STATE OF SOUTH DAKOTA

Richard Kneip, Governor

South Dakota Geological Survey
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Report of Investigations
No. 102

HYDROLOGY OF LAKE POINSETT

by
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for

South Dakota Department of Game, Fish, and Parks
F-25-R Completion Report

and

East Dakota Conservancy Sub-District

South Dakota Geological Survey
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ABSTRACT

Lake Poinsett, the largest natural lake in the State, is of glacial origin and is located in Hamlin County in east-central South Dakota. The results of test-hole drilling conducted in this area during the investigation indicate that an extensive outwash aquifer northeast of the lake hydraulically connects the Big Sioux River and Dry Lake to Lake Poinsett. For this reason Lake Poinsett and Dry Lake are treated as one unit with a combined surface area of approximately 9,830 acres.

Water recharging Lake Poinsett is from several sources including both surface and ground-water recharge, in addition to precipitation which adds 20.8 inches of water annually to the lake. Water leaves Lake Poinsett by surface and ground-water discharge along with an additional 34 inches removed annually by evaporation. The change in the balance between the total recharge and discharge of water is reflected by the water-level fluctuation of the lake.

At times, flooding occurs along the Big Sioux River. A diversion ditch equipped with gates was constructed to connect the Big Sioux River to Dry Lake so that Dry Lake and Lake Poinsett could be used for off-stream storage of Big Sioux River floodwater. Surface-water recharge to the lakes from the Big Sioux River is controlled at the diversion ditch during periods of normal water levels in the river, but in times of flooding a large quantity of water reaches Lake Poinsett through the outlet channel, by over-land flow and through the diversion ditch. After the flood of 1969, one-fourth of the water in the lake was floodwater. There is no simple technique for stopping the floodwater from reaching the lakes once it enters the study area; however, a dam constructed in the outlet channel will store water for longer periods in the lakes and will reduce lake-level fluctuation.

The nutrient level of the lake and river varies seasonally, being generally high, especially during flooding. One way to reduce the nutrient level in the lake water is to decrease the nutrients in water recharging the lakes. This can be accomplished by adopting soil conservation practices, introducing phosphate removal from municipal sewage reaching the Big Sioux River above Lake Poinsett, and constructing an adequate sewage system for cottages around the lake.

INTRODUCTION

Purpose and Scope

This report contains the results of a study conducted in two parts. The first part was conducted in the summer of 1967 to study the geology and hydrology of an area of approximately 25 square miles northeast and east of Dry Lake. Furthermore, this preliminary study was to include the task of identifying the connection between Dry Lake and Lake Poinsett.

The second part was conducted from July 1968 to July 1970 to study the geology and hydrology of an area northeast and east of Lake Poinsett in order to (1) identify the magnitude of the hydrological connection between the Big Sioux River and Lake Poinsett; (2) study the sources and quantity of waters recharging and discharging Lake Poinsett; (3) determine the quality of lake water and Big Sioux River water during different seasons; and (4) determine if it is possible, by constructing a dam on the outlet channel, to store water for longer periods of time in Lake Poinsett, thus reducing lake-level fluctuation.

Location and Extent of the Area

Lake Poinsett is located in Hamlin County and part of northwest Brookings County in east-central South Dakota. The Lake Poinsett study area includes approximately 76 square miles in the Coteau des Prairies division of the Central Lowland Physiographic Province (figs. 1 and 2).

Previous Investigations

Since the late nineteenth century the geology of the area has been studied by several geologists. The most recent works include Flint (1955), who prepared a reconnaissance map of the glacial geology of the eastern part of the State, and Steece (1958a, b, and c).

Methods and Procedures

In this investigation the surficial geologic map of the area was reviewed and modified. Data were compiled from eighty-four test holes which were drilled to define the extent of the shallow aquifer connected to the lake. In addition, thirty observation wells were installed in the area to study the ground-water fluctuation, and data obtained were used to construct water-table maps. Two aquifer tests (pump tests) were conducted in the area to identify the hydraulic characteristics of the aquifer and calculate the rate of ground-water recharge and discharge. Surface discharge from the lake through the outlet channel was measured, precipitation and evaporation data analyzed, and seventy-one surface-water and ground-water samples were collected and analyzed.

Acknowledgements

The first part of the field work, conducted for 40 days in the summer of 1967, was financed by the East Dakota Conservancy Sub-District and the South Dakota Geological Survey. The second part of the study, from July 1968 to July 1970, was financed by the South Dakota Department of Game, Fish, and Parks (D-J Project F-25-R).

The project was conducted under the direction of Duncan J. McGregor, State Geologist, and Merlin Tipton, Associate State Geologist. Equipment was provided by the South Dakota Geological Survey. Water samples were analyzed by the South Dakota Chemical Laboratory and the South Dakota Geological Survey.

The assistance of the employees of the South Dakota Department of Game, Fish, and Parks, and East Dakota Conservancy Sub-District, especially the help of Mr. Vern Butler, Manager-Engineer, is greatly appreciated.

Thanks are due to the local residents of the area who contributed information and otherwise aided in the completion of this study.

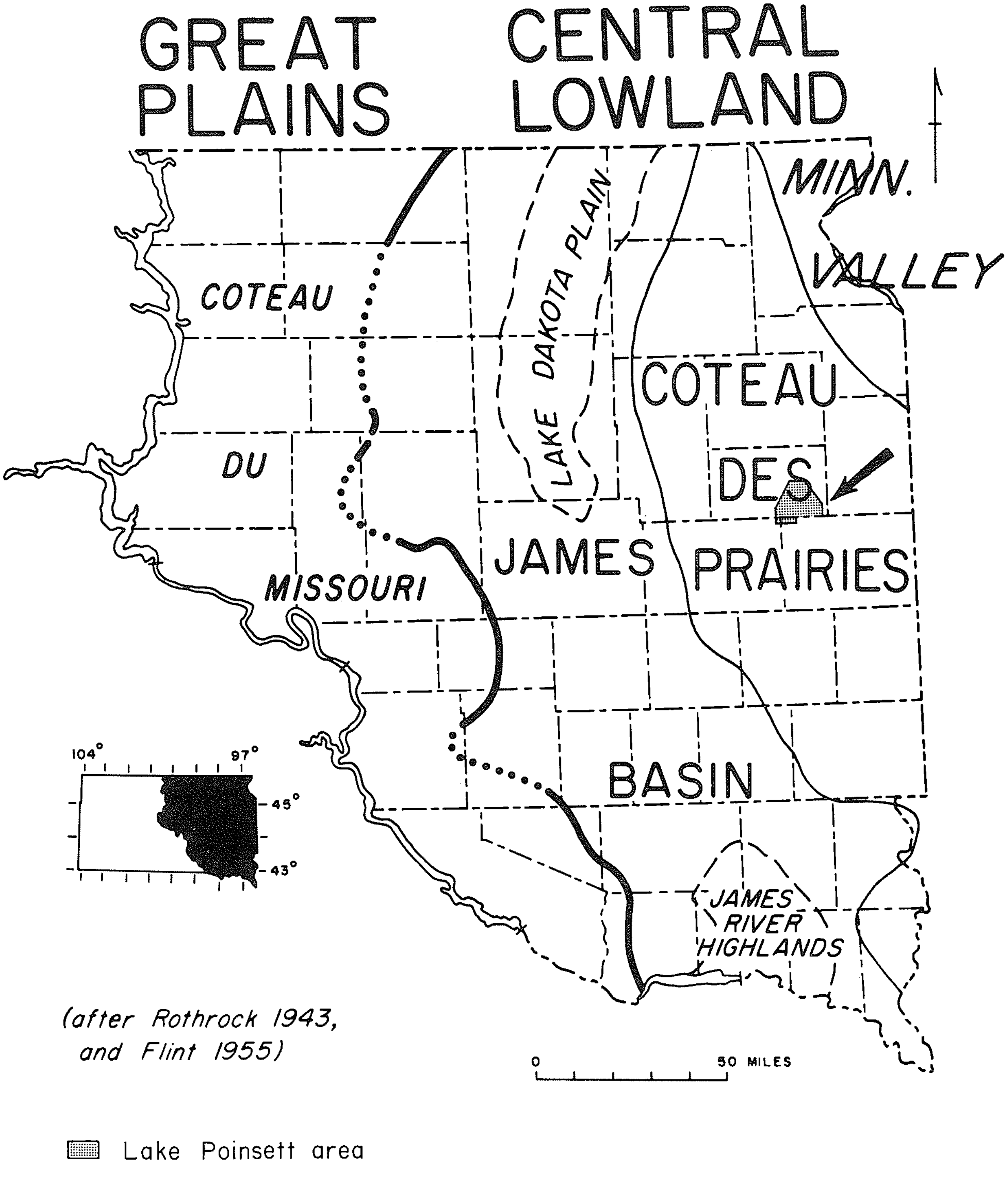
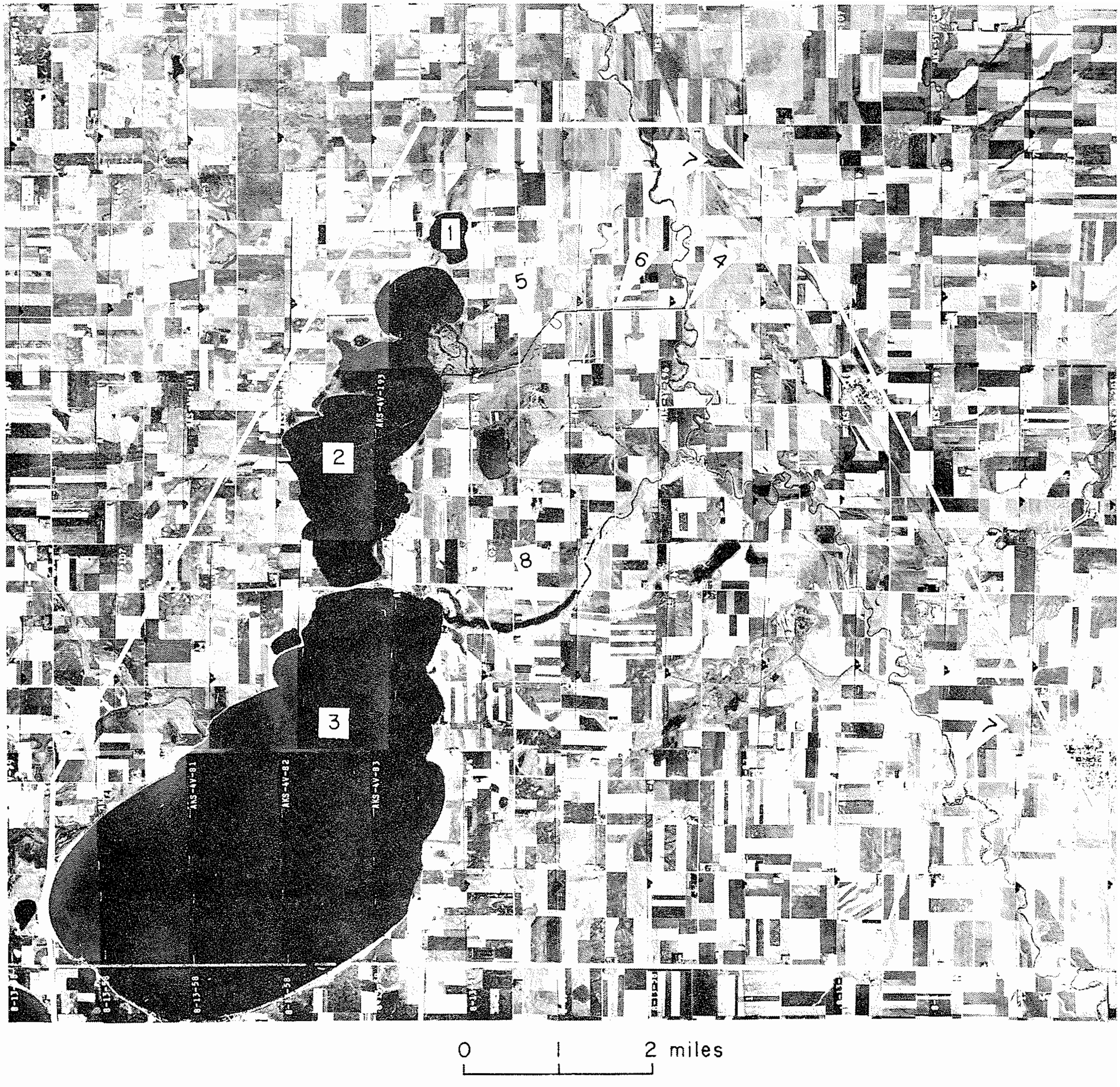


Figure 1. Map of eastern South Dakota showing the major physiographic divisions and location of the Lake Poinsett area.



1-Lake Florence
2-Dry Lake
3-Lake Poinsett
4-Boswell Dam
5-Diversion ditch
6-Gates
7-Big Sioux River
8-Lake Poinsett outlet

Figure 2. Vertical air photo of the Lake Poinsett study area.

Climate

The climate of the area is continental temperate with large daily and seasonal temperature fluctuations. The average daily temperature is 43.5 degrees Fahrenheit, and the average annual precipitation is 20.80 inches at the U. S. Weather Bureau Station at Castlewood, 8 miles north of Lake Poinsett.

Topography and Drainage

Topography of the Lake Poinsett area ranges from nearly flat in the north to gently undulating and rugged knob and kettle expressions to the east and northwest of the lake.

Maximum relief in the study area is 165 feet with land elevations ranging from 1800 feet northwest of Lake Poinsett in sec. 8, T. 113 N., R. 52 W., to 1635 feet southeast of the study area (pl. 1).

The main stream in the area is the Big Sioux River, and both surface and subsurface drainage is controlled directly or indirectly by this river.

Origin and History of Lake Poinsett

Lake Poinsett is a lake of glacial origin, its existence due to the action of glacial ice which covered this part of the State in the geologic past. It is the largest natural lake in South Dakota covering an area of approximately 7,868 acres. The combined surface area of Lake Poinsett and Dry Lake is 9,828.6 acres (fig. 3).

In the late nineteenth and early twentieth centuries it was proposed that the Big Sioux River floodwater be stored in Lake Poinsett and Dry Lake (Johnston, 1965, p. 16-18). East Dakota Conservancy Sub-District files show that W. S. Reeves, the former Chief Drainage Engineer for the State of South Dakota, proposed that controlling structures be built in conjunction with two highway bridges, and a diversion channel constructed so that Dry Lake and Lake Poinsett could be used for off-stream storage of the Big Sioux River floodwater.

As proposed, Boswell Dam and a bridge were built in 1929 between secs. 30 and 31, T. 114 N., R. 51 W., (figs. 2 and 4). The 86-foot long dam has four steel gates, each 20 feet long and 8 feet high, and each with its own electrical elevating and lowering device. The cost was paid jointly by the Department of Game, Fish, and Parks and Hamlin County.

The 111-foot long gates across the diversion channel were built in 1956 in conjunction with the new road bridge on the section line between sec. 30, T. 114 N., R. 51 W., and sec. 25, T. 114 N., R. 52 W. (figs. 2 and 4). The structure consists of five steel gates, each 20 feet long and 8 feet high, and each with its own electric motor for raising and lowering.

The operation of these facilities is under the jurisdiction of the South Dakota Department of Game, Fish, and Parks.

The natural outlet of the lake is located northeast of Lake Poinsett and connects the lake to the Big Sioux River (figs. 2 and 4).

GENERAL GEOLOGY

Surficial Deposits

The surficial deposits of the Lake Poinsett study area can be divided into two main groups: (1) glacial deposits and (2) stream deposits.

Glacial Deposits

During the late Pleistocene Epoch of geologic time, ice moved into the area and deposited glacial drift in the Lake Poinsett area. Drift can be divided into till and outwash deposits. Till consists of a heterogeneous mixture of boulders, pebbles, and sand in a matrix of clay directly deposited by the ice. Outwash material, on the other hand, is a sorted deposit

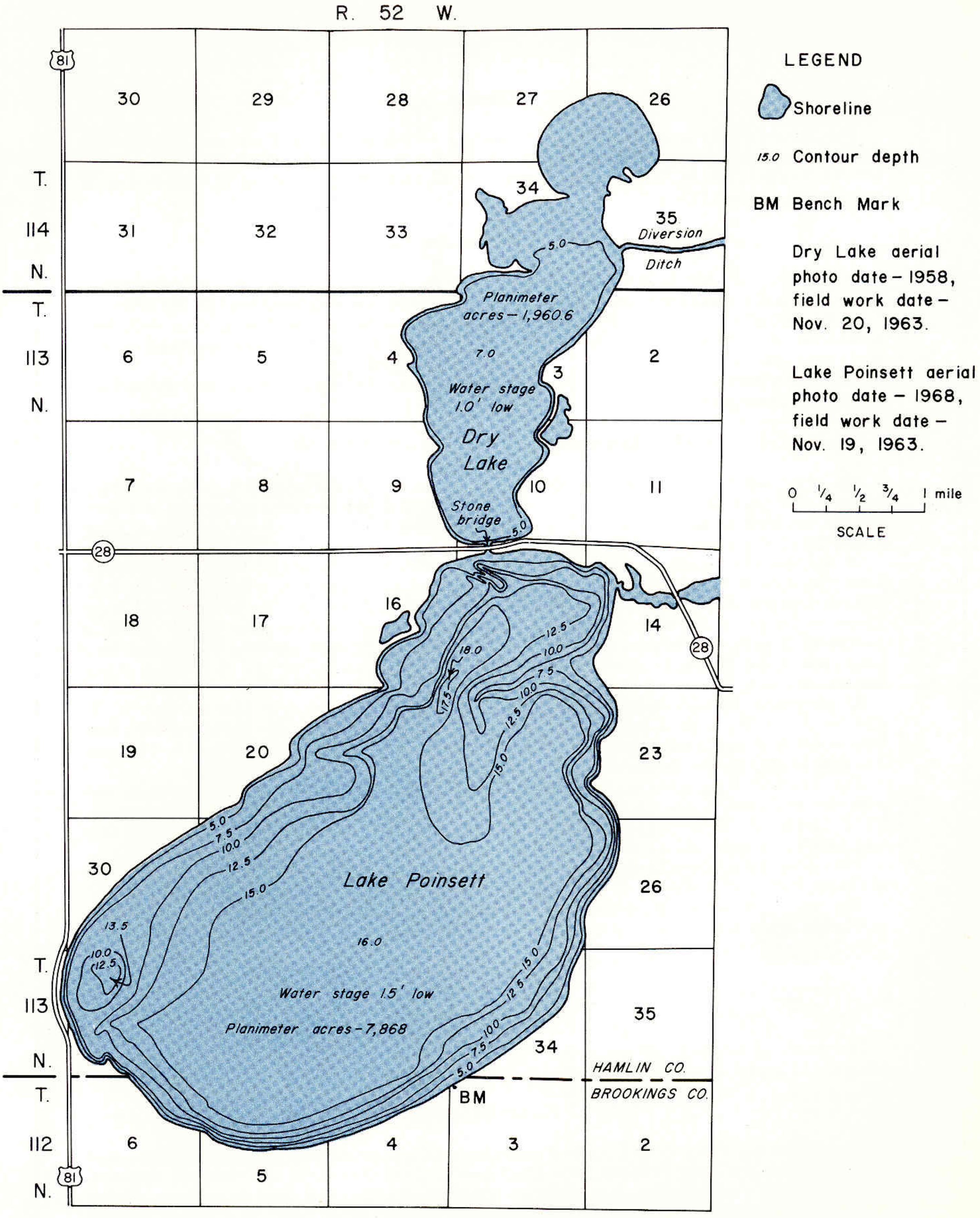


Figure 3. Depth contour map of Lake Poinsett and Dry Lake, *(from S. D. Dept. of Game, Fish and Parks).*

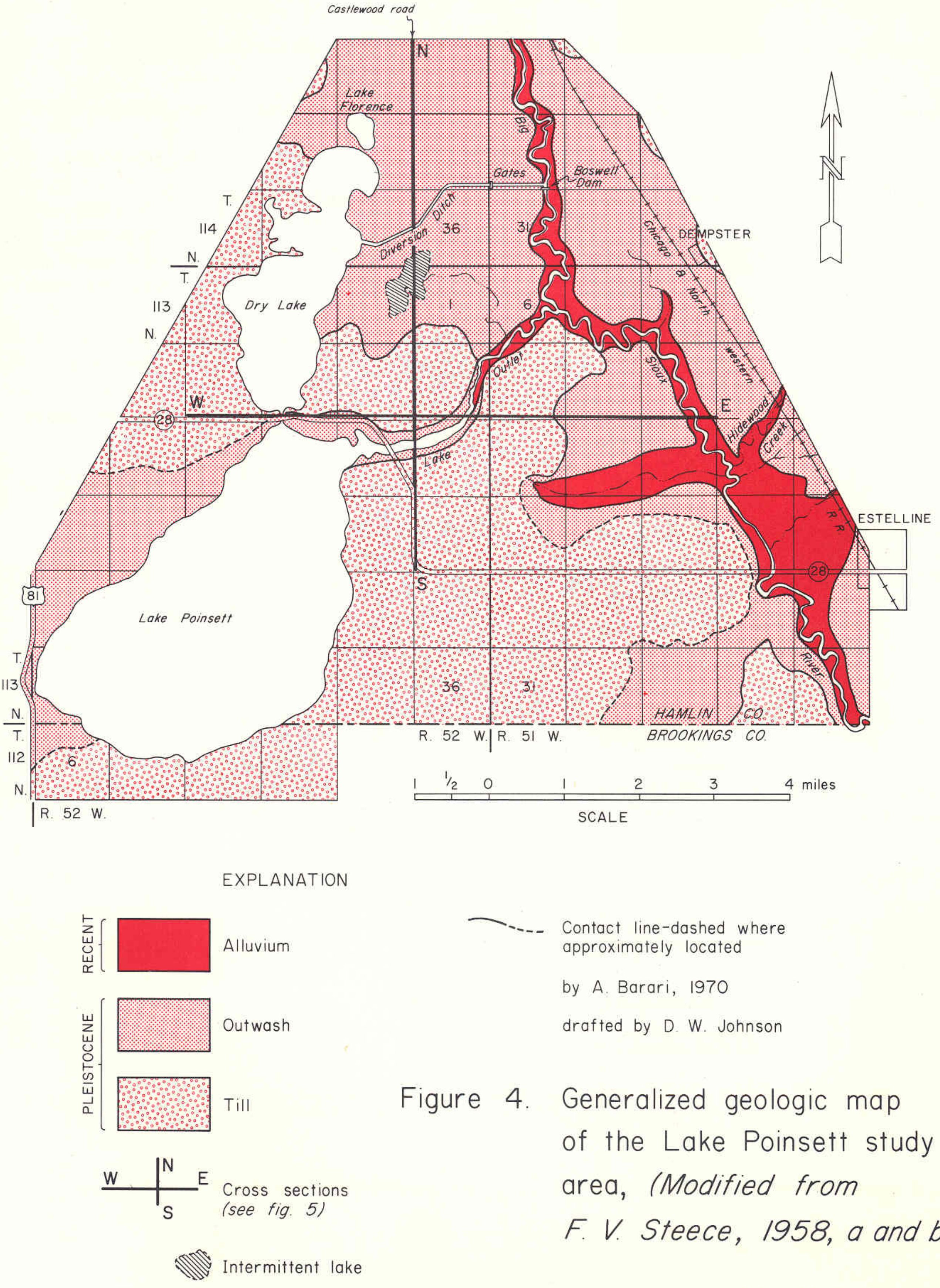


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Figure 4. Generalized geologic map of the Lake Poinsett study area, *(Modified from F. V. Steece, 1958, a and b).*

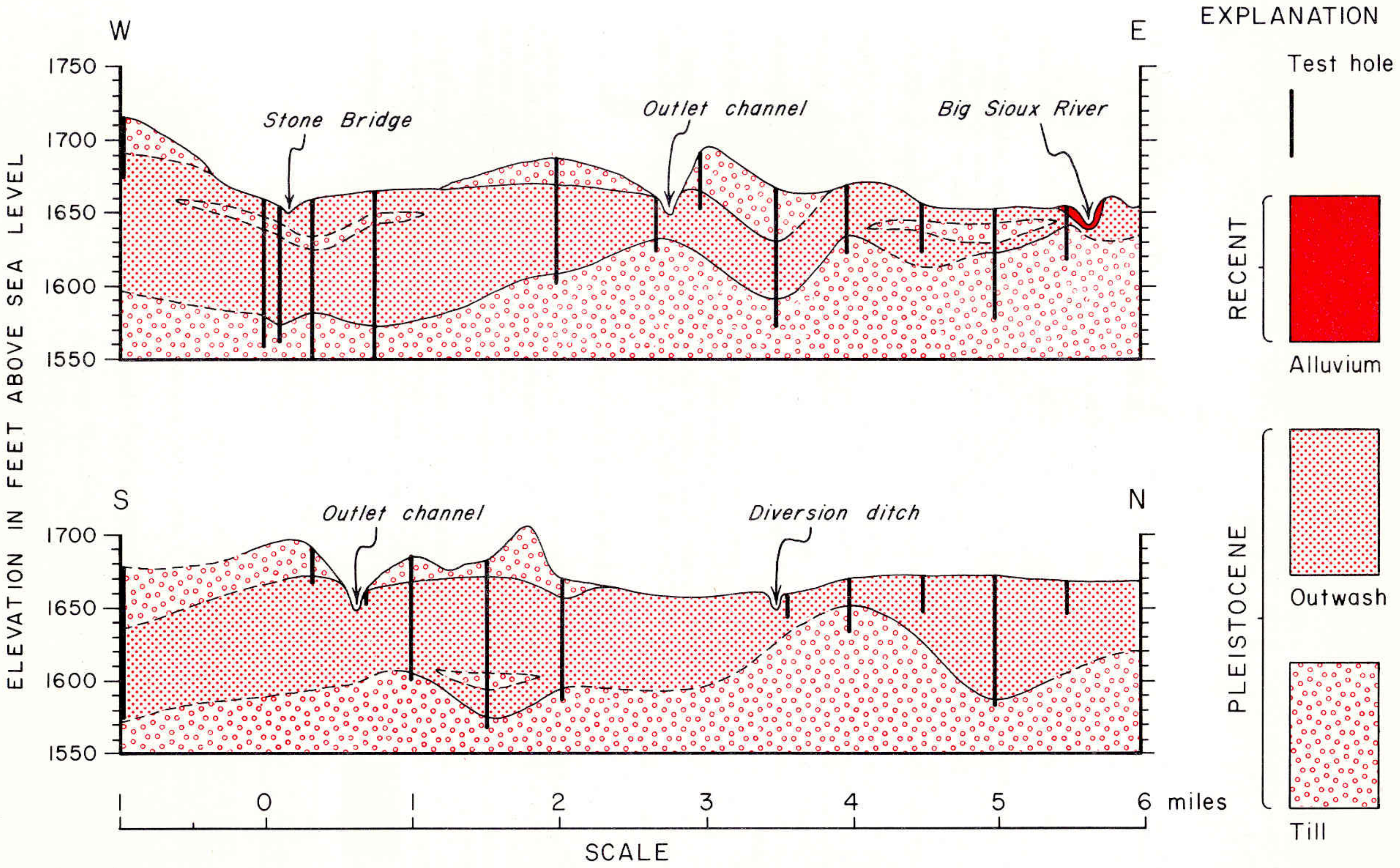

Figure 5. Geologic cross section along line W-E, S-N as shown on figure 4.

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consisting of mostly sand and gravel with minor amounts of clay that were deposited by meltwater streams issuing from the ice. Figures 4 and 5 show the areal distribution of these deposits.

Stream Deposits

The Big Sioux River and some of its tributaries have deposited alluvium in their channels (fig. 4). Alluvium in the study area consists of sand, gravel, and some clay.

Subsurface Bedrock

Subsurface information is extrapolated to the Lake Poinsett study area from a few water wells in Hamlin and adjacent counties.

Stratified sedimentary bedrock of Cretaceous age is present beneath approximately 400 feet of unconsolidated glacial deposits in the Lake Poinsett area. These deposits in descending order are Pierre Shale, Niobrara Marl, Carlile Shale, Greenhorn Limestone, Graneros Shale, and the Dakota Formation.

The Pierre Shale consists of light- to dark-gray clayey shale and is approximately 300 feet thick.

The Niobrara Marl is composed of light- to medium-gray chalk with shaly layers. These deposits are approximately 120 feet thick.

The Carlile Shale underlies the Niobrara Marl and consists of light-gray to black shale with thin silt and sand layers. The Carlile Shale is approximately 200 feet thick.

The Greenhorn Limestone is composed of hard, gray limestone. The approximate thickness of this deposit is 30 feet.

The Graneros Shale exhibits a gray color and may contain thin, cemented sandstone layers. The thickness of this formation is approximately 160 feet.

The Dakota Formation is a sequence of alternating sand, sandstone, and shale beds, and is probably over 200 feet thick in this area. Beneath the Dakota are rocks of Precambrian age, usually quartzite and granite.

HYDROLOGY OF LAKE POINSETT

The hydrology of a lake may be defined as the study of the factors controlling the quality and processes governing the depletion and replenishment of the water in a lake. It takes into consideration precipitation, evaporation, flow into and out of the lake from both surface and subsurface, and the effects of artificial control. Hydrology is the science by which the behavior of lakes may be analyzed.

The water level of a lake is a function of the volume of water contained in the lake basin. The rate of change of water volume is controlled by the rate at which water enters the basin from all sources, minus the rate at which water is lost by all sources.

The following formula shows the relationship between recharge, discharge, and resulting lake-level fluctuation:

$$\Delta h\,(A + \Delta A) = \Delta V = \text{Recharge} - \text{Discharge}$$

where

Δh is the change of water level in the lake,
A is the surface area of the lake,
ΔA is the change of the surface area of the lake due to fluctuation of the lake level, and
ΔV is the change in volume of water in the lake.

The following is the analysis of these factors with presently available data.

Recharge

Recharge into the lake includes water from all sources, and may be divided into three major categories: (1) direct precipitation, (2) ground-water recharge, and (3) surface-water recharge.

Direct Precipitation

The term precipitation, as used in hydrology, is a general term for all forms of water derived from atmospheric vapor deposited on the lake surface.

Precipitation received in this area is measured at the U. S. Weather Bureau Station at Castlewood, 8 miles north of the Lake Poinsett area. These records show that the average annual precipitation at this station is 20.80 inches.

Appendix A is a table of monthly and annual precipitation for the Lake Poinsett area (Castlewood) from January 1906 to December 1970. Figure 6 is a graph showing monthly precipitation from 1906 to 1935, and figure 7 shows the monthly precipitation and lake-level hydrograph at Lake Poinsett from January 1935 through December 1970.

Ground-Water Recharge

Occurrence of Ground Water

Ground water is defined as water contained in the voids or openings of rocks or sediments below the water table. The water table is the upper surface of the zone of saturation which is under atmospheric pressure. Practically all the pores of permeable rocks that lie below the water table are filled with water. Rocks (including the soil) that lie above the water table are in the zone of aeration. Some of the interstices in this zone are also filled with water, but the water is either held by molecular attraction or is moving downward toward the zone of saturation. Water in the ground moves downward through the unsaturated zone under the influence of gravity, whereas in the saturated zone it moves in a direction determined by the hydraulic gradient.

Nearly all ground water is derived from precipitation in the form of rain, melting snow, or ice. Water from these sources either evaporates, percolates directly downward to the water table and becomes ground water, or drains off as surface water. Surface water either evaporates, escapes to the lakes or ocean by streams, or percolates downward into the rocks.

Recharge is the addition of water to an aquifer (a formation having structures that permit appreciable amounts of water to move through it under ordinary field conditions), and is accomplished in four main ways: (1) by downward percolation of precipitation from the ground surface, (2) by downward percolation from surface bodies of water, (3) by lateral flow of ground water into the area, and (4) by artificial recharge, which takes place from excess irrigation, seepage from canals, and water purposely applied to augment ground-water supplies.

Discharge of ground water from an aquifer is accomplished in four main ways: (1) by evaporation from free-water surfaces and transpiration by plants, (2) by seepage upward or laterally into surface bodies of water, (3) by lateral movement of water out of the area, and (4) by pumping from wells, which constitutes the major artificial discharge of ground water.

Definitions

The porosity of a rock or soil is a measure of the contained open spaces and is expressed as the percentage of these open spaces to the total volume of the rock.

$$\propto = \frac{100W}{V}$$

where

$\propto$ is the porosity,
W is the volume of water required to fill all of the pore space, and
V is the total volume of the rock or deposit.

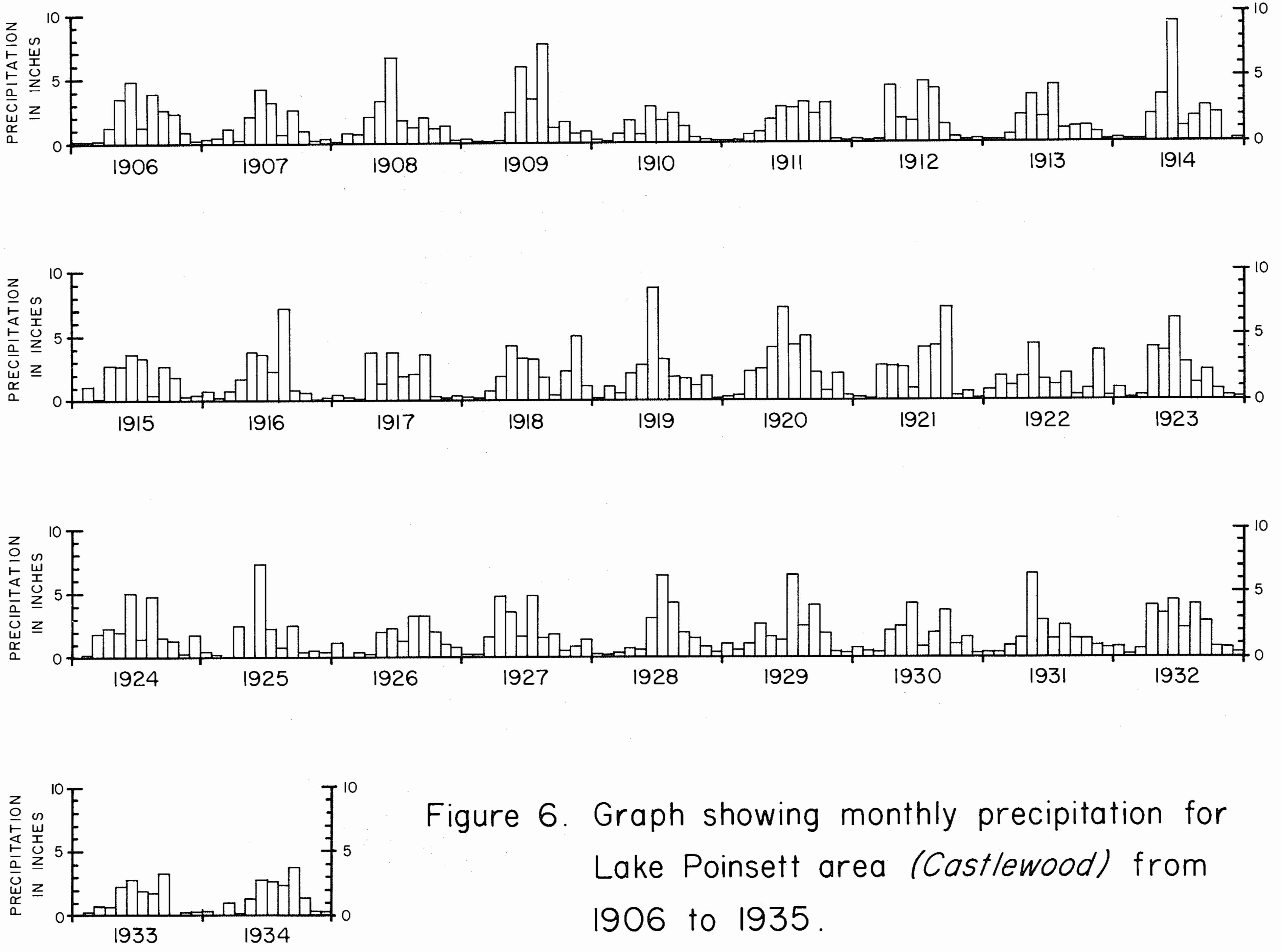


Figure 6. Graph showing monthly precipitation for Lake Poinsett area *(Castlewood)* from 1906 to 1935.

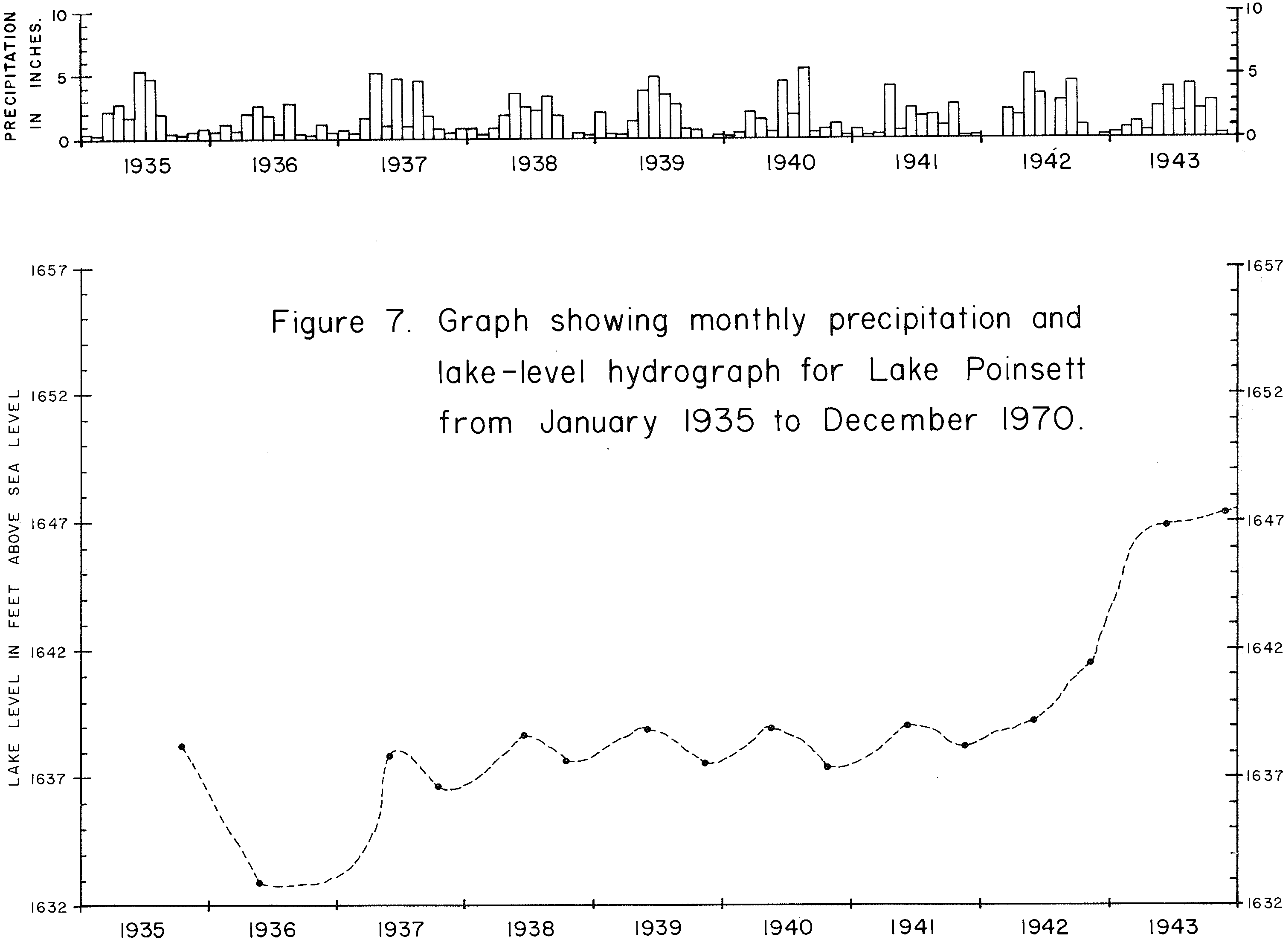


Figure 7. Graph showing monthly precipitation and lake-level hydrograph for Lake Poinsett from January 1935 to December 1970.

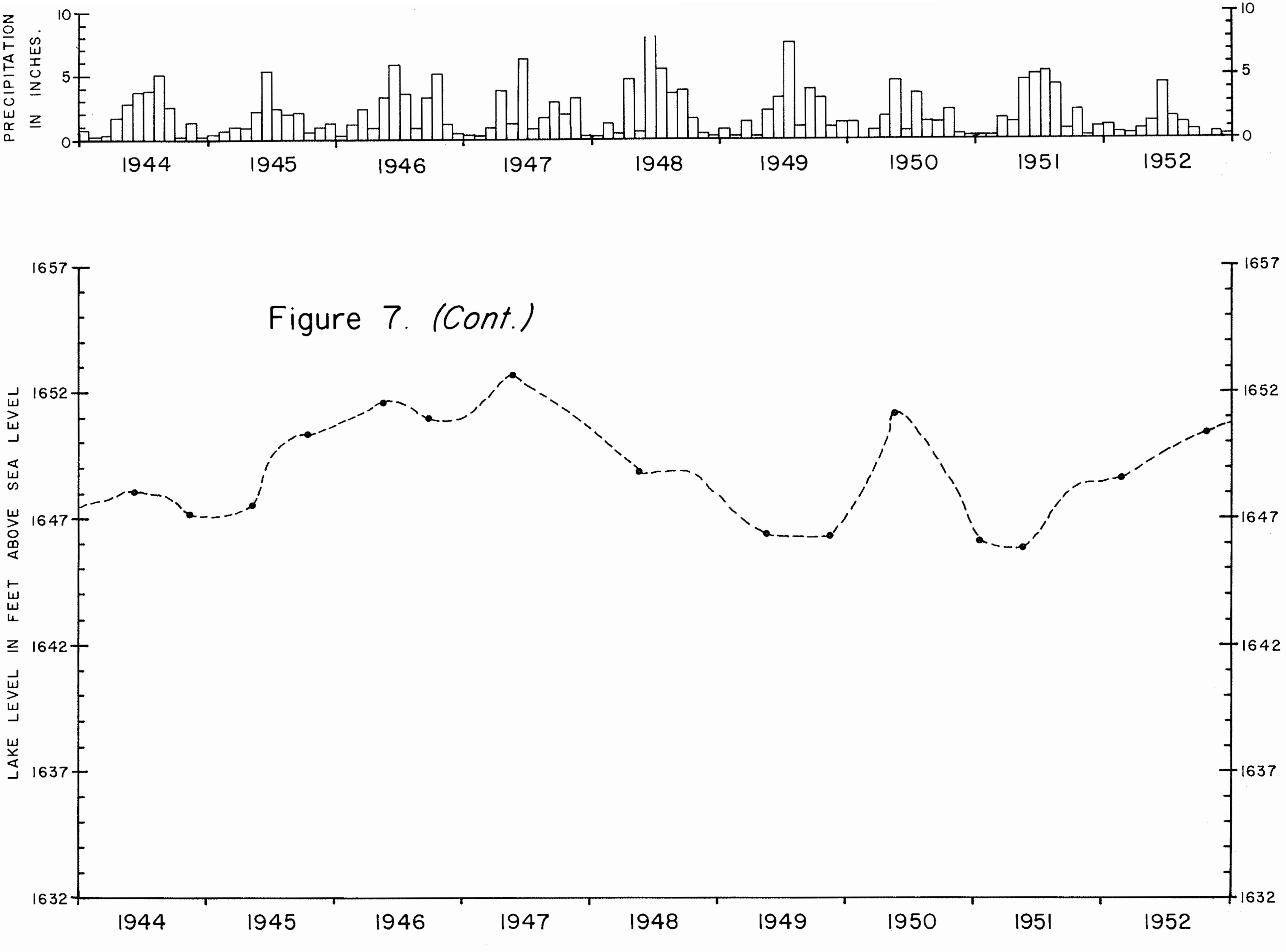


Figure 7. *(Cont.)*

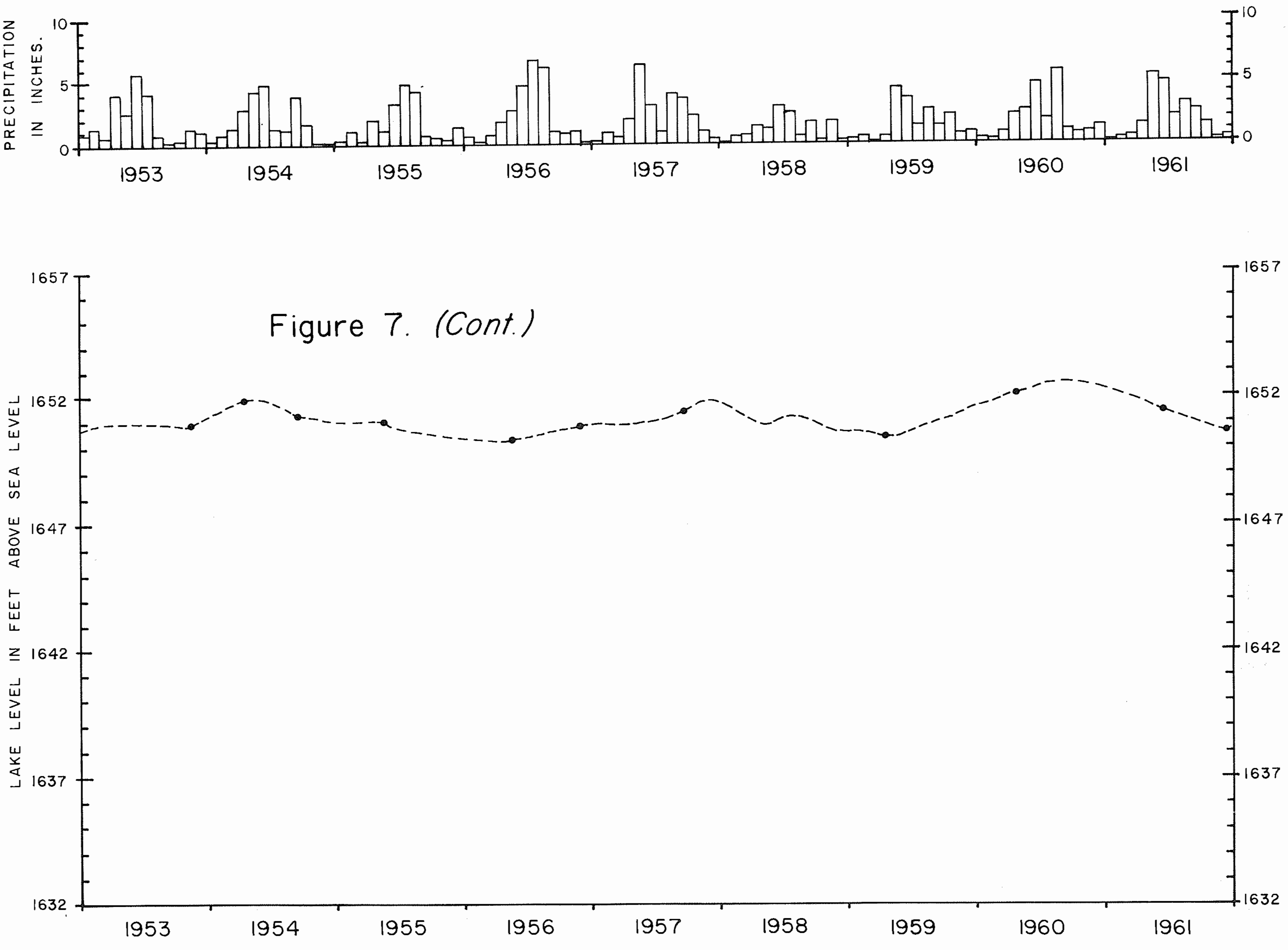


Figure 7. *(Cont.)*

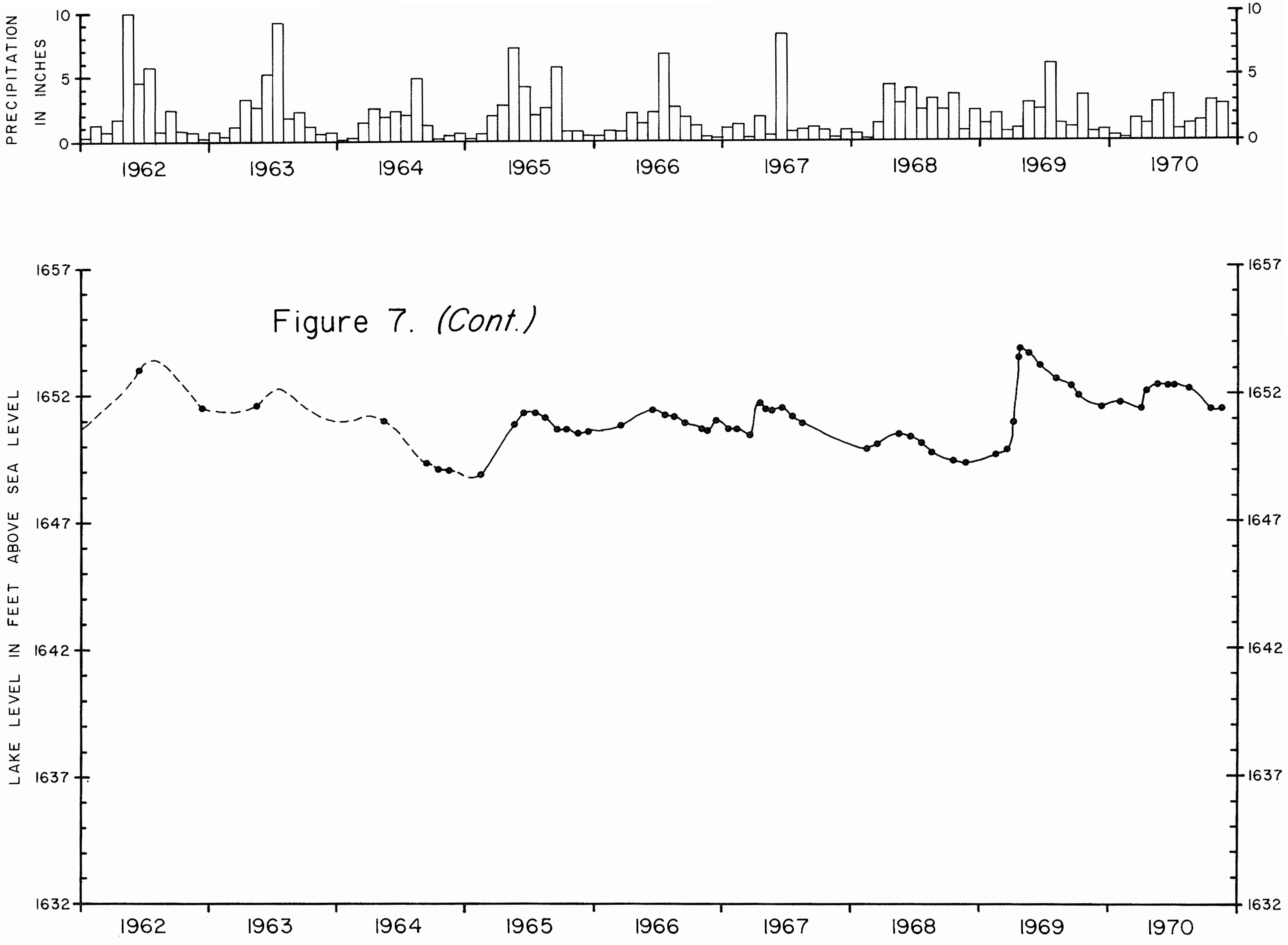


Figure 7. (Cont.)

The porosity of a sedimentary deposit depends mainly on (1) the shape and arrangement of its constituent particles, (2) the degree of sorting of its particles, (3) the cementation and compaction to which the sediments have been subjected since deposition, (4) the removal of mineral matter through solution by percolating waters, and (5) the fracturing of the rock, resulting in joints and other openings. Thus, the size of the material has little or no effect on porosity providing all other factors are equal. Porosities of rocks range from near zero to more than fifty percent, depending upon the above factors.

The permeability or hydraulic conductivity of a rock is its capacity for transmitting a fluid. The coefficient of permeability (K) is defined as the rate of flow of water in gallons per day through a cross-sectional area of one square foot under a unit hydraulic gradient. Water will pass through a material with interconnected pores, but will not pass through a material with unconnected pores, even if the latter material has a high porosity. Therefore, permeability and porosity are not synonymous terms.

The coefficient of transmissibility (T) is expressed as the rate of flow of water in gallons per day through a vertical strip of the aquifer one foot wide extending the full saturated thickness of an aquifer under a hydraulic gradient of 100 percent. The relation between the coefficient of permeability and transmissibility is shown by the following equation:

$$T = Km$$

where

T is the coefficient of transmissibility,
K is the coefficient of permeability, or hydraulic conductivity, and
m is the thickness of the saturated deposits.

The coefficient of storage (S) of an aquifer is the volume of water released from or taken into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface.

Specific yield is the ratio of the volume of water that a rock or soil will yield by gravity to the total volume of rock.

$$Sy = \frac{100\ Wy}{V}$$

where

Sy is the specific yield,
Wy is the volume of drained water, and
V is the total volume of the rock or soil.

The coefficient of storage of a water-table aquifer is essentially equal to the specific yield; however, for an artesian aquifer the coefficient of storage is generally much smaller than the specific yield.

All of the water contained in the ground could not be removed by pumping from a well or under the influence of gravity; thus, retained water is held against gravity by surface tension and other means. The specific retention of a rock or soil is expressed as the percentage of the volume of water an aquifer holds against the force of gravity to the total volume of the deposits.

$$Sr = \frac{100\ Wr}{V}$$

where

Sr is the specific retention,
Wr is the volume of water retained, and
V is the total volume of the deposits.

Extent of the Shallow Aquifer

To define the extent of the shallow aquifer in the area and the connection of this water-yielding deposit to Lake Poinsett, 84 test holes were drilled. Figure 8 shows the location of the test holes in the study area, and appendix B gives the description of deposits penetrated by the test holes. The results of test-hole drilling in the study area indicate that sand and gravel deposits connect Dry Lake to Lake Poinsett. In addition, an extensive outwash deposit lying northeast and east of Dry Lake and north and northeast of Lake Poinsett hydraulically connects the Big Sioux River to Dry Lake and Lake Poinsett. Figure 9 shows the thickness of saturated sand and gravel in the study area.

Aquifer Tests

Two pump tests were conducted in the area to identify the hydraulic characteristics of the outwash aquifer in the study area.

The first test was conducted on John Harrenga's irrigation well one-fourth mile west of Estelline, in the NE¼ sec. 26, T. 113 N., R. 51 W. (fig. 8). In this location the aquifer consists of well-sorted, very coarse sand and gravel with very little clay content. Before starting the test, the water table was approximately 8 feet below the ground surface with 28 feet of saturated sand and gravel. The test started on June 24, 1967, and the pump was shut off on June 27, 1967 after 72 hours of pumping at an average pumping rate of 810 gallons per minute. The recovery was practically complete after 75 hours. The average transmissibility was calculated as follows:

$T = 3.2X10^5$ gal/day/ft with an average permeability of $K = 1.1X10^4$ gal/day/ft^2.

The second test was conducted on an irrigation well at Spilde's farm 3 miles northwest of Estelline in the SE¼ sec. 3, T. 113 N., R. 51 W. (fig. 8). The aquifer consists of sand and gravel that is not as well sorted as the deposit at Harrenga's farm. The average saturated thickness of the sand and gravel is 40 feet. Pumping was started on July 18, 1967, and continued for 42 hours at a rate of 710 gallons per minute.

The average transmissibility was $T = 1.5X10^5$ gal/day/ft with an average permeability of $3.8X10^3$ gal/day/ft^2.

The average permeability of the aquifer determined from the two pump tests was $K = 7.4X10^3$ gal/day/ft^2, and the average storage coefficient or specific yield of the aquifer was $S = 0.10$.

Quantity of Ground-Water Recharge

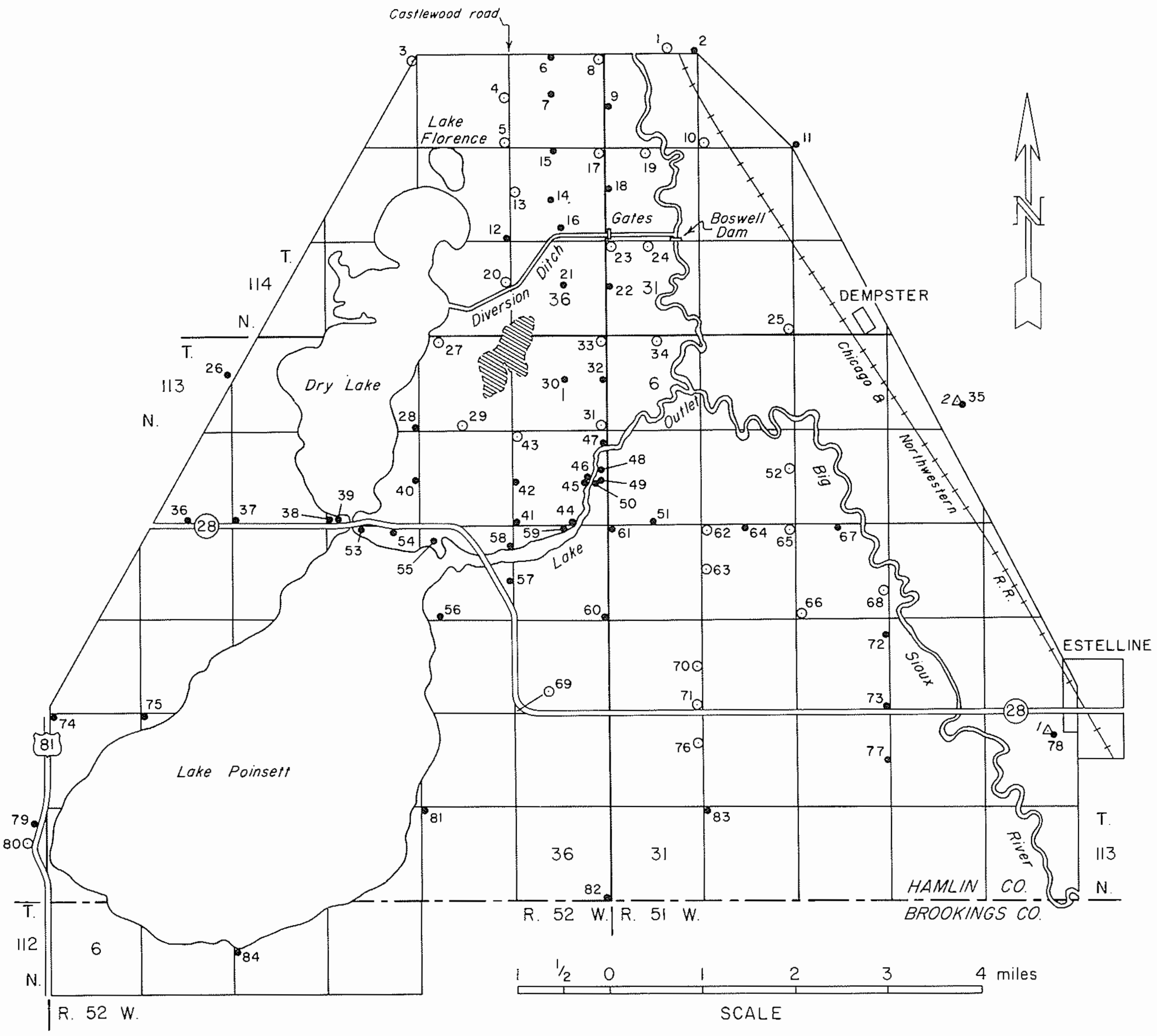
Figure 10 is a water-table map of the study area for August 3, 1970 (see app. C for water-level measurements). This figure shows that the ground water is moving into the study area from the north. The rate of this flow can be calculated by applying the following equation:

$$Q = KA\frac{dh}{dl} \qquad [1]$$

where

Q is the discharge per unit time (in gallons per day),
K is the coefficient of permeability or hydraulic conductivity of the aquifer in gallons per day per square foot,
A is the cross-sectional area,
$\frac{dh}{dl}$ is the hydraulic gradient (dh is the change of hydraulic head—dl is the change of horizontal distance).

Flow from the north is calculated for a cross-sectional area one-half mile south of the north boundary of the study area. Figure 9 shows that the average thickness of saturated



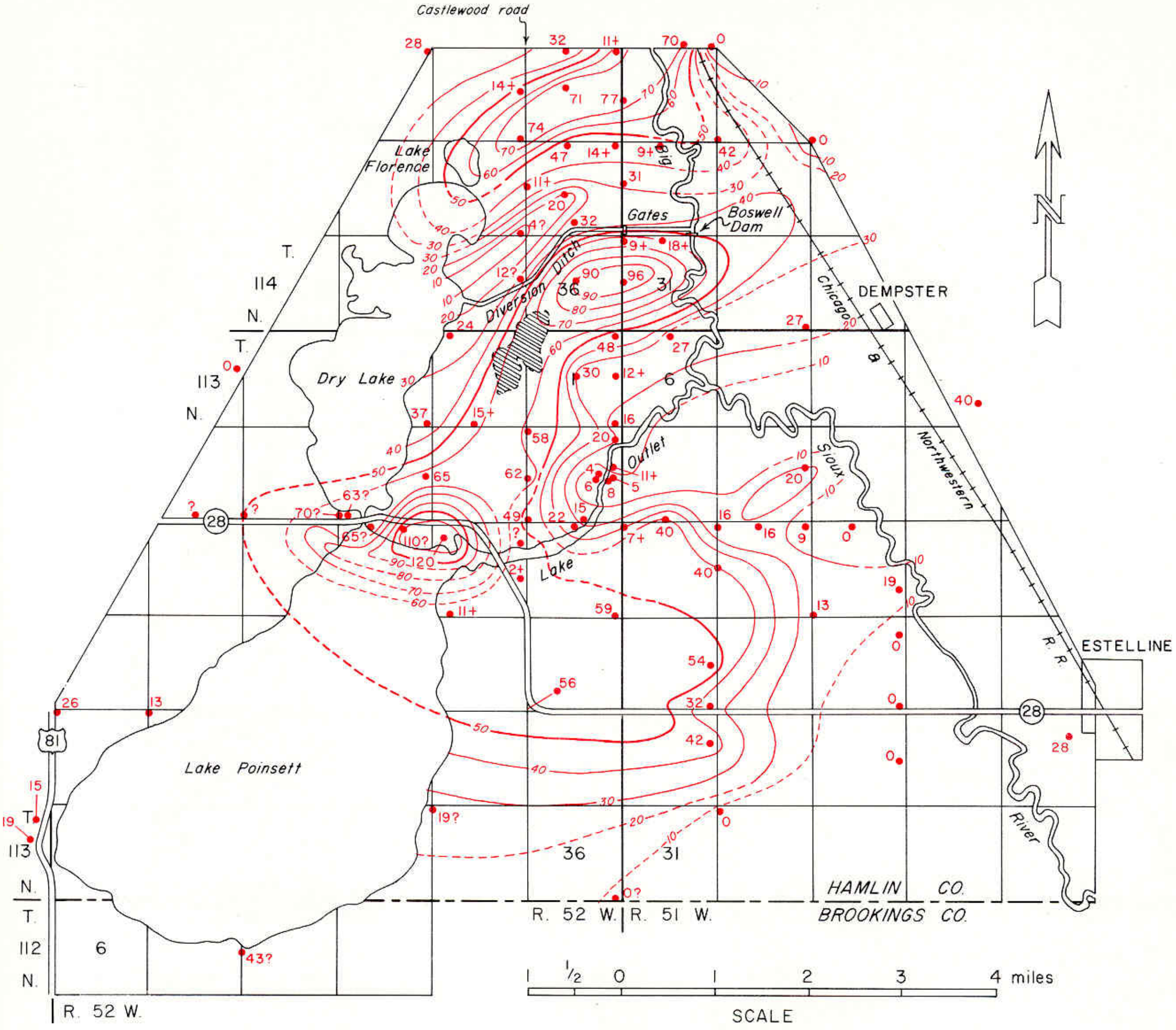
EXPLANATION

- ○66 Observation well
- ●37 Test hole
- ▨ Intermittent lake
- 2△ Pump-test well

by A. Barari, 1970

drafted by D. W. Johnson

Figure 8. Map showing location of test holes, observation wells, and pump-test wells in the Lake Poinsett study area.



EXPLANATION

70 Contour lines connect points of equal thickness of saturated sand and gravel *(dashed where approximately located)*

Contour interval = 10 feet *(dashed in areas of limited data)*

28● Test hole, number indicates thickness of saturated sand; a "+" indicates that full thickness of saturated sand was not penetrated; a "?" indicates drilling halted due to rocks.

▨ Intermittent lake

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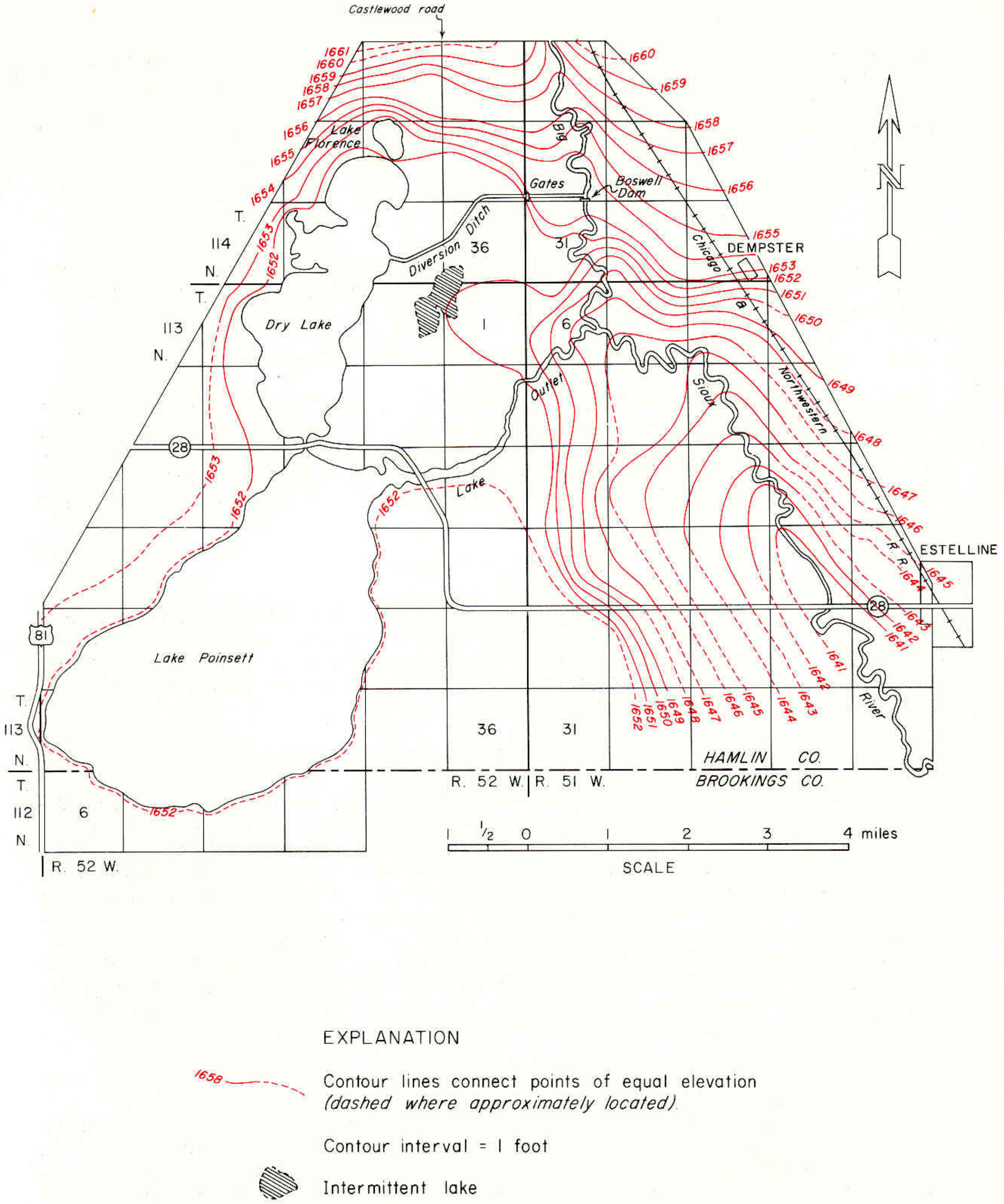
Figure 9. Map showing thickness of saturated sand and gravel in the Lake Poinsett study area.



EXPLANATION

1658 Contour lines connect points of equal elevation *(dashed where approximately located)*.

Contour interval = 1 foot

▨ Intermittent lake

by A. Barari, 1970 drafted by D. W. Johnson

Figure 10. Water-table map of the Lake Poinsett study area for August 3, 1970.

sand and gravel in the area is 50 feet and has a width of 4 miles. The hydraulic conductivity (permeability) of the aquifer in this location is assumed to be equal to the average hydraulic conductivity at the pump-test sites, or 7.4×10^3 gal/day/ft^2 (see aquifer tests), and the value of $\frac{dh}{dl} = \frac{6}{5280}$ was obtained from the water-table map (fig. 10). By substituting these values in equation 1, Q can be calculated:

$$Q = 7.4 \text{ X } 10^3 \text{ X} \frac{6}{5280} \text{X } 5280 \text{ X } 4 \text{ X } 50 = 8.9 \text{ X } 10^6 \text{ gal/day}$$

Figure 10 also shows that approximately 6/10 of the water is moving into the lakes and the rest is moving along the Big Sioux River. At this rate, on August 3, 1970 recharge to the lakes from the north was:

$$Q_1 = Q \text{ X } 0.6 = 8.9 \text{ X } 10^6 \text{ X } 0.6 = 5.3 \text{ X } 10^6 \text{ gal/day}$$

The second recharge area is from a shallow sand and gravel layer located west of Lake Poinsett connecting Lake Poinsett to Lake Albert and Lake St. John. Very few test holes have been drilled in this area, but based on the limited data, it is assumed that the average thickness of this aquifer is 20 feet, with a width of 2 miles. The rate of recharge to Lake Poinsett from this area in August 1969 could be obtained by substituting the values in equation 1:

$$Q_2 = 3.0 \text{ X } 10^5 \text{ gal/day}$$

The well inventory from this area (app. D) indicates that a deeper glacial aquifer is present in the NE¼ sec. 36, T. 113 N., R. 53 W. The Lake Region Golf Course is withdrawing water from this aquifer, but more information is required to define the extent and connection of this aquifer to Lake Poinsett. Furthermore, limited information from this aquifer prevented the calculation of the flow.

Surface-Water Recharge

Precipitation in the form of melting snow or rain reaching the ground surface becomes either surface runoff or infiltration, depending on whether or not the rain intensity exceeds the infiltration capacity. The low infiltration capacity of the clay (till) west of Dry Lake and east and southeast of Lake Poinsett, and the relatively high relief in these areas causes surface runoff into the lakes (pl. 1). Also, some surface-water flow takes place between Lake Albert and Lake Poinsett, but the magnitude of surface runoff and stream flow from west of Dry Lake and Lake Poinsett is small when compared with the magnitude of flow into the lake from the Big Sioux River. During flooding a large quantity of water enters Dry Lake through the man-made diversion ditch, by flowing over the land, and by flowing from Dry Lake into Lake Poinsett under Stone Bridge. In addition, Big Sioux River water reaches Lake Poinsett through the outlet channel.

Flood of 1969

The 1969 spring flood in the Big Sioux River valley can be attributed to an exceptionally thick blanket of snow which had accumulated in the winter and early spring of 1969. In early April when the snow melted, maximum stages and record discharges occurred in some stations on the Big Sioux River. Because of the lack of a stream gauge in the study area, the magnitude of water flowing in the Big Sioux River is not accurately known in the study area. However, records published by the United States Geological Survey (Anderson and Schwab, 1970, p. 517-522) indicate that the maximum record discharge at a station 9½ miles southeast of Brookings was 33,900 cfs on April 9, 1969. The maximum discharge in 1969 at a station 2½ miles northwest of Watertown was 1,750 cfs and occurred on April 8.

In 1969 water overflowed the banks of the Big Sioux River in the study area and entered Lake Poinsett through the outlet channel as can be seen from figures 11 and 12. Similarly,

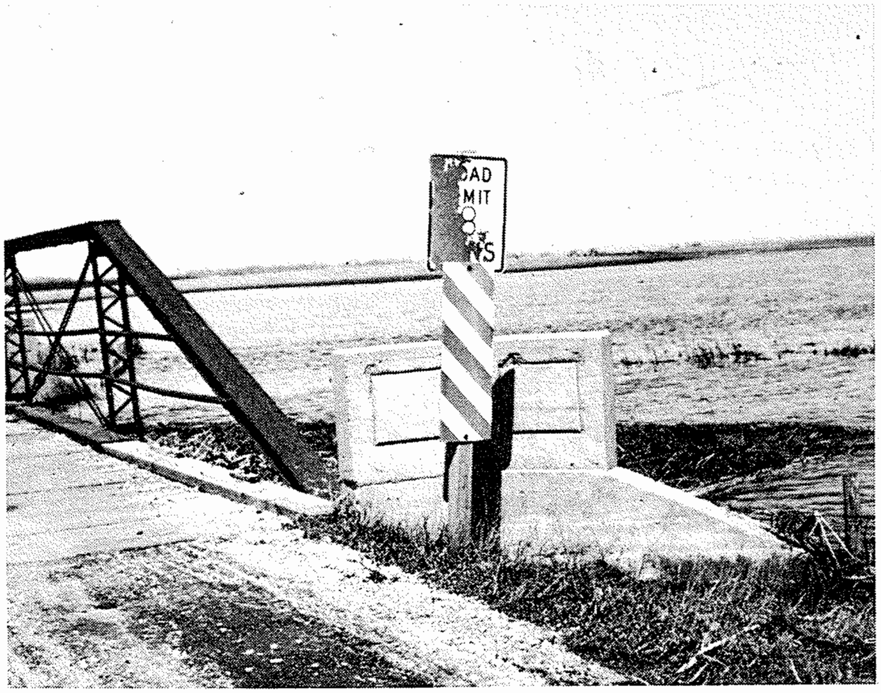


Figure 11. Photo showing Big Sioux River floodwater flowing through the outlet channel to Lake Poinsett (2 miles northeast of Highway 28 Bridge on the outlet, April 8, 1969).

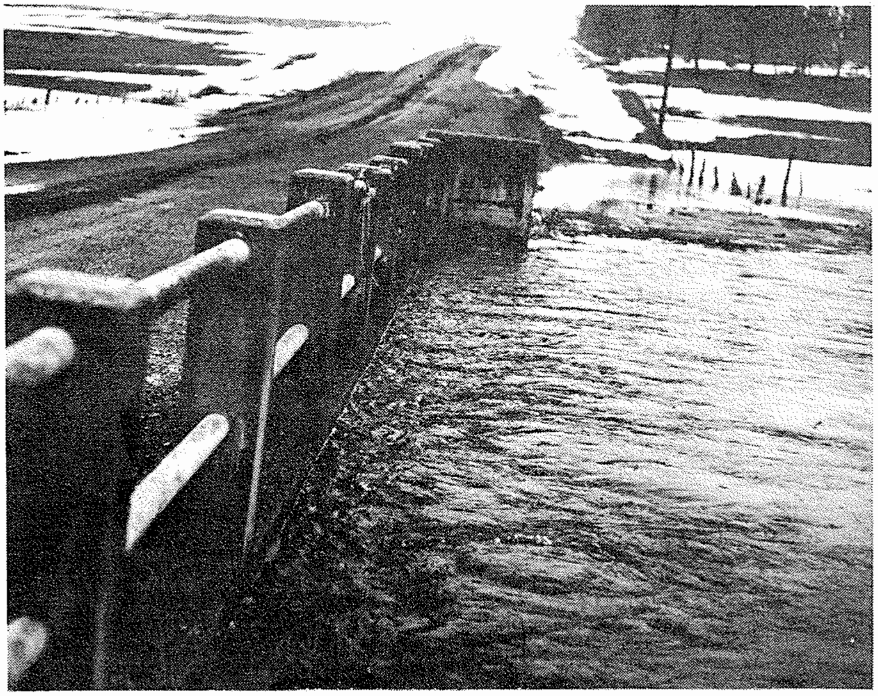


Figure 12. Photo showing Big Sioux River floodwater flowing through the outlet channel to Lake Poinsett (1-1/3 miles northeast of Highway 28 Bridge on the outlet, April 8, 1969).

water reached Dry Lake through the diversion ditch, with additional large quantities of water flowing over the land (figs. 13 and 14). Figure 13 is a photo taken from Castlewood Road north of Lake Poinsett showing a large quantity of water flowing over the road in this area.

Subsequently, water flowed from Dry Lake to Lake Poinsett because of increased hydraulic head in Dry Lake. The channel under Stone Bridge between Dry Lake and Lake Poinsett was not designed to carry such large volumes of water and, as a result, the west end of the bridge was destroyed by erosion (fig. 15). An early stage of erosion was also observed on the east side of the bridge. Figure 16 is a photo showing the repair of Castlewood Road after the flood of 1969.

Records of the East Dakota Conservancy Sub-District show that the Lake Poinsett water level was 1649.89 feet on March 31, 1969, and increased to 1653.76 feet by April 18, 1969 (app. E and fig. 7). This indicates that floodwater raised the lake level 3.87 feet. The combined volume of water in Lake Poinsett and Dry Lake was 105,000 acre-feet before the flood, and 38,037 acre-feet was added during the flood. It can be easily calculated that after the flood, slightly more than one-fourth (actually 26.6 percent) of the water contained in the lake was floodwater.

The high water level in the lake not only caused the lake to have a higher than normal lake level during 1969, but the lake level was high in the spring of 1970. Due to the high lake level in 1969, water flowed from the lake through the outlet channel and will be discussed in the surface-water discharge section of this report.

Discharge

The discharge from the lake includes all waters leaving the lake, and can be divided into (1) evapotranspiration, (2) surface-water discharge, (3) ground-water discharge, and (4) artificial discharge.

Evapotranspiration

All water, surface and subsurface, released into the atmosphere by the processes of evaporation and transpiration is called evapotranspiration.

Transpiration is the process whereby the moisture that has circulated through a plant structure is returned to the atmosphere, principally in the form of water vapor. The rate of transpiration depends on the climate and the type of vegetation.

Evaporation is the process by which a liquid (water) is changed into a vapor. The evaporation process occurs from the surface of land, lakes, ponds, and streams. Depth has a pronounced influence upon the rate of evaporation from any body of water. Likewise, water from a soil surface will evaporate initially at quite a high rate, but as soon as a thin layer of soil dries out the rate of evaporation is considerably reduced.

Evaporation from the surface of a lake in this area is 34 inches per year (Kohler and others, 1959). At this rate Lake Poinsett and Dry Lake, together, lose 28,000 acre-feet of water per year.

The evaporation was 8.37 inches for the month of August 1969 at Brookings (app. F). Using the conversion factor, 0.72 (Kohler and others, 1959), it can be found that during August 1969, evaporation from the surface of the lake in the study area was 6 inches. The total water loss by evaporation in August 1969 from the surface of the water in Lake Poinsett and Dry Lake amounts to 4900 acre-feet.

Surface-Water Discharge

The only surface-water discharge from Lake Poinsett is through the outlet channel which drains into the Big Sioux River. On August 9, 1969, the rate of flow of water was measured at a point 20 feet west of the junction between the outlet channel and the Big Sioux River (see Q_3, fig. 17). The rate of discharge was $Q_3 = 44$ cfs. Lake elevation was 1652.5 feet on the outlet channel next to the Highway 28 Bridge. If the lake level is higher than 1652.5 feet, the rate of discharge will increase due to the increased hydraulic head, and when the

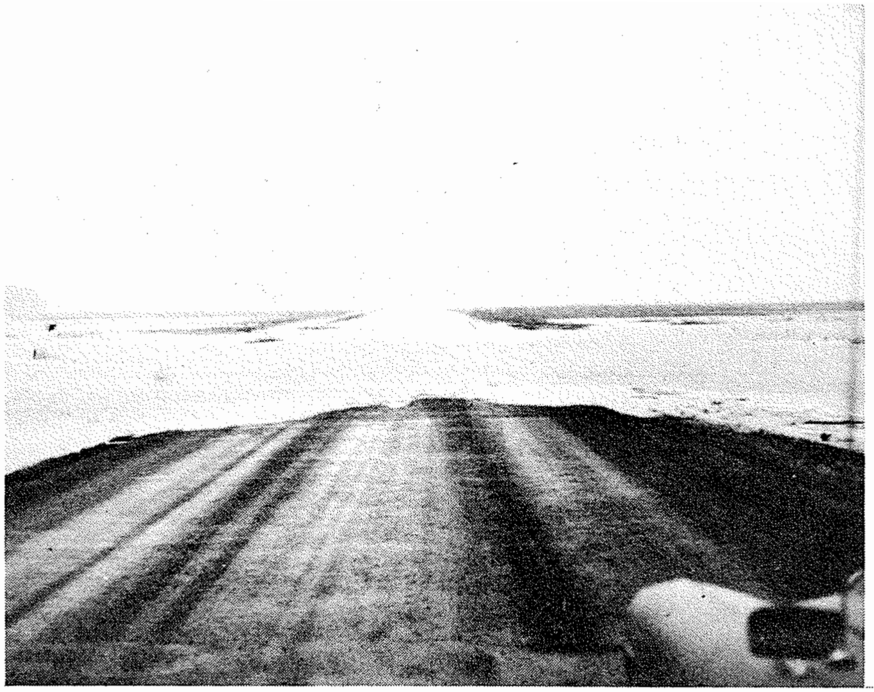


Figure 13. Photo showing Big Sioux River floodwater flowing over Castlewood Road to Dry Lake (1 mile north of Lake Poinsett, April 8, 1969).

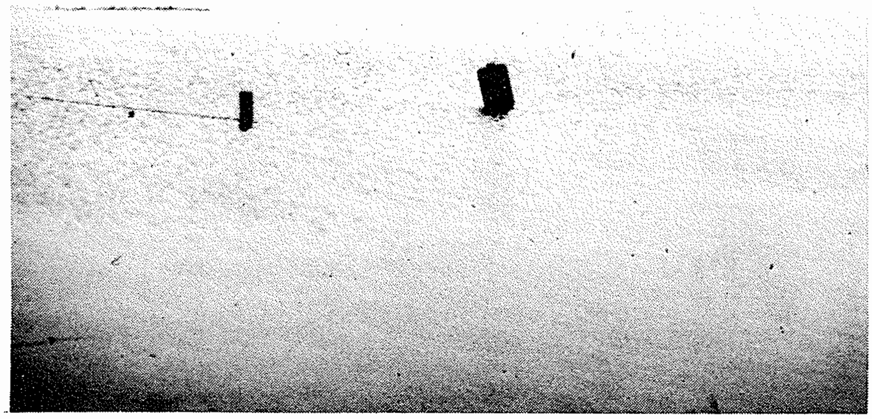
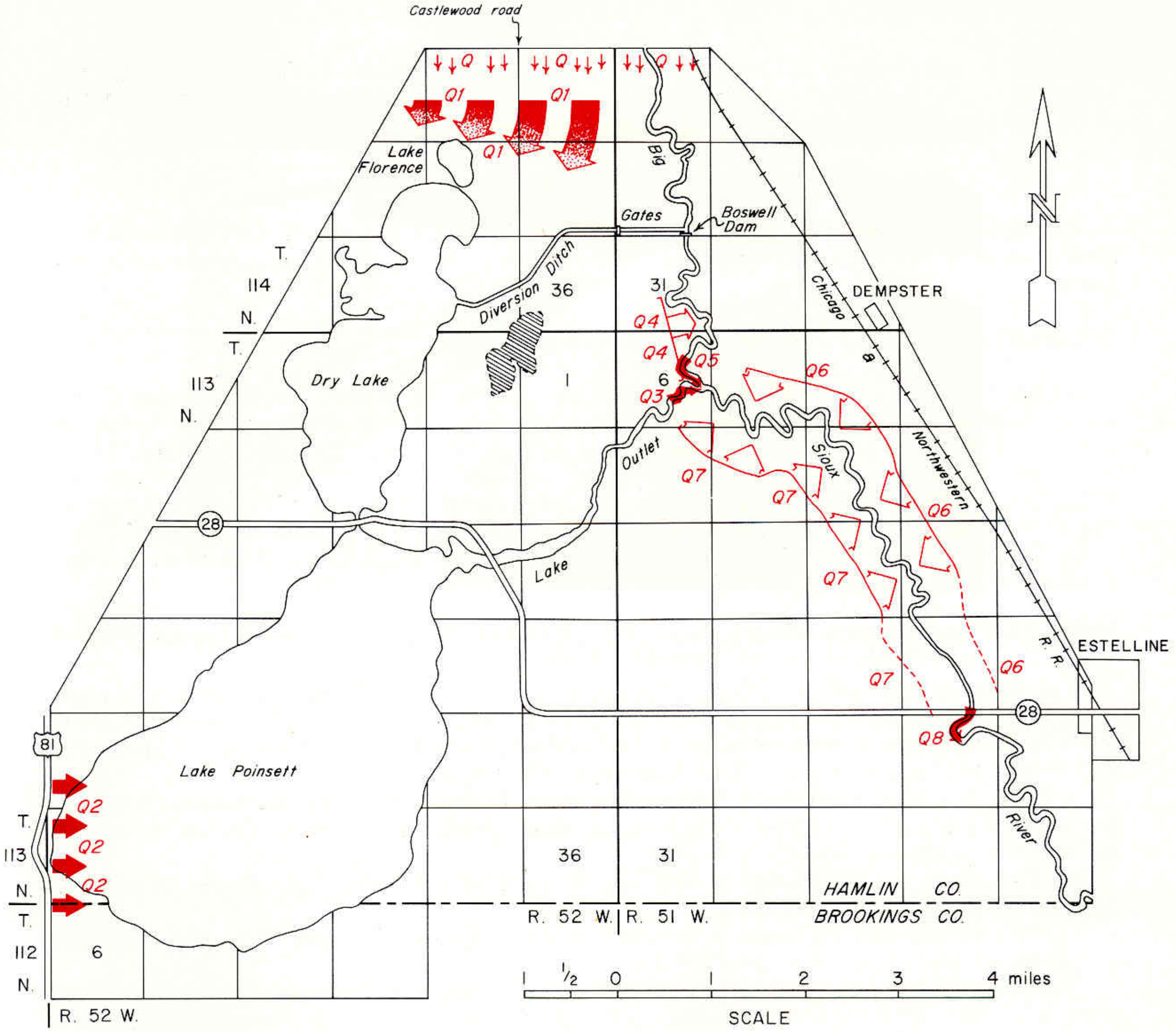


Figure 14. Photo showing floodwater on the west side of Castlewood Road (1 mile north of Lake Poinsett, April 8, 1969).

Figure 15. Photo showing erosion on the west end of Stone Bridge caused by water flowing from Dry Lake to Lake Poinsett (April 11, 1969).

Figure 16. Photo showing repair of Castlewood Road after the flood of 1969 (3 miles north of Lake Poinsett).



EXPLANATION

Q, Q1 and Q2	Ground-water recharge into the study area
Q4 and Q7	Ground-water discharge to the river
Q6	Ground-water and surface water discharge to the river
Q3, Q5 and Q8	Measurements of surface-water flow

Figure 17. Map showing components of inflow and outflow in the Lake Poinsett study area.

lake level is less than 1652.5 feet, the rate of flow is less than 44 cfs. Therefore, at the rate of Q_3 = 44 cfs, Lake Poinsett and Dry Lake lost 3.3 inches of water from the surface of the lakes in August 1969.

Ground-Water Discharge

Ground-water discharge to the Big Sioux River from Lake Poinsett, Dry Lake, and the aquifer east of Dry Lake and northeast of Lake Poinsett for August 1969 is discussed in two parts.

1. Ground-water discharge north of the outlet channel

Figure 18 shows the water-table map for August 1, 1969. This map shows that ground-water was discharging to the river from an area north of the junction between the outlet and the river (fig. 17). The discharge zone has a cross section approximately 1 mile wide and 20 feet thick (see fig. 9), located one-half mile south of Boswell Dam and extending to the point where the outlet channel joins the river (fig. 17). Substituting the values in equation 1 the discharge per day can be obtained: $Q_4 = 1.5X10^5$ gal/day. This is $1.5X10^5X31 = 4.6X10^6$ gallons in August 1969 which is equal to .02 inches of water discharged from both lakes.

2. Ground-water discharge from an area south of the river-outlet junction to Highway 28

The distance between the river-outlet junction and Highway 28 is approximately 7 miles along the west bank of the Big Sioux River. In order to calculate the ground-water discharge from this area, a direct measurement of stream flow was employed. The flow was measured in 3 locations (see Q_3, Q_5, Q_8, fig. 17) on August 9, 1969.

A. The flow was measured in the outlet channel 20 feet west of the river-outlet junction. As was discussed in the section of this report dealing with surface-water discharge, the rate of flow in this channel was Q_3 = 44 cfs.

B. The flow was measured in the Big Sioux River 15 feet north of the river-outlet junction. This flow was Q_5 = 30 cfs.

C. The flow in the Big Sioux River next to the bridge on Highway 28 (1-1/3 miles west of Estelline) was measured as Q_8 = 79 cfs.

The above figures show that between the outlet channel and Highway 28, the flow in the river increased by 5 cfs. The following equations show how the 5 cfs increase in the river water flow was determined:

$$Q_8 = Q_3 + Q_5 + Q_6 + Q_7$$

$$Q_8 - (Q_3 + Q_5) = (Q_6 + Q_7)$$

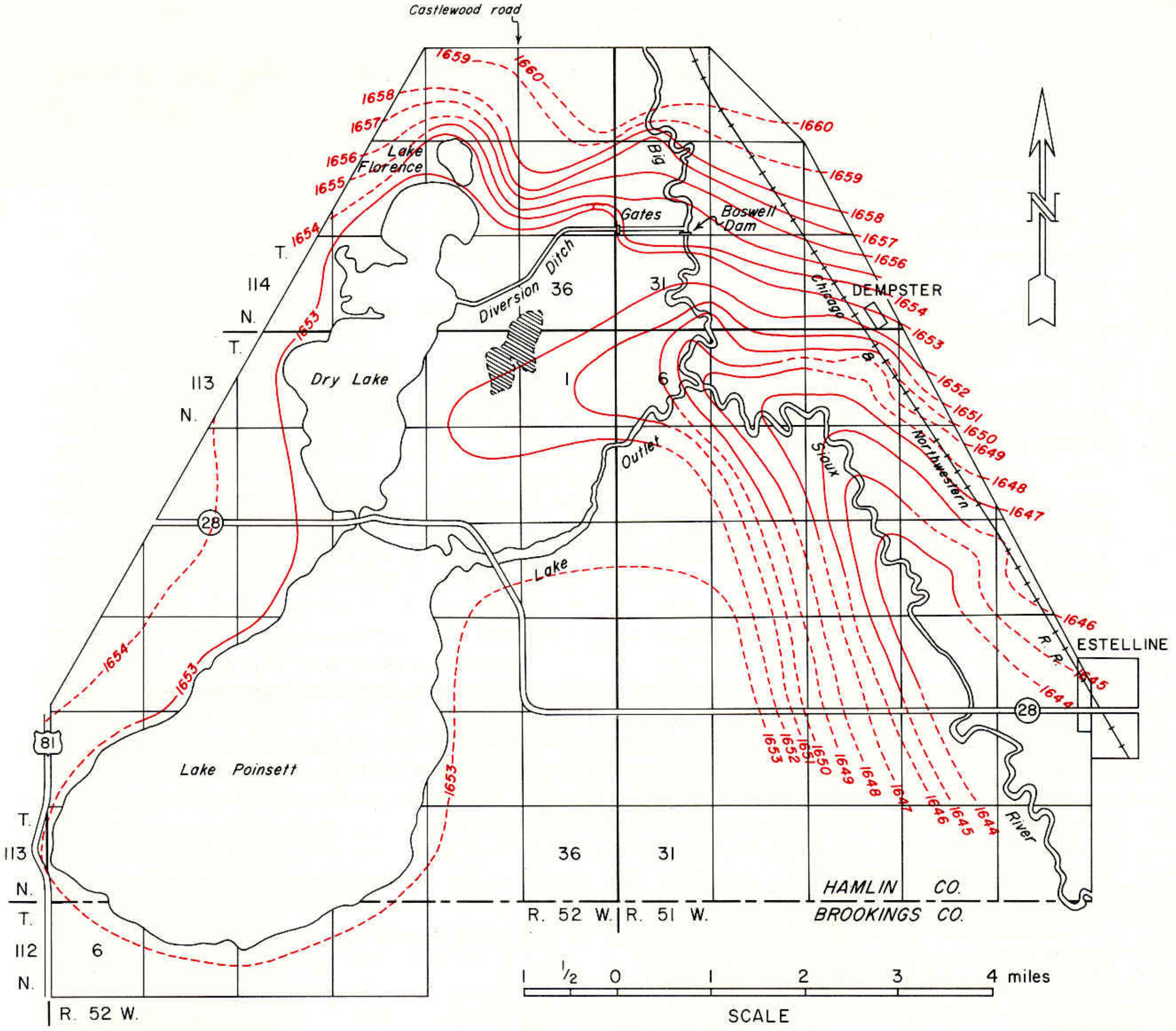
Substituting the values:

$$79 - (44 + 30) = 5 \text{ cfs} = (Q_6 + Q_7)$$

The increase in flow of 5 cfs can be accounted for if one considers two additional areas of recharge – Hidewood Creek and the deposits along the bank of the Big Sioux River. Estimated discharge to the river from Hidewood Creek and gravel along this creek and Bullhead Run Creek was Q_6 = 3 cfs.

Q_7 = 5 cfs - Q_6 = 5 - 3 = 2 cfs discharged from the deposits along the west bank of the Big Sioux River.

With a discharge rate of 2 cfs, the lakes and the aquifer lost 0.15 inches of water from the surface of both lakes in August 1969.



EXPLANATION

1646 — Contour lines connect points of equal elevation *(dashed where approximately located)*.

Contour interval = 1 foot

▨ Intermittent lake

by A. Barari, 1970 drafted by D. W. Johnson

Figure 18. Water-table map of the Lake Poinsett study area for August 1, 1969.

Artificial Discharge

The main artificial discharge of water from the lakes and the aquifer is from wells drilled for domestic use into the aquifer around the lake. The magnitude of this discharge is small when compared with other methods of discharge, and most of the artificial discharge is directly or indirectly returned to the aquifer or the lake.

Recharge and Discharge in August 1969

August 1969 was chosen to determine the magnitude of surface and ground-water discharge during a period of high lake level.

The following equation shows the relation between the recharge and discharge in terms of inches of water over the surface of Dry Lake and Lake Poinsett. The change of the surface area of the lake due to fluctuation of the water level was not great and for this reason it is not included in the equation.

$$\Delta h = [\text{Recharge}] - [\text{Discharge}] = [P + Q_1 + Q_2] - [E + Q_3 + Q_4 + Q_7] \qquad [2]$$

where

Δh is the change of water level in the lake in inches in August 1969.

P is precipitation in inches. The weather station at Castlewood recorded 1.16 inches and in Arlington the precipitation was 1.72 inches, the average being 1.44 inches (app. F).

Q_1 is the ground-water recharge to the lakes from the north. The rate of this flow for August 1970 was calculated to be $5.3\text{X}10^6$ gal/day. Since most of the observation wells were not constructed in August 1969, the relative similarity of hydraulic gradient in figures 10 and 18 suggests the use of values obtained for 1970 in place of 1969. Using these figures Dry Lake and Lake Poinsett gained 0.6 inches of water in August 1969.

Q_2 is the ground-water recharge from the shallow aquifer west of Lake Poinsett, and was calculated as $2.0\text{X}10^4$ gal/day for August 1970 (the same values will be used for August 1969). At this rate the lakes gained 0.04 inches.

E is the evaporation from the surface of the lakes equal to 6 inches (see app. F and use conversion factor 0.72).

Q_3 is the surface-water discharge through the outlet which discharged 3.3 inches from the surface of the lakes.

Q_4 is the ground-water discharge from the aquifer north of the outlet channel, which was calculated and is equal to .02 inches.

Q_7 is the ground-water discharge south of the outlet channel, and was equal to 0.15 inches.

Substituting the proper values in equation 2 one obtains:

$$\Delta h = (1.44 + .6 + .04) - (6 + 3.3 + .02 + .15)$$
$$\Delta h = -7.39 \text{ inches}$$

Appendix E shows that the lake level drop from August 1, 1969, to September 3, 1969, was 1652.82 - 1652.32 or .5 feet (6 inches).

The difference between calculated water level and actual water level as measured on the lake was -7.39 + 6 or -1.39 inches. This difference is attributed to four sources. (1) Recharge through the diversion ditch under the gates. The gates were closed, but a two-foot difference in the water levels on opposite sides of the gates caused some flow to take place under the gates. (2) Surface-water recharge to the lake through the ditch connecting Lake Albert to Lake Poinsett. (3) Ground-water recharge through the deep glacial aquifer between Lake Albert and Lake Poinsett (see Quantity of Ground-Water Recharge, p. 16). (4) Possible surface runoff from the land around the lakes on August 19, 1969 caused by 0.71 inches of rain in Castlewood and 0.61 inches of rain at Arlington (see app. F).

The water from the above four sources amounted to 1.39 inches.

Chemical Quality of Water

Ground water and surface water always contain dissolved chemical substances in various amounts. Contained chemicals are derived (1) from the atmosphere as water vapor condenses and falls, (2) from soil and underlying deposits as the water moves over the land and downward to the water table, and (3) from rocks below the water table where the water is moving. In general, the more chemical substances that a water contains, the poorer its quality; the suitability of the water being determined by the purpose for which it is used. A certain quality of water may be suitable for one purpose and unsuitable for another.

Table 1 shows the chemical quality of water samples collected in the summer of 1967. Except for sample W-29 which came from Lake Poinsett, all the samples in this table are ground-water samples. Furthermore, all the samples were collected from glacial aquifers except samples W-23 (from deep deposits) and W-29. Samples W-18, W-23, W-28, W-30, and W-36 have higher iron content than the recommended limits set by the U. S. Department of Health for drinking water standards. Total solids in samples W-2, W-7, W-23, W-28, and W-33 are higher than the recommended limits.

Table 2 shows the results of chemical analyses of water samples collected from 1968 through 1970 in the Lake Poinsett area. All the W-A samples were collected from the Big Sioux River on Castlewood Road 1 mile south of Castlewood. All W-B samples were collected from Lake Poinsett next to Stone Bridge Resort. All W-C samples were collected from the outlet channel next to the bridge on Highway 28. (For map location of these samples see figure 19.)

Because this section is concerned with the water quality of the lake, chemical levels in the following quotations from the Federal Water Pollution Control Administration are used to compare the water quality of samples in table 2. Extensive discussion of the biological aspect of the lake is beyond the scope of this report.

Eutrophication is a term used to mean enrichment of waters by nutrients.

> "Present knowledge indicates that the fertilizing elements contributing most to lake eutrophication are nitrogen and phosphorus. Iron and certain 'trace' elements are also important . . . As nutrient concentrations increase, the number of algal cells increase. . . Reservoirs or lakes are the settling basins of drainage areas. The potential productivity of a body of water is determined to a great extent by the natural fertility of the land over which the runoff drains and by the contributions of civilization. Biological activity within the lake influences such chemical characteristics as dissolved oxygen, pH, carbon dioxide, hardness, alkalinity, iron, manganese, phosphorus, and nitrogen; it is varied through temperature fluctuation and stimulated by nutrient variations (e.g., phosphorus and nitrogen). A lake's basin gives dimension to biological activity and may, because of unique physical characteristics, concentrate the nutrients it receives as well as the developing biomass. Sawyer (1947) studied the southern Wisconsin lakes and concluded that a 0.30 mg/l concentration of inorganic nitrogen (N) and a 0.01 mg/l concentration of soluble phosphorus (P) at the start of the active growing season could produce nuisance algal blooms . . . A continued high rate of nutrient supply is not necessary for continued algal production. After an initial stimulus, the recycling of nutrients within the lake basin may be sufficient to promote algal blooms for a number of years without substantial inflow from contributing sources." (MacKenthun and Ingram, 1967, p. 103-133).

Generally the samples listed in table 2 have higher nitrogen and phosphorus levels than the above figures. During the late stages of flooding, samples W-C_4 and W-D were collected from the outlet near Highway 28 Bridge and from Dry Lake respectively. These samples have higher nitrogen and phosphorus contents than sample W-B_3 collected from Lake Poinsett at the same time. Because W-B_3 was collected from the lake during the late stages

Table 1. Chemical analyses of water samples collected in the summer of 1967 in the Lake Poinsett area

Parts Per Million

Sample	Calcium	Magne-sium	Chlorides	Sulfate	Iron	pH	Hardness $CaCO_3$	Total Solids
A	—	—	250	500[1]	0.3	—	—	1000[1]
W-1	139	46	40	90	0	7.5	535	750
W-2	208	78	80	84	0	7.2	840	1130
W-3	144	79	28	60	0.06	8.2	685	980
W-4	92	32	8	0	0.05	8.2	360	564
W-5	86	23	16	0	0.10	8.3	310	490
W-6	112	25	0	0	0.11	8.2	385	566
W-7	172	65	47	312	0	7.2	690	1020
W-8	102	38	64	132	0	7.6	410	635
W-9	110	50	30	14	0.05	8.5	480	724
W-10	82	28	0	120	0	7.6	320	460
W-11	92	32	4	215	0.02	8.2	360	550
W-12	59	14	0	0	Trace	8.0	208	300
W-13	124	36		60		7.4	450	676
W-14	122	74	36	Trace	0.04	7.9	610	983
W-15	164	40	40	240	0	7.3	565	875
W-16	81	42	10	177	0.02	7.4	370	476
W-17	90	32	0	60	0	7.6	355	520
W-18	140	41	46	36	8	7.5	520	753
W-19	120	42		192		8.4	470	602
W-20	134	50	0	348	0.24	7.4	540	727
W-21	98	28	20	36	0	7.3	360	565
W-22	104	44	13	36	0	7.9	440	580
W-23	129	73	90	1200	2.8	7.4	520	2020
W-24	120	39	0	180	0	7.6	460	672
W-25	152	51	57	252	Trace	7.2	590	945
W-26	132	45	17	180	0.06	7.4	515	724
W-27	116	32	20	264	0.04	7.4	420	650
W-28	353	93	28	626	0.36	8.0	1260	1430
W-29	44	62	39	252	0	8.0	365	712
W-30	112	88	30	84	1.0	7.2	540	830
W-31	192	50	20	292	0.2	7.5	685	896
W-32	97	38	15	72	0.04	7.4	375	554
W-33	324	110	96	745	0.04	7.8	1260	1490
W-34	89	28	13	0	0	8.0	336	496
W-35	97	21	0	132	0.04	7.6	325	460
W-36	164	64	6	445	1.86	7.9	670	975

A. Drinking water standards, U. S. Public Health Service (1962).

[1] Modified for South Dakota by the Department of Health (written communication, Water Sanitation Section, March 20, 1968).

Samples were analyzed by the South Dakota Geological Survey.

Location of water samples collected in 1967
(For map location see fig. 19.)

W-1. NW¼NW¼SW¼ sec. 12, T. 114 N., R. 52 W., F. Kiihl, 60 feet deep, water table 35 feet.
W-2. SE¼NE¼NE¼ sec. 14, T. 114 N., R. 52 W., M. Pommer, 30 feet deep, water table 20 feet.
W-3. SE¼NE¼SE¼ sec. 14, T. 114 N., R. 52 W., A. Kannas, 55 feet deep, water table 20 feet.
W-4. NW¼NW¼SW¼ sec. 13, T. 114 N., R. 52 W., O. Pummer, 35 feet deep, water table 20 feet.
W-5. SW¼SW¼SE¼ sec. 13, T. 114 N., R. 52 W., W. Kiihl, 29 feet deep, water table 5? feet.
W-6. SE¼SW¼SE¼ sec. 18, T. 114 N., R. 51 W., A. Wattawa, 16 feet deep, water table 9 feet.
W-7. SE¼SE¼SE¼ sec. 17, T. 114 N., R. 51 W., M. Heemeyer, 45 feet deep, water table 35 feet.
W-8. SW¼SW¼SW¼ sec. 24, T. 114 N., R. 52 W., W. McGee, 20 feet deep, water table 18? feet.
W-9. SW¼SW¼NW¼ sec. 20, T. 114 N., R. 51 W., A. Pedersen, 9 feet deep, water table 7 feet.
W-10. NW¼NE¼NE¼ sec. 26, T. 114 N., R. 52 W., E. McCarriar, 24 feet deep, water table 16 feet.
W-11. SW¼SE¼NW¼ sec. 30, T. 114 N., R. 51 W., B. Ladwig, 14 feet deep, water table 10 feet.
W-12. NE¼SE¼NE¼ sec. 30, T. 114 N., R. 51 W., L. DeWall, 20 feet deep, water table 8 feet.
W-13. NW¼SW¼NW¼ sec. 28, T. 114 N., R. 51 W., D. Linneman, 27 feet deep, water table 16 feet.
W-14. NW¼NW¼NW¼ sec. 27, T. 114 N., R. 51 W., W. Schmidt, 30 feet deep, water table 20 feet.
W-15. SE¼SE¼SW¼ sec. 31, T. 114 N., R. 51 W., A. Poppen, 12 feet deep, water table 10 feet.
W-16. SE¼NE¼NE¼ sec. 32, T. 114 N., R. 51 W., E. VanDykhorst, 16 feet deep, water table 10 feet.
W-17. SE¼NW¼SE¼ sec. 33, T. 114 N., R. 51 W., B. Ludwig, 12 feet deep, water table 7 feet.
W-18. NE¼SW¼SE¼ sec. 33, T. 114 N., R. 51 W., P. Timmer, 27 feet deep, water table 6 feet.
W-19. SE¼SW¼SW¼ sec. 2, T. 113 N., R. 52 W., E. Bennett, 40 feet deep, water table 30 feet.
W-20. SW¼NW¼NW¼ sec. 6, T. 113 N., R. 51 W., H. Williscroft, 11 feet deep, water table 8 feet.
W-21. SW¼NW¼SW¼ sec. 4, T. 113 N., R. 51 W., K. Linneman, 13 feet deep, water table 6 feet.
W-22. SW¼NE¼SE¼ sec. 3, T. 113 N., R. 51 W., Spilde, 48 feet deep.
W-23. SW¼SW¼NW¼ sec. 2, T. 113 N., R. 51 W., F. Church, 410? feet deep, flowing well.
W-24 SE¼NE¼SE¼ sec. 2, T. 113 N., R. 51 W., H. Lantgen, 16 feet deep, water table 12 feet.
W-25. NE¼NE¼NE¼ sec. 8, T. 113 N., R. 51 W., J. Espertuedt, 15 feet deep, water table 9 feet.
W-26. SE¼SE¼SW¼ sec. 10, T. 113 N., R. 51 W., H. McFarland, 13 feet deep, water table 8 feet.
W-27. SW¼SW¼SW¼ sec. 11, T. 113 N., R. 51 W., E. Kaiser, 18 feet deep, water table 10 feet.
W-28. SW¼NW¼NE¼ sec. 16, T. 113 N., R. 52 W., F. Saaramen, 56 feet deep.
W-29. NW¼NE¼NW¼ sec. 15, T. 113 N., R. 52 W., Lake Poinsett lake water.
W-30. NE¼NE¼NW¼ sec. 15, T. 113 N., R. 52 W., Nitteberg Brothers, 15 feet deep, water table 4 feet.

Location of water samples collected in 1967–continued.

W-31. NW¼NE¼NE¼ sec. 13, T. 113 N., R. 52 W., M. Bakke, 59 feet deep, water table 51 feet.
W-32. NW¼NE¼NE¼ sec. 15, T. 113 N., R. 51 W., L. Hemer, 22 feet deep, water table 12 feet.
W-33. SW¼NW¼NW¼ sec. 20, T. 113 N., R. 52 W., J. Burchard, 24 feet deep, water table 20 feet.
W-34. SW¼SW¼ sec. 24, T. 113 N., R. 51 W., Estelline City water.
W-35. NE¼SW¼NE¼ sec. 26, T. 113 N., R. 51 W., J. Harrenga, 35 feet deep, water table 8 feet.
W-36. NW¼NE¼NE¼ sec. 36, T. 113 N., R. 53 W., Lake Region Golf Course, irrigation well, 88 feet deep, water table 20 feet.

Table 2. Chemical analyses of water samples collected from 1968 through 1970 in the Lake Poinsett area

Sample	Date	Parts Per Million Calcium	Sodium	Magnesium	Chloride	Sulfate	Iron	Manganese	Inorganic Nitrogen	Soluble Phosphorus	Fluoride	Alkalinity as $CaCO_3$ Methyl-orange	Hardness as $CaCO_3$	Total Solids
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
W-A$_1$	4-27-68	90	26	36	5	168	0.3	0	0.3		0.4	258	372	514
W-B$_1$	4-27-68	71	60	40	60	184	0.1	0	0.3		0.4	166	344	592
W-C$_1$	4-27-68	54	35	42	30	172	2.8	0.86	0.4		0.8	192	308	524
W-A$_2$	9-14-68	49	23	45	24	122	0.2	0.40	0.4		0.2	207	308	402
W-B$_2$	9-14-68	24	55	89	48	238	0.6	0	0.3		0.8	225	427	794
W-A$_3$	10-13-68	83	94		78	156	0	0	1.4		0.2	277	386	702
W-C$_2$	10-13-68	39	110	96	66	366	0	0	1.5		0.8	287	492	1044
W-A$_4$	11-10-68	56	71	61	80	170	0.5	0.6	<0.1		0.4	250	393	648
W-C$_3$	11-10-68	28	120	100	68	338	0.4	0	<0.1		0.8	262	482	926
W-F	4-8-69	4		12		24			1.5	1.3		38		118
W-B$_3$	4-11-69	6	7	16		42			0.6	0.3		52	81	154
W-C$_4$	4-11-69	16	3	11		28			1.1	0.9		58	86	134
W-D	4-11-69	7	4	12		28			0.8	0.5		46		114
W-A$_5$	5-3-69	36	11	32	6		0.14			0.3		158	222	310
W-B$_4$	5-3-69	54	36	62	30	216			1	0.2		236	392	630
W-A$_6$	7-23-69	68		39	23	78	0.10	0.05	0.4			228	330	513
W-B$_5$	7-23-69	44		59	33	233	0.06	0.05	<0.1			164	350	668
W-A$_7$	8-23-69	80		25	40	145	0	Trace	<0.1			240	310	543
W-B$_6$	8-23-69	44		56	38	320	0	Trace	<0.1			216	340	684

Table 2–continued.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
W-A$_8$	10-3-69	61	50	52	62	160	0.2		1.4		0.4	256	368	636
W-B$_7$	10-3-69	17	53	84	30	272	0.2		0.4		0.4	206	389	740
W-A$_9$	10-19-69	63	40	57	48	156	1.2	0.2	3.2		0.4	250	391	614
W-B$_8$	10-19-69	32	53	78	32	264			0.9		0.4	205	401	688
W-A$_{10}$	4-4-70	41	20	31	25	74			1.4	0.4		152	229	346
W-B$_9$	4-4-70	41	38	75	32	272			0.6	0.6	0.4	222		728
W-A$_{11}$	4-24-70	62	20	42	19	142				0.1	0.4	200	326	454
W-B$_{10}$	4-24-70	33	38	72	31	256				0.3	0.4	204	378	684
W-A$_{12}$	5-10-70	74	20	53	20	120	0.4			0.8	0.2	280	404	526
W-B$_{11}$	5-10-70	41	40	66	30	250			0.2	0.3	0.2	212	375	656
W-A$_{13}$	6-3-70	54	21	34	20	92	0.2	0	<0.1	<0.1	0.4	204	276	372
W-B$_{12}$	6-3-70	37	50	75	32	260	0.5	0	<0.1	<0.1	0.4	221	401	652
W-E	12-21-70	129	28	64	101	166	0	0	20.1	<0.1	0	399	586	838
W-G	12-21-70	96	73	32	50	148	0	0	57	<0.1	0	306	371	718
W-H	12-21-70	148	38	28		332	0	0	2.4	<0.1	0	347	484	784
W-I	12-21-70	115	10	43	21	86	0	0	20	<0.1	0	298	462	658

Samples W-A$_6$, W-B$_5$, W-A$_7$, and W-B$_6$ were analyzed by the South Dakota Geological Survey. The rest of the samples were analyzed by the South Dakota Chemical Laboratory.

Except for samples W-E, W-G, W-H, and W-I which are ground-water samples, all the samples are from surface water.

Location of water samples collected from 1968 through 1970 in the Lake Poinsett area
(For map location of water samples see fig. 19.)

W-A samples were collected from the Big Sioux River at SE¼SE¼SE¼ sec. 2, T. 114 N., R. 52 W.

W-B samples were collected from Lake Poinsett at Stone Bridge, NE¼NW¼ sec. 15, T. 113 N., R. 52 W.

W-C samples were collected from Lake Poinsett outlet on Highway 28, SW¼NE¼ sec. 14, T. 113 N., R. 52 W.

W-D sample was collected from Dry Lake at Stone Bridge, SE¼SW¼ sec. 10, T. 113 N., R. 52 W.

W-E sample was collected from A. Kannas' farm well, SE¼NE¼SE¼ sec. 14, T. 114 N., R. 52 W., 55 feet deep, water table 20 feet.

W-F sample was collected at bridge on outlet channel at NW¼NE¼ sec. 13, T. 113 N., R. 52 W., floodwater from the Big Sioux River flowing into Lake Poinsett.

W-G sample was collected from W. Magee's farm well, SW¼SW¼SW¼ sec. 24, T. 114 N., R. 52 W., 20 feet deep, water table 18 feet.

W-H sample was collected from C. Pommer's farm well, SW¼SW¼NW¼ sec. 25, T. 114 N., R. 52 W., 22 feet deep, water table 16 feet.

W-I sample was collected from M. Effting's farm well, SW¼NW¼NW¼ sec. 13, T. 113 N., R. 52 W., 26 feet deep, water table 13 feet.

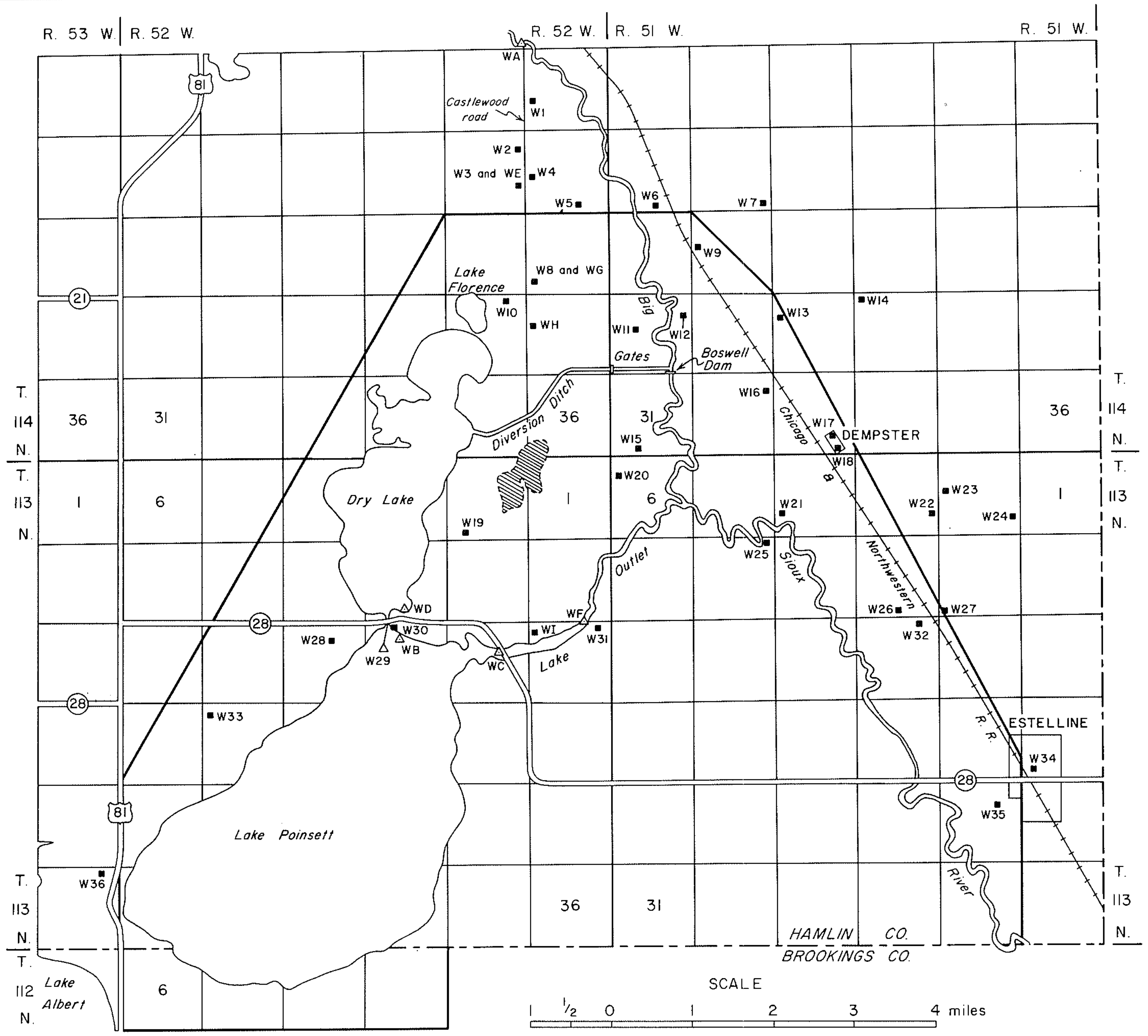


Figure 19. Map showing location of water samples collected from the Lake Poinsett area.

of flooding and some mixing with the floodwater had already occurred, it can be concluded that initially the lake water must have had an even lower concentration of nutrients than sample W-B_3. Even if the lake water did not have any phosphorus and nitrogen before flooding, the concentration of phosphorus after the flood would be raised to .32 ppm and the concentration of nitrogen would be .37 ppm (assuming that sample W-F is a representative sample of the floodwater). These figures are higher than the concentration needed to produce algal blooms, especially the concentration of phosphorus which would be 32 times greater.

The ground-water samples W-E, W-G, W-H, and W-I are high in nitrogen; however, some of this nitrogen is probably introduced locally from farms in the area.

The method used for analyzing phosphorus and nitrogen concentration did not detect amounts that were less than 0.1 ppm. For this reason it is not clear what concentration of phosphorus was carried by ground water to the lakes. More ground-water data are required to define the quantity of nutrients carried by the ground water to the lakes.

DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

A thick sand and gravel deposit hydraulically connects Dry Lake to Lake Poinsett; therefore, for the purpose of this report, these two lakes have been treated as one continuous body of water. Furthermore, an extensive aquifer northeast of Lake Poinsett connects the Big Sioux River to Dry Lake and Lake Poinsett.

The least variable factor in the total hydrological budget of the lakes is the evaporation, which annually removes 34 inches of water from the surface of the lakes. The independent variable is the precipitation which adds directly 20.80 inches of water to the lakes. Surface-water and ground-water recharge and also surface-water and ground-water discharge are the dependent variables. The change in the balance between recharge and discharge is reflected as fluctuations in lake level.

The control of precipitation, if any, is in the realm of weather modification, and it is not discussed in this report. The study of artificial recharge of the Big Sioux River water into the aquifer northeast of the lake in order to increase ground-water supplies and recharge to the lakes is also beyond the scope of this project. Control of surface-water recharge into the lake through the diversion ditch is possible during normal flow in the Big Sioux River. However, during flooding, because of very low relief (pl. 1) between the Big Sioux River, Dry Lake, and Lake Poinsett, a large quantity of water reaches the lakes by flowing over the land, through the outlet channel, and through the diversion ditch, even if the gates are closed. If the floodwater is not controlled upstream, there is no simple technique that can be employed to stop the water from reaching the lakes after it has reached the study area. Even if the water could be diverted from the lakes during flooding, the flood damages downstream would increase substantially, because these lakes are working as flood control reservoirs. Flooding in the magnitude of the flood of 1969 is rare; however, it has been reported that water frequently reaches the lake during high water level in the Big Sioux River through the outlet channel.

Surface-water discharge from the lakes takes place through the outlet channel northeast of Lake Poinsett. Lake Poinsett and Dry Lake lost an amount equal to 3.3 inches of water over both lake surfaces through this channel in August 1969. The average water level in the lake was 1652.5 feet during the same period. At a lake level higher than 1652.5 feet, the discharge will increase because of an increase in the hydraulic head, and for a lower lake level the rate of discharge will decrease. During August 1969, ground-water discharge was equal to a drop of 0.17 inches from the surface of Dry Lake and Lake Poinsett. This rate is small when compared with the rate of surface-water discharge during the same period (3.3 inches).

A dam, spillway, or small gates constructed in the outlet channel in the SE¼ sec. 12, T. 113 N., R. 52 W., where the sand and gravel layer is very thin (see fig. 9) will control the surface-water discharge through the outlet. Such a dam will reduce the water-level fluctuation in the lakes. The elevation of the top of this construction should be agreed upon by the South Dakota Water Resources Commission, South Dakota Department of Game, Fish, and Parks, East Dakota Conservancy Sub-District, and the residents in the area. It is also recommended that an agreement be obtained from the residents living along the outlet channel for construction of a dam and also for cleaning the channel from the dam site to the river.

Phosphorus and nitrogen content of the water is one of the prime concerns in the biological aspects of the lake (see page 29). The nutrient content of the lake water fluctuates seasonally; however, these chemicals are generally high in the lakes (see page 33). Ground water recharging the lake also has nutrients. The phosphorus in four ground-water samples collected in December 1970 is less than 0.1 ppm; the average nitrogen content of the same four samples is 23.3 ppm. Some of this nitrogen is probably introduced locally. More data concerning the nutrient level entering the lakes from ground-water recharge are necessary.

The nutrient content of surface water which recharges the lake fluctuates, but generally the quantity of these chemicals is high (see page 33). During the flood of 1969 the phosphorus content of the floodwater reaching the lake was 1.3 ppm. Even if phosphates were nonexistent in the lake, the influx of phosphates during flooding would be enough to raise the level to 0.32 ppm. As discussed in the chemical quality section of this report, the recycling of nutrients will promote algal bloom for a number of years even without the introduction of additional phosphates.

A reasonable way to reduce the nutrients in the lake water is by decreasing the nutrient in the waters recharging the lakes. Water samples collected during the flood of 1969 from north of Watertown show that the water had as high as 0.5 ppm phosphorus, which could be attributed to runoff from agricultural areas. Information on the quality of water upstream from the lake will be available in a forthcoming report dealing with the hydrology of Lake Kampeska (Barari, in preparation).

Presently, sewage treatment for the towns upstream from Lake Poinsett does not include phosphate removal. For example, water collected from treated sewage at Watertown where it enters the Big Sioux River shows a phosphorus content of 1.1 ppm. Sewage from the cabins around Lake Poinsett also add nutrients to the lake.

It is recommended that all possible steps be taken to reduce the nutrient from the waters feeding the lake. Soil conservation practices, and other means, should be employed to reduce the nutrient in surface and ground waters; municipal sewage treatment should include phosphorus removal (limiting the use of high phosphate detergents will help); and lakeshore cottages should be required to have an adequate sewage system.

Some of the recommendations cannot be implemented by the South Dakota Department of Game, Fish, and Parks or any other State agency alone. The cooperation of several governmental agencies such as the Department of Health, Soil Conservation Service, Department of Game, Fish, and Parks, Water Resources Commission, East Dakota Conservancy Sub-District, and the residents along the lake and upstream is necessary to accomplish the projects.

It is also recommended that the public and residents be more fully informed about the problems involved, in order to gain their cooperation and support. Ultimately the public will directly or indirectly finance the projects, and it is their decision to invest money in the projects as recommended in order to have a clean, natural, priceless lake.

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APPENDIX A

Table of monthly and annual precipitation for the Lake Poinsett area (Castlewood) from January 1906 to December 1970*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1906	.13	.08	.36	1.43	3.49	4.79	1.40	3.93	2.57	2.44	.92	.38	21.92
1907	.43	.44	1.16	.33	2.05	4.25	3.33	.62	2.52	.95	.22	.46	16.76
1908	.15	.86	.72	2.07	3.20	6.55	1.88	1.23	1.98	1.17	1.36	.16	21.33
1909	.42	.34	.20	.33	2.46	5.93	3.42	7.59	1.02	1.55	.73	.85	24.84
1910	.25	.10	.52	1.62	.55	2.85	1.62	2.42	1.31	.45	.38	.22	12.29
1911	.19	.11	.53	.86	1.81	2.86	2.67	3.26	2.36	3.04	.34	.15	18.18
1912	.21	.05	.09	4.46	1.86	1.74	4.63	4.27	1.40	.39	.03	.21	19.34
1913	.01	.06	.54	2.11	3.54	1.97	4.48	1.00	1.24	1.29	.78	.10	17.12
1914	.30	.24	.27	2.20	3.67	9.36	1.03	1.92	2.84	2.35	.00	.12	24.30
1915	.06	1.06	.07	2.72	2.71	3.55	3.32	.47	2.65	1.82	.35	.41	19.19
1916	.77	.22	.80	1.68	3.98	3.65	2.39	7.22	.89	.67	.02	.09	22.38
1917	.43	.38	.24	3.92	1.42	3.85	1.95	2.09	3.65	.25	.20	.41	18.79
1918	.39	.27	.74	1.95	4.37	3.26	3.12	1.84	.45	2.38	4.92	1.17	24.86
1919	.13	1.05	.48	2.02	2.72	8.68	3.15	1.71	1.62	1.11	1.97	.08	24.72
1920	.26	.30	2.30	2.34	4.03	7.11	4.29	4.90	2.14	.73	2.05	.40	30.85
1921	.20	.08	2.74	2.71	2.59	.84	4.10	4.22	7.21	.42	.60	.17	25.88
1922	.81	1.92	1.01	1.79	4.39	1.55	1.16	2.11	.41	.96	3.79	.22	20.12
1923	.93	.13	.39	4.08	3.86	6.38	2.74	1.29	2.37	.84	.25	.25	23.51
1924	.09	.24	1.96	2.32	2.11	5.08	1.53	4.92	1.52	1.39	.31	.80	22.27
1925	.50	.17	.06	2.52	.16	7.26	2.16	.85	2.05	.45	.59	.44	17.21
1926	1.23	.08	.54	.34	2.02	2.44	1.31	3.29	3.36	2.10	1.08	.83	18.62
1927	.27	.33	1.60	4.77	3.35	1.69	4.63	1.25	1.74	.53	.86	1.28	22.30
1928	.21	.21	.34	.69	.54	3.16	6.31	4.21	1.81	1.42	.74	.22	19.86
1929	1.06	.57	1.03	2.51	1.50	1.31	6.35	2.46	3.98	1.82	.29	.17	23.05
1930	.70	.47	.33	2.04	2.39	4.17	.74	1.91	3.52	.93	1.67	.06	18.93
1931	.04	.34	.79	1.44	6.44	2.88	1.31	2.46	1.32	1.47	.96	.76	20.21
1932	.47	.13	.58	3.89	3.39	4.41	2.31	4.05	2.68	.79	.78	.32	23.80
1933	.17	.25	.70	.60	2.35	2.83	1.90	1.77	3.26	.01	.28	.38	14.50
1934	.29	.04	1.11	.18	1.27	2.85	2.83	2.45	3.84	1.42	.41	.37	17.06
1935	.48	.35	2.17	2.93	1.61	5.43	4.77	2.04	.39	.32	.60	.76	21.85
1936	.64	1.18	.56	2.12	2.63	1.98	.37	2.84	.49	.25	1.17	.55	14.78
1937	.85	.42	1.59	5.16	1.00	4.79	1.00	4.50	1.79	.74	.46	.82	23.12
1938	.74	.39	.83	1.93	3.53	2.50	2.21	3.30	1.90	.08	.40	.27	18.08
1939	2.04	.49	.28	1.40	3.92	4.82	3.42	2.63	.86	.72	.00	.10	20.68
1940	.03	.46	2.10	1.59	.55	4.62	1.86	5.66	.56	.70	1.22	.26	19.61
1941	.72	.18	.26	4.20	.65	2.49	1.71	1.97	1.00	2.71	.10	.28	16.27
1942	.01	.05	2.27	1.80	5.08	3.57	2.48	3.12	4.51	1.13	.02	.44	24.48
1943	.50	.85	1.29	.60	2.57	4.04	2.18	4.39	2.22	3.09	.37	.00	22.10
1944	.79	.14	.40	1.62	2.86	3.63	3.38	5.07	2.61	.19	1.15	.04	21.88
1945	.22	.50	.90	.92	2.12	5.28	2.40	1.67	1.99	.45	.68	1.06	18.19
1946	.07	1.09	2.34	.71	3.14	5.78	3.50	.68	3.28	5.01	1.09	.26	26.95
1947	.39	.23	.83	3.83	1.14	6.28	.75	1.56	2.80	1.96	3.14	.05	22.96
1948	.00	1.17	.40	4.58	.51	8.01	5.43	3.55	3.83	1.54	.41	.11	29.54
1949	.77	.01	1.21	.02	2.02	3.32	7.61	.94	3.75	3.18	.99	1.33	25.15
1950	1.18	.02	.63	1.85	4.62	.52	3.51	1.43	1.44	2.14	.38	.25	17.97
1951	.23	.23	1.62	1.43	4.67	5.01	5.35	4.28	.79	2.36	.33	.91	27.21
1952	1.12	.49	.37	.80	1.40	4.49	1.79	1.36	.71	.00	.66	.30	13.49
1953	.78	1.24	.60	4.03	2.58	5.72	4.14	.81	.18	.30	1.26	1.10	22.74
1954	.25	.81	1.39	2.79	4.35	4.78	1.22	1.10	3.83	1.65	.10	.02	22.29
1955	.27	1.00	.13	1.95	1.09	3.33	4.83	4.29	.57	.51	.27	1.38	19.64

Appendix A--continued.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1956	.62	.15	.87	1.82	2.67	4.61	6.75	6.10	1.07	.91	1.06	.19	26.82
1957	.24	.95	.58	2.01	6.41	3.02	1.06	3.99	3.69	2.40	1.04	.47	25.86
1958	.15	.60	.67	1.47	1.21	3.16	2.54	.58	1.86	.37	1.76	.33	14.70
1959	.41	.53	.07	.54	4.44	3.60	1.46	2.74	1.41	2.32	.75	.85	19.12
1960	.35	.30	.95	2.28	2.62	4.78	1.93	5.75	1.01	.75	.91	1.31	22.94
1961	.13	.37	.53	1.49	5.24	4.79	2.05	3.33	2.55	1.50	.29	.56	22.83
1962	.26	1.25	.67	1.68	8.97	4.57	5.78	.73	2.41	.80	.66	.14	27.92
1963	.65	.44	1.11	3.31	2.61	5.17	9.23	1.74	2.38	1.18	.53	.61	28.96
1964	.05	.36	1.41	2.59	1.82	2.44	2.02	4.82	1.20	.04	.40	.58	17.73
1965	.36	.60	2.09	2.73	7.19	4.26	2.06	2.61	5.78	.75	.77	.48	29.68
1966	.41	.80	.75	2.16	1.38	2.13	6.78	2.69	1.96	1.02	.36	.31	20.75
1967	1.00	1.28	.13	1.97	.41	8.12	.64	.89	1.01	.78	.08	.74	17.05
1968	.52	.09	1.20	4.44	2.37	4.04	2.73	3.32	2.38	3.68	.69	2.37	27.83
1969	1.29	2.09	.60	.83	2.98	2.39	5.92	1.16	1.03	3.54	.53	.66	23.02
1970	.33	.06	1.60	1.32	2.95	3.50	.72	1.33	1.50	2.97	2.67		

*Walter Spuhler, Weather Bureau State Climatologist, oral communication, 1971.

APPENDIX B

Logs of test holes and observation wells in the Lake Poinsett study area

(For locations see fig. 8.)

Observation Well 1
Location: SW¼SE¼SW¼SE¼ sec. 18, T. 114 N., R. 51 W.
Top of observation well: 1668.81 feet
Depth to water: 4 feet

0- 1	Topsoil, black, sandy
1- 3	Sand, gray-brown, dry, very coarse; scattered pea-size gravel
3-40	Gravel, very coarse; some clay after 14 feet, not as coarse
40-74	Gravel; some clay approaching a till
74-78	Clay, gray, compact

* * * *

Test Hole 2
Location: SE¼SE¼SE¼SE¼ sec. 18, T. 114 N., R. 51 W.
Surface elevation: 1688 feet
Depth to water: Not measured

0- 1	Topsoil, black
1- 2	Sand, brown, medium-grained
2- 4	Clay, yellow
4-14	Clay, yellow, few pebbles, (till)
14-	Rock
	Moved 10 feet west, same as above
	Stopped drilling due to rocks

* * * *

Observation Well 3
Location: NE¼NE¼NE¼NE¼ sec. 22, T. 114 N., R. 52 W.
Top of observation well: 1668.61 feet
Depth to water: 2 feet

0- 1	Sand and gravel, light-gray, medium to coarse sand, small gravel
1- 3	Topsoil?, black, much organic material, few pebbles
3-10	Clay, gravelly, gray, medium sand to small gravel, gravel not rounded, much clay
10-30	Sand and gravel, gray, clean; medium to coarse sand; some small gravel
30-39	Clay, light-gray; some fine sand, pebbly, white streaks

* * * *

Observation Well 4
Location: SE¼SE¼SE¼NE¼ sec. 23, T. 114 N., R. 52 W.
Top of observation well: 1670.20 feet
Depth to water: 10 feet

0- 1	Topsoil
1- 3	Clay, sandy

Observation Well 4--continued.

3-24	Sand and gravel

* * * *

Observation Well 5
Location: SE¼SE¼SE¼SE¼ sec. 23, T. 114 N., R. 52 W.
Top of observation well: 1672.08 feet
Depth to water: 12 feet

0- 1	Topsoil
1- 4	Sand, brown, coarse, dry
4-12	Sand and gravel, brown, dry
12-24	Sand and pea-size gravel, brown, saturated
24-74	Gravel, very coarse, saturated
74-86	Gravel, less coarse, saturated
86-89	Clay, dark-gray, pebbly, dry to moist

* * * *

Test Hole 6
Location: NE¼NE¼NE¼NW¼ sec. 24, T. 114 N., R. 52 W.
Surface elevation: 1680 feet
Depth to water: 17 feet

0- 1	Topsoil
1- 5	Clay, tannish-brown
5- 9	Sand and gravel
9-17	Sand, brown
17-24	Sand, light-brown
24-49	Sand and gravel
49-64	Clay, pebbly, (till)

* * * *

Test Hole 7
Location: SE¼SE¼SE¼NW¼ sec. 24, T. 114 N., R. 52 W.
Surface elevation: 1675 feet
Depth to water: 15 feet

0- 1	Topsoil
1-19	Sand
19-86	Sand and gravel
86-94	Clay, yellowish-brown

* * * *

Observation Well 8
Location: NE¼NE¼NE¼NE¼ sec. 24, T. 114 N., R. 52 W.
Top of observation well: 1667.90 feet
Depth to water: 6 feet

0- 1	Topsoil
1-17	Sand and gravel

* * * *

Test Hole 9
Location: NW¼NW¼NW¼SW¼ sec. 19, T. 114 N., R. 51 W.
Surface elevation: 1668 feet
Depth to water: 5 feet

0- 1	Topsoil
1- 3	Sand and clay, dark-brown
3-40	Sand and gravel
40-44	Sand, fine to medium
44-82	Gravel
82-94	Clay, dark-gray, (till)

* * * *

Observation Well 10
Location: SW¼SW¼SW¼SW¼ sec. 20, T. 114 N., R. 51 W.
Top of observation well: 1674.02 feet
Depth to water: 10 feet

0- 5	Sand, brown, medium, clean
5- 9	Gravel, very coarse
9-25	Sand, brown, medium, clean
25-40	Gravel, gray-brown, fine; clay present
40-52	Sand, gray, very coarse; much clay present
52-59	Clay, gray, compact, unoxidized, (till)

* * * *

Test Hole 11
Location: SW¼SW¼SW¼SW¼ sec. 21, T. 114 N., R. 51 W.
Surface elevation: 1681 feet
Depth to water: 66 feet

0-16	Clay, yellow-brown, (till)
16-26	Clay, gray, unoxidized, (till)
26-40	Clay, gray, (lighter than above)
40-69	Clay, yellow, silty, moist

* * * *

Test Hole 12
Location: SE¼SE¼SE¼SE¼ sec. 26, T. 114 N., R. 52 W.
Surface elevation: 1674 feet
Depth to water: 14? feet

0- ½	Topsoil
½- 3	Clay, brown, pebbly
3- 9	Sand, brown, coarse, dry
9-18	Sand and gravel, saturated
18-49	Clay

* * * *

Observation Well 13
Location: SW¼SW¼SW¼NW¼ sec. 25, T. 114 N., R. 52 W.
Top of observation well: 1672.90 feet
Depth to water: 14 feet

Observation Well 13--continued.

0- 1	Topsoil
1-25	Sand and gravel

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Test Hole 14
Location: NE¼NE¼NE¼SW¼ sec. 25, T. 114 N., R. 52 W.
Surface elevation: 1664 feet
Depth to water: 7 feet

0- 1	Topsoil, black
1-14	Sand and gravel
14-27	Sand, fine- to medium-grained
27-39	Clay, dark-brown, pebbly

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Test Hole 15
Location: NE¼NE¼NE¼NW¼ sec. 25, T. 114 N., R. 52 W.
Surface elevation: 1670 feet
Depth to water: 11 feet

0- 1	Topsoil
1- 5	Clay, light-brown, sandy
5-19	Sand and gravel
19-24	Sand, fine- to medium-grained
24-58	Sand and gravel
58-74	Clay, blue-gray, pebbly, (till)

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Test Hole 16
Location: NW¼SW¼SW¼SE¼ sec. 25, T. 114 N., R. 52 W.
Surface elevation: 1665 feet
Depth to water: 8 feet

0- 7	Clay, black, sandy
7-17	Sand, light-gray
17-24	Sand and gravel, dark-gray
24-40	Gravel, dark-brown
40-49	Clay, dark-gray, pebbly, (till)

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Observation Well 17
Location: NE¼NE¼NE¼NE¼ sec. 25, T. 114 N., R. 52 W.
Top of observation well: 1664.20 feet
Depth to water: 3 feet

0- 9	Sand, fine
9-17	Sand and gravel

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Test Hole 18
Location: NW¼NW¼NW¼SW¼ sec. 30, T. 114 N., R. 51 W.
Surface elevation: 1664 feet
Depth to water: 7 feet

0-28	Sand and gravel
28-38	Sand, fine to medium
38-54	Clay, grayish-blue, (till)

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Observation Well 19
Location: NE¼NE¼NE¼NW¼ sec. 30, T. 114 N., R. 51 W.
Top of observation well: 1666.60 feet
Depth to water: 10 feet

0- 1	Topsoil
1- 4	Clay, dark-gray, sandy
4-10	Clay, dark-brown
10-19	Sand and gravel

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Observation Well 20
Location: SE¼SE¼SE¼NE¼ sec. 35, T. 114 N., R. 52 W.
Top of observation well: 1655.60 feet
Depth to water: 4 feet

0 - 1	Topsoil
1 -16?	Sand and clay, dark-gray
16?-19	Sandy, clay?

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Test Hole 21
Location: SW¼SW¼SW¼NE¼ sec. 36, T. 114 N., R. 52 W.
Surface elevation: 1658 feet
Depth to water: 3 feet

0- 1	Topsoil
1- 5	Clay
5- 9	Sand
9- 95	Sand and gravel
95-109	Clay, gray, pebbly

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Test Hole 22
Location: SW¼SW¼SW¼NW¼ sec. 31, T. 114 N., R. 51 W.
Surface elevation: 1661 feet
Depth to water: 2 feet

0- 4	Clay, black; some sand
4- 9	Sand and gravel; some clay
9- 34	Sand and gravel
34-100	Gravel, coarse
100-109	Clay, dark-gray, (till)

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Observation Well 23
Location: NW¼NW¼NW¼NW¼ sec. 31, T. 114 N., R. 51 W.
Top of observation well: 1662.15 feet
Depth to water: 3 feet

0- 1	Topsoil
1- 5	Clay, dark-gray
5- 9	Sand and clay, brownish-gray
9-14	Sand and gravel

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Observation Well 24
Location: NE¼NE¼NE¼NW¼ sec. 31, T. 114 N., R. 51 W.
Top of observation well: 1660.90 feet
Depth to water: 6 feet

0- 1	Topsoil
1- 6	Clay, dark-gray
6-24	Sand and gravel

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Observation Well 25
Location: SE¼SE¼SE¼SE¼ sec. 32, T. 114 N., R. 51 W.
Top of observation well: 1660.05 feet
Depth to water: 3 feet

0- 1	Silt, gray, moist
1-12	Sand, brown, coarse; scattered gravel; some clay
12-22	Sand, gray, very coarse, poorly sorted; unoxidized clay present
22-30	Sand, brown, medium, fairly clean, sorted
30-35	Clay, gray, gravelly, very compact, (till)

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Test Hole 26
Location: NE¼SE¼SE¼NE¼ sec. 5, T. 113 N., R. 52 W.
Surface elevation: 1695 feet
Depth to water: 45 feet

0- ½	Clay, yellowish-brown; some sand, medium to very coarse; streaks of gray clay
½- 5	Clay, yellow-brown, pebbly; some sand, fine; dry
5-12	Clay, dark-brown, pebbly; some sand, fine; dry, (till)
12-15	Clay, light-gray, pebbly, dry, (till)
15-45	Clay, brown, gradually turning to gray, pebbly; some pea-size gravel, dry and hard
45-72	Clay, gray, sandy; some small gravel; wet
72-87	Clay; some sand, fine to very coarse; much clay, soft
87-94	Clay, grayish-brown; some sand; gravel, medium-sized; much clay

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Observation Well 27
Location: NE¼NE¼NW¼NW¼ sec. 2, T. 113 N., R. 52 W.
Top of observation well: 1666.20 feet
Depth to water: 12 feet

Observation Well 27–continued.

0- 1	Topsoil
1- 7	Clay, pebbly
7-15	Sand and gravel
15-17	Sand and clay
17-36	Sand, brown, very coarse
36-49	Clay, grayish-brown, pebbly

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Test Hole 28
Location: SE¼SE¼SE¼SE¼ sec. 3, T. 113 N., R. 52 W.
Surface elevation: 1687 feet
Depth to water: 32 feet

0- 4	Topsoil, black
4- 6	Clay, yellow; some sand, fine, (till)
6-15	Clay, yellowish-brown; few large rocks, (till)
15-23	Clay, brown, (till)
23-32	Clay, gray, (till)
32-48	Clay, gray, gravelly
48-60	Sand, coarse, much clay present
60-85	Sand, coarse gradually changing to fine
85-89	Clay, gray, compact

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Observation Well 29
Location: SE¼SE¼SE¼SW¼ sec. 2, T. 113 N., R. 52 W.
Top of observation well: 1671.20 feet
Depth to water: 19 feet

0- 1	Topsoil, black
1- 4	Sand and gravel
4- 9	Clay, light-brown, (till)
9-19	Clay, gravelly, (till)
19-24	Sand and gravel
24-34	Sand and gravel; some clay

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Test Hole 30
Location: SW¼SW¼SW¼NE¼ sec. 1, T. 113 N., R. 52 W.
Surface elevation: 1669 feet
Depth to water: 22 feet

0- 1	Topsoil
1- 5	Clay, dark-brown, pebbly
5-12	Sand and gravel
12-29	Sand, fine
29-52	Sand and gravel
52-69	Clay, grayish-brown, pebbly

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Observation Well 31
Location: SE¼SE¼SE¼SE¼ sec. 1, T. 113 N., R. 52 W.
Top of observation well: 1656.20 feet
Depth to water: 5 feet

0- 1	Topsoil, black
1- 4	Clay, brown, sandy
4-12	Sand, brown, very coarse
12-21	Sand and gravel
21-44	Clay, grayish-brown, pebbly

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Test Hole 32
Location: SE¼SE¼SE¼NE¼ sec. 1, T. 113 N., R. 52 W.
Surface elevation: 1655 feet
Depth to water: 2 feet

0- 1	Clay, black
1- 4	Sand
4-14	Sand and gravel

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Observation Well 33
Location: NE¼NE¼NE¼NE¼ sec. 1, T. 113 N., R. 52 W.
Top of observation well: 1658.59 feet
Depth to water: 6 feet

0- 1	Topsoil
1-10	Clay, blackish-brown
10-15	Sand, gray, medium with some clay, saturated
15-20	Sand, dark-gray, fine to medium to some coarse
20-29	Sand, gray, coarse to very coarse; pea-size gravel; coal
29-34	Sand, light-brown, coarse to very coarse; pea-size gravel; coal
34-50	Gravel, brown
50-58	Gravel, very coarse gravel to rocks
58-64	Clay, brown, pebbly, moist

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Observation Well 34
Location: NW¼NW¼NW¼NE¼ sec. 6, T. 113 N., R. 52 W.
Top of observation well: 1657.04 feet
Depth to water: 3 feet

0- 1	Topsoil
1-14	Sand and gravel
14-30	Sand and gravel
30-44	Clay, grayish-brown, pebbly

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Test Hole 35
Location: SW¼NE¼SE¼ sec. 3, T. 113 N., R. 51 W.
Surface elevation: 1664 feet
Depth to water: 12 feet

Test hole 35–continued.

0- 2	Topsoil
2-52	Sand and gravel; some clay
52-69	Clay, blue

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Test Hole 36
Location: SW¼SW¼SW¼SE¼ sec. 8, T. 113 N., R. 52 W.
Surface elevation: 1748 feet
Depth to water: Not measured

0- 2	Topsoil, black
2- 8	Clay, brown, pebbly, (till)
8-	Rocks–moved 10 feet east; same as above Moved 20 feet east; same as above Abandoned hole due to rocks

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Test Hole 37
Location: SW¼SW¼SW¼SW¼ sec. 9, T. 113 N., R. 52 W.
Surface elevation: 1728 feet
Depth to water: not measured

0- 1	Topsoil
1-28	Clay, dark-brown
28-44	Sand and gravel; too hard to drill, abandoned the hole

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Test Hole 38
Location: SW¼SW¼SW¼SW¼ sec. 10, T. 113 N., R. 52 W.
Surface elevation: 1659 feet
Depth to water: 3 feet

0- 1	Topsoil
1- 13	Sand
13- 18	Clay, pebbly
18- 78	Sand and gravel
78-104	Clay, dark-gray, pebbly

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Test Hole 39
Location: SW¼SE¼SW¼SW¼ sec. 10, T. 113 N., R. 52 W.
Surface elevation: 1655 feet
Depth to water: 3 feet

0-16	Sand
16-27	Clay, pebbly
27-30	Boulders
30-81	Sand and gravel
81-94	Clay, dark-gray, pebbly

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Test Hole 40
Location: NE¼NE¼NE¼SE¼ sec. 10, T. 113 N., R. 52 W.
Surface elevation: 1695 feet
Depth to water: 57 feet

0- 1	Topsoil
1- 19	Clay, dark-brown
19- 26	Clay, olive-brown
26- 57	Clay, dark-gray
57-112	Sand and gravel, dark-gray
112-117	Clay
117-126	Sand and gravel
126-134	Clay, blue-gray, pebbly

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Test Hole 41 (Rotary Test Hole)
Location: SW¼SW¼SW¼SW¼ sec. 12, T. 113 N., R. 52 W.
Surface elevation: 1685 feet
Depth to water: 31? feet

0- 2	Topsoil
2-15	Clay
15-50	Sand
50-80	Sand and gravel
80-85	Clay?

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Test Hole 42
Location: NW¼NW¼NW¼SW¼ sec. 12, T. 113 N., R. 52 W.
Surface elevation: 1690 feet
Depth to water: 19 feet

0- 1	Topsoil
1- 9	Clay, dark-brown
9- 14	Clay, brown
14- 19	Sand
19- 24	Sand and gravel
24- 34	Gravel
34- 76	Sand and gravel
76- 86	Clay
86-110	Sand and gravel
110-120	Clay, olive-brown

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Observation Well 43
Location: NW¼NW¼NW¼NW¼ sec. 12, T. 113 N., R. 52 W.
Top of observation well: 1670.04 feet
Depth to water: 15 feet

0- ½	Topsoil
½-15	Clay, brown, pebbly, (till)
15-39	Sand and gravel, brown
39-49	Sand, grayish-brown, very coarse

Observation Well 43–continued.

49-73	Sand and gravel, light-brown
73-84	Clay, grayish-brown, pebbly

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Test Hole 44
Location: SW¼SE¼SW¼SE¼ sec. 12, T. 113 N., R. 52 W.
Surface elevation: 1652 feet
Depth to water: 7 feet

0- 7	Clay
7-22	Sand and gravel
22-49	Clay

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Test Hole 45
Location: SE¼NW¼NE¼SE¼ sec. 12, T. 113 N., R. 52 W.
Surface elevation: 1671 feet
Depth to water: 5 feet

0- 2	Topsoil
2-11	Sand and gravel
11-29	Clay

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Test Hole 46
Location: NW¼NW¼NE¼SE¼ sec. 12, T. 113 N., R. 52 W.
Surface elevation: 1671 feet
Depth to water: 3 feet

0- 3	Topsoil
3- 7	Sand and gravel
7-39	Clay

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Test Hole 47
Location: NE¼SE¼NE¼NE¼ sec. 12, T. 113 N., R. 52 W.
Surface elevation: 1658 feet
Depth to water: 1 foot

0- 1	Topsoil
1-21	Sand and gravel
21-30	Clay
30-54	Clay

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Test Hole 48
Location: NE¼SE¼SE¼NE¼ sec. 12, T. 113 N., R. 52 W.
Surface elevation: 1655.5 feet
Depth to water: 13 feet

Test Hole 48--continued.

0-10	Clay, brown, sandy
10-14	Gravel and sand
14-19	Sand, brown
19-24	Sand; some gravel

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Test Hole 49
Location: NW¼NE¼NE¼SE¼ sec. 12, T. 113 N., R. 52 W.
Surface elevation: 1661 feet
Depth to water: 11 feet

0- 2	Topsoil
2- 6	Clay, sandy
6-16	Sand and gravel
16-44	Clay

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Test Hole 50
Location: NW¼NE¼NE¼SE¼ sec. 12, T. 113 N., R. 52 W.
Surface elevation: 1665 feet
Depth to water: 3 feet

0- 3	Topsoil
3-11	Sand and gravel
11-39	Clay

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Test Hole 51
Location: SE¼SE¼SE¼SW¼ sec. 7, T. 113 N., R. 51 W.
Surface elevation: 1653 feet
Depth to water: 6 feet

0- 2	Topsoil
2-40	Clay, sandy
40-80	Sand and gravel
80-99	Clay

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Observation Well 52
Location: SE¼SE¼SE¼NE¼ sec. 8, T. 113 N., R. 51 W.
Top of observation well: 1646.65 feet
Depth to water: 5 feet

0-25	Sand and gravel, gray; gravel, coarse; sand, fine to coarse
25-30	Clay and gravel, brown, pebbly, compact

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Test Hole 53
Location: NE¼NW¼NE¼NW¼ sec. 15, T. 113 N., R. 52 W.
Surface elevation: 1660 feet
Depth to water: 7 feet

Test Hole 53–continued.

0- 28	Sand, fine to coarse
28- 34	Clay
34- 78	Sand and gravel
78-109	Clay, bluish-gray, pebbly, (till)

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Test Hole 54
Location: NE¼NE¼NW¼NE¼ sec. 15, T. 113 N., R. 52 W.
Surface elevation: 1667 feet
Depth to water: 6 feet

0- 14	Sand and gravel
14- 22	Clay
22- 32	Sand and gravel
32- 34	Clay layer?
34- 44	Sand and gravel
44-103	Gravel
103-109	Clay?
109-130	Sand and gravel
130-149	Clay, blue-gray, pebbly

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Test Hole 55
Location: NW¼SE¼NW¼NW¼ sec. 14, T. 113 N., R. 52 W.
Surface elevation: 1673 feet
Depth to water: 3 feet

0- 27	Sand, fine to coarse
27- 37	Sand with clay
37-123	Sand and gravel
123-129	Clay, bluish-gray, pebbly

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Test Hole 56
Location: SE¼SE¼SW¼SW¼ sec. 14, T. 113 N., R. 52 W.
Surface elevation: 1681 feet
Depth to water: 20? feet

0- 1	Topsoil
1-32	Clay, brownish-yellow
32-43	Sand and gravel, hard drilling, could not penetrate

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Test Hole 57
Location: NE¼NE¼NE¼SE¼ sec. 14, T. 113 N., R. 52 W.
Surface elevation: 1684 feet
Depth to water: dry hole

0-11	Clay, dark-brown
11-13	Sand, coarse, big boulders, stopped drilling

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Test Hole 58
Location: SE¼SE¼NE¼NE¼ sec. 14, T. 113 N., R. 52 W.
Surface elevation: 1655 feet
Depth to water: not determined

0-3	Very coarse gravel, could not drill Drilled three more holes, could not penetrate Hole abandoned at 3 feet

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Test Hole 59
Location: NW¼NW¼NW¼NE¼ sec. 13, T. 113 N., R. 52 W.
Surface elevation: 1655 feet
Depth to water: 6 feet

0- 4	Roadbed
4- 6	Clay, sandy
6-28	Sand and gravel
28-39	Clay, brownish-yellow, pebbly

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Test Hole 60
Location: SE¼SE¼SE¼SE¼ sec. 13, T. 113 N., R. 52 W.
Surface elevation: 1693 feet
Depth to water: 48 feet

0- 1	Topsoil
1- 25	Clay, pebbly
25- 33	Sand and gravel
33- 48	Sand and clay
48- 95	Sand and gravel
95-107	Gravel
107-124	Clay, dark-gray

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Test Hole 61
Location: NW¼NW¼NW¼NW¼ sec. 18, T. 113 N., R. 51 W.
Surface eeleation: 1695 feet
Depth to water: dry hole

0- 1	Topsoil
1-19	Clay, brownish-yellow
19-31	Clay, dark-gray
31-38	Gravel, too hard to drill, abandoned the hole

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Observation Well 62
Location: NW¼NW¼NW¼NW¼ sec. 17, T. 113 N., R. 51 W.
Top of observation well: 1668.33 feet
Depth to water: 19 feet

0- 6	Sand and gravel, dark-brown, coarse, dry

Observation Well 62–continued.

6- 7	Clay, light-brown; some sand, moist
7-19	Sand, dark-brown, medium to very coarse; some pea-size gravel, moist
19-28	Sand, grayish-brown, coarse to very coarse; pea-size gravel
28-35	Gravel, very coarse with sand
35-42	Clay, light-brown, pebbly, (till)

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Observation Well 63

Location: SW¼SW¼SW¼NW¼ sec. 17, T. 113 N., R. 51 W.
Top of observation well: 1653.17 feet
Depth to water: 4 feet

0- 6	Clay, grayish-brown, sandy
6-11	Sand, brown, medium- to coarse-grained
11-24	Sand, brown, medium-grained
24-36	Sand and gravel, brown, very coarse sand to medium gravel
36-46	Gravel, gray, medium- to coarse-grained
46-59	Clay, gray, (till)

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Test Hole 64

Location: NE¼NE¼NE¼NW¼ sec. 17, T. 113 N., R. 51 W.
Surface elevation: 1656 feet
Depth to water: 16 feet

0- 4	Clay, sandy
4- 9	Sand, fine
9-18	Clay, gray, (till)
18-34	Sand and gravel

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Observation Well 65

Location: NE¼NE¼NE¼NE¼ sec. 17, T. 113 N., R. 51 W.
Top of observation well: 1655.01 feet
Depth to water: 6 feet

0- 6	Sand and gravel, brown
6-15	Sand and gravel, light-gray, saturated
15-25	Clay, light-brownish-yellow, sandy
25-34	Sand?
34-74	Clay, dark-gray, very hard drilling

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Observation Well 66

Location: SW¼SW¼SW¼SW¼ sec. 16, T. 113 N., R. 51 W.
Top of observation well: 1657.83 feet
Depth to water: 17 feet

0- ½	Topsoil
½- 5	Sandy clay, light-brown, moist

Observation Well 66--continued.

5-11	Sand and gravel, rust-brown, dry
11-17	Clay, gray, pebbly, dry to moist
17-22	Clay, sandy, gray, fine to medium, saturated
22-29	Sand, gray, coarse to very coarse
29-30	Sand, light-brown, very coarse
30-34	Clay, gray, pebbly, moist

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Test Hole 67
Location: NE¼NE¼NE¼NW¼ sec. 16, T. 113 N., R. 51 W.
Surface elevation: 1651 feet
Depth to water: 4 feet

0- 4	Topsoil, black, very pebbly, some sand, fine
4- 9	Clay, light-gray, very pebbly
9-15	Clay and gravel, gray, much gravel, coarse
15-25	Clay, grayish; less gravel
25-34	Clay, brownish, pebbly, compact

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Observation Well 68
Location: SE¼SE¼NE¼SE¼ sec. 16, T. 113 N., R. 51 W.
Top of observation well: 1650.13 feet
Depth to water: 5 feet

0- 4	Topsoil
4- 9	Sand, gray, medium- to coarse-grained sand; some gravel pebbles; some clay; moist
9-24	Sand, gray, medium to very coarse, wet
24-29	Clay, brown, pebbly, compact, (till)

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Observation Well 69
Location: SW¼SW¼SW¼SW¼ sec. 24, T. 113 N., R. 52 W.
Top of observation well: 1672.98 feet
Depth to water: 20 feet

0- 1	Topsoil, black
1- 4	Clay, brown; some sand
4-14	Clay, reddish-brown; little sand
14-19	Clay, brownish-gray, moist to wet
19-28	Clay, dark-gray; sand, very fine, wet
28-32	Clay, dark-brownish-gray, very gravelly
32-43	Clay, dark-brownish-gray
43-99	Sand, grayish-brown, medium to coarse with some very coarse

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Observation Well 70
Location: NE¼NE¼NE¼SE¼ sec. 19, T. 113 N., R. 51 W.
Top of observation well: 1660.71 feet
Depth to water: 10 feet

Observation Well 70--continued.

0- 9	Sand and gravel, brown, coarse sand with gravel
9-15	Sand, brown, medium-grained sand with clay; clay increasing at 13 feet
15-20	Sand, gray, fine; clay
20-25	Sand, gray, medium-grained
25-40	Sand, gray, very coarse sand to gravel
40-52	Sand, gray, coarse to very coarse
52-66	Sand, fine to very fine sand with clay
66-79	Clay, dark-brown, (till)

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Observation Well 71
Location: SE¼SE¼SE¼SE¼ sec. 19, T. 113 N., R. 51 W.
Top of observation well: 1665.79 feet
Depth to water: 10 feet

0- 1	Topsoil
1- 6	Clay, light-brown; sand
6- 9	Clay, brown; gravel
9-27	Gravel and sand, brown, coarse to very coarse sand, medium gravel
27-41	Sand, light-gray, medium to very coarse; some gravel; little clay
41-54	Clay, dark-gray, pebbly, (till)

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Test Hole 72
Location: NE¼SE¼NE¼NE¼ sec. 21, T. 113 N., R. 51 W.
Surface elevation: 1670 feet
Depth to water: 18 feet

0- 3	Topsoil, black, sandy; some clay
3- 8	Sand and gravel, rust-brown, medium to very coarse sand, with coarse gravel, dry
8-11	Sand, brown, very coarse, dry to moist
11-18	Sand and gravel, brown, very coarse sand with coarse gravel
18-27	Clay, yellowish-brown, with some fine sand
27-39	Clay, gray, pebbly, compact

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Test Hole 73
Location: SE¼SE¼SE¼SE¼ sec. 21, T. 113 N., R. 51 W.
Surface elevation: 1705 feet
Depth to water: not measured

0- 5	Clay, brown, some medium sand, dry
5-12	Clay, dark-brown, more clay, no pebbles, compact
12-15	Clay, very dark-brown, few pebbles, compact
15-20	Clay, lighter-brown, few pebbles
20-24	Clay, yellowish-brown; some sand, very fine, pebbly
24-37	Clay, darker-brown, pebbly, compact
37-40	Clay, light brownish-gray, no pebbles; some sand, fine
40-74	Clay, dark-brown, pebbly, compact, (till)

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Test Hole 74
Location: NW¼NW¼NW¼NW¼ sec. 30, T. 113 N., R. 52 W.
Surface elevation: 1673 feet
Depth to water: 21 feet

0- 1	Topsoil, black
1- 2	Sand, brown, medium, dry
2- 9	Gravel, brown, fine, poorly sorted, dry
9-21	Clay, gray, moist
21-37	Clay, gray, sandy
37-63	Gravel, gray; much clay
63-77	Clay, gray, compact, pebbly, (till)

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Test Hole 75
Location: NW¼NW¼NW¼NW¼ sec. 29, T. 113 N., R. 52 W.
Surface elevation: 1670 feet
Depth to water: 19 feet

0- 1	Topsoil
1- 3	Clay, dark-brown
3-13	Sand and gravel
13-19	Clay, sandy
19-32	Sand and gravel
32-47	Clay, brown, pebbly
47-50	Sand and gravel
50-59	Clay, pebbly

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Observation Well 76
Location: SE¼NE¼SE¼NE¼ sec. 30, T. 113 N., R. 51 W.
Top of observation well: 1665.65 feet
Depth to water: 5 feet

0- 3	Topsoil, black, clay
3- 7	Clay, gray
7-11	Sand and clay, fine sand
11-14	Sand, medium to coarse with clay
14-19	Gravel, medium with clay
19-27	Gravel, well sorted, ½ cm diameter
27-32	Sand, light-gray, fine to coarse
32-44	Sand, brown, medium to coarse
44-49	Sand, brown, medium to very coarse; some gravel, fine
49-61	Clay, light-gray, pebbly, moist to wet, (till)
61-64	Clay, dark-grayish-brown, pebbly, compact, (till)

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Test Hole 77
Location: NE¼NE¼NE¼SE¼ sec. 28, T. 113 N., R. 51 W.
Surface elevation: 1677 feet
Depth to water: not measured

0- 2	Topsoil

Test Hole 77–continued.

2-31	Clay, yellowish-brown, (till)
31-46	Clay, brown, pebbly, (till)
46-59	Clay, dark-brown, (till)
59-65	Clay, gray, scattered large gravel, (till)
65-85	Clay, gray

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Test Hole 78
Location: NE¼SW¼NE¼ sec. 26, T. 113 N., R. 51 W.
Surface elevation: 1649 feet
Depth to water: 8 feet

0- 1	Topsoil
1- 8	Sand and gravel
8-35	Sand, coarse; gravel
35-44	Clay, dark-gray

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Test Hole 79
Location: NE¼SW¼NE¼NE¼ sec. 36, T. 113 N., R. 53 W.
Surface elevation: 1650 feet
Depth to water: 5 feet

0- 1	Topsoil
1-20	Sand and gravel
20-34	Clay, pebbly

* * * *

Observation Well 80
Location: NW¼SW¼SE¼NE¼ sec. 36, T. 113 N., R. 53 W.
Top of observation well: 1658.53 feet
Depth to water: 3 feet

0- 2	Topsoil, black, very sandy
2-11	Sand, brown, very coarse; some pea-sized gravel, fairly clean
11-22	Sand, blackish-brown; very coarse to fine gravel; much clay
22-28	Clay, gray, slightly sandy

* * * *

Test Hole 81
Location: NW¼NW¼NW¼NW¼ sec. 35, T. 113 N., R. 52 W.
Surface elevation: 1684 feet
Depth to water: 29 feet

0- 5	Roadbed
5- 19	Clay, brownish-gray, pebbly
19- 26	Clay, olive-brown, pebbly
26- 69	Clay, brownish-gray
69- 74	Clay, light-gray
74- 93	Sand and gravel

Test Hole 81--continued.

93-114	Clay, brown, pebbly

* * * *

Test Hole 82
Location: SE¼SE¼SE¼SE¼ sec. 36, T. 113 N., R. 52 W.
Surface elevation: 1761 feet
Depth to water: dry hole

0- 2	Topsoil, black
2-11	Clay, yellow, (till)
11-23	Clay, brown, scattered large rocks, (till) Abandoned hole at 23 feet due to rock

* * * *

Test Hole 83
Location: NW¼NW¼NW¼NW¼ sec. 32, T. 113 N., R. 51 W.
Surface elevation: 1703 feet
Depth to water: not measured

0- 1	Topsoil
1- 5	Clay, brown, pebbly; gravel
5- 6	Clay, brown, gravelly
6- 39	Clay, light-brown, sandy, moist to wet
39- 98	Clay, light-to dark-gray, some sand, moist to wet
98-104	Clay, dark-gray, pebbly, compact

* * * *

Test Hole 84
Location: NW¼NW¼NW¼SW¼ sec. 4, T. 112 N., R. 52 W.
Surface elevation: 1671 feet
Depth to water: 20 feet

0- 1	Topsoil
1- 17	Clay, pebbly
17- 25	Clay, dark-brown
25- 60	Clay, dark-gray
60- 78	Sand, fine
78- 93	Sand and gravel
93-103	Gravel
103-109	Clay, dark-olive
109-119	Clay, brownish-gray

* * * *

APPENDIX C

Water-level measurement for August 1, 1969 and August 3, 1970 in the Lake Poinsett study area*

Observation Well Number and Location	1969 (water level in feet)	1970 (water level in feet)
1. SW¼SE¼SW¼SE¼ sec. 18, T. 114 N., R. 51 W.	NC**	1661.36
3. NE¼NE¼NE¼NE¼ sec. 22, T. 114 N., R. 52 W.	NC	1663.47
4. SE¼SE¼SE¼NE¼ sec. 23, T. 114 N., R. 52 W.	1658.51	1657.98
5. SE¼SE¼SE¼SE¼ sec. 23, T. 114 N., R. 52 W.	NC	1657.32
8. NE¼NE¼NE¼NE¼ sec. 24, T. 114 N., R. 52 W.	1660.20	1659.08
10. SW¼SW¼SW¼SW¼ sec. 20, T. 114 N., R. 51 W.	NC	1658.71
13. SW¼SW¼SW¼NW¼ sec. 25, T. 114 N., R. 52 W.	1656.97	1656.51
17. NE¼NE¼NE¼NE¼ sec. 25, T. 114 N., R. 52 W.	1660.34	1657.57
19. NE¼NE¼NE¼NW¼ sec. 30, T. 114 N., R. 51 W.	1656.72	1655.93
20. SE¼SE¼SE¼NE¼ sec. 35, T. 114 N., R. 52 W.	1652.74	1651.17
23. NW¼NW¼NW¼NW¼ sec. 31, T. 114 N., R. 51 W.	1654.07	1651.54
24. NE¼NE¼NE¼NW¼ sec. 31, T. 114 N., R. 51 W.	1654.07	1653.17
25. SE¼SE¼SE¼SE¼ sec. 32, T. 114 N., R. 51 W.	NC	1653.45
27. NE¼NE¼NW¼NW¼ sec. 2, T. 113 N., R. 52 W.	1652.55	1651.50
29. SE¼SE¼SE¼SW¼ sec. 2, T. 113 N., R. 52 W.	1651.97	1651.70
31. SE¼SE¼SE¼SE¼ sec. 1, T. 113 N., R. 52 W.	1651.00	1650.70
33. NE¼NE¼NE¼NE¼ sec. 1, T. 113 N., R. 52 W.	NC	1650.49
34. NW¼NW¼NW¼NE¼ sec. 6, T. 113 N., R. 51 W.	1650.95	1650.07
43. NW¼NW¼NW¼NW¼ sec. 12, T. 113 N., R. 52 W.	NC	1651.78
52. SE¼SE¼SE¼NE¼ sec. 8, T. 113 N., R. 51 W.	NC	1646.65
62. NW¼NW¼NW¼NW¼ sec. 17, T. 113 N., R. 51 W.	NC	1647.86
63. SW¼SW¼SW¼NW¼ sec. 17, T. 113 N., R. 51 W.	NC	1645.99
65. NE¼NE¼NE¼NE¼ sec. 17, T. 113 N., R. 51 W.	NC	1644.20
66. SW¼SW¼SW¼SW¼ sec. 16, T. 113 N., R. 51 W.	NC	1643.42
68. SE¼SE¼NE¼SE¼ sec. 16, T. 113 N., R. 51 W.	NC	1641.43
69. SW¼SW¼SW¼SW¼ sec. 24, T. 113 N., R. 52 W.	NC	1652.26
70. NE¼NE¼NE¼SE¼ sec. 19, T. 113 N., R. 51 W.	NC	1648.29
71. SE¼SE¼SE¼SE¼ sec. 19, T. 113 N., R. 51 W.	NC	1650.76
76. SE¼NE¼SE¼NE¼ sec. 30, T. 113 N., R. 51 W.	NC	1658.06
Location of Measurement Stations		
Big Sioux River 2 miles north of Boswell Dam	1658.59	1658.69
Big Sioux River 2 miles south of Dempster	1644.29	1643.66
Big Sioux River one-half mile southwest of Dempster	1646.52	1646.03
Big Sioux River 1¾ miles west of Dempster	1649.63	1649.03
Big Sioux River at Boswell Dam	1654.53	1653.79
Big Sioux River at diversion ditch, west side of the gates	1652.83	1651.84
Big Sioux River at diversion ditch, east side of the gates	1654.55	1653.82
Big Sioux River diversion ditch at Castlewood Road	1652.83	1651.68
Lake Poinsett outlet channel at Jannsen's Bridge (2 miles northeast of Highway 28 Bridge)	1652.43	1651.48

*Water-level measurement conducted by East Dakota Conservancy Sub-District.

**NC—not constructed as of August 1, 1969.

Appendix C--continued.

Location of Measurement Stations*	1969	1970
Outlet channel at Bench Mark Bridge (1-1/3 miles northeast of Highway 28 Bridge on the outlet	1652.78	1652.00
Outlet channel at Stark Bridge (one-third mile east of Highway 28 Bridge on the outlet)	1652.81	1652.02
Outlet channel at Highway 28 Bridge	1652.79	1652.00
Dry Lake at Stone Bridge	1652.76	1651.57
Lake Poinsett on west side	1652.82	1652.21
Lake Florence	1653.96	1653.90
Lake Albert	1653.29	1653.10

*Water-level measurement conducted by East Dakota Conservancy Sub-District.

APPENDIX D

Well records in the Lake Poinsett area

Source: O, surface outwash; B, buried sand lenses and outwash
Use: D, domestic; S, stock; I, irrigation

Name	Location	Depth of Well (feet)	Depth to Water (feet)	Source	Use
Anderson, D.	SE¼SW¼SE¼ sec. 7, T. 114 N., R. 51 W.	80	50	B	D, S
Heemeyer, M.	NW¼SE¼SE¼ sec. 17, T. 114 N., R. 51 W.	45	20	B	D, S
Rhody, V.	NE¼NE¼NW¼ sec. 18, T. 114 N., R. 51 W.	16	7	0	D, S
Wattawa, A.	SE¼SW¼SE¼ sec. 18, T. 114 N., R. 51 W.	16	9	O	D, S
Hulscher, F.	SW¼NE¼NE¼ sec. 19, T. 114 N., R. 51 W.	28	20	O	D, S
Pedersen, A.	SW¼SW¼NW¼ sec. 20, T. 114 N., R. 51 W.	9	7	O	D, S
Schmidt, W.	NW¼NW¼NW¼ sec. 27, T. 114 N., R. 51 W.	30	20	O	D, S
Linneman, D.	NE¼SW¼NW¼ sec. 28, T. 114 N., R. 51 W.	27	16	O	D, S
Norman, H.	SE¼SW¼SW¼ sec. 29, T. 114 N., R. 51 W.	10	6	O	D, S
DeWall, L.	NE¼SE¼NE¼ sec. 30, T. 114 N., R. 51 W.	20	8	O	D, S
Ladwig, B.	SW¼SE¼NW¼ sec. 30, T. 114 N., R. 51 W.	14	10	O	D, S
Poppen, A.	SE¼SE¼SW¼ sec. 31, T. 114 N., R. 51 W.	12	10	O	D, S
Jongeling, R.	NE¼SW¼SW¼ sec. 32, T. 114 N., T. 51 W.	10		O	D, S
VanDykhorst, E.	SW¼NE¼NE¼ sec. 32, T. 114 N., R. 51 W.	16	10	O	D, S
Jongeling, R.	SW¼SE¼SE¼ sec. 32, T. 114 N., R. 51 W.	10	8	O	D, S
Ebbers, P.	NE¼NE¼NW¼ sec. 33, T. 114 N., R. 51 W.	15	10	O	D, S
Timmer, P.	NE¼SW¼SE¼ sec. 33, T. 114 N., R. 51 W.	27	6	O	D
Ludwig, B.	SE¼NW¼SE¼ sec. 33, T. 114 N., R. 51 W.	12	7	O	D, S
Janssen, M.	NW¼SW¼NW¼ sec. 34, T. 114 N., R. 51 W.	38	30	O	D, S
Kiihl, F.	NW¼NW¼SW¼ sec. 12, T. 114 N., R. 52 W.	60	35	B	D, S
Kiihl, W.	SW¼SW¼SE¼ sec. 13, T. 114 N., R. 52 W.	29		O	D, S
Pommer, O.	NW¼NW¼SW¼ sec. 13, T. 114 N., R. 52 W.	35	20	O	D, S
Pommer, M.	SE¼NE¼NE¼ sec. 14, T. 114 N., R. 52 W.	30	20	O	D, S

Appendix D--continued.

Name	Location	Depth of Well (feet)	Depth to Water (feet)	Source	Use
Walker, M.	SW¼SW¼NW¼ sec. 14, T. 114 N., R. 52 W.	28		O	D, S
Goeman, F.	NE¼NE¼NE¼ sec. 15, T. 114 N., R. 52 W.	28			D
Schlack, A.	NE¼SE¼SE¼ sec. 15 T. 114 N., R. 52 W.	30		O	D, S
Goeman, C.	SE¼NW¼SW¼ sec. 16, T. 114 N., R. 52 W.	60		B	D, S
Jumso, E.	NW¼NW¼NE¼ sec. 17, T. 114 N., R. 52 W.	80		B	D
Jacobson, C.	SE¼NE¼SW¼ sec. 20, T. 114 N., R. 52 W.	26		B	D, S
Anderson, D.	NE¼SW¼NW¼ sec. 20, T. 114 N., R. 52 W.	80		B	D
Reese, M.	SE¼NW¼SE¼ sec. 21, T. 114 N., R. 52 W.	505			D, S
Junso, E.	NE¼NE¼SW¼ sec. 22, T. 114 N., R. 52 W.	60?			D, S
Magee, W.	SW¼SW¼SW¼ sec. 24, T. 114 N., R. 52 W.	20	18	O	D, S
Pommer, C.	SW¼SW¼NW¼ sec. 25, T. 114 N., R. 52 W.	22	6	O	D, S
McCarrier, E.	NW¼NE¼NE¼ sec. 26, T. 114 N., R. 52 W.	24	16	O	D, S
Johnson, T. & R.	NE¼SE¼NE¼ sec. 28, T. 114 N., R. 52 W.	21		O	D
Pearson, R.	NE¼SE¼SE¼ sec. 3, T. 114 N., R. 52 W.	20		O	D, S
Namber, E.	SE¼NW¼NE¼ sec. 32, T. 114 N., R. 52 W.	27			D, S
Lantgen, H.	SE¼NE¼SE¼ sec. 2, T. 113 N., R. 51 W.	16	12	O	D, S
Church, F.	SW¼SW¼NW¼ sec. 2, T. 113 N., R. 51 W.	410?			D, S
Spilde	SW¼NE¼SW¼ sec. 3, T. 113 N., R. 51 W.	48	10	O	I
Linneman, K.	SW¼NW¼SW¼ sec. 4, T. 113 N., R. 51 W.	16	6	O	D, S
Ames, J.	NE¼NE¼SE¼ sec. 5, T. 113 N., R. 51 W.	9	7	O	D, S
Wiliscrodt, H.	SW¼NW¼NW¼ sec. 6, T. 113 N., R. 51 W.	11	8	O	D, S
Jonssen, J.	NW¼SW¼NW¼ sec. 7, T. 113 N., R. 51 W.	8	4	O	S
Jonssen, J.	NW¼SW¼NW¼ sec. 7, T. 113 N., R. 51 W.	4	2	O	D
Runge, H.	SE¼SE¼SW¼ sec. 7, T. 113 N., R. 51 W.	35		O	D, S
Licht, W.	NE¼SW¼SE¼ sec. 7, T. 113 N., R. 51 W.	15		O	D, S

Appendix D--continued.

Name	Location	Depth of Well (feet)	Depth to Water (feet)	Source	Use
Rust, L.	SW¼SW¼SW¼ sec. 8, T. 113 N., R. 51 W.	18	16	O	D, S
Linneman, F.	NE¼SE¼NE¼ sec. 9, T. 113 N., R. 51 W.	16	10	O	D, S
McFarland, H.	SE¼SE¼SW¼ sec. 10, T. 113 N., R. 51 W.	13	8	O	D, S
Popen, J.	NW¼SE¼SW¼ sec. 10, T. 113 N., R. 51 W.	14	10	O	D
Kaiser, E.	SW¼SW¼SW¼ sec. 11, T. 113 N., R. 51 W.	18	10	O	D, S
Foster, K.	SW¼NE¼SW¼ sec. 12, T. 113 N., R. 51 W.	27	18	O	D, S
Hemer, L.	NW¼NE¼NE¼ sec. 15, T. 113 N., R. 51 W.	22	12	O	D, S
DeYoung, T.	NW¼NW¼NW¼ sec. 17, T. 113 N., R. 51 W.	25		O	D, S
City of Estelline	SW¼SW¼ sec. 24, T. 113 N., R. 51 W.			O	D
Harrenga, J.	NE¼SW¼NE¼ sec. 26, T. 113 N., R. 51 W.	35	8	O	I
Swift, J.	NE¼NE¼NE¼ sec. 32, T. 113 N., R. 51 W.	40	went dry		D
Aloms, H.	SW¼SW¼SE¼ sec. 2, T. 113 N., R. 52 W.	32		O	D, S
Bennett, E.	SE¼SW¼SW¼ sec. 2, T. 113 N., R. 52 W.	40	30	O	D, S
Wattnem, G.	SE¼NE¼SW¼ sec. 4, T. 113 N., R. 52 W.	40		B	D, S
Anderson, E.	NW¼SE¼NW¼ sec. 4, T. 113 N., R. 52 W.	50		B	D, S
Issacson, E.	SE¼SE¼NE¼ sec. 6, T. 113 N., R. 52 W.	285?			S
Bernia, S.	SE¼SW¼NW¼ sec. 8, T. 113 N., R. 52 W.	35		B	S
Bjorkund, T.	SE¼SE¼SW¼ sec. 9, T. 113 N., R. 52 W.	50	38	B	D
Bjorkund, T.	SE¼SE¼SW¼ sec. 9, T. 113 N., R. 52 W.	70	60	B	S
Jongeling, G.	NE¼SW¼NE¼ sec. 12, T. 113 N., R. 52 W.	30		O	S
Bakke, M.	NW¼NE¼NE¼ sec. 13, T. 113 N., R. 52 W.	59	51	B	D, S
Beare, J.	NW¼NW¼SW¼ sec. 13, T. 113 N., R. 52 W.	45	30	B	D, S
Effting, M.	SW¼NW¼NW¼ sec. 13, T. 113 N., R. 51 W.	26	13	O	D
Rick, H.	NE¼SW¼SE¼ sec. 14, T. 113 N., R. 52 W.	34	20	B	D, S
Thies, A.	NW¼NW¼NW¼ sec. 14, T. 113 N., R. 52 W.	34	16	O	D, S

Appendix D–continued.

Name	Location	Depth of Well (feet)	Depth to Water (feet)	Source	Use
Nitteberg Brothers	NE¼NE¼NW¼ sec. 15, T. 113 N., R. 52 W.	15	5	O	D
Saaramen, F.	SW¼NW¼NE¼ sec. 16, T. 113 N., R. 52 W.	56		B	D, S
Burchard, J.	SW¼NW¼NW¼ sec. 20, T. 113 N., R. 52 W.	24	20	O	D, S
Rust, G.	NW¼NW¼NE¼ sec. 24, T. 113 N., R. 52 W.	70	60	B	D, S
Lake Region Golf Course	NW¼NE¼NE¼ sec. 36, T. 113 N., R. 53 W.	88	20	B	I

APPENDIX E

Water levels for Lake Poinsett from 1935 through 1970
(See fig. 7.)

Lake level measured by the South Dakota Geological Survey from 1935 to 1964 and by the East Dakota Conservancy Sub-District from 1964 through December 1970.

Date	Lake level (in feet)
10-20-35	1,638.2
5-31-36	1,632.9
5-31-37	1,637.9
10-10-37	1,636.7
6- 9-38	1,638.6
10- 9-38	1,637.6
5-30-39	1,638.8
11-19-39	1,637.5
5-15-40	1,638.9
10-25-40	1,637.4
6- 3-41	1,639.0
11-17-41	1,638.2
5-29-42	1,639.2
11- 2-42	1,641.5
6-17-43	1,646.9
11-28-43	1,647.3
7- 5-44	1,648.1
11-19-44	1,647.2
5- 5-45	1,647.5
10-13-45	1,650.3
5-22-46	1,651.6
9-30-46	1,650.9
5-22-47	1,652.6
5-13-48	1,648.8
5-19-49	1,646.4
11-10-49	1,646.2
5-16-50	1,651.2
1- 8-51	1,646.1
5- 7-51	1,645.8
2-26-52	1,648.6
10-22-52	1,650.3
11-15-53	1,651.0
4-19-54	1,651.9
9-17-54	1,651.3
5-11-55	1,651.0
5-17-56	1,650.3
11-29-56	1,650.9
9-12-57	1,651.4
4- -59	1,650.4
4-25-60	1,652.1
6- 6-61	1,651.5
12- 6-61	1,650.6
6- 7-62	1,653.0
12-14-62	1,651.5
5- 9-63	1,651.7
5-14-64	1,651.0
9-12-64	1,649.31
10-5-64	1,649.19
10-16-64	1,649.16
11-21-64	1,649.18
2-13-65	1,648.97
5- 8-65	1,650.8
5-11-65	1,651.06
5-26-65	1,651.39
6- 6-65	1,651.47
6-13-65	1,651.22
6-19-65	1,651.39
7-16-65	1,651.22
7-25-65	1,651.10
8- 8-65	1,651.10
8-16-65	1,650.86
9- 5-65	1,650.50
9-24-65	1,650.56
9-30-65	1,650.67
10- 2-65	1,650.71
10-21-65	1,650.69
11- 3-65	1,650.50
12-19-65	1,650.59
3-12-66	1,650.80
6-19-66	1,651.47
6-25-66	1,651.45
7-15-66	1,651.23
7-28-66	1,651.25
8-18-66	1,651.10
9-14-66	1,650.88
10- 1-66	Water level measured inside pipe on bank
10-29-66	1,650.59
11- 4-66	1,650.55
Perm. 2" obs. well	1,658.09
11- 4-66	1,650.52
11- 8-66	1,650.60
12-12-66	1,651.05
1-21-67	1,650.59
2- 9-67	1,650.61
3- 2-67	1,650.32
3-27-67	1,650.97
4- 1-67	1,651.17
4-15-67	1,651.53
4-25-67	1,651.57
4-29-67	1,651.47
5-18-67	1,651.28
6- 5-67	1,651.17
6-21-67	1,651.42
7-10-67	1,651.34
7-16-67	1,651.20
7-26-67	1,651.13
8- 9-67	1,650.80
8-28-67	1,650.53
2- 4-68	1,649.73
3-26-68	1,649.81
4- 1-68	1,649.81
5-13-68	1,650.39
6- 3-68	1,650.15
6- 7-68	1,650.31
6-20-68	1,650.35
7- 1-68	1,650.10
7-15-68	1,650.06
8- 1-68	1,649.81
8-16-68	1,649.71
8-30-68	1,649.57
10- 1-68	1,649.40
11-23-68	1,649.35
2- 2-69	1,649.64
3- 3-69	1,649.82
3-16-69	1,649.84
3-31-69	1,649.89
4- 9-69	1,650.94
4-12-69	1,653.37
4-18-69	1,653.76
5- 2-69	1,653.76
5-12-69	1,653.64
5-29-69	1,653.47
6-23-69	1,653.00
7- 1-69	1,652.90
8- 1-69	1,652.82
9- 3-69	1,652.32
10- 4-69	1,651.93
10-30-69	1,651.91
12- 2-69	1,651.75
1-31-70	1,651.81
3-30-70	1,651.28
4- 6-70	1,652.17
5- 1-70	1,652.39
6- 2-70	1,652.37
7- 1-70	1,652.37
8- 3-70	1,652.21
10- 1-70	1,651.41
10-15-70	1,651.45
11- 4-70	1,651.46

APPENDIX F

Daily precipitation at Castlewood and Arlington and evaporation at Brookings in August 1969*

Day of Month	Castlewood (precip. in inches)	Arlington (precip. in inches)	Brookings (evap. in inches)
1			--
2			.27
3			.31
4	.26	.32	.39
5			.16
6	Trace		.31
7			.36
8			.23
9		.22	.18
10			.27
11			.33
12			.30
13	.02		.42
14			.20
15			.28
16			.31
17			.44
18			.41
19	.71	.61	.17
20			.05
21			.18
22			.18
23			.33
24			.18
25			.35
26			.18
27			.30
28			.22
29			.45
30	.14	.57	.32
31	.03		.02
Total	1.16	1.72	8.37

*U. S. Department of Commerce, Climatological Data for South Dakota, August 1969, v. 74, no. 8, p. 119, 124.

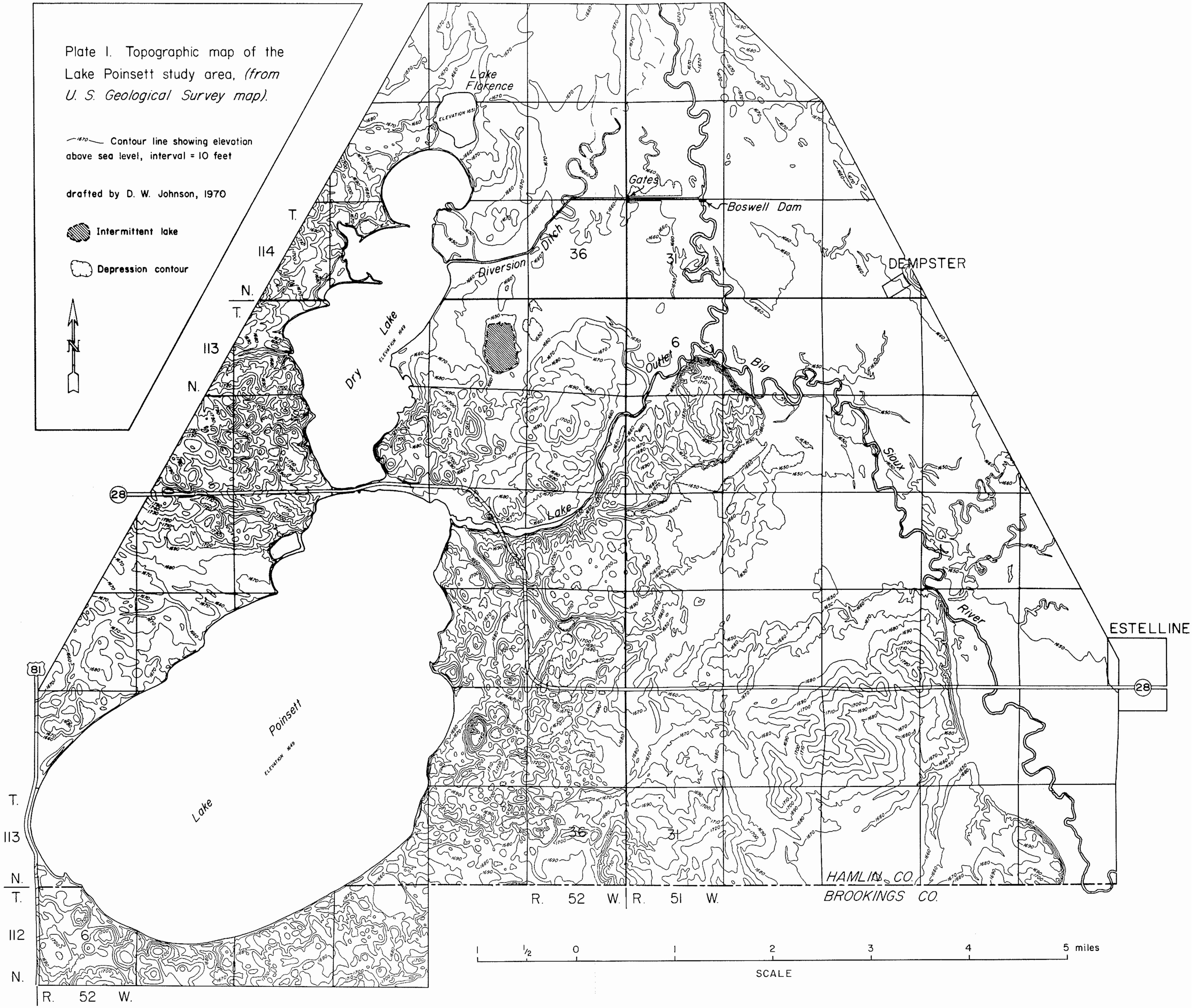

Plate I. Topographic map of the Lake Poinsett study area, *(from U. S. Geological Survey map)*.