State of South Dakota

George T. Mickelson, Governor

STATE GEOLOGICAL SURVEY

E.P. Rothrock, State Geologist

REPORT OF INVESTIGATIONS

No. 59

# GROUND WATER FLUCTUATIONS IN EASTERN SOUTH DAKOTA

by

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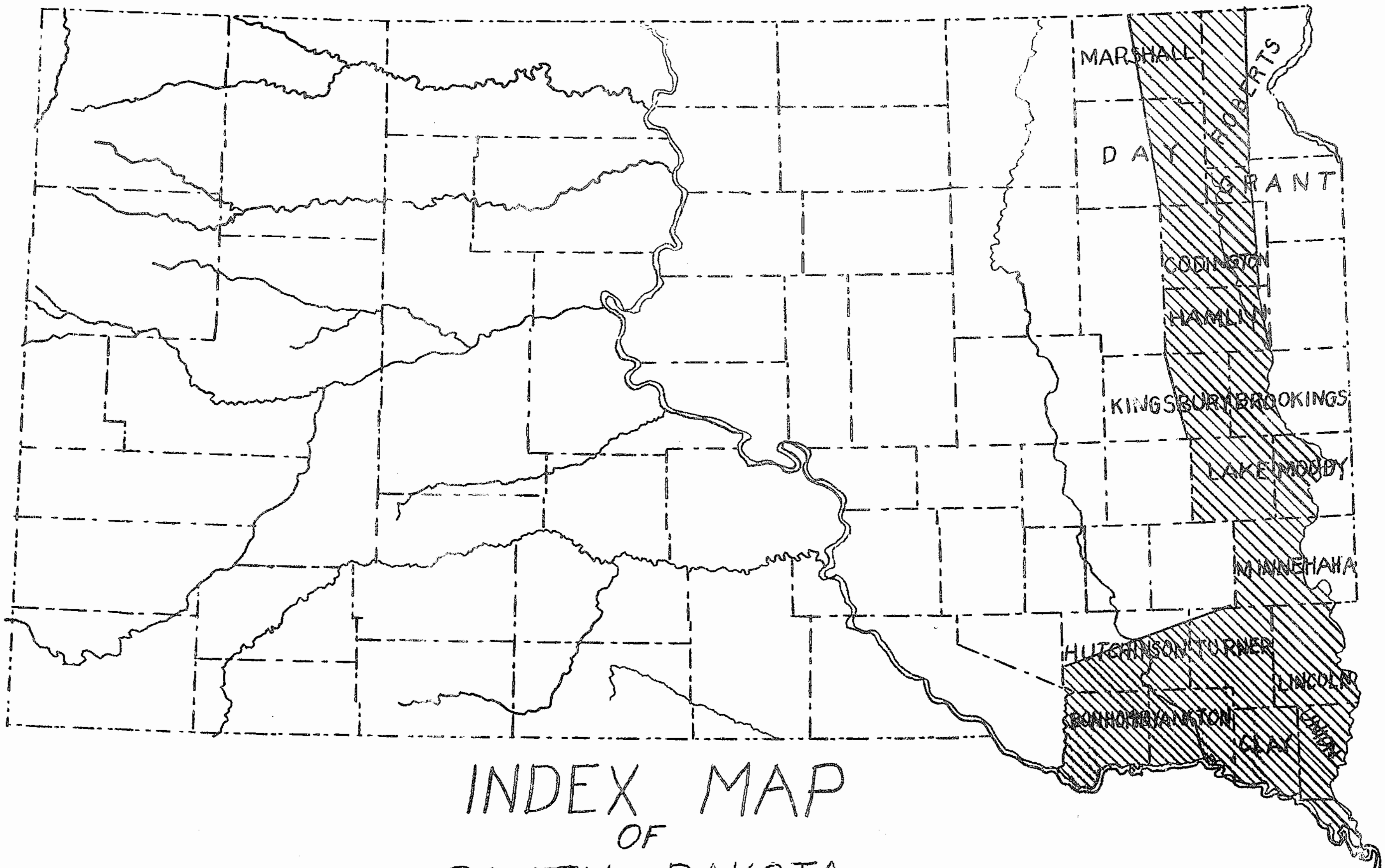
Vermillion, South Dakota
September, 1947

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# GROUND WATER FLUCTUATION IN EASTERN SOUTH DAKOTA

By

E.E. Caddes

## INTRODUCTION

The recent drought which made itself felt in 1932 and reached its climax in 1936 brought the importance of the water supply situation sharply to the attention of many persons in South Dakota. The drying up of many lakes and the depletion of city water supplies were the most noticeable manifestations. It became apparent at this time that an investigation should be undertaken to answer the questions arising in regard to city water supplies and possibilities of irrigating large and small areas in order to mitigate the lack of rainfall.

It became evident that the answer to most of these problems lay in the position of the ground water table; however no data was available either on its depth below the ground surface or the amount of fluctuation which might be expected during different times of the year or over long periods of time.

In 1935 when the lakes appeared to be at their lowest level, the State Geologist started a study of the elevations of various beaches reported by persons familiar with the lakes. It was thus possible to determine the rate at which the lakes had lowered. This study has been continued until the present time and now most of the lakes have again reached maximum fullness. These lake levels, therefore give an indication of the amount of fluctuation that can be expected in the water table of the region and the rate at which such fluctuation would normally take place.

A second attack on the problem was started in 1936 with the instigation of Dr. O. E. Meinzer of the Ground Water Division of the U.S. Geological Survey. At this time, the State Geological Survey started the measurement of the water levels in selected wells scattered over southeastern South Dakota and records have been kept of as many of these wells as possible since that time.

In November 1938 the State Geologist Dr. E. P. Rothrock and Dorothy Ullery compiled the information on ground water available to that date and published this data in Report of Investigations Number 30.

The following report is written for the purpose of compiling all of the data made available up to the present time.

## Ground Water and Water Table

The rock formations of the earth are great underground reservoirs in which a large part of the water that falls in the form of rain or snow is stored. After this water sinks beneath the surface of the earth it is called ground water. Water occurs beneath the earth's surface in two zones in which its presence and movements are markedly different. The lower zone is the zone of saturation and in it all openings and interstices of the rocks are completely filled with ground water. Movement in this zone is controlled by geologic structure, pore space and other characteristics of the water bearing materials. The upper zone is known as the zone of aeration. In it the openings of the rocks are largely filled with air. This zone is generally divided into three distinct belts; a capillary fringe, an intermediate zone and a belt of soil-water. Capillarity draws moisture up from the zone of saturation. The height to which this water rises varies with the size of materials, being only an inch or so in gravel and several feet in fine material. The belt of soil water constitutes the upper portion of the zone of aeration. It includes soil and other material near enough to the surface to discharge water in appreciable amounts into the atmosphere by evaporation. In places and at times when the soil water does not extend down to the capillary fringe there is an intermediate zone. This belt is thick where the top of the zone of saturation is low and thin or absent where it is high.

The zones of saturation and aeration are separated by the water table or ground water surface. The outcrop of this water table is marked by the uppermost limits of seepage, indications of which are, springs, permanently moistened areas, rivers, lakes, and swamps. This water level is not a plane surface, but has irregularities comparable with and related to, but not so pronounced as those of the land surface. It does not remain at a stationary position but fluctuates up and down. This fluctuation is due mainly to local gain and loss of water.

## Replenishment and Depletion of the Underground Reservoir

The underground reservoir is replenished mainly by that portion of the precipitation which sinks below the land surface. Various factors, the chief of which are rivers, springs, evaporation from lakes and swamps, and pumping from wells cause depletion of the ground water.

## Importance of the Ground Water Table

The importance of the ground water table is often somewhat overemphasized. As it is the boundary between the zones of saturation and aeration it records the level to which the subsurface reservoir is filled, the quantity of water stored, and the depth to the water supply. The depths of rivers and lakes depend on the height of this water table. Many city and rural water supplies also rely on water in the saturation zone.

The fluctuation of the ground water table has little effect on vegetation, however, as most plants are dependent on soil water for their supply. While the depths to which the roots of various plants go for water varies greatly, most of the ordinary grasses and field crops do not draw from depths of more than a few feet.

## Methods of Investigation

The water levels of lakes were determined by the establishing of permanent bench marks near the shores of the lakes investigated. Level lines run from these benches to the water surface of the lakes furnished the data used in this report. Where it was possible to do so, approximate sea level elevations were used. Where this was not possible the elevations of the bench marks were assumed. It is hoped that in the future sea level elevations can be brought to all bench marks, as a comparison of lake levels might shed considerable light on regional ground water conditions.

The water level of wells was measured with a steel tape weighted with a lead plummet. On each well the measuring point has been marked so that all measurements of a well are taken from the same point. In most cases abandoned or little used private wells are measured. The selection of such wells prevents errors which creep in when measuring wells that are pumped frequently. These errors are due to the cone of depression which forms around the well due to removal of water from the well. Unless the water bearing material is extremely porous, considerable time must elapse after each pumping to allow the water to reach its former level.

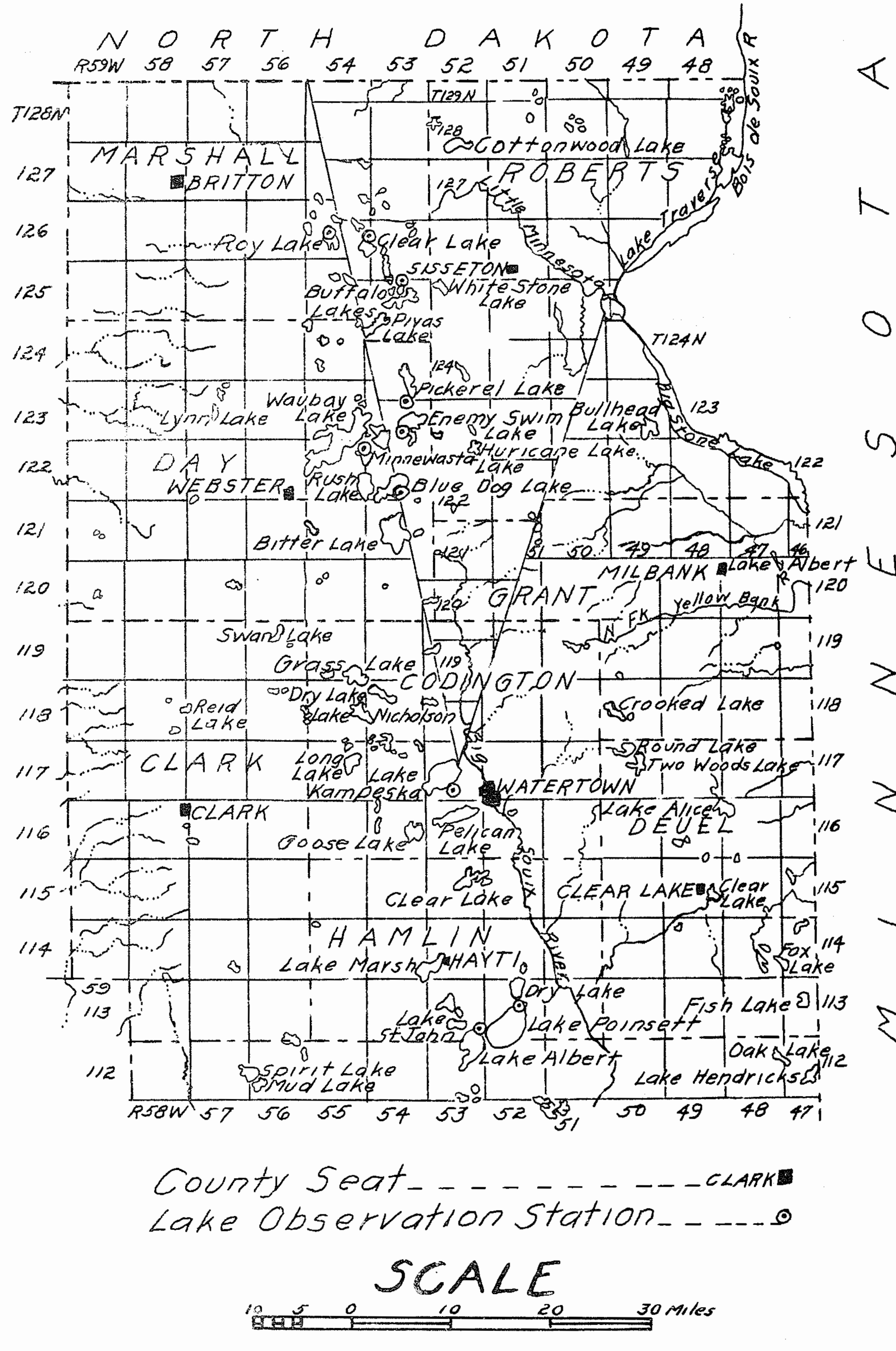
Lake levels are measured twice a year, once in the spring when the lakes should be at their highest level of the year, and once in the fall after drought and seepage have had a chance to bring them to their lowest levels. Unfortunately most of the readings had to be made in October or November before the minimum seasonal levels are reached. The lowest levels would normally come in December or January, but weather conditions make systematic readings at this time of year impossible. Though these seasonal readings are not as accurate as might be desired, they are within a few inches of the seasonal minumum. The record of Lake Kampeska, except for a few periods is continuous and is kept by the city of Watertown. It therefore, gives a much more accurate record than do those of the other lakes. Wells in the southeastern part of the State were read monthly and, therefore, give fairly accurate curves.

It is unfortunate that these records cannot be more complete, as a great deal of detail must necessarily be lost. The available information is, however sufficient to give a fairly clear and accurate picture of the rise and fall of the ground water table during the period covered by this report. It also shows the general trend of the water table fluctuations and the seasonal variations.

## Climatological Influences

The relation between weather and water levels was determined by the comparison of water level and precipitation curves. In one case, Buffalo Lakes, a temperature curve was also used. Weather information used was from U. S. Department of Commerce, Weather Bureau Climatological Data, annual and monthly reports, for the South Dakota Section. While other climatological factors, the chief of which are humidity and wind velocity, exert considerable influence on surface water levels, sufficient data was not available to determine their effect either on lake levels, or the ground water table.

# LAKE OBSERVATION STATIONS IN NORTHEASTERN SOUTH DAKOTA



# FLUCTUATIONS OF LAKE LEVELS

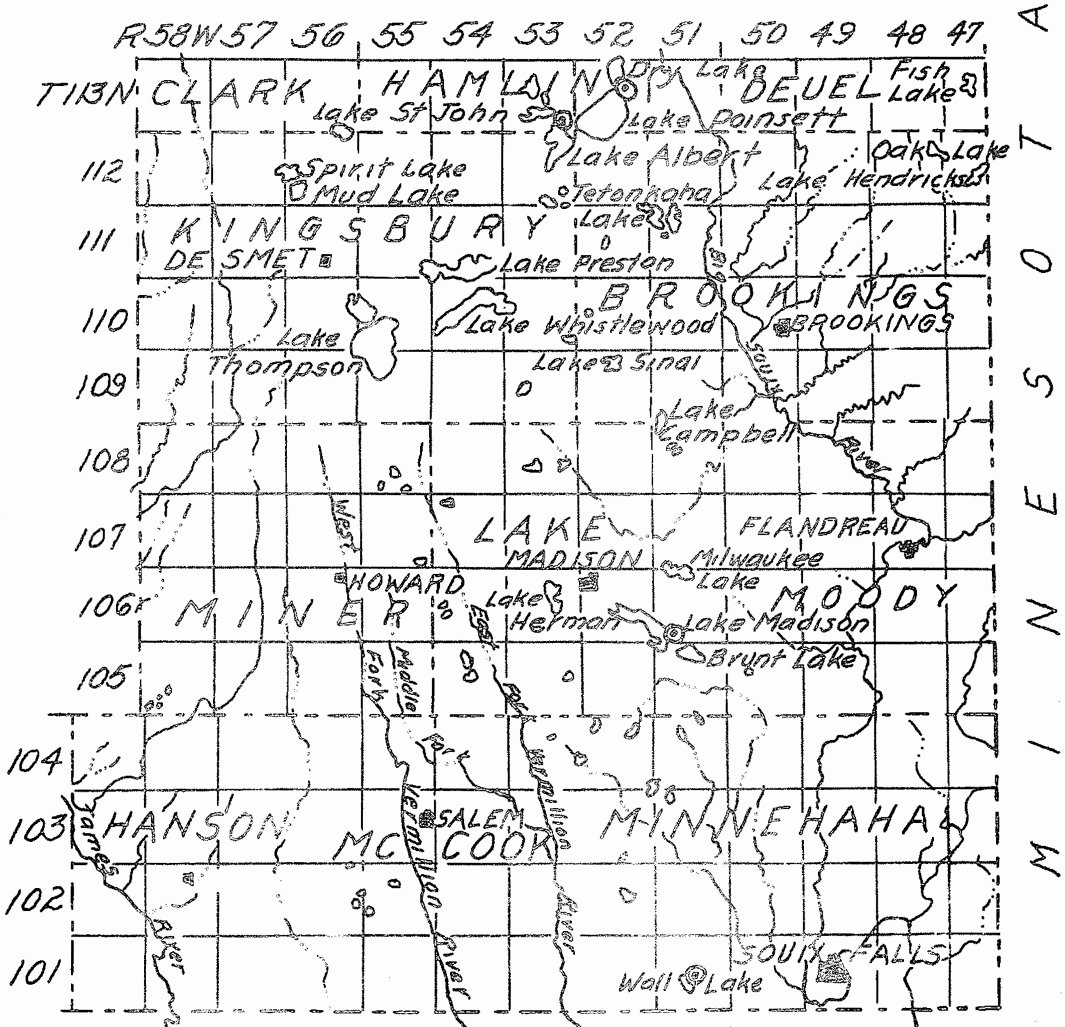
All of the lakes mentioned in this report lie in the Big Sioux Basin. As a matter of convenience they will be divided into three groups, each group including lakes in a region which has similar precipitation.

The first group lies in the northern Big Sioux Basin in Day and Marshall Counties. The lakes measured in this area were Clear, Roy, Buffalo, Pickeral, Enemy Swim, Blue Dog, and Minniwasta.

The central Big Sioux Basin includes Codington and Hamlin Counties. Lake levels were recorded of Kampeska, Poinsett, and Albert in this region.

Two lakes were measured in the southern Big Sioux Basin; Lake Madison in Lake County, and Wall Lake in Minnehaha County.

# LAKE OBSERVATION STATIONS IN EASTCENTRAL SOUTH DAKOTA




County Seat: ---------- SALEM

Lake Observation Station -----

SCALE

10 5 0 10 20 30 Miles

## North Big Sioux Basin

(Clear, Roy, Buffalo, Pickeral, Enemy Swim, Minnewasta, Blue Dog)

Clear Lake, lying in the east central part of Marshall County is skirted by South Dakota Highway Number 10. The lake has a surface area of approximately 1.8 square miles. Sea level elevations were carried to the water surface from a U. S. Coast and Geodetic bench mark in the gate post at the State Game Warden's station at the east end of the lake.

This lake made a temporary gain of about four and one-half feet from June 1936 until June 1937, after which time it decreased gradually until the fall of 1940 when it was almost dry. At this time a gravel bar divided the lake in two parts. The lake level rose rapidly from 1940 until June of 1945 at which time it apparently reached a maximum fullness.

Roy Lake lying a few miles west of Clear Lake in Marshall County is quite a large lake that was at one time a popular resort. The lake has a surface area of about 1.5 square miles. Along with the other lakes, Roy Lake became almost dry in the recent drought. According to a letter from Mr. G. Sommers of St. Paul, Minnesota, dated December 3, 1936, this lake was dry during the drought of 1894 and came back rather suddenly in 1910.

The bench mark used in water level measurements is a granite boulder about four feet in diameter on the west side of the lake and six feet west of a concrete house at Garland Park Resort. The elevations used were from an assumed datum plane, 100 feet being the elevation of the cross cut on the top of the boulder.

The records show that this lake remained at an almost constant level from 1935 to 1941, the lowest elevation occurring in the fall of 1939, at which time sticks and limbs were visible above water near the middle of the lake indicating only a few inches of water. The water level rose rapidly from 1941 to the present time and now the lake is full.

The precipitation data, used in plotting the precipitation curve of Figure 1, is from records of the weather station at Sisseton. While local showers may have resulted in a difference in rainfall at either Roy or Clear Lakes, the rainfall at either lake should correspond quite closely to the precipitation at Sisseton.

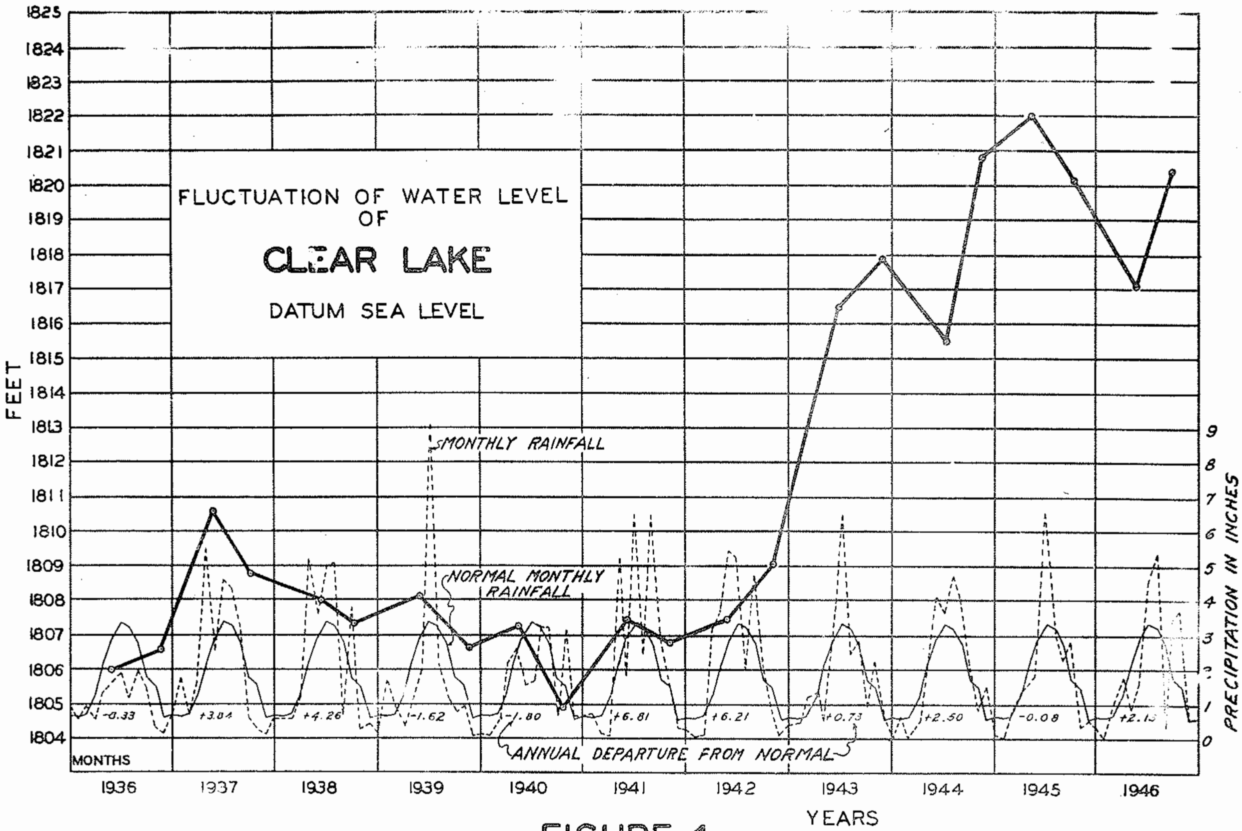



FIGURE 1

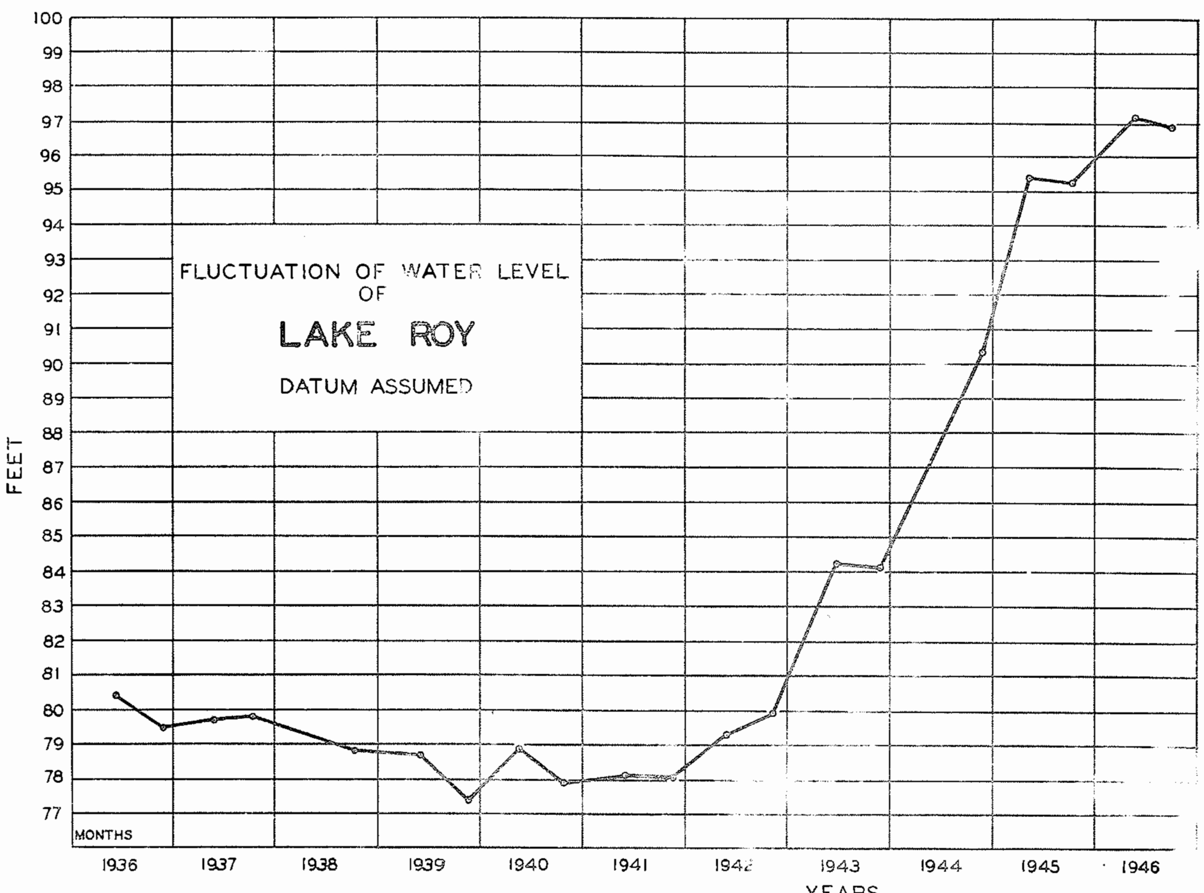



FIGURE 2

Buffalo Lakes (Figure 3) lie in the southeastern corner of Marshall County, about six miles west of the city of Eden. The lakes have a combined area of approximately four square miles and are quite shallow, their depth at the present time being about 14 feet. There were only a few small puddles near the middle of the largest lake in the fall of 1936. The water level rose about six feet in the spring of 1937, after which time it gradually dropped until 1940. It has shown a steady gain since 1940 and now is about 6 feet below the top of an ice wall, which probably marks the highest beach.

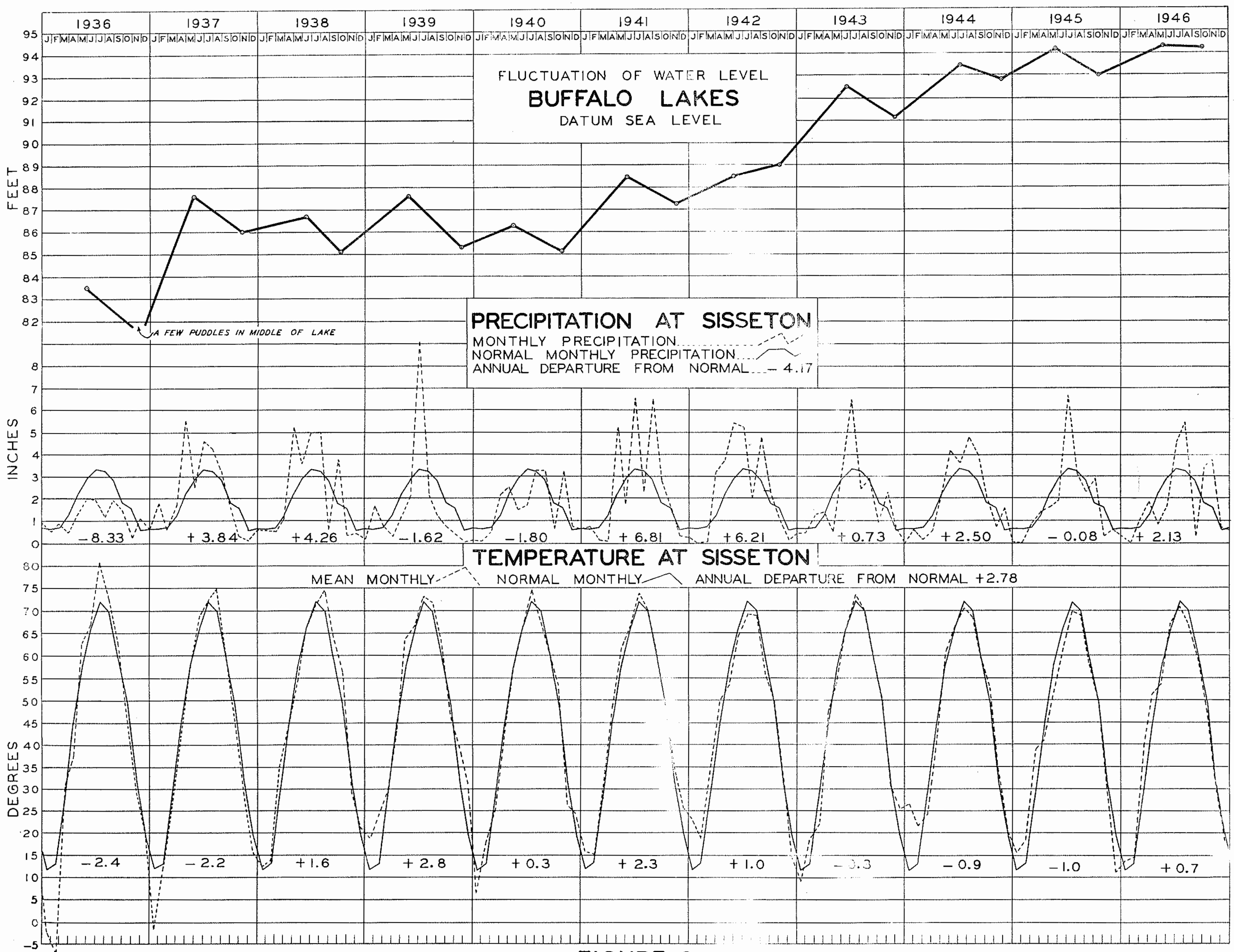
The water levels were measured from an X on top of a 3 foot granite boulder at the top of this ice wall near the Buffalo Lakes nursery and 100 feet east of the southwest corner of the garden fence.

The temperature and precipitation data is from records kept by the weather station at Sisseton, which is about 10 miles east of Buffalo Lakes. It is interesting to note that the fluctuations of the lake level correspond quite closely to the annual departure of precipitation from normal. This indicates that at this lake the normal annual precipitation of 21.99 inches is sufficient to hold the lake at a constant level, and that any departure from this normal precipitation will result in a rise or drop of the lake level.

Pickeral Lake (Figure 2) is located in the northeastern part of Day County. It is one of the most popular resort lakes in the state. The lake which is deep and narrow is surrounded by high moranic hills. It has a surface area of approximately 1.6 square miles and is reported to be about 60 feet deep. The lake is fed by runoff from a very small drainage area immediately surrounding it, seepage through the clay, and some large springs on the eastern side of the lake which are fed by a large gravel deposit. Apparently the only outlet is an overflow channel in the middle western side.

Measurements of this lake are taken from an X cut on a ciorite boulder which forms the top step of a short flight of stairs in front of the State Game Warden's cottage at the Fish Hatchery. The approximate elevation of this bench mark is 1836.3 feet above sea level.

The location of the 1928, 1932, 1933, and 1934 beaches is from information furnished by Deputy Game Warden, Ury Dahling. Since 1934 the water level has been measured twice a year.



FLUCTUATION OF WATER LEVEL
BUFFALO LAKES
DATUM SEA LEVEL
A FEW PUDDLES IN MIDDLE OF LAKE
PRECIPITATION AT SISSETON
MONTHLY PRECIPITATION
NORMAL MONTHLY PRECIPITATION
ANNUAL DEPARTURE FROM NORMAL — 4.17
TEMPERATURE AT SISSETON
MEAN MONTHLY
NORMAL MONTHLY
ANNUAL DEPARTURE FROM NORMAL +2.78
FEET
INCHES
DEGREES
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
J F M A M J J A S O N D
– 8.33
+ 3.84
+ 4.26
– 1.62
– 1.80
+ 6.81
+ 6.21
+ 0.73
+ 2.50
– 0.08
+ 2.13
– 2.4
– 2.2
+ 1.6
+ 2.8
+ 0.3
+ 2.3
+ 1.0
+ 0.9
– 1.0
+ 0.7


FIGURE 3

The water level of Pickeral Lake dropped slowly but at a fairly uniform rate from 1928 to 1936, then rose rapidly until in 1938 the lake had reached its maximum level. Since then the water level has never been more than a foot below the spillway. It is interesting to note that in the years from 1938 to 1941, a period when most of the lakes were almost dry, Pickeral Lake was full. This would indicate that the main source of recharge is a large gravel channel which stores the precipitation falling over a large land area. It also indicates that there is very little seepage from the lake.

Enemy Swim Lake lies about three miles south of Pickeral Lake in the eastern part of Day County. The lake, which has a surface area of approximately 3.3 square miles, is a popular fishing resort. It has not been dry during any of the droughts of which we have records. During the drought of 1890 to 1894 its surface area was reduced to less than two-thirds of its normal size, however, and the arms or bays were entirely dry. It was dry so long during this drought that a poplar grove grew across the south bay. During the summer of 1934 part of this bay was under 8 to 10 feet of water. The lake, in 1934, contained from 25 to 30 feet of water in its deep channels.

Enemy Swim lies in a gravel channel between two ranges of morainic hills. The Waubay moraine reaches its southwestern corner and forms the east bluffs of Campbells slough, which is a southern arm of the lake. The Pickeral moraine forms a long horseshoe around the northern end of the lake. The south and east sides are flanked by gravel hills of the outwash in front of the Pickeral moraine. The lake receives the surface runoff of the small drainage area immediately surrounding it. Its main supply of water, however, is from gravel channels to the north and east. An outlet channel to the south allows water to escape over the surface, in times of very high water, to Blue Dog Lake. Enemy Swim is also connected with Blue Dog by a gravel channel, which functions as the main spillway. The combination of these two outlets is sufficient to keep the lake water fresh.

The sea level elevations used in records of this lake were taken from highway profiles and, therefore, are only approximate. Three bench marks were set at the State Biological Station. They are: (a) SE corner of a concrete block used as a porch in front of the Biological Station's door (elevation 1840.5); (b) Eight penny nail three feet above the ground, in the north side of a cottonwood tree trunk on lower beach, southeast of laboratory, at the west side of the volleyball court (elevation 1836.0); (c) X on a concrete slab around the pump, at the south end of the camp, in front of the laboratory (elevation 1837.0).

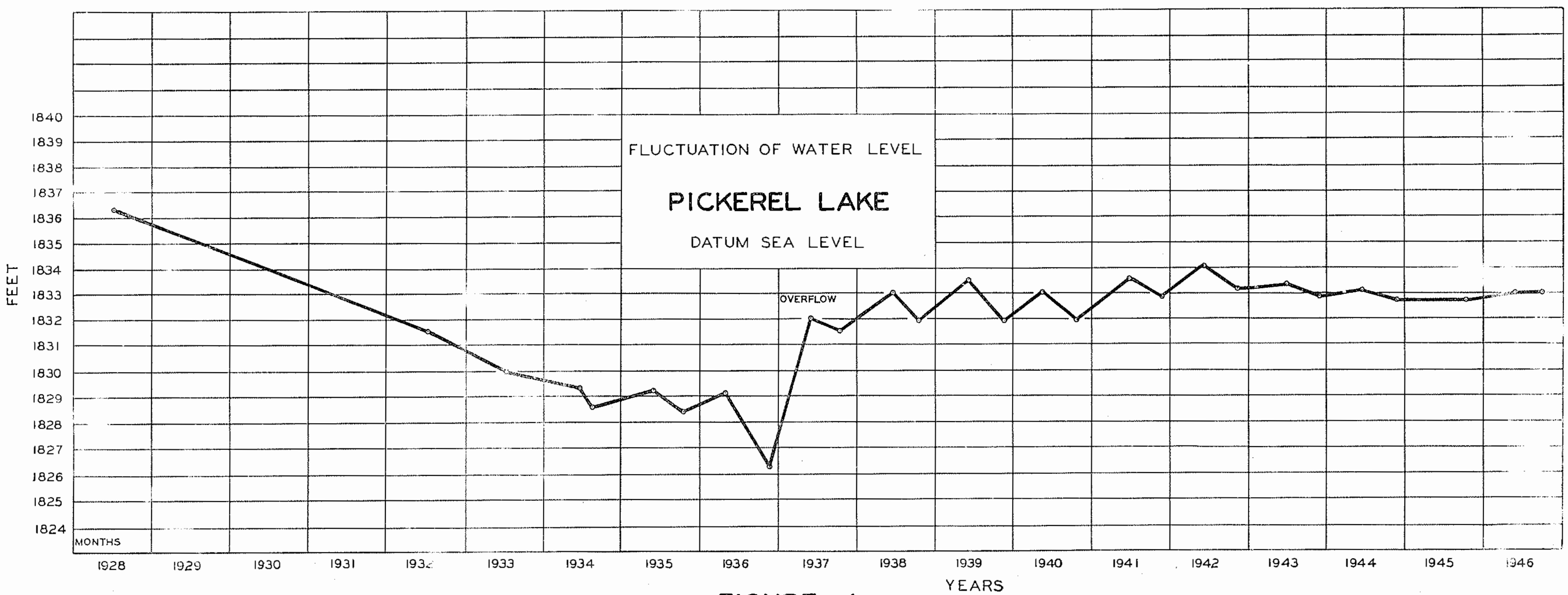

FLUCTUATION OF WATER LEVEL
PICKEREL LAKE
DATUM SEA LEVEL
FEET
1840
1839
1838
1837
1836
1835
1834
1833
1832
1831
1830
1829
1828
1827
1826
1825
1824
MONTHS
OVERFLOW
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
YEARS

FIGURE 4

The water levels previous to 1934 are from beaches identified by Professor S. R. Lipscomb of Northern State Teachers College, Director of the Biological Station, and several residents of the region. Measurements of the water level, have been taken twice a year since 1934.

The graph of Figure 5 shows the water level fluctuations through a complete cycle. It is of interest to note that both the decline and rise of Enemy Swim were slower than most of the lakes studied.

The data used to plot the precipitation curves of Figure 5 is from records of the Weather Bureau Station at Webster.

Blue Dog Lake lies at the northwest edge of the city of Waubay in Day County. It is quite shallow and has a surface area of about two square miles.

Blue Dog and Enemy Swim Lakes are in the same gravel channel. Blue Dog, however, lies about forty-five feet lower than Enemy Swim, making a gradient of about ten feet per mile between the lakes. This gravel channel is the main inlet since the surface drainage is confined to the hills immediately surrounding the lake. The seepage through this gravel has been sufficient to keep the lake full except for a short period during the recent drought when the water level was down about three or four feet. The outlet is largely seepage through the gravel channel which runs southward to Bitter Lake. An indefinite channel connects Blue Dog and Bitter Lake but carries a stream only in times of high water. The surface of Bitter Lake is about 25 feet below that of Blue Dog resulting in a gradient of 8 or 10 feet per mile in the gravels connecting the lakes. This outlet is sufficient to keep the lake water fresh, by carrying off the excess salts that would otherwise accumulate and make the water undesirable for ordinary purposes.

The elevations used in measurements of this lake were taken from a chiseled cross on the boulder used as the northwest pillar of the dance hall in the Waubay City Park. The elevation of this bench mark is 1789.9 feet above sea level.

Lake Minnewasta lies directly across the gravel channel between Waubay and Bitter Lake immediately southwest of Enemy Swim. It is a small shallow lake with an area of less than a square

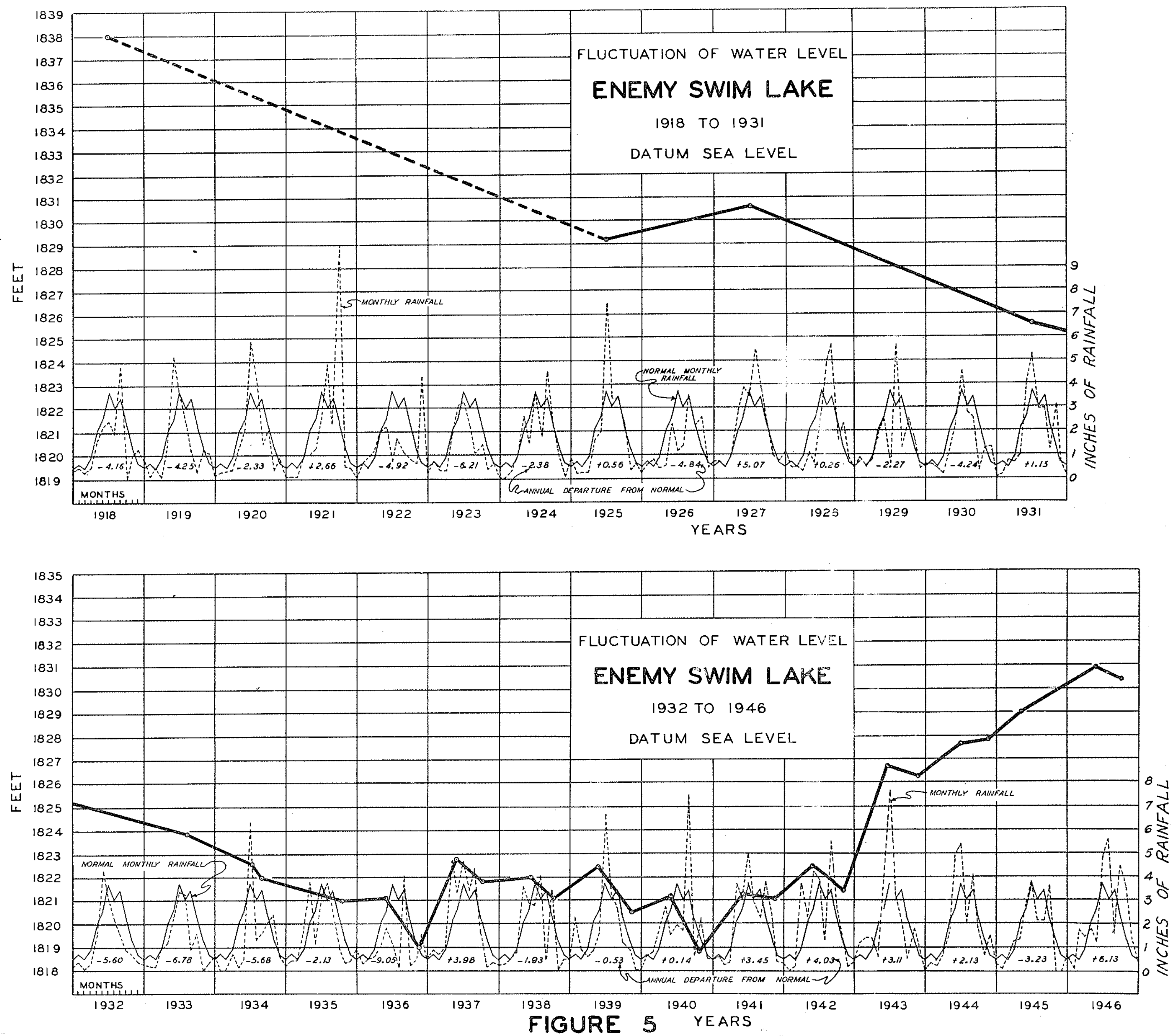

FLUCTUATION OF WATER LEVEL
ENEMY SWIM LAKE
1918 TO 1931
DATUM SEA LEVEL
FEET
INCHES OF RAINFALL
MONTHLY RAINFALL
NORMAL MONTHLY RAINFALL
ANNUAL DEPARTURE FROM NORMAL
MONTHS
YEARS
-4.16
-4.25
-2.33
+2.66
-4.92
-6.21
-2.38
+0.56
-4.84
+5.07
+0.26
-2.27
-4.24
+1.15
FLUCTUATION OF WATER LEVEL
ENEMY SWIM LAKE
1932 TO 1946
DATUM SEA LEVEL
FEET
INCHES OF RAINFALL
NORMAL MONTHLY RAINFALL
MONTHLY RAINFALL
ANNUAL DEPARTURE FROM NORMAL
MONTHS
YEARS
-5.60
-6.78
-5.68
-2.13
-9.05
+3.98
-1.93
-0.53
+0.14
+3.45
+4.03
+3.11
+2.13
-3.23
+6.13

**FIGURE 5**

mile and a maximum depth of about 14 feet. In ordinary times it drains southward to Rush Lake; however their elevations are so near the same that at times an overflow of Rush Lake backs into Minnewasta.

From 1936 to 1942 the lake consisted of only a small puddle near the middle. It was completely dry in the fall of 1939. In the spring of 1943 the lake filled up rapidly and has remained full or overflowing since that time.

Sea level elevations were carried to Minnewasta by levels to Waubay Lake and then from the water level of Waubay to the water level of Minnewasta. This of course gives only approximate elevations, but sufficient accuracy was obtained to make the elevations useful in comparison with other lakes in the vicinity. The bench mark used to measure the water level is a screw driven into the southwest side of a lone elm tree, on top of the highest gravel beach on the Helwig farm. The elevation of this bench mark is 1793.6 feet above sea level.

The elevation of Minnewasta was obtained in 1934 in respect to sea level and the elevation of this bench mark established as 1781.5 feet above sea level. In 1935 Dr. E. P. Rothrock found that the 1934 elevation of this bench mark was 12.1 feet too low and that it should be 1793.6 feet. The data on this lake published in Report of Investigations No. 30, Ground Water Fluctuations in Eastern South Dakota in November 1938 was computed from the 1934 elevation of the bench mark, and therefore all water levels of Minnewasta in the report are 12.1 feet too low.

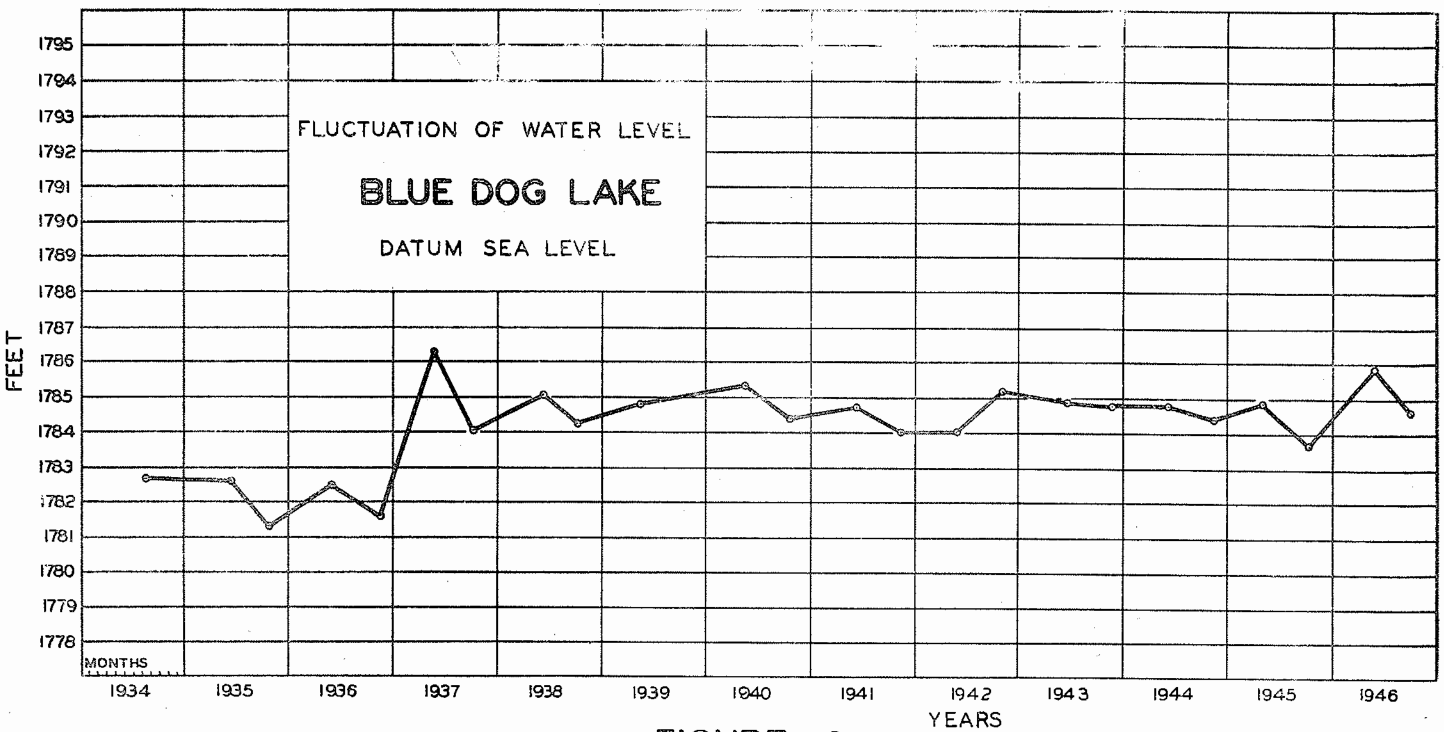



FIGURE 6

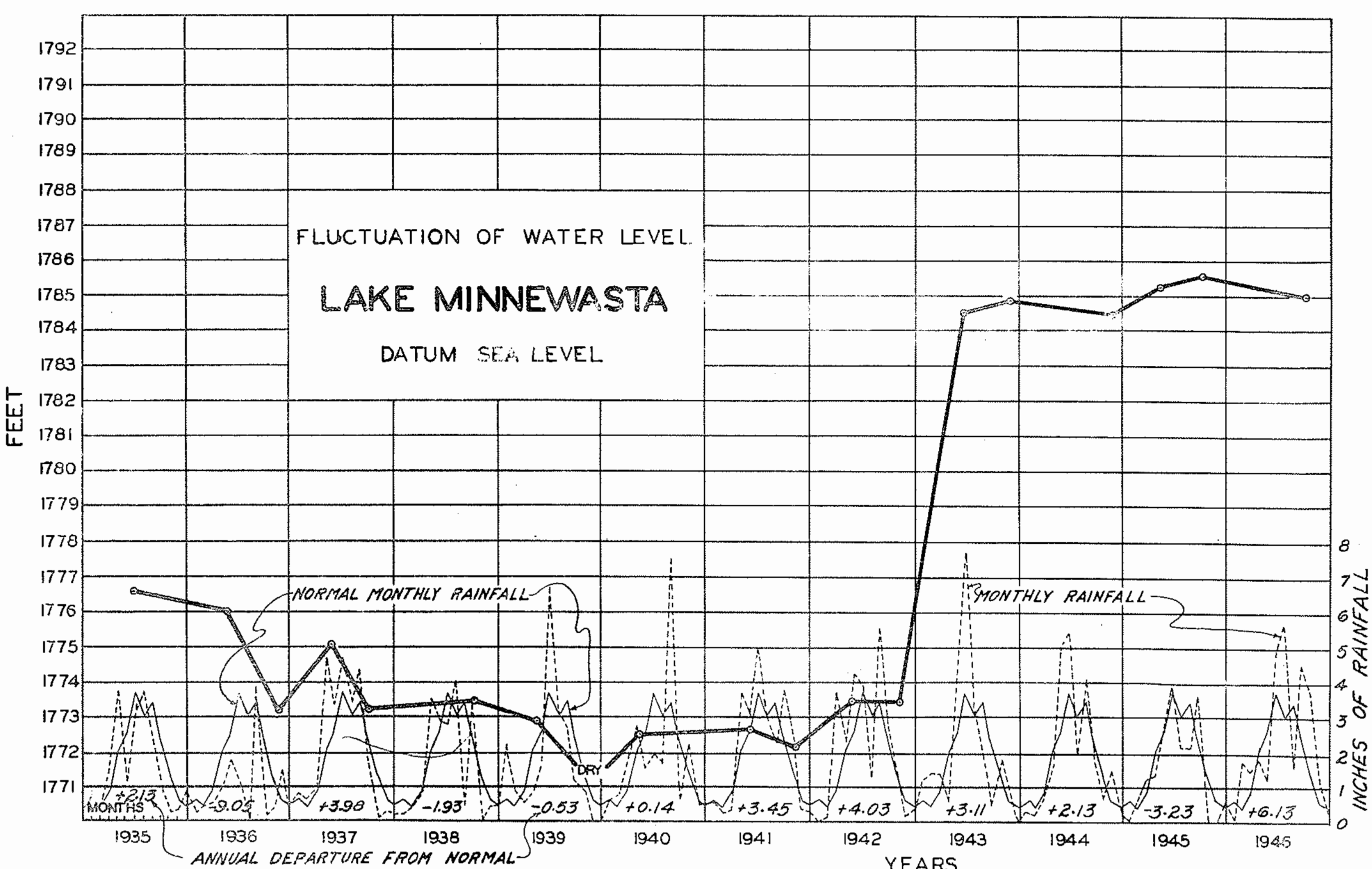



FIGURE 7

## Central Big Sioux Basin

(Lakes Kampeska, Albert, and Poinsett)

Lake Kampeska is a large shallow body of water about two miles northwest of the city of Watertown in Codington County. The lake which has a surface area of about 4.4 square miles lies at the convergence of three large gravel channels from the north. These gravel channels furnish the major portion of the lakes water supply. While it has an overflow which functions during wet periods, its principal outlet is through a gravel channel to the south along the Big Sioux River.

Kampeska had only a small puddle of water near the center from 1934 to 1936. While it did not go dry during either the recent drought or the drought of the 1890's its sister lake to the south, Pelican Lake, was dry during both of these droughts.

The data used in plotting the water level curve of Figure 8 is from observations made by Ralph Reed, the city engineer of Watertown. The precipitation data is from climatological records of the U.S. Weather Station at Watertown. It is of interest to note the close conformity of the water level and accumulative departure of precipitation from normal curves. The few non-conformities between the two curves are probably due to local precipitation conditions in the drainage areas to the north.

The rapid rise of the lake level in the spring of 1937 and the fact that Kampeska has been either full or nearly full since that time indicates that the drainage area of the lake is sufficient to keep the lake at maximum fullness except during periods of extreme drought.

Lake Albert, (Figure 9) is in the southeastern part of Hamlin County and the northeast corner of Kingsbury County, a short distance southwest of Lake Poinsett. It is a large shallow body of water with a surface area of approximately six square miles. The lake was dry in 1937; but is now full. There were no measurements taken of the lake level prior to 1942; but since that time it has been measured twice a year.

Elevations are taken from a cross chiseled in the top of a large limestone boulder at the east end of the lake, 100 feet

# ACCUMULATIVE DEPARTURE OF MONTHLY PRECIPITATION FROM NORMAL AT WATERTOWN AND WATER LEVEL OF LAKE KAMPESKA

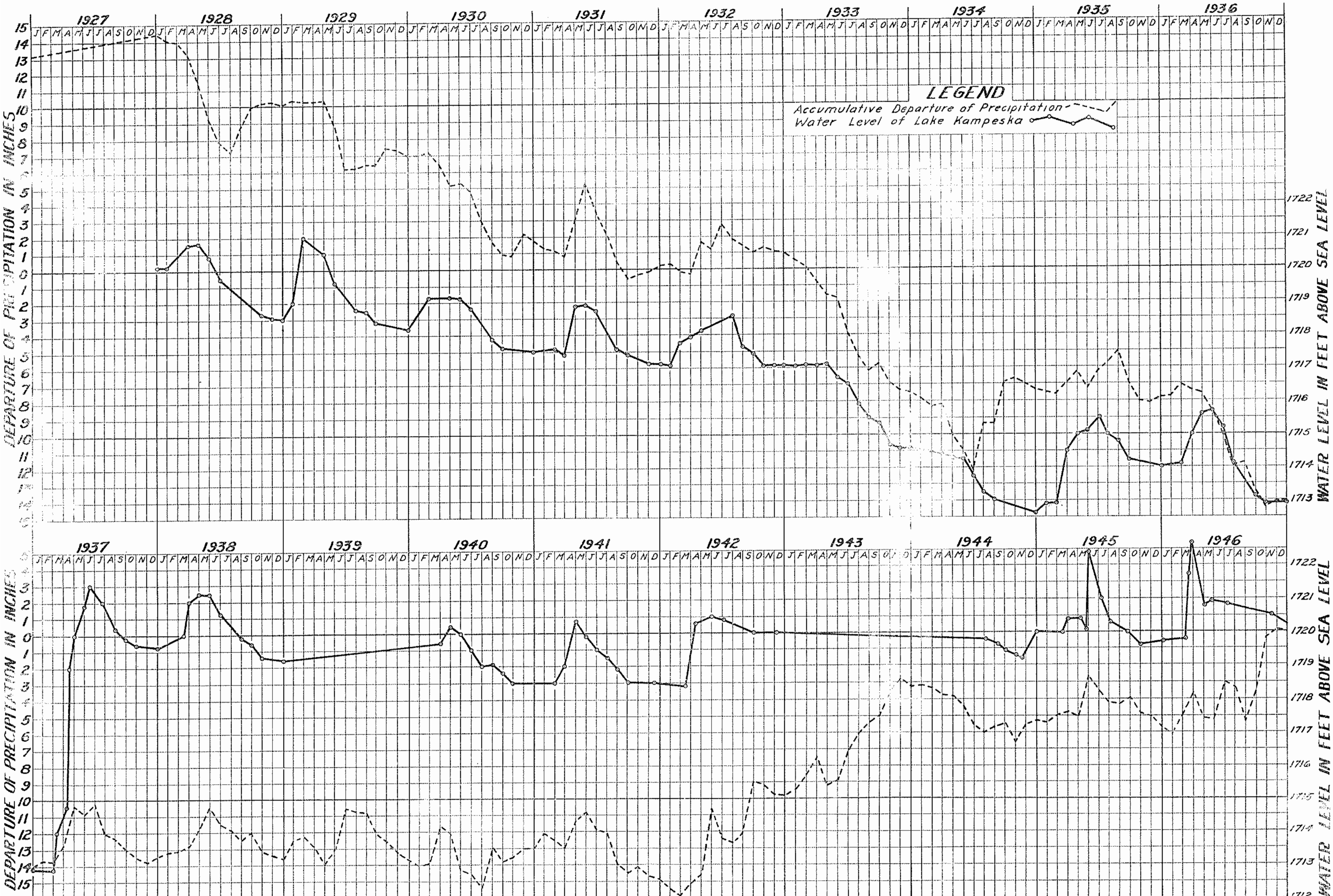



FIGURE 8

north of a point on the lake opposite A. Sorenson's lane and mail box. This bench mark has an assumed elevation of 100 feet.

<u>Lake Poinsett</u> is a large shallow body of water in the south-eastern corner of Hamlin County and the northwestern corner of Brookings County. It has a surface area of about 12 square miles.

Evaporation losses are large and probably keep the lake level below the water table of the surrounding area much of the time. The wide mud flat which surrounded Poinsett during the recent drought attests to this fact. However the fluctuations of the water table in the surrounding area should be similar to the fluctuations of the lake level.

Water levels are measured from a chiseled cross on the south-west rail of the concrete bridge which spans the waterway between Poinsett and Dry Lakes. This bench mark has an assumed elevation of 100 feet.

The data used to plot the precipitation curves of Figure 10 is from records of the Weather Station at Castlewood.

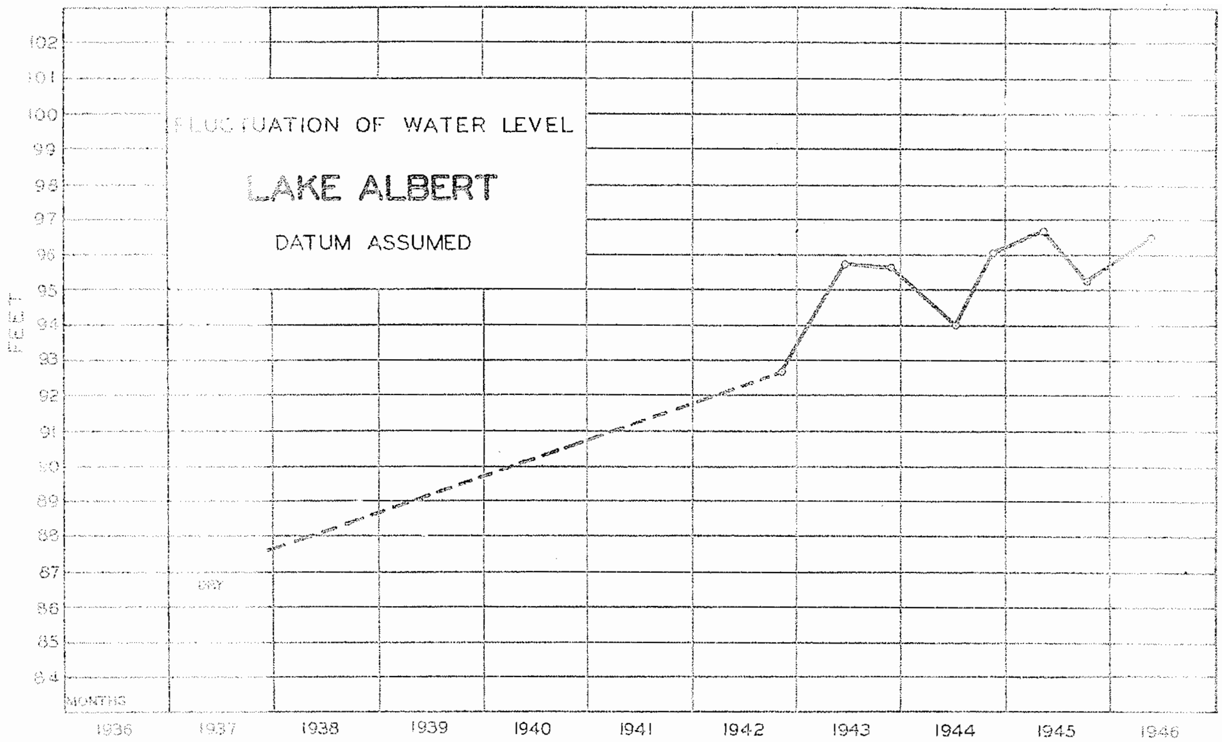



FIGURE 9

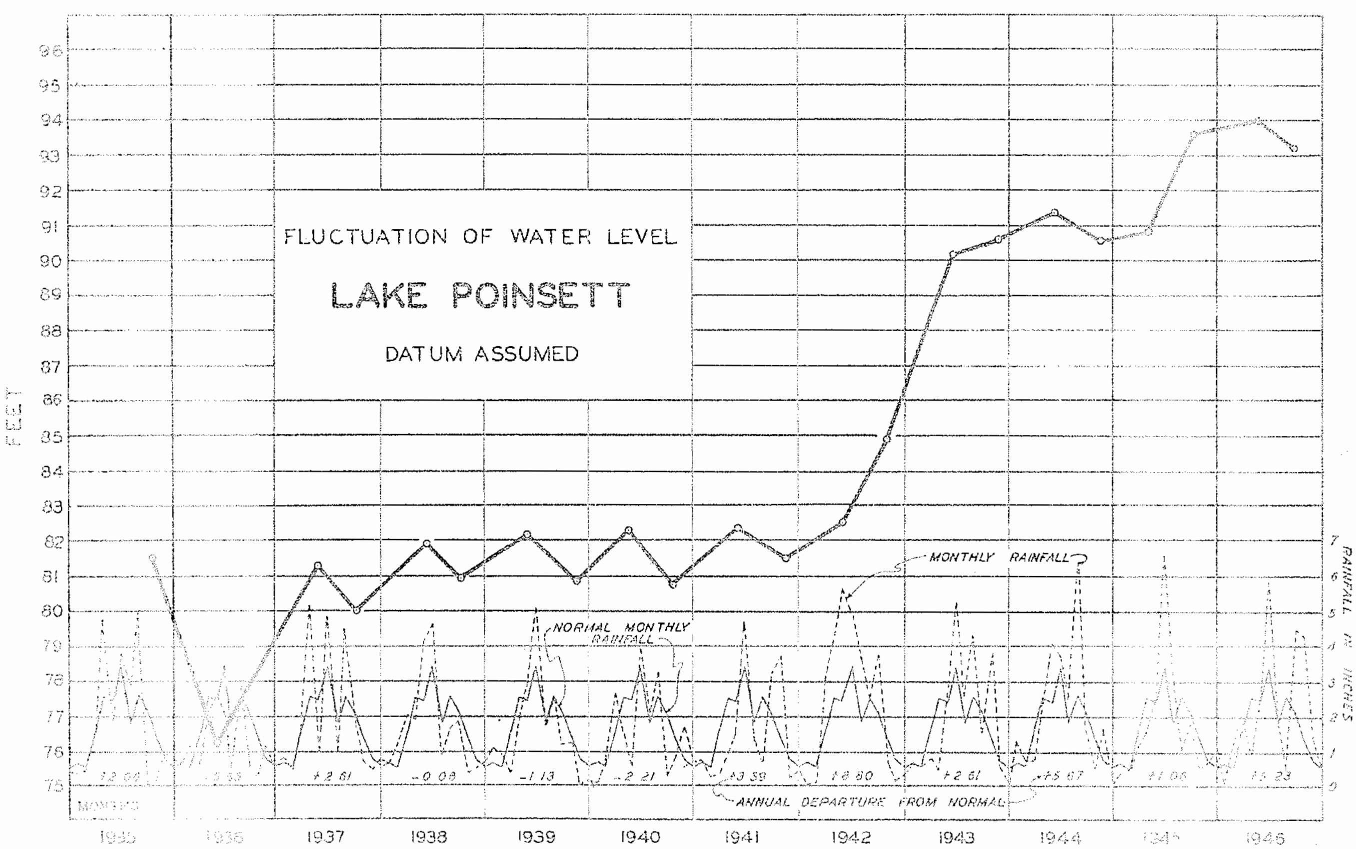



FIGURE 10

## Southern Big Sioux Basin

(Wall Lake and Lake Madison)

Wall Lake, (Figure 11) in the southern part of Minnehaha County about 12 miles west of Sioux Falls, is a small shallow kettle lake. The lake, which has a surface area of about one-half square mile and a maximum depth of about ten feet, is surrounded by clay hills and is not therefore subject to rapid fluctuation due to seepage. It was dry in the fall of 1940 and in 1941 but is now full.

The data for the precipitation curves is from records of the Weather Bureau Station at Sioux Falls.

Lake Madison is much used as a resort lake. It is a long shallow body of water in Lake County about two miles southeast of the city of Madison. The lake, which covers an area of over four square miles, lies in the gravel channel connecting Lake Herman and the Big Sioux Drainage system. It is therefore subject to greater seepage losses than lakes with clay basins. Its water level however should indicate fluctuations of the ground water table, since the lake would fill by inflow from the surrounding gravels when the water table is raised and drain by seepage when the water table lowers. Since the city of Madison draws its water supply from this same gravel channel, the lake level indicates the amount of water available for use by the city.

It is not definitely known whether the lake was dry during the drought of the 1890's, but it was dry during the recent drought. It filled up rapidly after 1940 and in May 1945 it had attained its maximum fullness.

The data on rainfall is from the Weather Station at Wentworth.

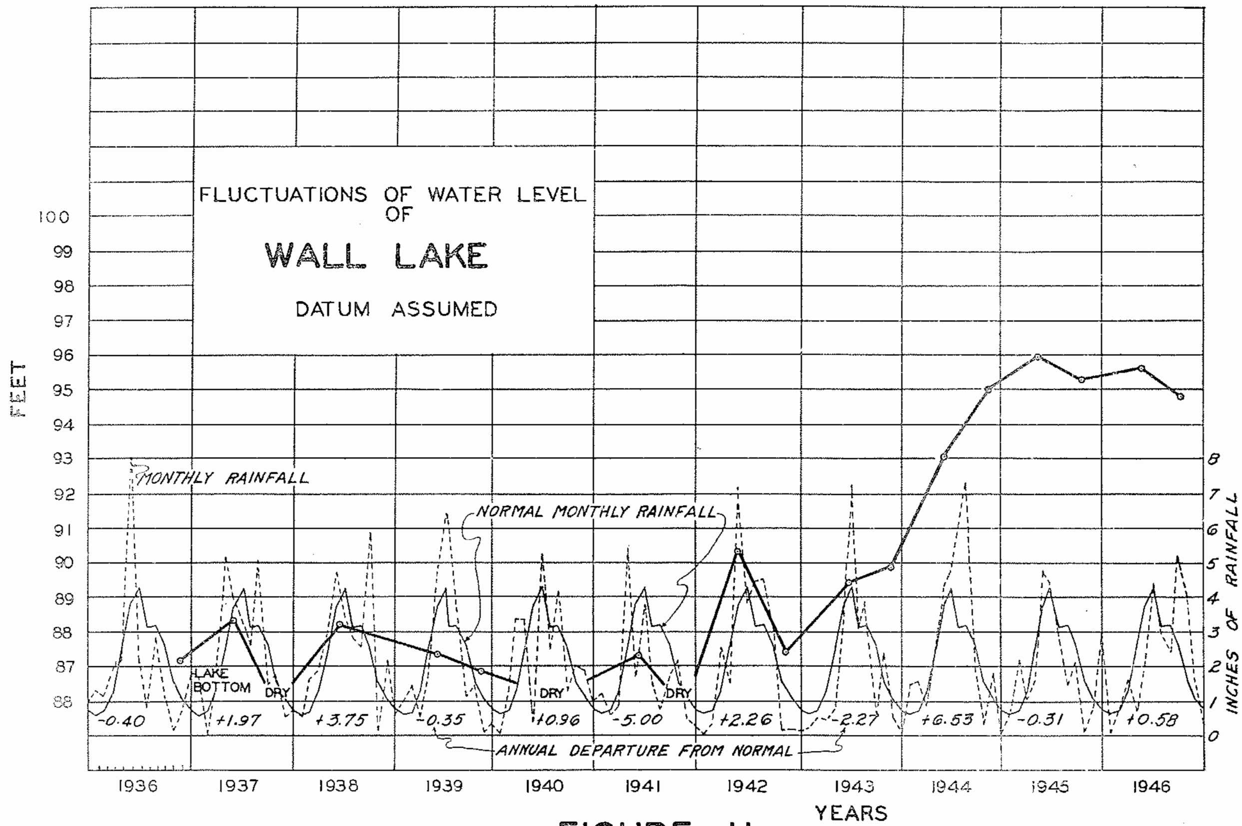



FIGURE 11

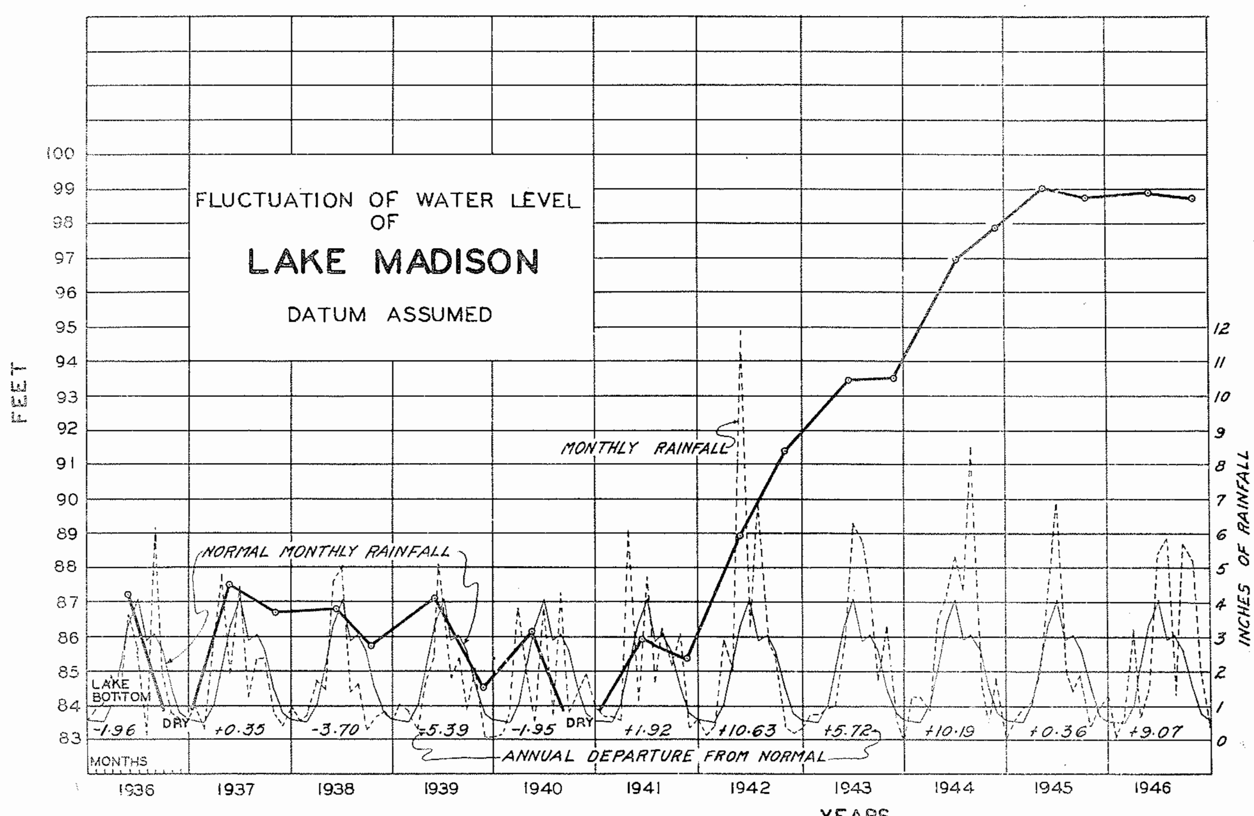



FIGURE 12

## Summary of Lake Level Fluctuations

Nearly all of the lakes were reported to have been at their highest levels between 1918 and 1920. After 1920 the water levels dropped gradually until 1936, at which time there had been a loss of about 15 feet in most of the lakes measured. In 1937 the lakes made a temporary gain of about three or four feet in most cases, after which they gradually dropped until in 1940 many of them had reached their lowest level of the recent drought. During 1941 and 1942 most of the lakes rose slowly and in 1943 and 1944 they filled up rapidly, so that by 1945 most of the lakes studied were full. Since 1945 most of the lakes have been overflowing. Two lakes, Blue Dog and Pickeral, were not seriously affected by the drought. The lowest points reached by each from maximum fullness was four feet by Blue Dog in 1936 and six feet by Pickeral, also in 1936. This lack of fluctuation indicates that both lakes have large drainage areas and consequently large inlets from gravel channels to the north.

It is interesting to note that the departure of precipitation from normal corresponds quite closely in most cases to the fluctuations of lake levels.

While this report covers an entire cycle for some of the lakes, and therefore indicates the ground water table through a complete cycle, it is not possible to forecast the dimensions of future cycles, either in years or amount of fluctuation, as long range forecasts in the past have proved to be quite inaccurate, especially in areas where the climatological data has been recorded for only relatively short periods of time.

Figure 13 shows that while the accumulative departure of precipitation from normal shows general cyclic trends, the periods of time between and the extent of droughts vary considerably. A year of drought may occur between two wet years, as in 1904 and 1907.

The water level of Lake Enemy Swim in 1894 as shown on Figure 13 was taken from the position of poplar stumps that grew in the south bay during the drought of the 1890's. The other water levels of Enemy Swim prior to 1934 are reported locations of beaches. Since 1934, the lake level has been measured twice a year. While the times that these beaches were formed may not be exact, they give the general picture of the lake level fluctuations through a complete cycle.

The Annual Accumulative Departure of Precipitation from Normal Curve was computed by figuring the average readings of a number of U. S. Department of Commerce Weather Bureau Stations in eastern South Dakota. While a number of these stations are not in the lake region it was necessary to use them in order to get a continuous curve over the longest possible time that would not too greatly reflect the effect of local storms. The Weather Stations whose records were used in the compilation of this data were Arlington, Brookings, Canistota, Canton, Castlewood, Centerville, Clark, DeSmet, Flandreau, Gelhaus Farm, Marion, Menno, Sioux Falls, Sisseton, Tyndall, Vermillion, Watertown, Webster, Wentworth, and Yankton.

It is interesting to note the similarity of the Enemy Swim water level curve to the Accumulative Departure of Precipitation from normal curve.

Figure 14 shows annual departure of precipitation from normal at six different Weather Bureau Stations in eastern South Dakota. The effects of local precipitation can be readily seen through the comparison of the departures from normal of the various stations during any given year. It appears that this effect of local storms accounts for the few nonconformities between departure of precipitation from normal and lake level curves.

## FLUCTUATION OF WELL LEVELS

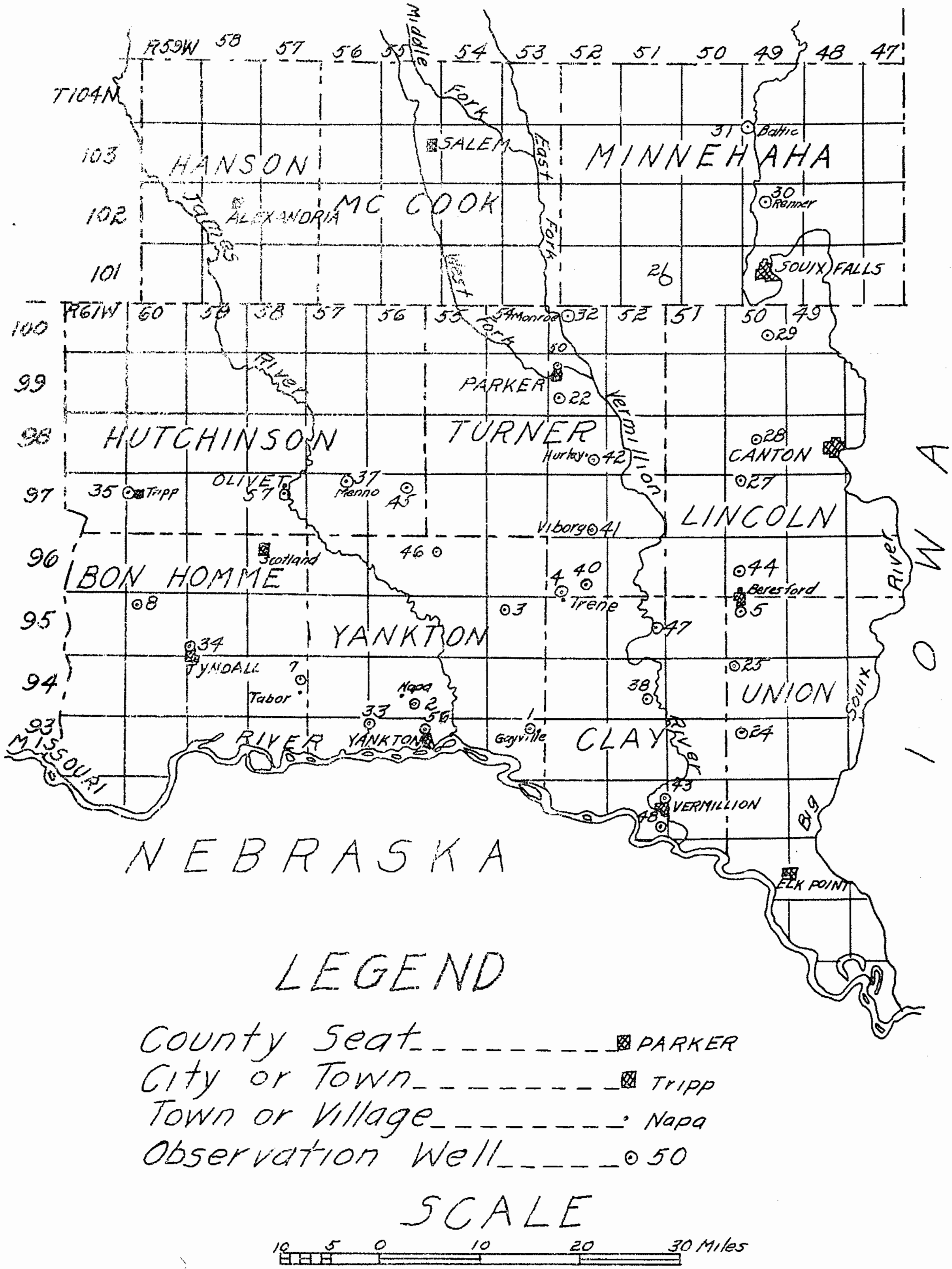
All of the water wells mentioned in this report are in the southeastern part of the state. For convenience of description they are divided into county groups.

The wells are in most cases either little used or abandoned water wells, and for this reason a number of them have been lost from time to time due to plugging or filling up by the owners. It is hoped that in the future observation wells can be drilled in order to have continuous ground water records.

The wells making up these county groups are Bon Homme County 7, 8, and 34; Clay County 38, 43, 47, and 48; Hutchinson County 35, 37, and 45; Lincoln County 27, 28, 29, and 44; Minnehaha County 21, 30, and 31; Turner County 4, 22, 32, 40, 41, 42, and 50; Union County 5, 24, and 25; and Yankton County 1, 2B, 3, 33, and 56.

Three of these wells were drilled as observation wells, Clay County 47 and 48 by the Ground Water Division of the U. S. Geological Survey, and Clay County 43 by the South Dakota Geological Survey.

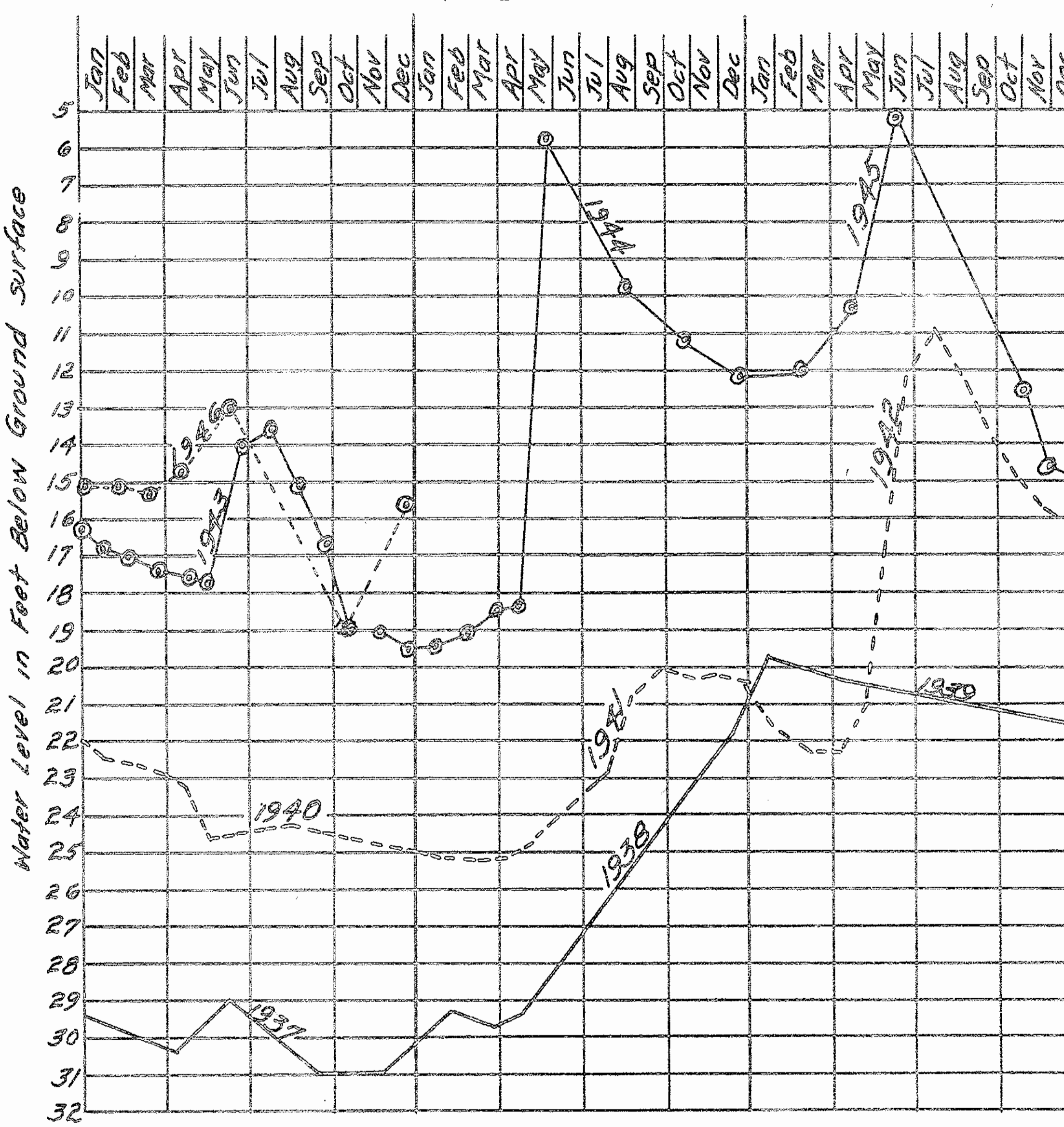
# OBSERVATION WELLS
## IN
## SOUTHEASTERN SOUTH DAKOTA



# BON HOMME COUNTY

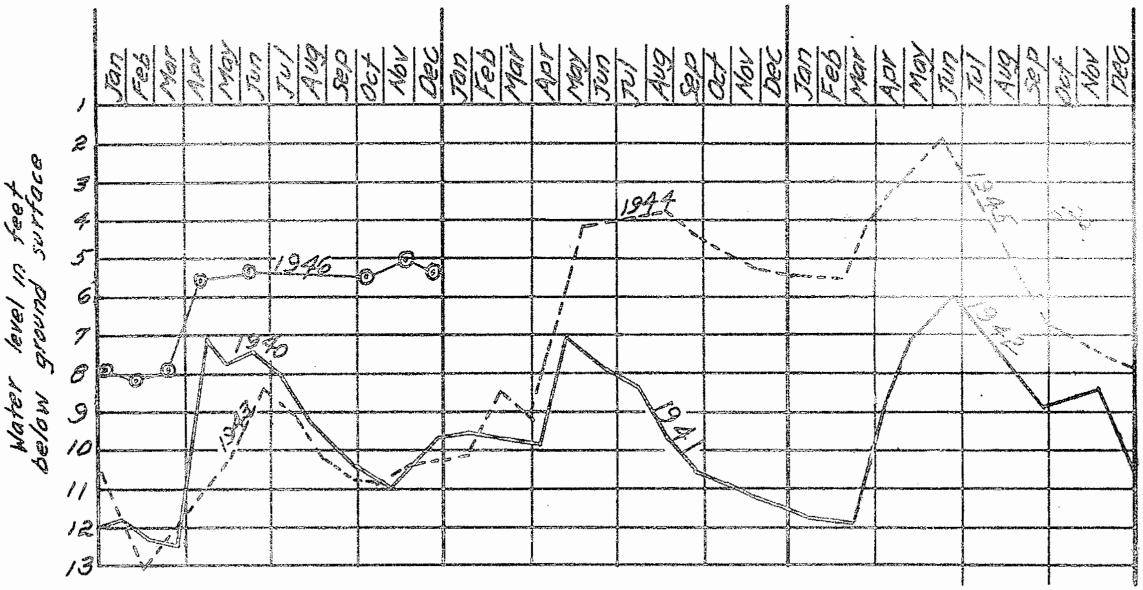
The following graphs show the fluctuation of water level in each of three shallow wells in Bon Homme County.

## WELL No 7



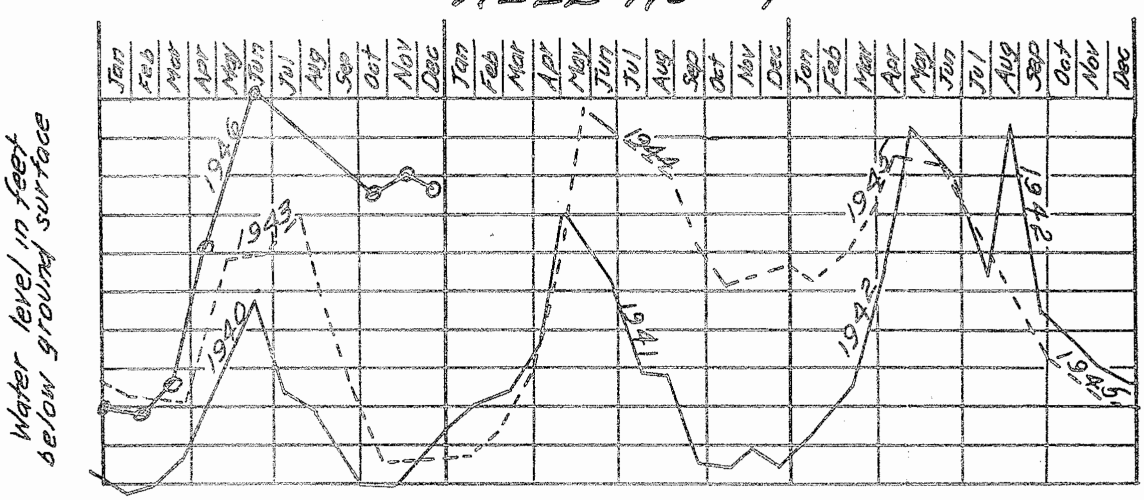

Well No 7 is on the farm of T. C. Dagovic in the SE 1/4 of the SW 1/4 of Sec 14, T94N, R54W. It is 1/2 mile west of the town of Tabor along Highway 50, on a hillside. The well is 30.5 feet deep, and is cased with wood.

## WELL No 8




This well is on the farm of Jake Berndt in the SW ¼ of the NW ¼ of Sec 8, T 95 N, R 60 W. The topography is rolling. It is a 12" tile cased well and is 47 feet deep

## WELL No 34

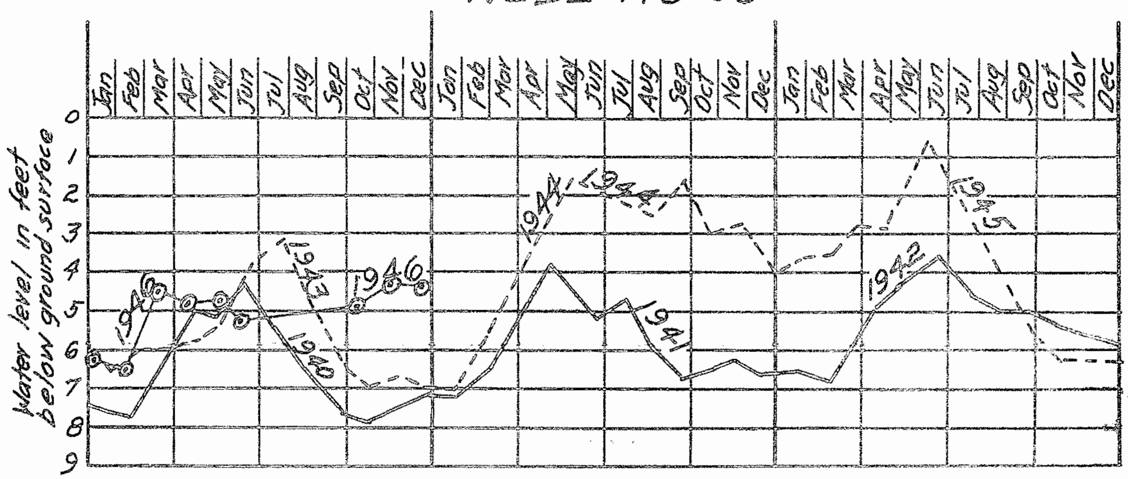



This well is on the property of Joseph Krejci in the NW ¼ of the NE ¼ of Sec 6, T 94 N, R 59 W. The well is north of the business section of Tyndall across the street from the First Methodist church.

# CLAY COUNTY

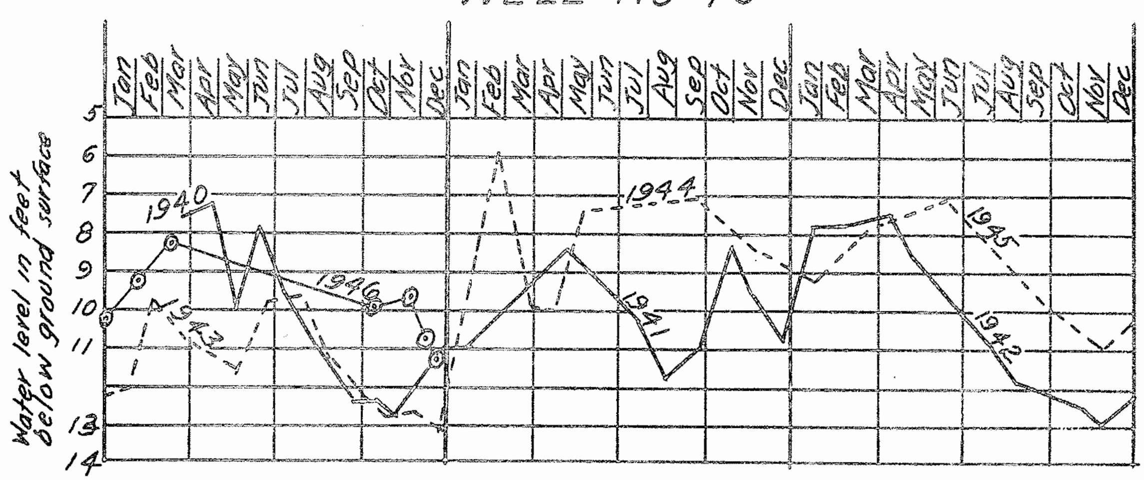
The following graphs show water level fluctuations in each of five shallow wells in Clay County

## WELL No 38



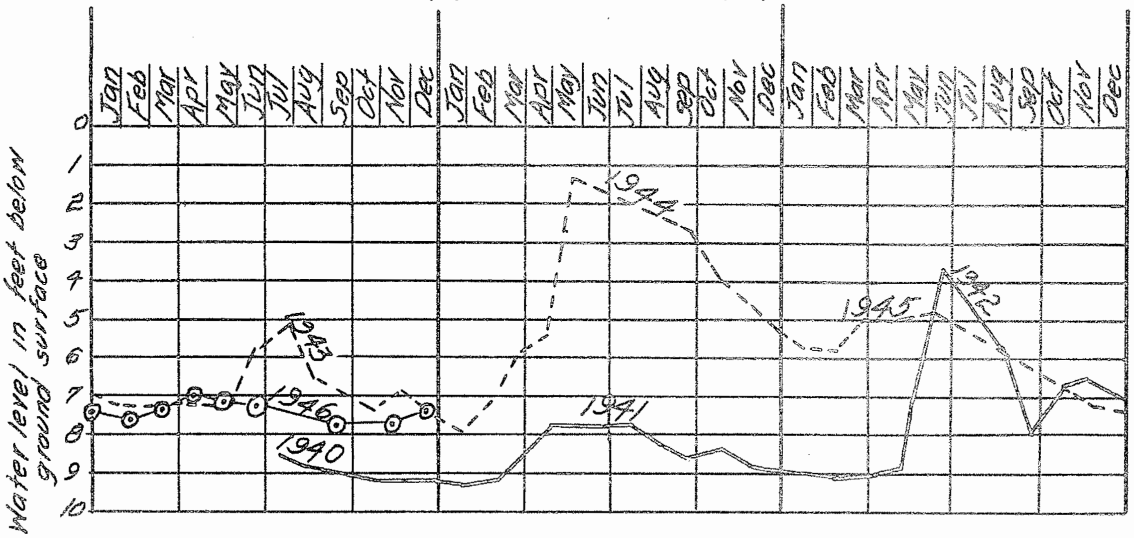

Well No 38 is on the Yusten farm in the SE 1/4 of the NW 1/4 of Sec 35, T94N, R 52 W. The well is located on a flat plain. It is a brick cribbed well 42" in diameter and 15 feet deep.

## WELL No 43



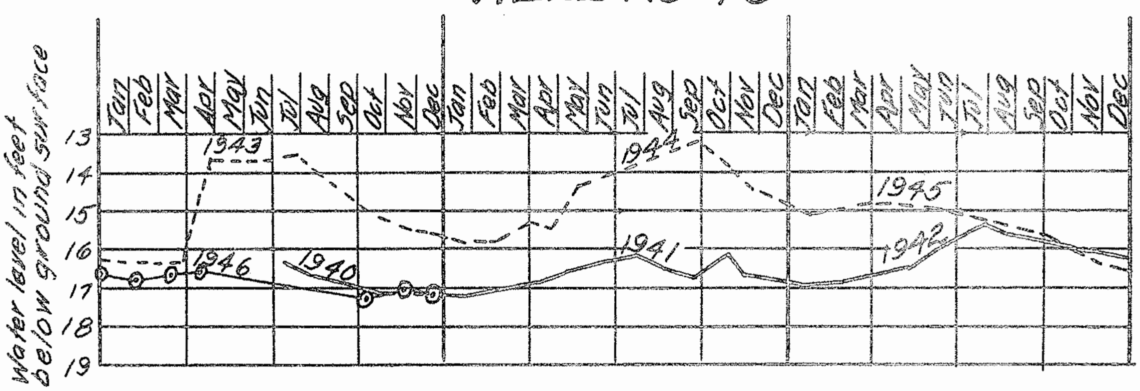

Well No 43 is located on the University of South Dakota campus about 60 feet north of the womens gymnasium. It was dug as an observation well by the S.D. Geological Survey March 21 1940.

## WELL No 47




Well No 47 is located in the NW 1/4 of the SW 1/4 of section 23, township 95 north range 52 west. It is in the flood plain of the Vermillion River. The well was drilled for observation purpose by the U S Geological Survey, June 12, 1940.

## WELL No 48

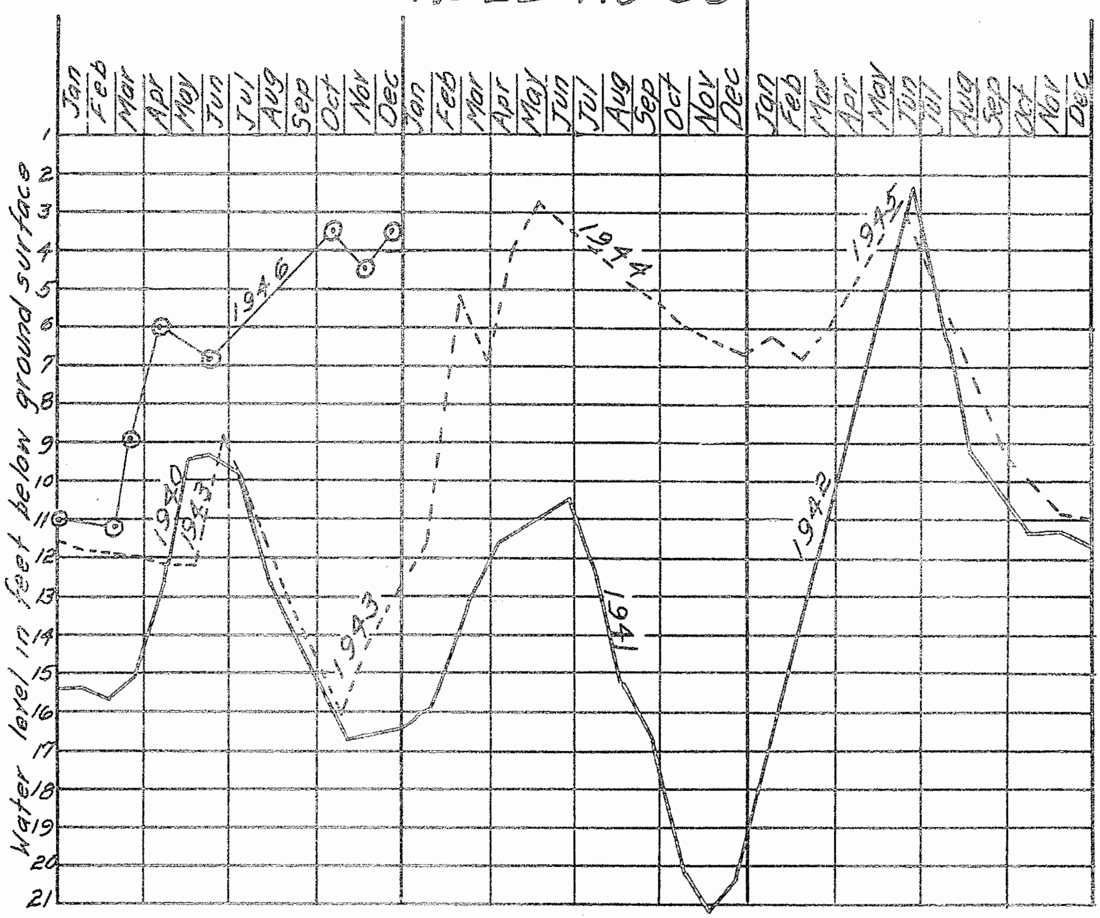



Well No 48 is located on the farm of Frank Powel in the NW 1/4 of the NW 1/4 of Sec 14, T 92 N, R 52 W. The well is located in the flood plain of the Missouri River. It was drilled by the U.S. Geological Survey, June 13, 1940 as an observation well.

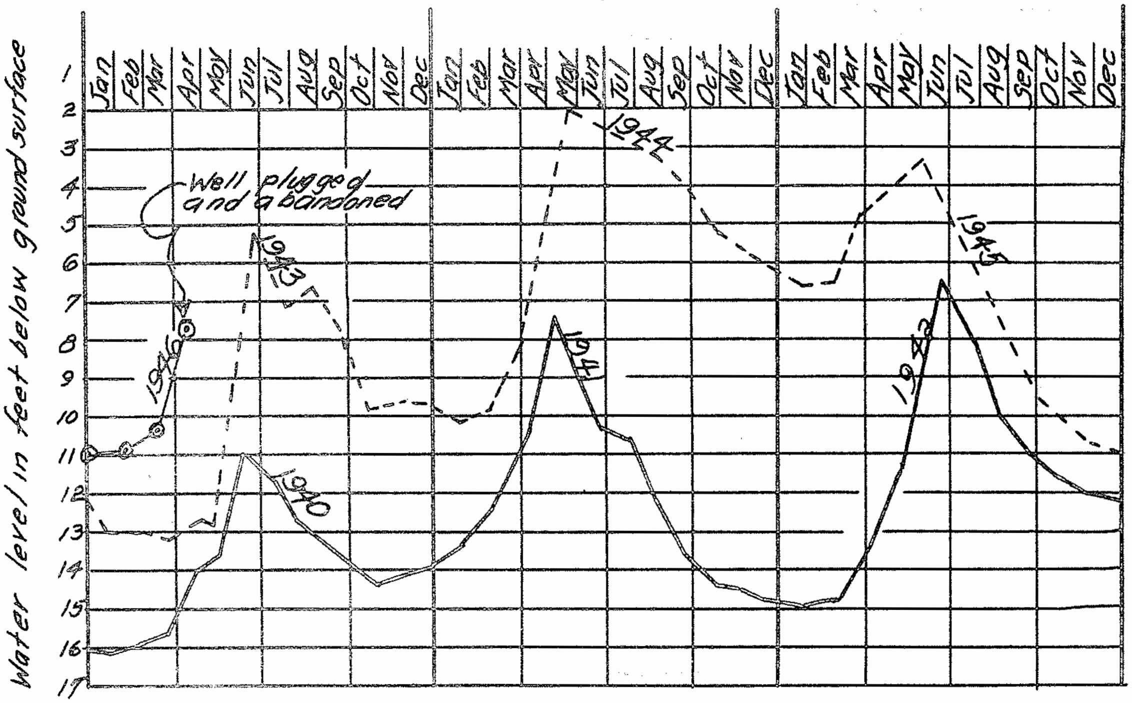
# HUTCHINSON COUNTY

The following graphs show the water level fluctuations of each of three shallow wells in Hutchinson County. One of these wells No 37 was plugged and abandoned in April 1945. Another shallow well, No 57, has been added to the number of observation wells in the county.

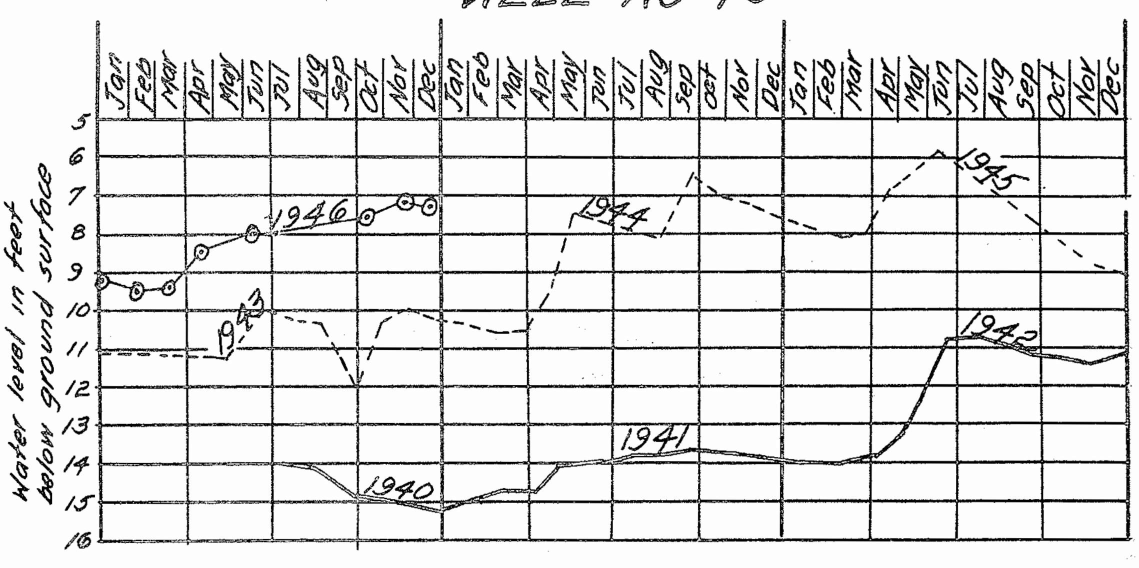
## WELL No 35




This well is on the property of Herman Krause in the town of Tripp. It is located on a hillside in the NE¼ of the SW¼ of Sec 8, T 97 N, R 60 W. The well has a 24" wood casing and is 29 feet deep.




Well No 37 is on the property of Ed C. Mettler in the town of Menno, in the NW 1/4 of the NW 1/4 of Sec 10, T97 N, R 57 W. The topography is flat. The well is cased with 18" vitrified tile and is 20 feet deep.

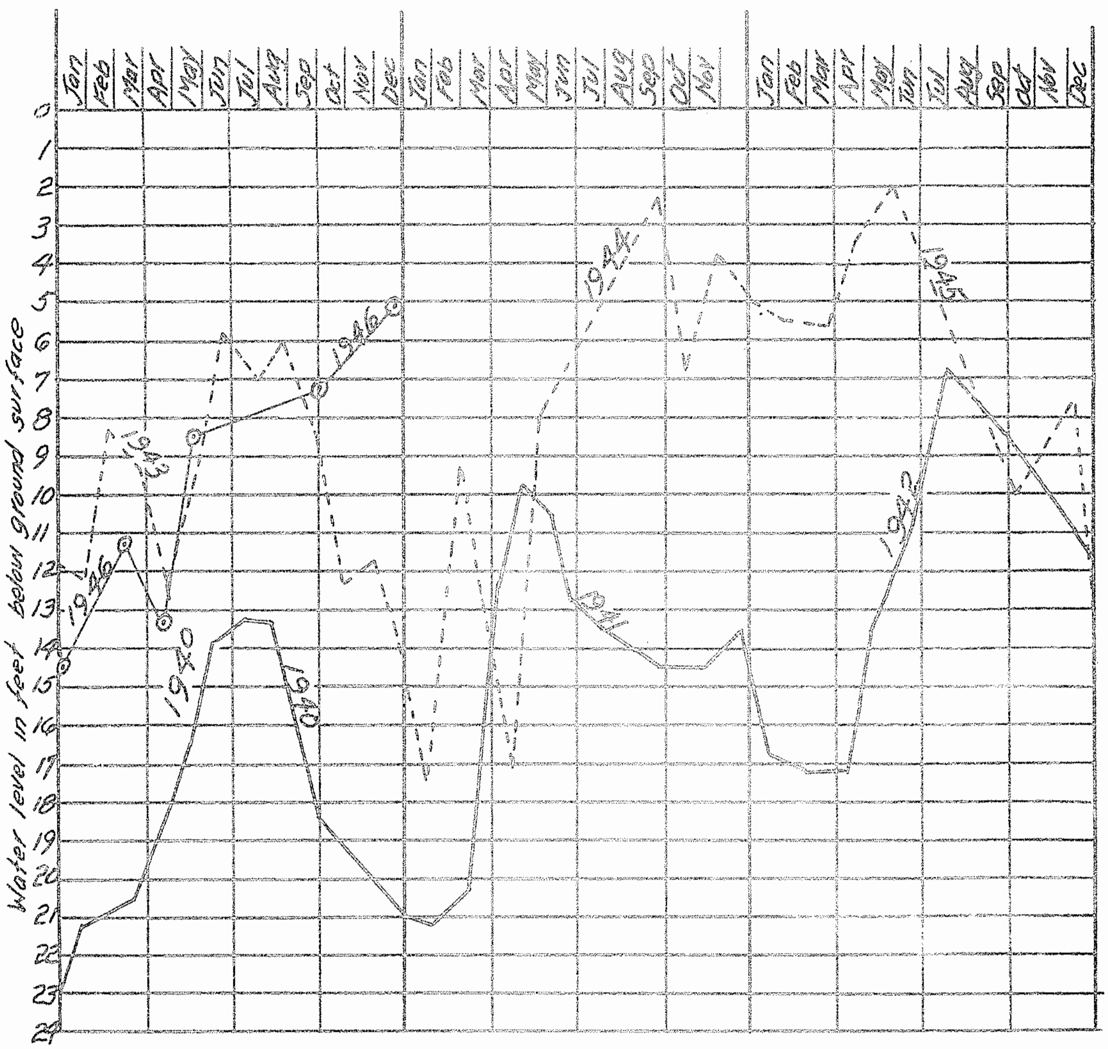



Well No 45 is located on the Chet Harnish farm in the NE 1/4 of the NW 1/4 of Sec 11, T97N, R56W. It is in the bottom of a small valley. The well is cased with wood, is 21" in diameter and 25 feet deep.

# LINCOLN COUNTY

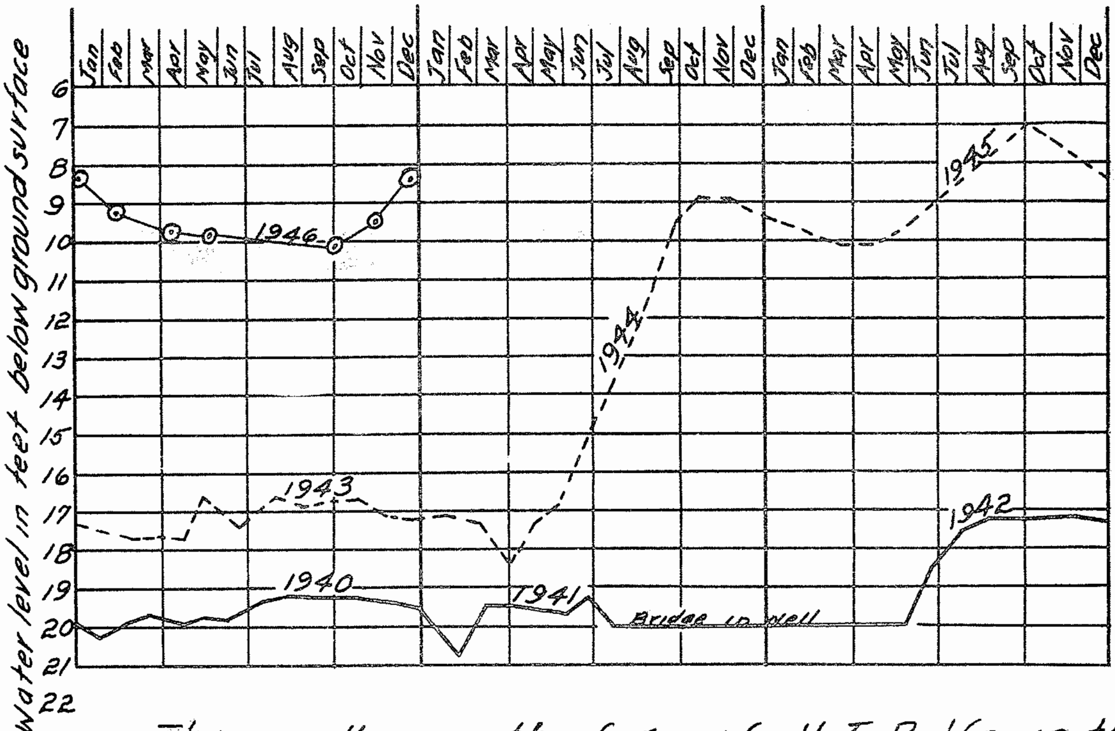
The following four graphs show water level fluctuations of each of four Lincoln County shallow wells. The chief aquifier of all of these wells is glacial drift.

WELL No 27



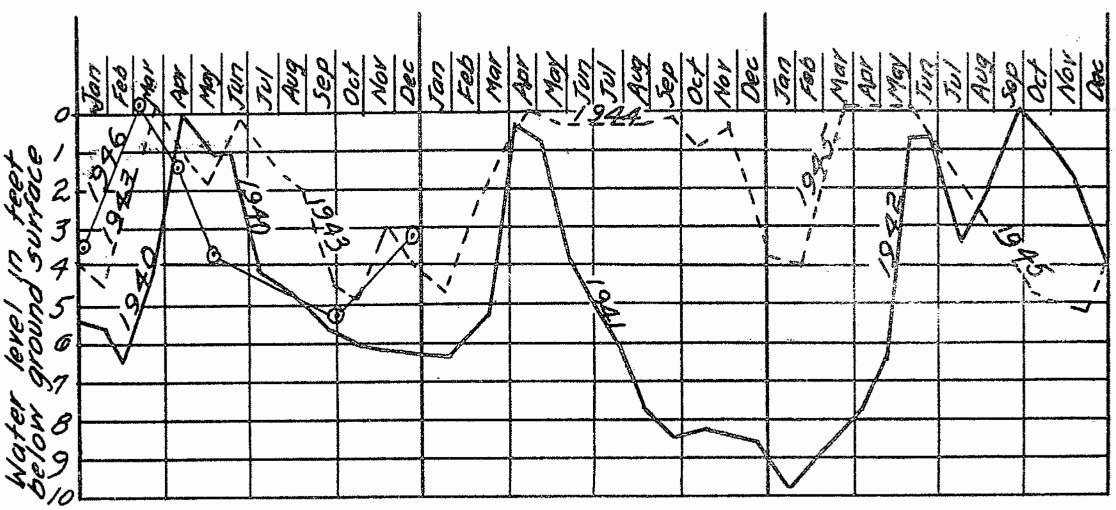

Well No 27 is located in the NW¼ of the NE¼ of Sec 5, T97N, R50W. It is on the farm of Andrew Lenna about ¼ mile SW of the junction of Highways 18 and 77. The well is cased with wood and vitrified tile, is 4 feet in diameter and 67 feet deep. It is used to water stock The topography is flat upland.

## WELL No 28



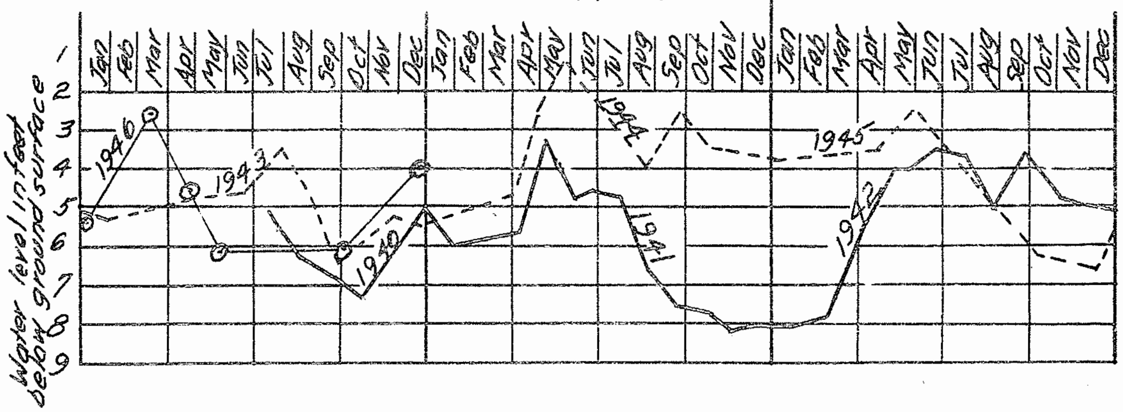

This well is on the farm of H.J. Rolfe, in the SE 1/4 of the SW 1/4 of Sec 15, T98 N, R30 W. It is an upland well, cased with 8" vitrified tile and is 63 feet deep. The well is not used.

## WELL No 29




This well is on the farm of Ed Devitt in the SW 1/4 of the SW 1/4 of Sec 26, T100 N, R50 W. The well is about 20 feet south of a drainage ditch, in a flat plain. It is cased with 30" concrete tile and is 30 feet deep.

## WELL No 44

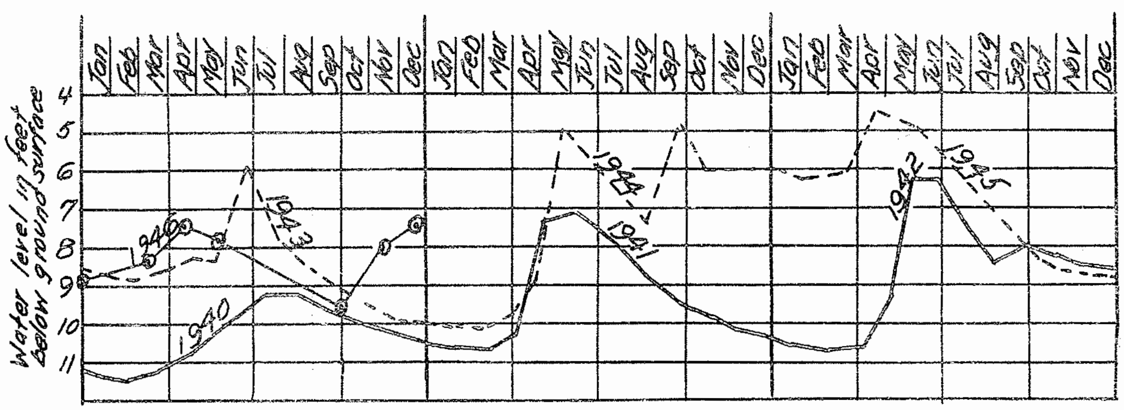



Well No 44 is located in the NE ¼ of the SE ¼ of SEc 20, T96N, R50W, at a T fence corner near a Quaker State Oil sign board. It was bored as an observation well by the US Geological Survey June 10 1940. It is a 3" well 14.4 feet deep. The Topography is slope to upland.

# MINNEHAHA COUNTY

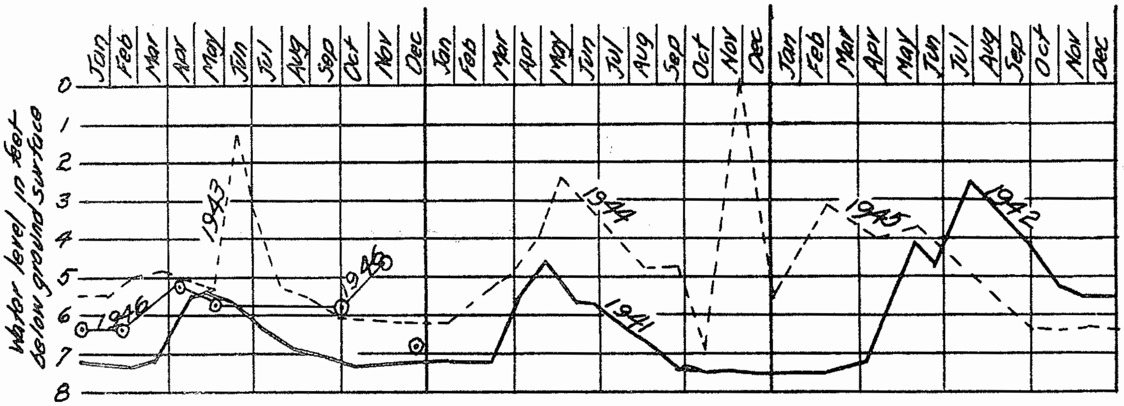
The following three graphs show water level fluctuations in each of three shallow observation wells in Minnehaha County.

## WELL No 21



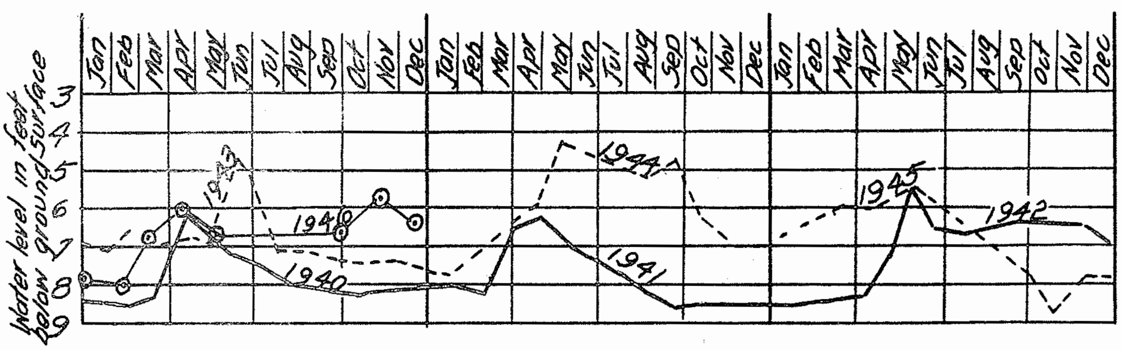

Well No 21 is located near the Kilieany Oil Station in the NE ¼ of the NE ¼ of Sec 21, T 101 N, R 51 W. The well is 48" in diameter and 12.5 feet deep.

## WELL No 30




Well No 30 is in the Renner Ball Park in the town of Renner in the NW ¼ of the NW ¼ of Sec 16, T 102 N, R 49 W. The well is in the flood plain of the Big Souix River. It is a 1¼" sand point well 19 feet deep.

## WELL No 31

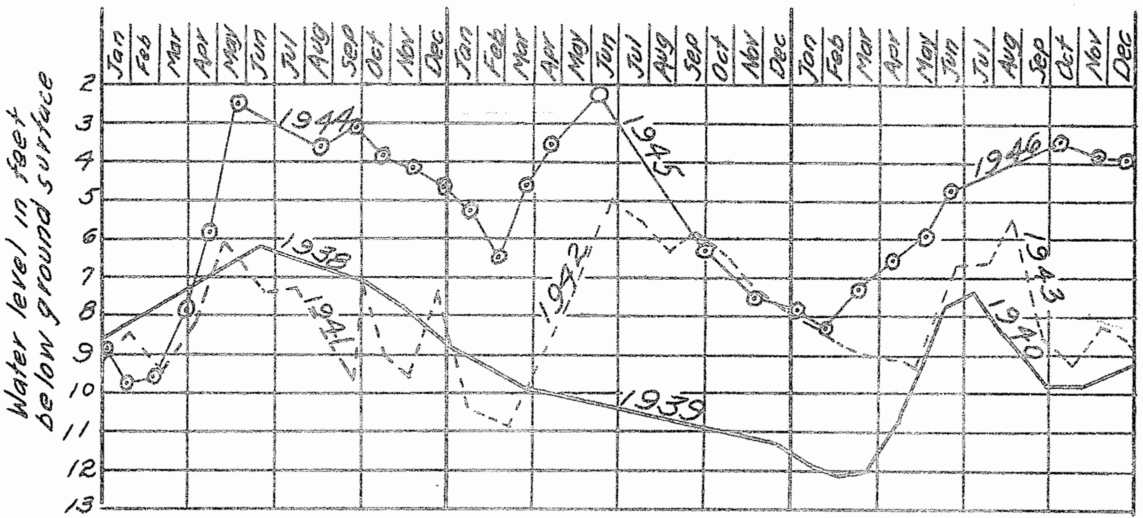



Well No 31 is located in the NW ¼ of the NE ¼ of Sec. 6, T 103 N, R 49 W. The well is one mile West of Baltic on the south side of the road about 20 feet west of a 24" cottonwood tree. It is in the flood plain of the Big Souix River. The well is cased with 10" vitrified tile and is 12.5 feet deep.

# TURNER COUNTY

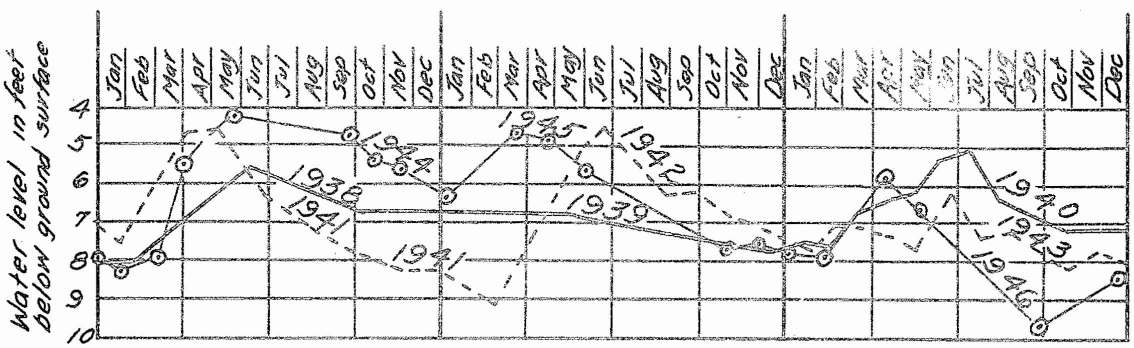
The following graphs show the fluctuations of water level in each of seven shallow wells in Turner County. One of these wells, well no 40 has been plugged and abandoned. Observations are being made on the water levels of the other six wells.

## WELL No 4



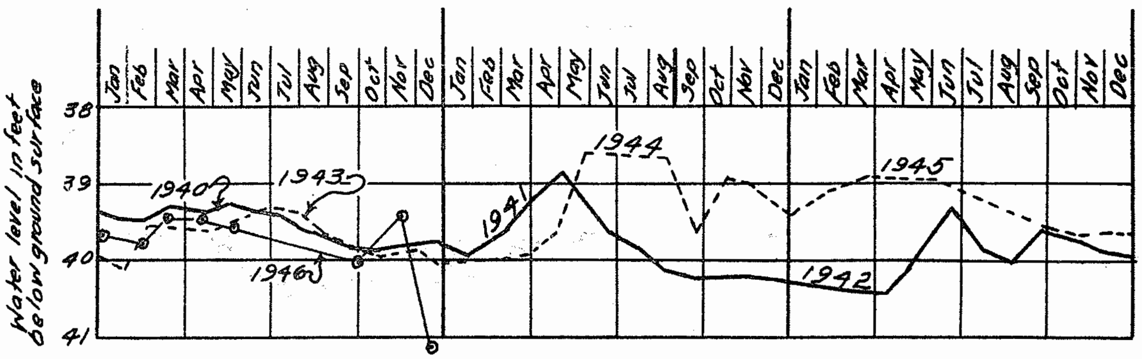

Well No 4 is located on the farm of J. H. Shaw in the SW¼ of the SW¼ of Sec 32, T96N, R53W. The well is one mile east of the town of Irene in the bottom of a small draw. The well has a 72" metal casing and is 26 feet deep.

## WELL NO 22



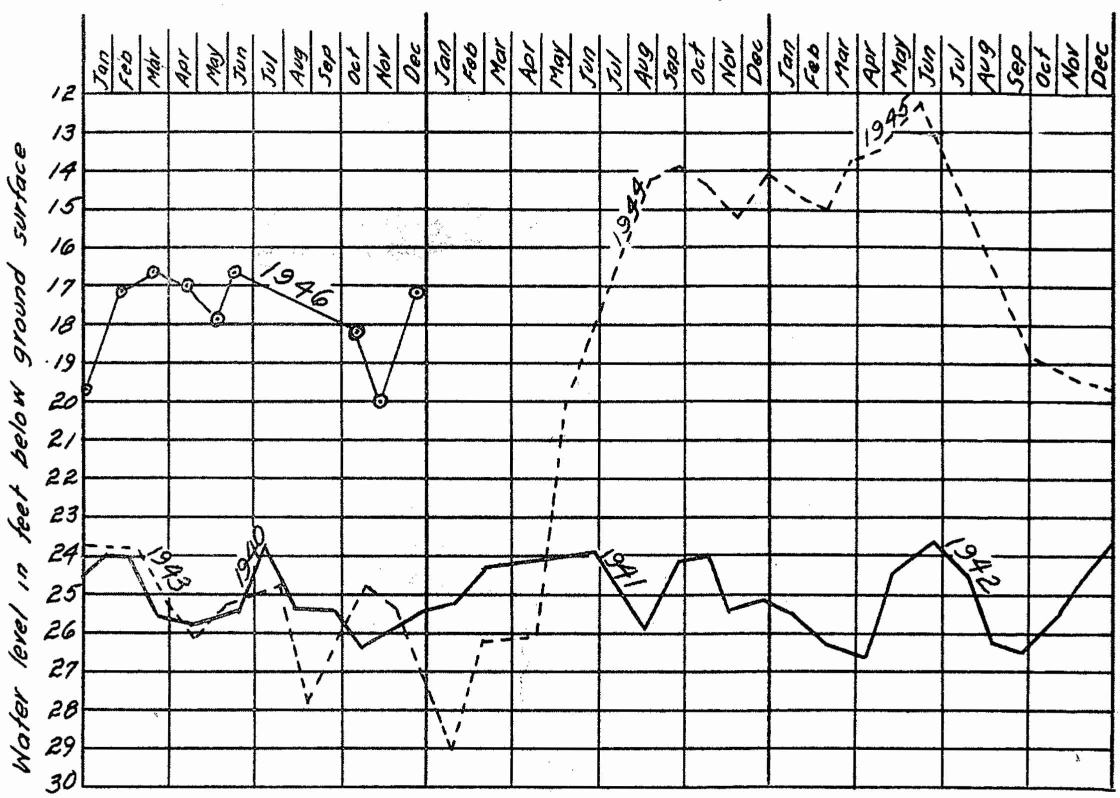

Well No 22 is located in the NE¼ of the NE¼ of Sec 29, T99N, R53W, in a creek bottom. This well has a 42" cement casing and is 12.5 feet deep.

# WELL NO 32



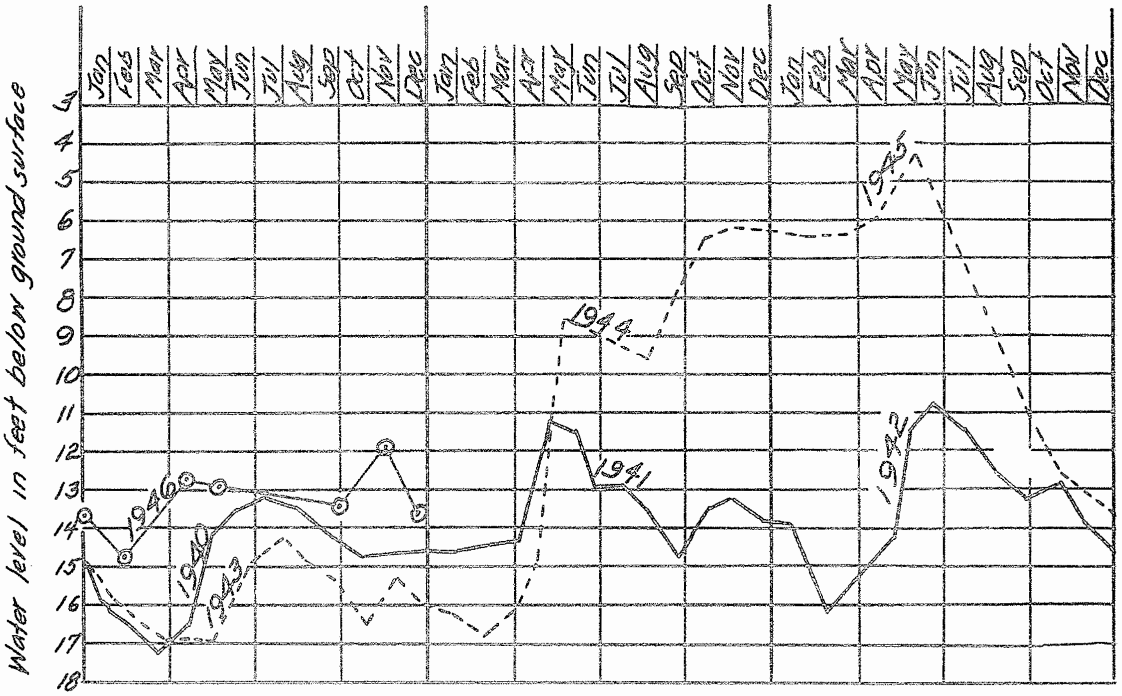

Well No 32 is located on the farm of Otto Kraemer in the SW 1/4 of the SW 1/4 of Sec 9, T 100 N, R 53 W. It is an upland well. It is on an abandoned farm 0.7 miles south of the county line. The well is cased with 4" G I pipe and is 90 feet deep.

# WELL NO 40



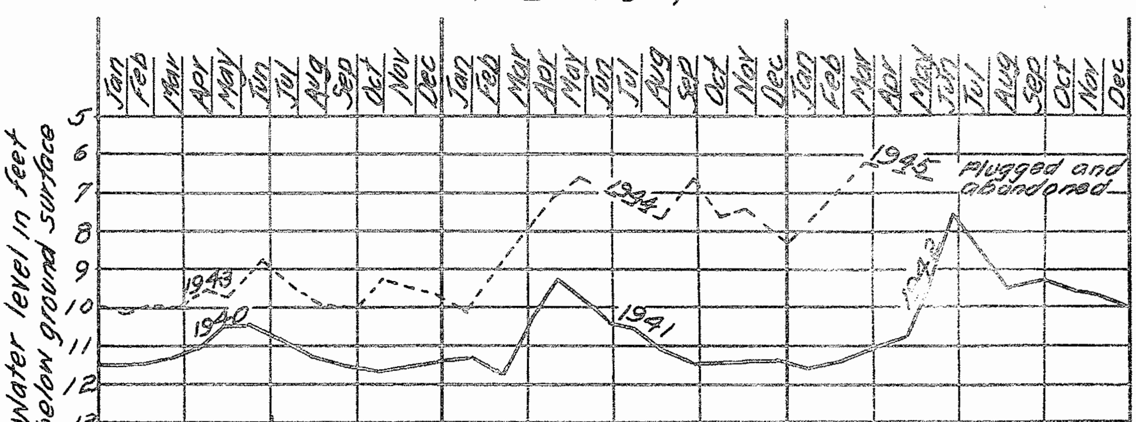

Well No 40 is located on the farm of W. C. Olson in the SE 1/4 of the SE 1/4 of Sec 27, T 96 N, R 53 W. The well is cased with wood, is 18" in diameter, and 31 feet deep. It is used to water stock.

## WELL NO 41



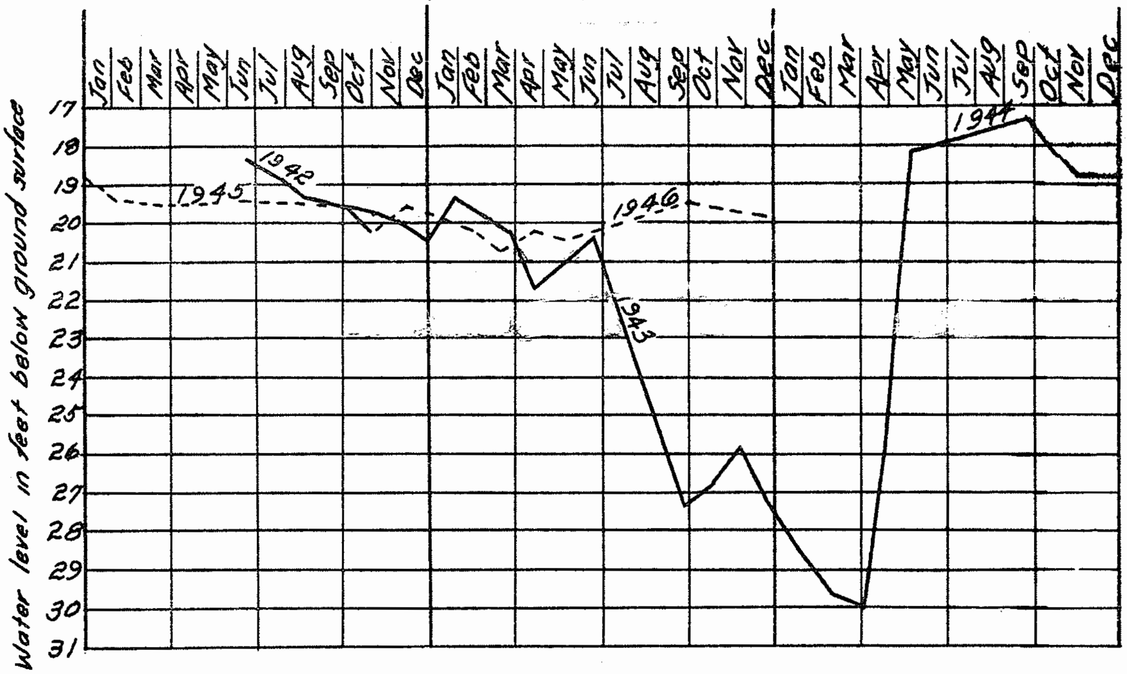

Well No 41 is located in the SW 1/4 of the SW 1/4 of Sec 35, T97N, R53W. It is in the town of Viborg on the Jorgenson Studio lot. The well has 24" wood casing and is 40 feet deep. It is not used.

## WELL No 42




Well No 42 is located in the SE 1/4 of the of Sec 26, T98N, R53W. The well has a 10" cast iron casing and is 16 feet deep. It was plugged and abandoned July 1945.

# WELL NO 50

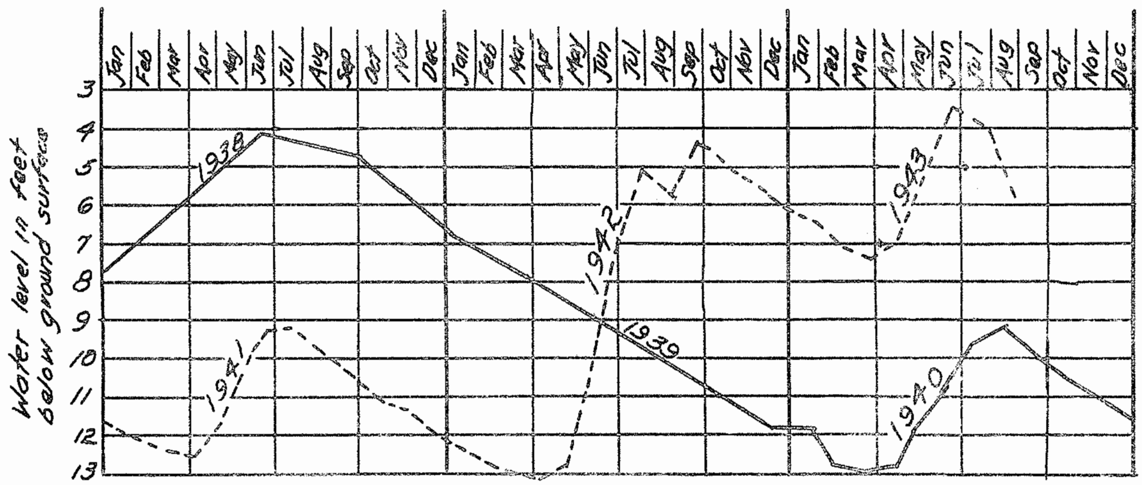



Well No 50 is located on the property of A.M. Fisher in the SE ¼ of the SW ¼ of Sec 8, T99 N, R53W. The well is in the north part of the town of Parker and is on the north side of Highway 19. The well is cased with 8" vitrified tile and is 40 feet deep. The topography of the well site is flat.

# UNION COUNTY

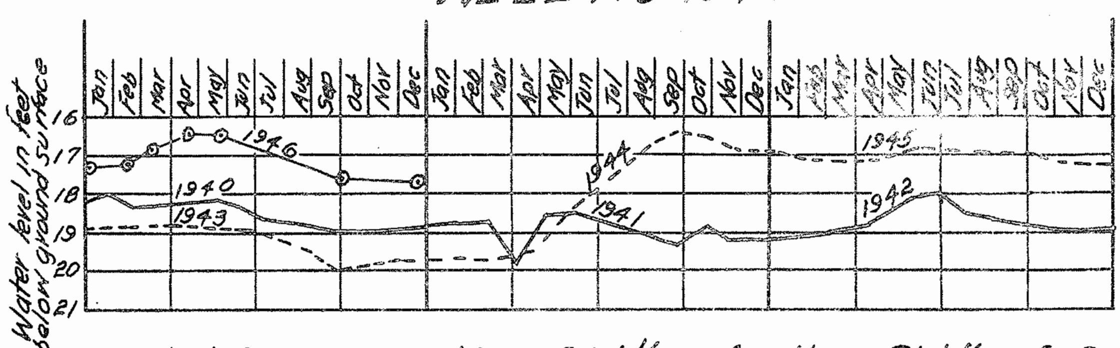
The following graphs show the fluctuation of water levels in each of three wells in Union County. Observations are not being taken by the State Geological Survey of Well No 5 at the present time. Periodic checks are made of the water levels of the other two wells.

## WELL No 5



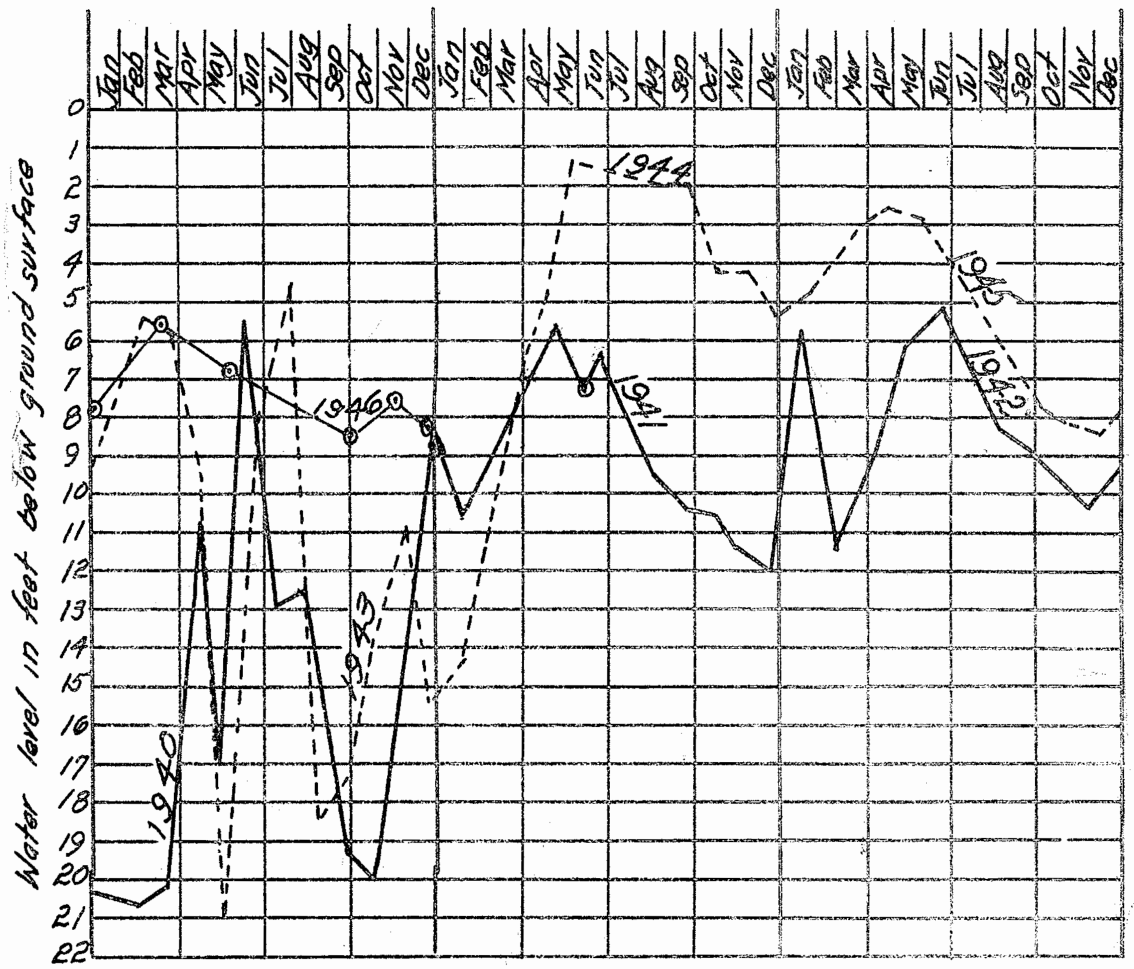

This well is located on the farm of J. J. Dolan in the NW 1/4 of the NE 1/4 of Sec 8, T 95 N, R 50 W. It is one mile south of the town of Beresford. It has a 24" tile casing and is 42.5 feet deep. The topography is rolling.

## WELL No 24




Well 24 is in the SW 1/4 of the SW 1/4 of Sec 8, T 93 N, R 50 W. It is on a Hillside. It has 24" concrete tile casing and is 24.5 feet deep. The well is in a road borrow pit.

WELL NO 25

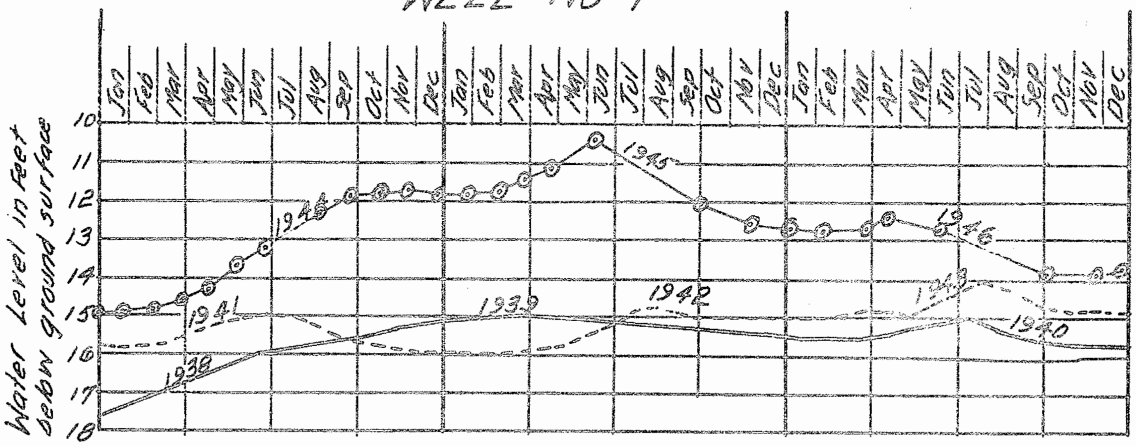



Well No 25 is on the farm of A. G. McGuire in the NE 1/4 of the SE 1/4 of Sec 6, T94 N, R50 W. It is in a hillside. The well is cased with 24" wood curbing and is 24 feet deep. It is not being used as a source of water.

# YANKTON COUNTY

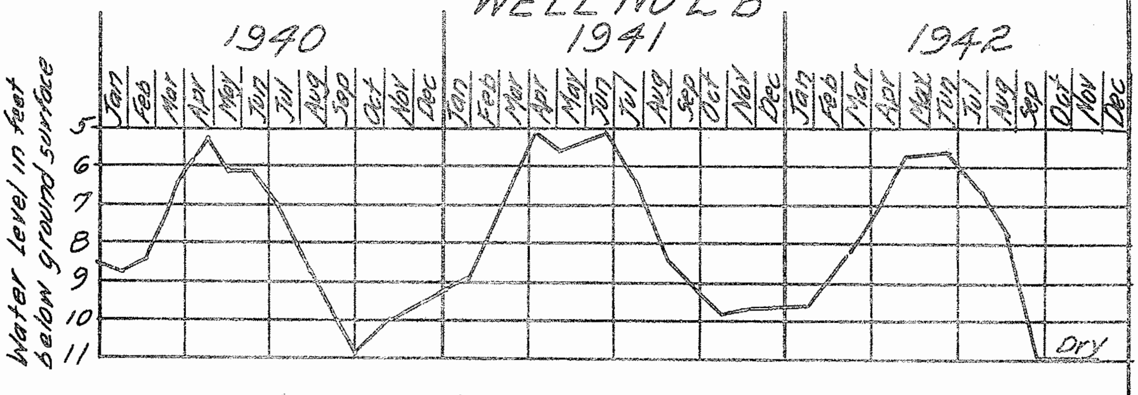
The following graphs show the fluctuations of water level in each of six shallow wells in Yankton County. Two of these wells, No 2B and No3 have been abandoned. Observations are made on the water levels of the other wells.

## WELL No 1



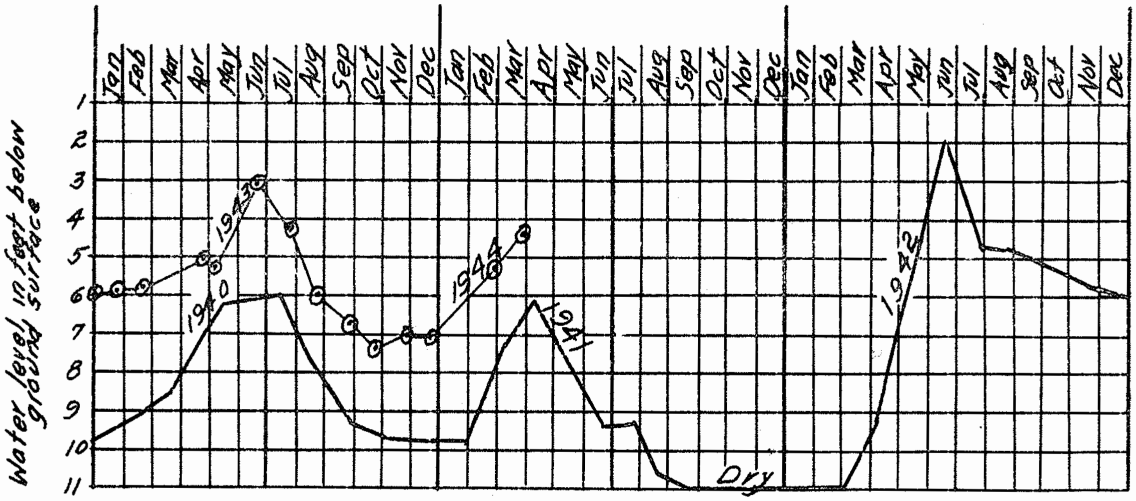

Well No1 is located in the NW ¼ of the NW ¼ of section 11, T93 N, R 54 W. The well is 0.8 miles north of the town of Gayville along old Highway 50 in the Gayville cemetery. It is in the flood plain of the Missouri River. The chief aquifier is the Missouri River sands.

## WELL No 2 B



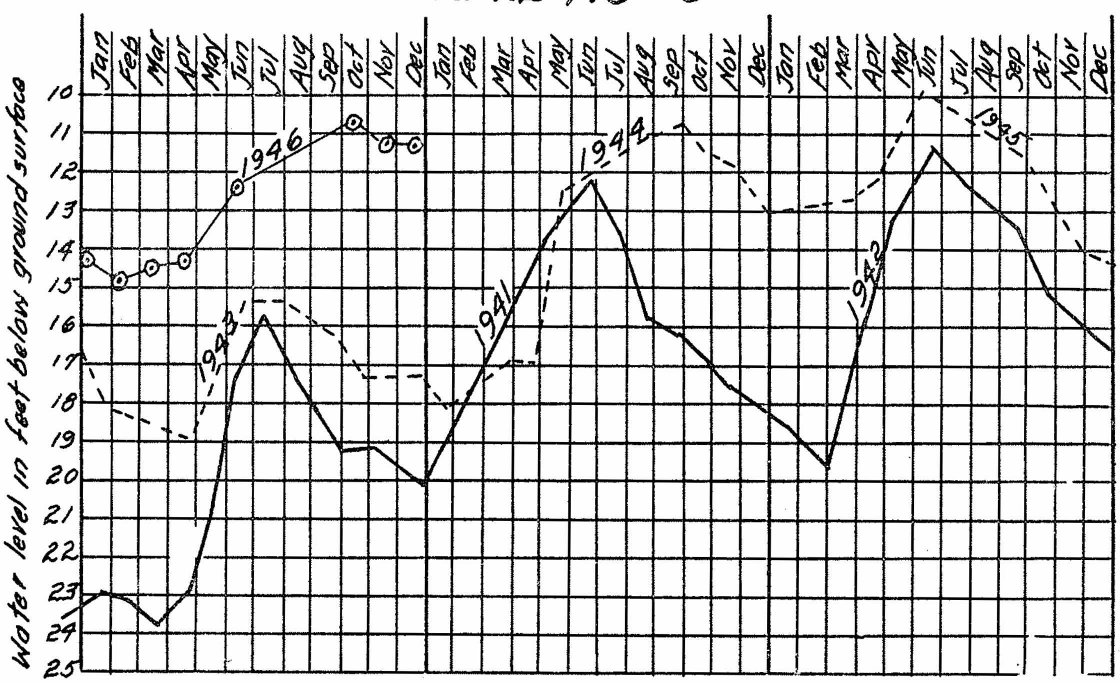

Well No 2B is located on the Yankton golf course in the SW¼ of the SE¼ of Sec 24, T94 N, R 56 W. The well is in the bottom of a small draw. The well was 11 feet deep and cased with wood. The casing collapsed and the well was abandoned in 1943.

## WELL No 3



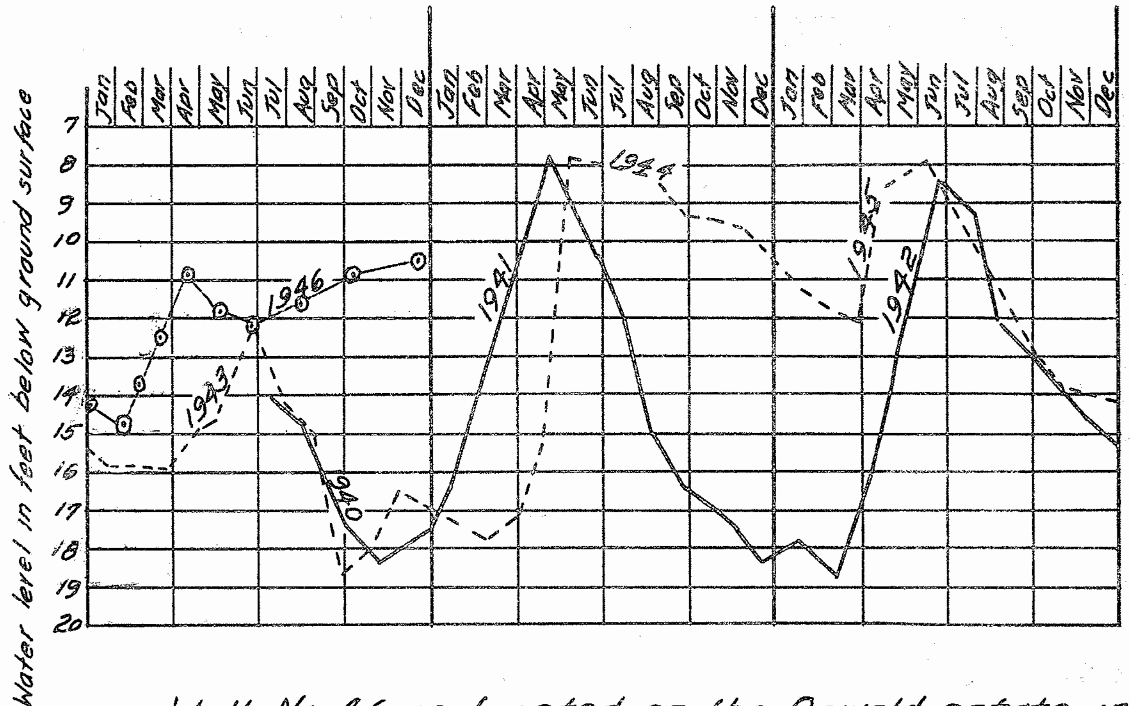

Well No 3 is located in the NW 1/4 of the NE 1/4 of Sec 5, T 95 N, R 54 W. The well is located at the botton of a small draw. It was filled in ond abandoned in April 1944.

## WELL No 33



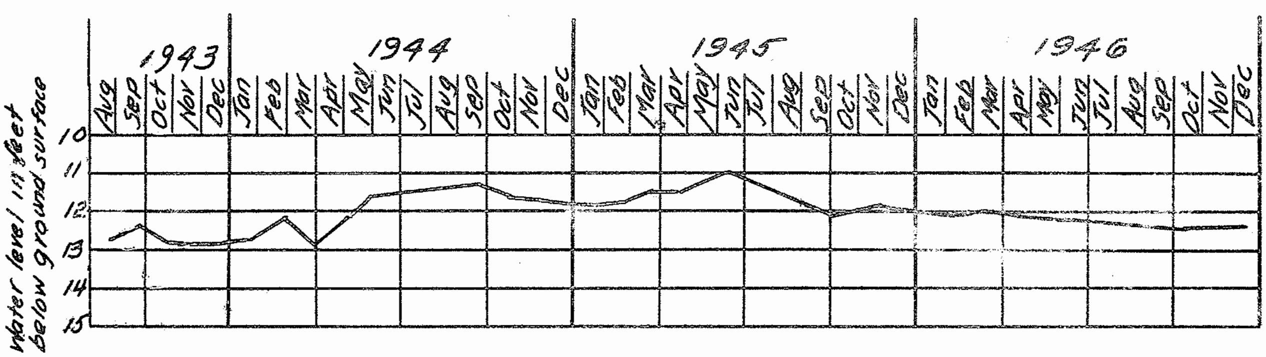

Well No 33 is located on the farm of Adolph Schoenfeldt in the NE 1/4 of the NE 1/4 of section 1, T 93 N, R 57 W., The well is cased with wood and tile and is 32.5 feet deep. It is located on a hillside.

# WELL No 46



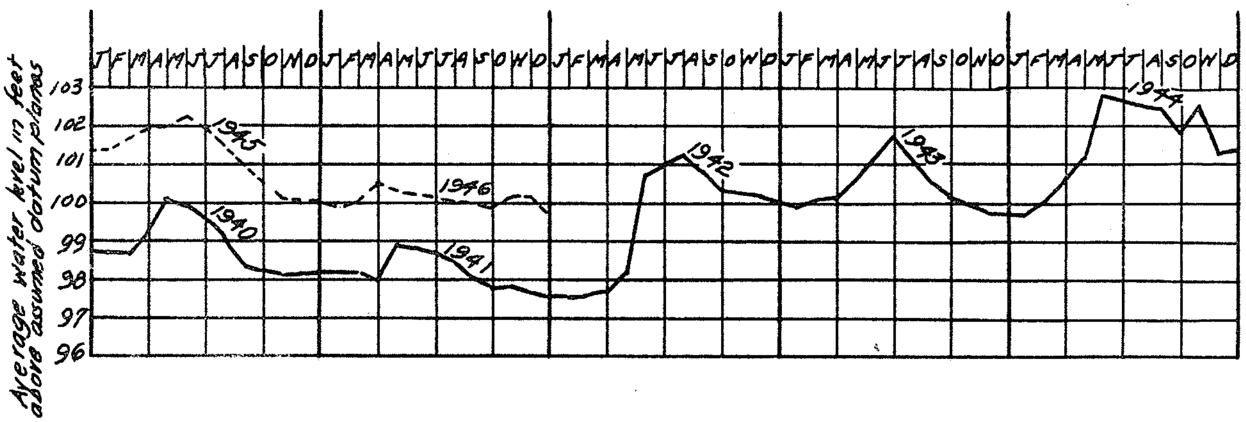

Well No 46 is located on the Oswald estate in the SW ¼ of the NW ¼ of Sec 7, T 96 N, R 55 W. It is located on a hillside near the base of the slope. It is a 27" well 34 feet deep with 2" vertical wood casing. The well is used to water stock.

# WELL No 56



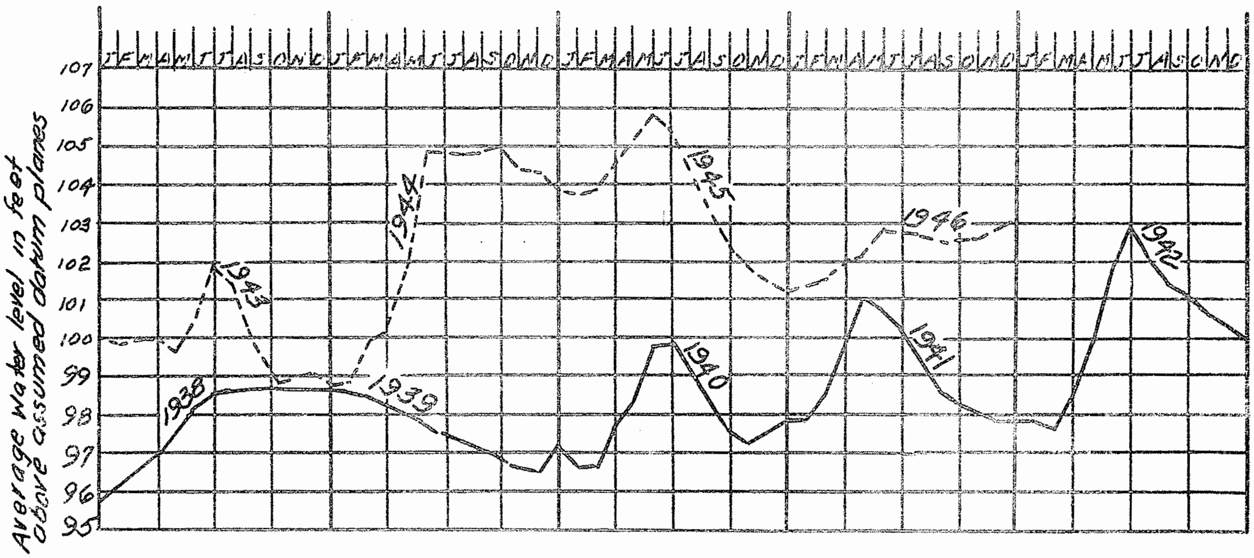

Well No 56 is located on the property of Thomas Bosteder in the SW ¼ of the NE ¼ of Sec 13, T 93 N, R 56 W. The well is in the north part of the city of Yankton, one block west of Highway 81 and 100 feet north of the Milwaukee Railroad tracks. It is located on a hillside just above the flood plain of the Missouri River.

# AVERAGE WATER LEVEL OF FLOOD PLAIN WELLS




The above chart shows fluctuations of the average water level in five shallow flood plain wells in southeastern South Dakota. The wells making up this group are Minnehaha County 30 and 31 both in the flood plain of the Big Souix River, Clay County 47 in the flood plain of the Vermillion River, Clay County 48 in the flood plain of the Missouri River and Yankton County 1 in the flood plain of the Missouri River.

# AVERAGE WATER LEVEL OF UPLAND WELLS




The above graphs show fluctuations of the average water level in shallow upland observation wells in southeastern South Dakota. The average water level in the years of 1938 and 1939 is of a group of four wells, and from 1940 to 1946 inclusive the average water level is of a group of 21 to 26 wells. The wells making up these groups are Bon Home County wells 7, 8, and 34, Clay County wells 38 and 43, Hutchinson County wells 35, 37, and 45, Lincoln County wells 27, 28, 29 and 44, Minnehaha County well 21, Turner County wells 4, 22, 32, 40, 41, and 42, Union County wells 5, 24, and 25, and Yankton County wells 3, 33 and 46.

## Summary of Well Water Fluctuations

Figure 15 shows the average water level of the flood plain wells, the average water level of the upland wells, and the accumulative departure of precipitation from normal curves. The average water level of each well above an assumed datum plane was arrived at by assuming that the water level of the well at the end of the year 1942 was 100 feet above the datum plane. The other water levels of the well were then figured in relation to this datum plane. Finally the average water level of each month was figured for each of the two groups of water wells. The accumulative departure of precipitation from normal curve was taken from U. S. Department of Commerce Weather Bureau Data for eastern South Dakota. Records of the stations at Canton, Centerville, Marion, Menno, Sioux Falls, Tyndall, Vermillion, and Yankton were used.

It can be noted from the preceeding charts that the amount of fluctuation of the water table varies considerably, due probably to the type of water bearing material, the topography of the locality, and the porosity of the top soil.

It is of interest to note the close conformity between the shapes of the water table curves of Figure 15 and the accumulative departure of precipitation from normal curve.

# ACCUMULATIVE DEPARTURE OF ANNUAL PRECIPITATION FROM NORMAL IN EASTERN SOUTH DAKOTA

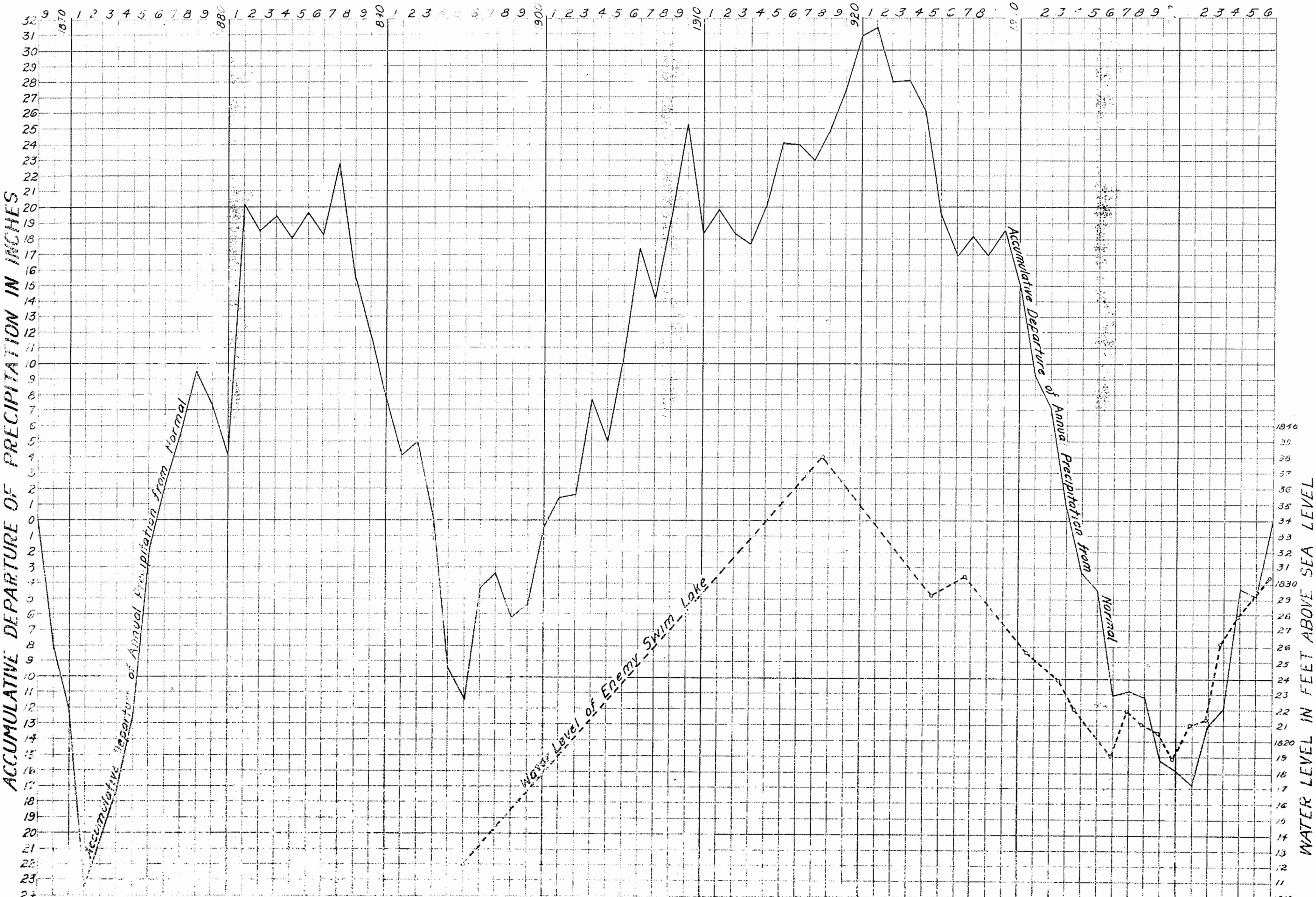



FIGURE 13

# PRECIPITATION IN EASTERN SOUTH DAKOTA

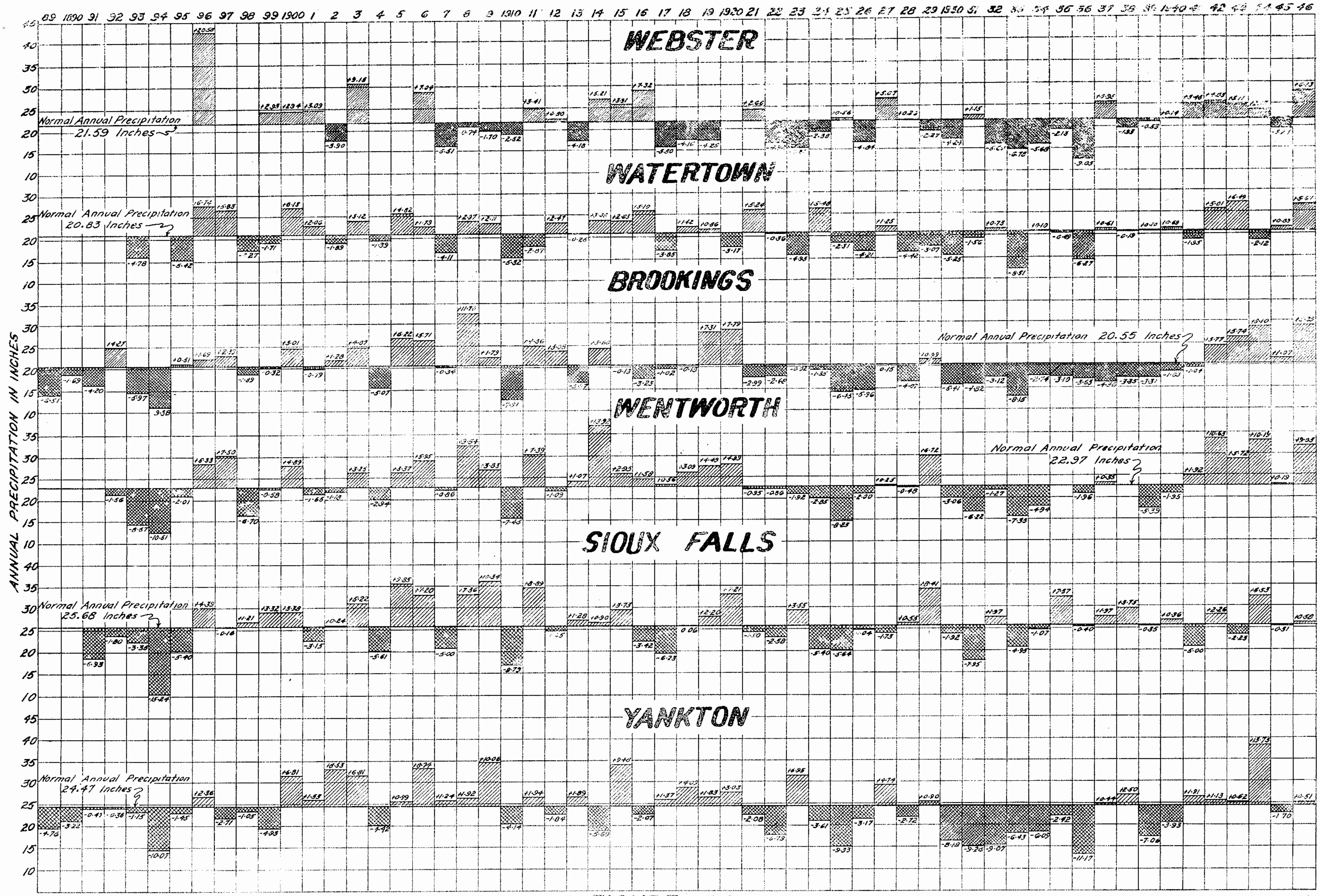



FIGURE 14

# ACCUMULATIVE DEPARTURE OF PRECIPITATION FROM NORMAL AND AVERAGE WATER LEVEL OF OBSERVATION WELLS IN SOUTHEASTERN SOUTH DAKOTA

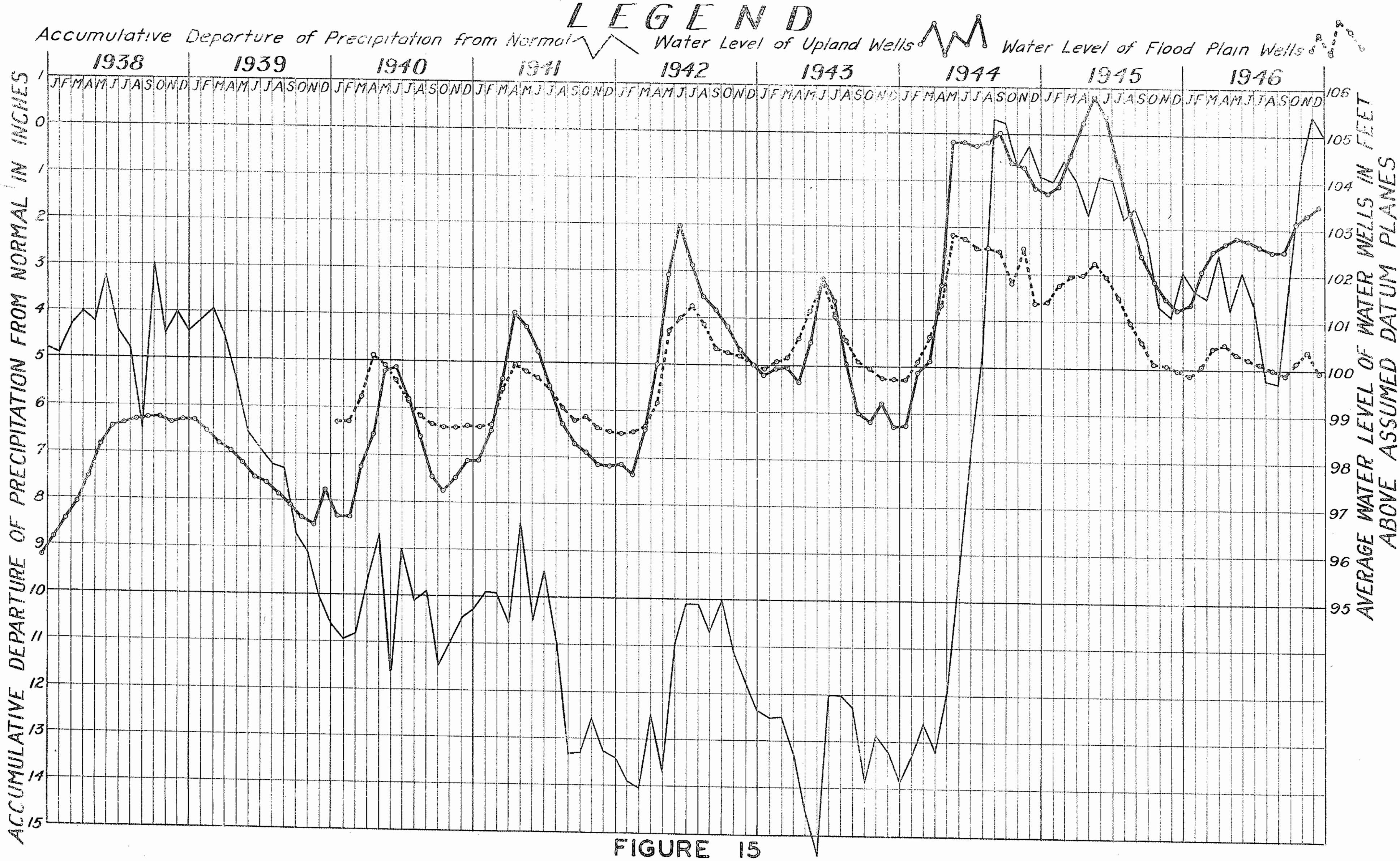



FIGURE 15