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DIVISION OF WATERS
MINNESOTA DEPARTMENT OF CONSERVATION

GROUND WATER IN ALLUVIAL CHANNEL DEPOSITS NOBLES COUNTY, MINNESOTA

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Prepared cooperatively by the
Geological Survey, U. S. Department of the Interior
and the
Division of Waters, Minnesota Department of Conservation

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STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION
SAINT PAUL 1

November 28, 1960

Mr. George A. Selke, Commissioner
Department of Conservation
Centennial Office Building
St. Paul, Minnesota

Dear Mr. Selke:

I am pleased to transmit herewith a report, entitled "Ground water in alluvial channel deposits Nobles County, Minnesota," by Ralph V. Norvitch, geologist, U. S. Geological Survey.

This report embodies part of the results of a three year study in Nobles County and in the vicinity of Worthington. It describes the occurrence of stream channel deposits of clay, silt, sand and gravel and the water-bearing capacity of these deposits. Because the application of the method need not be restricted to Nobles County, the report will be of general interest throughout the State.

Yours very truly,

Sidney A. Frellsen, Director

Division of Waters

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GROUND WATER IN ALLUVIAL CHANNEL DEPOSITS NOBLES COUNTY, MINNESOTA

By
Ralph F. Norvitch

ABSTRACT

The alluvial channel deposits described in this report are in Nobles County, Minn., about 150 miles southwest of Minneapolis and St. Paul. Although four municipalities and many farms obtain part or all of their water needs from the alluvium, it has not yet been fully developed for ground water.

The extent of the alluvial channel deposits was mapped on high-altitude aerial photographs, and a power auger was used to bore 43 test holes to determine the thickness of alluvium and the water level at each of the test sites.

Thicknesses of the alluvium differ in the several stream channels and across the same channel. The thickness ranges from zero to more than 61 feet and is expected to be greater in the trunk stream valleys than in most of the tributaries. Maximum thicknesses are expected to be similar along local segments in the same stream channel. The thickest section of alluvium is not necessarily coincident with the position of the present-day stream. A line of test holes across the stream valley is a positive means of determining the position of the thickest alluvial section.

In grain size the deposits range from clay to boulders, with all possible admixtures. Textural changes occur both laterally and vertically in very short distances. The coarser sections are overlain by clayey silt which ranges in thickness from a few inches to more than 11 feet.

The alluvial aquifers are under water-table conditions except where the coarser material is overlain by a relatively thick section of impermeable silt or clay and artesian conditions exist. The average water level in the 43 auger holes was about 7 feet below the land surface. If the average long-term storage coefficient of the alluvium is 0.2, about 1.5 gallons of water is available from storage in each cubic foot of saturated material. A pumping test on a well at Worthington showed the coefficient of transmissibility of the alluvium to be about 24,000 gpd per foot and the field coefficient of storage to be about 0.1.

The surficial expression of the alluvial deposits facilitates the selection of good well sites. Factors to be considered in selecting well sites are (1) depth and width of deposits; (2) permeability; (3) saturated thickness; (4) location near surface water bodies; (5) location at confluence of two channels; and (6) proximity of valley walls.

The water in the alluvium is of fairly good quality except that it is very hard. Five chemical analyses show a range in dissolved solids from 425 ppm (parts per million) to 870 ppm, and in hardness from 332 to 568 ppm. Some other ground waters in the county have dissolved solids and hardness of more than 1,000 ppm. The temperature of the water ranges from 46.5° to 51°F.

INTRODUCTION

Surficial alluvial channel deposits are a potentially important source of ground water in Nobles County, Minn. The deposits are an accumulation of water-laid clay, silt, sand, and gravel. Yields of ground water adequate for local demands have been obtained from the permeable saturated parts of the alluvium. Four municipalities and many farms obtain part or all of their water from these deposits. The deposits have not, as yet, been fully developed; the purpose of this report is to describe the occurrence and water-bearing potential of this source.

An areal investigation of the geology and ground-water resources of Nobles County and part of Jackson County is being made by the U. S. Geological Survey in cooperation with the Division of Waters of the Minnesota Department of Conservation. This report covers one phase of the areal investigation. The work was done under the general supervision of P. E. LaMoreaux, chief of the Ground Water Branch of the U. S. Geological Survey, and under the immediate supervision of Robert Schneider, district geologist for Minnesota.

Nobles County, in southwestern Minnesota (fig. 1), is about 150 miles southwest of Minneapolis and St. Paul and has an area of 719 square miles. The 1960 population was about 23,200. The principal occupation is agriculture; food processing is the major industry.

The Missouri-Mississippi River divide trends southeastward through the county from about the center of R. 42 W. on the north county line to about the center of T. 102 N. on the east county line. (See fig. 1.) All streams that head west of the divide ultimately drain into the Missouri River; all streams that head east of the divide ultimately drain into the Mississippi River.

Three glacial end moraines (belts of hilly ridges) and their associated ground moraines (low-lying, rolling terrain) characterize the area topographically. The moraines trend southward and southeastward and are cut by melt-water channels of glacial origin.

The channel deposits were delineated by H. B. Dyer on 1:70,000-scale aerial photographs and were later transferred to the base map by means of a vertical sketchmaster. Spot checks of the office mapping were made in the field. To obtain samples and determine the thickness of the deposits a power auger was used to bore 43 test holes at the locations shown on figure 1. Caving in the uncased auger holes prevented the recovery of representative samples of the alluvium from below the water table. However, it was possible to determine the thickness of the alluvium (depth to underlying glacial till) in most places and to measure the approximate water level at each site.

GEOLOGY

The surface of Nobles County is underlain by glacial drift of Pleistocene age and by some alluvial deposits of Recent age. The Recent deposits are thin, patchy accumulations of silt and sand which are restricted to stream channels, flood plains, and lake basins. The drift includes till and outwash and is mantled in places by windblown silt (loess). Till is a heterogeneous mixture of rock fragments ranging in size from clay to boulders which has received little or no sorting after its deposition from the glacial ice.

Outwash is dominantly an assorted deposit, which is generally made up of sand and gravel but which may contain fragments ranging in size from clay to boulders.

In Nobles County, melt-water channels were formed by streams emanating from the glacier fronts. They were filled with alluvium consisting of glacial outwash and an overlying layer of silt or clay. As used in this report, the term “alluvium” includes all of the valley-fill deposits of both Recent and Pleistocene age. For a detailed explanation of glacial processes see publications by Flint (1957) and Thwaites (1946).

Figure 1 shows some of the surficial features in Nobles County. The approximate limits of the alluvial deposits are shown, along with the generalized positions of the three ice fronts which traverse the county and which formed ridges of drift (moraines) where they stood. The positions of the morainal fronts were modified from those mapped by Leverett and Sardeson (1932, pl. 2), and dated in accordance with an unpublished Ph.D. dissertation by R. V. Ruhe (Univ. Iowa, 1950). The upstream termini of the alluvial deposits in the shallow, narrow tributaries were arbitrarily drawn.

The major alluvial areas and some minor areas of very little significance are outlined on the map. Deposits laid down in former lake basins are not shown, except where the lakes may have occurred within an alluvial channel. (Surficial lake deposits, in this area, are very fine grained and probably have little water-bearing potential.) The width of the alluvial deposits ranges from a few feet in the narrow tributaries to about a mile in the Kanaranzi Creek valley southwest of Adrian and in the Champepedan Creek valley at the west border of the county.

There are no known outcrops of bedrock in Nobles County. The glacial deposits are underlain by interbedded sandstone and shale of Cretaceous age which in turn are underlain by Precambrian crystalline rocks. In a few localities crystalline rocks lie directly beneath the drift.

History of the valleys

The stream valleys and their associated alluvium in Nobles County were formed during the Wisconsin stage of the Pleistocene epoch. The valleys in the southern and western part of the county were cut by proglacial streams debouching from the ice fronts. During later periods these melt-water streams became overloaded with debris from the ice fronts and filled their valleys with outwash. As the ice disappeared, stream loads were reduced, causing the streams to cut downward into the previously deposited channel alluvium. Terraces were formed in the valleys by subsequent stream erosion. Evidence of the large volumes of water that occupied the main valleys during glacial time is shown by the width of the valleys in comparison to the present-day streams, and by the height of the terraces above the present stream levels. On the basis of the positions of the alluvial terraces, three former stream levels are discernible in the proglacial channels; a high-level terrace, which may represent a fourth level or may be of ice-contact origin, is discernible in the channels west of the westernmost morainal front.

In describing the glacial geology of the area, Leverett (1932, p. 60) stated that the drainage down the Kanaranzi Creek valley seems to have been too weak to carry gravel from the morainal front as far as Adrian. However, auger samples show that gravel does occur throughout the entire reach of the valley within the county.

Jack, Elk, and Okabena Creeks in northeastern Nobles County drain the back slopes of the moraines and were probably formed during the waning phases of the Cary substage of glaciation. It appears that these streams had neither the volume of water nor the load that was available to the streams draining the front of the moraines. Therefore, their channels are relatively narrow and generally contain less alluvium.

The positions of the morainal fronts shown on figure 1 represent the maximum advance of the respective glaciers; local glacial movement within the county was toward the southwest. The age of the drift between successive morainal fronts (excluding the alluvium) is that of the front to the west. That is, the drift west of the Tazewell morainal front is of Iowan age; the drift between the Tazewell and Cary outer morainal front is of Tazewell age; and the drift east of the Gary outer morainal front is of Cary age. The following table presents the geologic sequence of deposition of the surficial deposits in Nobles County.

Geologic Time Units		
Recent epoch		
Pleistocene epoch	Wisconsin stage of glaciation	Cary glacial substage
		Tazewell and Cary interval
		Tazewell glacial substage
		Iowan and Tazewell interval
		Iowan glacial substage

No attempt was made to differentiate the outwash in the channels as to age. However, from the position of the morainal fronts, it appears that the Kanaranzi and Champepedan Creek valleys may contain outwash from the Iowan, Tazewell, and Cary drift sheets; the Elk Creek (western) valley may contain outwash of Iowan and Tazewell age; and the Little Rock River valley may contain outwash of Tazewell and Cary age. The creeks in the eastern part of the county apparently drained only the backs of the Cary moraines. It is possible that some of the valleys existed during earlier ice advances and contain outwash older than that at the present surface.

Thickness of the alluvium

The alluvium differs in thickness from one stream channel to another and across the same stream channel. Its maximum thickness is dependent upon the depth of scour of the streams that occupied the valleys during periods of abundant melt water. Table 1 lists the location of 43 auger holes bored into the channel deposits, together with the thickness of alluvium penetrated, the total depth of each hole, the approximate depth to water below the land surface, and the type of material in which the hole ended. The alluvium ranged from 4.5 to 61 feet in thickness. Owing to low permeability the more compact material (silty clay or clayey silt) penetrated at the bottoms of some holes was not included as part of the alluvial thicknesses listed in table 1. However, it is probably of alluvial origin, and coarser material may underlie it at depth.

It is expected that along local stream segments the maximum thickness of alluvium is approximately the same. That is, if 40 feet of alluvium is penetrated in a stream channel, another section of alluvium about 40 feet thick will occur elsewhere in the same channel, possibly as much as a mile up or down stream.

Figure 2 illustrates the variable thickness of alluvium across a stream channel. It is a generalized cross section based on auger-hole data for the Little Rock River valley (fig. 1). The thickest sand and gravel section was penetrated in a hole drilled on the upper terrace. The cross section shows that the deepest channel was cut east of the present-day stream. It would be coincidence if the present-day stream were flowing above the thickest section of channel alluvium. Probably the simplest and most positive means of determining the location of the thickest section of alluvium is to drill a line of holes across the stream valley. Electrical resistivity and seismic methods might be employed to good advantage as a supplement to test holes if the contrast in electrical and physical characteristics between the outwash and underlying till were sufficient.

Table 1 – Data from auger holes bored in the alluvial deposits in Nobles County, Minn.

Auger hole no.	Location	Thickness of alluvium (feet)	Depth of hole (feet below land surface)	Approx.depth to water(feet below land surface)	Hole finished in
41	SW¼SW¼SE¼ sec.22, T.101N., R.40W.	48.5	48.5	9	Alluvium
43	SW¼SW¼SW¼ sec.26, T.101N., R.40W.	61	63.5	2.5	Clay
42	NE¼NE¼NW¼ sec.27, T.101N., R.40W.	12	18.5	6	Till
15	SE¼NE¼NE¼ sec.17, T.101N., R.41W.	8.5	18.5	7	Till
40	NE¼NE¼NW¼ sec.15, T.101N., R.42W.	6.5	8.5	3	Till
14	NE¼NE¼NE¼ sec.24, T.101N., R.42W.	11.5	18.5	3.5	Till
13	NW¼NE¼NW¼ sec.25, T.101N., R.42W.	15	18.5	10.5	Till
11	NW¼SW¼NW¼ sec.25, T.101N., R.42W.	12	18.5	9	Till
12	SW¼SW¼NW¼ sec.25, T.101N., R.42W.	4.5	8.5	7.5	Till
10	NW¼NW¼NE¼ sec.35, T.101N., R.42W.	12	28.5	12.6	Till
1	NE¼NE¼NW¼ sec.35, T.101N., R.42W.	25	33.5	10	Till
2	NE¼NE¼NW¼ sec.35, T.101N., R.42W.	20	33.5	9	Till
3	NW¼NE¼NW¼ sec.35, T.101N., R.42W.	15	22	10	Till
4	SW¼NW¼NW¼ sec.35, T.101N., R.42W.	10.5	23.5	5	Till
5	SW¼NW¼NW¼ sec.35, T.101N., R.42W.	10.5	18.5	5.5	Till
6	NE¼SE¼NW¼ sec.35, T.101N., R.42W.	21	28.5	11	Till
7	NE¼SE¼SW¼ sec.35, T.101N., R.42W.	16	23.5	10	Till
8	SW¼SE¼SW¼ sec.35, T.101N., R.42W.	12.5	18.5	6.4	Till
9	SE¼SE¼SW¼ sec.35, T.101N., R.42W.	10	28.5	6.6	Till
37	SW¼SW¼SE¼ sec.19, T.101N., R.43W.	60±	78.5	8	Clay
36	NW¼SE¼SE¼ sec.20, T.101N., R.43W.	21	27	4.8	Till
39	NW¼NW¼NW¼ sec.29, T.101N., R.43W.	31	38.5	4	Clay
38	NE¼SE¼NW¼ sec.30, T.101N., R.43W.	26	31	23	Till
23	NE¼SE¼SE¼ sec.4, T.102N., R.42W.	16.5	18.5	5.3	Till
22	NW¼NE¼NE¼ sec.5, T.102N., R.42W.	18	23.5	7	Till
21	NE¼NE¼NW¼ sec.5, T.102N., R.42W.	23	32	5	Till
24	SW¼SW¼SW¼ sec.5, T.102N., R.42W.	22	32	3	Till
25	SE¼NE¼NE¼ sec.7, T.102N., R.42W.	16(?)	18.5	13.5	Till
27	SW¼SW¼SW¼ sec.7, T.102N., R.42W.	28	28.5	5.5	Clay
26	NW¼SW¼NW¼ sec.9, T.102N., R.42W.	17	20.5	7	Till
28	NE¼NE¼NW¼ sec.18, T.102N., R.42W.	25	33.5	12.5	Till
29	NW¼SW¼SW¼ sec.14, T.102N., R.43W.	27.5	33.5	3.5	Till
30	SE¼SW¼SW¼ sec.15, T.102N., R.43W.	35	38.5	10	Till
33	SW¼SW¼SW¼ sec.21, T.102N., R.43W.	26	37.5	2.8	Till
32	SW¼SW¼SE¼ sec.21, T.102N., R.43W.	31	37.5	5.5	Till
31	SE¼SW¼SE¼ sec.21, T.102N., R.43W.	10	23.5	3.4	Till
34	NE¼NE¼NW¼ sec.32, T.102N., R.43W.	34	38.5	11	Till
35	SW¼NW¼NW¼ sec.32, T.102N., R.43W.	29	37	8.4	Till
17	SW¼SW¼SE¼ sec.29, T.103N., R.41W.	14	18.5	5	Till
16	SE¼SE¼SE¼ sec.29, T.103N., R.41W.	17	18.5	4.1	Till
18	SE¼SW¼SE¼ sec.32, T.103N., R.41W.	17	28.5	3	Clay or Till
20	SE¼SE¼SW¼ sec.29, T.103N., R.42W.	28	32	2	Silt or Clay
19	NW¼NW¼NE¼ sec.32, T.103N., R.42W.	26	31	4	Till

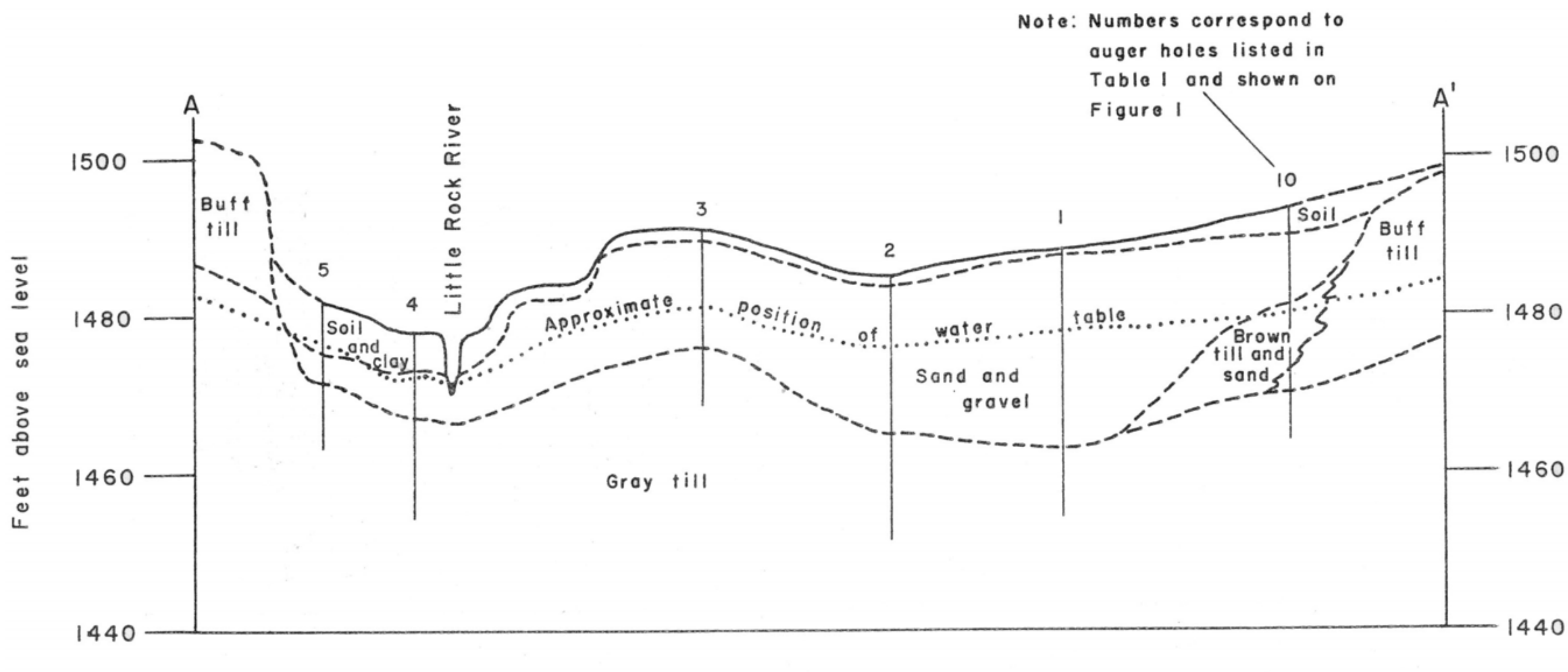

Figure 2.- Generalized cross section of Little Rock River valley, Nobles County, Minn.

Table 2 summarizes the auger-hole data listed in table 1. The maximum thicknesses of the alluvium are probably somewhat greater than those listed in the table, because the number of holes bored was not adequate to give positive assurance that the thickest alluvium was penetrated everywhere. The thickness of the deposits ranges from zero to more than 61 feet. It is expected that the valleys of the trunk streams contain greater thicknesses of alluvium than those of most tributaries.

Table 2 – Summary of data from auger holes bored in the alluvial deposits in Nobles County, MN

Stream segment	Number of tests used for average	Average thickness of alluvium (feet)	Average depth to water below land surface (feet)*	Maximum thickness of alluvium (feet)	Maximum saturated thickness of alluvium (feet)	Physical characteristics
Kanaranzi Creek from west county border to point 3¾ mi. north of US Highway 16	14	26	6	35	26	Much rounded sand & gravel; many fragments consist of limestone; broad terraces
Little Rock River from south county border to 4 mi. north of south county border	15	14	8.2	25	15	Alluvium appears clayey; overall brownish color; reports of low water levels in dry periods
Tributary of Kanaranzi Creek near Ellsworth	3	37	5.6	60 (?)	52(?)	Material in deepest hole appeared as mostly fine gray sand and some gravel
Tributary of Kanaranzi Cr. northeast of Adrian in sec. 4 & 9, T.102N., R.42W.	2	17	6.2	17	11.2	Alluvium appears clayey; brownish color.
North-south trending segment of Kanaranzi Cr. tributary in sec. 29 & 32, T.103N., R.41W.	3	16	4	17	14	Alluvium appears clayey; brownish color. Hole 18 penetrated lake clay from about 3-8ft below land surface
South outlet of Ocheda Lake, Ocheyedan River; 1-2 miles north of south county border	2	55	5.8	61	58.5	Alluvium made up of fine sand to coarse gravel. Best site appears to be at confluence of two stream segments in SE¼SE¼SE¼ sec.27, T.101N., R.40W.

* Water levels measured October 13-23, 1959.

Texture of the alluvium

The assortment of grain sizes within the channel deposits is extremely variable. A well-sorted sand and gravel section may grade laterally and vertically into much finer sediments within a very short distance. Generally, the coarser material may be expected to occur upstream, closer to the position of the ice fronts that provided the source material. An exception to this generalization occurs in the Ocheyedan River channel, where the alluvium of hole 41 is finer grained than that of hole 43 farther downstream (fig. 1). Reports of subsequent test drilling indicate that the material near hole 4l is made up largely of sand sizes, and the material at the site of hole 43 is predominantly sand and gravel. A logical explanation for this occurrence is that the tributary stream that joins the Ocheyedan River in the SE¼SE¼SE¼ sec. 27, T. 101 N., R. 40 W., carried coarser sediment than the glacial Ocheyedan River could sustain. Therefore, when the rapidly flowing waters of the tributary joined the more sluggish waters of the trunk stream, a large portion of its load was deposited at the junction and possibly downstream. If this interpretation is correct, it is reasonable to expect that the channel deposits at and below the confluence of these two streams will contain coarser sizes than the Ocheyedan channel deposits above the confluence. Inasmuch as the condition of differing velocities of joining streams likely was common, the confluences of streams are usually good places to search when looking for sizable accumulations of sand and gravel.

The coarser sections of the alluvium are overlain by water-laid deposits of black humic, clayey silt and buff loess ranging in thickness from a few inches to more than 11 feet. Modern soil profiles are being formed in these deposits. Where the soil is being formed on buff loess, the upper portion, or soil zone, is now a black silty loam. A channel fill of greenish-gray lake clay containing vegetal matter was penetrated from about 3 to 8 feet below the surface in auger hole 18. This channel must have been blocked at the constriction in the SE¼NE¼ sec. 5, T. 102 N., R. 41 W. (fig. 1), causing the formation of a lake immediately to the north. Hole 10, NW¼NW¼NE¼ sec. 35, T. 101 N., R. 42 W., was bored very near the boundary of the stream channel. The anomalous brown till (fig. 2) penetrated within the alluvial section may possibly be part of the channel walls which caved into the stream at the time of the channel cutting. The Adrian well (fig. 1) penetrated sand and gravel from about 3.5 to 39 feet below the land surface; the lower 13 feet was composed largely of medium sand to coarse gravel and contained rocks up to 6 inches in diameter.

GROUND WATER CONDITIONS

Ground water is stored beneath the land surface in the zone of saturation. Within this zone all voids, or pore spaces, are filled with water. The upper surface of the zone of saturation is called the "water table" except where that surface is overlain by an impermeable body, in which case the water table is absent. Water-table conditions occur where unconfined ground water is under atmospheric pressure and will not rise above the level at which it initially entered a well. Under artesian conditions the water-bearing material (aquifer) is overlain by a confining bed. Recharge entering the system from a higher elevation results in pressure being imposed on the ground water. In this case the water will rise above the level at which it first entered the well--that is, above the bottom of the confining bed.

Ground water in the alluvial deposits in Nobles County is generally under water-table conditions. In some parts of the alluvium, coarse sand and gravel is overlain by a thick section of less permeable silt or clay which acts as a confining bed, and artesian conditions result. In most places, the artesian conditions will change to water-table conditions if the water level is drawn down into the coarse-grained material by pumping or as a result of drought.

The alluvial deposits are recharged from precipitation; the recharge is at a maximum during the spring thaw and heavy summer rains. Natural discharge from the alluvial deposits takes place through seeps and springs flowing into surface streams and lakes, by evaporation through the soil zone, and by transpiration (plant utilization of ground water). Pumping from wells and digging of drainage ditches below the water table account for additional discharge.

The "static water level" in a well is the level at which the water rests when the well is not being pumped. It is recorded in tables 1 and 2, in feet below the land surface. The average water level in the auger holes bored during this investigation was about 7 feet. The static levels in the wells finished in the alluvial deposits coincide in most places with the water table. The water table is not truly static; it rises when recharge exceeds discharge, and vice versa; the annual range in some places is several feet.

Ground water moves in response to the hydraulic gradient, from areas of high pressure head to areas of low head. Inasmuch as the alluvial deposits follow generally the configuration of former stream channels, the expected direction of movement is that of the streamflow. However, natural movement may be affected locally by pumping a well. A decline of the water level (drawdown) occurs in and near the pumped well, and the depressed levels form an inverted cone (cone of depression) whose apex is at the well. Water will move down this steeper gradient created by the pumping and, in effect, will be funneled into the well. The cone will deepen and spread laterally until a large enough intake area is encompassed to balance the well's discharge. The configuration of the cone is dependent upon the transmissibility and storage coefficients of the aquifer and the rate and period of pumping.

The coefficient of transmissibility, as defined by Theis (1935), is expressed as the rate of flow of water, in gallons per day at the prevailing temperature, through a vertical strip of the aquifer 1 foot wide extending the full saturated height of the aquifer under a unit hydraulic gradient. The coefficient of storage denotes the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. Values for the coefficient of storage in water-table aquifers generally range from about 0.05 to 0.3. In a water-table aquifer the coefficient of storage is, for all practical purposes, equal to its specific yield, which is a ratio of the volume of water a saturated rock will yield by gravity to its own volume. Therefore, if it is assumed that the long-term storage coefficient of the alluvium averages about 0.2, about 1.5 gallons of water is available from storage per cubic foot of saturated alluvium.

Generally, the growth of the cone of depression of a well completed in a water-table aquifer is slow in comparison to that in an artesian aquifer. Because of this fact, water-table wells can be safely spaced more closely than artesian wells. Proper well spacing is necessary for continued high yields from a well field and should be determined only after a thorough study of the hydrologic properties of the aquifer.

The villages of Adrian, Ellsworth, and Lismore obtain their municipal supplies from wells finished in channel deposits. Adrian has four wells, all presumably completed in the alluvium. The Adrian well shown on figure 1 is about 39 feet deep and had a static water level of about 13 feet below the land surface in August 1957. It was test pumped at a rate of 400 gpm (gallons per minute) for 3 hours and had a drawdown of about 17 feet.

The city of Worthington has six wells completed in channel alluvium (fig. 1). Well 21, about 30 feet deep, was test pumped for about 2 hours at a rate of 200 gpm and had a drawdown of about 8 feet. Computations made from drawdown data obtained from a recording gage installed on an observation well 17 feet from well 21 showed the coefficient of transmissibility to be about 24,000 gpd (gallons per day) per foot and the storage coefficient to be about 0.1.

SIGNIFICANT FACTORS FOR LOCATING WELLS

Because of the surficial expression of the alluvial deposits, it was possible to map their areal extent as shown on figure 1. This map will greatly facilitate the location of wells within the alluvium. In selecting a well site the following factors should be considered:

(1) Depth and width of channel deposits; all other factors being equal, the widest and deepest section of the channel will allow more space for the lateral and vertical spread of the well's cone of depression.

(2) Permeability (capacity of material to transmit water). The better sorted coarse alluvium will transmit water more freely to wells. Hydraulic characteristics such as the coefficients of storage, transmissibility, and permeability may be obtained through field pumping tests.

(3) Saturated thickness (the thickness of alluvium that lies below the water table). As mentioned on page 12, the static water level in a well completed in the alluvium coincides in most places with the water table and may decline considerably during dry periods, as well as from pumping.

(4) Location near a surface-water body. If possible, a well should be placed near a surface-water body such as a lake or stream, so that the cone of depression which results from pumping may extend to and induce recharge from the surface-water body, increasing the well's total capacity. City of Worthington well 21 is about 850 feet south of Lake Okabena and may be receiving some recharge from the lake.

(5) Location at the confluence of two channels. Such a well would derive underflow from two channels thereby receiving more water and the deposits at the confluence probably would be coarser as mentioned previously. Also, a well completed downstream would have a larger recharge area and would receive more underflow than an upstream well.

(6) Proximity of valley walls. Where the buried valley wall is composed of clay till it will constitute a barrier to the spread of the cone of depression, causing the pumping level in a well to decline more rapidly. All other factors being considered, the well should be completed as far from the valley walls as possible, to allow more room for the spread of the well's cone of depression.

The foregoing considerations are directed primarily toward wells expected to yield more than 50 gpm. Farm wells, which are ordinarily pumped at only 3 to l0 gpm for relatively short periods, generally may be completed almost anywhere in the saturated alluvium.

In considering the placement of high-capacity wells for large ground water developments, a thorough study of the geologic and hydrologic conditions should be made. Because the deposits are thin, larger yields may be obtained from several wells of low capacity than from a single well of high capacity.

QUALITY OF WATER

The channel alluvium yields water whose quality is among the best available in Nobles County. Chemical analyses of five samples of this water were made by the Quality of Water Laboratories of the U. S. Geological Survey at Fayetteville, Arkansas, and Lincoln, Nebraska. The samples were collected from the Adrian, Ellsworth, and Lismore wells and from Worthington wells 16 and 21. The concentration of dissolved solids ranged from 425 ppm (parts per million) to 870 ppm, and the hardness ranged from 332 ppm to 568 ppm (to convert parts per million to grains per gallon, divide by 17.1). In contrast, most of the water in the aquifers overlain by glacial till has concentrations of dissolved solids and hardness which greatly exceed 1,000 ppm. The U. S. Public Health Service (1946) recommends that total solids in drinking water not exceed 500 ppm, altnough 1,000 ppm is permitted where better water is not available.

The temperature of the five water samples ranged from 46.5° to 51°F. The temperature of the shallow ground waters approximates the mean annual air temperature of the area, which is about 45°F, making the water desirable for cooling purposes in the summer.

CONCLUSIONS

The channel alluvium constitutes an important source of ground water in Nobles County. Water in moderate to large quantities can be obtained from permeable parts of the alluvium where they are sufficiently thick and have high static water levels. A yield of 400 gpm has been obtained for a limited period from a well completed in the sand and gravel. No information is available on maximum sustained yields; however, owing to the thinness of the deposits, maximum pumping rates should be set low enough to prevent water levels from reaching critical stages. For large developments, determinations of the geologic and hydrologic properties of the aquifers should be made before construction of permanent installations. Ordinary farm-well requirements, 3 to 10 gpm, may be obtained almost anywhere from saturated sections of the alluvium.

The alluvium is recharged from precipitation. Because the deposits are near the surface and are largely under water-table conditions, recharge is quite rapid. Maximum yields from wells may be expected during wet years and, conversely, minimum yields may be expected during dry years. As the alluvium is hydrologically connected with the streams that drain the area, a large part of the water that flows from the county in the streams has passed through these aquifers.

Because of the surface expression of the channel alluvium, its areal extent may be traced with relative ease. The thickest sections of the alluvium may be determined by drilling test holes across the valleys, thereby selecting the best sites for well locations. The areas where the trunk stream valleys are widest appear to be the most desirable locations for well sites for large developments.

REFERENCES

Flint, R. F., 1957, Glacial and Pleistocene geology: New York, John Wiley and Sons, 553 p.

Leverett, Frank, 1932, Quaternary geology of Minnesota and parts of adjacent States: U. S. Geol. Survey Prof. Paper 161, 149 p.

Leverett, Frank, and Sardeson, F. W., 1932, Map of the southern part of Minnesota showing surficial deposits in Leverett, Frank, 1932, Quaternary geology of Minnesota and parts of adjacent States: U. S. Geol. Survey Prof. Paper 161, 149 p.

Theis, C. V., 1935, The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage: Am. Geophys. Union Trans., pt. 2, p. 519-524.

Thwaites , F. T. , 1946, Outline of glacial geology: Ann Arbor, Edwards Bros., 129 p.

U. S. Public Health Service, 1946, Drinking water standards: Public Health Repts., v. 61, no. 11, p. 371-384.

Figure 1 – Map of Nobles County, MN, showing alluvial deposits, morainal fronts, auger holes, selected municipal wells, and the Missouri-Mississippi River divide.