SOUTH DAKOTA

STATE GEOLOGICAL SURVEY

E. P. Rothrock, State Geologist

REPORT OF INVESTIGATIONS

No. 17

# WATER SUPPLIES AND GEOLOGY OF LAKE KAMPESKA

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December, 1933
Reprint June, 1956

TABLE OF CONTENTS

## LIST OF ILLUSTRATIONS

# WATER SUPPLIES AND GEOLOGY

# OF

# LAKE KAMPESKA

## FOREWORD

The series of dry years preceding and including 1933 seriously lowered the levels of all lakes in South Dakota. Many dried up entirely and others were so low as to alarm those citizens who use them for pleasure or profit. Among them was Lake Kampeska in Codington County, which furnishes the water supply for the city of Watertown with a population of more than ten thousand.

In November, 1933 the water level of this lake was about three and one-half feet below normal, according to reports kept by the City Water Department. This laid bare a large proportion of the lake bottom and caused serious trouble at the intake of the city water supply as well as spoiling the quality of the water for public use.

At the request of officials of the city of Watertown, the State Geologist made the investigation herein reported in an effort to determine whether a feasible plan for raising the lake level could be found. A week spent in field work, combined with valuable data furnished by the Watertown officials and engineers, yielded the information and suggestions contained herein.

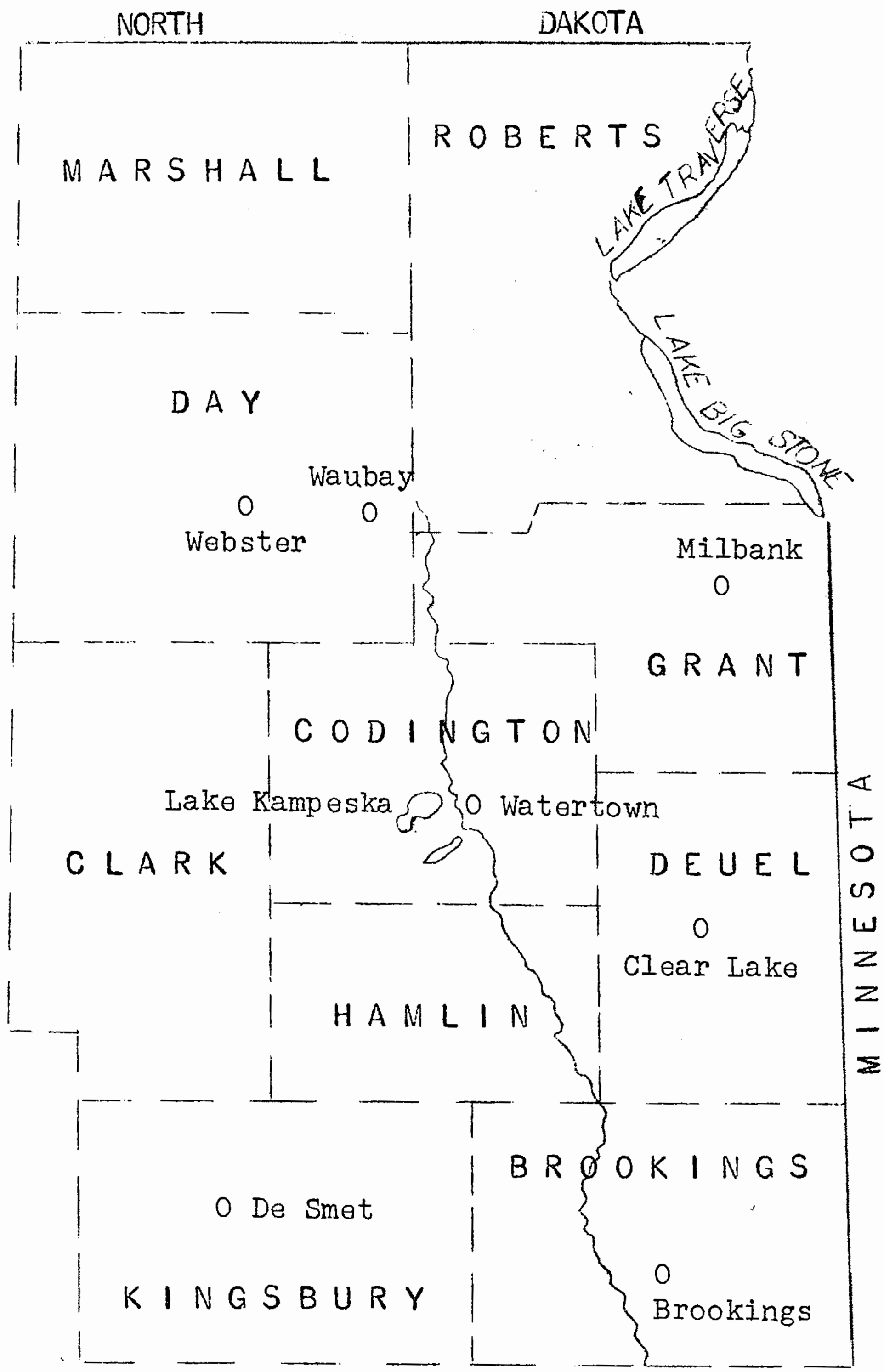



FIGURE I

INDEX MAP OF NORTHEASTERN SOUTH DAKOTA

SHOWING LOCATION

OF

LAKE KAMPESKA

# PART I

# THE WATER SUPPLIES OF LAKE KAMPESKA

# THE WATER SUPPLIES OF LAKE KAMPESKA

## Source of Water

Lake Kampeska, like all natural lakes in South Dakota, is of glacial origin. Its existence is due to the action of glacial ice which covered this section of the state in the geological recent past. It lies at the junction of three water channels down which torrents from the melting glaciers escaped to the Missouri River carrying with them enormous quantities of debris which eventually settled in the bottoms of the channels choking them with sands and gravels, and thus forming a large reservoir for the ground water which supplies Lake Kampeska (See Figs. 2 and 7). One channel enters the lake from the northwest where it follows the position of the ancient ice front, from the present Lake Porseline, a mile east of Medicine Lake, to Lake Kampeska. This channel, six miles in length and averaging two miles in width, carries an enormous volume of gravel in which rain water sinks readily, and through which it slowly moves southeastward into Lake Kampeska.

A second channel follows the present Big Sioux River, and its gravel fill was followed for more than ten miles north of Lake Kampeska. It probably could have been traced much farther as its head was some where in Roberts County. Five miles north of Lake Kampeska a side channel with an area of five square miles or more joins the Big Sioux channel. It may possibly extend farther west as the valley which it occupies can be traced past the city of Florence where it is also gravel filled. The slope of the Big Sioux valley and its tributaries is southward and ground water collecting in the gravels of both these channels eventually finds its way into the junction at Lake Kampeska.

A third channel enters the junction from the east following roughly the course of Gravel Creek. These gravels were evidently furnished by ice which lay in the vicinity of Punished Woman's Lake and poured its torrent down the channel occupied by the railroad station of Forestville. At the mouth of this narrow channel, gravels were spread over an area of approximately fifteen square miles and joined the gravels of the other two channels a mile southeast of Rauville. As the slope of this gravel deposit is southward all water collecting in it eventually runs into the junction at Lake Kampeska.

The three channels just described furnish the entire supply of water for Lake Kampeska. As shown on the accompanying geologic map (Fig. 7) no channel enters the lake from the southwest. Here it is surrounded by long clay slopes which rise westward for distances of a mile to a mile and a half. The rough clay

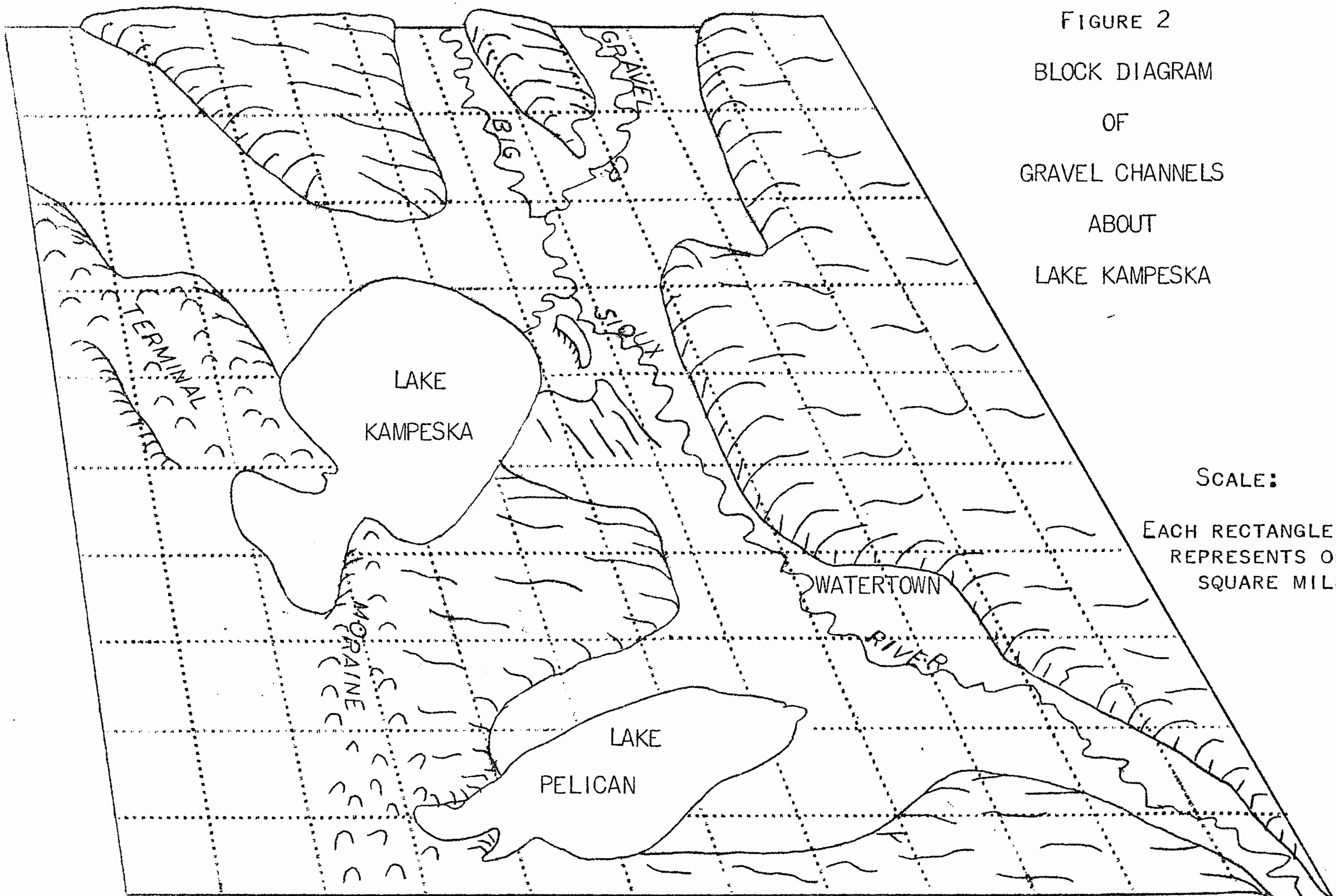



FIGURE 2

BLOCK DIAGRAM

OF

GRAVEL CHANNELS

ABOUT

LAKE KAMPESKA

SCALE:

EACH RECTANGLE
REPRESENTS ONE
SQUARE MILE.

hills to the south effectively block off any source of supply in that region. The amount of water added to the lake by rain and run off over these short slopes is negligible especially in years as dry as those under consideration. During rainy seasons when the gravels are well saturated with water much water flows through stream channels of the Big Sioux River and Gravel Creek, and some is reported to enter the lake through the channel known as "the Outlet". During dry seasons, however, when these channels are dry, the lake is fed entirely by underflow through the gravels. This water enters as springs at the northeastern end of the lake where the gravels are sixteen to eighteen feet deep. It will be seen, therefore, that the supply of water in the lake depends largely on the supply in the gravels of the three channels which feed it. The lake, therefore, will remain at its normal level so long as the ground water does not escape more rapidly than it is being fed into the lake.

## The Outlet

That the water is flowing out of Lake Kampeska is evidenced by the fact that the water is fresh. Lakes from which water escapes only by evaporation become alkaline. Medicine Lake, seven miles to the northeast of Lake Kampeska, is a good example. Its waters are so saline that medicinal salts are distilled from it. The only visible outlet for Lake Kampeska is the small channel, usually designated as "the Outlet", which connects it with the Big Sioux River. In dry years, it is empty since the bottom of the channel is approximately five to eight feet above the present (1933) water level.

It is evident, therefore, that the outlet of the lake is largely in the form of underflow. The only channel through which such an underflow could take place is through the gravels underlying the "Outlet" down the valley of the Big Sioux River below Lake Kampeska. As shown by gravel pits in the vicinity of Watertown, this valley is gravel filled to a depth of between ten and twenty-five feet, thus forming a continuous gravel and sand sheet, averaging more than a mile in width from Lake Kampeska past the eastern end of Lake Pelican and the city of Watertown to some point below the town of Appleby.

Lake Kampeska and the channel gravels belong to the same system. When the ground water in the gravel channels is high water is sent into the lake through springs, raising the level to correspond with the level in the gravel. When the level in the gravels is low, water seeps out of the lake by underflow and is lost down the channel of the Big Sioux.

## Suggestions on Controlling the Water Level in Lake Kampeska

Controlling the water level in Lake Kampeska during dry periods will have to consist of conserving as much water in the lake basin as possible. No large streams whose supply can be turned into the lake are available in this region. The two causes of water loss responsible for lowering the lake level are evaporation and underflow. The best data available indicate that the evaporation in this part of South Dakota will consume forty inches from an open water surface during normal years. In dry and windy years this is much increased. At this rate, Lake Kampeska is losing about five billion gallons a year during normal times. This is about 13,700,000 gallons per day. During a year of average rainfall, about twenty-two inches, the collecting area which supplies the lakes gathers about sixteen and one half billion gallons of water but when it drops to fifteen inches, only three billion gallons is supplied. In other words, in dry years, the rain water fails by about one billion gallons to supply the amount which is removed by evaporation. Weather reports show that the precipitation has been below normal at Watertown for several years.

| | |
|---|---|
| 1930 | 15.57 inches |
| 1931 | 19.27 inches |
| 1932 | 21.56 inches |
| 1933 | 12.31 inches |

Added to evaporation loss is the seepage due to underflow through the gravels of the Big Sioux valley. This underflow varies greatly with the height of the water in the lake, since it is this water level which controls the head under which the water flows through the gravels during dry weather. No measurement of the amount of water lost in this way has been made, but an approximation can be arrived at with a little computation. A natural dam crosses the valley near Watertown, approximately one and three quarters miles in length. It is overlaid with sand and gravel to an average depth of fourteen feet. When the lake is full, a gradient of more than one foot per mile is established in the underflow. Under this head water will move about two feet per day through medium sized gravel or coarse sand. Using these figures, the loss of water from the lake when it is full amounts to 1,900,000 gallons per day.

As the lake level lowers, this rate of seepage diminishes until it reaches a point where the head is entirely gone and no water moves in the gravel. This condition had been reached by the winter of 1933-34, when the head of water in the gravels was so low that water did not move into the lake fast enough to re-supply the evaporation loss. Water levels in the channel both east and southeast of the lake were higher than the level of the lake itself.

# THE

# BIG SIOUX GRAVEL CHANNEL

# AT

# WEST WATERTOWN

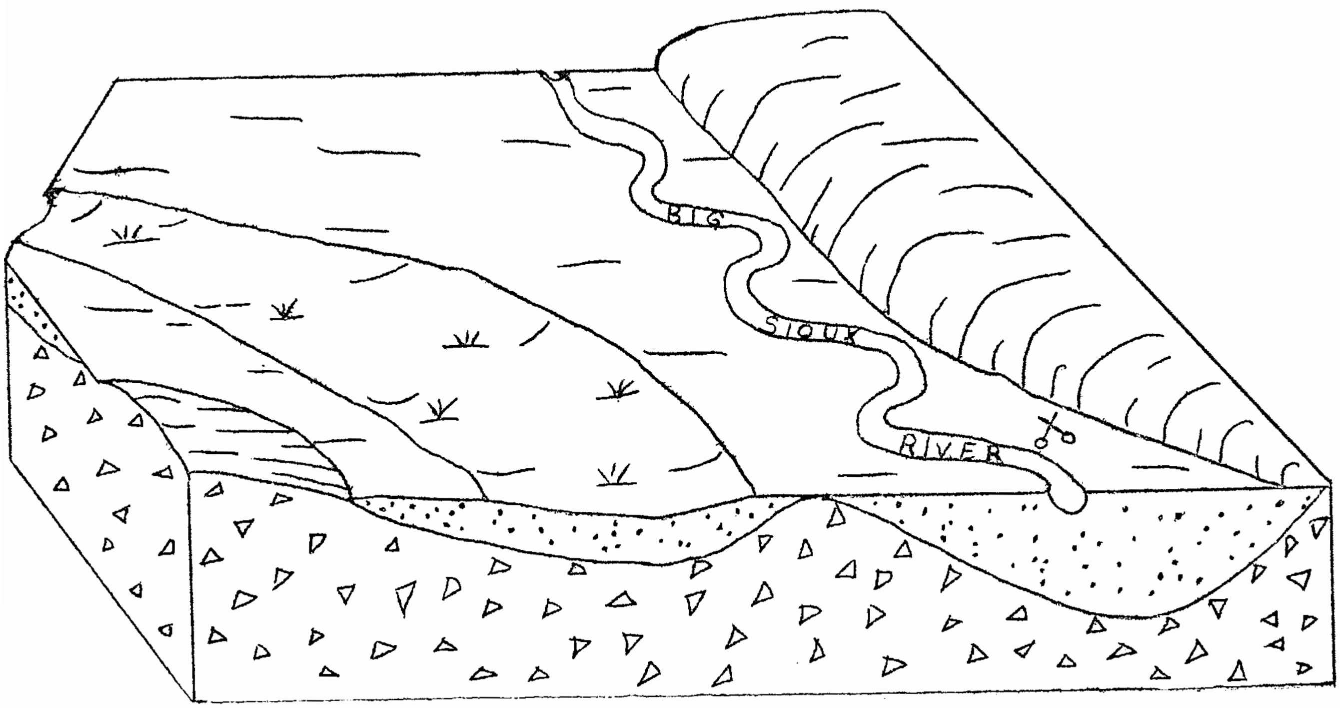



FIGURE 3

SCALE: 3 INCHES EQUALS 1 MILE.

LEGEND

SAND AND GRAVEL

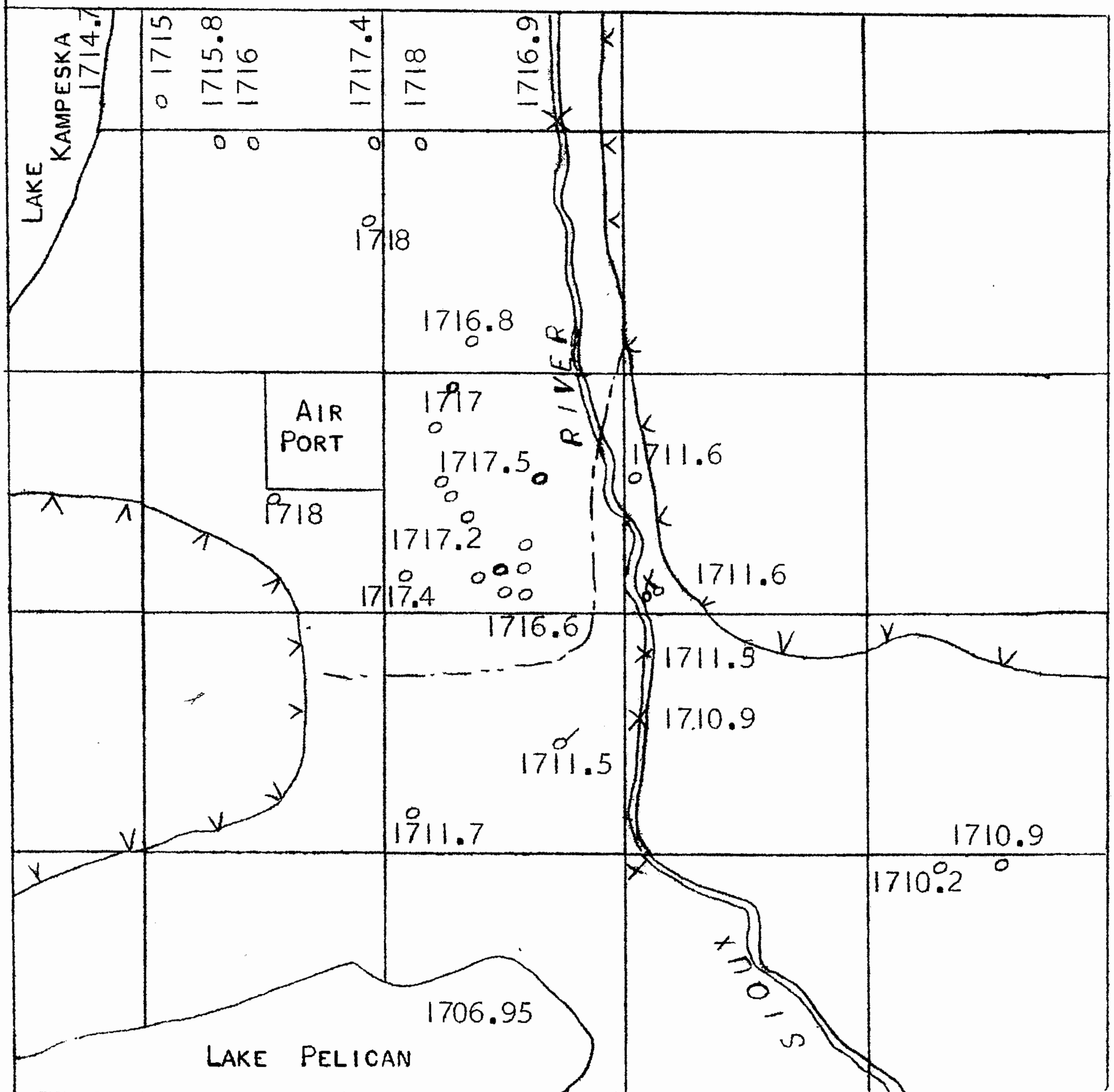
"CLAY" (GLACIAL DRIFT)

SWAMPY DEPRESSIONS

ZELLER GRAVEL PIT

## Figure 4

### Water Levels in the Big Sioux Gravel Channel at Watertown, S. Dak.




LEGEND

o Test Wells

Gravel Pits

River elevation

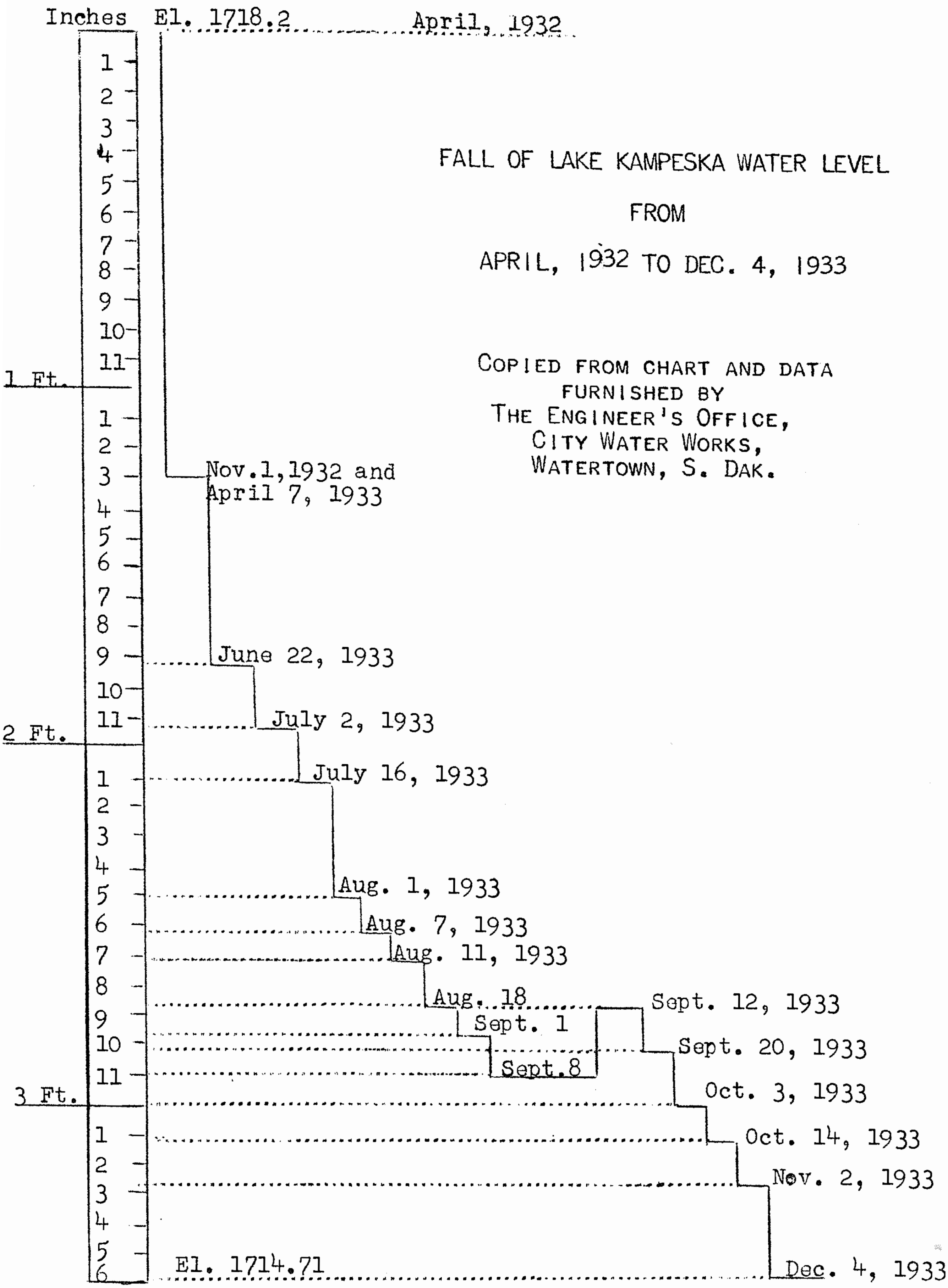
Scale 1½ inch = 1 mile

Position of natural dam

Edge of gravel channel

Figures indicate sea level elevations of water table measured December 1933

FIGURE 5

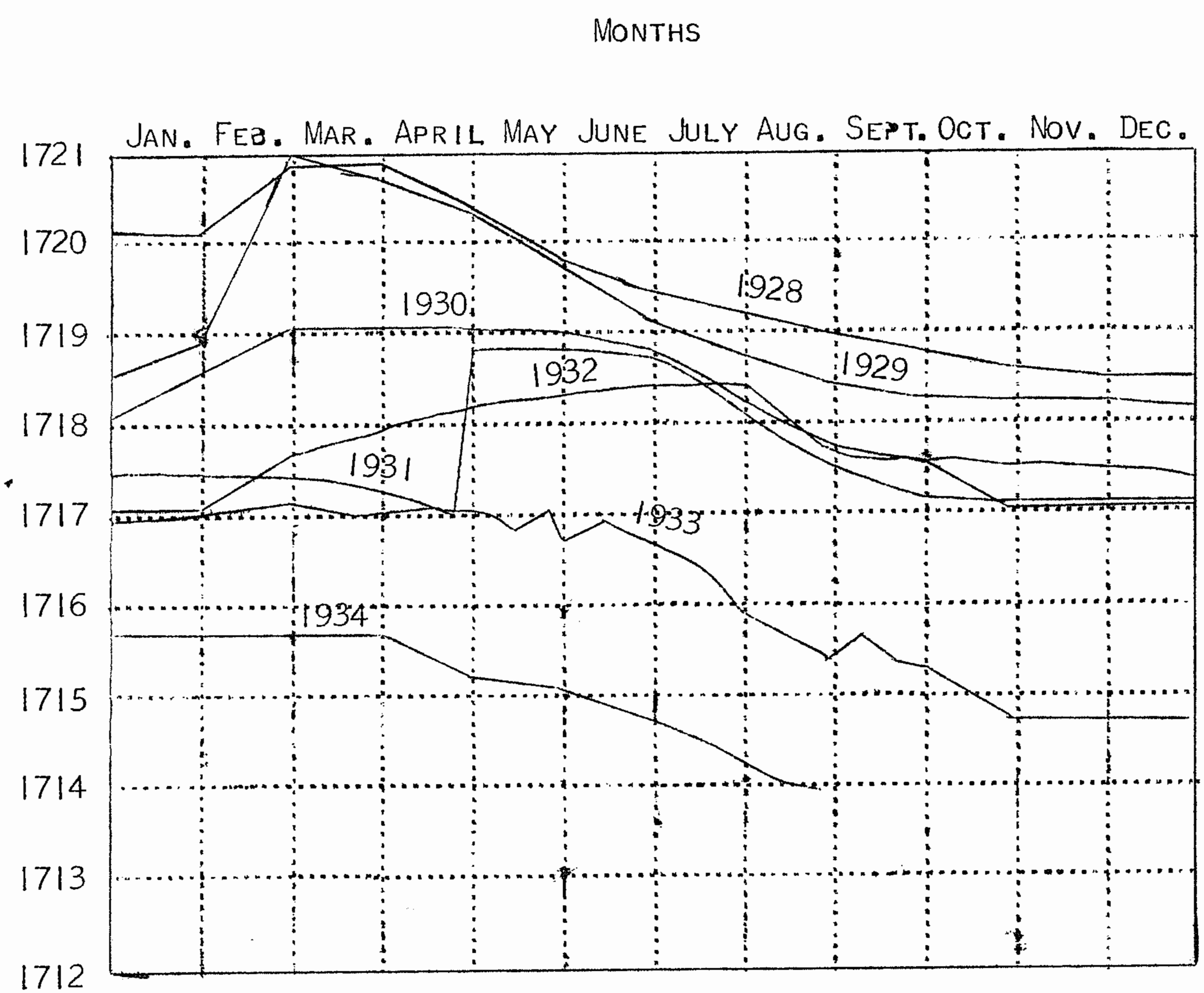



FALL OF LAKE KAMPESKA WATER LEVEL

FROM

APRIL, 1932 TO DEC. 4, 1933

COPIED FROM CHART AND DATA
FURNISHED BY
THE ENGINEER'S OFFICE,
CITY WATER WORKS,
WATERTOWN, S. DAK.




Fluctuation of Water Level
in
Lake Kampeska
1928 to 1934

Figure 5A

From the forgoing it is evident that checking surface runoff has little effect as a means of conserving the lake level. Surface runoff occurs only when the lake and its surrounding gravels are over full of water. During protracted drouths the lake level soon drops below the overflow level. Evaporation losses cannot be controlled by any practical means now available. Seepage loss however can be controlled to a considerable extent and this would have a retarding effect on the loss of water.

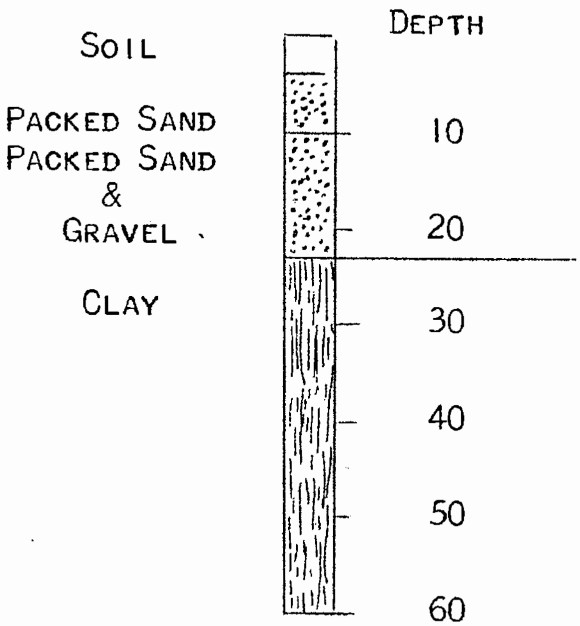
Seepage control could be accomplished by a subsurface dam across the valley at Watertown. Reference to the contour map of the clay bottom of the spillway at the back of this report, shows that a channel of deep gravels extends from Lake Kampeska southeastward across the present site of the Watertown airport to Watertown. An uneven clay surface forms minor channels and depressions in the spillway east of the large channel. At Watertown these channels end in a natural clay dam which projects eastward under the gravels from the western bluff of the spillway for about a mile. It then turns northward and joins the east bluff of the spillway about a mile north of Watertown.

This dam has effectively cut off seepage during dry periods. It is reported that during the drouth of 1893 and 1894 Lake Pelican became entirely dry and wagon teams were driven across its bottom at the deepest point while Lake Kampeska held water during the entire drouth. During the winter of 1933-34 the water levels in wells and test holes above the dam were 5 feet higher than were the levels in wells below it. This phenomenon shows that the dam is effective in retaining the water level at a sea level elevation of about 1717 feet and if it were not present the waters in the gravels and also the lake would have been drained out entirely.

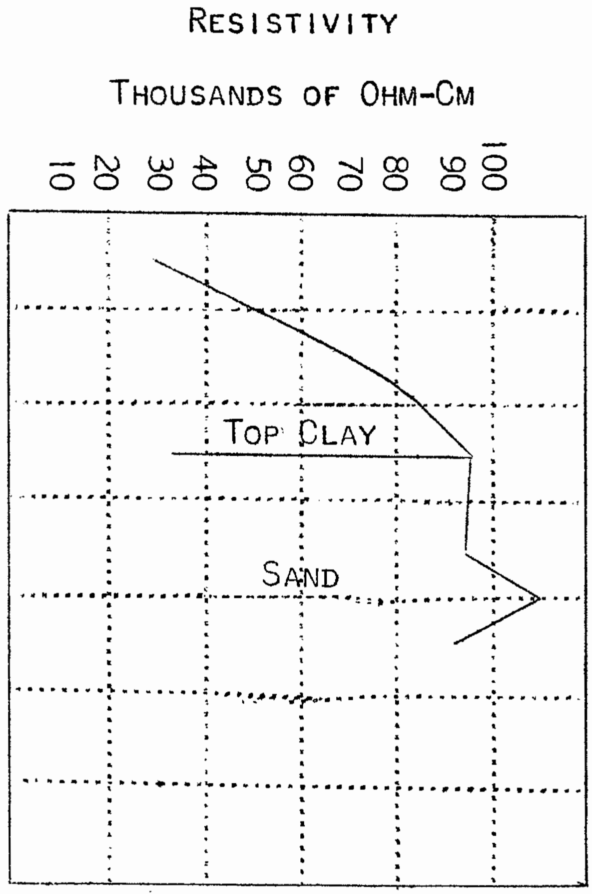
A clay filled ditch along the top of the natural dam could increase the level to any height at which it might be desired to impound water. To be effective however such a dam whether of clay, sheet-piling or other material, would have to be set on the clay bottom of the gravel channel. Otherwise seepage underneath the dam would render it only partially effective. The 1933 conditions suggest that a dam might be constructed to raise the water level to about 1720 foot elevation, that is 5 feet above the level at which the lake stood in the winter of 1933-34.

Such a dam might entail the flooding of depressions on the surface of the spillway unless the top of the dam was carefully planned to prevent it. As it is, the natural dam causes swampy areas in the spillway above it during years of normal rainfall.

Such seepage control could not guarantee a non-fluctuating lake level for Lake Kampeska, since seepage loss is but a small fraction of that produced by evaporation and since much depends on the supply of water fed into the lake from the gravel channels above it. It would have a retarding effect, however during times of dry weather and would create a greater storage capacity in the gravels, from which the city of Watertown could draw its supplies.




Log of Drilled Test Well




Resistance Curve
at
Test Well

Comparison of Resistance Curve

and

Drilled Well

N.W. corner of S.E. ¼, Sec. 36, T. 117 N, R. 53 W.

## THE GEOLOGY OF LAKE KAMPESKA

The following observations are not directly connected with the water supply problem of Lake Kampeska but are included here because they may be of use to those interested in the physiography and history of the region. No detailed geological investigation of the Lake Kampeska district is on record. It is fitting, therefore, that the scientific results of this reconnaissance should be recorded since they may throw some light on the geology and resources of the neighboring parts of South Dakota.

### The Bedrock

No exposures of bed rock were encountered during the survey, and no attempt was made to glean subsurface data from well logs or similar sources. From generalized information that is available it is assumed that the region is underlain by Cretaceous formations, including the Benton group and at least part of the Montana group. The published data on the subject indicates that Pierre shale forms the bed rock in Codington County.[1] Beyond these generalizations no statements will be made.

### Glacial Geology: General Statement

Lake Kampeska and its associated gravel channels owe their origin to the last of the four ice sheets which are known to have invaded the central part of the continent. As previously noted this lake lies in a region between the western edge of the Des Moines ice lobe and the eastern edge of the Dakota lobe of the Wisconsin ice sheet. These two lobes joined about fifty miles north of the lake forming a sharp reentrant in the ice down which both lobes drained. The valley of the Big Sioux carried the main streams of water and was sent by many outwashes and channels from both ice fronts. These drainage channels were cut in an older drift sheet, the remnants of which are still exposed on the highlands between the channels. Two distinct sets of glacial phenomena, therefore, are involved in the origin of Lake Kampeska;

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1. Darton, N. H., Geology of the Central Great Plains, U. S. G. S. Professional Paper 32, P. 216, 1903.
   Geological Map of South Dakota, S. Dak. Geological Survey, 1932.

the older drift sheet, whose surface characters determine the details of the drainage lines, and the younger drift sheet with its lake basins and attendant outwash deposits.

## The Older Drift

The location of the older drift is shown on the geologic map (Fig. 7). Its surface is characterized by long gently rolling slopes, so gentle in fact that much of it gives the impression of being flat. The surface is well drained, however, the valley being wide and shallow and swamps and undrained depressions being very rare. The drift carries pebbles and boulders in road cuts but they are not conspicuous on the surface. On the whole the surface gives the impression of a well drained surface which has been veneered with drift.

A similar drift topography was noted farther north in western Grant County where it lies between the lobes of the Wisconsin ice as it does in the vicinity of Lake Kampeska. It was also noted in Potter County, South Dakota, lying west of the western limit of the Dakota lobe of the Wisconsin ice sheet.[1] The topography in Potter County is described thus: "Long smooth slopes from the hills drain into stream valleys which eventually drain into the Missouri by way of the Little Cheyenne and Artichoke Creek. The swamps and lake beds which dot the surface of Faulk County (Wisconsin drift) so abundantly are almost entirely missing in Potter County. The few that do occur lie on the divide. * * * * The valleys are broad and shallow and toward the divide are not very definite. None of them contain permanent streams and even the channels are not marked in many."

No correlation of this drift will be attempted here, but it is of interest to note that Dr. Frank Leverett reported drift of Iowan age in the Big Sioux Valley of South Dakota.[2] The topography answers very closely the description given by Dr. J. E. Carman as characteristic of the Iowan drift in Iowa: "The entire surface of the Iowan drift is in slopes, mostly definite, but in some cases so gentle as to be almost imperceptible. The entire surface is therefore drained, although in some places poorly so. The undrained depressions which characterize the Wisconsin drift plain are entirely absent from the Iowan drift, but along some of the stream courses on the upland there are marshy areas and in several places the Iowan plain is so flat as to be poorly drained. * * * * A closer study shows, however, that the

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1. Rothrock, E. P., Sand and Gravel Deposits in Potter and Faulk County, Report of Investigation 11, Part I, Page 4, S. Dak. Geological Survey, 1932.
2. Leverett, Frank, Quaternary Geology of Minnesota and Parts of Adjacent States, U. S. G. S. Prof. Paper 161, pp. 29 and 58.

slopes are not long, smooth slopes due to erosion but are somewhat uneven and billowy and the valleys are more or less obstructed."[1]

## The Younger Drift

### Pre-Wisconsin Surface

The surface over which the last (Wisconsin) ice sheet moved into this region has been largely obliterated by the deposits of that glacier. Judging from the remnants of this surface now occupied by the older drift, it was very smooth with no great differences in elevation. Certain depressions persist, however, which, though cluttered with the debris from the Wisconsin ice, can still be readily traced and probably represent the master valleys of that region in pre-Wisconsin times. One such valley trends a little south of east and can be followed from the town of Wallace in the northwestern part of the county past Florence and into the Big Sioux Valley at a point six miles north of Lake Kampeska. It is filled with lakes and swamps which are sometimes designated as the "Chain of Lakes".

A second valley occupied by a similar chain of lakes lies south of the channel just described and empties into the northwest side of Lake Kampeska. In this channel lie Lake Nicholan, Medicine Lake and MacMillan's Lake.

A third valley is recorded by the depression in which Lake Pelican and Goose Lake lie.

The long gentle slope on the older drift surface points toward the Big Sioux Valley as being a depression probably occupied by a pre-Wisconsin stream north of Lake Kampeska. The information at hand will not permit of joining these scattered valleys into a system, but it is probable all four in some way connected. They probably flowed towards the southeast, bending near the city of Watertown to the southwest whence they flowed through the Pelican Lake depression and drained into the valley now occupied by the Vermillion River.

### Wisconsin Moraines

Over this surface ice moved westward from the Des Moines lobe in Minnesota until it reached South Shore in the northeastern part of Codington County. Here it deposited a scattered

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1. Carman, J. Ernest, Further Studies on the Pleistocene Geology of Northwestern Iowa, in Vol. XXXV, Iowa Geological Survey, pp. 40 and 41, 1931.

terminal moraine of which Punished Woman's Mound, two and one-half miles south of South Shore, is a conspicuous hill. Leverett calls this the Bemis moraine.[1] Near South Shore it filled a valley with a dam of drift which ponded the water in it, forming Punished Woman's and Round Lakes.

The Dakota lobe of the Wisconsin ice, which moved down the James Valley, spread eastward until its front halted near Lake Kampeska. A marked moraine some two miles wide and with very rough topography was built. Its position is shown on the diagram (Fig. 2) and geologic map (Fig. 7). It can be seen in a ridge of conspicuous hills five miles south of Pelican Lake which trend slightly west of north and skirt the extreme western edge of the lake. At this point the moraine bends to the northeast for three miles, ending at Stony Point in Lake Kampeska. On the opposite side of the lake it can again be picked up as a belt of very rough topography and follows almost directly northwestward to Medicine Lake. At Medicine Lake another bend to the northwest occurred and after crossing the two large valleys at Medicine Lake and east of Florence continues northwest on the west side of the Big Sioux Valley. The extremely rough topography of this moraine makes it easy to follow. Knobs and kettles with a fifty to seventy-five foot relief are closely packed. Kame-like gravel hills are common. Swamps and lakes mark its course. A large and conspicuous esker about two miles long lies back of the moraine northwest of Lake Kampeska.

Outwash

Much outwash was produced along the Wisconsin ice front in this vicinity, some washing over the slopes of the older drifts, but most of it collecting in definite channels and on outwash plains. The ice in the vicinity of Punished Woman's Lake discharged a large quantity of water down the channel in which Gravel Creek lies. Upon leaving this narrow channel about three miles south of the railroad station at Forestville, the water spread a great fan of gravel, covering fifteen or sixteen square miles north of Rauville, and discharged into the Big Sioux Valley northeast of Lake Kampeska, and the gravels connected with the gravels of the Big Sioux channel at this point.

Water also poured over the ice front between Lake Kampeska and Medicine Lake and built an outwash plain nearly three miles wide in front of the terminal moraine which connects those two lakes. This outwash plain covers about fourteen square miles. The waters which formed the outwash worked their way over and through the gravels toward the Big Sioux Valley to the east and joined the valley at Lake Kampeska itself.

At low points, such as the Pelican Lake Valley and the valley east of Florence, water poured off the ice, carrying with it

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1. Leverett, Frank, U. S. G. S. Prof. Paper 161, pp. 57-59.

enormous amounts of debris which were dumped as sand and gravels in these valleys between the moraine and the Big Sioux channel. The longest gravel filled channel was that now occupied by the Big Sioux Valley. It not only carried the run-off from the valleys mentioned, but also that from many other side channels which drained the ice fronts farther north.

## Origin of Lake Kampeska

Lake Kampeska lies in a hollow formed at the edge and in front of the Wisconsin ice sheet. Details of the origin are in part conjectural, but is evident that a large mass of ice, probably a tongue from the main glacier lay in a depression while sand and gravel were washed over and around it, probably covering it more or less completely. The fact that the lake is enclosed on all sides but the northeast by clay banks bears out this idea. This clay can be traced almost to the northeastern edge of the lake. Not far from the City Park the following section was taken:

| | |
|---|---|
| 4 to 6 ft. | Silt |
| 16 ft. | Gravel |
| 20 ft. | Boulder clay (till) |
| | Water Level |

These gravels perched on clay banks high above the Lake can be traced along the shore for nearly a mile between the City Light Plant and the City Park. From the City Park they can be seen as a scarp extending directly eastward for about another mile. From the lake and this scarp, the gravels slope to the southeast for about a mile, merging with the general level of the gravel flats of the Big Sioux Valley near Watertown. These gravels were probably deposited over the ice by waters which flowed across it from the outwash channel west of the Lake.

During or shortly after the high gravels were deposited, torrents flowing down the Big Sioux Valley and the Punished Woman's Lake channels added their outwash to that from the western channel, and washed gravel and sand in front of the ice tongue, making that part of the channel which is now occupied by the "Outlet" of Lake Kampeska and the Big Sioux River. This gravel fill at the northeastern edge of the lake is about sixteen to eighteen feet in depth.

The final retreat of the main ice sheet left the Kampeska ice block isolated and in more or less cold storage, since it was covered with glacial debris. The withdrawal of the main ice front also removed the possibility of further debris being added to the channels, and when the Kampeska ice block melted a hollow was left which was promptly filled with spring water flowing from the gravels. Thus Lake Kampeska as we know it today was formed.

CROSS SECTION ALONG SOUTHEAST SIDE OF LAKE KAMPESKA

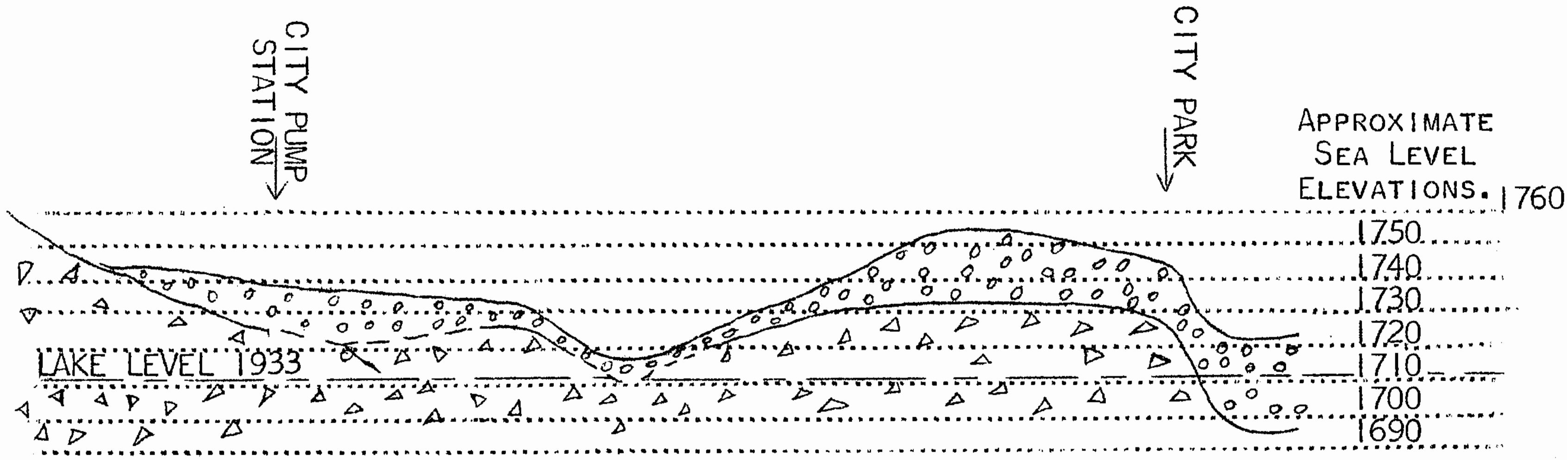
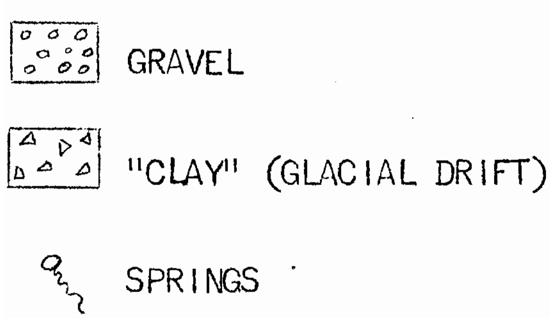
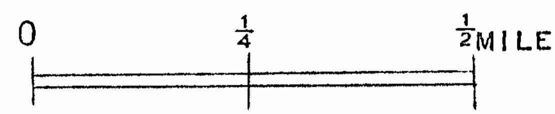



FIG. 6

LEGEND




SCALE



Though many details remain to be worked out, it is hoped that the preceding sketch of the geology of Lake Kampeska and its environs may prove useful as a summary of the situation and will lead to more definite knowledge of the drifts and history of the two ice sheets, whose remains have been briefly described in this report.