PROGRESS REPORT NUMBER 25

STATE OF MICHIGAN
DEPARTMENT OF CONSERVATION
GERALD E. EDDY, DIRECTOR
GEOLOGICAL SURVEY DIVISION
WILLIAM L. DAOUST, STATE GEOLOGIST

SUMMARY OF GROUND-WATER CONDITIONS IN THE ELSIE AREA, MICHIGAN

BY
KENNETH E. VANLIER

PREPARED COOPERATIVELY BY THE
UNITED STATES DEPARTMENT OF THE INTERIOR,
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SUMMARY OF GROUND-WATER CONDITIONS IN THE ELSIE AREA, MICHIGAN

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ABSTRACT

The area covered by this report includes all of Duplain Township, a rural agricultural area in northeastern Clinton County, Michigan. The village of Elsie is in the northeast corner of the township and has the only public water-supply system in the area.

The township is underlain by consolidated sedimentary rocks of Paleozoic age which are mantled by glacial deposits. The Saginaw and Grand River formations, the youngest and uppermost of the bedrock formations, are sources of fresh ground water--as are some of the glacial deposits. Strata below the Saginaw formation yield saline water.

The Saginaw formation is composed principally of sandstone and shale. The sandstone beds in the upper part of the formation are the source of water to many wells in the area, including two of the wells that supply the village of Elsie.

The Grand River formation, composed of red sandstone and red shale, is the uppermost of the bedrock formations in the area. This formation was exposed to erosion in preglacial time and to ice scour during the glacial epoch. Thus, only thin, discontinuous remnants of the formation are present in most of the township. In some places the formation is sufficiently thick and permeable to be a source of water to wells.

The glacial-drift deposits include some beds of sand and gravel that yield water to wells. The sand and gravel was washed out of the glacier and deposited in beds of meltwater streams and in deltas where these streams emptied into glacial lakes. Most of the deposits of sand and gravel and most wells tapping glacial deposits are in the southern half of the township, although two of the village-supply wells at Elsie also tap glacial deposits.

Ground water in the area commonly is hard and contains objectionable quantities of iron. Water from the glacial-drift aquifers generally is harder and contains more iron than water from the bedrock aquifers. One of the deeper village wells that tapped the Saginaw formation was reported to have yielded water containing excessive chlorides.

INTRODUCTION

Purpose and Scope of Investigation

During the latter part of World War II the village of Elsie, in Duplain Township of Clinton County, experienced considerable difficulty in obtaining water to supply municipal and industrial needs. As a part of the Statewide study of ground-water resources, a reconnaissance investigation of the Elsie area was begun by the U. S. Geological Survey in cooperation with Duplain Township and the Michigan Geological Survey.

The study consisted of collecting and cataloging readily available geologic and hydrologic data, and conducting aquifer (pumping) tests. It included a test-drilling program by the village of Elsie. This report presents and interprets the data collected during the study.

Cooperative investigations with the Michigan Geological Survey are directed jointly by W. L. Daoust, State Geologist, and Morris Deutsch, District Geologist, Ground Water Branch, U. S. Geological Survey.

Previous Investigations

Information and data concerning the general geology of the Southern Peninsula of Michigan are contained in reports of several studies made by various agencies during the past 75 years. Although these reports do not specifically outline the geology of the Elsie area, they do provide the background and basis for the geologic interpretations presented in this report. A report of the study of the Pleistocene (glacial geology) of Michigan and Indiana (Leverett and Taylor, 1915) was the source of most of the information on the glacial deposits of the Elsie area.

Acknowledgments

Appreciation is expressed to officials of the village of Elsie and to residents of the area who furnished much valuable information. Special thanks are extended to the well drilling firms of Charles Archer, Chapin, Mich.; Layne-Northern Co., Lansing, Mich.; and the Ohio Drilling Co., Massillon, Ohio.

Well-Numbering System

The well-numbering system used by the U. S. Geological Survey in Michigan indicates the location of wells with reference to the Michigan meridian and base line. The first two segments of a well number designate the township and range, the third segment designates both the section and the serial number arbitrarily assigned to the well in the section. As all the wells in this report are in Duplain Township (Township 8 North, Range 1 West) only the third segment of the well numbers is listed in the text, tables, and illustrations of this report. On some of the maps only the serial numbers of the wells are given, as the section numbers are evident from the well locations.

GEOGRAPHY

Location and Extent of the Elsie Area

The Elsie area, as described herein, includes all of Duplain Township, an area of about 36 square miles in the northeast corner of Clinton County, in south-central Michigan (fig. 1). The township is bounded on the north by Gratiot County and on the east by Shiawassee County. Elsie (fig. 2) is the only village in the township and operates the only public water-supply system.

Population and Economic Development

The village of Elsie is a small rural community which serves a thriving agricultural area. The population of Elsie, according to preliminary figures of the 1960 census, is 943. The village and township population has remained relatively static since 1940.

The economy of the area is related principally to its agricultural resources. General farming and related enterprises, including the processing of dairy products, provide most of the cash income. Some of the residents of the area commute to jobs in nearby industrial centers. The township is served by a network of improved county roads and by the Ann Arbor Railroad (fig. 3).

Physiography and Drainage

The topographic features of the Elsie area result principally from erosional and depositional processes associated with the glaciation of Michigan. The main topographic features are the relatively level lake plains and till plains, the glacial outwash channels and deltas, and the moderately hilly area of the Flint moraine (see fig. 5). Minor topographic

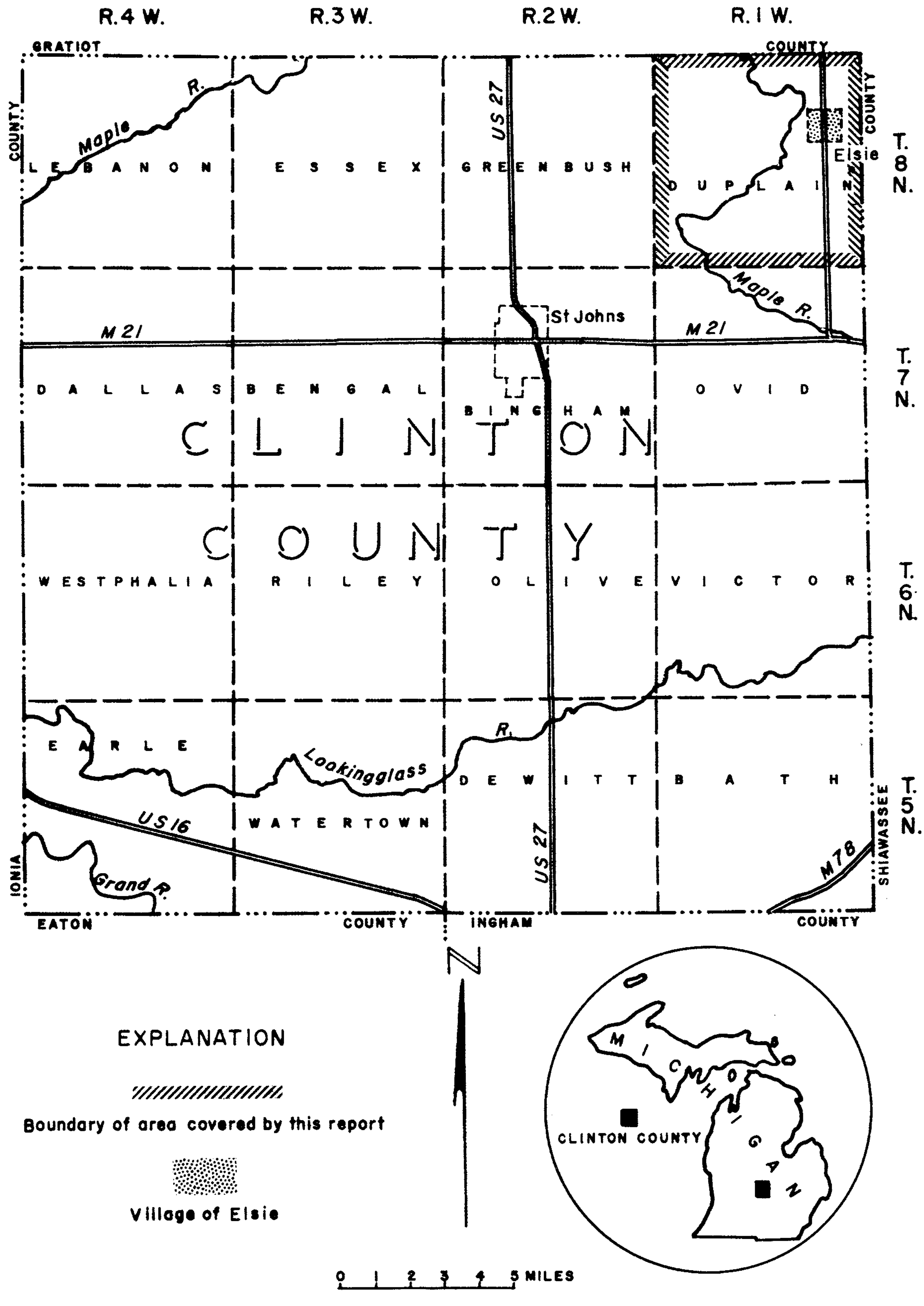

Figure 1. Index map showing location of the Elsie area, Michigan

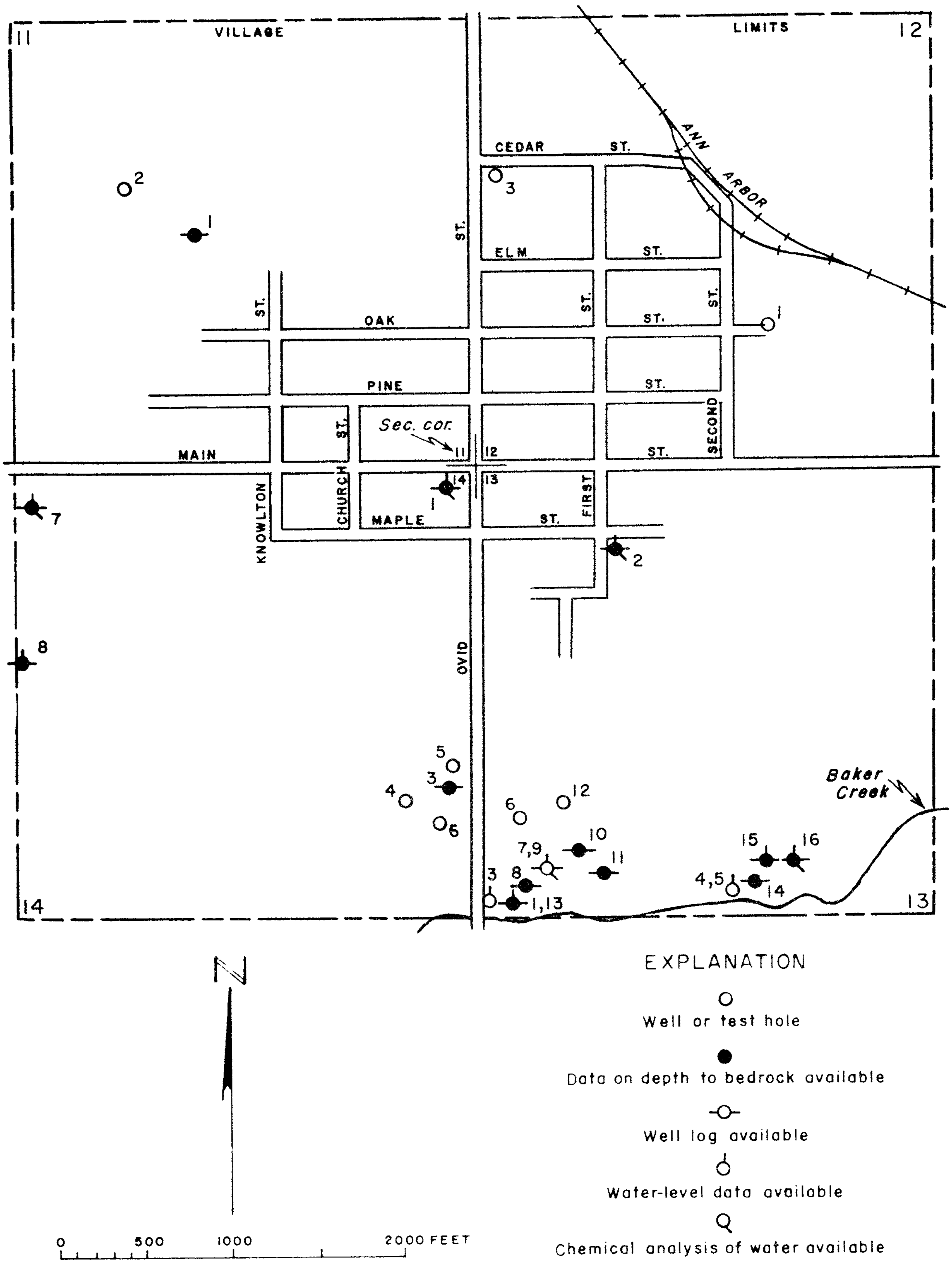

Figure 2. Map of the village of Elsie showing location of wells

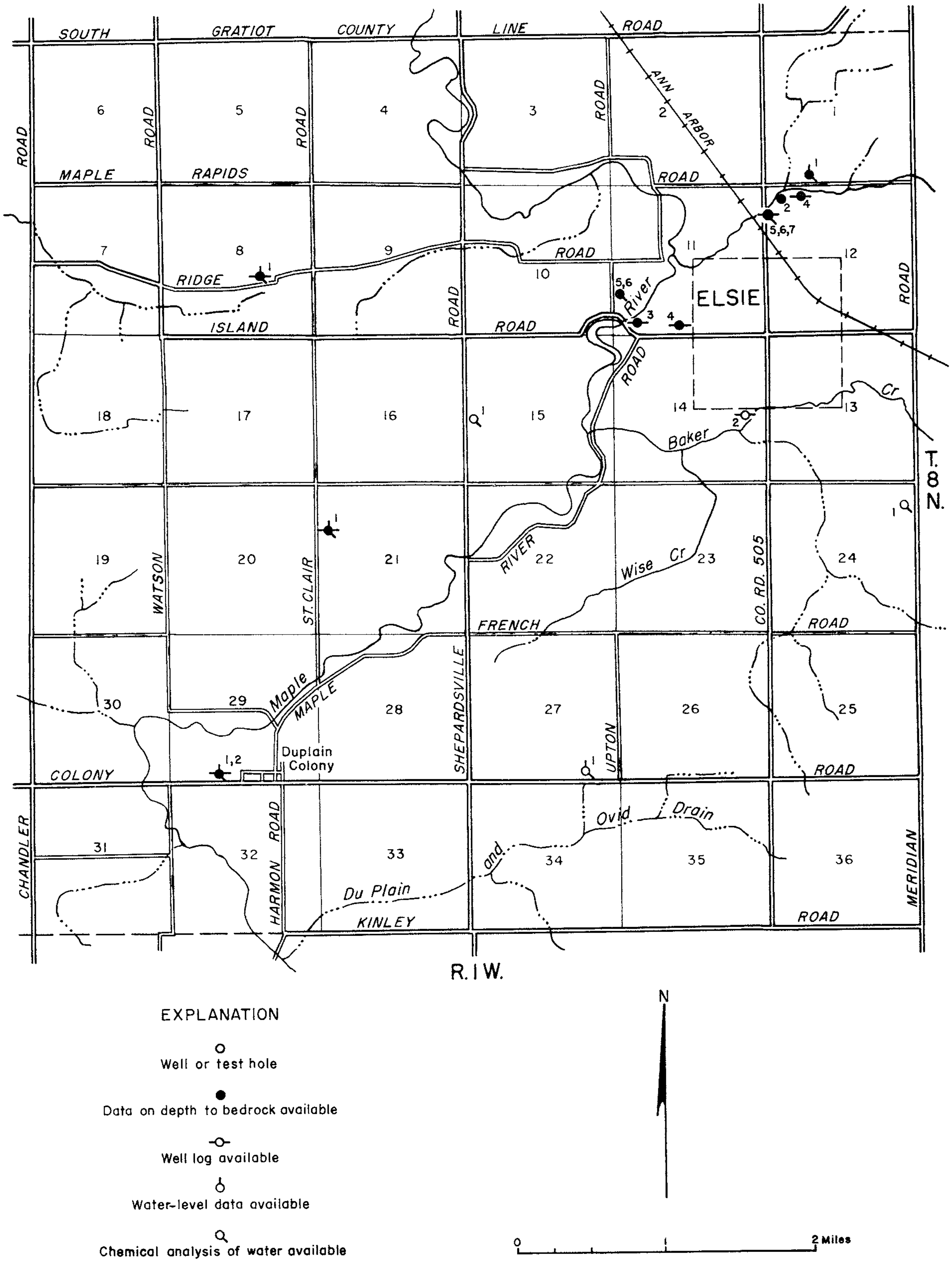

Figure 3. Map of Duplain Township showing location of wells outside the village of Elsie

features include bars, beaches, and other shoreline features of the glacial lakes that once covered the area.

The area in general is one of low relief. The highest hills are slightly above 800 feet. The lowest point (about 670 feet) is along the Maple River where it flows out of the township.

The township is drained by the Maple River, which is tributary to the Grand River. The Maple River flows northward along the courses of former glacial meltwater streams. In the vicinity of Elsie the direction of flow of the river is opposite to the direction of flow of the original glacial stream. Drains have been constructed throughout the area to improve the land for agricultural purposes.

Climate

Climatological data from the nearby city of Owosso in Shiawassee County provide an index to the climate of the Elsie area. They indicate a mean annual temperature of 49°F, ranging from a mean of 26° in January and February to 72° in July. The average date of the last killing frost in the spring is May 12, and of the first in the fall, October 2. Extremes of temperature have ranged from a low of -20° in February 1934 to 105° in July 1936. Winters have an average of 5 days with temperatures of 0° or lower. Only one summer out of four has a temperature of 100° or higher.

Annual precipitation averages 29.3 inches and ranges from a monthly low of 1.6 inches in February to a high of 3.5 inches in June. It is fairly well distributed during the year, although it is somewhat heavier during the growing season. Snowfall averages about 37 inches.

Table 1.--Hydrology of aquifers in the Elsie area

AGE			SUBDIVISION		THICKNESS (feet)	LITHOLOGY	HYDROLOGY
Cenozoic	Quaternary	Pleistocene (Wisconsin)	Glacial-lake deposits	Glacial Drift	35 to 200±	Well-sorted stratified sand and clayey silt.	Generally not a source
			Outwash			Well-sorted sand and gravel.	A source of moderate to large supplies of water.
			Till			Unsorted mixture of sand and gravel in a silt and clay matrix.	Not a source of water.
Paleozoic	Pennsylvanian		Grand River formation		0 to 50	Red sandstone, siltstone and shale.	Beds of sandstone yield small supplies of of water.
			Saginaw formation		300 to 400±	White and gray sandstone; black, blue, and gray shale; locally includes a few thin beds of limestone and (or) coal.	Beds of sandstone yield small to moderate supplies of water.

GEOLOGY

The area is underlain by unconsolidated sand, gravel, clay, and silt of glacial origin. These glacial deposits mantle a thick sequence of Paleozoic bedrocks. The upper 400-500 feet of this sequence is composed of beds of shale and sandstone of the Saginaw and Grand River formations (table 1).

Summary of Geologic History

The bedrock formations underlying the area were deposited in inland seas that covered the Southern Peninsula of Michigan during Paleozoic time. These marine sediments include sandstone, shale, limestone, gypsum, and salt. The uppermost bedrock formations, the Saginaw and Grand River, are composed principally of sandstone and shale.

The Elsie area was covered by the ice of large continental glaciers at least four times during the glacial (Pleistocene) epoch. During the melting stage of the last (Wisconsin) glacier a thick mantle of glacial drift was deposited over the bedrock surface.

As the Wisconsin glacier melted, its water flowed into glacial channels or spillways. As the glacier receded, the drainage system for the glacial meltwaters constantly changed. New outlets at lower elevations developed, leaving the older outlets "high and dry". Thus, the glacial drainage systems have a complex history. The Imlay Channel in the southwestern part of the area (see fig. 5) was one of the principal drainageways for the glacier in southeastern Michigan. The streams presently flowing through the glacial drainageways are much smaller than the original meltwater streams.

GROUND WATER

Ground water is the water contained in the rock strata that form the earth's crust. Most ground water is contained in, and moves through, the interstices (openings) between the individual rock particles, although in some formations water is contained in openings along fractures and solution channels. Nearly all rock formations contain water, but only those in which the openings are interconnected will yield water to wells.

A rock formation, part of a formation, or group of formations that yields water in usable quantities is called an aquifer. The imaginary surface connecting all points to which water would rise in wells tapping an aquifer is called the piezometric surface. Aquifers may be classed as water-table or artesian. In a water-table aquifer, ground water is unconfined; its surface is termed the "water table" and may be considered to be the piezometric surface of that aquifer. In an artesian aquifer, ground water is confined under pressure between relatively impermeable strata. Under natural conditions, the water in a well that is finished in an artesian aquifer will rise above the top of the aquifer. In topographically low areas, wells tapping artesian aquifers may flow at the land surface.

A measure of the capacity of an aquifer to transmit water is called its transmissibility. The coefficient of transmissibility (T) is defined as the number of gallons of water per day, at the prevailing temperature, that will move through a vertical strip of the aquifer 1 foot wide and of a height equal to the thickness of the aquifer under a hydraulic gradient of 100 percent, or 1 foot per foot. The field coefficient of permeability is equal to the coefficient of transmissibility

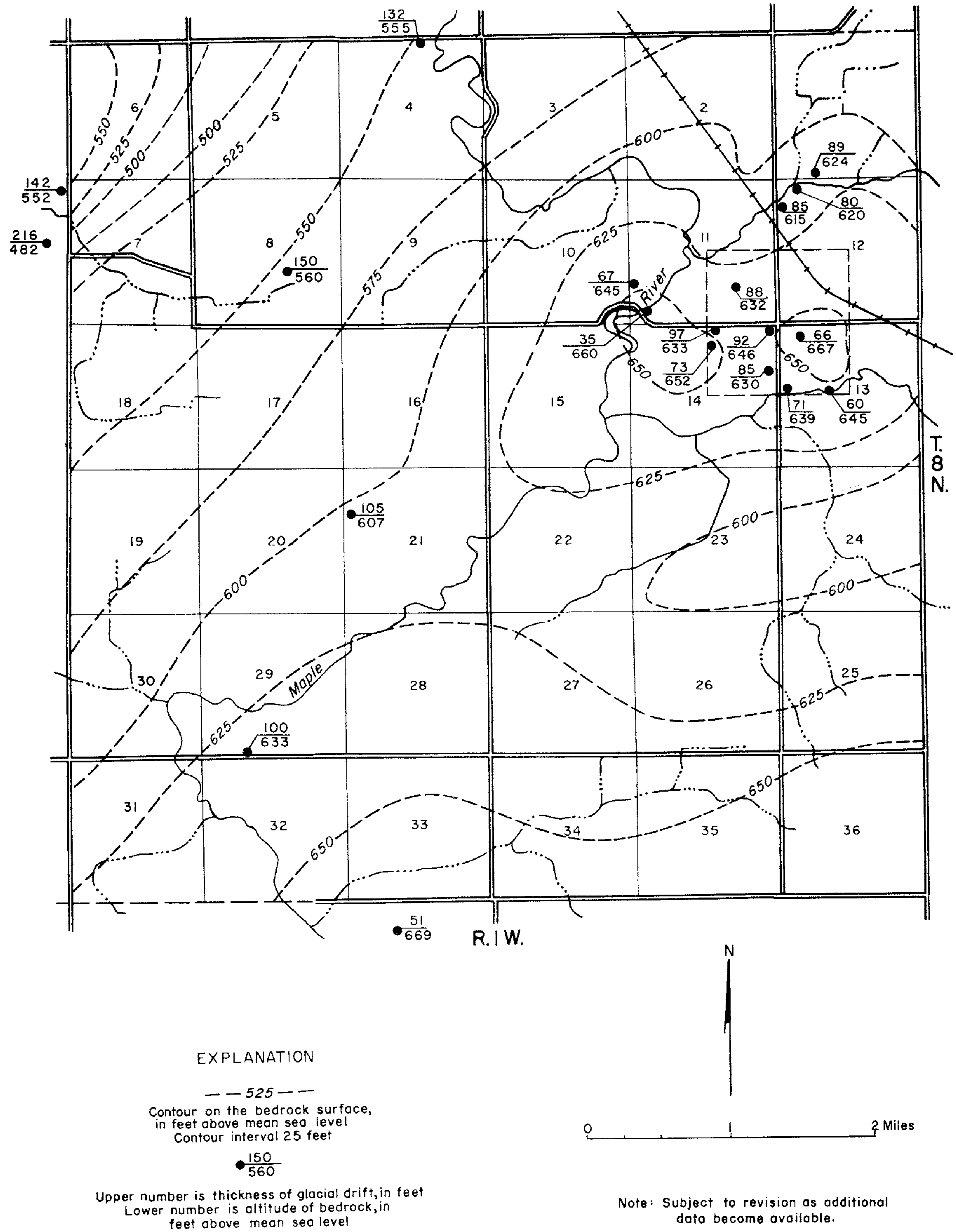

Figure 4. Map showing generalized contours on the bedrock surface of the Elsie area

divided by the thickness of the aquifer in feet. The yield of a well is a function of the transmissibility of the aquifer and the efficiency of the well.

Ground Water in Consolidated Rocks

The Saginaw and Grand River formations, which are the uppermost of the consolidated rock formations of the Elsie area, yield fresh water to wells (table 2). The Saginaw formation underlies all the area. Locally, the overlying Grand River formation has been partly removed by erosion, and data are not available to delineate accurately the areas where it is present.

The surface of the Saginaw formation is irregular, even where it is overlain by the Grand River formation. The bedrock formations slope generally to the northwest as does the bedrock surface (fig. 4).

Saginaw Formation of Pennsylvanian Age

The Saginaw formation is composed principally of sandstone and shale, and includes a few thin beds of limestone and coal. (See table 3, wells 13-2 and 14-1.) The sandstones are white to gray and the shales are commonly black or gray, although blue shales have been reported. It is probable that the formation has a minimum thickness of at least 300 feet throughout the area. The maximum thickness in the township is not known; however, well 13-2 penetrated 420 feet of the Saginaw formation.

The sandstone beds in the upper part of the Saginaw are a source of fresh water, but the deeper beds yield salty water. The yield of wells tapping the Saginaw formation varies greatly, depending principally upon the amount of sandstone penetrated, the permeability of the individual beds of sandstone, and the diameter of the wells. In the immediate vicinity of Elsie the formation yields small to moderate supplies of water. Data from adjacent areas indicate that the formation may yield large supplies of water locally within Duplain Township. However, test drilling and aquifer testing would be needed to evaluate the potential of the aquifer properly throughout the township. The Saginaw formation is an important source of water for domestic and stock needs in the area. Two of the village supply wells at Elsie also obtain water from this formation.

Grand River Formation of Pennsylvanian Age

The Grand River formation consists principally of red sandstone, which occupies channels cut into the shale and sandstone of the Saginaw formation (Michigan Geological Society, 1954). In some parts of the Elsie area the formation has been completely removed by erosion or remains as a veneer over the rocks of the Saginaw formation. Data are inadequate, however, for determining the thickness and areal extent of the remnants of the formation throughout Duplain Township. In some places, as much as 50 feet of the formation has been penetrated by wells (table 3, logs 8-1, 12-7, 13-2). In the vicinity of the village of Elsie the formation is reported to contain layers of red shale. Locally, the Grand River formation is sufficiently thick and permeable to provide ample water for domestic and farm needs.

Ground Water in the Glacial Drift

The glacial sediments of the area consist of clay, silt, sand, and gravel that were deposited by continental glaciers. The deposits are of three main types: till, which was deposited directly from glacial ice; lake deposits, which were laid down in ancient glacial lakes; and outwash, which was deposited by glacial meltwater streams. Figure 5 shows the type of glacial deposits present at the surface in the Elsie area. Although the map is a general aid in locating water supplies, it does not everywhere indicate the type of glacial deposit that may be present at depth. Wells tapping the glacial deposits commonly are shallower and cheaper than bedrock wells, but they generally require more maintenance. As a result some wells are completed in bedrock aquifers even though the drift is permeable and will yield water.

Till Deposits

Till is a heterogeneous mixture of rock debris ranging in size from clay to boulders. The till plains of the area are underlain by clayey and silty till with some sand and gravel. Locally, these till deposits mantle or include beds of permeable sand and gravel that are a source of water. The presence of such beds can be determined only by test drilling or geophysical means. If only moderate supplies are needed, an investigation to determine the presence of these beds would not be economically justified, as water can be obtained from the bedrock aquifers at reasonable cost. Apparently, the till underlying the Flint moraine in the southern part of the area is of greater permeability and includes more beds of sand and gravel than the till deposits in the northern part

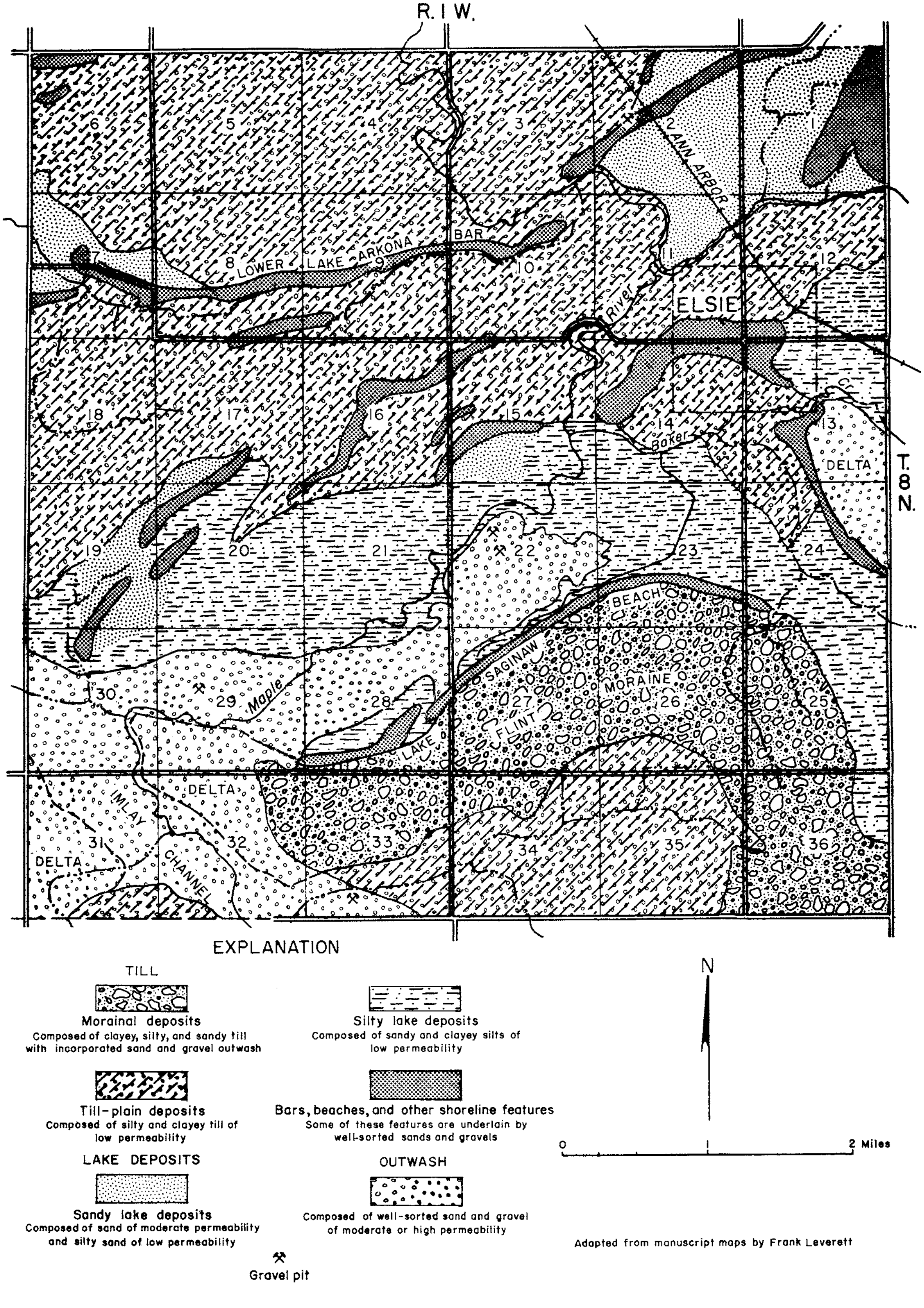

Figure 5. Surficial geology of the Elsie area

of the township. Most of the wells in the area of the Flint moraine are completed in shallow sand and gravel.

Lake Deposits

Much of Duplain Township is underlain by sediments deposited in the glacial lakes that once covered most of the area. The lake deposits generally form a veneer over other glacial sediments in the areas mapped as lake plain on figure 5. Bars and beaches were built up along the shores of the lakes. Ridge Road in the northern part of the report area runs along the top of a beach formed along the shore of glacial Lake Arkona.

Most of the lake deposits of the area consist of silty and sandy clay. Locally, however, they are composed principally of sand, and will yield water to shallow dug or driven wells. However, such wells are readily contaminated by farm and other sanitary wastes, and thus may not be satisfactory sources of water supply.

Locally, the lake deposits overlie sand and gravel outwash that yields moderately large supplies of water.

Outwash

Glacial outwash is rock material that was washed out of the melting glacier and deposited in the channels of meltwater streams. Outwash deposits are composed principally of well-sorted sand and gravel, the finer material having been carried downstream by running water.

Outwash occurs in the channels of meltwater streams and in deltas where the streams emptied into glacial lakes. Most of the courses of the larger meltwater streams, such as the Imlay channel in the southern part of the area (fig. 5), can still be recognized. However, some of the glacial drainage channels have been buried by later glacial action, especially by deposition in the glacial lakes. The largest deposits of outwash are in the southwestern part of the township, where sand and gravel is being removed from several pits for construction aggregate and road metal.

A few wells are completed in outwash at shallow depth along the courses of old meltwater streams and in outwash deltas. The log of well 29-1 shows gravel from the surface to a depth of 50 feet in a large outwash delta in the southwestern part of the area. Well 24-1, which is drilled in an outwash delta southeast of Elsie, penetrated 38 feet of sand and gravel.

Two wells used as a source of municipal supply at Elsie tap a stringer of outwash within a deposit of glacial till. Well 13-16 (Elsie well 5) which taps this aquifer, yielded 650 gpm (gallons per minute) when first drilled. Although the aquifer would not allow for continued pumping at this rate because of its limited width, it provides much of the village's water supply. An aquifer (pumping) test was conducted in September 1947 to determine the hydraulic characteristics of this aquifer. Well 13-7 (Elsie well 4) was pumped at a constant rate for several days and then shut down for 4 hours. Recovery of the water level was measured in observation well 13-3 (Elsie well 3). Then, well 13-7 was pumped at a rate of 120 gpm for about 1 day and the resulting decline in water level was measured in the observation well.

The test indicated that the coefficient of transmissibility of the aquifer is in the range of 7,000 gpd (gallons per day) per foot and the storage coefficient is 0.0002. The log of well 13-7 shows that the aquifer consists of about 20 feet of permeable sand and gravel, indicating that the aquifer materials have an average field coefficient of permeability of 350 gpd per foot.

Test drilling at this location revealed that the aquifer is bounded on the north and south by materials of low permeability. The aquifer test indicated the presence of at least one impermeable boundary. The presence of additional boundaries probably was obscured by induced recharge from Baker Creek.

Ground-Water Phase of Hydrologic Cycle

Recharge

The drift aquifers of the Elsie area are recharged directly from precipitation. In general, precipitation readily infiltrates into the sandy soils of the outwash and sandy lake plains. Runoff is greatest from the clayey and silty soils elsewhere in the township. The bedrock aquifers, which do not crop out at the surface, are recharged indirectly through leakage from the glacial drift.

Movement

Ground water moves by gravity from high areas to low areas, as does water on the surface. Ground water moves more slowly than surfact water, however, owing to friction between the water and the earth materials through which it moves. The movement of water in the bedrock aquifers is generally from the southeast to the northwest (fig. 6) except in the vicinity of the village of Elsie, where the ground-water gradients have been altered by municipal pumping. The pumping of the village wells has created a localized cone of depression in the piezometric surface.

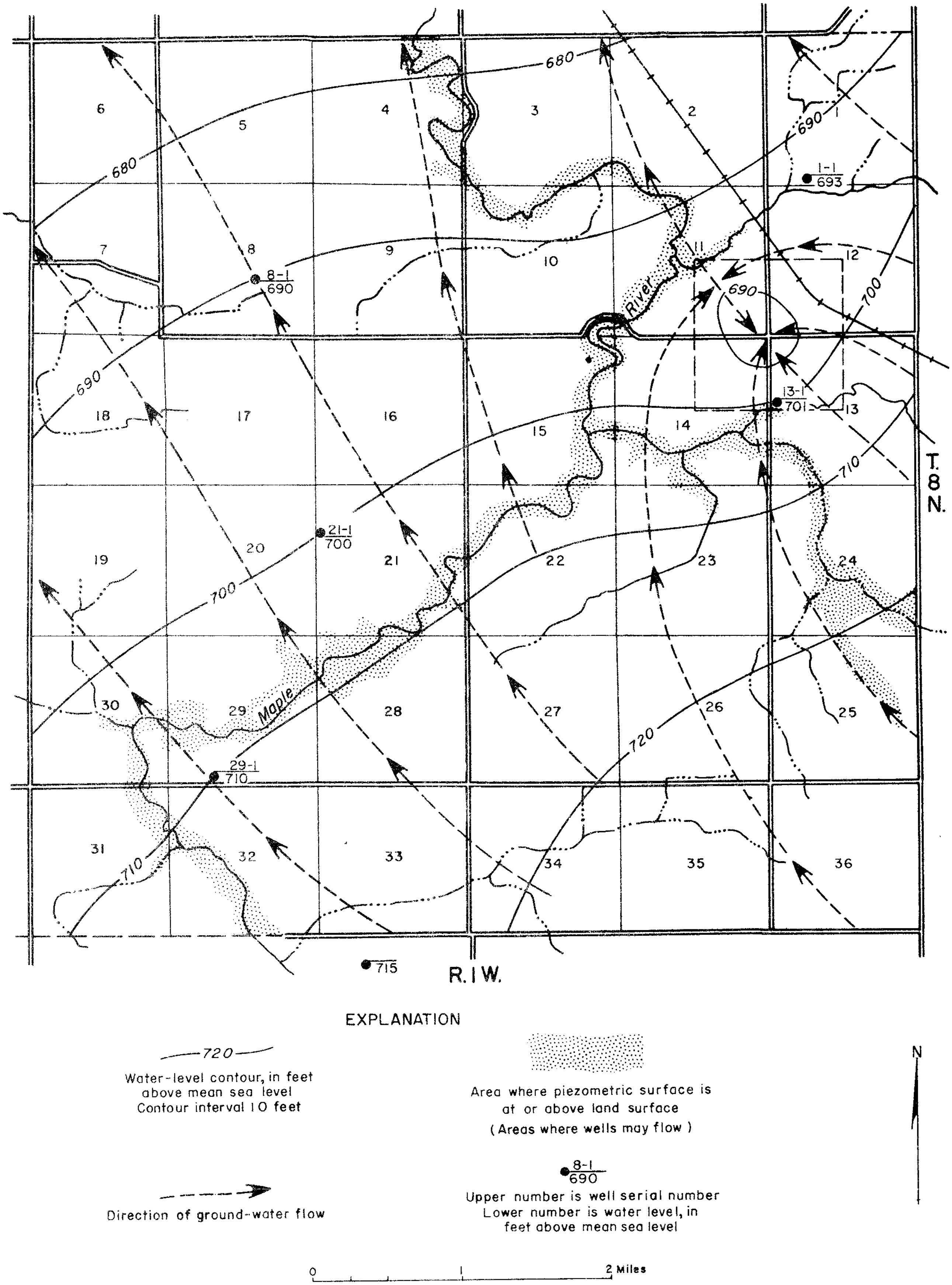

Figure 6. Hydrologic map of the bedrock aquifers in the Elsie area

The piezometric surface of the bedrock aquifers slopes to the northwest in conformance with the regional gradient of the land surface. The water table in the drift aquifers conforms roughly to the local topography and ground water moves generally toward the streams and ditches draining the area. Thus, the direction of movement of water in the shallow drift aquifers locally may be opposite to that in the deeper bedrock aquifers. Although local cones of depression in the drift aquifers undoubtedly have developed as a result of pumping in and near Elsie, not enough data are available for the preparation of a map showing water-table contours.

Discharge

Ground water is discharged via springs and seeps along streams and drains, through evapotranspiration, and also by pumping from wells. The quantity of water pumped from wells, however, is only a small part of the total ground water discharged in the area. Most of the water discharged by wells in the township is pumped from the village supply wells at Elsie.

Water Levels

Water levels in this area fluctuate in response to changes in the times and amount of precipitation falling in the area and to changes in the rate of withdrawals of water from wells. Although water levels decline somewhat during dry years, they recover during periods of above-normal rainfall. As no long-term climatic changes have been noted in this area, it can be assumed that no significant changes in the water table or piezometric surface have occurred except for those incidental to municipal pumping at Elsie or to drainage of agricultural land.

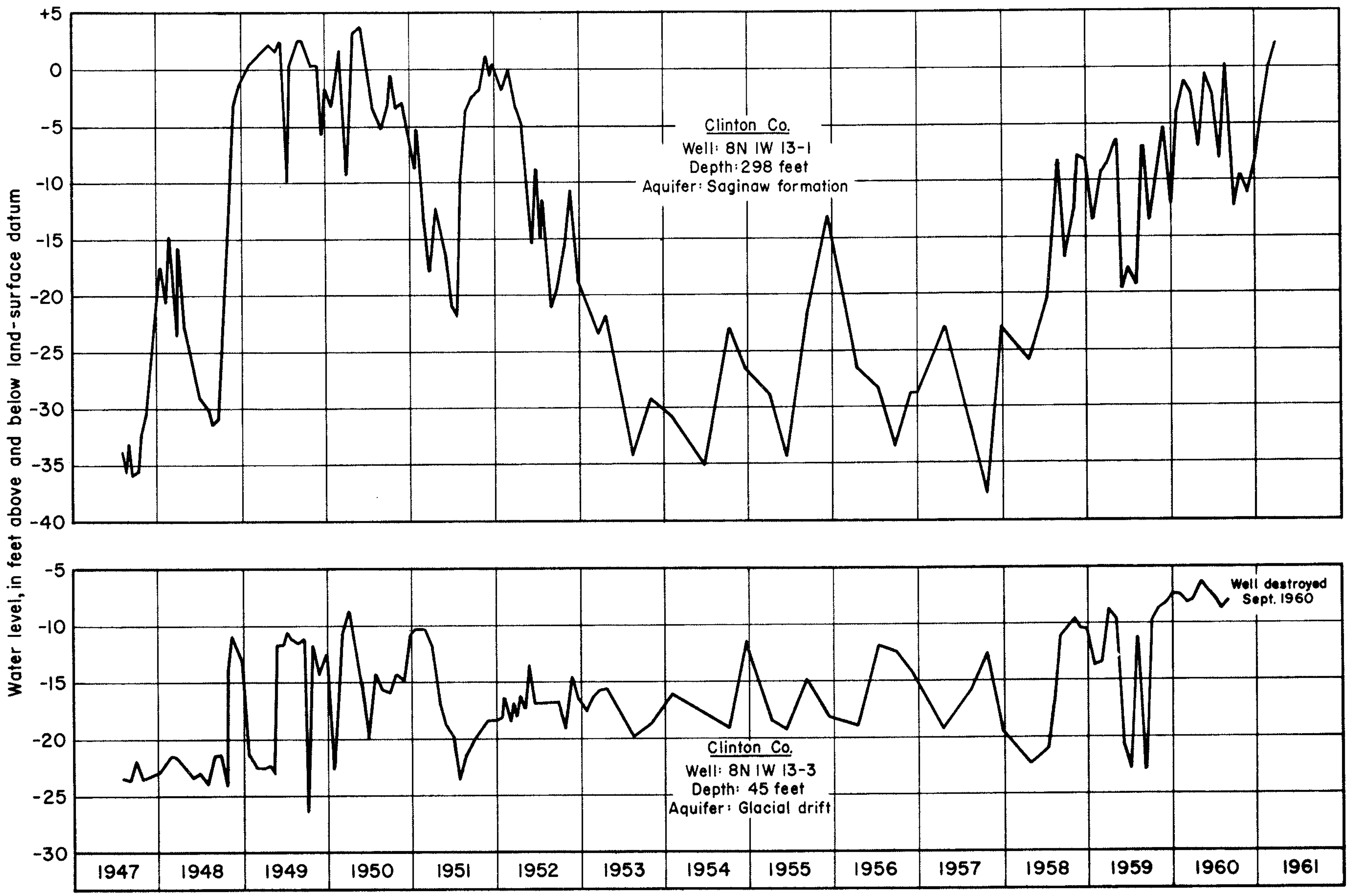

Figure 7. Hydrographs of two wells in the Elsie area

Throughout most of the area, water is pumped only for domestic and stock use and the pumping is not concentrated, so that the lowering of water levels by pumping is negligible.

Water levels decline during periods of heavy pumping by the village. The hydrograph of well 13-1 (fig. 7) indicates that withdrawal of water from the municipal wells tapping the Saginaw formation caused a significant decline in water levels during the periods 1947-48 and 1951-57. The upward trend in water levels in the period 1958-61 resulted chiefly from a decrease in the amount of water pumped. In early 1961, the water level in well 13-1 rose above land surface, for the first time in 10 years.

The hydrograph of observation well 13-3 shows that the water levels in the glacial aquifer tapped by the village wells have generally risen during the period of record. The highest water levels were measured in 1960.

The period 1949-52 was one of above-normal rainfall in Michigan. This is reflected in the higher water levels shown on both hydrographs during this time. Such a period of above-normal rainfall provides additional recharge to the aquifers and reduces the water demand for lawn and garden irrigation and other uses.

Chemical Quality

Water percolating through soils and rocks dissolves some of the material with which it comes in contact. The amount and character of the dissolved mineral matter in ground water depend on the chemical and physical composition of the soils and rocks through which the water moves, the duration of the contact, and other factors such as temperature, pressure, and amount of mixing, if any, with highly mineralized connate water (water entrapped at the time the sediment was deposited).

The ground water of the Elsie area is typical of the ground water in the southern part of the Southern Peninsula of Michigan. The principal chemical constituents are calcium, magnesium, and bicarbonate. However, significant amounts of sodium, sulfate, and chloride are present in some water in the area (table 4).

The hardness property of water is of special interest to most users of water. Although hardness of water is attributable to many cations--free acid, heavy metals, and the alkaline earths--it is chiefly attributable to the two alkaline earths, calcium and magnesium. Hardness of water has been classified by the Michigan Department of Health (1948) as follows:

Class	Hardness (parts per million)
Very soft	less than 50
Soft	50-100
Moderately hard	100-200
Hard	200-300
Very hard	more than 300

In terms of the preceding classifications, most of the water samples collected were hard to very hard. The only sample that had a hardness of less than 200 ppm was from well 15-1 (table 4), which is 209 feet deep and is believed to tap the Grand River formation. Only a few analyses of water from the Grand River formation are available, and hence it is not known whether water from this formation is generally softer than water from the other aquifers in the Elsie area.

Iron and manganese are objectionable in water because they produce staining and impart an unpleasant taste. More than 0.2 ppm of iron will cause staining, and total iron and manganese content greater than 0.3 ppm is considered objectionable. The U. S. Public Health Service (1961) recommended limit for iron is 0.3 ppm and for manganese it is 0.05 ppm. Iron content varied considerably. However, most of the samples analyzed contained objectionable quantities of iron.

Chlorides are objectionable in water because they produce a salty taste and are corrosive to water systems. The U. S. Public Health Service (1961) recommends that water containing more than 250 ppm of chloride not be used for water supply if other more suitable supplies are available. Chloride content of the water sampled ranged from less than 1 to 145 ppm. Water samples from the drift aquifers contained less than 40 ppm of chloride whereas those from the Saginaw Formation ranged from 8 to 145 ppm. Most of the water samples from the village wells tapping the Saginaw formation contained more than 100 ppm of chloride. The small chloride content of the sample taken from well 12-7 (8 ppm) is due to the fact that the well is seldom used, hence water high in chloride content has not migrated from below. Well 13-2 (Elsie well 2) reportedly was abandoned because it yielded water containing more than 250 ppm of chloride. Data substantiating this report are not available. However, at depth the Saginaw contains mineralized water that tends to migrate upward to heavily pumped wells. Well 13-2 was drilled to a greater depth than the other village wells tapping the Saginaw formation, and as a result the mineralized water was more readily induced to migrate to the well.

Sulfates in excess of 250 ppm are considered objectionable. None of the samples had a sulfate content greater than 150 ppm.

Apparently, a few wells in the Elsie area yield red water from the Grand River formation. The red color probably is due to a suspension of red clay in the water.

SUMMARY AND CONCLUSIONS

Fresh ground water in the Elsie area can be obtained from wells tapping beds of sandstone in the Saginaw and Grand River formations and also from sand and gravel in the glacial-drift deposits that mantle the bedrock formations. These aquifers supply all the water needs in the township.

Although water can be obtained from the Saginaw formation throughout the township, it is less costly to tap shallower overlying aquifers. Locally, however, water cannot be obtained from the shallow strata.

The ground water of the area is hard (hardness of water ranges from 124 to 425 ppm) and commonly contains enough iron to cause some staining of plumbing fixtures; otherwise the water is satisfactory for most uses. The objectionable characteristics of the water can be removed by common water treatment methods.

The wells supplying the village of Elsie tap the Saginaw formation or the glacial drift. Although the village wells tapping the Saginaw yield moderate supplies of water, the formation is not highly permeable in the vicinity of Elsie. Any large additional development from the Saginaw would result in excessive lowering of water levels and possible deterioration in chemical quality of the water produced. The glacial-drift aquifer presently tapped by two of the village wells is of relatively small areal extent. Increased withdrawals from this aquifer would not be practical because of the interference between wells.

The rising water levels in the aquifers tapped by the village wells indicate that existing water-supply facilities are adequate for present village needs and some additional development. Any large increase in water demands, however, would call for the development of additional sources of water supply. Test drilling and other studies indicate that additional sources would have to be obtained outside the present village limits. The outwash deposits underlying the delta southeast of the village appear to be favorable for development of supplemental supplies.

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Table 2.--Records of wells and test holes in the Elsie area.

Location: Wells outside of the village of Elsie are located to either 10 or 40-acre tracts within the sections. Wells within the village are located by distance and direction from designated street or road intersections; by the intersection of roads and the village limits; or distance and direction from other landmarks.

Aquifer:
- Qs - Glacial sand of Pleistocene (Quaternary) age
- Qg - Glacial gravel of Pleistocene (Quaternary) age
- Qsg - Glacial sand and gravel of Pleistocene (Quaternary) age
- Pg - Grand River formation of Pennsylvanian age
- Ps - Saginaw formation of Pennsylvanian age

Use: D, domestic; I, industrial; O, observation; P, public supply; S, stock or other farm use; T, test for water supply.

Water level: In feet below or above (+) land-surface datum; M, measured; R, reported.

Altitude: In feet above mean sea level.

Well number	Location	Owner	Driller	Owners number	Date Drilled	Diameter	Depth	Aquifer	Use	Water level	M or R	Date	Altitude	Remarks
8N 1W														
1-1	SW¼ SE¼ SW¼ sec. 1	Cecil Hammond	Oberlietner Bros.	-	1958	3	223	Ps	D,S	11	R	1958	704	Bedrock at 80 ft.
8-1	NW¼ SE¼ sec. 8	Donald Clark	Charles Archer		1960	3	200	Pg	D	20	R	1960	710	Bedrock at 150 ft.
11-1	1590 ft W. of Ovid, 1350 ft N. of Main	Village of Elsie	Layne Northern	TW 19	1947	6	93	Qg	T	-	-	-	720	Bedrock at 88 ft.
11-2	2000 ft W. of Ovid, 1650 ft N. of Main	do.	do.	TW 20	1947	6	83	Qg	T	-	-	-	710	
11-3	SW¼ SW¼ SW¼ sec. 11	do.	Ohio Drilling Co.	TW 7	1944	3	39	-	T	-	-	-	700	Bedrock at 35 ft.
11-4	100 ft N of Main, 400 ft W. of village limits	do.	do.	TW 4	1943	3	106	Qs	T	-	-	-	722	Bedrock at 90 ft.
11-5	SW¼ NW¼ SW¼ sec. 11	A. J. Bernath	Oberleitner Bros.	-	-	2	299	Ps	D	-	-	-	710	
11-6	SW¼ NW¼ SW¼ sec. 11	do.	-	-	-	2	71	Pg	S	-	-	-	700	Bedrock at 67 ft.
12-1	230 ft E. of Second, 320 ft S. of Elm	Clinton Creamery	Miller Bros.	-	-	10	621	Ps	T	-	-	-	728	Cased to 120 ft. Destroyed
12-2	NW¼ NW¼ NW¼ sec. 12	W. E. Castor	-	-	1931	6	670	Ps	T	-	-	-	696	Bedrock at 92 ft.
12-3	150 ft E. of Ovid, 100 ft S. of Cedar	Village of Elsie	Ohio Drilling Co.	TW 6	1944	3	35	Qs	T	-	-	-	720	
12-4	825 ft E. of Ovid, 300 ft S. of Maple Rapids	do.	Layne Northern	TW 57B	1957	-	150	-	T	-	-	-	700	Bedrock at 80 ft.
12-5	230 ft E. of Ovid, 700 ft S. of Maple Rapids	do.	do.	TW 57C	1957	8	62	Qs	T	-	-	-	695	
12-6	224 ft E. of Ovid, 700 ft S. of Maple Rapids	do.	do.	TW 57D	1957	8	71	Qs	T	-	-	-	700	Bedrock at 71 ft.
12-7	130 ft E. of Ovid, 800 ft S. of Maple Rapids	do.	do.	PW 6	1957	8	325	Ps	T	-	-	-	700	Bedrock at 85 ft.
13-1	70 ft N. of Baker Creek Bridge, 230 ft E. of Ovid	do.	-	-	-	12	298	Ps	O	+2.12	M	3-31-61	699	
13-2	750 ft E. of Ovid, 440 ft S. of Main	do.	Ohio Drilling Co.	PW 2	1939	8	536	Ps	P,Q	42	R	1939	733	Abandoned and plugged.
13-3	60 ft E. of Ovid, 105 ft N. of S. village limits	do.	-	PW 3	1947	12	45	Qg	O	23.5	R	8- 5-47	706	Drilled for public supply but never used.
13-4	1500 ft E. of Ovid, 150 ft N. of S. village limits	do.	-	-	1948	1.25	25	Qs	O	13.57	M	9- 1-51	700	
13-5	1500 ft E. of Ovid, 150 ft N of S. village limits	do.	-	-	1948	1.25	60	Qs	O	15.19	M	8-25-48	705	
13-6	275 ft E. of Ovid, 575 ft N. of S. village limits	do.	Ohio Drilling Co.	TW 15	1946	3	64	Qs	T	-	-	-	715	
13-7	375 ft E. of Ovid, 270 ft N. of S. village limits	do.	do.	PW 4	1944	12	61	Qg	P	12.6	R	8-31-44	710	
13-8	260 ft E. of Ovid, 150 ft N. of S. village limits	do.	do.	TW 8	1944	3	74	-	T	-	-	-	707	Bedrock at 71 ft.
13-9	375 ft E. of Ovid, 270 ft S. of village limits	do.	do.	TW 9	1944	3	65	Qg	T	-	-	-	712	PW 4 drilled at this site.
13-10	590 ft E. of Ovid, 360 ft N. of S. village limits	do.	do.	TW 10	1946	3	62	-	T	-	-	-	715	Bedrock at 60 ft.
13-11	720 ft E. of Ovid, 225 ft N. of S. village limits	do.	do.	TW 11	1946	3	57	-	T	-	-	-	710	Bedrock at 57 ft.
13-12	500 ft E. of Ovid, 665 ft N. of S. village limits	do.	do.	TW 12	1946	3	60	Qs	T	-	-	-	718	
13-13	300 ft SE of well 13-7 (PW 4)	do.	do.	TW 13	1946	3	52	-	T	-	-	-	700	Bedrock at 52 ft.
13-14	1600 ft E. of Ovid, 110 ft N. of Baker Creek	do.	Layne Northern	TW 21	1947	6	61	Qs	T	-	-	-	705	Bedrock at 60 ft.
13-15	1675 ft E. of Ovid, 290 ft N. of S. village limits	do.	do.	TW 22	1947	6	65	Qs	T	19	R	9-22-47	705	Bedrock at 60 ft.
13-16	1825 ft E. of Ovid, 200 ft N. of Bakers Creek	do.	do.	PW 5	1948	34	57	Qsg	P	6	R	1-13-48	709	Bedrock at 66 ft. Gravel pack construction.
14-1	165 ft W. of Ovid, 90 ft S. of Main	do.	Ohio Drilling Co.	PW 1	1937	8	341	Ps	P	40	R	1937	738	Bedrock at 92 ft.
14-2	250 ft W. of Ovid, 100 ft S. of S village limits	do.	do.	TW 5	1944	3	57	Qs	T	-	-	-	700	
14-3	125 ft W. of Ovid, 720 ft N. of S. village limits	do.	do.	TW 14	1946	3	87	Qsg	T	-	-	-	715	Bedrock at 85 ft.
14-4	385 ft W. of Ovid, 690 ft N. of S. village limits	do.	do.	TW 16	1947	3	74	-	T	-	-	-	715	
14-5	125 ft W. of Ovid, 870 ft N. of S. village limits	do.	do.	TW 17	1947	3	70	-	T	-	-	-	715	
14-6	190 ft W. of Ovid, 520 ft N. of S. village limits	do.	do.	TW 18	1947	3	62	-	T	-	-	-	715	
14-7	NW¼ NE¼ sec. 14	Mich. Milk Producers Assoc.	Mich. Well and Pump Co.	-	1954	8	299	Ps	I	50.25	M	2-10-54	730	Bedrock at 108 ft.
14-8	1500 ft W. of Knowlton, 1125 ft S. of Main	Village of Elsie	Layne Northern Co.	TW 57A	1957	8	105	Pg	T	27	R	10- 9-57	725	Bedrock at 73 ft. Yield adequate for domestic use.
15-1	NW¼ NW¼ SW¼ sec. 15	Emery Alvord	Charles Archer	-	1953	2	209	Pg	D,S	-	-	-	725	
21-1	SW¼ NW¼ sec. 21	Lloyd Whitford	do.	-	1960	3	210	Ps	D	12	R	1960	712	Bedrock at 105 ft.
24-1	SE¼ NE¼ NE¼ sec. 24	Merle Green	-	-	-	4	38	Qg	S	-	-	-	727	
27-1	SW¼ SE¼ SE¼ sec. 27	Charles Walker	-	-	-	24	30	Qsg	D,S	8	R	1961	755	Dug well equipped with sand points.
29-1	SE¼ SW¼ sec. 29	Roy Risley	Charles Archer	-	1960	215	3	Ps	D,S	23	R	1960	733	Bedrock at 50 ft.
29-2	SE¼ SW¼ sec. 29	do.	Roy Risley	-	-	18	1.25	Qg	D	-	-	-	733	Driven well.

Table 3. Logs of wells and test holes, Elsie area

Altitude of land surface, in feet above mean sea level

	Thickness (feet)	Depth (feet)
8-1 Altitude 710		
Glacial drift:		
Clay and gravel	15	15
Clay	27	42
Quicksand	8	50
Clay, brown	80	130
Drift, gravelly	20	150
Grand River (?) formation:		
Sandrock, red	50	200
11-1 Altitude 720		
Glacial drift:		
Soil	2	2
Clay, sandy	6	8
Sand, fine, and coarse gravel	3	11
Clay, sandy, blue	10	21
Sand, fine	5	26
Sand, fine, and gravel	3	29
Clay, sandy, hard	21	50
Gravel, and blue clay	12	62
Sand, medium to coarse	8	70
Sand, fine, with some clay	5	75
Gravel and blue clay	3	78
Sand, fine, with clay	10	88
Grand River formation:		
Rock, white	2	90
Shale, red	3	93
11-3 Altitude 695		
Glacial drift:		
Clay and stones	20	20
Clay, stones, and sand	15	35
Grand River formation:		
Red rock	3	38
11-4 Altitude 722		
Glacial drift:		
Sand	10	10
Sand (water)	5	15
Sand, coarse	5	20
Sand, fine, and clay	3	23
Sand, coarse	3	26
Clay, blue	4	30
Clay, blue, and boulders	5	35
Clay, blue, and stones	3	38
Clay and stones (hardpan)	27	65
Clay, sand and stones	15	80
Sand, clay, and boulders	10	90
Grand River formation(?):		
Sand and clay, red, and stones	13	103
Saginaw formation:		
Shale, blue	3	106
12-4 Altitude 700		
Glacial drift:		
Topsoil	1	1
Clay, brown soft	10	11
Creek bottom, soft	2	13
Clay, gray, and gravel	19	32
Clay, gray, and sand with gravel	15	47
Sand	2	49
Clay, sandy, gray, soft	11	60
Clay, sandy, gray with gravel	20	80
Grand River formation:		
Shale, red with broken sandstone	21	101
Saginaw formation:		
Shale	8	109
Shale with strips of sandstone	9	118
Shale, gray	32	150
12-6 Altitude 700		
Glacial drift:		
Topsoil	1	1
Sand	3	4
Clay, sandy, gray	36	40
12-6 (Continued)		
Sand, gray	15	55
Clay, sandy, gray	5	60
Sand and gravel	11	71
Grand River formation:		
Red shale at		71
12-7 Altitude 700		
Glacial drift:		
Topsoil	1	1
Sand and gravel	4	5
Clay, gray, soft	5	10
Clay, gray, gravelly	28	38
Sand, muddy	2	40
Clay, sandy, hard with gravel	33	73
Clay, sandy, soft	7	80
Clay, sandy, hard	5	85
Grand River formation:		
Sandstone, red, with strips of shale	45	130
Saginaw formation:		
Shale, gray, sandy	4	134
Sandstone	2	136
Shale	37	173
Sandstone, muddy	25	198
Shale, dark	4	202
Sandstone, muddy	26	228
Shale, dark	24	252
Shale	3	255
Sandstone and shale	10	265
Shale, sandy, black	13	278
Shale, sticky	47	325
13-2 Altitude 729		
Glacial drift:		
Sand and clay	11	11
Gravel and clay	10	21
Clay and sand	34	55
Sand, clay, and gravel	10	65
Clay, red, and sand	1	66
Grand River formation:		
Shale, red	49	115
Saginaw formation:		
Shale, blue	50	165
Sandrock	18	183
Shale, gray	15	198
Shale, black	40	238
Sandrock	60	298
Shale, gray	47	345
Shale, black	20	365
Shale, gray	9	374
Limestone shell, brown	20	394
Shale, light-gray	13	407
Sandrock	15	422
Shale, gray	16	438
Lime shells and shale	22	460
Sandrock and shells	16	476
Limerock	4	480
Sandrock	50	530
Limerock	5	535
13-8 Altitude 708		
Glacial drift:		
Clay, yellow, and stones	5	5
Clay, blue, soft, and stones	10	15
Clay and stones	15	30
Clay, blue, soft, and stones	16	46
Sand, some gravel, and clay	3	49
Sand, gravel, and some clay	4	53
Sand with clay	7	60
Clay and stones	5	65
Clay, stones, and red clay	6	71
Grand River (?) formation:		
Sandrock, gray	3	74
13-9 Altitude 712		
Glacial drift:		
Clay, yellow, and stones	10	10
Clay, blue, and stones	10	20
Clay, blue, and sand layers	5	25
13-9 (Continued)		
Clay and stones	10	35
Clay, blue, soft, and stones	5	40
Sand, fine, and clay	2	42
Sand and gravel, very little clay	4	46
Gravel, very good	4	50
Gravel, some clay, very loose	4	54
Gravel and sand	3	57
Gravel, and sand with some clay	5	62
Clay and sand	3	65
13-10 Altitude 715		
Glacial drift:		
Clay, yellow, and stones	10	10
Clay, blue, and stones	15	25
Clay and stones	25	50
Clay and boulders	2	52
Clay, red, and stones, boulders	3	55
Clay, red, and stones	5	60
Grand River formation:		
Sandrock, soft	2	62
13-11 Altitude 710		
Glacial drift:		
Clay, yellow, and stones	13	13
Clay, blue, and stones	7	20
Clay and stones	25	45
Clay, soft, and stones	5	50
Clay and stones	7	57
Grand River formation:		
Sandrock, soft, at		57
13-13 Altitude 700		
Glacial drift:		
Clay, yellow, and stones	5	5
Clay, blue, and stones	25	30
Clay, soft, and stones	17	47
Sand, red	4	51
Clay, red	1	52
Grand River formation:		
Sandrock at		52
13-14 Altitude 705		
Glacial drift:		
Topsoil	1	1
Clay, brown	15	16
Gravel, coarse	10	26
Clay	10	36
Sand, fine, white	6	42
Sand, coarse	18	60
Grand River formation:		
Sandstone, red	1	61
13-15 Altitude 705		
Glacial drift:		
Topsoil	1	1
Clay, gray	14	15
Gravel, muddy	5	20
Clay, gray	25	45
Sand, white, muddy	5	50
Sand, white, clean	10	60
Grand River formation:		
Sandrock, red, muddy	5	65
13-16 Altitude 709		
Glacial drift:		
Topsoil	1	1
Clay, very hard	13	14
Gravel, coarse	1	15
Gravel, coarse (water)	5	20
Clay, sandy, hard, gravelly	11	31
Sand, fine	19	50
Sand, medium to coarse and fine gravel	6	56
Gravel, coarse, with fine sand	10	66
Grand River formation:		
Sandstone, red, at		66

Table 3. Logs of wells and test holes, Elsie area.--Continued

	Thickness (feet)	Depth (feet)
14-1 Altitude 738		
Glacial drift:		
Sand	7	7
Clay and gravel	85	92
Clay, red, and sand	5	97
Grand River formation:		
Sandrock, red, soft	27	124
Saginaw formation:		
Shale, soft	8	132
Shale, firm	70	202
Coal, with fine clay	3	205
Shale	43	248
Sandrock	76	324
Shale	17	341
14-2 Altitude 700		
Glacial drift:		
Clay and stones	36	36
Clay, sand, and gravel (some water)	4	40
Clay, stones, and sand	17	57
14-3 Altitude 715		
Glacial drift:		
Clay, yellow, and stones	7	7
Clay, blue, and stones	16	23
Sand, gravel, and clay	3	26
Clay, stones, and boulders	20	46
Sand, gravel, and a little clay	3	49
Sand, gravel, and clay	3	52
Clay and stones, tight	5	57
Sand, gravel, and clay	3	60
14-3 (Continued)		
Sand, with some gravel and clay	5	65
Sand, clay, and stones	10	75
Clay, sand, and layers of stones	10	85
Clay and stones	2	87
Grand River formation:		
Rock, red, at		87
14-7 Altitude 730		
Glacial drift:		
Fill and yellow sand	6	6
Hardpan	2	8
Gravel and sand (dry)	20	28
Clay, soft	12	40
Clay, hard, and gravel	20	60
Boulder	2	62
Gravel	9	71
Clay and sand	2	73
Sand, muddy	24	97
Sand, cemented	11	108
Grand River formation:		
Shale, reddish and brown	7	115
Saginaw formation:		
Shale, blue, gummy	33	148
Shale, sandy, with hard chips	12	160
Shale, blue, gummy	6	166
Shale, black, gummy	12	178
Shale, blue	14	192
Sandrock, shaly	6	198
Sandrock, dirty, fine	22	220
14-7 (Continued)		
Sandrock, fine	29	249
Shale, white	1	250
Sandrock, coarse	20	270
Sandrock and shale mixed	5	275
Shale, blue	24	299
14-8 Altitude 725		
Glacial drift:		
Topsoil	1	1
Sand, with a little clay	8	9
Clay, blue	37	46
Sand and gravel	1	47
Clay, very sandy	26	73
Grand River formation:		
Sandstone, red	27	100
Shale	5	105
21-1 Altitude 712		
Glacial drift:		
Clay	45	45
Hardpan	45	90
Clay, brown	15	105
Saginaw formation:		
Shale	20	125
White sandrock	85	210
29-1 Altitude 733		
Glacial drift		
Gravel	50	50
Hardpan	50	100
Shale	50	150
Sandrock	65	215

Table 4.--Chemical analyses of ground-water samples from the Elsie area, Michigan

Analyst: M - Michigan Department of Health; C - Calgon, Inc.; U - U. S. Geological Survey

Aquifer: Ps - Saginaw formation; Pgr - Grand River formation; Qsg - Sand and gravel

Well	Aquifer	Analyst	Date collected	Chemical constituents (parts per million)													pH	Specific conductance (micromhos at 25°C)	Temperature (°F)
				Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) (Na + K)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$			
1-1	Ps	U	5- 2-61	-	0.34	62	20	14	1.5	285	8.4	12	-	-	301	237	7.5	483	-
8-1	Ps Pgr	U	4-13-61	-	1.0	79	32	14	1.4	398	24	10	-	-	359	329	7.3	653	-
11-5	Ps	U	5- 2-61	-	2.9	92	21	33	4.5	300	75	46	-	-	466	316	7.5	736	-
11-6	Pgr	U	5- 2-61	-	.38	67	22	8.6	1.1	325	11	0	-	-	285	258	7.5	487	-
12-7	Ps	M	12-30-59	12	1.2	68	22	4.6	.8	296	20	8	0	0	300	260	7.7	500	-
13-2	Ps	C	3- ?-43	-	2.9	99	21	-	-	323	-	145	-	-	-	333	7.4	-	-
13-7	Qsg	M	11-27-51	12	.25	70	29	32	2.1	312	53	39	.6	0	400	295	7.9	605	-
		M	11-26-52		-	-	-	-	-	-	50	34	-	-	-	260	-	690	-
		M	2-10-54	-	-	-	-	-	-	-	48	36	-	-	-	280	-	720	51
		M	10-12-54	-	-	-	-	-	-	-	45	36	-	-	-	280	-	700	51
		M	12-30-59	15	.7	64	26	23	1.6	296	47	21	.5	-	360	265	7.7	590	-
13-16	Qsg	M	5-24-49	12	3.2	98	33	18		332	110	24	.7	-	472	380	-	-	-
		M	2-10-54	-	-	-	-	-	-	325	43	29	-	-	-	300	-	710	50
		M	10-12-54	-	-	-	-	-	-	333	73	29	-	-	-	325	-	750	52
		M	4- 7-55	-	-	-	-	-	-	316	150	28	-	-	-	425	-	870	48
		M	12-12-56	-	-	-	-	-	-	325	57	30	-	-	-	310	-	725	51
		M	12-30-59	6	-	110	32	5.8	2.0	290	120	18	.4	32	504	405	7.5	800	-
14-1	Ps	C	4- ?-43	-	1.0	92	15	-	-	317	-	104	-	-	-	291	7.1	-	-
		M	8-19-53	8	.55	96	28	71	-	290	87	127	.4	.7	560	355	7.2	1000	52
		M	2-10-54	-	-	-	-	-	-	306	87	134	-	-	-	355	-	1080	52
		M	10-12-54	-	-	-	-	-	-	276	87	134	-	-	-	350	-	1030	52
		M	12-30-59	10	.7	102	24	76	9.0	292	75	145	.2	-	600	355	7.5	1000	-
14-7	Ps	U	10-12-54	7.5	.38	92	24	86	6.1	324	98	110	.2	.2	586	328	7.8	989	52
15-1	Pgr	U	5- 2-61	-	.34	35	8.8	28	3.1	220	52	0	-	-	200	124	7.7	344	-
21-1	Ps	U	4-13-61	-	.34	70	32	11	1.1	380	12	5.0	-	-	314	306	7.8	587	-
24-1	Qsg	U	5- 2-61	-	.89	96	25	4.1	1.4	330	69	11	-	-	402	343	7.5	640	-
27-1	Qsg	U	5- 2-61	-	1.7	87	26	4.1	.5	325	59	4.0	-	-	378	324	7.4	597	-
29-1	Ps	U	4-13-61	-	-	66	32	12	1.3	370	15	4.0	-	-	310	296	7.2	580	-