STATE OF OHIO
DEPARTMENT OF PUBLIC WORKS

OHIO WATER RESOURCES BOARD

THE GROUND-WATER RESOURCES OF THE GLACIAL DEPOSITS IN THE VICINITY OF CANTON, OHIO

Prepared in cooperation with the
U.S. Geological Survey
and the
City of Canton, Ohio

BULLETIN NO. 3
COLUMBUS, OHIO
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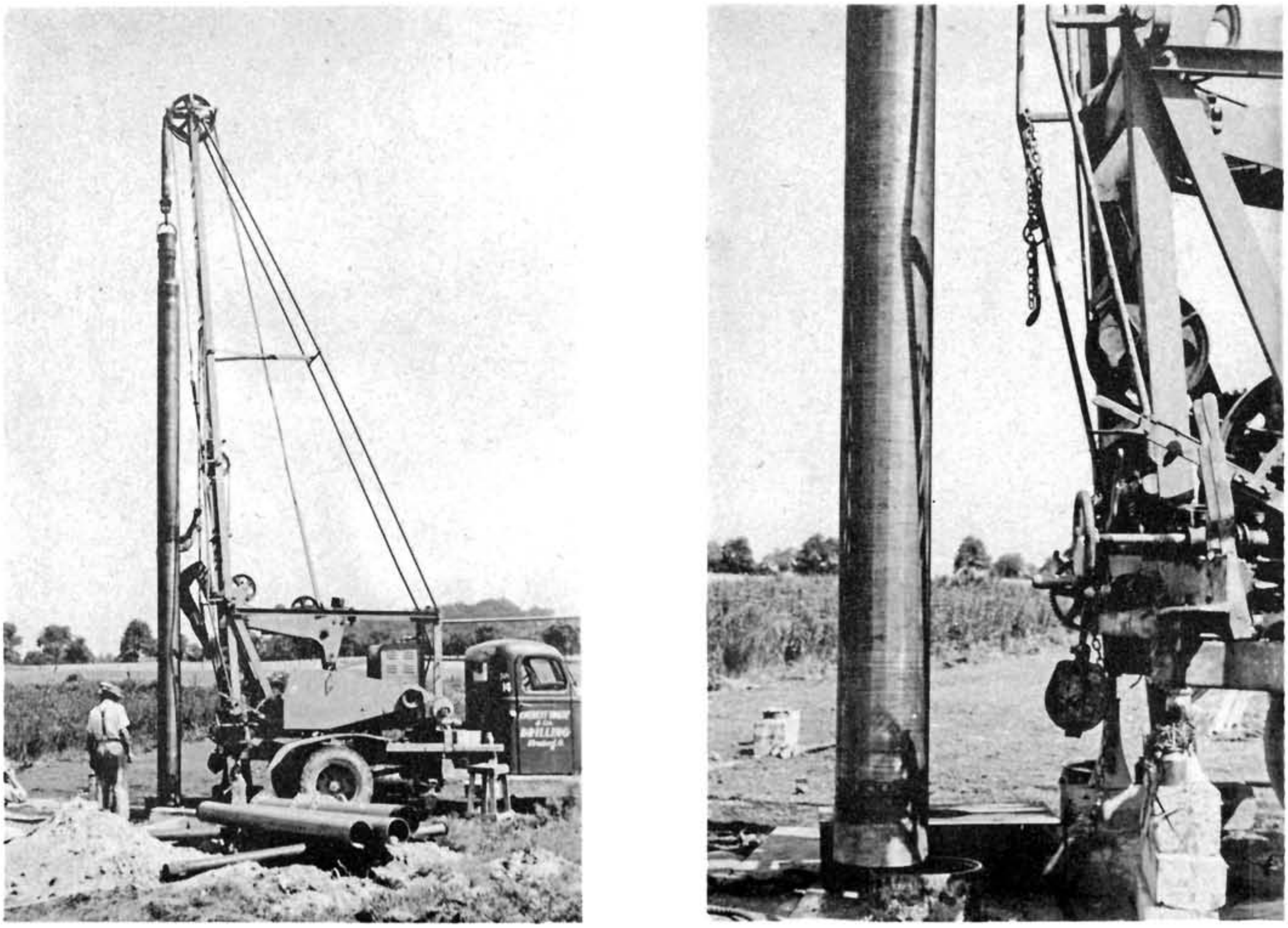

LOWERING A SCREEN INTO THE 12" PUMPING WELL FOR SIPPO WELL FIELD PUMPING TEST.

WEIR WITH RECORDING GAGE IN SHELTER TO RECORD FLOW OF SIPPO CREEK DURING PUMPING TEST.

Bulletin No. 3

Ohio Water Resources Board

Columbus, Ohio

THE GROUND WATER RESOURCES OF THE GLACIAL DEPOSITS IN THE VICINITY OF CANTON, OHIO

by

Edward J. Schaefer, George W. White,

and Donald W. Van Tuyl

Prepared in cooperation with

the U.S. GEOLOGICAL SURVEY

and

the CITY OF CANTON, OHIO

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COLUMBUS, OHIO

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LETTER OF TRANSMITTAL

Dean Charles E. MacQuigg, Chairman
Ohio Water Resources Board
Columbus, Ohio

Dear Sir:

I am transmitting herewith and recommending for publication the report "The Ground Water Supplies of the Glacial Deposits in the Vicinity of Canton, Ohio."

Large quantities of ground-water are pumped in the vicinity of Canton by the City and its industries. The present report analyzes the quantities of water pumped, the rate of recharge in various parts of the area, and the changes in ground water storage in the industrial area and in areas of municipal pumpage. The large difference in recharge in upland areas as compared to those areas traversed by through-flowing streams is apparent.

The report outlines in detail a pumping test of long duration on an unpumped area known as the Sippo well field. The purpose of the test was to determine the perennial yield of the area. The results obtained from the pumping test were verified by determining recharge rates and by measuring the outflow of ground water into Sippo Creek. The Sippo well field has been considered as an auxiliary supply for Canton.

The cooperation of the officials of the City of Canton and many of its citizens is hereby gratefully acknowledged.

Respectfully submitted

C.V. Youngquist
Chief Engineer

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ABSTRACT

This report describes the results of an investigation of the geology and ground-water resources of the glacial drift in and near Canton, Ohio. The investigation was carried on mainly throughout the year 1945 and the early part of 1946. However, an observation well program has been carried on in the heavily pumped parts of the area since 1939, and the conclusions regarding the trends of ground-water levels in the pumped areas are based on the records obtained from this program.

The work described in most detail in this report, relating to an estimate of the perennial yield in the Sippo Area, an area about $5\frac{1}{2}$ miles west of Canton in Stark County, was done by personnel of the U.S. Geological Survey and the Ohio Water Resources Board in financial cooperation with the City of Canton. The investigation in the Sippo Area included studies of the source and amount of recharge and the conduct of a pumping test to determine to what extent the recharge can be recovered by pumping from wells located in section 3, Perry Township. The report includes a map showing the types of surficial glacial deposits in an area which includes the central part of the Canton quadrangle and the eastern part of the Massillon quadrangle in Stark County. Two other maps, showing the approximate contours of the bedrock surface and the thickness of glacial drift, are also included.

U.S. Weather Bureau records show that the average annual precipitation at Canton, for 63 years of record, is 38.52 inches. Precipitation is well distributed throughout the year. The maximum precipitation occurring in any year during the period of record was 54.02 inches in 1890 and the minimum was 28.29 inches in 1944. The mean annual temperature has averaged 50° F. The summer mean is about 70° F. although temperatures above 90° are often recorded. The winters are moderately cold, the mean temperature being 29°. From late in November to March the temperature frequently falls below zero.

The Canton quadrangle lies wholly within the glaciated portion of the Allegheny Plateau. The glacial drift is deposited on bedrock of Pennsylvanian age. The bedrock is mainly shale and sandstone, with occasional thin beds of coal, fire clay, and limestone.

The glacial materials lying on the bedrock in the vicinity of Canton were deposited during at least two glacial stages, the Illinoian and the Wisconsin. These materials vary from relatively impermeable till in the areas of ground moraine to cleanly washed gravels in the outwash plains and valley trains. These materials range in thickness from less than 50 feet in the uplands to more than 200 feet in the buried valleys.

Those parts of the area traversed by deep buried valleys filled with permeable glacial materials and where conditions of recharge are suitable, offer the best sites for obtaining large ground-water supplies for municipal and industrial purposes. Good ground-water supplies for farm purposes are available from the glacial drift throughout most of the Canton quadrangle except in some of the ground-moraine areas covered with impermeable till. Some of the ground-moraine areas, however, are underlain with permeable gravels.

Large ground-water supplies are obtained by the City of Canton and its industries from outwash and valley train gravels deposited in a system of buried valleys underlying the Middle and East Branches of Nimishillen Creek and continuing through the city proper in a westerly direction to the Tuscarawas River. A survey of ground-water pumpage made by the Ohio Water Resources Board in 1944 shows that a total of 38 million gallons a day of ground water was pumped by the city and its industries in 1944. Of this amount 7 million gallons a day was pumped from the bedrock formations and 31 million gallons a day was pumped from the glacial deposits in and near the city. Approximately 19 million gallons a day was pumped from the outwash gravels underlying the city proper and 11.9 million gallons a day was pumped from the gravels underlying the Northeast and Grovemiller well fields. The Northeast well field is located at Trump, along the Middle Branch of Nimishillen Creek, and the Grovemiller field is located along Tuscarawas Avenue about 3 miles west of the city.

Water-level measurements obtained in an observation well in the Northeast well field since 1941 show that the pumpage in that area, which has averaged 7.6 million gallons a day from the beginning of 1941 through 1945, has been well within the amount of recharge received in that period. Measurements obtained in an observation well located about 1¼ miles north of the Northeast field show that recharge in the area is received mainly, in the first six months of each year from direct precipitation, from the flood waters of Nimishillen Creek, and probably from direct infiltration from Nimishillen Creek. It is possible that an additional supply of ground water can be obtained north of the Northeast well field in the vicinity of sections 13 and 24, Plain Township, but the amount cannot be predicted on the basis of data now available.

Ground-water levels have been measured since 1939 in two observation wells in Canton proper. These records show that from 1939 until the end of 1944 the water levels declined nearly 30 feet and that pumping exceeded recharge in the city proper. A net rise in water levels of about 5 feet occurred from the end of 1944 to the end of April, 1946. It is estimated that in the period 1939 through 1945, the pumping in Canton proper exceeded the recharge by about 3½ million gallons a day and the recharge amounted to 15.6 million gallons a day.

The records of water levels in observation wells in the Grovemiller well field indicate that pumping in that field has not exceeded the average amount of recharge available. It is estimated that recharge in the Grovemiller area averaged about 400,000 gallons a day per square mile in the period January 1, 1943 to December 31, 1945.

Studies made in the Sippo area indicate that the average recharge within the natural ground-water divides will average from 374,000 to 460,000 gallons a day per square mile. Since the natural ground-water divides encompass an area of about 9 square miles, the total recharge available would be about 3½ to 4 million gallons a day. The investigation and pumping test conducted on property owned by the City of Canton in section 3, Perry Township, indicate that the depth and permeability of the gravels in the main buried valley and in the tributary buried valleys are sufficient to permit the recovery of most of the recharge available in the area. The perennial yield of the Sippo area to wells located in section 3, Perry Township, is therefore estimated to be from 3½ to 4 million gallons a day.

INTRODUCTION

Purpose and Scope of the Report

The city of Canton is situated in northeastern Ohio 57 miles south of Cleveland and 23 miles south of Akron at longitude 81°22' W and latitude 40°48' N. The population of Canton according to the 1940 census was 108,401. It is estimated that an increase of about 6% in population has occurred since 1940 so that the present population is probably about 115,000. Canton is an important industrial center, the largest industries being those engaged in the production of metal products.

This report describes the results of an investigation of the geology and ground-water resources of the glacial drift in and near Canton, Ohio. It is one of a series of such reports to be prepared by the Ohio Water Resources Board and the U.S. Department of the Interior, Geological Survey, and supplements a report on water supply in Stark County, published by the Ohio Water Resources Board in August 1943. The investigation was carried on in financial cooperation with the city of Canton. The major portion of the investigation was devoted to a study of the buried valley passing through Canton and continuing westward to the Tuscarawas River. The report describes the trends of ground-water levels in the parts of the buried valley now pumped by the city of Canton and its industries, and considers the possibility of obtaining an additional supply from this valley in the Sippo Creek area in Perry Township.

The investigation in the Sippo Creek area included a water-table survey and the conduct of a pumping test to aid in predicting the perennial yield of the area. Studies were also made of the flow of Sippo Creek for the same purpose.

As an aid to development of additional water supplies for municipal, industrial, and farm use in the glacial drift in the vicinity of Canton, the report includes geologic maps showing contours of the bedrock surface and thickness of glacial drift for the entire Canton quadrangle. Another map shows the types of glacial drift existing at the surface in the part of the Canton quadrangle below the Summit County-Stark County line and in a small portion of the Massillon quadrangle. The water-bearing properties of the different types of drift are also described in the report.

The types of glacial drift were determined by field studies of exposures in road cuts, gravel pits, quarries, house excavations, and from drilling records. The maps showing the bedrock surface and thickness of drift were prepared mainly from a compilation of bedrock depths by Reese[1/] and from well logs contained in the files of the Ohio Water Resources Board, the Geological Survey of Ohio, the Ohio Division of Mines, and the Canton Water Department.

Acknowledgments

O.E. Meinzer, Geologist in Charge, U.S. Geological Survey, Ground Water Division, C.V. Youngquist, Chief

1/ Reese, George A. Report on Canton Water Supply, March 1939.

Engineer, Ohio Water Resources Board, and A.E. Ransom, Superintendent, Canton Water Department, exercised general supervision of the investigation, and the preparation and review of this report.

In addition to those named above, the authors acknowledge the assistance of the following in the conduct of the investigation: R.J. Bernhagen, Chief Geologist, and J.W. Cummins, Geologist, Ohio Water Resources Board; H.E. Byers and T.T. Paumier, Canton Water Department; B.H. Davis, Geologist, and J.O. Riordan, Hydrographic Field Assistant, U.S. Geological Survey; Everett and Donald Waltz and J.W. Goetz, drilling contractors. Special thanks are due Miss Evelyn Hoffman and J.C. Krolczyk, draftsmen, Ohio Water Resources Board, who prepared the illustrations contained in the report.

CLIMATE

Ohio lies in the humid part of the United States, as distinguished from the arid or semi-arid parts of the country. It is characterized by perennially flowing streams, the flow being maintained during dry periods by ground-water runoff, except in some rock areas where conditions are not suitable for storage of ground water.

The U.S. Weather Bureau has obtained precipitation records at a station north of Canton along Middle Branch Nimishillen Creek since 1883. This record is the eighth longest obtained in Ohio. Geographically, the Canton area is placed by the Weather Bureau in the Northern Division, Ohio Section.

The average annual precipitation for the 63 years of record is 38.52 inches compared to a State average of 37.93 inches and a Northern Division average of 35.60 inches. The average precipitation at Canton approaches the Middle Division average of 38.20 inches more nearly than it does the Northern Division average. The maximum precipitation occurring in any year during the period of record was 54.02 inches in 1890 and the minimum was 28.29 in 1944.

The average annual precipitation of 38.52 inches is well distributed throughout the year, being greatest during the summer months and smallest during the fall months as shown in table 1.

Table 1

Average monthly precipitation in inches and seasonal distribution at Canton, Ohio, 1883-1945

Month	Average	Month	Average
December	2.69	June	4.07
January	2.96	July	4.45
February	2.62	August	3.45
Winter	8.27	Summer	11.97
March	3.32	September	3.10
April	3.16	October	2.48
May	3.67	November	2.55
Spring	10.15	Fall	8.13

Monthly precipitation for the period 1941 through 1945 is shown on the graph in figure 1.

Although the average precipitation for the summer is greater than the averages for other seasons of the year, summer rainfall contributes the least to ground-water recharge because of high losses to the atmosphere by transpiration and evaporation.

The amount of precipitation contributed to ground-water recharge in the other seasons depends on the intensity of the rainfall, on temperature and relative humidity, ground conditions, and vegetal cover. In general, ground-water level records collected in Ohio indicate that the greatest amount of recharge is received from precipitation falling in the late winter and spring. Long droughts occurring in this period have a pronounced effect on the total amount of recharge received in any particular year. Table 2 summarizes notable dry periods at Canton since 1934.[2/]

Table 2

Notable Dry Periods at Canton, Ohio
1934-45

Amt. rain (inches)	No. days	Period began
0.66	33	1-10-34
.57	44	4-24-34
.19	27	11-5-36
.41	27	9-6-37
.22	31	8-12-38
.56	42	9-23-38
.40	26	11-25-38
.80	43	8-14-39
.49	31	11-1-39
.21	25	8-31-40
.98	55	3-13-41
.02	22	9-11-41
.45	32	4-13-42
.39	26	6- 2-43
.22	25	9-18-43
.46	55	11-18-43
.49	35	1- 7-44

The long dry periods beginning in January 1934, March 1941, April 1942, and January 1944 are examples of periods having an adverse effect on the amount of ground-water recharge received in those years.

2/ Mindling, G.W. Weather Headlines in Ohio, Ohio Engineering Experiment Station Bulletin number 120, 1944.

The mean annual temperature in the Canton area is 50°F. The summer mean is 70°. Hot spells sometimes occur between May and September, when the temperature rises above 90°, and these are usually attended by high relative humidity.

The winters are moderately cold, the mean for the winter months being 29°. From the latter part of November to March the temperature frequently falls below zero. The coldest spells generally occur in February, when an absolute minimum of -20° has been observed. January is also a cold month. The ground is often covered with snow in both January and February and the snow provides a source of appreciable ground-water recharge when it melts.

PHYSIOGRAPHY AND DRAINAGE

The Canton quadrangle is located almost wholly within the glaciated portion of the Allegheny Plateau. The boundary between the glaciated and unglaciated portions of the plateau is slightly beyond and south-southeast of the quadrangle, with the exception of a small unglaciated area in the southeast corner.

The surface, covered almost entirely by glacial drift, is gently rolling to undulating to hummocky. The elevation ranges from 1150 to 1250 feet above sea level except in the valleys, where the elevation is about 1000 feet. The relief is about 250 feet. The surface is maturely dissected in the Illinoian drift region southeast of Canton but the remainder of the region, within the Wisconsin drift, is in a youthful stage of dissection.

Beneath the drift of the plateau is a maturely dissected bedrock surface having an elevation on the uplands of about 1100 feet, except in the eastern part where it reaches 1200 feet, as shown in plate 3. Several deep, rather narrow valleys have been cut in the bedrock of the plateau. The rock surface is covered by a mantle of glacial drift, ranging in thickness from less than 50 feet on the uplands to over 200 feet in the deeper valleys (plate 2).

Most of the Canton quadrangle is drained by Nimishillen Creek and its tributaries. West Branch and its tributaries drain the area from Canton to North Canton and Greentown, Middle Branch the area north-northeast and northeast of Canton, and East Branch the area east of Canton. East Branch and Middle Branch join in the northeastern part of Canton and the combined stream is joined by West Branch in the southern part of the city to form Nimishillen Creek, which then flows southward to join Sandy Creek, thence to the Tuscarawas River at Bolivar. Sippo Creek rises in east-central Jackson Township just southeast of McDonaldsville and flows south into Perry Township where it is joined by tributaries from southeastern Jackson Township and Sippo Lake. It then flows westward through the northern part of Perry Township to northeastern Massillon and thence southwest to join the Tuscarawas River in the central part of that city. The northern part of the Canton quadrangle is drained by Congress Lake Outlet and by the headwaters of the Tuscarawas River. The Tuscarawas River rises in the northern part of the Canton quadrangle near Uniontown, flows in a general westerly direction to Barberton in Summit County, where it turns south, re-entering Stark County and continuing southward across the western part of the county. Congress Lake, in the northern part of the quadrangle, is the largest of several lakes and ponds. Meyers Lake, at the northwest edge of Canton, has had its outlet raised by a dam. Lake O'Springs and Cable Lake in Jackson Township have been formed by dams across the upper part of Sippo Creek valley. Sippo Lake in northeastern Perry Township has been enlarged by a dam at the outlet. All of these lakes, except Cable Lake and Lake O'Springs, rest in kettlehole-like depressions in the glacial drift.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Bedrock Formations

The bedrock in the Canton area is mainly shale and sandstone, but thin beds of coal, fire clay and limestone also occur in some places. The oldest strata belong to the Pottsville formation of Pennsylvanian age, which are overlain by those of the Allegheny formation. The uppermost member of the Pottsville is the Brookville clay and the lowest member of the Allegheny is the Brookville coal, which is overlain by the gray Putnam Hill limestone member. Strata of the Conemaugh formation are preserved several miles southeast of Canton. The strata are essentially horizontal, dipping only 14 feet per mile to the southeast.[3/]

3/ Harker, D.H. and Bernhagen, R.J., Water Supply in Stark County, Ohio Water Supply Board Report, 1943, p. 17.

All of the sandstones may be water-bearing, but the two lowest sandstone members of the Pottsville formation are the only ones of importance. A discussion of these is not within the scope of this report.

Outcrops of bedrock are rare in the region of Wisconsin drift west and north of Canton, but are common in the region of Illinoian drift south and southeast of the city. The Putnam Hill limestone and underlying Brookville coal and clay, outcrop at several places in Canton and nearby: at the level of tracks just north of the Wheeling and Lake Erie Railroad shops in the southwest part of the city; in the pits of the Metropolitan Brick Company, just south of the city limits; in the bank at the north end of the cemetery on Twelfth Street; and in the cliffs on the west side of West Branch Nimishillen Creek about 300 yards north of Fulton Street.

Sandstone and shale of Mississippian age underlie the Pennsylvanian strata, but do not outcrop. They are penetrated in drilling, and may form the rock wall in contact with the drift which fills the lower part of the buried valley in the Sippo area.

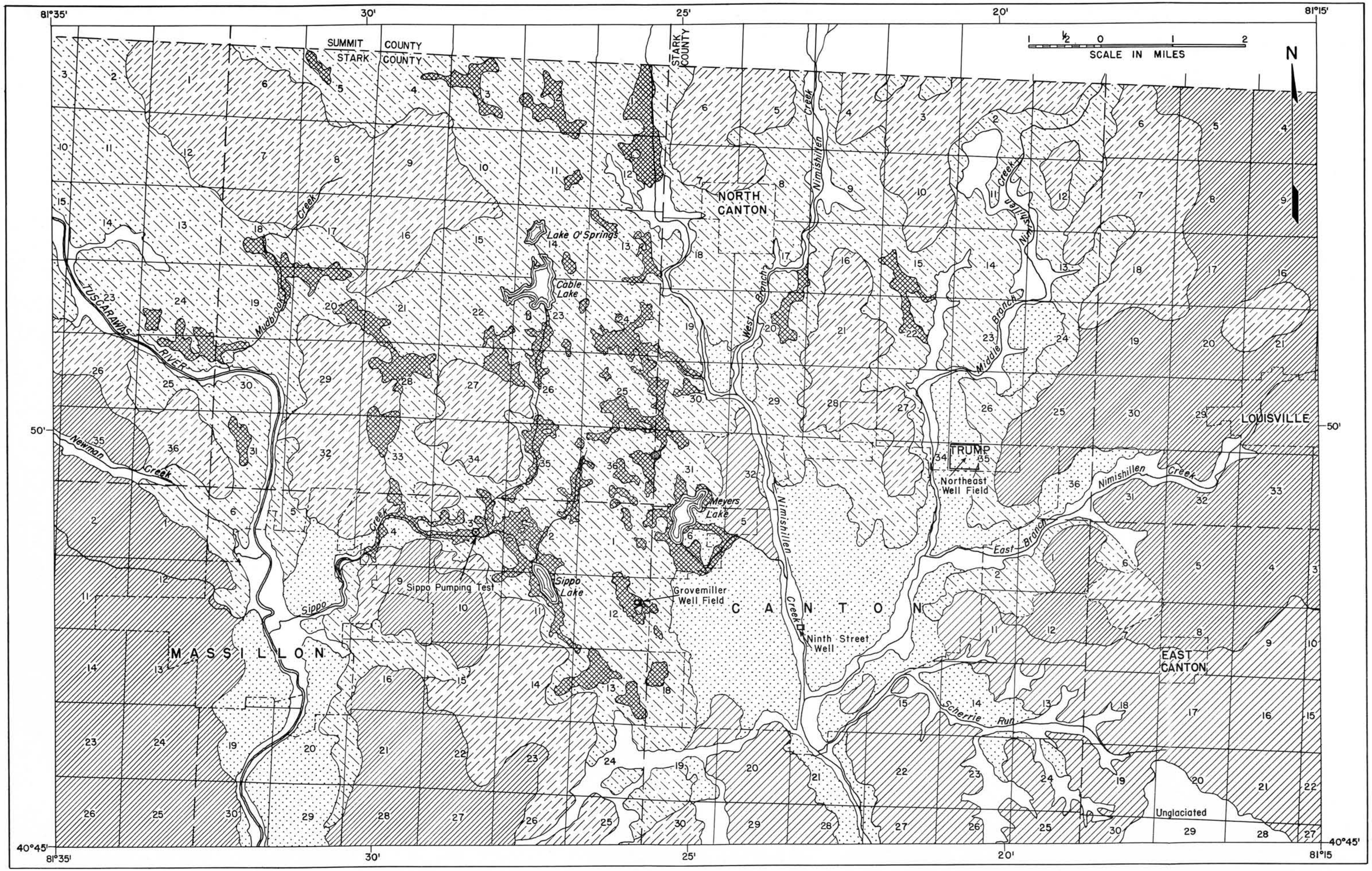
UNCONSOLIDATED DEPOSITS

Glacial Drift

Glacial drift may be divided into two general types - that deposited directly by an ice sheet in passing over an area and that deposited by the meltwater from the ice. The ice-laid material is till, a mixture of rock materials varying in size from minute particles to boulders. It is compact and generally relatively impervious. The till of the ground-moraine areas contains more clay and is generally more compact and impervious than the till of the terminal-moraine areas, which is more sandy and which sometimes includes isolated permeable masses of gravel. Wells of large yield such as those generally used to obtain industrial or municipal water supplies cannot be developed in till, although many farm water supplies are obtained from wells in till areas.

The meltwater materials were deposited as kames, and outwash plains and valley trains. The kames consist of gravel deposited at the ice front or in holes in the ice. Generally they contain poorly sorted gravel in irregular beds and some till masses. The gravel is quite permeable, providing excellent storage for ground water and is capable of yielding considerable water to wells. However, the outwash plains and valley trains, deposited by meltwater flowing away from the front of the ice provide even larger storage and supply wells of larger yield. Such materials were generally subjected to more thorough washing by the meltwaters than those occurring in the kame areas. Thus the gravel is better sorted, is in more regular beds, and contains less fine materials. Wells of exceptionally large yield have been developed in the outwash and valley train areas in the vicinity of Canton.

The map in plate 1 shows the glacial deposits in the southern two-thirds of the Canton quadrangle and the



LEGEND

RECENT

MARSHES — Muck and peat, generally in kettle holes

FLOODPLAINS — Silty alluvium

PLEISTOCENE

WISCONSIN STAGE

GROUND MORAINE — Compact till

TERMINAL MORAINE — Sandy till with some gravel

TERMINAL MORAINE, KAME AREAS — Gravel, may include small amount of till

OUTWASH and VALLEY TRAIN GRAVEL

ILLINOIAN STAGE

GROUND MORAINE — Thin, discontinuous till

Plate I. — Map showing surficial glacial deposits in and near the City of Canton, Stark County, Ohio.

southeastern part of the Massillon quadrangle. The Canton quadrangle is covered by glacial drift except for about two square miles in the southeastern part. The Illinoian ice sheet first covered the region. Later the Wisconsin ice sheet covered all except the central and southern parts of Canton and Osnaburg Townships, (plate 1), and removed or concealed the earlier Illinoian deposits.

Illinoian Drift

The drift of the region south of a line between East Canton and Canton and south of the city is Illinoian. A small "island" of Illinoian drift between Meyers Lake and West Branch Nimishillen Creek extending from 12th Street northward for two miles remains unaffected by Wisconsin glaciation. The Illinoian drift is composed of thin, patchy, deeply weathered till. At many places it is so reduced by erosion that only scattered cobbles of glacial origin remain on the bedrock surface. This till is much thinner and distinctly more weathered than the Wisconsin till to the north and west and is therefore older than the Wisconsin.[4/] It has a weathering profile similar to Illinoian till in the eastern central part of Ohio[5/] and the older till of the Canton area is therefore believed to be Illinoian. The Illinoian drift because of its low permeability is unimportant as a source of ground water.

4/ White, G.W., Illinoian and Wisconsin Drift of the Grand River Lobe in Eastern Ohio (abstract), Bull. Geol. Soc. Am., vol. 53, 1942, p. 1813.

5/ ibid., Illinoian Drift of Eastern Ohio, Am. Jour. Science, vol. 237, 1939, pp. 161-174.

Wisconsin Drift

The Wisconsin drift is part of the deposit made by two lobes of the Wisconsin ice sheet, the Grand River lobe on the east, and the Killbuck lobe on the west. The margin of the drift of the Grand River lobe extends through East Canton, to northeastern Canton and past the County Infirmary to a point in the valley of West Branch one mile north of Fulton Street, where it joins the drift of the Killbuck lobe. The gravelly knolls (kames) of the terminal moraine are numerous in the northern part of Canton, especially in the vicinity of the Infirmary. The margin of the drift of the Killbuck lobe extends almost due south from the junction with the Grand River lobe, along the east side of Myers Lake, thence southward beyond the limits of the Canton quadrangle. From Tuscarawas Street south to the Wheeling and Lake Erie Railroad, Buck Hill, a prominent north-south morainal ridge, is the eastern margin of the drift of the Killbuck lobe.[6/]

Ground Moraine - As shown on the map in plate 1, tracts of ground moraine exist in the area of the drift of the Grand River lobe north and south of Louisville and in the area of the drift of the Killbuck lobe in Perry and Tuscarawas townships. In these tracts the surface is

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6/ The contrast between the thick, gravelly, fresh Wisconsin drift of Buck Hill and the very thin, much weathered and discontinuous Illinoian drift on the rock hill between the southern end of Buck Hill and Harrison Avenue is striking. This is one of the best localities in the Canton region to observe the contrast between the two drifts.

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smoother than that in the terminal moraine, being undulating to almost flat, rather than hummocky. The surface may have undrained sags, but no actual kettleholes.

The till of these areas is more silty (to almost clayey) than that of the terminal moraine and tends to be more compact. It is not very permeable and is the poorest ground-water reservoir material in the area occupied by the Wisconsin drift.

Terminal Moraine - The terminal moraine of the Grand River lobe is not well developed east of Canton, but in the city and to the north large knolls from 20 to 60 feet high are massed to form an impressive moraine. These knolls of gravel are called kames.

The terminal moraine of the Killbuck lobe is only 2 miles wide on the south but northward it widens rapidly, occupying the area from Canton to the Tuscarawas River. It is composed of areas of sandy till, aggregated in hummocks and knolls, generally on the uplands, and of areas of well developed gravel kames and ridges from 20 to 80 feet high with irregular kettle holes between.

Northward from the junction of the terminal moraines of the Killbuck and Grand River lobes a large area of interlobate moraine, consisting of a high proportion of kames, extends beyond the limits of the Canton quadrangle to Akron. In some places this morainic area is over 10 miles wide.

Kames - Within the areas mapped as "Terminal Moraine" in plate 1 are certain parts designated as "Kame Areas".

These consist of rounded to irregular ridge-like hills from 20 to 80 feet high. They are composed of moderately well sorted to poorly sorted gravel in irregular, usually steeply dipping, beds. The gravel is composed of sand, pebbles, and cobbles of 1 foot or more in diameter. There are also occasional boulders ranging up to 3 or 4 feet in diameter. The gravels contain irregular till masses from 2 or 3 to 20 feet or more in largest dimension. These are the remains of material sloughed off the ice edge so rapidly that sorting action by melt water from the ice could not remove the finer clay-size particles before part of the unworked-on till was buried in gravel and thus preserved unsorted. These till masses are of particular importance in interpreting well records, and the amount and thickness of till ("clay, sand, and stones") reported from adjacent wells in the gravel kame area vary markedly. Usually such till encountered in one well cannot be correlated with till from another well, because no continuous sheet of till is present. This does not mean that continuous clay or till sheets, in addition to irregular till masses, could not be present in the deeper deposits.

There are numerous kettle holes within the terminal moraine, especially in the kame areas. They are larger, deeper, and much more numerous in the moraine of the Killbuck lobe, being especially prominent in eastern and northern Jackson and northeastern Lawrence townships. The larger kettle holes are shown on the map in plate 1, but the many smaller ones could not be shown on a map of this scale. They range in depth from a few feet to more than 40 feet, and in size from an acre or less to 250 acres. They were formed by ice blocks detached from the main body of the glacier and buried in the drift. When these buried blocks melted, the drift surface collapsed and kettle holes were formed.

The bottoms of some of the kettle holes are above the water table and are dry, but in many of them the bottoms are at or below the water table. These often form swamps or lakes. Meyers Lake rests in such a kettle hole. Since glacial time, organic deposits of peat and muck have accumulated in the depressions, at places to depths of many feet. Many of the present peat swamps were originally lakes which became filled with organic material, the lakes slowly changing to bogs.

Within the area mapped as terminal moraine are included tracts in the Tuscarawas valley north of Massillon in Section 30 and 31, Jackson Township, west of the river; in the northern part of that city east of the river; and in the southeastern part of Massillon, which are gravel terraces covered with from 8 to 20 feet of till. These are interpreted as "kame terraces",[7] formed by deposition of gravel along masses of ice or deposited as the result of the melting of included blocks of ice. Soon after the deposition of the gravel and before the melting of the included ice blocks, the main mass of the glacier readvanced, spreading a veneer of till over the gravel. Later the

7/ White, G.W., An Area of Glacial Stagnation in Ohio, Jour. Geology, Vol. 40, 1932, p. 247.

buried ice blocks in the gravel melted, allowing both the gravel and the overlying till to collapse, forming pits and kettle holes in the surface. As may be seen in sections in gravel pits the till forms a veneer over the gravel on the walls and bottoms of the kettle holes of the same thickness and character as between the holes. Good examples of this are in the excavations north of Massillon on the west side of the valley.

The distance the readvancing ice moved beyond the Tuscarawas River is unknown, but evidence of gravel underlying till in a test drill hole two miles east of the river, on the Jackson-Perry township line, may indicate a readvance of the ice to at least this point.[8/]

The kame areas of the terminal moraine, with the exceptions of the outwash plain and valley train areas, are the most promising ground-water areas.

Outwash and Valley Train Deposits - In the western part of the city of Canton, from Meyers Lake on the north to a point 2 miles south, a smooth plain slopes from Buck Hill which is the outermost (eastern) part of the terminal moraine of the Killbuck lobe, southeastward to Nimishillen Creek. Its elevation declines from about 1120 feet at the moraine to about 1040 feet near the creek. This is a gravel outwash plain deposited by meltwater flowing away from the margin of the glacier when it stood at its most easterly position.

8/ Till mixed with gravel in such a way as to indicate ice readvance has been noted in the Portage Lakes vicinity in Summit County. A till sheet 8 to 15 feet thick overlies outwash gravel in a large gravel pit 1 mile southeast of Navarre (6 miles south of Massillon) and indicates at least local ice readvance.

The central part of Canton is built on a similar outwash plain deposited by meltwater from the margin of the ice of the Grand River lobe. The elevation of the plain is approximately 1120 feet in the northern part of the city, declining to about 1040 feet in the south-central part in a distance of 2 miles. The material at the head of the outwash plain is well exposed in a pit near Fulton and 23rd Streets as 35 feet of coarse, cobbly to bouldery, poorly-bedded gravel. Many large, angular boulders up to 3 feet in diameter are present. To the south, the gravel rapidly becomes finer and bedding is better developed. In general, the gravel of the outwash plains is well washed, in horizontal beds made up of coarse sand, well rounded pebbles, and cobbles ranging up to 4 or 5 inches, with occasional 6 to 8 inch cobbles.

In the southern part of Canton the outwash plains unite and continue southward down the valley of Nimishillen Creek as a valley train confined between the walls of a valley. The deposit continues southward beyond the limits of the Canton quadrangle to North Industry, is absent through the narrow gorge-like portion of the valley (col) to Howenstine, and reappears to continue to Sandy Creek. Nimishillen Creek has cut from 10 to 20 feet below the valley train. The character of this gravel is the same as that of the outwash plains.

As shown on the map in plate 1, valley train gravels are also present in the valleys of Middle Branch, East Branch, and the Tuscarawas River from Massillon southward.

The small area in Sherrie Run Valley, southeast of Canton, contains finer materials than that of the other outwash areas because it is a slack-water deposit.

Except for the very coarse material at the head of the outwash plain, the material of the valley trains and outwash plains is horizontally bedded gravel, composed of coarse sand and well rounded pebbles and cobbles, few cobbles being over 6 inches in diameter. This material often is highly permeable and is an excellent source of ground water. The Northeast well field and the Ninth Street well pumped by the Canton Water Department as well as many industrial wells in Canton, derive water from this material.[9/]

Thickness of the Drift - From numerous well records the map in plate 2 has been constructed to show by contours the depth of the drift covering the bedrock in the Canton quadrangle. In the area of Illinoian drift south of East Canton and southeast of Canton the drift is considerably less than 50 feet thick and at many places bedrock is exposed. In the Wisconsin drift, areas where the drift is less than 50 feet thick are on the uplands between the buried valleys. One such area extends from the northeastern part of Canton northward to the village of Middle Branch and thence expands eastward. Another area of thin drift is in the vicinity of Meyers Lake in the northwestern

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9/ The continuance of such material from the surface to the bedrock cannot be assumed, but should be confirmed by test drilling. Outwash plain and valley train gravels may be only a few feet thick, resting upon bedrock or upon glacial deposits of different character and origin.

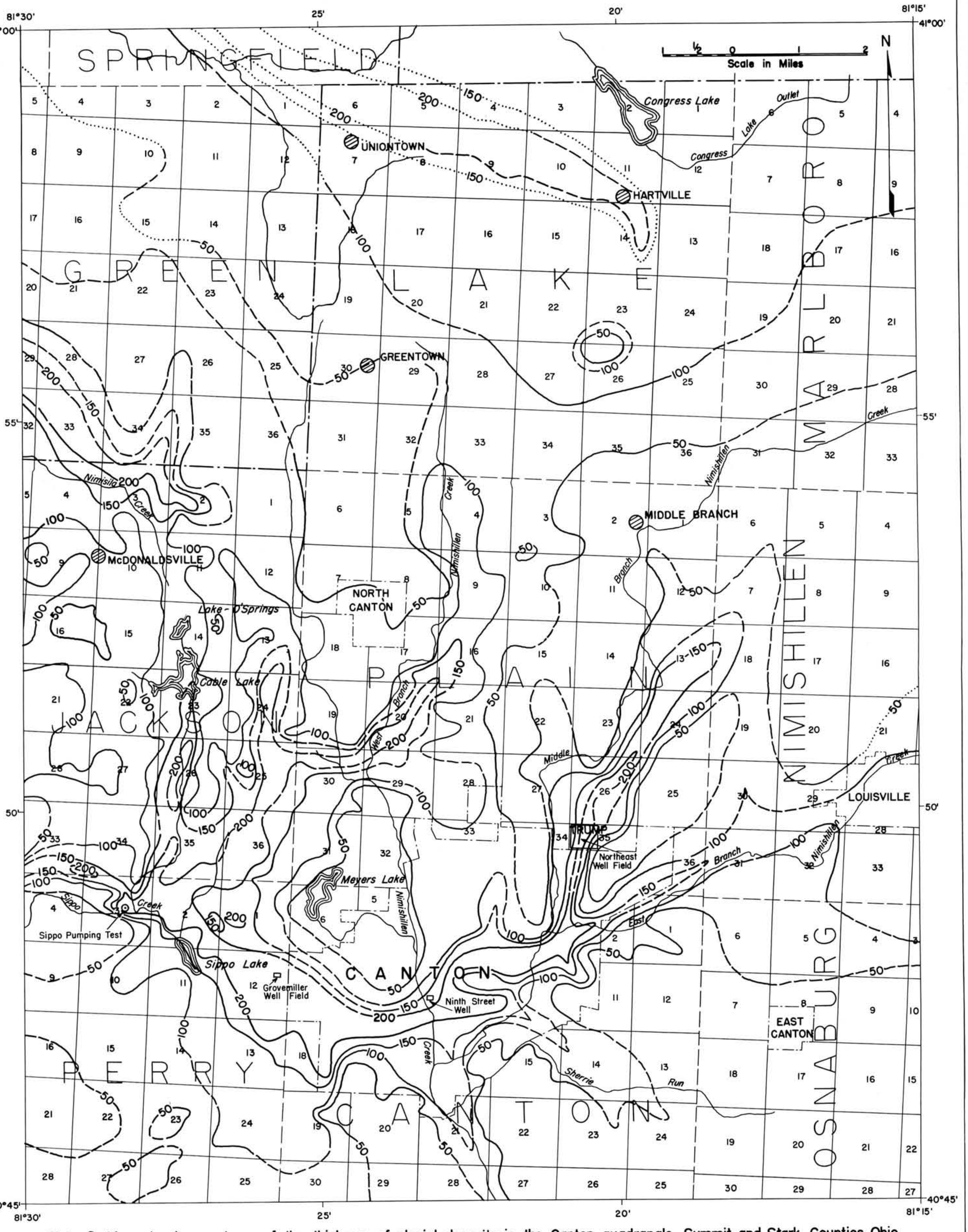

Plate 2.-Map showing contours of the thickness of glacial deposits in the Canton quadrangle, Summit and Stark Counties Ohio.

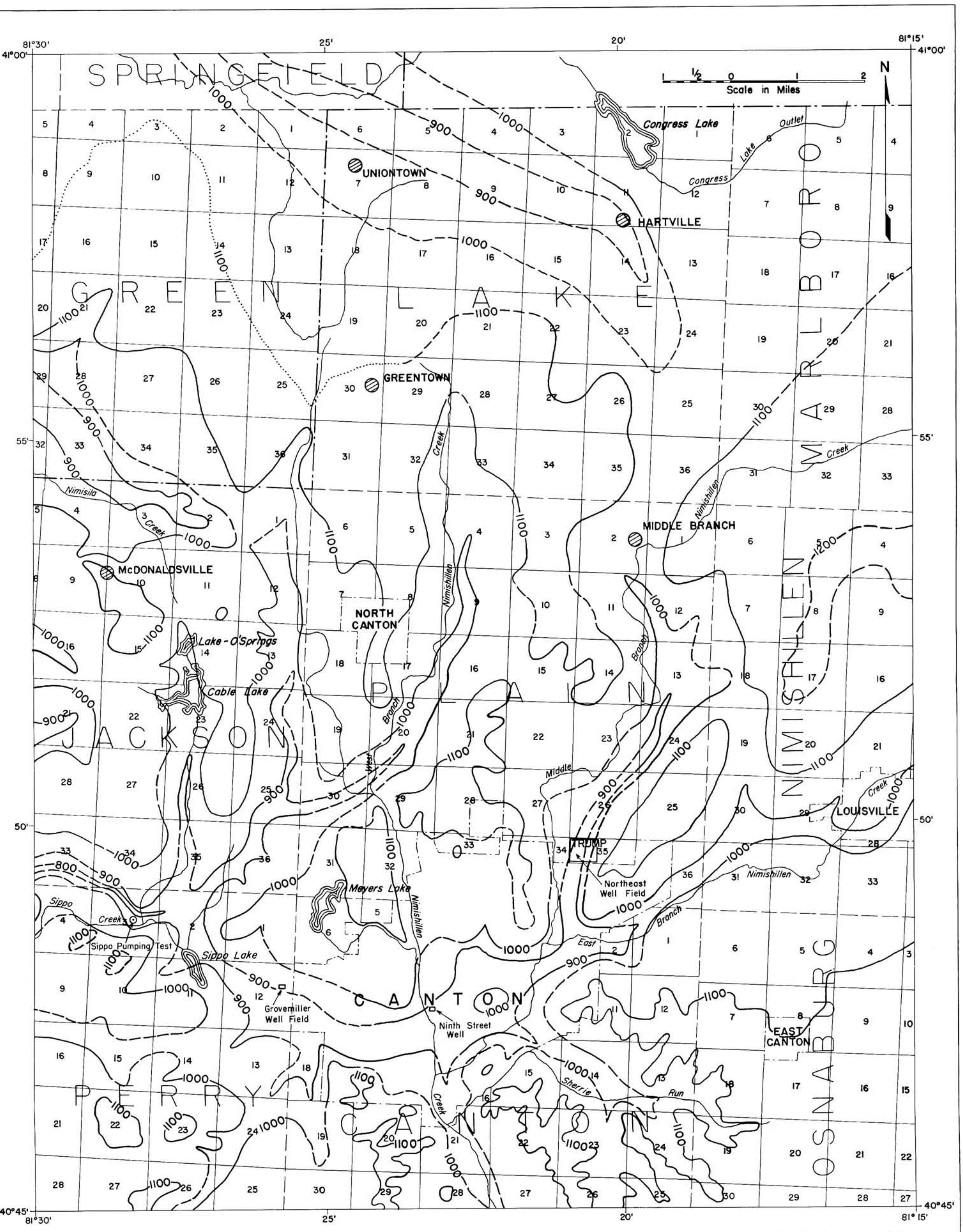

Plate 3.- Map showing contours of the elevation of the bedrock surface in the Canton quadrangle, Summit and Stark Counties, Ohio.

part of Canton. East and northeast of the lake bedrock outcrops in the "island" of Illinoian drift (plate 1). The thinness of the Wisconsin outwash material southeast of the lake is well shown on Twelfth Street just east of West Branch Nimishillen Creek and north of the cemetery, where bedrock is exposed beneath the veneer of gravel. Another area of thin drift extends from North Canton to Greentown and thence northwest. The drift is thin also in the southwestern corner of the quadrangle and to the west of Sippo Lake. Coal was mined by drifting in Section 4, Perry Township, and bedrock outcrops in the western part of Section 5, a quarter of a mile north of Sippo Creek.

The thickest drift occurs in the buried valleys, and in places is more than 200 feet thick. The correspondence of the areas of thickest drift, shown on plate 2, to the buried valleys, shown on plate 3, is evident. The unusual thickness of the drift in the Canton area is due to the combination of well-developed end moraine and the presence of the buried valleys.

Recent Alluvium

Flood plains have been developed along many of the streams as shown in plate 1, ranging in width from only a few feet to as much as half a mile. Few are wider than a quarter of a mile. The flood plain deposits are silty to clayey.

BURIED VALLEYS

Deep valleys, now partly or wholly filled and concealed by glacial drift, are important features of the geology of the Canton quadrangle. The map, plate 3, shows by means of contours the bedrock surface and the deep valleys in the bedrock. These valleys in the rock do not necessarily follow the courses of present day streams. Some present day streams flow high above the rock floors of buried valleys, while other valleys are so completely filled with drift that no surface sag nor present stream indicates their presence beneath the drift.

These buried valleys offer the best possibilities for obtaining large ground-water supplies in the Canton area. However, large perennial supplies can be obtained only when permeable drift has been deposited in them and when conditions of recharge are suitable. The largest supplies are obtained in the valleys occupied by deeply-cut streams because additional recharge is received from flood waters and sometimes from direct infiltration of water from streams.

The following paragraphs describe the locations of the buried valleys known to exist in the Canton area. Except for the valleys already heavily pumped, assurance that large ground-water supplies can be pumped from these valleys can be obtained only from test drilling and pumping tests to determine the suitability of the water-bearing materials and from studies of the conditions of recharge.

The buried valleys of the central and southern part of the Canton quadrangle, from which large ground-water supplies are derived, are parts of a single drainage system, as shown on plate 3. One branch of the system originates east of Louisville at an elevation of about 1000 feet above sea level, passing through that village and Fairhope to Crystal Park in Canton, where the rock elevation is less than 900 feet. The East Branch of Nimishillen Creek flows upon the drift filling this ancient valley. Another branch originates at Middle Branch village and has a southerly course to Crystal Park, where it joins the branch from Louisville. Middle Branch flows upon the drift which does not completely fill this valley. The Canton Water Department Northeast well field is located in this valley at Trump.

The valley formed by the junction of the branches at Crystal Park passes southwest through the center of Canton. At Crystal Park the valley bottom is at elevation 824 feet, and in southwestern Canton at 810 feet. A minor northwestward sloping tributary valley is in the rock surface approximately beneath Sherrie Run and a northward sloping valley is in the rock surface beneath Nimishillen Creek which now flows southward. The main valley through Canton makes a loop northward, as shown on the map. There is no buried valley under the present course of West Branch from central Canton to a point several miles northwest.

From the southwestern part of Canton the main valley continues west under Buck Hill, thence northwest and underneath Sippo Lake to the northern border of Perry Township in Section 2. From there it follows a winding westerly course to the buried valley underlying the Tuscarawas River.

The buried valley continues westward to a point, as yet not determined, north of Massillon, to join a deep valley in the approximate position of the present Tuscarawas River. The Grovemiller well field is in the drift filling the buried valley east of Reedurban, and the Sippo area overlies the drift in Section 3, Perry Township. The courses of the valley in northern Perry Township and its tributaries in southeastern Jackson Township are shown by the detailed map of the rock surface, plate 5, in addition to plate 3, a map of the whole region. It will be noted that a tributary originating near Marchand (northeastern Jackson Township) joins another originating northeast of North Canton, in Section 25, Jackson Township. The valley thus formed joins the main valley in Section 2, Perry Township. A smaller tributary rises near Lake O'Springs and joins the main valley in Section 2, Perry Township. A tributary rises in southeastern Perry Township and trends northeast to join the main valley at Buck Hill, just east of the Canton-Perry township line. Its depth is less than that of other tributaries of comparable size. The main valley floor declines from 810 feet in southwestern Canton to 779 feet in Section 3, Perry Township, in the Sippo area. It is believed that no drill hole has reached the rock floor in the deepest part of the valley westward from the Sippo area to the margin of the quadrangle.

The main valley varies in total width from one mile in the northeastern part of Canton to two miles in the central and western parts of the city. It is somewhat wider west of Canton for several miles but narrows to a little over a mile in Section 3, Perry Township, and Section 34, Jackson Township. The inner part of the valley, between the 900 foot contour lines, is about a half mile wide from Canton to Sippo Lake, but is not more than a quarter of a mile wide in Section 3, Perry Township and Section 33, Jackson Township. Depths to rock vary markedly over short distances across this latter part of the valley, and one well drilled in 1945 (observation well W7) appeared to be along the face of a cliff at least 40 feet in height.

In addition to this system of buried valleys in the territory near Canton, a deep valley of another system extends west-northwest from Hartville in the northern part of the quadrangle. Another buried valley extends northwest from a point 2 miles northeast of McDonaldsville.

The buried valleys described were cut in two stages, which in part may be differentiated. In pre-glacial time valleys one to two miles wide, constituting an integrated drainage system, had been cut down to about a 950 to 1000 foot level in the Canton region, or about 150 feet below the general upland level. This wide valley stage, (buried under drift in northern Ohio and particularly near Canton), is well exhibited in southern Ohio and has been called "Teays" or "Parker Strath" stage.[10/] Such valley floors

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10/ Leverett, F., Glacial Formations and Drainage Features of the Erie and Ohio Basins, U.S. Geol. Surv. Mon 41, 1902, p. 105. Stout, W., and Lamb, G.F., Physiographic Features of Southeastern Ohio, Ohio Jour. of Science, vol. 38, 1938, pp. 49-83.

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may have been over a mile wide in places. During the Teays stage, valleys were especially widened where tributaries joined main streams, or where two or more streams united. The wide ancient valley in which the city of Canton is located is at the junction of three buried valleys. The greater width of the valley at the Perry-Canton township line (Grovemiller area) is related to two tributary valleys entering from the south. The greater width of the ancient valley in Section 2, Perry Township, (just north of Sippo Lake, plates 3 and 5), is at the junction of two large tributaries from the north and a smaller one from the south.

In early glacial time the advance of an early ice sheet, either the Nebraskan or Kansan, deranged the drainage over part of Ohio, forcing many of the streams to cut new courses. However, in the Canton area there is no evidence of an early ice sheet and therefore no derangement, so that the streams continued to flow in their former "Teays" valleys and in their original directions. However, base level appears to have been lower and all streams, whether glacially deranged or not, rapidly deepened their valleys from 100 to 150 feet below the "Teays" level, forming narrow gorges within the earlier wider valleys. This stream system has been called "Deep Stage."[11/] Valleys were cut in the Canton region to

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11/ Coffey, G.N., Preglacial, Interglacial and Postglacial Changes of Drainage in Northeastern Ohio with special reference to the Upper Muskingum Drainage Basin, Ohio Jour. of Science, vol. 30, 1930, pp. 373-384.

(References continued on next page)

elevations of less than 800 feet. The "Deep Stage" water flowed westward from Canton to a stream which flowed north through Massillon to Lake Erie.[12/] Figure 4, a cross section of the buried valley in the Sippo area, shows the narrow, gorge-like inner, or "Deep Stage" valley, and the upper, wider, shallower "Teays" valley.

When the Illinoian ice sheet advanced it deranged the "Deep Stage" streams and filled the valleys with 100 to 200 or more feet of drift (till or outwash). It is probable that after the Illinoian ice disappeared, the stream from the Canton region was able to resume a westward course toward Massillon, but at a level perhaps 150 feet above the floor of the "Deep Stage" valley.

The Wisconsin ice sheet prevented the waters from flowing westward from Canton and, as the divide south of Canton was not covered by Wisconsin ice, the waters escaped southward past Howenstine and East Sparta, forming the present Nimishillen Creek which now flows into Sandy

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11/ (Continued)
Lamborn, R.E., The Newark Drainage System in Knox, Licking, and Northern Fairfield Counties, Ohio Jour. of Science, vol. 32, 1932, pp. 449-466.

Ver Steeg, K., The Buried Topography of North-Central Ohio and its Origin, Jour. of Geology, vol. 42, 1934, pp. 602-620.

White, G.W., Drainage History of North Central Ohio, Ohio Jour. of Science, vol. 34, 1934, pp. 365-382.

Stout, W., and Lamb, G.F., op. cit.

12/ Leverett, F., op. cit., p. 167.

Ver Steeg, K., op. cit., Fig. 2, p. 616.

Stout, W., and Lamb, G.F., op. cit., p. 73 and map, p. 71.

Creek and the Tuscarawas River. After the Wisconsin ice disappeared, the drainage maintained this course. The narrow trench through the divide at Howenstine is a striking example of a stream course that has been in existence but a short time. The gorge-like valley of West Branch Nimishillen Creek for a mile north of Fulton Street is of the same age and was taken across the rock ridge between two ancient valleys when the Wisconsin ice of the Killbuck lobe prevented any escape to the west and forced the drainage from the Grand River lobe to cut a gorge in its escape to the ice-free territory to the south.

GENERAL HYDROLOGY

The ground-water reservoirs formed by the permeable glacial deposits in the vicinity of Canton are integral parts of the drainage system of the area.

Where not affected by pumping, these reservoirs are essentially full to overflowing. The excess recharge from precipitation discharges into streams and lakes, and where the water table is near the land surface the water is transpired and evaporated to the atmosphere.

In the uplands away from through-flowing streams, the recharge to the glacial deposits is derived entirely from precipitation falling locally. In valley train and outwash gravels bordering flowing streams such as along Middle Branch Nimishillen Creek, immediately north of Canton, in Canton proper, and along the Tuscarawas River recharge is sometimes received from flood waters. In these areas heavy pumpage from wells also induces recharge from stream flow when ground-water levels are lowered below the stream level. Thus the ground-water recharge to permeable gravels bordering through-flowing streams is often several times greater per unit of area than in the uplands. Assuming equal depths of water-bearing materials and equal transmission and storage properties, ground-water supplies can be obtained from wells more economically in the areas of through-flowing streams, because less lowering of ground-water levels is required to salvage the recharge and because more recharge per unit of area is usually available.

In general, ground water in the glacial deposits near Canton occurs under water-table conditions although many local artesian areas caused by till lenses and impermeable lake deposits of limited extent exist and have a pronounced effect on the drawdowns produced by pumping from wells. For example, water-level measurements made in many of the 59 test wells drilled immediately northwest of Canton in 1924, 1925 and 1930 and completely penetrating the deeper glacial deposits, correspond closely with water-level measurements made in shallow wells whether in the higher or lower portions of the area.

Further evidence of this conditions was furnished by the pumping test conducted in the buried valley in the Sippo area during the investigation. Water levels in observation wells penetrating the deeper deposits dropped in immediate response to pumping. Shortly afterwards water levels in the shallow observation wells dropped in response to the pumping, showing that a hydraulic connection exists between the deep and shallow deposits. Finally, water levels in observation wells, whether deep or shallow, respond quickly during periods of recharge. An example of this is shown by the record of water levels obtained in well T-50 in the Sippo area, shown in figure 5.

GROUND WATER CONDITIONS BY AREAS

As described in the geologic section of this report, two deep buried valleys, one originating at Middle Branch village and the other at Louisville, join in the northeast section of Canton proper and then follow a westerly course as a single valley through Buck Hill and past Sippo Lake to the Tuscarawas River. The courses of these valleys and the depths of glacial fill in them are clearly indicated on the maps shown in plates 2 and 3. Most of the ground water pumped in Canton and vicinity by the city and its industries is obtained from wells penetrating the glacial deposits in these valleys. In general, these glacial deposits are unusually permeable, allowing development of wells of large yield. Wells 12 inches in diameter in the Northeast well field at Trump, for example, ranging from 132 feet to 209 feet in depth, yield from 900 to 1500 gallons a minute. Another well at the same field, 28 inches in diameter and 179 feet deep, produces 2000 gallons a minute. The City Water Department Ninth Street well, which is 30 inches in diameter and 180 feet deep, yields 2800 gallons a minute. A water collector at a large industrial plant in the city yields more than 7000 gallons a minute.

The most recent survey of ground-water pumpage in the Canton area was made by Perry M. Allen, of the Ohio Water Resources Board, in 1944. This survey indicated that a total of about 38 million gallons a day was pumped from wells in and near Canton in 1944. Of this amount, about 24 million gallons a day was pumped by 53 industrial and commercial establishments, and about 14 million gallons a day was pumped by the city water department from wells in the Northeast, Ninth Street, and Grovemiller well fields. All of the water pumped by the water department was from wells ending in gravel.

The distribution of pumpage at the city well fields in 1944 was as follows:

	Million Gallons a Day
Northeast well field	6.7
Ninth Street well field*	2.3
Grovemiller well field	5.2

*Pumping started June 21

Of the total industrial and municipal pumpage, 7 million gallons a day was pumped from bedrock formations, and 31 million gallons a day was pumped from the glacial deposits. The outwash gravels in the city proper yielded 19 million gallons a day. The gravels in the area bordering Middle Branch Nimishillen Creek north of the city at Trump yielded 6.7 million gallons a day, and the Grovemiller area west of the city yielded 5.2 million gallons a day.

The effect of this pumping on water levels in the Canton area is shown by water-level records obtained from observation wells by the Canton Water Department and the U.S. Geological Survey during the past several years. These records are published annually by the Geological Survey in its Water Supply Papers.13/ The following paragraphs summarize the significance of the records thus far obtained.

Buried Valley along Middle Branch Nimishillen Creek

Measurements of water levels have been made periodically since 1941 in two observation wells tapping the gravel deposits in this valley. Natural changes in ground-water levels are best seen in the record for observation well 12 (Goughnour well), shown in figure 1. This well is located about 1½ miles northeast of the Canton Water Department Northeast Well Field at Trump. The record shows that most of the recharge to the ground-water reservoir is received in the first half of each year. The rises in water levels in this well have averaged 6.7 feet a year for the period of record, but have varied considerably. The largest rise amounted to 10.5 feet in 1945 and the smallest amounted to 3.9 feet in 1944. The large rise in February and March of 1945 was caused by flood waters from Nimishillen Creek. It seems probable that a great deal of the recharge to the buried valley is received from this source.

13/ Meinzer, O.E., Wenzel, L.K. and others, Water Levels and Artesian Pressures in Observation Wells in the United States; U.S. Geol. Survey Water Supply Papers 886 (1939), 906 (1940), 936 (1941), 944 (1942), 986 (1943). (Reports for 1944 and 1945 under same title now in preparation.)

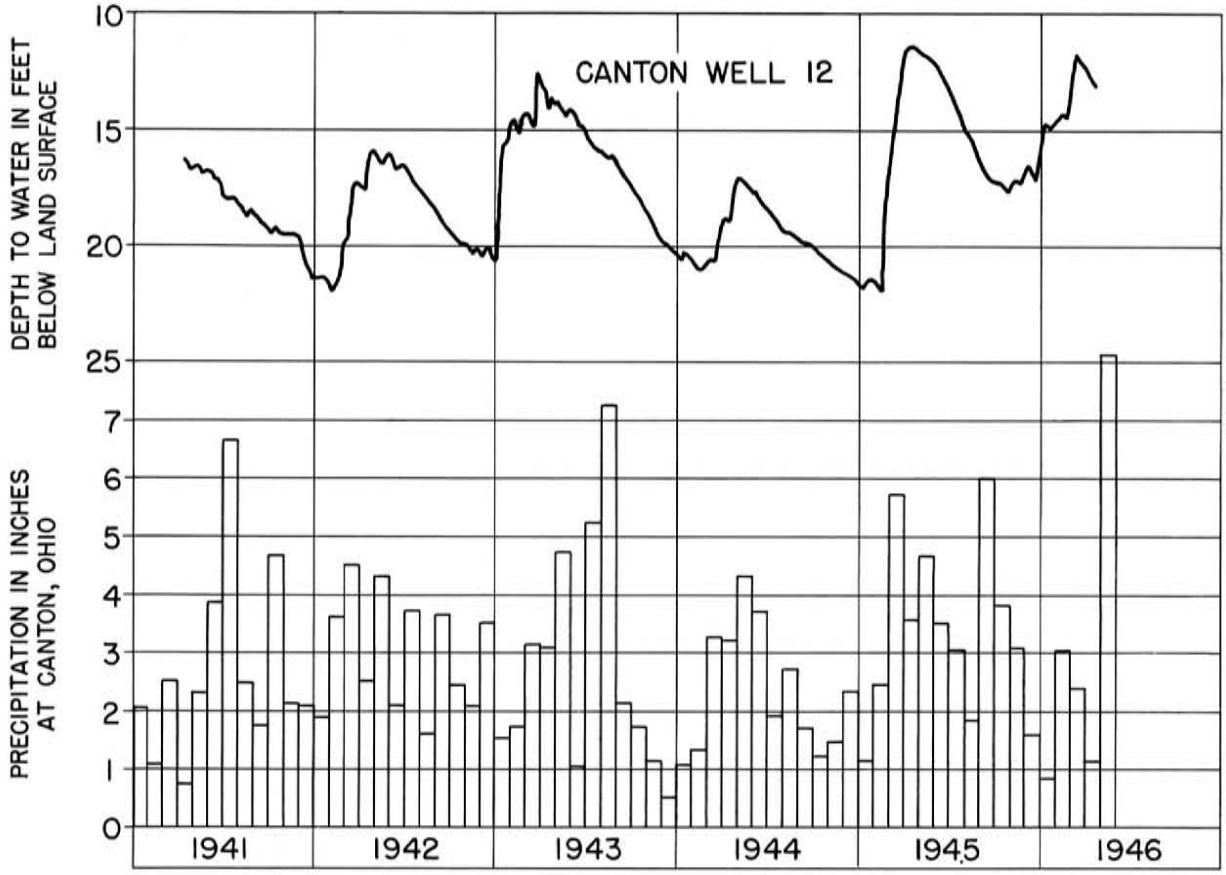

Figure 1.— Graphs showing monthly precipitation at Canton and water levels in Canton well 12 (Goughnour well), Stark County, Ohio.

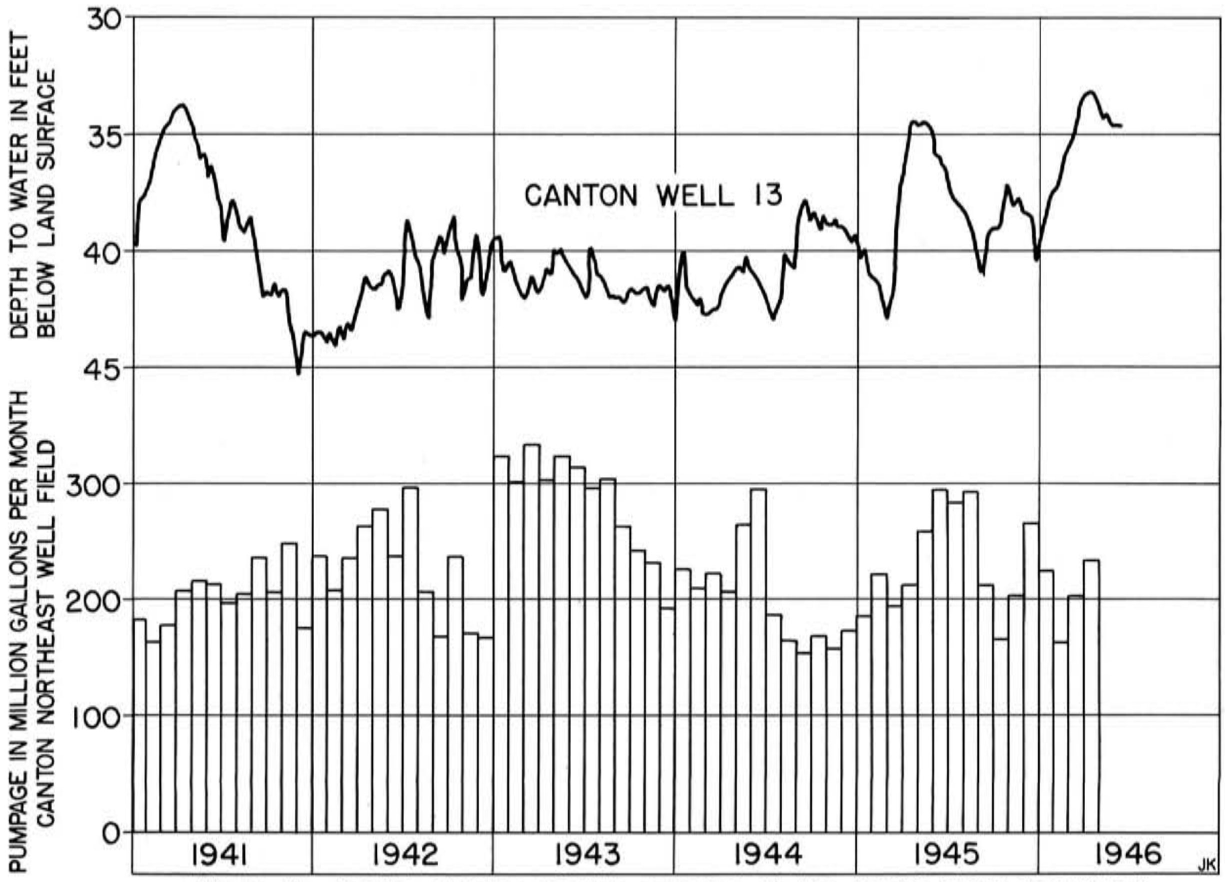

Figure 2.— Graphs showing monthly pumpage at the Canton water department Northeast well field and water levels in Canton well 13 (Northeast well field observation well), Stark County, Ohio.

A record of water levels obtained in Canton well 13, an observation well at the Northeast well field, together with the pumpage from this well field, is shown in figure 2. The fluctuations of the water level in this well are caused mainly by changes in the rate of pumping in the Northeast well field. It should be noted that the Canton water department in the period 1942 through 1944 varied the pumping to maintain a fairly constant water level in this field. As a result less water was pumped in the last half of each year than in the first half when recharge occurred. Similarly, a much greater amount of water was pumped in 1943 without a serious lowering of water level than in 1944, because a greater amount of recharge was received in 1943 than in 1944. This may be seen by inspecting the Goughnour record for these years.

The water-level records from both the Goughnour and the Northeast observation wells indicate that pumping in the Northeast well field, which has averaged 7.6 million gallons a day from 1941 through 1945, has not exceeded the available recharge.

Sufficient evidence is not available at this time to show definitely whether all the available recharge in the Middle Branch buried valley is being recovered by the pumping at the Northeast field. Water levels at the Northeast field usually stand at 40 or more feet below the surface, while 1½ miles north at the site of the Goughnour well in section 23 the water level varies from about 12 to 22 feet below the surface, depending on climatic conditions and possibly to some extent on the rate of pumping in the Northeast field. It seems probable, therefore, that all the natural discharge from Trump north to the Goughnour area is now being recovered, since the ground-water level is below the level of Nimishillen Creek and low enough to cut off most of the transpiration and evaporation losses from the water table. Furthermore, additional recharge from the flood waters of Nimishillen Creek can now be accommodated in the storage space thus provided between the present ground-water level and the land surface. It does not seem probable that more water can be induced from stream flow by further lowering of ground-water levels. The amount of natural discharge that could be salvaged from an area farther north would depend on the degree to which these same conditions exist north of the Goughnour well.

Buried Valley in Canton Proper

Water -level measurements have been obtained in two observation wells in the central part of Canton since 1939. This program was started by A.N. Sayre, of the U.S. Geological Survey. The city of Canton also has made measurements of water levels in the Ninth Street production well. The records obtained from observation wells 20 and 21A are shown in figure 3. Well 20 is a gravel well 140 feet deep and is located in a city dump at Lippert Street and Warner Road. Weekly measurements in this well have been made by E.V. Beftoulides since January 1939. Well 21A is

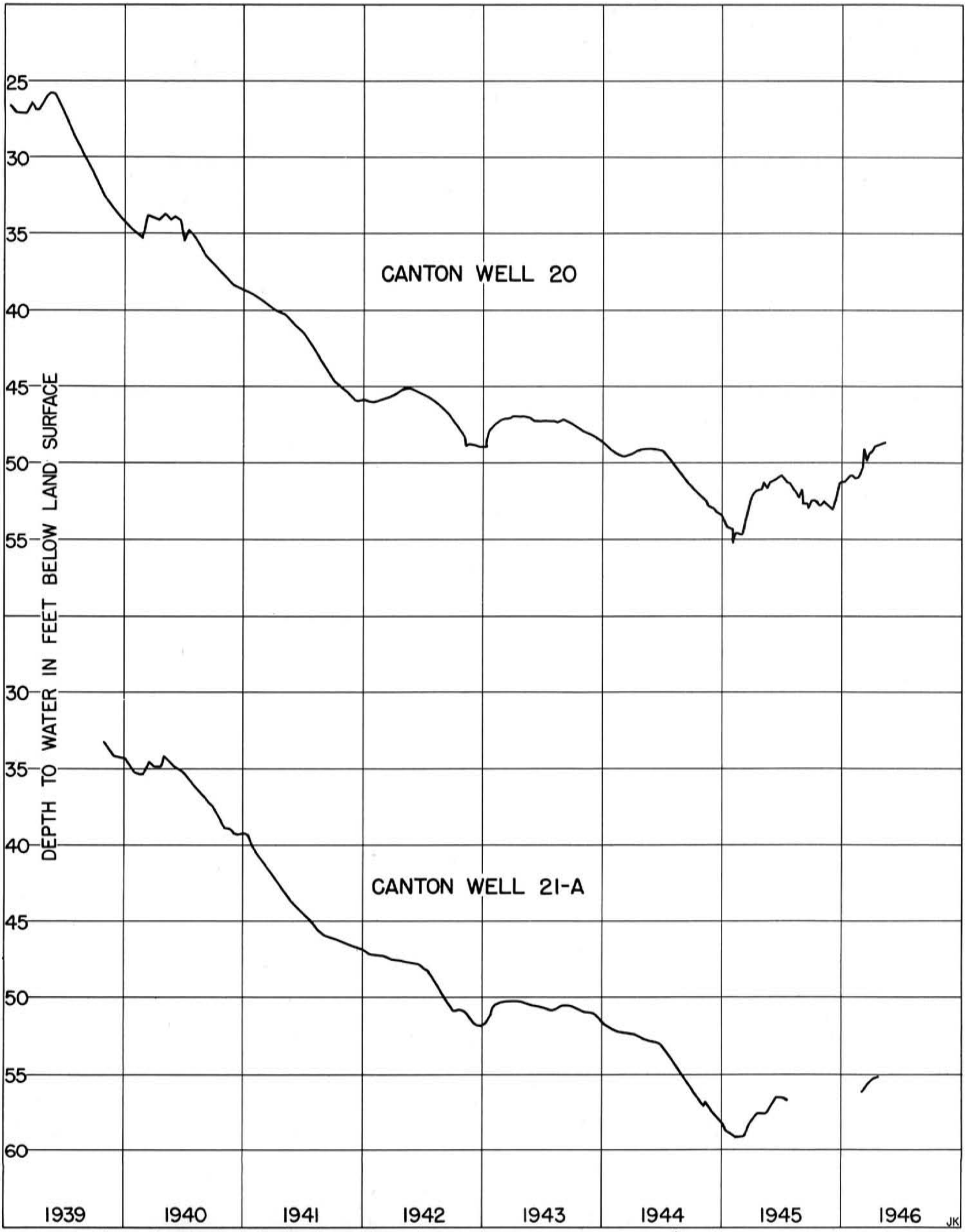

Figure 3.— Graphs showing fluctuations of water levels in Canton well 20 (Republic Steel Corporation), and Canton well 21-A (Ohio Power Company), Stark County, Ohio.

a gravel well drilled to a depth of about 60 feet below the street level and is located in a building owned by the Ohio Power Company at Savannah and Second Streets, S.W.

Both of these records show a general downward trend from 1939 to the end of 1944 and a general upward trend during 1945 and the first five months of 1946. The decline was due in great part to an increase in pumping by the industries, following the years of business depression. However, deficient recharge, especially during 1941, is also a factor in this decline.

The rise in the first half of 1945 was undoubtedly caused by exceptional recharge, as shown by the record for the Goughnour well. The rise beginning in December 1945 and continuing to May 1946 can probably be attributed to a decrease in pumping during industrial reconversion and strikes after the end of World War II.

The net drop in water level in observation well 20, the longest record available, was about 24 feet from the beginning of 1939 to the end of 1945, a period of 7 years. Considering the extremely high permeability of the outwash gravels underlying Canton it seems reasonable that this decline is fairly representative of the decline occurring throughout the area of these deposits which cover about 8.7 square miles. The specific yield of similar coarse gravels in the Miami Valley was found by Klaer and Kazmann [14] to be about 0.2; that is, about 0.2 cu. ft. of water will

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14/ Klaer, Fred H. Jr., and Kazmann, Raphael G., A Quantitative Study of the Well Field of the Mill Creek Valley Water Supply Project, Butler County, Ohio, U.S.G.S. mimeographed report, July 1943.

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drain by gravity from 1 cu. ft. of water-bearing material. Assuming that this is the average specific yield of the materials underlying Canton, a drop in water level of 24 feet would be equivalent to removal of water from storage averaging 3.4 million gallons a day in the 7 year period.

As has been previously stated, the average pumpage from the outwash gravels as determined by the Ohio Water Resources Board in Canton proper in 1944 amounted to about 19 million gallons a day. It seems probable that approximately this rate prevailed throughout the period 1939 through 1945. Under this assumption and deducting the 3.4 million gallons a day pumped from storage, it is evident that about 15.6 million gallons a day was received from the various sources of recharge in the area, which include direct precipitation, some water from flooding close to the streams, and water derived from seepage from stream flow. An appreciable amount of the recharge from direct precipitation is salvaged from underflow from the morainal hills east, north, and west of the city. This underflow would normally discharge into the several branches of Nimishillen Creek but is now salvaged from stream flow because ground-water levels throughout the city have been lowered below stream level. Thus the water is diverted to the pumping wells instead of flowing into the streams.

Buried Valley in Grovemiller Area

Two wells have been pumped since September 1941 by the City of Canton at the Grovemiller well field located along Tuscarawas Avenue about 3 miles west of the center of Canton. These wells penetrate the gravels in the same buried valley from which large ground-water supplies are obtained in the city proper. The water is derived from direct precipitation on the area overlying the buried valley and from ground-water underflow from the morainal hills to the north, south and east. No deeply-cut surface stream contributes recharge from outside the area. A ground-water divide exists in Buck Hill between the Grovemiller well field and the outwash gravels in Canton proper. Ground water flowing east from the divide is recovered by the wells in Canton and that flowing west is recovered by the Grovemiller wells. Before pumping began, the recharge now recovered by the Grovemiller wells escaped into Sippo Lake and the branch of Sippo Creek which drains Sippo Lake. Some of this recharge was also dissipated to the atmosphere by transpiration and evaporation from the marshy area west of the Grovemiller field.

The average pumpage in million gallons a day from the Grovemiller wells for each year since the beginning of 1942 has been as follows:

1942	4.09 m.g.d.
1943	5.01 m.g.d.
1944	5.06 m.g.d.
1945	3.70 m.g.d.

The pumpage for the entire period 1942 through 1945 has averaged 4.5 million gallons a day. The water-table contour map, drawn from water-level measurements made in observation wells in August 1945 and shown in plate 4, indicates that the influence of the Grovemiller pumping covers an area of about 8 square miles.

Water-level measurements have been made since 1942 in two observation wells close to the Grovemiller pumping wells. From the records of water levels in these wells a rough estimate can be made of the amount of recharge recovered by pumping in the Grovemiller field. In the three year period January 1, 1943 to December 31, 1945 a net decline of 4 feet occurred in both of the observation wells. In the same period the pumpage from the Grovemiller wells averaged 4.5 million gallons a day. If the decline of 4 feet occurred over the entire area of influence of the pumping, and the specific yield is assumed to be 0.2, it is computed that water was removed from storage in the aquifer at a rate of about 1.2 million gallons a day during the three year period. Therefore the amount of water derived from recharge was about (4.5-1.2)=3.3 million gallons a day. Since this was obtained from an area of about 8 square miles, the recharge over the three year period averaged about 400,000 gallons a day per square mile.

Buried Valley in Sippo Area

Records of the 59 test wells drilled by the City of Canton in 1925, 1926, and 1930 in an area of about 10

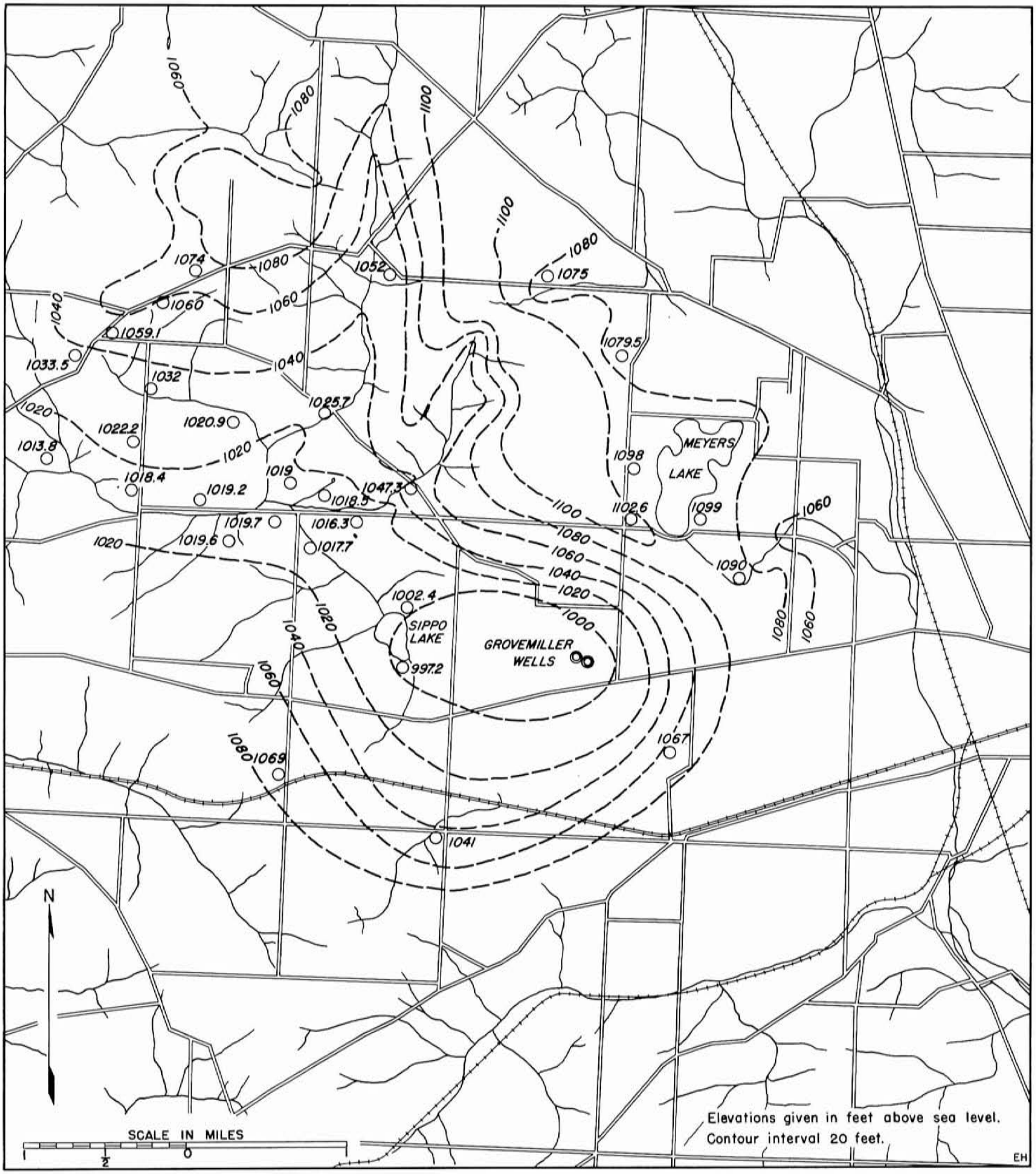

Plate 4.- Map showing contours of the piezometric surface based on measurements of water levels August 20-31, 1945, in the Sippo and Grovemiller areas, Stark County, Ohio.

square miles in the northeast and southeast quarters of Perry and Jackson townships respectively, indicated that the coarsest and most permeable water-bearing materials in the area are in the vicinity of section 3, Perry township, about 5½ miles west of Canton, in the main channel of the buried valley. This is the same buried valley from which large ground-water supplies are pumped to the east at Canton. Because this area is drained by Sippo Creek and its tributaries, it is called the Sippo area in this report.

An intensive investigation of the geology and hydrology of the Sippo area was conducted throughout 1945 and the early part of 1946 to determine approximately the amount of water that can be derived perennially from the area.

The shape of the bedrock surface in the Sippo area is shown on the detailed bedrock contour map in plate 5. The map was drawn from bedrock depths determined from test holes drilled by the City of Canton, from oil drive-pipe records in the files of the Geological Survey of Ohio and from the records of several test wells drilled in 1945. The map also shows that the main buried valley is joined by two tributary valleys converging in section 2, Perry township, and then loops northwestward as a deep gorge to the margin of the map. From there it follows a generally westward coarse as yet undetermined, to join the buried valley underlying the Tuscarawas River. The path of the valley can also be traced by inspection of

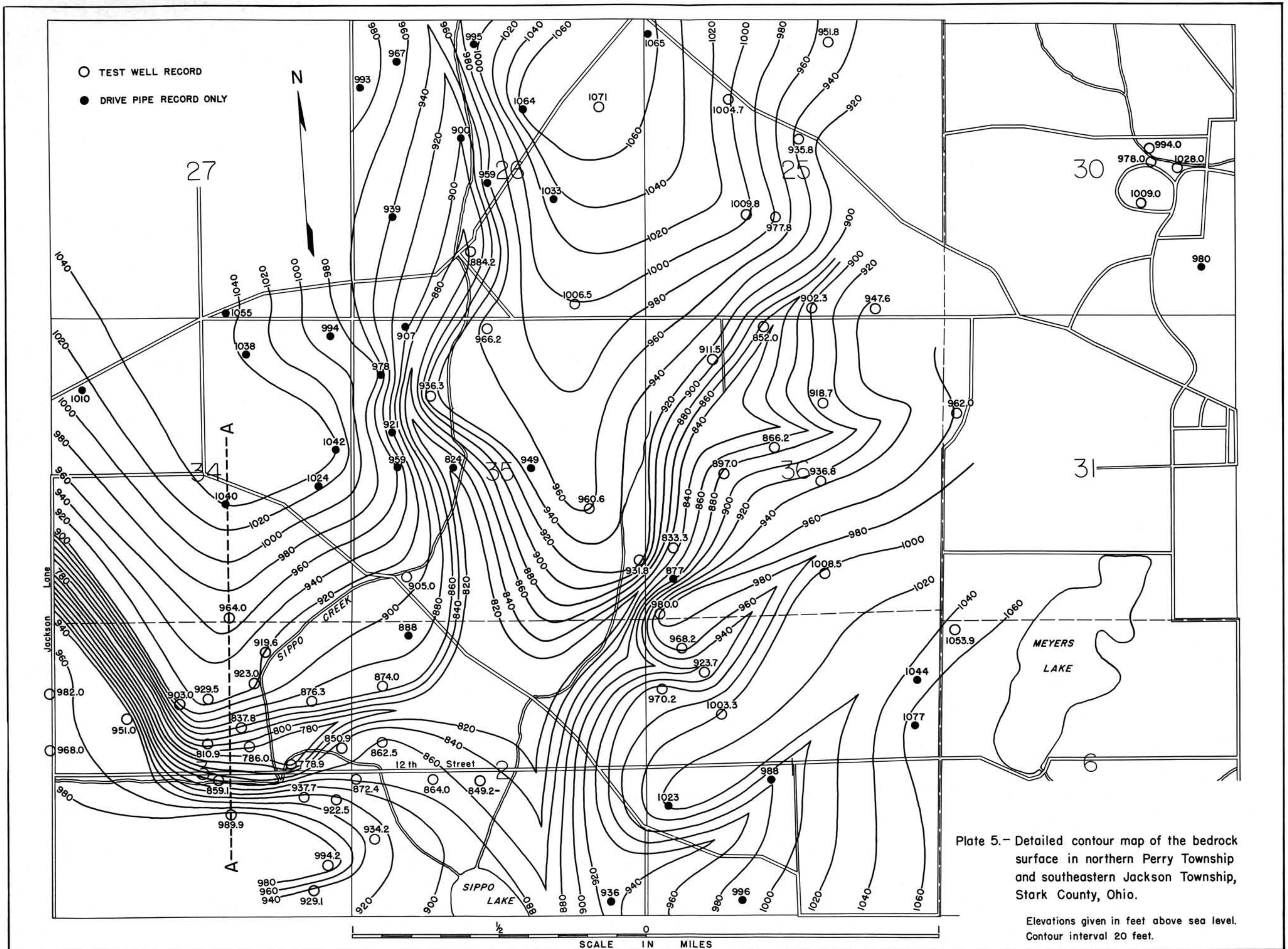

Plate 5.– Detailed contour map of the bedrock surface in northern Perry Township and southeastern Jackson Township, Stark County, Ohio.

Elevations given in feet above sea level.
Contour interval 20 feet.

the map in plate 2, which shows thickness of drift in the Canton quadrangle.

To a large extent the amount of water that can be derived from the buried valley in the Sippo area is limited by boundaries existing on both sides of the valley. Immediately south of 12th Street in section 3, Perry township, and to the west in sections 4 and 33, the valley is bounded by bedrock hills covered by a thin veneer of drift. In the hills to the north, however, the drift generally exceeds 50 feet in thickness and the water table slopes to the lower area through which the buried valley passes. Thus recharge to the buried valley, other than that which is derived directly from precipitation on the area overlying it, is also derived from underflow from the drift to the north. The underflow under natural conditions is eventually lost to stream flow and to transpiration and evaporation from the water table.

The shape of the bedrock floor of the buried valley and the thickness of drift in it can be seen in the cross section of the valley shown in figure 4. In the deepest part of the valley the glacial materials are about 240 feet thick. However, this V-shaped portion of the valley is only about a third of a mile wide. The entire width of the valley is slightly more than 1 mile and the thickness of drift in the shallowest part of the cross section is about 65 feet.

An estimate of the perennial yield of the glacial materials in the Sippo area required first an estimate

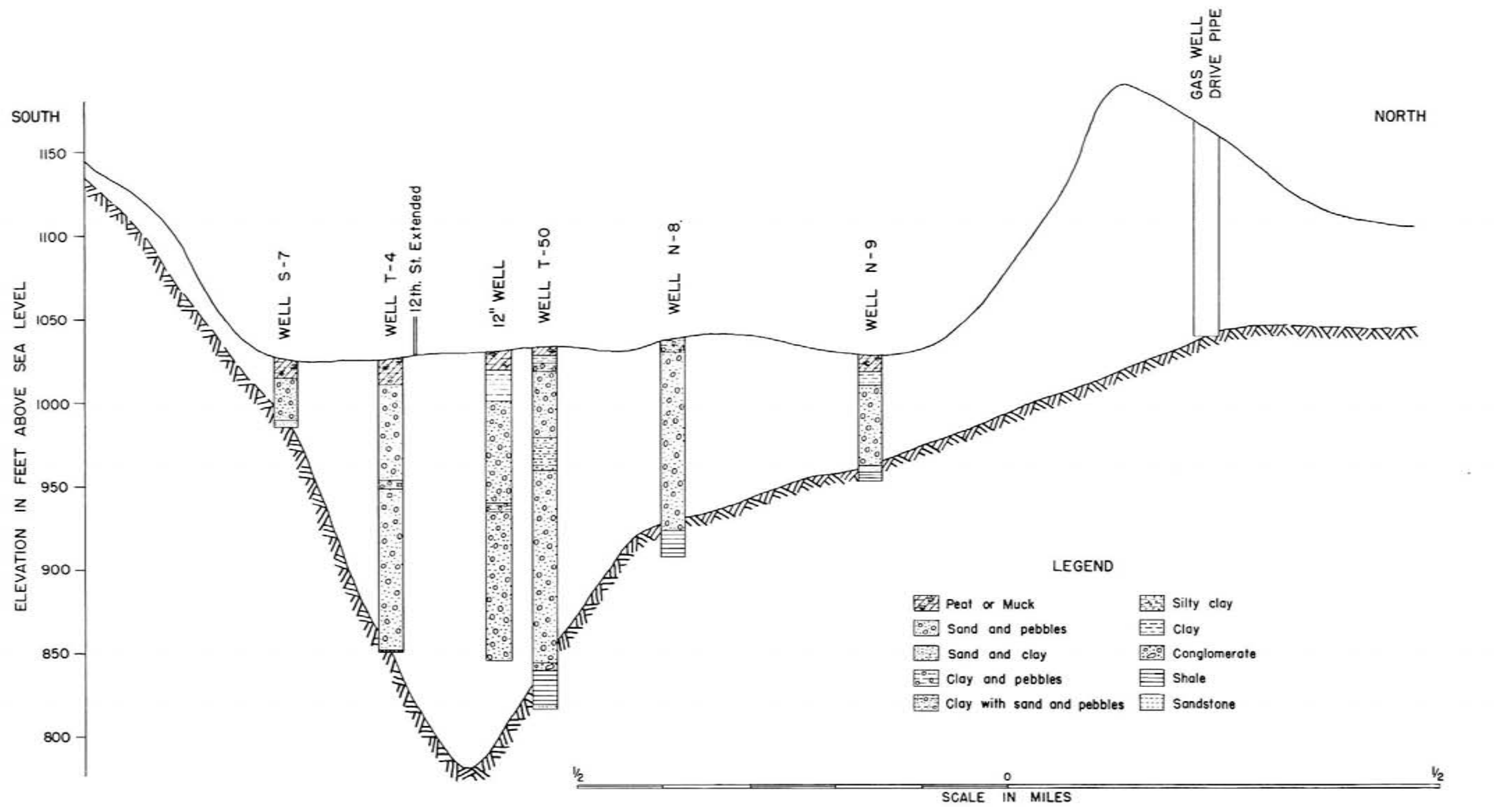

Figure 4.- Cross section of buried valley showing graphic logs along line A-A on Plate 5, Perry Township, Stark County, Ohio.

of the recharge to be expected per square mile in the area and then a study of the extent to which this recharge can be salvaged by pumping from wells. The methods of arriving at a quantitative estimate of these factors are described in succeeding sections of this report.

Estimate of Recharge

An estimate of average recharge to be expected in the Sippo area was made by consideration of the losses from the water table to stream flow and to the atmosphere by transpiration and evaporation. The amount of water discharged from the water table is equal to the amount of recharge received plus or minus whatever change in ground-water storage takes place.

The drainage area of Sippo Creek above 12th Street was used as a sample area to estimate the ground-water runoff into streams. The flow in Sippo Creek was measured periodically by means of a current meter from October 2, 1944 until April 25, 1945. After that time the flow was measured by means of a standard rectangular weir equipped with an automatic water-stage recorder. The rating of the weir was checked periodically by current-meter measurements. All stream-flow measurements were made at a point on Sippo Creek about 500 feet north of 12th Street in Section 3, Perry township. The drainage area of Sippo Creek above this point is 4.3 square miles.

Most of the stream-flow measurements made before the weir was installed were made during periods of low steady flow when surface runoff was at a minimum. The rates of flow measured during this period are approximately the rates of ground-water runoff. After installation of the weir, the ground-water runoff was estimated by elimination of the flood peaks from the hydrograph of total flow, the remainder being approximately the ground-water runoff.

The assumption was made that ground-water runoff into Sippo Creek in the water year 1944-45 (October 1, 1944 to Sept. 30, 1945) was approximately average. This assumption is supported by a study of records of precipitation at Canton in that period and the record of water levels obtained from well T-50 (figure 5). Records of water levels in observation wells in Ohio show that ground-water recharge is received almost entirely in the first six months of each calendar year. To a large extent the precipitation occurring in this period determines the amount of ground-water recharge received. In the first six months of 1945, precipitation at Canton amounted to 21.13 inches, 1.33 inches above the average for 63 years of record. However, precipitation in the last six months of 1944 was considerably below average, so that a deficiency in soil moisture existed at the beginning of 1945. It is believed that this deficiency offset the excess of 1.33 inches of precipitation received in the first six months of 1945.

Further evidence of the validity of this assumption is given by the record for well T-50 in the water year 1944-45, which shows that the water level at the end of

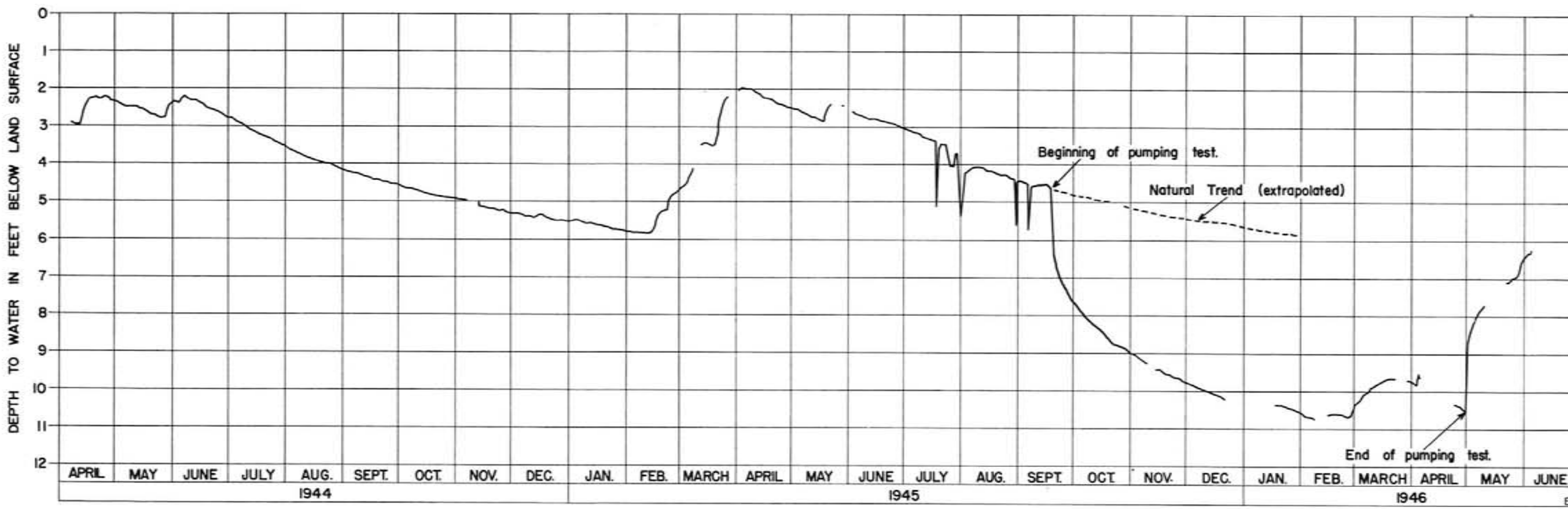

Figure 5.— Graph showing fluctuations of water level in well T-50, Perry Township, Stark County, Ohio.

September 1945 was only about 0.2 foot lower than at the end of September 1944. This indicates that the discharge from the aquifer was approximately balanced by the recharge received in the water year and that only a minor net change in ground-water storage took place in the period. Since a year of deficient ground-water recharge under natural conditions would result in a net decline in ground-water levels and a year of greater-than-average recharge would result in a net rise in ground-water levels, it seems reasonable to assume that a year in which the net change in ground-water levels was negligible could be considered an average year.

The average rate of ground-water runoff into Sippo Creek (determined from the flow of Sippo Creek as described above) was 1.91 cubic feet a second in the water year 1944-1945. The drainage area contributing to this flow is 4.3 square miles. The ground-water runoff during the year is therefore computed to be equivalent to 6 inches of the yearly rainfall, or an average of 288,000 gallons a day per square mile. To this must be added the amount of ground water dissipated to the atmosphere by transpiration and evaporation from the water table.

No direct method exists for estimating closely the amount of ground water lost to transpiration and evaporation in the Sippo area. Meinzer[15/] estimates that at least one-third of the total ground-water discharge in the eastern

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15/ Meinzer, O.E. Ground Water in the United States, A Summary, U.S. Geol. Survey Water Supply Paper 836-D, page 186, 1939.

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part of the United States occurs through transpiration and evaporation. Inasmuch as the ground-water runoff into streams was computed to be about 6 inches of the total rainfall, 3 inches of the total rainfall would be lost to transpiration and evaporation in the Sippo area if the above estimate is applicable to the Sippo area.

In the Sippo area most of the loss of ground water to transpiration and evaporation occurs in the marshy areas bordering Sippo Creek and its tributaries, where the water table is usually close to the ground surface. A rough check of the magnitude of these losses was made by considering ground-water runoff and the corresponding drop of the water level in well T-50 during a period of low transpiration and evaporation losses as compared with a period of high losses. The record for well T-50 was used because it is the only record of sufficient length to furnish two periods suitable for analysis.

In the Canton area the months of November and December 1944 and January 1945 constituted a period of low precipitation, low temperatures, and uniform stream flow. Since atmospheric losses from the water table are at a minimum during winter months, it is apparent that the lowering of the water level in well T-50 was caused almost entirely by ground-water runoff into streams. The average rate of flow in Sippo Creek during these months for the drainage area measured was 1.58 cubic feet a second. In the same period the average drop in water level in observation well T-50 was 0.3 foot a month.

In comparison the average drop in water levels in well T-50 from April 1, 1945 through September 30, 1945 (omitting a short period in the latter part of May when recharge occurred) amounted to 0.59 foot a month. In this period the average rate of ground-water runoff estimated from the hydrograph of the flow of Sippo Creek was 1.96 cubic feet a second for the drainage area measured. If transpiration and evaporation losses had not occurred in these months, the increase in the summer rate of ground-water runoff as compared with the winter rate would have been approximately proportional to the changed rate of drop in well T-50.

This increase in rate of ground-water runoff would have been $(\frac{0.59}{0.3} \times 1.58) = 3.10$ cubic feet a second. However the actual flow in the summer months averaged 1.96 cubic feet a second, indicating that losses to the atmosphere were occurring at a rate of $(3.10-1.96) = 1.14$ cubic feet a second. This is equivalent to 1.8 inches of the annual rainfall or 86,000 gallons a day per square mile if computed on a yearly basis.

It must be realized that this is not a precise determination of the ground-water losses to transpiration and evaporation in the Sippo area. Many observation wells would be needed for such a determination and assurance would be needed that a change in specific yield does not occur in the formation in the range of the fluctuations of the water level in well T-50. However, it does add assurance that the magnitude of the transpiration losses in the area are in the order of the estimate furnished by Meinzer. In the absence of precise data, the transpiration losses from the water table in the Sippo area are assumed to be from 2 to 4 inches of the annual rainfall, or from 86,000 to 172,000 gallons a day per square mile. Adding the 288,000 gallons a day computed for ground-water runoff into streams it is estimated that the total recharge to be expected in the Sippo area is in the order of 374,000 to 460,000 gallons a day per square mile. This estimate agrees closely with the estimate of 400,000 gallons a day per square mile for the Grovemiller area, where recharge conditions are similar.

Pumping Test

When a well is first pumped, most of the water is derived from storage in the part of the water-bearing formation immediately surrounding the well. Hydraulic gradients toward the well are created and, as the period of pumping increases, water is brought to the well from greater and greater distances, forming a depression in the water table or piezometric surface. This depression is commonly called the cone of depression. The shape of the cone of depression is dependent primarily on the storage and transmission properties of the water-bearing materials, the areal extent and the total saturated thickness of those materials and conditions existing along their margins. The slopes of the hydraulic gradients created toward the pumping well determine to a large extent the amount of water that can be conducted to the well from a distance without excessive lowering of water levels at the well.

Consideration of these factors is of primary importance in the Sippo area, because ground water is discharged into Sippo Creek and its tributaries at many places, and is transpired and evaporated to the atmosphere at other places where the water table is close to the ground surface. The salvaging of this natural discharge by pumping from wells requires that water levels be lowered over a large area without excessive lowering of water levels in the immediate vicinity of the wells.

A pumping test was conducted as part of the investigation preceding this report in order to determine the approximate shape of the cone of depression to be expected by pumping from wells tapping the deep gravels in the buried valley in Section 3, Perry township.

A 12-inch well 185 feet deep was constructed in the summer of 1945 on property owned by the City of Canton at a location 500 feet north of 12th Street and 850 feet west of Sippo Creek. A description of the materials encountered in the drilling of this well is given in table 4.

A discharge pipe was run directly south to Sippo Creek to dispose of the water pumped during the test. To measure the amount of water pumped a flow meter was installed in the discharge pipe. Observation wells were driven about 50 feet deep on lines running approximately north and south and east and west from the 12-inch well.

A deep-well turbine pump was used in the test. On the first trial of the pump it was noted that water levels dropped in the observation wells in response to the pumping but at a slower rate than had been expected. It was also noted that when the new elevations of the water surface, as determined by measurements of depth to water in the observation wells, were plotted on cross-section paper, the water surface did not form a characteristic cone of depression around the pumping well. The obvious conclusion was that an artesian condition exists in the immediate vicinity of the pumping well. Upon examination of samples of the materials removed in drilling the 12-inch well, it was found that the only impermeable materials encountered were specimens of boulder clay obtained at depths of between 95 and 100 feet below the surface.

Well E-3 was then deepened by increments of 10 to 20 feet and tested each time by pumping the 12-inch well and measuring the depth to water in E-3. This procedure was continued until quick response to pumping occurred, which indicated that the well had penetrated the same impervious stratum as the 12-inch well. This proved that the boulder clay encountered at 95 to 100 feet was the cause of the artesian condition. Observation well E-3 was finished at 120 feet.

To permit observation of hydraulic conditions in both strata, 12 more of the 2-inch wells were then deepened to about 120 feet, and the others were left at their original depths. The map in plate 6 shows the final

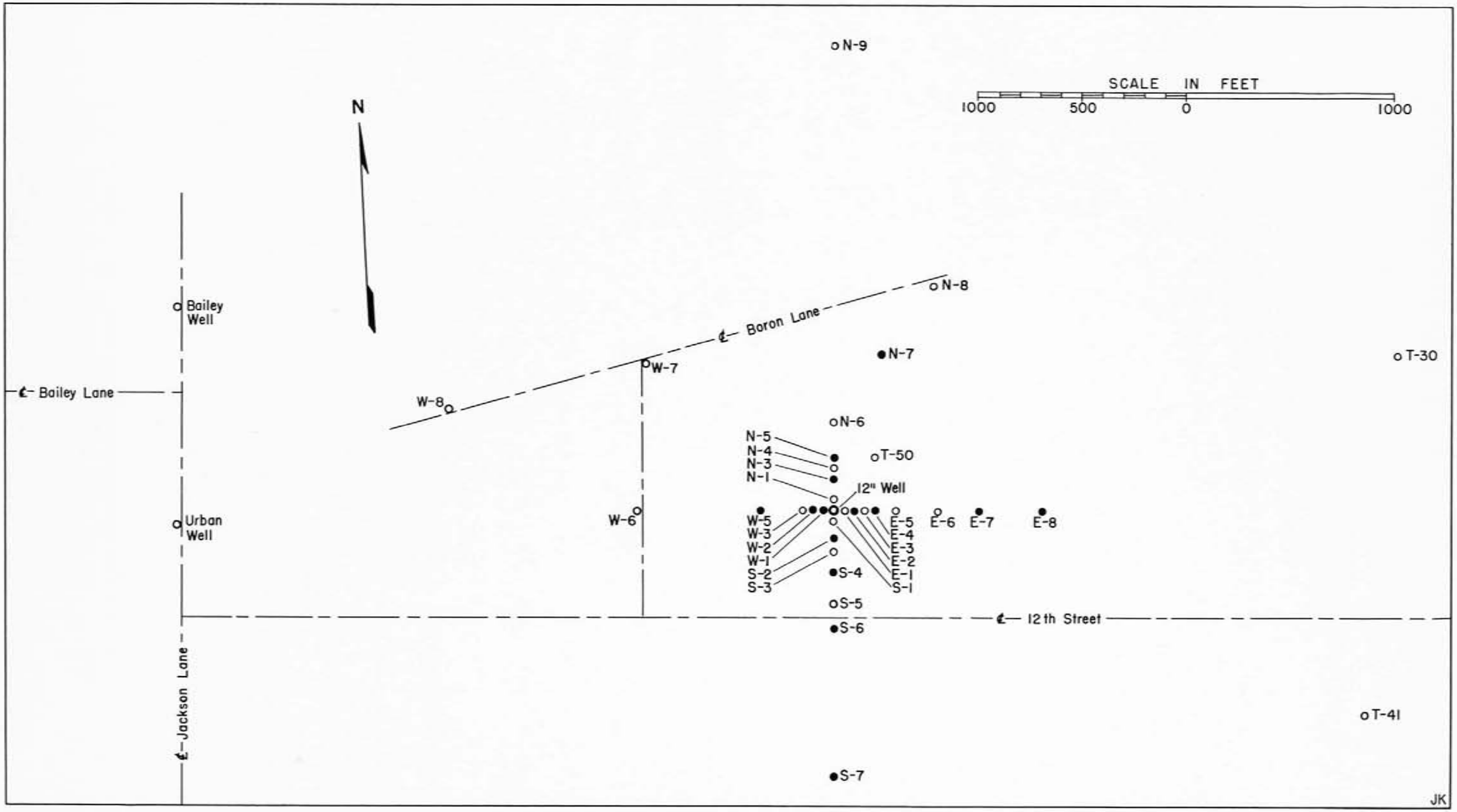

Plate 6.– Map showing locations of 12-inch well and observation wells for pumping test in Perry Township, Stark County, Ohio.

Table 4

Log of 12-inch well used for pumping test in Sippo Area, Perry township, Stark County, Ohio (Location shown on plate 6)

Depth below land surface (in feet)	Description of geologic materials encountered
0-10	Black muck
10-29	Dark gray clay, no pebbles
29-50	Fine to coarse, grayish brown sand with few pebbles up to ½-inch in diameter
50-60	Coarse grayish brown sand with high percentage of pebbles ranging from 1/8 to 1/2 inch in diameter
60-78	Small percentage coarse sand. Remainder pebbles ranging from 1/8 to 1/2 inch. Few pebbles up to 1 inch. Mixture grayish brown in color.
78-90	Fine, grayish brown sand, few small pebbles.
90-95	Pebbles and stones up to 1 inch. Small amount of sand.
95-100	Light gray clay with pebbles and stones ranging from ¼ to 1½ inches, no water.
100-110	Pebbles ranging from 1/8 to 1¼ inches. Fair percentage of coarse sand.
110-115	50% coarse sand, 50% pebbles up to 1½ inches in diameter.
115-120	Pebbles ranging from 1/8 to 1 inch with small percentage of sand.
120-125	About 50% coarse sand and 50% small pebbles.
125-131	Pebbles and stones up to 1½ inches. Small amount of coarse sand.

Table 4 (Cont.)

Depth below land surface (in feet)	Description of geologic materials encountered
131-142	Pebbles and stones up to 2 inches. Small amount of coarse sand.
142-157	Pebbles and stones up to 2 inches. Fair amount of sand.
157-187.5	Pebbles and stones up to 2 inches with small amount of sand and few small boulders up to 4 inches.

arrangement of observation wells for the pumping test, 6 of the 4-inch wells drilled in 1945 to determine bedrock depths, and 3 of the test wells drilled in 1925, 1926, and 1930 by the city of Canton.

A 30-day pumping test was planned, but was prolonged after it was found that water from the deep stratum was much better in quality than that from the shallow stratum. The danger existed that the poor water from the shallow deposits might eventually affect the quality of the water from the deep deposits. Pumping of the 12-inch well at a rate of approximately 1,000 g.p.m. was started at 9 a.m. on September 19, 1945 and continued until 3 p.m. on April 30, 1946, a period of 223 days.

To determine the effect of pumping on ground-water levels in the area surrounding the pumping well, measurements of depth to water were made in the observation wells by means of weighted steel tapes chalked at the bottom to give clear water marks. During the first day of the test, measurements were made as often as possible. In addition, continuous records of water levels were obtained with automatic water-stage recorders installed on six observation wells. After the first day of pumping, water levels were dropping at a decreasing rate, and measurements were spaced further apart. At the end of a month only weekly measurements were required to follow the trend.

Profiles of the water surface in the deep stratum, drawn from water-level measurements made immediately before the pumping test and at three times after pumping had started, are shown in figures 6 and 7. Inspection of these profiles reveals that the slopes of the drawdown curves close to the pumping well reached approximate stability in a very short time after pumping began. The slopes after 135 days of pumping, for instance, do not vary appreciably from those existing after only 15 hours of pumping, although water levels in all the observation wells dropped several feet in that period. Similarly, the slopes of the drawdown curves at distances of as much as 2200 feet did not differ greatly after 135 days of pumping from those established after 35 days of pumping.

The profiles also reveal that the entire cone of depression lowered at a steadily decreasing rate. Extrapolation of the water-level record obtained from observation well T-50 (figure 5) before pumping had started, shows that the rate of drop in water level was continuously greater than would have occurred from the natural discharge of the aquifer until recharge occurred in the spring of 1946. Thus true equilibrium was never reached in the period of the test. However, the decrease in the rate of decline of the ground-water levels indicated that recharge in greater amounts was being diverted to the pumping well from the areas of natural discharge of the aquifer.

Hydrographs of water-level records obtained in the observation wells along the east line are included

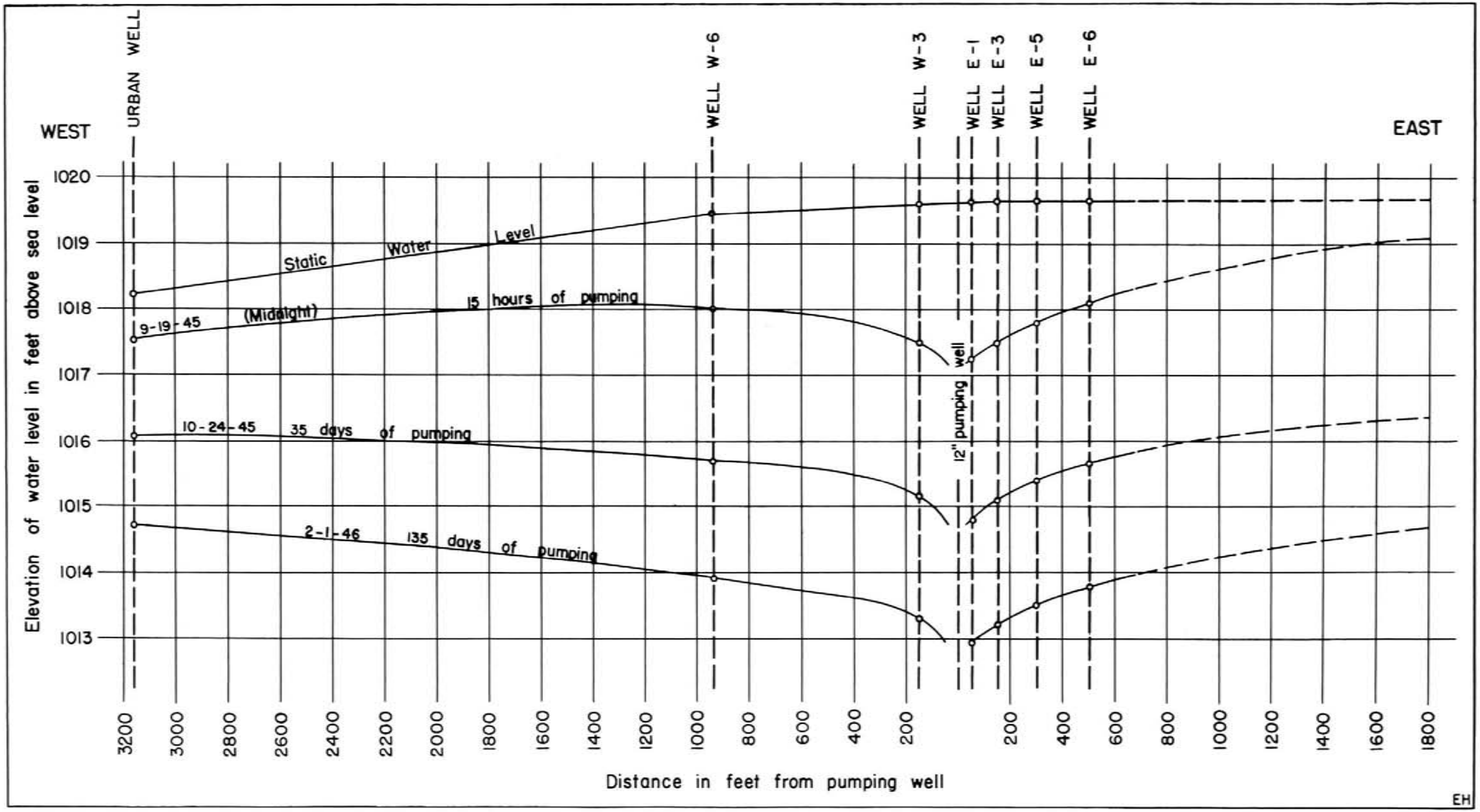

Figure 6.- Profile of piezometric surface along East-West line through 12-inch well in Perry Township, Stark County, Ohio.

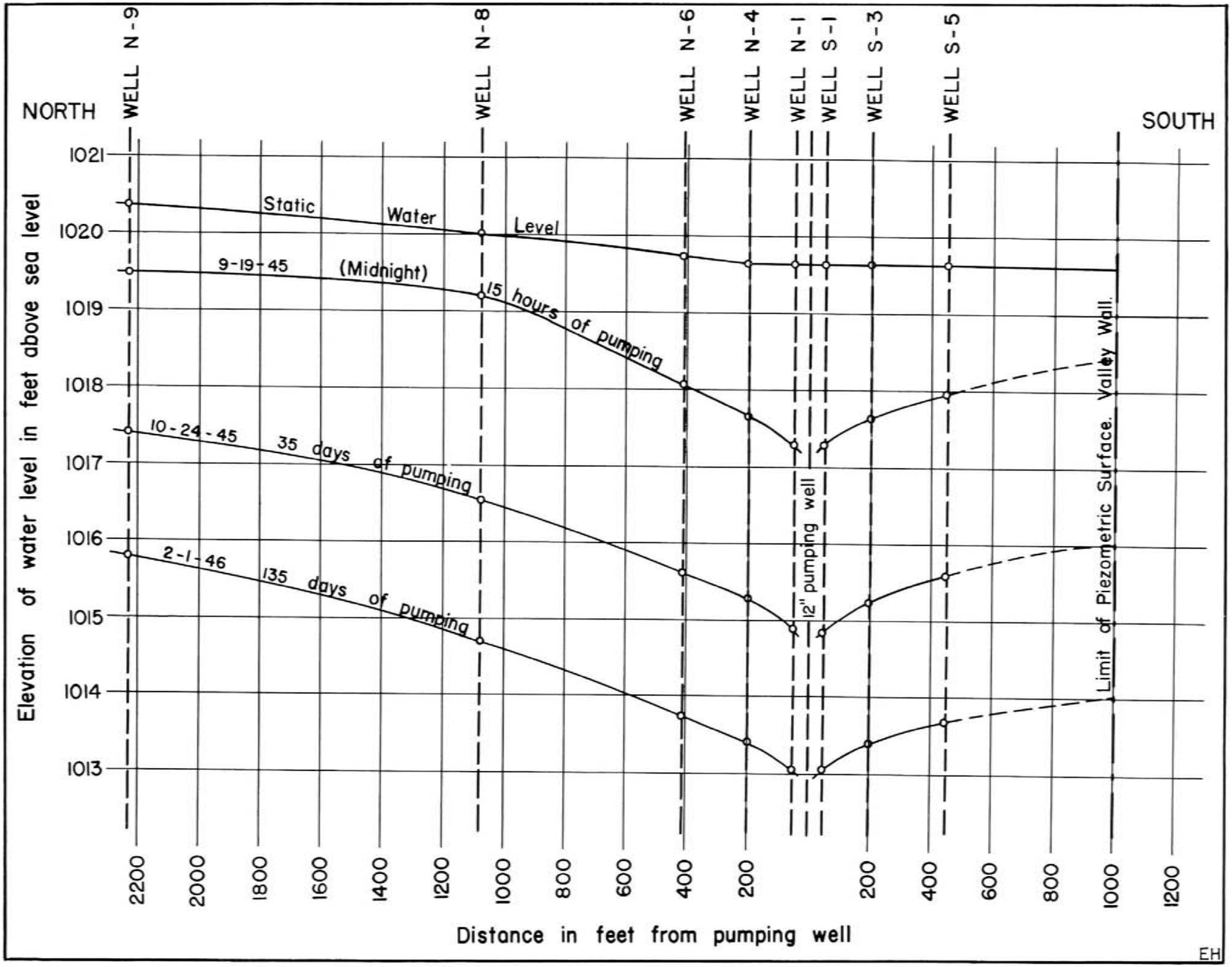

Figure 7.– Profile of piezometric surface along North-South line through 12-inch well in Perry Township, Stark County, Ohio.

in the appendix at the end of this report. These hydrographs show that water levels in the deep wells responded almost immediately to pumping, the lowering being much greater than in the shallow wells in the early part of the test. However, examination of the hydrographs for the shallow wells shows definitely that the water levels in the shallow wells were affected and continued to drop throughout the test. The pumping test proved that a hydraulic connection exists between the deep and shallow gravel deposits and that precipitation falling locally and percolating into the shallow deposits is drawn into the deeper deposits by pumping.

The test also shows that the permeability of the gravels in the buried valley is exceptionally high, as evidenced by the flat slopes of the drawdown curves. The average permeability as computed by the Theim method [16/] was found to be 8500 gallons per day per square foot. That is, each strip of the formation 1 mile wide and 1 foot thick measured at right angles to the direction of flow will transmit 8500 gallons of water a day under a hydraulic gradient of 1 foot per mile. This value of permeability is high in comparison with most sand and gravel deposits and is due to the deposits being extremely coarse and cleanly washed. Permeabilities of most good sand and gravel deposits in the United States usually range from 500 to 2,000.

16/ Wenzel, Leland K., The Theim method for determining permeability of water bearing materials. U.S. Geol. Survey Water Supply Paper 679-A, 1936.

Finally, the test showed clearly that no large source of recharge exists in the immediate vicinity of the pumping well. This is evidenced by the fact that water levels dropped appreciably throughout the test at a slowly decreasing rate, except near the end when recharge from rainfall temporarily counterbalanced the downward trend caused by pumping. Since the test was conducted over a period of about 8 months it is apparent that salvage of the natural discharge from the aquifer was accomplished very slowly, indicating that the discharge occurs at many scattered places. Thus a lowering of water levels over a relatively large area is required to salvage the discharge.

Estimate of Perennial Yield

Previously in this report it was estimated that recharge in the Sippo area would average 374,000 to 460,000 gallons a day per square mile. The area enclosed by the natural drainage divides, which approximate the natural ground-water divides, is about 9 square miles. Thus the total recharge available in the area would be $3\frac{1}{2}$ to 4 million gallons a day. The perennial yield to wells located in section 3, Perry township, where a new ground-water development is under consideration by the city of Canton, would depend on the amount of recharge that could be salvaged from the natural discharge of the aquifer.

The map (plate 4) of the piezometric surface shows that a portion of the ground-water flow in the Sippo area is south across the buried valley to the main channel of Sippo Creek paralleling 12th Street. Some of the ground water also discharges from the north into three branches of Sippo Creek traversing parts of the area and some is lost to the atmosphere by transpiration and evaporation in the marshy areas bordering the streams. A small amount also discharges from the south into the main channel of Sippo Creek. To salvage all of the recharge by pumping from wells would require that water levels be lowered along all of the streams a sufficient amount to cut off the natural discharge.

The process of diverting ground-water flow by pumping a well is illustrated by the series of piezometric profiles in figure 6, which shows the changes in ground-water gradients that occurred on an east-west line during the pumping test. Before pumping was started the ground-water gradient was downward to the west from the pumping well to the limit of the profile, or about 3200 feet. As pumping continued the cone of depression gradually expanded until at the end of 35 days the hydraulic gradient was reversed throughout most of the profile west of the pumping well. The profile for 135 days of pumping shows that the gradient was completely reversed throughout the entire 3200 feet. Extrapolation of the profile for 135 days of pumping, which is assumed to represent a condition of approximate equilibrium, shows that the reversal of gradient occurred considerably beyond this distance. Allowing 1.25 feet for the natural drop in water level that would have occurred with no pumping (as estimated from the record of well T-50), the pumping gradient would intersect the natural gradient at a distance of about 5800 feet from the pumping well. If pumping had been at a rate of 4 million gallons a day (the estimated maximum recharge) the lowering of water level at any point along the profile would have been increased in approximate direct proportion to the increased rate of pumping. From the slope of the draw-down curve determined in this manner it is estimated that a lowering of water levels of about 25 feet in the immediate vicinity of the pumping well would eventually occur with a lowering of 5 feet at the western boundary of the area, 1.6 miles from the pumping well. The lowering of water level in the pumping well itself would be somewhat greater than 25 feet, depending largely on the construction and efficiency of the well.

The above analysis assumes that a lowering of 5 feet at the boundaries of the area of recharge would be the minimum necessary to cut off most of the natural ground-water losses and thus salvage all the available recharge.

The greatest distance over which water levels would have to be lowered in the area is $2\frac{1}{2}$ miles, northward along the axis of the tributary buried valley toward Cable Lake, in the center of section 26, Jackson township. Using the same assumed conditions as for the line running west, the lowering of water levels in the vicinity of pumping would be 23 feet. This computation was based on the 135-day profile along a line running northeast from the pumping well.

It should be noted that the lowering required is less than that computed for a shorter distance in a westerly direction. This is due to the greater depth of water-bearing material in the buried valley to the north than in the area to the west. Since the northerly direction presents the most severe requirement to be expected, it is believed that most of the recharge in the Sippo area can be intercepted by pumping in section 3, Perry township. The assumption has been made that one well would be used. The use of several wells with adequate spacing would give greater assurance that the recharge would be intercepted. Because of the lower rate of pumping from each well, there would be less drawdown within the pumping wells.

Undoubtedly a small amount of recharge will be lost to stream flow where the water table near the streams is perched above the main water table. However, it is believed that at least an equal amount of water will be induced from stream flow during periods of high surface runoff as a result of lowering of the main water table below the level of the streams. It seems reasonable, therefore, that a perennial ground-water supply of $3\frac{1}{2}$ to 4 million gallons a day can be obtained in the Sippo area from wells located on the property owned by the city of Canton in section 3, Perry township.

QUALITY OF THE GROUND WATER

A number of analyses of water obtained from the glacial drift in and near Canton have been given by Foulk and by Harker in publications of the Geological Survey of Ohio [17] and the Ohio Water Supply Board. [18] Table 3 gives analyses of water from gravel wells in the 9th Street, Grovemiller, and Northeast well fields of the Canton Water Department and from the 12-inch well used for the pumping test in section 3, Perry township, in the Sippo area.

In all, analyses from 14 wells are available for study and comparison. These analyses show total hardness ranging from 159 to 622 parts per million. Total solids ranged from 260 to 938 parts per million. The iron in only three samples exceeded one part per million, and was 2.0, 2.6, and 7.5 parts per million. The iron in the remaining 11 samples varied from 0.1 to 0.8 part per million and averaged 0.4 part per million.

Analyses for fluoride are available for 7 of the samples. They show variations from 0.04 to 0.2 parts per million. Chlorides varied from 3 to 42 parts per million.

In general the water from the glacial deposits in the Canton area would be considered very hard, and to be thoroughly satisfactory for household use would require

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17/ Foulk, C.W., Industrial Water Supplies of Ohio, Geological Survey of Ohio, pages 242 to 247 inclusive, 1925.

18/ Harker, David H. and Bernhagen, Ralph J., Report on Water Supply in Stark County, Ohio, Ohio Water Supply Board, page 58, Aug. 15, 1943.

Table 3

Analyses of water from wells
in the
glacial deposits in the Canton area

Analyses by the Ohio Department of Health
(Parts per million)

Date of collection, Jan. 11, 1946	1	2	3	4
Silica (SiO_2)	6	7	7	6
Iron (Fe)	2.0	0.6	0.1	0.25
Manganese (Mn)	.5	.25	.4	.35
Calcium (Ca)	182	106	84	145
Magnesium (Mg)	39	23	23	30
Sodium (Na)	---	----	----	-----
Potassium (K)	---	----	----	-----
Bicarbonate (HCO_3)	378	306	271	332
Sulfate (SO_4)	---	----	----	-----
Chloride (Cl)	30	8	3	8
Fluoride (F)	.1	.1	.1	.2
Nitrate (NO_3)	---	----	----	-----
Dissolved solids	854	443	342	642
Total hardness as $CaCO_3$	615	359	277	485
pH	7.2	7.4	7.5	7.4

1 - 9th Street well
2 - Grovemiller well 2
3 - 12" well in Sippo area
4 - Northeast well field, well 10

softening, although softening is not done by the Canton water department at this time. Extreme hardness results in excessive use of soap. Hard water is also objectionable for some industrial processes and for boiler use. When used in boilers, such water, unless softened with a boiler compound, forms a scale that adheres to walls of the tubes or the shell of the boiler. The insulating properties of this scale reduce boiler efficiency.

Objectionable amounts of iron occurred in three of the 14 samples for which analyses are available. Excessive iron in water stains clothing when laundered and discolors bath room and kitchen equipment. In large concentrations it also imparts a disagreeable taste to the water. It is also undesirable in water for many industrial processes.

Fluorides in water may cause mottled teeth when the fluoride content exceeds 1 part per million. The amounts in the samples analyzed, ranging from 0.1 to 0.2 parts per million, are well below the limit of tolerance. Dental caries (decay) is decreased by the use of water containing fluoride, when in amounts not over 1 part per million.

The chloride concentrations ranging from 3 to 42 parts per million, are within allowable limits for water for household and drinking purposes. The higher concentration might be objectionable for some special industrial processes.

The analyses given in table 3 show that the water obtained from the 12-inch well in the Sippo area contained a lower concentration of objectionable mineral constituents than the water obtained from the well fields now used by the city of Canton. The quality of the water obtained from the Sippo well did not change noticeably during the 7½ months of the pumping test.

CONCLUSIONS

The investigation of ground-water conditions in the Canton area shows that overpumping has occurred only in the outwash gravels underlying the city proper. This overpumping occurred in the period from 1939 to the end of 1944. The pumping in 1945 and to May 1946 was less than the recharge received in the area, resulting in a rise in ground-water levels of about 5 feet. The over-pumping has not as yet caused a serious lowering of water levels, the present non-pumping levels being about 50 feet below the land surface in most parts of the city. The depth of water-bearing materials within the buried valley in this area generally ranges from 100 to 200 or more feet.

The investigation also showed that an additional supply of $3\frac{1}{2}$ to 4 million gallons a day of ground water can be obtained from the buried valley in the Sippo area located about $5\frac{1}{2}$ miles west of Canton.

The maps included in the report should be of special value to aid in determining the most promising sites for development of additional ground-water supplies in the future. For example, plates 2 and 3 show a buried valley north of Meyer's Lake passing south and east through sections 20 and 30 of Plain township. The thickness of the drift in the deepest part of the valley probably exceeds 200 feet. For a mile or more to the north the drift is from 50 to 100 feet thick. In addition West Branch Nimishillen Creek and a tributary on the west traverse the buried valley and the relatively thick drift to the northwest and northeast, offering good possibilities for recharge. However, no test holes have been drilled in the deep part of this valley and the nature of the underlying glacial materials is not known.

The determinations of the amount of recharge available in the Sippo and Grovemiller areas should prove of value in estimating the perennial yield of other glacial areas where conditions are similar, particularly in areas not traversed by through-flowing streams.

The investigation brought out the large difference in the amount of recharge to be expected in the upland areas as compared with areas traversed by through-flowing streams. About 400,000 gallons a day per square mile of recharge is available in the Sippo and Grovemiller areas, where recharge depends upon local precipitation, while well over one million gallons a day per square mile is available in Canton proper, where the glacial outwash is traversed by several branches of Nimishillen Creek.

APPENDIX A

Observation Well Data and Logs
of Selected Drilled Wells Used in Pumping Test
in Sippo Area, Perry Township, Stark County, Ohio

Sippo Pumping Test

OBSERVATION WELL DATA

Well No.	Diameter, inches	Distance from 12-in. well (feet)	Altitudes, in feet above sea level: Measuring point	Land Surface	Bottom of well	Top of bedrock
S-1	2	52.6	1023.47	1022.5	908.6	
S-2	6	141.2	1025.97	1022.3	969.8	
S-3	2	199.8	1023.19	1022.2	908.2	
S-4	2	299.8	1024.70	1022.7	979.4	
S-5	2	449.8	1024.41	1023.4	908.4	
S-6	2	671.2	1027.12	1025.1	982.8	
S-7	4	1271.2	1027.92	1026.6	985.9	991.9
W-1	2	49.6	1024.89	1022.9	944.9	
W-2	2	99.6	1025.42	1022.9	980.4	
W-3	2	149.6	1024.92	1023.9	909.6	
W-5	6	363.0	1035.52	1031.6	985.0	
W-6	2	935.0	1027.51	1026.5	913.2	
W-7	4	1150	1043.95	1039.7		
W-8	4	1920	1038.41	1035.0	954.0	954.0
Urban	4	3160	1028.40	1025.7	960.4	970.4
Bailey	4	3320	1067.81	1067.5	982.8	982.8
D-10	$1\frac{1}{4}$	4600	1041.37	1038.0	1017.4	
N-1	2	48.0	1023.96	1023.0	909.7	
N-3	2	148.8	1025.54	1023.5	976.8	
N-4	2	198.8	1024.93	1023.9	910.3	
N-5	6	249.8	1027.40	1024.6	987.4	
N-6	2	413.8	1035.07	1031.0	919.3	
N-7	2	780	1035.79	1032.9	991.1	
N-8	4	1170	1040.51	1038.7	909.0	925.5
N-9	4	2230	1030.25	1029.2	954.2	964.2
T-50	6	330	1028.02	1024.2	806.2	829.2
T-42	3	3600	1025.82	1025.2	918.2	932.2
T-41	3	2730	1026.38	1025.4	910.4	935.4
T-40	3	4600	1032.18	1031.1	848.9	848.9
T-30	3	2800	1027.07	1026.5	867.4	867.4
D-4	$1\frac{1}{4}$	3600	1028.13	1025.2	1005.7	
12-in.	12		1022.67	1022.5	835.2	
T-35	3	3700	1029.06	1026.8	868.8	868.8
E-1	2	48.0	1023.69	1022.7	909.6	
E-2	2	98.0	1024.76	1022.8	969.1	
E-3	2	147.6	1024.74	1023.7	904.2	
E-4	2	197.6	1025.09	1023.1	980.1	
E-5	2	297.6	1024.66	1023.7	910.0	
E-6	2	497.6	1025.55	1024.6	910.5	
E-7	2	697.6	1026.21	1024.2	982.6	
E-8	6	998.0	1028.93	1025.2	983.9	

Detailed log of Bailey well, Sippo Area,
Perry Township, Stark County, Ohio
(Location shown on plate 6)

Depth below land surface (in feet)	Description of geologic materials encountered
0-15	Light brown sandy clay and few small pebbles
15-22	Very coarse dark gray sand with pebbles and admixture of clay
22-30	Very coarse dark brown sand with few pebbles up to $\frac{1}{2}$-inch
30-40	Coarse grayish brown sand with pebbles up to $\frac{1}{2}$-inch
40-64	Medium coarse grayish brown sand with pebbles up to $\frac{1}{2}$-inch and few stones up to $1\frac{1}{4}$-inch
64-70	About 50% coarse sand and 50% pebbles $\frac{1}{4}$-inch to 1-inch
70-80	Pebbles and stones up to $1\frac{1}{2}$-inches and small amount of coarse sand
80-85	Mixture of sand, small pebbles and medium gray clay
85-88	Bluish gray plastic shale
88-90	Hard sandy bluish gray shale
90-97	Light gray plastic shale
97	Reddish brown sandstone and few pieces of hard shale

Detailed log of well N-8, Sippo Area
Perry Township, Stark County, Ohio
(Location shown on plate 6)

Depth below land surface (in feet)	Description of geologic materials encountered
0-8	Sandy clay with few pebbles
8-30	Small pebbles up to 3/8-inch with small amount of coarse sand
30-40	Very coarse dark gray sand with pebbles up to ½-inch
40-60	Medium coarse dark gray sand with few pebbles
60-70	Medium coarse dark gray sand with fair percentage of pebbles up to 1-inch
70-80	Very coarse dark gray sand with very few pebbles
80-90	Small pebbles with small amount of sand
90-100	Medium coarse sand with pebbles up to ½-inch
100-110	Pebbles up to 3/4-inch with coarse dark gray sand
110-115	Medium coarse dark gray sand with pebbles up to ½-inch
115-131.6	Bluish gray plastic shale

Detailed log of well N-9, Sippo Area,
Perry Township, Stark County, Ohio
(Location shown on plate 6)

Depth below land surface (in feet)	Description of geologic materials encountered
0-10	Dark gray muck and clay
10-18	Mixture of sand and clay
18-30	Coarse sand with pebbles up to 3/4 inch in diameter
30-40	Pebbles and stones up to $1\frac{1}{2}$-inches in diameter. Small amount of coarse sand.
40-45	Mostly pebbles up to 1-inch in diameter and a few stones about 2 inches in diameter. Fair percentage of coarse sand.
45-60	Medium dark gray sand. No pebbles.
60-66	Medium dark gray sand. Few small pieces of sandstone, clay and a few small pebbles.
66-70	Light gray sandstone and a few pieces of light gray plastic shale.
70-76	Medium gray plastic shale

Detailed log of well S-7, Sippo Area,
Perry Township, Stark County, Ohio
(Location shown on plate 6)

Depth below land surface (in feet)	Description of geologic materials encountered
0-12	Brown muck, some sand and few pebbles up to $\frac{1}{4}$-inch
12-27	Clean mixture of brown sand and pebbles $\frac{1}{4}$-inch to $\frac{1}{2}$-inch
27-36	Fine sand with pebbles ranging from $\frac{1}{4}$-inch to $\frac{1}{2}$-inch
36-42	Fine grained white sandstone

Detailed log of Urban Well, Sippo Area
Perry Township, Stark County, Ohio
(Location shown on plate 6)

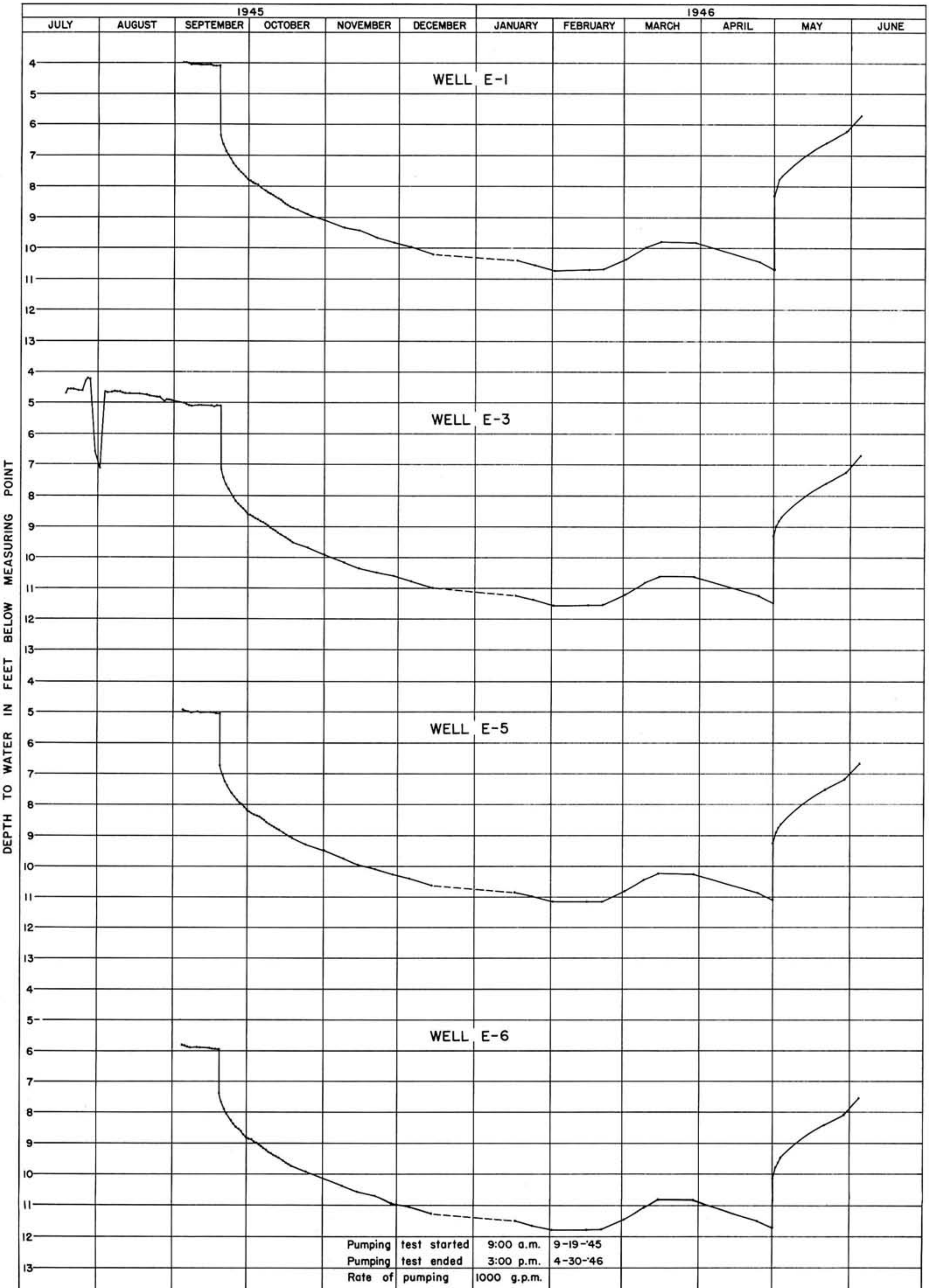
Depth below land surface (in feet)	Description of geologic materials encountered
0-10	Clay and sand with pebbles up to $\frac{1}{2}$-inch.
10-27	Clay and sand with pebbles up to $\frac{1}{2}$-inch. Few stones up to $1\frac{1}{4}$-inches.
27-30	Drilled through limestone boulder.
30-41	Medium sand, dark gray, with fair percentage of pebbles up to 3/4 inch.
41-46	Pebbles up to $\frac{1}{2}$-inch with fair amount of sand
46-58	Mostly light brown sand with few small pebbles. (Encountered sandstone at 58 feet)
58-68	Medium coarse reddish brown sandstone

Detailed log of well W-8, Sippo Area
Perry Township, Stark County, Ohio
(Location shown on plate 6)

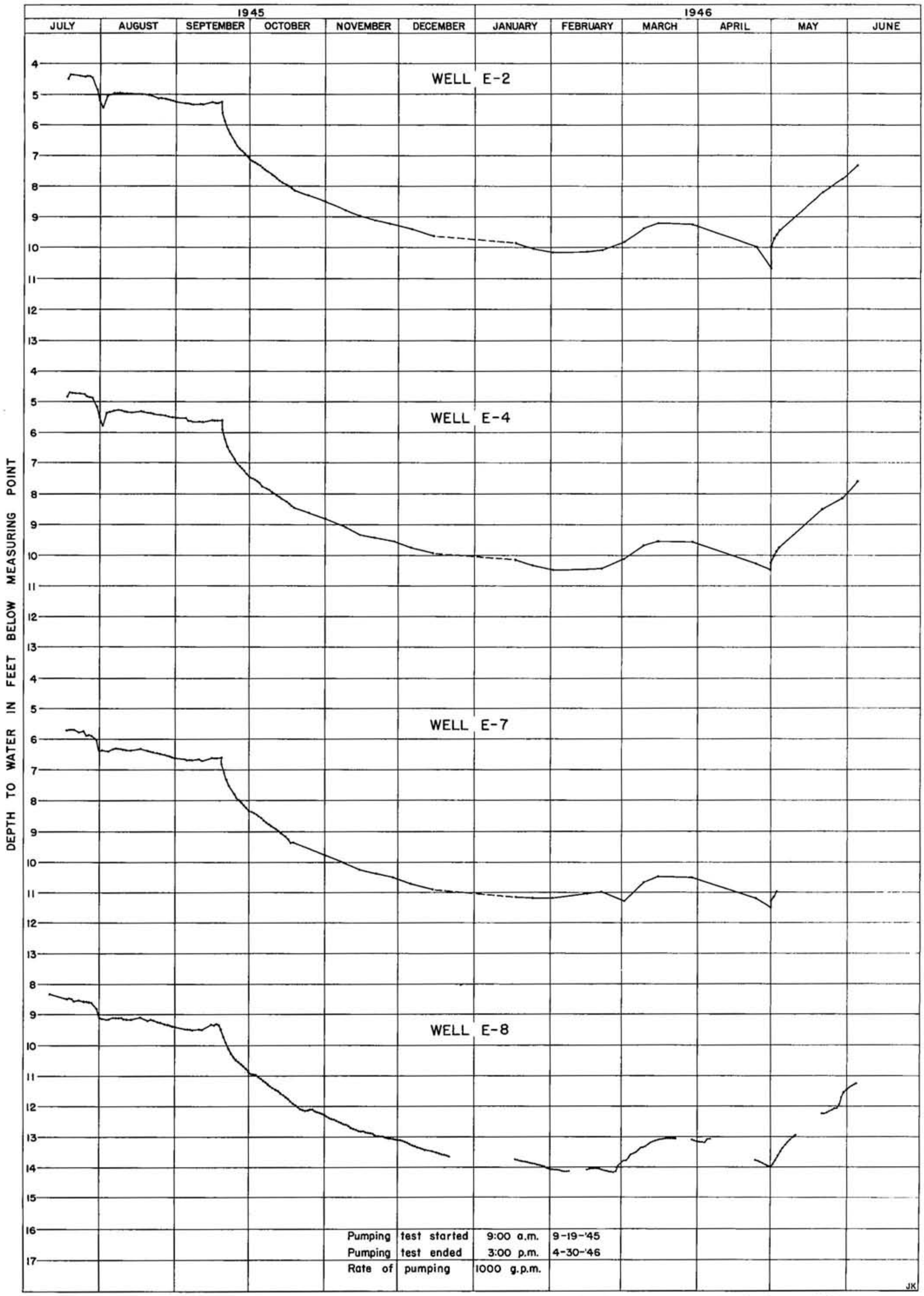
Depth below land surface (in feet)	Description of geologic materials encountered
0-11	Chocolate brown sandy clay with few pebbles
11-20	Chocolate brown sandy clay with many pebbles
20-25	Chocolate brown sandy clay. No pebbles
25-44	Fine brownish gray sand and a few lumps of coal. No pebbles
44-50	Dark gray clay, sand and pebbles
50-60	Coarse gray sand, pebbles and stones up to 1 inch
60-70	Medium sand with few 1/8-inch pebbles
70-80	Medium sand and considerable number of pebbles up to ½-inch
80-84	Mixture of fine to coarse sand, pebbles, and pieces of sandstone up to 1 inch
84-94	Reddish brown medium grained sandstone

Appendix B

Hydrographs showing fluctuations of water levels in selected observation wells in the Sippo Area during pumping test in 1945 and 1946



Graphs showing fluctuations of water levels in deep wells on East line in Sippo Area, Stark County, Ohio.



Graphs showing fluctuations of water levels in shallow wells on East line in Sippo Area, Stark County, Ohio.