Ground-Water Conditions in Southwestern Langlade County Wisconsin

By A. H. HARDER *and* W. J. DRESCHER

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GROUND-WATER CONDITIONS IN SOUTHWESTERN LANGLADE COUNTY, WISCONSIN

By A. H. Harder and W. J. Drescher

ABSTRACT

Glacial outwash sand and gravel deposits are the principal aquifer in southwestern Langlade County, Wis. The underlying bedrock of pre-Cambrian age contains little or no water. The source of ground water is local precipitation. Information was collected on more than 300 wells in the area. Movement of ground water is generally southward and locally toward streams. Discharge is by streams and subsurface flow. Fluctuations of water levels in wells show a close correlation with seasonal precipitation and with average precipitation over a period of years. Pumping tests made at the city of Antigo's well field gave a coefficient of transmissibility of 62,000 gpd per ft and a coefficient of storage of 0.15 for the outwash deposits. It is estimated that recharge to a 90-square-mile area of the Antigo flats averages about 30,000 acre-feet per year. Of the 1,100 acre-feet pumped from wells in 1948, 69 percent was for municipal supply, 26 percent for rural supply, and 5 percent for irrigation. Use of water for irrigation has caused no measurable decline of water levels in the area as a whole.

INTRODUCTION

In 1945 the legislature of the State of Wisconsin provided funds to the Board of Regents of the University of Wisconsin "*** for the purpose of investigating the underground-water resources of the state, determining the present use and depletion thereof and recommending to the legislature such action as may be deemed necessary to conserve these underground-water supplies as a public resource." The bill further authorized the University "*** to cooperate with the appropriate agencies of the Federal government in conducting such a study."

In 1946 the U. S. Geological Survey, in cooperation with the University of Wisconsin, began a program of ground-water studies. Observation wells were established at selected points throughout the State so that fluctuations of ground-water levels could be determined, and detailed investigations of ground-water conditions in various areas in the State were started.

This report is a summation of a study, begun in 1948, of the ground-water resources of southwestern Langlade County. The field work for this report was begun by W. E. Price, geologist, U.S. Geological Survey, and continued by the authors under the general direction of A. N. Sayre, chief of the Ground Water Branch of the U. S. Geological Survey.

PURPOSE AND SCOPE

The purpose of this study was to determine the occurrence of ground water, the amount of ground water available, and the effect of irrigation on ground-water levels in southwestern Langlade County. Special attention was given to the source of the ground water, its direction of movement, its discharge, the fluctuations of water levels in wells, and the use made of the ground water.

An inventory of the wells in the area was made and an observation-well program was started. Table 4 lists the number and types of wells scheduled during the investigation. Geologic and piezometric maps were constructed and analyzed, and estimates were made of the quantities of ground water being used. Some of the data on which this report is based were taken from reports written by earlier workers (Bean, Martin, and Williams, 1913; Thwaites, 1943; Weidman, 1907) in this area.

ACKNOWLEDGMENTS

The authors wish to thank the many people who aided them in making this study. Many of the residents of Langlade County supplied information about their wells. The irrigators supplied all the data on the amount of water being used for irrigation. Weekly water-level measurements have been made in well La-118 by the Wisconsin Public Service Corp, since 1942. Henry A. Ehlers, superintendent of the Antigo Water Department, gave full cooperation at all times. The authors are obligated to Professor F. T. Thwaites, University of Wisconsin, who furnished well-log data and gave helpful information on geology, and to G. F. Hanson, State geologist, and E. F. Bean, State geologist retired, for their review of this report.

WELL LOCATIONS

Wells in Langlade County are designated by the prefix La, an abbreviation for this county, followed by a number denoting a specific well in the county. The locations and descriptions of all wells mentioned are given in table 9 and the locations of wells in which water-level measurements were made are shown on plate 1. On plate 1 the county prefix was eliminated for the sake of simplicity. Logs of wells were collected from the files of the State Board of Health, from well drillers, and from well owners.

GEOGRAPHY

LOCATION

Langlade County is in north-central Wisconsin and has an area of 875 square miles (pl. 1). The area studied occupies the southwestern three-fourths of the county. Antigo, the only city and the county seat, is in T. 31 N., R. 11 E.

CLIMATE

The climate of Langlade County is typical of that of the North Central States. The summers are cool, with few hot days. The winters are long and are very cold for short periods. Snow, usually beginning in the latter part of November, covers the ground throughout most of the winter. The average number of frost-free days at Antigo is 138. The highest temperature ever recorded at Antigo during the years 1894–1951 was 101° F, the lowest, -40° F; the mean annual temperature is 42.2° F. The average yearly precipitation during this period was 29.86 inches, approximately two-thirds of which occurred during the spring and fall. Table 1 gives a summary of climatic data for the United States Weather Bureau station in Antigo.

CULTURE

In 1950 the population of Langlade County was 21,996 and that of Antigo was 9,902. The county is primarily agricultural. Dairying is the most important industry. Crops produced are hay, oats, potatoes, corn, peas, barley, wheat, buckwheat, and rye. Potatoes have become a major crop in recent years as a result of the adaption of irrigation. Operation of summer resorts and the tourist trade constitute an important part of the county's industry. Industries located in Antigo include a railway repair shop, a shoe factory, a glove factory, woodworking shops, a cannery, and dairy plants.

Table 1.—*Temperature and precipitation data for Antigo, Wis.*

Month	Temperature				Precipitation				
	1951	1893-1951			1951	1893-1951			
	mean (°F)	Mean (°F)	Absolute maximum (°F)	Absolute minimum (°F)	(inches)	Mean (inches)	Total amount for the driest year (1906) (inches)	Total amount for the wettest year (1904) (inches)	Average depth of snow on ground (inches)
December	17.4	19.3	60	-28	0.90	0.99	0.43	2.70	8.7
January	12.4	13.8	55	-36	.42	1.04	1.51	.20	10.2
February	17.4	15.5	59	-40	1.40	1.01	.32	1.15	9.7
Winter	15.7	16.2	60	-40	2.73	3.04	2.26	4.05	9.5
March	24.9	27.4	78	-23	3.12	1.40	1.35	.90	8.7
April	41.3	42.1	88	-2	3.63	2.36	1.66	2.30	4.8
May	58.8	54.4	100	17	2.59	3.48	4.01	8.60	.4
Spring	41.7	41.3	100	-23	9.34	7.24	7.02	11.80	4.6
June	60.6	63.9	99	26	4.06	4.35	2.81	7.55	.0
July	67.4	68.5	101	34	5.40	3.86	2.02	5.18	.0
August	62.5	65.5	98	30	5.37	3.29	1.75	3.74	.0
Summer	63.5	66.0	101	26	14.83	11.50	6.58	16.47	.0
September	54.7	58.3	94	13	3.09	3.97	2.25	7.41	Trace
October	46.6	46.3	84	4	3.28	2.49	1.26	5.52	.7
November	23.9	31.8	73	-12	1.92	1.62	.25	2.45	5.7
Fall	41.7	45.5	94	-12	8.29	8.08	5.96	13.18	2.1
Year	40.6	42.2	101	-40	35.18	29.86	21.86	45.50	

TOPOGRAPHY

The generalized contours on the land surface as shown on figure 1 were taken from a topographic map drawn by F. T. Thwaites (1943). All well elevations used in this report were established with reference to mean sea level by use of an aneroid altimeter or a spirit level with U. S. Coast and Geodetic Survey benchmarks as control points. The point of lowest measured elevation, 1,315 feet, is in the southeastern part of the area; the point of highest elevation, 1,832 feet, is on a hill in sec. 17, T. 32 N., R. 12 E.

Residents of the area and earlier writers describing this area have long called the outwash plain surrounding the city of Antigo the "Antigo flats." It is a triangular plain of about 135 square miles

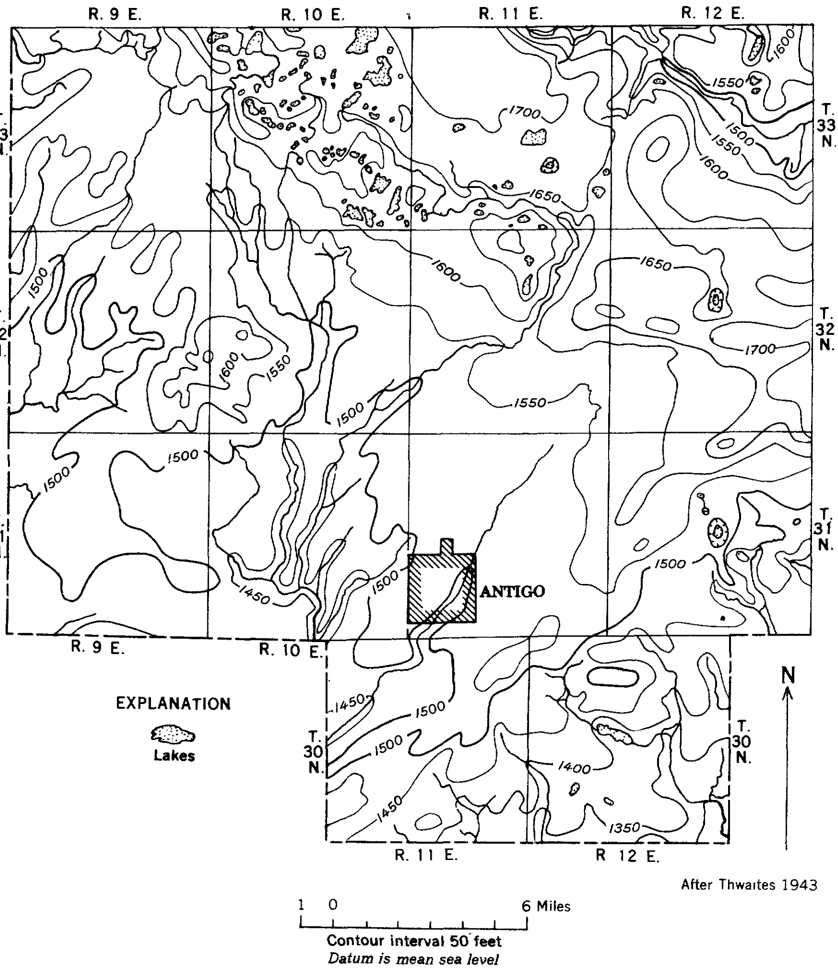

Figure 1. —Topographic map of southwestern Langlade County, Wis.

sloping to the southeast at 12 to 14 feet per mile. Altitudes on the plain range from 1,440 feet at the southeast edge to 1,670 feet at the eastern point. Drainage of the flats is to the east and west branches of the Eau Claire River and to Spring Brook. Spring Brook, as its name implies, is fed by springs, issuing from the Antigo flats. The valleys are wide, steep sided, flatfloored, and range in depth from 5 to 20 feet or more; they generally are large in relation to the size of the streams occupying them, for their shapes and sizes result from the large volumes of glacial melt water they were once required to carry. The plain is bordered on the northeast and southeast by terminal moraines and on the west by ground moraine (fig. 2).

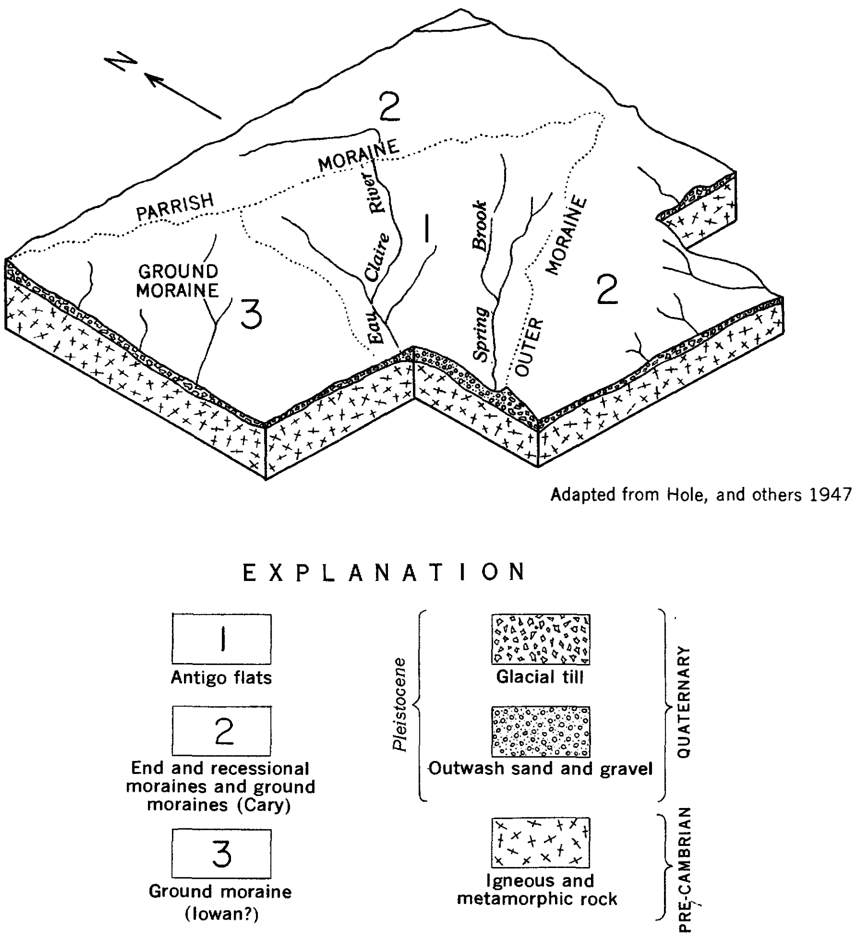

Figure 2. —Block diagram showing the location of the Antigo flats and areas of Cary and Iowan(?) moraine.

The Outer moraine (Thwaites, 1943) extends from sec. 26, T. 32 N., R. 12 E., through sec. 30, T. 30 N., R. 11 E., into Marathon County and ranges in altitude from about 1,700 feet at the northeast end to about 1,450 feet at the southwest end of the moraine.

The Parrish moraine of Thwaites extends from sec. 26, T. 32 N., R. 12 E., through sec. 31, T. 34 N., R. 9 E., into Lincoln County. It ranges in altitude from 1,832 feet near the southeast end to about 1,600 feet at the northwest end of the moraine.

Behind and roughly parallel to the terminal moraines are ground moraine and many recessional moraines. The recessional moraines are generally smaller than the terminal moraines and are discontinuous. Patches of outwash, knobs, and kettles occur on and behind the moraines. The topography is extremely rough throughout the morainic area. The poorly developed drainage of the morainic area is to the Eau Claire River and to the Wolf River and its tributaries. Undrained, swampy kettles and spring-fed kettle lakes without outlets are common.

The extreme western part of Langlade County is an area of rolling bedrock hills mantled by ground moraine. The large hill in T. 32 N., Rs. 9 and 10 E., the highest point in the area—1,680 feet—is a high on the pre-Cambrian rock surface that in places is mantled with a few feet of glacial drift. Drainage of this western area is to the Pine and Trapp Rivers, Black Brook, Hay Meadow Creek, and the west branch of the Eau Claire River. Poorly drained, swampy areas are common.

GEOLOGY

The character of the subsurface material largely controls the occurrence of ground water in any area. The control in southwestern Langlade County is furnished by the pre-Cambrian bedrock of schist, gneiss, and granite and by the overlying Pleistocene deposits. Figure 3 is a geologic map of southwestern Langlade County. It is based on a soil map of the area, on maps and reports made by other writers (Hole and others, 1947, p. 8; Weidman, 1907, p. 489; Thwaites, 1943, pl. 10), on field observations made by the authors of this report, and on aerial photographs.

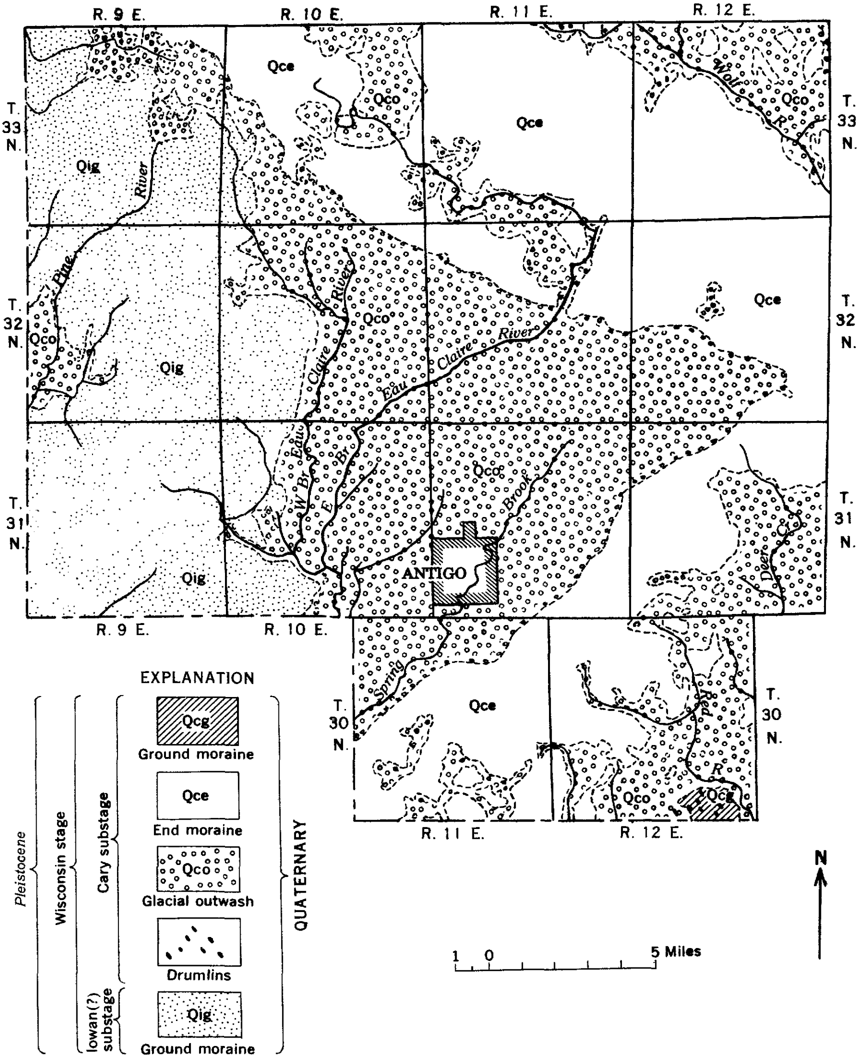

Figure 3. —Geologic map of southwestern Langlade County, Wis.

BEDROCK

The bedrock in southwestern Langlade County consists of granite, gneiss, and schist of pre-Cambrian age. These rocks crop out in Ackley Township (T. 31 N., Rs. 9 and 10 E.) and along the Wolf River. The surface of the bedrock has a relief of several hundred feet in this area, as indicated by elevations at outcrops and in wells. The logs of wells La-233 and -197 show decomposed granite, gneiss, and schist overlying fresh bedrock. Logs of wells La-5, -70, -194, -202, -220, -229, and -278 indicate fresh, hard rock at the top of the pre-Cambrian. The log of well La-5 indicates the presence of joints or other cracks in the bedrock. E. F. Bean (oral communication) reports that these openings seldom extend to depths greater than 30 feet below the rock surface.

GLACIAL DEPOSITS

Glacial drift of Pleistocene age may be classified under two general types—till and outwash.

Till is generally described as being an unsorted and unstratified material that is heterogeneous with regard to size, shape, and type of contained rock. It consists mainly of mechanically broken fragments of bedrock deposited by glacial ice without subsequent movement by wind or water. Constituents of till range in size from fine-grained material, which usually makes up the bulk of the till, to boulders several feet in diameter.

Outwash is a more or less stratified and sorted deposit of rock particles laid down by glacial melt waters. The particles may be angular or well rounded. They range in size from fine clay and silt to coarse gravel. Rock types found in outwash deposits are usually the same as those found in the till in adjoining areas. Outwash deposits occur as lenses and beds of clay, silt, sand, and gravel on, in, under, or adjoining till. Outwash plains, formed of material washed from the ice front, usually adjoin moraines and are of wide areal extent.

Terminal and recessional moraines are ridges of till, often containing bodies of outwash, deposited by a glacier where its front remained stationary for a period of time. Terminal moraines mark the position of farthest advance of a glacier. Recessional moraines mark the position where a glacier front halted temporarily or was rejuvenated, during retreat from a terminal moraine. Ground moraine is till and outwash spread over a wide area where the ice retreated at a fairly uniform rate.

Large blocks of ice buried in or surrounded by till were often left behind by the retreating ice front. Melting of the ice blocks and slumping in of the till produced depressions on the land surface called kettles. Such kettles may be several miles in diameter and may be occupied by lakes—for example, Summit Lake in T. 33 N., R. 10 E.

Continental glaciers made at least two advances over southwestern Langlade County in Pleistocene time, the first during the Iowan(?) substage and the second during the Cary substage of Wisconsin glaciation (Thwaites, 1943). The Iowan(?) glacier probably moved southward into Langlade County. As the ice melted, it deposited the drift which now forms or mantles the smooth rolling hills of the extreme western part of Langlade County and, at least in places, underlies the sands and gravels of the Antigo flats and the area to the north and east. The Iowan(?) till ranges in thickness from a few inches to more than 200 feet and is missing where rocks of pre-Cambrian age crop out. A period of weathering followed the melting of the Iowan(?) glacier.

In Cary time two ice lobes entered Langlade County, the Langlade lobe of Thwaites from the northeast and the Green Bay lobe from the southeast. The terminal moraines, the Parrish and Outer moraines of Thwaites, respectively, deposited by these lobes merge in the eastern portion of the county, forming a V-shaped area. The morainic deposits include drumlins formed in the southeastern (fig. 3) and northeastern part of Langlade County. Sand, gravel, and some clay and silt derived from the melting ice were deposited within this V forming an outwash plain—the Antigo flats (fig. 2). The known thickness of the outwash is as much as 190 feet, at well La-237, south of Antigo. The extent and thickness of the Iowan(?) deposits, underlying the Cary deposits, are not known because few wells pass through the Iowan(?) deposits. Breaks in the terminal moraines, such as that now occupied by the east branch of the Eau Claire River, occur where glacial streams emptied onto the outwash plain. The maximum thickness of the drift in the terminal moraines is estimated to be 300 feet; few data are available because only a small number of wells have reached bedrock.

As the ice front retreated, halts or rejuvenations resulted in the formation of recessional moraines and intramorainal outwash deposits. Melt waters from the Langlade lobe of Thwaites continued to cross the Antigo flats, whereas drainage from the Green Bay lobe was diverted southward away from the flats by the Outer moraine of Thwaites. The ground moraine and outwash deposits making up the hilly lands behind the recessional moraines were deposited by the melting ice. Logs of wells La-233, -235, -236, -257, -258, and -278 show that thick layers of till and clay underlain by sand and gravel occur in many places behind the Outer and Parrish moraines of Thwaites.

The type of rock found in till is indicative of the material over which the glacier has passed. In a pebble sample taken from the Parrish moraine the most common rock types were schist, quartzite, gneiss, and granite, all of pre-Cambrain age (table 2). A pebble sample taken from the Outer moraine showed pink granite, dolomite, and sandstone to be the most common rock types. The large number of dolomite pebbles in the Outer moraine indicates movement of the Green Bay lobe over the Paleozoic formations of

Table 2.—*Pebble samples*

[Collected by Thwaites (1943) except last sample, which was collected by W. E. Price]

Location	Dominant rock types (with percent in sample)	Geologic environment
NW¼NW¼ sec. 1, T. 33 N., R. 12 E...	Granite (34), basalt (26)...	Recessional moraine behind Parrish moraine of Thwaites.
Sec. 24, T. 32 N., R. 12 E..............	Granite (28), basalt (20) quartz (14).	Parrish moraine.
SE¼NW¼ sec. 26, T. 32 N., R. 12 E...	Granite (54), basalt (24)...	Do.
Sec. 31, T. 32 N., R. 12 E..............	Granite (36), limestone (38).	Antigo flats.
NE¼SE¼ sec. 9, T. 31 N., R. 12 E......	Dolomite (54), granite (30).	Outer moraine of Thwaites.
SE¼NW¼ sec. 14, T. 31 N., R. 12 E..	Dolomite (32), granite (30), basic rocks (16).	Outwash behind Outer moraine.
SE¼SW¼ sec. 10, T 30 N., R. 11 E....	Granite (43), dolomite (28), sandstone (6).	Outer moraine.

eastern Wisconsin, whereas the almost complete absence of dolomite in the Parrish moraine indicates movement of the Langlade lobe over the area of pre-Cambrian rocks to the north.

Table 3 shows the age relationships of the formations and deposits. A brief description of the deposits and their relative water-bearing properties is also given.

Table 3.—*Geologic formations in southwestern Langlade County, Wis. and their water-bearing properties*

Age			Lithology	Approximate maximum thickness (feet)	Character of material	Water-bearing properties
System and series	Stage	Substage				
Quaternary (Pleistocene)	Wisconsin	Cary	Till	300	Heterogeneous and unsorted. Size range—clay to boulders. Scattered sand and gravel lenses.	Poor in most places. Yields may be sufficient for domestic and stock use.
			Outwash	100	Sorted and stratified. Size range—clays, silts, and gravels.	Good to excellent. Yields up to 800 gpm in irrigation pits.
		Iowan(?)	Till	100	Heterogeneous and unsorted. Very clayey. Some stones. Few lenses of outwash.	Poor to fair. Yields may be sufficient for domestic and stock use.
Pre-Cambrian			Crystalline rocks	?	Hard, brittle. Cracks in places in upper few tens of feet. Occasional layers of decomposed rock at surface.	Very poor. Small yields obtained from cracks or layers of decomposed rock.

HYDROLOGY

Meinzer (1923, p. 38) defines ground water as "that part of the subsurface water which is in the zone of saturation." It is the water that is available to wells or is discharged through springs. The source of essentially all ground water is precipitation in the form of rain or snow. Part of this precipitation runs off over the surface of the ground directly into streams or lakes, part is returned to the atmosphere by evaporation and transpiration, and the remainder percolates down into the ground replenishing the ground-water reservoir, later to be discharged into surface-water bodies or by evapotranspiration.

The amount of water that a rock can hold is a function of its porosity. If the pore spaces are large and interconnected, as they commonly are in sand and gravel, water is transmitted more or less freely, and the rock is said to be permeable. Where the pore spaces are very small, as in clay, or very poorly connected, as in crystalline rock, water is transmitted very slowly or not at all, and the rock is said to be impermeable. Outwash deposits of sand and gravel are usually very permeable and therefore are good aquifers. Till deposits and outwash clays are relatively impermeable and are considered poor aquifers, yielding little or no water to wells.

Ground water occurs under water-table conditions in areas where water falling on the surface of the ground can percolate downward through pore spaces, cracks, and joints in the ground to the zone of saturation. The upper surface of the zone of saturation is the water table. Artesian conditions exist where the water-bearing formation (aquifer) is overlain by a relatively impermeable formation and the water in the aquifer is under hydrostatic pressure. Water levels in wells in an artesian aquifer will rise to a level independent of that of the water table. Nowhere in the area covered by this report were artesian conditions found.

WELLS

Wells in the Antigo flats obtain water from the sand and gravel of Cary age and from the underlying deposits of Iowan(?) age. The two deposits make up the ground-water reservoir in this area. Known depths to water in the flats range from 1 to 117 feet, averaging about 25 feet. The greatest depth to water (117.68 feet below the land surface in well La-107 in October 1950) is in the easternmost part of the plain (fig. 4).

Wells outside the flats obtain water from sand and gravel lenses within the till, from scattered patches of outwash at the surface,

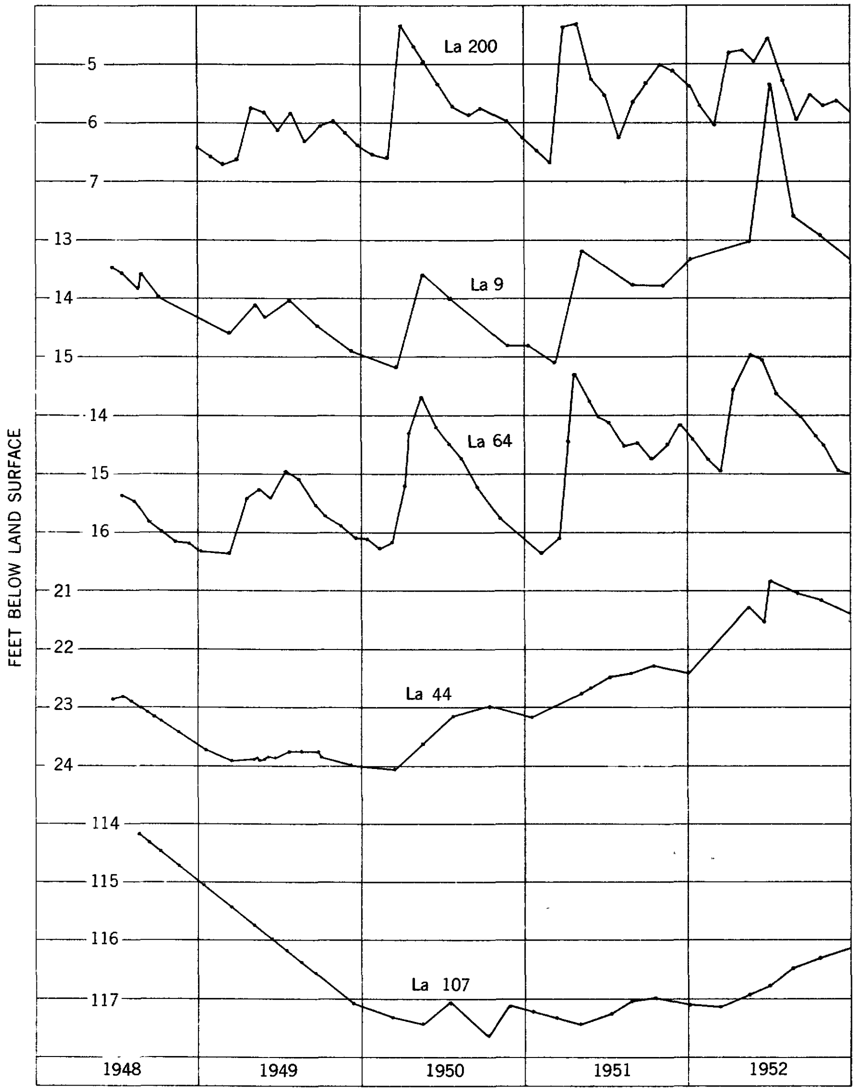

Figure 4. —Fluctuations of water levels in observation wells in southwestern Langlade County, Wis.

or, in a few places, from bedrock. Figure 5 shows two wells penetrating the bedrock. Well 1 intersects some of the fractures and will produce water, whereas well 2, even though it is deeper, intersects none of the cracks and, therefore, will not produce water. Wells constructed in the overlying glacial deposits usually obtain sufficient water for farm use only from sand and gravel deposits. Depths to water range from 1 to 138 feet below the land surface, the greater depths being beneath the hills of the moraines.

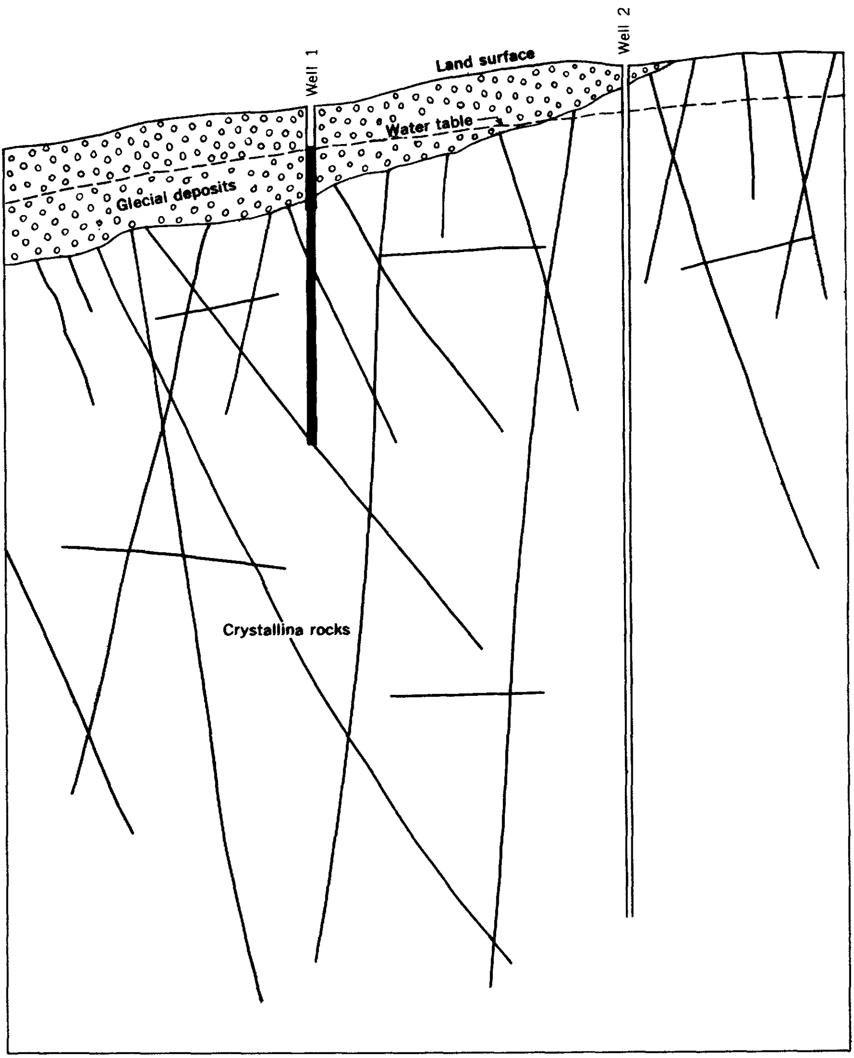

Figure 5. —Ground water in crystalline rocks.

Table 4 lists the uses and types of wells in southwestern Langlade County. The table does not include all wells in the area. Of the 305 wells visited, 129 were domestic and stock wells, most of which were drilled or dug. Most municipal and industrial wells were drilled. There are 3 drilled, 1 driven, and 32 dug irrigation wells on the Antigo flats. The dug wells, or pits, are circular or rectangular in outline, ranging in size from 25 feet in diameter to about 110 feet wide by 200 feet long. They are from 10 to 60 feet deep, and are usually located in swales or in stream valleys, where the ground water is nearest the surface.

Table 4.—*Uses and types of wells scheduled in Langlade County*

Number of wells scheduled......305
Number of scheduled wells for which logs are available...... 44
Number of scheduled wells in which water-level measurements were made......245

Original use	Number of wells for indicated type					Total
	Dug (for indicated diameter, in feet)		Driven	Drilled	Jetted	
	< 20	> 20				
Public supply	....	2	....	20	....	22
Irrigation	....	32	1	3	....	36
Observation	....	....	18	....	1	19
Industrial	....	....	....	4	....	4
Domestic and stock	33	....	13	83	....	129
Spraying insects	2	....	17	....	....	19
Unknown (abandoned)	29	1	6	40	....	76
Total	64	35	55	150	1	305

WATER LEVELS

Plate 1 is a piezometric map of southwestern Langlade County. Such a map shows the hydrostatic head of the ground water; in this area it shows the position of the water table. Contour lines—lines connecting points of equal head—were drawn using the measured altitudes of water levels in wells as control points. The direction of movement of ground water is along flow lines, lines crossing all contours at right angles.

The piezometric surface, as shown by water levels in wells, does not remain in a fixed position with relation to the surface of the ground. It rises and falls in response to variations in the amount of water held in storage in the aquifer. The principal water-level fluctuation is seasonal. Minor fluctuations as a result of precipitation may occur in days or hours, and long-term fluctuations as a result of climatic changes may occur during a period of many years.

Indications as to the type of recharge to or discharge from an aquifer may be obtained by a study of water-level fluctuations in conjunction with data on precipitation and water use. Plate 1 shows the locations of observation wells in southwestern Langlade County, and figure 4 shows the hydrographs of some of these wells. Normal variation of the water table in the area during the seasons of the year and over a period of years is shown by the hydrograph of well La-64. The rise of water level shown during the spring is a result of snow melt and spring rains. The amount of rise depends on the amount of rainwater and of snow melt entering the ground. From the high level in early summer until the end of the growing season in the fall, the water level declines as a result of normal ground-water drainage to streams and of the withdrawal of water by evaporation and transpiration. The slight decrease in the rate of decline

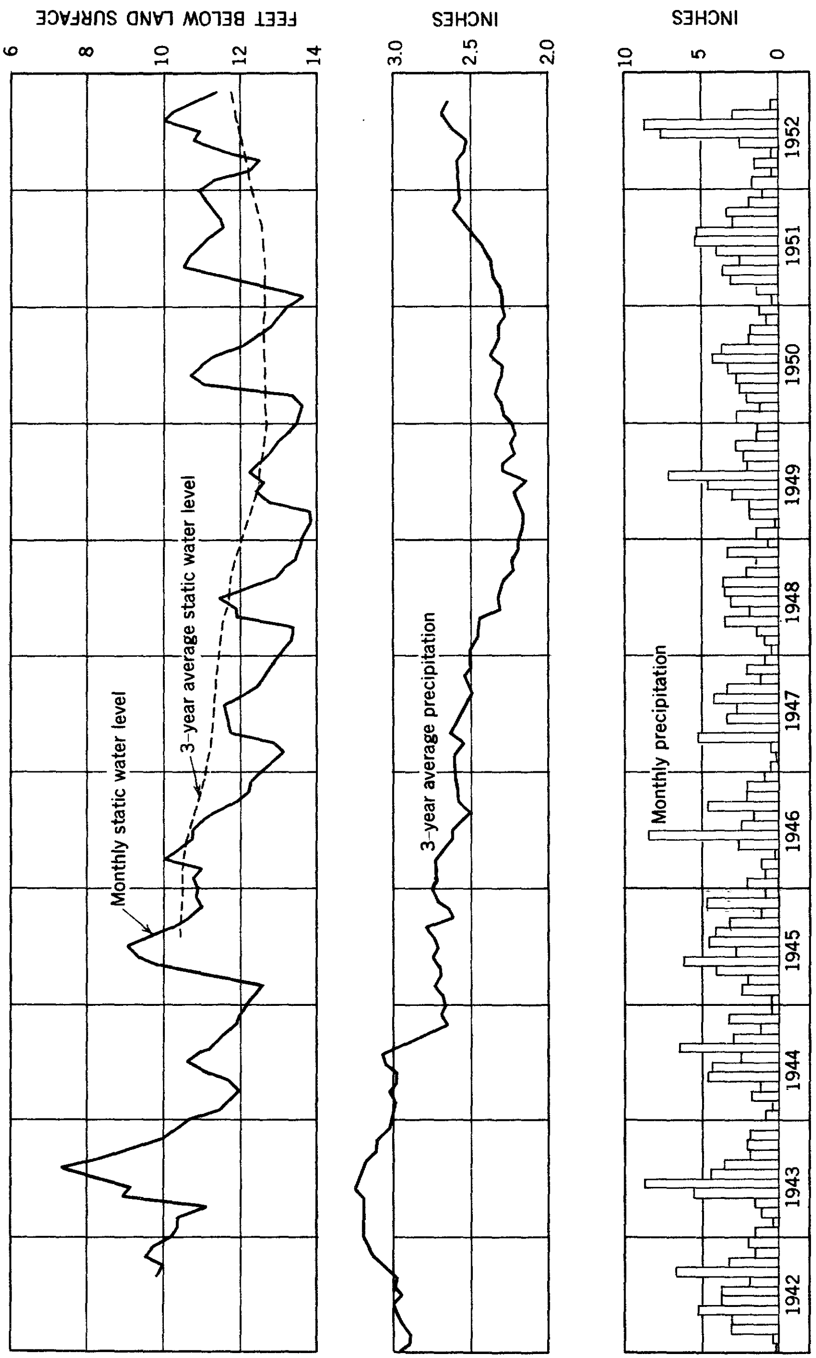

Figure 6. —Graph showing water levels in well La-118 and precipitation at Antigo, Wis.

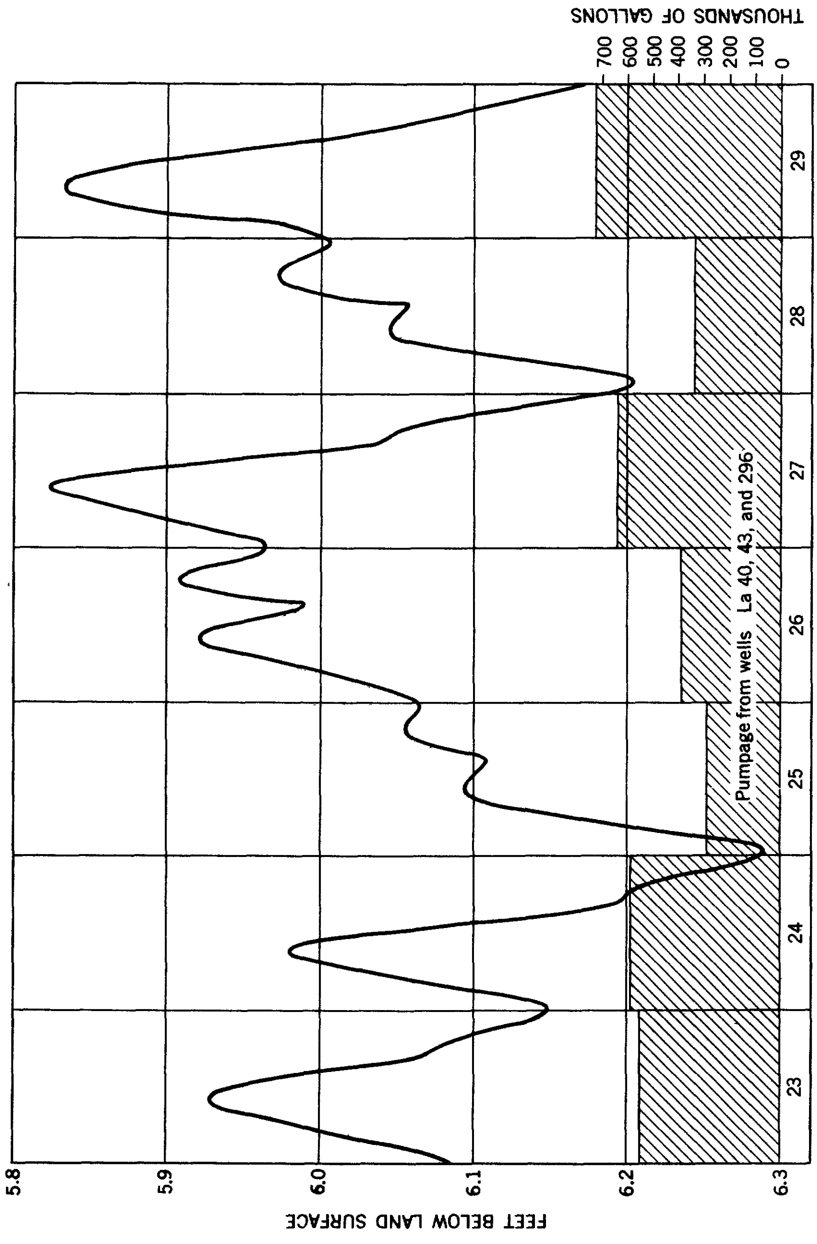

Figure 7. —Water level in well La-200, from recorder charts, August 23-29, 1951.

of the water level starting in the fall is a result of a decrease in the amount of withdrawal of water by evaporation and transpiration. From the time the ground becomes frozen, usually in November, until it thaws in the spring, the water level continues to decline, owing to natural discharge of the ground water into streams.

In 1951 water levels in Langlade County generally followed the usual pattern until about September (fig. 4). At that time, above-normal rainfall caused the water levels in many wells to decline more slowly than usual or even to start rising. This unseasonal trend continued for several months and is best illustrated by the hydrographs of wells La-9 and -64 (fig. 4) and La-118 (fig. 6).

The relation between water levels and precipitation is shown on figure 6. The upper solid-line graph shows monthly water-level measurements in well La-118. The bar graph at the bottom shows monthly precipitation at Antigo. The closer correlation of water levels and precipitation over a period of years is shown by the dashed-line graph and the lower solid-line graph. Those graphs show 3-year running averages of water levels and precipitation, respectively. For example, the 2.3 inches of precipitation shown for May 1950 means that precipitation averaged 2.3 inches per month for the 36 months from June 1947 to May 1950, inclusive. The 2.4 inches shown for July 1950 is the average for the 36 months from August 1947 to July 1950, inclusive. The generally good correlation between precipitation and water levels is brought out clearly.

Few data are available concerning daily water-level fluctuations. Figure 7 shows the fluctuation in well La-200, a well equipped with a recording gage. This well is located within the city of Antigo's well field and is about 180 feet from the nearest pumped well. Changes in the water level during the day are due mainly to pumping from the city wells.

PUMPING TESTS

The object of a pumping test is to determine the hydraulic characteristics of an aquifer. Information on these characteristics is needed so that the effect and location of possible hydraulic boundaries can be determined and so that the effect of withdrawals of water from wells at various locations can be predicted.

When a well is pumped, water moves from the surrounding area through the formation to and into the well. Withdrawal of water from the aquifer creates a funnel-shaped cone of depression in the piezometric surface around the well. Water levels in the vicinity of the pumped well decline and the cone of depression expands until recharge to the area equals the discharge of the well. The amount and rate of change of the water level depends upon the hydraulic characteristics of the aquifer, upon the effect of possible hydraulic boundaries, upon the amount of water pumped, and upon the rate of pumping. The hydraulic characteristics of an aquifer may be expressed in terms of its coefficients of transmissibility and storage. The coefficient of transmissibility may be expressed as the number of gallons of water that will pass in 1 day through a vertical strip of the aquifer 1 foot wide, having a height equal to the saturated thickness of the aquifer, under a hydraulic gradient of 100 percent. The coefficient of storage may be expressed as the amount of water, measured as a fraction of a cubic foot, that will be released from storage in each column of the aquifer having a base of 1 square foot and a height equal to the saturated thickness of the aquifer, when the water level is lowered 1 foot.

The nonequilibrium formula using the coefficients of transmissibility and storage to describe the hydraulic characteristics of an aquifer was developed in 1935 under the direction of C. V. Theis (Theis, 1935). Certain ideal conditions were assumed in deriving this formula which must be kept in mind in applying values determined by the formula. These assumptions are (1) that the aquifer is of infinite areal extent and of uniform thickness; (2) that no recharge is added to the formation during the pumping period; (3) that the formation is homogeneous and isotropic (transmits water equally in all directions); (4) that water is released from storage instantaneously with a lowering of hydrostatic pressure; and (5) that water enters the well throughout the full thickness of the formation.

The nonequilibrium formula is:

$$s = \frac{114.6Q}{T} W(u)$$

where $W(u) = -0.577216 - \log_e u + u - \frac{u^2}{2 \cdot 2!} + \frac{u^3}{3 \cdot 3!} - \frac{u^4}{4 \cdot 4!} \ldots$

and $u = \frac{1.87r^2S}{Tt}$

where s = drawdown, in feet, at observation well
Q = discharge, in gallons per minute
T = coefficient of transmissibility, in gpd/ft
r = distance, in feet, from observation well to pumped well
S = coefficient of storage
t = time, in days, since pumping started

During the period November 15-19, 1948, pumping tests were made using the city of Antigo's municipal wells. Fluctuations of the water levels in the area were caused by pumping one or more

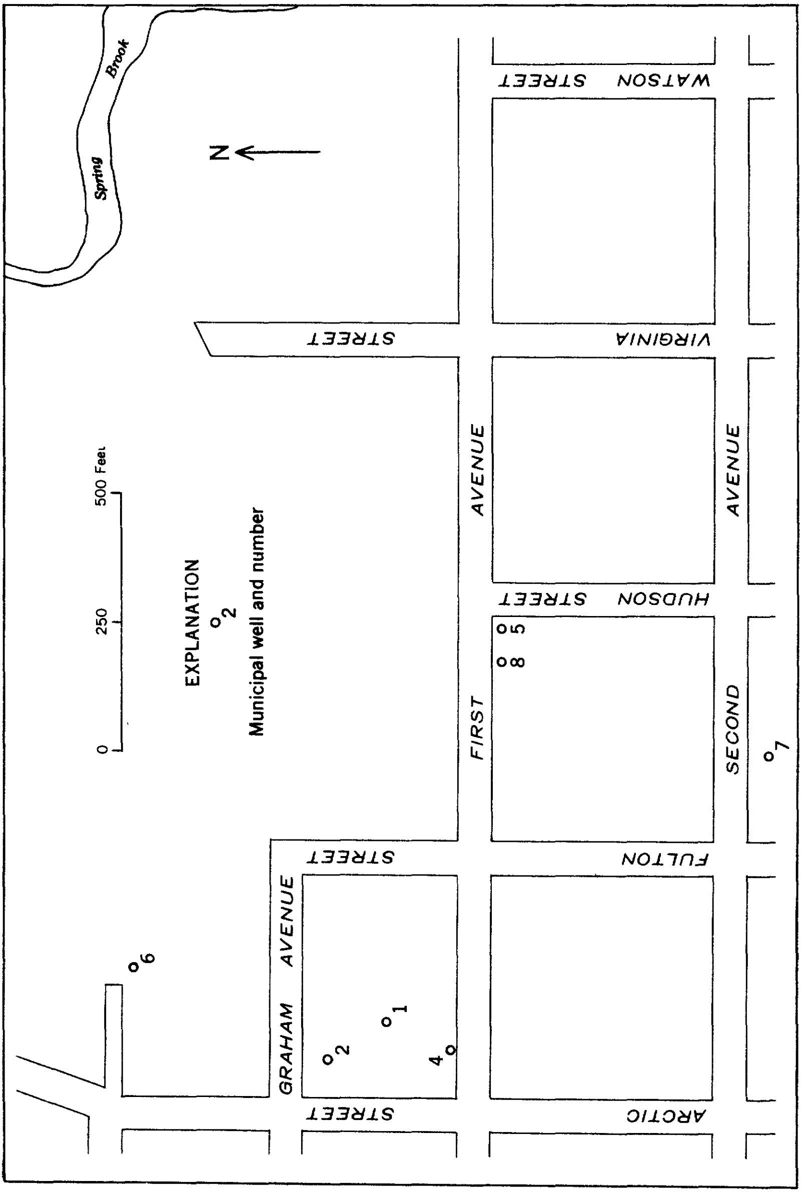

Figure 8. —Map showing locations of wells used during pumping test at Antigo, Wis.

Table 5.—*Distances, in feet, between wells used during pumping test and to the wells from Spring Brook at Antigo, Wis.*

[Example, city of Antigo well 1 is 138 feet from city of Antigo well 4 and 1,520 feet from Spring Brook]

	1	2	4	5	6	7	8
2	135						
4	138	245					
5	780	900	820				
6	500	420	640	970			
7	900	1,040	850	570	1,300		
8	725	850	760	64	930	550	
Spring Brook	1,520	1,540	1,300	1,130	1,400	780	1,150

wells. Discharge measurements at the pumped wells were made using water meters. Water levels were measured by means of steel tapes or air lines. Figure 8 shows the locations of the wells and table 5 shows distances between wells and to the wells from Spring Brook. Figure 9 shows the hydrographs of city wells 1, 2, and 4 during the tests. Table 6 gives the actual and average values of T and S obtained.

Using the average values of T and S and a Q of 400 gallons per minute, theoretical curves were computed showing drawdown at the end of 1, 10, and 100 days of continuous discharge and at distances of 50, 500, and 1,000 feet (figs. 10 and 11). From the formula used, it is apparent that the drawdown is directly proportional to the discharge. For example, the drawdown caused by a well pumping 800 gallons per minute would be twice that shown in figures 10 and 11. When applying these values it must be remembered that

Table 6.—*Coefficients of transmissibility and storage at Antigo, Wis.*

Date of test Nov. '48	No. of city of Antigo well used as— Pumped well	Observation well	Coefficient of transmissibility (gpd/ft)	Coefficient of storage	Duration of test (hours)
15	4 on	4	66,500		15
	4 on	1	67,300	0.189	20
16	4 off	2	85,700	.161	20
	4 off	4	66,500		16
	4 off	1	70,300	.187	16
	4 off	2	96,000	.244	16
Do	5 on	5	53,500		20
	5 on	8	61,200	.0748	28
17	5 off	5	43,500		20
	5 off	8	41,300	.125	19
18	6 off	6	66,500		20
Do	8 on	5	40,700	.0875	16
19	8 off	8	49,500		5
	8 off	5	53,800	.113	5
Average			61,600	0.148	
Rounded off			62,000	0.15	

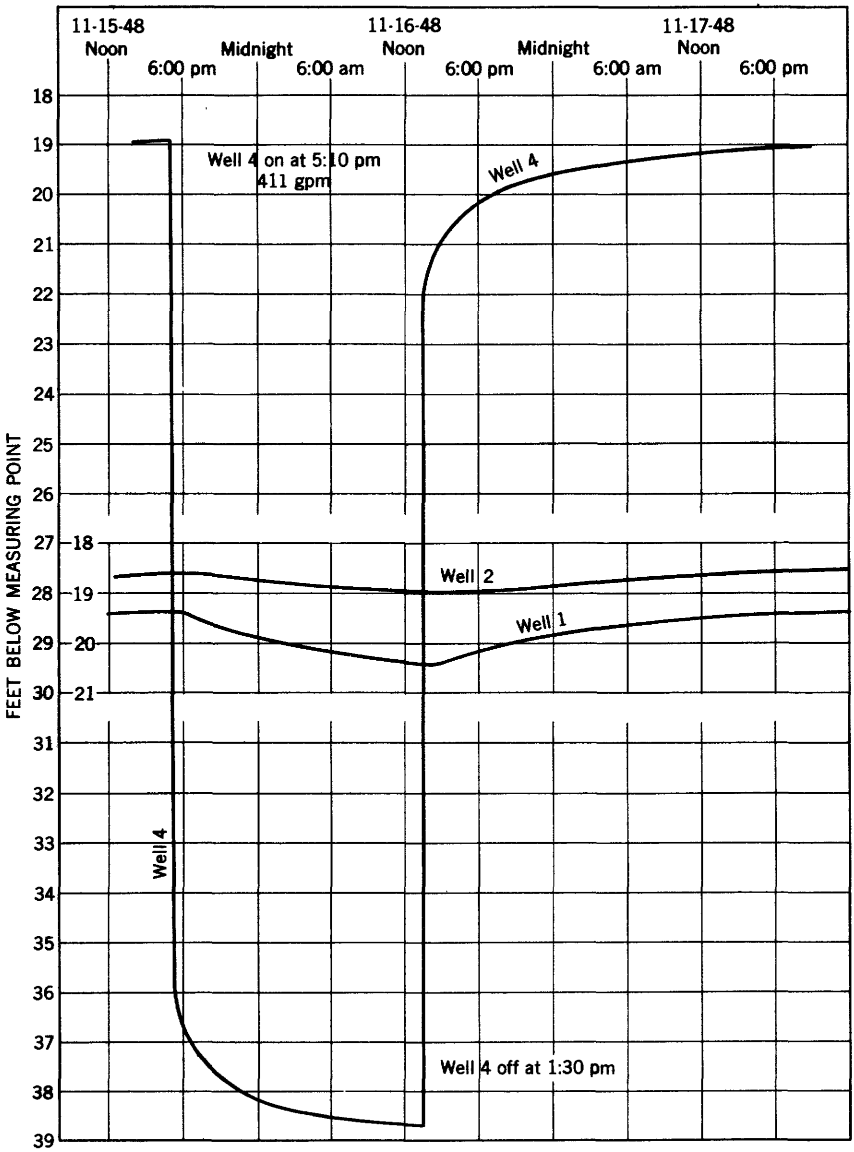

Figure 9.—Water levels in city of Antigo wells 1, 2, and 4 during pumping test at Antigo, Wis.

fluctuations of the water table due to forces other than pumping have not been taken into account.

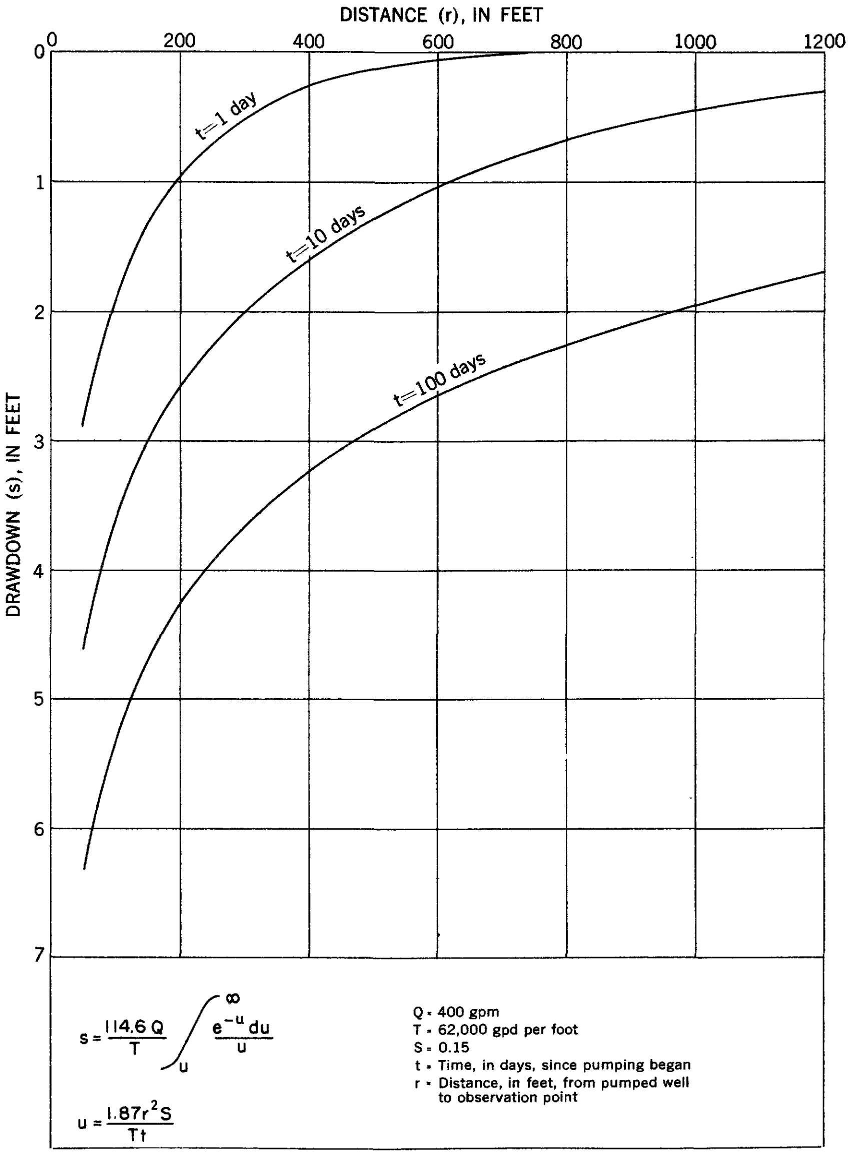

Figure 10. —Relation of drawdown to distance from pumped well in the aquifer underlying Antigo, Wis. (Not adjusted for boundaries.)

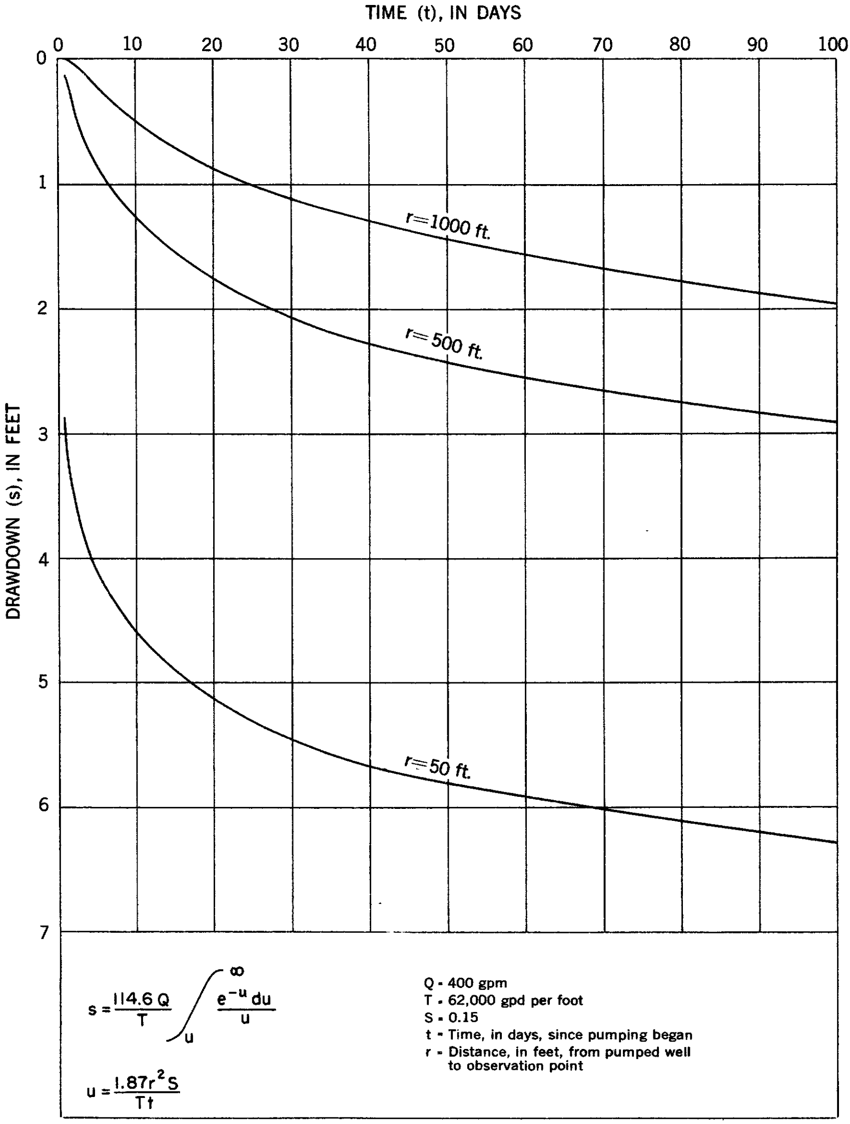

Figure 11.—Relation of drawdown to time since discharge began in the aquifer underlying Antigo, Wis. (Not adjusted for boundaries.)

RECHARGE AND DISCHARGE

The aquifers in southwestern Langlade County are recharged by local precipitation. The streams in the area are effluent, or discharging, except in a few places where the water table is below the level of the streams. In the immediate vicinity of streams or lakes, recharge may take place when the water table is lowered by pumping from wells. Discharge of ground water from the area is by streams, by movement to adjacent areas, and by evapotranspiration. Water that is artificially withdrawn is discharged eventually into streams or by evapotranspiration.

Movement of the ground water is dominantly in a southerly direction. Locally movement occurs toward the streams crossing the area, as indicated by the shape of the contours on plate 1. A major ground-water divide separates water flowing southwesterly into the Mississippi River via Spring Brook and other streams and water flowing southeasterly into Green Bay via the Wolf and Fox Rivers. This ground-water divide lies on a line between the Eau Claire and the Wolf Rivers and, through the flats, extending southwestward parallel and just to the east of Spring Brook. The exact location of this divide varies. During dry years when the headwaters of Spring Brook dry up, it probably is slightly west of the stream bed.

Some recharge to the Antigo flats comes from the Parrish moraine of Thwaites to the north. The catchment area for recharge to the Antigo flats by precipitation on the moraine is a relatively narrow belt. This belt extends approximately 4 or 5 miles back from the front of the moraine to a ground-water divide, which probably coincides with the surface-water divide. Logs of wells La-89 and -258, located in the Parrish moraine, show layers of till and clay of sufficient thickness to impede the downward percolation of water to the water table, thus limiting the amount of recharge.

A quantitative analysis was made of recharge to the Antigo flats. The technique used consisted of determining the amount of water passing from the Parrish moraine into the Antigo flats and the quantity of water added to ground-water storage by precipitation on the flats.

Application of this technique was as follows:

1. An area, ABON on plate 1, having well-controlled piezometric contour lines and having no streams, was selected.

2. Computations were made of the number of gallons per day of ground water crossing contour lines DE, GH, JK, and LM, between flow lines AN and BO, using the formula $Q = TIL$, where

Q = Quantity of water, in gallons per day
$Q_1 - Q_2$ = Difference in quantity of water crossing successive contour lines
T = Coefficient of transmissibility, 62,000 gpd per ft, as determined by the pumping test at Antigo
I = Hydraulic gradient, in feet per mile
L = Length of contour line, in miles, between flow lines AN and BO

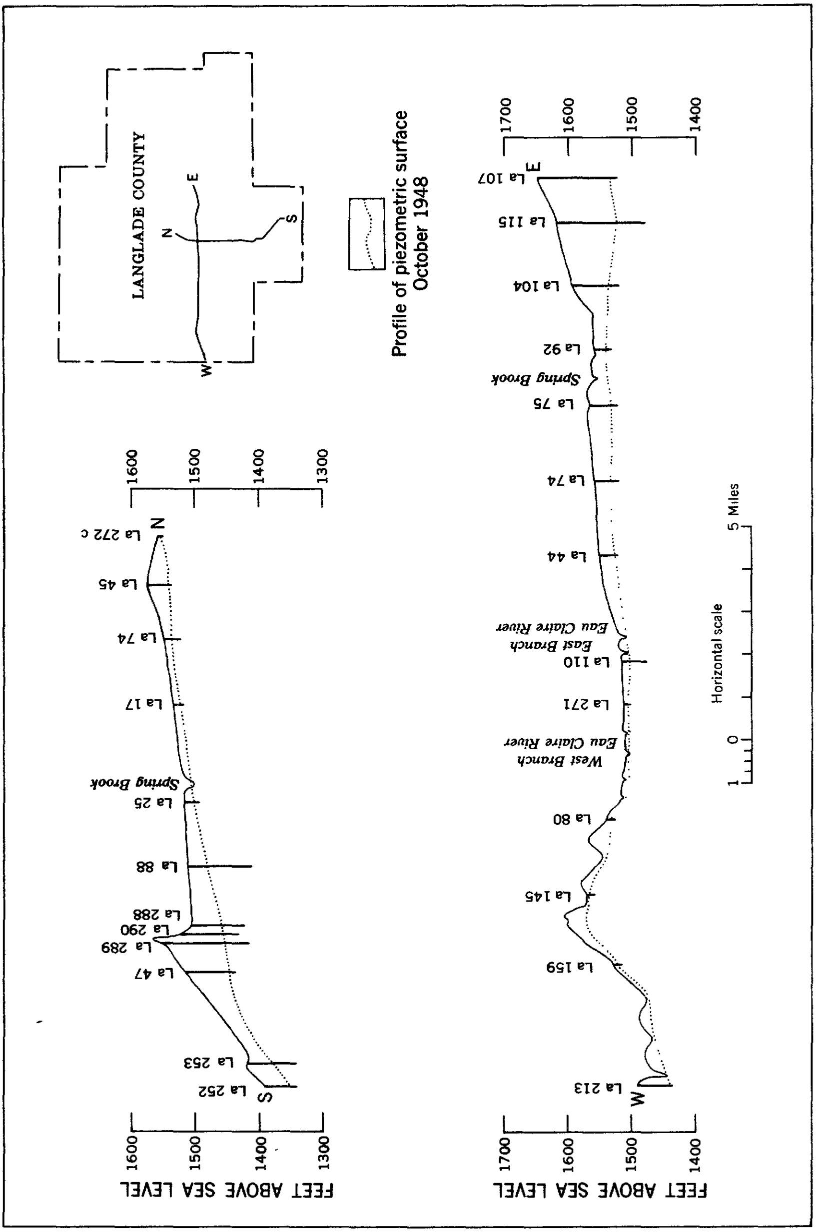

Figure 12. —Profiles of piezometric surface in southwestern Langlade County, Wis.

3. The amount of recharge, in gallons per square mile or in inches per year by downward percolation of precipitation on areas DEHG, GHKJ, and JKML, was computed by dividing the difference ($Q_1 - Q_2$) in quantities crossing contour lines by the area A between contour lines.

Table 7 gives a summary of the computations and results of the analysis.

Table 7.—*Computation of recharge to the Antigo flats*

Contour	Length of contour line L (miles)	Hydraulic gradient I (ft./mile)	Quantity of water $Q = TIL$ (gpd)	Area: Location on pl. 1	Area: Size A (sq. miles)	Recharge $\frac{Q_1 - Q_2}{A}$: $\frac{\text{gpd}}{\text{sq. mile}}$	Recharge $\frac{Q_1 - Q_2}{A}$: $\frac{\text{in.}}{\text{yr.}}$
DE..........	0.45	6.7	187,000	DEHG	1.21	267,000	5.6
GH..........	1.23	6.7	510,000	GHKJ	3.20	206,000	4.3
JK..........	2.55	7.4	1,170,000	JKML	4.15	294,000	6.2
LM..........	4.05	9.5	2,390,000				
Average..........						256,000	5.4

The average recharge to the part of the Antigo flats lying east of the east branch of the Eau Claire River, 90 square miles, was computed using the results from table 7 and the method described. The average recharge from precipitation on the flats was computed to be 23 mgd (256,000 gpd per sq. mile x 90 sq. miles). The quantity of water moving across the 1,550-foot contour line between points A and P was computed to be 3 mgd, using the method described above. Thus, the total recharge to the flats east of the east branch of the Eau Claire River averages about 26 mgd, of which about 12 percent comes from the area north of the flats.

All the above computations are based on the assumption that the transmissibility of the outwash sands is constant throughout the flats. It is further assumed that the shape of the piezometric surface remains essentially the same as that shown on plate 1. This assumption is justifiable on the basis of the hydrographs shown on figure 4. It is felt that the values for recharge are of the proper magnitude and so are of use in arriving at an understanding of the recharge to ground water in the Antigo flats.

There is no recharge to the Antigo flats from the area of Iowan(?) ground moraine west of the flats. Water originating there is discharged into effluent streams lying between the two areas, as is indicated by the cross section on figure 12.

UTILIZATION OF GROUND WATER

In southwestern Langlade County ground water is used principally for municipal supplies, for general farm use, and for irrigation (table 8).

Table 8.—*Cround water used in southwestern Langlade County, 1948–51*

Use	Quantity during—				
	1948		1949	1950	1951
	In millions of gallons	In percent of total	In millions of gallons		
Municipal (city of Antigo)	251	69	250	246	241
Rural domestic and stock[1]	95	26	95	95	95
Irrigation[2]	19	5	6	4	.5
Total	365	100	351	345	336.5

[1]Estimates based on population.
[2]Estimates based on reports by irrigators.

The largest consumer of ground water is the city of Antigo. During 1948 the city pumped an average of 690,000 gallons of water a day for all purposes. Water meters at the municipal water plant make accurate measurements of the amount of water pumped.

The consumption shown for rural areas is based on an estimated use of 30 gallons of water per day per person. The rural population is about 8,500. Therefore, about 260,000 gallons a day is pumped by rural users of ground water for domestic and general farm use.

Estimates of the amounts of ground water used for irrigating farm crops are based on pumpage data supplied by irrigators. This information is collected from each irrigator at the end of the pumping season. During 1948 approximately 52,000 gallons of water a day, 5 percent of the total used, was pumped for irrigation. The large decrease in the amount of water used for irrigation purposes during 1949-51, as shown in table 8, was due to the increase in rainfall. Because of the decrease in amount of water used, few data are available on the effect of irrigation on the water table. Measurements of water levels made in observation wells before, during, and after irrigation show no significant lowering of ground-water levels as a result of irrigation except in the immediate vicinity of the point of withdrawal.

QUALITY OF GROUND WATER

Chemical analyses were made by the Wisconsin State Board of Health (1935) of water from six of the municipal wells at Antigo. The water from the six wells ranges in total hardness from 104 to 134 ppm and averages 114 ppm. Dissolved solids range in content from 155 to 166 and average 162 ppm; iron, from 0.05 to 1.0 and averages 0.35 ppm. Hole (1947, p. 38) states that ground water is relatively low in dissolved solids (25-100 ppm) in the western half of the county and relatively high in dissolved solids (100-300 ppm) in the eastern half.

SUMMARY AND CONCLUSIONS

Southwestern Langlade County is underlain by crystalline rocks of pre-Cambrian age. Overlying the bedrock are glacial deposits of the Iowan(?) and Cary substages of Wisconsin glaciation of Pleistocene age.

Large quantities of ground water are available from glacial outwash, particularly in the area known as the Antigo flats. In the morainal areas north and southeast of the flats small quantities of water are available from till, and moderate to large quantities are available from local areas of outwash. In the area west of the flats small quantities of ground water are available from lenses of sand and gravel within the Iowan(?) ground moraine. Very small quantities of water are available from decomposed or fractured bedrock.

Recharge to glacial outwash in the part of the Antigo flats east of the east branch of the Eau Claire River is estimated to be about 26 mgd, or about 30,000 acre-feet per year. The use of water for all purposes in 1948 was about 1,100 acre-feet and in 1951, about 1,000 acre-feet. Use of water has caused no measurable decline of water levels in the area as a whole.

Additional data concerning the hydraulic characteristics of the aquifers are needed to make a more accurate analysis of recharge and discharge. Collection of water-level and pumpage data should continue so that the effect of pumpage on water levels can be analyzed.

WELL DESCRIPTIONS AND WELL LOGS

Table 9.—*Well descriptions*

Well no. La-	Location	Owner	Altitude of land surface (feet)	Depth of well (feet)	Diameter or size of well (inches unless otherwise specified)	Type of well	Water level: Below land surface (feet)	Water level: Date of measurement	Use
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1	SE¼SE¼ sec. 22, T. 31 N., R. 11 E.	Prosser Bros.	1521	63	12	Drilled	33.70	July 1950	Irrigation.
2	SE¼NE¼ sec. 25, T. 31 N., R. 11 E.	Dahlke	1599	128	4	...do...	124.72	May 1948	Unused.
3	SW¼NW¼ sec. 4, T. 31 N., R. 12 E.	J. Vcelak	1599	82.9	4	...do...	82.47	August 1949	Do.
5	SW¼SW¼ sec. 6, T. 31 N., R. 10 E.	School district	1489	32	5	...do...	5.00	August 1951	Do.
6	SW¼NE¼ sec. 17, T. 31 N., R. 11 E.	H. Igl	1509	20	50 x 100 feet	Dug	7.00	June 1948	Irrigation.
9	SW¼NE¼ sec. 35, T. 31 N., R. 10 E.	U. S. Geological Survey	1470	19	1¼	Driven	13.85	October 1951	Observation well.
10	NW¼SW¼ sec. 36, T. 31 N., R. 10 E.	J. Opichka	1479	52	4	Drilled	13.90	August 1951	Unused.
12	NW¼SW¼ sec. 31, T. 31 N., R. 11 E.	....	1483	25	1¼	Driven	21.08	June 1948	
17	NW¼SW¼ sec. 3, T. 31 N., R. 11 E.	Prosser Bros.	1537	20	1¼	...do...	15.37	August 1951	
18	NW¼SW¼ sec. 9, T. 31 N., R. 11 E.	H. Igl	....	20	30 x 40 feet	Dug	....	....	Irrigation.
19	SW¼NE¼ sec. 7, T. 31 N., R. 11 E.	...do...	....	20	60 feet	...do...	9.00	June 1948	Do.
21	SW¼SE¼ sec. 27, T. 31 N., R. 11 E.	L. Brown	1522	....	4	Drilled	44.62	June 1948	Unused.
23	NE¼NE¼ sec. 4, T. 30 N., R. 11 E.	F. Zeloski	1471	16	1½	Driven	8.64	May 1951	Spraying.
24	NW¼NW¼ sec. 28, T. 31 N., R. 11 E.	....	1505	26	1¼	...do...	18.39	June 1948	Unused.
25	NW¼NW¼ sec. 22, T. 31 N., R. 11 E.	....	1517	18.8	6	Drilled	20.93	June 1948	Domestic, destroyed May 1950.
26	SE¼NE¼ sec. 7, T. 31 N., R. 11 E.	C. & N. W. Ry.	1522	23.3	1¼	Driven	7.46	August 1951	Observation.
27	NW¼NW¼ sec. 8, T. 31 N., R. 12 E.	J. Boelter	1594	....	4	Drilled	79.51	June 1948	Stock.
29	NE¼SE¼ sec. 2, T. 31 N., R. 11 E.	F. Zeloski	1539	22	1½	Driven	16.36	August 1951	Spraying.
30	NW¼NW¼ sec. 1, T. 31 N., R. 11 E.	...do...	1550	33	1½	...do...	23.40	July 1950	Do.
31	NE¼NE¼ sec. 12, T. 31 N., R. 11 E.	....	1577	....	4	Drilled	56.87	June 1948	Stock.
34	NW¼NW¼ sec. 21, T. 31 N., R. 11 E.	....	1517	21	1¼	Driven	17.08	June 1948	Spraying.
36	NW¼SW¼ sec. 17, T. 31 N., R. 11 E.	Prosser Bros.	....	....	40 x 210 feet	Dug	....	....	Irrigation.
37	NE¼NW¼ sec. 29, T. 31 N., R. 11 E.	City of Antigo no. 1	1501	27	20 feet	...do...	18.88	June 1948	Public supply.
38	...do...	City of Antigo no. 2	1502	27	20 feet	...do...	17.85	June 1948	Do.
39	...do...	City of Antigo no. 4	1500	54	12	Drilled	....	....	Do.
40	...do...	City of Antigo no. 5	1501	57	12	...do...	....	....	Do.
41	...do...	City of Antigo no. 6	1502	60	12	...do...	19.00	November 1948	Do.
42	SE¼NW¼ sec. 29, T. 31 N., R. 11 E.	City of Antigo no. 7	1501	57	12	...do...	....	....	Do.
43	NE¼NW¼ sec. 29, T. 31 N., R. 11 E.	City of Antigo no. 8	1500	60	18	...do...	....	....	Do.
44	NE¼NW¼ sec. 32, T. 32 N., R. 11 E.	J. Jacobus	1548	26	1¼	Driven	22.39	October 1951	Unused.
45	NW¼NW¼ sec. 22, T. 32 N., R. 11 E.	....	1576	39.5	4	Drilled	34.32	August 1951	Do.

46	SE¼NW¼ sec. 3, T. 30 N., R. 11 E.	....	1480	25	80 x 45 feet	Dug	19.00	June 1948	Irrigation pit.
47	SW¼SE¼ sec. 1, T. 30 N., R. 11 E.	....	1517	79.8	4	Drilled	70.45	June 1948	Unused.
48	NW¼NE¼ sec. 33, T. 31 N., R. 11 E.	O. Gresch	....	69	8	...do.	22.00	June 1948	Irrigation.
54	SE¼SE¼ sec. 6, T. 31 N., R. 12 E.	....	1594	....	5	...do.	78.31	June 1948	Stock.
56	NE¼NE¼ sec. 25, T. 32 N., R. 9 E.	H. Space	1670	....	4	...do.	39.10	August 1951	Unused.
57	SE¼SW¼ sec. 17, T. 31 N., R. 11 E.	Prosser Bros.	1514	36	6	...do.	14.17	May 1949	Do.
64	NW¼SE¼ sec. 20, T. 31 N., R. 11 E.	Wisconsin Conservation Dept.	1508	19.5	2	Driven	15.08	July 1949	Observation.
67	NW¼SW¼ sec. 32, T. 31 N., R. 11 E.	A. Allen	1493	27.3	1¼	...do.	20.28	August 1951	Unused.
68	NE¼SE¼ sec. 12, T. 31 N., R. 10 E.	J. Shafel	1513	22.6	1¼	...do.	6.16	July 1950	Stock.
70	NW¼SW¼ sec. 6, T. 31 N., R. 10 E.	E. Anstutz	....	266	6	Drilled	....	....	
71	SW¼NW¼ sec. 6, T. 31 N., R. 10 E.	F. Anstutz	1534	20	2	Driven	9.99	October 1951	Unused.
73	NW¼NE¼ sec. 27, T. 32 N., R. 11 E.	E. Higginson	1574	....	4	Drilled	34.93	July 1948	Domestic.
74	NW¼NW¼ sec. 34, T. 32 N., R. 11 E.	C. Pinkner	1557	33.9	1¼	Driven	24.29	August 1951	Unused.
75	SW¼SE¼ sec. 26, T. 32 N., R. 11 E.	G. Gallenburg	1563	....	4	Drilled	30.76	July 1948	Domestic.
77	SE¼NW¼ sec. 23, T. 31 N., R. 10 E.	T. Baginski	1480	15	90 x 55 feet	Dug	5.50	July 1948	Irrigation pit.
79	NW¼NW¼ sec. 27, T. 31 N., R. 10 E.	R. Berg	1495	20	30 x 50 feet	...do.	.49	July 1948	Stock pond.
80	SE¼SW¼ sec. 29, T. 32 N., R. 10 E.	W. Balis	1536	9	44	...do.	6.06	August 1951	Unused.
81	SE¼NE¼ sec. 30, T. 32 N., R. 10 E.	do.	1550	....	4	Drilled	5.90	July 1948	Do.
82	SW¼NE¼ sec. 31, T. 32 N., R. 10 E.	....	1538	4.8	36	Dug	3.90	July 1948	Stock.
86	NW¼SE¼ sec. 16, T. 32 N., R. 10 E.	Fisher	1524	48	4	Drilled	7.75	October 1951	Unused.
87	SE¼SW¼ sec. 10, T. 32 N., R. 10 E.	F. Zeloski	1533	13	1¼	Driven	5.49	July 1950	Domestic.
88	SW¼NW¼ sec. 27, T. 31 N., R. 11 E.	J. Lucht	1510	102	5	Drilled	31.00	August 1951	Do.
89	SW¼SW¼ sec. 22, T. 32 N., R. 11 E.	J. Mattek	1571	39	4	...do.	32.10	July 1948	Stock.
90	SE¼SE¼ sec. 24, T. 32 N., R. 11 E.	A. Schmiege	1547	....	60 x 130 feet	Dug	3.32	August 1949	Irrigation pit.
91	NW¼NW¼ sec. 16, T. 32 N., R. 12 E.	Bouldin	1680	....	3½	Drilled	127.71	July 1948	Unused
92	NW¼SW¼ sec. 30, T. 32 N., R. 12 E.	F. Zelbski	1558	27	1½	Driven	21.70	August 1951	Spraying.
93	NW¼SW¼ sec. 31, T. 32 N., R. 10 E.	....	1530	....	36	Dug	6.94	July 1948	Unused.
94	NW¼NW¼ sec. 4, T. 30 N., R. 11 E.	F. Zeloski	1466	....	65 x 190 feet	...do.	5.61	July 1948	Irrigation.
95	NW¼NW¼ sec. 4, T. 30 N., R. 10 E.	do.	1471	19.5	1½	Driven	11.15	July 1948	Spraying.
97	NW¼SW¼ sec. 36, T. 32 N., R. 11 E.	T. O'Brien	1534	22.5	50 x 90 feet	Dug	10.50	July 1948	Irrigation.
99	NE¼SW¼ sec. 8, T. 31 N., R. 11 E.	French	1518	....	15 x 30 feet	...do.	4.00	July 1948	Do.
100	NW¼NE¼ sec. 18, T. 30 N., R. 11 E.	Kretz	1449	19.5	1¼	Driven	9.88	August 1951	Spraying.
101	SW¼NW¼ sec. 31, T. 32 N., R. 12 E.	L. Diercks	1567	....	4	Drilled	38.14	September 1948	Unused.
104	SW¼NE¼ sec. 32, T. 32 N., R. 12 E.	do.	1593	....	4	...do.	59.17	September 1948	Domestic.
107	SW¼NW¼ sec. 26, T. 32 N., R. 12 E.	Carlsen	1651	128	5	...do.	114.09	August 1948	Do.
108	NW¼NE¼ sec. 7, T. 32 N., R. 11 E.	F. Psenicka	1621	60	4	...do.	50.29	August 1948	Do.
109	NE¼NW¼ sec. 25, T. 32 N., R. 10 E.	H. Wirtz	1527	....	1¼	Driven	2.85	August 1951	Unused.
110	SE¼SE¼ sec. 26, T. 32 N., R. 10 E.	Dolezel	1514	40	4	...do.	10.66	August 1951	Domestic.
111	NE¼SE¼ sec. 4, T. 31 N., R. 10 E.	Pilecy	1488	21	1¼	...do.	7.12	August 1951	Unused.
112	NE¼NE¼ sec. 10, T. 31 N., R. 11 E.	J. Spychalla	1520	....	....	Dug	4.00	August 1948	Irrigation.
114	SW¼SW¼ sec. 27, T. 32 N., R. 12 E.	Cowell	....	111	4	Drilled	....	....	Stock.
115	SW¼SW¼ sec. 27, T. 32 N., R. 12 E.	do.	1618	140	3	...do.	97.38	August 1951	Domestic.

Table 9.—*Well descriptions*—Continued

Well no. La-	Location	Owner	Altitude of land surface (feet)	Depth of well (feet)	Diameter or size of well (inches unless otherwise specified)	Type of well	Water level: Below land surface (feet)	Water level: Date of measurement	Use
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
116	SE¼ SE¼ sec. 33, T. 32 N., R. 12 E.	J. Hunter	1626	130	....	Drilled	108.36	August 1951	Unused.
117	SE¼ SE¼ sec. 21, T. 32 N., R. 12 E.	....	1608	72	4	...do...	74.02	August 1951	Do.
118	NE¼ NW¼ sec. 20, T. 31 N., R. 11 E.	Wisconsin Public Service Corp.	1511	21.8	1½	Driven	11.40	August 1951	Observation.
120	NE¼ SE¼ sec. 24, T. 32 N., R. 11 E.	A. Rine	1570	28.5	1¼	...do...	24.40	August 1948	Domestic.
121	SE¼SE¼ sec. 20, T. 32 N., R. 10 E.	K. Knappe	1535	15	36	Dug	3.85	August 1951	Stock.
123	NW¼NW¼ sec. 34, T. 33 N., R. 9 E.	L. Simon	1580	....	5	Drilled	10.43	August 1951	Do.
125	SE¼ NE¼ sec. 21, T. 33 N., R. 9 E.	J. Simon	....	29	4	...do...	9.30	March 1949	Domestic.
128	SW¼SW¼ sec. 31, T. 33 N., R. 10 E.	....	1590	140	5	...do...	22.28	August 1951	Do.
129	SE¼SE¼ sec. 31, T. 33 N., R. 9 E.	....	1521	7.8	36	Dug	.83	May 1949	Unused.
130	SE¼ SW¼ sec. 35, T. 33 N., R. 9 E.	M. Zovko	1596	30	24	...do...	9.91	August 1951	Domestic.
133	SE¼SW¼ sec. 36, T. 33 N., R. 9 E.	Galligan	1601	41	4	Drilled	19.12	May 1949	Do.
134	NE¼SE¼ sec. 33, T. 33 N., R. 9 E.	A. Lukas	1537	9	3	Dug	4.42	May 1949	Do.
142	NE¼ NE¼ sec. 27, T. 31 N., R. 9 E.	....	1483	5	36	...do...	.86	May 1949	Unused.
143	SW¼SW¼ sec. 19, T. 31 N., R. 9 E.	M. Jensen	1504	35	10	...do...	23.64	May 1949	Domestic.
145	NW¼NE¼ sec. 36, T. 32 N., R. 9 E.	A. Petrowski	1569	14	36	...do...	3.55	May 1949	Do.
148	NE¼ NW¼ sec. 4, T. 32 N., R. 9 E.	Forstes Bros.	1535	19.7	3	...do...	16.68	May 1949	Do.
149	SW¼NW¼ sec. 34, T. 33 N., R. 9 E.	....	1557	9.7	19	...do...	6.46	May 1949	Unused.
150	SE¼ SW¼ sec. 18, T. 32 N., R. 10 E.	....	1599	....	60	...do...	2.40	August 1951	Do.
152	SW¼SW¼ sec. 17, T. 32 N., R. 10 E.	Badger School	1614	86	6	Drilled	20.27	August 1951	Public supply.
154	SW¼NE¼ sec. 22, T. 32 N., R. 10 E.	....	1517	....	6	...do...	13.13	May 1949	Unused.
157	SE¼NE¼ sec. 26, T. 32 N., R. 9 E.	Elmwood School	1600	16.5	36	Dug	7.70	May 1949	Do.
159	SE¼SE¼ sec. 27, T. 32 N., R. 9 E.	....	1526	9.5	48	...do...	7.70	August 1951	Domestic.
160	NW¼NE¼ sec. 35, T. 32 N., R. 9 E.	Mr. Hipke	1563	....	36	...do...	12.87	May 1949	Unused.
162	SW¼NW¼ sec. 28, T. 32 N., R. 9 E.	E. Remington	1454	16	36	...do...	11.22	May 1949	Domestic.
163	NW¼NW¼ sec. 29, T. 32 N., R. 9 E.	....	1437	4.8	....	...do...	3.92	May 1949	Unused.
177	NE¼SW¼ sec. 5, T. 30 N., R. 11 E.	H. Guenthner	1471	24.2	1¼	Driven	17.05	August 1951	Spraying.
178	NW¼NW¼ sec. 5, T. 32 N., R. 9 E.	Mr. Robinson	1551	40	48	Dug	15.15	August 1951	Domestic.
179	SW¼NW¼ sec. 6, T. 32 N., R. 9 E.	H. Kaiser	1556	69	5	Drilled	42.28	June 1949	Do.
188	NW¼NE¼ sec. 15, T. 33 N., R. 9 E.	F. Callsen	....	44	4	...do...	28.18	August 1951	Do.
192	SE¼NE¼ sec. 27, T. 33 N., R. 9 E.	J. Steger	1569	....	5	...do...	15.21	August 1951	Do.
193	NE¼SE¼ sec. 28 T. 33 N., R. 9 E.	F. Simon	1626	....	5	...do...	55.04	June 1948	Do.
194	SW¼SE¼ sec. 10, T. 32 N., R. 9 E.	I. Pelotska	....	32	6	...do...	7.45	June 1949	Stock.
197	NE¼NE¼ sec. 15, T. 32 N., R. 9 E.	G. O'Neill	1527	39	6	...do...	7.13	August 1951	Unused.

200	NE¼ NW¼ sec. 29, T. 31 N., R. 11 E.	City of Antigo	1491	15	6	Jetted	6.40	December 1948	Observation.
202	NW¼ SW¼ sec. 13, T. 32 N., R. 9 E.	A. Hetzel	1565	39	4	Drilled	11.57	July 1949	Domestic.
203	SE¼ SE¼ sec. 14, T. 32 N., R. 9 E.	F. Zaitz	1551	36	...	Dug	17.64	July 1949	Do.
207	NW¼ SE¼ sec. 21, T. 32 N., R. 9 E.	Tichacek	1491	...	...	...do...	16.01	August 1951	Do.
210	SW¼ SW¼ sec. 31, T. 32 N., R. 9 E.	G. Skoog	1453	42	6	Drilled	16.41	August 1951	Do.
211	NW¼ SW¼ sec. 31, T. 32 N., R. 9 E.	A. Boquist	1433	41	6	...do...	16.28	August 1951	Do.
212	NW¼ NW¼ sec. 30, T. 32 N., R. 9 E.	W. Remington	1462	...	1¼	Driven	6.19	July 1949	Do.
213	NW¼ SE¼ sec. 32, T. 32 N., R. 9 E.	H. Peterson	1500	...	5	Drilled	58.75	July 1949	Do.
214	SE¼ SE¼ sec. 19, T. 30 N., R. 11 E.	E. Hitz	1455	30	6	...do...	15.47	August 1951	Do.
217	NW¼ SW¼ sec. 8, T. 32 N., R. 10 E.	...	1543	12.9	36	Dug	1.26	July 1949	Unused.
219	SE¼ SW¼ sec. 20 T. 32 N., R. 10 E.	M. Simons	...	68	4	Drilled	...	...	Domestic.
220	NW¼ NE¼ sec. 20, T. 32 N., R. 10 E.	G. O'Neill	1583	100	6	...do...	38.75	July 1949	Stock.
221	NW¼ NW¼ sec. 21, T. 32 N., R. 10 E.	A. Fisher	1546	...	4	...do...	21.63	August 1951	Do.
227	NW¼ NW¼ sec. 20, T. 32 N., R. 12 E.	F. Luhring	1637	111	4	...do...	94.58	August 1951	Unused.
229	SE¼ NE¼ sec. 31, T. 31 N., R. 11 E.	G. Baughiet	...	81	6	...do...	...	...	Domestic.
231	SW¼ SW¼ sec. 29, T. 32 N., R. 10 E.	F. Sorano	...	95	6	...do...	...	...	Do.
232	NW¼ NE¼ sec. 12, T. 31 N., R. 12 E.	J. Lambert	1585	115.5	4	...do...	108.26	August 1951	Unused.
233	SE¼ SE¼ sec. 32, T. 30 N., R. 11 E.	W. Wecke	1425	51	6	...do...	...	...	Public supply.
234	SW¼ SW¼ sec. 26, T. 30 N., R. 11 E.	C. Marsicek	1415	56	6	...do...	21.50	March 1949	Domestic.
235	NE¼ NE¼ sec. 25, T. 30 N., R. 11 E.	A. Schweitzer	1405	60	6	...do...	...	...	Do.
236	NW¼ NW¼ sec. 24, T. 30 N., R. 11 E.	J. Lenzer	1470	64	5	...do...	...	...	Stock.
237	SW¼ NW¼ sec. 5, T. 30 N., R. 11 E.	A. Drexler	...	190	5	...do...	...	...	Do.
238	SW¼ NE¼ sec. 6, T. 30 N., R. 11 E.	H. Guenthner	1456	...	45 x 85 feet	Dug	4.00	July 1949	Irrigation.
252	NE¼ SE¼ sec. 20 T. 30 N., R. 12 E.	C. McLean	1390	...	5	Drilled	39.84	July 1949	Domestic.
253	SE¼ SE¼ sec. 17, T. 30 N., R. 12 E.	E. Korth	1419	80	4	...do...	40.0	June 1948	Do.
254	SW¼ SE¼ sec. 2, T. 30 N., R. 12 E.	May King School	1420	...	...	...do...	41.05	July 1949	Unused.
257	NE¼ NE¼ sec. 29, T. 31 N., R. 12 E.	E. Dalton	...	84	5	...do...	...	...	Public supply.
258	NW¼ SW¼ sec. 19, T. 31 N., R. 12 E.	F. Krechlin	1591	165	4	...do...	114.84	July 1950	Domestic.
271	SE¼ SE¼ sec. 27, T. 32 N., R. 10 E.	...	1510	13	1¼	Driven	3.28	May 1951	Unused.
272c	SE¼ NE¼ sec. 15, T. 32 N., R. 11 E.	U. S. Geological Survey	1561	10	1¼	...do...	6.44	August 1950	Observation.
275	NE¼ NW¼ sec. 27, T. 32 N., R. 10 E.	Friebel School	...	83	4	Drilled	15.00	September 1949	Public supply.
288	SE¼ SE¼ sec. 33, T. 31 N., R. 11 E.	E. Arndt	1503	85	4	...do...	37.70	July 1951	Domestic
289	SE¼ NW¼ sec. 1, T. 30 N., R. 11 E.	C. Sharp	1554	138	4	...do...	103.97	August 1951	Do.
290	NE¼ NW¼ sec. 1, T. 30 N., R. 11 E.	Donahue	1534	103	6	...do...	82.52	August 1951	Do.
292	SE¼ SW¼ sec. 32, T. 32 N., R. 12 E.	W. Diercks	...	132	6	...do...	...	...	Industrial.
296	NE¼ NW¼ sec. 29, T. 31 N., R. 11 E.	City of Antigo no. 9	...	73	16	...do...	...	...	Public supply.

WELL LOGS

Well La 1, SE¼SE¼ sec. 22, T. 31 N., R. 11 E.

	Thickness (feet)	Depth (feet)
Gravel, sandy, brown	5	5
Sand, coarse to pebbly, brown	15	20
Sand, coarse to very coarse, gray	5	25
Sand, medium to coarse, gray	5	30
Gravel, coarse, sandy	5	35
Sand, fine to coarse, gray	10	45
Sand, medium to fine, gray	5	50
Sand, medium to coarse, gray	5	55
Sand, medium, gray	5	60
Gravel, coarse, sandy	5	65
Sand, coarse to pebbly, gray	5	70
Sand, medium, gray	10	80
Till, very sandy, yellow-brown	7	87
Gravel, fine, stony	5	92
Till, sandy, brown	9	101

Well La 5, SW¼SW¼ sec. 6, T. 31 N., R. 10 E.

Topsoil, clay, blue	8	8
"Shell(?) rock"	5	13
Granite, very hard; seam, water-bearing	19	32

Well La 43, NE¼NW¼ sec. 29, T. 31 N., R. 11 E.

Sand and gravel	60	60

Well La 48, NW¼NE¼ aec. 33, T. 31 N., R. 11 E.

Sand, fine, silty, brown-gray	5	5
Sand, medium to small pebbles, brown-gray above to gray below	30	35
Sand, fine to very coarse, light-gray	15	50
Sand, medium to coarse, light-gray	10	60
Sand, medium to small pebbles, light-gray	9	69

Well La 70, NW¼SW¼ sec. 6, T. 31 N., R. 10 E.

Topsoil, clay	3	3
Granite	263	266

Well La 88, SW¼NW¼ sec. 27, T. 31 N., R. 11 E.

Clay, red	18	18
Sand and clay	12	30
Gravel	15	45
Clay, sandy	40	85
"Hardpan"	10	95
Sand, gravel	7	102

Well La 89, SW¼SW¼ sec. 22, T. 32 N., R. 11 E.

Topsoil, clay red	8	8
Clay, sandy	35	43
Gravel	4	47

Well La 114, SW¼SW¼ sec. 27, T. 32 N., R. 12 E.

Old drilled well	90	90
"Hardpan", stone	4	94
?	7	101

Well La 125, SE¼NE¼ sec. 21, T. 33 N., R. 9 E.

Sand	9	9
"Hardpan"	11	20
Grsvel	9	29

Well La 188, NW¼NE¼ sec. 15, T. 33 N., R. 9 E.

"Hardpan"	40	40
Gravel	4	44

Well La 194, SW¼SE¼ sec. 10, T. 32 N., R. 9 E.

Topsoil, clay blue	24	24
Granite, water-bearing	8	32

Well La 197, NE¼NE¼ sec. 15, T. 32 N., R. 9 E.

	Thickness (feet)	Depth (feet)
Topsoil, clay, blue	24	24
Rock, soft	8	32
Granite, water-bearing	7	39

Well La 202, NW¼SW¼ sec. 13, T. 32 N., R. 9 E.

"Hardpan"	37	37
Rock, solid	2	39

Well La 219, SE¼SW¼ sec. 20, T. 32 N., R. 10 E.

"Hardpan"	60	60
Gravel	8	68

Well La 220, NW¼NE¼ sec. 20, T. 32 N., R. 10 E.

Topsoil, clay, red	20	20
Clay, red, sandy	48	68
Granite, water-bearing	32	100

Well La 229, SE¼NE¼ sec. 31, T. 31 N., R. 11 E.

Clay, red	18	18
Sand and gravel	50	68
Clay, red	4	72
Granite	9	81

Well La 231, SW¼SW¼ sec. 29, T. 32 N., R. 10 E.

Topsoil, clay, red	18	18
Clay, blue	52	70
"Shell(?) rock", water-bearing	25	95

Well La 232, NW¼NE¼ sec. 12, T. 31 N., R. 12 E.

Topsoil, clay	18	18
Gravel, "hardpan", boulders	90	108
Gravel, water-bearing	7½	115½

Well La 233, SE¼SE¼ sec. 32, T. 30 N., R. 11 E.

Clay, red	22	22
Clay, blue	27	49
Granite, rotten	2	51

Well La 234, SW¼SW¼ sec. 26, T. 30 N., R. 11 E.

Topsoil, sand	36	36
"Hardpan"	18	54
Gravel, water-bearing	2	56

Well La 235, NE¼NE¼ sec. 25, T. 30 N., R. 11 E.

Topsoil, clay	20	20
"Hardpan"	37	57
Gravel, water-bearing	3	60

Well La 236, NW¼NW¼ sec. 24, T. 30 N., R. 11 E.

Clay, red	20	20
Clay, sandy	36	56
"Hardpan"	5	61
Sand and gravel	3	64

Well La 237, SW¼NW¼ sec. 5, T. 30 N., R. 11 E.

Clay, red	30	30
Clay, red, sandy	158	188
Sand, fine, and gravel	12	200

Well La 253, SE¼SE¼ sec. 17, T. 30 N., R. 12 E.

Clay	23	23
Gravel, clay	15	38
"Hardpan"	10	48
Sand, gravel	32	80

Well La 257, NE¼NE¼ sec. 29, T. 31 N., R. 12 E.

	Thickness (feet)	Depth (feet)
Clay, red, sandy	37	37
Clay, gray, sandy	38	75
Sand, yellow	4	79
Gravel	5	84

Well La 258, NW¼SW¼ sec. 19, T. 31 N., R. 12 E.

	Thickness (feet)	Depth (feet)
Topsoil, clay	20	20
"Hardpan"	104	124
Sand and gravel	36	160
Gravel, water-besring	5	165

Well La 275, NE¼NW¼ sec. 27, T. 32 N., R. 10 E.

	Thickness (feet)	Depth (feet)
Topsoil	2	2
Clay, red	28	30
Sand, red	48	78
"Hardpan", gray	4	82
Gravel	1	83

Well La 278, SE¼SE¼ sec. 35, T. 34 N., R. 10 E.

	Thickness (feet)	Depth (feet)
Clay, red	150	150
Clay, red, sandy	45	195
Granite	20	215

Well La 292, SE¼SW¼ sec. 32, T. 32 N., R. 12 E.

	Thickness (feet)	Depth (feet)
Gravel, fine, gray	25	25
Sand, coarse to very coarse, light-gray	5	30
Gravel, fine, sandy, gray	20	50
Sand, very coarse to medium, light-gray	30	80
Gravel, fine sandy	5	85
Sand, very coarse to medium, light-gray	5	90
Gravel, fine, very aandy	5	95
Sand, coarse to medium, light-gray	25	120
Gravel, fine, weathered, rusty-brown	10	130
Sand, very coarse	5	135
Gravel, very sandy, gray	5	140

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