Indiana (18)

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Ground-water levels in Indiana

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U. S. Geological Survey

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Introduction

Water has been recognized as one of the necessities of life ~~since civilization began many centuries ago~~, and water from underground sources obtained through wells and springs has played a major part in the development of our modern world. The existence of the early nomads mentioned in the Bible was controlled largely by the sources of water supply and the locations of existing wells and springs. In our modern world, however, because of the relative ease with which the average citizen is supplied with water, with little or no effort on his part, the difficulties in obtaining adequate water supplies are often forgotten.

The rocks and other surficial materials of the earth's crust nearly always contain openings of one sort or another, in which water is stored. The types and character of these openings vary within wide limits, and, therefore, the rocks containing them vary widely in their capacities to store and to yield ground water.

In 1935, the Indiana Department of Conservation, realizing the importance of ground-water supplies in the agricultural and industrial development of the state, began an observation-well program in cooperation with the United States Geological Survey. As a part of the program a number of wells were selected for observation and measurements of water level in the wells were made at regular intervals. This program has been continued to date. In 1943, the Indiana State Legislature expanded the cooperative water-resources investigations of the Department of Conservation and the U. S. Geological Survey. The observation-well program was likewise expanded and now includes nearly 170 wells throughout the state.

Importance of water levels

The zone in the earth's crust in which the openings in the rocks are filled with water, is called the zone of saturation. The top of this zone, except where the top is formed by an impermeable formation, is the water table and its position is shown in a general way by the water levels in wells. In formations where the top of the zone of saturation is formed

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Slide 1 - Occurrence of ground water under water table and artesian conditions.

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by an impermeable cover, the water levels in wells will rise generally above the impermeable cover and the water in the formation is said to be under artesian pressure. Under artesian conditions, the surface represented by the water levels in wells is the pressure-indicating or piezometric surface.

The rock formations of the earth's crust are large underground reservoirs which are replenished by water from precipitation, and under certain conditions seepage from lakes and streams. Water is removed from the reservoir by natural drainage through springs and into streams, by evaporation and transpiration or plant use, and by pumping from wells. The stage to which the reservoir is full is indicated under water-table conditions by the water levels in wells.

The ways in which rainfall is dissipated is shown by the hydrologic

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Slide 2 - How the water cycle is measured.

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water cycle. Water falls on the earth as rain, snow, or hail. Part of it evaporates as it falls, part is intercepted by plants and trees before it reaches the earth, and the remainder reaches the land surface. In turn, part runs off as surface flow into streams and lakes, part is evaporated from the land surface, and another part seeps into the ground. Of the portion that seeps into the ground, part is used by plants and is returned to the atmosphere, and a part eventually reaches the zone of saturation from which it ~~part~~ drains naturally into surface streams and lakes, or is ~~and part is stored underground and may eventually be~~ recovered by wells. It has been estimated that, of the total rainfall in Indiana, an average of 65 to 72 percent is lost through evaporation and transpiration, 8 to 20 percent runs off ~~by~~ directly at the surface ~~runoff~~, and 10 to 20 percent is recharged to the ground-water reservoir, from which it is later discharged naturally or through wells. [Observation-well program]

The observation-well program which was started in 1935, included 46 wells, mainly in the northern half of the state. These wells were measured by personnel of the Indiana Department of Conservation, the Civilian Conservation Corps, the Soil Conservation Service, and various municipalities. During 1936, measurements of water level were started in an additional 25 wells in the southern part of the state. The program has been continued to date and has been expanded to include 168 wells, the majority of which are measured at weekly intervals, and 35 of which are equipped with automatic water-level recorders that give a continuous record of water-level changes. The locations of these wells are shown in slide 3.

Slide 3 - Observation wells in Indiana, 1948.

The wells selected for observation purposes are unused wells that have been abandoned for one reason or another. They include ~~All types of wells have been used~~ of all types. They have been selected mainly on the basis of geographic distribution, considering, however, local geologic and topographic conditions. The main purpose of the observation-well program has been to determine the seasonal variations and general long-time trends in ground-water levels and to study the relationship between rainfall and ground-water levels in different parts of the state.

Most of the water-level measurements are made by local observers either voluntarily or employed by the U. S. Geological Survey. The depth to the water surface below a permanent measuring point is measured, by means of a chalked steel tape and weight. The water-level information is checked and tabulated and is published in annual water level reports as Water-Supply Papers of the U. S. Geological Survey.

Slide 4 - Water level recorder installed in an observation well.

Many of the observation wells, particularly in areas of heavy pumping from wells, are equipped with water-level recorders. This equipment is placed on a shelf over the well. A copper float is placed in the well, and is attached to a cable that passes over the large wheel at the right of the instrument. This wheel causes the drum on which the recorder chart is placed to rotate as the water level moves up and down. A clock at the front of the instrument allows a pen carriage to be pulled across the chart at a regular rate of speed, making a record of the water-level changes.

Water-level fluctuations

The water level in a well is nearly always changing in response to the effects of natural and unnatural influences. Many of the changes are of minor importance, but in many wells, the effects of these minor changes must be eliminated in detailed studies of water-level records.

Water is added to the underground reservoirs by natural recharge or replenishment from precipitation. The effect of rain on ground-water levels is often very pronounced, as shown in the next slide, showing the

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Slide 5 - Effect of precipitation on water level.

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effect on the ground-water levels of about three-quarters of an inch of rain in one 24-hour period. The well in which the change was noted is about 107 feet deep, ending in limestone, and is equipped with a water-level recorder. The chart, as shown, covers a period of about 8 days, as indicated by the horizontal scale. The change in water level was about 0.63 foot, as indicated by the vertical scale. The shaded portion indicates the cumulative rainfall, in inches, for the period of the rain.

It is noted that the water level continued to decline for nearly 12 hours after the rain started. However, between 3:15 a.m. and 6:00 a.m. on May 6, only 0.04 of an inch of rain fell and this was apparently insufficient to cause any noticeable effect on the water table. No change in water level occurred until about 0.17 inches of rainfall had fallen. The water level rose rapidly and continued to rise for nearly 72 hours after the rain stopped. The total rise in ground-water level was about 10 times as great as the actual rainfall. This is quite natural, as the openings in the rock make up only a small part of the total. ~~were only about 10 percent or less than the total volume of the rock.~~ If all the rain water reached the water table, the rise would indicate an effective porosity of about 10 percent in the rock. Actually, some of the rain water probably was held by the soil, so that less than 0.75 inch reached the water table. This indicates that the porosity of the rock is less than 10 percent.

Water may be removed from the ground-water reservoirs by natural drainage into streams, by losses due to evaporation and transpiration, and by pumping from wells. The next slide shows the effects of transpiration losses or use by vegetation on ground-water levels. It should

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Slide 6 - Effects of transpiration on ground-water levels.

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be noted that during the daylight hours when the sun is out and plant growth is vigorous, the water level slowly declines. During the night hours, plant growth more or less ceases and the water level generally rises. This well is located in a grove of fairly large locust trees.

The effect of pumping from a nearby supply well on the water level in an observation well is shown in the next slide. A well about

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Slide 7 - Effects of pumpage on ground water levels.

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10 feet away is operated automatically to supply water for the ammonia condenser of an air-conditioning system. The water level in the observation well is drawn down about 1½ feet each time the nearby well is pumped. The fluctuations of water level on Saturday, Sunday, and Monday, when the department store in which the well is located is closed, are quite different from those during the rest of the week.

Other factors affecting water levels in wells include changes in barometric pressure, the passage of railroad trains, and earth tides; but these are of relatively minor importance, except in extremely detailed analysis of water-level records.

General trends in ground-water levels

Before discussing in detail the ~~general~~ trends in ground-water levels in Indiana, several general facts must be considered. When water is pumped from a well, the water level in the well must be lowered in order to cause additional water to move into the well to replace that which is pumped out. The water level in the formation around the well is also lowered, causing a depression in the water table that is shaped more or less like an inverted cone. This lowering is called the <u>cone of</u>

depression. It is also true that, when many wells in a given area are pumped, the individual cones of depression often merge and a regional cone of depression is developed. The size and shape of the regional cone of depression is determined by many factors, one of the most important being the quantity of water being pumped. The cone of depression normally will continue to expand and deepen until the quantity of ~~water crossing its outer limit plus the~~ recharge occurring within ~~the cone of depression~~ it is equal to the quantity of water being pumped. In most areas, both the recharge and the pumpage vary from day to day, and thus the cone of depression seldom remains constant in size or shape. A decline in ground-water levels does not necessarily indicate overdevelopment of the available ground-water supplies of a given area, but may indicate merely the normal expansion of the cone of depression necessary to cause the required quantities of water to flow to the wells from which it is pumped.

The increased efficiency of pumps and the widespread use of electricity has greatly increased the use of water. ~~Since~~ Because it is easier to pump larger quantities of water now than it was 20 years ago, many new uses are found for water and the average requirements ~~for water~~ have been steadily increasing. The increased use of water for industrial processes, for air conditioning and cooling, and the widespread use of water in rural areas, for sanitary plumbing facilities, for washing, and cooling, has placed a much greater demand on our sources of water. It has been estimated that an average of ~~nearly~~ about 20 billion gallons of ground water a day was pumped during 1945, nearly twice ~~that~~ the pumped during 1935.

The increased use of water is something that many people fail to realize. It is easy to turn on a faucet or press a button to turn on a pump, and as long as the water is there why worry about it? Yet, many of the wells supplying these increased demands were never really expected to yield as much water as they do now. A well that supplied 10 gallons a minute 15 years ago probably provided all the water that could be used and there is no real reason why it should be expected to produce 25 or 50 gallons per minute at the present time after 15 years of use.

Water levels throughout the state fluctuate seasonally, and the amount of seasonal change is greater than many people realize. Ground water levels generally reach their highest stage in the spring, usually decline throughout the summer months, and reach a low stage sometime between October and January. During the late winter and spring, they usually rise again. The seasonal variation in ground-water levels in Indiana may be as much as 20 or 30 feet in some wells. The comparison of water levels measured at different seasons of the year may often give misleading results.

It should also be realized that ground-water levels in Indiana bear a close relationship to precipitation. The average annual

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Slide 8 - Departure from average annual precipitation.

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precipitation for the state for the period of record of 61 years from 1887 through 1947 is 39.22 inches, according to the U. S. Weather Bureau. In order to compare precipitation with trends in ground-water levels, the actual departure from average precipitation for each year from 1935 through 1948 has been plotted as a bar graph. The dotted pattern indicates rainfall above normal and the diagonal pattern shows deficient precipitation. The years 1936, 1940, 1941, and 1944 have often been called "drought years". Rainfall in 1937 was well above normal and in 1945 was the highest on record. During the past 14 years, rainfall has been above normal about half the time.

If the departures from the average are added together, during the period 1935 to 1948 inclusive, the cumulative departure curve is obtained as shown by the dashed line. This curve shows the cumulative effect of precipitation in past years and is often used for comparison with trends in ground-water levels. It should be noted that the cumulative departure curve was extremely low in 1941 and 1944.

In 1912, W. J. McGee of the United States Bureau of Soils, obtained information on changes in ground-water levels throughout the United States by sending out questionnaires. The records of 28,906 wells were tabulated by counties throughout the United States. On the basis of his study he found that "the total lowering (in ground-water levels) since settlement ... was 14 feet or over in Indiana..." This statement has often been used in discussions of general trends of ground-water levels.

O. E. Meinzer, formerly Chief of the Ground Water Division, now the Ground Water Branch of the U.S. Geological Survey, ~~has~~ raised several questions regarding the validity of McGee's conclusions and considers that they may be misleading for a number of reasons. The principal factors that may have led to erroneous conclusions include the fact that seasonal variation in ground water levels was apparently not considered, the possibility that many wells may have filled in, and the fact that 1910 was an unusually dry year throughout the United States.

In Indiana, where the period of record of ground-water levels is quite short, generally not exceeding 14 years, no attempt has been made by the present investigation to estimate the possible decline in water level throughout the state since settlement. However, in a large part of the state, ground-water levels are less than 20 feet below the land surface and it is hard to believe that water levels in these areas were originally 14 feet higher.

There are shown in the next slide the graphs of water levels in

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Slide 9 - Graphs of water levels in Steuben 1, Montgomery 1, and Clark 1.

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3 wells in different parts of the state. Well Steuben 1 is a 1¼-inch driven well 14 feet deep, in the Pokagon State Park in northeastern Indiana. Well Montgomery 1 is a dug well 18 feet deep at Waveland, in west-central Indiana, and well Clark 1 is a dug well, 35 feet deep, in the Clark State Forest in southern Indiana.

The general trends in ground-water levels may be determined from graphs of this type in several ways. The highest or lowest levels reached each year may be compared or the water level at a given time each year may be compared. Inasmuch as the lowest level reached each year appears to be most significant from the standpoint of the well owner and well driller, this level has been used in determining general trends.

It is significant that in all three wells shown the seasonal changes is as much or more than the annual change throughout the period of record. It should also be noted that the water levels were lowest in 1940, 1941, 1944, and 1946, all years during which rainfall was more than 2 inches below normal. The lowest levels for the period of record for each of the wells occurred at different times, probably because of differences in the distribution of rainfall. It is apparent, however, that ground-water levels in these wells have not declined seriously during the past 12 years.

The graphs of several other wells throughout the state will be

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Slide 10 - Graphs of water levels in Noble 5, Boone 2, Jackson 1, and Harrison 3.

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shown as examples. Well Noble 5 is a dug well about 30 feet deep in an area of gently rolling topography. The major changes in water levels are seasonal and the seasonal change is about 6 feet. The general trend since the low level of 1941 is generally upward corresponding to a similar trend in precipitation.

Well Boone 2 is a dug well near Lebanon about 25 feet deep in an area of flat till plain. The fluctuations in water level are somewhat more rapid than in Noble 5, although the general seasonal changes are quite similar. The low water level in 1948 was about 2 feet higher than the low level during 1940.

Jackson 1 is a dug well in the Jackson State Forest, and is about 15 feet deep. The surrounding area is gently rolling and the surficial materials are the weathered soils of thin Illinoian glacial drift. The changes in water level are abrupt and the seasonal range in water level is 5 to 8 feet. Starting probably in 1946, the well was used to supply a family living nearby. It is estimated that only about 500 gallons of water a week is pumped from the well, but the effect of the pumping has greatly increased the seasonal range in water level. It should be noted that the high level each spring is about the same.

Well Harrison 3 is a dug well about 25 feet deep in the Harrison State Forest near Leavenworth. The seasonal change in water level is 3 to 5 feet and the general trend is similar to that of precipitation.

The wells for which graphs of water level have been shown are generally shallow wells less than 50 feet deep. However, the general trends in deeper wells ~~is often~~ similar. Pulaski 1, in the Jasper-

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Slide 10 - Graphs of water levels in Pulaski 1, Hamilton 2, Marion 2, and Marion 10.

Pulaski State Game Preserve near Medaryville, is a drilled well 149 feet deep, ending in limestone. The seasonal change in water level is somewhat smaller than that in the shallow wells, and the general trend appears to be slowly upward. Unfortunately, the record during 1944 was very poor and the high and low levels for that year were not measured.

Well Hamilton 2 at Noblesville, is a drilled well about 265 feet deep in limestone. The water level in this well is probably affected by pumping from several gravel wells nearby and perhaps by the White River. The seasonal range in water level is variable, but the general trend again follows that of precipitation.

The two wells in the lower half of the graph are in the downtown area of Indianapolis and the water level in these wells is seriously affected by pumping from many nearby wells. The major annual fluctuation is caused largely by the seasonal pumping of ground water for air-conditioning. Marion 2 is a gravel well and Marion 10 ends in the underlying limestone. The general trend was rapidly downward, prior to 1941, partly because of deficient precipitation and partly to the continually increasing pumpage for air-conditioning in the downtown area. Since 1941, however, the trend has been reversed and is now slowly upward. This has been due to more normal or excessive precipitation and to a probable decrease in pumping in the area, that came about voluntarily because of increasing costs of ground water for air-conditioning use.

Conclusions

We have seen the records of a number of wells of different types and in different parts of the state. We have seen the close relationship between trends in annual precipitation and trends in ground-water levels. Most of the wells for which records of water level were shown were in rural areas and water levels were generally not affected by pumping from nearby wells. The wells shown were selected primarily because of the continuity of the records, although other records show the same general trends.

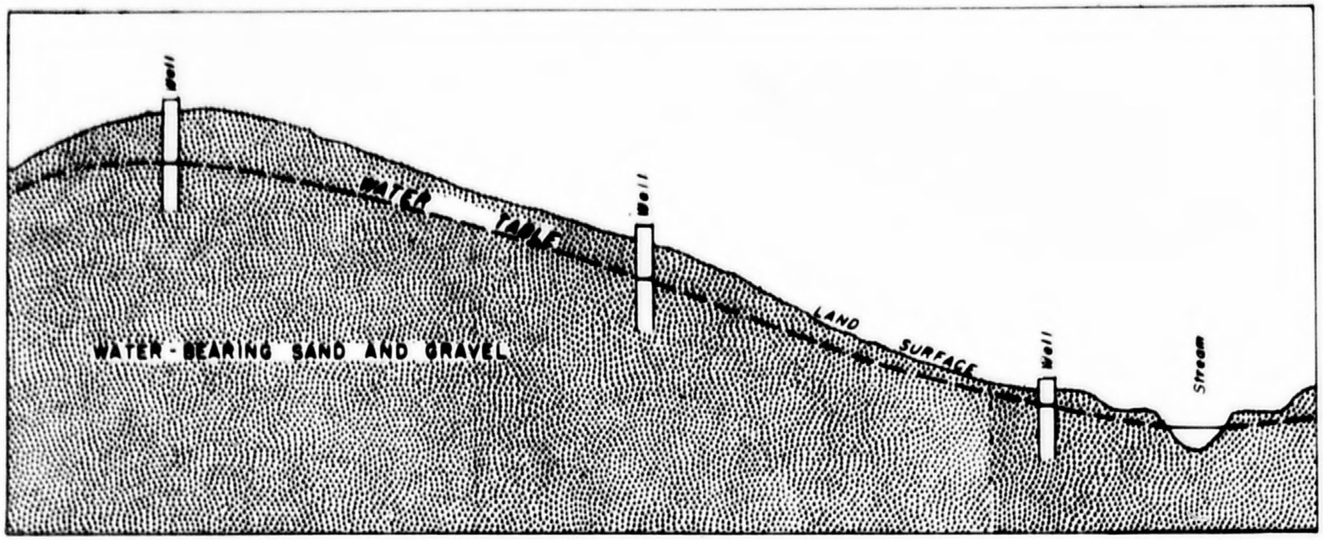
One question that is frequently asked is "Has the ground-water level in Indiana declined seriously?" I should like to answer by saying that the ground-water level in Indiana doubtless has declined to some extent since settlement of the state began. The decline, however, does not appear to be serious, except in a relatively few areas in the state where large quantities of ground water are pumped from wells or where formations have been drained by quarrying or mining operations. In many areas the lowering of ground-water levels has cut down the natural losses from the ground-water reservoirs due to drainage into surface streams and by evaporation and transpiration. In many industrial areas of the state, ground-water levels have declined necessarily in order to draw water to the wells from which it is pumped.

The general trend in ground-water levels during the past 14 years was downward through 1941 and has been more or less upward since 1941, following the trends in precipitation. It is believed that, if we experience another period of deficient rainfall, ground-water levels will probably decline again. It is essential, however, to continue measurements of changes in ground-water levels in order to be forewarned of possible overdevelopments. in areas of heavy pumping or areas of generally scanty supplies.

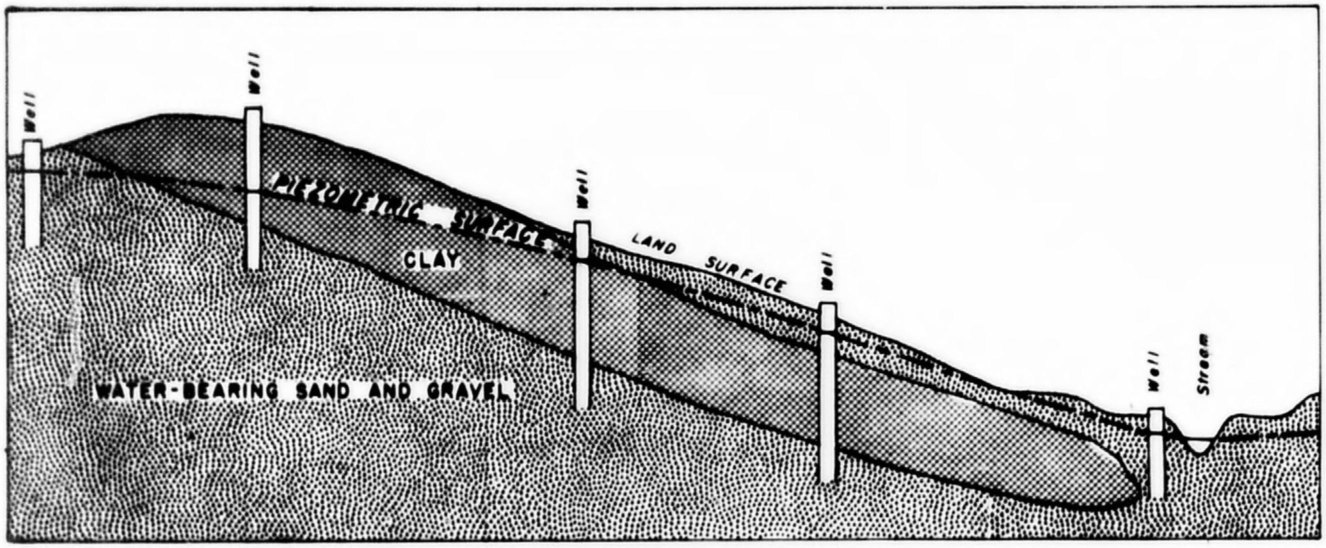
Another question that is often asked is, "Are the ground-water supplies in Indiana being exhausted?" Generally speaking, it is believed that the ground-water supplies of Indiana are not being exhausted and that additional ground-water supplies may be developed. Over-all Replenishment of the ground-water reservoirs is still greater than the withdrawals and large quantities of ground water are draining naturally into surface streams. Some of the natural drainage could be salvaged by properly spaced wells and be put to beneficial use.

There are ~~many~~ areas in the state where the ground-water supplies ~~may be developed to~~ the capacity of the source of supply. In many ~~local~~ areas, difficulty is experienced in maintaining adequate ground-water supply, mainly because of close spacing of wells and ~~to~~ the decrease in yield of individual wells.

We will continue to increase our demands for water and ground water will become increasingly important in our daily lives. We must continue our inventory of the ground-water resources of the state so that remedial measures ~~may~~ be taken to protect this valuable resource when such measures become necessary.



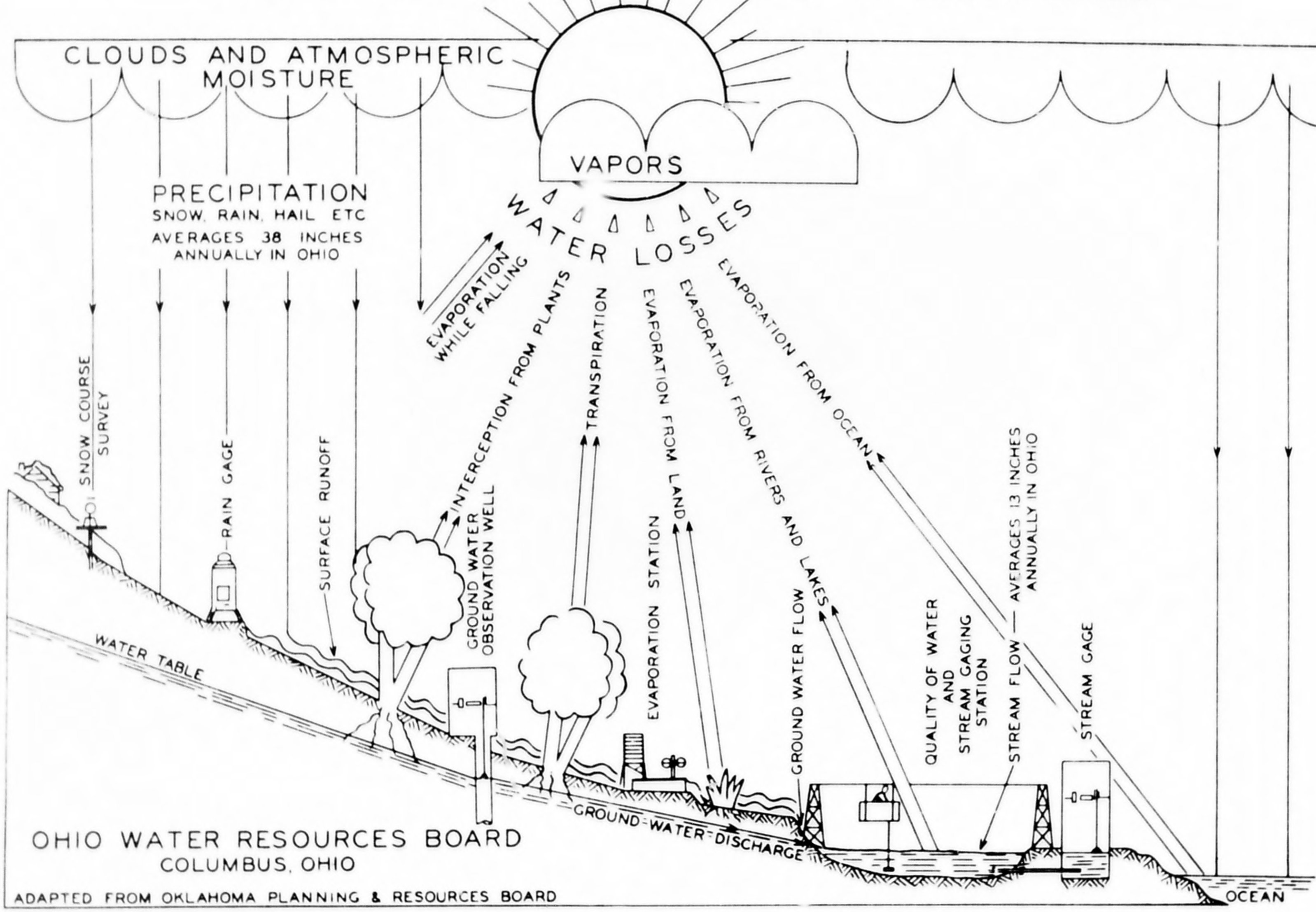
THE OCCURRENCE OF GROUND WATER UNDER WATER TABLE CONDITIONS.

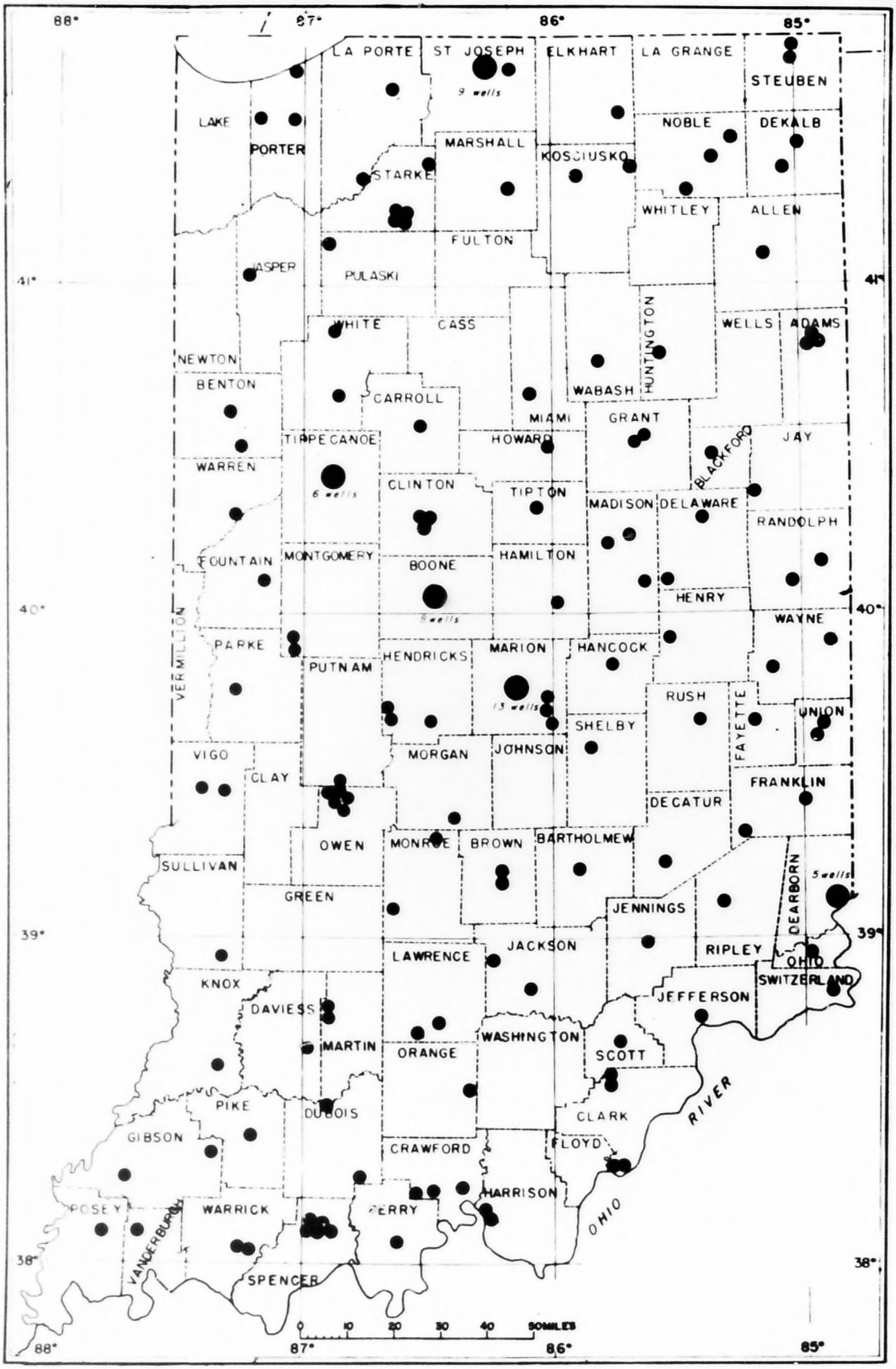


THE OCCURRENCE OF GROUND WATER UNDER ARTESIAN CONDITIONS.

Slide 1

HOW THE WATER CYCLE IS MEASURED





OBSERVATION WELLS IN INDIANA - 1948

slide 3

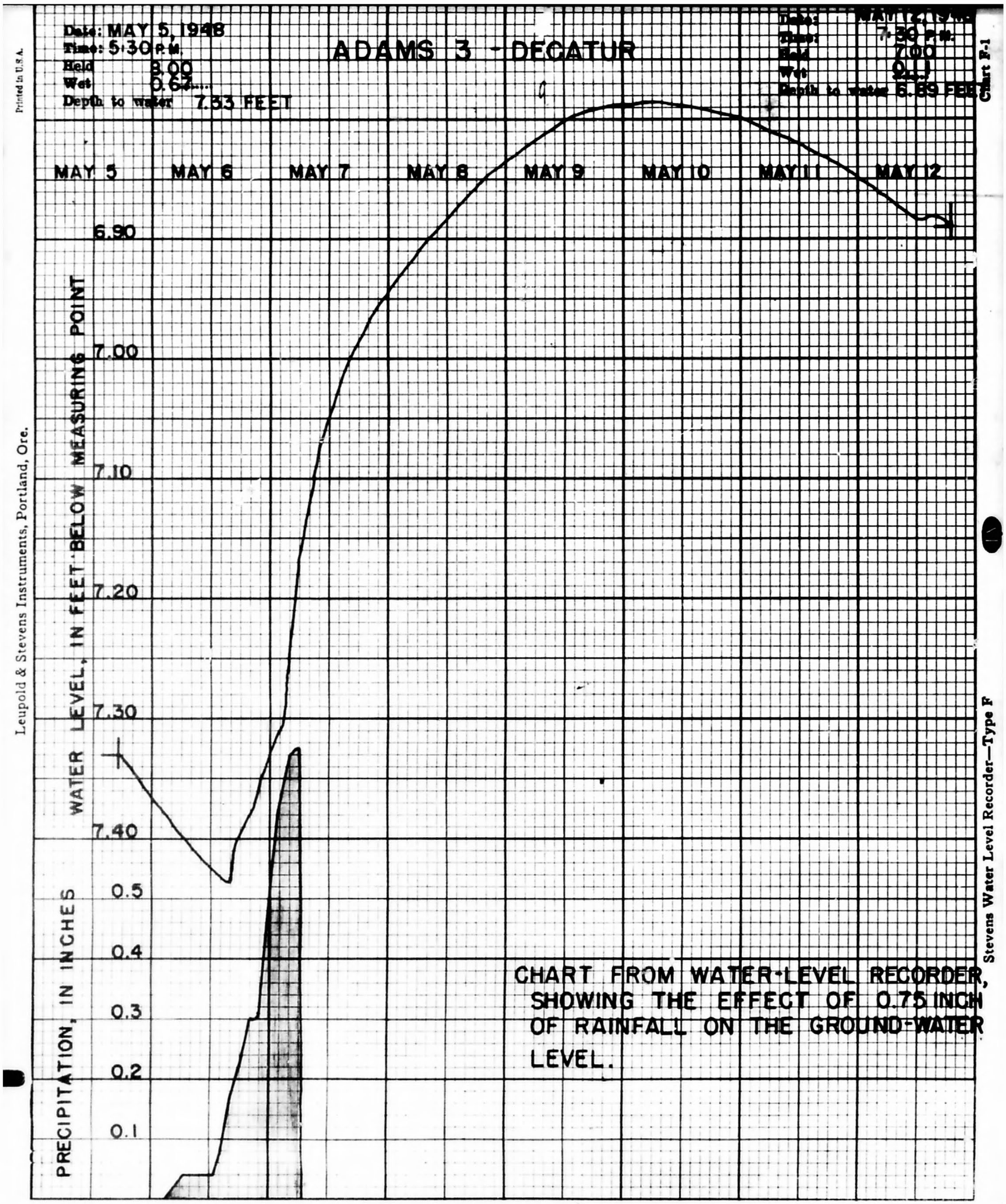


CHART FROM WATER-LEVEL RECORDER, SHOWING THE EFFECT OF 0.75 INCH OF RAINFALL ON THE GROUND-WATER LEVEL.

Slides

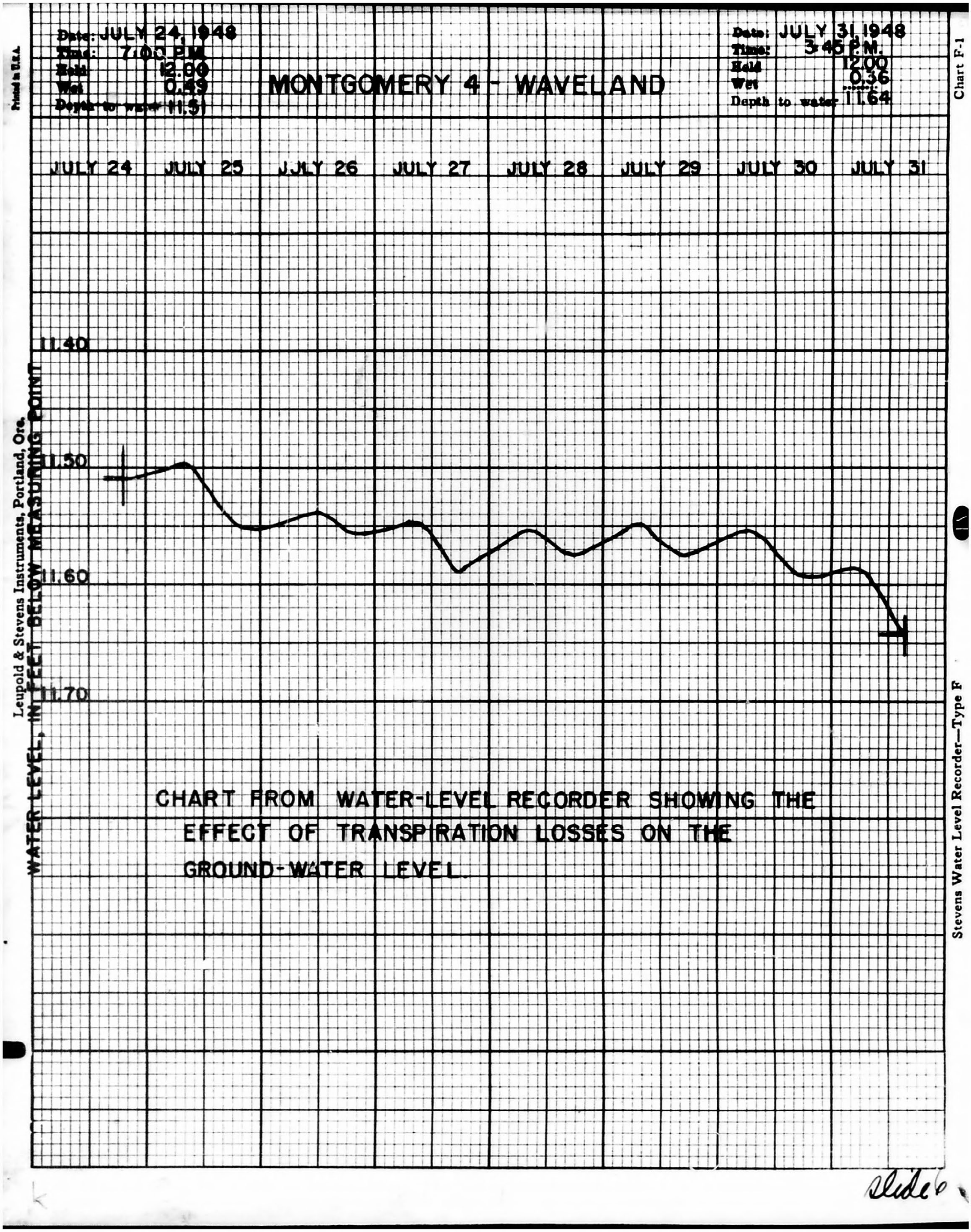


CHART FROM WATER-LEVEL RECORDER SHOWING THE EFFECT OF TRANSPIRATION LOSSES ON THE GROUND-WATER LEVEL.

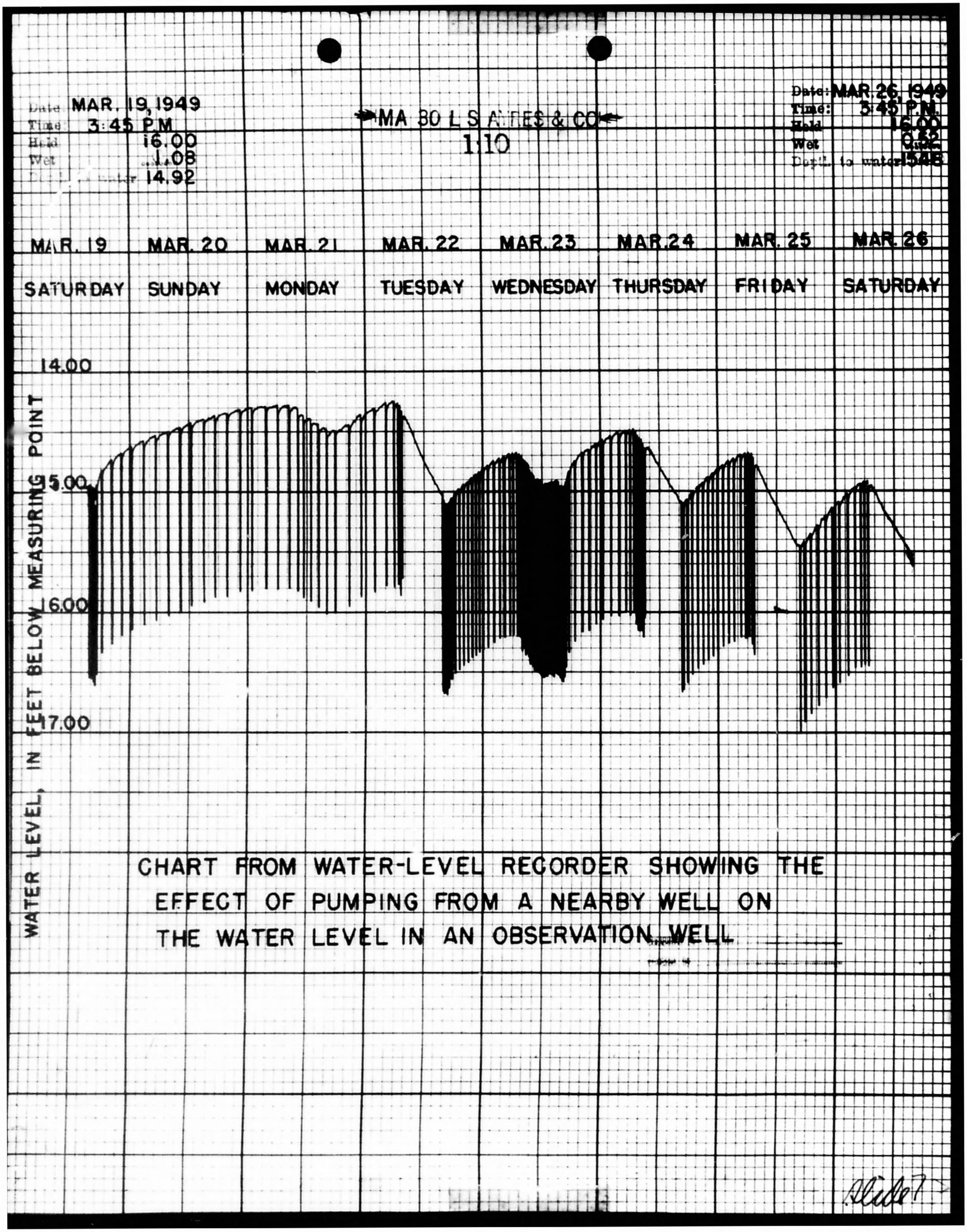
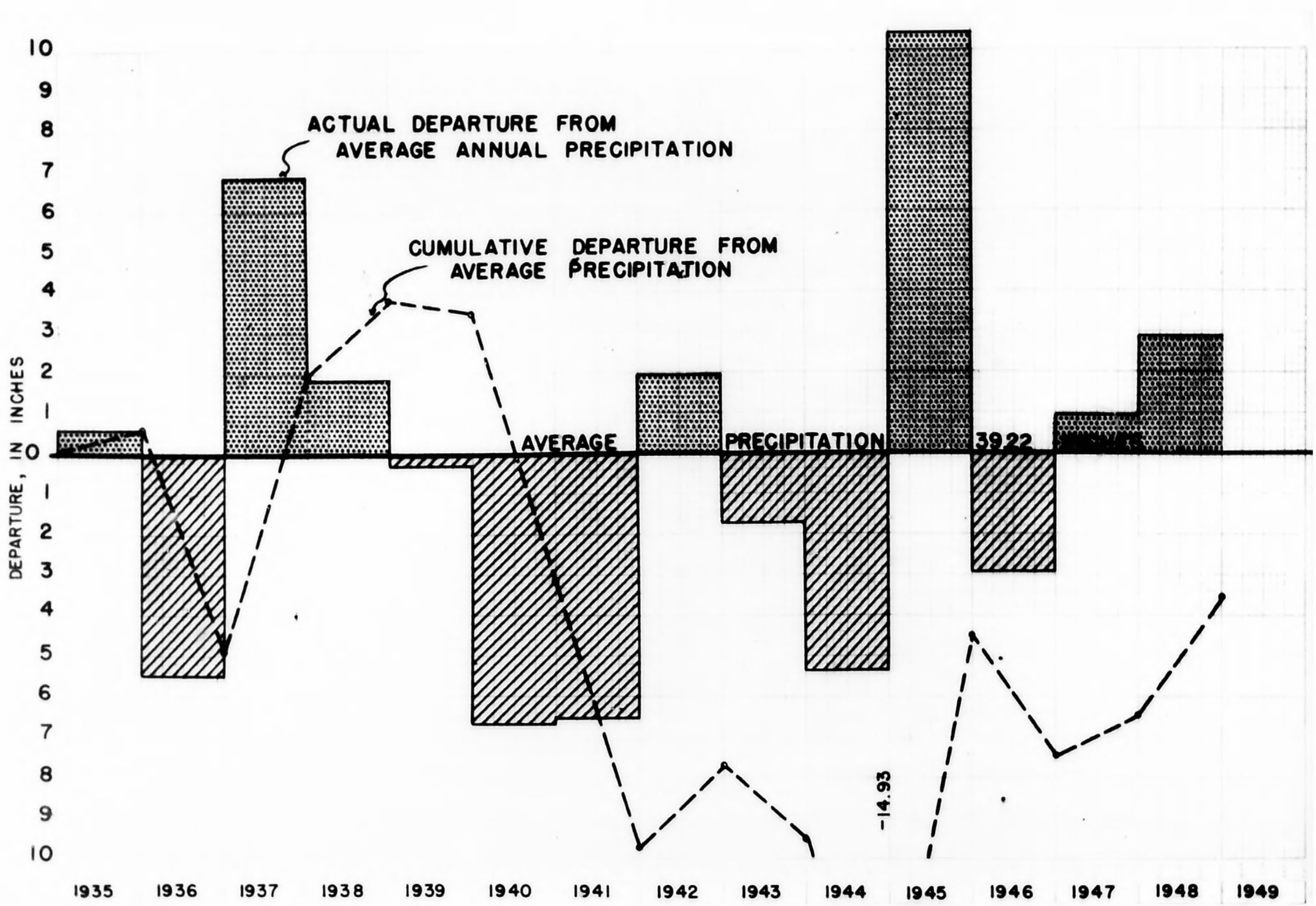


CHART FROM WATER-LEVEL RECORDER SHOWING THE EFFECT OF PUMPING FROM A NEARBY WELL ON THE WATER LEVEL IN AN OBSERVATION WELL



ACTUAL DEPARTURE FROM AVERAGE ANNUAL PRECIPITATION
CUMULATIVE DEPARTURE FROM AVERAGE PRECIPITATION
AVERAGE PRECIPITATION 39.22
-14.93
DEPARTURE, IN INCHES
10
9
8
7
6
5
4
3
2
1
0
1
2
3
4
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9
10
1935
1936
1937
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1941
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1946
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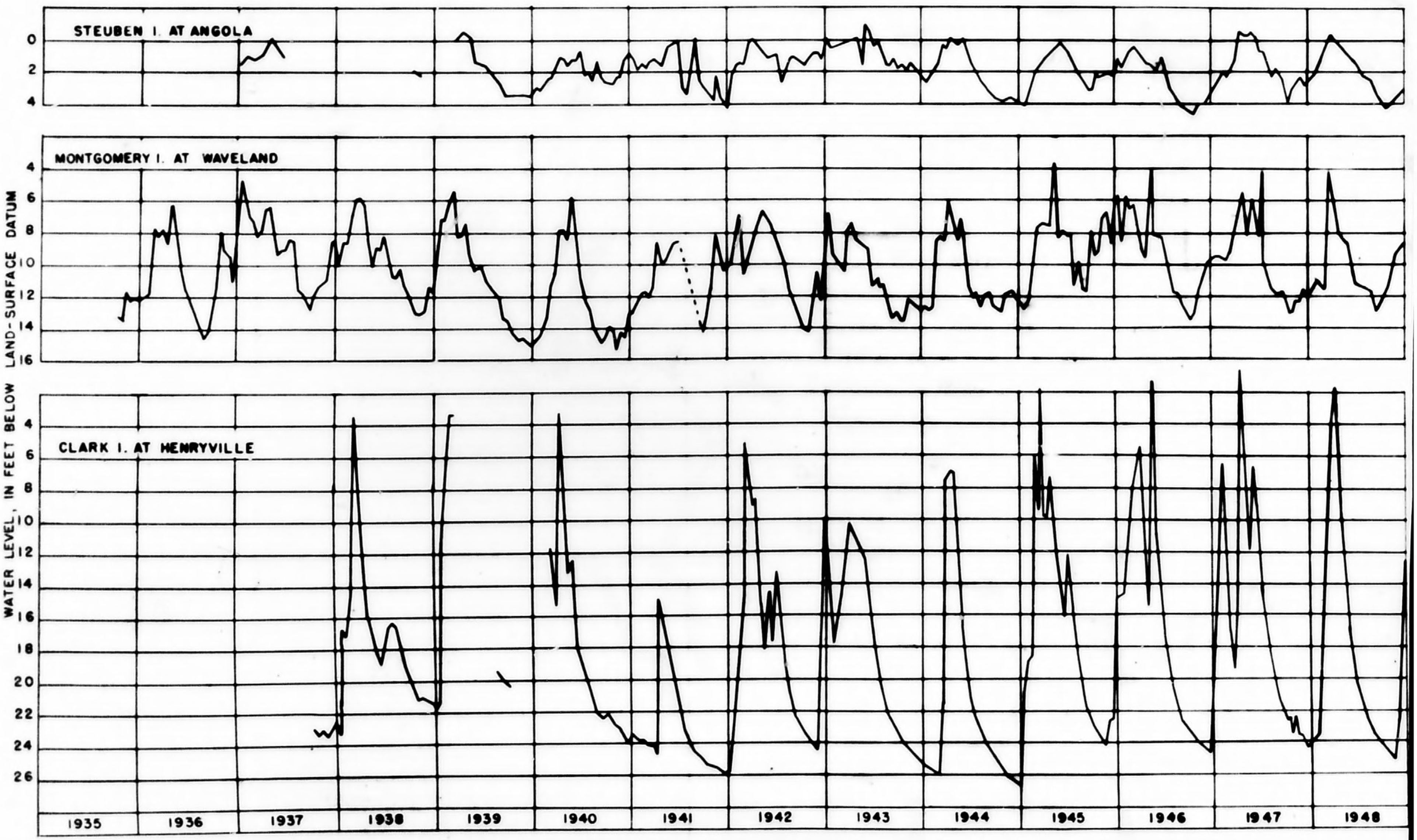
1948
1949



STEUBEN I. AT ANGOLA
MONTGOMERY I. AT WAVELAND
CLARK I. AT HENRYVILLE
WATER LEVEL, IN FEET BELOW LAND-SURFACE DATUM
0
2
4
6
8
10
12
14
16
18
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22
24
26
1935
1936
1937
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1939
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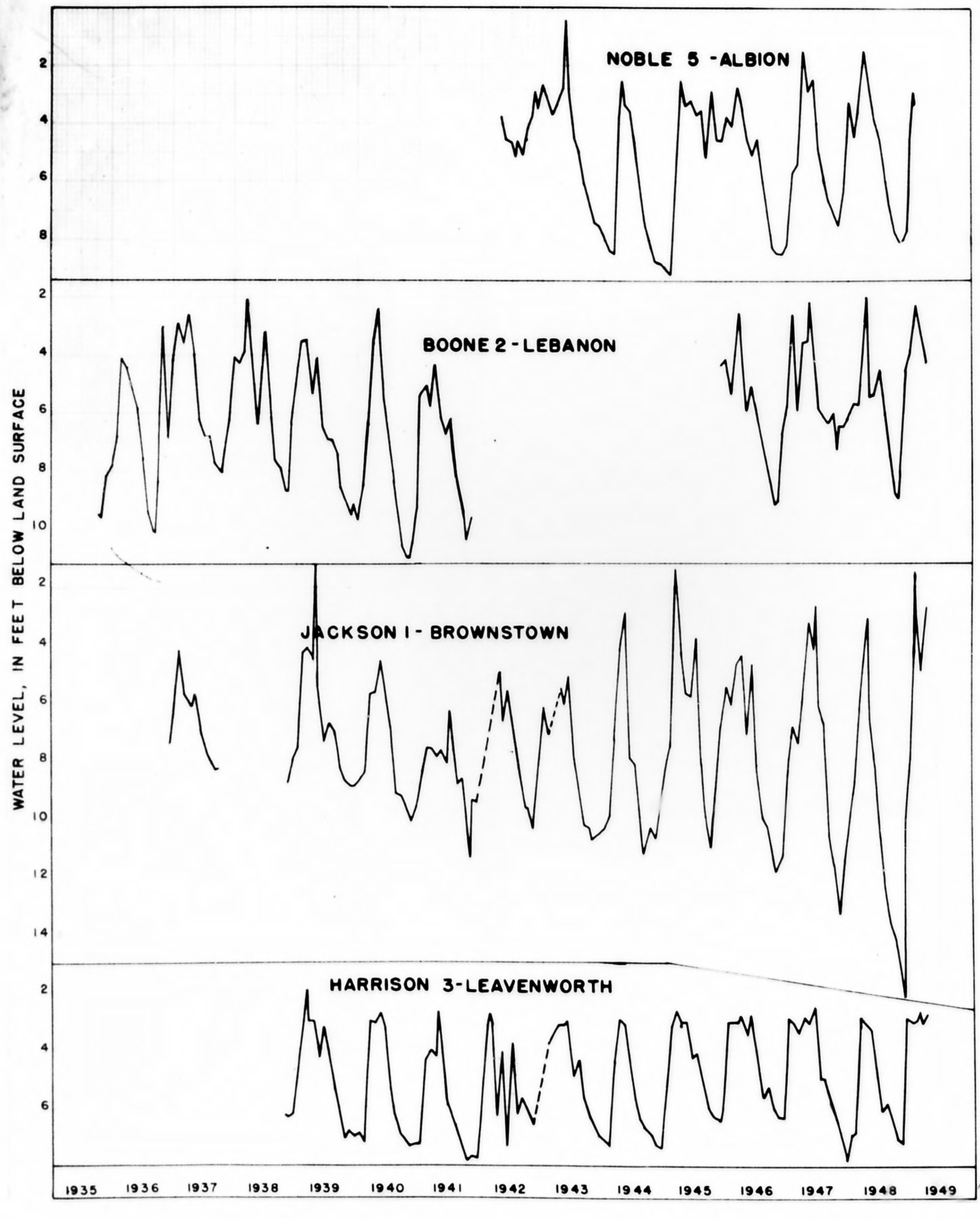
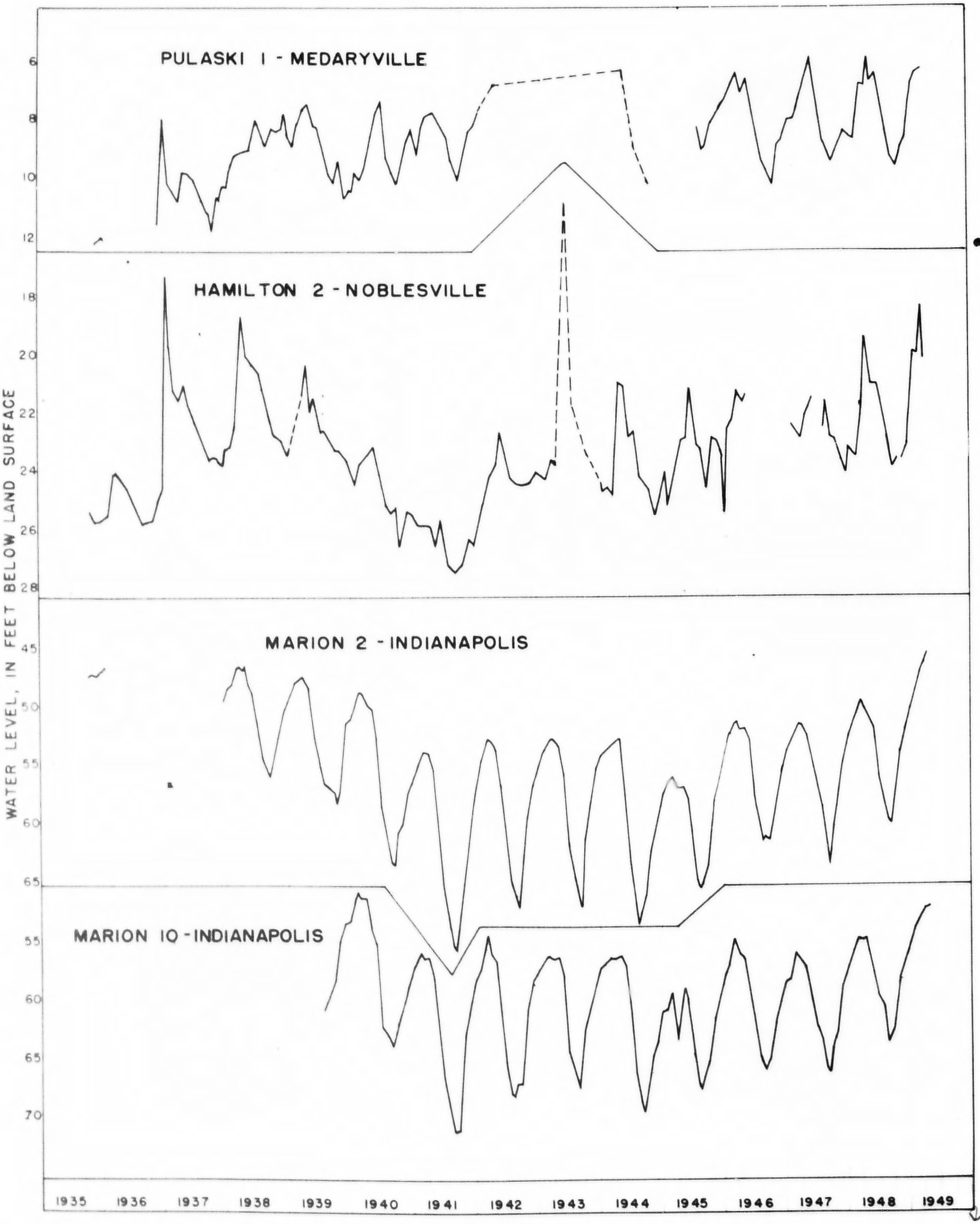
1948

Slide 9



NOBLE 5 - ALBION
BOONE 2 - LEBANON
JACKSON 1 - BROWNSTOWN
HARRISON 3 - LEAVENWORTH
WATER LEVEL, IN FEET BELOW LAND SURFACE
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949

Slide 10


PULASKI 1 - MEDARYVILLE
HAMILTON 2 - NOBLESVILLE
MARION 2 - INDIANAPOLIS
MARION 10 - INDIANAPOLIS
WATER LEVEL, IN FEET BELOW LAND SURFACE
6
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10
12
18
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24
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45
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60
65
55
60
65
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1935
1936
1937
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1949

Slide