrations from top to bottom of lakes studied, July 1965 to July 1967 . . . . . . . . . . . . . . . . . . . . | 29 |
| 4 | Average pH of lakes studied, July 1965 to July 1967 . . . . . . . . . . . . . . . . . . . . | 32 |
| 5 | Average specific conductance of lake waters (micromhos per centimeter at 25 C), July 1965 to July 1967 . . . . . . . . . . . . . . . . . . . | 35 |
| 6 | Average carbonate and bicarbonate alkalinities (as mg/l $CaCO_3$) of lakes studied, July 1965 to July 1967 . . . . . . . . . . . . . . . . . . . . | 41 |
| 7 | Average sulfate ion concentrations (mg/l) of lakes studied, July 1965 to July 1967 . . . . . | 45 |
| 8 | Mean chloride ion concentrations (mg/l) of lakes studied, July 1965 to July 1967 . . . . . | 50 |
| 9 | Average concentrations of total and non-carbonate hardness (as mg/l $CaCO_3$) from lakes studied, July 1965 to July 1967 . . . . . . . . | 52 |

| Table | | Page |
|---|---|---|
| 10 | Average concentrations of calcium and magnesium (mg/l) from lakes studied, July 1965 to July 1967 . . . . . . . . . . . . . . . . | 55 |
| 11 | Average concentrations of sodium and potassium (mg/l) from lakes studied, July 1965 to July 1967 . . . . . . . . . . . . . . . . . . . . . . | 59 |
| 12 | Average concentrations of ammonia and nitrate (as mg/l nitrogen) from lakes studied, July 1965 to July 1967 . . . . . . . . . . . . . . . | 64 |
| 13 | Average total phosphate concentrations (mg/l) of lakes studied, July 1965 to July 1967 . . . | 67 |
| 14 | Mean concentrations of iron, manganese, and silica (mg/l) of lakes studied, July 1965 to July 1967 . . . . . . . . . . . . . . . . . . . . | 69 |
| 15 | Mean concentrations of trace elements (mg/l) from lakes studied, July 1965 to July 1967 . . | 72 |
| 16 | Average concentrations of chlorophyll _a_ (mg/l) from lakes studied, July 1965 to July 1967 . . | 75 |
| 17 | Comparison of highest average chlorophyll _a_, mean total nitrogen, and mean total phosphate concentrations (mg/l) of lakes studied, July 1965 to July 1967 . . . . . . . . . . . . . . . | 78 |

## LIST OF FIGURES


| Figure | | Page |
|---|---|---|
| 1 | Average annual precipitation and air temperature for South Dakota . . . . . . . . . . . . . . . . | 3 |
| 2 | Average annual lake evaporation in inches (Period 1946-1955) . . . . . . . . . . . . . . . | 4 |
| 3 | Physical divisions of South Dakota . . . . . . . | 5 |
| 4 | Vertical temperature distributions of second order lakes, by season, July 1965 to July 1967 . | 17 |
| 5 | Relation between depth and light transmission, expressed as relative intensity of surface light, for a series of South Dakota lakes . . . | 26 |
| 6 | Mean specific conductance of South Dakota lakes | 38 |
| 7 | Predominant anions (mg/l) of lakes studied . . . | 47 |
| 8 | Predominant cations (mg/l) of lakes studied . . | 57 |

# INTRODUCTION

An understanding of limnological relationships including physical, chemical, and biological aspects is essential for maximum utilization of water resources. Physical and chemical parameters should be determined first to provide a basis for biotic evaluations. Physical factors are important as they limit length of growing season and affect the chemical and biological constituents. Hayes (1964) found that area and depth of lakes affect standing crop. The level of total dissolved solids is important in determining lake productivity (Northcote and Larkin, 1956). Ball (1948), Carlander (1955), and Turner (1960) reported that standing crop of fishes are directly related to levels of alkalinity in lakes and ponds. Moyle (1956) showed that the type of biological community is influenced by concentrations of chemical nutrients.

Limnological relationships have been intensively studied in other areas, but such information is limited for South Dakota waters. A comparative study of selected physical, chemical, and biological aspects of 45 lakes in South Dakota was initiated in July 1965 and terminated July 1967. The influences of climatic conditions, soil groups, geologic associations, and lake morphometry on biological, physical, and especially chemical factors were considered.

# STUDY AREA

South Dakota has a continental climate with extremes of summer heat, winter cold, and extreme temperature fluctuations. The average number of days without frost varies from 130 days in the northern part of the state to 160 days in the southeastern part (Westin, Puhr, and Buntley, 1959). Annual precipitation varies from 14 inches in the northwest to 24 inches in the southeast, and average temperature varies from 43 to 45 F (Figure 1). Average annual lake evaporation varies from 32 to 44 inches from northeast to southwest (Figure 2). Climatic classification ranges from Moist subhumid in the southeast to Semiarid in the west (Thornthwaite, 1948).

The state can be divided into two main areas; the Central Lowland which occupies the eastern one third, and the Missouri Plateau (Figure 3). The Central Lowland and that portion of the Missouri Plateau east of the Missouri River were glaciated during the Wisconsin glacial age. The Missouri Plateau west of the Missouri River is unglaciated except for localized areas near the river. Soils of the Central Lowland belong to the Chernozem group, while the Missouri Plateau has mainly Chestnut soils.

The Central Lowland and Missouri Plateau were divided into 12 physical divisions. These physical divisions and the natural land forms were described by Flint (1955) and Rothrock (1943). Soil groups within these divisions were described by Westin, et al. (1959).

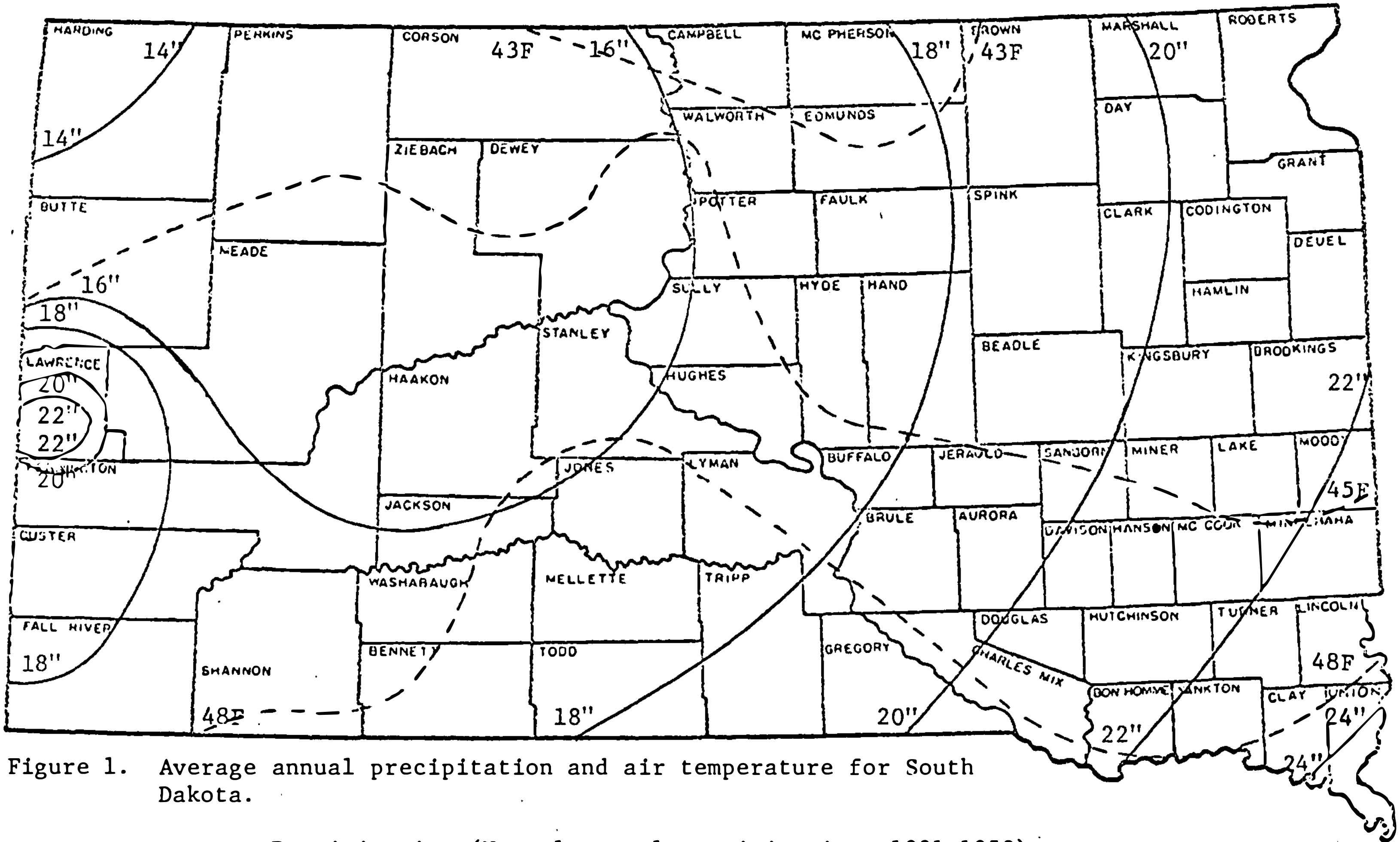


Figure 1. Average annual precipitation and air temperature for South Dakota.

______ Precipitation (Normal annual precipitation, 1921-1950).
\- - - Temperature.
Source: U. S. Weather Bureau Records.

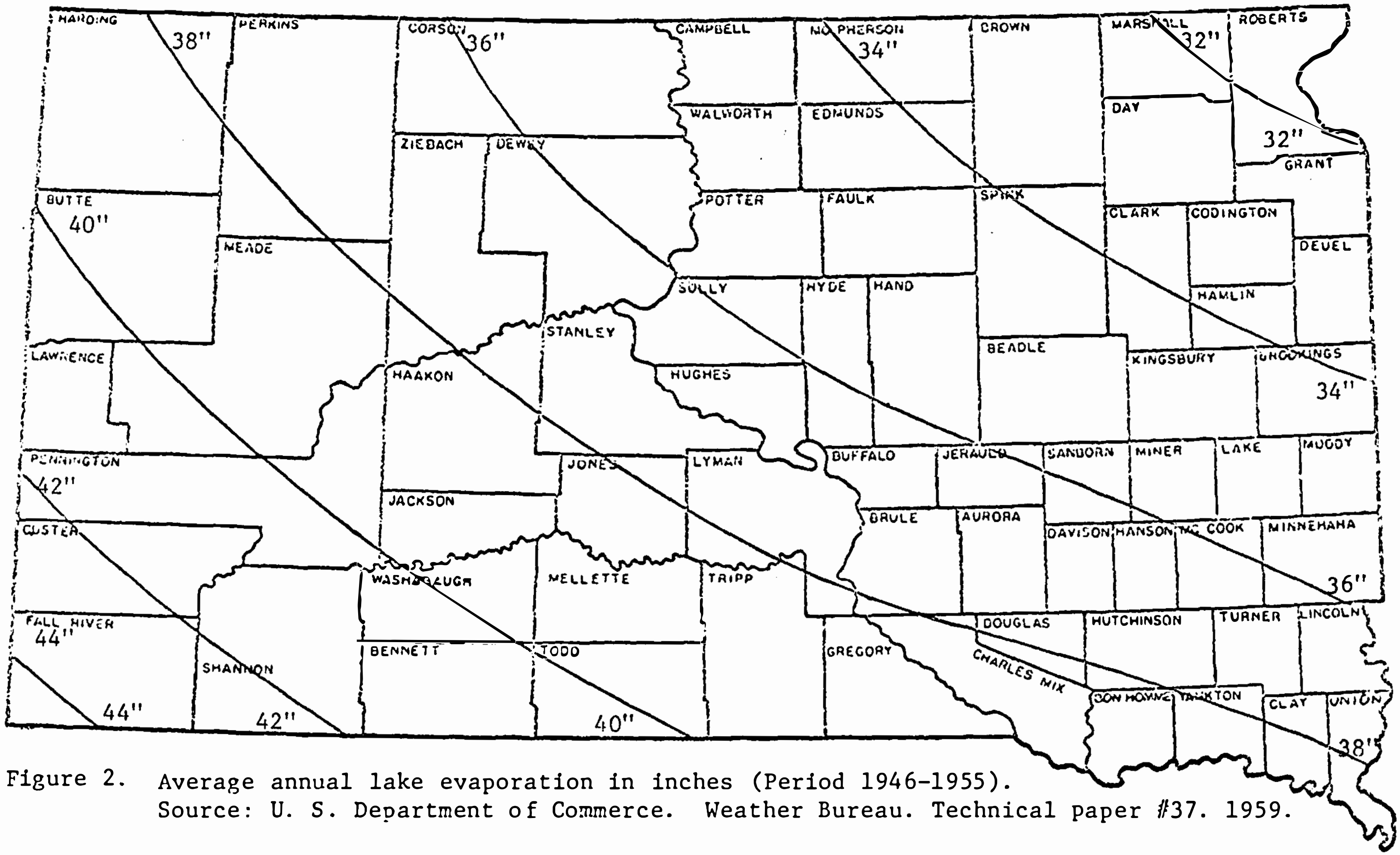


Figure 2. Average annual lake evaporation in inches (Period 1946-1955).
Source: U. S. Department of Commerce. Weather Bureau. Technical paper #37. 1959.

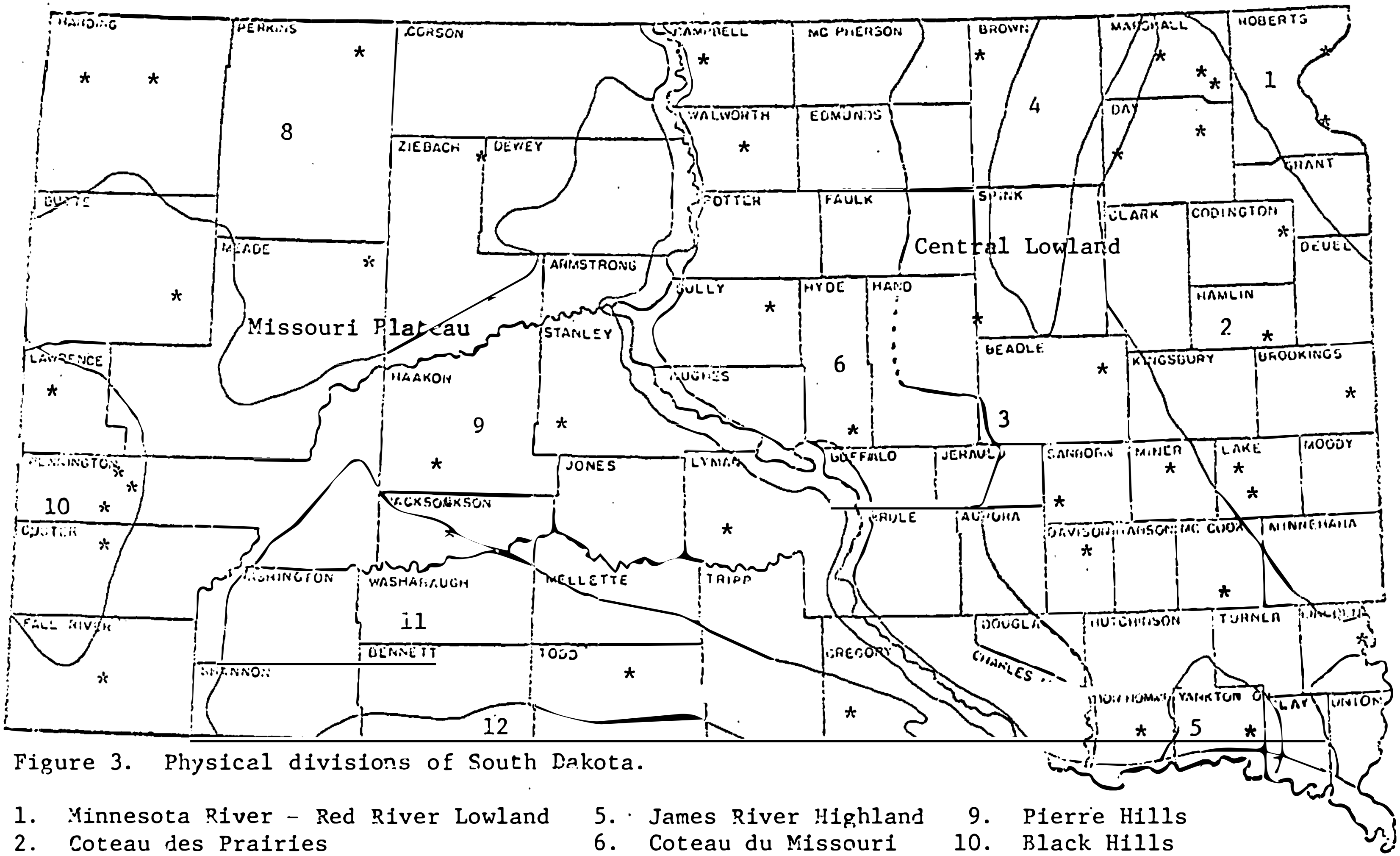


Figure 3. Physical divisions of South Dakota.

1. Minnesota River - Red River Lowland
2. Coteau des Prairies
3. James River Lowland
4. Lake Dakota Plain
5. James River Highland
6. Coteau du Missouri
7. Missouri River Trench
8. Northern Plateaus
9. Pierre Hills
10. Black Hills
11. Southern Plateaus
12. Sand Hills

Source: Flint, R. F. Prof. Paper 262, USGS.

* Location of lakes studied.

Locations of the 45 lakes studied and their positions in physical divisions of South Dakota are shown in Figure 3; morphometric data are given in Table 1.

## Physical Divisions

### Minnesota River - Red River Lowland

Located in extreme northeastern South Dakota, this division is a broad valley-like area 900 to 1,100 feet above sea level. The continental divide between drainage to the Arctic Ocean and to the Gulf of Mexico is midway between Lake Traverse and Bigstone Lake. The trench occupied by these lakes was formed by overflow from glacial Lake Agassiz. Lakes studied in this division include Bigstone and Traverse.

### Coteau des Prairies

This division is a plateau irregularly covered with glacial drift. Its rough surface is attributed to morainic deposits of the Wisconsin ice age. The coteau slopes gently to the south where it is drained by the Big Sioux river. Elevations range from 1,600 to 2,000 feet above sea level. Lakes studied in this area were; Buffalo, Enemy Swim, Hendricks, Herman, Madison, Poinsett, Punished Woman, Roy, and White.

The Coteau des Prairies and the Minnesota River - Red River Lowland lie in Chernozem soil which has developed in a cool moist climate. Normal annual precipitation is 20 to 22 inches, while

Table 1. Morphometry of lakes studied.

| Lake | County | Type | Surface Area (acres) | Depth in Feet | |
|---|---|---|---|---|---|
| | | | | Maximum | Average |
| Alvin | Lincoln | Artificial | 100 | 30 | 12 |
| Amsden | Day | Artificial | 240 | 27 | 9 |
| Angostura | Fall River | Artificial | 5,000 | 79 | 30 |
| Bigstone | Roberts | Natural | 21,120 | 15 | 10 |
| Bismarck | Custer | Artificial | 22 | 24 | 16 |
| Brakke | Lyman | Artificial | 135 | 18 | 8 |
| Buffalo | Marshall | Natural | 1,780 | 15 | 6 |
| Burke | Gregory | Artificial | 27 | 16 | 8 |
| Byron | Beadle | Natural | 1,300 | 10 | 8 |
| Carthage | Miner | Artificial | 38 | 14 | 8 |
| Catron Pond (sw 1/4 Sec 19, T18N, R2E) | Harding | Artificial | 30 | 14 | 6 |
| Cottonwood | Sully | Artificial | 1,000 | 11 | 6 |
| Durkee | Meade | Artificial | 80 | 16 | 6 |
| Elm | Brown | Artificial | 1,187 | 35 | 18 |
| Enemy Swim | Day | Natural | 1,975 | 26 | 10 |
| Gardner | Harding | Artificial | 210 | 20 | 10 |
| Hayes | Stanley | Artificial | 100 | 23 | 10 |
| Henry | Bon Homme | Artificial | 70 | 30 | 15 |
| Hendricks | Brookings | Natural | 1,600 | 10 | 5 |
| Herman | Lake | Natural | 1,350 | 8 | 4 |
| Hiddenwood | Walworth | Artificial | 30 | 15 | 5 |
| Horse Thief | Pennington | Artificial | 19 | 64 | 24 |
| Iron Creek | Lawrence | Artificial | 23 | 32 | 15 |
| Isabell | Dewey | Artificial | 130 | 20 | 8 |
| Kadoka | Jackson | Artificial | 120 | 14 | 6 |
| Madison | Lake | Natural | 3,200 | 17 | 8 |
| Merindahl | Yankton | Artificial | 110 | 30 | 13 |
| Mission | Todd | Artificial | 62 | 12 | 6 |

Table 1. (continued)

| Lake | County | Type | Surface Area (acres) | Depth in Feet | |
|---|---|---|---|---|---|
| | | | | Maximum | Average |
| Mitchell | Davison | Artificial | 670 | 29 | 15 |
| Newell | Butte | Artificial | 164 | 35 | 13 |
| Pactola | Pennington | Artificial | 797 | 150 | 76 |
| Pocasse | Campbell | Artificial | | 30 | |
| Poinsett | Hamlin | Natural | 8,000 | 18 | 6 |
| Punished Woman | Codington | Natural | 400 | 8 | 5 |
| Rose Hill | Hand | Artificial | 75 | 32 | 10 |
| Roy | Marshall | Artificial | 200 | 20 | 8 |
| Shadehill | Perkins | Artificial | 5,000 | 90 | 45 |
| Sheridan | Pennington | Artificial | 384 | 90 | 41 |
| Stephen Mission Dam | Hyde | Artificial | 120 | 18 | 8 |
| Traverse | Roberts | Natural | 11,000 | 12 | 9 |
| Twin | Sanborn | Natural | 300 | 12 | 6 |
| Twin | Spink | Natural | 1,500 | 17 | 6 |
| Vermillion | McCook | Artificial | 550 | 23 | 12 |
| Waggoner | Haakon | Artificial | 107 | 30 | 14 |
| White | Marshall | Artificial | 200 | 20 | 8 |

Source: South Dakota Department of Game, Fish, and Parks records.

average temperature is 43 to 45 F. Average annual lake evaporation is 30 to 34 inches. These conditions favor accumulation of organic matter and retard its destruction. Soils of this region are differentiated from soils which adjoin them on the west by having 1) deeper lying horizons of carbonate accumulation, 2) deeper lying horizons of salt accumulation, and 3) higher content of organic matter and total nitrogen in the surface horizons (Westin, et al., 1959).

James River Lowland

The James River Lowland is a gently undulating plain lying lower than the Coteau des Prairies or the Coteau du Missouri with elevations from 1,300 to 1,400 feet. The area is drained to the south by the James River. Water falling on most of the basin never reaches the stream valley because it is retained in glacier-built hollows until it evaporates or sinks into the ground.

Climatic conditions in the James River Lowland vary. Normal annual precipitation in the north is 18 to 20 inches while average annual temperature varies from 43 to 45 F. Lakes studied in this northern area: Amsden, Byron, Carthage, Elm, Mitchell, Twin Lake in Spink County, and Twin Lake in Sanborn County lie in Chernozem soils which developed in a drier, cooler environment than is found in the southern James River Lowland. The southern Lowland receives 20 to 22 inches normal annual precipitation, and average temperature is 45 to 48 F. These warmer and more moist conditions result in a higher rate of organic matter destruction and nitrogen release. The depth of carbonate leaching in this region is greater than in any of the other regions. Lakes Alvin, Henry, and Vermillion were in this warm, moist area of the Lowland.

James River Highland

The area south of the Lowland is the James River Highland. This division is composed of three ridges of drift covered bedrock. These ridges: Turkey, James, and Yankton are underlain by relatively resistant chalk and limestone. Climatic conditions are similar to those found in the southern James River Lowland. Lake Merindahl was studied in this division.

Coteau du Missouri

The portion of the Missouri Plateau lying east of the Missouri River is the Coteau du Missouri. This highland area is covered with glacial drift and underlain by Pierre shale and other formations. Elevations range to heights of over 2,100 feet above sea level. Drainage of the area is eastward to the James River basin and westward to the Missouri River basin. All lakes studied in this area lie in Chestnut soils which are characterized by lighter color and less leaching of carbonates than Chernozem soils. Lakes studied in this division include Cottonwood, Hiddenwood, Pocasse, Rose Hill, and Stephen Mission.

Missouri Trench

The Missouri Trench averages slightly over a mile in width with the valley floor 300 to 600 feet below the tops of the dissected bluffs. A series of man-made reservoirs occupies the trench. These reservoirs were not studied.

Missouri Plateau

The Missouri Plateau is the main plateau region from which the Coteau du Missouri was separated by the Missouri River. This plateau occupies the remainder of the state except for the Black Hills and the Sand Hills. Elevations range from approximately 2,000 feet near the Missouri River to over 3,000 feet in the west. All major drainage is to the east. There are three major divisions of the Missouri Plateau in South Dakota.

Southern Plateaus

The southern division of the Missouri Plateau is the Southern Plateaus. Lakes Burke and Mission were studied in this area. These lakes lie in an extension of the Chernozem soils. Average annual precipitation is 18 to 20 inches, while the mean temperature varies from 45 to 48 F.

Pierre Hills

The central portion of the Missouri Plateau is the Pierre Hills. It consists of a series of smooth hills and ridges with rounded tops. This area is underlain almost entirely by Pierre shale which breaks down into a dark pliable clay. The Bad, Cheyenne, and White rivers drain the area eastward to the Missouri River. Lakes studied in the Pierre Hills include Brakke, Hayes, Kadoka, Newell, and Waggoner.

## Northern Plateaus

The Northern Plateaus is a series of plateaus and isolated buttes underlain by Fox Hills sandstone and younger Cretaceous strata. The area is drained eastward by the Grand and Moreau Rivers. The Little Missouri river crosses the northwestern corner of the area, and drains northward. Catron Pond, Durkee, Gardner, Isabell, and Shadehill lakes were studied in this division.

Chestnut soils of the Northern Plateaus and the Pierre Hills receive 14 to 18 inches of moisture annually. Mean temperatures of this area range from 43 to 48 F.

## Black Hills

The Black Hills is a mountainous region formed simultaneously with the Rocky Mountains. It consists of four general areas: 1) a central core of metamorphic and igneous rocks encircled by 2) rings of sedimentary rocks which form high plateaus on the north and west and steep ridges on the east and south, 3) the Red Valley, and 4) the Hogback Ridge. Grey Wooded soils occur in local alluvial positions in the central core and in places on the broad limestone plateaus. These soils, developed in a humid climate with annual precipitation of 20 to 25 inches and an average temperature of 40 to 45 F, have deep carbonate leaching. Chestnut soils occur in the Red Valley. Lakes studied in the Black Hills were Angostura, Bismarck, Horse Thief, Iron Creek, Pactola, and Sheridan.

# METHODS

Measurements of selected physical parameters and water samples for laboratory analysis were obtained quarterly. Each lake was studied for a one-year period. Lakes in the northern half of South Dakota were sampled from July 1965 to July 1966, and lakes in the southern area were sampled from July 1966 to July 1967. Samples were taken at one to five stations on each lake; the number of stations was determined by lake size. Water samples were taken at 1.5 meter depth intervals in shallow lakes and at the surface, mid-depth, and bottom of deeper lakes. A composite sample from each depth interval was analyzed in the laboratory since time precluded analysis of individual samples. Composite samples were frozen in plastic bags until laboratory analyses were conducted. Analyses of alkalinity, dissolved oxygen concentration, pH, light penetration, and temperature patterns were conducted in the field. Temperature was measured with an electrical resistance bridge thermometer. Light transmission was measured with a relative irradiance meter powered by two photocells in circuit with a galvanometer and variable potentiometer.

Except as otherwise noted chemical analyses followed procedures outlined by Hach Chemical Co. (Hach Chemical Co., Cat. No. 9). Volumetric titrations were used for hardness, alkalinity, sulfate, and chloride. Other Hach procedures utilized were colorometric. Color development was measured with a Bausch & Lomb "Spectronic 20" spectrophotometer. The mercuric nitrate method was used for chloride determinations. Sulfate concentrations were determined by titrating with barium perchlorate using Thorin as an indicator (Fritz, 1955). Analysis for dissolved oxygen, phosphate, sodium, and potassium were conducted according to Standard Methods for the Examination of Water and Wastewater (Am. Pub. Health Assoc., 1965). Dissolved oxygen concentrations were determined by the Winkler method. The stannous chloride method for phosphate determination was used only from July 1966 to July 1967. Sodium and potassium concentrations were determined by flame photometry.

Samples for determination of chlorophyll concentrations were obtained in the field by filtering one liter of the composite sample through a cellulose Millipore filter having a pore size of 0.47 microns. Pigments were extracted with 90 per cent acetone according to procedures outlined by the National Research Council (1964). Concentrations of pigments were determined by the method described by Richards with Thompson (1952).

# RESULTS AND DISCUSSION

## Physical Considerations

### Temperature

The lakes studied were second or third order temperate lakes as defined in Welch (1952). Temperature of the bottom waters of second order lakes varies but not far from 4 C. These lakes have two circulation periods each year. Third order lakes have the temperature of the bottom waters very similar to that of surface water, and exhibit continuous circulation except when ice covered.

Most of the lakes studied were third order lakes since prevailing winds maintained continuous circulation while the water was open. Third order lakes had small temperature variations from top to bottom. This range seldom exceeded 3 C at any given time.

The vertical temperature distributions of second order lakes included in this study are shown in Figure 4. These lakes all exhibited thermocline formation and low hypolymnetic temperatures. Depth to the top of thermocline varied from three to ten meters in separate lakes.

The maximum surface temperature recorded during the study was 28 C. Temperatures of 23 to 25 C were common throughout the summer months. Most lakes studied developed inverse temperature gradients under ice cover. These inverse gradients ranged from 1 C at the surface to about 4 C at the bottom. Inverse temperature gradients may have occurred in all lakes studied but were not observed since sampling was limited to once per season.

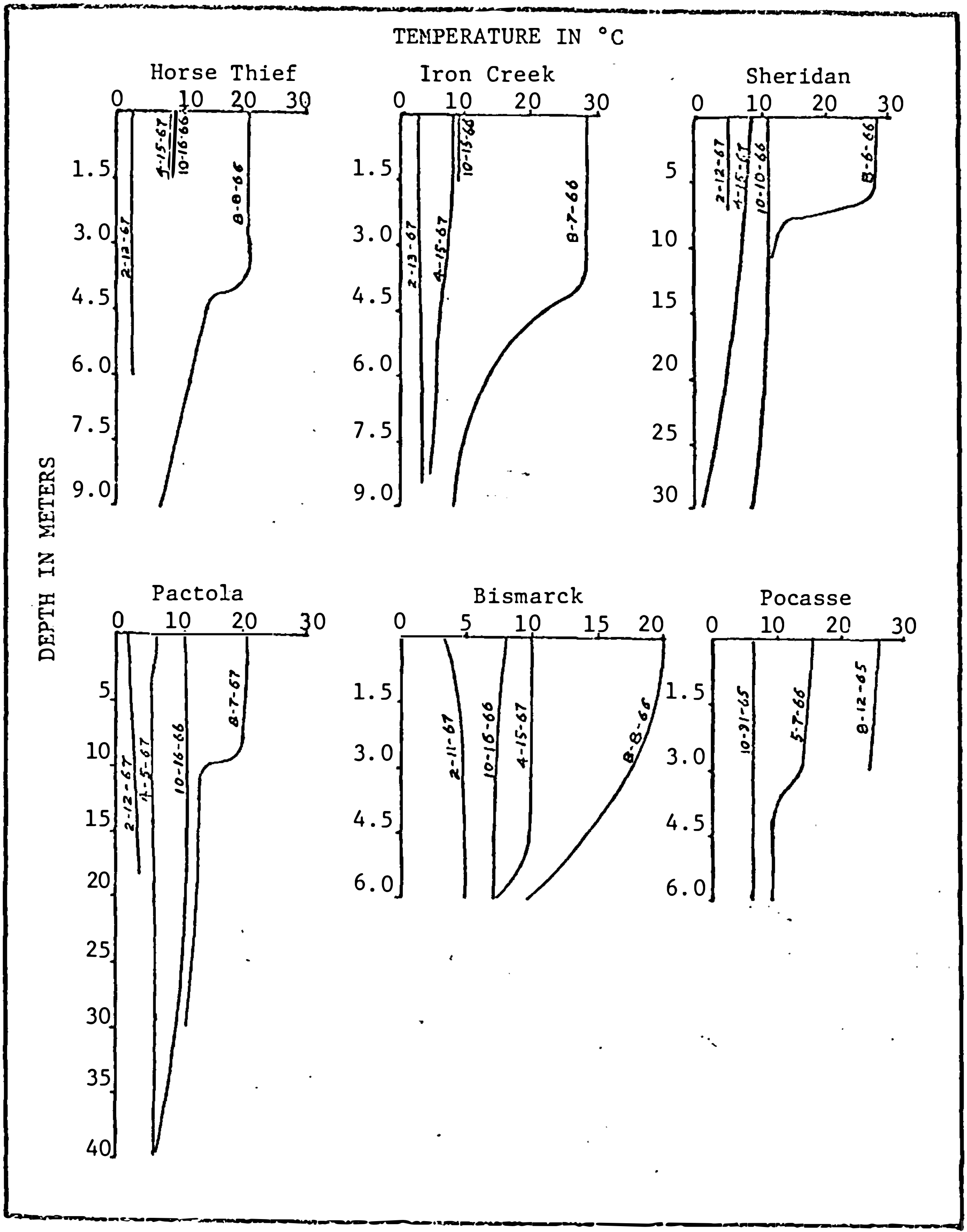


Figure 4. Vertical temperature distributions of second order lakes, by season, July 1965 to July 1967.

Periods of complete ice cover are considerably longer in the northern than in the southern parts of the state. Ice formation in the northeast occurred in mid-November 1965, and break up occurred in mid-April 1966. Ice formed on lakes in the southern portions of the state in mid-November 1966, but ice break up was complete by April 1, 1967. Maximum ice thickness encountered ranged from over 100 centimeters in the northeast to about 20 centimeters in the southwest.

## Light Transmission and Turbidity

Light available for photosynthesis affects the entire aquatic ecosystem through its influence on primary productivity. Available light is dependent upon surface light intensity and subsequent extinction during penetration of water. In general, as water depth increases arithmetically the available light decreases geometrically (Welch, 1952). Many influences modify this relationship, but this rule usually held true for lakes studied. Light transmission values were determined during periods of open water.

Turbidity is the opaqueness of water resulting from the presence of suspended materials. These materials may be settling or non-settling and their sources are innumerable. Among the most important of these are detritus, fine sand, particles of clay, and plankton. Turbidity measurements (Jackson Turbidity Units) are expressed as averages of all depths sampled.

I believe the turbidity readings are biased since all samples were frozen and taken to the laboratory before turbidity was determined. As a check on the reliability of this method turbidity determinations were made on one set of samples before and after freezing for one month at -15 C. After freezing turbidity measurements were 31 per cent higher than before freezing.

Data from series of light transmission and turbidity measurements for lakes studied are shown in Table 2. Light transmission is expressed as relative intensity of light falling on the surface. It is apparent from these data that light transmission varies greatly by season within individual lakes. In general, light transmission shows an inverse relationship to the degree of turbidity. Turbidity was generally lowest in the winter and highest in the summer and fall. This is probably due to stirring of bottom sediments by wind action and the development of dense algal blooms in some lakes in the late summer and fall.

Hutchinson (1957) states that some investigators have concluded that it is better to neglect supposed variations in vertical illumination due to the height of the sun. They claim that the observed values of the slope of the line obtained by plotting intensity logarithmically against depth on semilogarithmic paper do not vary with the angular height of the sun.

The relation between light transmission and depth for some of the lakes studied is shown in Figure 5. This shows a wide variability in light transmission in lakes throughout the state; the depth to

Table 2. Summary of data pertaining to turbidity and light transmission. Light transmission is expressed as relative intensity of surface radiation.

| Lake and Date | Turbidity (J.T.U.) | Light Transmission: % at 4 cm. | Light Transmission: Depth of 1% transmission (in meters) | Lake and Date | Turbidity (J.T.U.) | Light Transmission: % at 4 cm. | Light Transmission: Depth of 1% transmission (in meters) |
|---|---|---|---|---|---|---|---|
| Alvin | | | | Bismarck | | | |
| Aug. 15, 1966 | 59 | 50 | 0.9 | Aug. 8, 1966 | 36 | 50 | 4.1 |
| Nov. 5, 1966 | 48 | 60 | 2.1 | Oct. 16, 1966 | 47 | 70 | 2.2 |
| Feb. 8, 1967 | 23 | | | Feb. 11, 1967 | 43 | | |
| Apr. 5, 1967 | 52 | 50 | 1.9 | Apr. 15, 1967 | 39 | 54 | 1.4 |
| Amsden | | | | Brakke | | | |
| Aug. 6, 1965 | 24 | 70 | 3.5 | Aug. 10, 1966 | 61 | 45 | 1.8 |
| Nov. 7, 1965 | 20 | 71 | 3.9 | Oct. 8, 1966 | 45 | 61 | 2.4 |
| Feb. 19, 1966 | 11 | | | Feb. 9, 1967 | 26 | | |
| May 6, 1966 | | 65 | 1.1 | Apr. 12, 1967 | 49 | 45 | 1.0 |
| Angostura | | | | Buffalo | | | |
| Aug. 9, 1966 | 23 | 66 | 5.3 | July 30, 1965 | 61 | 73 | 2.8 |
| Oct. 17, 1966 | 20 | 70 | 6.6 | Nov. 26, 1965 | 30 | | |
| Feb. 11, 1967 | 13 | | | Feb. 11, 1966 | 30 | | |
| Apr. 16, 1967 | 22 | 54 | 7.5 | Apr. 24, 1966 | 26 | 65 | 3.7 |
| Bigstone | | | | Burke | | | |
| July 14, 1965 | 50 | 35 | 1.0 | Aug. 11, 1966 | | 57 | 1.5 |
| Nov. 11, 1965 | 54 | 37 | 3.9 | Oct. 9, 1966 | 45 | 62 | 2.7 |
| Feb. 18, 1966 | 65 | | | Feb. 9, 1967 | 60 | | |
| Apr. 23, 1966 | | 74 | 2.9 | Apr. 11, 1967 | 26 | 50 | 4.4 |

Table 2. (continued)

| Lake and Date | Turbidity (J.T.U.) | Light Transmission % at 4 cm. | Light Transmission Depth of 1% transmission (in meters) | Lake and Date | Turbidity (J.T.U.) | Light Transmission % at 4 cm. | Light Transmission Depth of 1% transmission (in meters) |
|---|---|---|---|---|---|---|---|
| Byron | | | | Durkee | | | |
| Aug. 8, 1965 | 25 | 42 | 1.1 | Aug. 28, 1965 | 35 | 60 | 2.1 |
| Nov. 5, 1965 | 55 | 43 | 1.1 | Oct. 16, 1965 | 44 | 61 | 3.2 |
| Feb. 21, 1966 | 42 | | | Feb. 25, 1966 | 23 | | |
| June 3, 1966 | 22 | 56 | 3.0 | May 10, 1966 | 22 | 58 | 2.3 |
| Carthage | | | | Elm | | | |
| July 31, 1966 | 34 | 70 | 4.5 | Aug. 6, 1965 | 35 | 83 | 3.0 |
| Nov. 7, 1966 | 48 | | | Nov. 6, 1965 | 33 | 65 | 3.7 |
| Feb. 3, 1967 | 44 | | | Feb. 19, 1966 | 12 | | |
| Apr. 18, 1967 | 58 | 65 | 1.9 | May 7, 1966 | 44 | 60 | 1.9 |
| Catron Pond | | | | Enemy Swim | | | |
| Aug. 26, 1965 | 104 | 52 | 1.2 | July 29, 1965 | 49 | 85 | 5.8 |
| Oct. 18, 1965 | 44 | 72 | 1.3 | Nov. 13, 1965 | 50 | 57 | 6.5 |
| Feb. 26, 1966 | 140 | | | Feb. 11, 1966 | 16 | | |
| May 9, 1966 | 68 | 65 | 3.5 | Apr. 25, 1966 | 11 | 68 | 7.1 |
| Cottonwood | | | | Gardner | | | |
| Aug. 11, 1965 | 54 | 54 | 0.9 | Aug. 26, 1965 | 53 | 63 | 4.9 |
| Oct. 30, 1965 | 30 | 63 | 1.9 | Oct. 18, 1965 | 48 | 69 | 3.9 |
| Feb. 20, 1966 | 80 | | | Feb. 26, 1965 | 32 | | |
| June 4, 1966 | 42 | 48 | 1.4 | May 9, 1966 | 30 | 71 | 2.0 |

Table 2. (continued)

| Lake and Date | Turbidity (J.T.U.) | Light Transmission % at 4 cm. | Light Transmission Depth of 1% transmission (in meters) |
|---|---|---|---|
| Hayes | | | |
| Aug. 17, 1966 | 37 | 76 | 3.9 |
| Oct. 8, 1966 | 49 | 60 | 5.4 |
| Feb. 13, 1967 | 56 | | |
| Apr. 12, 1967 | 51 | 60 | 3.0 |
| Henry | | | |
| Apr. 16, 1966 | 25 | 60 | 3.3 |
| Nov. 6, 1966 | 22 | 80 | 3.7 |
| Feb. 5, 1967 | 30 | | |
| Apr. 6, 1967 | 44 | | |
| Hendricks | | | |
| July 27, 1965 | 111 | 71 | 1.0 |
| Dec. 2, 1965 | 55 | | |
| Feb. 19, 1966 | 61 | | |
| Apr. 22, 1966 | | 50 | 0.8 |
| Herman | | | |
| July 16, 1966 | 81 | 52 | 1.8 |
| Nov. 4, 1966 | 82 | 50 | 0.9 |
| Feb. 3, 1967 | 54 | | |
| Apr. 4, 1967 | 81 | | |
| Hiddenwood | | | |
| Aug. 29, 1965 | 65 | 70 | 1.6 |
| Oct. 30, 1965 | 90 | 42 | 0.8 |
| Feb. 20, 1965 | 47 | | |
| May 7, 1966 | 32 | 60 | 1.8 |
| Horse Thief | | | |
| Aug. 8, 1966 | 23 | 55 | 5.1 |
| Oct. 16, 1966 | 39 | | |
| Feb. 12, 1967 | 56 | | |
| Apr. 15, 1967 | | | |
| Iron Creek | | | |
| Aug. 7, 1966 | 24 | 60 | 5.2 |
| Oct. 15, 1966 | 22 | | |
| Feb. 13, 1967 | 23 | | |
| Apr. 15, 1967 | 23 | 60 | 2.5 |
| Isabell | | | |
| Aug. 29, 1965 | 41 | 62 | 1.8 |
| Nov. 19, 1965 | 37 | 62 | 4.1 |
| Feb. 27, 1966 | 16 | | |
| May 8, 1966 | 22 | 68 | 3.5 |

Table 2. (continued)

| Lake and Date | Turbidity (J.T.U.) | Light Transmission % at 4 cm. | Light Transmission Depth of 1% transmission (in meters) | Lake and Date | Turbidity (J.T.U.) | Light Transmission % at 4 cm. | Light Transmission Depth of 1% transmission (in meters) |
|---|---|---|---|---|---|---|---|
| Kadoka | | | | Mitchell | | | |
| Aug. 9, 1966 | 125 | | 0.3 | Aug. 11, 1966 | 78 | 57 | 1.8 |
| Oct. 8, 1966 | 104 | | | Nov. 7, 1966 | 38 | 65 | 2.0 |
| Feb. 10, 1967 | 106 | | | Feb. 4, 1967 | 35 | | |
| Apr. 12, 1967 | 153 | | 0.1 | Apr. 7, 1967 | 49 | | |
| Madison | | | | Newell | | | |
| July 16, 1966 | 51 | 50 | 0.9 | Aug. 25, 1965 | 12 | 76 | 7.0 |
| Nov. 4, 1966 | 32 | 60 | 4.5 | Oct. 17, 1965 | 12 | 62 | 4.5 |
| Feb. 3, 1967 | 100 | | | Feb. 26, 1966 | | | |
| Apr. 5, 1967 | 73 | 50 | 0.9 | May 10, 1966 | 22 | 65 | 5.0 |
| Merindahl | | | | Pactola | | | |
| Aug. 15, 1966 | 67 | | | Aug. 7, 1966 | 31 | | |
| Nov. 6, 1966 | 29 | 60 | 1.9 | Oct. 16, 1966 | 9 | 87 | 12.0 |
| Feb. 5, 1967 | 22 | | | Feb. 12, 1967 | 31 | | |
| Apr. 8, 1967 | 43 | | | Apr. 15, 1967 | 21 | 59 | 12.1 |
| Mission | | | | Pocasse | | | |
| Aug. 10, 1966 | 50 | 40 | 0.5 | Aug. 12, 1965 | 66 | 29 | 0.5 |
| Oct. 9, 1966 | 57 | 55 | 2.6 | Oct. 31, 1965 | 115 | 35 | 0.5 |
| Feb. 10, 1967 | 25 | | | Feb. 20, 1966 | 53 | | |
| Apr. 11, 1967 | 77 | 40 | 0.2 | June 7, 1966 | 58 | 40 | 0.5 |

Table 2. (continued)

| Lake and Date | Turbidity (J.T.U.) | Light Transmission % at 4 cm. | Light Transmission Depth of 1% transmission (in meters) |
|---|---|---|---|
| Poinsett | | | |
| Aug. 5, 1965 | 65 | 69 | 0.5 |
| Nov. 7, 1965 | 51 | 54 | 1.9 |
| Feb. 23, 1966 | 29 | | |
| June 18, 1966 | 19 | 68 | 4.6 |
| Punished Woman | | | |
| July 14, 1965 | 47 | | |
| Nov. 26, 1965 | 54 | | |
| Feb. 18, 1966 | 87 | | |
| Apr. 22, 1966 | 44 | 72 | 2.4 |
| Rose Hill | | | |
| Aug. 17, 1966 | | 55 | 1.8 |
| Oct. 30, 1966 | 58 | 65 | 7.0 |
| Feb. 4, 1967 | 32 | | |
| Apr. 8, 1967 | 50 | | |
| Roy | | | |
| July 29, 1965 | 66 | 69 | 3.6 |
| Nov. 13, 1965 | 34 | | |
| Feb. 11, 1966 | 15 | | |
| Apr. 25, 1966 | 16 | 67 | 6.7 |

| Lake and Date | Turbidity (J.T.U.) | Light Transmission % at 4 cm. | Light Transmission Depth of 1% transmission (in meters) |
|---|---|---|---|
| Shadehill | | | |
| Aug. 27, 1965 | 68 | 61 | 3.6 |
| Oct. 19, 1965 | 55 | 66 | 4.1 |
| Feb. 27, 1966 | 16 | | |
| May 8, 1966 | 28 | 73 | 3.2 |
| Sheridan | | | |
| Aug. 6, 1966 | 23 | 64 | 4.5 |
| Oct. 16, 1966 | 24 | 73 | 7.0 |
| Feb. 12, 1967 | 36 | | |
| Apr. 15, 1967 | 19 | 40 | 4.2 |
| Stephen Mission | | | |
| Aug. 17, 1967 | 62 | 50 | 0.5 |
| Oct. 29, 1966 | 65 | | |
| Feb. 4, 1967 | 46 | | |
| Apr. 8, 1967 | 57 | | |
| Traverse | | | |
| July 13, 1965 | 81 | | 0.5 |
| Nov. 11, 1965 | 74 | 65 | 1.4 |
| Feb. 18, 1966 | 76 | | |
| Apr. 23, 1966 | | 54 | 1.8 |

Table 2. (continued)

| Lake and Date | Turbidity (J.T.U.) | Light Transmission: % at 4 cm. | Light Transmission: Depth of 1% transmission (in meters) |
|---|---|---|---|
| Twin (Sanborn Co.) | | | |
| Aug. 16, 1966 | 119 | | 0.5 |
| Nov. 7, 1966 | 98 | 77 | 1.9 |
| Feb. 4, 1967 | 99 | | |
| Apr. 7, 1967 | 51 | | 1.1 |
| Twin (Spink Co.) | | | |
| Aug. 7, 1965 | 87 | 53 | 0.5 |
| Nov. 6, 1965 | 44 | 50 | 1.5 |
| Feb. 21, 1966 | 47 | | |
| June 4, 1966 | 68 | 52 | 1.8 |
| Vermillion | | | |
| Aug. 15, 1966 | 62 | 71 | 1.9 |
| Nov. 5, 1966 | 51 | 64 | 1.0 |
| Feb. 8, 1967 | 21 | | |
| Apr. 5, 1967 | 43 | | |
| Waggoner | | | |
| Aug. 9, 1966 | 39 | 45 | 2.6 |
| Oct. 29, 1966 | 17 | 67 | 4.1 |
| Feb. 13, 1967 | 26 | | |
| Apr. 12, 1967 | 42 | 45 | 1.4 |
| White | | | |
| July 29, 1965 | 65 | 72 | 1.2 |
| Oct. 12, 1965 | 27 | 67 | 3.7 |
| Feb. 11, 1966 | 39 | | |
| June 3, 1966 | | 59 | 1.1 |

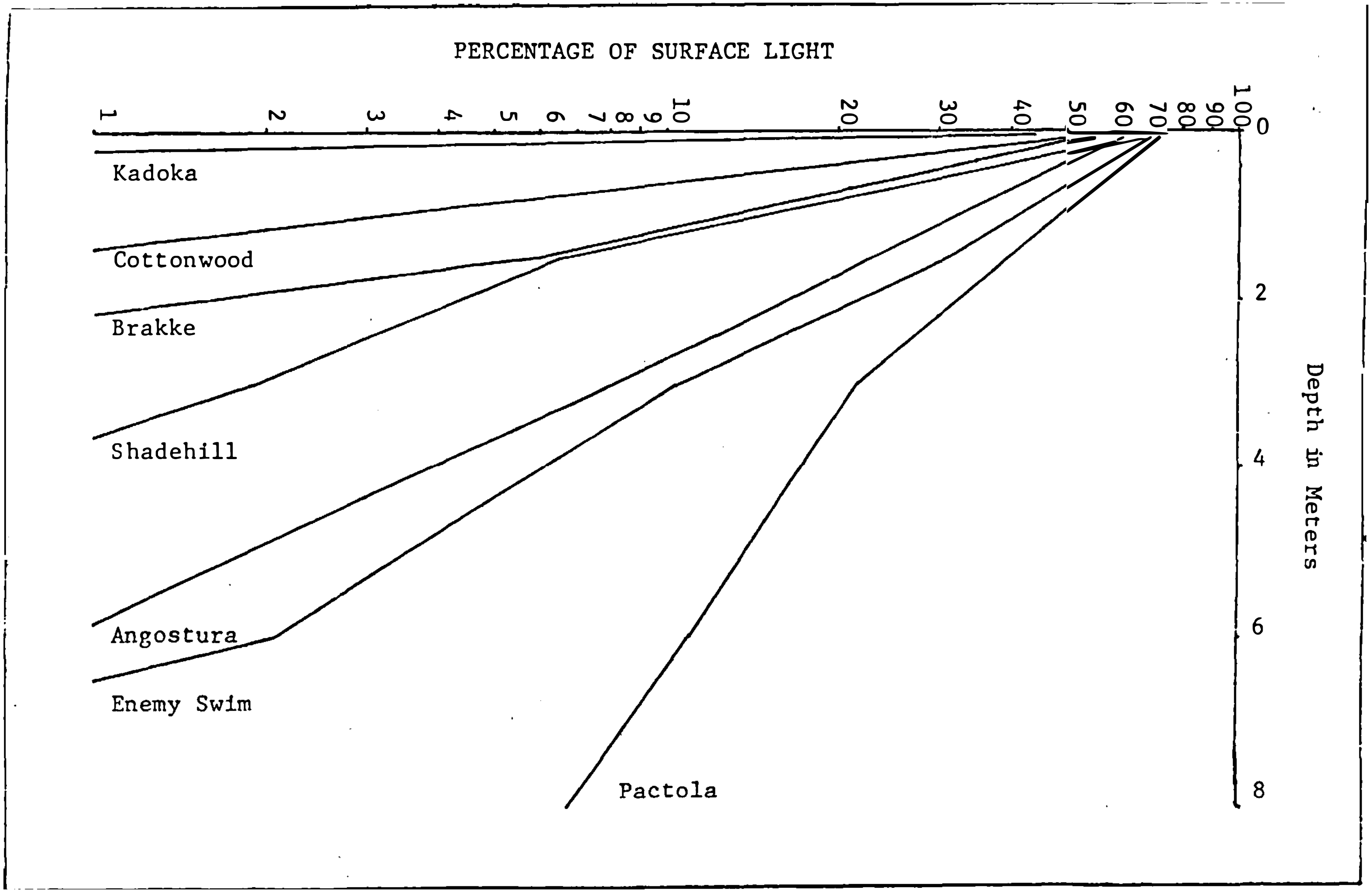


Figure 5. Relation between depth and light transmission, expressed as relative intensity of surface light, for a series of South Dakota lakes.

which 1 per cent of the surface light intensity penetrated varied from 0.2 meters (Kadoka) to 12.0 meters (Pactola). Some of the deeper reservoirs show a slight increase in rate of light transmission with increase in depth (Figure 5). Hutchinson (1957) attributes this phenomenon to highly colored waters which change the spectral composition of the light penetrating the lake. Since these waters did not appear to be highly colored it appears that plankton populations may have reduced the rate of light transmission in the upper few meters of water. A decrease in rate of light penetration with increased depth was evident in a number of shallow lakes. This decrease is probably due to an increase in opacity of bottom waters caused by stirring of the bottom sediments.

## Chemical Considerations

Data obtained from samples taken at all depths were averaged by season for each lake. All data so designated is referred to as an average or seasonal value. This allows seasonal comparisons within each lake. Seasonal values of each lake were averaged to obtain an annual value which permits comparisons among lakes. This value is designated as the mean. Mean values were averaged to obtain representative values for groups of lakes in contrasting physical divisions or geologic areas of the state. These values are referred to as regional means.

### Dissolved Oxygen

The Aquatic Life Advisory Committee (1955) recommended that dissolved oxygen not go below 5 parts per million for more than 8 hours in 24, and never below 3 parts per million unless the population consists of coarse fish which can tolerate dissolved oxygen concentrations as low as 0.5 parts per million. They recommend a minimum of 6 parts per million for coldwater fish habitats. Douderoff and Shumway (1967) accept these standards as sound under present knowledge.

Dissolved oxygen in all lakes was fairly constant from surface to bottom during the spring and fall (Table 3). Lakes Angostura and Hayes showed a pronounced decrease in oxygen with increased depth in the summer only. The following lakes showed a marked decrease in oxygen with increased depth in the winter: Buffalo, Catron Pond, Durkee, Henry, Herman, Hiddenwood, Isabell, Stephen Mission, Traverse,

Table 3. Ranges of dissolved oxygen concentrations from top to bottom of lakes studied, July 1965 to July 1967.

| Lake | Summer | Fall | Winter | Spring |
|---|---|---|---|---|
| Alvin | 8.6 - 4.7 | 10.7 - 10.8 | 5.0 - 1.4 | 9.5 - 7.4 |
| Amsden | 12.1 - 7.2 | 11.4 - 11.4 | 7.2 - 2.7 | 11.5 - 11.1 |
| Angostura | 6.6 - 0.3 | 8.1 - 8.1 | 12.0 - 14.0 | 10.1 - 10.1 |
| Bigstone | 11.8 - 7.1 | 10.5 - 10.4 | 10.5 - 9.3 | 14.2 - 13.5 |
| Bismarck | 7.2 - 0.0 | 8.0 - 6.1 | 4.6 - 0.1 | 10.1 - 7.0 |
| Brakke | 8.2 - 7.8 | 9.9 - 8.4 | 13.2 - 10.6 | 9.6 - 9.6 |
| Buffalo | 7.4 - 6.9 | 12.9 - 12.1 | 8.5 - 5.1 | 11.0 - 11.0 |
| Burke | 7.9 - 4.4 | 8.4 - 7.7 | 1.0 - 0.1 | 9.7 - 10.0 |
| Byron | 6.4 - 5.8 | 10.4 - 9.8 | 11.0 | 7.7 - 7.7 |
| Carthage | 5.3 - 3.4 | 12.3 - 12.1 | 10.6 - 10.8 | 9.7 - 9.7 |
| Catron Pond | 7.5 - 7.5 | 8.5 - 8.1 | 10.5 - 6.5 | 7.7 - 7.7 |
| Cottonwood | 6.1 - 5.8 | 9.7 - 0.0 | 8.0 - 7.2 | 7.5 - 7.0 |
| Durkee | 8.0 - 8.0 | | 11.1 - 7.7 | 9.1 - 9.1 |
| Elm | 9.6 - 5.9 | 11.0 - 11.0 | 10.8 - 10.6 | 9.7 - 9.5 |
| Enemy Swim | 8.1 - 7.8 | 10.9 - 10.3 | 11.5 - 9.5 | 11.3 - 11.5 |
| Gardner | 8.0 - 8.0 | 9.8 - 9.9 | 13.4 - 12.0 | 8.7 - 8.6 |
| Hayes | 7.8 - 2.1 | 9.7 - 7.8 | 14.0 | 9.0 - 8.8 |
| Henry | 6.0 - 5.1 | 10.8 - 9.8 | 11.6 - 4.0 | 9.7 - 9.5 |
| Hendricks | 7.6 - 6.6 | 15.0 - 14.3 | 6.9 - 6.8 | 11.5 - 10.6 |
| Herman | 9.6 - 10.4 | 11.6 - 11.6 | 4.7 - 0.3 | 11.0 - 10.7 |
| Hiddenwood | | 7.6 - 7.0 | 0.2 | 9.6 - 5.7 |
| Horse Thief | 8.7 - 0.0 | 6.8 | 12.5 - 1.2 | 9.7 |
| Iron Creek | 7.5 - 0.0 | 7.4 | 3.5 - 0.4 | 7.4 - 0.0 |
| Isabell | 8.3 - 7.9 | 9.7 - 9.5 | 12.1 - 5.6 | 9.4 - 9.4 |
| Kadoka | 7.0 | 9.7 | 13.5 | 8.9 |
| Madison | 6.1 - 5.6 | 10.8 - 10.8 | 16.4 - 18.2 | 9.7 - 9.3 |
| Merindahl | 7.6 - 2.3 | 12.0 - 11.8 | 11.5 - 0.9 | 10.7 - 10.4 |
| Mission | 7.5 - 6.0 | 9.3 - 9.5 | 10.6 - 11.8 | 9.9 |

Table 3. (continued)

| Lake | Summer | Fall | Winter | Spring |
|---|---|---|---|---|
| Mitchell | 7.1 - 4.5 | 11.5 - 11.3 | 11.3 - 9.5 | 10.6 - 10.6 |
| Newell | 8.1 - 7.5 | 9.8 - 9.4 | 13.3 - 10.9 | 9.2 - 9.5 |
| Pactola | 7.2 - 8.0 | 8.3 - 3.9 | 10.0 - 3.4 | 10.4 - 8.4 |
| Pocasse | 12.7 - 7.0 | 9.5 - 9.5 | 9.3 - 8.2 | 10.2 - 8.8 |
| Poinsett | 8.5 - 8.0 | 10.2 - 9.8 | | 8.2 - 5.5 |
| Punished Woman | 10.9 - 7.9 | 13.0 - 13.6 | 13.9 - 13.5 | 11.9 - 12.2 |
| Rose Hill | 8.0 - 0.0 | 10.8 - 10.8 | 14.1 - 0.6 | 8.2 - 7.5 |
| Roy | 9.8 - 9.6 | 10.9 - 10.9 | 11.6 - 9.1 | 11.7 - 11.7 |
| Shadehill | 7.4 - 7.1 | 10.0 - 9.8 | 12.4 - 11.0 | 10.7 - 11.7 |
| Sheridan | | 7.5 - 7.5 | 11.2 - 9.0 | 10.4 - 8.0 |
| Stephen Mission | 8.4 - 7.2 | 10.8 - 9.7 | 12.2 - 7.2 | 9.6 - 9.4 |
| Traverse | 10.9 - 10.0 | 10.7 - 10.3 | 11.0 - 8.1 | 12.3 - 12.4 |
| Twin (Sanborn) | 9.6 - 10.0 | 12.3 - 12.0 | 11.8 | 10.6 |
| Twin (Spink) | 8.3 - 7.8 | 10.3 - 10.0 | 10.2 - 7.6 | 7.1 - 7.1 |
| Vermillion | 8.0 - 6.6 | 12.8 - 11.7 | 6.0 - 3.2 | 9.6 - 9.4 |
| Waggoner | 10.1 - 9.9 | 10.8 - 10.6 | 12.7 | 9.1 - 8.9 |
| White | 11.6 - 11.1 | 10.9 - 10.9 | 12.7 - 12.2 | 8.0 - 7.5 |

Twin (Spink Co.), and Vermillion. Many lakes developed a pronounced oxygen concentration decrease in both summer and winter. These lakes include: Alvin, Amsden, Bismarck, Burke, Horse Thief, Iron Creek, Merindahl, and Rose Hill. Eighteen of the 45 lakes studied had lower than the recommended oxygen concentrations at some time during the study. Although many lakes did not exhibit marked oxygen stratification or depletion during sampling dates this depletion may have developed during other parts of the seasons.

## pH

Water in all lakes studied was basic, ranging in pH from 7.1 to 11.3 (Table 4). The pH was usually quite uniform from top to bottom or slightly more acid at the bottom. Most lakes which stratified thermally also showed greater variation in pH. Lakes Bismarck, Iron Creek, Rose Hill, and Sheridan exhibited pH differences of over 1.0 from top to bottom.

## Specific Conductance

Specific conductance is a measure of a water's capacity to carry an electric current. This measure may be correlated with salinity or total dissolved solids since salinity is defined as the total concentration of the ionic components.

Rawson (1951) and Northcote and Larkin (1956) attributed much of the difference in plankton, bottom fauna, and fish production between lakes to differences in total dissolved solid content. Most lakes occupying open basins have a total dissolved solid concentration

Table 4. Average pH of lakes studied, July 1965 to July 1967.

| Lake | Summer | Fall | Winter | Spring |
|---|---|---|---|---|
| Alvin | 8.5 | 8.4 | 7.5 | 7.9 |
| Amsden | 8.5 | 8.8 | 8.4 | 8.7 |
| Angostura | 7.7 | 8.1 | 8.2 | 8.1 |
| Bigstone | 8.4 | 8.0 | 8.5 | 8.9 |
| Bismarck | 7.6 | 7.1 | 7.1 | 7.6 |
| Brakke | 8.7 | 8.7 | 8.0 | 8.3 |
| Buffalo | 8.6 | 8.7 | 8.0 | 8.4 |
| Burke | 9.0 | 8.4 | 7.4 | 8.3 |
| Byron | 8.5 | 8.4 | 8.7 | 8.2 |
| Carthage | 8.2 | 8.3 | 7.9 | 8.1 |
| Catron Pond | 8.8 | 8.0 | 8.4 | 8.2 |
| Cottonwood | 9.0 | 8.7 | 8.8 | 8.7 |
| Durkee | 8.9 | 8.2 | 8.5 | 8.0 |
| Elm | 8.8 | 8.7 | 8.7 | 7.8 |
| Enemy Swim | 8.4 | 8.4 | 8.4 | 8.4 |
| Gardner | 8.3 | 8.9 | 8.7 | 8.1 |
| Hayes | 8.2 | 8.3 | 8.4 | 8.1 |
| Henry | 8.3 | 8.1 | 7.4 | 8.3 |
| Hendricks | 8.5 | 8.7 | 8.3 | 8.4 |
| Herman | | 8.7 | 7.9 | 8.7 |
| Hiddenwood | 8.7 | 7.7 | 8.3 | 7.9 |
| Horse Thief | 7.4 | 6.8 | 7.2 | 7.2 |
| Iron Creek | 7.7 | 7.6 | 7.4 | 7.3 |
| Isabell | 8.0 | 8.5 | 8.8 | 7.9 |
| Kadoka | 8.6 | 8.6 | 8.3 | 8.5 |
| Madison | | 11.3 | 8.4 | 8.3 |
| Merindahl | 8.0 | 8.5 | 7.6 | 8.2 |
| Mission | 8.4 | 8.6 | 7.8 | 8.6 |

Table 4. (continued)

| Lake | Summer | Fall | Winter | Spring |
|---|---|---|---|---|
| Mitchell | 8.2 | 8.3 | 8.0 | 8.3 |
| Newell | 8.4 | 8.1 | 8.3 | 7.8 |
| Pactola | 7.9 | 8.0 | 8.3 | 8.3 |
| Pocasse | 9.1 | 7.8 | 8.5 | 7.8 |
| Poinsett | 8.9 | 8.5 | 8.6 | 8.7 |
| Punished Woman | 8.8 | 8.3 | 8.2 | 8.0 |
| Rose Hill | 8.2 | 8.7 | 8.0 | 7.6 |
| Roy | 8.7 | 9.0 | 8.7 | 8.7 |
| Shadehill | 8.4 | 8.6 | 8.8 | 7.9 |
| Sheridan | 7.8 | 7.4 | 8.4 | 8.2 |
| Stephen Mission | 8.6 | 8.4 | 7.9 | 8.0 |
| Traverse | 8.2 | 8.0 | 8.2 | 8.6 |
| Twin (Sanborn) | 8.6 | 7.8 | 7.7 | 8.2 |
| Twin (Spink) | 9.0 | 8.9 | 8.9 | 8.7 |
| Vermillion | 9.3 | 9.0 | 7.8 | 8.1 |
| Waggoner | 9.6 | 8.7 | 8.3 | 8.1 |
| White | 8.5 | 7.8 | 8.0 | |

of between 100 and 200 ppm (Reid, 1961). Evaporation from lakes with closed basins may concentrate dissolved solids to over 100,000 ppm causing pronounced changes in species and numbers of fauna and flora present.

The American Public Health Association (1965) stated: "The amount of dissolved ionic matter in a sample may often be estimated by multiplying the specific conductance by an emperical factor. This factor may vary from 0.55 to 0.9, depending on the soluble components of the particular water and the temperature of the measurement. Relatively high factors may be required for saline or boiler waters, whereas lower factors may apply where considerable hydroxide or free acid is present."

The correction of specific conductance measurements to specific conductance at a standard temperature is accomplished by applying a temperature coefficient. Smith (1962) gave this coefficient as a two per cent rate of change of conductance for each degree centigrade temperature change in dilute aqueous solutions.

Specific conductance in shallow lakes (maximum depth less than 15 feet) increased from a spring or summer minimum to a winter maximum (Table 5). This winter maximum was more pronounced in lakes of northern South Dakota (e.g. Bigstone, Buffalo, Gardner, and Hiddenwood). The deeper lakes in this area (e.g. Amsden, Pocasse, Roy, and White) also showed maximum specific conductance during the winter while deeper lakes in the southern part of the state did not. This maximum conductance was probably due to concentration of mineral

Table 5. Average specific conductance of lake waters (micromhos per centimeter at 25 C), July 1965 to July 1967.

| Lake | Summer | Fall | Winter | Spring |
|---|---|---|---|---|
| Alvin | 503 | 442 | 440 | 363 |
| Amsden | 865 | 1288 | 1520 | |
| Angostura | 1700 | 2200 | 1620 | 1700 |
| Bigstone | 655 | 853 | 1093 | |
| Bismarck | 103 | 118 | 118 | 112 |
| Brakke | 493 | 309 | 450 | 383 |
| Buffalo | 580 | 505 | 887 | 568 |
| Burke | 290 | 245 | 290 | 263 |
| Byron | 2400 | 3900 | 4800 | 1750 |
| Carthage | 340 | 305 | 362 | 320 |
| Catron Pond | 408 | 530 | 790 | 185 |
| Cottonwood | 2867 | 2600 | 4750 | 1700 |
| Durkee | 196 | 265 | 359 | 225 |
| Elm | 599 | 747 | 661 | 230 |
| Enemy Swim | 420 | 439 | 571 | 465 |
| Gardner | 517 | 767 | 973 | 120 |
| Hayes | 333 | 273 | 320 | 301 |
| Henry | 1307 | 957 | 940 | 1000 |
| Hendricks | 527 | 850 | 650 | |
| Herman | 750 | 908 | 840 | 685 |
| Hiddenwood | 453 | 593 | 970 | 180 |
| Horse Thief | 70 | 68 | 53 | 82 |
| Iron Creek | 106 | 140 | 112 | 113 |
| Isabell | 318 | 433 | 513 | 80 |
| Kadoka | 368 | 380 | 450 | 400 |
| Madison | 1280 | 1175 | 1375 | 1055 |
| Merindahl | 827 | 875 | 840 | 1650 |
| Mission | 268 | 194 | 236 | 180 |

Table 5. (continued)

| Lake | Summer | Fall | Winter | Spring |
|---|---|---|---|---|
| Mitchell | 527 | 870 | 790 | 785 |
| Newell | 508 | 468 | 880 | 470 |
| Pactola | | 247 | 221 | 226 |
| Pocasse | 510 | 476 | 883 | 165 |
| Poinsett | 780 | 1282 | 1233 | 840 |
| Punished Woman | 430 | 383 | 700 | 380 |
| Rose Hill | 313 | 234 | 268 | 232 |
| Roy | 1150 | 1210 | 1518 | 1165 |
| Shadehill | 1055 | 1700 | 1730 | 543 |
| Sheridan | 173 | 157 | 160 | 172 |
| Stephen Mission | 367 | 423 | 475 | 393 |
| Traverse | 905 | 1025 | 1650 | |
| Twin (Sanborn) | 3650 | 3700 | 3200 | 2800 |
| Twin (Spink) | 3225 | 4400 | 6000 | 2117 |
| Vermillion | 420 | 522 | 555 | 335 |
| Waggoner | 440 | 447 | 655 | 535 |
| White | 800 | 997 | 1175 | |

elements under the ice, and was more pronounced in the northern area where ice depth was greatest. The pronounced decrease in specific conductance in north central and northwestern South Dakota during spring 1966 may be attributed to increased spring runoff caused by a severe March blizzard. The U. S. Department of Commerce (1966) showed that precipitation over much of this area deviated +2.0 inches or more from normal during the first three months of 1966. Resulting increased runoff could cause dilution or flushing in lakes which normally receive limited precipitation. Lakes affected were: Byron, Catron Pond, Cottonwood, Elm, Gardner, Hiddenwood, Isabell, Pocasse, Shadehill, and Twin (Spink Co.).

The mean specific conductance of lakes studied, and of lakes studied by the U. S. Department of Interior (1964 and 1965) are plotted in Figure 6. Variation in specific conductance among lake waters was usually associated with physical divisions of the state and substages of the Wisconsin glacial age. Most lakes east of the Missouri River which lie in soil deposited by the Mankato substage had much higher mean specific conductance (330 to 1260 micromhos at 25 C) than did lakes in the Cary and Iowan substages (260 to 880 micromhos at 25 C). Exceptions were lakes occupying closed basins or overlying aquifers (Figure 6). These lakes had increased mean specific conductance ranging from 1780 to 3940 micromhos at 25 C in the Mankato, and from 800 to 16,000 micromhos at 25 C in the Cary and Iowan substages.

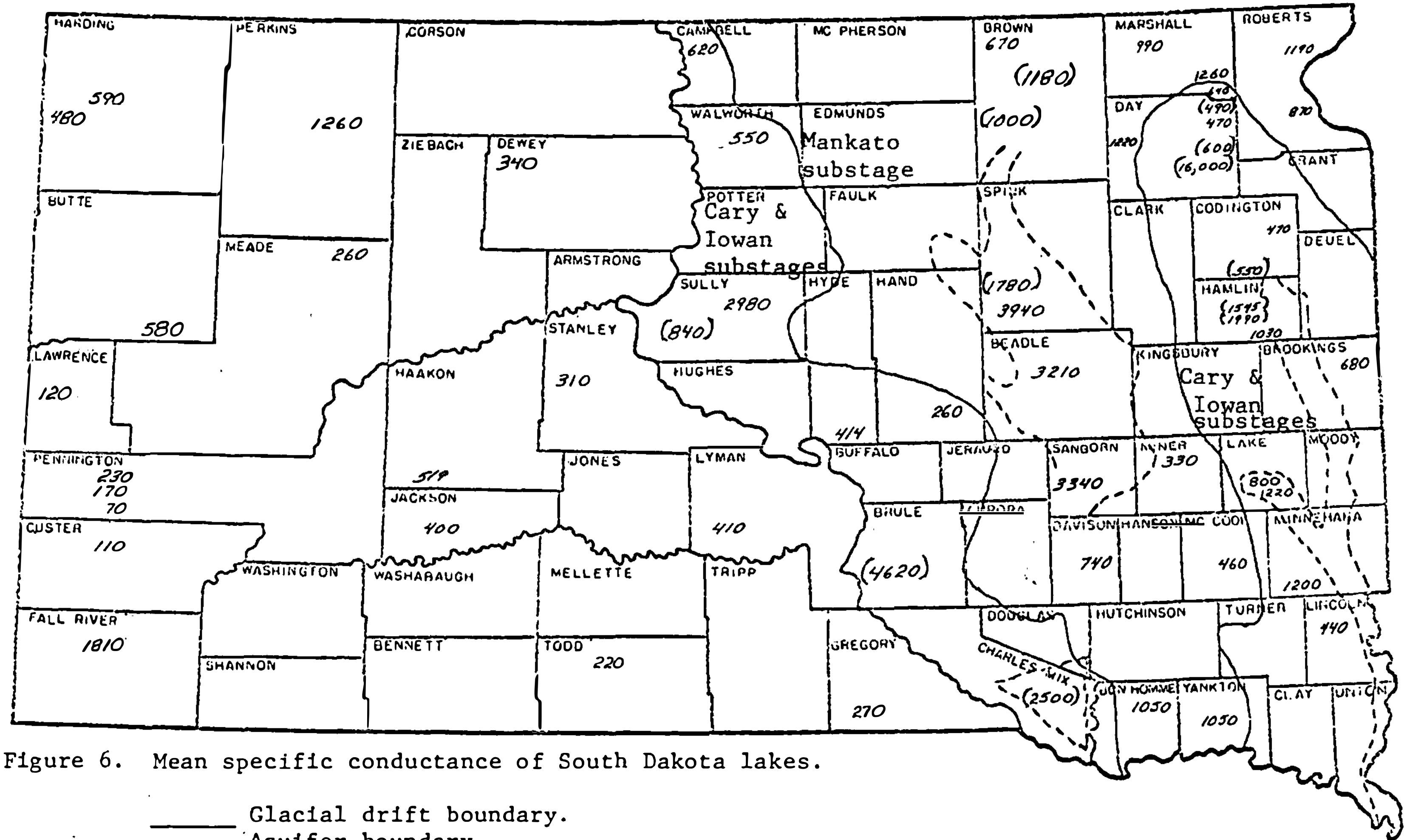


Figure 6. Mean specific conductance of South Dakota lakes.

______ Glacial drift boundary.

\- - - Aquifer boundary.

Values in parenthesis indicate U. S. Department of Interior data.

Lakes in the unglaciated portion of the state, west of the Missouri River, generally had lower mean specific conductance values than did lakes east of the river. The lowest mean specific conductance readings were obtained in the Black Hills (70 to 230 micromhos at 25 C). The next lowest values were in lakes of the Southern Plateaus ranging from 220 to 270 micromhos at 25 C. The remaining lakes in the unglaciated area, except for Shadehill and Angostura, ranged from 310 to 590 micromhos at 25 C. The high mean specific conductance of Angostura, 1810 micromhos at 25 C, is attributed to the influent Cheyenne River. Water from the Cheyenne River has a higher dissolved solids content than the water from any of the other major streams in South Dakota (U. S. Geological Survey and U. S. Bureau of Reclamation, 1964). Drainage from irrigation projects contributes much of the dissolved solids in this water.

## Alkalinity

Ball (1948), Carlander (1955), and Turner (1960) found that lakes with high alkalinities usually have higher standing crops of fish than do lakes with low alkalinities. Moyle (1946) states that where alkalinity is above 40 ppm there seems to be no relationship between increased carbonate and yield. He considers this a natural separation point between soft and hard water.

Alkalinity is usually imparted by hydroxide, carbonate, and bicarbonate. Hydroxide alkalinity was not found in any of the lakes studied but carbonate alkalinity occurred commonly. Alkalinity relationships were calculated stoichiometrically (carbonate = 2X phenolphthalein and bicarbonate = total - carbonate) from the phenolphthalein and bromo cresol green-methyl orange alkalinities. Carbonate and bicarbonate alkalinities, as mg/l $CaCO_3$, were averaged seasonally and presented in Table 6.

Little variation was found in the seasonal pattern of alkalinity values among lakes. They generally increased from a spring minimum to a winter maximum. Variations in total alkalinity from top to bottom of individual lakes were usually small. In deep lakes where there is a thermocline total alkalinity is usually greater below than above the thermocline (Moyle, 1956). Several lakes showed a marked increase in total alkalinity from top to bottom during the summer. The increase in the alkalinity of bottom waters of these lakes is indicated below: Angostura, 17 mg/l; Bismarck, 19 mg/l; Horse Thief, 17 mg/l; Iron Creek, 58 mg/l; Rose Hill, 83 mg/l; and Sheridan, 21 mg/l.

Mean total alkalinity west of the Missouri River ranged from 38-264 mg/l. Alkalinity was lowest in the Black Hills, ranging from 38 to 141 mg/l. Horse Thief was the only soft water lake with 38 mg/l $CaCO_3$. Lakes of the Southern Plateaus had a small mean total alkalinity range of 188-210 mg/l. Lakes in the Pierre Hills area ranged from 85 mg/l in the west to 177 mg/l in the east. Lakes of the Northern Plateaus ranged from 123 to 214 mg/l with highest values in the northwest which has a high evaporation to rainfall ratio.

Table 6. Average carbonate and bicarbonate alkalinities (as mg/l $CaCO_3$) of lakes studied, July 1965 to July 1967.

| Lake | Summer | | Fall | | Winter | | Spring | |
|---|---|---|---|---|---|---|---|---|
| | Carbonate | Bicarbonate | Carbonate | Bicarbonate | Carbonate | Bicarbonate | Carbonate | Bicarbonate |
| Alvin | 13 | 101 | 0 | 113 | 0 | 157 | 0 | 131 |
| Amsden | 48 | 130 | 30 | 158 | 26 | 204 | 22 | 169 |
| Angostura | 1 | 112 | 1 | 107 | 3 | 116 | 0 | 113 |
| Bigstone | 47 | 100 | 0 | 171 | 12 | 128 | | |
| Bismarck | 1 | 59 | 0 | 55 | 0 | 165 | 0 | 54 |
| Brakke | 20 | 129 | 17 | 169 | 0 | 192 | 5 | 163 |
| Buffalo | 36 | 175 | 21 | 211 | 0 | 291 | 7 | 182 |
| Burke | 55 | 126 | 16 | 210 | 0 | 231 | 7 | 191 |
| Byron | 7 | 129 | 20 | 303 | 64 | 304 | 22 | 206 |
| Carthage | 4 | 135 | 5 | 166 | 0 | 200 | 0 | 137 |
| Catron Pond | 113 | 117 | 0 | 216 | 11 | 265 | 10 | 197 |
| Cottonwood | 192 | 340 | 110 | 437 | 122 | 848 | 60 | 315 |
| Durkee | 44 | 99 | 3 | 105 | 8 | 134 | 0 | 96 |
| Elm | 37 | 134 | 9 | 180 | 23 | 103 | 0 | 117 |
| Enemy Swim | 45 | 194 | 10 | 197 | 0 | 260 | 6 | 207 |
| Gardner | 50 | 190 | 33 | 184 | 29 | 278 | 6 | 209 |
| Hayes | 6 | 95 | 5 | 124 | 8 | 169 | 0 | 143 |
| Henry | 14 | 170 | 0 | 165 | 0 | 221 | 6 | 194 |
| Hendricks | 17 | 134 | 20 | 186 | 8 | 112 | 9 | 136 |
| Herman | 91 | 77 | 26 | 197 | 0 | 300 | 43 | 176 |
| Hiddenwood | 60 | 120 | 0 | 165 | 14 | 201 | 7 | 132 |
| Horse Thief | 0 | 32 | 0 | 39 | 0 | 44 | 0 | 35 |
| Iron Creek | 7 | 84 | 0 | 73 | 0 | 94 | 0 | 91 |
| Isabell | 0 | 146 | 1 | 129 | 11 | 167 | 0 | 89 |
| Kadoka | 10 | 166 | 16 | 119 | 10 | 275 | 20 | 203 |

Table 6. (continued)

| Lake | Summer | | Fall | | Winter | | Spring | |
|---|---|---|---|---|---|---|---|---|
| | Car-bon-ate | Bi-car-bonate | Car-bon-ate | Bi-car-bonate | Car-bon-ate | Bi-car-bonate | Car-bon-ate | Bi-car-bonate |
| Madison | 39 | 117 | 13 | 182 | 10 | 237 | 4 | 171 |
| Merindahl | 1 | 147 | 12 | 114 | 0 | 156 | 4 | 139 |
| Mission | 13 | 126 | 13 | 178 | 0 | 243 | 9 | 167 |
| Mitchell | 9 | 131 | 6 | 129 | 0 | 167 | 4 | 153 |
| Newell | 13 | 74 | 0 | 81 | 6 | 75 | 0 | 88 |
| Pactola | 0 | 131 | 0 | 139 | 0 | 148 | 0 | 147 |
| Pocasse | 67 | 104 | 0 | 195 | 22 | 235 | 0 | 92 |
| Poinsett | 75 | 154 | 9 | 213 | 27 | 225 | 67 | 135 |
| Punished Woman | 39 | 117 | 8 | 175 | 15 | 140 | 10 | 140 |
| Rose Hill | 7 | 124 | 10 | 100 | 3 | 149 | 0 | 100 |
| Roy | 54 | 209 | 44 | 182 | 42 | 262 | 24 | 218 |
| Shadehill | 32 | 268 | 19 | 251 | 21 | 226 | 10 | 225 |
| Sheridan | 7 | 88 | 0 | 100 | 2 | 99 | 0 | 99 |
| Stephen Mission | 21 | 93 | 3 | 125 | 0 | 162 | 0 | 112 |
| Traverse | 43 | 131 | 0 | 191 | 11 | 171 | 20 | 150 |
| Twin (Sanborn) | 23 | 66 | 0 | 94 | 0 | 127 | 2 | 109 |
| Twin (Spink) | 194 | 170 | 118 | 320 | 149 | 466 | 80 | 259 |
| Vermillion | 60 | 68 | 29 | 92 | 0 | 137 | 0 | 115 |
| Waggoner | 51 | 21 | 0 | 79 | 10 | 100 | 0 | 87 |
| White | 34 | 133 | 0 | 168 | 0 | 216 | 4 | 178 |

Patterns of total alkalinity concentrations were not as evident east of the Missouri River. Alkalinity of lakes with open basins was generally highest in the north (160-260 mg/l) and lowest in the south (100-160 mg/l) where rainfall was greater and carbonate leaching deeper. This relationship is modified in those lakes occupying closed basins or overlying aquifers as they have high total alkalinities (194-606 mg/l) as well as high specific conductance.

## Sulfate

Sulfate is important in natural waters in many ways. Sulfur is an essential component of protoplasm and is necessary for plant growth. Lack of sulfate can inhibit development of phytoplankton populations thus limiting production (Reid, 1961). Moyle (1945) pointed out that there is a noticeable biological relationship between concentration of sulfates and distribution of aquatic plants in Minnesota. Rawson and Moore (1944) studied lakes in Saskatchewan with high sulfate salinity and found a decrease in number of fish species when salinity exceeded 7,000 ppm.

Eddy (1963) stated that waters in southwestern and extreme western Minnesota and extending westward into the Dakotas are extremely high in dissolved salts. In these waters the concentration of sulfate salts (as sulfate ions) often exceeds the concentration of carbonates (as carbonate ion). Moyle (1945) found that in Minnesota such waters typically have a sulfate ion concentration greater than

150 ppm. He states that waters high in sulfates are usually high in carbonates, nitrates, and phosphates.

Seasonal concentrations of sulfate ions for South Dakota lakes are shown in Table 7. Sulfate ion concentrations did not show any consistent seasonal patterns among lakes. Some lakes had maximum concentrations of sulfates in the winter while others reached their maximum value in the spring, summer, or fall. Areas where concentrations of sulfate salts (as sulfate ions) exceed carbonate salts (as carbonate ions) in lakes are shown in Figure 7. Carbonate exceeded sulfate in the region west of the Missouri River except for portions of the Pierre Hills drained by the main tributaries of the Belle Fourche and Cheyenne Rivers and part of the Grand River drainage. In lakes east of the Missouri River concentrations of sulfate exceeded carbonate except in a small area of the Coteau des Prairie.

Lakes west of the Missouri River were lowest in sulfate ion concentration. The lakes in the Black Hills and the Southern Plateaus divisions had a regional mean concentration of 23 mg/l sulfate ion. Angostura reservoir had a considerably higher mean concentration of 689 mg/l. Patterns were not evident in the Pierre Hills or Northern Plateaus. The regional mean sulfate ion concentration of lakes in these divisions was 116 mg/l.

Lakes east of the Missouri River had consistently higher sulfate ion concentration than those west of the river. Highest concentrations were found in lakes lying in Mankato drift (Figure 6). Lakes

*Table 7.* Average sulfate ion concentrations (mg/l) of lakes studied, July 1965 to July 1967.

| Lake | Summer | Fall | Winter | Spring | Mean |
|---|---|---|---|---|---|
| Alvin | 145 | 130 | 160 | 105 | 135 |
| Amsden | 450 | 176 | 175 | | 207 |
| Angostura | 701 | 765 | 565 | 725 | 689 |
| Bigstone | 225 | 136 | 310 | | 224 |
| Bismarck | 10 | 11 | 12 | 13 | 12 |
| Brakke | 74 | 72 | 112 | 87 | 86 |
| Buffalo | 225 | 92 | 250 | 115 | 171 |
| Burke | 12 | 5 | 37 | 15 | 17 |
| Byron | 1000 | 400 | 1950 | 210 | 890 |
| Carthage | 67 | 78 | 45 | 60 | 63 |
| Catron Pond | 65 | 87 | 30 | 35 | 54 |
| Cottonwood | 1030 | 600 | 855 | 425 | 728 |
| Durkee | 25 | 18 | 45 | 90 | 45 |
| Elm | 152 | 112 | 100 | | 121 |
| Enemy Swim | 125 | 91 | 49 | 55 | 80 |
| Gardner | 136 | 210 | 80 | | 142 |
| Hayes | 75 | 65 | 82 | 70 | 73 |
| Henry | 387 | 287 | 347 | 385 | 352 |
| Hendricks | 325 | 142 | 186 | | 218 |
| Herman | 227 | 280 | 240 | 238 | 246 |
| Hiddenwood | 80 | 125 | 140 | | 115 |
| Horse Thief | 10 | 8 | 12 | 20 | 13 |
| Iron Creek | 3 | 8 | 27 | 0 | 10 |
| Isabell | 40 | 106 | 50 | 10 | 52 |
| Kadoka | 35 | 45 | 68 | 55 | 51 |
| Madison | 400 | 282 | 537 | 392 | 403 |
| Merindahl | 345 | 352 | 450 | 400 | 387 |
| Mission | 20 | 5 | 10 | 7 | 11 |

Table 7. (continued)

| Lake | Summer | Fall | Winter | Spring | Mean |
|---|---|---|---|---|---|
| Mitchell | 248 | 352 | 337 | 287 | 306 |
| Newell | 150 | | 230 | | 190 |
| Pactola | 50 | 48 | 43 | 49 | 48 |
| Pocasse | 160 | 150 | 155 | | 155 |
| Poinsett | 290 | 116 | 275 | 207 | 222 |
| Punished Woman | 150 | 60 | 120 | 120 | 113 |
| Rose Hill | 32 | 47 | 54 | 38 | 43 |
| Roy | 450 | 600 | 640 | 390 | 520 |
| Shadehill | 348 | 160 | 300 | 65 | 218 |
| Sheridan | 18 | 25 | 25 | 32 | 25 |
| Stephen Mission | 123 | 140 | 140 | 122 | 131 |
| Traverse | 250 | 240 | 448 | | 313 |
| Twin (Sanborn) | 2100 | 2000 | 1350 | 1850 | 1825 |
| Twin (Spink) | 850 | 491 | 285 | 323 | 487 |
| Vermillion | 140 | 145 | 210 | 105 | 150 |
| Waggoner | 100 | 182 | 245 | 192 | 180 |
| White | 325 | 150 | 420 | | 298 |

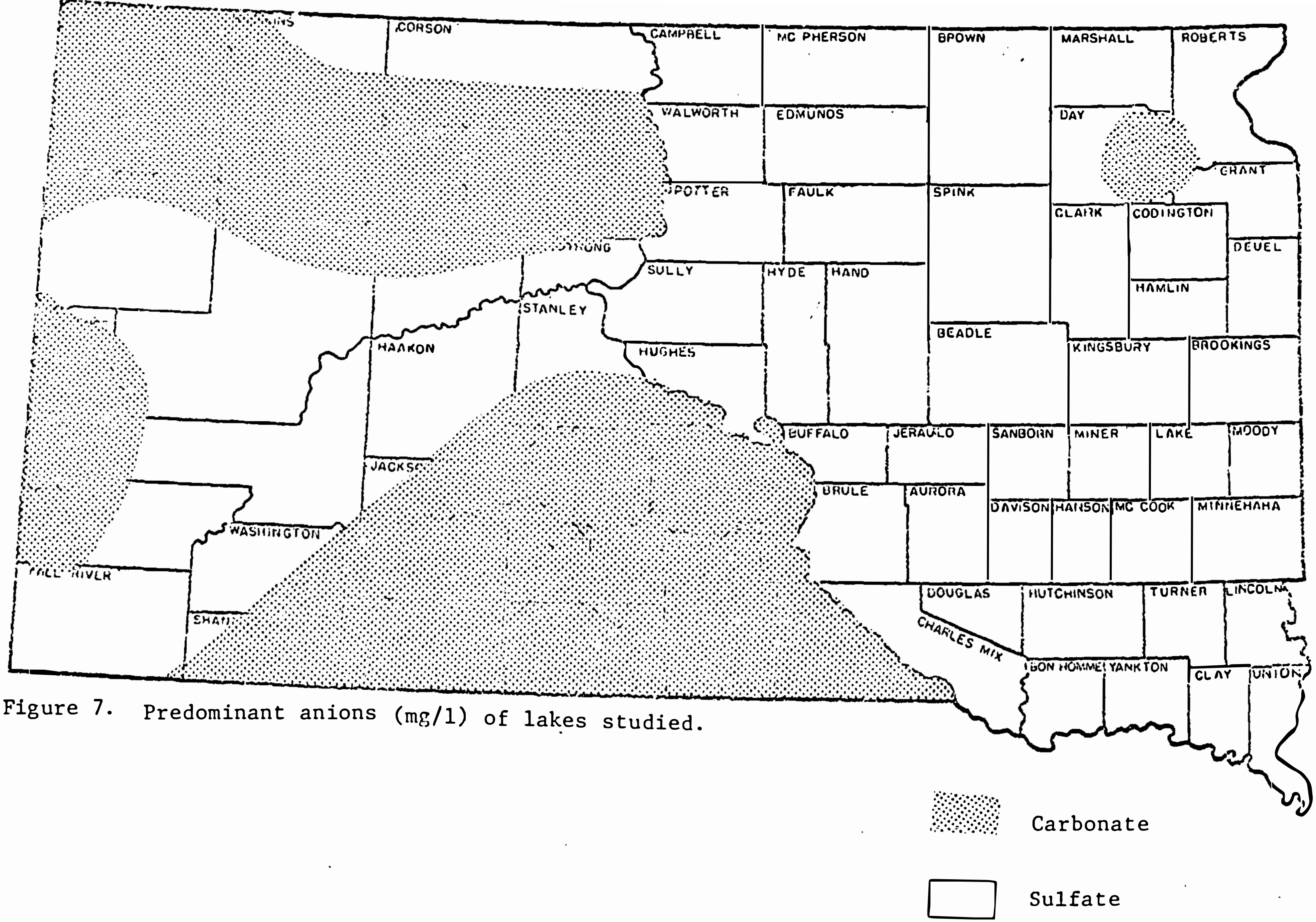


Figure 7. Predominant anions (mg/l) of lakes studied.

occupying closed basins or overlying aquifers in this area had higher mean concentrations ranging from 487 to 1825 mg/l. Lakes with open basins in the Mankato drift had a regional mean concentration of 273 mg/l.

Lakes in the Cary and Iowan till generally had lower concentrations of sulfate ions. Mean concentration of those occupying closed basins or overlying aquifers ranged from 135 to 728 mg/l while the other lakes in the Cary and Iowan till had a regional mean of 128 mg/l sulfate ion.

Chloride

Moyle (1956) stated that high concentrations of sulfates and chlorides usually occur together. It has long been known that high concentrations of chlorides are related to plant distribution. This may be an osmotic effect since Gerloff, Fitzgerald, and Skoog (1950) demonstrated that there are optimum osmotic concentrations for plants.

High concentrations of chlorides in areas where chloride concentrations are normally low may indicate pollution. Purified effluent liquids from sewage treatment plants tend to be high in chloride (Moyle, 1956). One lake with unusually high chloride content is Lake Madison in Lake County. This lake receives sewage effluent from the treatment plant at the city of Madison. Mean annual chloride content in this lake was 113 mg/l. Lake Herman which is in the same drainfield had a mean chloride concentration of 5 mg/l.

Mean chloride concentration for this series of analyses, ranged from 0.6 to 518.6 mg/l. Thirty-three of forty-five lakes examined had less than 15.0 mg/l chloride (Table 8). Lakes west of the Missouri River were lowest in chloride ion concentration. Lakes in the Black Hills had a mean regional concentration of 1.9 mg/l. The remaining lakes west of the Missouri River, except Angostura, had a regional mean concentration of 4.9 mg/l. Angostura reservoir had a mean concentration of 129.4 mg/l.

Lakes east of the Missouri River had consistently higher chloride ion concentrations than did lakes west of the river. Highest concentrations were found in the Mankato drift of the Wisconsin ice age (Figure 6). Lakes overlying aquifers (Figure 6) or occupying closed basins had higher concentrations than lakes occupying open basins. Among these are: Byron, 177.3 mg/l; Cottonwood, 136.8 mg/l; Twin (Sanborn Co.), 149.0 mg/l; and Twin (Spink Co.,), 518 mg/l. The U. S. Geologic Survey and U. S. Bureau of Reclamation (1964) gave results from chemical analyses of waters from principle aquifers in the state. According to these analyses glacial drift aquifers probably have a greater range in chemical quality than any of the other principle aquifers.

Lakes occupying open basins in the Mankato drift had a regional mean concentration of 21.4 mg/l chloride ion, while similar lakes in soils deposited by the Cary and Iowan substages had a regional mean concentration of 5.3 mg/l.

Table 8. Mean chloride ion concentrations (mg/l) of lakes studied, July 1965 to July 1967.

| Lake | Mean | Lake | Mean |
|---|---|---|---|
| Alvin | 4.9 | Isabell | 3.3 |
| Amsden | 14.0 | Kadoka | 9.2 |
| Angostura | 129.4 | Madison | 113.0 |
| Bigstone | 13.8 | Merindahl | 5.1 |
| Bismarck | 2.5 | Mission | 1.9 |
| Brakke | 11.7 | Mitchell | 22.6 |
| Buffalo | 5.6 | Newell | 5.5 |
| Burke | 5.4 | Pactola | 1.5 |
| Byron | 177.3 | Pocasse | 5.3 |
| Carthage | 4.9 | Poinsett | 41.5 |
| Catron Pond | 1.0 | Punished Woman | 6.9 |
| Cottonwood | 136.8 | Rose Hill | 3.8 |
| Durkee | 3.9 | Roy | 12.8 |
| Elm | 23.9 | Shadehill | 5.8 |
| Enemy Swim | 5.6 | Sheridan | 3.5 |
| Gardner | 0.6 | Stephen Mission | 9.8 |
| Hayes | 4.6 | Traverse | 15.7 |
| Henry | 70.5 | Twin (Sanborn) | 149.0 |
| Hendricks | 4.2 | Twin (Spink) | 518.6 |
| Herman | 5.0 | Vermillion | 3.5 |
| Hiddenwood | 4.5 | Waggoner | 8.3 |
| Horse Thief | 1.2 | White | 14.5 |
| Iron Creek | 0.6 | | |

Hardness Relationships

Total hardness measures the divalent cations capable of reacting with soap to form precipitates. The principle divalent cations are calcium and magnesium. Temporary hardness or alkalinity are indicators of the carbonate and bicarbonate content of waters expressed as calcium carbonate. Since alkalinity is an indicator of productivity in aquatic ecosystems it has been discussed separately. Non-carbonate hardness (total hardness-alkalinity) is considered to be primarily due to sulfates, chlorides, and nitrates of the metallic ions causing hardness. Negative non-carbonate hardness indicates that more bicarbonate ions are present than are needed to satisfy the divalent metallic ions present. These excess bicarbonate ions are related to monovalent metallic ions, such as sodium and potassium.

Seasonal and mean concentrations of total and non-carbonate hardness, as mg/l calcium carbonate, are presented in Table 9. Both total and non-carbonate hardness tended to be at a maximum during the winter.

Those portions of the state with a predominance of carbonate and bicarbonate as the major anions (Figure 7) usually had these ions in excess of the calcium and magnesium equivalents. Negative non-carbonate hardness was associated primarily with sodium and potassium. Areas with positive non-carbonate hardness paralleled those portions of the state where sulfate and chloride were predominant anions (Figure 7).

Table 9. Average concentrations of total and non-carbonate hardness (as mg/l $CaCO_3$) from lakes studied, July 1965 to July 1967.

| Lake | Summer | | Fall | | Winter | | Spring | | Mean | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total | Non-carbonate | Total | Non-carbonate | Total | Non-carbonate | Total | Non-carbonate | Total | Non-carbonate |
| Alvin | 255 | 141 | 178 | 65 | 229 | 72 | 196 | 65 | 215 | 86 |
| Amsden | 250 | 72 | 274 | 86 | 573 | 343 | | | 366 | 167 |
| Angostura | 617 | 504 | 679 | 571 | 717 | 598 | 753 | 640 | 692 | 578 |
| Bigstone | 196 | 49 | 268 | 97 | 371 | 231 | | | 278 | 126 |
| Bismarck | 46 | -14 | 48 | -7 | 51 | -114 | 51 | -3 | 49 | -34 |
| Brakke | 117 | -32 | 83 | 103 | 88 | -104 | 133 | -35 | 105 | -68 |
| Buffalo | 198 | -13 | 210 | -22 | 446 | 155 | 279 | 90 | 283 | 52 |
| Burke | 115 | -66 | 130 | -96 | 131 | -100 | 126 | -72 | 126 | -83 |
| Byron | 370 | 234 | 474 | 151 | 980 | 612 | 364 | 136 | 547 | 283 |
| Carthage | 162 | 23 | 144 | -27 | 181 | -19 | 153 | 16 | 160 | -2 |
| Catron Pond | 32 | 198 | 44 | -172 | 100 | -176 | 48 | -159 | 56 | -176 |
| Cottonwood | 384 | -148 | 410 | -137 | 644 | -326 | 290 | -85 | 432 | -174 |
| Durkee | 26 | -117 | 57 | -51 | 79 | -63 | 32 | -64 | 49 | -74 |
| Elm | 106 | -65 | 187 | -2 | 178 | 52 | 76 | -41 | 137 | -14 |
| Enemy Swim | 140 | -99 | 182 | -25 | 291 | 31 | 233 | 20 | 213 | -18 |
| Gardner | 36 | -204 | 42 | -175 | 59 | -248 | 26 | -189 | 41 | -201 |
| Hayes | 93 | -8 | 85 | -44 | 124 | -53 | 103 | -40 | 101 | -36 |
| Henry | 618 | 434 | 327 | 162 | 363 | 142 | 434 | 234 | 436 | 243 |
| Hendricks | 186 | 35 | 203 | -3 | 527 | 407 | | | 305 | 147 |
| Herman | 331 | 163 | 485 | 262 | 690 | 390 | 409 | 190 | 479 | 251 |
| Hiddenwood | 94 | -86 | 131 | -34 | 198 | -17 | 60 | -79 | 121 | -54 |
| Horse Thief | 25 | -7 | 32 | -7 | 34 | -10 | 32 | -3 | 31 | -7 |
| Iron Creek | 48 | -43 | 62 | -11 | 54 | -40 | 58 | -33 | 56 | -32 |
| Isabell | 30 | -116 | 87 | -43 | 82 | -96 | 24 | -65 | 56 | -80 |

Table 9. (continued)

| Lake | Summer | | Fall | | Winter | | Spring | | Mean | |
|---|---|---|---|---|---|---|---|---|---|---|
| | To-tal | Non-car-bonate | To-tal | Non-car-bonate | To-tal | Non-car-bonate | To-tal | Non-car-bonate | To-tal | Non-car-bonate |
| Kadoka | 45 | -131 | 50 | -85 | 56 | -229 | 52 | -171 | 51 | -154 |
| Madison | 503 | 347 | 513 | 318 | 561 | 314 | 875 | 700 | 613 | 420 |
| Merindahl | 361 | 213 | 336 | 210 | 368 | 212 | 415 | 272 | 370 | 227 |
| Mission | 89 | -50 | 91 | -100 | 101 | -142 | 80 | -96 | 90 | -97 |
| Mitchell | 259 | 119 | 290 | 155 | 359 | 192 | 433 | 276 | 335 | 186 |
| Newell | 98 | 11 | 139 | 58 | 187 | 106 | 145 | 57 | 142 | 58 |
| Pactola | 109 | -22 | 119 | -20 | 113 | -35 | 129 | -18 | 118 | -24 |
| Pocasse | 110 | -61 | 115 | -80 | 223 | -34 | 54 | -38 | 126 | -53 |
| Poinsett | 213 | -16 | 277 | 55 | 477 | 225 | 319 | 117 | 322 | 95 |
| Punished Woman | 144 | -12 | 158 | -25 | 267 | 113 | 144 | -6 | 178 | 18 |
| Rose Hill | 124 | -7 | 94 | -16 | 128 | -24 | 101 | 1 | 112 | -11 |
| Roy | 422 | 159 | 433 | 207 | 768 | 464 | 599 | 357 | 556 | 297 |
| Shadehill | 74 | -226 | 76 | -194 | 134 | -113 | 59 | -176 | 86 | -177 |
| Sheridan | 69 | -26 | 89 | -11 | 72 | -29 | 83 | -16 | 79 | -20 |
| Stephen Mission | 169 | 55 | 196 | 68 | 265 | 103 | 217 | 105 | 212 | 83 |
| Traverse | 288 | 114 | 307 | 116 | 525 | 343 | | | 373 | 192 |
| Twin (Sanborn) | 800 | 711 | 812 | 718 | 770 | 643 | 1252 | 1141 | 909 | 803 |
| Twin (Spink) | 435 | 71 | 805 | 367 | 1072 | 457 | 443 | 104 | 689 | 250 |
| Vermillion | 226 | 98 | 193 | 72 | 328 | 191 | 236 | 121 | 246 | 121 |
| Waggoner | 118 | 46 | 168 | 89 | 228 | 118 | 244 | 157 | 190 | 102 |
| White | 260 | 93 | 304 | 136 | 515 | 299 | | | 360 | 177 |

Calcium and Magnesium

These two elements usually constitute the most abundant ions in fresh waters. Calcium is usually the most abundant of these two ions. Reid (1961) stated that in soft waters calcium makes up, on the average, about 48 per cent and magnesium about 14 per cent of the total cations present. In average hard waters the proportion of magnesium to calcium increases, giving approximately 53 per cent of calcium and 34 per cent of magnesium.

Moyle (1946) indicated that calcium is not a critical factor in the productivity of waters having a total alkalinity greater than 15 ppm. Gerloff et al. (1950) found that calcium concentrations of 9.8 ppm and magnesium concentrations of 0.13 ppm allowed for optimum growth of *Coccochloris peniocystis.*

Seasonal and mean annual concentrations of calcium and magnesium are presented in Table 10. These ions were usually more concentrated under ice cover during the winter months particularly in lakes of northern South Dakota. Figure 8 shows the areas of South Dakota where calcium and magnesium ions in lakes are predominant over sodium and potassium ions. This predominance was based on weight/volume measurements.

Lakes west of the Missouri River usually had lower concentrations of calcium and magnesium than did lakes east of the river. Mean concentrations of calcium for lakes of the Black Hills, Northern Plateaus, and Southern Plateaus was usually less than 20 mg/l with magnesium concentrations less than 10 mg/l. Other lakes west of the Missouri

Table 10. Average concentrations of calcium and magnesium (mg/l) from lakes studied, July 1965 to July 1967.

| Lake | Summer | | Fall | | Winter | | Spring | | Mean | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Calcium | Magnesium | Calcium | Magnesium | Calcium | Magnesium | Calcium | Magnesium | Calcium | Magnesium |
| Alvin | 43.2 | 35.7 | 21.6 | 30.1 | 46.5 | 27.3 | 40.3 | 23.2 | 37.9 | 29.1 |
| Amsden | 29.6 | 42.8 | 42.9 | 36.5 | 48.3 | 55.9 | 45.4 | 119.7 | 41.6 | 63.7 |
| Angostura | 172.2 | 45.4 | 181.3 | 55.1 | 204.1 | 50.3 | 203.4 | 59.6 | 190.3 | 52.6 |
| Bigstone | 22.4 | 34.0 | 40.3 | 40.7 | 44.8 | 63.0 | | | 35.8 | 45.9 |
| Bismarck | 12.4 | 3.7 | 11.2 | 4.9 | 12.1 | 5.0 | 13.6 | 4.1 | 12.3 | 4.4 |
| Brakke | 21.7 | 15.3 | 16.0 | 10.5 | 17.2 | 10.9 | 26.0 | 16.6 | 20.2 | 13.3 |
| Buffalo | 20.0 | 36.0 | 20.4 | 38.7 | 56.9 | 73.8 | 39.7 | 43.7 | 34.3 | 48.1 |
| Burke | 34.0 | 8.2 | 35.2 | 10.2 | 38.0 | 8.8 | 35.1 | 9.3 | 35.6 | 9.1 |
| Byron | 27.2 | 73.4 | 35.6 | 93.6 | 88.1 | 184.7 | 28.4 | 71.2 | 44.8 | 105.7 |
| Carthage | 38.8 | 15.9 | 27.4 | 18.3 | 31.2 | 25.1 | 37.7 | 14.3 | 33.8 | 18.4 |
| Catron Pond | 8.0 | 2.9 | 6.4 | 6.3 | 20.4 | 11.9 | 12.0 | 4.4 | 11.7 | 6.4 |
| Cottonwood | 47.2 | 64.6 | 38.4 | 76.3 | 37.2 | 133.9 | 30.0 | 52.5 | 38.2 | 81.8 |
| Durkee | 10.4 | 2.9 | 22.7 | 9.7 | 31.4 | 9.0 | 22.4 | 5.8 | 21.7 | 6.9 |
| Elm | 21.6 | 12.6 | 22.7 | 31.6 | 32.1 | 20.5 | 19.2 | 6.8 | 23.9 | 17.9 |
| Enemy Swim | 14.4 | 25.3 | 18.8 | 32.7 | 38.8 | 47.0 | 34.6 | 35.5 | 26.7 | 35.1 |
| Gardner | 4.8 | 5.8 | 5.9 | 6.6 | 11.5 | 7.3 | 8.8 | 1.0 | 7.8 | 5.2 |
| Hayes | 19.1 | 11.1 | 15.1 | 11.4 | 22.4 | 16.8 | 27.1 | 8.7 | 20.9 | 12.0 |
| Henry | 57.9 | 115.0 | 56.6 | 45.0 | 59.3 | 52.3 | 66.0 | 65.4 | 60.0 | 69.4 |
| Hendricks | 32.0 | 25.8 | 41.6 | 24.1 | 42.4 | 102.3 | | | 38.7 | 50.7 |
| Herman | 53.3 | 48.2 | 59.3 | 81.9 | 62.1 | 130.0 | 48.4 | 69.4 | 55.8 | 82.4 |
| Hiddenwood | 20.0 | 10.7 | 22.4 | 18.2 | 24.0 | 33.5 | 14.4 | 5.8 | 20.2 | 17.1 |
| Horse Thief | 6.4 | 2.3 | 6.4 | 3.9 | 5.3 | 4.8 | 8.8 | 2.4 | 6.7 | 3.4 |
| Iron Creek | 10.1 | 5.4 | 12.0 | 7.8 | 11.7 | 5.9 | 12.0 | 6.8 | 11.5 | 6.5 |
| Isabell | 8.8 | 1.9 | 10.7 | 14.6 | 20.0 | 7.8 | 7.2 | 1.5 | 11.7 | 6.5 |

Table 10. (continued)

| Lake | Summer | | Fall | | Winter | | Spring | | Mean | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Calcium | Magnesium | Calcium | Magnesium | Calcium | Magnesium | Calcium | Magnesium | Calcium | Magnesium |
| Kadoka | 10.4 | 4.7 | 13.6 | 3.9 | 8.0 | 8.7 | 12.0 | 5.3 | 11.0 | 5.7 |
| Madison | 68.4 | 80.7 | 62.5 | 86.8 | 81.7 | 86.7 | 98.1 | 153.1 | 77.7 | 101.9 |
| Merindahl | 109.2 | 21.5 | 88.4 | 28.0 | 113.2 | 24.1 | 112.9 | 30.1 | 105.9 | 25.9 |
| Mission | 18.9 | 10.2 | 18.4 | 10.9 | 22.4 | 10.9 | 13.6 | 11.2 | 18.3 | 10.8 |
| Mitchell | 48.0 | 33.7 | 52.9 | 38.4 | 74.5 | 42.2 | 82.5 | 55.2 | 64.5 | 42.4 |
| Newell | 28.0 | 6.8 | 39.2 | 10.0 | 45.6 | 17.6 | 39.9 | 11.5 | 37.9 | 11.5 |
| Pactola | 14.9 | 17.4 | 16.8 | 16.3 | 15.5 | 18.1 | 19.7 | 19.3 | 16.7 | 17.8 |
| Pocasse | 38.4 | 3.4 | 22.2 | 14.4 | 41.6 | 28.8 | 14.8 | 4.1 | 29.3 | 12.7 |
| Poinsett | 17.6 | 46.2 | 23.7 | 52.8 | 38.4 | 92.5 | 32.8 | 57.5 | 28.1 | 62.3 |
| Punished Woman | 16.8 | 24.8 | 21.6 | 25.3 | 47.7 | 35.9 | 26.4 | 19.0 | 28.1 | 26.3 |
| Rose Hill | 20.3 | 17.9 | 15.5 | 12.9 | 20.1 | 18.9 | 27.2 | 7.9 | 21.0 | 14.4 |
| Roy | 22.4 | 88.9 | 24.5 | 90.2 | 49.0 | 156.9 | 33.6 | 125.2 | 32.4 | 115.3 |
| Shadehill | 11.2 | 11.2 | 10.4 | 12.2 | 22.3 | 17.7 | 11.7 | 7.1 | 13.9 | 12.1 |
| Sheridan | 14.9 | 7.7 | 17.6 | 11.0 | 13.5 | 9.6 | 18.4 | 8.9 | 16.1 | 9.3 |
| Stephen Mission | 39.5 | 16.8 | 42.8 | 21.6 | 50.9 | 33.5 | 51.9 | 21.2 | 46.3 | 23.3 |
| Traverse | 28.0 | 53.0 | 52.1 | 43.0 | 74.1 | 82.7 | | | 51.4 | 59.6 |
| Twin (Sanborn) | 320.3 | 264.3 | 324.9 | 198.9 | 308.3 | 298.9 | 501.3 | 201.2 | 363.7 | 240.8 |
| Twin (Spink) | 19.2 | 94.0 | 15.1 | 186.4 | 24.8 | 245.5 | 20.8 | 94.9 | 20.0 | 155.2 |
| Vermillion | 40.0 | 30.6 | 26.4 | 30.8 | 49.2 | 49.9 | 37.4 | 34.7 | 38.3 | 36.5 |
| Waggoner | 24.0 | 13.9 | 42.0 | 15.1 | 76.1 | 23.5 | 67.7 | 17.9 | 52.5 | 17.6 |
| White | 40.0 | 33.9 | 52.9 | 41.8 | 81.9 | 77.3 | | | 58.3 | 51.0 |

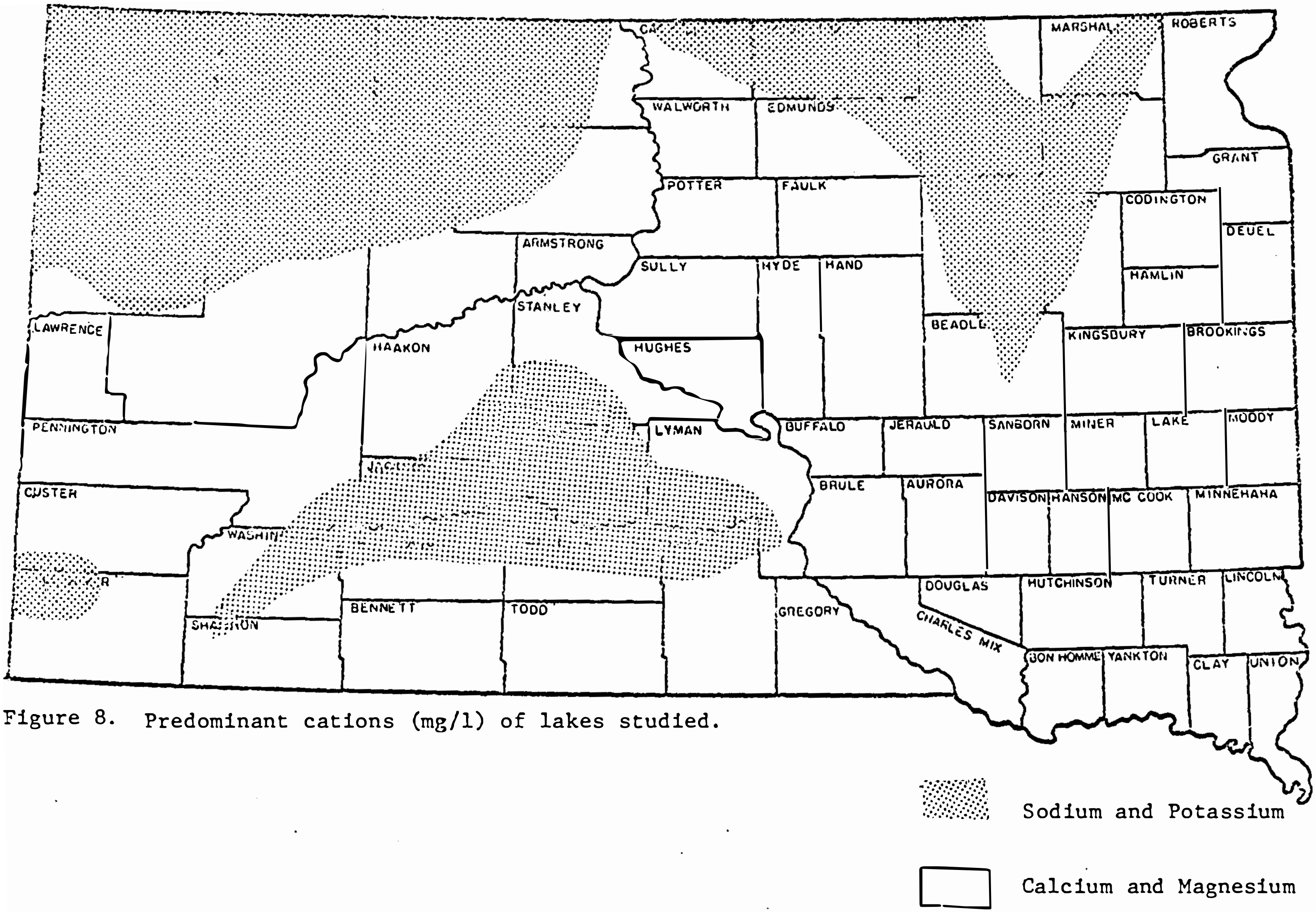


Figure 8. Predominant cations (mg/l) of lakes studied.

River ranged from about 20 to 50 mg/l calcium, while magnesium concentrations in this area ranged from 10 to 20 mg/l. Highest concentrations of calcium and magnesium west of the Missouri were in Angostura reservoir with 190 and 52 mg/l respectively.

Lakes east of the Missouri River generally had higher concentrations of these two elements than those west of the river. Highest concentrations were found in lakes lying in the Mankato drift, with mean calcium and magnesium concentrations ranging from 20-364 mg/l and 18-241 mg/l respectively. Lakes in the Cary and Iowan till had lower ranges of calcium and magnesium varying from 20-78 and 13-102 mg/l respectively.

Sodium and Potassium

Sodium and potassium concentrations usually follow calcium and magnesium in waters of open river systems. Reid (1961) stated that where sodium and potassium occur in low concentrations the proportion of sodium is only slightly greater than that of potassium. As the total content of both increases the concentration of sodium greatly exceeds that of potassium.

Concentrations of sodium and potassium varied widely throughout the state. Mean concentrations of sodium ranged from 3-558 mg/l, while potassium ranged from 1-51 mg/l. Seasonal and mean annual concentrations of these elements are presented in Table 11. The areas in which sodium and potassium are the predominant cations are shown in Figure 8.

Table 11. Average concentrations of sodium and potassium (mg/l) from lakes studied, July 1965 to July 1967.

| Lake | Summer | | Fall | | Winter | | Spring | | Mean | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Sodium | Potassium | Sodium | Potassium | Sodium | Potassium | Sodium | Potassium | Sodium | Potassium |
| Alvin | 15.0 | 12.3 | 15.5 | 12.1 | 17.0 | 12.6 | 13.0 | 11.7 | 15.1 | 12.2 |
| Amsden | 91.2 | 12.6 | 18.6 | 12.1 | 115.2 | 11.0 | | | 75.0 | 11.9 |
| Angostura | 252.0 | 8.2 | 240.0 | 8.7 | 220.0 | 11.0 | 130.0 | 7.9 | 210.5 | 9.0 |
| Bigstone | 40.8 | 8.2 | 10.8 | 12.3 | 43.2 | 13.4 | | | 31.6 | 11.3 |
| Bismarck | 5.4 | 7.2 | 5.5 | 4.1 | 6.0 | 4.6 | 6.0 | 4.1 | 5.7 | 5.0 |
| Brakke | 58.0 | 12.9 | 69.0 | 13.4 | 75.0 | 16.2 | 56.0 | 11.7 | 64.5 | 13.6 |
| Buffalo | 14.6 | 18.6 | 5.4 | 15.4 | 16.8 | 18.6 | 10.2 | 12.3 | 11.8 | 16.2 |
| Burke | 15.0 | 16.4 | 15.0 | 17.4 | 13.0 | 16.6 | 15.0 | 14.8 | 14.5 | 16.3 |
| Byron | 384.0 | 27.0 | 468.0 | 16.3 | 936.0 | 48.0 | 420.0 | 26.4 | 552.0 | 29.4 |
| Carthage | 14.0 | 15.0 | 16.5 | 18.6 | 16.0 | 19.6 | 13.0 | 18.3 | 14.9 | 17.9 |
| Catron Pond | 78.0 | 8.4 | 17.5 | 11.8 | 150.0 | 8.7 | 108.0 | 3.0 | 88.4 | 8.0 |
| Cottonwood | 588.0 | 60.0 | 576.0 | 16.4 | 768.0 | 90.0 | 456.0 | 36.0 | 597.0 | 50.6 |
| Durkee | 31.2 | 8.2 | 7.0 | 3.4 | 43.2 | 9.0 | 33.6 | 8.2 | 28.8 | 7.2 |
| Elm | 64.8 | 16.3 | 72.0 | 15.6 | 180.0 | 19.2 | 15.6 | 11.4 | 83.1 | 15.6 |
| Enemy Swim | 12.0 | 13.2 | 7.2 | 12.0 | 10.8 | 12.1 | 8.4 | 8.4 | 9.6 | 11.4 |
| Gardner | 110.0 | 5.0 | 22.6 | 7.2 | 192.0 | 6.9 | 21.0 | 1.3 | 86.4 | 5.1 |
| Hayes | 35.0 | 8.2 | 37.0 | 9.0 | 42.0 | 9.7 | 35.0 | 9.0 | 37.3 | 9.0 |
| Henry | 105.0 | 16.2 | 77.0 | 15.0 | 109.0 | 15.6 | 54.0 | 86.3 | 86.3 | 15.6 |
| Hendricks | 10.0 | 16.0 | 4.8 | 13.0 | 10.2 | 14.6 | | | 8.3 | 14.5 |
| Herman | 35.0 | 19.5 | 53.0 | 18.7 | 66.0 | 21.1 | 46.5 | 11.9 | 50.1 | 17.8 |
| Hiddenwood | 36.3 | 15.0 | 11.4 | 14.8 | 58.8 | 19.2 | 15.6 | 5.8 | 26.6 | 13.7 |
| Horse Thief | 6.0 | 2.6 | 4.0 | 2.6 | 3.7 | 2.8 | 5.0 | 2.2 | 4.7 | 2.6 |
| Iron Creek | 2.4 | 1.0 | 4.0 | 0.7 | 3.0 | 1.4 | 3.0 | 1.0 | 3.1 | 1.0 |
| Isabell | 48.0 | 9.0 | 14.4 | 8.7 | 66.0 | 9.3 | 10.8 | 1.4 | 34.8 | 7.1 |

Table 11. (continued)

| Lake | Summer | | Fall | | Winter | | Spring | | Mean | |
|---|---|---|---|---|---|---|---|---|---|---|
| | So-dium | Pot-tas-sium | So-dium | Pot-tas-sium | So-dium | Pot-tas-sium | So-dium | Pot-tas-sium | So-dium | Pot-tas-sium |
| Kadoka | 74.0 | 7.8 | 75.0 | 7.4 | 96.5 | 7.2 | 87.0 | 7.3 | 83.1 | 7.4 |
| Madison | 109.2 | 22.6 | 115.0 | 22.0 | 130.0 | 29.5 | 96.5 | 18.3 | 112.7 | 23.1 |
| Merindahl | 23.0 | 16.2 | 24.5 | 15.8 | 31.0 | 19.7 | 28.0 | 15.6 | 26.6 | 16.8 |
| Mission | 16.6 | 16.2 | 14.0 | 14.8 | 17.0 | 11.4 | 13.0 | 9.5 | 15.2 | 13.0 |
| Mitchell | 64.2 | 16.1 | 25.0 | 17.0 | 83.0 | 17.3 | 72.0 | 14.7 | 73.6 | 16.3 |
| Newell | 55.2 | 4.9 | 84.0 | 7.2 | 76.2 | 6.3 | 28.8 | 4.9 | 61.0 | 5.8 |
| Pactola | 4.8 | 1.3 | 3.5 | 2.8 | 3.3 | 3.6 | 3.0 | 2.9 | 3.7 | 2.7 |
| Pocasse | 66.0 | 17.2 | 14.4 | 16.5 | 132.0 | 19.0 | 7.2 | 14.4 | 54.9 | 16.8 |
| Poinsett | 67.2 | 22.4 | 15.6 | 22.2 | 74.4 | 24.0 | 60.0 | 19.4 | 54.3 | 22.0 |
| Punished Woman | 7.2 | 5.4 | 4.8 | 7.2 | 17.2 | 17.0 | 15.6 | 7.8 | 11.2 | 9.4 |
| Rose Hill | 14.5 | 12.0 | 15.0 | 12.2 | 16.5 | 13.4 | 11.0 | 11.3 | 14.3 | 12.2 |
| Roy | 52.8 | 70.8 | 13.2 | 40.2 | 50.4 | 36.6 | 37.2 | 30.6 | 38.4 | 44.6 |
| Shadehill | 204.0 | 8.6 | 37.8 | 11.2 | 336.0 | 7.2 | 84.0 | 4.5 | 165.5 | 7.9 |
| Sheridan | 6.0 | 8.4 | 7.5 | 16.9 | 6.3 | 5.4 | 7.2 | 5.2 | 6.8 | 9.0 |
| Stephen Mission | 27.6 | 13.2 | 27.0 | 12.0 | 35.0 | 12.6 | 27.0 | 11.2 | 29.2 | 12.3 |
| Traverse | 27.6 | 11.0 | 14.4 | 14.9 | 64.8 | 13.9 | | | 35.6 | 13.3 |
| Twin (Sanborn) | 380.0 | 48.0 | 365.0 | 48.0 | 340.0 | 43.0 | 500.0 | 52.8 | 396.3 | 48.0 |
| Twin (Spink) | 504.0 | 45.0 | 288.0 | 18.0 | 888.0 | 87.6 | 552.0 | 54.2 | 558.0 | 51.2 |
| Vermillion | 16.2 | 13.8 | 15.0 | 13.8 | 12.0 | 12.0 | 9.2 | 12.3 | 13.1 | 13.0 |
| Waggoner | 31.2 | 14.4 | 37.0 | 8.0 | 33.5 | 8.6 | 37.0 | 7.9 | 34.7 | 9.7 |
| White | 33.6 | 16.8 | 10.8 | 15.9 | 38.4 | 16.2 | | | 27.6 | 16.3 |

Sodium concentrations were lowest in the Black Hills division which had a regional mean of 5 mg/l. The highest concentration measured during this study was 597 mg/l in Cottonwood Lake, a semi-closed lake in Sully County. Relationships between physical divisions of the state or soil types and the concentration of sodium ions were not well defined.

Potassium concentrations were lower west of the Missouri River than east of the river. Mean concentration for all lakes west of the river ranged from 1-16 mg/l, with a combined average of 8 mg/l. Lakes east of the Missouri which occupied closed basins or were underlain by aquifers ranged from 18-51 mg/l, while the remaining lakes in eastern South Dakota ranged from 9-17 mg/l potassium ion.

## Nitrogen and Phosphorous

Nitrogen and phosphorous are essential to living organisms due to their role in protein metabolism and energy transfer. Of all the elements present in living organisms phosphorous is likely to be the most important ecologically; it is more likely to limit production than any other element. Sawyer (1954) stated that nitrogen is often considered the element which determines the extent of biological productivity, and phosphorous is often considered the governor of the "biological machine" which controls the speed changes which can occur.

Lakes which receive sewage or much agricultural drainage have higher concentrations of total phosphorous than are found in uncontaminated waters. Sawyer (1944) concluded that any lake showing concentrations in excess of 0.01 ppm of inorganic phosphorous and 0.30 ppm of inorganic nitrogen at the time of spring turnover could be expected to produce algal blooms of such density as to cause nuisance.

Chu (1942) investigated the requirements of algae. Using pure chemicals he found that phosphorous concentrations below 0.05 ppm limited growth. He also found that the nitrogen and phosphorous requirements for different planktonic algae were approximately the same.

The total fish production of Minnesota lakes was shown to rise linearly from 100 to 400 pounds per acre as the phosphorous increased from 0.2 to 1.4 mg/l (Moyle, 1956).

Lackey (1945) has related the production of algal blooms in Wisconsin lakes to the concentrations of nutrients in the water and hence to the amount of sewage entering the lake. Lackey and Sawyer (1945) stated that some of these lakes receive annual dosages of saline nitrogen as high as 422 pounds per acre.

Since nitrogen can be fixed from the atmosphere, it may be concluded that phosphorous is the key element in the fertilization of natural bodies of water. Therefore, control of the amount of phosphate entering lakes is critical to production. Srainth and Pillai (1966) stated that it is possible to eliminate phosphorous from sewage by the use of chemical coagulents, but this treatment may be expensive and the stability of the resultant effluent may not be satisfactory. They suggest the most efficient biological treatment method, from other considerations, followed by tertiary treatment to economically remove phosphorous from sewage effluent.

Combined nitrogen in water exists as inorganic compounds (ammonia, nitrate, and nitrite) and organic compounds. In the present investigation ammonium nitrogen was determined by the direct Nesslerization method while concentrations of nitrate and nitrite nitrogen were determined by the Hach Nitra Ver II method.

Seasonal concentrations of nitrogen as ammonia and nitrate are shown in Table 12. Nitrogen is discussed as the total of ammonia and nitrate since both are available to plants. Concentrations of nitrogen did not show any consistent seasonal patterns.

Mean concentrations of nitrogen ranged from 0.34 to 3.07 mg/l. Lowest concentrations of nitrogen (less than 0.5 mg/l) were in lakes of the Black Hills which receive little agricultural or sewage pollution. These lakes include Horse Thief, Pactola, and Sheridan with 0.46, 0.34, and 0.50 mg/l of nitrogen, respectively. Lakes Amsden and Enemy Swim in the Coteau des Prairies also had low nitrogen concentrations with 0.36 and 0.48 mg/l, respectively.

Phosphorous is known to occur in several forms. Those of greater concern in natural waters are soluble phosphate phosphorous, soluble organic phosphorous, and particulate organic phosphorous (Reid, 1961).

During this study samples for phosphate determination were frozen prior to analysis. Other investigations have shown that freezing samples as a method of preservation changes the level of

Table 12. Average concentrations of ammonia and nitrate (as mg/l nitrogen) from lakes studied, July 1965 to July 1967.

| Lake | Summer | | Fall | | Winter | | Spring | | Mean | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Ammonia | Nitrate | Ammonia | Nitrate | Ammonia | Nitrate | Ammonia | Nitrate | Ammonia | Nitrate |
| Alvin | 1.43 | 0.4 | | 0.2 | 0.87 | 0.6 | 0.79 | 0.6 | 1.03 | 0.4 |
| Amsden | 0.45 | 0.0 | 0.00 | 0.2 | 0.34 | 0.2 | | | 0.26 | 0.1 |
| Angostura | 0.18 | 0.2 | | 0.0 | 0.93 | 0.5 | 0.21 | 0.2 | 0.44 | 0.2 |
| Bigstone | 0.00 | 0.1 | 0.27 | 0.8 | 0.24 | 0.7 | | | 0.17 | 0.5 |
| Bismarck | 0.41 | 0.7 | 0.88 | 0.1 | 1.78 | 0.4 | 0.49 | 0.5 | 0.89 | 0.4 |
| Brakke | 0.60 | 0.3 | 0.06 | 0.2 | 0.22 | 0.6 | 0.25 | 0.3 | 0.28 | 0.4 |
| Buffalo | 0.70 | 0.0 | 0.46 | 0.6 | 0.00 | 0.4 | 0.30 | 0.4 | 0.36 | 0.4 |
| Burke | | 0.2 | 0.34 | 0.8 | 0.67 | 0.8 | 0.24 | 0.2 | 0.42 | 0.5 |
| Byron | 2.35 | 0.6 | 2.43 | 1.8 | 0.30 | 2.1 | 0.25 | 0.8 | 1.33 | 1.3 |
| Carthage | | 0.2 | 0.20 | 0.6 | 0.29 | 0.3 | 0.78 | 0.6 | 0.42 | 0.4 |
| Catron Pond | 0.28 | 0.8 | 0.64 | 0.6 | 0.60 | 1.0 | 0.25 | 0.4 | 0.44 | 0.7 |
| Cottonwood | 0.29 | 0.4 | 0.98 | 0.8 | 0.36 | 1.1 | 0.25 | 0.3 | 0.47 | 0.6 |
| Durkee | 0.87 | 0.7 | 0.66 | 0.3 | 0.23 | 0.2 | 0.30 | 0.2 | 0.52 | 0.4 |
| Elm | 1.33 | 0.4 | 1.80 | 1.3 | 0.29 | 0.7 | 0.35 | | 0.94 | 0.8 |
| Enemy Swim | 0.61 | 0.0 | 0.25 | 0.4 | 0.00 | 0.1 | 0.25 | 0.2 | 0.28 | 0.2 |
| Gardner | 0.00 | 0.8 | 0.49 | 0.6 | 0.37 | 0.5 | 0.00 | | 0.22 | 0.6 |
| Hayes | 0.60 | 0.3 | | 0.1 | 0.16 | 0.2 | 0.09 | 0.5 | 0.28 | 0.3 |
| Henry | | 0.5 | 2.69 | 0.7 | 1.50 | 0.6 | 0.50 | 0.2 | 1.56 | 0.5 |
| Hendricks | 1.64 | 0.0 | | 0.9 | 0.28 | 0.8 | | | 0.96 | 0.6 |
| Herman | 0.43 | 1.0 | | 0.8 | 1.50 | 0.2 | 0.54 | 0.7 | 0.82 | 0.7 |
| Hiddenwood | 0.30 | 0.2 | 0.46 | 0.7 | 0.35 | 0.8 | 0.00 | | 0.28 | 0.6 |
| Horse Thief | 0.00 | 0.4 | 0.20 | 0.1 | 0.70 | 0.4 | 0.12 | 0.0 | 0.26 | 0.2 |
| Iron Creek | 0.00 | 0.3 | 0.90 | 0.1 | 0.27 | 0.0 | 0.45 | 0.8 | 0.40 | 0.3 |
| Isabell | 0.05 | 0.4 | 0.60 | 0.5 | 0.36 | 1.1 | 0.25 | 0.1 | 0.32 | 0.5 |

Table 12. (continued)

| Lake | Summer | | Fall | | Winter | | Spring | | Mean | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Ammo-nia | Ni-trate | Ammo-nia | Ni-trate | Ammo-nia | Ni-trate | Ammo-nia | Ni-trate | Ammo-nia | Ni-trate |
| Kadoka | 0.40 | 0.8 | | 0.4 | 0.55 | 0.5 | 0.32 | 0.6 | 0.42 | 0.6 |
| Madison | 0.41 | 0.8 | 1.28 | 0.6 | 0.52 | 0.8 | 0.62 | 0.5 | 0.71 | 0.8 |
| Merindahl | 1.32 | 0.7 | 0.99 | 0.1 | 0.40 | 0.4 | 0.09 | 0.2 | 0.70 | 0.4 |
| Mission | 0.40 | 0.8 | 0.16 | 0.2 | 1.35 | 0.4 | 0.22 | 0.4 | 0.53 | 0.4 |
| Mitchell | 0.00 | 0.4 | 1.12 | 0.2 | 0.24 | 0.1 | 0.24 | 0.4 | 0.40 | 0.3 |
| Newell | 0.74 | 0.2 | 2.43 | 0.6 | 0.14 | 0.6 | 0.19 | | 0.88 | 0.4 |
| Pactola | 0.19 | 0.2 | 0.25 | 0.3 | 0.02 | 0.1 | 0.12 | 0.5 | 0.14 | 0.3 |
| Pocasse | 0.95 | 0.8 | 0.50 | 1.1 | 0.38 | 1.2 | 0.23 | | 0.52 | 1.0 |
| Poinsett | 1.32 | 0.5 | 0.00 | 1.2 | 0.91 | 0.5 | 0.30 | 0.6 | 0.63 | 0.7 |
| Punished Woman | 0.00 | 0.4 | 0.32 | 0.6 | 0.25 | 0.5 | 0.30 | 0.1 | 0.22 | 0.4 |
| Rose Hill | | 0.2 | 2.93 | 3.4 | 2.18 | 0.6 | 0.49 | 0.5 | 1.87 | 1.2 |
| Roy | 0.73 | 0.0 | 1.37 | 0.5 | 0.00 | 0.4 | 0.21 | 0.2 | 0.58 | 0.3 |
| Shadehill | 0.00 | 0.8 | 0.44 | 0.3 | 0.27 | 0.5 | 0.25 | 0.2 | 0.24 | 0.4 |
| Sheridan | 0.22 | 0.5 | | 0.0 | 0.17 | 0.3 | 0.21 | 0.5 | 0.20 | 0.3 |
| Stephen Mission | 0.00 | 0.4 | 0.21 | 0.6 | 0.19 | 0.2 | 0.56 | 0.6 | 0.24 | 0.4 |
| Traverse | 0.68 | 0.0 | 0.25 | 0.7 | 0.31 | 0.4 | | | 0.41 | 0.4 |
| Twin (Sanborn) | | 0.6 | 2.40 | 0.6 | 1.30 | 0.3 | 1.16 | 0.5 | 1.62 | 0.5 |
| Twin (Spink) | 0.86 | 0.9 | 1.86 | 1.2 | 0.54 | 1.1 | 0.41 | 0.6 | 0.92 | 1.0 |
| Vermillion | 0.00 | 0.4 | | 0.1 | 0.68 | 0.4 | 0.70 | 0.2 | 0.46 | 0.3 |
| Waggoner | 0.31 | 0.5 | 0.21 | 0.5 | 0.03 | 0.3 | 0.21 | 0.3 | 0.19 | 0.4 |
| White | 0.52 | 0.0 | 0.27 | 0.6 | 0.00 | 0.8 | | | 0.26 | 0.5 |

inorganic phosphate (Gilmartin, 1967), and affects release of phosphate from algae which may be in the sample (Fitzgerald and Faust, 1967). Since freezing causes the above mentioned changes, phosphorous was reported only as total phosphate.

Seasonal concentrations of total phosphate are shown in Table 13. Due to problems encountered during analysis, many of these values may be higher than actually occurred. Mean concentrations of total phosphate ranged from 0.16 to 3.00 mg/l.

## Iron and Manganese

Iron and manganese may be highly important in certain lakes since most lakes contain relatively small amounts of these elements. Both iron and manganese form the active site of many enzymes and are involved in the photosynthetic process. Manganese is also essential for nitrate assimilation.

Mean concentrations of total iron (Table 14) ranged from 0.02 to 0.78 mg/l, but only five of the lakes studied had mean concentrations over 0.2 mg/l. Mean concentrations of manganese (Table 14) ranged from 0.02 to 0.55 mg/l.

## Silica

Silicon is almost universally present in some form in all natural waters. It is a major nutrient for diatoms and may be a limiting factor since it is normally found in low concentrations. Mean silica content ranged from 1.1 to 28.5 mg/l (Table 14), but only 10 lakes had over 15.0 mg/l. Silica concentrations of lakes in

Table 13. Average total phosphate concentrations (mg/l) of lakes studied, July 1965 to July 1967.

| Lake | Summer | Fall | Winter | Spring | Mean |
|---|---|---|---|---|---|
| Alvin | 0.21 | 0.49 | 0.09 | 0.26 | 0.26 |
| Amsden | *1.15 | *0.04 | *0.18 | | *0.46 |
| Angostura | *0.36 | *1.18 | 0.05 | 0.10 | 0.42 |
| Bigstone | *0.10 | *1.57 | *0.22 | | *0.63 |
| Bismarck | *0.70 | 0.07 | 0.07 | 0.41 | 0.31 |
| Brakke | *0.18 | 0.15 | 0.05 | 0.17 | 0.14 |
| Buffalo | *0.00 | *0.29 | *1.02 | *0.46 | *0.44 |
| Burke | *2.22 | 1.28 | 1.48 | 0.78 | 1.44 |
| Byron | *2.17 | *1.91 | *1.01 | *1.01 | *1.52 |
| Carthage | *2.08 | 0.20 | 0.25 | 0.71 | 0.81 |
| Catron Pond | *1.00 | *0.40 | *0.18 | *0.23 | *0.45 |
| Cottonwood | *4.25 | *2.08 | *2.48 | *3.20 | *3.00 |
| Durkee | *0.33 | *0.23 | *0.08 | *0.06 | *0.17 |
| Elm | *2.66 | *3.06 | *0.80 | *0.41 | *1.83 |
| Enemy Swim | *1.24 | *2.28 | *1.16 | *0.60 | *1.32 |
| Gardner | *0.20 | *0.27 | *0.07 | *0.11 | *0.16 |
| Hayes | *0.13 | *0.28 | 0.13 | 0.26 | 0.20 |
| Henry | | 0.45 | 0.12 | 0.05 | 0.21 |
| Hendricks | *0.76 | *0.12 | *0.18 | | *0.35 |
| Herman | *2.54 | 2.26 | 1.50 | 1.13 | 1.86 |
| Hiddenwood | *2.60 | *0.44 | *0.53 | *0.30 | *0.97 |
| Horse Thief | *0.87 | 0.05 | 0.05 | 0.14 | 0.28 |
| Iron Creek | *0.58 | 0.05 | 0.26 | 0.29 | 0.30 |
| Isabell | *0.50 | *0.15 | *0.09 | *0.07 | *0.20 |
| Kadoka | *1.14 | *0.78 | 0.12 | 0.20 | 0.56 |
| Madison | *1.24 | 0.60 | 0.20 | 0.19 | 0.56 |
| Merindahl | 0.09 | 0.10 | 0.05 | 0.55 | 0.20 |
| Mission | *0.76 | 0.05 | 0.06 | 0.18 | 0.26 |

Table 13. (continued)

| Lake | Summer | Fall | Winter | Spring | Mean |
|---|---|---|---|---|---|
| Mitchell | *0.58 | 0.07 | 0.07 | 0.23 | 0.24 |
| Newell | *0.22 | *0.30 | *0.09 | *0.09 | *0.18 |
| Pactola | *0.86 | 0.06 | 0.05 | 0.23 | 0.30 |
| Pocasse | *0.48 | *0.05 | *0.06 | *0.10 | *0.17 |
| Poinsett | *1.48 | *1.71 | *1.74 | *0.86 | *1.45 |
| Punished Woman | *0.16 | *0.64 | *0.17 | *1.01 | *0.50 |
| Rose Hill | *2.06 | 0.05 | 0.08 | 1.04 | 0.81 |
| Roy | *0.12 | *0.22 | *0.27 | *0.29 | *0.22 |
| Shadehill | *0.49 | *0.61 | *0.14 | *0.46 | *0.42 |
| Sheridan | *0.35 | *0.63 | 0.05 | 0.18 | 0.30 |
| Stephen Mission | *1.31 | 0.14 | 0.08 | 0.30 | 0.46 |
| Traverse | *1.22 | *1.62 | *0.57 | | *1.14 |
| Twin (Sanborn) | *1.22 | 0.14 | 0.08 | 0.18 | 0.41 |
| Twin (Spink) | *2.46 | *1.06 | *0.39 | *0.55 | *1.12 |
| Vermillion | *1.37 | *2.12 | 0.16 | 0.34 | 1.00 |
| Waggoner | 0.19 | 0.09 | 0.05 | 0.35 | 0.17 |
| White | *0.05 | *2.53 | *1.14 | | *1.24 |

* Due to problems in analysis these values may be higher than actually occurred.

Table 14. Mean concentrations of iron, manganese, and silica (mg/l) of lakes studied, July 1965 to July 1967.

| Lake | Iron | Manganese | Silica |
|---|---|---|---|
| Alvin | 0.08 | 0.47 | 3.0 |
| Amsden | 0.05 | 0.23 | 8.2 |
| Angostura | 0.07 | 0.10 | 5.6 |
| Bigstone | 0.04 | 0.47 | 14.9 |
| Bismarck | 0.78 | 0.22 | 7.1 |
| Brakke | 0.08 | 0.10 | 2.4 |
| Buffalo | 0.06 | 0.30 | 7.6 |
| Burke | 0.14 | 0.06 | 19.4 |
| Byron | 0.07 | 0.31 | 25.3 |
| Carthage | 0.10 | 0.36 | 11.9 |
| Catron Pond | 0.26 | 0.12 | 9.1 |
| Cottonwood | 0.11 | 0.02 | 20.8 |
| Durkee | 0.14 | 0.14 | 1.2 |
| Elm | 0.08 | 0.83 | 22.3 |
| Enemy Swim | 0.02 | 0.27 | 15.4 |
| Gardner | 0.10 | 0.03 | 1.1 |
| Hayes | 0.09 | 0.06 | 2.1 |
| Henry | 0.50 | 0.24 | 6.1 |
| Hendricks | 0.08 | 0.33 | 11.4 |
| Herman | 0.16 | 0.44 | 13.1 |
| Hiddenwood | 0.16 | 0.31 | 13.0 |
| Horse Thief | 0.17 | 0.15 | 4.0 |
| Iron Creek | 0.37 | 0.16 | 3.1 |
| Isabell | 0.18 | 0.08 | 1.3 |
| Kadoka | 0.14 | 0.24 | 2.8 |
| Madison | 0.08 | 0.15 | 4.9 |
| Merindahl | 0.06 | 0.11 | 4.5 |
| Mission | 0.06 | 0.12 | 15.6 |

Table 14. (continued)

| Lake | Iron | Manganese | Silica |
|---|---|---|---|
| Mitchell | 0.05 | 0.08 | 5.7 |
| Newell | 0.03 | 0.64 | 2.4 |
| Pactola | 0.04 | 0.10 | 4.4 |
| Pocasse | 0.17 | 0.46 | 19.5 |
| Poinsett | 0.15 | 0.32 | 19.9 |
| Punished Woman | 0.06 | 0.27 | 9.0 |
| Rose Hill | 0.11 | 0.30 | 2.4 |
| Roy | 0.06 | 0.12 | 4.1 |
| Shadehill | 0.06 | 0.10 | 3.7 |
| Sheridan | 0.19 | 0.08 | 2.6 |
| Stephen Mission | 0.09 | 0.18 | 6.7 |
| Traverse | 0.07 | 0.55 | 28.5 |
| Twin (Sanborn) | 0.30 | 0.28 | 9.6 |
| Twin (Spink) | 0.13 | 0.40 | 13.9 |
| Vermillion | 0.08 | 0.33 | 10.6 |
| Waggoner | 0.07 | 0.17 | 4.2 |
| White | 0.11 | 0.23 | 17.2 |

the unglaciated area west of the Missouri River ranged from 1.1 to 9.1 mg/l, while lakes east of the river had concentrations ranging from 2.4 to 28.5 mg/l.

Aluminum, Barium, Boron, Copper

These four elements were never found in high concentrations (Table 15). It is not known if any of these elements limit aquatic life in any of the lakes studied. Mean annual concentrations of these elements ranged as follow: aluminum, 0.00 to 0.04 mg/l; barium, 0.2 to 3.8 mg/l; boron, 0.06 to 1.60 mg/l; and copper, 0.00 to 0.33 mg/l.

Table 15. Mean concentrations of trace elements (mg/l) from lakes studied, July 1965 to July 1967.

| Lake | Aluminum | Barium | Boron | Copper |
|---|---|---|---|---|
| Alvin | 0.01 | 0.9 | 0.06 | 0.05 |
| Amsden | 0.03 | 0.7 | 0.13 | 0.20 |
| Angostura | 0.01 | 0.8 | 0.22 | 0.24 |
| Bigstone | 0.00 | 1.5 | 0.27 | 0.07 |
| Bismarck | 0.03 | 1.0 | 0.39 | 0.00 |
| Brakke | 0.00 | 0.5 | 0.20 | 0.02 |
| Buffalo | 0.01 | 1.6 | 0.24 | 0.08 |
| Burke | 0.02 | 0.9 | 0.12 | 0.03 |
| Byron | 0.03 | 1.9 | 1.60 | 0.05 |
| Carthage | 0.03 | 1.6 | 0.16 | 0.04 |
| Catron Pond | 0.04 | 2.4 | 0.05 | 0.09 |
| Cottonwood | 0.00 | 1.9 | 0.84 | 0.02 |
| Durkee | 0.00 | 1.1 | 0.12 | 0.00 |
| Elm | 0.00 | 0.3 | 0.36 | 0.01 |
| Enemy Swim | 0.02 | 1.0 | 0.19 | 0.19 |
| Gardner | 0.01 | 1.8 | 0.48 | 0.23 |
| Hayes | 0.01 | 0.8 | 0.18 | 0.03 |
| Henry | 0.00 | 1.1 | 0.45 | 0.05 |
| Hendricks | 0.01 | 2.5 | 0.28 | 0.33 |
| Herman | 0.02 | 3.8 | 0.22 | 0.02 |
| Hiddenwood | 0.02 | 2.5 | 0.14 | 0.03 |
| Horse Thief | 0.03 | 0.2 | 0.34 | 0.04 |
| Iron Creek | 0.00 | 0.3 | 0.50 | 0.00 |
| Isabell | 0.02 | 1.6 | 0.15 | 0.03 |
| Kadoka | 0.02 | 1.2 | 0.61 | 0.01 |
| Madison | 0.01 | 0.6 | 0.24 | 0.03 |
| Merindahl | 0.00 | 0.8 | 0.63 | 0.10 |
| Mission | 0.02 | 0.6 | 0.05 | 0.04 |

Table 15. (continued)

| Lake | Aluminum | Barium | Boron | Copper |
|---|---|---|---|---|
| Mitchell | 0.01 | 1.2 | 0.49 | 0.02 |
| Newell | 0.01 | 0.2 | 0.16 | 0.02 |
| Pactola | 0.02 | 0.6 | 0.38 | 0.03 |
| Pocasse | 0.01 | 2.6 | 0.14 | 0.06 |
| Poinsett | 0.01 | 0.5 | 0.14 | 0.04 |
| Punished Woman | 0.01 | 2.1 | 0.10 | 0.03 |
| Rose Hill | 0.02 | 1.0 | 0.25 | 0.04 |
| Roy | 0.02 | 0.6 | 0.75 | 0.07 |
| Shadehill | 0.00 | 1.5 | 0.92 | 0.07 |
| Sheridan | 0.02 | 0.8 | 0.18 | 0.02 |
| Stephen Mission | 0.02 | 1.4 | 0.08 | 0.07 |
| Traverse | 0.04 | 2.2 | 0.32 | 0.08 |
| Twin (Sanborn) | 0.02 | 3.2 | 0.84 | 0.13 |
| Twin (Spink) | 0.03 | 2.9 | 1.23 | 0.03 |
| Vermillion | 0.02 | 1.1 | 0.11 | 0.06 |
| Waggoner | 0.01 | 0.8 | 0.15 | 0.04 |
| White | 0.02 | 1.0 | 0.12 | 0.18 |

# Biological Considerations

## Chlorophyll Concentrations

Concentrations of chlorophyll is commonly used as a measure of standing crop of phytoplankton. Since photosynthesis is dependent upon chlorophyll it would seem that primary production could be calculated from chlorophyll content. Steele and Baird (1961) and Ryther (1956) have pointed out many limitations of this method. The more important of these limitations are as follows: 1) chlorophyll measured in water is partly inactive, 2) assimilation numbers (mg carbon assimilated per mg chlorophyll *a* per hour) vary with light intensity, turbidity, and total dissolved solids, 3) there is a diurnal fluctuation in chlorophyll content, 4) the ratio of the chlorophyll components *a*, *b*, and *c* varies in different organisms, and 5) photosynthesis is light adaptive. Consequently, knowledge of chlorophyll content alone cannot provide a basis for productivity estimates. Data concerning chlorophyll *a* concentrations (Table 16) are used as general indices of standing crop of phytoplankton.

Chlorophyll *a* is the predominant chlorophyll pigment in both Chlorophyceae and Myxophyceae (Strickland, 1960). Chlorophyll *b* is present in Chlorophyceae but is a minor pigment. Since most dense algal blooms encountered were of Myxophyceae, and because the Richard-Thompson method does not give sufficient differentiation of pigments to enable taxonomic sorting (Strickland, 1960), only quantities of chlorophyll *a* were determined.

Table 16. Average concentrations of chlorophyll a (mg/l) from lakes studied, July 1965 to July 1967.

| Lake | Summer | Fall | Winter | Spring |
|---|---|---|---|---|
| Alvin | 4.393 | 10.584 | 0.245 | 1.233 |
| Amsden | 3.937 | 1.412 | | 1.318 |
| Angostura | .074 | 0.242 | .065 | .067 |
| Bigstone | 15.865 | 0.205 | | 3.115 |
| Bismarck | 0.658 | 0.845 | 0.380 | 2.926 |
| Brakke | 2.456 | 1.032 | 0.202 | 0.099 |
| Buffalo | 1.178 | 0.733 | 1.554 | 1.094 |
| Burke | 3.993 | 0.886 | 0.378 | 0.389 |
| Byron | 6.260 | 1.114 | | 0.072 |
| Carthage | 0.779 | 0.098 | 0.072 | 0.092 |
| Catron Pond | 19.114 | 0.366 | | 0.219 |
| Cottonwood | 3.098 | 4.355 | | |
| Durkee | 4.461 | 0.544 | | 0.213 |
| Elm | 4.929 | 0.563 | | 0.185 |
| Enemy Swim | 0.861 | | 0.074 | |
| Gardner | 0.662 | 0.059 | | 0.073 |
| Hayes | 0.346 | 0.188 | 1.669 | 0.138 |
| Henry | 0.464 | 0.069 | 0.034 | 0.149 |
| Hendricks | 7.079 | 1.207 | 0.700 | 4.670 |
| Herman | 14.256 | 0.603 | 0.070 | 5.686 |
| Hiddenwood | 3.268 | | | 0.500 |
| Horse Thief | 1.035 | 0.187 | 1.138 | 1.481 |
| Iron Creek | 0.834 | 0.288 | 0.190 | 0.416 |
| Isabell | 0.952 | | 0.328 | |
| Kadoka | 0.328 | 0.378 | 0.161 | 0.098 |
| Madison | 16.638 | 0.366 | 9.149 | 2.648 |
| Merindahl | 0.446 | 1.967 | 0.152 | 0.810 |
| Mission | 1.266 | 0.247 | 0.077 | 1.810 |

Table 16. (continued)

| Lake | Summer | Fall | Winter | Spring |
|---|---|---|---|---|
| Mitchell | 0.870 | 0.504 | 0.456 | 0.983 |
| Newell | 0.352 | | | |
| Pactola | 0.175 | 0.134 | 0.113 | 0.176 |
| Pocasse | 18.037 | 0.658 | | 2.341 |
| Poinsett | 13.811 | 5.073 | 3.565 | 1.667 |
| Punished Woman | 0.745 | 0.766 | 2.345 | 1.951 |
| Rose Hill | 1.079 | 2.077 | 0.850 | 1.820 |
| Roy | 1.765 | | 0.230 | |
| Shadehill | 0.095 | | | 0.258 |
| Sheridan | 0.219 | 0.451 | 0.922 | 0.405 |
| Stephen Mission | 1.144 | 1.232 | 1.016 | 2.279 |
| Traverse | 7.804 | | | 1.937 |
| Twin (Sanborn) | 0.617 | 0.531 | 1.200 | 1.334 |
| Twin (Spink) | 4.122 | 3.308 | | 1.226 |
| Vermillion | 2.560 | 9.120 | 0.044 | 1.788 |
| Waggoner | 9.662 | 0.563 | 0.280 | 0.280 |
| White | 8.746 | | 1.205 | 2.523 |

Highest concentrations of chlorophyll a were observed in the late summer or fall and were usually caused by blue-green algae. *Aphanizomenon* and *Microcystis* were the genera forming most of the nuisance algal blooms.

The highest seasonal concentrations of chlorophyll a are compared with the mean annual concentrations of total nitrogen and total phosphate in Table 17. Little association was observed between total phosphate ion concentration and concentration of chlorophyll a. This relationship may have been obscured because of problems encountered during analyses for phosphate. Lakes which had high mean total nitrogen content (more than 0.75 mg/1) often developed dense blooms of phytoplankton.

Table 17. Comparison of highest average chlorophyll *a*, mean total nitrogen, and mean total phosphate concentrations (mg/l) of lakes studied, July 1965 to July 1967.

| Lake | Chlorophyll a | Nitrogen | Phosphate |
|---|---|---|---|
| Catron Pond | 19.11 | 1.14 | 0.45 |
| Pocasse | 18.04 | 1.52 | 0.17 |
| Madison | 16.64 | 1.51 | 0.56 |
| Bigstone | 15.86 | 0.67 | 0.63 |
| Herman | 14.26 | 1.52 | 1.86 |
| Poinsett | 13.81 | 1.33 | 1.45 |
| Alvin | 10.50 | 1.43 | 0.26 |
| Waggoner | 9.66 | 0.59 | 0.17 |
| Vermillion | 9.12 | 0.76 | 1.00 |
| White | 8.74 | 0.76 | 1.24 |
| Traverse | 7.80 | 0.82 | 1.14 |
| Hendricks | 7.08 | 1.56 | 0.35 |
| Byron | 6.26 | 2.66 | 1.52 |
| Elm | 4.93 | 1.74 | 1.73 |
| Durkee | 4.46 | 0.92 | 0.17 |
| Cottonwood | 4.36 | 1.07 | 3.00 |
| Twin (Spink) | 4.12 | 1.92 | 1.12 |
| Burke | 3.99 | 0.92 | 1.44 |
| Amsden | 3.94 | 0.36 | 0.46 |
| Hiddenwood | 3.27 | 0.88 | 0.97 |
| Bismarck | 2.92 | 1.29 | 0.31 |
| Brakke | 2.46 | 0.68 | 0.14 |
| Punished Woman | 2.34 | 0.62 | 0.50 |
| Stephen Mission | 2.28 | 0.64 | 0.46 |
| Rose Hill | 2.08 | 3.07 | 0.81 |
| Merindahl | 1.97 | 1.10 | 0.20 |

Table 17. (continued)

| Lake | Chlorophyll a | Nitrogen | Phosphate |
|---|---|---|---|
| Mission | 1.81 | 0.93 | 0.26 |
| Roy | 1.76 | 0.88 | 0.22 |
| Hayes | 1.67 | 0.58 | 0.20 |
| Horse Thief | 1.48 | 0.46 | 0.28 |
| Twin (Sanborn) | 1.33 | 2.12 | 0.41 |
| Buffalo | 1.18 | 0.76 | 0.44 |
| Mitchell | 0.98 | 0.70 | 0.24 |
| Isabell | 0.95 | 0.82 | 0.20 |
| Sheridan | 0.92 | 0.50 | 0.30 |
| Enemy Swim | 0.86 | 0.48 | 1.32 |
| Iron Creek | 0.83 | 0.70 | 0.30 |
| Carthage | 0.78 | 0.82 | 0.81 |
| Gardner | 0.66 | 0.82 | 0.16 |
| Henry | 0.46 | 2.06 | 0.21 |
| Kadoka | 0.38 | 1.02 | 0.56 |
| Newell | 0.35 | 1.28 | 0.18 |
| Shadehill | 0.26 | 0.64 | 0.42 |
| Angostura | 0.24 | 0.64 | 0.42 |
| Pactola | 0.18 | 0.34 | 0.30 |

# SUMMARY

Maximum water temperature at the surface reached 28 C; temperatures of 23 to 25 C were common. Most of the lakes studied exhibited continous circulation except when ice covered. Temperature in these lakes seldom varied more than 3 C from top to bottom at any given time. Six of the 45 lakes studied developed thermoclines. Maximum ice depth encountered ranged from over 100 cm in the northeast to about 20 cm in the southwest.

Light transmission was influenced by turbidity and varied greatly among lakes and within individual lakes during the year. The depth to which one per cent of the incident radiation penetrated the water varied from 0.2 m (Kadoka Lake) to 12.0 m (Pactola Lake). Turbidity was generally highest in the fall or summer due to stirring of sediments by wind action and development of algae blooms.

Dissolved oxygen concentrations ranged from near saturation to less than the recommended minimum for fish life. Many lakes showed decreased oxygen near the bottom. Lowest concentrations were encountered during the winter. All lakes studied were basic ranging in pH from 7.1 to 11.3. The pH was quite uniform throughout individual lakes or slightly more acid at the bottom.

Variations in specific conductance of lake waters were associated with physical divisions of the state and various drift types of the Wisconsin glacial age. Specific conductance of lakes occupying open basins was lowest in the unglaciated area west of the Missouri River and highest in the glacial drift east of the Missouri River. Open

lakes in the Black Hills had the lowest specific conductance (70-230 micromhos at 25 C) while lakes in the Mankato drift were highest (330-1260 micromhos at 25 C). Closed lakes or lakes overlying glacial drift aquifers had higher specific conductance than those lakes occupying open basins. Individual lakes showed maximum specific conductance during the winter due to concentration of the mineral elements under the ice.

Most of the major anions and cations followed concentration patterns similar to those described for specific conductance. Alkalinity of the lakes east of the Missouri River tended to vary according to the depth of carbonate leaching in the soil. Relationships between sodium concentrations and physical divisions or drift types were not obvious. Ranges of mean concentration for the major anions and cations in lakes with open basins are as follows: carbonate 38-260 mg/l (as $CaCO_3$), sulfate 10-520 mg/l, calcium 7-364 mg/l, magnesium 3-241 mg/l, sodium 3-210 mg/l, and potassium 1-17 mg/l.

Mean concentration of total nitrogen ranged from 0.34 to 3.07 mg/l, and total phosphate ranged from 0.16 to 3.00 mg/l among lakes studied. Mean concentrations of total iron and manganese ranged from 0.02 to 0.78 and 0.02 to 0.83 mg/l respectively. Silica concentrations in lakes west of the Missouri River ranged from 1.1-9.1 mg/l; lakes east of the Missouri River had concentrations ranging from 2.4 to 28.5 mg/l. Aluminum, barium, boron, and copper were never found in high concentrations but were present in most lakes studied.

Chlorophyll *a* concentrations were usually highest in the summer or fall due to the blooms of the blue-green algae *Aphanizomenon* or *Microcystis*. Little association was observed between concentrations of total phosphate and chlorophyll *a*. This relationship may have been obscured because of problems encountered during the analyses for phosphate.

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# APPENDIX

Appendix A. Physical and chemical analyses of selected South Dakota lakes, July 1965 to July 1967. (Chemical analyses expressed as mg/l)

| Lake and Date of Collection | Depth in Meters | Temperature (°C) | Oxygen ($O_2$) | pH | Specific conductance (micromhos at 25°C) | Alkalinity as $CaCO_3$: Bicarbonate | Alkalinity as $CaCO_3$: Carbonate | Sulfate ($SO_4$) | Chloride (Cl) | Hardness as $CaCO_3$: Calcium, magnesium | Hardness as $CaCO_3$: Noncarbonate | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Phosphate ($PO_4$) | Nitrogen as ppm (N): Ammonia ($NH_3$) | Nitrogen as ppm (N): Nitrate ($NO_3$) | Iron (Fe) | Silica ($SiO_2$) | Aluminum (Al) | Barium (Ba) | Boron (B) | Copper (Cu) | Manganese (Mn) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alvin 8-15-66 | 0.0 | 23.0 | 8.6 | 8.60 | 510 | 102 | 16 | | | 260 | | 44.0 | 36.5 | | | 0.23 | 1.12 | 0.3 | 0.10 | | | | | | |
| | 3.0 | 23.0 | 9.5 | 8.40 | 495 | 106 | 4 | 145 | 5.0 | 238 | | 43.2 | 31.6 | 15.0 | 12.3 | 0.19 | 1.45 | 0.4 | 0.13 | 6.7 | 0.03 | 0.0 | 2.00 | 0.03 | 0.51 |
| | 6.0 | 22.0 | 4.7 | 8.60 | 500 | 96 | 20 | | | 266 | | 42.4 | 38.9 | | | 0.18 | 1.69 | 0.5 | 0.12 | | | | | | |
| 11-5-66 | 0.0 | 5.0 | 10.7 | 8.40 | 490 | 115 | 10 | | | 176 | | 22.4 | 29.2 | | | 0.50 | | 0.3 | 0.03 | | | | | | |
| | 3.0 | 5.0 | 10.7 | 8.44 | 385 | 113 | 10 | 130 | 5.5 | 176 | | 20.8 | 30.1 | 15.5 | 12.1 | 0.50 | | 0.2 | 0.03 | 0.3 | 0.00 | 2.5 | 0.10 | 0.03 | 0.22 |
| | 6.0 | 5.0 | 10.8 | 8.48 | 460 | 112 | 10 | | | 182 | | 21.6 | 31.1 | | | 0.46 | | 0.1 | 0.02 | | | | | | |
| 2-8-67 | 0.0 | 5.0 | 5.0 | 7.50 | 430 | 154 | 0 | | | 230 | | 49.6 | 25.8 | | | 0.05 | 0.59 | 0.5 | 0.08 | | | | | | |
| | 3.0 | 6.0 | 3.4 | 7.48 | 410 | 154 | 0 | 160 | 5.0 | 235 | | 46.0 | 29.9 | 17.0 | 12.6 | 0.05 | 0.52 | 0.6 | 0.08 | 2.5 | 0.00 | 0.0 | 0.10 | 0.13 | 0.80 |
| | 6.0 | 6.5 | 1.4 | 7.42 | 490 | 166 | 0 | | | 218 | | 44.0 | 26.2 | | | 0.18 | 1.52 | 0.6 | 0.08 | | | | | | |
| 4-5-67 | 0.0 | 11.0 | 9.5 | 8.00 | 358 | 133 | 0 | | | 184 | | 34.4 | 23.8 | | | 0.33 | 0.84 | 0.7 | 0.10 | | | | | | |
| | 3.0 | | 8.7 | 8.00 | 358 | 129 | 0 | 105 | 4.0 | 194 | | 38.4 | 23.8 | 13.0 | 11.7 | 0.22 | 0.64 | 0.6 | 0.08 | 2.4 | 0.01 | 1.0 | 0.09 | 0.02 | 0.35 |
| | 6.0 | 10.0 | 7.4 | 7.83 | 375 | 132 | 0 | | | 210 | | 46.0 | 21.9 | | | 0.24 | 0.90 | 0.6 | 0.13 | | | | | | |
| Madison 8-6-65 | 0.0 | 28.0 | 12.1 | 8.10 | 460 | 130 | 30 | | | | | | | | | | | | | | | | | | |
| | 1.5 | 26.0 | 9.7 | 8.60 | 950 | 127 | 60 | 450 | 15.0 | 250 | 63 | 79.6 | 42.8 | 91.2 | 12.6 | 1.01 | 0.80 | 0.0 | 0.10 | 4.9 | 0.07 | 0.0 | 0.00 | | 0.35 |
| | 3.0 | 25.0 | 8.9 | 8.60 | 900 | 136 | 48 | | | | | | | | | 1.20 | 0.21 | 0.0 | 0.10 | | | | | | |
| | 4.5 | 5.0 | 7.2 | 8.60 | 950 | 128 | 54 | | | | | | | | | 1.23 | 0.35 | 0.0 | 0.30 | | | | | | |
| 11-7-65 | 0.0 | 6.0 | 11.4 | 8.73 | 1300 | 158 | 30 | | 14.0 | 280 | 92 | 52.1 | 30.5 | | | | 0.00 | 0.0 | 0.00 | | | | | | |
| | 1.5 | 6.0 | 11.4 | 8.80 | 1400 | 155 | 30 | 176 | 13.0 | 234 | 66 | 33.6 | 36.5 | 18.6 | 12.1 | 0.04 | 0.00 | 0.0 | 0.02 | 7.6 | 0.01 | 0.0 | 0.35 | 0.26 | 0.33 |
| | 3.0 | 6.0 | 11.4 | 8.90 | 1100 | 157 | 30 | | 12.0 | 260 | 73 | 39.4 | 39.9 | | | | 0.00 | 0.0 | 0.13 | | | | | | |
| | 6.0 | | 11.4 | 8.90 | 1350 | 158 | 30 | | 12.0 | 320 | 132 | 40.0 | 53.5 | | | | 0.00 | 1.0 | 0.03 | | | | | | |
| 2-10-66 | 0.0 | | 7.8 | 8.45 | 1300 | 162 | 25 | | 15.5 | 472 | 262 | 66.5 | 74.4 | | | 0.14 | 0.45 | 0.0 | 0.02 | | | | | | |
| | 1.5 | | 7.2 | 8.50 | 2000 | 245 | 24 | 175 | 14.0 | 600 | 331 | 56.1 | 111.8 | 115.2 | 11.0 | 0.21 | 0.30 | 0.3 | 0.03 | 7.2 | 0.01 | 2.0 | 0.00 | 0.33 | 0.27 |
| | 3.0 | | 7.3 | 8.60 | 1680 | 214 | 28 | | 13.0 | 588 | 366 | 43.2 | 116.6 | | | 0.14 | 0.30 | 0.4 | 0.02 | | | | | | |
| | 4.5 | | 2.7 | 8.60 | 1900 | 196 | 24 | | 17.5 | 630 | 410 | 36.0 | 130.7 | | | 0.23 | 0.30 | 0.3 | 0.03 | | | | | | |
| 5-5-66 | 0.0 | 12.0 | 11.5 | 8.70 | | 169 | 24 | | | | | | | | | | | | | | | | | | |
| | 1.5 | 11.0 | 11.9 | 8.80 | | 157 | 26 | | | | | | | | | | | | | | | | | | |
| | 3.0 | 11.0 | 11.7 | 8.75 | | 168 | 24 | | | | | | | | | | | | | | | | | | |
| | 4.5 | 11.5 | 11.5 | 8.70 | | 170 | 20 | | | | | | | | | | | | | | | | | | |
| | 6.0 | 10.0 | 11.1 | 8.70 | | 172 | 16 | | | | | | | | | | | | | | | | | | |
| Angostura 8-9-66 | 0.0 | 22.0 | 6.6 | 7.92 | 1650 | 103 | 2 | | | 660 | 555 | 181.8 | 50.1 | | | 0.23 | 0.18 | 0.2 | 0.04 | | | | | | |
| | 10.0 | 19.0 | 2.5 | 7.90 | 1700 | 111 | 0 | 708 | 122.0 | 605 | 491 | 162.5 | 55.2 | 252.0 | 8.2 | 0.44 | 0.20 | 0.2 | 0.05 | 6.5 | 0.01 | 2.0 | 0.10 | 0.2* | 0.13 |
| | 20.0 | 16.0 | 0.3 | 7.56 | 1750 | 122 | 0 | | | 586 | 464 | 162.4 | 40.8 | | | 0.42 | 0.20 | 0.3 | 0.04 | | | | | | |
| 10-17-66 | 0.0 | 13.3 | 8.1 | 8.08 | 1900 | 106 | 2 | | | 665 | 576 | 165.8 | 53.5 | | | 0.95 | | 0.0 | 0.16 | | | | | | |
| | 10.0 | 13.3 | 9.5 | 8.08 | 2300 | 106 | 2 | 795 | 120.0 | 600 | 472 | 172.8 | 57.3 | 260.0 | 8.7 | 0.95 | | 0.0 | 0.06 | 5.3 | 0.01 | 0.0 | 0.10 | 0.36 | 0.13 |
| | 18.0 | 13.3 | 8.1 | 8.08 | 2400 | 108 | 0 | | | 675 | 566 | 180.2 | 54.6 | | | 1.46 | | 0.0 | 0.42 | | | | | | |
| 2-11-67 | 9.0 | 4.0 | 12.0 | 8.25 | 1590 | 114 | 5 | | | 660 | 519 | 200.2 | 15.2 | | | 0.05 | 1.25 | 0.4 | 0.03 | | | | | | |
| | 3.0 | 4.0 | 13.6 | 8.23 | 1710 | 115 | 4 | 565 | 100.0 | 570 | 551 | 181.8 | 28.2 | 220.0 | 11.0 | 0.05 | 0.80 | 0.7 | 0.03 | 5.3 | 0.01 | 0.0 | 0.20 | 0.33* | 0.00 |
| | 6.0 | 4.0 | 14.0 | 8.22 | 1660 | 115 | 2 | | | 620 | 605 | 222.2 | 47.5 | | | 0.05 | 0.73 | 0.5 | 0.04 | | | | | | |
| 4-18-67 | 0.0 | 6.75 | 10.1 | 8.11 | 1700 | 113 | 0 | | | 800 | 697 | 200.2 | 25.3 | | | 0.10 | 0.22 | | 0.00 | | | | | | |
| | 10.0 | 6.75 | 10.1 | 8.11 | 1600 | 113 | 0 | 725 | 88 | 660 | 527 | 200.2 | 15.0 | 130.0 | 7.9 | 0.10 | 0.20 | 0.2 | 0.00 | 5.5 | 0.01 | 1.0 | 0.50 | 0.17 | 0.05 |
| | 20.0 | 6.75 | 10.1 | 8.11 | 2000 | 113 | 0 | | | 820 | 307 | 211.8 | 64.5 | | | 0.10 | 0.22 | 0.2 | 0.03 | | | | | | |
| Stockade 7-14-65 | 0.0 | 23.0 | 11.8 | 8.60 | 655 | 108 | 62 | | | | | | | | | 0.21 | 0.00 | 0.6 | 0.10 | | | | | | |
| | 1.5 | 23.0 | 9.3 | 8.40 | 655 | 96 | 38 | 125 | 17.5 | 196 | 66 | 27.6 | 32.0 | 40.8 | 8.2 | 0.00 | 0.00 | 0.0 | 0.06 | 9.3 | 0.00 | 0.0 | 0.20 | | 0.40 |
| | 3.0 | 23.0 | 7.1 | 8.20 | 655 | 92 | 40 | | | | | | | | | 0.09 | 0.00 | 0.0 | 0.06 | | | | | | |
| 11-11-65 | 0.0 | 5.0 | 10.5 | 7.95 | 925 | 170 | | | | 310 | 140 | 42.2 | 46.2 | | | 0.90 | 0.40 | 0.9 | 0.06 | | | | | | |
| | 1.5 | 5.0 | 10.2 | 7.95 | 850 | 172 | | 116 | 10.5 | 270 | 98 | 36.8 | 43.3 | 10.8 | 12.3 | 2.27 | 0.21 | 0.6 | 0.03 | 19.2 | 0.01 | 2.5 | 0.00 | 0.06 | 0.30 |
| | 3.0 | 5.0 | 10.4 | 8.05 | 785 | 171 | | | | 224 | 52 | 36.8 | 32.1 | | | 1.56 | 0.21 | 0.9 | 0.04 | | | | | | |
| 2-18-66 | 0.0 | | 10.5 | 8.65 | 1000 | 122 | 16 | | 22 | 380 | 262 | 69.6 | 62.2 | | | 0.28 | 0.21 | 0.7 | 0.02 | | | | | | |
| | 1.5 | | 10.3 | 8.50 | 1000 | 122 | 10 | 115 | 9.5 | 354 | 227 | 63.2 | 59.8 | 43.2 | 13.4 | 0.21 | 0.25 | 0.8 | 0.02 | 16.2 | 0.00 | 2.0 | 0.60 | 0.08 | 0.72 |
| | 3.0 | | 9.3 | 8.29 | 1280 | 150 | 10 | | 8.5 | 380 | 230 | 61.6 | 67.1 | | | 0.17 | 0.25 | 0.5 | 0.03 | | | | | | |
| 4-23-66 | 0.0 | 9.5 | 14.2 | 8.85 | | | | | | | | | | | | | | | | | | | | | |
| | 1.5 | 9.5 | 13.8 | 8.85 | | | | | | | | | | | | | | | | | | | | | |
| | 3.0 | 9.5 | 13.5 | 8.85 | | | | | | | | | | | | | | | | | | | | | |
| Bismarck 8-8-66 | 0.0 | 20.0 | 7.2 | 8.15 | 00 | 69 | 2 | | | 50 | -1 | 12.0 | 4.9 | | | 0.42 | 0.35 | 0.7 | 0.10 | | | | | | |
| | 3.0 | 17.0 | 2.0 | 7.65 | 0 | 56 | | 10 | 2.0 | 64 | -10 | 15.2 | 1.5 | 5.4 | 7.2 | 0.62 | 0.63 | 0.8 | 0.13 | 9.9 | 0.03 | 2.5 | 0.50 | 0.00 | 0.51 |
| | 6.0 | 9.0 | 0.0 | 7.10 | 0 | 75 | | | | 44 | -31 | 10.0 | 4.6 | | | 1.07 | 0.45 | 0.5 | 0.68 | | | | | | |
| 10-16-66 | 0.0 | 8.0 | 8.0 | 7.10 | 0 | 55 | | | | 50 | -5 | 11.2 | 5.3 | 6.0 | 4.1 | 0.06 | 0.87 | 0.2 | 1.64 | | | | | | |
| | 4.0 | 7.0 | 6.5 | 7.10 | 0 | 55 | | 11 | 2.5 | 50 | -5 | 12.0 | 4.9 | 5.5 | 4.1 | 0.15 | 1.07 | 0.1 | 1.73 | 4.5 | 0.03 | 1.0 | 0.20 | 0.02 | 0.09 |
| | 8.0 | 7.0 | 6.1 | 7.10 | 5 | 55 | | | | 44 | -11 | 10.4 | 4.4 | 5.5 | 4.1 | 0.01 | 0.70 | 0.0 | 1.55 | | | | | | |
| 2-11-67 | 0.0 | 3.5 | 4.6 | 7.20 | 5 | 165 | | | | 56 | -111 | 13.6 | 4.9 | | | 0.05 | 1.52 | 0.4 | 0.24 | | | | | | |
| | 3.0 | 4.5 | 0.5 | 7.16 | 0 | 165 | | 12 | 3.0 | 50 | -115 | 11.6 | 5.1 | 6.0 | 4.6 | 0.30 | 1.86 | 0.4 | 0.42 | 8.4 | 0.03 | 0.0 | 0.10 | 0.00 | 0.20 |
| | 6.0 | 5.0 | 0.1 | 7.08 | 8 | 165 | | | | 49 | -166 | 11.2 | 5.1 | | | 0.05 | 1.96 | 0.4 | 0.18 | | | | | | |
| 4-15-67 | 0.0 | | 10.1 | 7.67 | 2 | 53 | | | | 48 | -5 | 13.6 | 3.4 | | | 0.29 | 0.46 | 1.3 | 0.91 | | | | | | |
| | 3.0 | | 10.0 | 7.75 | 2 | 55 | | 13 | 2.5 | 52 | -3 | 13.6 | 4.4 | 6.0 | 4.1 | 0.29 | 0.50 | 0.1 | 0.32 | 5.5 | 0.03 | 0.5 | 0.77 | 0.00 | 0.09 |
| | 6.0 | | 7 | 7.44 | 2 | 53 | | | | 52 | -1 | 13.6 | 4.4 | | | 0.66 | 0.52 | 0.2 | 1.22 | | | | | | |

Appendix A. (continued)

| Lake and Date of Collection | Depth in Meters | Temperature (°C) | Oxygen ($O_2$) | pH | Specific conductance (micromhos at 25°C) | Alkalinity as $CaCO_3$: Bicarbonate | Alkalinity as $CaCO_3$: Carbonate | Sulfate ($SO_4$) | Chloride (Cl) | Hardness as $CaCO_3$: Calcium, magnesium | Hardness as $CaCO_3$: Noncarbonate | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Phosphate ($PO_4$) | Nitrogen as ppm (N): Ammonia ($NH_3$) | Nitrogen as ppm (N): Nitrate ($NO_3$) | Iron (Fe) | Silica ($SiO_2$) | Aluminum (Al) | Barium (Ba) | Boron (B) | Copper (Cu) | Manganese (Mn) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bradke 8-10-66 | 0.0 | 23.0 | 8.2 | 8.75 | 340 | 130 | 20 | | | 120 | -30 | 20.8 | 6.5 | | | 0.11 | 0.60 | 0.7 | 0.10 | | | | | | |
| | 2.5 | 23.0 | 8.2 | 8.75 | 490 | 128 | 20 | 76 | 10.0 | 100 | -48 | 21.2 | 1.6 | 38.0 | 12.9 | 0.15 | 0.60 | 0.3 | 0.12 | 1.2 | 0.00 | 1.0 | 0.00 | 0.00 | 0.28 |
| | 5.0 | 23.0 | 7.8 | 8.70 | 450 | 129 | 20 | | | 132 | -17 | 23.2 | 8.0 | | | 0.27 | 0.60 | 0.4 | 0.06 | | | | | | |
| 10-8-66 | 0.0 | 16.0 | 9.9 | 8.38 | 295 | 148 | 19 | | | 84 | -102 | 16.0 | 0.7 | | | 0.05 | 0.07 | 0.3 | 0.08 | | | | | | |
| | 1.5 | 15.5 | 9.9 | 8.35 | 322 | 152 | 22 | 72 | 11.6 | 82 | -102 | 16.0 | 0.2 | 69.0 | 13.4 | 0.25 | 0.05 | 0.1 | 0.06 | 3.5 | 0.00 | 0.0 | 0.35 | 0.00 | 0.20 |
| | 3.0 | 14.0 | 8.4 | 8.45 | | 172 | 12 | | | | | | 0.7 | | | 0.05 | 0.16 | 0.6 | 0.10 | | | | | | |
| 2-9-67 | 1.0 | 5.5 | 13.2 | 8.06 | 435 | 188 | 6 | | | 84 | -106 | 14.0 | 1.2 | 75.0 | 16.2 | 0.05 | 0.26 | 0.6 | 0.08 | 2.7 | 0.00 | 0.0 | 0.10 | 0.00 | 0.00 |
| | 4.0 | 6.0 | 10.6 | 7.92 | 465 | 196 | 0 | 112 | 15.0 | 92 | -106 | 18.4 | 3.0 | | | 0.17 | 0.18 | 0.7 | 0.06 | | | | | | |
| 6-17-67 | 0.0 | 10.0 | 9.6 | 8.20 | 430 | 142 | 4 | | | 144 | -18 | 29.6 | 21.9 | 56.0 | 11.7 | 0.29 | 0.34 | 0.0 | 0.13 | 2.0 | 0.01 | 0.0 | 0.35 | 0.06 | 0.00 |
| | 2.5 | 10.0 | 9.4 | 8.28 | 325 | 164 | 6 | 87 | 10.0 | 146 | -24 | 22.4 | 10.9 | | | 0.03 | 0.32 | 0.6 | 0.03 | | | | | | |
| | 5.0 | 10.0 | 9.6 | 8.29 | 345 | 164 | 8 | | | 110 | -62 | 26.0 | | | | | | | | | | | | | |
| Buffalo 7-30-65 | 0.0 | 25.0 | 7.4 | 8.50 | 580 | 176 | 36 | | | | | | | | | 0.00 | 0.75 | 0.0 | | | | | | | |
| | 1.5 | 25.0 | 7.3 | 8.60 | 580 | 174 | 38 | 225 | 6.0 | 190 | -16 | 20.0 | 36.0 | 14.6 | 18.6 | 0.00 | 0.61 | 0.0 | | 4.7 | 0.00 | 0.0 | 0.00 | | 0.00 |
| | 3.0 | 25.0 | 6.9 | 8.62 | 580 | 177 | 34 | | | | | | | | | 0.00 | 0.75 | 0.0 | | | | | | | |
| 11-30-65 | 0.0 | 0.6 | 11.9 | 8.63 | 590 | 212 | 20 | | | 220 | -12 | 23.2 | 39.4 | | | 0.30 | 0.48 | 0.6 | 0.03 | | | | | | |
| | 1.5 | 1.0 | 11.1 | 8.65 | 420 | 208 | 22 | 92 | 5.0 | 200 | -31 | 17.6 | 37.9 | 5.4 | 15.4 | 0.16 | 0.45 | 0.6 | 0.03 | 3.0 | 0.02 | 3.5 | 0.00 | 0.00 | 0.35 |
| 2-11-66 | 0.0 | | 8.5 | 8.55 | 910 | 289 | | | 6.5 | 434 | 145 | 36.1 | 73.4 | | | 0.36 | 0.00 | 0.7 | 0.03 | | | | | | |
| | 1.5 | | 6.6 | 7.98 | 900 | 291 | | 250 | 6.0 | 444 | 153 | 39.3 | 75.9 | 14.8 | 18.6 | 0.95 | 0.00 | 0.5 | 0.02 | 12.4 | 0.00 | 1.0 | 0.77 | 0.17 | 0.23 |
| | 3.0 | | 5.1 | 7.90 | 850 | 294 | | | 7.0 | 460 | 166 | 35.3 | 78.2 | | | 1.76 | 0.00 | 0.1 | 0.10 | | | | | | |
| 6-24-66 | 0.0 | 9.0 | 11.0 | 8.35 | 605 | 199 | 8 | | 5 | 276 | 68 | 39.2 | 43.3 | | | 0.57 | 0.30 | 0.4 | 0.06 | | | | | | |
| | 1.5 | 8.0 | 11.0 | 8.35 | 575 | 183 | 6 | 115 | 4.5 | 280 | 91 | 40.0 | 43.7 | 10.2 | 12.3 | 0.36 | 0.30 | 0.4 | 0.03 | 9.5 | 0.03 | 2.0 | 0.20 | 0.06 | 0.43 |
| | 3.0 | 8.0 | 11.0 | 8.35 | 525 | 193 | 6 | | 5.0 | 280 | 91 | 48.0 | 43.7 | | | 0.44 | 0.30 | 0.3 | 0.06 | | | | | | |
| Burke 8-11-66 | 0.0 | 23.0 | 7.9 | 9.02 | 280 | 129 | 32 | | | 116 | -45 | 38.0 | 5.0 | | | 2.46 | 0.00 | 0.1 | 0.08 | | | | | | |
| | 2.0 | 23.0 | 5.4 | 9.02 | 290 | 122 | 60 | 12 | 6.0 | 118 | -44 | 31.6 | 9.3 | 15.0 | 16.6 | 2.27 | 0.00 | 0.4 | 0.08 | 17.0 | 0.03 | 1.0 | 0.00 | 0.02 | 0.00 |
| | 4.0 | 23.0 | 4.4 | 9.02 | 300 | 128 | 52 | | | 112 | -68 | 33.6 | 9.2 | | | 1.91 | 0.00 | 0.1 | 0.08 | | | | | | |
| 10-9-66 | 0.0 | 13.0 | 8.4 | 8.48 | 265 | 210 | 16 | | | 128 | -98 | 34.4 | 10.2 | | | 1.33 | 0.37 | 0.9 | 0.08 | | | | | | |
| | 1.5 | 12.0 | 7.7 | 8.46 | 325 | 210 | 16 | 5 | 5.5 | 132 | -94 | 38.0 | 10.2 | 15.0 | 17.4 | 1.22 | 0.30 | 0.7 | 0.08 | 22.0 | 0.02 | 2.0 | 0.10 | 0.00 | 0.00 |
| 2-9-67 | 1.0 | 5.0 | 1.0 | 7.48 | 290 | 231 | 0 | | | 130 | -101 | 36.6 | 9.2 | | | 1.44 | 0.67 | 0.9 | 0.24 | | | | | | |
| | 4.0 | 5.0 | 1.0 | 7.46 | 190 | 231 | 0 | 37 | 5.0 | 132 | -99 | 39.2 | 6.3 | 13.0 | 16.6 | 1.52 | 0.67 | 0.8 | 0.34 | 18.6 | 0.03 | 0.0 | 0.40 | 0.00 | 0.13 |
| 6-11-67 | 0.0 | 12.0 | 9.7 | 8.12 | 260 | 197 | 0 | | | 124 | -73 | 33.6 | 8.5 | | | 0.80 | 0.25 | 0.6 | 0.16 | | | | | | |
| | 2.5 | 12.0 | 9.4 | 8.37 | 250 | 187 | 10 | 35 | 5.5 | 124 | -73 | 32.8 | 10.2 | 15.0 | 14.0 | 0.79 | 0.22 | 0.3 | 0.16 | 20.0 | 0.01 | 0.5 | 0.00 | 0.11 | 0.09 |
| | 5.0 | 12.0 | 10.0 | 8.37 | 280 | 128 | 10 | | | 130 | -68 | 36.0 | 9.2 | | | 0.75 | 0.25 | 0.2 | 0.16 | | | | | | |
| Brown 4-8-65 | 0.0 | 22.0 | 6.4 | 8.50 | 2700 | 125 | 62 | | | | | | | | | 2.72 | 2.18 | 0.7 | 0.13 | | | | | | |
| | 1.5 | 21.0 | 5.8 | 8.40 | 2600 | 132 | 86 | 1000 | 170.0 | 370 | 152 | 27.2 | 73.4 | 384.0 | 27.0 | 1.42 | 2.52 | 0.6 | 0.13 | 22.4 | 0.04 | 0.0 | 2.40 | | 0.40 |
| 11-3-65 | 0.0 | 8.0 | 10.4 | 8.40 | 3800 | 305 | 20 | | | 500 | 275 | 36.0 | 99.1 | | | 2.20 | | 1.6 | 0.06 | | | | | | |
| | 1.5 | 7.0 | 9.8 | 8.45 | 4000 | 300 | 20 | 408 | 145.0 | 448 | 128 | 34.4 | 88.0 | 468.0 | 16.3 | 1.62 | 2.43 | 1.9 | 0.06 | 00.0 | 0.03 | 0.0 | 1.10 | 0.02 | 0.35 |
| 2-21-66 | 0.5 | | 11.0 | 8.70 | 4800 | 304 | 64 | 1950 | 290.0 | 980 | 612 | 88.1 | 184.7 | 930.0 | 48.0 | 1.01 | 0.30 | 2.1 | 0.03 | 38.4 | 0.00 | 3.5 | 2.15 | 0.11 | 0.40 |
| 6-3-66 | 0.0 | 25.0 | 7.7 | 8.22 | 2750 | 206 | 22 | 210 | 104.0 | 364 | 136 | 28.4 | 71.2 | 420.0 | 26.6 | 1.01 | 0.25 | 0.8 | 0.06 | 13.0 | 0.04 | 4.0 | 0.77 | 0.02 | 0.09 |
| | 1.5 | 22.0 | 7.7 | | | | | | | | | | | | | | | | | | | | | | |
| | 3.0 | 22.0 | | | | | | | | | | | | | | | | | | | | | | | |
| Carthage 7-11-66 | 0.0 | 27.0 | 5.3 | 8.20 | 340 | 113 | 8 | | | 164 | 43 | 34.0 | 5.5 | 14.0 | 14.3 | 1.45 | 0.00 | 0.0 | 0.08 | | | | | | |
| | 1.5 | 27.0 | 5.3 | 8.20 | 345 | 146 | 6 | 47 | 5 | 166 | 14 | 39.6 | 6.3 | 14.0 | 14.5 | 2.34 | 0.00 | 0.2 | 0.08 | 13.0 | 0.05 | 4.0 | 0.10 | 0.05 | 0.80 |
| | 3.0 | 27.0 | 3.4 | 8.20 | 335 | 145 | 6 | | | 145 | 14 | 40.0 | 5.8 | 14.0 | 16.5 | 2.66 | 0.00 | 0.6 | 0.06 | | | | | | |
| 11-7-66 | 0.0 | 5.0 | 12.3 | 8.30 | 280 | 145 | 6 | | | 143 | -28 | 25.6 | 9.2 | | | 0.24 | 0.20 | 0.5 | 0.08 | | | | | | |
| | 2.0 | 5.0 | 12.1 | 8.30 | 330 | 166 | 4 | 74 | 5 | 144 | -26 | 29.2 | 7.3 | 16.5 | 18.6 | 0.16 | 0.20 | 0.7 | 0.06 | 15.7 | 0.00 | 0.0 | 0.35 | 0.08 | 0.05 |
| 2-3-67 | 0.0 | 4.0 | 10.6 | 7.85 | 364 | 194 | 0 | | | 180 | -19 | 30.4 | 5.3 | | | 0.26 | 0.25 | 0.3 | 0.28 | | | | | | |
| | 2.5 | 5.0 | 10.6 | 7.85 | 364 | 200 | 0 | 65 | 5 | 172 | -28 | 32.8 | 1.9 | 16.0 | 19.6 | 0.30 | 0.30 | 0.3 | 0.02 | 10.8 | 0.00 | 0.5 | 0.20 | 0.07 | 0.25 |
| | 5.0 | 5.0 | 10.8 | 7.88 | 357 | 201 | 0 | | | 192 | -9 | 30.4 | 8.2 | | | 0.20 | 0.31 | 0.3 | 0.06 | | | | | | |
| 6-19-67 | 0.0 | 10.0 | 9.7 | 8.15 | 320 | 138 | 0 | | | 150 | 12 | 33.2 | 6.3 | | | 0.63 | 0.70 | 0.3 | 0.16 | | | | | | |
| | 2.0 | 10.0 | 9.7 | 8.14 | 320 | 137 | 0 | 60 | 4.5 | 160 | 23 | 40.8 | 4.1 | 13.0 | 18.3 | 0.76 | 0.70 | 0.5 | 0.15 | 7.4 | 0.06 | 2.0 | 0.00 | 0.00 | 0.35 |
| | 4.0 | 10.0 | 9.7 | 8.15 | 320 | 137 | 0 | | | 150 | 13 | 39.2 | 2.6 | | | 0.73 | 0.94 | 0.7 | 0.27 | | | | | | |
| Cotton Pond 5-26-65 | 0.0 | 19.0 | 7.5 | 8.80 | 405 | 108 | 104 | | | | | | | | | 1.13 | 0.37 | 1.1 | 0.24 | | | | | | |
| | 1.5 | 19.0 | 7.5 | 8.75 | 405 | 148 | 126 | 65 | 1.0 | 32 | -240 | 8.0 | 1.9 | 78.0 | 8.4 | 0.87 | 0.21 | 0.7 | 0.29 | 12.0 | 0.03 | 3.5 | 0.10 | | 0.46 |
| | 3.0 | 19.0 | 7.5 | 8.70 | 415 | 95 | 110 | | | | | | | | | 1.01 | 0.25 | 0.6 | 0.35 | | | | | | |
| 10-18-65 | 0.0 | 4.0 | 8.5 | 7.80 | 320 | 210 | | | | 42 | -168 | 6.4 | 6.3 | | | 0.36 | 0.44 | 0.7 | 0.06 | | | | | | |
| | 1.5 | 6.0 | 8.1 | 8.20 | 340 | 221 | | 67 | | 46 | -175 | 6.4 | 6.3 | 17.2 | 11.0 | 0.44 | 0.64 | 0.3 | 0.31 | 9.6 | 0.03 | 0.0 | 0.00 | 0.06 | 0.00 |
| 2-16-65 | 0.0 | | 10.5 | 8.35 | 770 | 264 | 12 | | | 110 | -166 | 30.8 | 24.1 | | | 0.14 | 0.30 | 1.2 | 0.28 | | | | | | |
| | 1.5 | | 6.5 | 8.35 | 810 | 265 | 14 | 30 | | 90 | -185 | 20.0 | 9.7 | 150.0 | 8.7 | 0.23 | 0.49 | 0.9 | 0.30 | 9.9 | 0.08 | 6.0 | 0.10 | 0.00 | 0.00 |
| 9-9-66 | 1.5 | 11.0 | 7.7 | 8.20 | 185 | | | 35 | 3.0 | | | | 4.4 | 108.0 | 3.0 | 0.23 | 0.25 | 0.4 | 0.26 | 4.2 | 0.04 | 0.0 | 0.00 | 0.20 | 0.10 |
| Cottonwood 8-11-65 | 0.0 | 24.0 | 6.1 | 9.0 | 2900 | 370 | 160 | | | | | | | | | 3.04 | 0.48 | 0.3 | 0.28 | | | | | | |
| | 1.5 | 24.0 | 5.8 | 9.0 | 2850 | 343 | 194 | 1030 | 353.5 | 384 | -153 | 47.2 | 64.6 | 380.0 | 66.0 | 3.65 | 0.25 | 0.2 | 0.20 | 17.3 | 0.00 | 2.0 | 1.70 | | 1.60 |
| | 3.0 | 24.0 | 5.8 | 9.0 | 2850 | 308 | 224 | | | | | | | | | 4.06 | 0.15 | 0.8 | 0.24 | | | | | | |
| 10-30-65 | 1.5 | 12.0 | 9.4 | 8.72 | 3600 | 848 | 132 | 600 | 120.0 | 410 | -137 | 38.4 | 76.5 | 374.0 | 16.4 | 3.39 | 0.90 | 0.8 | 0.06 | | 0.00 | 0.0 | 0.50 | 0.00 | 0.90 |
| 2-20-66 | 0.0 | | 6.5 | 8.80 | 4000 | 828 | 112 | | 175.0 | 528 | -472 | 40.0 | 104.0 | | | 3.72 | 0.35 | 1.2 | 0.03 | | | | | | |
| | 1.5 | | 7.2 | 8.80 | 3500 | 315 | 60 | 855 | 200.0 | 760 | -180 | 34.4 | 163.8 | 760.0 | 90.0 | 3.82 | 0.37 | 1.0 | 0.06 | 39.2 | 0.00 | 2.0 | 0.95 | 0.02 | 0.90 |
| 6-4-66 | 1.5 | 19.5 | 7.0 | 8.70 | 1700 | | | 425 | 83.5 | 355 | -85 | 30.0 | 52.2 | 456.0 | 36.0 | 2.76 | 0.23 | 0.3 | 0.12 | 4.0 | 0.00 | 3.5 | 0.20 | 0.03 | 0.40 |

Appendix A. (continued)

| Lake and Date of Collection | Depth in Meters | Temperature (°C) | Oxygen ($O_2$) | pH | Specific conductance (micromhos at 25°C) | Alkalinity as $CaCO_3$: Bicarbonate | Alkalinity as $CaCO_3$: Carbonate | Sulfate ($SO_4$) | Chloride (Cl) | Hardness as $CaCO_3$: Calcium, magnesium | Hardness as $CaCO_3$: Noncarbonate | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Phosphate ($PO_4$) | Nitrogen as ppm (N): Ammonia ($NH_3$) | Nitrogen as ppm (N): Nitrate ($NO_3$) | Iron (Fe) | Silica ($SiO_2$) | Aluminum (Al) | Barium (Ba) | Boron (B) | Copper (Cu) | Manganese (Mn) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Burton | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8-28-65 | 0.0 | 18.0 | 8.0 | 8.90 | 222 | 106 | 44 | | | | | | | | | 0.28 | 1.01 | 0.6 | 0.13 | | | | | | |
| | 1.5 | 18.0 | 8.0 | 8.90 | 218 | 93 | 44 | 33 | 1.5 | 26 | -111 | 10.6 | 2.9 | 31.3 | 8.1 | 0.46 | 0.58 | 0.9 | 0.20 | 1.3 | 0.02 | 1.5 | 0.50 | | 0.20 |
| | 3.0 | 18.0 | 8.0 | 8.90 | 148 | 94 | 44 | | | | | | | | | 0.25 | 1.02 | 0.7 | 0.22 | | | | | | |
| 10-16-65 | 0.0 | 9.0 | | 8.00 | 300 | 78 | 0 | | 2.0 | 72 | -6 | 20.0 | 12.6 | | | 0.26 | 0.64 | 0.2 | 0.13 | | | | | | |
| | 1.5 | 9.0 | | 8.20 | 175 | 120 | 4 | 18 | 2.0 | 48 | -76 | 19.2 | 8.3 | 7.0 | 3.4 | 0.34 | 0.66 | 0.4 | 0.22 | 2.2 | 0.00 | 0.0 | 0.00 | 0.00 | 0.00 |
| | 3.0 | 9.0 | | 8.25 | 320 | 116 | 4 | | 2.0 | 50 | -72 | 20.0 | 8.3 | | | 0.09 | 0.69 | 0.4 | 0.29 | | | | | | |
| 2-25-66 | 0.0 | | 11.1 | 8.68 | 340 | 128 | 10 | | 4.5 | 84 | -50 | 33.2 | 11.7 | | | 0.12 | 0.22 | 0.1 | 0.03 | | | | | | |
| | 1.5 | | 10.6 | 8.40 | 375 | 131 | 4 | 63 | 4.5 | 74 | -61 | 29.4 | 8.3 | 43.3 | 9.0 | 0.09 | 0.21 | 0.2 | 0.02 | 6.6 | 0.00 | 1.0 | 0.00 | 0.00 | 0.09 |
| | 3.0 | | 9.1 | 8.60 | 380 | 139 | 12 | | 4.0 | 74 | -77 | 29.6 | 8.3 | | | 0.04 | 0.25 | 0.3 | 0.03 | | | | | | |
| | 4.5 | | 7.7 | 8.35 | 340 | 137 | 6 | | 3.0 | 78 | -65 | 31.2 | 7.6 | | | 0.07 | 0.25 | 0.3 | 0.06 | | | | | | |
| 5-10-66 | 3.0 | 12.5 | 9.1 | 8.05 | 225 | 96 | 0 | 90 | 7.5 | 32 | -64 | 23.4 | 3.8 | 33.0 | 8.3 | 0.06 | 0.30 | 0.2 | 0.12 | 0.6 | 0.00 | 2.0 | 0.00 | 0.00 | 0.35 |
| Elm | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8-6-65 | 0.0 | 25.0 | 9.4 | 8.90 | 600 | 137 | 0 | | | | | | | | | 3.36 | 1.28 | 0.6 | 0.30 | | | | | | |
| | 1.5 | 24.0 | 9.8 | 8.90 | 595 | 128 | 46 | 132 | 26.5 | 106 | -68 | 21.6 | 13.6 | 66.8 | 16.3 | 1.30 | 1.39 | 0.4 | 0.16 | 17.0 | 0.00 | 0.0 | 0.00 | | 0.80 |
| | 3.0 | 24.0 | 9.0 | 8.70 | 595 | 118 | 34 | | | | | | | | | 3.00 | 0.98 | 0.3 | 0.13 | | | | | | |
| | 4.5 | 24.0 | 7.1 | 8.70 | 595 | 117 | 58 | | | | | | | | | 1.66 | 1.15 | 0.3 | 0.12 | | | | | | |
| | 6.0 | 24.0 | 5.9 | 8.70 | 610 | 148 | 29 | | | | | | | | | 1.97 | 1.84 | 0.3 | 0.08 | | | | | | |
| 11-6-65 | 0.0 | 8.0 | 11.0 | 8.65 | 1050 | 158 | 32 | | 30.0 | 236 | 66 | 69.6 | 7.8 | | | 3.00 | 0.00 | 1.5 | 0.08 | | | | | | |
| | 1.5 | 7.0 | 11.4 | 8.70 | 730 | 108 | 28 | 112 | 30.5 | 186 | 50 | 56.8 | 34.5 | 72.0 | 15.6 | 2.66 | 1.80 | 1.1 | 0.02 | 0.0 | 0.00 | 0.0 | 0.00 | 0.00 | 0.90 |
| | 3.0 | 7.0 | 11.0 | 8.70 | 460 | 104 | 26 | | 33.0 | 120 | 90 | 48.0 | 37.9 | | | 3.32 | 0.00 | 1.3 | 0.08 | | | | | | |
| 2-19-66 | 0.0 | | 10.8 | 8.72 | 950 | 41 | 6 | | 32.0 | 68 | 21 | 14.1 | 27.2 | | | 0.98 | 0.35 | 0.8 | 0.02 | | | | | | |
| | 1.5 | | 10.1 | 9.00 | 730 | 181 | 6 | 100 | 33.5 | 200 | 13 | 33.2 | 23.8 | 100.9 | 19.1 | 1.01 | 0.30 | 1.0 | 0.02 | 26.0 | 0.00 | 1.0 | 0.50 | 0.02 | 0.90 |
| | 3.0 | | 11.2 | 8.65 | 670 | 179 | 12 | | 31.0 | 210 | 19 | 31.6 | 24.3 | | | 0.64 | 0.30 | 0.5 | 0.02 | | | | | | |
| | 6.0 | | 10.4 | 8.55 | 295 | | 0 | | 7.0 | 130 | | 23.2 | 22.4 | | | 0.55 | 0.21 | 0.4 | 0.02 | | | | | | |
| 3-7-66 | 0.0 | 12.0 | 9.7 | 7.70 | 270 | 117 | 0 | | 3.5 | 88 | -29 | 30.0 | 8.7 | | | 0.42 | 0.33 | 0.0 | 0.06 | | | | | | |
| | 3.0 | 11.0 | 9.5 | 7.80 | 190 | 117 | 0 | | 5.5 | 64 | -53 | 17.6 | 4.9 | 15.6 | 11.4 | 0.40 | 0.00 | 0.0 | 0.06 | | 0.00 | 0.0 | 0.93 | 0.00 | 0.00 |
| [illegible] | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7-19-65 | 0.0 | 25.0 | 8.1 | 8.40 | 420 | 190 | 50 | | | | | | | | | 0.00 | 0.61 | 0.0 | | | | | | | |
| | 1.5 | 25.0 | 8.1 | 8.40 | 420 | 197 | 40 | 125 | 5.0 | 140 | -97 | 14.6 | 25.3 | 12.0 | 13.2 | 1.91 | 0.61 | 0.0 | | 11.0 | 0.00 | 0.0 | 0.00 | | 0.00 |
| | 3.0 | 25.0 | 7.9 | 8.40 | 420 | 193 | 44 | | | | | | | | | 0.13 | 0.61 | 0.0 | | | | | | | |
| | 4.5 | 23.0 | 7.7 | 8.40 | 420 | 194 | 46 | | | | | | | | | 0.86 | 0.61 | 0.0 | | | | | | | |
| | 6.0 | 23.0 | 7.0 | 8.40 | 420 | 193 | 46 | | | | | | | | | 0.11 | 0.61 | 0.0 | | | | | | | |
| 11-13-65 | 0.0 | 3.0 | 10.85 | 8.30 | 495 | 201 | 10 | | | 34 | 5 | 24.0 | 7.4 | | | 3.00 | 0.20 | 0.5 | 0.03 | | | | | | |
| | 1.5 | 3.0 | 10.8 | 8.40 | 410 | 200 | 10 | 91 | 12.5 | 52 | -58 | 20.0 | 4.8 | 7.2 | 12.0 | 2.14 | 0.40 | 0.4 | 0.16 | 22.0 | 0.05 | 1.5 | 0.00 | 0.27 | 0.13 |
| | 3.0 | 3.0 | 10.7 | 8.40 | 445 | 193 | 10 | | | 70 | -33 | 16.0 | 1.6 | | | 1.45 | 0.20 | 0.4 | 0.24 | | | | | | |
| | 6.0 | 3.0 | 10.3 | 8.40 | 405 | 190 | 10 | | | 92 | -4 | 13.2 | 36.9 | | | 0.55 | 0.20 | 0.2 | 0.06 | | | | | | |
| 3-11-66 | 0.0 | | 11.5 | 8.40 | 570 | 250 | | | | 90 | 40 | 38.4 | 7.2 | | | 1.76 | 0.00 | 0.0 | 0.00 | | | | | | |
| | 1.5 | | 10.8 | 8.50 | 560 | 255 | | 49 | 2.5 | 86 | 31 | 38.4 | 6.2 | 10.0 | 12.1 | 1.34 | 0.00 | 0.0 | 0.00 | 15.0 | 0.00 | 0.0 | 0.00 | 0.29 | 0.74 |
| | 3.0 | | 10.4 | 8.30 | 580 | 265 | | | | 84 | 21 | 39.2 | 5.7 | | | 1.07 | 0.00 | 0.2 | 0.00 | | | | | | |
| | 6.0 | | 9.5 | 8.25 | 575 | 270 | | | | [illegible] | 30 | 39.2 | 9.1 | | | 0.50 | 0.00 | 0.1 | 0.00 | | | | | | |
| 4-25-66 | 0.0 | 8.0 | 11.3 | 8.40 | 460 | 206 | 8 | | 2.5 | 32 | 16 | 39.2 | 2.6 | | | 0.62 | 0.25 | 0.3 | 0.03 | | | | | | |
| | 1.5 | 7.0 | 11.3 | 8.40 | 460 | 206 | 8 | 55 | 2.0 | 32 | 14 | 36.0 | 4.5 | 8.4 | 8.4 | 0.90 | 0.25 | 0.3 | 0.06 | 13.6 | 0.05 | 2.5 | 0.77 | 0.02 | 0.20 |
| | 3.0 | 7.0 | 11.2 | 8.40 | 480 | 206 | 6 | | 2.5 | 34 | 22 | 32.0 | 7.4 | | | 0.50 | 0.25 | 0.2 | 0.12 | | | | | | |
| | 4.5 | 7.0 | 11.3 | 8.40 | | 208 | 4 | | | | | | | | | | | | | | | | | | |
| | 6.0 | 7.0 | 11.3 | 8.40 | 460 | 206 | 4 | | 2.0 | 232 | 20 | 31.3 | 37.4 | | | 0.74 | 0.35 | 0.0 | 0.03 | | | | | | |
| Gardner | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8-26-65 | 0.0 | 21.0 | 8.0 | 8.30 | 540 | 205 | 50 | | | | | | | | | 0.21 | 0.00 | 0.8 | 0.16 | | | | | | |
| | 1.5 | 21.0 | 8.0 | 8.30 | 490 | 190 | 50 | 150 | | | | | | | | 0.28 | 0.00 | 0.7 | 0.13 | | | | | | |
| | 3.0 | 21.0 | 8.0 | 8.30 | 520 | 175 | 50 | | | 36 | -189 | 6.0 | 3.0 | 120.0 | 3.0 | 0.11 | 0.00 | 0.8 | 0.31 | 0.9 | 0.00 | 3.9 | 1.30 | 0.34 | 0.00 |
| 10-18-65 | 0.0 | 8.0 | 9.8 | 8.80 | 650 | 292 | 12 | | 2.0 | 50 | -154 | 7.2 | 7.8 | | | 0.32 | 0.58 | 0.8 | 0.03 | | | | | | |
| | 1.5 | 7.0 | 9.8 | 8.90 | 900 | 180 | 40 | 210 | 1.5 | 36 | -184 | 6.0 | 5.8 | 11.6 | 7.3 | 0.25 | 0.45 | 0.7 | 0.10 | 1.5 | 0.01 | 1.0 | 0.00 | 0.17 | 0.00 |
| | 3.0 | 7.0 | 9.9 | 8.90 | 750 | 200 | 44 | | 1.5 | 40 | -188 | 5.6 | 6.3 | | | 0.25 | 0.43 | 0.4 | | | | | | | |
| 2-26-66 | 0.0 | | 13.4 | 8.70 | 990 | 290 | 34 | | | 66 | -258 | 12.0 | 8.7 | | | 0.12 | 0.40 | 0.5 | 0.12 | | | | | | |
| | 1.5 | | 12.4 | 8.70 | 900 | 254 | 26 | 80 | | 40 | -237 | 10.4 | 3.3 | 193.0 | 4.9 | 0.06 | 0.35 | 0.6 | 0.03 | 0.8 | 0.01 | 2.0 | 0.10 | 0.15 | 0.09 |
| | 3.0 | | 12.0 | 8.75 | 1030 | 294 | 26 | | | 62 | -238 | 12.0 | 7.8 | | | 0.06 | 0.33 | 0.3 | 0.06 | | | | | | |
| 3-8-66 | 3.0 | 12.0 | 8.6 | 8.10 | 120 | 209 | 6 | | 1.0 | 26 | -189 | 0.8 | 1.0 | 31.0 | 1.3 | 0.11 | 0.00 | 0.0 | 0.08 | | 0.00 | | 0.50 | | |
| Bryan | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8-17-66 | 0.0 | 22.0 | 7.8 | 8.61 | 360 | 86 | 10 | | | 86 | -10 | 9.6 | 9.0 | | | 0.13 | 0.60 | 0.4 | 0.08 | | | | | | |
| | 1.5 | 21.0 | 6.5 | 8.21 | 300 | 98 | 8 | 73 | 4.5 | 96 | -10 | 9.2 | 11.7 | 35.0 | 8.1 | 0.10 | 0.60 | 0.4 | 0.06 | 1.7 | 0.02 | 0.5 | 0.00 | 0.02 | 0.13 |
| | 3.0 | 21.0 | 2.1 | 7.90 | 340 | 100 | 0 | | | 98 | -2 | 8.4 | 12.6 | | | 0.14 | 0.60 | 0.1 | 0.18 | | | | | | |
| 10-8-66 | 0.0 | 12.0 | 9.7 | 8.45 | 200 | 117 | 10 | | 6.0 | 58 | -69 | 9.6 | 8.3 | | | | | 0.0 | 0.08 | | | | | | |
| | 1.5 | 11.5 | 9.3 | 8.35 | 325 | 125 | 6 | 65 | 5.0 | 112 | -19 | 8.0 | 16.3 | 37.0 | 9.0 | 0.25 | | 0.3 | 0.06 | 0.8 | 0.00 | 0.0 | 0.00 | 0.02 | 0.00 |
| | 3.0 | 11.0 | 7.8 | 8.20 | 295 | 129 | 0 | | 4.0 | 84 | -45 | 7.6 | 9.7 | | | 0.32 | | 0.1 | 0.00 | | | | | | |
| 3-13-67 | 0.5 | 3.0 | 16.0 | 8.35 | 320 | 169 | 8 | 82 | 5.5 | 124 | -55 | 2.4 | 16.8 | 42.0 | 9.7 | 0.13 | 0.16 | 0.2 | 0.08 | 2.3 | 0.00 | 2.5 | 0.20 | 0.00 | 0.00 |
| 4-12-67 | 0.0 | 12.0 | 9.0 | 8.12 | 304 | 141 | 0 | | | 100 | -41 | 5.2 | 9.0 | | | 0.20 | 0.13 | 0.4 | 0.08 | | | | | | |
| | 2.0 | 11.0 | 8.9 | 8.12 | 300 | 144 | 0 | 70 | 4.0 | 100 | -44 | 8.0 | 7.3 | 25.0 | 9.0 | 0.56 | 0.10 | 0.5 | 0.10 | 3.7 | 0.01 | 0.6 | 0.50 | 0.08 | 0.09 |
| | 4.0 | 11.0 | 8.8 | 8.12 | 300 | 144 | 0 | | | 110 | -34 | 8.0 | 9.7 | | | 0.21 | 0.03 | 0.5 | 0.08 | | | | | | |

Appendix A. (continued)

| Lake and Date of Collection | Depth in Meters | Temperature (°C) | Oxygen ($O_2$) | pH | Specific conductance (micromhos at 25°C) | Alkalinity as $CaCO_3$: Bicarbonate | Alkalinity as $CaCO_3$: Carbonate | Sulfate ($SO_4$) | Chloride (Cl) | Hardness as $CaCO_3$: Calcium, magnesium | Hardness as $CaCO_3$: Noncarbonate | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Phosphate ($PO_4$) | Nitrogen as ppm (N): Ammonia ($NH_3$) | Nitrogen as ppm (N): Nitrate ($NO_3$) | Iron (Fe) | Silica ($SiO_2$) | Aluminum (Al) | Barium (Ba) | Boron (B) | Copper (Cu) | Manganese (Mn) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Henry 4-16-66 | 0.0 | 14.0 | 6.0 | .30 | 1330 | 370 | 14 | | | 382 | 398 | 56.1 | 107.4 | 105.0 | 14.2 | | | | 1.23 | | | | | | |
| | 1.5 | 14.0 | 5.8 | .30 | 1170 | 370 | 14 | 387 | 79.5 | 336 | 332 | 49.6 | 95.3 | 108.0 | 14.2 | | | 0.5 | 1.62 | 2.2 | 0.00 | 3.0 | 0.35 | 0.02 | 0.17 |
| | 3.0 | 14.0 | 5.1 | .30 | 1400 | 370 | 14 | | | 355 | 371 | 60.3 | 142.2 | 101.0 | 14.2 | | | | 1.30 | | | | | | |
| 11-6-66 | 0.0 | 7.0 | 10.6 | .08 | 980 | 165 | 0 | | | 342 | 177 | 59.3 | 47.1 | | | 0.52 | 2.56 | | | | | | | | |
| | 2.0 | 7.0 | 10.3 | .08 | 945 | 165 | 0 | 287 | 32.0 | 318 | 153 | 56.1 | 43.3 | 77.0 | 15.0 | 0.33 | 3.56 | 0.7 | | 5.9 | 0.02 | 1.0 | 0.60 | 0.53 | 0.27 |
| | 4.0 | 7.0 | 9.8 | .08 | 945 | 165 | 0 | | | 320 | 155 | 54.4 | 44.7 | | | 0.51 | 2.92 | | | | | | | | |
| 2-5-67 | 0.0 | 4.5 | 11.6 | .35 | 940 | 205 | 0 | | | 356 | 151 | 57.7 | 51.5 | | | 0.11 | 1.30 | 0.7 | 0.10 | | | | | | |
| | 4.0 | 4.0 | 6.0 | .38 | 940 | 236 | 0 | 367 | 35.0 | 330 | 134 | 60.9 | 53.0 | 109.0 | 15.6 | 0.14 | 1.70 | 0.6 | 0.10 | 8.1 | 0.00 | 0.0 | 0.35 | | [illegible] |
| 6-6-67 | 0.0 | 11.0 | 9.7 | .25 | 1010 | 193 | 6 | | | 328 | 319 | 68.1 | 84.6 | | | 0.03 | 0.52 | 0.3 | 0.01 | | | | | | |
| | 5.0 | 11.0 | 9.5 | .36 | 990 | 194 | 6 | 365 | 15.5 | 350 | 150 | 66.1 | 46.2 | 56.0 | 15.6 | 0.05 | 0.46 | 0.2 | 0.03 | 8.3 | 0.00 | 0.5 | 0.36 | 0.11 | [illegible] |
| Hendricks 7-22-65 | 0.0 | 26.0 | 7.6 | 8.60 | 520 | 339 | 22 | | | | | | | | | | 0.83 | 0.0 | 0.08 | | | | | | |
| | 1.5 | 25.0 | 7.2 | 8.50 | 520 | 327 | 20 | 323 | 4.0 | 186 | 39 | 32.0 | 25.8 | 10.8 | 16.0 | 0.76 | 0.92 | 0.0 | 0.06 | 4.0 | 0.03 | 3.5 | 0.50 | | 0.52 |
| | 3.0 | 25.0 | 6.6 | 8.30 | 540 | 335 | 10 | | | | | | | | | | 3.16 | 0.0 | 0.03 | | | | | | |
| 12-2-65 | 0.0 | | 15.0 | 8.75 | 850 | 186 | 20 | | 3.5 | 224 | 16 | 40.8 | 29.6 | | | | | 1.2 | 0.18 | | | | | | |
| | 1.5 | | 14.3 | 8.55 | 850 | 185 | 20 | 142 | 4.0 | 182 | -23 | 42.4 | 18.5 | 4.8 | 13.0 | 0.32 | | 0.4 | 0.06 | 24.0 | 0.00 | 0.0 | 0.35 | 0.06 | [illegible] |
| 3-19-66 | 0.0 | | 6.9 | 8.30 | 650 | 112 | 10 | | 3.0 | 330 | 408 | 44.0 | 102.1 | | | 0.11 | 0.31 | 0.8 | 0.03 | | | | | | |
| | 1.5 | | 6.8 | 8.10 | 650 | 112 | 6 | 184 | 3.0 | 324 | 406 | 40.8 | 102.5 | 10.2 | 14.6 | 0.25 | 0.35 | 0.7 | 0.06 | 4.1 | 0.00 | 4.0 | 0.50 | [illegible] | [illegible] |
| Herman 7-16-66 | 0.0 | 25.0 | 9.6 | | 750 | 78 | 90 | | | 336 | 168 | 57.7 | 46.3 | | | 2.66 | 0.43 | 1.0 | 0.03 | | | | | | |
| | 1.5 | 25.0 | 10.4 | | 750 | 76 | 92 | 227 | 1.0 | 326 | 158 | 48.8 | 49.6 | 35.0 | 19.5 | 2.41 | 0.43 | 0.9 | 0.08 | 18.3 | 0.03 | 1.0 | 0.00 | 0.02 | [illegible] |
| 11-4-66 | 0.0 | 2.5 | 11.6 | 8.45 | 1000 | 198 | 25 | | | 510 | 386 | 68.1 | 82.6 | 51.0 | 18.0 | 2.26 | | | 0.31 | | | | | | |
| | 1.5 | 2.5 | 11.6 | 8.65 | 815 | 196 | 26 | 280 | 7.0 | 460 | 238 | 50.5 | 81.2 | 55.0 | 19.4 | 1.76 | | 0.8 | 0.36 | 8.5 | 0.02 | 9.0 | 0.20 | [illegible] | [illegible] |
| 2-3-67 | 1.0 | 4.0 | | 7.85 | 840 | 300 | 0 | 240 | 6.3 | 690 | 390 | 62.1 | 130.0 | 66.0 | 21.1 | 1.50 | 1.50 | 0.2 | 0.06 | 20.4 | 0.00 | 2.5 | 0.50 | [illegible] | [illegible] |
| 6-5-67 | 0.0 | 9.0 | 11.0 | 8.48 | 700 | 378 | 60 | | | 415 | 197 | 48.8 | 71.2 | | | 1.10 | 0.53 | 0.8 | 0.18 | | | | | | |
| | 2.0 | 9.0 | 10.7 | 8.29 | 470 | 173 | 46 | 238 | 3.5 | 402 | 163 | 45.0 | 68.5 | 46.5 | 11.9 | 1.16 | 0.55 | 0.6 | 0.22 | 5.3 | 0.01 | 3.5 | 0.26 | [illegible] | [illegible] |
| Middlewood 8-2-65 | 0.0 | 10.0 | | 8.70 | 440 | 135 | 60 | | | | | | | | | 1.34 | 0.30 | 0.3 | 0.26 | | | | | | |
| | 1.5 | 15.0 | | 8.60 | 430 | 125 | 60 | 80 | 3.5 | 94 | -91 | 20.0 | 10.7 | 36.3 | 13.0 | 3.87 | 0.30 | 0.2 | 0.27 | 16.0 | 0.04 | 3.5 | 0.20 | | 0.35 |
| 10-30-65 | 0.0 | 10.0 | 7.6 | 7.75 | 595 | 165 | | | 3.0 | 136 | -31 | 31.6 | 19.4 | | | 0.38 | 0.56 | 0.5 | 0.24 | | | | | | |
| | 1.5 | 10.0 | 7.0 | 7.10 | 590 | 165 | | 125 | 5.0 | 125 | -37 | 33.2 | 27.0 | 11.6 | 14.8 | 0.50 | 0.37 | 0.9 | 0.35 | 20.0 | 0.02 | 1.5 | 0.00 | 0.53 | [illegible] |
| 2-20-66 | 0.5 | | 0.2 | 8.27 | 970 | 201 | 14 | 140 | 8.0 | 198 | -17 | 24.0 | 33.5 | 38.8 | 19.2 | 0.33 | 0.35 | 0.8 | 0.03 | 3.0 | 0.00 | 3.5 | 0.00 | 0.53 | [illegible] |
| 5-7-65 | 1.5 | | | 7.90 | 380 | 132 | 7 | | 2.5 | 60 | -79 | 14.4 | 5.8 | 15.6 | 5.8 | 0.30 | 0.00 | | 0.03 | | 0.01 | | 0.33 | | |
| Horse Thief 8-8-66 | 0.0 | 21.0 | 0.7 | 7.30 | 70 | 25 | 0 | | | 26 | -1 | 6.0 | 2.3 | | | 0.65 | 0.00 | 0.6 | 0.03 | | | | | | |
| | 4.5 | 15.0 | 0.3 | 7.20 | 70 | 10 | 0 | 10 | 0.2 | 24 | -6 | 4.4 | 2.9 | 6.0 | 2.6 | 0.16 | 0.00 | 0.4 | 0.06 | 1.8 | 0.04 | 0.1 | 1.00 | 0.53 | [illegible] |
| | 9.0 | 7.0 | 0.0 | 7.20 | 70 | 42 | 0 | | | 28 | -14 | 6.8 | 2.7 | | | 1.81 | 0.00 | 0.2 | 0.16 | | | | | | |
| 10-14-66 | 0.0 | | 6.8 | 6.80 | 65 | 39 | 0 | 8 | 1.0 | 32 | -7 | 6.4 | 3.9 | 4.0 | 2.6 | 0.05 | 0.20 | 0.1 | 0.40 | 3.5 | 0.04 | 0.0 | 0.25 | 0.02 | [illegible] |
| 2-12-67 | 0.0 | 1.0 | 12.5 | 7.40 | 45 | 42 | 0 | | | 36 | -8 | 7.2 | 3.6 | | | 0.05 | 0.35 | 0.3 | 0.10 | | | | | | |
| | 3.0 | 3.0 | 12.5 | 7.35 | 34 | 40 | 0 | 12 | 2.5 | 36 | -4 | 4.8 | 5.3 | 3.7 | 2.8 | 0.01 | 0.33 | 0.3 | 0.08 | 5.9 | 0.02 | 0.0 | 0.00 | 0.00 | [illegible] |
| | 6.0 | 3.0 | 1.2 | 6.97 | 60 | 49 | 0 | | | 32 | -17 | 4.0 | 5.3 | | | 0.05 | 1.42 | 0.5 | 0.08 | | | | | | |
| 6-13-67 | 0.0 | 14.0 | 9.7 | 7.21 | 72 | 35 | 0 | 20 | 1.0 | 37 | -3 | 6.8 | 2.4 | 3.0 | 2.2 | 0.14 | 0.17 | 0.0 | 0.08 | 4.6 | 0.03 | 0.5 | 0.10 | 0.03 | [illegible] |
| Iron Creek 5-7-66 | 0.0 | [illegible] | 7.5 | .35 | 87 | 42 | 20 | | | 39 | -23 | 7.2 | 5.1 | | | .25 | 0.00 | 0.4 | 0.06 | | | | | | |
| | 5.0 | [illegible] | 0.3 | .40 | 95 | 90 | 0 | 3 | 0.2 | 42 | -48 | 8.8 | 4.9 | 2.4 | 1.0 | .25 | 0.00 | 0.1 | 0.03 | 2.2 | 0.01 | 0.3 | 1.00 | 0.00 | 0.01 |
| | 10.0 | .0 | 0.0 | .30 | 135 | 120 | 0 | | | 42 | -58 | 14.4 | 6.3 | | | .23 | 0.00 | 0.5 | 0.16 | | | | | | |
| 10-15-66 | 0.0 | .0 | 7.6 | .55 | 140 | 73 | 0 | 8 | 1.5 | 42 | -11 | 12.0 | 7.8 | 4.0 | 0.7 | .03 | 0.90 | 0.1 | 0.08 | 2.2 | 0.00 | 0.5 | 0.20 | 0.00 | 0.25 |
| 2-13-67 | 0.0 | .5 | 3.5 | .48 | 115 | 91 | 0 | | | 35 | -36 | 12.0 | 6.1 | | | .14 | 0.55 | 0.0 | 0.03 | | | | | | |
| | 4.0 | .25 | 1.2 | .31 | 115 | 96 | 0 | 27 | 0.2 | 56 | -46 | 12.8 | 5.6 | 3.0 | 1.6 | .32 | 0.01 | 0.0 | 0.03 | 3.7 | 0.00 | 0.5 | 0.20 | 0.00 | 0.20 |
| | 8.0 | .5 | 0.1 | .34 | 107 | 96 | 0 | | | 50 | -46 | 10.4 | 5.8 | | | .31 | 0.25 | 0.0 | 0.58 | | | | | | |
| 6-15-67 | 0.0 | .0 | 7.4 | .45 | 114 | 81 | 0 | | | 56 | -25 | 9.6 | 7.8 | | | .38 | 0.18 | 0.4 | 0.08 | | | | | | |
| | 5.5 | .5 | 5.1 | .30 | 100 | 92 | 0 | 0 | 0.5 | 54 | -28 | 12.0 | 3.8 | 3.0 | 1.0 | .27 | 0.18 | 0.0 | 0.12 | 4.3 | 0.01 | 0.0 | 0.60 | 0.02 | 0.11 |
| | 11.0 | .5 | 0.0 | .27 | 126 | 110 | 0 | | | 64 | -46 | 14.4 | 6.8 | | | .22 | 1.00 | 1.9 | 3.07 | | | | | | |
| Isabell 6-29-65 | 0.0 | 18.0 | 8.3 | 8.00 | 320 | 43 | 0 | | | | | | | | | 0.68 | 0.13 | 0.3 | 0.29 | | | | | | |
| | 1.5 | 14.0 | 8.3 | 8.00 | 320 | 45 | 0 | 40 | 5.0 | 30 | -115 | 8.8 | 1.9 | 48.0 | 9.0 | 0.62 | 0.00 | 0.5 | 0.31 | 1.0 | 0.04 | 1.5 | 0.20 | | 0.20 |
| | 3.0 | 18.0 | 7.9 | 8.00 | 315 | 48 | 0 | | | | | | | | | 0.40 | 0.00 | 0.3 | 0.29 | | | | | | |
| 11-19-65 | 0.0 | 8.5 | 9.7 | 8.40 | 440 | 28 | 4 | | 3.0 | 124 | -8 | 10.4 | 23.8 | | | 0.19 | 0.38 | 0.4 | 0.38 | | | | | | |
| | 1.5 | 8.0 | 9.6 | 8.50 | 400 | 30 | 0 | 106 | 2.0 | 72 | -50 | 10.4 | 11.2 | 14.4 | 8.7 | 0.14 | 0.50 | 0.6 | 0.32 | 3.5 | 0.00 | 0.0 | 0.00 | 0.00 | 0.00 |
| | 3.0 | 6.0 | 9.5 | 8.45 | 460 | 30 | 0 | | 3.0 | 64 | -66 | 11.2 | 8.7 | | | 0.11 | 0.72 | 0.5 | 0.16 | | | | | | |
| 2-27-66 | 0.0 | | 12.1 | 8.00 | 470 | 56 | 14 | | 2.5 | 80 | -90 | 19.2 | 7.8 | | | 0.16 | 0.21 | 1.0 | 0.06 | | | | | | |
| | 1.5 | | 11.0 | 8.00 | 500 | 70 | 10 | 50 | 3.5 | 80 | -100 | 19.2 | 7.8 | 66.0 | 9.3 | 0.06 | 0.30 | 1.1 | 0.06 | 0.5 | 0.00 | 1.0 | 0.20 | 0.00 | 0.05 |
| | 3.0 | | 5.6 | 8.70 | 570 | 76 | 10 | | 3.0 | 84 | -100 | 21.6 | 7.8 | | | 0.06 | 0.56 | 1.3 | 0.20 | | | | | | |
| 5-8-66 | 1.5 | | 9.4 | 7.90 | 80 | 89 | 0 | 10 | 2.0 | 24 | -65 | 7.2 | 1.5 | 10.8 | 1.4 | 0.07 | 0.25 | 0.1 | 0.00 | 0.3 | 0.02 | 4.0 | 0.20 | 0.03 | 0.09 |
| Kadoka 8-9-66 | 0.0 | 19.0 | 7.0 | 8.55 | 355 | 165 | 10 | | | 40 | -131 | 8.8 | 4.4 | | | 1.16 | 0.46 | 0.6 | 0.13 | | | | | | |
| | 1.5 | 19.0 | 7.0 | 8.55 | 380 | 167 | 10 | 35 | 2.1 | 50 | -127 | 13.0 | 4.9 | 74.0 | 7.8 | 1.13 | 0.40 | 0.7 | 0.37 | 7.9 | 0.03 | 6.0 | 2.00 | 0.05 | 0.09 |
| 10-8-66 | 0.0 | 14.0 | 9.7 | 8.60 | 380 | 139 | 16 | 45 | 10.0 | 50 | -85 | 13.4 | 3.9 | 73.0 | 7.4 | 0.78 | | 0.4 | 0.03 | 4.0 | 0.03 | 3.0 | 0.35 | 0.00 | 0.20 |
| 3-10-67 | 0.0 | 6.0 | 13.5 | 8.30 | 450 | 275 | 10 | 68 | 13.5 | 56 | -229 | 8.0 | 6.7 | 96.5 | 7.3 | 0.12 | 0.35 | 0.5 | 0.18 | 4.8 | 0.01 | 2.0 | 0.10 | 0.00 | 0.60 |
| 6-13-67 | 0.0 | 11.0 | 8.9 | 8.49 | 400 | 203 | 20 | 35 | 11.0 | 52 | -151 | 12.0 | 5.3 | 87.0 | 7.3 | 0.20 | 0.32 | 0.6 | 0.20 | 1.8 | 0.02 | 1.0 | 0.00 | 0.00 | 0.31 |

Appendix A. (continued)

| Lake and Date of Collection | Depth in Meters | Temperature (°C) | Oxygen ($O_2$) | pH | Specific conductance (micromhos at 25°C) | Alkalinity as $CaCO_3$: Bicarbonate | Alkalinity as $CaCO_3$: Carbonate | Sulfate ($SO_4$) | Chloride (Cl) | Hardness as $CaCO_3$: Calcium, Magnesium | Hardness as $CaCO_3$: Noncarbonate | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Phosphate ($PO_4$) | Nitrogen as ppm (P): Ammonia ($NH_3$) | Nitrogen as ppm (P): Nitrate ($NO_3$) | Iron (Fe) | Silica ($SiO_2$) | Aluminum (Al) | Barium (Ba) | Boron (B) | Copper (Cu) | Manganese (Mn) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Madison 7-16-66 | 0.0 | 25.0 | 6.1 | | 1280 | 119 | 38 | | | 328 | 363 | 73.7 | 81.6 | | | 1.34 | 0.37 | 0.7 | 0.02 | | | | | | |
| | 1.5 | 25.0 | 3.6 | | 1280 | 116 | 40 | 400 | 115.0 | 492 | 336 | 65.7 | 79.7 | 109.2 | 22.6 | 1.23 | 0.43 | 0.9 | 0.02 | 7.0 | 0.01 | 1.0 | 0.00 | 0.02 | 0.44 |
| | 3.0 | 25.0 | 5.6 | | 1280 | 117 | 39 | | | 494 | 340 | 65.7 | 80.7 | | | 1.14 | 0.43 | 0.8 | 0.02 | | | | | | |
| 11-4-66 | 0.0 | 3.0 | 10.9 | 11.35 | 1200 | 181 | 14 | | | 532 | 337 | 64.1 | 90.4 | | | 0.63 | 1.20 | 0.4 | 0.00 | | | | | | |
| | 1.5 | 3.0 | 10.8 | 11.30 | 1150 | 183 | 12 | 282 | 105.0 | 494 | 299 | 60.9 | 83.2 | 115.0 | 22.0 | 0.37 | 1.35 | 0.7 | 0.06 | 3.5 | 0.00 | 0.0 | 0.35 | 0.03 | 0.00 |
| 2-3-67 | 0.0 | 1.0 | 16.4 | 8.35 | 1375 | 245 | 20 | | | 556 | 391 | 78.5 | 87.5 | | | 0.31 | 0.45 | 0.7 | 0.03 | | | | | | |
| | 1.5 | 4.0 | 10.4 | 8.20 | 1375 | 229 | 0 | 537 | 130.0 | 565 | 336 | 84.9 | 85.0 | 130.0 | 29.5 | 0.19 | 0.60 | 0.8 | 0.10 | 10.3 | 0.02 | 1.0 | 0.35 | | 0.00 |
| 4-5-67 | 0.0 | 9.0 | 9.7 | 8.30 | 1030 | 175 | 0 | | | 950 | 775 | 108.1 | 165.3 | | | 0.26 | 0.66 | | 0.19 | | | | | | |
| | 7.0 | 9.0 | 9.3 | 8.35 | 1080 | 166 | 8 | 392 | 102.0 | 800 | 626 | 88.1 | 140.0 | 96.5 | 18.3 | 0.11 | 0.37 | 0.5 | 0.13 | 5.0 | 0.01 | 0.5 | 0.20 | 0.03 | 0.13 |
| Norlandahl 8-15-66 | 0.0 | 24.0 | 7.6 | 8.17 | 830 | 142 | 2 | | | 384 | 40 | 114.1 | 22.0 | | | 0.05 | 1.41 | 0.7 | 0.00 | | | | | | |
| | 4.0 | 24.0 | 6.3 | 8.00 | 800 | 145 | 0 | 345 | 5.0 | 350 | 03 | 106.1 | 21.9 | 33.0 | 16.2 | 0.05 | 1.23 | 0.3 | 0.00 | 4.6 | 0.00 | 0.0 | 1.00 | 0.15 | 0.23 |
| | 8.0 | 24.0 | 2.3 | 7.80 | 850 | 155 | 0 | | | 350 | 95 | 107.3 | 19.9 | | | 0.17 | 1.31 | 0.7 | 0.18 | | | | | | |
| 11-6-66 | 0.0 | 8.0 | 12.0 | 8.52 | 895 | 114 | 17 | | | 330 | 04 | 90.5 | 25.3 | | | 0.05 | 0.90 | | 0.03 | | | | | | |
| | 3.0 | 8.0 | 11.9 | 8.52 | 855 | 114 | 12 | 352 | 5.0 | 358 | 32 | 86.3 | 34.3 | 24.3 | 15.6 | 0.05 | 1.12 | 0.1 | 0.03 | 6.1 | 0.00 | 2.0 | 0.50 | 0.00 | 0.05 |
| | 6.0 | 8.0 | 11.8 | 8.52 | 875 | 114 | 12 | | | 320 | 94 | 88.1 | 24.3 | | | 0.19 | 0.96 | | 0.08 | | | | | | |
| 3-5-67 | 0.0 | 1.0 | 11.5 | 7.70 | 840 | 156 | 0 | | | 366 | 10 | 107.3 | 23.8 | | | | 0.35 | | | | | | | | |
| | 3.0 | 3.0 | 11.1 | 7.62 | 840 | 157 | 0 | 450 | 5.5 | 370 | 13 | 108.1 | 24.3 | | | 0.05 | 0.45 | 0.4 | 0.03 | 3.6 | 0.00 | 1.0 | 0.50 | | 0.00 |
| | 6.0 | 4.0 | 0.9 | 7.45 | | 156 | 0 | | | | | 124.1 | | 31.0 | 19.7 | 0.05 | | 0.4 | 0.10 | | | | | | |
| 6-8-67 | 0.0 | 11.0 | 10.7 | 8.22 | 840 | 136 | 8 | | | 430 | 284 | 116.1 | 29.2 | | | 0.52 | 0.03 | 0.1 | 0.06 | | | | | | |
| | 3.0 | 11.0 | 10.5 | 8.22 | 840 | 136 | 4 | 400 | 5.0 | 430 | 294 | 109.7 | 34.0 | 28.0 | 15.6 | 0.91 | 0.06 | 0.3 | 0.06 | 3.8 | 0.01 | 0.0 | 0.50 | 0.27 | 0.13 |
| | 6.0 | 11.0 | 10.4 | 8.22 | 790 | 144 | 0 | | | 386 | 242 | | 27.2 | | | 0.23 | 0.13 | 0.1 | 0.08 | | | | | | |
| Nielsen 8-10-66 | 0.0 | 21.0 | 7.5 | 8.46 | 285 | 126 | 12 | | | 90 | -48 | 16.8 | 11.7 | | | 0.07 | 0.43 | 0.8 | 0.08 | | | | | | |
| | 1.5 | 21.0 | 7.2 | 8.45 | 260 | 126 | 12 | 20 | 1.0 | 68 | -30 | 20.0 | 9.2 | 16.6 | 16.2 | 0.55 | 0.40 | 0.5 | 0.08 | 3.4 | 0.03 | 1.0 | 0.10 | 0.02 | 0.29 |
| | 3.0 | 21.0 | 6.8 | 8.12 | 260 | 126 | 14 | | | 90 | -50 | 20.0 | 9.7 | | | 0.67 | 0.37 | 1.1 | 0.08 | | | | | | |
| 10-9-66 | 0.0 | 12.0 | 9.3 | 8.60 | 187 | 178 | 12 | | | 98 | -92 | 20.0 | 11.7 | | | 0.05 | 0.18 | 0.2 | 0.03 | | | | | | |
| | 1.1 | 12.0 | 9.5 | 8.40 | 205 | 178 | 14 | 5 | 1.5 | 86 | -108 | 26.0 | 10.3 | 14.0 | 14.8 | 0.05 | 0.13 | 0.2 | 0.03 | 14.0 | 0.02 | 0.0 | 0.10 | 0.08 | 0.13 |
| 3-10-67 | 0.0 | 5.0 | 10.6 | 7.79 | 217 | 226 | 0 | | | 95 | -131 | 21.4 | 10.0 | | | 0.08 | 1.25 | 0.4 | 0.06 | | | | | | |
| | 3.0 | 5.0 | 11.8 | 7.73 | 255 | 260 | 0 | 10 | 3.0 | 106 | -154 | 23.2 | 11.7 | 17.0 | 11.4 | 0.05 | 1.45 | 0.4 | 0.03 | 26.0 | 0.00 | 0.2 | 0.00 | 0.03 | 0.00 |
| 4-11-67 | 0.0 | 9.5 | 9.9 | 8.39 | 180 | 167 | 9 | 7 | 2.0 | 80 | -96 | 13.6 | 11.2 | 13.0 | 9.5 | 0.18 | 0.22 | 0.4 | 0.10 | 19.0 | 0.03 | 1.0 | 0.00 | 0.02 | 0.09 |
| Mitchell 8-11-66 | 0.0 | 24.0 | 7.1 | 8.20 | 680 | 128 | 10 | | | 354 | 16 | 47.2 | 33.0 | | | 0.62 | 0.00 | 0.3 | 0.02 | | | | | | |
| | 3.0 | 24.0 | 5.9 | 8.30 | 670 | 129 | 10 | 248 | 22.5 | 282 | 43 | 48.8 | 38.9 | 64.2 | 16.1 | 0.71 | 0.00 | 0.6 | 0.02 | 8.3 | 0.03 | 1.0 | 0.35 | 0.00 | 0.25 |
| | 6.0 | 24.0 | 4.5 | 8.20 | 650 | 137 | 6 | | | 240 | 47 | 48.0 | 29.2 | | | 0.42 | 0.09 | 0.4 | 0.06 | | | | | | |
| 11-7-66 | 0.0 | 3.0 | 11.5 | 8.30 | 855 | 129 | 6 | | | 280 | 65 | 54.5 | 33.0 | | | 0.01 | 1.20 | | 0.02 | | | | | | |
| | 3.0 | 3.0 | 11.6 | 8.30 | 880 | 129 | 6 | 353 | 22.0 | 302 | 67 | 53.7 | 40.8 | 75.0 | 17.0 | 0.13 | 1.20 | 0.2 | 0.03 | 3.3 | 0.00 | 1.0 | 0.50 | 0.03 | 0.05 |
| | 6.0 | 3.0 | 11.3 | 8.30 | 875 | 129 | 6 | | | 288 | 53 | 50.5 | 39.4 | | | 0.06 | 0.96 | | 0.03 | | | | | | |
| 3-6-67 | 2.0 | 4.5 | 11.3 | 8.00 | 795 | 162 | 0 | | | 418 | 56 | 76.1 | 33.6 | | | 0.05 | 0.25 | 0.1 | 0.03 | | | | | | |
| | 5.0 | 4.5 | 9.2 | 7.90 | 785 | 172 | 0 | 337 | 25.0 | 300 | 28 | 72.9 | 28.7 | 83.0 | 17.3 | 0.10 | 0.22 | | 0.03 | 4.3 | 0.00 | 1.0 | 0.60 | 0.03 | 0.00 |
| 6-7-67 | 0.0 | 10.0 | 10.6 | 8.33 | 810 | 156 | 4 | | | 418 | 50 | 80.1 | 31.0 | | | 0.17 | 0.22 | 0.3 | 0.06 | | | | | | |
| | 3.5 | 10.0 | 10.6 | 8.33 | 740 | 152 | 4 | 287 | 21.0 | 420 | 64 | 80.1 | 33.5 | 73.0 | 14.7 | 0.28 | 0.25 | 0.4 | 0.16 | 4.8 | 0.01 | 2.0 | 0.50 | 0.03 | 0.00 |
| | 5.0 | 10.0 | 10.4 | 8.33 | 805 | 150 | 4 | | | 470 | 16 | 87.5 | 41.2 | | | 0.24 | 0.25 | 0.4 | 0.12 | | | | | | |
| Powell 8-23-65 | 0.0 | 23.0 | 8.1 | 8.[illegible]0 | 578 | 2 | 16 | | | | | | | | | 0.26 | 0.77 | 0.2 | 0.18 | | | | | | |
| | 1.5 | 23.0 | 7.9 | 8.[illegible]0 | 517 | 4 | 14 | 150 | 6.0 | 98 | 18 | 28.0 | 6.0 | 55.2 | 4.9 | 0.30 | 0.56 | 0.2 | 0.08 | 1.0 | 0.04 | 0.0 | 0.10 | | 1.50 |
| | 3.0 | 23.0 | 7.7 | 8.[illegible]0 | 460 | 9 | 12 | | | | | | | | | 0.33 | 0.69 | 0.3 | 0.06 | | | | | | |
| | 4.5 | 22.0 | 7.8 | 8.[illegible]0 | 478 | 0 | 10 | | | | | | | | | 0.11 | 0.93 | 0.3 | 0.08 | | | | | | |
| 10-17-65 | 3.0 | 8.5 | 9.75 | 8.[illegible]0 | 515 | 2 | | | 6.5 | 64 | 94 | 39.3 | 16.3 | 84.0 | 7.2 | 0.29 | 2.43 | 0.6 | 0.00 | | 0.00 | 0.0 | 0.00 | 0.02 | 0.30 |
| | 6.0 | 8.5 | 9.4 | 8.[illegible]0 | 420 | 9 | | | | 12 | 33 | 39.2 | 3.4 | | | 0.30 | 0.00 | 0.6 | 0.00 | | | | | | |
| 3-26-66 | 0.0 | | 13.3 | 8.[illegible]0 | 920 | 8 | 8 | | 6.5 | 88 | 102 | 48.0 | 16.3 | | | 0.37 | 0.23 | 0.7 | 0.00 | | | | | | |
| | 1.5 | | 12.8 | 8.[illegible]5 | 800 | 8 | 4 | 130 | 7.0 | 88 | 106 | 47.2 | 17.0 | 76.2 | 6.3 | 0.09 | 0.13 | 0.2 | 0.00 | 3.0 | 0.00 | 0.5 | 0.20 | 0.03 | 0.13 |
| | 3.0 | | 11.7 | 8.[illegible]5 | 850 | 7 | 4 | | 6.0 | 82 | 101 | 43.3 | 18.0 | | | 0.09 | 0.00 | 0.4 | 0.02 | | | | | | |
| | 6.0 | | 10.9 | 8.[illegible]5 | 950 | 7 | 6 | | 6.0 | 88 | 113 | 44.0 | 19.0 | | | 0.08 | 0.13 | 0.8 | 0.02 | | | | | | |
| 5-10-66 | 0.0 | 11.0 | 9.2 | 7.[illegible]0 | 460 | [illegible] | | | 5.5 | 50 | 63 | 38.4 | 13.1 | | | 0.14 | 0.31 | | 0.03 | | | | | | |
| | 3.0 | 11.0 | 9.5 | 7.[illegible]6 | 490 | [illegible] | | | 5.0 | 46 | 58 | 39.2 | 11.6 | 28.0 | 6.9 | 0.09 | 0.13 | | 0.03 | | 0.06 | | 0.33 | | |
| | 6.0 | 11.0 | 9.5 | 7.[illegible]5 | 460 | 8 | | | 5.5 | 38 | 50 | 39.2 | 9.7 | | | 0.04 | 0.21 | | 0.03 | | | | | | |

Appendix A. (continued)

| Lake and Date of Collection | Depth in Meters | Temperature (°C) | Oxygen ($O_2$) | pH | Specific conductance (micromhos at 25°C) | Alkalinity as $CaCO_3$: Bicarbonate | Alkalinity as $CaCO_3$: Carbonate | Sulfate ($SO_4$) | Chloride (Cl) | Hardness as $CaCO_3$: Calcium, magnesium | Hardness as $CaCO_3$: Noncarbonate | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Phosphate ($PO_4$) | Nitrogen as ppm (N): Ammonia ($NH_3$) | Nitrogen as ppm (N): Nitrate ($NO_3$) | Iron (Fe) | Silica ($SiO_2$) | Aluminum (Al) | Barium (Ba) | Boron (B) | Copper (Cu) | Manganese (Mn) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Portola 8-7-66 | 0.0 | 21.0 | 7.2 | 8.05 | | 117 | 16 | | | 114 | -19 | 6.0 | 8.0 | | | 0.32 | 0.18 | 0.2 | 0.02 | | | | | | |
| | 15.0 | 13.0 | 4.0 | 7.90 | | 136 | 0 | 50 | 1.5 | 102 | -27 | 2.8 | 8.2 | 4.8 | 1.3 | 0.40 | 0.20 | 0.2 | 0.03 | 3.3 | 0.02 | 2.0 | 0.20 | 0.06 | [illegible] |
| | 30.0 | 11.0 | 6.0 | 7.75 | | 131 | 0 | | | 106 | -27 | 4.0 | 4.0 | | | 1.86 | 0.20 | 0.2 | 0.02 | | | | | | |
| 10-16-66 | 0.0 | 11.0 | 4.3 | 8.16 | 238 | 139 | 2 | | | 114 | -27 | 3.6 | 9.4 | 3.3 | 3.8 | 0.04 | 0.27 | 0.3 | 0.03 | | | | | | |
| | 20.0 | 11.0 | 6.0 | 8.16 | 248 | 143 | 0 | 48 | 2.0 | 144 | 1 | 0.0 | 5.5 | 3.5 | 2.0 | 0.12 | 0.19 | 0.5 | 0.02 | 4.1 | 0.00 | 0.0 | 0.35 | 0.02 | [illegible] |
| | 40.0 | 4.5 | 3.9 | 7.58 | 255 | 135 | 0 | | | 100 | -35 | 6.6 | 4.1 | 3.5 | 2.8 | 0.01 | 0.30 | 0.2 | 0.03 | | | | | | |
| 2-12-67 | 0.0 | 2.0 | 10.0 | 8.30 | 145 | 148 | 2 | | | 102 | -48 | 4.4 | 6.0 | | | 0.05 | 0.00 | 0.0 | 0.02 | | | | | | |
| | 9.0 | 3.5 | 10.0 | 8.30 | 208 | 148 | 2 | 43 | 2.0 | 110 | -40 | 4.6 | 8.0 | 3.3 | 3.6 | 0.05 | 0.00 | 0.3 | 0.02 | 5.0 | 0.01 | 0.0 | 0.20 | 0.02 | [illegible] |
| | 18.0 | 4.0 | 9.4 | 8.29 | 260 | 149 | 0 | | | 125 | -21 | 7.6 | 0.4 | | | 0.05 | 0.05 | 0.1 | 0.02 | | | | | | |
| 4-15-67 | 0.0 | 4.5 | 10.6 | 8.21 | 230 | 147 | 0 | | | 130 | -17 | 0.8 | 9.0 | | | 0.24 | 0.13 | 1.2 | 0.08 | | | | | | |
| | 22.0 | 6.0 | 15.4 | 8.28 | 228 | 147 | 0 | 49 | 0.5 | 128 | -19 | 0.0 | 9.0 | 3.0 | 2.9 | 0.06 | 0.03 | 0.0 | 0.06 | 5.0 | 0.03 | 0.5 | 0.22 | 0.03 | [illegible] |
| | 42.0 | 6.0 | 8.4 | 8.30 | 220 | 146 | 2 | | | 128 | -20 | 9.4 | 9.9 | | | 0.36 | 0.18 | 0.2 | 0.08 | | | | | | |
| [illegible] 9-17-65 | 0.0 | 26.6 | 12.7 | 9.40 | 320 | 83 | 96 | | | | | | | | | 1.23 | 1.3 | 1.5 | 0.18 | | | | | | |
| | 1.5 | 25.0 | 8.5 | 9.00 | 310 | 106 | 62 | 160 | 6.5 | 110 | -38 | 38.4 | 3.4 | 64.0 | 17.2 | 1.38 | 0.3 | 0.5 | 0.45 | 13.0 | 0.00 | 4.0 | 0.20 | | [illegible] |
| | 3.0 | 24.0 | 7.0 | 8.40 | 300 | 123 | 46 | | | | | | | | | 1.62 | 0.0 | 0.7 | 0.32 | | | | | | |
| 10-31-65 | 0.0 | 6.0 | 9.5 | 7.80 | 550 | 192 | | | 7.0 | 116 | -78 | 21.6 | 14.6 | | | 1.81 | 0.2 | 1.0 | 0.02 | | | | | | |
| | 1.5 | 6.0 | 9.5 | 7.75 | 500 | 195 | | 150 | 5.5 | 122 | -73 | 24.0 | 15.1 | 14.4 | 16.5 | 1.04 | 0.3 | 1.2 | 0.20 | 19.0 | 0.04 | 1.0 | 0.15 | 0.11 | [illegible] |
| | 3.0 | 6.0 | 9.5 | 7.70 | 380 | 195 | | | 3.5 | 106 | -89 | 20.0 | 13.6 | | | 2.56 | 0.5 | 1.1 | 0.00 | | | | | | |
| | 4.5 | 6.0 | 9.5 | 7.89 | 475 | 197 | | | 5.5 | 116 | -81 | 23.2 | 14.1 | | | 1.76 | 0.5 | 1.2 | 0.00 | | | | | | |
| 2-2?-66 | 0.0 | | 9.3 | 8.60 | 950 | 284 | 34 | | 7.5 | 252 | -66 | 41.6 | 36.0 | | | 0.81 | 0.7 | 1.5 | 0.06 | | | | | | |
| | 1.5 | | 10.7 | 8.50 | 910 | 203 | 24 | 155 | 8.5 | 216 | -11 | 44.0 | 25.8 | 132.0 | 19.0 | 0.46 | 0.7 | 1.1 | 0.06 | 24.4 | 0.00 | 1.5 | 0.20 | 0.04 | [illegible] |
| | 3.0 | | 9.1 | 8.40 | 870 | 260 | 10 | | 7.0 | 230 | -40 | 44.0 | 29.2 | | | 0.44 | 0.0 | 1.6 | 0.02 | | | | | | |
| | 6.0 | | 8.2 | 8.35 | 800 | 192 | 22 | | 6.5 | 192 | -22 | 36.8 | 24.3 | | | 0.44 | 0.0 | 0.7 | 0.10 | | | | | | |
| 5-7-66 | 0.0 | 15.5 | 10.2 | 7.90 | 210 | 92 | | | 2.0 | 66 | -26 | 16.0 | 6.3 | | | | 0.5 | | 0.16 | | | | 0.35 | | |
| | 1.5 | 15.0 | 10.0 | 7.80 | 120 | 92 | | | 1.0 | 42 | -50 | 13.6 | 1.9 | 7.2 | 14.4 | 0.36 | 0.1 | | 0.03 | | | | | | |
| [illegible] 9-5-65 | 0.0 | 25.0 | 8.5 | 9.00 | 870 | 156 | 72 | | | | | | | | | 0.76 | 1.04 | 0.6 | 0.58 | | | | | | |
| | 1.5 | 25.0 | 8.1 | 8.90 | 620 | 132 | 80 | | | 192 | -39 | | | 67.3 | 22.4 | | 1.93 | 0.4 | 0.38 | | | | | | |
| | 3.0 | 25.0 | 8.0 | 8.90 | 830 | 157 | 74 | 290 | 40.0 | 234 | 3 | 17.6 | 46.2 | | | 3.20 | 0.98 | 0.4 | 0.16 | 17.6 | 0.00 | 0.0 | 0.00 | | [illegible] |
| 11-7-65 | 0.0 | 7.5 | 10.2 | 8.50 | 1127 | 211 | 0 | | 39.5 | 286 | 75 | 31.2 | 50.5 | | | | 0.00 | 1.2 | 0.12 | | | | | | |
| | 1.5 | 7.0 | 10.0 | 8.50 | 1200 | 210 | 16 | 116 | 35.0 | 306 | 78 | 26.4 | 57.8 | 35.6 | 22.2 | 1.71 | 0.00 | 1.4 | 0.12 | 21.0 | 0.00 | 0.0 | 0.20 | 0.03 | 0.23 |
| | 3.0 | 7.0 | 9.8 | 8.50 | 1020 | 217 | 10 | | 33.0 | 240 | 13 | 13.6 | 50.2 | | | | 0.00 | 1.0 | 0.18 | | | | | | |
| 3-23-66 | 0.0 | | | 8.50 | 1250 | 258 | 22 | | | 508 | 220 | 39.2 | 49.3 | | | 2.56 | 0.86 | 0.6 | 0.06 | | | | | | |
| | 1.5 | | | 8.60 | 1350 | 221 | 24 | 273 | 59.0 | 468 | 223 | 43.2 | 67.5 | 76.6 | 24.0 | 0.64 | 0.98 | 0.5 | 0.03 | 27.0 | 0.00 | 1.0 | 0.20 | 0.03 | 0.33 |
| | 3.0 | | | 8.73 | 1300 | 196 | 36 | | | 462 | 230 | 32.8 | 42.3 | | | 2.02 | 0.88 | 0.4 | 0.02 | | | | | | |
| 4-18-66 | 0.0 | 21.5 | 8.2 | 8.60 | 900 | 126 | 80 | | 35.0 | 330 | 1[illegible] | 36.0 | 58.3 | | | 0.78 | 0.25 | 0.6 | 0.02 | | | | | | |
| | 1.5 | 20.0 | 8.0 | 8.82 | 920 | 139 | 40 | 207 | 36.0 | 336 | 137 | 32.8 | 61.7 | 60.0 | 19.4 | 0.90 | 0.10 | 0.6 | 0.03 | 13.8 | 0.03 | 1.0 | 0.15 | 0.04 | 0.29 |
| | 3.0 | 19.0 | 5.5 | 8.87 | 730 | 139 | 60 | | 29.0 | 290 | 91 | 29.6 | 52.5 | | | 0.90 | 0.35 | 0.4 | 0.06 | | | | | | |
| Punished Woman 7-16-65 | 0.0 | 25.0 | 10.1 | 8.80 | 430 | 109 | 48 | | | 144 | -15 | | | | | 0.07 | 0.00 | 0.4 | 0.06 | | | | | | |
| | 1.5 | 24.0 | 7.5 | 8.70 | 430 | 125 | 30 | 150 | 11.0 | 144 | -11 | 16.8 | 24.8 | 7.2 | 3.4 | 0.26 | 0.00 | 0.3 | 0.06 | 6.5 | 0.00 | 0.0 | 0.00 | | 0.35 |
| 11-26-65 | 0.0 | 0.0 | 13.0 | 8.35 | 370 | 177 | 6 | 60 | 2.5 | 158 | -27 | 21.6 | 25.3 | 4.8 | 7.2 | 0.40 | 0.25 | 0.6 | 0.04 | | | | | | |
| | 1.5 | 2.0 | 13.6 | 8.30 | 395 | 172 | 8 | | 7.0 | 158 | -22 | 21.6 | 25.3 | | | 0.87 | 0.40 | 0.7 | 0.06 | 14.0 | 0.02 | 3.0 | 0.00 | 0.00 | 0.33 |
| 3-18-66 | 0.0 | | 13.9 | 7.90 | 660 | 160 | 14 | | | 274 | 120 | 65.7 | 26.7 | | | 0.17 | 0.25 | 0.5 | 0.02 | | | | | | |
| | 1.5 | | 13.5 | 8.40 | 760 | 139 | 16 | 120 | 5.5 | 260 | 105 | 39.6 | 45.2 | 17.4 | 17.0 | 0.17 | 0.25 | 0.5 | 0.03 | 10.4 | 0.00 | 2.0 | 0.20 | 0.03 | 0.32 |
| 4-22-66 | 0.0 | 7.0 | 11.9 | 8.00 | 389 | 140 | 10 | 120 | 6.0 | 154 | -6 | 26.4 | 19.0 | 15.6 | 7.8 | 1.01 | 0.30 | 0.1 | 0.12 | 5.0 | 0.03 | 3.5 | 0.20 | 0.0[illegible] | 0.09 |
| Rose Hill 8-17-66 | 0.0 | 22.0 | 8.0 | .46 | 00 | 83 | 20 | | | | 5 | 10.0 | 14.1 | | | 0.46 | | 0.0 | 0.0 | | | | | | |
| | 4.0 | 22.0 | 4.0 | .22 | 00 | 103 | 0 | 32 | 2.5 | 108 | 24 | 0.0 | 18.7 | 14.5 | 12.0 | 0.39 | | 0.0 | 0.0 | 2.7 | 0.01 | 0.5 | 0.35 | 0.03 | 0.2[illegible] |
| | 8.0 | 19.0 | 0.0 | .30 | 0 | 186 | 0 | | | 127 | -48 | 0.9 | 20.9 | | | 5.12 | | 0.6 | 0.7 | | | | | | |
| 10-30-66 | 0.0 | 8.5 | 10.8 | .70 | 0 | 100 | 10 | | | 134 | -19 | 6.8 | 11.9 | | | 0.05 | 3.75 | 4.4 | 0.0 | | | | | | |
| | 4.0 | 8.5 | 10.8 | .70 | 0 | 100 | 10 | 47 | 5.0 | 93 | -14 | 7.6 | 12.6 | 15.0 | 12.2 | 0.05 | 3.75 | 4.4 | 0.0 | 0.8 | 0.03 | 1.0 | 0.10 | 0.01 | 0.00 |
| | 8.0 | 8.5 | 10.8 | .70 | 2 | 100 | 10 | | | 96 | -14 | 5.2 | 14.1 | | | 0.05 | 1.30 | 1.5 | 0.06 | | | | | | |
| 2-6-67 | 0.0 | 5.0 | 14.1 | .40 | 2 | 156 | 10 | | | 96 | -47 | 7.6 | 18.2 | | | 0.08 | 2.33 | 0.4 | 0.06 | | | | | | |
| | 5.0 | 3.5 | 2.8 | .78 | 2 | 143 | 0 | 56 | 4.0 | 119 | -14 | 0.8 | 18.7 | 16.5 | 13.4 | 0.05 | 2.60 | 0.5 | 0.06 | 4.3 | 0.03 | 0.5 | 0.10 | 0.03 | 0.39 |
| | 8.0 | 4.5 | 0.6 | .60 | 0 | 149 | 0 | | | 129 | -13 | 2.0 | 19.7 | | | 0.11 | 1.40 | 0.5 | 0.3 | | | | | | |
| 4-8-67 | 0.0 | 10.0 | 8.2 | .41 | 0 | 100 | 0 | 38 | 3.5 | 136 | 0 | 7.2 | 7.8 | 11.0 | 11.3 | 1.31 | 0.44 | 0.5 | 0.0 | 3.7 | 0.02 | 1.5 | 0.35 | 0.00 | 0.40 |
| | 4.0 | 9.0 | 8.2 | .43 | 7 | 100 | 0 | | | 100 | 0 | 5.6 | 8.7 | | | 1.10 | 0.52 | 0.4 | 0.0 | | | | | | |
| | 8.0 | 9.0 | 7.5 | .47 | 0 | 100 | 0 | | | 100 | 2 | 6.8 | 7.3 | | | 0.72 | 0.52 | 0.2 | 0.3 | | | | | | |

Appendix A. (continued)

| Lake and Date of Collection | Depth in Meters | Temperature (°C) | Oxygen ($O_2$) | pH | Specific conductance (micromhos at 25°C) | Alkalinity as $CaCO_3$: Bicarbonate | Alkalinity as $CaCO_3$: Carbonate | Sulfate ($SO_4$) | Chloride (Cl) | Hardness as $CaCO_3$: Calcium, magnesium | Hardness as $CaCO_3$: Noncarbonate | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Phosphate ($PO_4$) | Nitrogen as ppm (N): Ammonia ($NH_3$) | Nitrogen as ppm (N): Nitrate ($NO_3$) | Iron (Fe) | Silica ($SiO_2$) | Aluminum (Al) | Barium (Ba) | Boron (B) | Copper (Cu) | Manganese (Mn) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Roy 7-29-65 | 0.0 | 25.5 | 9.8 | 8.70 | 1150 | [illegible]07 | 34 | | | | | | | | | 0.00 | 0.10 | 0.0 | 0.00 | | | | | | |
| | 1.5 | 25.5 | 9.9 | 8.70 | 1150 | [illegible]19 | 2 | 450 | 13.0 | 422 | 171 | 33.4 | 88.9 | 53.8 | 70.8 | 0.19 | 0.45 | 0.0 | 0.00 | 2.1 | 0.01 | | 0.00 | | 0.09 |
| | 3.0 | 25.5 | 9.6 | 8.69 | 1150 | [illegible]00 | 6 | | | | | | | | | 0.16 | 0.95 | 0.0 | 0.00 | | | | | | |
| 11-13-65 | 0.0 | 2.0 | 10.9 | 9.00 | 1200 | [illegible]81 | 6 | | | 430 | 233 | 26.4 | 93.3 | | | 0.30 | 0.20 | 0.6 | 0.20 | | | | | | |
| | 1.5 | 2.0 | 10.9 | 9.00 | 1180 | [illegible]87 | 0 | 600 | 17.5 | 436 | 209 | 22.4 | 92.3 | 13.2 | 40.2 | 0.21 | 1.60 | 0.4 | 0.13 | 3.9 | 0.00 | 1.5 | 1.00 | 0.02 | 0.13 |
| | 3.0 | 2.0 | 10.9 | 9.00 | 1250 | [illegible]77 | 5 | | | 412 | 179 | 24.8 | 85.2 | | | 0.14 | 0.30 | 0.4 | 0.12 | | | | | | |
| 2-11-66 | 0.0 | | 11.6 | 8.65 | 1500 | [illegible]57 | 6 | | 11.0 | 754 | 451 | 48.8 | 153.6 | | | 0.30 | 0.00 | 0.2 | 0.00 | | | | | | |
| | 1.5 | | 11.8 | 8.70 | 1520 | [illegible]58 | 2 | 640 | 13.0 | 776 | 476 | 48.0 | 159.4 | 50.4 | 36.8 | 0.28 | 0.00 | 0.6 | 0.00 | | | | | | |
| | 3.0 | | 11.7 | 8.63 | 1500 | [illegible]58 | 6 | | 11.0 | 762 | 458 | 51.3 | 154.3 | | | 0.14 | 0.00 | 0.4 | 0.00 | 4.6 | 0.00 | 0.5 | 0.00 | 0.13 | 0.11 |
| | 4.5 | | 9.1 | 8.60 | 1550 | [illegible]76 | 2 | | 10.0 | 780 | 472 | 48.0 | 160.4 | | | 0.36 | 0.00 | 0.2 | 0.02 | | | | | | |
| 4-25-66 | 0.0 | 7.0 | 11.7 | 8.65 | 1180 | [illegible]20 | 4 | | 8.0 | 594 | 360 | 31.6 | 123.9 | | | 0.38 | 0.31 | 0.2 | 0.06 | | | | | | |
| | 1.5 | 6.5 | 12.0 | 8.65 | 1180 | [illegible]14 | 0 | 390 | 8.0 | 602 | 358 | 42.4 | 120.5 | 37.2 | 30.6 | 0.17 | 0.21 | 0.2 | 0.06 | | | | | | |
| | 3.0 | 6.5 | 11.6 | 8.63 | 1180 | [illegible]17 | 8 | | 8.0 | 600 | 355 | 32.0 | 126.4 | | | 0.44 | 0.21 | 0.2 | 0.06 | 5.9 | 0.03 | 0.2 | 2.00 | 0.06 | 0.13 |
| | 5.0 | 6.5 | 11.7 | 8.65 | 1180 | [illegible]19 | 4 | | 7.5 | 600 | 357 | 20.4 | 123.8 | | | 0.33 | 0.21 | 0.2 | 0.02 | | | | | | |
| Shadehill 8-27-65 | 0.0 | 22.0 | 7.4 | 8.45 | 990 | 276 | 36 | | | | | | | | | 0.75 | 0.00 | 0.9 | 0.10 | | | | | | |
| | 3.0 | 22.0 | 7.2 | 8.40 | 975 | 252 | 30 | 340 | 13.0 | 70 | -212 | [illegible]1.2 | [illegible]10.2 | 202.6 | 9.6 | 0.31 | 0.00 | 0.8 | 0.08 | 4.5 | 0.00 | 1.0 | 2.70 | 0.15 | 0.06 |
| | 6.0 | 22.0 | 7.1 | 8.40 | 1200 | 275 | 30 | | | 78 | -204 | [illegible]1.2 | [illegible]2.2 | 206.4 | 7.7 | 0.42 | 0.00 | 0.[illegible] | 0.20 | | | | | | |
| 10-19-65 | 3.0 | 7.0 | 9.8 | 8.55 | 1500 | 250 | 20 | | 3.0 | 74 | -196 | [illegible]0.4 | [illegible]1.7 | | | [illegible].46 | 0.[illegible]3 | 0.3 | 0.00 | | | | | | |
| | 6.0 | 7.0 | 9.8 | 8.55 | 1900 | 251 | 18 | 160 | 6.5 | 78 | -191 | [illegible]0.4 | [illegible]2.6 | 37.8 | 11.2 | [illegible].76 | 0.[illegible]5 | 0.3 | 0.00 | 4.6 | 0.01 | 1.3 | 0.15 | 0.06 | 0.05 |
| 2-27-66 | 0.0 | | 12.4 | 8.78 | 2000 | 280 | 10 | | 2.5 | 135 | -163 | [illegible]3.2 | [illegible]8.7 | | | [illegible].09 | 0.[illegible]3 | 0.5 | 0.01 | | | | | | |
| | 1.5 | | 12.0 | 8.80 | 2000 | 260 | 18 | 300 | 2.0 | 139 | -139 | [illegible]1.6 | [illegible]0.7 | 356.0 | 7.2 | [illegible].33 | 0.[illegible]3 | 0.7 | 0.01 | 4.0 | 0.00 | 1.8 | 0.50 | 0.06 | 0.05 |
| | 3.0 | | 11.4 | 8.90 | 3400 | 261 | 18 | | 2.0 | 129 | -150 | [illegible]1.6 | [illegible]9.2 | | | [illegible].14 | 0.[illegible]0 | 0.4 | 0.03 | | | | | | |
| | 4.5 | | 12.2 | 8.05 | 1600 | 265 | 26 | | 1.0 | 131 | -160 | [illegible]3.4 | [illegible]7.7 | | | [illegible].17 | 0.[illegible]0 | 0.3 | 0.03 | | | | | | |
| | 6.0 | | 11.0 | 8.50 | 1650 | 262 | 26 | | 2.5 | 135 | -153 | [illegible]1.6 | [illegible]3.1 | | | [illegible].21 | 0.[illegible]5 | 0.4 | 0.06 | | | | | | |
| 5-8-66 | 0.0 | 8.0 | 10.7 | 7.70 | 450 | 225 | 10 | | 2.5 | 48 | -187 | [illegible]0.4 | [illegible]5.3 | | | [illegible].33 | 0.[illegible]5 | | 0.08 | | | | 0.15 | | |
| | 1.5 | 8.0 | 10.9 | 8.20 | 750 | 225 | 10 | | 3.5 | 70 | -165 | [illegible]2.0 | [illegible]9.7 | | | [illegible].25 | 0.[illegible]5 | | 0.03 | | 0.01 | | 0.50 | | |
| | 4.0 | 8.0 | 11.7 | 7.90 | 430 | 225 | 10 | 65 | 3.5 | 58 | -177 | [illegible]2.8 | [illegible]6.3 | 84.0 | 6.5 | [illegible].09 | 0.[illegible]0 | 0.2 | 0.08 | 1.9 | 0.03 | 2.3 | 0.60 | 0.06 | 0.32 |
| Sheridan 8-6-66 | 0.0 | 20.0 | | 8.05 | 160 | 62 | 27 | | | 58 | -26 | 11.2 | 7.3 | | | 0.16 | 0.21 | 0.4 | 0.03 | | | | | | |
| | 15.0 | | | 7.75 | 160 | 97 | 0 | 18 | 3.5 | 59 | -38 | 15.2 | 5.1 | 6.0 | 8.6 | 0.66 | 0.25 | 0.6 | 0.03 | 5.5 | 0.06 | 7.0 | 0.55 | 0.00 | 0.25 |
| | 30.0 | | | 7.65 | 200 | 105 | 0 | | | 90 | -15 | 18.4 | 10.9 | | | 0.66 | 0.21 | 0.5 | 0.10 | | | | | | |
| 10-14-66 | 0.0 | [illegible].0 | 7.3 | 7.50 | 150 | 94 | 0 | | 3.0 | 84 | -10 | 18.0 | 9.3 | | | 0.64 | | 0.0 | 0.08 | | | | | | |
| | 15.0 | [illegible].1 | 7.5 | 7.50 | 155 | 92 | 0 | 25 | 3.0 | 90 | -2 | 26.0 | 13.2 | 7.5 | 16.9 | 0.63 | | 0.0 | 0.02 | 3.8 | 0.00 | 0.0 | 0.00 | 0.02 | 0.00 |
| | 30.0 | [illegible].0 | | 7.13 | 165 | 113 | 0 | | 3.2 | 94 | -19 | 18.8 | 11.4 | | | | | 0.0 | 0.12 | | | | | | |
| 2-17-67 | 0.0 | [illegible].0 | 11.7 | 8.45 | 165 | 97 | 6 | | | 76 | -25 | 14.0 | 10.0 | | | 0.05 | 0.18 | 0.3 | 0.06 | | | | | | |
| | 3.5 | [illegible].0 | 12.0 | 8.37 | 158 | 99 | 2 | 25 | 3.5 | 72 | -29 | 12.0 | 10.2 | 6.3 | 5.4 | 0.05 | 0.19 | 0.3 | 0.06 | 1.0 | 0.00 | 1.0 | 0.15 | 0.02 | 0.05 |
| | 7.0 | [illegible].0 | 9.0 | 8.11 | 157 | 102 | 0 | | | 72 | -30 | 14.4 | 8.7 | | | 0.05 | 0.16 | 0.2 | 0.06 | | | | | | |
| 6-15-67 | 0.0 | [illegible].5 | 10.4 | 8.22 | 170 | 100 | 0 | | | 84 | -16 | 18.4 | 9.2 | | | 0.21 | 0.22 | 0.2 | 0.00 | | | | | | |
| | 15.0 | [illegible].5 | 9.5 | 8.20 | 170 | 101 | 0 | 37 | 4.0 | 82 | -19 | 18.4 | 8.7 | 7.2 | 5.2 | 0.25 | 0.18 | 1.0 | 0.00 | 1.0 | 0.03 | 0.0 | 0.20 | 0.03 | 0.05 |
| | 30.0 | [illegible].5 | 8.0 | 8.03 | 175 | 99 | 0 | | | 82 | -17 | 18.4 | 8.7 | | | 0.06 | 0.22 | 0.2 | 0.10 | | | | | | |
| Stephen Mission 8-17-66 | 0.0 | [illegible].0 | 8.4 | 8.55 | 340 | 84 | 27 | | | 162 | 56 | 38.4 | [illegible]6.0 | | | 1.04 | 0.00 | 0.4 | 0.08 | | | | | | |
| | 1.5 | [illegible].0 | 7.9 | 8.73 | 380 | 98 | 20 | 123 | 9.5 | 172 | 54 | 40.0 | [illegible]7.0 | 27.6 | 13.2 | 1.13 | 0.00 | 0.4 | 0.03 | 12.4 | 0.03 | 0.5 | 0.00 | 0.13 | 0.13 |
| | 3.0 | [illegible].0 | 7.1 | 8.60 | 380 | 98 | 20 | | | 172 | 54 | 40.0 | [illegible]7.5 | | | 1.76 | 0.00 | 0.4 | 0.03 | | | | | | |
| 10-29-66 | 0.0 | [illegible].0 | 10.8 | 8.40 | 430 | 124 | 2 | | | 192 | 66 | 42.0 | [illegible]1.1 | | | 0.03 | 0.24 | 0.5 | 0.08 | | | | | | |
| | 2.5 | [illegible].0 | 10.7 | 8.40 | 420 | 125 | 4 | 140 | 10.0 | 218 | 89 | 48.0 | [illegible]3.8 | 27.0 | 12.0 | 0.08 | 0.20 | 0.8 | 0.12 | 4.5 | 0.01 | 1.0 | 0.20 | 0.06 | 0.40 |
| | 5.0 | [illegible].0 | 10.7 | 8.40 | 420 | 125 | 4 | | | 178 | 49 | 38.4 | [illegible]9.9 | | | 0.28 | 0.19 | 0.5 | 0.06 | | | | | | |
| 2-6-67 | 0.0 | [illegible].0 | 13.1 | 7.97 | 455 | 159 | 0 | | | 270 | 111 | 52.1 | [illegible]4.0 | | | 0.10 | 0.19 | 0.2 | 0.08 | | | | | | |
| | 4.0 | [illegible].0 | 7.2 | 7.90 | 495 | 164 | 0 | 140 | 11.5 | 260 | 96 | 47.8 | [illegible]3.0 | 33.0 | 12.6 | 0.06 | 0.19 | 0.2 | 0.08 | 4.1 | 0.00 | 2.0 | 0.00 | 0.00 | 0.20 |
| 4-8-67 | 0.0 | [illegible].0 | 9.6 | 7.97 | 395 | 110 | 0 | | | 253 | 143 | 57.7 | [illegible]6.3 | | | 0.22 | 0.46 | 0.5 | 0.12 | | | | | | |
| | 3.0 | [illegible].0 | 9.4 | 8.02 | 375 | 113 | 0 | 122 | 8.0 | 192 | 79 | 32.4 | [illegible]5.3 | 27.0 | 11.2 | 0.36 | 0.52 | 0.6 | 0.26 | 5.7 | 0.02 | 2.0 | 2.10 | 0.08 | 0.00 |
| | 6.0 | [illegible].0 | 9.4 | 8.12 | 385 | 112 | 0 | | | 206 | 94 | 46.4 | [illegible]1.9 | | | 0.31 | 0.69 | 0.6 | 0.10 | | | | | | |
| Traverse 7-13-65 | 0.0 | 28.0 | 10.9 | 8.00 | 910 | 132 | 46 | | | | | | | | | 1.61 | 1.35 | 0.0 | 0.12 | | | | | | |
| | 1.5 | 27.0 | 10.3 | 8.40 | 900 | 130 | 40 | 230 | 20.8 | 286 | 118 | 29.0 | 53.8 | 27.6 | 11.0 | 0.84 | 0.00 | 0.0 | 0.03 | 12.0 | 0.10 | 0.0 | 0.20 | | 0.48 |
| 11-11-65 | 0.0 | 4.5 | 10.7 | 8.00 | 1000 | 191 | | | | 364 | 123 | 36.5 | 60.8 | | | 1.91 | 0.23 | 0.7 | 0.07 | | | | | | |
| | 1.5 | 4.5 | 10.3 | 8.05 | 1050 | 191 | | 240 | 12.5 | 310 | 119 | 49.6 | 65.2 | 14.6 | 14.9 | 1.34 | 0.30 | 0.7 | 0.13 | 34.6 | 0.02 | 4.5 | 0.13 | 0.06 | 0.48 |
| 3-16-66 | 0.0 | | 11.0 | 8.35 | 1400 | 174 | 6 | | 14.5 | 320 | 140 | 76.2 | 80.2 | | | 0.48 | 0.25 | 0.3 | 0.03 | | | | | | |
| | 1.5 | | 8.1 | 8.30 | 1500 | 167 | 16 | 448 | 14.5 | 330 | 147 | 72.1 | 85.1 | 64.8 | 13.9 | 0.96 | 0.37 | 0.6 | 0.03 | 39.0 | 0.08 | 2.0 | 0.93 | 0.10 | 0.30 |
| Twin (Sanborn County) 8-16-66 | 0.0 | 26.0 | 9.6 | 8.50 | 3400 | 65 | 26 | | | 864 | 771 | 344.3 | 203.1 | 380.0 | 40.0 | 1.13 | | | 0.36 | | | | | | |
| | 1.5 | 25.0 | 10.0 | 8.61 | 3900 | 67 | 22 | 2100 | 190.0 | 760 | 651 | 296.3 | 243.4 | 300.0 | 48.0 | 1.30 | | 0.6 | 0.36 | 10.4 | 0.06 | 7.0 | 0.95 | 0.17 | 0.20 |
| 11-7-66 | 0.0 | 3.0 | 12.3 | 7.80 | 3500 | 94 | 0 | | | 817 | 723 | 327.1 | 248.6 | | | | 2.40 | 0.5 | 0.16 | 12.6 | 0.01 | 2.0 | 0.00 | 0.21 | 0.60 |
| | 2.0 | 3.0 | 12.0 | 7.80 | 3500 | 94 | 0 | 1000 | 154.0 | 806 | 712 | 322.7 | 149.2 | 365.0 | 48.0 | 0.24 | | 0.6 | 0.16 | | | | | | |
| 2-6-67 | 0.5 | 4.2 | 11.8 | 7.65 | 3200 | 127 | 0 | 1350 | 160.0 | 770 | 643 | 308.3 | 396.9 | 340.0 | 43.0 | 0.06 | 1.30 | 0.3 | 0.18 | 10.2 | 0.00 | 2.5 | 1.30 | 0.03 | 0.46 |
| 4-7-67 | 0.0 | 10.0 | 10.6 | 8.20 | 2900 | 109 | 7 | 1850 | 130.0 | 1252 | 1141 | 301.3 | 283.2 | 500.0 | 32.0 | 0.18 | 1.16 | 0.5 | 0.50 | 5.8 | 0.06 | 1.8 | 1.18 | 0.11 | 0.13 |
| Twin (Spink County) 6-7-65 | 0.0 | 23.0 | 8.5 | 9.00 | 3200 | 163 | 104 | | | 433 | | | | | | 3.00 | 0.09 | 1.1 | 0.36 | | | | | | |
| | 1.5 | 23.0 | 7.8 | 9.00 | 3250 | 178 | 104 | 850 | 490.0 | 500 | 65 | 19.3 | 94.0 | 506.0 | 65.0 | 2.84 | 0.63 | 0.7 | 0.27 | 13.0 | 0.05 | 13 | 2.60 | | 0.43 |
| 11-6-65 | 0.0 | 6.6 | 10.5 | 8.93 | 2800 | 320 | 130 | 600 | 475.0 | 1220 | 70 | 14.4 | 113.7 | | | 0.84 | 1.89 | 1.8 | 0.03 | | | | | 0.03 | |
| | 1.5 | 6.0 | 10.0 | 8.93 | 6000 | 320 | 126 | 382 | 650.0 | 1346 | 664 | 16.0 | 260.0 | 280.0 | 18.0 | 1.27 | 1.86 | 1.6 | 0.10 | | 0.00 | 0.0 | 0.55 | 0.00 | 0.31 |
| 3-21-66 | 0.0 | | 10.2 | 8.80 | 6000 | 600 | 192 | | 780.0 | 790 | 554 | 34.0 | 312.3 | | | 0.30 | 0.53 | 1.0 | 0.08 | | | | | | |
| | 1.5 | | 7.6 | 8.90 | 6000 | 321 | 106 | 385 | 740.0 | 520 | 371 | 25.4 | 138.4 | 868.0 | 87.6 | 0.48 | 0.56 | 1.2 | 0.08 | 38.0 | 0.01 | 4.0 | 1.40 | 0.03 | 0.23 |
| 6-3-66 | 0.0 | 19.5 | 7.1 | 8.45 | 2400 | 266 | 74 | | 297.0 | 476 | 183 | 25.8 | 110.8 | | | 1.56 | 0.45 | 0.8 | 0.13 | | | | | | |
| | 1.5 | 19.5 | 7.1 | 8.84 | 2400 | 260 | 80 | 415 | 312.0 | 332 | 136 | 18.4 | 104.3 | 332.0 | 54.0 | 0.19 | 0.40 | 0.7 | 0.18 | 6.8 | 0.02 | 5.0 | 0.77 | 0.00 | 0.30 |
| | 3.0 | 19.5 | 7.1 | 8.80 | 1550 | 251 | 64 | 230 | 184.0 | | -5 | 18.4 | 69.3 | | | 0.12 | 0.40 | 0.2 | 0.10 | | | | | | |

Appendix A. (continued)

| Lake and Date of Collection | Depth in Meters | Temperature (°C) | Oxygen ($O_2$) | pH | Specific conductance (micromhos at 25°C) | Alkalinity as $CaCO_3$: Bicarbonate | Alkalinity as $CaCO_3$: Carbonate | Sulfate ($SO_4$) | Chloride (Cl) | Hardness as $CaCO_3$: Calcium, magnesium | Hardness as $CaCO_3$: Noncarbonate | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Phosphate ($PO_4$) | Nitrogen as ppm (N): Ammonia ($NH_3$) | Nitrogen as ppm (N): Nitrate ($NO_3$) | Iron (Fe) | Silica ($SiO_2$) | Aluminum (Al) | Barium (Ba) | Boron (B) | Copper (Cu) | Manganese (Mn) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vermillion 8-15-66 | 0.0 | 21.0 | 8.0 | 9.30 | 420 | 65 | 62 | | | 4 | 97 | 9.6 | 29.6 | | | [illegible] | 0.00 | 0.4 | 0.03 | | | | | | |
| | 3.0 | 21.0 | 7.4 | 9.30 | 445 | 64 | 64 | 140 | 1.5 | 8 | 100 | 1.1 | 31.1 | 16.2 | 13.8 | [illegible] | 0.00 | 0.3 | 0.02 | 15.7 | 0.01 | 0.5 | 0.00 | 0.08 | 0.13 |
| | 6.0 | 21.0 | 6.6 | 9.25 | 395 | 75 | 54 | | | 6 | 97 | 1.1 | 31.1 | | | [illegible] | 0.00 | 0.3 | 0.08 | | | | | | |
| 11-5-66 | 0.0 | 3.5 | 12.8 | 8.97 | 330 | 92 | 30 | | | 90 | 78 | 0.6 | 30.6 | | | [illegible] | | 0.1 | 0.12 | | | | | | |
| | 3.0 | 3.5 | 12.0 | 8.97 | 335 | 90 | 30 | 145 | 4.5 | 2 | 72 | 9.6 | 29.6 | 15.0 | 13.8 | [illegible] | | 0.8 | 0.02 | 9.9 | 0.00 | 1.0 | 0.35 | 0.08 | 0.30 |
| | 6.0 | 3.5 | 11.7 | 8.97 | 320 | 93 | 28 | | | 6 | 65 | 7.1 | 32.1 | | | [illegible] | | 0.1 | 0.10 | | | | | | |
| 2-8-67 | 0.0 | 3.5 | 6.0 | 7.70 | 440 | 137 | 0 | | | 56 | 124 | 6.9 | 36.5 | | | [illegible] | 0.35 | 0.4 | 0.14 | | | | | | |
| | 5.0 | 4.5 | 3.2 | 7.80 | 470 | 143 | 0 | 210 | 6.0 | 90 | 258 | 1.2 | 63.2 | 12.0 | 12.0 | [illegible] | 0.82 | 0.5 | 0.08 | 8.5 | 0.01 | 1.0 | 0.00 | 0.03 | 0.48 |
| 4-5-67 | 0.0 | 10.0 | 9.6 | 8.12 | 318 | 115 | 0 | | | 4 | 109 | 6.5 | 34.5 | | | [illegible] | 0.64 | 0.3 | 0.08 | | | | | | |
| | 3.5 | 10.0 | 9.3 | 8.15 | 366 | 115 | 0 | 105 | 2.5 | 0 | 215 | 9.2 | 49.1 | 9.2 | 12.3 | [illegible] | 0.64 | 0.3 | 0.08 | 8.1 | 0.07 | 2.0 | 0.10 | 0.03 | 0.20 |
| | 7.0 | 10.0 | 9.4 | 8.15 | 320 | 115 | 0 | | | 4 | 29 | 0.6 | 20.4 | | | [illegible] | 0.82 | 0.1 | 0.08 | | | | | | |
| Wassomet 9-9-66 | 0.0 | 21.0 | 10.1 | 9.55 | 340 | 19 | 32 | | | 130 | 39 | 24.0 | 16.3 | | | 0.14 | 0.25 | 0.5 | 0.10 | | | | | | |
| | 2.5 | 21.0 | 10.0 | 9.55 | 300 | 21 | 32 | 100 | 5.5 | 130 | 57 | 23.6 | 15.9 | 31.2 | 14.4 | 0.17 | 0.30 | 0.5 | 0.08 | 3.2 | 0.01 | 2.5 | 0.60 | 0.00 | 0.20 |
| | 5.0 | 21.0 | 9.9 | 9.55 | 280 | 24 | 48 | | | 93 | 21 | 21.4 | 6.4 | | | 0.26 | 0.37 | 0.5 | 0.08 | | | | | | |
| 10-29-66 | 0.0 | 9.0 | 10.8 | 8.65 | 460 | 78 | 10 | | | 160 | 72 | 43.2 | 12.5 | | | 0.10 | 0.15 | 0.5 | 0.08 | | | | | | |
| | 1.5 | 9.0 | 10.7 | 8.65 | 440 | 74 | 10 | 182 | 7.0 | 164 | 79 | 40.0 | 16.3 | 37.0 | 8.0 | 0.11 | 0.15 | 0.7 | 0.08 | 1.8 | 0.01 | 0.5 | 0.00 | 0.08 | 0.20 |
| | 3.0 | 9.0 | 10.6 | 8.65 | 440 | 81 | 8 | | | 174 | 87 | 42.8 | 16.6 | | | 0.07 | 0.34 | 0.6 | 0.03 | | | | | | |
| 2-13-67 | 0.0 | 4.0 | 12.7 | 8.30 | 655 | 100 | 10 | 245 | 10.0 | 288 | 178 | 76.1 | 23.5 | 33.5 | 8.6 | 0.05 | 0.03 | 0.3 | 0.12 | 4.8 | 0.00 | 0.0 | 0.00 | 0.00 | 0.00 |
| 4-12-67 | 0.0 | 13.0 | 9.1 | 8.08 | 535 | 86 | 0 | | | 246 | 160 | 65.9 | 17.8 | | | 0.36 | 0.25 | 0.4 | 0.08 | | | | | | |
| | 3.0 | 12.5 | 8.9 | 8.12 | 550 | 88 | 0 | 192 | 7.5 | 243 | 155 | 68.1 | 17.5 | 37.0 | 7.9 | 0.28 | 0.22 | 0.4 | 0.12 | 6.3 | 0.03 | 0.0 | 0.00 | 0.08 | 0.09 |
| | 6.0 | 12.5 | | | 520 | | | | | 247 | | 66.1 | 18.5 | | | 0.40 | 0.15 | 0.2 | | | | | | | |
| White 7-29-65 | 0.0 | 22.0 | 11.6 | 8.50 | 800 | 133 | 34 | | | | | | | | | 0.00 | 0.43 | 0.0 | 0.00 | | | | | | |
| | 1.5 | 26.0 | 11.1 | 8.40 | 800 | 133 | 34 | 325 | 13.5 | 260 | 93 | 40.0 | 33.9 | 33.0 | 16.0 | 0.03 | 0.61 | 0.0 | 0.00 | 3.0 | 0.03 | 0.0 | 0.00 | | 0.20 |
| 11-12-65 | 0.0 | 3.0 | 10.9 | 7.90 | 1000 | 170 | 0 | | | 298 | 128 | 50.5 | 41.8 | | | 2.86 | 0.30 | 0.5 | 0.06 | | | | | | |
| | 1.5 | 3.0 | 10.9 | 7.80 | 1070 | 164 | 0 | 150 | 21.0 | 240 | 112 | 47.2 | 39.4 | 10.8 | 15.9 | 4.54 | 0.40 | 0.6 | 0.31 | 29.6 | 0.02 | 0.5 | 0.35 | 0.21 | 0.33 |
| | 3.0 | 3.0 | 10.9 | 7.40 | 920 | 165 | 0 | | | 334 | 169 | 60.9 | 66.2 | | | 1.20 | 0.10 | 0.8 | 0.06 | | | | | | |
| 2-11-66 | 0.0 | | 12.7 | 8.10 | 1150 | 213 | 0 | | 7.0 | 552 | 339 | 69.7 | 91.9 | | | 0.41 | 0.00 | 0.9 | 0.02 | | | | | | |
| | 1.5 | | 11.9 | 8.00 | 1180 | 211 | 0 | 420 | 4.5 | 534 | 323 | 79.3 | 81.6 | 30.4 | 16.2 | 0.92 | 0.00 | 0.9 | 0.06 | 19.0 | 0.00 | 2.5 | 0.00 | 0.15 | 0.13 |
| | 3.0 | | 12.2 | 8.08 | 1170 | 215 | 0 | | 4.0 | 524 | 309 | 82.5 | 77.3 | | | 1.50 | 0.00 | 0.8 | 0.06 | | | | | | |
| | 4.5 | | | 7.90 | 1200 | 225 | 0 | | 4.5 | 480 | 255 | 96.1 | 30.3 | | | 1.34 | 0.00 | 0.7 | 0.20 | | | | | | |