GROUND WATER IN IONIA COUNTY, MICHIGAN

Thesis for the Degree of M. S.
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ABSTRACT

GROUND WATER IN IONIA COUNTY, MICHIGAN

By

David Eugene Swanson

The report area has an abundant ground water resource which is readily available throughout most of the county. Domestic water supplies are obtained from glacial drift or bedrock aquifers. Shallow high capacity wells are possible utilizing recharge through permeable glacial spillway and outwash deposits which are found adjacent to the channels of the Maple, Grand, Looking Glass, and Flat Rivers. No critical supply problems were encountered.

Widespread problems exist with water quality. Typically, the ground water is hard to very hard and at times contains objectionable concentrations of sulfate and iron. Quality problems are often the result of gypsum deposits and the iron content of some bedrock units.

To assist the non-professional, basic ground water principles are discussed and related to the geology and ground water conditions within the county. Maps depicting geology and ground water conditions and tables of basic data are included for reference.

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By

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GLOSSARY

Aquaclude - A formation which transmits water slowly.

Aquifer - Subsurface zone capable of producing water as from a well.

Artesian - Ground water under enough pressure to cause the water to rise above the aquifer containing it.

Bedrock - Solid consolidated rock.

Capacity - Refers to the amount of water an aquifer will yield.

Clay - Soil consisting of inorganic material, the grains of which have diameters smaller than .005 millimeters (very fine grained).

Consolidated - Earth materials which have been pressed or cemented into a compact mass.

Contour - Line connecting points of equal value. Commonly used on topographic maps to reflect the undulations of a surface.

Drift - Term used to collectively refer to all of the glacial deposits.

Dolomite - A rock which is composed primarily of the mineral dolomite. A calcium magnesium carbonate. Looks like limestone.

Erosion - Processes by which earth materials are loosened and carried away from its original location. Erosion by rivers and streams is common in this climatic area.

Formation - A bedrock unit which has features which distinquish it from adjoining units.

Geology - The science or study of the earth, the rocks of which it is composed, and the processes which have changed and are changing the earth.

Geophysical survey - To apply the methods and instruments of physics and engineering to geological problems.

Ground water table - Generally a gradational zone or surface which separates the zone of subsurface saturation from the overlying unsaturated zone.

Ground water - Subsurface water which is in the zone of saturation (below the water table).

Gypsum - A mineral formed from the continued evaporation of sea water. Calcium sulfate ($CaSO_4 \cdot 2H_2O$). Used in plaster of paris.

Limestone - A rock formation that consists of calcium carbonate.

Mg/l - Milligrams per liter. Measure of concentration equivalent to one part in one million parts of water.

Permeability - Measurement of the resistance encountered by water in its attempt to move through a porous material.

Porosity - A measure of the percentage of a porous material which is open spaces.

Piezometric - The surface to which the water from an aquifer will rise under its full pressure.

Recharge - Replenishing the ground water with natural precipitation or through artificially induced infiltration.

Sandstone - A cemented or otherwise compacted rock which is predominantly composed of sand sized particles.

Shale - Clay which has been compacted to form a hard laminated rock.

Topography - The relief and contour of the land or other such surface. The configuration of a surface.

INTRODUCTION

The objective of this report is to present information about the ground water in Ionia County and the factors affecting it. An attempt has been made to present this information in a manner intelligible to all interested readers regardless of their background. The broad target audience plus the desire to present as many of the pertinent ground water factors as possible has necessitated a generalized treatment for some of the sections in this report.

Ionia County was chosen as the problem area because it typified what the author believed to be an average Michigan county from a ground water point of view, because of its accessibility for field work, and because there has been no previous detailed study of the county. The ground water problems within the county are probably not as pressing as in the more populated regions of the state, but this study was not undertaken as a primary problem solving study. Rather, the study was designed to further aquaint the author with problems associated with basic data collection, manipulation, and presentation.

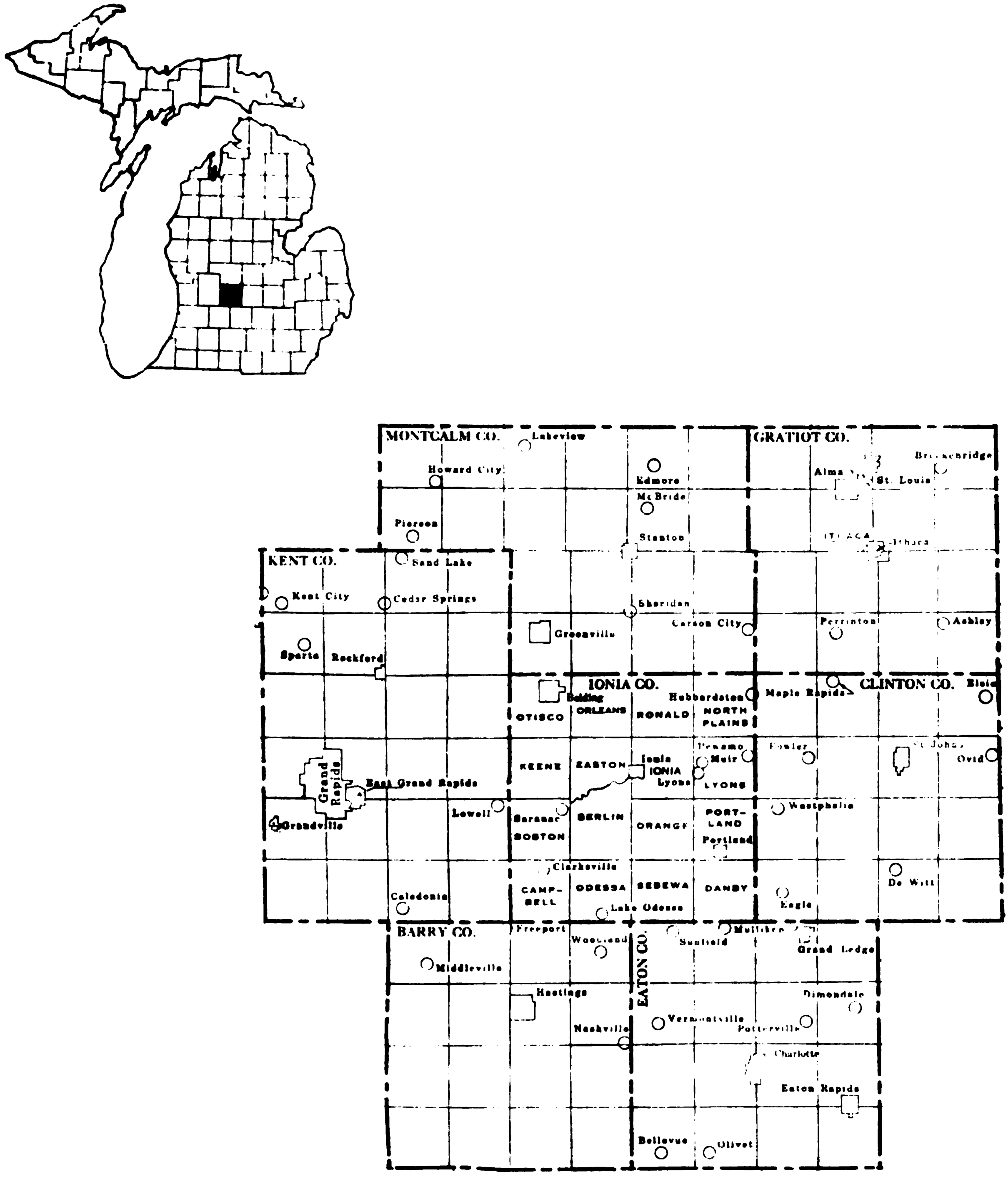

Figure 1. The Report Area and Surrounding Counties

CHAPTER I

DESCRIPTION OF THE COUNTY

Location and Size

Ionia County is a 575 square mile area[1] located in the south central portion of Michigan's lower penninsula. It is approximately 60 miles east of Lake Michigan and about 100 miles north of the Indiana border.

The land surface is predominantely level to gently rolling except near several deeply incised river channels where the local relief may exceed 180 feet. The highest elevation is over 950 feet above mean sea level in the extreme northwest corner of the county and the lowest elevation is 620 feet where the Grand River crosses the western county line.

Population and Employment

Agriculture and agricultural related industries are important to the economy of the county. In 1959 over 83 percent of the land (306,679 acres) was farm land, but this figure has been decreasing slowly during the past decade.[2]

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[1] Michigan Economic Development Department (compiler), "Ionia County Economic Data Sheet" (Mimeographed, 1961), p.1.

[2] *Ibid.*, p.7.

The important farm products are grains, fruits, and livestock. Machinery manufacturing and fabricated metal products are also important employment areas.[3]

Since 1940, Ionia County has experienced a steady increase in population which is expected to continue into the future as shown by Figure 2.[4] Along with present growth

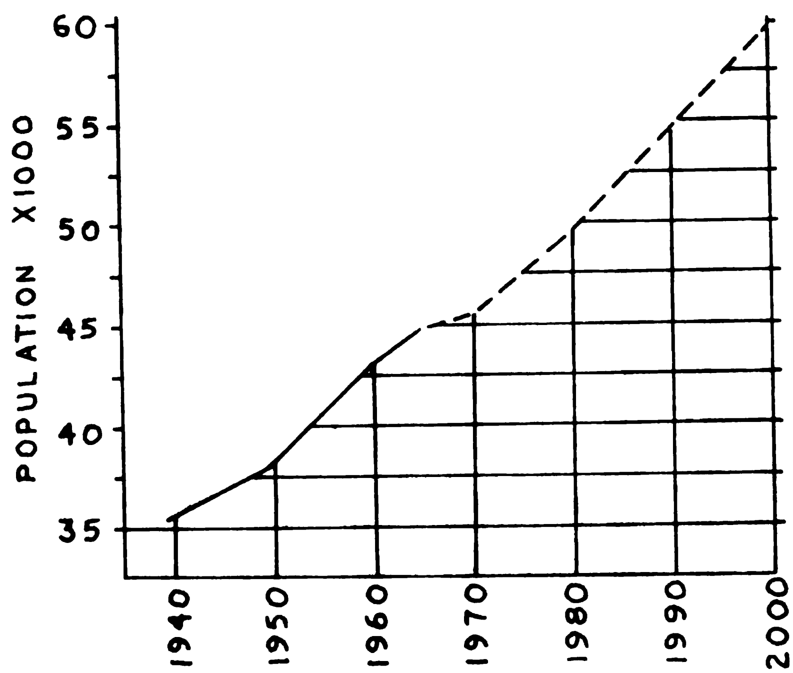

Figure 2. Past and Future Population Trends for Ionia County

centers, one can expect the future population distribution within the county to be affected by the continued growth of the Lansing and Grand Rapids metropolitan areas along present transportation routes.

[3] *Ibid.*, p.3.

[4] Michigan Department of Commerce (compiler), "Ionia County" Economic Profile Sheet 1-1 and 1-2 (mimeographed, 1966)

Climate

Lake Michigan influences the county's climate although not as greatly as counties to the west. When westerly winds occur, the lake tends to moderate the temperature and to increase the precipitation, but this effect decreases as one moves eastward, away from the lake. If winds come from the south, then the effects of Lake Michigan are lost and the climate tends to be of the continental type.

The average monthly temperature is 48.1 degrees and has varied from a recorded low of 25 degrees below zero (Feb. 12, 1899) to a high of 103 degrees (Aug. 5, 1947).[5] Typically, the temperature varies throughout the year as shown in Figure 3.

The average monthly precipitation varies only two inches between the summer high and the winter low (Figure 4), but more importantly, from a ground water point of view, it varies greatly from year to year (Figure 5). The relationship between precipitation and ground water will be discussed in a later section.

Water Supply

Presently, all of the county's cities and villages with populations over 400 have municipal water supplies except for the village of Lyons. The State reformitory, prison,

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[5] U. S. Weather Bureau, Climatological Summary of Ionia, Michigan, Climatography of the U.S., no. 20-20, (Washington: U. S. Government Printing Office, 1962), 2pp.

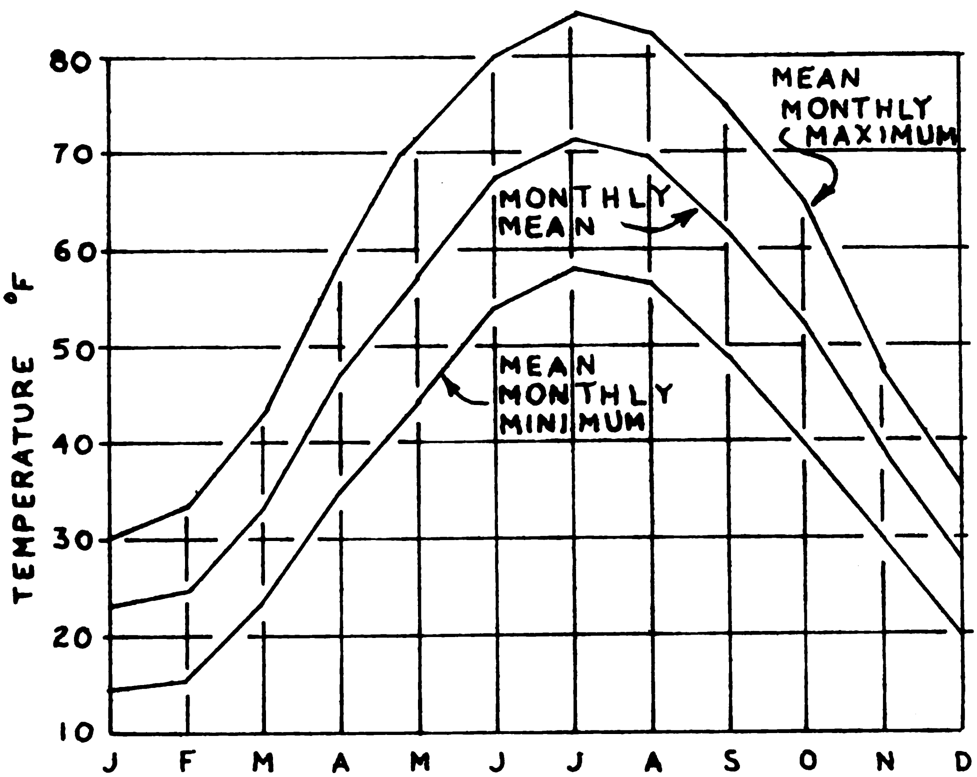

Figure 3. Average Monthly Temperature at Ionia

Mean values are based on 1939 - 1964 period at Ionia.[1] Winters generally have nine days in which the temperature is below zero. Temperatures over 100 degrees are experienced in one summer out of four. The coldest month on record was February 1901 when the average temperature was 14.6°F. The warmest month was July 1901 when temperatures averaged 77.2°F.[2]

[1]U.S. Weather Bureau, Annual Climatological Data for Michigan (Washington: U.S. Government Printing Office, 1924 to present).

[2]U.S. Weather Bureau, Climatological Summary of Ionia, Michigan, Climatography of the U.S., no. 20-20, (Washington: U. S. Government Printing Office, 1962), 2pp.

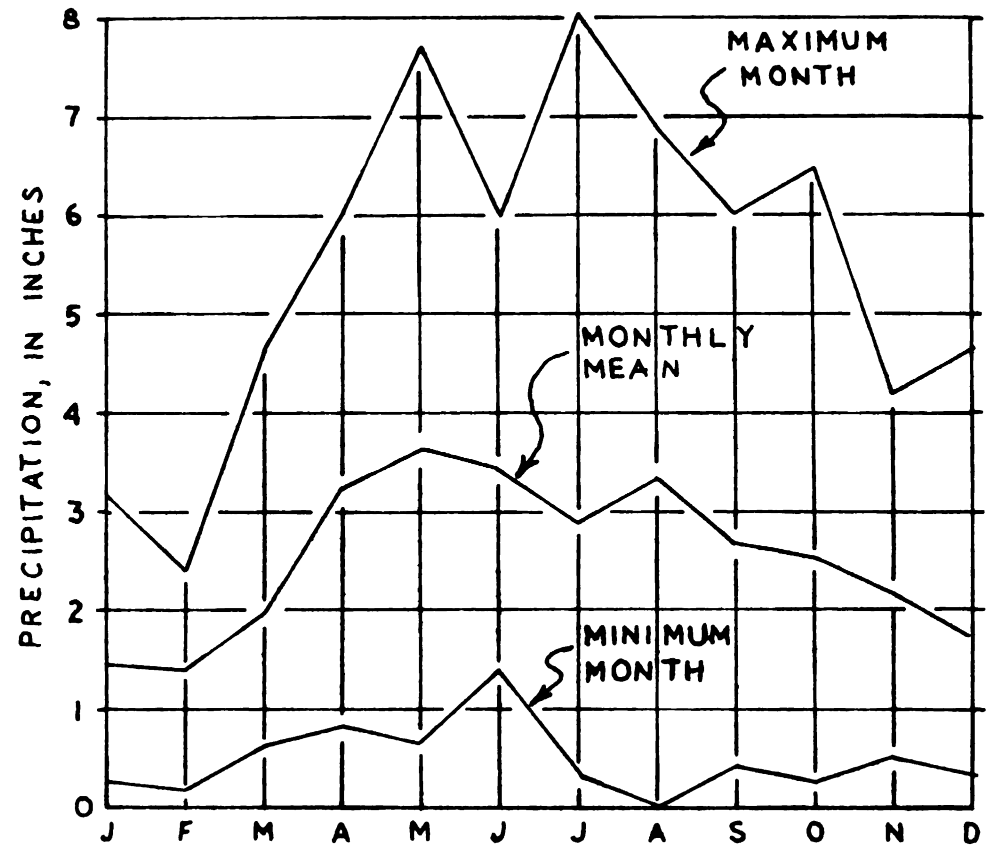

Figure 4. Average Monthly Precipitation at Ionia

These mean values are based on the period 1939 - 1964 with winter values converted to the snow's water equivalent.[1] The growing season has the greatest amount of precipitation; the period April-September has 63 percent of the total annual precipitation. The maximum precipitation received in one month was 8.02 inches in July, 1950. The minimum for a month was 0.01 of an inch in August, 1899.[2]

[1]U.S. Weather Bureau, Annual Climatological Data for Michigan (Washington: U.S. Government Printing Office, 1924 to present).

[2]U.S. Weather Bureau, Climatological Summary of Ionia, Michigan, Climatography of the U.S., no. 20-20, (Washington: U.S. Government Printing Office, 1962), 2pp.

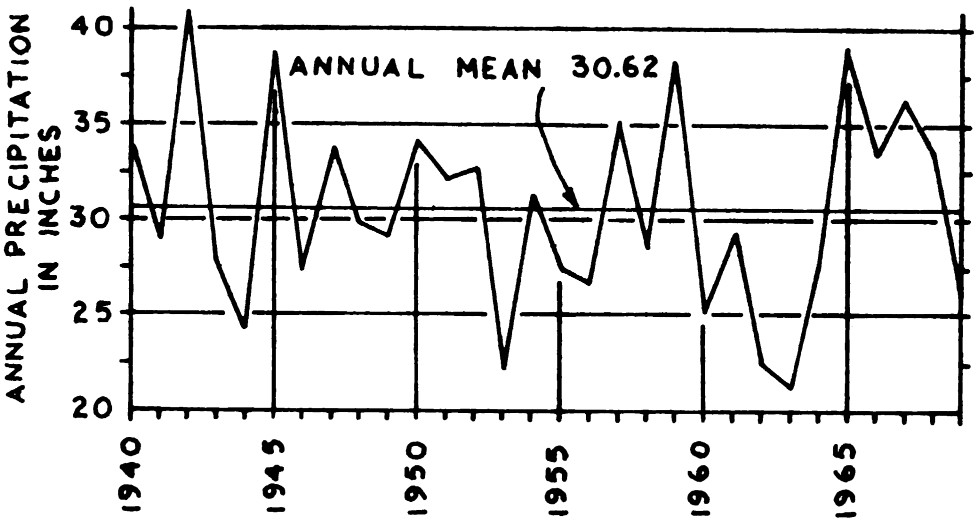

Figure 5. Total Annual Precipitation at Ionia

Precipitation varies greatly from year to year, often as much as 15 inches.[1]

[1]U.S. Weather Bureau, Annual Climatological Data for Michigan (Washington: U.S. Government Printing Office, 1924 to present).

and hospital also have water systems which service a large number of people. The fact that all of these water supplies have been obtained from wells within the organisations property limits is a general indication of readily available ground water.

The majority of the county's population do not receive the benefits of a municipal water system. In 1960, more than half the population was rural.[6] Fortunately, very few areas of the county have been found in which individual domestic water supplies were impossible. In the future, however, this statement may be modified because of the increasing number of subdivisions with individual home water wells.

[6]Michigan Economic Development Department, Loc. cit.

Irrigation systems generally utilize small artificial ponds or other types of surface water as an inexpensive water source. The nearness of the ground water table to the land surface in many areas of the county make this a practical proceedure.

Table 1. Municipal Water Supplies[1]

City or Village	Population served	Annual pumpage (million gal.)	Industrial use
Belding	5400	750	large - 82% of total
Ionia	6745	360	moderate
Portland	3100	118	none
Lake Odessa	2000	75	small; previous years - large
Saranac	1081	129	large - 58% of total
Muir	650	23	none
Pewamo	460	27	none
Lyons	687	from private wells	
Hubbardston	348	" " "	
Clarksville	371	" " "	

[1]Except for the city of Ionia, this data was obtained from personal interviews with municipal presidents, managers, and utility foremen. Data for Ionia was obtained from 1960 records at the U. S. Geological Survey, Lansing.

CHAPTER II

GROUND WATER OCCURRENCE

Ground Water is Related to Geology

At some depth below the ground surface one generally encounters what is called the ground water table. Below the water table the voids between the rock particles are saturated with water while above the water table both air and water are found in the voids. Rarely is the ground water table a precise surface which separates saturated from unsaturated. Usually it is a gradational zone in which increasing amounts of water are encountered.

The amount of water that can be contained in a saturated volume of rock material depends upon the percentage of the material which is open spaces. This percentage is called porosity. Thus, a material with a high porosity can hold a large quantity of water. In general, material which is composed of small grains tend to have high porosity. For example, certain clays may have up to 85 per cent porosity while a coarse sand may have only 39 per cent. Also, a material will have high porosity if all of the individual grains are equal in size as in a uniform sand, but it will be lower when a number of grain sizes are mixed as in a sand and gravel combination. Bedrock formations may also have what is called secondary porosity which is a result of fracturing, solution channels, or other such openings.

If water can easily move through the pores in a material, the material is said to have good permeability. Permeability then, represents the friction encountered by water in its attempt to move through a porous media. Sufficient porosity must be present before there can be high permeability, but high porosity does not insure that there will be high permeability. Most clays, as noted above, have high porosity, but their permeability is very low due to the very small openings between the clay particles. Sand or gravel, on the other hand, have a high permeability. In general, permeability will be high for material with large grains of uniform size.

With the above points in mind, one can see that a region underlain with clay can potentially absorb and store a large quantity of water, but the waters movement will be restricted. A region underlain by sand might not store as much water, but its movement will be freer.

A subsurface zone which is below the water table and has sufficient permeability is called an aquifer. A zone of low permeability, such as shale or clay, is called an aquatard if it will transmit only a small amount of water.

In the report area, there are five subsurface strata that may be aquifers depending upon local conditions. The bedrock may be separated into four of the units, and the glacial drift comprises the other potential aquifer. These units will be described below.

Table 2. Subsurface Deposits and Their General Suitability as Aquifers

Gravel	excellent aquifers
Coarse sand	(high permeability)
Medium sand	↑
Fine sand	│
Sandstone	│
Limestone	↓
Clayey sand	very poor aquifers
Shale or clay	(low permeability)

Bedrock Geology

In the subsurface of Ionia County there is a layer of unconsolidated material that ranges in thickness from 0 to over 500 feet. These are glacial deposits that lay on top of the consolidated bedrock formations which were formed millions of years ago.

The bedrock formations in and around Michigan's lower penninsula form what is geologically called a sedimentary basin. The bedrock strata that form this basin have often been compared to a set of shallow mixing bowls of varing diameters which are nested together. The smallest, inside bowl would correspond to the youngest rock formation and as one progresses away from the center, the increasingly older rock formations would compare to the increasingly larger bowls. The rock strata slopes or dips toward the center of the basin which is located approximately near the center of the lower penninsula, and thus, the bedrock formations which are found beneath Ionia County dip toward the northeast (Figure 13, pages 41-42).

The oldest rock formation underlying Ionia County is the Michigan formation which was deposited in shallow seas during the Mississippian period. The Michigan formation consists of grey shale, gypsum, anhydrite, limestone, dolomite, and thin lenses of sandstone. The formation varies in thickness from 80 feet to 200 feet.

The Michigan formation occurs directly beneath the glacial drift in the south and western parts of the county (Figure 14, pages 43-44). It actually can be found at depth throughout the county, but it is buried by younger rock formations and is thus unimportant for the purposes of this report.

The sandstones found in the Michigan formation can provide an adequate supply of water for domestic purposes. However, the abundance of gypsum in the formation causes most of the water in this formation to be highly mineralized. Problems associated with gypsum are discussed in more detail in the water quality section. Saline water is encountered in this formation also. If the sandstones are near the top of the bedrock surface, and if they are sufficiently separated from the gypsum by shale, then the sandstones may be a suitable aquifer for low capacity wells.

Lying on top of the Michigan formation is the younger Bayport limestone which is also of Mississippian age. The Bayport is primarily limestone or dolomite, but occasionally it has thin interbedded sandstone lenses. A period of erosion occurred after the Bayport was deposited which explains the absence of the formation in places and its variable thickness. In the report area, it ranges in thickness from zero to 50 feet.

The Bayport may potentially be used for domestic water supplies, but its characteristics as an aquifer are largely unknown. In other areas of the state, the formation yields water which ranges in quality from good to mineralized or yields no water. However, it is felt that further testing is needed before this formation can be ruled out as a water source.

Overlying the Bayport limestone, and at times the Michigan formation, one finds the Saginaw formation which is the most widespread bedrock unit in Ionia County. The Saginaw consists of lenticular beds of sandstone, sandy shale, grey shale, underclay, coal, black shale, and limestone which were cyclically deposited during the Pennsylvanian period. Individual rock strata can seldom be traced far due to the numerous erosional periods which occurred locally during deposition. The sandstone beds are particularly variable in thickness and extent. In places thick sandstone beds and thick shale beds are found. The formation averages approximately 100 feet in total thickness but is quite variable because of the erosion that took place before and after deposition.

The Saginaw is an important aquifer for the entire mid-Michigan area. If thick sandstone beds are encountered, wells may produce 500 gallons of water per minute (gpm). Small domestic wells can usually obtain 50 gpm. In general, the water yielding capacity of the Saginaw is directly related to the thickness of the sandstone encountered.

The water found in the Saginaw is hard to very hard, but in general, it is of better quality than the overlying drift.[1] Mineralized water is encountered if wells are deep or if the formation is tapped at a location where it is near to the Michigan formation. The quality of the water is also influenced by the overlying bedrock units which contain both iron and gypsum.

After a period of erosion, the <u>Grand River formation</u> was deposited on top of the Saginaw. This formation is primarily a mottled red and white sandstone, but it also contains shale and at times a conglomerate can be found near the base of the formation. It is often iron stained and the sand grains are cemented together with iron oxide. The Ionia sandstone member of this formation is familiar to residents in Ionia County because of its use as a building stone. The old quarry for this stone is located just southeast of the city of Ionia. In places, the Grand River formation may attain 100 feet in thickness, but usually it is much thinner.

The formation is not widely used as an aquifer because of its low permeability and high iron content. In other areas of the state, it is successfully used as an aquifer and thus should not be discounted as a possible water source.

The youngest bedrock unit found in Michigan is called the <u>Red Beds</u>. The formation consists of clay, shale, sand,

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[1]Warren W. Wood, "Geochemistry of Ground Water of the Saginaw Formation in the Upper Grand River Basin, Michigan" (unpublished Ph.D. dissertation, Mich. State University, 1969).

and gypsum which are generally red and range from unconsolidated to poorly consolidated. The Red Beds do not form a persistent unit but rather, have a spotty occurrance. It is interesting to note that the Red Beds generally are found on bedrock topographic highs within the report area.

This formation is not used as an aquifer in the report area due to the highly mineralized water it contains, because of its impermeability, and also because better aquifers are usually available in the same area. Outside of the county, some wells have successfully tapped the Red Beds.

Where the Grand River formation or the Red Beds are thin, better quality water may be obtained by drilling deeper into the underlying Saginaw formation.

Glacial Geology

After the Red Beds were formed, there was an extended period during which the land remained relatively unaltered. The last geologic event of major proportions began some 1 to 2 million years ago during the Pleistocene period and is referred to as the Ice Age or glacial period.

Ionia County was invaded on four different occasions by continental glaciers, the last of which was called the Wisconsin Glacier. After this last glacier disappeared, the land surface looked similar to todays landscape. The glaciers which came from the north before the Wisconsin Glacier are known to exist from their deposits in states south and west of Michigan; but in the report area, they have left no known traces.

In Ionia County, the glacial deposits are a result primarily of a lobe of the Wisconsin Glacier which spread southwestward in fan-like fashion from the Saginaw Bay region. Appropriately, this ice lobe was named the Saginaw lobe. Counties to the west of Ionia were affected by a lobe of ice moving southward and spreading outward from the Lake Michigan basin.

Except for the small rock quarry mentioned previously, the report area is completely covered by unconsolidated sands, gravels, clays, and boulders which were deposited by the glacier. Collectively, this unconsolidated material is called glacial drift. The thickness and character of the drift varies greatly, and only test drilling can accurately establish what material will be encountered at a particular location. In the absence of geologic test borings, a general idea of the composition of the drift can be obtained by a careful examination of the surface topography, soil types, and water well logs.

Glacial drift is deposited either by the direct action of the ice or by water which results from the melting ice. The former deposits are termed glacial till and are a jumbled combination of clay, silt, sand, stones, and boulders in varying mixtures. Deposits resulting from the melted water are called glaciofluvial and generally are more "pure", that is, they generally consist of rock particles that have been sorted as to size. Glaciofluvial sediments may range from clay to boulders, also, but most commonly are sand or gravel.

Variations in the climatic conditions cause the glacial front to advance, retreat, remain stationary, or to stagnate. The drift composition and resulting landforms will vary accordingly. Ideally, moraines are formed when the leading edge of the ice remains relatively stationary. This results in an elongated series of hills which are composed primarily of till. If the ice front maintains a rather steady retreat or advance, then a gently rolling till plain results. Glaciofluvial materials can be deposited at any time but are most commonly formed as the glacier retreats. It is important to note that many advances, retreats and stagnations occurred while the Saginaw lobe occupied Ionia County, and thus a variety of glacial deposits can be found buried beneath the present land surface.

The last events of the glacial period in the report area were associated with the large volume of water which formed from the retreating glacier. Blocked by the glacier to the northeast, the meltwater flowed westward carving several deep channels, the largest of which are now occupied by the Grand, Maple, and Looking Glass Rivers. After the initial erosion, the ancient rivers began to deposit the material they were carrying so that today, numerous sand, gravel, and clay deposits are found in these channels.

With the type of data presently available, it is almost impossible to estimate the thickness of each glacial feature shown on the glacial geologic map (Figure 15, pages 45 -46). The glacial spillway, which has been extensively explored over small areas, appears to vary in maximum thickness from 20 to 60 feet but may be considerably thicker. The entire drift sheet varies considerably in thickness (Figure 16, pages 47-48) from zero to possibly more than 500 feet.

The glacial deposits in the county as elsewhere in the state are an important source of good quality ground water. Unfortunately, the highly complex nature of the drift makes it extremely difficult to predict with certainty where good aquifers will be found unless geologic test drilling programs or geophysical surveys are conducted.

The most obvious regions that may contain high capacity shallow drift aquifers are those areas mapped as outwash channels and spillways on the glacial geologic map (Figure 15, pages 45-46). Most of these water-lain surface deposits are adjacent to rivers and, thus, present several problems. First, even though a certain amount of purification takes place by water filtrating through earth materials, the quality of the water reaching a well near a river will be influenced by the quality of the river water. High capacity wells will actually be drawing a portion of its water from the river, which is desirable, but adequate isolation from the river should be assured to prevent contamination of the aquifer. Secondly, flooding may contaminate improperly constructed wells located within the flood plain.

Moraines and till plains are somewhat more difficult to analyze. Typically, these landforms are thought of as being composed of till, but as pointed out earlier, sand

and gravel deposits are often found buried beneath till deposits. The majority of the domestic wells within the county are located on either moraines or till plains and tap buried outwash deposits. In general, the possibility of encountering a buried outwash deposit are increased as the thickness of the drift increases.

The quality of ground water in the drift is rather variable but generally is quite hard and often has objectionable amounts of iron and other minerals. The quality of drift water will be influenced by the type of bedrock the glacier passes over before depositing the debris. Thus, the drift will generally have the same quality problems as water in the underlying bedrock.

In the areas where the Saginaw formation is known to be a good aquifer, the drift is commonly bypassed as a water source. Commonly, the Saginaw is of better quality, generally has a more predictable yield, and wells are usually easier to develop and maintain than in a drift aquifer.

CHAPTER III

GROUND WATER MOVEMENT AND WATER LEVELS

Water Cycle in Ionia County

Ground water is continuously being removed from the ground by man, vegetation, evaporation, and its natural discharge to lakes and rivers. This local segment of the water cycle is illustrated in figure 6 with approximate

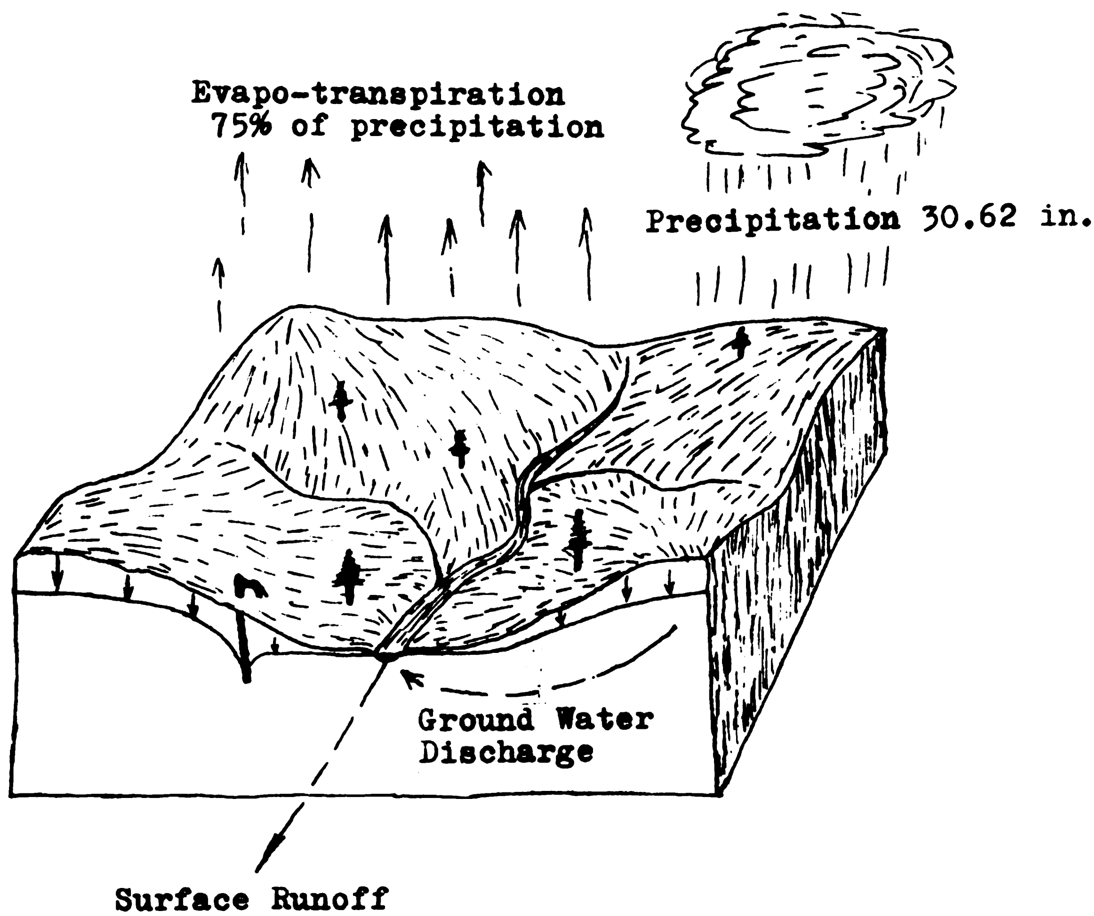

Figure 6. The Water Cycle in Ionia County

Percentage figures are approximate only, and will vary considerably with time and area.

values for the various components. Mans consumption of water is a very small portion of what is cycled through the county annually.

Precipitation and Ground Water Levels

Precipitation is the major source of ground water recharge. Even though only a small percentage of the annual precipitation reaches the ground water, its effects are easily demonstrated. The relationship is illustrated by Figure 7.

The seasonal variation in the water table elevation is rarely of the same degree throughout an area. In the regions where the ground water is discharging (near most lakes and rivers) the water table will vary only slightly during precipitation deficient years. At higher elevations away from discharge areas, the depth of the water table may vary greatly in response to precipitation variations. In Figure 8, note the possible variation in water levels beneath the hill as compared to near the lake.

The lakes in Ionia County are water table lakes like the one shown in Figure 8. The "water table" is actually above the surface in such cases. Because of this relationship, the lake level will vary with the ground water table in response to precipitation. The opposite of a water table lake is a perched lake whose level is above the surrounding water table. A perched lake must rely upon precipitation entirely to maintain its level since it does not receive ground water discharge. The levels of such lakes will vary radically.

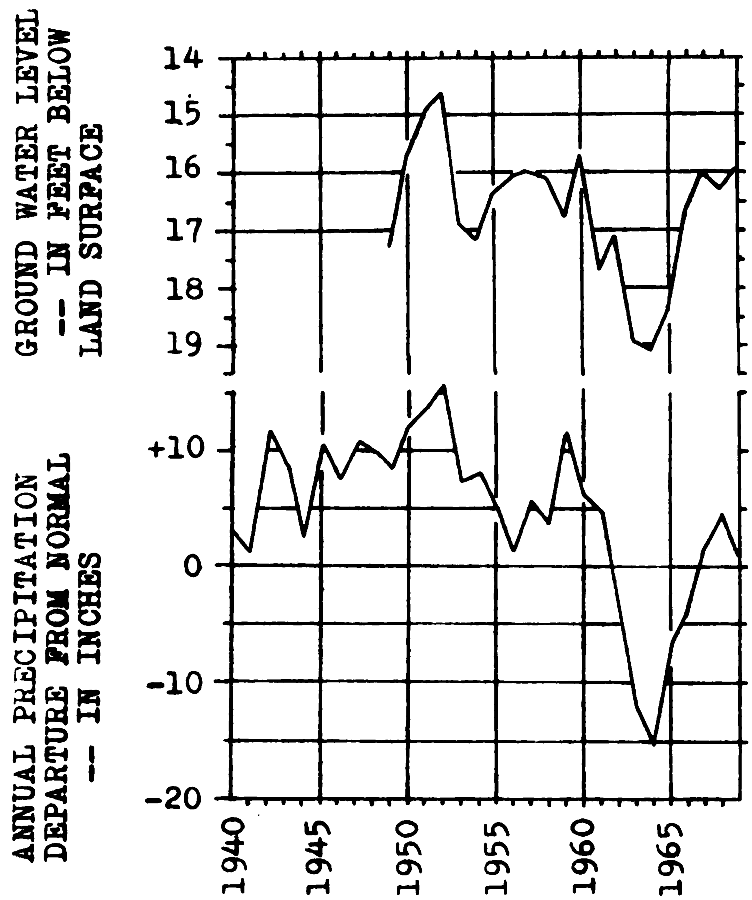

Figure 7. Rainfall Influences Ground Water Levels

The bottom portion of this figure was obtained by algebraically adding the annual precipitation departures from the long term mean and plotting each yearly subtotal.[1] Where the graph increases (1965 to 1968 for example), there was greater than normal precipitation and where it decreases (1960 to 1964), there was less than normal. The top graph is the recorded ground water levels for a nearby observation well.[2] During the years in which the precipitation was less than normal, the water table was also generally lower, especially so during the early sixties drought.

[1]U.S. Weather Bureau, Annual Climatological Data for Michigan (Washington: U.S. Government Printing Office, 1924 to present).

[2]Water level information obtained from the U.S. Geological Survey, Lansing.

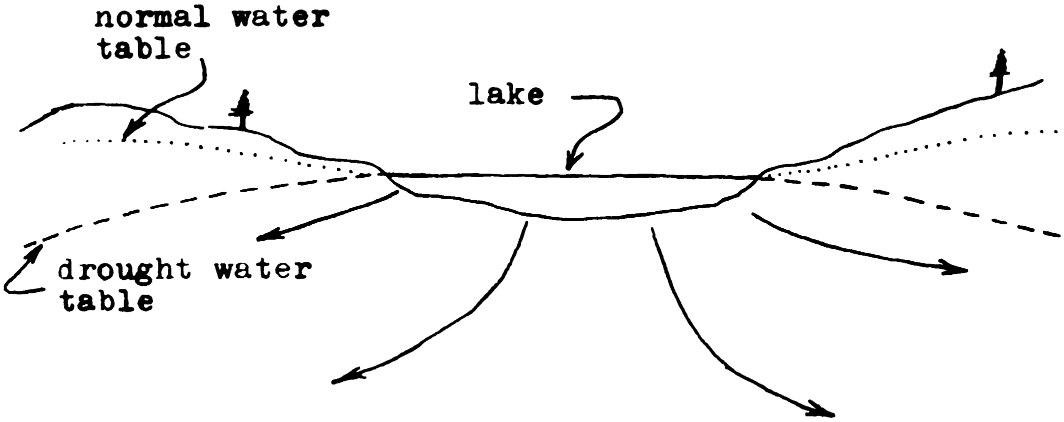

Figure 8. Normal and Drought Water Tables

With normal conditions, the water table will generally conform to the land topography, and ground water will flow toward the lake. With drought conditions (illustrated in its extreme here), water will flow from the lake into the ground as shown by the arrows.

Water Table and Artesian Wells

Water levels in a well are dependent upon the hydrologic characteristics of the aquifer being tapped. In some cases, the water level in the well will be of the same elevation as the water table. Such wells are said to be under water table conditions. Artesian wells result when the aquifer being tapped has water under pressure, a condition which may exist either in the drift or in the bedrock. An artesian well does not necessarily mean it is a flowing well as commonly believed, in fact, most must be pumped.

The artesian situation is often pictured as shown in Figure 9 in which both water table and confined situations exist. In this figure, ground water enters the sandstone at some recharge point "up-hill" and is contained in the sandstone by a less permeable shale bed. Hydrostatic pressure develops due to the weight of the water. If there were no friction, the water in the sandstone when tapped would

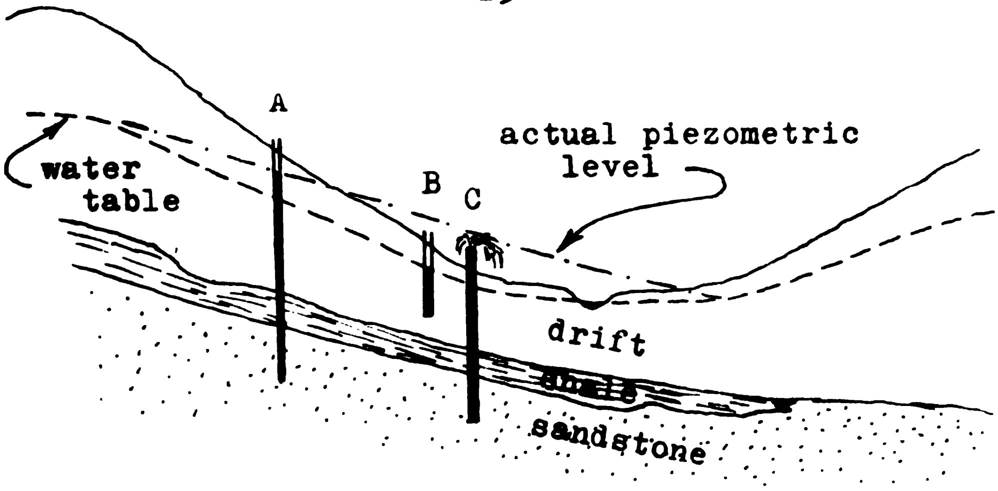

Figure 9. The Artesian Situation

rise to a level (theoretical piezometric level) equal to the water level at the recharge point. But friction is present, and thus the pressure is reduced resulting in an actual piezometric level which is somewhat lower than the theoretical. Where the actual piezometric level is above the ground, a flowing well results when the aquifer is tapped such as Well C. Well B is finished in the drift where the water is not under pressure and thus is a water table well. Well A is an artesian well similar to C, but it does not flow because there is not sufficient pressure to lift the water above the land surface. A number of flowing wells in an area which are allowed to flow freely may reduce the pressure within the aquifer to such a degree that the wells will have to be pumped.

Most of the flowing wells found in Ionia County are in the flood plains of the larger rivers or on the banks leading to the flood plains. There are both drift wells and wells from the Saginaw formation in this situation. A few flowing wells are found inland. In the report area, the Saginaw formation is often artesian, but the piezometric levels are generally comparable to the regular water table.

Ground Water Recharge

The character of the surface soils influence to a great degree the rate of precipitation infiltration. Sandy soils absorb a large portion of the precipitation whereas clay soils cause a larger surface runoff to lakes and streams. Level land, as found in many parts of Ionia County, assists precipitation infiltration also by reducing rapid overland runoff during rain storms.

Ground water levels are maintained in several areas of the country where heavy pumpage takes place by a method called artificial recharge. The two common procedures used to accomplish this are recharge wells and seepage pits. Recharge wells simply pump water of a specified quality from a surface water source into the aquifer which is being used for the water supply. In some cases, regular production wells are used for supply and recharge on an alternating basis with other similar wells. Artificial recharge with wells can be an expensive operation if the water used for recharge requires extra treatment to prevent clogging of the well screen and contamination of the aquifer.

Seepage pits are more widely used than recharge wells. The pits are usually located near a surface water source from which water can be taken when desired. The bottoms of the pits are generally lined with sand or gravel to facilitate seepage downward. This bottom liner may have to be replaced periodically if it becomes clogged with silt.

With either method, frequent checks must be made on the quality of the water being recharged. This is because artificially recharged water generally reaches the water supply zone more rapidly than does natural recharge and thus bypasses much of the natural filtering normal ground water receives. Usually, temperature, turbidity (very fine suspended particles), and bacteria are examined periodically, but it is felt that a complete chemical analysis should be made frequently to prevent chemical contamination of the water supply.

Wells in a river flood plain operate in a manner similar to seepage pits in that the pumping well induces recharge from the river through the permeable flood plain deposits. The water supplies for Belding, Ionia State Hospital, and Portland utilize this principle to varing degrees.

Direction of Ground Water Movement

The direction of ground water movement can be determined by examining a topographic map of the water table (Figure 18, pages 51-52). The water will move from higher elevations to lower elevations and thus move perpendicular to the contours shown on the map. Generally, the topography of the water table roughly corresponds to the topography of the land surface.

In cross section, the vertical movement is somewhat more complex. Each water particle follows a smooth curved line from point of recharge to discharge area as shown in Figure 10.

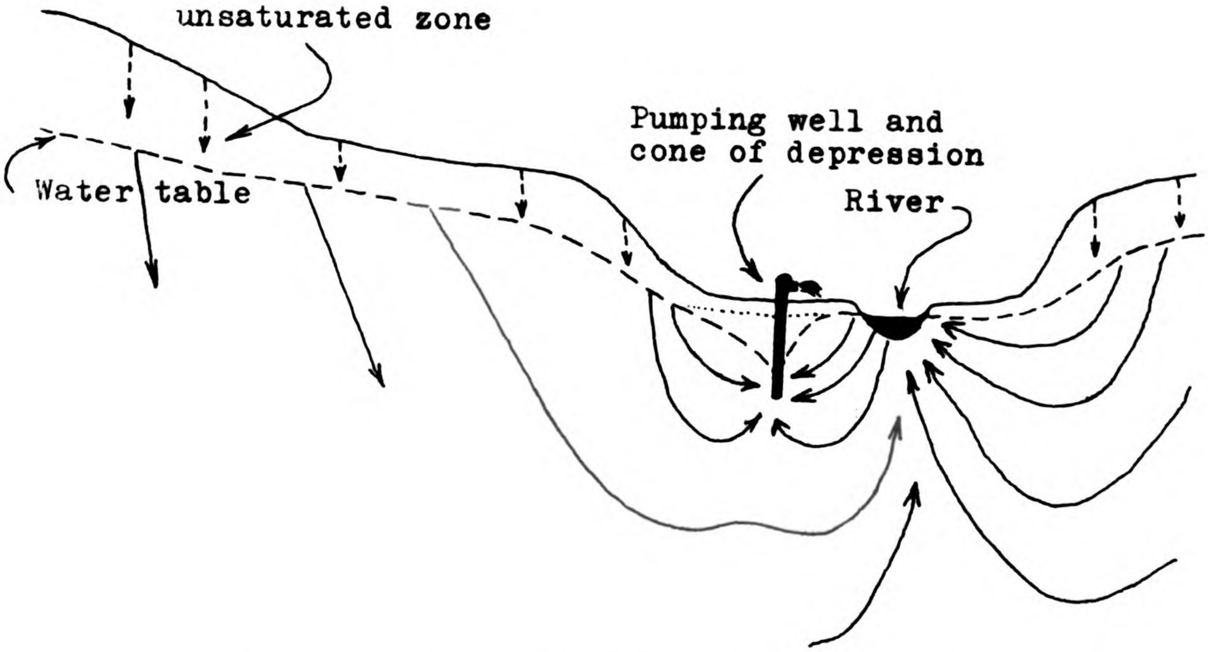

Figure 10. Ground Water Movement in the Subsurface

The water will move vertically downward until the water table is encountered, and then, will move as indicated by the arrows.

A pumping well will locally alter the direction of water movement by causing the ground water for some distance surrounding the well to move toward the well rather than the normal discharge area. The water removed by pumping creates a cone of depression in the water table as shown in Figure 10.

Some water during its travel from recharge to discharge point will encounter the bedrock surface. If permeable bedrock formations are encountered, the water will enter the bedrock and continue its normal flow pattern. If shale or other impermeable rock is encountered, the direction of flow will be influenced by the topography of the bedrock surface in a manner similar to surface drainage (that is, from topographic highs to topographic lows). Lenses of clay in the drift will have the same effects but to a lesser degree. With these points in mind, Figure 17 (pages 49-50) may be of assistance in exploring for large water supplies.

CHAPTER IV

WATER QUALITY

Rain water has often been coveted by some people because of its softness and hence its ability to form a lather with soap. This attribute of rain water is due to a low percentage of solids which are dissolved in the water, a property which is soon lost as the rain water percolates downward into the ground.

Water has often been referred to as a universal solvent, that is, it is able to dissolve and carry in solution many different types of solids and liquids. Thus, as water percolates through the soil and rocks, it dissolves many of the minerals which formerly were part of the rock or soil. Some minerals are easily dissolved such as rock salt, others such as silica are quite difficult to dissolve. The quantity of each of these dissolved constituents can be determined by means of a chemical analysis and sometimes, less accurately, by taste, smell, or appearance. At times a chemical analysis will give an indication of the type of rock material the ground water has been associated with, but the relationship is quite complex. Table 3 is a listing of the chemical characteristics most commonly investigated and their significance

Table 3. Water Quality Parameters and Their Significance [a]

Constituent or physical property	Source or cause	Significance
Silica (SiO_2)	Dissolved from practically all rocks and soils, usually in small amounts—1-30 mg/l	Forms hard scale in pipes and boilers. Carried over in steam of high pressure boilers to form deposits on blades of steam turbines. Inhibits deterioration of zeolite-type water softeners.
Iron (Fe)	Dissolved from practically all rocks and soils. May also be derived from iron pipes, pumps, and other equipment.	On exposure to air, iron in ground water oxidizes to reddish-brown sediment. More than about 0.3 mg/l stains laundry and utensils reddish brown. Objectionable for food processing, beverages, dyeing, bleaching, ice manufacture, brewing and other processes. Iron and manganese together should not exceed 0.3 mg/l Larger quantities cause unpleasant taste and favor growth of iron bacteria but does not endanger health.
Manganese (Mn)	Dissolved from some rocks and soils. Not so common as iron. Large quantities often associated with high iron content and with acid waters.	Same objectionable features as iron. Causes dark brown or black stain. Iron and manganese together should not exceed 0.3 mg/l for taste and asthetic reasons.
Calcium (Ca) and Magnesium (Mg)	Dissolved from practically all soils and rocks but especially from limestone, dolomite, and gypsum. Calcium and magnesium are found in large quantities in some brines.	Cause most of the hardness and scale-forming properties of water; soap consuming. (See hardness.) Waters low in calcium and magnesium desired in electroplating, tanning, dyeing, and textile manufacturing.
Sodium (Na) and Potassium (K)	Dissolved from practically all rocks and soils. Found also in ancient brines, some industrial brines, and sewage.	Large amounts give a salty taste when combined with chloride. Moderate quantities have little effect on the usefulness of water for most purposes. Sodium salts may cause foaming in steam boilers and a high sodium ratio may limit the use of water for irrigation.
Bicarbonate (HCO_3) and Carbonate (CO_3)	Action of carbon dioxide in water on carbonate rocks such as limestone and dolomite.	Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium decompose in steam boilers and hot-water facilities to form scale and release corrosive carbon dioxide gas.
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Usually present in some industrial wastes.	Sulfate in water containing calcium forms hard scale in steam boilers. In large amounts, sulfate in combination with other ions gives bitter taste to water. Concentrations above 250 mg/l may have a laxative effect, but 500 mg/l is considered safe.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and found in large amounts in ancient brines and industrial brines.	Chloride salts in excess of 100 mg/l give salty taste to water. When combined with calcium and magnesium may increase the corrosive activity of water. It is recommended that chloride content should not exceed 250 mg/l.
Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils.	Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of enamel calcification. However, it may cause mottling of the teeth depending on the concentration of fluoride, the age of the child, the amount of drinking water consumed, and the susceptibility of the individual. 0.8-1.5 mg/l is considered optimum depending upon the air temperature. 1.5 mg/l is considered the maximum allowable.
Nitrate (NO_3)	Decaying organic matter, sewage, nitrates in soil and chemical fertilizers.	Concentrations much greater than the local average may suggest pollution. High concentrations are generally a characteristic of individual wells and not of whole aquifers. Nitrate has shown to be helpful in reducing intercrystalline cracking of boiler steel. It encourages growth of algae and other organisms which produce undesirable tastes and odors. There is evidence that more than about 45 mg/l may cause a type of methemoglobinemia in infants, sometimes fatal.
Phosphate (PO_4)	Dissolved from rocks and fertilizers. Detergents, treated waters, and wastes in domestic and industrial service effluents.	Inhibits scale formation in industrial processes and cooling waters. Encourages bacterial growth.
Dissolved solids	Chiefly mineral constituents dissolved from rocks and soils. Includes all material in water that is in solution.	Dissolved solids should not exceed 500 mg/l but amounts up to 1000 mg/l are considered acceptable for drinking water if no other supply is available. Amounts over 1000 mg/l are unacceptable for most uses.
Hardness as $CaCO_3$	In most waters nearly all the hardness is due to calcium and magnesium. All the metallic cations other than the alkali metals also cause hardness.	Hard water consumes soap before a lather will form; deposits soap curd on bathtubs; forms scale in boilers, water heaters, and pipes. Hardness equivalent to the bicarbonate and carbonate is called carbonate hardness. Any hardness in excess of this is called noncarbonate hardness. Waters of hardness as much as 60 mg/l are considered soft; 61 to 120 mg/l moderately hard; 121 to 200 mg/l hard; and more than 200 mg/l very hard.

Table 3 (continued).

Constituent or physical property	Source or cause	Significance
Specific conductance (micromhos per centimeter at 25°C.)	Mineral content of the water.	Specific conductance is a measure of the capacity of the water to conduct an electrical current. Varies with concentration and degree of ionization of the constituents. Varies with temperature; reported at 25°C.
Hydrogen-ion concentration (pH)	Acids, acid-generating salts, and free carbon dioxide lower the pH. Carbonates, bicarbonates, hydroxides and phosphates, silicates, and borates raise the pH.	A pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote increasing alkalinity; values lower than 7.0 indicate increasing acidity. pH is a measure of the activity of the hydrogen ions. Corrosiveness of water generally increases with decreasing pH. However, excessively alkaline waters may also attack metals.
Hydrogen sulfide (H_2S)	Natural decomposition of organic material and from the reduction of sulfates.	Causes objectionable odor when in concentrations above 1 mg/l and taste when in excess of .05 mg/l. Presence may limit waters usefulness in the food and beverage industry.

[a]The data in this table was obtained from a combination of three sources:

U.S. Public Health Service, The Public Health Service Drinking Water Standards -- 1962, U.S. Public Health Service, Pub. no. 956 (Washington: U.S. Government Printing Office, 1962).

J. E. McKee, and H. W. Wolf, Water Quality Criteria, The State Agency of California, State Water Quality Board (California State Printing Office, 1963), 548pp.

J. D. Hem, Study and Interpretation of the Chemical Characteristics of Natural Water, U.S. Geological Survey Water Supply Paper 1473 (Washington: U.S. Government Printing Office, 1959), 269pp.

in regard to water use.

The most plentiful minerals in the ground water of Ionia County are calcium, magnesium, bicarbonate, sulfate, and chloride (Table 5, in Appendix). Iron is commonly found in amounts which are considered objectionable, but it does not constitute a large percentage of the total dissolved constituents.

Most of the analysis within the county reveal that the water is characteristically very hard (greater than 200 mg/l). This is due to large amounts of calcium and magnesium which are major constituents in many rocks, especially limestone, dolomite, and gypsum. Fortunately, this undesirable characteristic can be reduced to acceptable levels by the use of a water conditioner.

Gypsum, which is very soluable and is found in many places in the county, is the outstanding contributor to the high sulfate content and also the hardness of the ground water. Several analyses near the city of Ionia which exibit the effects of gypsum are shown by analysis numbers 52, 55, 64, and 65 in Table 5 (in Appendix).

Gypsum, as noted in the geology section, is found in the Michigan formation and in the Red Beds. Water wells drilled where the Michigan formation underlies the drift may produce fresh water, but if sulfate water is encountered, then, a drift well is the only solution. Sulfate problems associated with the Red Beds might be solved by drilling deeper into the underlying Saginaw formation and adequately casing the well past the contaminating interval.

Hydrogen sulfide which may locally be a problem is often found to exist in the same areas in which high sulfates are found. The "rotten egg" gas is usually a result of sulfate reduction by bacterial action.

Iron is a problem throughout the county but appears to be especially troublesome where the Red Beds-Grand River formation is found. Both of these rock units are high in iron content as exibited by their red color. Numerous drift wells yield water high in iron also. The direction of the glaciers movement and the fact that the above two rock units are within the county suggest that the glacial drift throughout the report area will contain a large amount of Grand River-Red Bed material. Iron content may be reduced by means of a special water conditioner.

Wood, in his study,[1] noted that the Saginaw formation in the upper Grand River basin (up stream from Ionia) had water of better quality than the drift. Specifically iron, calcium, sulfate, and chlorides were found in higher concentrations in drift wells than in wells tapping the Saginaw formation. It appears that this situation may also be true for the parts of Ionia County in which the Grand River formation and the Red Beds are absent, but a more detailed study is needed.

Chemical analysis for several rivers within the county are included in Table 5 (in Appendix). It can be seen that they compare favorably with the general ground water quality. However, it should be noted that the quality of a surface water source is likely to vary considerably from time to time and is much more susceptable to contamination by dangerous chemicals and microscopic organisms not found in the ground water. Water wells near rivers which utilize the rivers for induced recharge may also be contaminated by foreign chemical.

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[1] Wood, Op. cit.

CHAPTER V

GROUND WATER AVAILABILITY

Except for a few isolated areas, the glacial drift is capable of supplying domestic water wells throughout Ionia County. The drift is also capable of yielding large amounts of water as shown by numerous municipal wells (Table 4, in Appendix). Further exploration will undoubtably find high yield drift aquifers outside of the favorably located municipal regions.

With present data, it appears that the largest area with poor drift aquifers is located at the village of Lyons. Unfortunately, the Saginaw formation has water of inferior quality there also. Exploration of the drift to the east of this village might be advisable if a municipal supply is desired.

In most parts of the county, the bedrock aquifers are good to potentially good for domestic wells. Some of the county's bedrock aquifers are poor due to their great depth or to their poor quality water. Figure 19 (pages 53-54) can be used as a rough guide to the potential for domestic bedrock wells.

Table 4 (in Appendix) may be of assistance for information on a particular area. This table is a listing of the important characteristics of most of the well records that were used during this study. Unfortunately, the data is not evenly distributed throughout the county. A limited amount of additional information for each well listed can be obtained from the Michigan Geological Survey whose office is in Lansing.

Large water withdrawals from small areas (single high capacity wells or subdivisions with individual domestic wells) present special problems which would be difficult to analyze in a report such as this. It is suggested that a professional hydrologist be consulted when such withdrawals are anticipated. Often test drilling and pumping tests are required to adequately define the aquifers' capabilities.

Introduction to Figures 12 Thru 19

The preparation of geologic maps such as those which follow is dependent almost entirely upon a source of subsurface information. The most useful source of information is in the form of well logs which are a listing of the subsurface materials penetrated and information as to the physical characteristics of the well. Fortunately, the Michigan Legislature recently passed an Act which, in addition to other things, requires water well drillers to submit a well log to the well owner, the county health agency, and the State Geological Survey.[1] Since 1965, water well drillers in the county have been providing information

[1]Michigan Legislature, Act 294, Public Act 1965.

which is very valuable to workers in the geological sciences. Previous to this, a few water well drillers voluntarily provided the state with such information. Oil well drillers have been required to submit logs for their wells for some time now. During the course of this investigation, over 500 logs in Ionia County and surrounding townships were examined. Many of these wells are shown in Table 4 (in Appendix).

Maps such as those in Figures 16, 17, and 18 cannot be prepared unless the elevation of the wells can be accurately determined. Most of the state has been topographically mapped from aerial photographs by the United States Geological Survey (U.S.G.S.). Such maps are available for Ionia County except for the northwestern section (north of the city of Ionia and west of Palo). Consequently, the three above mentioned figures are somewhat inaccurate in this region.

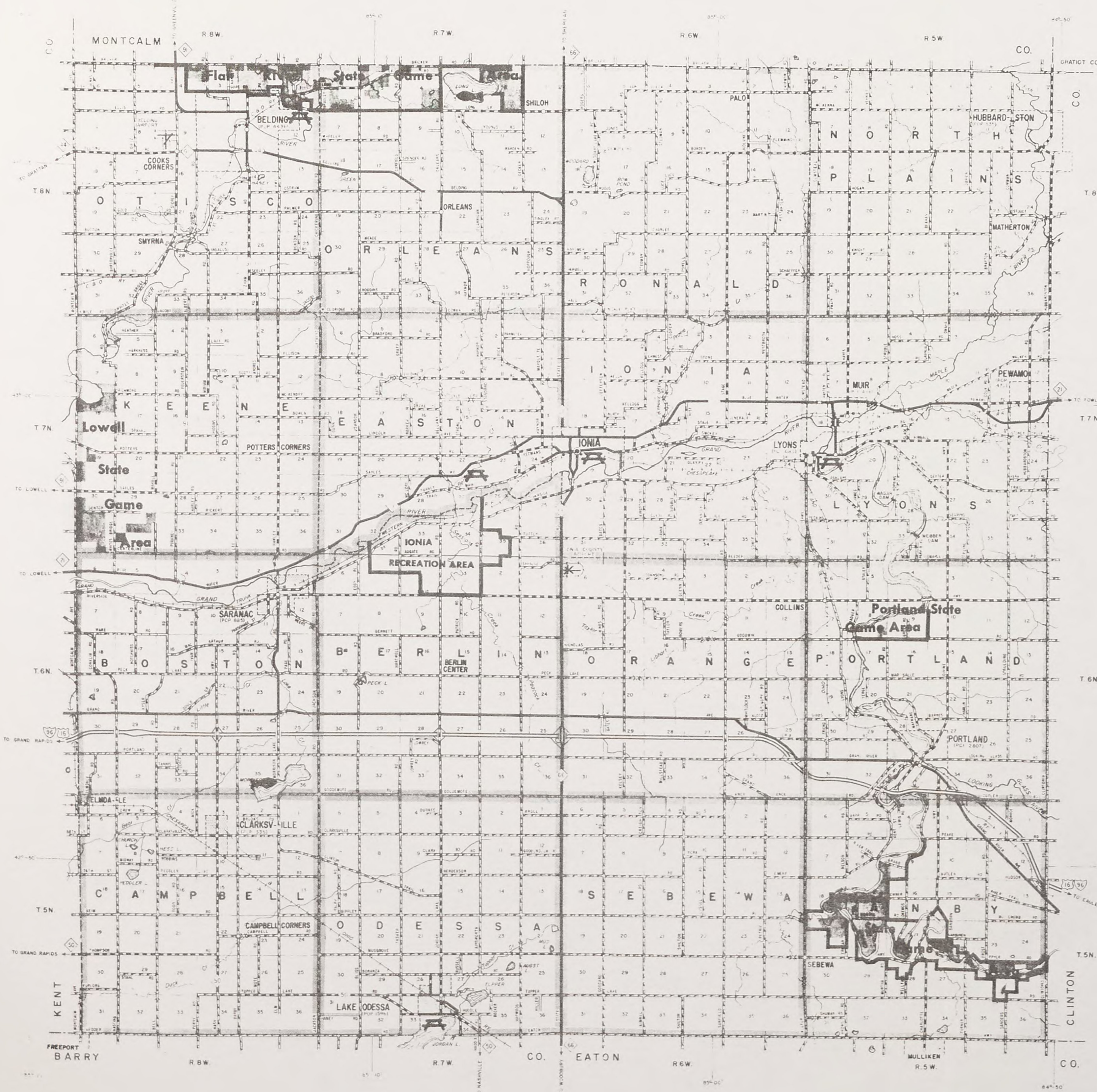
It is important to recognize that the following geologic maps are assumed to be accurate only for a limited time. This is due to the fact that no matter how carefully a map is constructed, new information may invalidate certain assumptions made when the map was originally constructed. Often such maps are constructed in pencil in anticipation of future changes. The portions of the following maps which are most likely to need revision in the future have been drawn with dashed lines.

The base map for Figures 14 through 19 was redrafted with slight modifications from a Michigan Department of

Natural Resources base map. Figures 13, 14, 16, 17, 18, and 19 are the authors original work. The data used was obtained from well logs on file at the Michigan Geological Survey and from other sources as noted in each individual figure.

Figure 12. Base Map

This map, in a slightly larger size, is obtainable from the Michigan Department of Natural Resources in Lansing.



MICHIGAN
DEPARTMENT OF CONSERVATION

IONIA COUNTY

SCALE IN MILES
0 1 2

N

BASE MAP BY MICHIGAN STATE HIGHWAY DEPARTMENT

LEGENU

ROADS

UNIMPROVED ROAD
GRADED AND DRAINED ROAD
SOIL SURFACED ROAD
GRAVEL OR SIMILAR ROAD
BITUMINOUS SURFACED ROAD
PAVED ROAD
DIVIDED HIGHWAY
DIVIDED HIGHWAY WITH FRONTAGE ROAD

ROAD SYSTEM DESIGNATION

INTERSTATE HIGHWAY 94
UNITED STATES HIGHWAY 27
STATE HIGHWAY 78
BUSINESS LOOP BL
BUSINESS ROUTE BR
BUSINESS SPUR BS

AIRPORTS

(WITH FIELD LIMITS AND RUNWAYS)

MILITARY FIELD (SOME FACILITIES AVAILABLE)
AIRPORT, COMPLETE FACILITIES (COMMERCIAL OR MUNICIPAL)
AIRFIELD, LIMITED FACILITIES
LANDING AREA OR STRIP (INCLUDING PRIVATE AIRFIELDS)

RAILROADS

RAILROAD (ANY NUMBER TRACKS) USED BY SINGLE OPERATING COMPANY
RAILROAD (ANY NUMBER TRACKS) USED BY MORE THAN ONE OPERATING COMPANY ON SAME OR ADJACENT RIGHTS OF WAY (NOT TRACKAGE RIGHTS)
RAILROAD STATION
RAILROAD ABOVE ROAD
RAILROAD BELOW ROAD
RAILROAD TUNNEL

HIGHWAY BRIDGES

(20 TO 200FT LENGTH)

GENERAL
DRAWBRIDGE

(200FT LENGTH OR OVER)

GENERAL
DRAWBRIDGE
SUSPENSION
ARCH
TRUSS OR GIRDER
HIGHWAY GRADE SEPARATION
INTERCHANGE SHOWING RAMPS

DRAINAGE

NARROW STREAM
WIDE STREAM (OVER 250FT)

NAVIGATION

FREE FERRY
TOLL FERRY

DAMS

DAM WITH ROAD
DAM WITHOUT ROAD

BOUNDARIES

NATIONAL BOUNDARY
STATE BOUNDARY
COUNTY BOUNDARY
CIVIL TOWNSHIP BOUNDARY
CONGRESSIONAL (U.S. LAND) TOWNSHIP BOUNDARY
SECTION LINE

CITY AND VILLAGE

STATE CAPITAL
COUNTY SEAT
UNINCORPORATED COMMUNITIES
INCORPORATED CITY OR VILLAGE

CONSERVATION LEGEND

STATE LANDS DEDICATED FOR STATE FOREST, PARKS AND OTHER PUBLIC CONSERVATION USES
FEDERAL GOVERNMENT LANDS IN NATIONAL FORESTS
BOUNDARIES, STATE AND NATIONAL PROJECTS
CONSERVATION DEPARTMENT UNITS
PUBLIC ACCESS SITES
MUNICIPAL AND ROADSIDE PARKS
STATE AND NATIONAL FOREST CAMP GROUNDS
WILDLIFE FLOODING

NOTE
IT IS THE POLICY TO RETAIN STATE LANDS IN STATE OR NATIONAL PROJECT AREAS. FOR FURTHER INFORMATION INQUIRE LANDS DIVISION, DEPARTMENT OF CONSERVATION, LANSING, MICH. 48926

Figure 13. Generalized Cross Section

Oil well logs, several deep water well logs, and the topographic maps were used in the construction of this section. Few of the wells fell directly on the cross section line but none were offset more than a mile.

This figure was designed to give the reader a general idea of what the various rock formations look like if they could be viewed from the side. It is impossible to show lithologic subdivisions smaller than the formations due to the complex interbedding found in the formations, the scale used, and the distribution of the data available.

The reader should note that the vertical scale is exaggerated as compared to the horizontal. The undulations in each line of the cross section are actually not as pronounced as shown here.

GENERALIZED CROSS SECTION

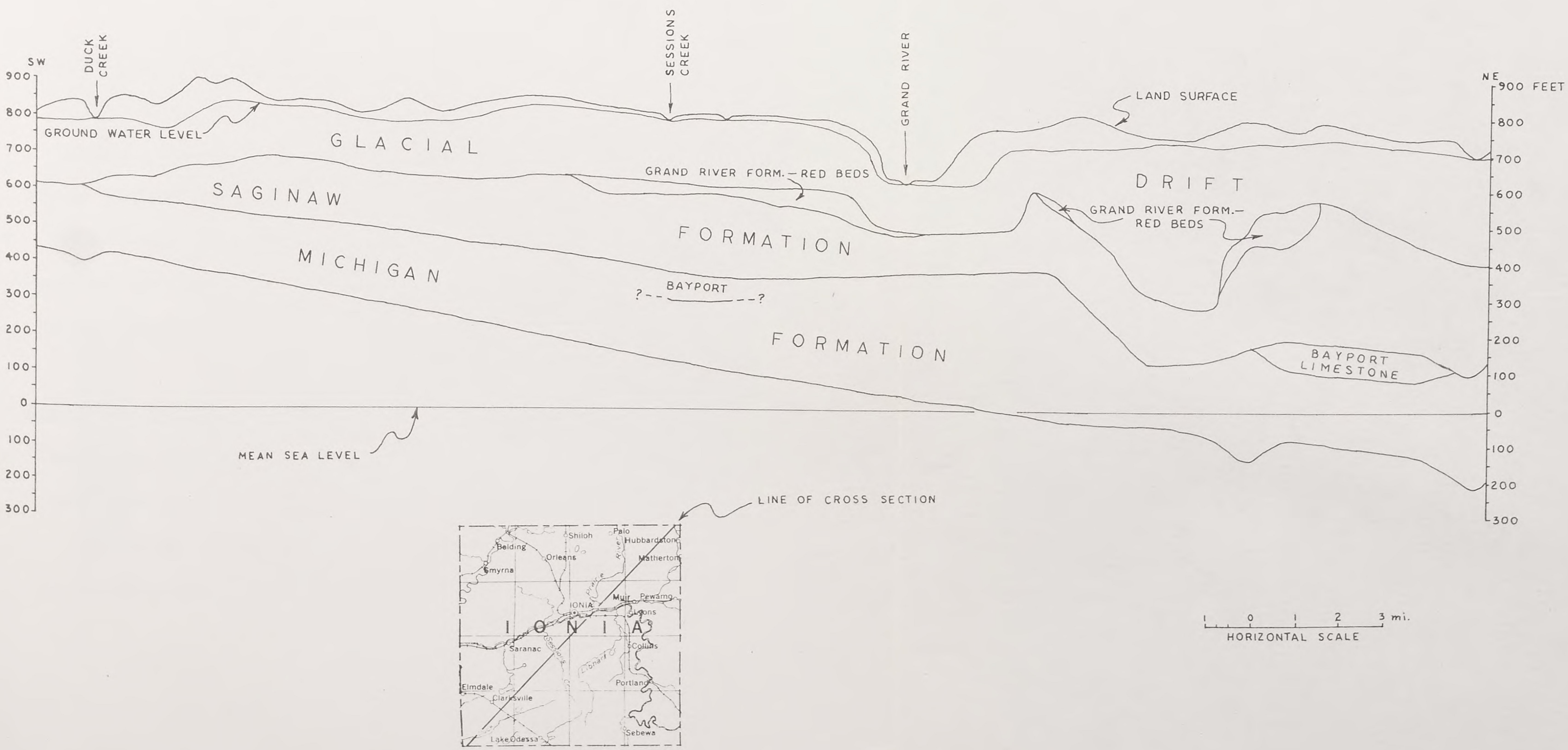


Figure 14. Bedrock Geology

Water well logs, oil well logs, and Figure 17 were used to construct this map.

Descriptions of the bedrock formations in the various well logs used were not complete enough to separate the Grand River formation from the younger Red Beds. Since red sandstones occur in both units, additional notes about other characteristics are needed to adequately separate the two formations. Future workers may be able to define the areas of Red Bed occurrance by means of sulfate occurrance in the ground water.

Vanlier feels that the Grand River formation is found primarily in drainage channels on the top of the Saginaw formation.[2] In the report area, it appears that the Red Beds are found on bedrock topographic highs. In other regions of the state, the Red Beds can be found either on topographic highs or lows.

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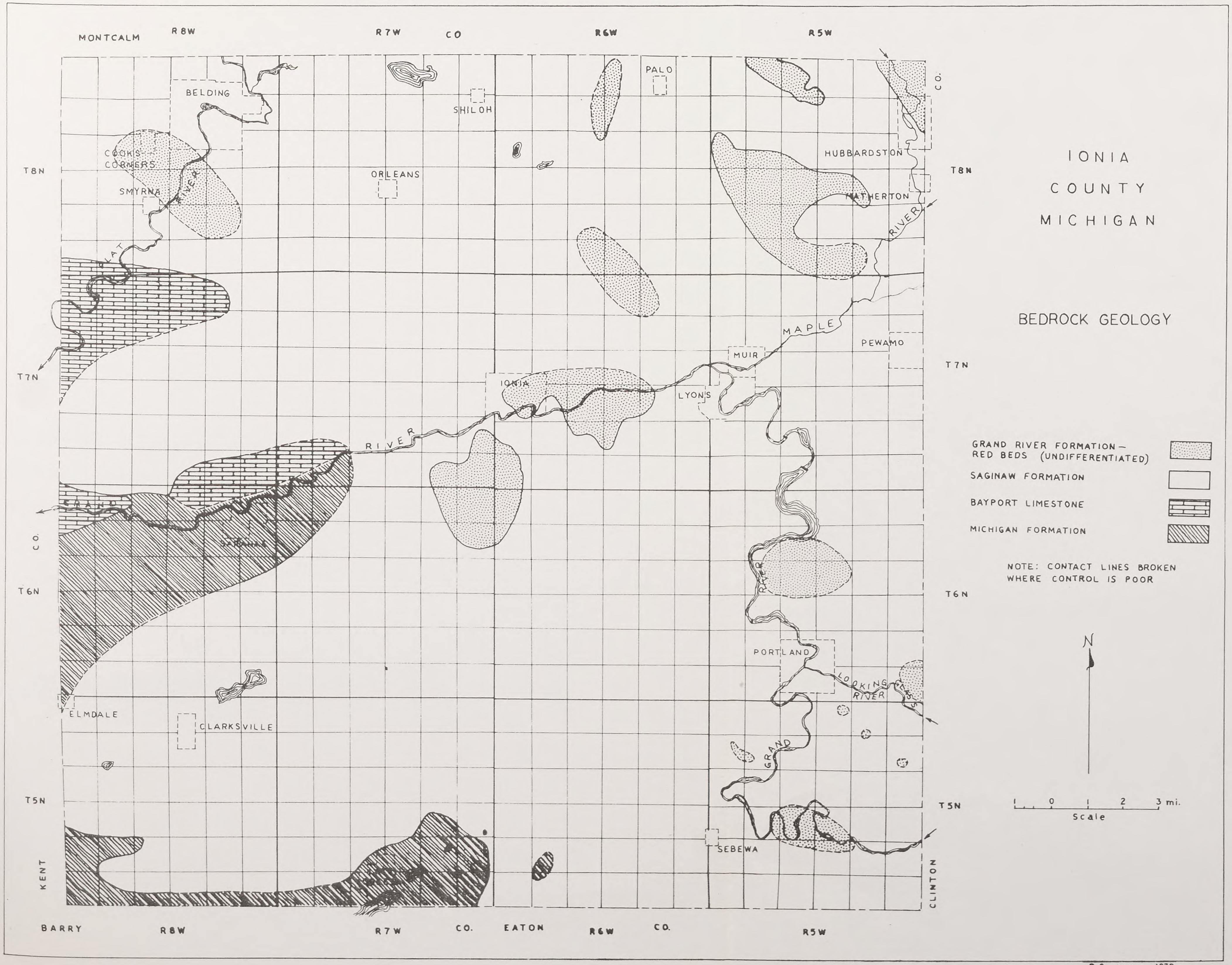
[2] K. E. Vanlier, personal communication.



D. Swanson-1970

Figure 15. Glacial Geology

Some authors prefer to call a map such as this a surficial geologic map and thus imply that the map is accurate only for an unknown thickness of surface material. As indicated in the previous text, it is very difficult to determine the thicknesses for any of the glacial landforms shown.

The contact lines which separate the glacial features are not to be thought of as precise division lines. Rather, they generally indicate a gradational zone from one feature to the adjoining one.

This map is redrafted from the larger State map compiled by Helen Martin.[3]

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[3] H. M. Martin, Map of the Surface Formations of the Southern Penninsula of Michigan, Michigan Geological Survey, pub. 49. (Lansing: Michigan Geological Survey, 1955).

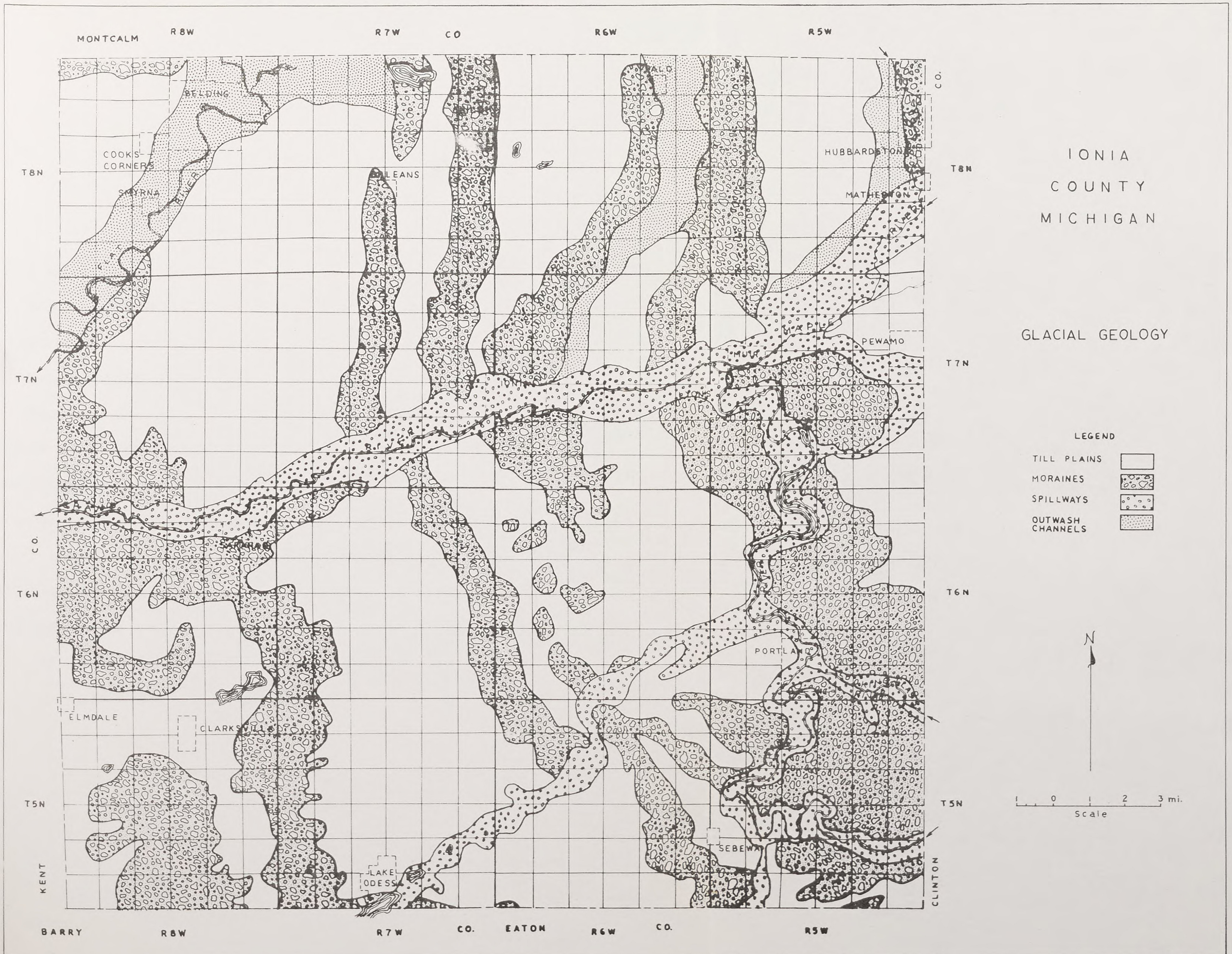

IONIA
COUNTY
MICHIGAN
GLACIAL GEOLOGY
LEGEND
TILL PLAINS
MORAINES
SPILLWAYS
OUTWASH CHANNELS
N
0
2
3 mi.
Scale
MONTCALM
R8W
R7W
CO
R6W
R5W
CO.
T8N
T7N
T6N
T5N
BELDING
COOKS CORNERS
SMYRNA
ORLEANS
HUBBARDSTON
MATHERTON
PEWAMO
PORTLAND
ELMDALE
CLARKSVILLE
LAKE ODESSA
SEBEWA
KENT
CO.
CLINTON
BARRY
EATON
D. Swanson - 1970

Figure 16. Glacial Drift Thickness

The data for this map was obtained by subtracting the bedrock surface elevation (from figure 17) from the land surface elevation (U.S.G.S. topographic maps) at numerous points within each township, usually at each section corner. Fewer data points were used where both the bedrock surface and the land surface are relatively flat than where either of these surfaces are rapidly changing in elevation. Since the data in figure 17 was heavily relied upon, this map will have the same inaccuracies as figure 17 does.

The contours in the northwestern portion of the county are lacking since there is no accurate surface topographic maps for this area. Wells which penetrate the drift in this area are plotted with the drift footage noted.

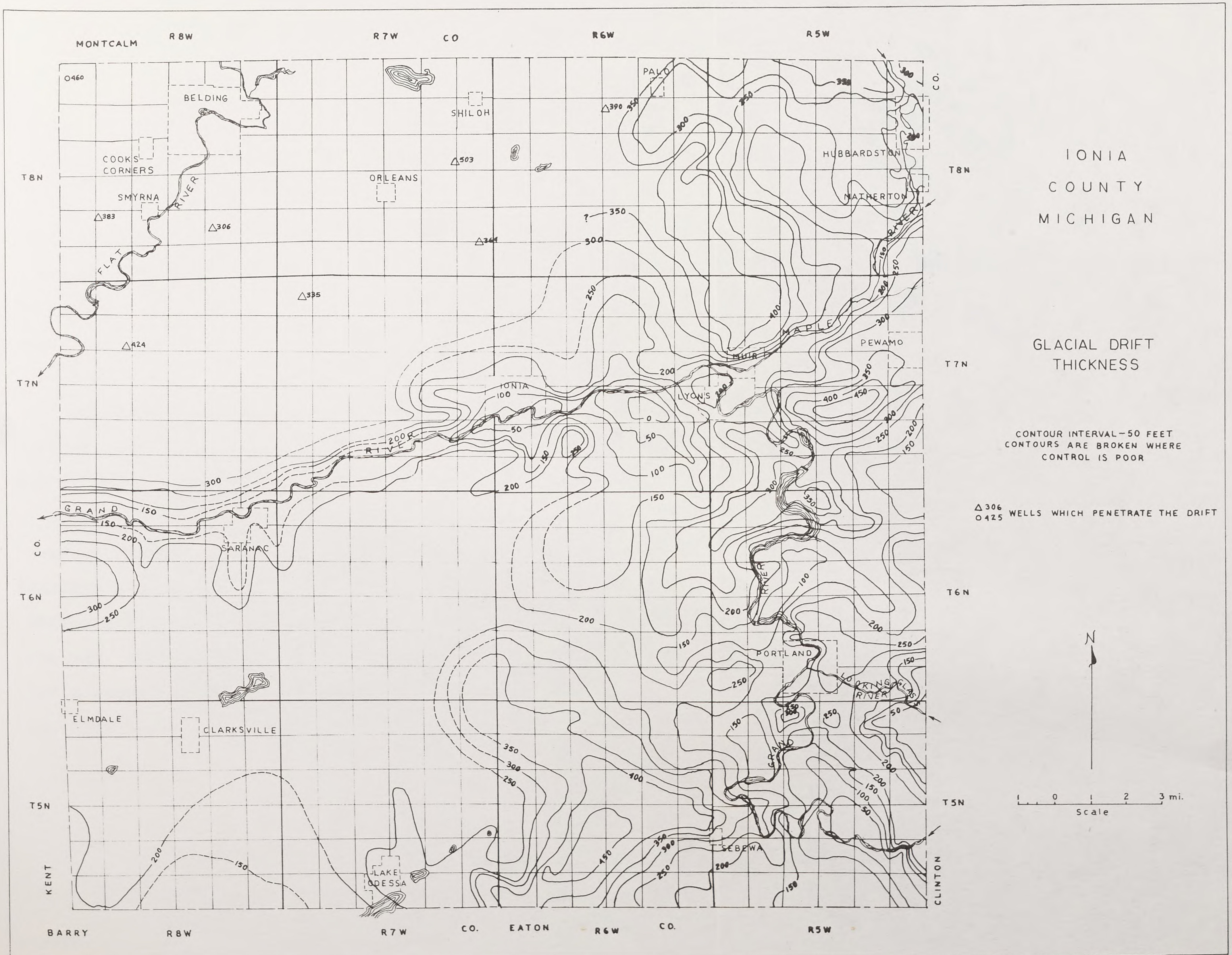
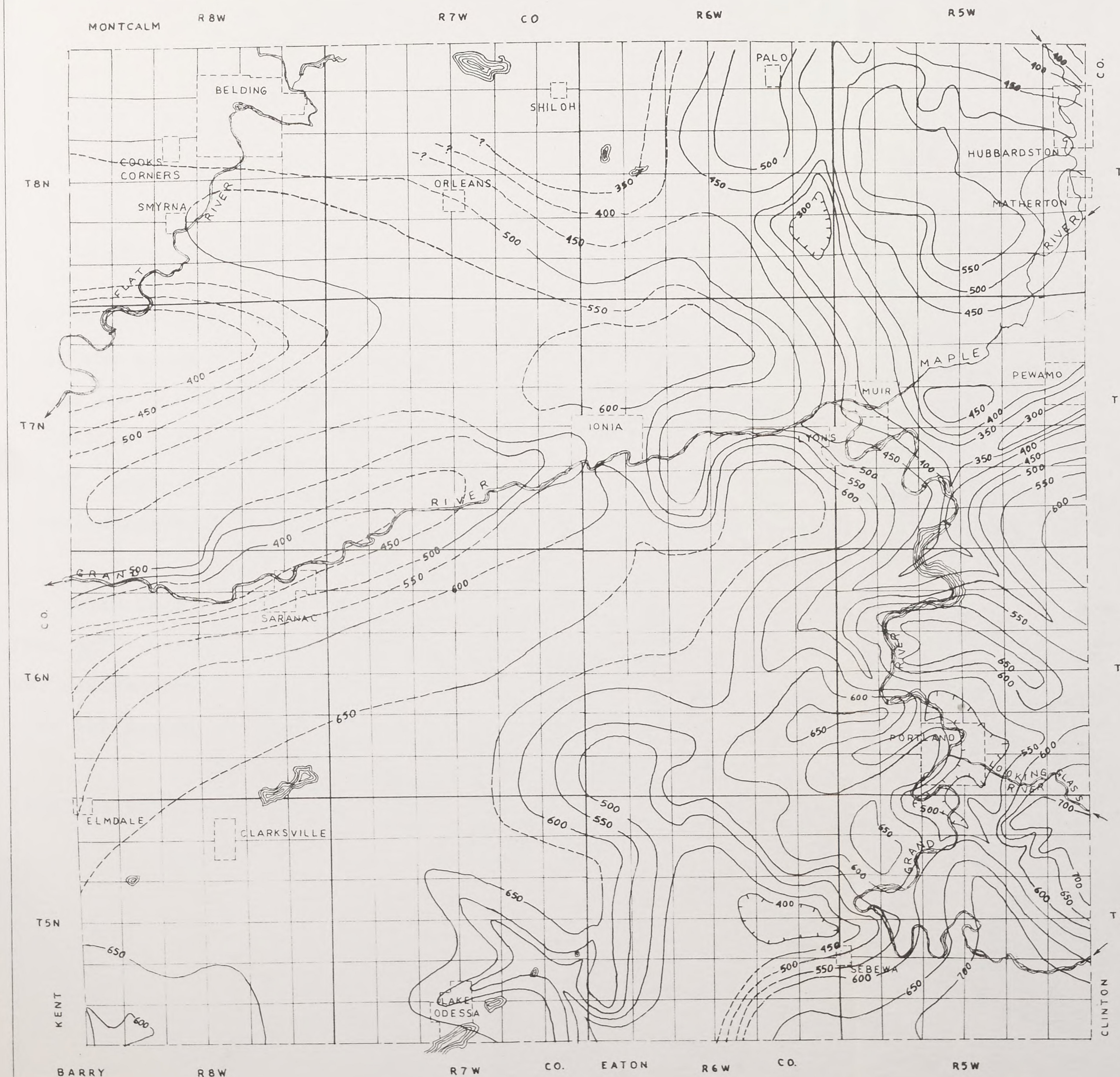

IONIA
COUNTY
MICHIGAN
GLACIAL DRIFT
THICKNESS
CONTOUR INTERVAL—50 FEET
CONTOURS ARE BROKEN WHERE
CONTROL IS POOR
△306
○425 WELLS WHICH PENETRATE THE DRIFT
N
0 1 2 3 mi.
Scale
MONTCALM
R8W
R7W
CO
R6W
R5W
CO.
T8N
T7N
T6N
T5N
CO.
KENT
BARRY
EATON
CLINTON
BELDING
SHILOH
PALO
HUBBARDSTON
MATHERTON
COOKS CORNERS
SMYRNA
ORLEANS
PEWAMO
IONIA
LYONS
MUIR
SARANAC
PORTLAND
ELMDALE
CLARKSVILLE
LAKE ODESSA
SEBEWA
FLAT RIVER
GRAND RIVER
MAPLE RIVER
LOOKING GLASS RIVER
D. Swanson-1970

Figure 17. Topography of the Bedrock Surface

This map was constructed with the data obtained from wells which penetrate the drift. Since this data is not evenly distributed throughout the county, some portions of this map will be somewhat more accurate than others. Contours which are most likely to change when new data is available have been dashed. The northwestern portion of the county does not have accurate surface topographic maps, and thus, the contours here are either dashed or not shown.

After the deposition of the youngest bedrock formations, normal erosion caused the development of a drainage pattern. This drainage pattern was subsequently modified and altered by the more recent glacier advances. The process which was most effective in modifing the bedrock surface is difficult to determine as the effects of both can be seen.



IONIA COUNTY MICHIGAN

TOPOGRAPHY OF THE BEDROCK SURFACE

CONTOUR INTERVAL—50 FEET
CONTOURS ARE BROKEN WHERE CONTROL IS POOR

DATUM IS MEAN SEA LEVEL

D. Swanson–1970

Figure 18. Topography of the Ground Water Surface

The elevations of the ground water surface were established from measured static water levels for wells drilled during the period 1965 to 1970. This information was supplemented by elevations for various surface water bodies obtained from the U.S.G.S. surface topographic maps. Thus, this is a map of the water table surface and artesian levels.

Due to the uneven distribution of water level data, some areas are more accurately mapped than others. The contours are dashed where little information is available. The northwestern portion of the county cannot be mapped due to the absence of surface topographic maps there.

In general, the topography of the ground water surface is similar to the topography of the land surface.

IONIA COUNTY MICHIGAN

TOPOGRAPHY OF THE GROUND WATER SURFACE

CONTOUR INTERVAL – 25 AND 50 FEET

CONTOURS ARE BROKEN WHERE CONTROL IS POOR

DATUM IS MEAN SEA LEVEL

N

0 1 2 3 mi.
Scale

DATA OBTAINED FROM WATER WELL SCHEDULES FOR WELLS DRILLED BETWEEN 1965 AND 1970 AND FROM U.S.G.S. TOPOGRAPHIC MAPS.

D. Swanson – 1970

Figure 19.

General Water Characteristics of Bedrock Aquifers

Well logs, chemical analysis, and drillers notes were used in the construction of this map. It is necessarily generalized and local conditions may vary from the following descriptions:

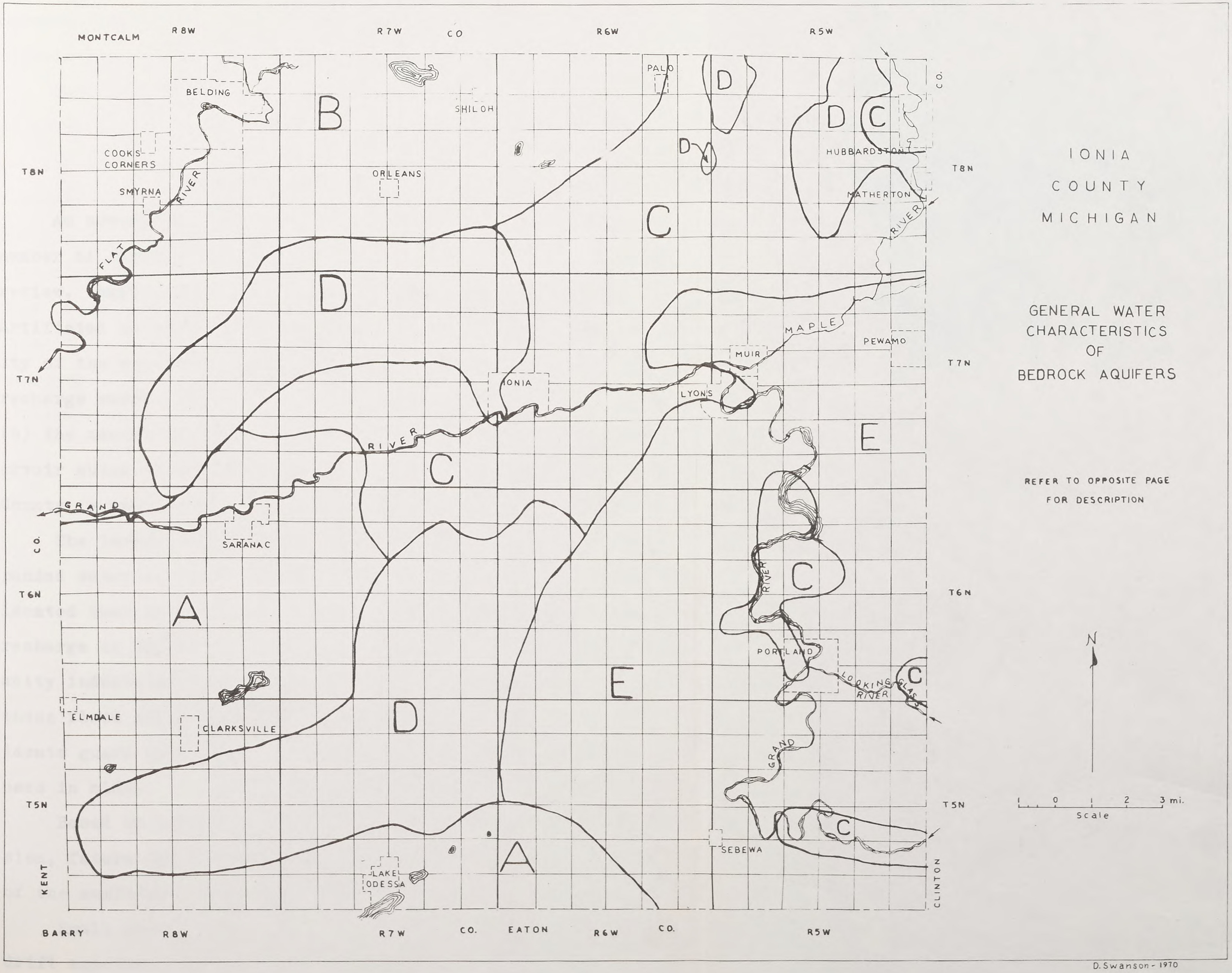
Area A. Bedrock wells should be avoided. Drift wells range in depth from shallow (30 feet) to deep (100+ feet). Deep drift wells (finished near the bedrock top) may encounter quality problems, especially in the southern arm of this area. Sandstone which is at the bedrock top and underlain by shale will probably be adequate aquifers for domestic wells.

Area B. Bedrock wells are rarely used. Deep drift wells are common and bedrock data is not abundant in this area. Bedrock data which is available indicates that sandstone aquifers are deeply buried and are probably highly mineralized. Limestone in the southern part of this area may provide adequate domestic wells, but additional data is needed.

Area C. Bedrock aquifers are generally deep or have somewhat mineralized water. This area is considered to be potentially better than area B. Where sandstone aquifers are not deeply buried, domestic wells are possible, but the water will probably be of lesser quality than the drift wells. Wells in the northern portion of this area (T.8N. R.5&6W.) will probably encounter more problems than southern parts of the area.

Area D. Bedrock probably capable of domestic supplies. This area might be viewed as a subdivision of area C in that excessively deep aquifers and quality problems may exist. Deep bedrock wells in townships 5 north will probably encounter quality problems as the Saginaw formation is thin there. The area northwest of the city of Ionia lacks abundant data but appears to be potentially adequate for deep domestic wells.

Area E. Excellent bedrock wells usually obtainable. High capacity wells are possible, but additional data is needed. Bedrock water quality will generally be better than in the other areas. Numerous wells are tapping the Saginaw formation in this area.


IONIA
COUNTY
MICHIGAN
GENERAL WATER
CHARACTERISTICS
OF
BEDROCK AQUIFERS
REFER TO OPPOSITE PAGE
FOR DESCRIPTION
MONTCALM
R8W
R7W
CO
R6W
R5W
CO.
T8N
T7N
T6N
T5N
KENT
CO.
BARRY
EATON
CLINTON
BELDING
SHILOH
PALO
COOKS CORNERS
SMYRNA
ORLEANS
HUBBARDSTON
MATHERTON
PEWAMO
MUIR
IONIA
LYONS
SARANAC
PORTLAND
ELMDALE
CLARKSVILLE
LAKE ODESSA
SEBEWA
FLAT RIVER
GRAND RIVER
MAPLE RIVER
LOOKING GLASS RIVER
A
B
C
D
E
N
0
2
3 mi.
Scale
D. Swanson - 1970

CHAPTER VI

SUMMARY AND CONCLUSIONS

An adequate ground water supply is dependent upon a number of factors as noted in the preceeding sections. In review, these factors are: (1) the amount of recharge water, artificial or natural, the aquifer receives; (2) the quality of the water within the aquifer and the quality of the recharge water; (3) the permeability of the aquifer; and (4) the amount of water stored in the ground water reservoir which is available for withdrawal. In general, Ionia County is well situated with respect to all of these factors.

The larger urban areas which will probably need expanded water systems sometime in the future are suitably located near rivers which can be utilized for artificial recharge or induced recharge if required. Shallow high capacity industrial and irrigation wells are also possible in these flood plain regions. It is suggested that local residents guard the quality of these rivers with such future uses in mind.

Based on present pumping capacity and planned expansion, future supply problems are not anticipated for any of the mumicipal water systems examined.

Small capacity domestic wells are easily obtained from drift aquifers throughout the county. Domestic wells which utilize bedrock aquifers are found primarily in the southeastern portion of the county, but a much larger area can potentially support such wells.

Objectionably mineralized water is the most widespread problem facing county residents at the present time. The quality of water in both bedrock and drift aquifers is influenced by the composition of local bedrock formations. Thus, a more detailed bedrock geologic map will assist in outlining poor water quality regions. It is also suggested that additional chemical analyses be made on samples from existing wells throughout the county. Information on poor water quality regions might be used in future land use considerations.

BIBLIOGRAPHY

BIBLIOGRAPHY

Cohee, G. V., Macha, C., and Holk, M. Upper Devonian and Carboniferous Rocks of Michigan. United States Geological Survey Oil and Gas Investigation, Chart OC-41. Washington: U. S. Government Printing Office, 1951.

Firouzian, A. "Hydrological Studies of the Saginaw Formation in the Lansing, Michigan Area." Unpublished Master's thesis, Department of Geology, Michigan State University, 1963.

Hem, J. D. Study and Interpretation of the Chemical Characteristics of Natural Water. U. S. Geological Survey Water-Supply Paper 1473. Washington: U.S. Government Printing Office, 1959.

Kelly, W. A. Pennsylvanian System of Michigan. Geological Survey Division, Pub. 40, Geol. Ser. 34, ptII. Lansing: Michigan Geological Survey Division, 1936.

Leverett, F., and Taylor, F. B. The Pleistocene of Indiana and Michigan and the History of the Great Lakes. U. S. Geological Survey, Mon. 53. Washington: U. S. Government Printing Office, 1915.

Martin, H. M. (compiler). The Centennial Geologic Map of the Southern Penninsula of Michigan. Geological Survey Division, Pub. 39, Geol. Ser. 33. Lansing: Michigan Geological Survey Division, 1936.

________. Map of the Surface Formations of the Southern Penninsula of Michigan. Geological Survey Division, Pub. 49. Lansing: Michigan Geological Survey Division, 1955.

McKee, J. E., and Wolf, H. W. Water Quality Criteria. The Resources Agency of California, State Water Quality Board, Pub. 3-A. Sacramento: California State Printing Office, 1963.

Mencenberg, F. E. "Ground-Water Geology of the Saginaw Group in the Lansing, Michigan Area." Unpublished Master's thesis, Department of Geology, Michigan State University, 1963.

Michigan Economic Development Department (compiler)."Ionia County Economic Data Sheet 1961."(Mimeographed), 1961.

Michigan Department of Commerce (compiler)."Ionia County" Economic Profile Sheet 1-1 and 1-2. (Mimeograpned), 1966.

Michigan Department of Health. Data on Public Water Supplies in Michigan. Michigan Department of Health, Engineering Bulletin 4. Lansing: Michigan Department of Health, 1961.

Swartz, D. H. "The Red Beds of Michigan." Unpublished Master's thesis, Department of Geology, University of Michigan, 1951.

Stramel, G. J., Wisler, C. O., and Laird, L. B. Water Resources of the Grand Rapids Area, Michigan. U. S. Geological Survey, Circular no. 323. Washington: U. S. Government Printing Office, 1954.

Threlkeld, G., and Alfred, S. Soil Survey of Ionia County, Michigan. U. S. Department of Agriculture, Soil Conservation Service. Washington: U. S. Government Printing Office, 1967.

U. S. Army Engineering District. Grand River Basin - Comprehensive Water Resources Study. U. S. Army Engineering District (compilers), Appendix C (Climate). Detroit: U. S. Army Engineering District, Feb. 1967.

U. S. Geological Survey. Grand River Basin - Comprehensive Water Resources Study. U. S. Army Engineering District (compilers), Appendix E (Geology and Ground Water). Detroit: U. S. Army Engineering District, Feb. 1967.

U. S. Weather Bureau. Annual Climatological Data For Michigan. U. S. Department of Commerce, Weather Bureau. Washington: U. S. Government Printing Office, 1924 to present.

________. Climatological Summary of Ionia, Michigan. U. S. Department of Commerce, Weather Bureau, Climatography of the U. S., no. 20-20. Washington: U. S. Government Printing Office, 1962.

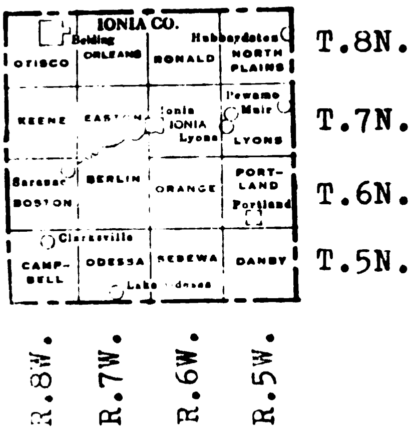
U. S. Public Health Service. The Public Health Service Drinking Water Standards -- 1962. U. S. Public Health Service, Pub. 956. Washington: U. S. Government Printing Office, 1962.

Vanlier, K. E. Personal communication. Hydrologist, U. S. Geological Survey, Water Resources Division.

Vanlier, K. E., Wood, W. W., and Brunett, J. O. A Rapidly Urbanizing Area and Its Water -- Tri-County Region, Michigan. U. S. Geological Survey Water Supply Paper. Washington: U. S. Government Printing Office, in print.

Wood, W. W. "Geochemistry of Ground Water of the Saginaw Formation in the Upper Grand River Basin, Michigan." Unpublished Ph.D. thesis, Department of Geology, Michigan State University, 1969.

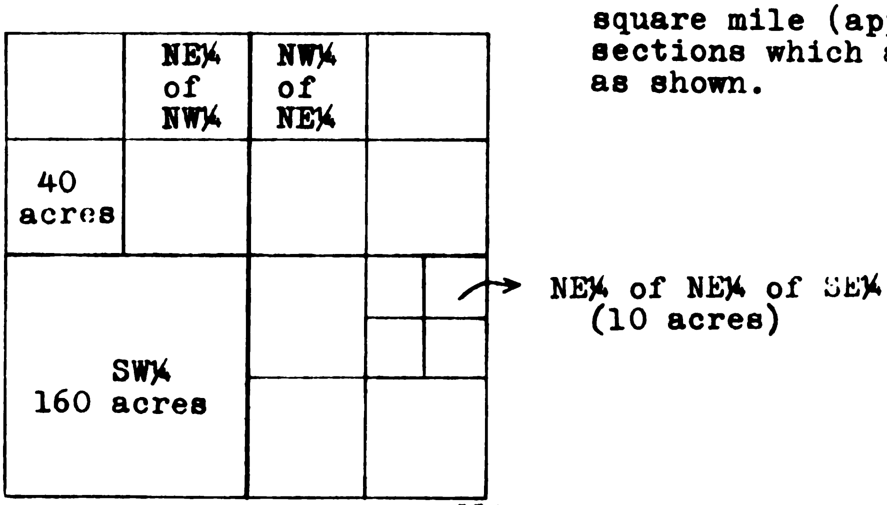
APPENDIX



Ionia County has 16 townships which are identified by political name or by their relationship to the Michigan meridian and base line. The boundries with each designation are the same except for Easton and Berlin townships.

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Each township is approximately six miles square, and is subdivided into one square mile (approximately) sections which are numbered as shown.



The section may be further subdivided into various sized parcels of land which are described as shown.

The complete description of a parcel of land is as follows: N.E.¼ of the N.E.¼ of the S.E.¼ of Section 31, Township 5 North, Range 5 West of the Michigan Meridian. Abbreviated as in the following tables: NE NE SE 31 (with the township and range designation located above each series of data).

Figure 11. Property Description

Table 4. Selected Wells in Ionia County.

LOCATION	ALT	AQU	DPTH	DI	YLD	DD	QU	REMARKS
								DANBY TOWNSHIP T.5N. R.5W.
SW SE SE 1	770	d	30	2	8	--	--	
NE NE SE 2	760	Sag	125	4	---	--	--	
SE SW SW 2	800	Sag	215	4	30	15	--	
NE SW SW 2	800	Sag	125	4	40	9	--	
SE SE SW 2	810	Sag	240	4	60	45	--	GR - top of bedrock
NE SW NE 3	760	Sag	345	4	---	--	--	GR - top of bedrock
SW NW NE 3	760	Sag	305	4	60	20	--	
SE NW NW 3	790	Sag	280	4	---	--	--	
SE SE SW 3	780	Sag	270	4	50	33	--	
SW SW 4	780	Sag	280	4	30	--	--	
SW SW NE 5	810	d	96	4	30	--	--	
NE NW NE 5	720	Sag	260	4	50	18	--	
SE NE SE 7	825	Sag	270	4	21	70	--	GR - top of bedrock
SW SW SE 10	815	Sag	230	4	18	50	--	
SE SW NW 10	800	Sag	245	4	50	20	--	
SW SW SE 11	840	Sag	290	4	30	18	--	
SW SW SW 11	820	Sag	275	4	50	13	--	
NW NW NE 11	800	Sag	260	4	---	--	--	
NW NW SW 12	820	Sag	275	4	---	--	--	
NE SW SW 12	800	Sag	360	4	45	17	--	
NE SE SW 12	820	Sag	270	4	---	--	--	GR also tapped
NW SE NE 13	810	Sag	140	--	40	22	--	
SE SE NE 13	830	Sag	155	4	40	20	--	
NE NE SE 13	825	Sag	170	4	30	50	--	
SW SW NE 14	820	d	32	2	5	--	--	
SE SE NE 15	830	Sag	185	4	50	10	--	
NE NE 15	810	Sag	260	3	15	16	--	
NW NE 15	800	Sag	230	4	40	10	--	
NW NE SW 16	800	Sag	215	4	40	50	--	
SW SE SW 17	830	---	98	2	---	--	--	
NW NW SW 19	815	Sag	460	4	50	10	--	
SW NE SW 21	760	Sag	240	4	---	--	1	flowing well in 1958
NE NE NE 27	760	Sag	145	--	---	--	--	GR also tapped
NE NE NW 31	820	Sag	245	4	60	22	--	
NW NW NW 31	832	Sag	260	4	50	7	--	
NE NE NW 31	820	Sag	245	4	50	48	--	
SE SE SW 33	850	Sag	200	4	40	8	--	
NE NW NE 35	810	Sag	170	4	40	15	--	
								SEBEWA TOWNSHIP T.5N. R.6W.
SW NW SW 1	830	Sag	420	4	---	--	--	
SW SW NW 4	816	Sag	2374	--	---	--	--	Oil test well. Sag flows at 303 feet.
SW SW NE 4	819	Sag	2919	--	---	--	--	Oil test well
NW NW SE 5	840	d?	105	2	20?	--	--	
SE SE SE 12	830	Sag	336	3	---	--	--	

Table 4. (con't)

LOCATION	ALT	AQU	DPTH	DI	YLD	DD	QU	REMARKS
								SEBEWA TOWNSHIP (con't)
NW NW SW 14	820	Sag	480	4	100	24	--	
SW SW NW 17	840	Sag	2323	--	---	--	--	Oil test well
NW SW SW 25	835	Sag	305	4	50	23	--	
SW SE SW 29	865	Sag	580	4	20	50	--	Aquifer may be Mich.
SE SE SW 29	869	Mi	2311	--	---	--	--	Oil test well
NE NE NW 31	865	Sag	320	4	30	10	--	
								ODESSA TOWNSHIP
								T.5N. R.7W.
SE SW SW 5	860	s	130	3	---	--	--	
NW NW NW 11	850	s	165	4	50	--	--	
SE SE SE 13	845	Sag	260	4	---	--	--	
NE NE NE 14	860	g	114	4	---	--	--	
SE SW SW 15	860	Sag	----	--	---	--	--	
SE NE NE 17	840	s	52	2	---	--	--	
SE SW SE 22	840	s+g	76	2	12	9	--	
NW NW NE 23	850	s+g	121	4	10	--	--	
NE NE NE 23	855	s	64	2	10	--	--	
NW SW SE 28	875	Mi	555	12	---	--	--	V. Lake Odessa. Well abandon - quality poor. TW#1
SE SE NW 33	865	---	177	4	---	--	--	V. Lake Odessa. TW#67-A
NE NE NE 33	860	s+g	74	48	800	50	--	V. Lake Odessa.
SW NE SW 33	840	s	61	4	60	--	6	
NE SE SE 36	865	Sag	570	4	30	48	--	
NE SE SE 20	884	s	122	4	42	--	2	
NW SW NW 22	870	Sag	360	4	60	41	--	
								CAMPBELL TOWNSHIP
								T.5N. R.8W.
NE NE NE 2	810	d	123	2	7	57	--	
NE NE NE 2	810	d	126	3	---	--	--	
SW SW SW 2	820	s	46	2	10	--	--	
NW NW SE 3	820	s	41	2	---	--	--	
SW SW NE 6	820	s	82	3	16	--	--	
NW SE SW 8	810	s	38	4	25	--	8	
SE NE NW 10	830	s	30	3	20	--	--	
SW SW SE 10	880	s	210	4	---	--	--	
SE SE SE 11	850	s	150	4	---	--	--	
SW SW NE 15	900	s+g	105	4	25	--	--	
SW SE SE 18	860	g	79	4	15	7	--	
SW SE SW 27	860	s	114	2	7	--	9	
SW SE NE 28	806	Sag	5700	--	---	--	--	Oil test well
NW SW SE 29	831	Sag	2468	--	---	--	--	" " "
SE SE NE 29	850	Mi	2200	--	---	--	--	" " "
SW SW NW 30	787	Ba?	----	--	---	--	--	" " "
SW SE NW 31	805	Mi	2453	--	---	--	--	" " "
NW NW NW 32	832	Mi	2153	--	---	--	10	" " " Analysis from 372 feet in Mi.

Table 4. (con't)

LOCATION	ALT	AQU	DPTH	DI	YLD	DD	QU	REMARKS
								CAMPBELL TOWNSHIP (con't)
NE SW SW 32	825	Mi	2128	--	---	--	--	Oil test well
NE SE NW 34	870	s+g	114	4	42	--	11	
								PORTLAND TOWNSHIP T.6N. R.5W.
SW SE SW 1	755	g	75	4	15	--	--	
SE SW SW 1	760	g	83	4	---	--	--	
NW NW NE 2	750	Sag	305	4	---	--	--	
NW NW NE 3	765	s+g	79	2	---	--	--	
SE SE SW 3	765	Sag	310	4	20	10	--	
E½ SW SE 5	762	Sag	2870	--	---	--	--	Oil test well
SW SE SE 7	771	Sag	260	4	50	49	--	
NW SW 8	760	Sag	215	4	40	52	--	
NE SW 9	745	GR	123	2	---	--	--	
NE NW NE 11	770	g	76	4	---	--	--	
NW NW NE 14	790	s+g	80	2	---	--	--	
SE NE SE 17	770	GR	145	4	15	10	--	
SE SE NE 17	770	GR	160	4	---	--	--	
NE NE NW 19	762	---	-----	--	---	--	--	
SW SW 20	785	Sag	230	4	---	--	--	
NW NW NE 22	785	g	76	4	20	--	--	
SW SE SE 22	770	Sag	305	4	---	--	--	
NW NW NW 23	780	g	84	4	10	--	--	
NE NE NW 25	780	Sag	320	4	---	--	--	
SE 28	710	g	65	26	500	--	16	V. Portland PW#4
N½ SE 28	710	s+g	75	26	608	17	15	V. Portland PW#5 & TW#3
SE SE NE 30	785	Sag	215	4	30	59	--	
NE NE SW 30	780	Sag	279	4	15	31	--	
SE SE NW 30	780	g	160	4	---	--	--	
NW NW SE 30	785	Sag	315	4	50	21	--	
NE NE NE 31	810	Sag	370	4	40	--	--	
NE NE NE 31	800	s	39	3	8	--	--	
NW NE NE 31	815	s+g	44	4	---	--	--	
SE SE SW 31	820	Sag	295	4	30	19	--	
SW SE NE 32	790	Sag	230	4	40	15	--	
NE NE NE 32	790	Sag	295	4	50	21	--	
SE NW SE 32	790	Sag	230	4	35	13	--	
NE SE NE 32	790	Sag	260	4	---	--	--	
SE NE 32	790	s	99	4	---	--	--	
								ORANGE TOWNSHIP T.6N. R.6W.
SW SW SE 5	800	s+g	47	4	---	--	--	
NW 6	805	s	121	4	20	--	--	Ionia Co. Airport
SE SE SW 11	787	Sag	2807	--	---	--	--	Oil test well
SW SW SE 13	780	Sag	245	4	---	--	--	

Table 4. (con't)

LOCATION	ALT	AQU	DPTH	DI	YLD	DD	QU	REMARKS
								ORANGE TOWNSHIP (con't)
SE SE SE 16	800	Sag	460	4	20	20	--	
SW SW SE 25	800	Sag	320	4	45	48	--	
NE NW NE 27	810	Sag	350	4	60	20	--	
N½ SE 29	820	g	264	4	30	--	18	Weigh station
NW SW SW 30	860	Sag	490	4	---	--	--	
SE SW SW 32	820	s+g	40	4	---	--	--	
								BERLIN TOWNSHIP T.6N. R.7W.
NW SW SW 4	790	s	100	4	50	--	20	
SE SE 6	780	s	129	4	30?	--	21	
NE NE NE 7	760	s	116	4	---	--	--	
NE NE NE 11	820	s	144	4	50	--	22	
SW SW NE 12	846	GR	4570	--	---	--	--	Oil test well
SW SW SW 12	840	s	50	4	50	--	23	
NW NE NE 12	810	s+g	65	3	25	--	--	
SW SW SW 17	820	s	62	4	20	--	--	
NW NW NW 18	800	Sag?	202	4	---	--	--	
NE SE SE 26	845	s+g	50	2	---	--	--	
NW SW NW 26	860	Sag	420	4	80	36	--	GR - top of bedrock. well may penetrate to Mi
NW SW NW 29	850	s	142	4	35	--	24	
NE NE NE 30	840	s	76	3	15	--	--	
								BOSTON TOWNSHIP T.6N. R.8W.
SW SE 1	670	s	102	18	300	25	26	V. Saranac PW#1
SW SE 1	670	s	125	8	300	--	25	" " PW#2
SW SE 1	670	---	210	6	---	--	--	" " TW#1
NW SE 1	640	s+g	134	8	600	67	--	" " PW#3c
NW SW NW 2	760	s	173	3	18	--	--	
SW NW SW 2	640	s	30	2	10	--	--	
SE NW 4	680	Mi?	6090	--	---	--	--	Oil test well
NE NE 4	718	Sag	6146	--	---	--	--	" " "
NW SE NW 6	672	Bay	2550	--	---	--	--	" " "
NW NW NW 7	680	s	94	3	25	--	--	
NE SE NE 8	660	s	60	4	50	--	--	
NE SE NE 12	780	g	130	3	---	--	--	
NW NE NE 12	700	g	78	4	---	--	--	
NW NE NE 12	710	g	102	4	60	--	27	
SW SE SE 14	740	s	113	4	---	--	--	
SE NE NW 15	800	s	150	4	60	--	--	
NW SE NE 15	800	s	141	4	45	--	--	
NW NE SW 16	874	Mi	----	--	---	--	--	Oil test well
NW NW SE 18	850	s	140	4	25	--	28	
SE SW SE 20	850	s	59	4	---	--	--	
NE NE NW 21	860	s	160	4	---	--	--	
SE SE SE 22	835	s	80	2	---	--	--	

Table 4. (con't)

LOCATION	ALT	AQU	DPTH	DI	YLD	DD	QU	REMARKS
								BOSTON TOWNSHIP (con't)
SE SE NE 23	760	s	84	2	13	--	--	
SW SW SW 24	800	s	100	4	---	--	--	
SW SW NW 25	825	s	116	4	---	--	--	
NW NE NW 28	830	s	73	4	40	--	--	
NE NE NW 29	850	c	226	4	---	--	--	
NE SW NW 33	830	s	96	3	---	--	--	
NE NE SE 33	840	s	85	4	50	--	29	
SW SW SW 35	820	g	150	4	25	25	--	
NE NW NW 35	820	s	94	4	50	--	30	
SE SW SW 36	820	s+g	116	4	25	--	--	
								LYONS TOWNSHIP T.7N. R.5W.
SE SW SW 1	745	s	70	2	12	--	--	
SW SE SE 7	738	s+g	154	10	302	20	33	V. Muir PW#2
SE SE NW 8	751	Sag	2921	--	---	--	--	Oil test well
SW NW NW 11	734	Sag	2915	--	---	--	--	" " "
SE SW SW 12	737	Sag	485	10	---	--	34	V. Pewamo PW#1 & TW#1
SW SW 13	680	Sag	395	4	30	--	--	flowing well
SE SE SW 15	750	g	88	4	---	--	--	
SW SW SE 15	740	s	100	4	50	55	--	
SW SW NE 16	677	Sag	2862	--	---	--	--	Oil test well
NW 17	---	s+g	145	10	610	--	--	V. Muir PW#1. DD-8½ ft. while pumping 200 gpm.
19	---	Sag	360	4	30	50	--	
SW NE 19	654	Sag	300	8	---	--	--	flowing well
NW NE NE 20	760	s	191	4	---	--	--	
SE SW NW 21	766	Sag	2932	--	---	--	--	Oil test well
NE NE SW 24	730	s	89	4	30	--	--	
SW NW NE 26	755	s	160	4	80	93	35	
NW NW SW 28	692	Sag	2850	--	---	--	--	Oil test well
NE NW SW 28	680	Sag	241	4	20	--	--	Consumers Power Co. flowing well.
SW 31	750	s	39	2	14	--	--	
N½ N½ NE 33	676	Sag	2826	--	---	--	--	Oil test well
SE SE SE 33	750	s+g	350	4	30	9	--	
								IONIA TOWNSHIP T.7N. R.6W.
SW SW 3	---	s+g	95	4	---	--	--	
SW NE SE 3	793	Red	3002	--	---	--	--	Oil test well
NE SW 3	---	s+g	140	4	50	--	37	
NW SW NE 4	---	s	115	4	---	--	--	
SE SE NW 5	---	s	107	4	---	--	--	
NW NW NW 7	---	s	48	4	---	--	--	
NE SE NE 8	---	---	135	2	---	--	38	
SW SE SW 11	760	g	91	4	---	--	--	
NE NW NW 14	760	Sag	270	4	---	--	--	

Table 4. (con't)

LOCATION	ALT	AQU	DPTH	DI	YLD	DD	QU	REMARKS
								IONIA TOWNSHIP (con't)
SW SW 16	680	s+g	73	6	60	10	40	
NE NE SW 16	660	s	52	4	60	--	41	
SE NE NW 16	680	s	45	4	---	--	--	
NW NE SE 16	745	---	121	2	---	--	39	
SW NW SE 18	767	---	120	3	---	--	--	City of Ionia TW#10. est. yield - 700gpm. TW#5,6,7, and 9 in SE 18
NE SW 18	825	---	180	3	---	--	--	City of Ionia TW#8 TW#11 at same location.
NE SW NE 18	755	s+g	110	--	700	11	--	City of Ionia PW#5
SE NW SE 18	757	s+g	107	12	1200	19	45	" " " PW#9
SW NW SE 18	759	s+g	108	12	800	13	47	" " " PW#10
SE NE SW 18	760	s+g	107	12	700	16	48	" " " PW#11
19	640	Sag	336	--	---	--	--	" " " PW#1
SE NW 19	660	Sag	362	--	---	--	--	Ionia Co. Road Comm,
NE 19	682	Sag	340	--	30	--	--	flowing well
NW NE SW 20	640	Sag	318	--	---	--	--	
SW NE NE 20	720	s	47	4	50	--	50	
NE 27	---	Sag	91	--	---	--	--	flowing well
NW NE 27	680	Sag	60	2	---	--	51	
SW NW SW 28	780	Sag	305	4	---	--	--	
SE SE NW 29	780	s	35	4	10	4	--	
C NW 30	650	---	28	2	10	--	--	
NE NW SW 30	780	Sag	393	3	40	--	56	
NW SE NW 30	650	Sag	246	4	50	10	53	
NW NW SW 31	810	s	57	4	---	--	--	
SE SE SE 36	765	Sag	215	4	45	20	--	
								EASTON AND BERLIN TOWNSHIPS T.7N. R.7W.
SW SW SE 2	---	s	46	4	---	--	--	
SW SW NE 2	---	s+g	47	2	10	--	--	
SE SE NW 4	---	s	112	4	---	--	--	
NE NW SE 6	841	Sag	----	--	---	--	--	Oil test well
NW NW SE 10	---	d	35	2	---	--	--	
SE SE SW 14	780	g	115	4	---	--	--	
SE NE NW 16	---	s	109	4	---	--	--	
NW NE SW 19	830	s	125	4	---	--	--	
NW NW NE 19	825	s	137	4	---	--	--	
SW SW NW 20	820	GR?	113	4	---	--	--	
SE SW NW 21	820	s	100	4	---	--	--	
SE SE NW 21	830	s	153	4	---	--	--	
NE NW SE 21	820	s	115	4	---	--	--	
NW SW SW 22	720	g	51	4	---	--	--	
NE SE NE 23	720	s+g	108	2	---	--	--	
NE SW NW 23	730	s+g	119	12	536	32	--	State Prison PW#1
SW NE NW 23	750	s+g	130	12	556	42	--	" " PW#2
SW NE NW 23	754	s+g	185	6	125	32	--	" " TW#1
SW SE NW 23	726	s+g	216	6	---	--	--	" " TW#2
NE SW NW 23	740	s+g	140	6	90	55	60	" " TW#3

Table 4. (con't)

LOCATION	ALT	AQU	DPTH	DI	YLD	DD	QU	REMARKS
								EASTON AND BERLIN TOWNSHIPS (con't)
SE NW NW 23	742	s	127	6	---	--	--	State Prison TW#4 also used as U.S.G.S. obs. well.
SE 24	650	Sag	228	--	10	--	--	flowing well
NE SE 24	640	Sag	313	--	---	--	--	
25	639	g	29	6	200	9	--	Ionia State Hosp. TW#1-60
NE SW NE 25	636	s+g	23	6	132	13	63	" " " TW#2-60 this well now U.S.G.S. observation well.
NW SE 25	744	Sag	160	6	---	--	--	Ionia State Hosp. TW#2
SW SW 25	753	g	100	6	---	--	--	" " " TW#5
NE SW NE 25	644	g	48	6	345	5	--	" " " TW#6
25	---	g	20	8	200	10	--	" " " PW#5
SW NE 25	638	g	28	8	310	10	--	" " " PW#4
SE 25	---	Sag	264	4	---	--	64	GR - top of bedrock
NE NE 26	640	Sag	320	8	300	--	--	State Prison. High sulphur - not used. flow
NE NE NE 28	720	d	58	2	17	--	--	flowing well
SW NW SW 29	800	s	116	4	---	--	--	
NW SE NE 31	740	s	55	4	---	--	--	
SW SE SE 33	700	Sag	274	4	20	10	--	flows at 9gpm
SE NE NE 36	810	s	81	4	---	--	--	
NW NW 36	811	g	240	6	210	75	--	Ionia State Hosp. TW#4
								<u>KEENE TOWNSHIP</u> <u>T.7N. R.8W.</u>
SW NE NW 3	---	g	131	4	---	--	--	
SE SE SE 8	823	Sag	----	--	---	--	--	Oil test well
NW NE NE 9	---	s	98	4	---	--	--	
SW NW 14	840	s+g	80	4	---	--	--	
SW NW 19	780	s	65	3	18	--	--	
SW NW NW 19	790	s	42	3	20	--	--	
NW NE SE 24	840	s+g	106	2	10	--	--	
SW SE NW 28	820	s	110	3	14	--	--	
SE SE NE 31	740	s	80	4	60	--	--	
NE SE SE 31	710	s	102	3	---	--	--	
SE SE SE 32	750	s	135	4	30	--	--	
SE SW SE 33	740	s+g	154	4	20	--	66	
SE SW 34	765	Bay	6201	--	---	--	--	Oil test well
NW SW 35	810	Bay	6313	--	---	--	--	" " "
								<u>NORTH PLAINS TOWNSHIP</u> <u>T.8N. R.5W.</u>
SE SE SE 1	740	s	101	--	12	--	--	
SW NW NW 1	712	Red	3060	--	---	--	--	Oil test well
SE NE NE 3	775	g	98	4	89	55	--	

Table 4. (con't)

LOCATION	ALT	AQU	DPTH	DI	YLD	DD	QU	REMARKS
								NORTH PLAINS TOWNSHIP (con't)
SE SW SE 3	762	Sag	3030	--	---	--	--	Oil test well
SW NW SE 4	782	Sag	3048	--	---	--	--	" " "
NE SE SE 4	783	Red	3120	--	---	--	--	" " "
NE NW SE 4	788	Red	3045	--	---	--	--	" " "
SE NE SW 4	793	Red	3052	--	---	--	--	" " "
SE NW SW 4	765	Red	3027	--	---	--	--	" " "
NW SW SE 4	785	Red	3042	--	---	--	--	" " "
NW NW NW 5	796	Red	2653	--	---	--	--	" " "
NW NW NE 5	778	Sag	2682	--	---	--	--	" " "
NW NE NE 6	817	Sag	2653	--	---	--	--	" " "
SE NW NE 6	803	Sag	3068	--	---	--	--	" " "
NW NW NE 6	807	Sag	2696	--	---	--	--	" " "
NE NW NW 6	825	Sag	2729	--	---	--	--	" " "
SE SE NE 6	796	Sag	3058	--	---	--	--	" " "
NW SW SW 6	795	g	51	2	16	7	--	
SE SW SW 9	770	Sag	322	3	---	--	67	
SW NE NW 9	778	Sag	3066	--	---	--	--	Oil test well
NW NE SW 10	763	Sag	3113	--	---	--	--	" " "
NE SE NE 10	745	Sag	3102	--	---	--	--	" " "
NE NW NW 11	749	Sag	3080	--	---	--	--	" " "
SW NW SW 12	761	Sag	3064	--	---	--	--	" " "
SW SW SE 12	710	s+g	210	3	7	13	68	St. John's Church. Flows
NE SE 12	735	s	126	4	40	86	--	
NW NE SE 12	737	Sag	360	4	60	116	--	High School well. Red Beds - top of bedrock.
NE NE SE 12	750	Sag	360	4	70	58	--	Red beds - top of rock
NE SE SE 12	690	s+g	64	4	---	--	--	
SE SE SE 16	778	Sag	287	4	---	--	--	
NE NW NW 16	773	s+g	135	4	---	--	--	
SW SE 17	766	Red	3006	--	---	--	--	Oil test well
SE SE SW 18	797	Red	2993	--	---	--	--	" " "
NW NE SW 18	802	Red	3027	--	---	--	--	" " "
SW SE NW 18	793	d	82	2	---	--	69	
NE NW NW 18	810	s	159	4	---	--	--	
SE NW NE 19	773	Red	2970	--	---	--	--	Oil test well
NE NW SE 21	788	Red	3020	--	---	--	--	" " "
NE NE NE 21	785	s	125	4	---	--	--	
SW SE SE 22	772	Sag	2963	--	---	--	--	Oil test well
SE SW SW 23	767	Red	2974	--	---	--	--	" " "
NW NW SW 23	779	Red	2996	--	---	--	--	" " "
SW SW NE 23	748	Sag	2974	--	---	--	--	" " "
NE NW NW 27	796	s+g	211	4	30	160	--	
NW SE 28	792	Sag	3034	--	---	--	--	Oil test well
NW NW SE 29	790	Red	3049	--	---	--	--	" " "
SE NE SE 30	772	s	35	2	---	--	--	
SE NE NW 34	760	g	166	4	30	--	--	
								RONALD TOWNSHIP T.8N. R.6W.
SE NE NW 1	793	d	133	2	15	--	--	

Table 4. (con't)

LOCATION	ALT	AQU	DPTH	DI	YLD	DD	QU	REMARKS
								RONALD TOWNSHIP (con't)
NW SW SE 2	795	s	52	2	10	--	--	
NE NE SW 2	795	s	137	--	17	--	--	
SW NW SW 6	---	d	110	2	---	--	70	
NW SW NW 10	856	Red	3193	--	---	--	--	Oil test well
NW NE NW 12	767	Sag	3027	--	---	--	--	" " "
SE SE NW 13	767	Sag	3019	--	---	--	--	" " "
SE SE SE 13	763	Sag	2961	--	---	--	--	" " "
NW SE SW 14	805	s	64	3	---	--	--	
NE NE NE 16	---	s	70	4	15	3	--	
SE SW SW 18	---	s	51	4	---	--	--	
SW NW 19	---	s+g	221	12	825	104	--	
NE SE SE 22	790	Sag	3026	--	---	--	--	Oil test well
SE NW NE 24	755	Sag	3095	--	---	--	--	" " "
NW NW NW 27	---	s	94	4	---	--	--	
NE SW NE 33	795	Red	----	--	---	--	--	Oil test well
NE NW SE 36	752	Sag	2994	--	---	--	--	" " "
SE SW SE 36	770	s	61	2	---	--	--	
SW SE SE 36	760	s	70	2	---	--	--	
								ORLEANS TOWNSHIP T.8N. R.7W.
SW SW SW 1	---	s+g	41	2	10	--	--	
SE SE 3	---	s	36	4	---	--	--	
SE NE SE 5	---	s	133	4	---	--	--	
NE SE SE 12	---	s+g	45	2	12	--	--	
NE SE SE 14	830	Sag	3045	--	---	--	--	Oil test well
NW NW NW 14	---	s	74	--	---	--	--	
SW SW NW 17	---	s	55	4	---	--	--	
NE NW NE 20	---	s	45	4	---	--	--	
NE NE NW 21	---	s	45	4	---	--	--	
NW NW NW 23	---	s+g	58	2	10	--	--	
SE SW SW 24	---	s	211	4	---	--	--	
E½ SW 32	---	d	47	2	15	--	--	
SE SE SE 34	---	s	40	4	---	--	--	
SE NW SW 35	---	s	124	4	---	--	--	
NW NW SE 35	---	s	41	4	---	--	--	
SW SW SE 35	---	s	40	4	---	--	--	
NW NW NE 36	839	Sag	3000	--	---	--	--	Oil test well
								OTISCO TOWNSHIP T.8N. R.8W.
NE NE NE 2	---	s+g	64	2	35	--	--	
SW SW NE 4	---	s+g	74	2	10	--	--	
SE SE SW 5	---	s+g	62	2	10	--	--	
SW 6	---	s	240	12	608	57	--	
NE SW NW 6	---	s+g	297	12	500	72	--	composite of 3 wells. bedrock is Red Beds?
NW NW SW 6	740	s+g	245	12	300	35	75	

Table 4. (con't)

LOCATION	ALT	AQU	DPTH	DI	YLD	DD	QU	REMARKS
								OTISCO TOWNSHIP (con't)
NE SW 6	---	s+g	145	4	---	--	--	
NE NW NE 9	---	s+g	70	2	10	--	--	
NW NW NW 10	---	s	137	4	20	5	--	
SE 10	---	s	86	8	---	--	--	City of Belding TW#3
SE NE 10	---	s+g	36	24	240	--	71	" " " PW#2
NE NW SE 11	---	g	161	30	---	--	73	" " " PW#4
NW 12	---	s+g	45	2	10	--	--	flowing well
NW SW SW 14	---	s+g	44	2	10	--	--	
NE NE NE 16	---	s+g	60	2	10	--	--	
NE NE SE 18	---	s	186	4	---	--	--	
SW SW SE 21	---	s	100	2	10	--	--	
SW SE SE 21	---	s	52	2	10	--	--	
SW NW 22	---	s+g	118	2	10	--	--	
NE NW SE 24	---	s+g	65	2	10	--	--	
NE NW SW 26	870	Red	3001	--	---	--	--	Oil test well
SW NW NW 29	900	Sag	----	--	---	--	--	" " "
SE NE SE 30	---	s	119	4	---	--	--	
SE SW SW 30	---	s	60	4	34	--	--	
NW SE SW 34	---	s	117	4	---	--	--	

Description of the heading:

LOCATION - as described at beginning of Appendix. Except for oil test wells, a location less than three quarter sections indicates inability to locate closer than what is shown.
ALT - altitued of well in feet above mean sea level (majority were located to within ±10 feet).
AQU - aquifer which is tapped or first bedrock encountered by oil wells:
- d - drift (undifferentiated)
- s - sand
- g - gravel
- c - clay
- s+g - sand and gravel
- GR - Grand River formation
- Sag - Saginaw formation
- Red - Red Beds
- Bay - Bayport limestone
- Mi - Michigan formation

DPTH - depth of well
DI - diameter of well
YLD - yield of well
DD - drawdown of water level in well when pumped
QU - refers to reference number in Table 5 (analysis available)
REMARKS - shows owner if municipal or State. PW refers to production well, TW refers to test well.

All wells listed here are availabe for examination or purchace at the Michigan Geological Survey in Lansing, Michigan.

Table 5. Chemical Analysis for Ground Water and Rivers in Ionia County

NO.	LOCATION	OWNER	DEPTH	AQU.	DATE	A	TDS	SiO_2	Fe	Ca	Mg	Na	K	NO_3	Cl	SO_4	HCO_3	Hard.	F	pH	Cond.
		DANBY TOWNSHIP T.5N. R.5W.																			
1	SW 21	private	240	Sag	1-65	U	---	--	3.5	---	----	----	---	.2	5	[illegible]	362	[illegible]	--	7.5	[illegible]
		ODESSA TOWNSHIP T.5N. R.7W.																			
2	NE SE SE 20	private	122	s	11-69	D	---	--	.3	---	----	----	----	----	---	----	---	342	-	---	----
3	SW SE 28	Lake Odessa Sherman St.	109	---	10-55	M	[illegible]	18	1.4	86	31.7	5.8	---	n	15	23	380	345	0	7.4	[illegible]
4	NE NE SE 33	L. Odessa-4 wells at Jordan Lake St. & Jordan Lake Ave.	40	d	10-53	M	346	13	.1	80	24.3	5.8	---	n	3	18	358	310	0	7.8	600
5	33?	L. Odessa-Cold Storage prop.	104	---	12-61	-	500	17	1.5	108	39.	9.2	1.0	n	26	52	437	430	.6	7.7	800
6	SW NE SW 33	private	61	d	2-69	D	---	--	1.0	---	----	----	---	----	---	----	---	342	--	---	----
		CAMPBELL TOWNSHIP T.5N. R.8W.																			
7	SE SE NE 7	private	130	g	12-69	D	---	--	t	---	----	----	---	----	---	----	---	308	--	---	----
8	NW SE SW 8	private	38	s	11-68	D	---	--	.3	---	----	----	---	----	---	----	---	376	--	---	----
9	SW SE SW 27	private	114	s	8-69	D	---	--	.3	---	----	----	---	----	---	----	---	325	--	---	----
10	NW NW NW 32	oil test well	372	Mi	1-49	M	---	--	--	---	----	----	---	----	180	1580	---	1675	--	---	----
11	NE SE NW 34	private	114	s+g	10-68	D	---	--	.3	---	----	----	---	----	---	----	---	427	--	---	----
		PORTLAND TOWNSHIP T.6N. R.5W.																			
12	NW 2	private	275	Sag	1-65	U	---	--	1.2	---	----	----	---	1.1	2	18	442	362	--	7.5	675
13	NE 19	private	126	Sag	1-65	U	---	--	1.8	---	----	----	---	.5	4	34	332	[illegible]	--	8.0	558
14	SW 28	Portland well#6	80	d	6-68	M	502	13	.1	112	28.	6.5	2.0	7.3	13	66	[illegible]	395	.2	6.9	710
15	N½ SE 28	Portland well#5	75	s+g	10-57	M	430	11	.4	100	27.	7.8	1.6	6.0	15	59	346	360	.0	7.5	[illegible]
16	SE 28	Portland well#4	65	s+g	10-57	M	436	11	.0	104	28.	7.4	2.8	12.	13	55	366	375	.0	7.4	[illegible]
17	NW 36	private	260	Sag	2-65	U	---	--	1.8	---	----	----	---	1.0	4	11	425	[illegible]	--	7.5	644
		ORANGE TOWNSHIP T.6N. R.6W.																			
18	SW 29	Mich. Dept. State Highway	264	g	1-65	U	---	-	12*	---	----	----	---	.9	1	3	448	358	--	7.3	724
19	NW 29	" " " "	133	g	1-65	U	---	--	2.7	---	----	----	---	3.2	2	2	402	284	--	7.7	592
		BERLIN TOWNSHIP T.6N. R.7W.																			
20	NW SW SW 4	private	100	s	8-69	D	---	--	1.0	---	----	----	---	----	---	----	---	291	--	---	----
21	SE SE 6	private	129	s	9-68	D	---	--	1.0	---	----	----	---	----	---	----	---	255	--	---	----
22	NE NE NE 11	private	144	s	9-69	D	---	--	.3	---	----	----	---	----	---	----	---	306	--	---	----
23	SW SW SW 12	private	50	s	10-69	D	---	--	t	---	----	----	---	----	---	----	---	342	--	---	----
24	NW SW NW 29	private	142	s	1-69	D	---	--	1.0	---	----	----	---	----	---	----	---	324	--	---	----
		BOSTON TOWNSHIP T.6N. R8W.																			
25	SW SE 1	Village of Saranac well#2	125	s	10-57	M	364	13	0	87	24	5.7	1.1	4.4	4	45	312	305	.0	7.5	600

Table 5. (con't)

NO.	LOCATION	OWNER	DEPTH	AQU	DATE	A.	TDS	SiO_2	Fe	Ca	Mg	Na	K	NO_3	Cl	SO_4	HCO_3	Hard.	F	pH	Cond.
		BOSTON TOWNSHIP (con't)																			
26	SW SE 1	Village of Saranac well#1	112	s	10-57	M	372	13	0	92	21.	6.9	2.0	6.	6	43	330	315	.0	7.4	600
27	NW NE NE 12	private	112	g	9-68	D	---	---	>.1	---	---	---	---	---	---	---	---	359	-	---	---
28	NW NW SE 18	private	140	s	11-69	D	---	---	t	---	---	---	---	---	---	---	---	325	--	---	---
29	NE NE SE 33	private	65	s	1-69	D	---	---	.3	---	---	---	---	---	---	---	---	290	--	---	---
30	NE NW NW 35	private	94	s	8-69	D	---	---	1.5	---	---	---	---	---	---	---	---	376	--	---	---
31	SW SE SW 36	private	116	—	10-68	D	---	---	1.5	---	---	---	---	---	---	---	---	513	--	---	---
		LYONS TOWNSHIP T.7N. R.5W.																			
32	7?	Village of Muir well#1	147	--	4-55	M	336	12	.3	70	26.6	13.3	←	2.2	5	19	344	285	.5	7.4	600
33	SW SE SE 7	" " " well#2	153	s+g	3-61	M	320	12	.0	74	24.	8.7	1.2	2.0	5	23	335	285	.0	7.4	510
34	SE SW SW 12	Village of Pewamo well#1	485	Sag	12-56	M	334	15	.8	84	28.	14.	1.4	0	10	0	410	325	.2	7.5	610
35	SW NW NE 26	private	160	s	1-68	D	---	---	.5	---	---	---	---	---	---	---	---	308	—	7.0	---
36	NW 28	spring	---	--	1-65	U	---	---	.8	---	---	---	---	1.7	5	53	375	338	—	7.4	653
		IONIA TOWNSHIP T.7N. R.6W.																			
37	NE SW 3	private	140	s+g	8-68	D	---	---	.5	---	---	---	---	---	---	---	---	256	--	---	---
38	NE 8	private	135	ss	11-54	U	---	---	---	---	---	---	---	.4	3	20	352	304	--	7.6	551
39	SE 16	private	121	ss	10-56	U	---	---	---	---	---	---	---	52.	5	22	215	242	--	7.6	470
40	SW SW 16	private	73	s+g	11-66	D	---	---	t	---	---	---	---	---	---	---	---	205	—	---	---
41	NE NE SW 16	private	52	s	12-69	D	---	---	.3	---	---	---	---	---	---	---	---	342	—	---	---
42	18?	City of Ionia-unit 8 of lot E of pumping plant	---	---	---	-	390	10	3.4	88	27.9	12.6	←	---	t	67	354	330	.3	---	---
43	18	City of Ionia-composite sample-chlorinated	---	d	11-52	M	370	10	.3	86	29.2	3.	---	n	6	59	335	335	.0	8.0	610
44	SE SW 18	City of Ionia well#7	62	s+g	1-59	M	362	9	.3	79	26.	4.4	1.0	0	10	45	301	305	.0	7.5	600
45	SE NW SE 18	" " " well#9	107	s+g	4-57	-	---	---	.8	---	---	---	---	---	5	---	---	338	—	---	---
46	SE NW SE 18	" " " well#9	107	s+g	1-59	M	354	8	.2	82	27.	4.1	1.0	0	6	53	321	315	.0	7.4	600
47	SW NW SE 18	" " " well#10	108	s+g	4-57	-	---	---	.7	---	---	---	---	---	4	---	---	336	--	---	---
48	SE NE SW 18	" " " well#11	107	s+g	5-57	-	---	---	t	---	---	---	---	---	5	---	---	335	—	---	---
49	SE NE SW 18	" " " well#11	107	s+g	1-59	M	358	8	.4	84	28.	4.4	1.0	0	5	52	334	325	.0	7.5	610
50	SW NE NE 20	private	47	s	12-69	D	---	---	t	---	---	---	---	---	---	---	---	358	--	---	---
51	NE 27	private	60	ss	6-55	U	---	---	---	---	---	---	---	.4	2	46	408	375	—	7.4	670
52	SE NW 30	Ionia Co. Road Comm.	77	ss	8-67	M	---	---	1.6	---	---	---	---	---	9	1570	---	1650	--	---	---
53	NW SE NW 30	" " " "	246	Sag	6-67	M	---	---	.9	---	---	---	---	---	36	195	---	355	--	8.0	---
54	SE NW SW 30	private	223	Sag	7-68	M	---	---	5.2	---	---	---	---	---	10	170	---	375	--	7.1	---
55	SW SW NW 30	private	267	Sag	7-68	M	---	---	3.1	---	---	---	---	---	10	1060	---	1440	--	7.2	---
56	NE NW SW 30	private	393	Sag	8-69	D	---	---	1.0	---	---	---	---	---	---	---	---	581	--	---	---

Table 5. (con't)

NO.	LOCATION	OWNER	DEPTH	AQU	DATE		TDS	SiO_2	Fe	Ca	Mg	Na	K	NO_3	Cl	SO_4	HCO_3	Hard	F	pH	Cond
		IONIA TOWNSHIP (con't)																			
57	NE SE SE 30	private	---	---	-----	M	---	--	1.1	---	---	---	---	---	8	52	---	365	--	7.2	---
		EASTON & BERLIN TOWNSHIPS T.7N. R.7W.																			
58	?	Mich. Reformatory well#1	85	---	7-60	M	512	10	.0	106	29.	30.	4.0	22.	46	82	348	385	.0	7.7	820
59	?	" " well#4	85	---	7-60	M	514	9	.0	120	27.	16.	2.0	7.	27	120	332	410	.0	7.9	800
60	NE SW NW 23	State Prison	140	s+g	12-54	D	---	--	1.8	---	---	---	---	---	1	---	---	310	--	---	---
61	SW NE 25	Ionia State Hosp. well#1	26	s+g	5-60	M	430	10	.1	98	26.	13.	1.5	22.	21	60	325	350	.0	7.5	700
62	SW NE 25	" " " well#3	28	s+g	5-60	M	434	8	.0	100	23.	10.	2.0	20.	14	95	285	345	.0	7.5	700
63	NE SW NE 25	" " " TW#2-60	23	s+g	4-60	D	---	--	.0	---	---	---	---	>20.	18	---	370	---	--	---	---
64	SE 25	private	264	Sag	7-68	D	---	--	3.1	---	---	---	---	---	10	1060	---	1440	--	7.2	---
65	SW SW NW 25	private	276	---	11-68	M	---	--	3.7	---	---	---	---	---	4	1270	---	1600	--	---	---
		KEENE TOWNSHIP T.7N. R.8W.																			
66	SE SW SE 33	private	154	s+g	8-69	D	---	--	.3	---	---	---	---	---	---	---	---	274	--	---	---
		NORTH PLAINS TOWNSHIP T.8N. R.5W.																			
67	SE SW SW 9	private	322	Sag	1-65	U	---	--	---	---	---	---	---	.1	5	23	320	194	--	7.8	533
68	SW SW SE 12	St. Johns Church	210	Sag	1-65	U	---	--	---	---	---	---	---	2.3	500	354	302	696	--	7.4	2530
69	SW SE NW 18	private	82	s	12-57	U	---	--	---	---	---	---	---	.2	5	31	328	292	--	7.5	561
		RONALD TOWNSHIP T.8N. R.6W.																			
70	SW NW SW 6	private	110	Sag	4-59	U	---	--	---	---	---	---	---	.2	2	24	265	238	--	7.7	441
		OTISCO TOWNSHIP T.8N. R.8W.																			
71	SE NE 10	Belding well#2	36	s	55	M	254	9	n	60	20.7	4.	---	n	2	26	256	235	.0	7.8	460
72	SE 10	" well#3	120	---	3-55	M	334	11	.5	72	24.3	6.4	←	n	7	55	276	280	.0	7.8	500
73	NE NW SE 11	" well#4	161	s	4-57	M	344	14	.4	77	21.5	11.	.7	0.	22	38	278	280	.0	7.5	580
74	NE 11	" well#5	180		8-63	M	222	11	.2	54	16.	3.9	.6	.0	4	20	224	200	.2	7.8	370
75	NW NW SW 6	private	245	s+g	58	D	---	--	1.	---	---	---	---	---	13	---	---	274	--	7+	---
76	NW NW SW 6	(same well as above)			63	D	---	--	1.5	---	---	---	---	---	25	---	---	---	--	---	---
		SURFACE WATER QUALITY																			
	T.6N. R.5W.	Grand River @ Portland			9-63	U	448	--	.2	71	22.	54.	4.5	---	72	74	258	268	--	7.9	738
	T.7N. R.5W.	Stoney Cr. near Pewamo			9-63	U	352	--	---	66	32.	11.	3.2	---	10	55	306	296	--	7.3	573
	T.7N. R.5W.	Grand River @ Lyons bridge			4-63	M	380	--	.7	78	21.	11.	2.6	20.	16	96	212	280	--	7.7	570
	T.7N. R.5W.	" " " "			12-62	M	422	3	.1	92	19.	26.	2.7	7.1	33	66	305	310	.4	8.2	670
	T.7N. R.6W.	Prairie Cr. near Ionia			9-63	U	344	--	---	71	27.	7.7	1.2	---	8	57	290	288	--	7.3	556
	T.7N. R.6W.	" " " "			11-52	M	310	10	.2	74	22.	4.5		n	6	45	285	275	.1	8.1	570
	T.7N. R.6W.	Grand River @ Ionia			9-63	U	391	--	.2	66	25.	36.	3.3	---	51	59	257	268	--	7.1	665

Table 5. (con't)

NO.	LOCATION	OWNER	DEPTH	AQU.	DATE	A	TDS	SiO_2	Fe	Ca	Mg	Na	K	NO_3	Cl	SO_4	HCO_3	Hard.	F	pH	Cond.
		SURFACE WATER QUALITY (con't)																			
	T.7N. R.6W.	Grand River @ Ionia			7-60	M	512	10	0	106	29.	34.	←	----	46	82	348	385	0	---	----
	T.8N. R.8W.	Flat River w Bricker road			4-63	M	250	--	.2	52	16.	5.1	.9	4.0	9	30	190	195	-	7.9	380
	T.8N. R.8W.	" " " "			5-62	M	258	5	.2	56	18.	6.2	.9	2.7	10	28	230	215	.0	8.1	420
	T.8N. R.8W.	Flat River @ Smyrna			9-63	U	261	--	.1	50	21.	8.0	.9	----	12	35	216	212	-	7.0	430

Description of heading:

NO. - reference number.
LOCATION - as described at beginning of Appendix.
OWNER - domestic wells are listed as private; municipal wells or State wells are listed by name and well no.
DEPTH - total depth of well except as noted.
AQU. - aquifer which is tapped:
- d - drift (undifferentiated)
- s - sand
- g - gravel
- s+g - sand and gravel
- Sag - Saginaw formation
- Mi - Michigan formation
- ss - sandstone of uncertain age -- probably Saginaw or Grand River.

DATE - date of analysis.
A - agency making analysis:
- D - driller of well
- U - United States Geological Survey
- M - Michigan Department of Health

Description continued on next page.

Description (con't)

for the following, also refer to table 3:

- TDS - total desolved solids
- SiO_2 - silica
- Fe - iron
- Ca - calcium
- Mg - magnesium
- Na - sodium
- K - potassium
- NO_3 - nitrate
- Cl - chloride
- SO_4 - sulfate
- HCO_3 - bicarbonate
- Hard. - hardness as $CaCO_3$
- F - fluoride
- pH - hydrogen ion concentration
- Cond. - specific conductance

Notes:

- * total iron analyzed
- ⟵ indicates potassium and sodium analyzed together
- n - none
- $>$ - greater than number listed
- t - trace

All analysis in parts per million (ppm) = milligrams per liter (mg/l).