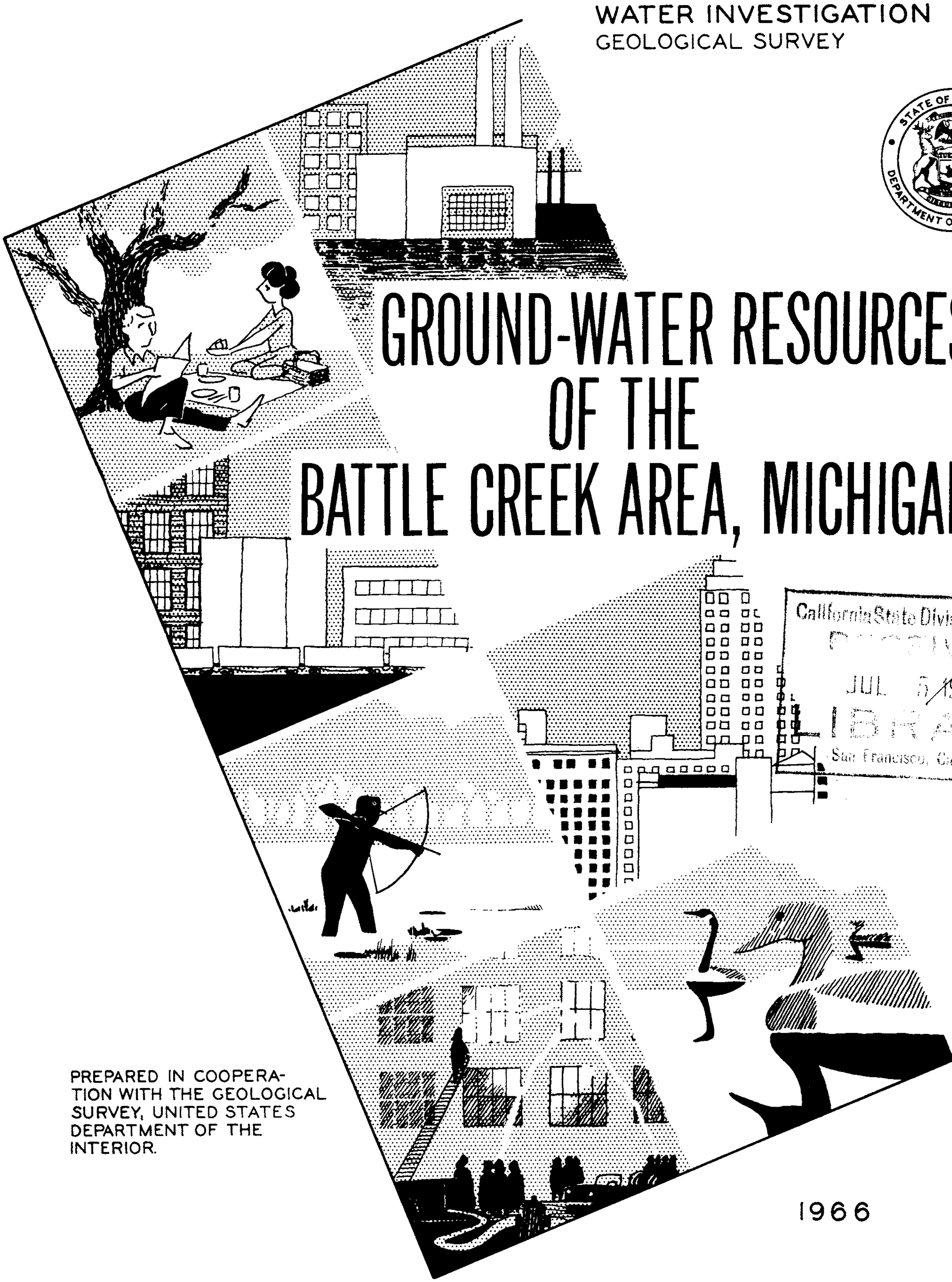
WATER INVESTIGATION 4
GEOLOGICAL SURVEY



GROUND-WATER RESOURCES OF THE BATTLE CREEK AREA, MICHIGAN

PREPARED IN COOPERATION WITH THE GEOLOGICAL SURVEY, UNITED STATES DEPARTMENT OF THE INTERIOR.

1966

the MICHIGAN GEOLOGICAL SURVEY and
the UNITED STATES GEOLOGICAL SURVEY
have cooperated officially for many years
producing basic information on water resources

this report is a product of that continuing program

GEOLOGICAL SURVEY DIVISION

WATER INVESTIGATION 4

GROUND-WATER RESOURCES OF THE BATTLE CREEK AREA, MICHIGAN

BY
KENNETH E. VANLIER

PREPARED IN COOPERATION WITH THE
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Appreciation is also expressed to the many well drillers who contributed much information, and to personnel of various government agencies, particularly the Sanitary Engineering Division of the Michigan Health Department.

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Lansing, Michigan
October, 1965

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ABSTRACT

The Battle Creek area covers about 54 square miles in the central part of the industrialized southern half of Michigan's Lower Peninsula.

The two sources of ground water are the Marshall Formation and glacial drift. The Coldwater Shale, underlying the Marshall Formation and the glacial drift, is not a source of fresh water.

Wells tapping the Marshall Formation at Battle Creek's Verona Station in the central business and industrial area, and the Battle Creek Township well field, produce most of the water used in the area.

The glacial deposits are composed mainly of permeable sand and gravel. These deposits are not extensively used for water supply; however, they are an especially important source of water where the sandstone is not present in the southwest part of the area.

Water from both the sandstone and the glacial deposits is hard to very hard, and locally contains excessive amounts of iron. The chief problem caused by water development to date (1964) has been the gradual increase in iron content of water at the Verona Station. The principal cause for the increase is believed to be in the infiltration of "iron-rich" water from sediments in the bed of a nearby creek.

Water levels have declined less than a foot or two over most of the area. Downstream from the center of Battle Creek, levels have declined about 8 feet since mid-1958 as a result of the lowering of the levels of the Kalamazoo River. In the central part of the Verona Well Station, levels are about 15 feet lower than they were in 1915, but only about 6 feet lower than in 1939.

The water level data indicate that ground-water withdrawals in the area can be increased 3 to 4 times before the decline in water levels becomes serious.

INTRODUCTION

An investigation of the ground-water resources of the Battle Creek area was started shortly after World War II, when officials of the city of Battle Creek became concerned that the two well fields supplying the city might be inadequate for future needs. The early phase of the investigation involved a rather detailed study of the geology and hydrology of the area in the vicinity of the city's two well fields. As a result of the investigation, it was realized that the water-supply potential of the Verona Well Station was far greater than was originally assumed. Thus, the city based its plans for water development on expansion of the Verona Station. As the city expanded this field, it placed the other well field (Goguac Station) on an emergency standby basis. The early phase of the investigation was completed in 1947.

Investigation since 1947 has consisted of a continuing program of water level observation which has provided considerable data significant to the development of the water resources of the area. Interpretations made in this report are based upon information collected since 1947.

Purpose and Scope

The purpose of this report is to summarize and interpret the ground-water resources in the Battle Creek area to aid in their future development and management.

Description of the Area

The Battle Creek area is in the northwest part of Calhoun County in south-central Michigan (fig. 1). The area coincides with the 7 1/2-minute Battle Creek quadrangle, an area of about 54 square miles, including parts of Bedford, Pennfield, Battle Creek, and Emmett Townships (fig. 2).

Battle Creek is in the central part of the industrialized southern half of Michigan's Lower Peninsula and is on Interstate Highway I-94 connecting the Detroit and Chicago industrial regions. The city of Battle Creek is famous for the manufacturing of breakfast cereals, its main industry. A variety of other industries are in the area, many of them supplying or servicing the cereal manufacturers. Some farms are situated in the area. However, most of the rural residents are employed in non-agricultural jobs. The population totalled about 90,000 in 1960.

The region receives an average of about 33 inches of precipitation a year. Of this about two-thirds is returned to the atmosphere by evaporation, and transpiration from plants. The remaining third moves to the streams by direct runoff or infiltrates or percolates into the ground and moves to the streams by underground flow. The two main streams draining the area are the Kalamazoo River and Battle Creek. The area includes two large lakes (Goguac and Beadle) and several small lakes or ponds. Some of these lakes are drained by streams tributary to the Kalamazoo River; the others do not have surface inlets or outlets.

The total surface relief is less than 200 feet. The highest hills, in the southern part of the area, are about 980 feet above sea

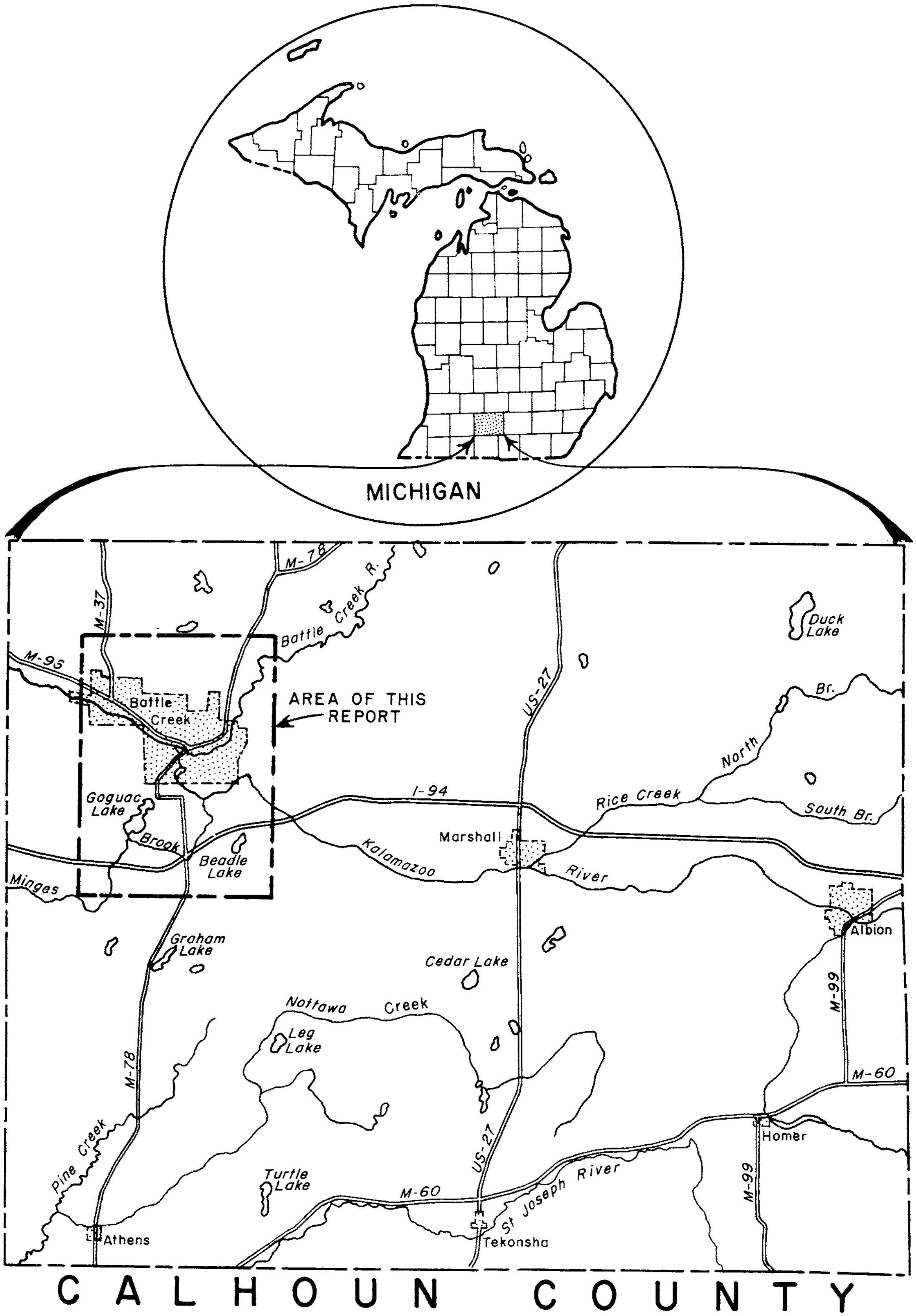


Figure 1. – Index map of the Battle Creek area.

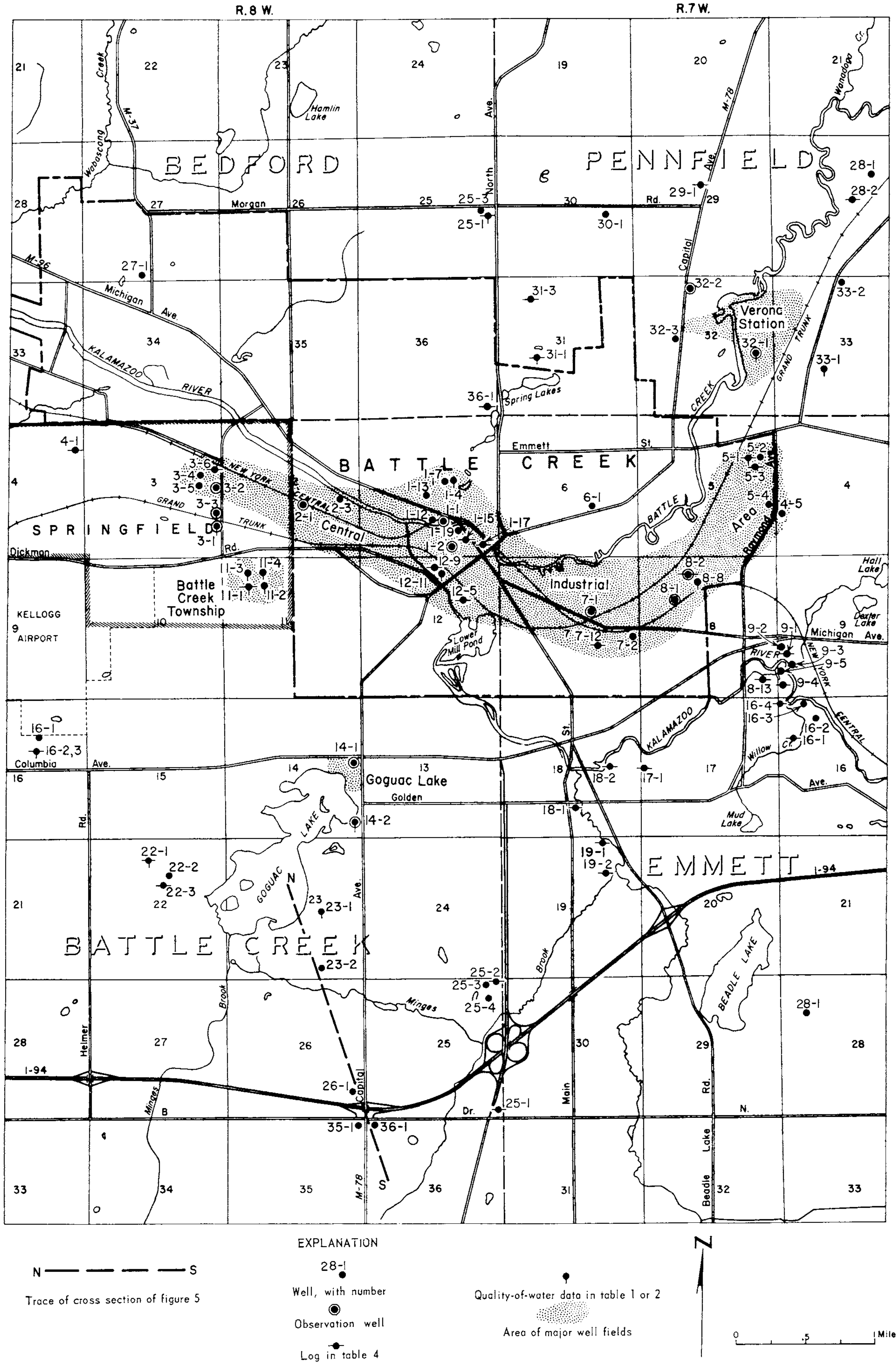


Figure 2. – Map of the Battle Creek area showing location of major well fields and selected wells.

level; the lowest elevations are along the Kalamazoo River, which is just below 800 feet where it leaves the area (fig. 2). Battle Creek enters from the northeast and joins the Kalamazoo River in the central part of the area. The creek flows along a valley cut by a larger glacial stream, as does the Kalamazoo River downstream from its junction with the Battle Creek. This broad glacial stream valley cuts through the central part of the area.

History of Water Development

The early settlers obtained their water supplies from streams, springs, and wells. Many of the first wells were dug by hand. The need for a municipal water system for the city of Battle Creek became apparent during the latter part of the 19th century, and such a system was initiated in 1887, Goguac Lake being used as the source of supply. In 1903 the city began a test-drilling program in the search for additional water supplies. Because of the favorable results of this program, a tract was purchased northeast of the city, now known as the Verona Well Station. This station was not used until 1915, when several wells were put in service to supplement the Goguac Lake supply. In 1929 the city drilled several wells at the Goguac Lake pumping station and discontinued use of the lake as a source of supply. During the period 1940 to 1950 the Verona Station became the major source of the city's water supply, and since 1950 it has produced all the water used by the city. The Goguac Lake station presently (1964) is maintained only as an emergency source of water.

After World War II Bedford, Pennfield, and Battle Creek townships also developed public water-supply systems using ground water. The city of Springfield is supplied by the Battle Creek Township public water system.

The abundance of ground water and the low cost of ground-water development in the Battle Creek area stimulated a number of industries and other institutions to develop their own water supply systems. A large part of the water used for industrial and institutional purposes in the area is taken from privately-owned wells. Several dozen wells in the central business area of Battle Creek are used during the summer months to supply cooling water for air-conditioning units.

The rural residents obtain their water from wells. Most of these domestic wells are less than 200 feet deep.

SOURCES OF GROUND WATER

The two principal sources of ground water in the area are the Marshall Formation underlying all but the southwest part of the area, and glacial "drift" deposits of sand and gravel mantling the bedrock nearly everywhere. In many places large supplies of water (300 to 2000 gpm per well) are available from wells tapping the Marshall Formation. Locally, drift deposits are sources of large supplies of water, but mostly the drift yields small to moderate amounts of water. The Coldwater Shale underlying these two aquifers generally is not a source of fresh water. The Coldwater and the formations underlying it commonly yield only small supplies of mineralized water.

Marshall Formation

The Marshall Formation is one of the principal aquifers in the Southern Peninsula of Michigan, as well as the source of most of the ground water produced in the Battle Creek area. It is composed of medium to fine-grained sandstone. Some of the beds are hard, others are soft. Well drillers report that some beds are composed of loose fine sand, which they term "quicksand". This loose sand may result from removal of the material that cemented the grains of sand together. Water moving through the formation possibly has dissolved this cementing material. In most places the hard beds contain cracks and crevices. Some of these openings are large enough to receive some of the cuttings produced and lost when a well is drilled. In some wells, no samples of drill cuttings were obtained for 25-foot intervals. (See log of well 1S 7W 33-40, table 4.)

The Marshall is blue or yellow. The yellow sandstone probably is that part of the formation that was exposed to weathering at land surface prior to glaciation; the blue sandstone represents unweathered sandstone.

The surface topography of the sandstone (mantled by drift) is quite irregular and includes several valleys eroded by streams before the area was glaciated (fig. 3). These streams may have developed along weak zones in the sandstone. Whether such easily-eroded zones are also zones where the sandstone is more intensively creviced or fractured has not been determined.

The sandstone is thickest (about 140 feet) in the northeast part of the quadrangle and is thinnest or missing in the southwest part (fig. 4). Thickness varies considerably, however, from one locality to another, mostly because of erosion during preglacial and glacial time. Thickness also varies because of the irregularity of the bottom surface of the sandstone. High spots or "hills" in the underlying Coldwater Shale were buried in a "sea" of sand deposited during Marshall time. Where the sandstone was subsequently eroded away, these high spots form islands of shale. The irregularities in both the upper and lower surfaces explain why some wells penetrate significant amounts of sandstone while others, only a few hundred feet away, may encounter only shale (fig. 5).

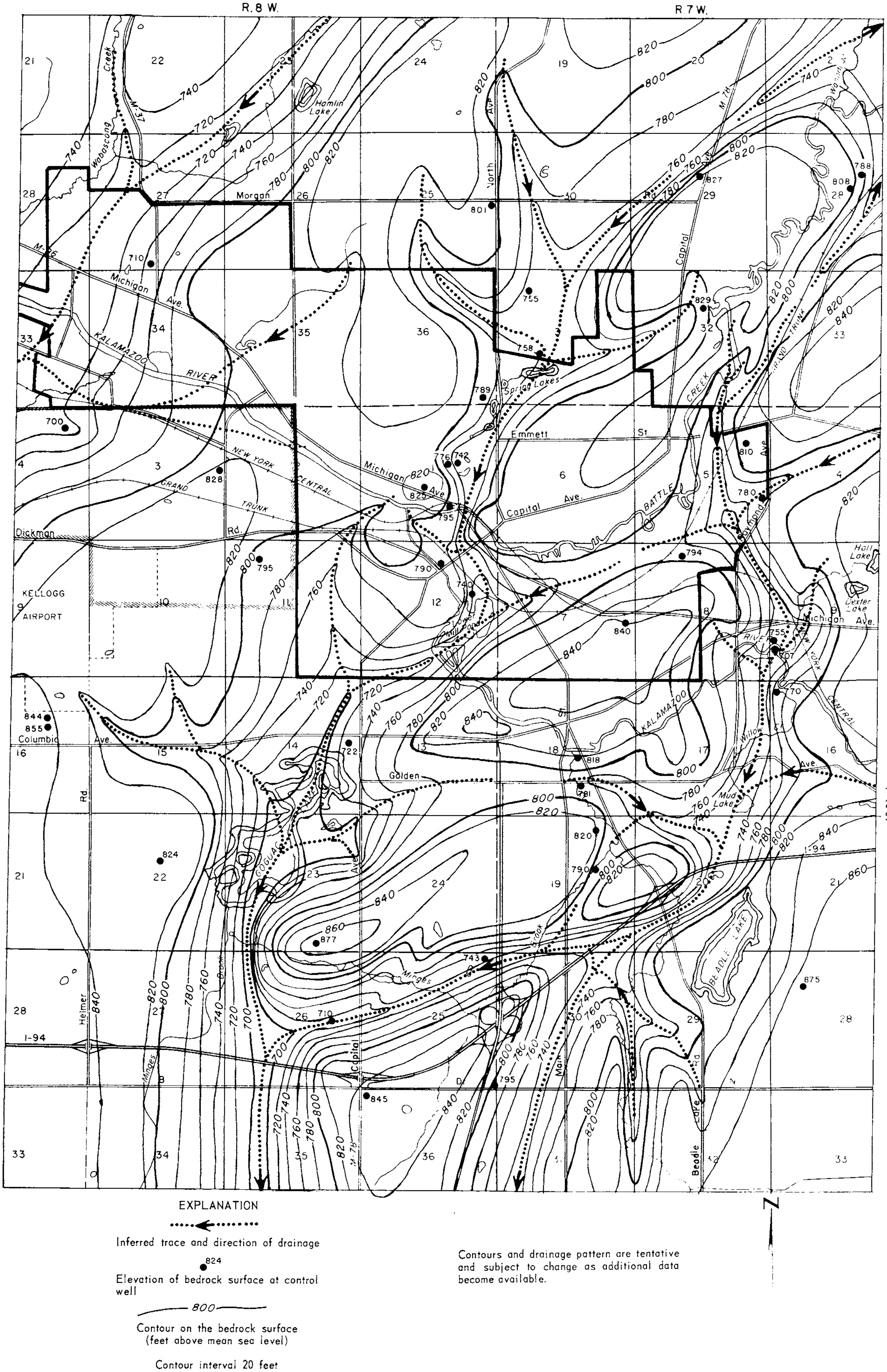


Figure 3. – Map of the bedrock surface. The surface is rugged as a result of pre-glacial stream erosion.

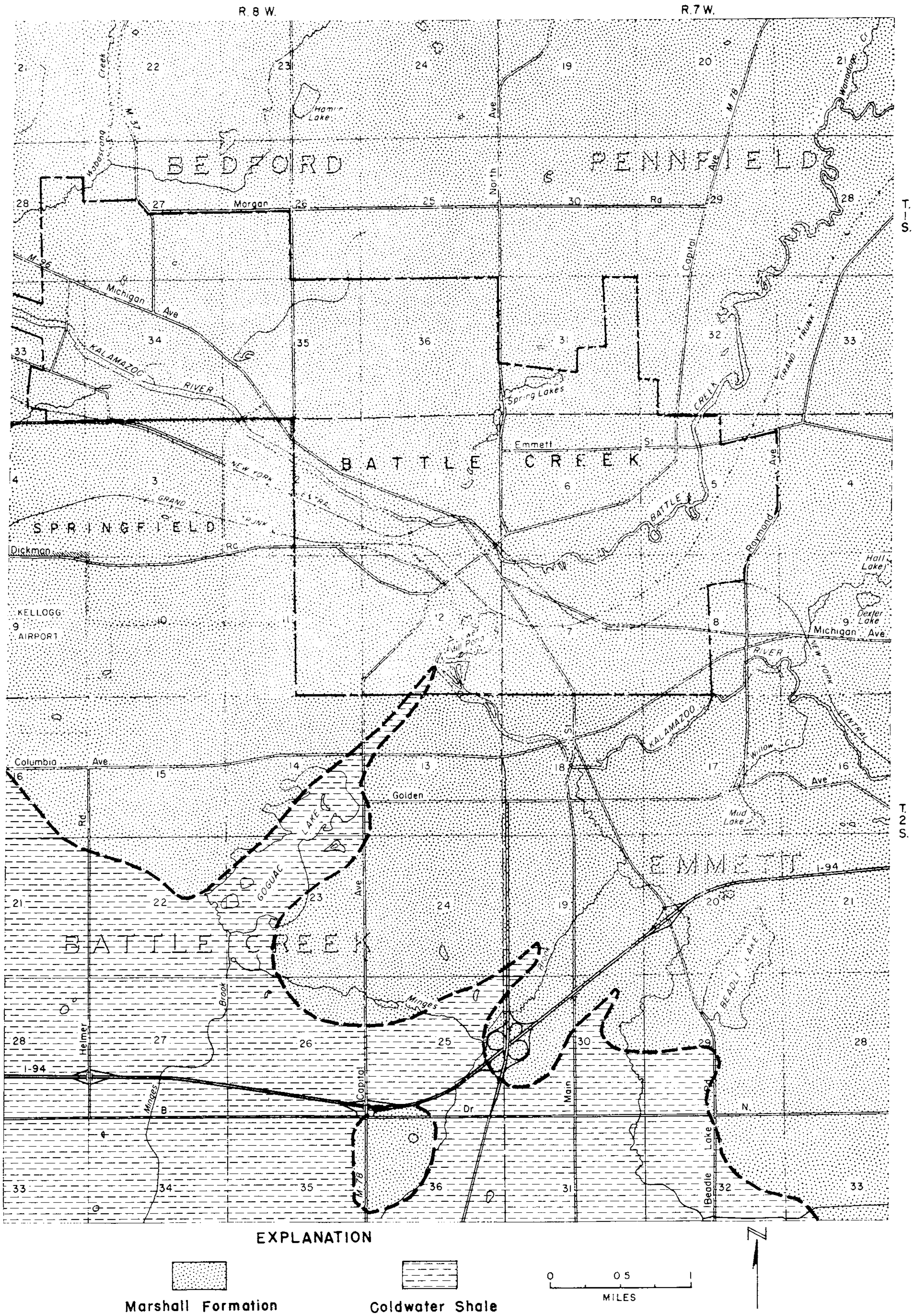


Figure 4. – Map of the bedrock geology shows that the Marshall Formation underlies all but the southwestern part of the area.

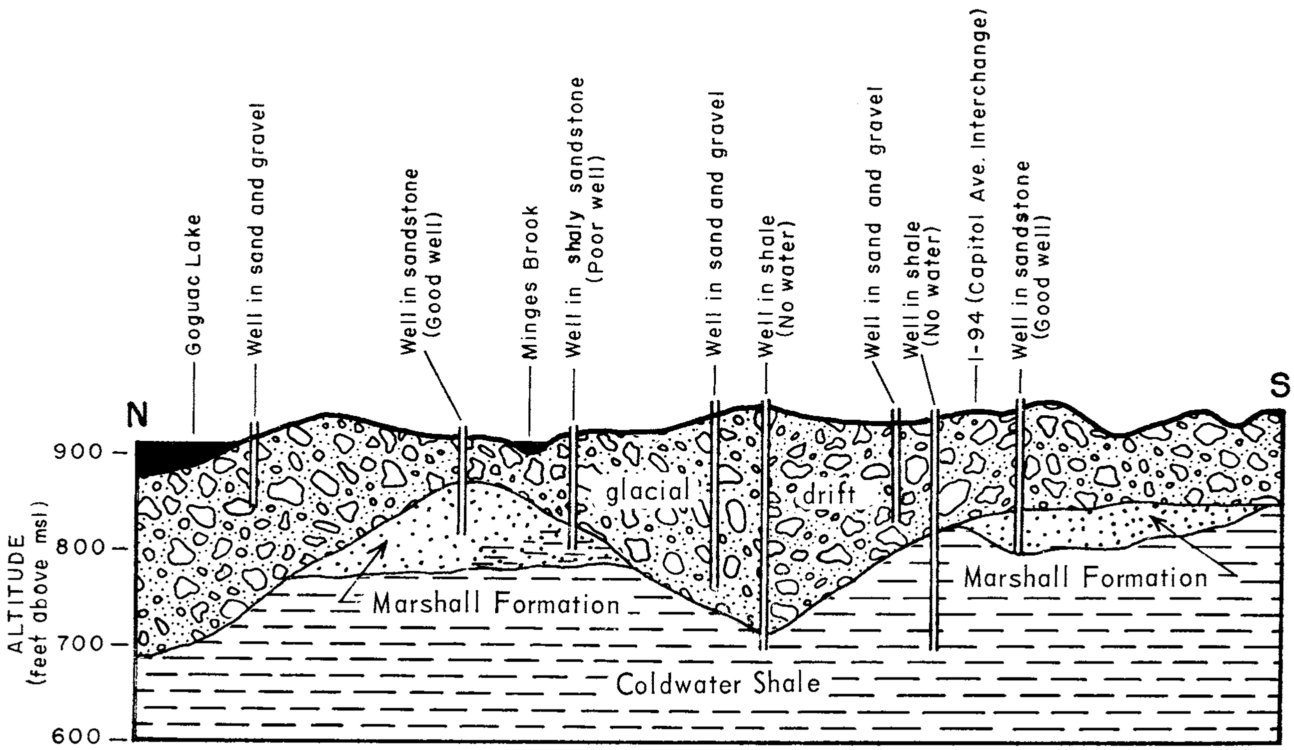


Figure 5. – Geologic cross section along line N-S (fig. 2) shows that wells a few hundred feet apart penetrate different rock strata.

Hydrology

The soils of the Battle Creek area commonly are moderately to highly permeable, and in much of the area rain and snow infiltrate readily into the ground. Thus, over most of the area there is little surface runoff, and a larger proportion of the precipitation infiltrates to the ground-water reservoirs. Nearly all the water recharged to the Marshall Formation moves to it through the overlying glacial-drift aquifer. In most places, water can move readily from the drift to the sandstone.

The water table or piezometric surface (see Glossary, p. 40) in the sandstone conforms somewhat to the land surface (fig. 6). The "hills" in the water table underlie hills seen on the land. The "lows" in the water table coincide with low areas on the land (except around pumping wells).

The movement of water in the sandstone is from the hills (highs) to the valleys (lows) where it is discharged as springs and seeps, or in wells. Most of the dry weather flow of streams is ground water discharge.

Although most of the precipitation infiltrating to the sandstone is eventually discharged to streams, a considerable amount is also pumped from wells. When a well is pumped, the water table in the vicinity of the well declines. The water reservoir flows by gravity to the low caused by the pumping well. If the pumping of wells lowers the water table below the surface of an adjacent stream, water will infiltrate from the stream to the sandstone, and eventually move to the well. Where the sandstone crops out at the surface along a stream, water will be recharged directly to the sandstone. In most places, however, the sandstone is mantled by glacial drift. In these places, water moves through the drift to the sandstone.

The relationship between stream levels and water levels in wells in the sandstone is close. In 1958, as a part of a flood-control project, the U. S. Corps of Engineers dredged and straightened the channel of the Kalamazoo River for several miles downstream from the center of Battle

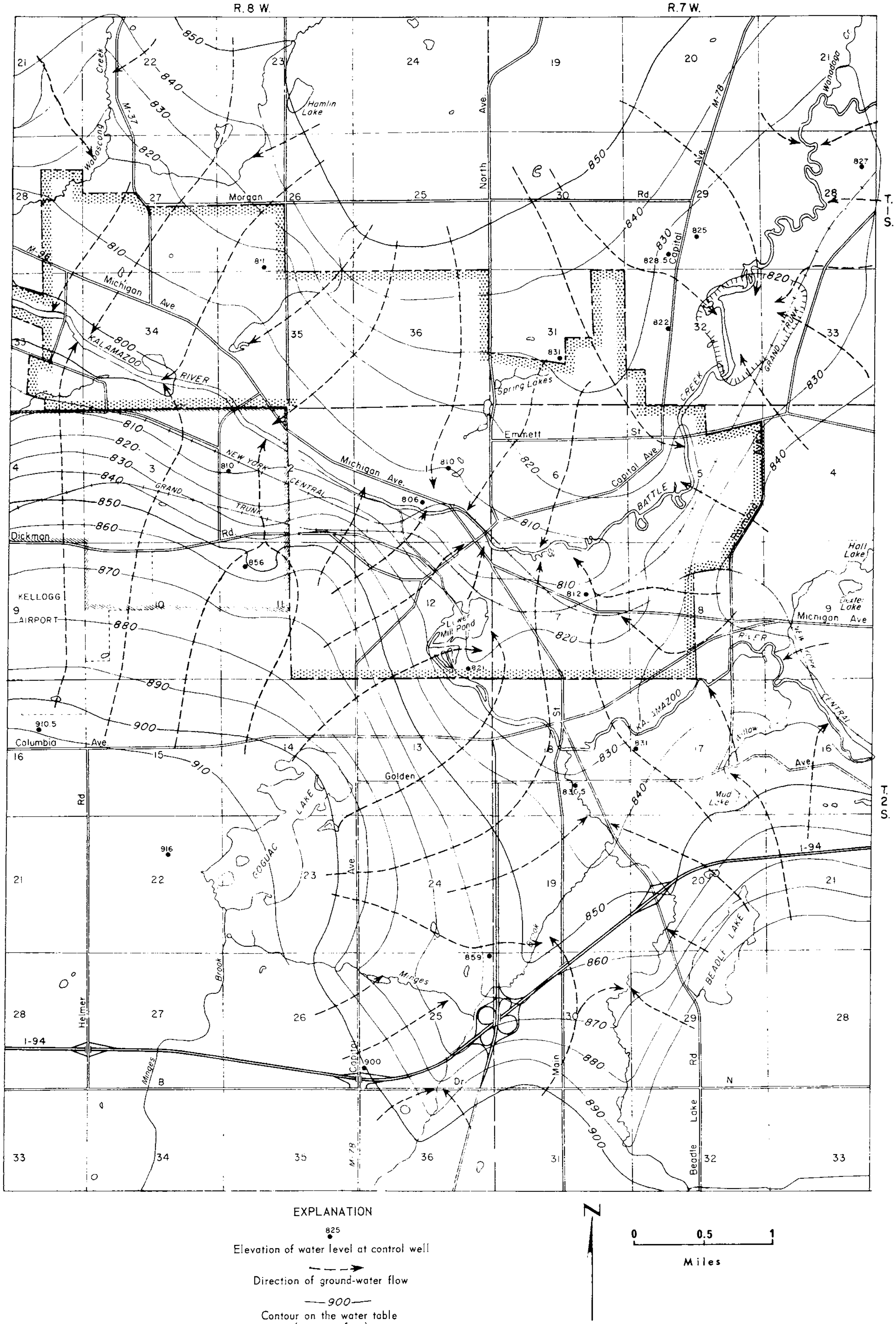


Figure 6. – Map showing direction of ground-water movement. Ground water moves from areas of high water-table elevation to areas of low elevation.

Creek. As a result of this channel improvement, the water surface of the river was lowered about 8 feet. The lowering of the stream caused the water level in a nearby observation well to decline about 6 feet (fig. 7). The lowering of the stream had its greatest effect on ground-water levels in areas immediately adjacent to the stream, and a lesser effect with increased distance from the stream.

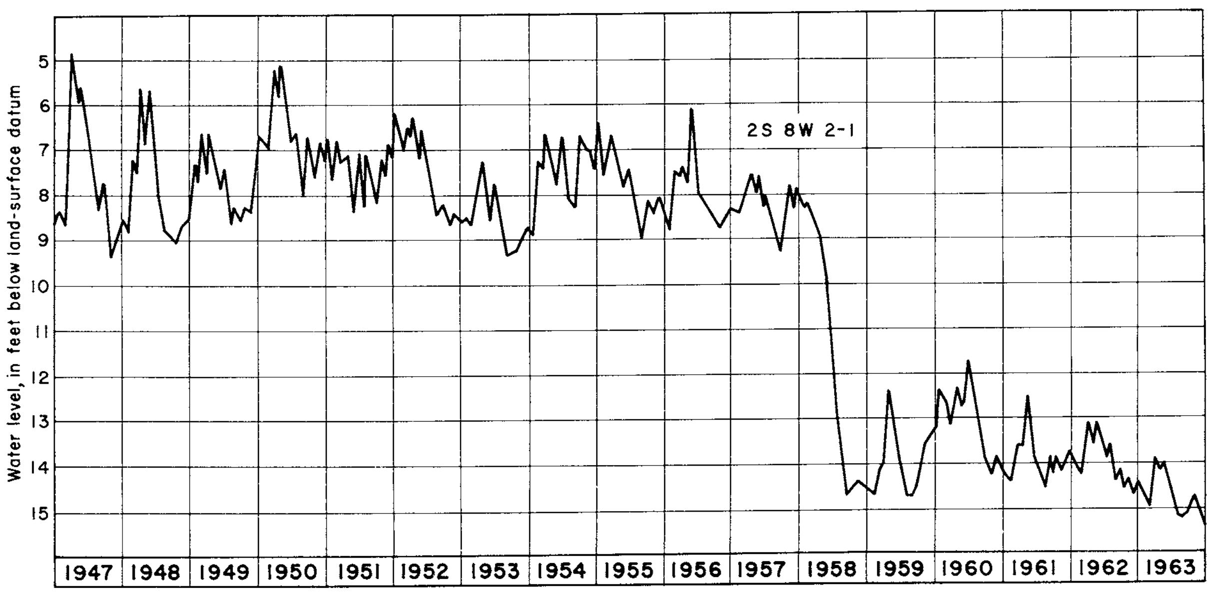


Figure 7. – Graph of water level in well 2S 8W 2-1 shows the effect of lowered river levels in mid-1958.

Wells 2S 7W 17-1 and 18-1 (table 3) tap the sandstone in an area where only small amounts of ground water are used and nearby stream levels have not been lowered. The water levels in these wells show little or no decline since 1945 (fig. 8).

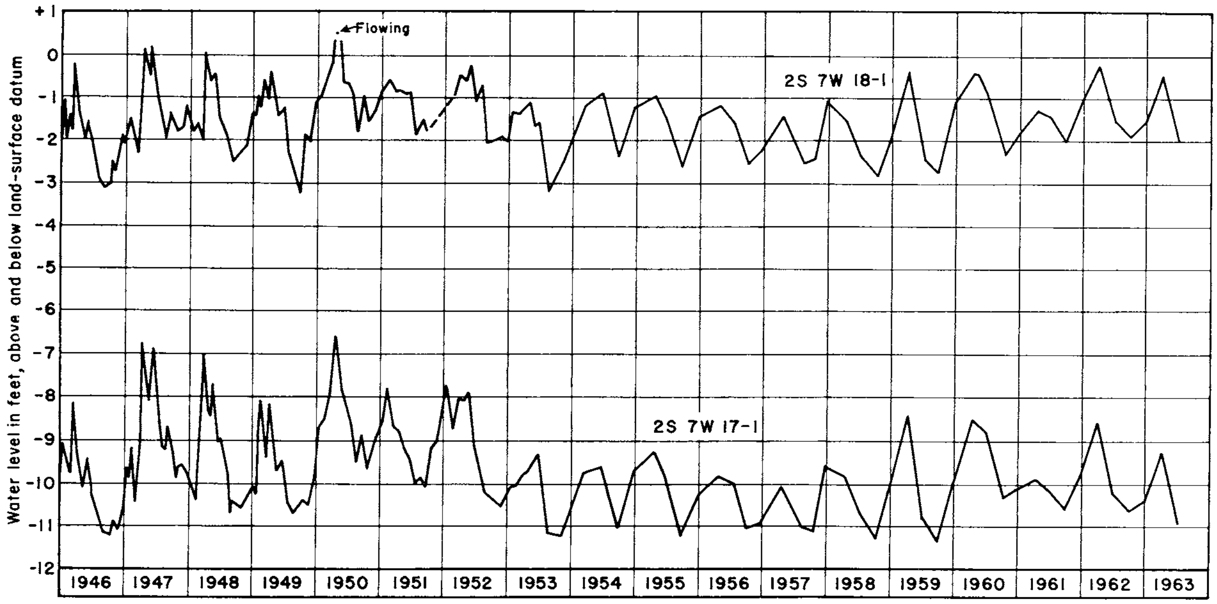


Figure 8. – Graph of water levels in wells 2S 7W 17-1 and 18-1 show little declining trend since 1945.

Water Quality

The sandstone in this area generally yields water of good chemical quality, although it generally is hard to very hard and contains objectionable amounts of iron (table 1). (More than 0.3 ppm of iron will cause staining of laundry and plumbing fixtures and hence is considered objectionable.) With commonly used water-treatment methods, the water could be softened and the iron removed so that it would be of excellent quality and suitable for all common uses. Several "sandstone" wells in the area produced "sulfur" water (water containing hydrogen sulfide gas which gives it an objectionable odor). Most of these wells are no longer used.

Major Well Fields

The largest withdrawals of water from the sandstone are from the large-capacity municipal and industrial wells and well fields. Individual small-capacity wells supplying homes, farms, and small businesses in the suburban and rural areas probably produce less than one-fourth of the water pumped from the sandstone.

Verona Station, city of Battle Creek. -- The Verona well field in the northeast part of the area is one of the most productive in the state. The wells at this station supply all the water for the Battle Creek municipal water system. This system also supplies large quantities of water to industries. During the period 1915 to 1964 nearly 90 billion gallons were produced from this station. Average annual production during the period 1960-63 was about 3.5 billion gallons or about 10 mgd (million gallons per day). In 1964 there were 29 producing wells at the station, yielding from 100 to 300 gpm (gallons per minute) per well.

The sandstone at the Verona well field contains many crevices or fracture openings (see logs of wells 1S 7W 32-18, 33-27, 33-40, table 4), and as a result it is very permeable and productive. Well drillers report that some wells at the Verona Station penetrate openings more than a foot wide.

The well field is located in flatland along Battle Creek. The Marshall Formation is only 12 feet below the surface through much of the field, but in the south-central part it is about 40 feet below the surface (fig. 9). The field is also bordered on the east by a bedrock valley. The soils and subsoils in and adjacent to the field are sandy and permeable.

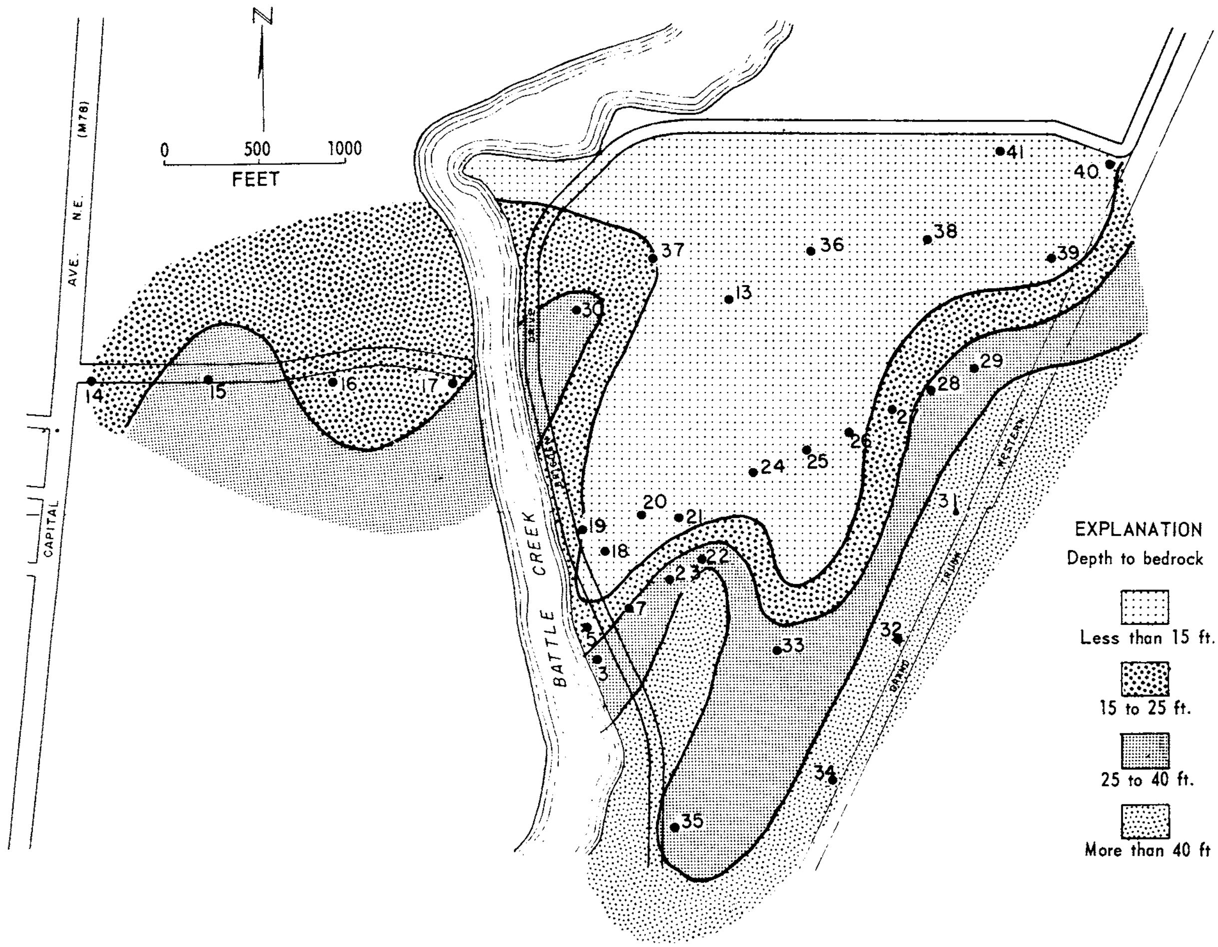


Figure 9. – Map showing depth to the top of the Marshall Formation at the Verona Station shows that much of the formation is less than 15 feet below land surface.

The specific capacity (see "Glossary of Terms") of wells at the station range from about 50 to as much as 650 gpm. Production tests, however, indicate that the specific capacity of some wells has declined with use. The specific-capacity data indicate that the coefficient of T (transmissibility) (see "Glossary of Terms") of the aquifer ranges from about 500 thousand to 1 million gallons per day per foot.

Aquifer tests conducted at the site indicate a similar range of T. It should be noted, however, that the crevices or fracture openings in the sandstone result in considerable variation in T within the well field. The cone of drawdown or recovery caused by pumping or cessation of pumping of wells during most aquifer tests at the field was distorted in shape (fig. 10).

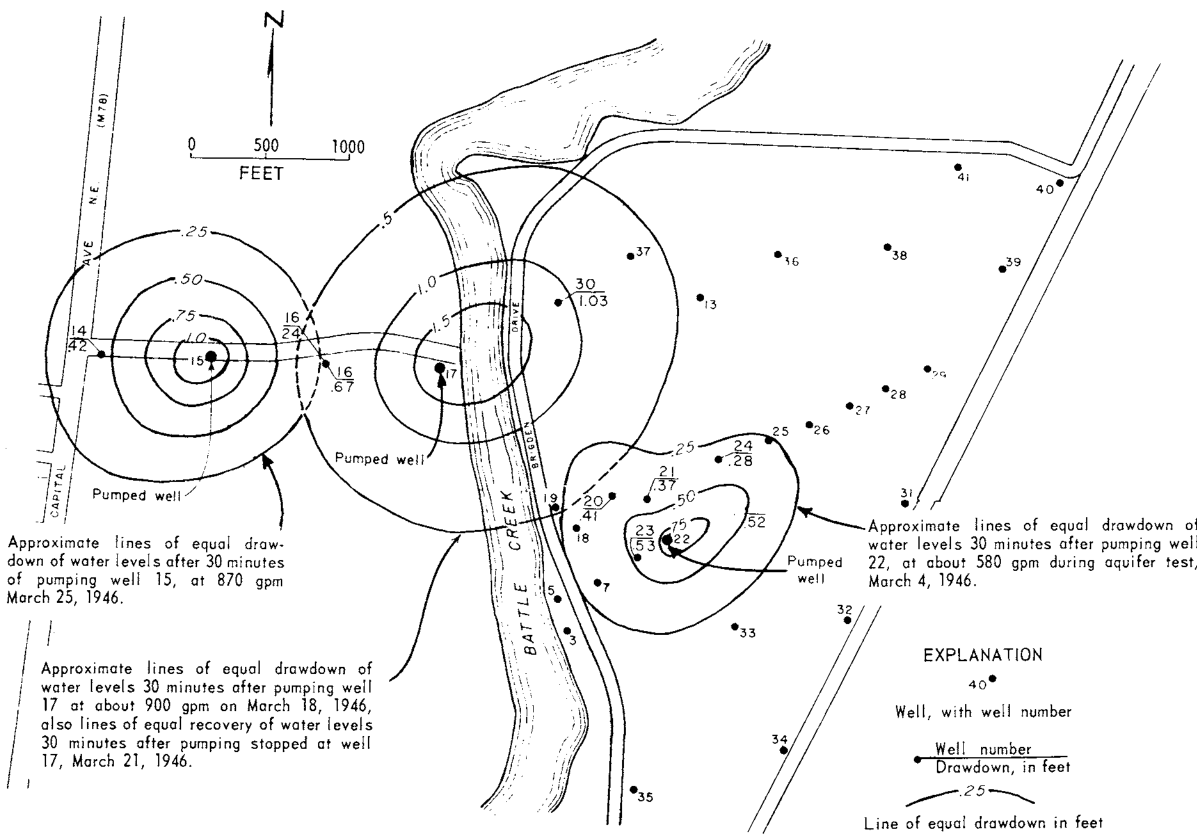


Figure 10. – Map of drawdown during aquifer tests at the Verona Station shows assymetrical shapes of drawdown cones.

That is, the drawdown was greater in one direction than in another direction. Distortion of the cone of drawdown could result from recharge or from impermeable boundaries in the aquifer. The presence of such boundaries, however, is not substantiated by geologic or hydrologic data. Thus, the distortion probably results from variations in permeability within the well field. The large rånge in specific capacities of the production wells at the station may also result from variations in permeability.

The variations in permeability probably result from the character and number of openings in the sandstone. Figure 11 shows a pattern of increased permeability due to fracturing, which in part explains the difference in yields from the various wells. Although the pattern of increased permeability shown hypothetical and is not based on any specific geologic data, the zones trending northeast align generally with the long axis of the cone of influence of pumped wells in several of the aquifer tests.

A flow net constructed on the basis of water-level measurements made during January 1963 (fig. 12) also reveals distrotion that can be explained only by variations in permeability as previously expressed. Analysis of the flow net indicates that T is in the range of 250,000 gpd/ft. The transmissibility figures obtained by aquifer tests and by flow-net analysis are only estimates, however, as the aquifer does not meet the physical limits necessary for accurate analysis. I believe that the estimate of T obtained from the flow net is more accurate than that obtained from the aquifer tests.

The Verona well field is located where considerable water was discharged to Battle Creek under natural conditions; that is, before any wells were drilled in the area. An estimate of the ground-water discharge

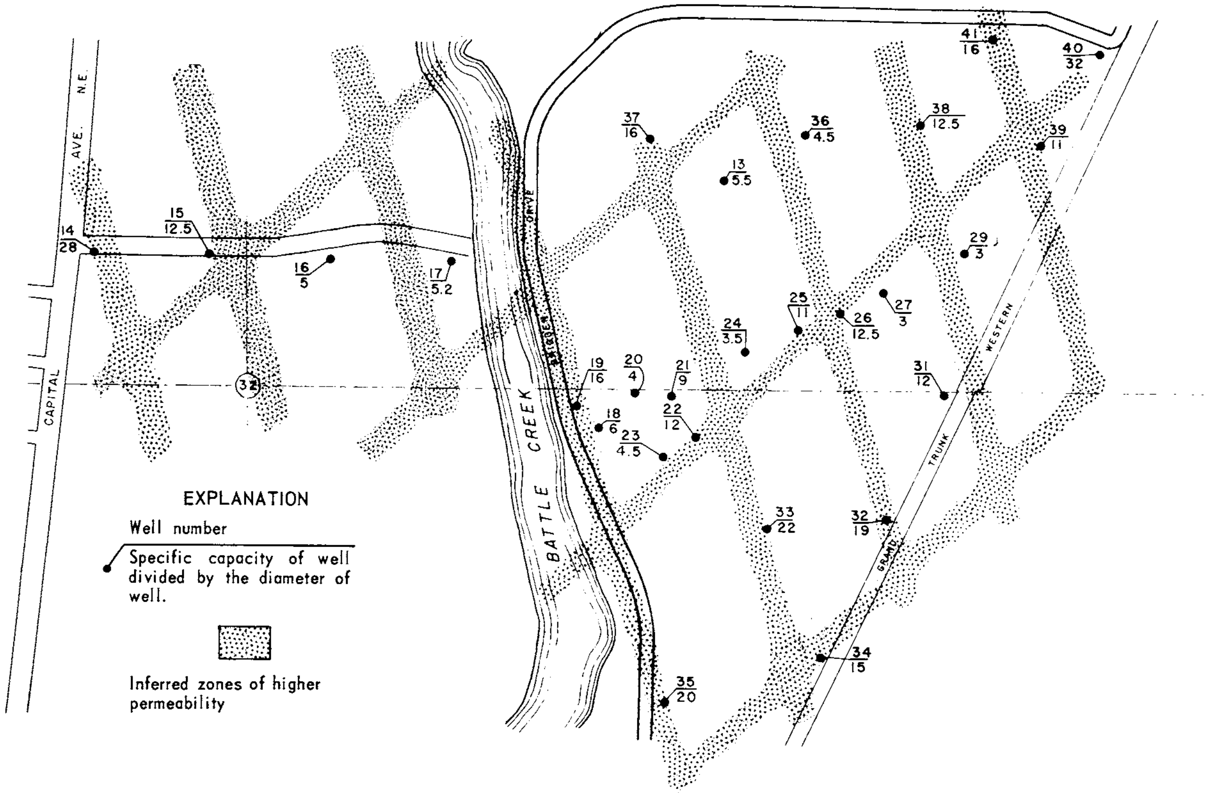
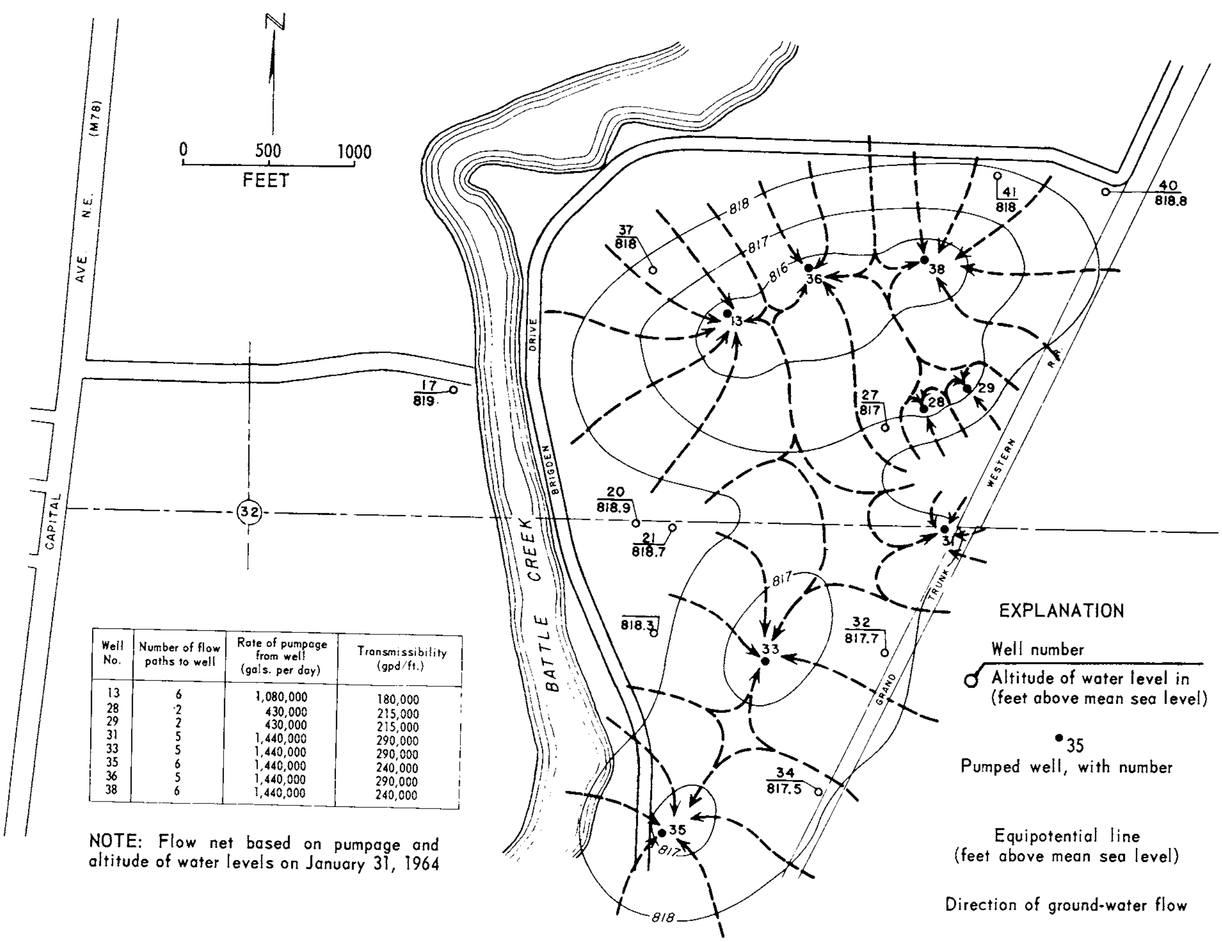


Figure 11. – Map of inferred zones of higher permeability at the Verona Station shows angular, intersecting pattern.



Well No.	Number of flow paths to well	Rate of pumpage from well (gals. per day)	Transmissibility (gpd/ft.)
13	6	1,080,000	180,000
28	2	430,000	215,000
29	2	430,000	215,000
31	5	1,440,000	290,000
33	5	1,440,000	290,000
35	6	1,440,000	240,000
36	5	1,440,000	290,000
38	6	1,440,000	240,000

NOTE: Flow net based on pumpage and altitude of water levels on January 31, 1964

Figure 12. – Flow net diagram of the Verona Station.

to the creek under natural conditions can be made by using the formula

$$Q = 2\ T\ I$$

where

Q = the amount of water, in gallons per day, moving to a mile strip of the creek

T = the coefficient of transmissibility, in gallons per day per foot

I = estimated average hydraulic gradient toward the river, in feet per mile (under natural conditions).

Inflow from both sides of the stream is taken care of by the factor 2 in formula.

Using the estimated minimum transmissibility of 250,000 and a hydraulic gradient of 10 feet per mile, $Q = 2 \times 250{,}000 \times 10 = 5{,}000{,}000$ gallons per day. As the estimates of T and I are conservative, the estimate of water (mgd) discharged to a mile of the creek in the vicinity of the station is reasonable. The above computations indicate that most of the water presently pumped from the well field (about 10 mgd) would under natural conditions have been discharged in the 2-mile reach of the creek adjacent to the station, but under present conditions some of the pumped water is diverted from the creek through the sandstone to the wells.

Water-level fluctuations have been observed and recorded at the Verona Station since 1939 (fig. 13). Although there has been a general decline in water levels in the observation well at the station during the period of record, the net decline since 1939 is only about 6 feet. Most of the decline has occurred since 1952. The period 1952-64, however, has been one of increased pumping at the station and a general decrease in the amount of precipitation in the area. Part of the lowering of water levels can be attributed also to pumping of industrial and other wells in adjacent areas. Some of these wells intercept water that under natural conditions would move to the Verona well field.

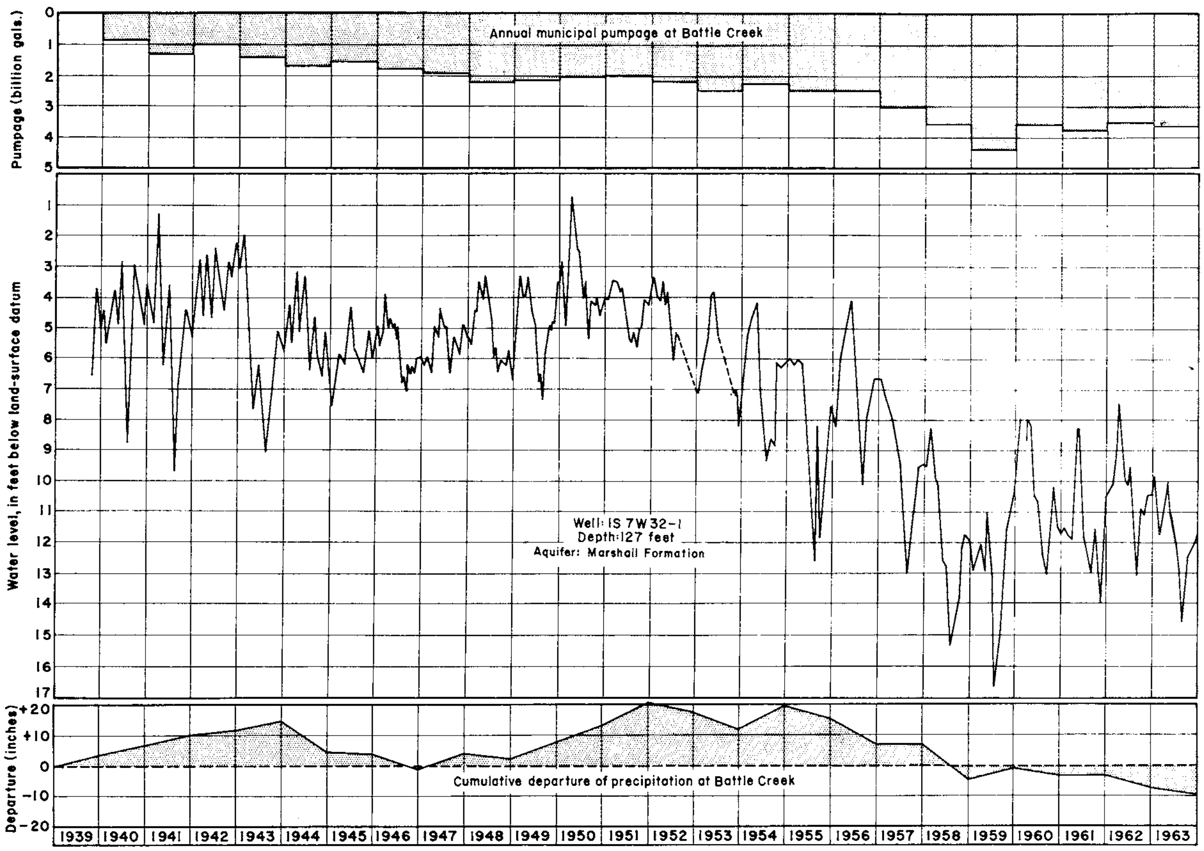


Figure 13. – Graph of municipal pumpage; and net decline of water levels at the Verona Station and cumulative departure of precipitation at Battle Creek.

The quality of water from wells at the station is similar to that from other wells tapping the sandstone except that several wells yield water containing above average concentrations of iron and two wells yield water containing hydrogen sulfide, a gas with a "rotten egg" odor. The iron content, however, ranges from less than 0.05 ppm in several of the wells to more than 5 ppm in one well. The wells producing water of high iron content are those nearest the creek (fig. 14), and in some of these the iron content has increased markedly since 1950. The exact source of the iron is not known. Studies by Oborn and Hem (1961, 1962) indicate that aquatic vegetation growing in a stream can increase the iron content of the sediments in the bed of the stream, and that water moving through a streambed or through such sediments may pick up high concentrations of iron through the action of micro-organisms in the stream bed. The bed of the stream at Verona Station is covered with aquatic vegetation, and water seeps through the stream bed to the aquifer.

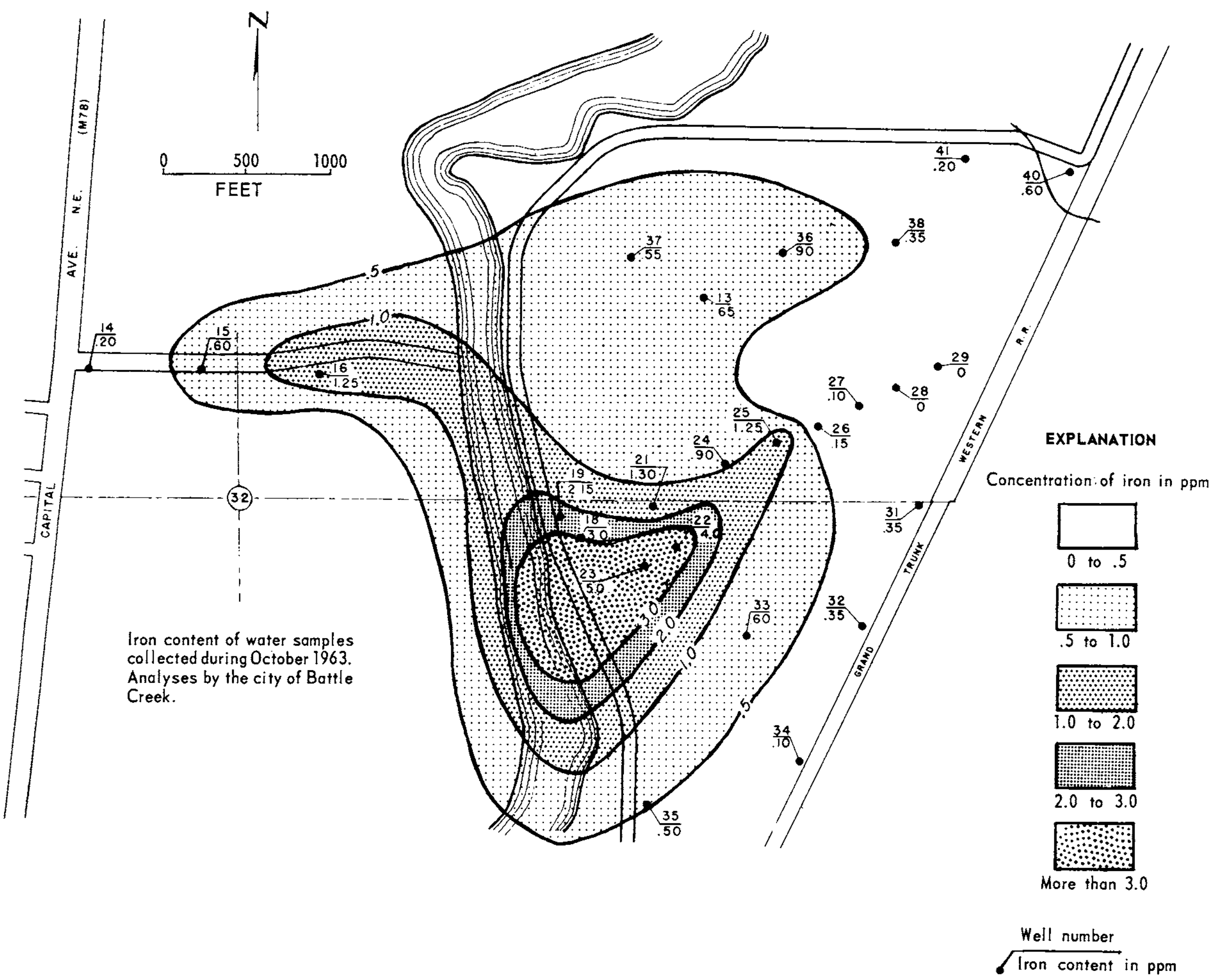


Figure 14. – Sketch of iron content of water samples from the Verona Station, October 1963, indicates Battle Creek is the source of the "iron water".

This iron-rich water would tend to move from the creek to the wells along paths of greatest permeability in the sandstone or in the overlying sediments. Thus, the pattern of iron concentration (fig. 14) may in part be the result of its migration along a path of greater permeability in the sandstone roughly in alignment with wells 23, 22, and 25. The pattern of iron concentration shown on figure 14 may also result in part from iron-rich water migrating along a path of greater permeability in the sand and gravel overlying the sandstone. One such path would be the beds of sand and gravel filling the depression in the bedrock surface south of wells, 3, 7, 23, and 22 (fig. 9).

It is not uncommon for iron content of water to increase during the life of a well field or to vary considerably from one well to another within a well field. Although factors other than infiltration of water from the river may affect the iron content of water, I believe that increased pumping and coincident lowering of ground-water levels below the creek level are mainly responsible for the increase in iron content. With the continued lowering of water levels, which will result from future increases in pumping, more water will infiltrate from the creek. This will probably cuase a progressive increase in the iron content of water from some of the wells presently yielding water of low iron content. The increase in iron content does not coincide exactly with an increase in pumping. There is a lag as it takes time for the iron-rich water to move from the stream to the wells.

The iron content of wells 24, 25, and 26 has increased significantly during the period 1961 through 1963 (fig. 15) although the annual rate of pumpage has remained relatively steady. The increase in iron content in these wells probably is the result of an increase in pumping during the period 1956 through 1958 and also a reduction in pumping from wells nearer the creek.

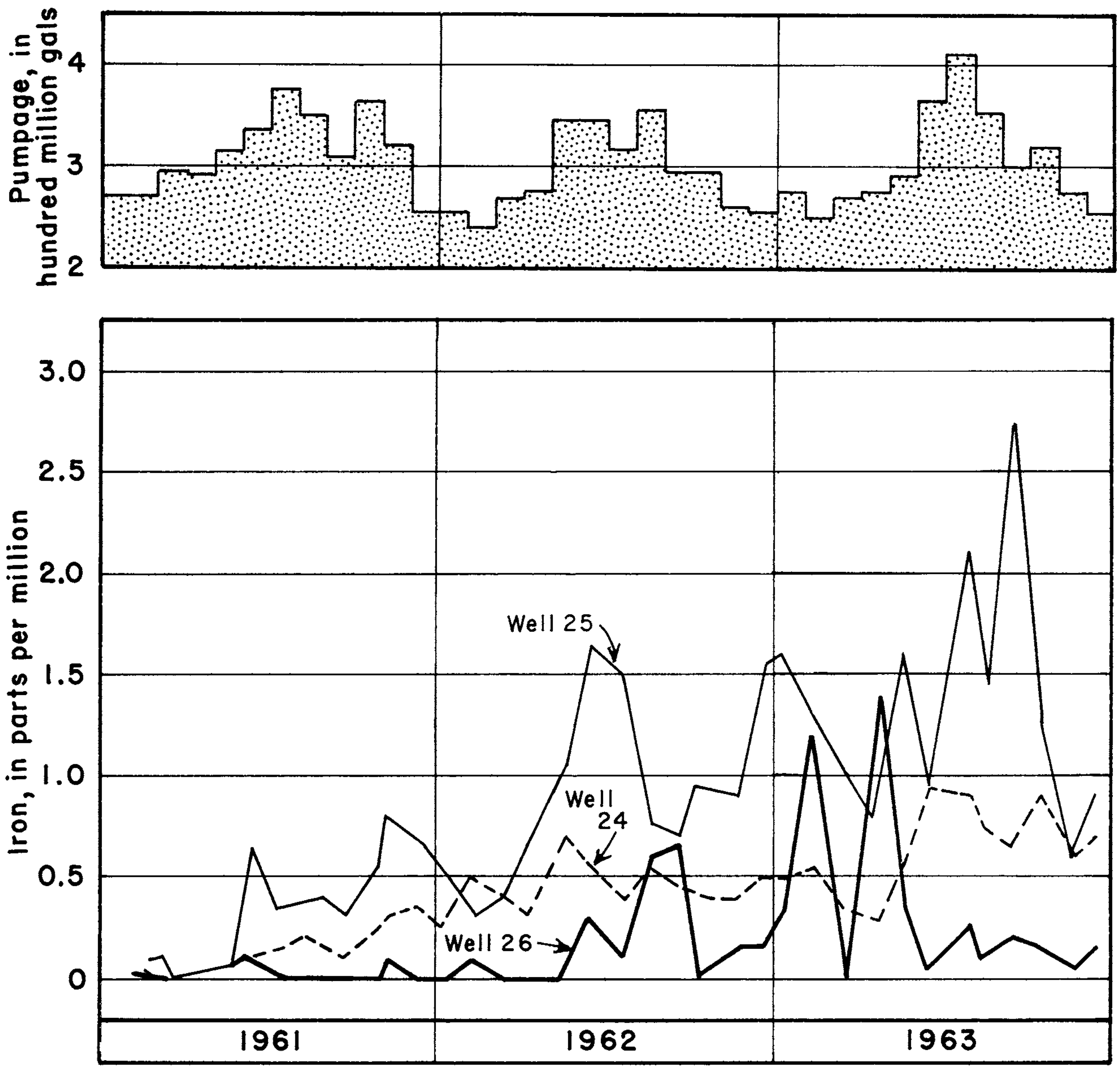


Figure 15. – Graph showing pumpage and iron content of water from wells 24, 25, and 26 at the Verona Station, 1961-63.

When wells near the creek are not pumped, water of high iron content migrates to wells farther from the creek. Figure 15 shows that the iron content of water tended to increase with an increase in the rate of pumping at the station. This tendency is masked somewhat by the practice of reducing or discontinuing pumping from wells yielding water of high iron content.

Wells 1S 7W 32-16 and 32-30 yield water containing hydrogen sulfide (0.5 ppm for well 32-16 and 0.1 ppm for well 32-30 in samples collected during June, 1964; analyses by the Michigan Department of Health). Apparently, the hydrogen sulfide water has migrated into the well field from the area to the northwest. Several wells in this area are reported to have yielded "hydrogen sulfide" water and thus were abandoned or destroyed. The original source or cause for the presence of hydrogen sulfide in the water from the Marshall Formation is not fully known.

Further study of the "hydrogen sulfide" problem at the station is needed.

Wells in the central industrial and business area. -- More than 50 industries, business firms, and institutions in the central part of the city of Battle Creek obtain part or all of their water supply from wells tapping the Marshall Formation. Water from these wells is used principally for air-conditioning and industrial use. Some wells, such as those at the Battle Creek Federal Center, are used for drinking, washing, and other household uses.

The thickness of the sandstone varies considerably within the central area of Battle Creek. Most wells penetrate about 60 feet of sandstone, a few penetrate less than 30 feet, and several more than 100 feet of sandstone.

The specific capacity of large wells in this area ranges from about 10 to about 100 gpm per foot of drawdown. Specific-capacity figures indicate that T in this area ranges from about 20,000 gpd/ft to about 200,000 gpd/ft. An aquifer (pumping) test conducted on wells of the Ralston Purina Co., however, indicates that T is about 500,000 gpd/ft, while a test at the Battle Creek Federal Center indicates a T of about 130,000 gpd/ft. The great range in transmissibility probably is due to the large variation in thickness of sandstone and in the amount of crevices or fracture openings in the sandstone.

Water levels in an observation well tapping the sandstone in the western part of the central industrial and business area declined during the period 1946 to 1964 (fig. 7). Most of this decline, however, can be attributed to the lowering of the water level in the Kalamazoo River in 1958. The river acts as a base level for the water levels in the aquifer. Observation wells in the eastern part of this area have shown no significant downward or upward trend since 1946 (fig. 16).

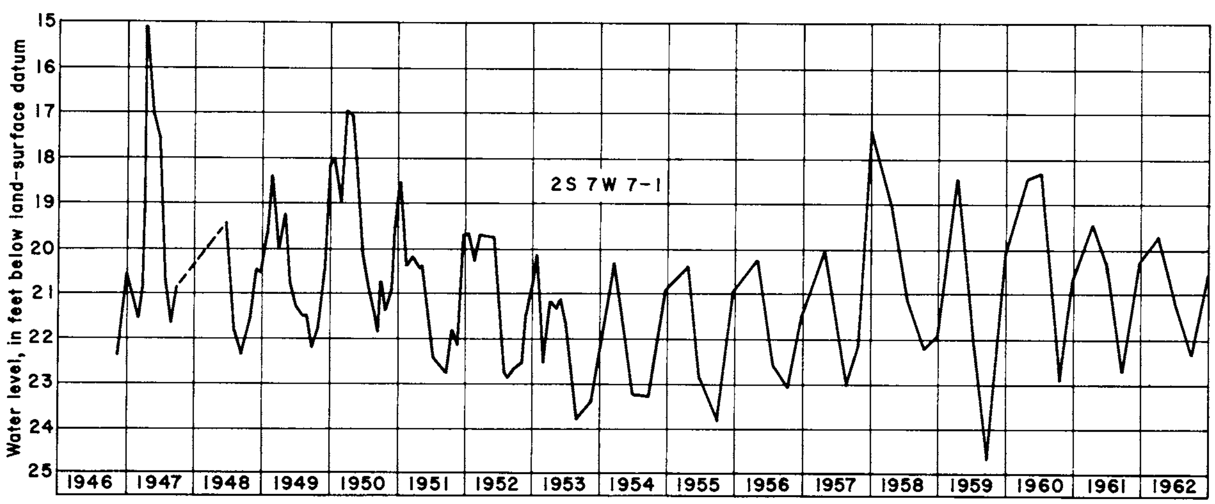


Figure 16. – Graph of the water level in well 2S 7W 7-1 in the eastern part of the central business and industrial area.

The water from wells in the sandstone in the central business and industrial area generally is hard to very hard and contains objectionable amounts of iron.

Battle Creek Township well field. -- Battle Creek Township obtains most of the water for its public system from a well field in the eastern part of the city of Springfield. The township system supplies most of the residents of the township and the city of Springfield. In 1963 about 421 million gallons (about 1.3 mgd) was pumped from the field, an increase of about 20 percent over 1962.

The amount of sandstone penetrated by the four wells at the field ranges from about 25 feet to about 50 feet. This variation results principally from the undulations in the bedrock surface, as well as from the amount of shale interbedded with the sandstone. Specific capacities of the wells at the station range from about 10 to 20 gpm. The water level in well 2S 8W 11-2 was 39 feet below land surface in January 1964. This indicates a decline of about 13 feet since 1947.

The demand for water in the township has increased steadily during the period 1950 to 1964. Township officials, recognizing the need for an additional source of water, began a test-drilling program in 1961 which continued into 1963.. As a result of the program, the township purchased a tract of land in the northeast quarter of section 16. Early in 1964 two production wells were drilled at this new well field.

Glacial Drift Aquifer

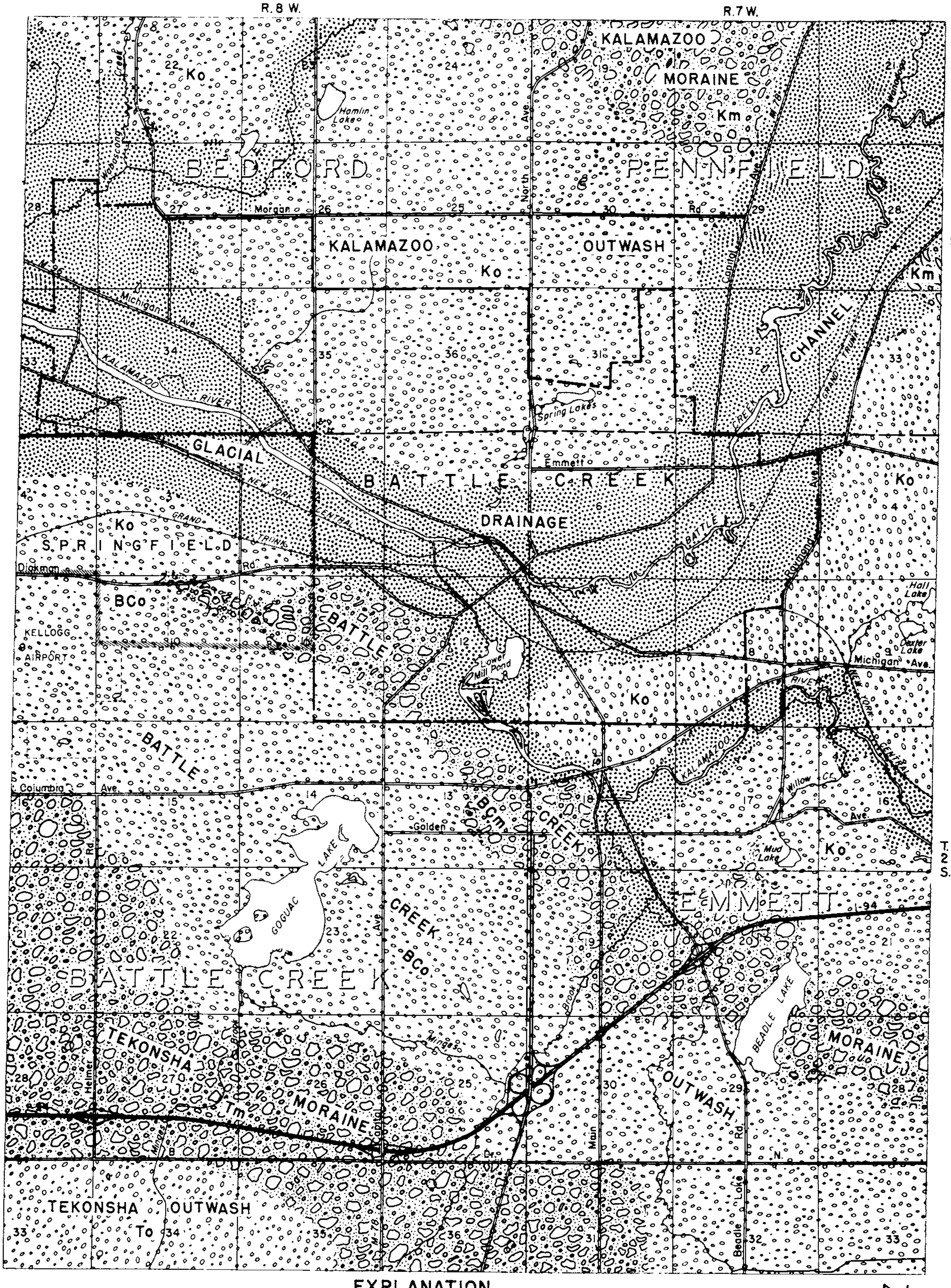
Deposits of glacial drift mantle nearly all the Battle Creek area. These deposits yield small supplies of water to wells, and locally, are capable of yielding moderate to large supplies. In the southwest part of the area where the sandstone is not present (fig. 4) the glacial aquifers are especially important, as they are the only source of fresh ground water.

The drift deposits are not extensively developed for water supply, principally because the underlying Marshall Formation is a more productive and dependable source. Also, wells tapping the sandstone generally need less maintenance than wells tapping glacial aquifers, and in some areas the sandstone is less susceptible to contamination than the shallow drift aquifers.

The glacial materials were deposited by the last of the great continental glaciers which pushed southward across the State. The glacial deposits of the area are composed largely of sand and clay derived principally from sandstones and shales occurring north of the area. The glacial deposits also include rock materials transported from Canada far to the north.

Parts of the Tekonsha, Battle Creek, and Kalamazoo moraines (fig. 17) in the area mark temporary halts of the ice front as the glacier retreated northeast. Associated with these moraines are the sandy outwash plains formed by braided meltwater streams flowing off and along the front of the glacier. The drift underlying the moraines generally includes significant amounts of silt and clay, which reduce permeability. The fine sand, silt, and clay, however, were washed out of many of the beds of sand and gravel deposited in the outwash areas. Hence, these outwash deposits commonly are highly permeable.

A significant part of the area is underlain by outwash (fig. 17). The largest of the outwash deposits is associated with and directly southwest of the Kalamazoo Moraine. Most of the sand and gravel locally used for construction aggregate or road metal is produced from gravel pits in the Kalamazoo outwash deposit.



EXPLANATION

MORAINE

- Km Kalamazoo moraine
- BCm Battle Creek moraine
- Tm Tekonsha moraine

OUTWASH

- Ko Kalamazoo outwash
- BCo Battle Creek outwash
- To Tekonsha outwash

GLACIAL DRAINAGE CHANNEL

0 0.5 1
Miles

N

Figure 17. – Map of the surficial geology shows that most of the area is underlain by outwash sand and gravel.

A third prominent glacial feature of the area is the broad glacial drainage channel crossing the area (fig. 17). This channel was cut by a large meltwater stream flowing from the glacier when it had retreated to a line about 20 miles to the north. The meltwater stream eroded away most of the glacial drift in the channel and exposed the Marshall Formation in several places. Locally, the drift deposits underlying the channel are 40 to 50 feet thick. However, because the sandstone is at shallow depth, the drift deposits in the area of the channel are not utilized as a source of ground water.

Although extensive deposits of sand and gravel which would yield considerable water are present in the Battle Creek area, in many places the beds lie above the water table, are relatively thin, or are near the surface, and might easily become contaminated. The best glacial drift aquifers are along the valleys in the bedrock surface (fig. 3). Goguac Well Station taps a glacial aquifer filling the bedrock valley crossing the central part of the area. Although the glacial aquifers within the bedrock valley along the east edge of the area presently are not tapped by wells, they do offer considerable potential for future development. The site along the Kalamazoo River in secs. 8, 9, and 16, T. 2S., R. 7W., was tested in 1903 by the city of Battle Creek in the search for a new well field. The site was not developed, but records of the wells indicate that this drift aquifer will yield considerable water.

Hydrology of the Drift Aquifer

The soils of the Battle Creek area are commonly very sandy and permeable and in many parts of the area there is little or no direct surface runoff. Much of the rain and melted snow percolates or filters into the ground and recharges the drift aquifers. Thus, water levels in "drift" wells rise rather sharply in the spring when the snow melts and after periods of heavy rainfall. Water levels decline during periods of dry weather and in the winter when the precipitation (snow) accumulates on the surface. They decline also in response to pumping of wells.

Generally, water is able to move from the drift to the sandstone or from the sandstone to the drift, thus maintaining the same level in both aquifers. When, for example, the Kalamazoo River level was lowered in the area downstream from the center of the city, the water levels declined in wells tapping the drift and in those tapping the sandstone (fig. 18). In some areas, the two aquifers function as a single hydraulic unit.

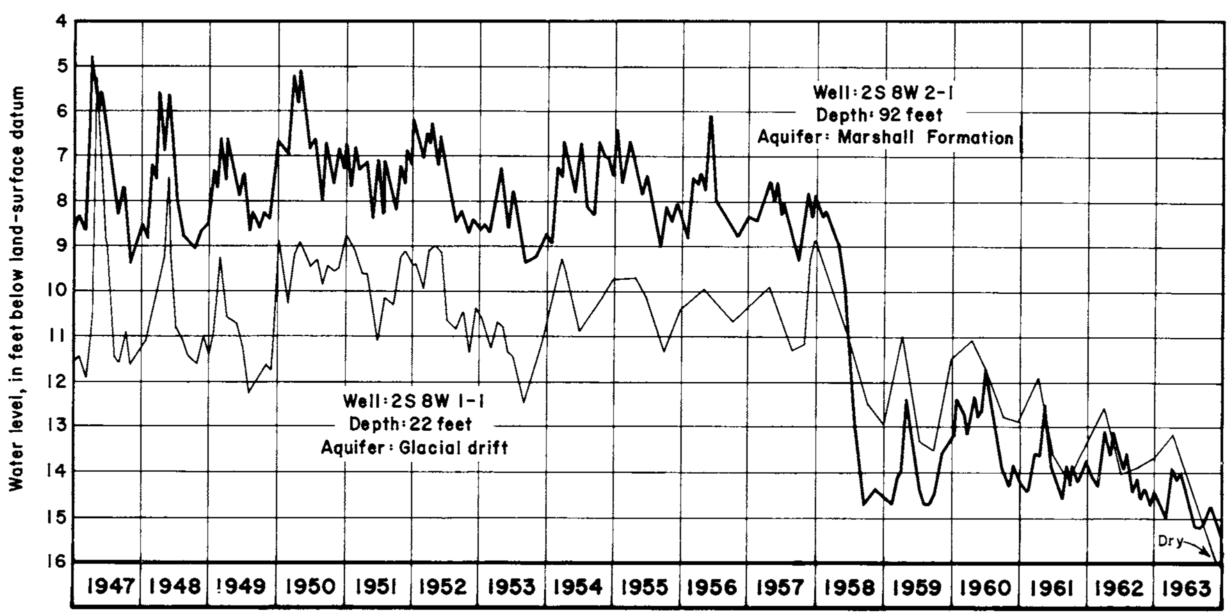


Figure 18. – Hydrograph showing similar water-level fluctuations in wells tapping the glacial drift and the Marshall Formation.

The movement of water through the drift aquifer is from high areas to low areas, and in the same general direction as the water in the Marshall Formation (fig. 6). Most of the water recharged to the drift aquifer, however, eventually moves to the Marshall and is discharged to the streams or by wells.

Quality of Water from Drift Aquifers

The water from the drift aquifers is generally similar in chemical quality to that from the Marshall Formation. It is hard or very hard, sometimes containing excessive amounts of iron (table 2).

Goguac Well Field

The only large-capacity "drift" wells in the area are at the Goguac Lake Well Station. This station formerly was one of the main sources of water for the Battle Creek municipal system. Since about 1949 the Goguac Station has been maintained only as an emergency source of supply.

The drift aquifers at the Goguac Station are quite complex. Although more than 200 feet of drift was penetrated by some of the test wells (see well 2S 8W 14-36, table 4), two of the production wells are less than 100 feet deep, and only one is more than 150 feet deep (table 3, 2S 8W 14-6).

Water levels at the Goguac Station rose sharply when the city gradually stopped pumping the wells during the period 1947-50 (fig. 19). Fluctuations since 1950 reflect only natural influences caused mostly by variations in the amount of precipitation in the area.

Although the Goguac Well Station is a good source of water supply, the city has restricted the use of the wells, in order to avoid conflict with Goguac Lake frontage owners concerned about possible decline in the lake level.

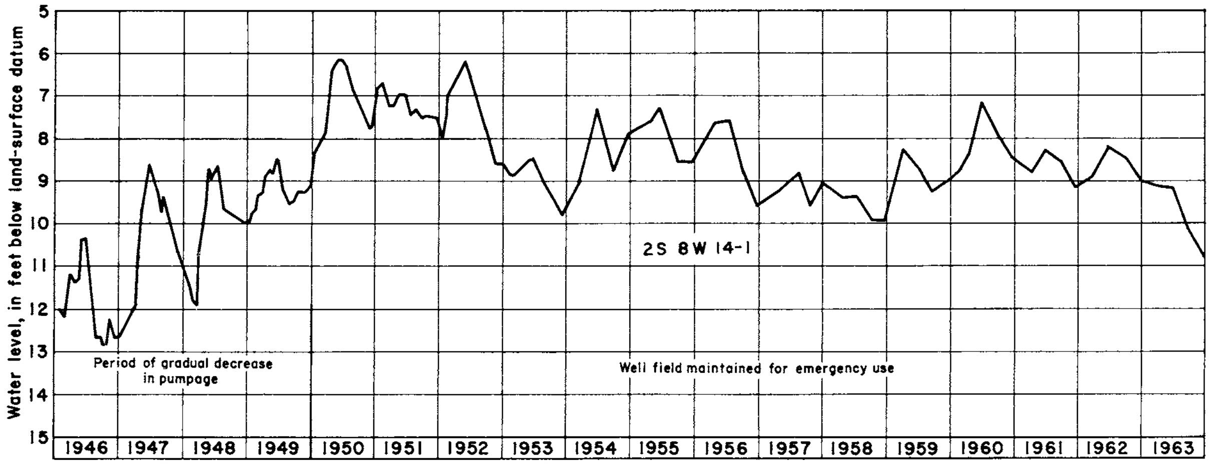


Figure 19. – Graph of water level in well 2S 8W 14-1 at Goguac Station showing rise when pumping was gradually discontinued during the period 1946-49.

SUMMARY AND CONCLUSIONS

Nearly all the water used by the municipalities, industries, and institutions and business firms in the Battle Creek area is withdrawn from wells tapping the Marshall Formation. The Verona Well Station is one of the most productive well fields in the State. The Marshall Formation has considerable potential for future development of ground-water supplies in this area.

The glacial drift includes some fairly productive aquifers but is not extensively used as a source of water supply. The drift aquifers are important, however, in the southwest part of the area where the Marshall Formation is not present. The chief reason the glacial aquifers have not been developed more extensively is that the Marshall Formation is a productive and dependable aquifer.

Local ground-water levels have declined several feet since 1945 as a result of large ground-water withdrawals. The lowering of the level of the Kalamazoo River as part of a flood-control project has also caused a decline of water levels. Little or no decline has been observed in wells located a mile or more from the centers of pumping, or where the level of the Kalamazoo River was lowered.

The decline of water levels in the area is insignificant compared to many other cities in the state and nation. Although water levels in the Battle Creek area have declined as much as 15 feet in a few places as a result of pumping, over most of the area, they have declined only a foot or two, or not at all. Water cannot be pumped from the ground, however, without lowering levels in the vicinity of the pumped wells. Thus, any increase in the rate of withdrawal of water in the area will cause a corresponding decline in ground-water levels.

I believe that ground-water withdrawals in the area can be increased 3 or 4 times the present rate before decline becomes a serious problem.

However, increases of this magnitude would entail development of a new well fields in the Marshall Formation and glacial drift aquifers.

Most of the water pumped from wells is water that would discharge to streams or lakes under natural conditions. Locally, additional water will infiltrate from the streams to the ground-water reservoirs when ground-water levels are lowered by pumping. Hence, the effect of withdrawal on the flow of adjacent streams and on the level of nearby lakes must be considered in water supply development.

The chief problem associated with development of the ground-water resources in the area to date has been a gradual increase in iron content of water at the Verona Station. Many of the wells at this station have shown a progressive increase in iron content since 1955. I believe that the iron content will eventually increase also in other wells at the station presently (1964) yielding water of low iron content. Fortunately, the iron can be removed from the water with common methods.

During the early part of 1964 it became apparent that two wells at the station were yielding water containing hydrogen sulfide gas. The development of a "hydrogen sulfide" problem at the station may become more significant as additional and larger quantities of water are withdrawn from the station. Fortunately, the hydrogen sulfide gas also can be removed with common methods.

The Marshall Formation in the area contains many openings or crevices. The origin and patterns or extent of the crevices is not known. Because these fracture zones are generally favorable well sites, the origin and extent of these fractures should be investigated.

Some of the wells at the Verona Station show a considerable reduction in specific capacity since being drilled. The exact causes for the reduction are not known. Additional study is needed to determine whether and how these wells can be redeveloped.

GLOSSARY

<u>Aquifer</u> Earth materials that will yield water to wells in usable quantities.

<u>Evaportranspiration</u> The return of water to the atmosphere as a vapor from water surfaces, from the soil, and from living plants.

<u>Hardness of water</u> A quality of the water associated with the forming of scum in the use of soap and with the forming of scale in boilers and teakettles. It may be said that hardness represents the soap-consuming power of a water. Water with 121 to 180 ppm of hardness is classified as hard, and water with over 180 ppm is classified as very hard.

<u>Parts per million</u> (ppm) A term used for expressing the amount or concentration of dissolved (or suspended) minerals in a selected volume (weight) of water. Thus, 10,000 ppm of a dissolved mineral is equivalent to 1 percent of the mineral by weight, or would be equal to 10,000 pounds of the mineral in 1,000,000 pounds of water.

<u>Permeability</u> The capacity of earth materials to allow water to flow through them.

<u>Piezometric surface</u> The surface to which the water from a given aquifer will rise under its full head. As used in this report, it refers to the water table.

<u>Specific capacity</u> The rate in gallons per minute (gpm), at which water can be pumped from a well for each foot the water level is lowered in the pumped well.

GLOSSARY -- Continued

Transmissibility (T) = coefficient of transmissibility. The rate of underground flow of water, in gallons per day, through a strip of the aquifer 1 foot wide having a height equal to the thickness of the aquifer and under a hydraulic gradient of 1 foot per foot. It is the flow, in gallons per day, through a mile-long plane cutting the aquifer when the piezometric surface slopes 1 foot per mile. (Thus, the flow of water under a mile-long segment of a water-table contour is equal to the transmissibility multiplied by the slope of the water table in feet per mile at the contour line.)

Transpiration The emission of water vapor from living plants to the atmosphere.

Water table As used in this report, the water table is the surface below which all the openings, or voids, in the ground are filled with water. It is the surface at which water stands in shallow wells, or would stand if a well were drilled.

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Table 1.--Chemical Analyses of Water from the Marshall Formation

Analyses by: M - Michigan Department of Health; U - U. S. Geological Survey

Use : P - public; T - test well; D - domestic; In - industrial

Well No.	Owner	Analyses by	Use	Date sampled	Chemical constituents (parts per million) Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Dissolved solids	Hardness as $CaCO_3$	pH	Specific conductance (Micromhos at 25°C)	Temperature (F°)	Remarks
1S 8W																				
25-1	Bedford Township	M	P	5-12-58		0.25							4	0.0		220	8.0			
1S 7W																				
31-1	City of Battle Creek	M	T	6-20-52	9.1	.7	66	23	3		274	39	2	.2	310	260	7.7	415	51	
32-16	City of Battle Creek (Verona No. 16)	U	P	9-28-54	13	.84	72	20	2.9	0.8	256	52	5	.0	290	262	7.6	487	51	
32-19	City of Battle Creek (Verona No. 19)	M	P	4- 2-54							254	43	6			240		550		
32-21	City of Battle Creek (Verona No. 21)	M	P	4- 2-54							276	67	5			290		650		
32-23	City of Battle Creek (Verona No. 23)	M	P	6-20-52	8.8	.1	74	25	7.3		280	59	10		332	285	7.6	550	51	
		M	P	1-21-53							268	57	9			285		550	51	
		M	P	3-17-54							258	55	9			265		570	51	
32-24	City of Battle Creek (Verona No. 24)	M	P	8-21-53	10	.1	68	25	5		285	40	5	0	254	270	7.4	520		
		M	P	4- 2-54							293	39	3			270		590		
33-1	W. McPherson	M	D	8-12-60		16										260				H_2S
33-27	City of Battle Creek (Verona No. 27)	M	P	4- 2-54							288	44	3			270		590		
33-29	City of Battle Creek (Verona No. 29)	M	P	1-21-53	9		64	21	3		257	39	2	.1	300	245	7.6	530	50	
2S 8W																				
1-4	Battle Creek Federal Center	M	P	6-20-52	10	1.2	92	26	14		339	64	22	.1	430	335	7.4	700		
3-3	P. E. Slayton	U	D	4-10-59	2.1	.12	30	23	8.5	1.4	172	26	16	.1	185	170	7.8	362		
11-1	Battle Creek Township (No. 1)	M	D	11- 7-57	15	1.0	87	23	7.4	.8	326	40	10	.0	356	312	7.4	600		
11-2	Battle Creek Township (No. 2)	M	P	6-20-52	11.3	.6	74	23	7.9		325	33	6	.1	318	280	7.6	580	51	
		M	P	11- 7-57	15	1.0	91	21	6.0		326	40	8	.0	352	315	7.4	600		
11-3	Battle Creek Township (No. 3)	M	P	6-11-58	13	.5	95	27	10	.9	340	55	17	0	424	350	7.4	660		
11-4	Battle Creek Township (No. 4)	M	P	12-17-59	15	1.2	92	25	6.5	.8	348	35	13	.0	380	335	7.6	640		
12-11	Ralston Purina Co.	U	In	4-19-55	12	.4	130	29	20	3.5	383	122	37	.4	560	444	7.1	892	55	
16-3	Battle Creek Twp.	M	P	1-31-64	13	5.8	74	21	3.5	.7	322	6	2	.1	344	270	7.4	500		
2S 7W																				
5-1	Grand Trunk Western Railroad	M	In	1-23-53	11	.4	68	21	3		266	39	3		280	255	7.5	500	51	
8-8	Kellogg Company	M	In	6-20-52	7.5	.3	82	25	14		300	75	17	.2	400	310	7.7	625	52	
		M		1-21-53							312	73	20			330		700	51	

Table 2.--Chemical Analyses of Water from Glacial Drift

Analyses by: M - Michigan Department of Health; U - U. S. Geological Survey

Use: P - public; T - test well; D - domestic; In - industrial

Well No.	Owner	Analyses by	Date sampled	Chemical constituents (parts per million) Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Dissolved solids	Hardness as $CaCO_3$	pH	Specific conductance (Micromhos at 25°C)	Temperature (F°)
2S 8W																		
3-1	Dominic Conto	M	6-20-52	6.7	15.3	104	27	9.4		366	70	16	0.2	504	370	7.4	690	52
14-2	City of Battle Creek	U	4-10-59	11	1.9	74	17	4.6	0.5	316	0.2	5	.1	478	255	7.5	478	
14-4	City of Battle Creek	M	1-21-53	10	1.1	50	16	4		232	10	2		210	190	7.7	410	53
22-1	Westlake School	M	12-15-59		.8							2			220	7.4		
23-1	Battle Creek Country Club	M	6-20-52	11	3.5	60	16	4		278		4	.2	262	215	7.4	410	51

Table 3.--Records of wells in Battle Creek area, Michigan

Location: Most wells are located to the nearest 10-acre tract in the section, some to the nearest 40-acre tract. Others are located by well station (see fig. 2), street number, or corner of nearest street intersection.

Aquifer: G, glacial drift; M, Marshall Formation.

Use: AC, air conditioning; D, domestic; F, fire fighting; In, industrial; O, observation well; P, public supply; T, test well.

Water level: In feet below land-surface datum; M, measured; R, reported.

Altitude: Land-surface datum, in feet above mean sea level, estimated from U.S. Geological Survey topographic maps; reported to 0.1 foot where established by instrumental leveling.

Remarks: L, Log in table 4; Q, Quality of water analysis in table 1 or 2.

Well No.	Location in section ¼ ¼ ¼	Owner	Year drilled	Diameter (in.)	Depth (ft)	Aquifer	Use	Specific capacity	Water level	M or R	Date Measured	Altitude	Depth to bedrock	Remarks
1S 8W														
25-1	NE¼ NE¼ SE¼ sec 25	Bedford Twp. No. 1	1958	10	226	M	P	170	43	R	3- ?-58	890	89	L, Q
25-3	NE¼ NE¼ SE¼ sec 25	Bedford Twp. TW 1	1958	6	220	M	T	170	42	R	3- ?-58	890	84	
27-1	SE¼ SE¼ SW¼ sec 27	Urbandale School	----	--	140	M	P	---	-----	-	--------	830	120	
36-1	SE¼ SE¼ sec 36	City of Battle Creek TW 2	1926	2	53	M	T	---	-----	-	--------	838	49	L
1S 7W														
28-1	NW¼ SE¼ NE¼ sec 28	Pennfield Twp.	1950	6	110	M	F	---	11	M	1-30-64	838	50	
28-2	SW¼ SW¼ NE¼ sec 28	C. Milburn	1963	--	55	M	D	---	-----	-	--------	845	37	L
29-1	SE¼ NW¼ section 29	Doo Drop Inn	----	6	57	M	P	---	16	R	1960	848	21	L, nearby well produced water containing H_2S
30-1	NW¼ NE¼ SE¼ sec 31	Dr. J. Sleight	----	4	166	M	D	---	-----	-	--------	900	126?	
31-1	NW¼ NE¼ SW¼ sec 31	City of Battle Creek TW 1	1926	2	140	M	D	---	2.82	M	11-21-45	838.9	83	L, Q
31-3	SE¼ NW¼ NW¼ sec 31	Pennfield Twp.	1958	6	203	M	D	---	34	R	2- ?-58	875	120	L
32-1	Verona Well Station	City of Battle Creek	1919	8	127	M	O	---	-----	-	--------	830.7	42	Q
32-2	120' E of Capitol Ave, 1500' N of Bridge St.	Mrs. Harriet Rice	1940	2	43	M	O	---	13.96	M	1- 3-46	842.9	---	
32-3	SW corner of Capitol Ave. and Hopkins St.	Pennfield Twp.	1950	6	96	M	F	---	17	R	1950	845	40	
32-13	Verona Well Station	City of Battle Creek (13)	1936	12	127	M	P	66-105	7	R	11- ?-36	834	12	
32-14	Verona Well Station	City of Battle Creek (14)	1939	12	127	M	P	330	9	R	2- ?-39	834	38	
32-15	Verona Well Station	City of Battle Creek (15)	1939	12	138	M	P	85-170	8.61	M	12-29-49	835	34	
32-16	Verona Well Station	City of Battle Creek (16)	1939	12	133	M	P	60	7.87	M	12-29-49	828	22	Q
32-17	Verona Well Station	City of Battle Creek (17)	1939	12	133	M	P	63	6.16	M	12-29-49	828	24	
32-18	Verona Well Station	City of Battle Creek (18)	1915	10	126	M	P	50	5.5	R	8- ?-15	833	14	L
32-19	Verona Well Station	City of Battle Creek (19)	1915	8	125	M	P	120	2	R	4- ?-15	830	15	Q
32-20	Verona Well Station	City of Battle Creek (20)	1904	8	140	M	P	32	+1	R	8- ?-04	832	12	
32-21	Verona Well Station	City of Battle Creek (21)	1915	10	131	M	P	76	14	R	2- ?-61	832	12	Q
32-22	Verona Well Station	City of Battle Creek (22)	1918	10	113	M	P	94	18	R	3- ?-61	832	40	
32-23	Verona Well Station	City of Battle Creek (23)	1913	8	110	M	P	35	17	R	3- ?-61	834	39	L, Q
32-24	Verona Well Station	City of Battle Creek (24)	1926	8	117	M	P	28	24	R	3- ?-61	834	12	Q
32-25	Verona Well Station	City of Battle Creek (25)	1926	8	114	M	P	88	24	R	3- ?-61	834	12	
32-30	Verona Well Station	City of Battle Creek (30)	1904	8	151	M	P	---	4	R	12- ?-04	830	35	
32-33	Verona Well Station	City of Battle Creek (33)	1948	16	150	M	P	125-330	8	R	5- ?-48	836	31	
32-34	Verona Well Station	City of Battle Creek (34)	1948	16	140	M	P	30-300	9.5	R	6- ?-48	839	48	
32-35	Verona Well Station	City of Battle Creek (35)	1948	16	132	M	P	360	15	R	6- ?-48	839	36	L

Table 3.--Records of wells.--Continued

Well No.	Location in section ¼ ¼ ¼	Owner	Year drilled	Diameter (in.)	Depth (ft)	Aquifer	Use	Specific capacity	Water level	M or R	Date Measured	Altitude	Depth to bedrock	Remarks
1S 7W														
32-36	Verona Well Station	City of Battle Creek (36)	1957	16	147	M	P	72	15	R	3- ?-57	837	15	
32-37	Verona Well Station	City of Battle Creek (37)	1957	16	145	M	P	260	9.5	R	3- ?-57	831	15	L
33-1	Clifton and Poulson	W. McPherson	----	2	132	M	D	---	-----	-	--------	925	100	Q
33-2	Gorseline and Bellevue	Pennfield School	----	4	154	M	P	---	-----	-	--------	850	105	
33-26	Verona Well Station	City of Battle Creek (26)	1926	8	115	M	P	100	23	R	3- ?-61	835	12	
33-27	Verona Well Station	City of Battle Creek (27)	1926	8	116	M	P	25	12	R	3- ?-61	835	22	L, Q
33-28	Verona Well Station	City of Battle Creek (28)	1926	8	115	M	P	25	14.5	R	3- ?-61	834	26	
33-29	Verona Well Station	City of Battle Creek (29)	1926	8	121	M	P	25	10	R	3- ?-61	834	35	Q
33-31	Verona Well Station	City of Battle Creek (31)	1948	16	125	M	P	81-185	9	R	6- ?-48	836	53	
33-32	Verona Well Station	City of Battle Creek (32)	1948	16	120	M	P	155-310	9	R	5- ?-48	837	50	
33-38	Verona Well Station	City of Battle Creek (38)	1959	16	152	M	P	200-470	20	R	10- ?-59	837	15	
33-39	Verona Well Station	City of Battle Creek (39)	1960	16	145	M	P	175-375	15	R	8- ?-60	837	12	
33-40	Verona Well Station	City of Battle Creek (40)	1962	16	148	M	P	600	21	R	10- ?-62	840	15	L
33-41	Verona Well Station	City of Battle Creek (41)	1962	16	147	M	P	380	21	R	11- ?-62	839	11	
2S 8W														
1-1	22 Barney Street	H.B. Sherman Mfg. Co.	----	2	22	G	O	---	19.71	M	8-22-46	825.2	---	
1-2	64 S. McCamly St.	Honir Brewing Co.	----	2	61	M	O	---	7.50	M	12- 5-45	819.1	---	
1-4	Washington and Champion Streets	Battle Creek Federal Center	1913	8	120	M	P	---	16	R	1913	836	60	Q
1-7	Washington and Champion Streets	Battle Creek Federal Center	----	12	125	M	P	9.3	21	R	1945	836	94	L
1-12	22 Barney Street	H.B. Sherman Mfg. Co.	1959	8	103	M	In	---	17	R	1959	830	35	
1-13	Washington and Van Buren Streets	Hart Hotel	1934	12	117	M	AC	---	30	R	1934	845	20	
1-15	McCamly and Jackson Streets	Bijou Theater	----	8	100	M	AC	---	12	R	1946	828	6	L
1-17	35 W. Michigan Ave.	Kresge Co.	1940	8	110	M	AC	---	12	R	1940	826	28	L
1-19	W. Michigan Avenue	Michigan Theatre		8	100	M	AC	---	12	R	1941	825	75	
2-1	400 NW, Angell St., 240 SW, Lafayette St.	Oliver Electric Mfg. Company	1930	10	95	M	O	---	8.10	M	1-11-46	820.0	---	
2-3	Parish and Hayes St.	Michigan Carton Co.	----	6	190	M	In	---	-----	-	--------	810	---	
3-1	630 Upton Ave.	Dominick Conto	1930	2	18	G	O	---	9.66	M	8-29-46	862	---	Q
3-2	Ave. C and 20th St.	Eaton Mfg. Co.	----	10	80	M	O	---	20.51	M	8-22-46	834.4	---	
3-3	Ave. A and 20th St.	P. E. Slayton	----	4	90	M	O	---	13.14	M	12- 4-45	849.5	---	Q
3-4	Ave. C and 20th St.	Eaton Mfg. Co.	----	8	100	M	In	---	23	R	1946	834	---	Produces "sulfur" water
3-5	Ave. C and 20th St.	Eaton Mfg. Co.	----	8	127	M	In	75	24	R	1945	834		
3-6	Ave. C and 20th St.	Rich Steel Products Company	1924	8	50	M	In	60	13.8	R	1924	838	10	L
4-1	NE of NE¼ section 4	City of Springfield (TW 1)	1959	6	135	M	T	---	-----	-	--------	818	130	L
11-1	NW¼ NW¼ section 11	Battle Creek Twp (1)	1947	12	180	M	P	22	12	R	3- ?-47	895	120	L, Q
11-2	NE¼ NW¼ section 11	Battle Creek Twp (2)	1947	12	172	M	P	9	26	R	3- ?-47	895	106	Q
11-3	NW¼ NW¼ section 11	Battle Creek Twp (3)	1952	12	135	M	P	---	3	R	1952	885	90	Q
11-4	NE¼ NW¼ section 11	Battle Creek Twp (4)	1958	12	146	M	P	---	-----	-	--------	885	118	Q
12-2	Fountain and Monroe Streets	Battle Creek Gas Co. (1)	1910	4	110	M	In	---	10	R	1910	828	88	
12-5	Fountain and Monroe Streets	Battle Creek Gas Co. (TW 2)	1927	--	92	M	T	---	9	R	3- ?-27	828	90	L
12-9	150 S. McComly St.	Ralston Purina Co. (1)	1938	10	120	M	In	---	12	R	1938	820	30	L
12-11	150 S. McComly St.	Ralston Purina Co. (4)	1952	12	110	M	In	---	10	R	1955	825	---	Q
14-1	Goguac Well Station	City of Battle Creek	1928	2	70	G	D	---	21.5	R	11- ?-28	916.0	---	
14-2	Goguac Well Station	City of Battle Creek	----	26	89	G	O	---	12.51	M	12- 7-45	915.0	---	Q
14-3	Goguac Well Station	City of Battle Creek (3)	1930	26	85	G	P	---	20	R	4- ?-30	915	---	
14-4	Goguac Well Station	City of Battle Creek (4)	1931	26	112	G	P	---	15	R	10- ?-31	915	---	L, Q
14-5	Goguac Well Station	City of Battle Creek (1)	1925	18	82	G	P	---	27.5	R	4- ?-27	915	---	
14-6	Goguac Well Station	City of Battle Creek (2)	1930	26	163	G	P	---	16	R	4- ?-30	915	---	
14-7	NE¼ SE¼ section 14	City of Battle Creek (TW 3)	1929	--	90	G	P	---	-----	-	--------	915	---	One of 7 test wells drilled in 1929.
14-13	NE¼ SE¼ section 14	City of Battle Creek	1931	4	105	G	P	---	21	R	4- ?-30	915	---	One of 6 test wells drilled in 1931.

Table 3.--Records of wells.--Continued

Well No.	Location in section $\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$	Owner	Year drilled	Diameter (in.)	Depth in feet	Aquifer	Use	Specific capacity	Water level	M or R	Date Measured	Altitude	Depth to bedrock	Remarks
2S 8W														
14-19	SE$\frac{1}{4}$ SE$\frac{1}{4}$ section 14	City of Battle Creek (TW 2)	----	4	87	G	P	---	-----	-	--------	915	---	One of 8 test wells drilled in 1928.
14-35	NE$\frac{1}{4}$ SE$\frac{1}{4}$ section 14	City of Battle Creek	1903	6	430	G	P	---	-----	-	--------	920	198	L, One of 4 test wells drilled about 1900.
16-1	SW$\frac{1}{4}$ NE$\frac{1}{4}$ section 16	Battle Creek Twp (TW 1)	1963	8	155	M	T	4	4.5	R	7- ?-63	917	84	
16-2	SW$\frac{1}{4}$ NE$\frac{1}{4}$ section 16	Battle Creek Twp (TW 2)	1963	8	150	M	T	70	6.5	R	8- ?-63	917	62	L
16-3	SW$\frac{1}{4}$ NE$\frac{1}{4}$ section 16	Battle Creek Twp (1)	1964	14	150	M	P	---	-----	-	--------	917		Q, at site of TW 2.
22-1	NE$\frac{1}{4}$ NW$\frac{1}{4}$ section 22	Westlake School	1959	6	75	G	P	19	38	R	1959	945	---	L, Q
22-2	SW$\frac{1}{4}$ NE$\frac{1}{4}$ section 22	Battle Creek Twp (TW 1)	1961	8	110	G	T	---	0	R	1961	917	---	
22-3	SW$\frac{1}{4}$ NE$\frac{1}{4}$ section 22	Battle Creek Twp (TW 2)	1961	8	200	M	T	6	+1	R	1961	917	93	L
23-1	NW$\frac{1}{4}$ SE$\frac{1}{4}$ section 23	Battle Creek Country Club	----	2	53	G	P	---	-----	-	--------	930	---	Q
23-2	19 Wealthy Street	Nelson Alleshouse	1963	--	80	M	D	---	15	R	1963	917	40	
25-1	SE$\frac{1}{4}$ SE$\frac{1}{4}$ section 25	Michigan State Highway Department	1959	6	148	G	P	6	43	R	12- ?-59	935	140?	L
25-2	NE$\frac{1}{4}$ NE$\frac{1}{4}$ section 25	Battle Creek Twp (TW 1)	1962	8	130	G	T	---	1.5	R	1962	860	117	L
25-3	NE$\frac{1}{4}$ NE$\frac{1}{4}$ section 25	Battle Creek Twp (TW 2)	1962	8	76	G	T	6	1.5	R	1962	860	---	
25-4	NE$\frac{1}{4}$ NE$\frac{1}{4}$ section 25	Battle Creek Twp (TW 3)	1962	8	120	-	T	---	2	R	1962	860	118	
26-1	Capitol Ave at I94	Standard Oil Co.	1961	4	70	G	P	---	38	R	1961	935	---	
35-1	Capitol Ave at I94	Bill Knapps Restaurant	1961	4	130	M	P	---	38	R	1961	945	100	
36-1	Capitol Ave at I94	Holiday Inn	1961	4	150	M	P	---	38	R	1961	945	100	
2S 7W														
4-5	1010 Raymond Rd.	Modern Transit Mix	1961	4	123	M	In	---	21	R	1961	860	70	
5-1	SE$\frac{1}{4}$ NE$\frac{1}{4}$ section 5	Grand Trunk Western RR	1939	16	116	M	In	---	-----	-	--------	840	39	L, Q
5-2	SE$\frac{1}{4}$ NE$\frac{1}{4}$ section 5	Grand Trunk Western RR	1939	16	121	M	In	---	9.5	R	1939	840	30	
5-3	SE$\frac{1}{4}$ NE$\frac{1}{4}$ section 5	Grand Trunk Western RR	1939	16	90	G	T	---	12	R	1939	840	30	L
5-4	1021 Raymond Rd.	Nichols Wire and Steel	----	4	135	M	In	---	-----	-	--------	855	75	
6-1	Wabash and Capitol Sts	J. Kilosky	----	8	125	M	-	---	39	R	--------	855	---	
7-1	150 NE Michigan, 470 SE Huron St.	Oliver Farm Equipment	1910	6	71	M	O	---	19.52	R	11- ?-46	831.5	---	
7-2	NE$\frac{1}{4}$ SE$\frac{1}{4}$ Section 7	General Foods Corp (1)	1918	8	87	M	In	---	22.20	R	1945	850	---	One of 13 production wells, 95 to 119 feet deep.
7-12	NE$\frac{1}{4}$ SE$\frac{1}{4}$ section 7	General Foods Corp (2)	1951	--	117	M	In	---	-----	-	--------	875	35	L
8-1	SE$\frac{1}{4}$ NW$\frac{1}{4}$ section 8	Kellogg Co.	----	8	100	M	O	---	-----	-	--------	847.4	---	
8-2	NE$\frac{1}{4}$ NW$\frac{1}{4}$ section 8	Kellogg Co.	1933	16	119	M	O	---	-----	-	--------	845±	51	L
8-8	NE$\frac{1}{4}$ NW$\frac{1}{4}$ section 8	Kellogg Co. No. 8	1933	16	119	M	In	22	35	R	1933	845	51	Q, One of 11 production wells at plant.
8-13	SE$\frac{1}{4}$ SE$\frac{1}{4}$ section 8	City of Battle Creek (TW 7)	1903	2	73	G	T	---	-----	-	--------	837	---	L
9-1	NW$\frac{1}{4}$ SW$\frac{1}{4}$ section 9	City of Battle Creek (TW1)	1903	2	70	G	T	---	-----	-	--------	838	---	L
9-2	NW$\frac{1}{4}$ SW$\frac{1}{4}$ section 9	City of Battle Creek (TW 2)	1903	2	115	G-M	T	---	-----	-	--------	840	85	
9-3	SW$\frac{1}{4}$ SW$\frac{1}{4}$ section 9	City of Battle Creek (TW 3)	1903	2	131	G	T	---	-----	-	--------	838	---	
9-4	SW$\frac{1}{4}$ SW$\frac{1}{4}$ section 9	City of Battle Creek (TW 5)	1903	2	113	G	T	---	8	R	1903	838	---	L, Water level is 5 feet below level of river.
9-5	SW$\frac{1}{4}$ SW$\frac{1}{4}$ section 9	City of Battle Creek (TW 6)	1903	2	100	G	T	---	-----	-	--------	838	---	
16-1	SW$\frac{1}{4}$ NW$\frac{1}{4}$ section 16	City of Battle Creek (TW 8)	1903	2	81	G	T	---	-----	-	--------	842	---	L
16-2	NE$\frac{1}{4}$ NW$\frac{1}{4}$ section 16	City of Battle Creek (TW 9)	1903	2	62	G	T	---	-----	-	--------	839	---	
16-3	NW$\frac{1}{4}$ NW$\frac{1}{4}$ section 16	City of Battle Creek (TW 10)	1903	2	100	G	T	---	-----	-	--------	836	---	
16-4	NW$\frac{1}{4}$ NW$\frac{1}{4}$ section 16	City of Battle Creek (TW 4)	1903	2	93	M	T	---	-----	-	--------	840	70	L
17-1	NW$\frac{1}{4}$ SW$\frac{1}{4}$ section 17	City of Battle Creek	1926	2	91	M	T	---	10.02	M	11-14-45	841.8	15	L
18-1	SW$\frac{1}{4}$ SE$\frac{1}{4}$ section 18	City of Battle Creek	1926	2	90	M	T	---	1.89	M	11-14-45	832.5	52	L
18-2	NE$\frac{1}{4}$ SE$\frac{1}{4}$ section 18	City of Battle Creek	1926	2	75	M	T	---	-----	-	--------	833	15	L
19-1	NW$\frac{1}{4}$ NE$\frac{1}{4}$ section 19	City of Battle Creek	1926	2	73	M	T	---	-----	-	--------	851	31	L
19-2	SE$\frac{1}{4}$ NE$\frac{1}{4}$ section 19	City of Battle Creek	1926	2	74	M	T	---	-----	-	--------	845	54	L
28-1	SW$\frac{1}{4}$ NW$\frac{1}{4}$ section 28	Michigan Woodworks	----	6	117	M	In	---	38	R	1963	935	60	

Table 4.--Logs of wells and test wells

Logs as recorded by well drillers, except those from samples of drill cuttings. Altitudes estimated from U. S. Geological Survey Topographic Maps are reported to the nearest foot. Those determined by instrumental leveling are reported to the nearest tenth of a foot.

	Thickness (feet)	Depth (feet)
Well 1S 8W 25-1; NE¼ SE¼ section 25, Bedford Twp. No. 1 Altitude 890 feet		
Topsoil and sand	5	5
Sand, brown	15	20
Clay, gray	10	30
Clay, brown	40	70
Sand and gravel	19	89
Sandstone, brown	91	180
Sandstone, white	44	224
Shale	2	226
Well 1S 8W 36-1; SE¼ SE¼ section 36, City of Battle Creek No. 2 Altitude 838 feet		
Muck	1	1
Fine sand	48	49
Sandstone	4	53
Well 1S 7W 28-2; SW¼ NE¼ section 28, Clarence Milburn Altitude 845 feet		
Clay and sand	6	6
Sand and gravel	31	37
Soft sandstone	18	55
Well 1S 7W 29-1; SE¼ NW¼ section 29, Doo Drop Inn Altitude 848 feet		
Clay and sand	21	21
Sand rock	36	57
Note: Nearby well 86 ft. deep produced "sulfur" water (water containing H_2S.		
Well 1S 7W 31-1; NE¼ SW¼ section 31, City of Battle Creek Altitude 838.9 feet		
Loam	1	1
Sand, fine	82	83
Sandstone, blue, cavernous	56	139
Shale	1	140
Well 1S 7W 31-3; NW¼ NW¼ section 31, Penfield Twp. Altitude 875 feet		
Sand and gravel, fine to coarse and clay	80	80
Clay, sandy, gravelly	4	84
Sand and gravel, fine to coarse	6	90
Sand, fine to medium	5	95
Sand and gravel, cemented	10	105
Clay, gravelly	11	116
Gravel (water bearing)	2	118
Gravel and sandstone (water bearing)	2	120
Sandstone, white (water bearing)	30	150
Sandstone, shaly	48	198
Shale, blue gray	5	203

	Thickness (feet)	Depth (feet)
Well 1S 7W 32-18; NE¼ SE¼ section 32, City of Battle Creek (Verona No. 18) Altitude 833 feet		
Fine sand	14	14
Soft sandstone	5	19
Very hard sandstone	61	80
Softer sandstone, many openings	30	110
Fine-grained sandstone, fewer openings	16	126
Well 1S 7W 32-23; NE¼ SE¼ section 23, City of Battle Creek (Verona No. 23) Altitude 834 feet		
Quick sand	30	30
Hardpan	9	39
Soft sandstone	4	43
Hard sandstone	67	110
Well 1S 7W 32-35; SE¼ SE¼ section 32, City of Battle Creek (Verona No. 35) Altitude 839 feet		
Sand	15	15
Sand and gravel	21	36
Broken, muddy sandrock	20	56
Clean sandrock	54	110
Shale	2	112
Muddy sandrock	18	130
Shale	2	132
Well 1S 7W 32-37; SE¼ NE¼ section 32, City of Battle Creek (Verona No. 37) Altitude 831 feet		
Yellow sand	15	15
Yellow sandstone	5	20
Gray sandstone	5	25
Brownish gray sandstone	8	33
Gray sandstone, hard	26	59
Light gray sandstone	20	79
Gray sandstone	31	110
Gray sandstone and shale	7	117
Gray sandstone, dirty	7	124
Gray sandstone, crevices	4	128
Gray sandstone	11	139
Gray sandstone and shale	4	143
Shale	2	145
Well 1S 7W 33-27; SW¼ NW¼ section 33, City of Battle Creek (Verona 27) Altitude 835 feet		
Yellow sand, some stone	5	5
Sand, gravel, and stone	17	22
Sandstone, yellow and gray	5	27
Medium soft sandstone	13	40
Hard sandstone, few caverns	5	45
Hard sandstone	5	50
Hard sandstone, four 2-inch caverns	18	68
Hard cavernous sandstone	44	112
Scaly flint rock	4	116

Table 4.--Logs of wells and test wells.--Continued

	Thickness (feet)	Depth (feet)
Well 1S 7W 33-40;		
NW¼ NW¼ section 33		
City of Battle Creek (Verona 40)		
Altitude 840 feet		
Sand	11	11
Gravel and broken rock	4	15
Soft broken sandstone	10	25
Gray sandstone	35	60
Hard sandstone	4	64
Gray sandstone, no cuttings	1	65
Gray sandstone	25	90
Gray sandstone, no cuttings	25	115
Gray sandstone	19	134
Gray sandstone, no cuttings	8	142
Gray sandstone	5	147
Shale	1	148
Well 2S 8W 1-7;		
SW¼ NE¼ section 1		
Battle Creek Federal Center (5)		
Altitude 836 feet		
Fill, clay	4	4
Gravel, sand, muddy	50	54
Mud, clay	6	60
Gravel and clay layers	30	90
Soft clay	4	94
Sandstone	11	105
Shale, hard	2	107
Sandstone, shale	4	111
Shale	14	125
Well 2S 8W 1-15;		
SE¼ SE¼ section 1		
Bijou Theater		
Altitude 828 feet		
-------	6	6
Sandstone, brown	44	50
Sandstone, gray	50	100
Well 2S 8W 1-17;		
SE¼ SE¼ section 17		
Kresge Co.		
Altitude 826 feet		
Fill	8	8
Sand and clay	20	28
Sandstone and shale	22	50
Sandstone	28	78
Shale, hard, sandy	4	82
Sandstone (water)	20	102
Shale	8	110
Well 2S 8W 3-6;		
SE¼ NE¼ section 3		
Rich Steel Products Co.		
Altitude 838 feet		
Sand and boulders	10	10
Soft sandstone	19	29
Blue sandstone	7	36
Fissure at 36 ft.		
Blue sandstone	14	50
Well 2S 8W 4-1;		
NE¼ NE¼ section 4		
City of Springfield TW No. 1		
Altitude 818 feet		
Log from samples of drill cuttings by the Michigan Geological Survey		
Pleistocene:		
Drift		
Clay, yellow, coarse sand, and fine to medium gravel	20	20

	Thickness (feet)	Depth (feet)
2S 8W 4-1 (Continued)		
Gravel, fine to coarse, medium to coarse sand, very clayey	5	25
Sand, light brown, medium to coarse, few pebbles	5	30
Gravel, medium to coarse, some fine	5	35
Gravel, fine to coarse and medium to coarse sand	5	40
Sand, fine to coarse	5	45
Sand, light yellow, very fine to medium, pebbly		
Some coarse sand and clay	10	55
Sand, very fine to medium, silty, little coarse sand and fine gravel	5	60
Sand, light gray, fine to medium	5	65
Sand and gravel, fine to medium	10	75
Sand, light brown, medium to coarse, some fine gravel and pebbles	5	80
Gravel, fine to coarse and sand medium to coarse	5	85
Gravel, fine and sand, coarse, some medium sand and gravel	5	90
Gravel, fine to coarse, sand, medium to coarse, large pebbles	5	95
Sand, medium to coarse, gravel, fine to medium, few pebbles	5	100
Gravel, fine to coarse and sand, medium to coarse	5	105
Sand, light brown, medium, some coarse sand	10	115
Gravel, fine to medium, some coarse; sand, medium to coarse	5	120
Clay, light gray; coarse sand and fine to medium gravel	5	125
Clay, light gray, some fine to medium gravel	5	130
Mississippian:		
Coldwater Shale:		
Shale, gray soft	5	135
Well 2S 8W 11-1;		
NW¼ NW¼ section 11		
Battle Creek Twp. (1)		
Altitude 895 feet		
Top soil and clay	8	8
Clay, gravel, soft	22	30
Clay, blue	35	65
Sand	5	70
Clay	40	110
Rock, broken; clay, sand and gravel	10	120
Sandrock	30	150
Shale	30	180
Well 2S 8W 12-5;		
SE¼ NE¼ section 12		
Battle Creek Gas Co. (TW No. 2)		
Altitude 828 feet		
Filled earth	4	4
Clay, sandy	12	16
Gravel	49	65
Sand	25	90
Sandrock (?)	2	92
Well 2S 8W 12-9;		
NW¼ NE¼ section 12		
Ralston Purina Co. No. 1		
Altitude 820 feet		
Sand and gravel	30	30
Sandstone (Marshall)	78	108
Shale (Coldwater)	--	120

Table 4.--Logs of wells and test wells.--Continued

	Thickness (feet)	Depth (feet)
Well 2S 8W 14-4; NE¼ SE¼ section 14 City of Battle Creek (Goguac No. 4) Altitude 915 feet		
Fill dirt and gravel	10	10
Clay	18	28
Hardpan	2	30
Clay, gravel	2	32
Medium gravel	10	42
Coarse sand	12	54
Fine sand	16	70
Medium sand	18	88
Gravel	2	90
Sand	3	93
Gravel and coarse sand	19	112
Well 2S 8W 14-35' NE¼ SE¼ section 14 City of Battle Creek Altitude 920 feet		
Lake sand and gravel	15	15
Lake sand	55	70
Dark gravel (sulfur odor)	10	80
Quicksand and some lake sand	118	198
Soft blue clay	10	208
Blue shale rock	199	407
Hard dark sandrock (dry)	3	410
Soft blue shale	20	430
Well 2S 8W 16-2; SW¼ NE¼ section 16 Battle Creek Twp. (TW No. 2-1963) Altitude 917 feet		
Sandy clay, strips of gravel	18	18
Gravel	14	32
Sandy clay, red streaks	28	60
Gravel, clean	2	62
Green sandstone	28	90
Gray and white sandstone	55	145
Shale, gray	5	150
Well 2S 8W 22-1; NE¼ NW¼ section 22 Westlake School Altitude 945 feet		
Clay, yellow	30	30
Clay, blue, heavy	30	60
Sand, fine	2	62
Sand, gravel, water	13	75
Well 2S 8W 22-3; SW¼ NE¼ section 22 Battle Creek Twp. (TW No. 2-1961) Altitude 917 feet		
Muck	7	7
Marl	8	15
Fine sand, dirty	15	30
Sand and gravel, dirty	4	34
Gravel and clay	59	93
Green shale	5	98
Gray shale and sandstone	7	105
Sandstone and gray shale	27	132
Gray shale, some limestone	68	200
Well 2S 8W 25-1; SE¼ SE¼ section 25 Michigan State Highway Dept. Altitude 935 feet		
Fill	2	2
Sand, clay and stones	5	7
Sand and clay	15	22
Sand, clay and boulders	16	38
Sand and clay, brown	30	68
2S 8W 25-1 (Continued)		
Sand and clay, blue	4	72
Sand gravel and clay	10	82
Sand and gravel	6	88
Sand, gravel and clay	9	97
Clay sand and stones	15	112
Sand and gravel	2	114
Sand and gravel, dirty	3	117
Sand, dirty	8	125
Sand, clean	4	129
Sand and gravel, dirty	7	136
Sand and gravel	4	140
Clay, blue	8	148
Well 2S 8W 25-2; NE¼ NE¼ section 25 Battle Creek Twp. (TW No. 1, 1962) Altitude 860 feet		
Sand fill	2	2
Muck	14	16
Sand, fine	39	55
Gravel	19	74
Soft clay and sand	6	80
Sand and clay	13	93
Gravel and clay	13	106
Fine sand	4	110
Sand and clay	7	117
Shale, black	13	130
Well 2S 7W 5-1; SE¼ NE¼ section 5 Grand Trunk Western RR (2) Altitude 840 feet		
Fill	4	4
Sand, dirty	14	18
Sand	12	30
Sand, dirty	9	39
Shale	2	41
Sand rock	9	50
Sand rock, shale mixed	7	57
Sand rock	6	63
Sand rock, some shale	4	67
Sand rock	41	108
Shale	4	112
Sand rock	4	116
Shale at	--	116
Well 2S 7W 5-3; SE¼ NE¼ section 5 Grand Trunk Western RR (Tw 1) Altitude 840 feet		
Fill	1	1
Sand and boulders	15	16
Gravel and sand	14	30
Shale, blue	1	31
Shale sandy	11	42
Sand, fine	1	43
Shale, sandy	10	53
Sand	6	59
Shale and mud	31	90
Well 2S 7W 7-12; NE¼ SE¼ section 7 General Foods Corp. Altitude 875 feet Log from samples of drill cuttings by the Michigan Geological Survey		
Sand, very fine to coarse	10	10
Sand, very fine with yellow clay	30	40
Mississippian:		
Marshall Formation:		
Sandstone, gray very fine grained	30	70
No sample	5	75
Sandstone, gray, very fine grained	35	110
Shale, gray, soft, very sandy	7	117

Table 4.--Logs of wells and test wells.--Continued

	Thickness (feet)	Depth (feet)
Well 2S 7W 8-2; NE¼ NW¼ section 8 Kellogg Co. Altitude 845 feet		
Fill and cinders	24	24
Sand	24	48
Clay	3	51
Shale and sandstone	9	60
Sandstone, gray	51	111
Shale	8	119
Well 2S 7W 8-13; SE¼ SE¼ section 8 City of Battle Creek (TW 7, 1903) Altitude 837 feet		
Coarse sand and gravel	26	26
Fine sand	47	73
Well 2S 7W 9-1; NW¼ SW¼ section 9 City of Battle Creek (TW 1, 1903) Altitude 838 feet		
Very fine sand	50	50
Coarse sand and fine gravel	18	68
Coarse gravel	2	70
Large boulder at		70
Well 2S 7W 9-4; SW¼ SW¼ section 9 City of Battle Creek (TW 5, 1903) Altitude 838 feet		
Sand and medium gravel	30	30
Fine sand	10	40
Coarse sand	10	50
Fine sand	10	60
Sand, medium	6	66
Coarse sand and gravel	29	95
Sand, medium	5	100
Coarse sand and gravel	13	113
Well 2S 7W 16-1; SW¼ NW¼ section 16 City of Battle Creek (TW 8-1903) Altitude 842 feet		
Fine sand	50	50
Coarse sand and fine gravel	15	65
Fine sand	16	81
Well 2S 7W 16-4; NW¼ NW¼ section 16 City of Battle Creek (TW 4, 1903) Altitude 840 feet		
Fine gray to yellow sand	70	70
Marshall sandstone	20	90
Shale	3	93
Well 2S 7W 17-1; NW¼ SW¼ section 17 City of Battle Creek Altitude 841.8 feet		
Loam	1	1
Sand, fine	14	15
Sand, yellow and sandstone	10	25
Sand and sandstone, gray	10	35
Sandstone, blue and sandstone	12	47
Sandstone, blue, cavernous	42	89
Clay	2	91
Well 2S 7W 18-1; SW¼ SE¼ section 18 City of Battle Creek Altitude 832.5 feet		
Muck	2	2
Sand, coarse and fine	8	10
Sand, fine	21	31
Sand, very fine, with some clay	10	41
Sand, some fine gravel	5	46
Quicksand	6	52
Sandstone, fine blue	35	87
Clay, blue	3	90
Well 2S 7W 18-2; NE¼ SE¼ section 18 City of Battle Creek Altitude 833 feet		
Loam	1	1
Clay and sand	4	5
Sand and fine gravel	10	15
Soft yellow sandstone	5	20
Soft yellow and gray sandstone	7	27
Blue sandstone	46	73
Silty clay	2	75
Well 2S 7W 19-1; NW¼ NE¼ section 19 City of Battle Creek Altitude 851 feet		
Muck	2	2
Fine sand	8	10
Gravel and sand	21	31
Blue sandstone	41	72
Blue clay	1	73
Well 2S 7W 19-2; SE¼ NE¼ section 19 City of Battle Creek Altitude 845 feet		
Muck	2	2
Sand and fine gravel	8	10
Clay and sand	44	54
Slightly cavernous sandstone	18	72
Clay	2	74

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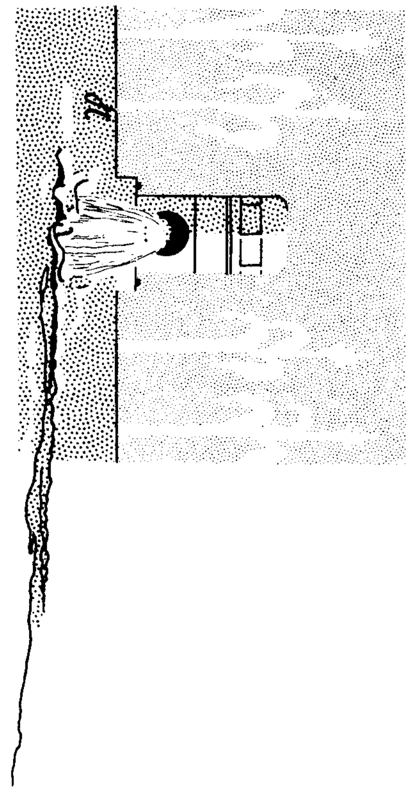

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