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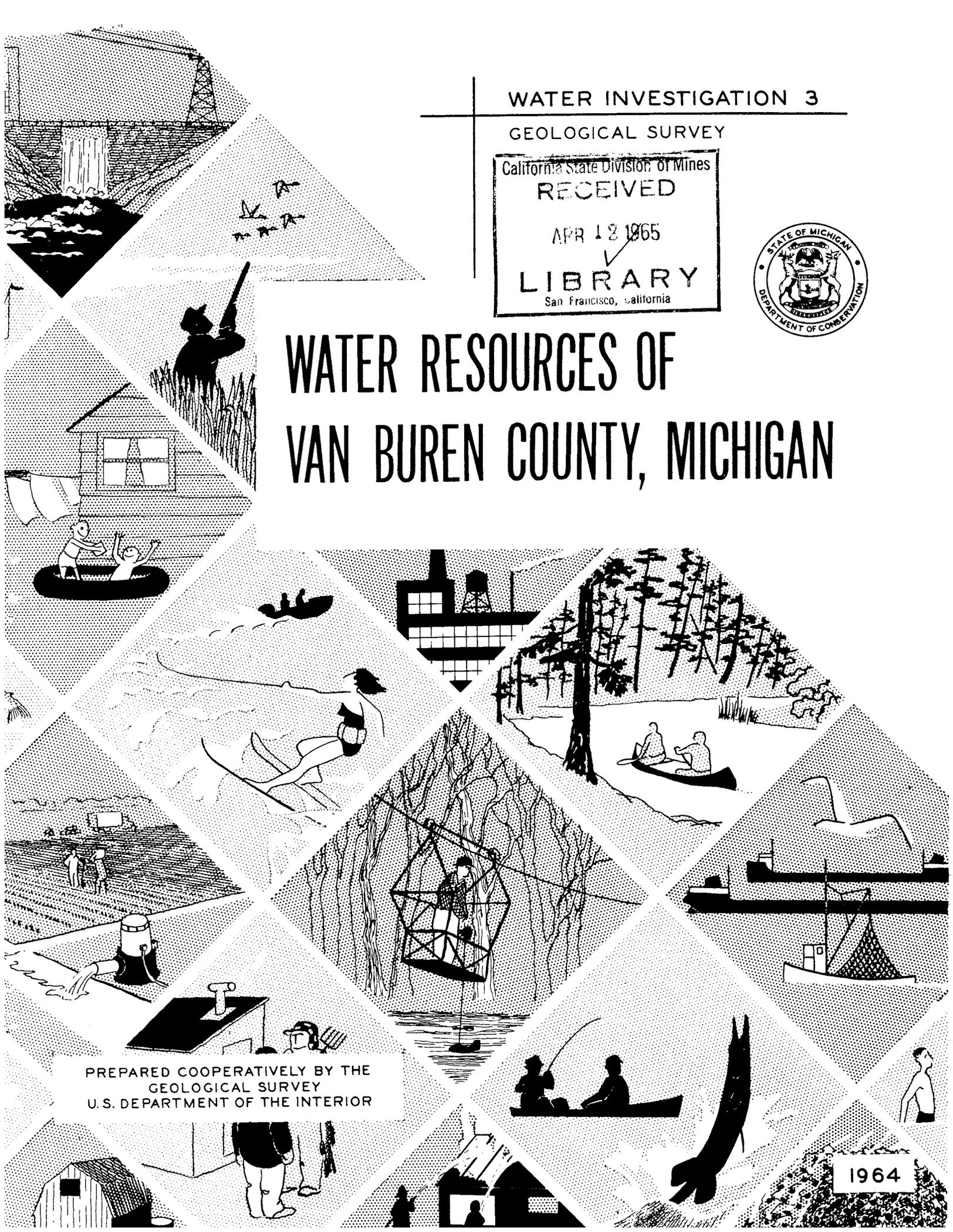
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# WATER RESOURCES OF VAN BUREN COUNTY, MICHIGAN



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WATER RESOURCES OF VAN BUREN COUNTY, MICHIGAN

BY

P. R. Giroux, G. E. Hendrickson, L. E. Stoimenoff,  
and G. W. Whetstone

U. S. Geological Survey

1964

## ACKNOWLEDGMENTS

Acknowledgment is made to personnel of Federal and State agencies, municipalities, industrial concerns, to well drillers, and the many others whose cooperation has contributed to the accumulation of the basic data presented in this report.

The authors are deeply indebted to Messrs. G. E. Eddy and J. G. Rulison of the Michigan Geological Survey, Norman Billings of the Michigan Water Resources Commission, Mr. J. R. Fleming of the Van Buren County Health Department, and many other County officials for their assistance in the editing and review of the report.

This investigation was made in cooperation with the County of Van Buren and the Michigan Geological Survey. The continuing cooperative program between the State and Federal Geological Surveys is under the joint direction of G. E. Eddy, State Geologist, and G. E. Hendrickson, District Geologist for the U. S. Geological Survey in Michigan.

Cover by James M. Campbell, Graphic Presentation Designer,  
Michigan Department of Conservation

TABLE OF CONTENTS

	Page
Abstract . . . . .	1
Introduction . . . . .	3
Why this report was written . . . . .	3
General description of Van Buren County . . . . .	3
The specific water problems . . . . .	4
Previous studies of the water resources of the county . . . . .	4
How can this report be used? . . . . .	4
Occurrence and availability of water . . . . .	7
The hydrologic cycle . . . . .	7
Geologic setting . . . . .	7
Ground water . . . . .	8
What is ground water and how does it occur? . . . . .	8
How much water is stored in the ground? . . . . .	11
The source of the county's ground-water supplies . . . . .	11
Glacial deposits in Van Buren County . . . . .	12
Logs of wells in glacial aquifers in the county . . . . .	12
Are ground-water levels falling? . . . . .	15
Inland lakes . . . . .	26
Origin of the inland lakes . . . . .	26
The life span of the lakes . . . . .	31
Are inland lake levels falling? . . . . .	31
Lake Michigan . . . . .	33
Farm ponds . . . . .	33
Streams . . . . .	34
Major streams in the county and their drainage areas . . . . .	34
Annual runoff from streams in the county . . . . .	34
The effect of surface geology and soil types on streamflow . . . . .	34
Streamflow records and what they show . . . . .	34
Using the annual 7-day minimum flows . . . . .	40
Floods . . . . .	40
Quality of water . . . . .	47
The source and significance of dissolved minerals in the county's water supplies . . . . .	47
Suitability of the county's water for various uses . . . . .	47
The quality of the water from wells . . . . .	49
Hardness . . . . .	49
Iron . . . . .	49
Chlorides . . . . .	54
Nitrates . . . . .	54

TABLE OF CONTENTS.--Continued

	Page
Quality of water (Continued)	
The quality of the water from streams . . . . .	54
The quality of the water from inland lakes . . . . .	61
The quality of water from Lake Michigan . . . . .	64
Are pesticides contaminating the water supplies of the county? . .	64
How the water is presently obtained and used . . . . .	67
By cities and villages . . . . .	67
By agriculture . . . . .	69
By industry . . . . .	70
By public establishments other than municipal . . . . .	71
For power . . . . .	72
For domestic and stock supplies . . . . .	72
By the public for recreation . . . . .	72
Inland lakes . . . . .	73
Farm ponds . . . . .	73
Lake Michigan . . . . .	73
Streams . . . . .	73
How present water problems can be solved . . . . .	75
Ground water . . . . .	75
Can enough water for a domestic supply be obtained everywhere in the county? . . . . .	75
Can additional large supplies of ground water be developed? .	75
What can be done to minimize the possible future lowering of the water table in the irrigated area? . . . . .	76
Can surface water impoundments increase the amount of ground-water storage? . . . . .	76
Are water levels dropping in the vicinity of municipal and industrial wells? . . . . .	76
How can ground-water recharge be increased? . . . . .	77
Can large supplies of ground water be developed in the South Haven area? . . . . .	77
Surface water . . . . .	81
Can streams furnish large quantities of water? . . . . .	81
Can surface impoundments be used to increase the low flow of streams? . . . . .	81
What can be done about falling lake levels? . . . . .	85
Quality of water . . . . .	87
What can be done about the salty water in some wells? . . . .	87
What can be done about hard water and water high in iron obtained from most wells in the county? . . . . .	89
What can be done about the high nitrate content of water from some wells? . . . . .	89
What can be done about contamination of streams by sewage and other wastes? . . . . .	89

TABLE OF CONTENTS.--Continued

	Page
How future water problems can be solved . . . . .	91
Surface water . . . . .	91
Ground water . . . . .	91
Quality of water . . . . .	92
Using the recorded information . . . . .	92
Summary . . . . .	93
References . . . . .	95
Appendix A - Description of municipal supplies in the county . . . . .	97
Appendix B - Ground-water availability maps and tables of wells . . . . .	105
Appendix C - Relation between diameter and yield in wells . . . . .	143

ILLUSTRATIONS AND TABLES

	Page
Figure 1.--Graphs showing monthly ranges of temperature and precipitation . . . . .	2
2.--Diagram showing the annual hydrologic cycle in the County . . . . .	6
3.--Map showing the surface geology (after Terwilliger) . . . . .	9
4.--Map showing glacial drift thickness . . . . .	13
5.--Graph showing cumulative departure of precipitation from long-term average, 1954-63 . . . . .	22
6.--Bar graphs showing annual precipitation, 1899-1963 . . . . .	23
7.--Map showing location of well and lake data collection sites. . . . .	24
8.--Graphs of water levels showing effects of pumping and barometric pressure, 1963-64 . . . . .	25
9.--Graphs of water levels showing seasonal trends, 1963-64 . . . . .	27
10.--Graphs of water levels showing net declines, 1963-64 . . . . .	28
11.--Graphs of water levels of land-locked inland lakes, 1963-64. . . . .	29
12.--Graphs of water levels of lakes with outlets, 1963-64, and of lakes Michigan-Huron, 1954-63 . . . . .	30
13.--Map showing distribution of farm ponds . . . . .	32
14.--Generalized map of ground-water contribution to dry-weather flow of streams . . . . .	37
15.--Graph of daily flow of the Paw Paw River at Riverside, 1963. . . . .	38
16.--Map showing base-flow measurement sites . . . . .	39
17.--Graph showing variation of mean annual flood with drainage area . . . . .	42
18.--Graph showing frequency of annual floods . . . . .	43
19.--Map showing flood regions and hydrologic areas . . . . .	44
20.--Map showing distribution of hardness in ground water . . . . .	52
21.--Map showing areas where ground water contains more than 1 part per million of iron . . . . .	53
22.--Map showing distribution of chloride in ground water . . . . .	55
23.--Map showing wells where concentration of nitrates in ground water exceeded 4 ppm . . . . .	56
24.--Map showing buried bedrock valleys in the South Haven area (after Klasner, 1964) . . . . .	79
25.--Map showing location of buried bedrock valleys in the County (after Terwilliger) . . . . .	83
26.--Possible reservoir sites in the County . . . . .	86
27.--Graph showing duration curve of daily discharges for the Paw Paw River at Riverside, 1963 . . . . .	88
Figures 28-45.--Maps of townships showing the general availability of ground water to wells	
Figure 28.--Almena Township . . . . .	107
29.--Antwerp Township . . . . .	109
30.--Arlington Township . . . . .	111
31.--Bangor Township . . . . .	113
32.--Bloomingdale Township . . . . .	115

ILLUSTRATIONS AND TABLES.--Continued

Page

Figures 28-45.--Maps of townships showing the general availability of ground water to wells.--Continued

Figure 33.--Columbia Township . . . . .	117
34.--Covert Township . . . . .	119
35.--Decatur Township . . . . .	121
36.--Geneva Township . . . . .	123
37.--Hamilton Township . . . . .	125
38.--Hartford Township . . . . .	127
39.--Keeler Township . . . . .	129
40.--Lawrence Township . . . . .	131
41.--Paw Paw Township . . . . .	133
42.--Pine Grove Township . . . . .	135
43.--Porter Township . . . . .	137
44.--South Haven Township . . . . .	139
45.--Waverly Township . . . . .	141
46.--Curve showing relation between diameter and yield in wells having same depth, same screens, and in same formation.	142
Table 1.--Logs and specific capacities of selected wells . . . . .	16
2.--These are drainage areas in the county . . . . .	35
3.--Results of base flow measurements on selected streams; mean annual 7-day minimum flows . . . . .	41
4.--Chemical analyses of water from wells . . . . .	50
5.--Chemical analyses of water from streams . . . . .	57
6.--Chemical analyses of water from lakes . . . . .	62

Tables 7-24.--Records of selected wells by townships

Table 7.--Almena Township . . . . .	106
8.--Antwerp Township . . . . .	108
9.--Arlington Township . . . . .	110
10.--Bangor Township . . . . .	112
11.--Bloomington Township . . . . .	114
12.--Columbia Township . . . . .	116
13.--Covert Township . . . . .	118
14.--Decatur Township . . . . .	120
15.--Geneva Township . . . . .	122
16.--Hamilton Township . . . . .	124
17.--Hartford Township . . . . .	126
18.--Keeler Township . . . . .	128
19.--Lawrence Township . . . . .	130
20.--Paw Paw Township . . . . .	132
21.--Pine Grove Township . . . . .	134
22.--Porter Township . . . . .	136
23.--South Haven Township . . . . .	138
24.--Waverly Township . . . . .	140

**WATER RESOURCES OF VAN BUREN COUNTY, MICHIGAN**

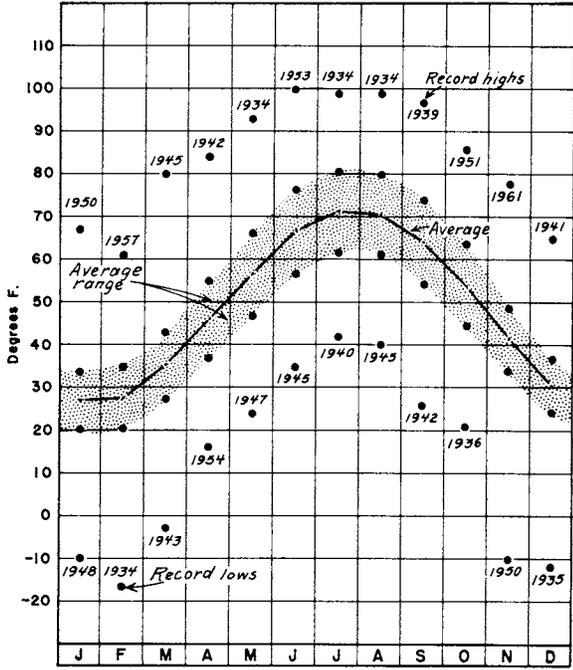
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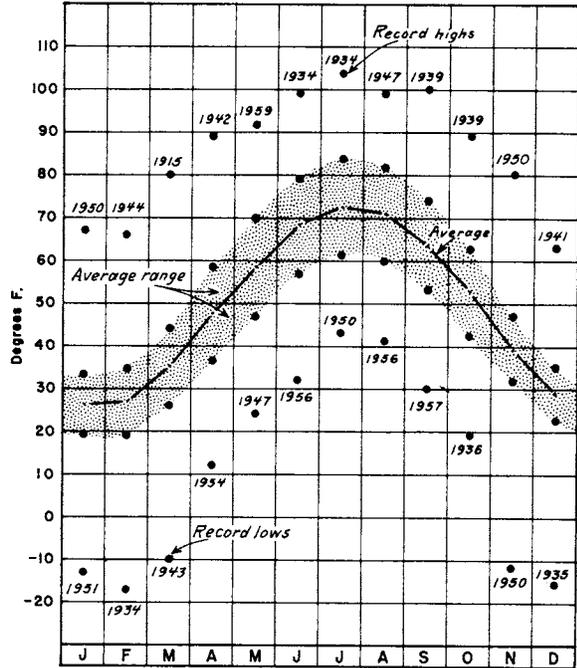
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**ABSTRACT**

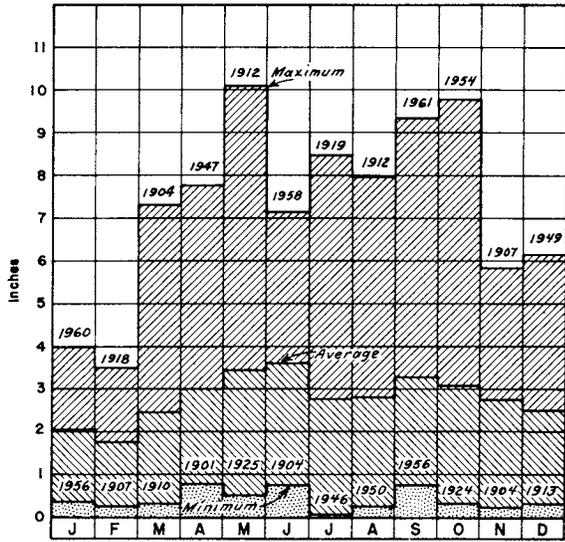
The water resources of Van Buren County include productive ground-water reservoirs, a network of perennial streams, about 60 major inland lakes, and Lake Michigan. Most water users obtain their supplies from wells. The ground-water reservoirs in the glacial drift can provide several times the amount of water now used, but large withdrawals of ground water may lower the levels of nearby lakes or diminish the flow of nearby streams. Permeable soils and drift account for the relatively high base flows of streams in the southeastern two-thirds of the county. Less permeable surficial materials in the northwest part of the county result in relatively low base flows there. The water from wells is generally hard and high in iron content but is otherwise suitable for most uses. Water from streams and lakes is similar to that from wells except that iron-content is not a problem, and some of the inland lakes have very soft water. The availability of ground water, the base flow of streams, and the chemical character of water in the county are summarized in maps and tables accompanying this report.



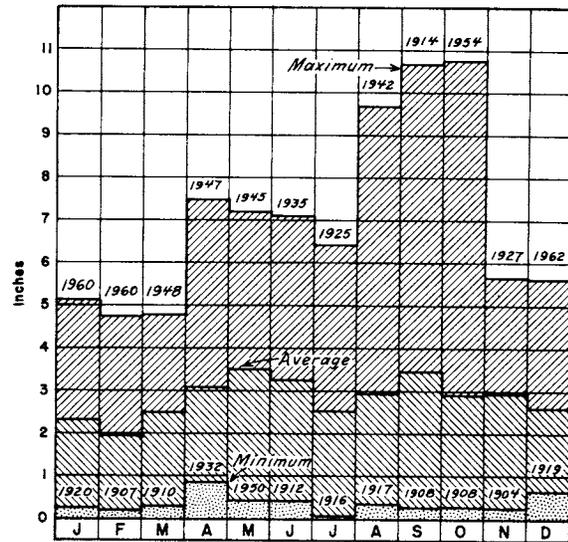
Monthly temperatures at South Haven, 1933-1962.



Monthly temperatures at Bloomingdale 1932-1961



Monthly precipitation at South Haven, 1895-1963.



Monthly precipitation at Bloomingdale, 1904-1963.

FIGURE 1.--GRAPHS SHOWING MONTHLY RANGES OF TEMPERATURE AND PRECIPITATION.

On the average, monthly precipitation is well distributed throughout the year with somewhat heavier amounts during the crop season. Temperatures warm slowly in the spring and remain warmer in the fall because of the moderating effect of Lake Michigan.

## INTRODUCTION

### Why This Report Was Written

This report was written to describe the availability and quality of water resources, especially the ground-water resources, in Van Buren County so that the best use of these resources can be made by municipalities, industries, agricultural interests, and private individuals. This report was written for the use of county officials, engineers, well drillers, water users, and all other persons interested in the water resources of the county.

The report consists primarily of an appraisal of the availability and quality of ground-water resources; the quality of water in lakes and streams; an evaluation of the base flow of streams; a limited appraisal of the quantity of water resources; and a discussion of specific water problems and possible solutions. The use of the data in this report should make possible the solution of many of the water problems in the county.

### General Description of Van Buren County

Van Buren County borders Lake Michigan in southwestern Michigan and consists of an area of 607 square miles composed mainly of cultivated fields, orchards, woodlands, and pasture. The topography ranges from flat plains to rolling hills.

The climate and the mostly light and well-drained soils make the county a very productive fruit and vegetable growing area. The influence of Lake Michigan is quite strong in the county. The prevailing westerly winds are warmed in the winter and cooled in the summer while crossing Lake Michigan, moderating the climate considerably. The slow warmup in the spring retards the fruit buds until the danger of frost is over and the reverse is true in the fall, allowing fruit to ripen before killing frosts occur (fig. 1).

The county had a population of 48,000 in 1960, and 18,000 of these lived in incorporated cities and villages. In addition to the permanent residents are large numbers of migrant workers who come to Van Buren County to help harvest fruit and other crops, and summer resort residents who come from neighboring areas and states.

The economy of the county is largely dependent on the production and processing of fruits and vegetables, and these, in turn, are dependent on an adequate water supply. Although many crops in the county are produced without irrigation, crop yields and profits generally are higher where irrigation water is used to supplement the natural supply. Adequate public water supplies of suitable quality are also essential to urban growth, and adequate domestic supplies are needed by all rural residents. Recreational values of the county also are dependent on adequate and clean water in the lakes and streams.

### The Specific Water Problems

Some of the specific water problems in the county are:

1. The difficulty of obtaining ground-water supplies of sufficient quantity and quality for present and future needs in the northwestern part of the county. Here an evaluation of ground-water potentials was needed to determine whether adequate to large supplies of good quality water could be developed or whether facilities for using water from Lake Michigan should be expanded.
2. Concern that a serious lowering of ground-water and lake levels could result from increased use of water for irrigation.
3. Lack of information on the extent and seriousness of quality of ground-water problems such as excessive iron, chlorides, nitrates, and hardness.
4. Lack of data on the possible effects, on ground and surface water supplies, of the use of pesticides.
5. Great concern in regard to the problem of very low lake levels and so-called "dying" lakes.

### Previous Studies of the Water Resources of the County

Two previous reports on the water resources of the Van Buren area were valuable sources of information for this report. Terwilliger (1954) described the glacial geology and ground-water resources of the county and the Michigan Water Resources Commission (1955) reported on the water resources of the Paw Paw River basin which includes a large part of Van Buren County. The Commission's 1955 report on the Paw Paw River basin was revised and updated in 1964.

### How Can This Report Be Used?

Anyone wanting to develop a water supply can use this report to find out approximately how much water can be obtained from wells at a given site, how much water is available for diversion from a stream, and whether the quality of water from either source will be suitable for his intended use.

For example, Farmer A decides that he needs to develop a water supply for irrigation on his farm in Lawrence Township. Assuming that he has at least thumbed through the report to become familiar with its contents, he turns to the ground-water availability map of Lawrence Township in the appendix. He finds that his farm is located in area II where "large-diameter wells less than 200 feet deep generally yield enough water for irrigation, municipal, and industrial supplies (more than 100 gallons per minute)". In other words he has better than an even chance of obtaining the water he needs from a well. Next he looks at the table of selected wells in Lawrence Township and finds that two 10-inch wells within a half mile of his farm yield enough water for irrigation, and one of these is reported to yield more than 400 gpm. The table of well logs (table 1) tells him that the well yielding 400 gpm is bot-tomed in 25 feet of gravel and sand under 125 feet of fine sand and clay.

There is no log of the other well. The water-quality maps (figs. 20, 21, 22, and 23) indicate that the water obtained from a well in his area is likely to be hard and high in iron but low in chlorides and generally suitable for irrigation use. He decides that he has a better than even chance of obtaining both the quantity and quality of water he needs from a 10-inch well at a depth of 150 to 200 feet.

But he has an alternate possible supply in a creek that runs through his farm. Table 3 shows that the dry-weather flow of this creek at a point about one mile downstream from his farm was 0.4 cfs (cubic feet per second) or about 180 gpm on July 8, 1963. If he diverts 100 gpm for irrigation during summer droughts, his neighbor downstream may have less than 80 gpm left for his use. Farmer A decides to drill a well for his irrigation supply.

If he has read the section of the report on water problems, he knows that his new well will also divert some of the water normally discharged to the creek and thus reduce the flow of the creek. He knows also that the farther his well is located from the stream the less the immediate effect of well discharge on streamflow. He decides to drill the well as far from the creek as his irrigation needs permit.

As another example, officials B in one of the villages find that all of their 4 wells, located near the center of the village, pumped together cannot maintain sufficient pressures during peak demand periods during the hot summer months. A consultant is called in and decides that from the availability maps a test well should be installed in area I where most wells are successful. The water quality maps (figs. 20-23) and the analyses of water from both the city wells and nearby domestic wells indicate that the water from the new well is likely to be very hard and high in iron content but otherwise suitable for public supply.

Industrial manager C is considering discharging waste products from his food-processing plant into a nearby river. He calls in a consulting firm. They refer to table 3 showing base flow measurements on selected streams in the county. It is found that the base flow of the river about  $\frac{1}{2}$  mile upstream from the plant site was 16 cfs on July 8, 1963. This is determined to be insufficient to adequately dilute the untreated waste expected from the plant. The consultant suggests treatment of the waste products before disposal to the river.

Looking over the quality-of-water maps (figs. 20-23), farmer D finds that his farm is located in an area where several wells produce water that is higher than average in nitrates. He collects a water sample from his shallow-driven well (15 feet deep) and sends it to state or county health authorities for analysis. The report he receives shows nitrates greater than 50 ppm (parts per million) and also shows bacterial contamination. Reading the text of the report under "ground water quality" he finds that shallow wells are more likely to produce water higher in nitrates than deeper wells. The table of well logs (table 1) shows a well near his farm penetrated 5 feet of sand and gravel after drilling through 80 feet of sand and clay. He decides to drill a new well, hoping to penetrate a water-bearing formation that will yield water of satisfactory quality at a depth between 50 and 100 feet.

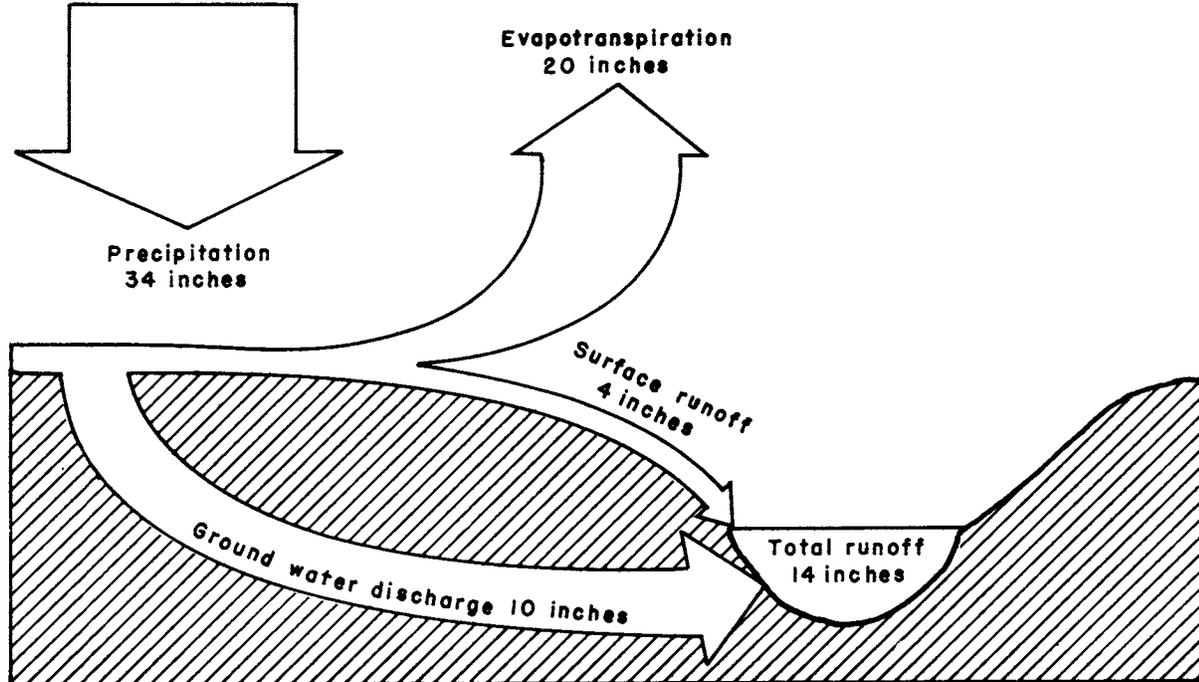


FIGURE 2.--DIAGRAM SHOWING THE ANNUAL HYDROLOGIC CYCLE IN THE COUNTY.

The average annual rainfall is probably distributed as shown.

## OCCURRENCE AND AVAILABILITY OF WATER

### The Hydrologic Cycle

Rain and snow are the initial source of all water supplies used in the county. The water falling on the earth travels three routes. Part of it runs over the surface to streams, lakes, or swamps; part soaks down to the water table and becomes ground water; and part is returned to the atmosphere by evaporation or transpiration of plants.

In Van Buren County about 20 inches of the 34 inches falling each year on the land is lost by evaporation and transpiration (fig. 2). The 14 inches remaining is discharged by streams. It is estimated that about 10 of the 14 inches discharged by streams is ground-water discharge, and 4 inches reaches the streams as surface runoff. However, in areas where wells are pumped the ground-water discharge to streams would be lessened by the amount of consumptive use.

### Geologic Setting

The plains, hills and valleys, and lakes and streams of the county all owe their origin to conditions resulting from glaciation. The glacial drift was deposited by the continental glaciers which covered the area more than 10,000 years ago. The ice, advancing from the northwest, eroded the land over which it moved, picking up and scraping the bedrock to make up its load of clay, silt, sand, and rounded fragments of rock. This load was moved forward along the bottom of the ice and pushed out to the front of the advancing tongue. Occasionally the moving ice overrode a part of its load.

When the rate of melting of the ice front was approximately equal to the rate of ice advance terminal moraines (mapped simply as moraines on figure 3) were pushed up at the ice front. Because these moraines were dumped from the melting ice with little or no sorting, the materials are generally a random mixture of clay, silt, sand, and rock fragments called till.

At the same time the meltwaters streaming out of the ice front carried a suspended load of clay, silt, sand, and gravel. The coarser sand and gravel were generally deposited near the ice front and the finer silt and clay carried further out. These water-sorted materials are called outwash deposits because the material was washed out from the ice front. The outwash deposits were built up by a network of braiding, shifting streams, and consist of beds and lenses of sand, gravel, silt, and some clay. When the rate of melting became faster than the rate of ice advance the ice front retreated, but deposition of outwash continued so long as meltwaters were sufficient to carry a suspended load. The wasting ice

dropped the material carried in and on the ice to form ground moraine, mapped as till plains on figure 3. Like terminal moraine, ground moraine is composed of till.

Water pouring out from the retreating ice generally drained off to the southwest between the ice front and adjacent highlands. Temporary blocking of these drainageways by ice, drift, or backwaters, caused lakes and ponds to form. The meltwaters deposited water-sorted sediments, chiefly sand and silt, in these lakes and drainageways. These deposits, shown as lake plains and drainageways on figure 3, generally are thin and may overlie either outwash or till.

Topographically the terminal moraines are knobby ridges trending northerly or northeasterly, at right angles to the direction of ice advance. The oldest moraine is in the southeast part of the county with successively younger moraines to the northwest and west. Enclosed depressions or "kettles" in the moraine are chiefly the result of melting ice blocks in the drift. Some of these depressions contain lakes, such as Bankson, Huzzy, and Shafer Lakes. Ground moraines or till plains (fig. 3) are characterized by gently rolling topography. Outwash plains are relatively flat, but in places are interrupted by numerous pits or depressions, many of which contain lakes. Grand Lake, Eagle Lake, and Keeler Lake are examples. Lake plains and drainageways generally are relatively flat and occupy topographically low areas. Most of the present streams follow these old drainageways, at least in part, but the wide valleys obviously were not cut by the present streams.

The soils of Van Buren County also are related to the underlying glacial deposits, with well-drained sandy loams generally overlying outwash deposits and silt and clay loams overlying the till.

### Ground Water

#### What is Ground Water and How Does It Occur?

In Van Buren County ground water consists of the water that completely fills the spaces between the grains of sand and gravel in the glacial drift aquifers overlying the Coldwater Shale. "Aquifers" are beds of sand and gravel that yield water to wells in usable quantities. The imaginary surface consisting of all points to which water will rise in wells tapping an aquifer is called the "piezometric surface". Aquifers may be classified as "water table" or "artesian". In a water table aquifer, ground water is unconfined; its surface within the aquifer is termed the "water table" and may be considered the "piezometric" surface of that aquifer. In an artesian aquifer, ground water is confined under pressure below relatively impermeable strata (strata through which water does not move readily). Under natural conditions, the water in a well that is finished in an artesian aquifer and tightly cased through the overlying confining bed will rise above the bottom of that bed and therefore the piezometric surface is above the top

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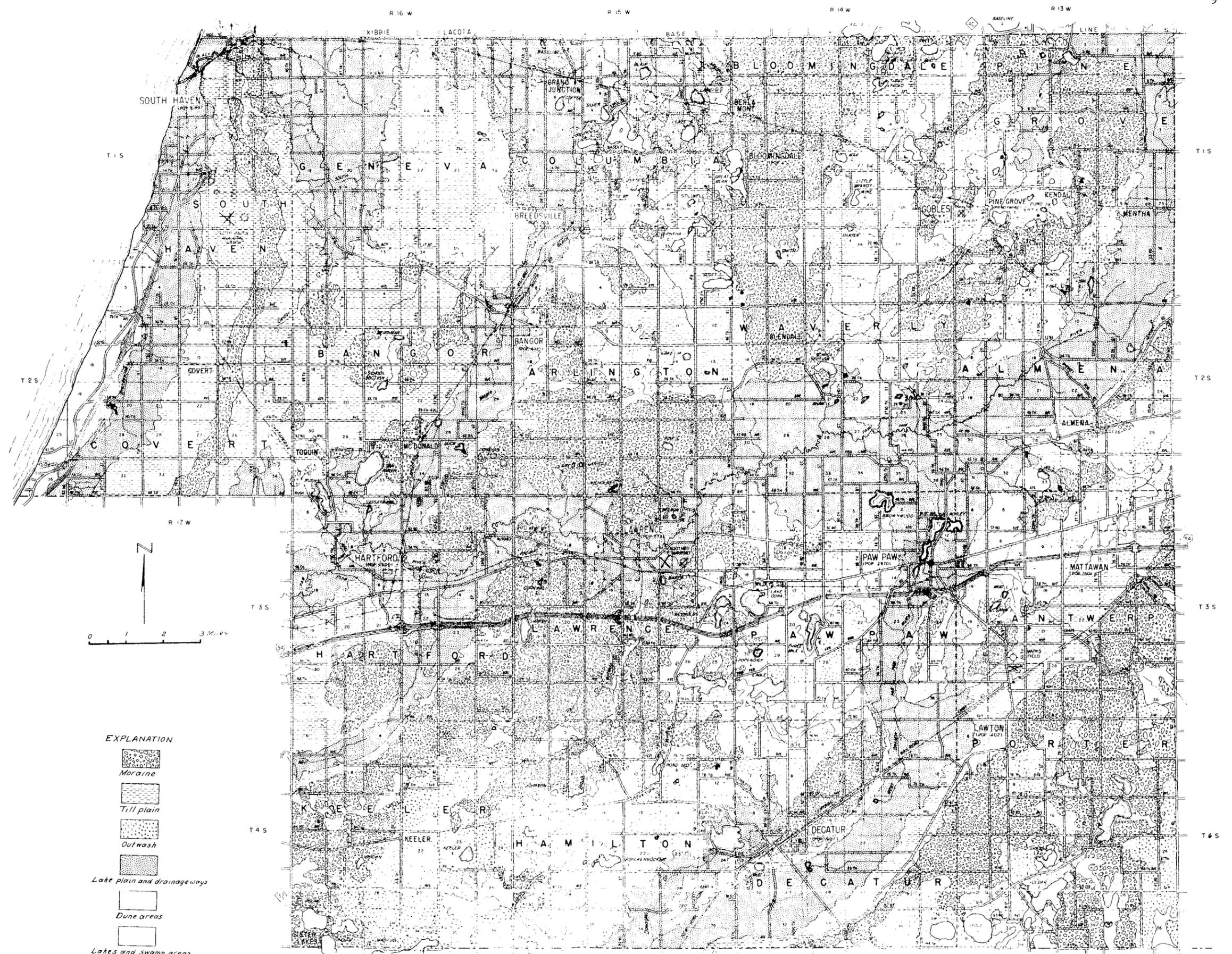


FIGURE 3.--MAP SHOWING THE SURFACE GEOLOGY (After Terwilliger).  
The outwash materials yield the largest quantities of ground water.

of the aquifer. An artesian aquifer is full of water at all times, even when water is being removed from it. In topographically low areas, wells tapping artesian aquifers may flow at the surface.

Ground water moves slowly from areas of recharge to areas of discharge. Areas of recharge include most of the county, but recharge is greatest where permeable soils and glacial drift are at the surface. Areas of discharge usually are limited to the vicinity of streams, lakes, or swamps, and other areas where the water table is at or near the surface. It is quite possible for an area which is one of recharge during wet seasons to become one of discharge during droughts.

The movement of water through the glacial materials is very slow--probably on the order of a few hundred feet a year. The capacity of the material to transmit water (that is, to allow water to move through it) is called transmissibility. This is commonly defined as the amount of water, in gallons, that will move in one day through a cross section of the full thickness of the aquifer one mile wide with a water table sloping one foot per mile. Records of well yields and specific capacities in Van Buren County wells (table 1) indicate that the transmissibility of sand and gravel aquifers in the county probably ranges from 20,000 to 150,000 gallons per day per foot. The transmissibility of glacial till is much less--possibly less than 1,000 gallons per day per foot. (Specific capacity is the amount of water, in gallons per minute, that can be obtained from a well with each foot of draw-down of water level in the well.)

#### How Much Water is Stored in the Ground?

The amount of water stored in the first 50 feet of glacial drift below the water table is estimated to be equal to 10 feet of water over the entire county, or roughly 1,250 billion gallons or more than 25 million gallons for each resident of the county. If we were able to utilize all of the water that is annually recharged to the glacial aquifers in the county, we would have at least 100 billion gallons a year. However, it is not economically feasible to recover all of this water. Furthermore, if we were to use all of the natural recharge, we would dry up all the streams (except during periods of direct runoff) and would lower the level of all the lakes in the county. The amount of ground water that can be withdrawn each year is limited by the reduction in streamflow and lake levels that will be tolerated.

#### The Source of the County's Ground-Water Supplies

The glacial drift is the only known source of fresh ground water in the county. The drift consists of: till, which is a mixture of silt, clay, sand, and gravel deposited directly by ice; sand and gravel outwash, deposited by glacial streams; and silt, sand, and clay, deposited in glacial lakes.

The underlying bedrock is chiefly shale which generally yields little water or only salty water. All the glacial deposits are capable of yielding some water to wells, but the sand and gravel outwash deposits yield the largest quantities. These outwash areas are shown on the map, figure 3. The largest area of outwash extends in a broad band from the southwest corner of the county near Keeler northeastward to the area between Lawrence and Paw Paw. It is no coincidence that some of the largest-yielding wells in the county are located in this belt of outwash.

The moraines, which are hilly sections built up by moving ice, (fig. 3) are made up of sand, gravel, silt, clay, and boulders (glacial till) in various mixtures, and generally it is not easy to find a good water-bearing formation in the moraine areas. A high-yielding well may be obtained in one spot, whereas only a few hundred feet away little water may be obtained.

The areas shown as till plains on the map are underlain by materials similar to those in the moraines, but the amount of sand and gravel in the till generally is less. The till plains are not usually favorable for obtaining large amounts of ground water. However, the till deposits in places overlie beds of sand and gravel outwash. In these areas, as southwest of Hartford, large yields of water are obtained by drilling through the till into the underlying outwash.

The lake plains and drainage ways generally are areas of thin deposits of silt, sand, and some clay which may overlie either productive outwash deposits or unproductive glacial till. Large amounts of water are obtained from sand and gravel under the lake plains deposits at Bangor, Lawrence, and Paw Paw. On the other hand, it is very difficult to obtain a good well in the lake plains area at South Haven.

The area of dunes along Lake Michigan is not generally favorable for obtaining large supplies of groundwater. Probably most of the dune sand is above the water table and most wells must be drilled into the underlying lake deposits.

#### Glacial Deposits in Van Buren County

The glacial drift is only 100 feet thick in places in Almena Township; in the deep bedrock valley east of South Haven it is 600 feet thick (fig. 4). The map showing thickness of glacial drift is generalized from Terwilliger's (1954) bedrock map and the topographic maps of the area. Although not all the glacial drift will yield significant amounts of water to wells, in general the thicker the drift the better the chance of penetrating a water-bearing formation.

#### Logs of Wells in Glacial Aquifers in the County

Since the materials that underlie the surface of the earth cannot be seen, driller's logs of wells must be used to determine where water-bearing formations are, how deep they are and how thick. Such logs in table 1 show that

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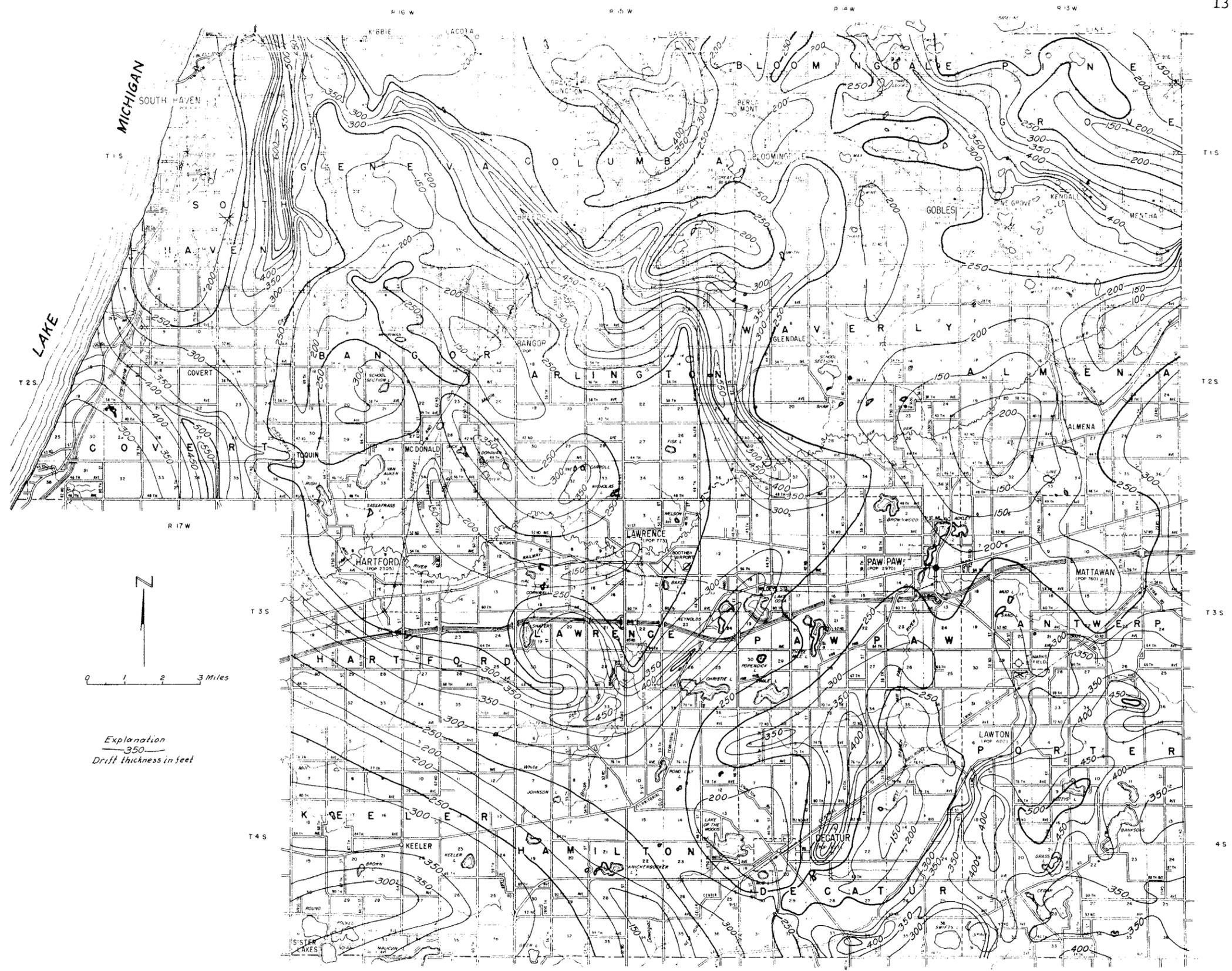


FIGURE 4.--MAP SHOWING GLACIAL DRIFT THICKNESS.

The glacial drift is thickest in the moraine areas and over the buried bedrock valleys shown in figs. 24 and 25.

beds of sand or gravel are encountered in most wells, but the depth and thickness of these beds varies greatly in short distances. For example, one well 100 feet deep may encounter a 30-foot bed of sand and gravel capable of yielding several hundred gpm while another nearby, drilled to the same depth, may encounter only a few feet of sand which will yield only a few gpm.

The logs in table 1 give the general character of glacial materials in a given area and may be especially valuable if it is planned to drill a well very near one that is logged. But it should not be expected that the new well will encounter exactly the same materials as the logged well, even if the two wells are only a few hundred feet apart.

### Are Ground Water Levels Falling?

Below-average rainfall during the time of this study (1962-64) caused a drop in ground-water levels, but a few wet years could reverse this trend. The total precipitation during the two-year period 1962 through 1963 was below average by 23 inches at Paw Paw, 12 inches at South Haven, and 10 inches at Bloomingdale (fig. 5). The record at Paw Paw may be subject to some error, because the site of the rain gage was shifted during the 10-year period. There can be no doubt, however, that there has been a substantial deficiency in precipitation during the two years.

Ground-water levels are low because precipitation has been low, but there is no reason to believe that water levels will continue low indefinitely. There have been many periods of below-average precipitation in the past which were followed by above-average rainfall (fig. 6). Attempts have been made to relate droughts and wet periods to cyclic changes in order to predict future conditions, but there is as yet no general agreement as to the nature of these cycles. All that can be said for sure is that rainfall will increase again at some time and ground-water levels will rise. How soon and how fast this rise will occur is not known.

Changes in ground-water levels in the county were measured in 10 observation wells the location of which is shown in figure 7. Three of these were equipped with automatic recorders which provide a continuous record of fluctuation; seven were measured about once a month.

Water levels in two of the wells show the effects of pumping of nearby wells (fig. 8). The abrupt fluctuations are the result of drawdown and recovery when the pumps on nearby wells are turned on or shut off, but the general downward trend in water levels from July 1963 to March 1964 are attributed to the dry weather. The slight recovery in April 1964 was not nearly enough to bring the levels back to the July 1963 levels.

Short-term fluctuations in the well south of South Haven (fig. 8) probably result from fluctuations in barometric pressures. The rising trend from September 1963 to March 1964 probably represents a recovery of water levels from recharge after frosts had killed the summer vegetation.

Table 1.--Logs and specific capacity of selected wells.

Logs are from drillers' reports and describe glacial drift materials penetrated. Where shale is indicated, it is interpreted to be the Coldwater Shale.

Altitude: Land surface at well in feet above mean sea level (estimated from topographic maps).

Specific capacity: (spec. cap.) gallons per minute per foot of drawdown of water level in well as reported by driller.

ALMENA TOWNSHIP			Village of Lawton # 4 NW 1/4 SE 1/4 Section 32 Altitude: 785			J. Zirbel NW 1/4 SW 1/4 Section 13 Altitude: 690		
Thick- ness (ft)	Depth (ft)		Thick- ness (ft)	Depth (ft)		Thick- ness (ft)	Depth (ft)	
County Road Commission NW 1/4 NW 1/4 Section 2 Altitude: 730			Sand, yellow and gravel 4 4			Muck 4 4		
Gravel, with large stones	1	1	Sand, yellow, fine	26	30	Clay	21	25
Sand, brown, fine, moist	8	9	Sand and gravel	2	32	Gravel, coarse	5	30
Clay, brown, sandy, wet	1	10	Sand, yellow, fine	23	55	(spec. cap. 6.7)		
Sand, brown, medium	67	77	Clay, blue	27	82			
(Cased and screened to 23' for use as observation well)			Sand, dirty and gravel	4	86			
			Sand, fine	24	110			
			(spec. cap. 15.5)					
Wolf Lake State Hatchery NW 1/4 SW 1/4 Section 13 Altitude: 770			ARLINGTON TOWNSHIP			B. Hills SE 1/4 NE 1/4 Section 17 Altitude: 660		
Sand, some gravel	17	17	County Road Commission NW 1/4 SW 1/4 Section 3 Altitude: 680			Sand 20 20		
Sand, gravel silt	15	32	Gravel with small stones 6 6			Quicksand and sand 10 30		
Sand	28	60	Gravel with stones to 2" 1 7			Clay, gravelly 36 66		
Sand, white, very fine	at	60	Gravel, brown, fine 10 17			Sand, medium 10 76		
(spec. cap. 1.8)			Sand, brown, fine, wet 20 37			Gravel, fine, clean 12 88		
			(used as observation well)			(spec. cap. 20)		
ANTWERP TOWNSHIP			Village of Bangor (Test) SW 1/4 SW 1/4 Section 6 Altitude: 660			H. Wakeman NW 1/4 SW 1/4 Section 28 Altitude: 780		
International Research Company NW 1/4 SW 1/4 Section 12 Altitude: 840			Sand 58 58			Clay, yellow 4 4		
Sand, fine	66	66	Clay	7	65	Sand, clay, stones 53 57		
Clay, blue	2	68	Gravel	14	79	Gravel and stones 3 60		
Gravel, gray, fine	18	86	Gravel, muddy	5	84	Clay, yellow 3 63		
(spec. cap. 13.3)			Clay	13	97	Clay, blue 3 66		
			Quicksand	33	130	Clay, yellow, sandy 30 96		
Glaser-Crandall Company # 1 SW 1/4 NW 1/4 Section 13 Altitude: 880			Gravel, muddy 3 133			Clay, hard, sandy 75 171		
Fill	5	5	Quicksand	4	137	Sand, fine 8 179		
Sand, clay, gravelly	12	17	Sand	12	149	Sand and gravel (spec. cap. 9.8) 36 215		
Sand, fine, gravelly, clayey	18	35	Quicksand, blue	4	153			
Sand, fine, clay	15	50	Sand	4	157	BANGOR TOWNSHIP		
Sand, fine, clay, gravelly	20	70	Sand, muddy	25	182	Village of Bangor # 3 NE 1/4 SE 1/4 Section 1 Altitude: 660		
Sand, fine, clay	10	80	Gravel	4	186	Sand and clay 10 10		
Clay, sand, fine gravel	8	88	Sand	14	200	Clay 25 35		
Sand, clayey, gravelly	12	100	Shale, gray	6	206	Sand, fine 5 40		
Sand, gravel, boulder	10	110				Gravel, coarse 5 45		
Sand, gravel, clayey	10	120	Village of Bangor # 4 NE 1/4 SW 1/4 Section 7 Altitude: 660			Sand 10 55		
			Topsoil 1 1			Gravel 3 58		
			Sand, silty 13 14			Sand (spec. cap. 15.5) 17 75		
			Clay, blue 19 33			Piper Brothers NW 1/4 NE 1/4 Section 11 Altitude: 670		
			Sand, coarse 19 52			Sand, dirty, little clay 46 46		
			Sand, fine 8 60			Sand, water 5 51		
			(spec. cap. 8.9)			Clay 24 75		
			Village of Bangor # 5 NE 1/4 SW 1/4 Section 7 Altitude: 660			Clay, sandy 20 95		
			Topsoil 2 2			Sand 37 132		
			Sand, silty 8 10			Gravel and sand 16 148		
			Clay, blue 33 43			Sand 3 151		
			Sand, coarse and some gravel 8 51			Sand and clay (spec. cap. 15.5) 2 153		
			Sand, gray, coarse 13 64			Village of Bangor (Test) NE 1/4 SE 1/4 Section 12 Altitude: 660		
			(spec. cap. 5.6)			Sand 18 18		
			Village of Bangor (Test) NE 1/4 NW 1/4 Section 7 Altitude: 680			Clay 27 45		
			Sand, yellow, dirty 25 25			Sand 10 55		
			Clay, blue 33 58			Sand and some gravel 3 58		
			Sand, yellow, fine 31 89			Sand, fine 18 76		
			Clay, blue 41 130			Sand, medium 14 90		
			Sand, gray, fine 11 141			Sand and gravel 14 104		
			Clay, sandy 3 144			Gravel 5 109		
			Sand, gray, fine 6 150			Shale and gravel 21 130		
			Hardpan 5 155			Quicksand 8 138		
			Sand, gray 1 156			Gravel 4 142		
			Hardpan 34 190			Sand and mud 3 145		
			E. Root SE 1/4 NW 1/4 Section 8 Altitude: 720			Sand and gravel 11 156		
			Sand and clay 50 50			Shale, gray 2 158		
			Clay 28 78			Village of Bangor 1 & 2 NE 1/4 NE 1/4 Section 12 Altitude: 660		
			Sand, water 8 86			Sand 10 10		
			(spec. cap. 4)			Clay, blue 40 50		
						Gravel 10 60		



Table 1.--Logs and specific capacity of selected wells.--Continued.

Thick- ness (ft)		Depth (ft)		Thick- ness (ft)		Depth (ft)		Thick- ness (ft)		Depth (ft)	
HAMILTON TOWNSHIP - Continued				Village of Hartford NW¼ SW¼ Section 15 Altitude: 660				Auto Specialties Mfg. Co. -Continued			
H. Nagle Nursery-Continued				Sand and muck 8 8				Sand 15 50			
Gravel, dirty	14	140		Sand and gravel	10	18		Sand, fine	8	58	
Sand, dirty	55	195		Sand, gray	22	40		Clay	30	86	
Sand, fine, clean	5	200		Sand and gravel	20	60		Sand (water)	7	95	
Sand, coarse	5	205		Hardpan	15	75		Hardpan and gravel	8	103	
Gravel	10	215		(spec. cap. 7)				Sand, coarse (water)	37	140	
(spec. cap. 7.8)								-----			
H. Baushke, Jr. E¼ SW¼ Section 15 Altitude: 790				John Faulkner SE¼ NE¼ Section 15 Altitude: 660				Auto Specialties Mfg. Co. (West well) NW¼ NW¼ Section 20 Altitude: 670			
Topsoil	1	1		No log				Topsoil	8	8	
Sand	29	30		(spec. cap. 15.7)				Sand, clay	19	27	
Clay, sandy	62	92						Sand, dirty	23	50	
Hardpan	5	97		-----				Sand, gray, dry	11	61	
Clay, sandy	23	120		Village of Hartford (Ely Park) NE¼ SE¼ Section 16 Altitude: 660				Sand, with some clay	32	93	
Sand and gravel	21	141		Topsoil, gravel and clay	22	22		Sand, gray, rather fine	7	100	
Gravel, coarse	14	155		Sand, very fine, gray	23	45		Sand, gray, coarse (water)	19	119	
(spec. cap. 94.3)				Sand, gray, coarse	2	47		Gravel (water)	25	144	
-----				Hardpan and clay	19	66		-----			
D. Zechiel S¼ SW¼ Section 17 Altitude: 790				Sand, gray, fine	11	77		F. Hillah NE¼ NE¼ Section 25 Altitude: 745			
Topsoil	5	5		Sand, gray, coarse	5	82		Sand	21	21	
Sand and clay	50	55		Sand, gray, coarse and gravel	11	93		Clay, blue	42	63	
Clay	13	68		Sand, very fine, dirty	4	97		Sand, fine	26	89	
Hardpan	18	86		(spec. cap. 11.9)				-----			
Sand	7	93		-----				Dowd Orchards SE¼ SE¼ Section 26 Altitude: 805			
Gravel	2	95		Village of Hartford (Test) SE¼ SE¼ Section 16 Altitude: 660				Clay with large boulders	58	58	
Gravel, dirty	9	104		Topsoil	2	2		Sand, fine	4	62	
Sand, dirty	14	118		Sand, gray, fine, dirty	42	44		Clay, blue	73	135	
Gravel	13	131		Sand and gravel	6	50		Stones	15	150	
Sand and gravel	3	134		Gravel, coarse	2	52		Sand, coarse	13	163	
Sand	4	138		Sand and gravel, clay balls	33	85		-----			
(spec. cap. 39.0)				Gravel	5	90		L. Kling SW¼ SE¼ Section 29 Altitude: 770			
-----				Sand and gravel, clay balls	11	101		Topsoil	5	5	
D. Zechiel S¼ SW¼ Section 17 Altitude: 790				Gravel	6	107		Clay	25	30	
No log				Clay	1	108		Clay, sandy	65	95	
(spec. cap. 62.5)				(spec. cap. 39.2)				Hardpan	14	109	
-----				-----				Sand and gravel	6	115	
E. Frochlich (8") SE¼ SE¼ Section 18 Altitude: 790				Village of Hartford (Test) SW¼ NE¼ Section 16 Altitude: 660				Sand, dirty	10	125	
Topsoil	5	5		Sand, yellow	18	18		Sand	16	141	
Clay and sand	74	79		Sand, coarse and gravel	13	31		Sand, coarse	5	146	
Gravel, coarse	23	102		Sand, gray, fine	19	50		(spec. cap. 4)			
(spec. cap. 30)				Sand and gravel	6	56		-----			
-----				Sand, gray, fine	27	83		G & S Geisler SE¼ SW¼ Section 31 Altitude: 720			
E. Frochlich (12") SE¼ SE¼ Section 18 Altitude: 790				Sand, fine, and clay with some gravel	19	102		Topsoil	1	1	
Topsoil	1	1		Sand, water and gravel	6	108		Sand	4	5	
Clay and sand	78	79		Gravel	6	114		Clay	8	13	
Sand, clean	10	89		Sand, dry and clay	8	122		Sand, muddy	47	60	
Sand and gravel	2	91		Sand, water and gravel	3	125		Sand, very fine	5	65	
Gravel	11	102		Clay, dirty and gravel	5	130		Sand, fine	18	83	
(spec. cap. 18)				Shale	10	140		(spec. cap. 9.9)			
-----				-----				-----			
HARTFORD TOWNSHIP				Village of Hartford N. Parking Lot # 1 NE¼ SE¼ Section 16 Altitude: 660				G & S Geisler (Test well) SW¼ SW¼ Section 31 Altitude: 720			
C. Drake NE¼ NW¼ Section 11 Altitude: 770				Sand	8	8		Topsoil	1	1	
Sand, with stones	30	30		Gravel	30	38		Sand	54	55	
Stones, some sand	24	54		Sand, water	9	47		Sand, fine	3	58	
Clay, blue	61	115		Clay	9	56		Gravel and clay	12	70	
Sand, medium, and gravel, fine	20	135		Sand, coarse, clean	33	89		Clay	10	80	
-----				Hardpan	6	95		Sand, fine, muddy	10	90	
Hartford Farm Supply, Inc. NE¼ NW¼ Section 13 Altitude: 680				C & O Railroad NW¼ SE¼ Section 19 Altitude: 660				Sand, clay	7	97	
No log				Clay, red, sandy	20	20		(site abandoned)			
(spec. cap. 143)				Clay, gray, gummy	18	38		-----			
-----				Boulders, blue	1	39		KEELER TOWNSHIP			
Milo Schilber SE¼ NE¼ Section 14 Altitude: 665				Sand, red, medium	6	45		J. Thar SE¼ SE¼ Section 1 Altitude: 800			
Sand and topsoil	15	15		Sand, gray, coarse	14	59		No log			
Clay, blue and brown	3	18		Gravel, red, coarse, water bearing	10	69		(spec. cap. 2.8)			
Sand	2	20		Clay balls, and boulders, coarse	1	70		-----			
Gravel, clay and sand	8	28		Sand, gray, medium	35	105		G & S Geisler SW¼ NE¼ Section 6 Altitude: 700			
Gravel, fine and sand	1	29		Sand, gray, fine, muddy	5	110		No log			
Gravel, fine and sand with some clay	1	30		Clay, gray	25	135		(spec. cap. 10.2)			
Sand, medium to coarse	18	48		-----				Auto Specialties Mfg. Co. (E. Well) NW¼ NW¼ Section 20 Altitude: 670			
Sand, coarse, and gravel, fine	7	55		Topsoil	3	3		Topsoil			
				Sand, yellow	5	8		Sand, yellow			
				Clay and sand	13	21		Clay			
								Clay and sand			
								Sand			
								Gravel, clay and sand			
								Gravel, fine and sand			
								Gravel, fine and sand with some clay			
								Sand, medium to coarse			
								Sand, coarse, and gravel, fine			

Table 1.--Logs and specific capacity of selected wells.--Continued.

Thick- ness (ft)		Depth (ft)		Thick- ness (ft)		Depth (ft)		Thick- ness (ft)		Depth (ft)	
KEELER TOWNSHIP.--Continued				A. Wendzel NE½ NE¼ Section 15 Altitude: 800				Village of Lawrence (West)--Continued			
J. Falkner SW¼ SE¼ Section 10 Altitude: 800				Sand, fine, dirty 78 78				Sand 12 12			
Sand, yellow 78 78				Clay, blue, sandy 22 100				Clay, blue 38 50			
Sand, gray, fine 35 113				Sand, fine, gray, water 9 109				Clay and gravel 15 65			
Clay, sandy 41 134				Sand, dirty and gravel 17 126				Sand and gravel 2 67			
Sand and gravel, fine 1 155				Clay 33 159				Sand, coarse 13 80			
Gravel (spec. cap. 15.7) 12 167				Clay, sandy 3 162				Clay at 80'			
-----				Sand, fine, silt 3 165				-----			
William Foster Farm SE¼ SW¼ Section 13 Altitude: 800				Sand, water 28 193				Village of Lawrence (East well) SE¼ SE¼ Section 9 Altitude: 680			
Sand, yellow 55 55				Still in sand 28 193				Sand 18 18			
Sand, gray, fine 15 70				(spec. cap. 16.4)				Clay, blue 27 45			
Sand, dirty, fine 40 110				-----				Gravel, clean 29 74			
Clay 24 134				M. Seel SE¼ NE¼ Section 21 Altitude: 805				Sand, fine 3 77			
Gravel, coarse and sand (spec. cap. 49) 13 147				Topsoil 5 5				-----			
-----				Sand and clay 15 20				Lawrence Packing Co. NW SW¼ SW¼ Section 10 Altitude: 680			
M. Seel SE¼ NE¼ Section 14 Altitude: 790				Clay, sandy 120 140				Fill 1 1			
Sand, yellow and stone 10 10				Sand 6 146				Sand and gravel 16 17			
Sand, yellow 17 27				Gravel, coarse (spec. cap. 21.8) 8 154				Clay, blue 29 46			
Clay, blue, sandy 56 83				-----				Sand and gravel (spec. cap. 18.3) 36 82			
Clay, blue 27 110				Frigid Foods # 1 NW¼ NW¼ Section 22 Altitude: 805				-----			
Hardpan 4 114				Sand 18 18				Lawrence Packing Co. SE SW¼ SW¼ Section 10 Altitude: 690			
Sand, dirty, fine 8 122				Sand and gravel 12 30				Till 4 4			
Gravel, dirty, coarse 6 128				Clay, sandy 50 80				Clay, sandy 16 20			
Hardpan, sandy 22 150				Clay 10 90				Clay, blue, soft 70 90			
Sand and gravel 1 151				Sand, fine, dirty 10 125				Sand, gray and some gravel 14 104			
Sand, fine, clean 10 161				Sand and gravel 10 135				Clay, blue 14 118			
Sand, clean 20 181				(spec. cap. 122.5)				(spec. cap. 20)			
-----				-----				-----			
O. Klett (Observation well) SE¼ SW¼ Section 14 Altitude: 800				Burnette Farms Packing Inc. SW¼ SW¼ Section 22 Altitude: 800				C. Sill SE¼ NE¼ Section 15 Altitude: 690			
Topsoil 2 2				Sand, yellow 19 19				Topsoil 8 8			
Sand and clay 28 30				Sand, gravel 19 38				Sand and clay 7 15			
Sand 10 40				Sand, coarse 14 52				Clay, blue 10 25			
Clay and sand 30 70				Sand, dirty, fine 8 60				Sand 5 30			
Clay, soft 42 112				Sand, fine and clay 32 92				Gravel, coarse 14 44			
Sand 17 129				Clay, soft 21 113				-----			
Sand and gravel 6 135				Gravel 5 118				H. Dillenbeck SW¼ SW¼ Section 15 Altitude: 720			
Sand, medium 25 160				Sand 9 127				Soil 8 8			
Gravel, dirty and sand 3 163				Clay, blue 2 129				Sand, fine 6 14			
Sand, medium 27 190				(spec. cap. 25.6)				Sand, clayey 7 21			
Sand and clay at 190				-----				Hardpan 2 23			
-----				Burnette Farms Packing Inc. SW¼ SW¼ Section 22 Altitude: 800				-----			
O. Klett SE¼ SW¼ Section 14 Altitude: 800				Sand, yellow 18 18				Hilltop Orchards SW¼ SW¼ Section 17 Altitude: 780			
Topsoil 12 12				Sand, gray 2 20				Clay, sandy 15 15			
Sand, fine to medium 29 41				Sand and gravel 29 49				Sand, dirty 15 30			
Sand to silt 23 64				Sand, gray, fine 20 69				Sand 55 85			
Clay, silty 44 108				Clay, sandy 25 94				Sand, dirty 30 115			
Sand, silty 7 115				Clay 6 100				Sand and clay 15 130			
Clay 1.5 116.5				Sand, dirty, fine 8 108				Clay 10 140			
Gravel and sand 5.5 122				Gravel, coarse 7 115				Clay, sandy 40 180			
Stone, no gravel or sand 4 126				Sand, coarse 8 123				Sand, fine 45 225			
Sand, gravel, stone 7.5 133.5				Clay, blue 3 126				Sand, fine 70 295			
Sand, some gravel .5 134				(spec. cap. 25)				(spec. cap. 11.2)			
Sand, fine 1 135				-----				G. Gould SE¼ NW¼ Section 19 Altitude: 740			
-----				Burnette Farms Packing Inc. SW¼ SW¼ Section 22 Altitude: 800				Sand 38 38			
M. Poland NW¼ SE¼ Section 14 Altitude: 800				Sand 20 20				Clay, brown with sand 2 40			
Topsoil 2 2				Sand and gravel 17 37				Sand 20 60			
Sand 23 25				Clay, sandy 63 100				Clay, blue and gravel 14 72			
Sand and clay 15 40				Sand, soupy 45 145				Sand, coarse 18 90			
Sand 13 53				Sand and gravel 15 160				Clay, blue and gravel 5 95			
Clay, sandy 27 80				Clay, sandy 27 187				Sand, coarse and gravel, fine 17 112			
Clay 40 120				-----				-----			
Sand and clay, dirty 36 156				C. Kays NW¼ SW¼ Section 27 Altitude: 800				Hilltop Orchards NW¼ NW¼ Section 19 Altitude: 770			
Sand, fine 8 164				Sand and gravel 23 23				Sand, and clay, red 45 45			
Gravel 3 167				Sand 64 87				Clay, red 10 55			
Sand, coarse 30 197				Clay 11 98				Sand, coarse 3 58			
(spec. cap. 39.1)				Sand, fine, water 12 112				Clay, blue and gravel 14 72			
-----				Sand, clean, coarse 5 117				Sand, coarse 18 90			
H. Anthony SE¼ SE¼ Section 14 Altitude: 800				Hardpan 12 129				Clay, blue and gravel 5 95			
Sand 31 31				Gravel, coarse 10 139				Sand, coarse and gravel, fine 17 112			
Clay, blue 74 105				-----				-----			
Clay, blue, sandy 25 130				LAWRENCE TOWNSHIP				-----			
Sand, dirty 5 135				Village of Lawrence (West well) SE¼ SE¼ Section 9 Altitude: 680				-----			
Sand, fine, clean 38 173				Sand and gravel 64 87				-----			
Sand, clean, coarser (spec. cap. 15) 18 191				Clay 11 98				-----			
				Sand, fine, water 12 112				-----			
				Sand, clean, coarse 5 117				-----			
				Hardpan 12 129				-----			
				Gravel, coarse 10 139				-----			



Table 1.--Logs and specific capacity of selected wells.--Continued.

	Thick- ness (ft)	Depth (ft)		Thick- ness (ft)	Depth (ft)		Thick- ness (ft)	Depth (ft)
<u>PINE GROVE TOWNSHIP</u>			Michigan Fruit Cannery # 2 NW¼ SE¼ Section 3 Altitude: 580			Stevie Brothers SW¼ NE¼ Section 22 Altitude: 640		
City of Gobles # 1 NW¼ NW¼ Section 30 Altitude: 815			Muck	15	15	Clay	100	100
Gravel	30	30	Sand, fine	12	27	Sand, dirty, clay and gravel	33	133
Clay	70	100	Sand, clean	16	43	Gravel, medium	7	140
Gravel	10	110	Clay at (spec. cap. 7.6)		43			
City of Gobles # 2 NW¼ NW¼ Section 30 Altitude: 812			Michigan Fruit Cannery # 3 NW¼ SE¼ Section 3 Altitude: 580			R. Nelson SE¼ SW¼ Section 23 Altitude: 645		
No log (spec. cap. 2.4)			Muck	6	6	Sand	15	15
			Sand, lake	1	7	Clay	50	65
			Clay	2	9	Clay and sand streaks	20	85
			Sand, fine	2	11	Clay and rocks	27	112
			Sand, with strips of clay	29	40	Sand, coarse, dry	170	282
			Gravel (spec. cap. 7.6)	2	42	Sand, medium, wet	at	282
City of Gobles # 3 NW¼ NW¼ Section 30 Altitude: 815			Everett Piano Company SW¼ SW¼ Section 10 Altitude: 630			<u>WAVERLY TOWNSHIP</u>		
Sand and gravel	60	60	Clay	18	18	Sernatinger SE¼ NW¼ Section 31		
Sand and hsrpnan	35	95	Sand	2	20	Sand	20	20
Sand and gravel, water-bearing	15	110	Clay	2	20	Clay	30	50
Hardpan, sandy (spec. cap. 12.7)	25	135	Clay	153	173	Sand	8	58
			Gravel	20	193	Gravel, coarse, heavy	7	65
<u>PORTER TOWNSHIP</u>			City of South Haven (Test) SW¼ SW¼ Section 10 Altitude: 635			County Road Commission NE¼ NW¼ Section 35 Altitude: 690		
Honeybear Packing Co. NE¼ NW¼ Section 5 Altitude: 790			Clay	86	86	Sand, yellow, dry	4	4
Sand and gravel	14	14	Sand, coarse	6	92	Sand, yellow, moist	6	10
Clay, sand	4	18	Sand, fine	4	96	Sand, yellow, wet	3	13
Sand, hardpack	4	22	Sand, coarse	2	98	Clay, gray to light brown, wet	52	65
Sand and gravel	5	27	Sand, fine, muddy	4	102	Clay, light brown and sand, medium	10	75
Clay, sandy	9	36	Sand, coarse and gravel	4	106	Clay, with stones	5	80
Sand, fine, muddy	14	50	Sand, fine, muddy	20	126	Clay	2	82
Sand, fine, clean	21	71	Sand, coarse	3	129			
Clay	4	75	Clay, hard	5	134			
Sand, gray, fine, muddy	27	102	Sand, coarse and gravel, fine	10	144			
Boulders, some clay	2	104	Clay and gravel	9	153			
Sand and gravel (spec. cap. 2.7)	5	109	Sand, medium	7	160			
			Sand, coarse	19	179			
			Clay and gravel	7	186			
			Rock at		186			
Porter Township SE¼ SE¼ Section 16 Altitude: 940			M. Steive SW¼ SW¼ Section 15 Altitude: 620					
Sand and gravel	5	5	Clay, pebbly	50	50			
Gravel	31	36	Clay, bouldery	40	90			
Stones	6	42	Sand, hard and clay	60	150			
Sand, light brown with clay, fine	38	80	Shale	30	180			
Sand, medium with pebbles	15	95						
Clay	5	100						
(cased and screened to 83 for observation well)								
			<u>SOUTH HAVEN TOWNSHIP</u>					
			Michigan Fruit Cannery # 1 NW¼ SE¼ Section 3 Altitude: 580					
No log (spec. cap. 5)			Lambert Subdivision NE¼ SE¼ Section 15 Altitude: 630					
			Sand and topsoil	5	5			
			Clay	55	60			
			Clay, stone, and sand	14	74			
			Sand	10	84			
			Sand and clay	3	87			

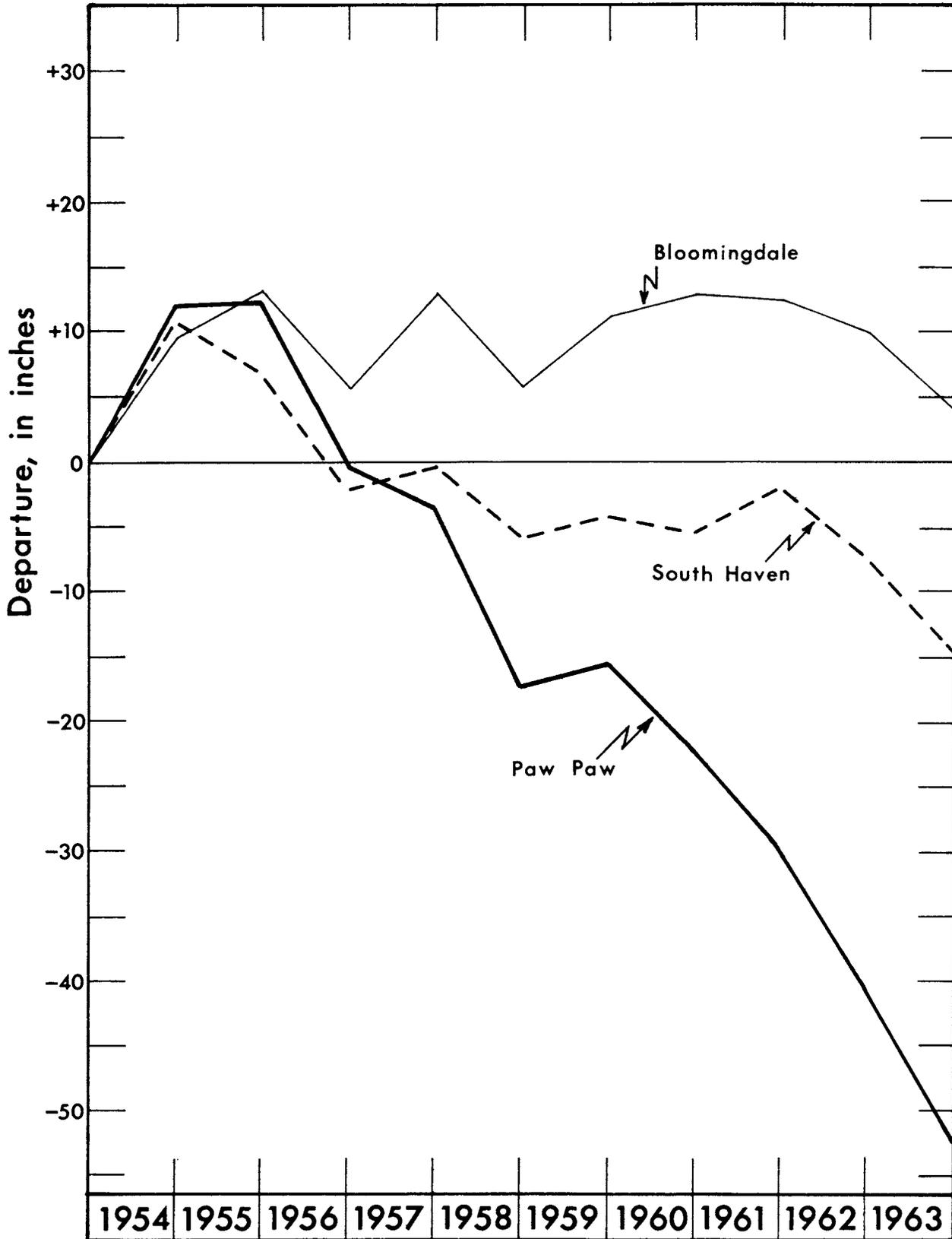


FIGURE 5.--GRAPH SHOWING CUMULATIVE DEPARTURE OF PRECIPITATION FROM LONG-TERM AVERAGE, 1954-63.

Precipitation was especially deficient during the 1962-63 period of this study. Graph was constructed by adding the annual departures from average for the 10-year period.

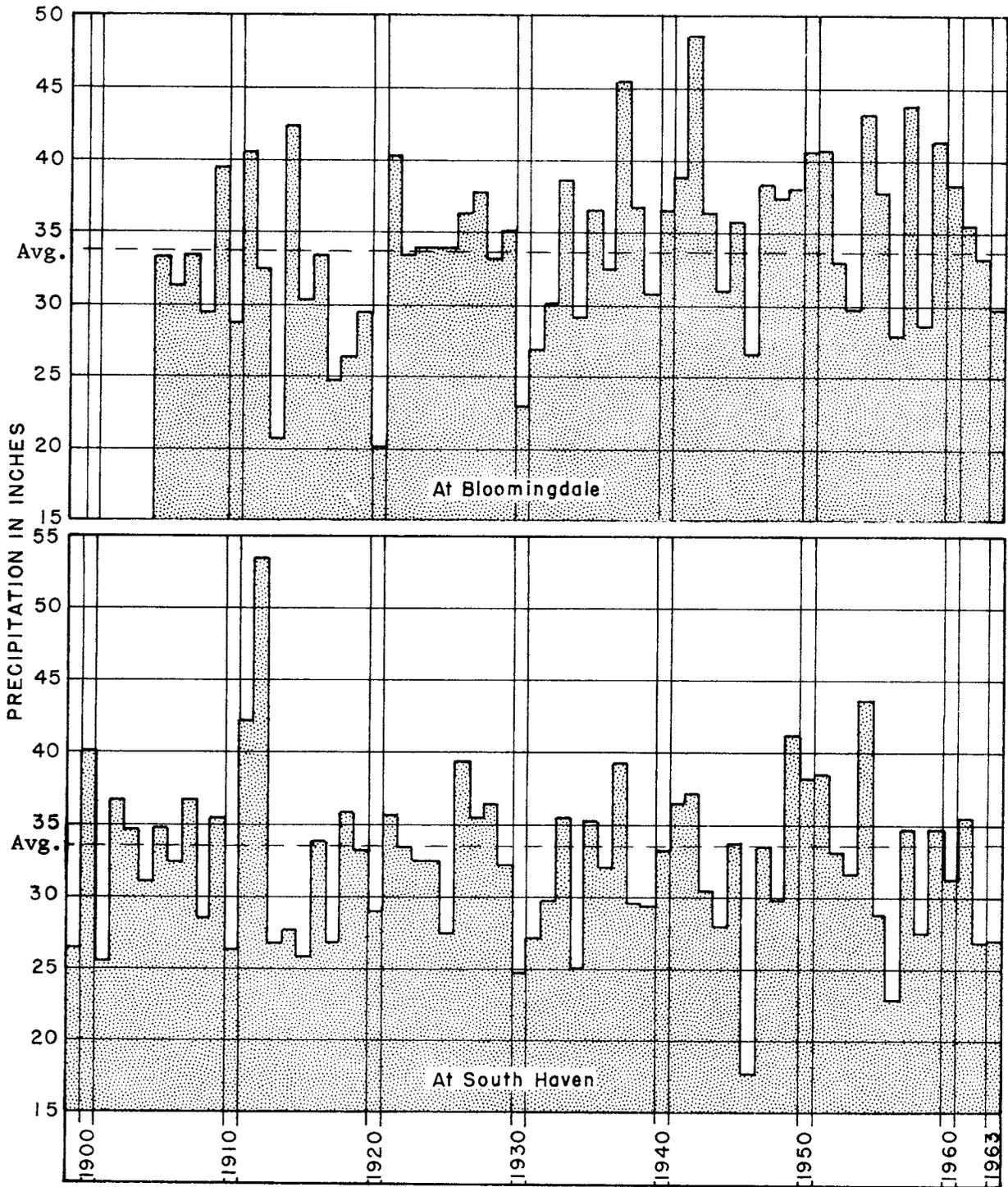


FIGURE 6.--BAR GRAPHS SHOWING ANNUAL PRECIPITATION, 1899-1963.

A series of dry years is generally followed by a series of wet years.

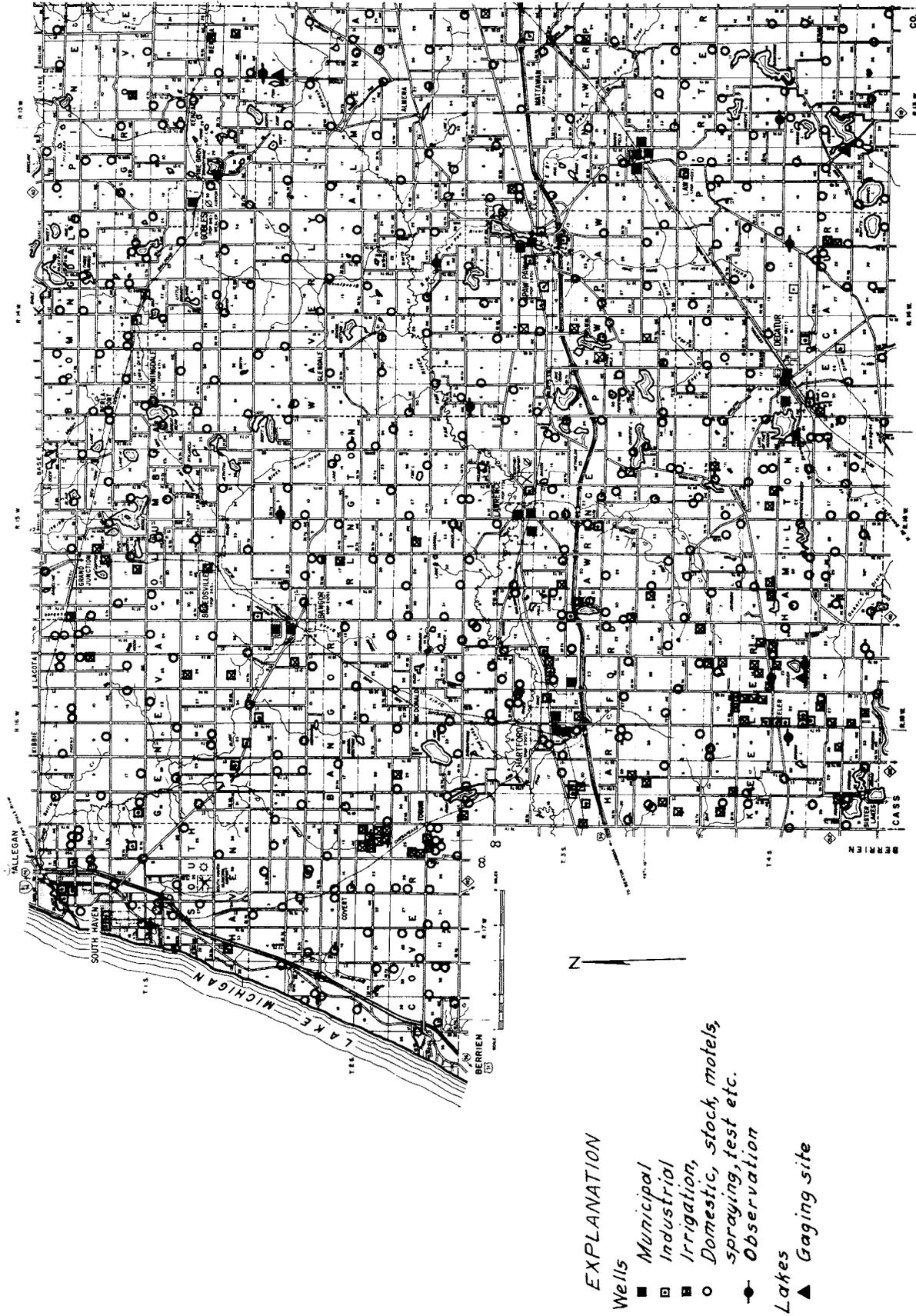


FIGURE 7.--MAP SHOWING LOCATION OF WELL AND LAKE DATA COLLECTION SITES.

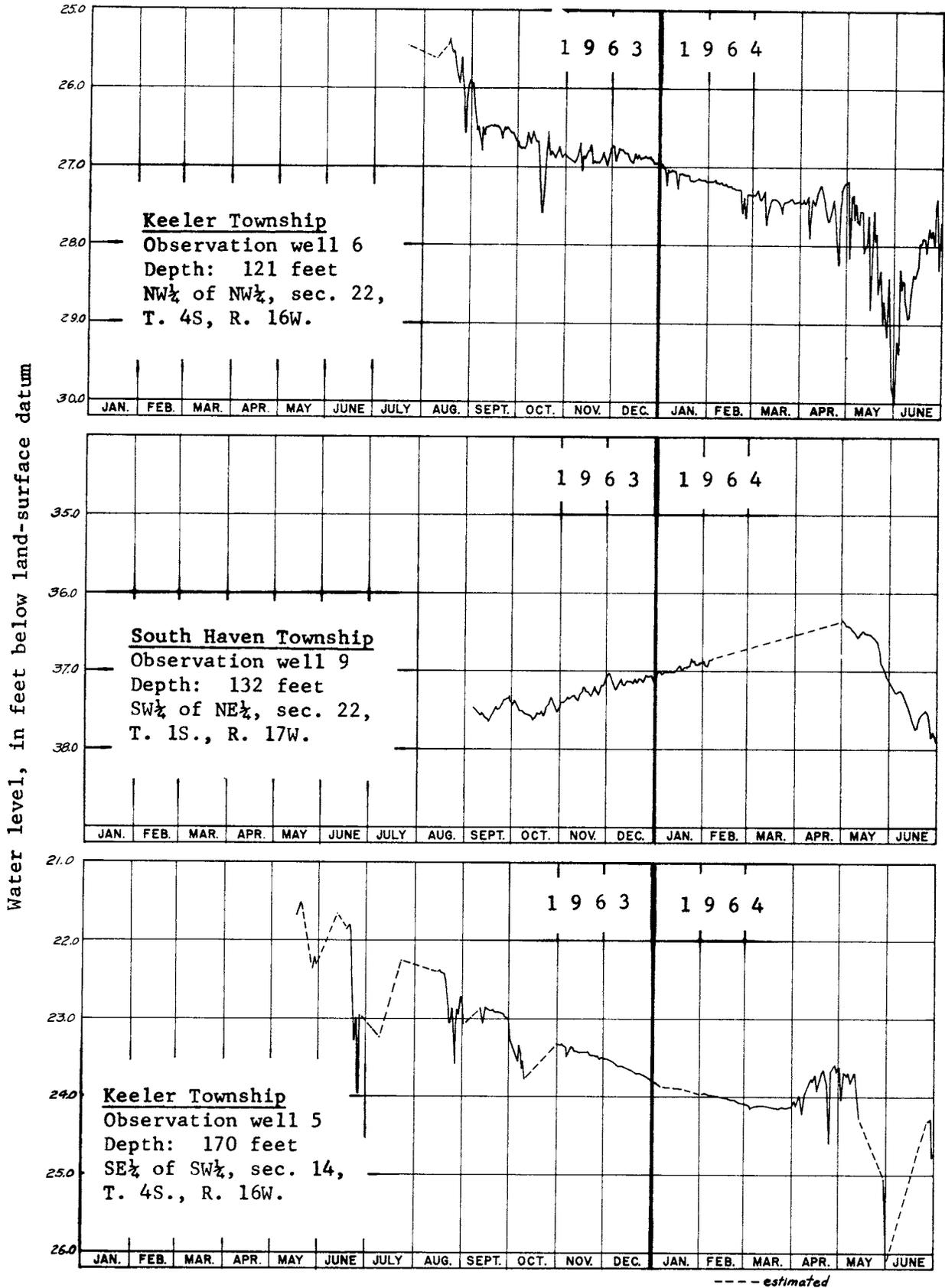


FIGURE 8.--GRAPHS OF WATER LEVELS SHOWING EFFECTS OF PUMPING AND BAROMETRIC PRESSURE, 1963-64.

Levels in no. 5 and 6 wells reflect industrial and irrigation pumpage in the area. Levels in no. 9 reflect barometric pressure.

Under natural conditions there is an annual cycle of ground-water levels. Water levels generally rise in the spring when rain and melting snow recharges the aquifers and decline during the summer and early fall when vegetation and evaporation uses up most of the water that otherwise would be available for recharge. The decline may continue through fall and winter in some of the deeper wells when fall rains are not enough to replenish the deficient soil moisture (fig. 9, well 7 and fig. 10, wells 1, 2, and 3). In shallower wells the recovery of water levels usually begins after the first killing frosts in the fall (fig. 9, wells 4 and 8).

In spite of the seasonal recoveries water levels in 6 of the 10 observation wells were substantially lower in May 1964 than they were a year earlier. The net decline for the year in these 6 wells ranged from about 0.3 to 2.3 feet.

### Inland Lakes

There are more than a hundred lakes in the county, containing an estimated 64,000 acre-feet of water in storage. The lakes are of two main types -- the land-locked lakes whose water levels fluctuate with the water table, and the lakes having surface outlets whose levels fluctuate little and reflect the levels of the connecting streams.

For example, the hydrographs of Keeler and of Cedar Lakes, (fig. 11), resemble those of the water-table wells in figure 10. This is to be expected as these two lakes are land-locked and, like the wells, reflect changes in the water table. They are similar hydrologically to large-diameter wells and to farm ponds that intercept the water table.

In marked contrast to the land-locked lakes the hydrographs of Fish and Lake of the Woods lakes, (fig. 12), have a rather flat appearance. The latter lakes have outlets and their fluctuations resemble those of stream hydrographs. This type of lake might be referred to as a "wide place in a stream".

### Origin of the Inland Lakes

Most inland lakes first appeared when meltwaters from the retreating ice filled the enclosed depressions in the glacial deposits. Some lakes, like Cora Lake, are termed "pit lakes". These "pit lakes" were probably formed by the isolation of a glacial ice block which became covered with debris and melted later, allowing the material above to settle. A report "Inland Lakes of Michigan" (Scott, 1920) gives very detailed information on the origin and development of Michigan lakes including some located in Van Buren County.

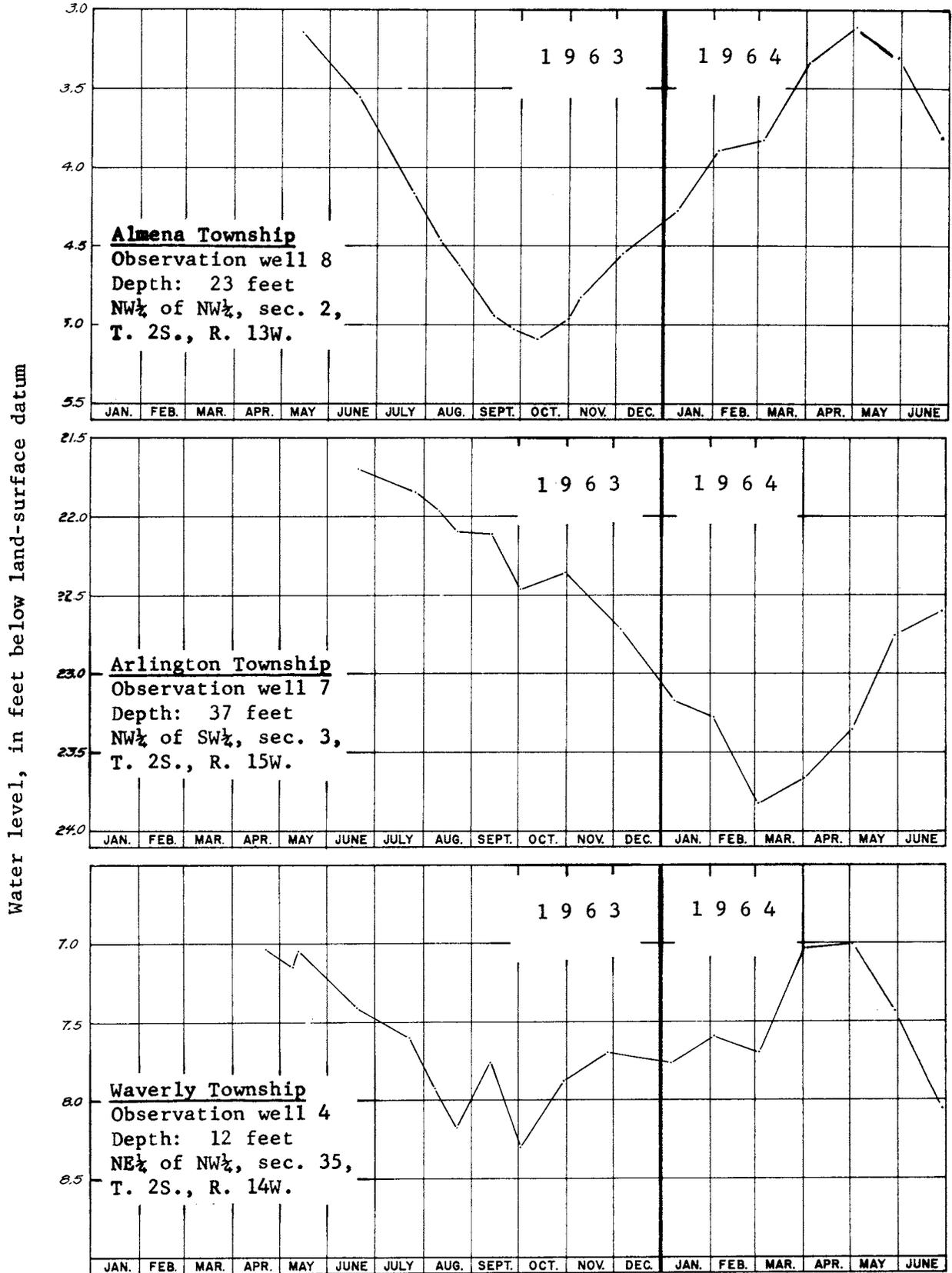


FIGURE 9.--GRAPHS OF WATER LEVELS SHOWING SEASONAL TRENDS, 1963-64.

Water levels in wells no. 4 and 8 show a seasonal decline and recovery. Levels in no. 7 were a foot lower in June, 1964 than in June, 1963.

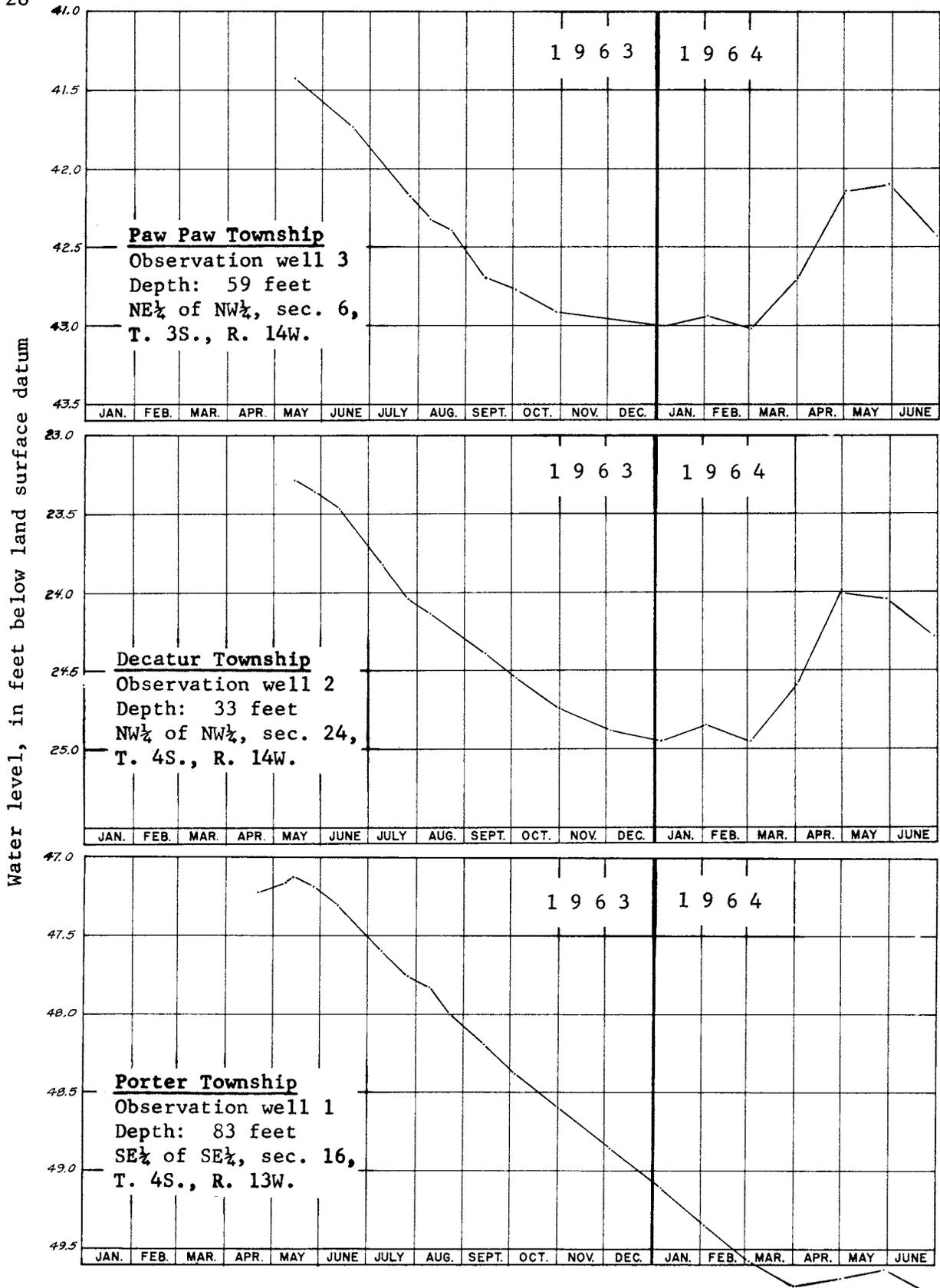


FIGURE 10.--GRAPHS OF WATER LEVELS SHOWING NET DECLINES, 1963-64.

Levels in all 3 wells were lower in May and June, 1964 than in the corresponding months of 1963.

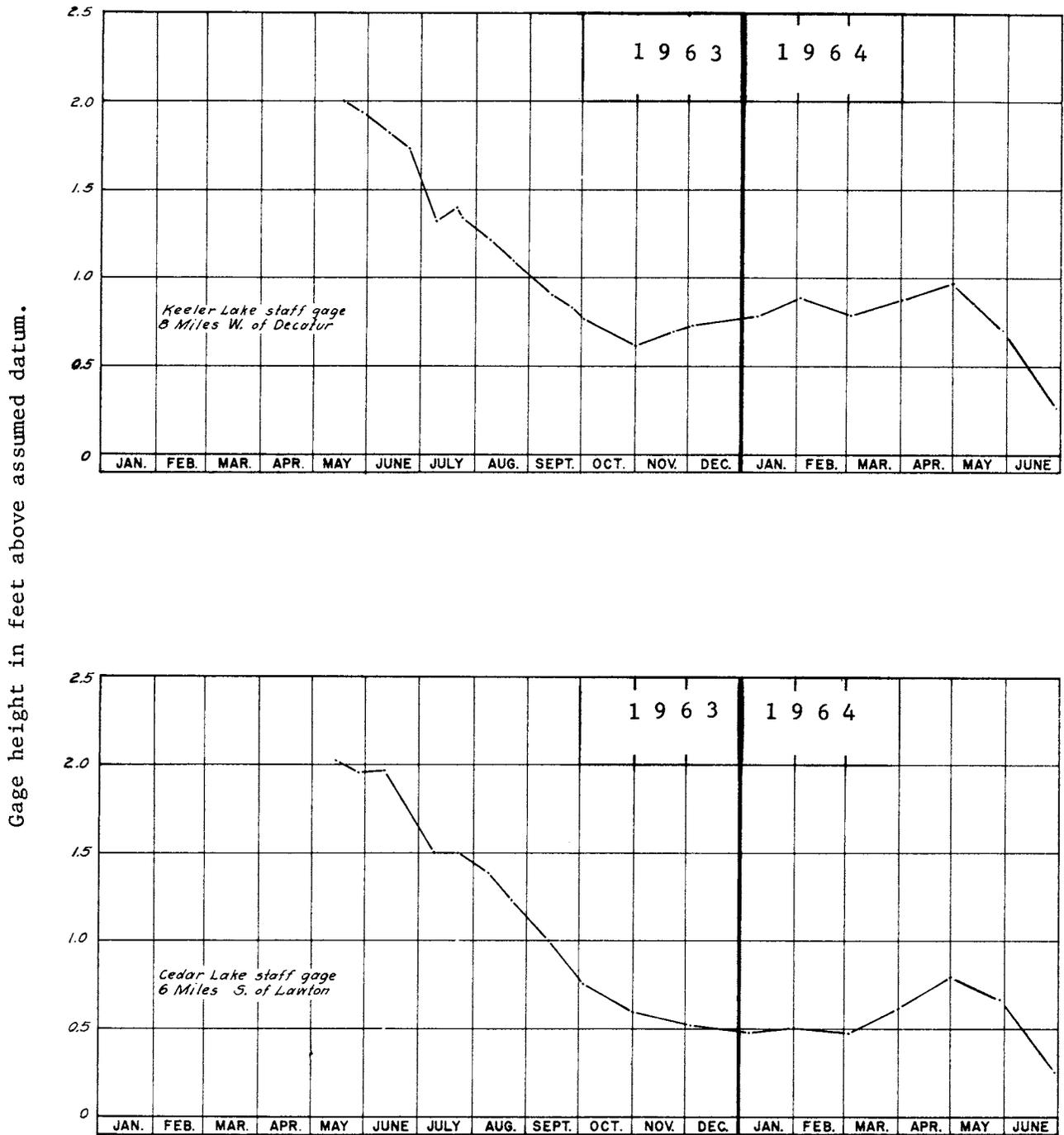


FIGURE 11.--GRAPHS OF WATER LEVELS OF LAND-LOCKED INLAND LAKES, 1963-64.

These two land-locked or ground-water lakes, reflect changes in the water table elevations and their hydrographs resemble those of observation wells no. 2 and 3 in figure 10.

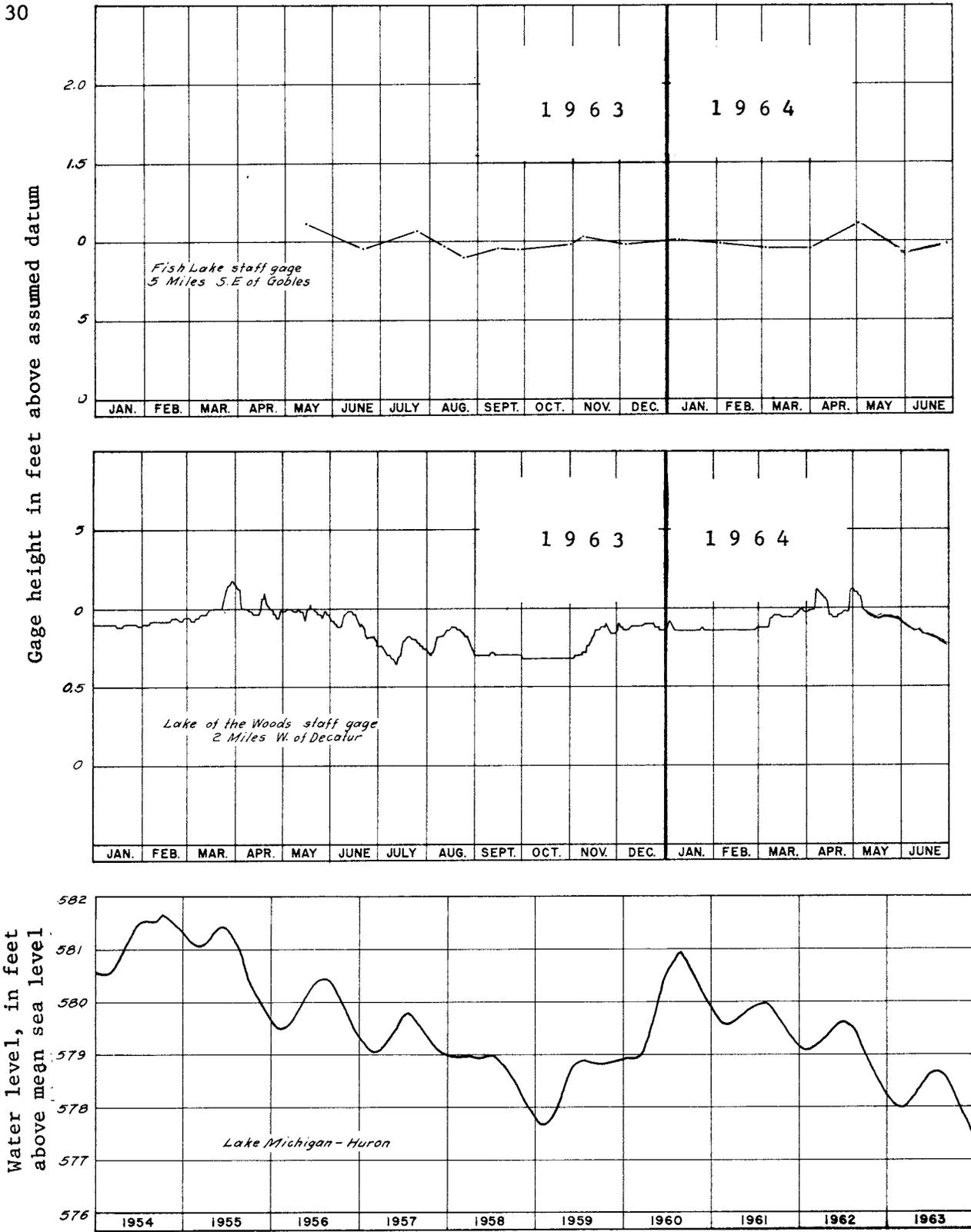


FIGURE 12.--GRAPHS OF WATER LEVELS OF LAKES WITH OUTLETS, 1963-64, AND OF LAKES MICHIGAN-HURON, 1954-63.

Hydrographs of Fish and Lake of the Woods lakes are rather flat with little fluctuation. These graphs are typical of a lake with a stream outlet. Levels of Lakes Michigan-Huron, at the end of 1963, were the lowest since 1860.

## The Life Span of the Lakes

Lakes begin to "die" as soon as they are born, but in terms of human history they may survive a long time. Generally, it is the small, shallow lakes that disappear first. Ultimately, lakes become extinct as the result of the filling of their beds by various processes. Some of these processes are: (1) sedimentation by materials carried in by surface runoff; (2) deposition of vegetal and animal remains; (3) chemical deposition such as the deposits of calcium carbonate or lime from the lake water, resulting in marl-type bottoms; (4) downcutting of the surface outlet of some lakes will eventually drain them. In addition, depletion of the lakes may occur as rivers deepen their valleys and thus lower the water table which is the level of land-locked lakes.

In the smaller lakes and in lagoons, where the water is calm, an important cause of their deterioration is the process of filling by vegetation. Water-loving plants die at the close of the growing season and sink to the bottom. Being covered with water, this debris only partially decomposes. The yearly residue accumulates, eventually becoming deposits of peat. The intertwined stems and roots of water vegetation floating on the surface become bogs (sometimes called "quaking bogs"). These bogs may cover the entire surface of the lake before the basin is completely filled, and are thus underlain by clear water. The droppings from the underside of the bog finally fill in the space underneath and the process is completed. A probable example of this type of filling is Grass Lake in section 21 of Porter Township.

Marl may be formed in lakes to considerable thickness by the death of myriads of small animals whose hard parts are made of calcium carbonate. Marl beds, as much as 40 feet in thickness, have been found in Michigan lakes. The marl is usually considered to be a mixture of calcium carbonate and clastic sediments from several sources.

### "Are Inland Lake Levels Falling?"

A substantial decline in lake levels was observed at Keeler and Cedar Lakes (fig. 11). Longer records of lake levels in nearby areas of Michigan substantiate the decline in lake levels of recent years. These generally low levels are the result of generally deficient precipitation in most of the State during the last few years. It must be remembered that lake levels have been low before and have recovered following relatively wet years.

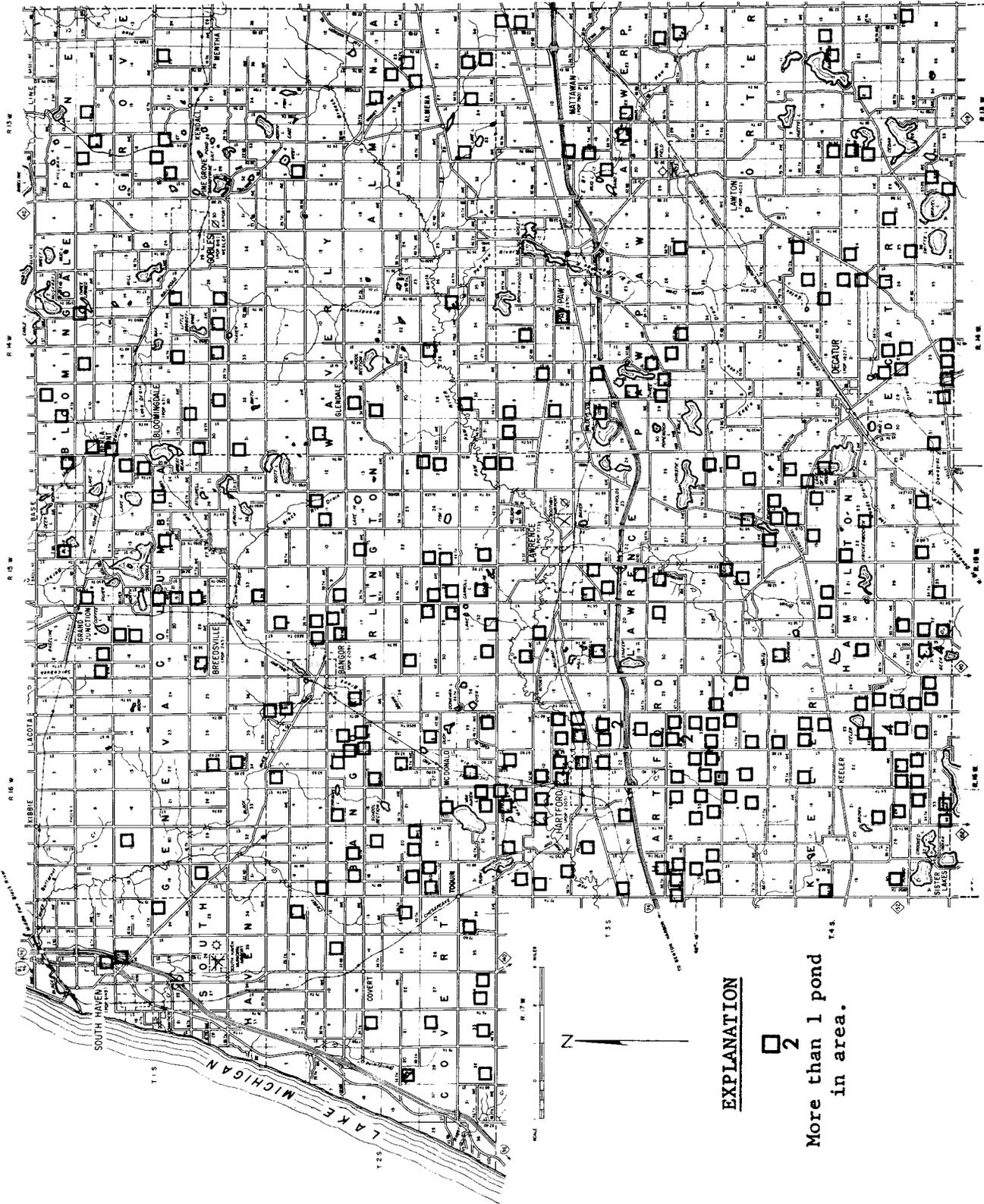


FIGURE 13.--MAP SHOWING DISTRIBUTION OF FARM PONDS.

About 300 farm ponds supply nearly half the water used for irrigation and spraying of crops and orchards.

EXPLANATION

□<sub>2</sub>

More than 1 pond  
in area.

## Lake Michigan

The levels of Lake Michigan reflect the general drought conditions of the past few years (fig. 12). In late 1963 and early 1964 stages of the lake were the lowest ever observed for the period of record dating back to 1860. The low levels do not preclude the use of the lake for water supply but do point out the need for deep intake pipes if the lake is used as a water source. Because of the high cost of transporting water the chief value of Lake Michigan as a water source is to the townships that border the lake.

## Farm Ponds

The more than 300 farm ponds in the county (fig. 13) provide nearly half of the water used for irrigation, spraying of crops with pesticides, and for watering livestock. It is estimated that these farm ponds hold about 750 million gallons of water in storage, based on an average depth of 8 feet and average size of one acre. Actual depths range from about 6 to 15 feet and sizes from 0.1 to as much as 48 acres. Most are less than one acre in size. The amount of water that can be obtained is far greater than the amount in storage as most of them tap the water table and are continually being replenished as they are used. If the ponds are excavated in permeable sand or gravel, they are rapidly replenished, but if they are in clay or muck, the water seeps in slowly and the water levels may not recover for a long period after pumping withdrawals. In some instances the water level may remain relatively low for months until water is added by direct precipitation or surface runoff into the pond. The land-locked farm pond is also subject to variations in level from fluctuations in the water table of 2 to 3 feet, as occurs in water-table wells and land-locked lakes (figs. 10 and 11).

Where farm ponds were constructed by damming streams fluctuations in level may be small. The hydrograph of this type of pond would probably resemble the hydrograph of a lake having an outlet as in figure 12. Where farm ponds intercept surface streams or surface runoff the ponded water may increase the local ground-water recharge.

The source of the water supplying most farm ponds in the county is ground water. Most of the ponds are simple, large-diameter wells excavated to below the ground-water table surface. They are usually located at the lowest elevation on the farm thus taking advantage of the shallower depth to water at that point. There are a few, however, that obtain water by damming small streams.

## Streams

### Major Streams in the County and Their Drainage Areas

The major streams are the Paw Paw River which drains about 300 square miles of the eastern and southern parts of the county and the Black River which drains about 160 square miles in the northwestern part of the county. A small area in the northeastern part of the county drains into the Kalamazoo River, and a small area in the southwestern part drains into Dowagiac Creek, a tributary of the St. Joseph River. A few small streams in the western part drain directly into Lake Michigan.

The drainage areas of various segments of the major streams and tributaries in the county are listed in table 2. The drainage areas of each stream are listed in downstream order. These drainage areas must be known in order to estimate the low flow and flood frequency at any point on any stream in the county.

### Annual Runoff from Streams in the County

An estimated 150 billion gallons runs off in streams in the county in an average year. This volume represents a depth of about 14 inches of water over the entire county (fig. 2).

### The Effect of Surface Geology and Soil Types on Streamflow

The permeable soils and underlying glacial drift that predominate in the southeastern two thirds of the county result in large contributions of ground water to the streams, thus creating relatively high base flows in this area (fig. 14). The steady flow of the Paw Paw River, which is typical of streams having a high base flow, is illustrated in figure 15. The less-permeable soils and drift in the northwestern one-third of the county transmit smaller amounts of ground water to the streams, and the base flows in this area are lower.

### Streamflow Records and What They Show

Four series of measurements were made at 35 sites on streams in the county to determine base flow of streams. The sites at which these measurements were made are shown in figure 16, and the results are given in table 3. The location numbers on the map correspond to the tabulated sites in the table.

Table 2.--These are drainage areas in the county.

<u>Dowagiac Creek</u>	<u>Sq. Mi.</u>
Dowagiac Drain at 50th Street (misc. meas. site), SW $\frac{1}{4}$ sec. 35, T.4 S., R.15 W. . . . .	21.9
Dowagiac Drain above Lake of the Woods Drain, SE $\frac{1}{4}$ sec. 34, T.4 S., R.15 W. . . . .	22.0
Lake of the Woods at outlet, center sec. 24, T.4 S., R.15 W. . . . .	8.39
Lake of the Woods Drain near mouth, (misc. meas. site) SE $\frac{1}{4}$ sec. 27, T.4 S., R.15 W. . . . .	13.1
Lake of the Woods Drain at mouth, SE $\frac{1}{4}$ sec. 34, T.4 S., R.15 W. . . . .	14.1
North Branch Dowagiac Creek at Lake of the Woods Drain, SE $\frac{1}{4}$ sec. 34, T.4 S., R.15 W. . . . .	36.1
North Branch Dowagiac Creek above Osborn Drain, NW $\frac{1}{4}$ sec. 9, T.5 S., R.15 W. . . . .	44.1
Osborn Drain near Pitcher Lake, (misc. meas. site) SE $\frac{1}{4}$ sec. 31, T.4 S., R.15 W. . . . .	15.5
Osborn Drain at mouth, NW $\frac{1}{4}$ sec. 9, T.5 S., R.15 W. . . . .	18.6
North Branch Dowagiac Creek at Osborn Drain, NW $\frac{1}{4}$ sec. 9, T.5 S., R.15 W. . . . .	62.7
North Branch Dowagiac Creek above Silver Creek, SE $\frac{1}{4}$ sec. 23, T.5 S., R.16 W. . . . .	86.5
Silver Creek at mouth, SE $\frac{1}{4}$ sec. 23, T.5 S., R.16 W. . . . .	12.7
N. Branch Dowagiac Creek at Silver Creek, SE $\frac{1}{4}$ sec. 23, T.5 S., R.16 W. . . . .	99.2
<u>Paw Paw River</u>	
Gates Drain above Eagle Drain (headwaters of Paw Paw River, misc. meas. site) NW $\frac{1}{4}$ sec. 35, T.3 S., R.14 W. . . . .	26.0
Eagle Lake Drain at 39th Street, (misc. meas. site), SE $\frac{1}{4}$ sec. 34, T.3 S., R.14 W. . . . .	13.8
Eagle Lake Drain at mouth, SW $\frac{1}{4}$ sec. 26, T.3 S., R.14 W. . . . .	14.4
Gates Drain at Eagle Lake Drain, SW $\frac{1}{4}$ sec. 26, T.3 S., R.14 W. . . . .	40.4
South Branch Paw Paw River above Maple Lake, (misc. meas. site), SE $\frac{1}{4}$ sec. 14, T.3 S., R.14 W. . . . .	52.1
South Branch Paw Paw River above East Branch Paw Paw River, SW $\frac{1}{4}$ sec. 12, T.3 S., R.14 W. . . . .	52.6
East Branch Paw Paw River near Lawton, Mich. (misc. meas. site), SE $\frac{1}{4}$ sec. 22, T.3 S., R.13 W. . . . .	11.4
East Branch Paw Paw River near Paw Paw, Mich. (misc. meas. site), NW $\frac{1}{4}$ sec. 13, T.3 S., R.14 W. . . . .	31.5
East Branch Paw Paw River at mouth, SW $\frac{1}{4}$ sec. 12, T.3 S., R.14 W. . . . .	35.1
South Branch Paw Paw River at East Branch Paw Paw River, SW $\frac{1}{4}$ sec. 12, T.3 S., R.14 W. . . . .	87.7
South Branch Paw Paw River near Paw Paw, Mich., N $\frac{1}{2}$ sec. 35, T.2 S., R.14 W. . . . .	96.1
South Branch Paw Paw River above North Branch, SE $\frac{1}{4}$ sec. 27, T.2 S., R.14 W. . . . .	96.7
North Branch at Highway M-34, (misc. meas. site), NE $\frac{1}{4}$ sec. 16, T.2 S., R.13 W. . . . .	30.6
North Branch near Paw Paw, Mich. (misc. meas. site), W $\frac{1}{2}$ sec. 25, T.2 S., R.14 W. . . . .	63.5
North Branch above Brandywine Creek, NE $\frac{1}{4}$ sec. 26, T.2 S., R.14 W. . . . .	63.8
Brandywine Creek at 37th Street, (misc. meas. site), NW $\frac{1}{4}$ sec. 11, T.2 S., R.14 W. . . . .	9.05
Brandywine Creek at Highway M-43, (misc. meas. site), NE $\frac{1}{4}$ sec. 15, T.2 S., R.14 W. . . . .	26.4
Brandywine Creek near Austin School, (misc. meas. site), NE $\frac{1}{4}$ sec. 23, T.2 S., R.14 W. . . . .	32.2
Brandywine Creek at mouth, NE $\frac{1}{4}$ sec. 26, T.2 S., R.14 W. . . . .	32.8
North Branch at Brandywine Creek, NE $\frac{1}{4}$ sec. 26, T.2 S., R.14 W. . . . .	96.6
North Branch at mouth, SE $\frac{1}{4}$ sec. 27, T.2 S., R.14 W. . . . .	98.2
Paw Paw River at confluence of South Branch Paw Paw River and North Branch, SE $\frac{1}{4}$ sec. 27, T.2 S., R.14 W. . . . .	195.
Paw Paw River near Cross School, NW $\frac{1}{4}$ sec. 31, T.2 S., R.14 W. . . . .	215.
Paw Paw River above Brush Creek, NW $\frac{1}{4}$ sec. 10, T.3 S., R.15 W. . . . .	225.
Brush Creek at 72th Avenue, (misc. meas. site), NE $\frac{1}{4}$ sec. 4, T.4 S., R.15 W. . . . .	16.0
Brush Creek above Red Creek, NE $\frac{1}{4}$ sec. 33, T.3 S., R.15 W. . . . .	16.9
Red Creek at 54th Street, (misc. meas. site), NW $\frac{1}{4}$ sec. 33, T.3 S., R.15 W. . . . .	6.89
Red Creek at mouth, NE $\frac{1}{4}$ sec. 33, T.3 S., R.15 W. . . . .	7.72
Brush Creek at Red Creek, NE $\frac{1}{4}$ sec. 33, T.3 S., R.15 W. . . . .	24.6
Brush Creek at Highway 12, (misc. meas. site), SW $\frac{1}{4}$ sec. 10, T.3 S., R.15 W. . . . .	39.9
Brush Creek at mouth, NW $\frac{1}{4}$ sec. 10, T.3 S., R.15 W. . . . .	40.1
Paw Paw River at Brush Creek, NW $\frac{1}{4}$ sec. 10, T.3 S., R.15 W. . . . .	265.
Paw Paw River at Lawrence, Mich., NW $\frac{1}{4}$ sec. 10, T.3 S., R.15 W. . . . .	265.
Paw Paw River at 54th Street, SW $\frac{1}{4}$ sec. 16, T.3 S., R.15 W. . . . .	269.
Paw Paw River at 58th Street, SW $\frac{1}{4}$ sec. 6, T.3 S., R.15 W. . . . .	276.
Paw Paw River near Hartford, Mich., NW $\frac{1}{4}$ sec. 12, T.3 S., R.16 W. . . . .	282.
Paw Paw River at Hartford, NE $\frac{1}{4}$ sec. 9, T.3 S., R.16 W. . . . .	292.
Paw Paw River above Mud Lake Drain, NW $\frac{1}{4}$ sec. 9, T.3 S., R.16 W. . . . .	292.
Mud Lake Drain at 52nd Ave., (misc. meas. site), SW $\frac{1}{4}$ sec. 4, T.3 S., R.16 W. . . . .	9.84
Mud Lake Drain at mouth, NW $\frac{1}{4}$ sec. 9, T.3 S., R.16 W. . . . .	16.9
Paw Paw River at Mud Lake Drain, NW $\frac{1}{4}$ sec. 9, T.3 S., R.16 W. . . . .	309.
Paw Paw River above Pine Creek, SW $\frac{1}{4}$ sec. 8, T.3 S., R.16 W. . . . .	311.
Pine Creek at mouth, (misc. meas. site), SW $\frac{1}{4}$ sec. 8, T.3 S., R.16 W. . . . .	10.7
Paw Paw River at Pine Creek, SW $\frac{1}{4}$ sec. 8, T.3 S., R.16 W. . . . .	321.
Paw Paw River above Paw Paw Lake Outlet, SE $\frac{1}{4}$ sec. 14, T.3 S., R.17 W. . . . .	326.
Paw Paw Lake at Outlet, SE $\frac{1}{4}$ sec. 14, T.3 S., R.17 W. . . . .	17.0
Paw Paw Lake Outlet at mouth, SE $\frac{1}{4}$ sec. 14, T.3 S., R.17 W. . . . .	17.1
Paw Paw River at Paw Paw Lake Outlet, SE $\frac{1}{4}$ sec. 14, T.3 S., R.17 W. . . . .	343.
Paw Paw River above Mill Creek, SW $\frac{1}{4}$ sec. 23, T.3 S., R.17 W. . . . .	345.
Mill Creek near Keeler, Mich., (misc. meas. site), SE $\frac{1}{4}$ sec. 1, T.4 S., R.17 W. . . . .	11.3
Mill Creek at mouth, SW $\frac{1}{4}$ sec. 23, T.3 S., R.17 W. . . . .	28.8
Paw Paw River at Mill Creek, SW $\frac{1}{4}$ sec. 23, T.3 S., R.17 W. . . . .	374.
Paw Paw River at Coloma, Mich., SE $\frac{1}{4}$ sec. 20, T.3 S., R.17 W. . . . .	381.
Paw Paw River near Riverside, (Recording gage), SE $\frac{1}{4}$ sec. 23, T.3 S., R.18 W. . . . .	390.
Paw Paw River above Blue Creek, center sec. 4, T.4 S., R.18 W. . . . .	401.
Blue Creek at mouth, center sec. 4, T.4 S., R.18 W. . . . .	21.0
Paw Paw River at Blue Creek, center sec. 4, T.4 S., R.18 W. . . . .	422.
Paw Paw River above Ox Creek, NW $\frac{1}{4}$ sec. 18, T.4 S., R.18 W. . . . .	432.
Ox Creek at mouth, NW $\frac{1}{4}$ sec. 18, T.4 S., R.18 W. . . . .	11.9
Paw Paw River at Ox Creek, NW $\frac{1}{4}$ sec. 18, T.4 S., R.18 W. . . . .	444.
Paw Paw River at mouth, NW $\frac{1}{4}$ sec. 24, T.4 S., R.18 W. . . . .	446.
<u>Lake Michigan</u>	
Rogers Creek at mouth, NW $\frac{1}{4}$ sec. 36, T.2 S., R.18 W. . . . .	7.02
Brandywine Creek near mouth, (misc. meas. site), NE $\frac{1}{4}$ sec. 8, T.2 S., R.17 W. . . . .	16.7
Brandywine Creek at mouth, NW $\frac{1}{4}$ sec. 8, T.2 S., R.17 W. . . . .	17.0
Deerlick Creek near mouth, (misc. meas. site), NE $\frac{1}{4}$ sec. 21, T.1 S., R.17 W. . . . .	7.76
Deerlick Creek at mouth, NW $\frac{1}{4}$ sec. 21, T.1 S., R.17 W. . . . .	8.17

Table 2.--These are drainage areas in the county.--Continued.

<u>Black River</u>	Sq.Mi.
Black River Drain (headwaters of Black River) above Haven and Max Drain (misc. meas. site), NW¼ sec. 34, T.1 S., R.15 W. . . . .	23.6
Haven and Max Drain at 20th Ave. (misc. meas. site), SW¼ sec. 27, T.1 S., R.15 W. . . . .	16.8
Haven and Max Drain at mouth, NW¼ sec. 34, T.1 S., R.15 W. . . . .	16.9
Black River at Haven and Max Drain, NW¼ sec. 34, T.1 S., R.15 W. . . . .	40.5
Black River at Mill Pond Outlet, (misc. meas. site), SE¼ sec. 11, T.2 S., R.16 W. . . . .	52.3
Black River above Maple Brook, SW¼ sec. 1, T.2 S., R.16 W. . . . .	52.5
Maple Brook at Alexander Street, Bangor, Mich., (misc. meas. site), NW¼ sec. 12, T.2 S., R.16 W. . . . .	12.1
Maple Brook at mouth, SW¼ sec. 1, T.2 S., R.16 W. . . . .	14.8
Black River at Maple Brook, SW¼ sec. 1, T.2 S., R.16 W. . . . .	67.4
Black River above MerrimansLake Outlet, SE¼ sec. 34, T.1 S., R.16 W. . . . .	74.7
MerrimansLake Outlet at Highway M-43, (misc. meas. site), NE¼ sec. 3, T.2 S., R.16 W. . . . .	6.19
MerrimansLake Outlet at mouth, SE¼ sec. 34, T.1 S., R.16 W. . . . .	6.27
Black River at Merrimans Lake Outlet, SE¼ sec. 34, T.1 S., R.16 W. . . . .	81.0
Black River at 16 Avenue, (misc. meas. site), NE¼ sec. 29, T.1 S., R.16 W. . . . .	86.0
Black River above unnamed tributary, SE¼ sec. 20, T.1 S., R.16 W. . . . .	86.1
Unnamed tributary near mouth, (misc. meas. site), SE¼ sec. 20, T.1 S., R.16 W. . . . .	7.22
Unnamed tributary at mouth, SE¼ sec. 20, T.1 S., R.16 W. . . . .	7.27
Black River at unnamed tributary, SE¼ sec. 20, T.1 S., R.16 W. . . . .	93.4
Black River above Cedar Creek, SW¼ sec. 20, T.1 S., R.16 W. . . . .	93.8
Cedar Creek at 16th Avenue, (misc. meas. site), NW¼ sec. 29, T.1 S., R.16 W. . . . .	17.6
Cedar Creek at mouth, SW¼ sec. 20, T.1 S., R.16 W. . . . .	20.2
Black River at Cedar Creek, SW¼ sec. 20, T.1 S., R.16 W. . . . .	114.
Black River above Butternut Creek, NW¼ sec. 6, T.1 S., R.16 W. . . . .	120.
Butternut Creek at 68th Street, (misc. meas. site), SE¼ sec. 6, T.1 S., R.16 W. . . . .	9.31
Butternut Creek at mouth, NW¼ sec. 6, T.1 S., R.16 W. . . . .	9.71
Black River at Butternut Creek, NW¼ sec. 6, T.1 S., R.16 W. . . . .	130.
Black River at 70th Street, (misc. meas. site), NW¼ sec. 1, T.1 S., R.17 W. . . . .	130.
Black River above Middle Fork Black River, SW¼ sec. 36, T.1 N., R.17 W. . . . .	132.
Middle Fork Black River above Melvin Creek, SW¼ sec. 35, T.1 N., R.15 W. . . . .	5.12
Melvin Creek above Lake Moriah, (misc. meas. site), SW¼ sec. 1, T.1 S., R.15 W. . . . .	7.10
Melvin Creek at mouth, SW¼ sec. 35, T.1 N., R.15 W. . . . .	16.5
Middle Fork Black River at Melvin Creek, SW¼ sec. 35, T.1 N., R.15 W. . . . .	21.6
Middle Fork Black River above Barber Creek, SW¼ sec. 21, T.1 N., R.15 W. . . . .	30.3
Barber Creek near Grand Junction, Mich., (misc. meas. site), SW¼ sec. 3, T.1 S., R.15 W. . . . .	4.76
Barber Creek at mouth, SW¼ sec. 21, T.1 N., R.15 W. . . . .	13.8
Middle Fork Black River at Barber Creek, SW¼ sec. 21, T.1 N., R.15 W. . . . .	44.1
Middle Fork Black River above Scott Creek, SW¼ sec. 13, T.1 N., R.16 W. . . . .	48.0
Scott Creek at mouth, SW¼ sec. 13, T.1 N., R.16 W. . . . .	16.1
Middle Fork Black River at Scott Creek, SW¼ sec. 13, T.1 N., R.16 W. . . . .	64.0
Middle Fork River above Spicebush Creek, SW¼ sec. 23, T.1 N., R.16 W. . . . .	65.9
Spicebush Creek at mouth, SW¼ sec. 23, T.1 N., R.16 W. . . . .	10.1
Middle Fork Black River at Spicebush Creek, SW¼ sec. 23, T.1 N., R.16 W. . . . .	76.0
Middle Fork Black River above North Fork Black River, NE¼ sec. 31, T.1 N., R.16 W. . . . .	82.7
North Fork Black River at mouth, NE¼ sec. 31, T.1 N., R.16 W. . . . .	67.6
Middle Fork Black River at North Fork Black River, NE¼ sec. 31, T.1 N., R.16 W. . . . .	150.
Middle Fork Black River at Baseline Road, (misc. meas. site), SW¼ sec. 31, T.1 N., R.16 W. . . . .	151.
Middle Fork Black River at mouth, SW¼ sec. 36, T.1 N., R.16 W. . . . .	152.
Black River at Middle Fork Black River, SW¼ sec. 36, T.1 N., R.16 W. . . . .	284.
Black River at mouth, NW¼ sec. 10, T.1 S., R.17 W. . . . .	287.
<u>Kalamazoo River Basin</u>	
Pine Creek above Baseline Creek, SE¼ sec. 31, T.1 N., R.12 W. . . . .	35.6
Baseline Creek above Clear Lake Outlet, SE¼ sec. 34, T.1 N., R.13 W. . . . .	12.6
Clear Lake Outlet at 2nd Avenue, (misc. meas. site), NW¼ sec. 3, T.1 S., R.13 W. . . . .	7.43
Clear Lake Outlet at mouth, SE¼ sec. 34, T.1 N., R.13 W. . . . .	7.82
Baseline Creek at Clear Lake Outlet, SE¼ sec. 34, T.1 N., R.13 W. . . . .	20.4
Baseline Creek at mouth, SE¼ sec. 31, T.1 N., R.12 W. . . . .	33.7
Pine Creek at Baseline Creek, SE¼ sec. 31, T.1 N., R.12 W. . . . .	69.3

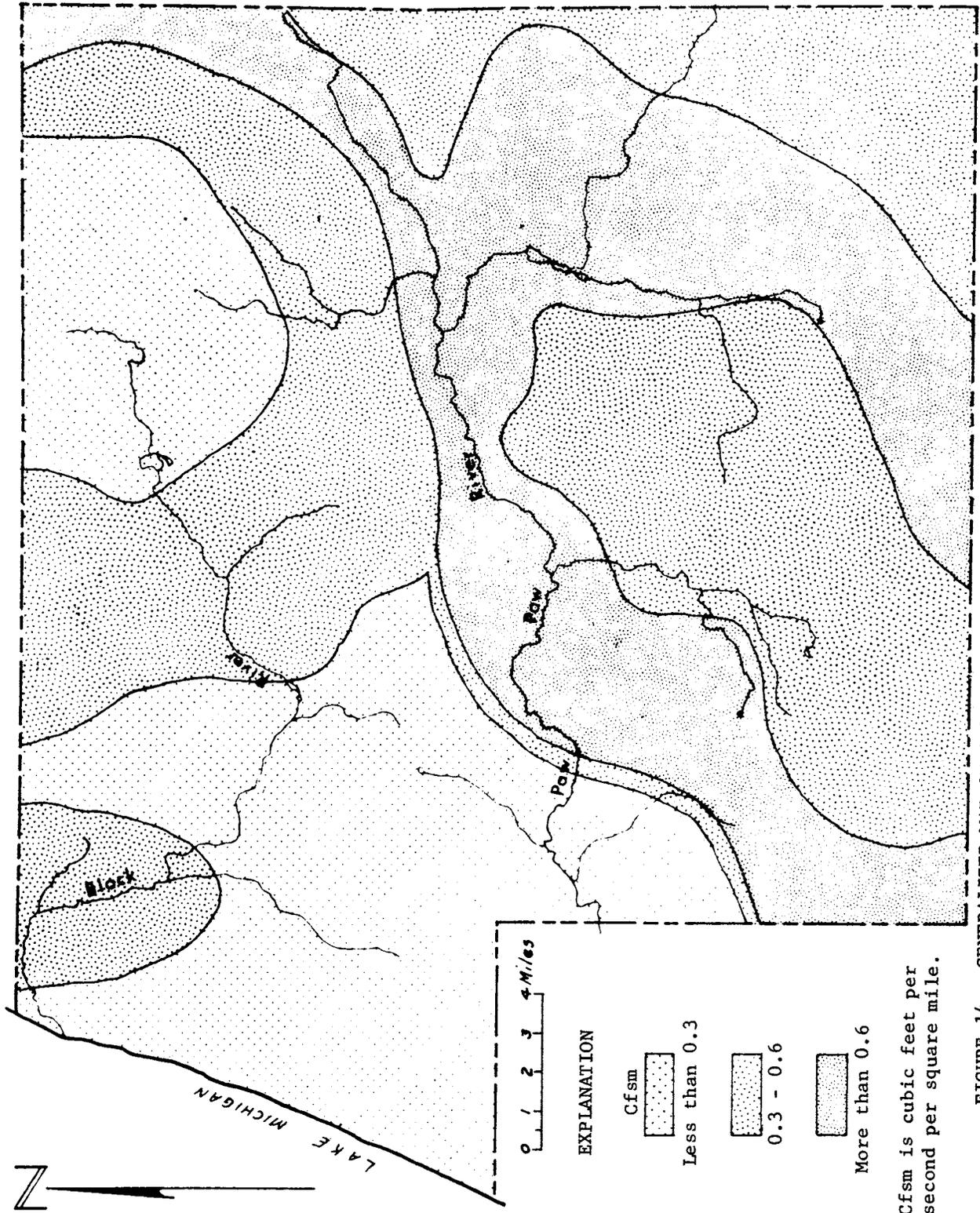


FIGURE 14.--GENERALIZED MAP OF GROUND-WATER CONTRIBUTION TO DRY-WEATHER FLOW OF STREAMS.

The southeastern part of the county has the more permeable soils thus contributing more ground-water flow to streams.

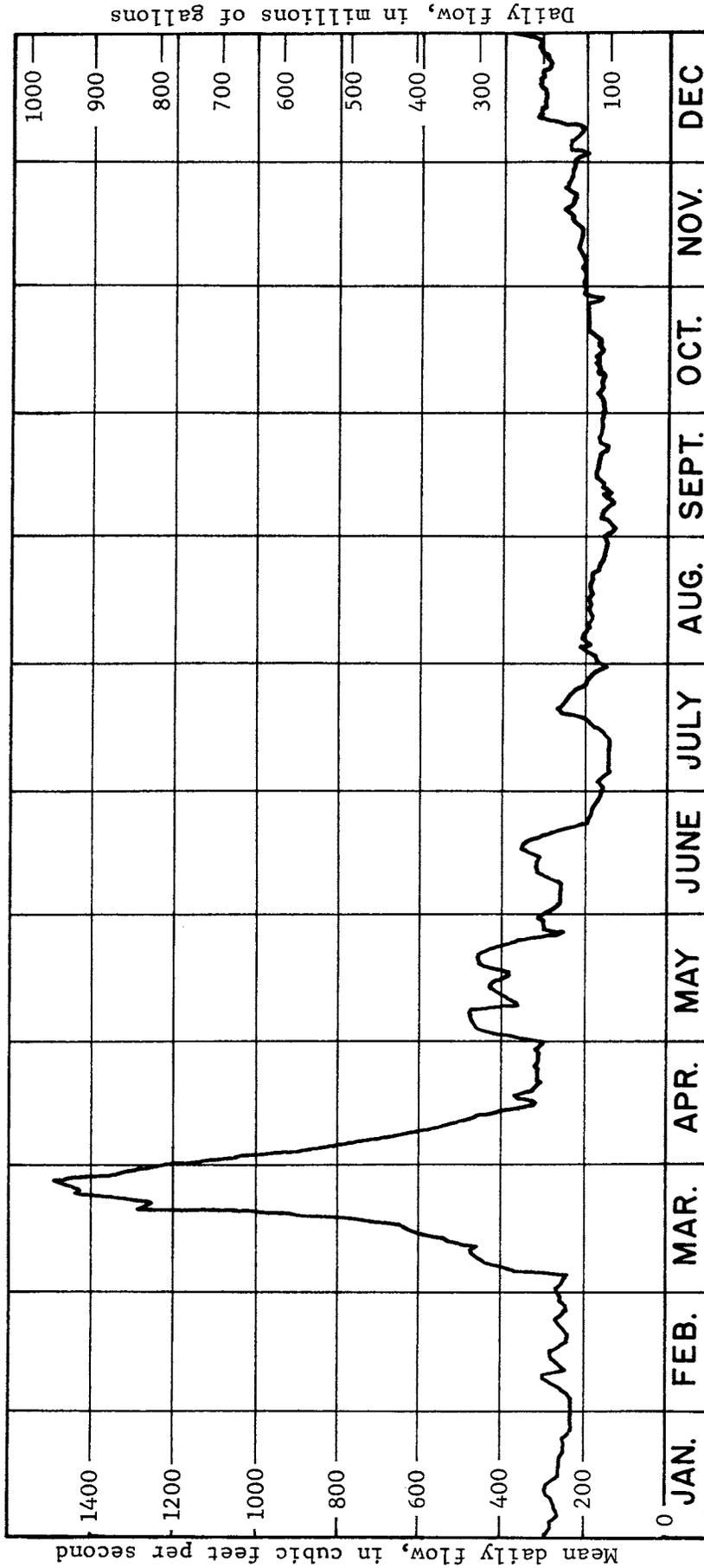


FIGURE 15.--GRAPH OF DAILY FLOW OF THE PAW PAW RIVER AT RIVERSIDE, 1963.

The river has a steady flow for most of the year.



From these measurements the mean annual 7-day minimum flow was determined for each site. An annual minimum 7-day average flow is computed by taking a year's record, finding the 7 consecutive daily figures of flow that give the smallest total, and dividing that total by 7. The mean annual 7-day minimums (table 3) were computed on the basis of the base-flow measurements and the gaging-station record for the Paw Paw River at Riverside. They are the figures of lowest annual 7-day average flow which can be expected to occur, on the average, once every two years. For example, for Red Creek (No. 15 on the location map), a flow of 6.2 cfs could be expected to occur as an annual minimum 7-day average about 25 times in the next 50 years.

The July 8, 1963 base-flow measurements were made during the lowest 7-day average flow at the Riverside gaging station for the period of record of 12 years. Thus it is reasonable to assume that the figures of flow shown for July 8 in table 3 also represent, approximately, the lowest 7-day average flows for the past 12 years at the respective locations.

Figure 14 is a map of the county showing, in a general way, the contribution of ground water to streams during their low-flow periods. It is based on table 3 and maps of surface geology and soil types.

#### Using the Annual 7-Day Minimum Flows

Where no storage is provided, the minimum flows are critical in the use of the stream as a source of water or as a diluting medium for sewage or industrial wastes. Because the July 8, 1963, measurements apparently represent rather severe drought conditions, they can be used to estimate the amount of water available for water supply or for sewage dilution during drought periods. Examples of the use of these minimum flows in solving practical problems are given in the introduction to this report.

#### Floods

Floods are a minor problem in the county. However, a knowledge of the magnitude and frequency of floods is essential for the design of structures in and across stream channels or encroaching on flood plains. Without this knowledge, a structure may be so underdesigned that it suffers destruction or frequent damage, or so overdesigned that it is unnecessarily expensive. With a knowledge of flood frequency, the design flood may be selected on a sound economic basis.

Figures 17 and 18, abstracted from a report on flood frequencies in the St. Lawrence River Basin (in preparation), permit estimation of the magnitude and frequency of floods in Van Buren County. The curves shown are based on a regionalized analysis of flood data for many gaged streams in southern Michigan. Thus, even though flood data are available for only the Paw Paw River at Riverside (just outside the county), the relationships expressed in the curves afford a means of making flood-frequency estimates at other points. Because of the limited data, however, the possibility of large errors cannot be discounted.

Table 3.--Results of base flow measurements on selected streams; mean annual 7-day minimum flows.

Explanation.--Cfs - cubic feet per second; Cfsm - cubic feet per second per square mile.  
 Note.--\*See figure 16 for locations.

Stream	* Map No.	Drainage area (sq mi)	Base flow measurements					Mean annual 7-day minimums cfsm
			Flow in Cfs					
			9-27-62	4-15-63	7-8-63	10-18-63	cfs	
Dowgiac Drain	1	21.9	17.4	30.6	14.8	15.6	19	0.87
Lake of the Woods Drain	2	13.1	2.91	9.85	3.30	9.93	3.7	.28
Osborn Drain	3	15.5	2.05	4.90	1.04	1.34	1.8	.12
Gates Drain	4	26.0	16.1	29.1	12.1	15.1	16	.62
Eagle Lake Drain	5	13.8	4.40	5.95	4.37	3.61	4.4	.32
South Branch Paw Paw River	6	52.1	31.8	52.0	25.2	32.2	32	.61
East Branch Paw Paw River	7	11.4	3.44	6.35	2.30	3.32	3.4	.30
East Branch Paw Paw River	8	31.5	17.3	23.4	16.1	16.2	18	.57
North Branch	9	30.6	26.9	-	16.8	25.7	27	.88
North Branch	10	63.5	39.5	58.0	30.8	37.6	39	.61
Brandywine Creek	11	9.05	.22	.73	.08	.09	.16	.018
Brandywine Creek	12	26.4	.79	12.3	.53	.41	1.0	.038
Brandywine Creek	13	32.2	2.99	18.1	2.87	2.28	3.7	.11
Brush Creek	14	16.0	6.66	9.36	5.62	5.29	6.4	.40
Red Creek	15	6.89	.52	2.47	.42	.46	6.2	.90
Brush Creek	16	39.9	16.7	23.6	14.5	14.4	17	.43
Mud Lake Drain	17	9.84	1.47	5.52	1.51	.88	1.6	.16
Pine Creek	18	10.7	1.63	4.53	1.95	1.56	2.0	.19
Mill Creek	19	11.3	7.64	9.70	5.81	6.03	7.0	.62
Brandywine Creek	20	16.7	.90	11.4	1.36	1.04	1.6	.096
Deerlick Creek	21	7.76	0	2.77	0	0	-	-
Black River Drain	22	23.6	6.30	22.2	6.68	7.97	8.6	.36
Haven and Max Lake Drain	23	16.8	.85	20.4	1.83	2.00	2.3	.14
Black River	24	52.3	21.1	56.0	15.9	16.2	22	.42
Maple Brook	25	12.1	1.67	6.80	1.96	1.52	2.1	.17
Black River Tributary	26	6.19	1.08	4.15	1.23	1.02	1.3	.21
Black River	27	86.0	20.4	76.3	24.6	22.9	28	.33
Black River Tributary No. 2	28	7.22	1.11	3.95	1.10	.96	1.3	.18
Cedar Creek	29	17.6	1.54	9.71	1.36	1.09	1.8	.10
Butternut Creek	30	9.31	1.67	6.30	2.32	2.04	2.4	.26
Black River	31	130	34.3	105	29.4	29.4	37	.28
Melvin Creek	32	7.10	1.24	8.73	1.11	1.04	1.5	.21
Barber Creek	33	4.76	2.67	-	2.50	2.01	-	-
Middle Fork Black River	34	151	36.3	145	37.3	33.8	44	.29
Clear Lake Outlet	35	7.43	.37	1.19	.06	.06	.16	.022

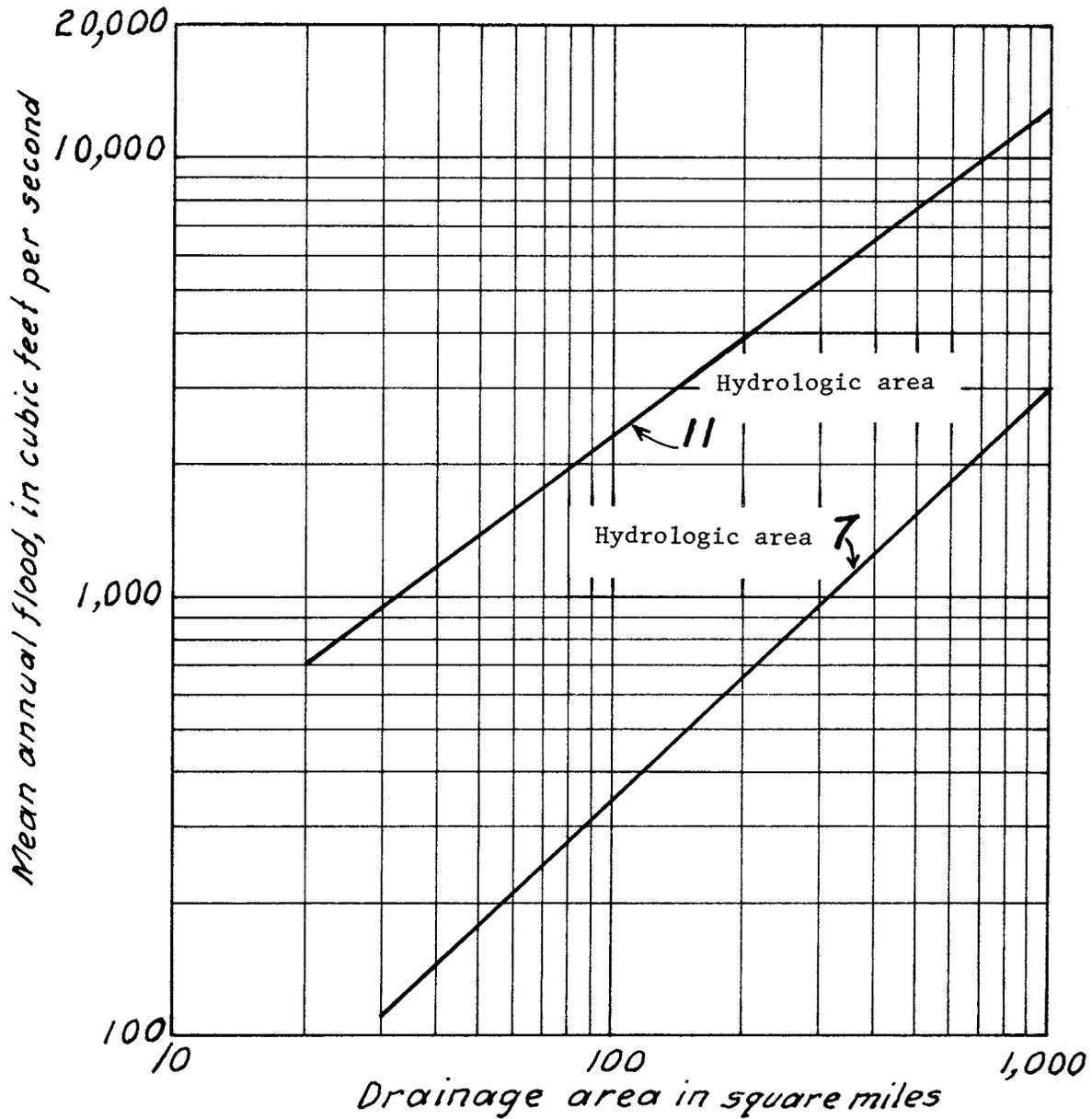


FIGURE 17.--GRAPH SHOWING VARIATION OF MEAN ANNUAL FLOOD WITH DRAINAGE AREA.  
(see figure 19 for map of flood regions)

For the same size drainage area, floods in area 11 are much greater in magnitude than in area 7.

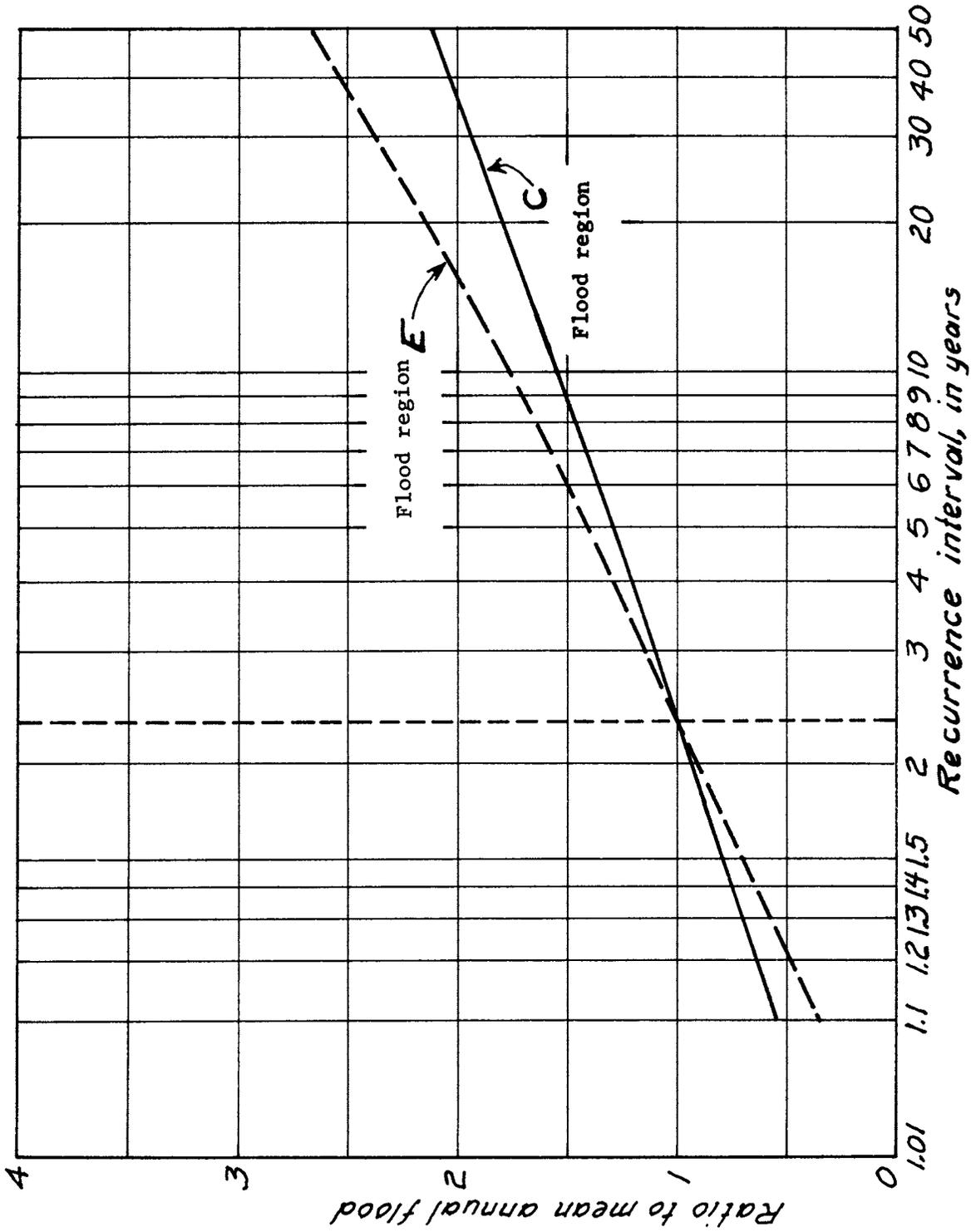
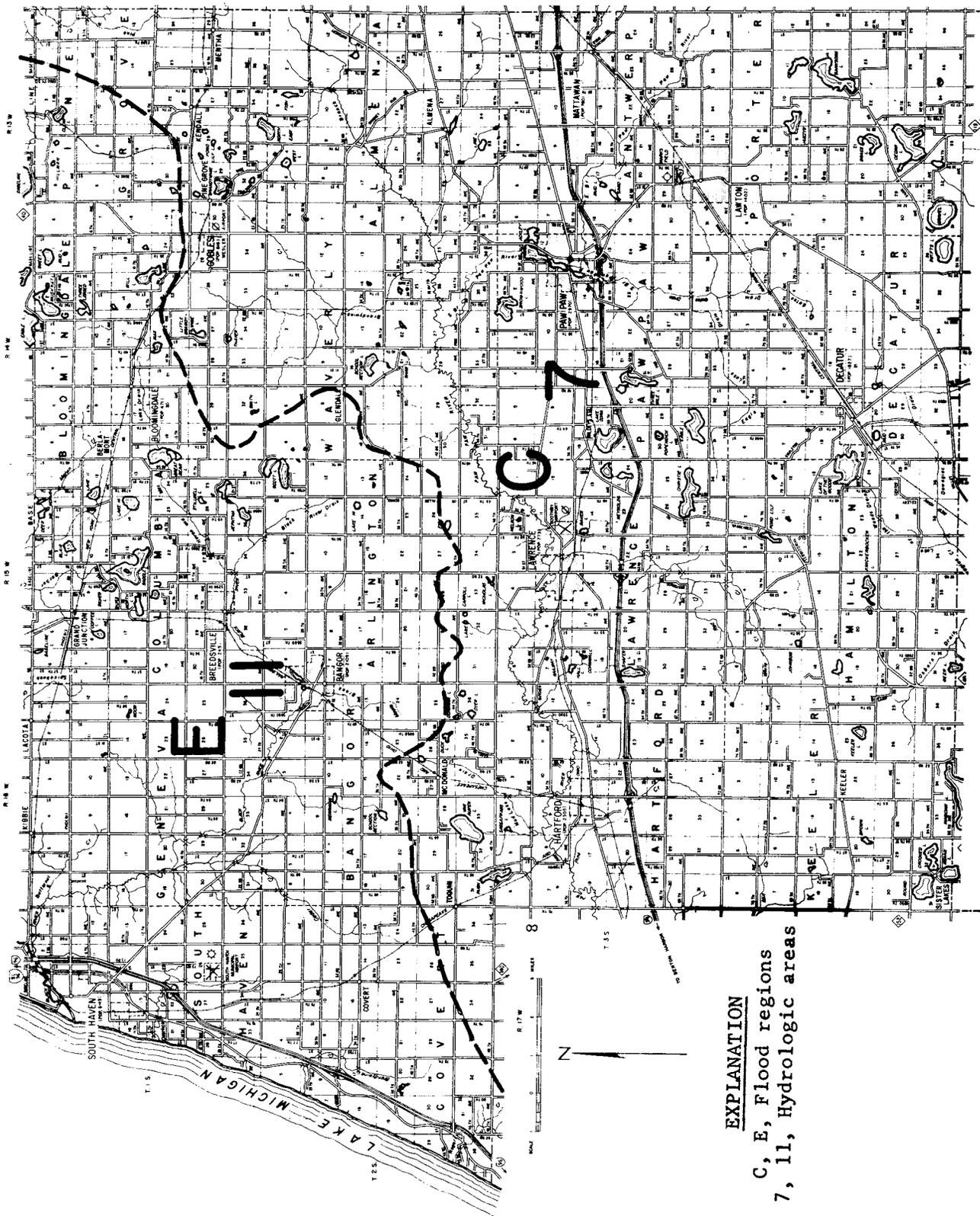


FIGURE 18.--GRAPH SHOWING FREQUENCY OF ANNUAL FLOODS.

The intersection of the vertical dashed line and the number 1 ratio line shows that the mean annual (or index flood) is expected to occur about every 2-1/3 years. From the graph then, a flood of twice this index flood can be expected about every 16 years for region E and about every 36 years for region C.



**EXPLANATION**  
 C, E, Flood regions  
 7, 11, Hydrologic areas

**FIGURE 19.--MAP SHOWING FLOOD REGIONS AND HYDROLOGIC AREAS.**  
 Boundaries of hydrologic areas and flood regions coincide in Van Buren County.

Estimates of flood frequencies as applied to this area involve the use of two curves -- the relation between size of drainage area and the magnitude of the mean annual flood (fig. 17), and the relation between recurrence interval and the ratio to mean annual flood (fig. 18). For convenient reference, the areas to which the first relation applies are called "hydrologic areas" and those to which the second relation applies are called "flood regions". Two hydrologic areas and two flood regions have been delineated for Van Buren County. Their boundaries happen to coincide in Van Buren County (fig. 19). The designations of the areas and curves are the same as those contained in the report from which they were taken.

In order to determine the magnitude of a flood of given frequency, the following procedure is suggested:

1. Determine the drainage area in square miles above the selected site (see table 2).
2. Determine from figure 19 the hydrologic area and flood region in which the site is located.
3. Determine the mean annual flood for the site from the appropriate curve in figure 17.
4. Determine the ratio to mean annual flood for the flood of the selected recurrence interval from the appropriate curve in figure 18.
5. Multiply the ratio to mean annual flood (step 4) by the mean annual flood (step 3) to obtain the desired flood magnitude.

A complete flood-frequency curve for any site can be obtained by repeating steps 4 and 5 for various recurrence intervals.

As an example, assume that the magnitude of the 30-year flood for the Paw Paw River at Lawrence is desired. The drainage area at the site is 265 square miles (table 2). From figure 19, the site is in hydrologic area 7 and flood region C. From figure 17, the mean annual flood is 850 cfs (cubic feet per second). From figure 18, the ratio of the 30-year flood to the mean annual flood is 1.94. Therefore, the magnitude of the 30-year flood is  $1.94 \times 850 \text{ cfs} = 1,650 \text{ cfs}$ . The reverse procedure may be used to determine the frequency of a flood of known discharge at a given site.

The highest flood of each year of record, the annual flood, was used in the regional flood-frequency analyses. The recurrence interval then must be interpreted as the average interval of time in years during which a given flood is equaled or exceeded once as an annual maximum. No periodicity is implied. For example, the 30-year flood will not be equaled or exceeded at exactly 30-year intervals, but chances are that 4 floods of equal or greater magnitude will occur in 120 years. Or, in other words, there is one chance in 30 that a flood of equal or greater magnitude will occur in any one year. The curves shown do not apply to streams that are materially affected by man-made regulation or diversion.

Inspection of the curves in figures 17 and 18 reveals that the northwestern third of the county has a greater flood potential than the southeastern two-thirds. This is believed to be largely due to the greater preponderance of relatively impermeable soils and drift in the northwestern part of the county.

## QUALITY OF WATER

Now that the occurrence and availability of the water resources have been described, the next question is how good is the water for the many and varied uses required in the county?

### The Source and Significance of Dissolved Minerals in the County's Water Supplies

The dissolved materials in the water in streams, lakes, and ground-water reservoirs are derived chiefly from the earth materials with which the water comes in contact. The earth materials over or through which the water moves include the soils and unconsolidated sands, gravels, silts, and clays of the glacial drift and consolidated shale, sandstone, and limestone of the bedrock. The soils and glacial materials are the most important because almost all circulation of fresh water passes over or through them. Particles of limestone and dolomite together comprise about 50 percent of the material in the gravels and 20 percent of the material in the sands of the glacial drift. The carbonates of calcium and magnesium constitute the most abundant source of soluble material in the area of free circulation, and these are the most abundant dissolved materials in almost all natural waters in the county.

These dissolved materials affect the usability of the water in various ways. The source and significance of the major dissolved constituents and of important physical properties of water are summarized on the following page.

### Suitability of the County's Water for Various Uses

Water from most wells, streams, and lakes in the county is satisfactory for most intended uses, although water-treatment may be desirable or necessary in some instances. The major quality problems are excessive hardness and high iron content in some sources. Water from most wells and streams is hard to very hard, but water from many lakes is relatively soft. Many wells produce water containing more iron than is desirable for most uses, but water in streams and lakes is almost entirely free of dissolved iron. Fortunately, both hardness and iron can be removed from water by standard home water conditioners. High chlorides and high nitrates are problems in a few small areas of the county.

The significance of the dissolved mineral contents and the physical properties of water are explained.

Constituent or physical property	Source or cause	Significance
Silica (SiO <sub>2</sub> ) .....	Dissolved from practically all rocks and soils, usually in small amounts--1-30 ppm. High concentrations, as much as 100 ppm, generally occur in highly alkaline waters.	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 ppm stains laundry and utensils reddish brown. Objectionable for food processing, beverages, dyeing, bleaching, ice manufacture, brewing and other processes. Federal drinking water standards state that iron and manganese together should not exceed 0.3 ppm. Larger quantities cause unpleasant taste and favor growth of iron bacteria.
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. Magnesium is present in large quantities in sea water.	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, sea water, some industrial brines, and sewage.	Large amounts as chlorides give a salty taste. 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 <sub>3</sub> ) and Carbonate (CO <sub>3</sub> ) .....	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 <sub>4</sub> ) .....	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Usually present in mine waters and 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. Some calcium sulfate is considered beneficial in the brewing process. Federal drinking water standards recommend that the sulfate content should not exceed 250 ppm.
Chloride (Cl) .....	Dissolved from rocks and soils. Present in sewage and found in large amounts in ancient brines, sea water, and industrial brines.	In large amounts chloride salts give salty taste to water. In large quantities increases the corrosiveness of water. Federal drinking water standards recommend that the chloride content should not exceed 250 ppm.
Nitrate (NO <sub>3</sub> ) .....	Decaying organic matter, sewage, and nitrates in soil.	Concentrations much greater than the local average may suggest pollution. There is evidence that more than about 45 ppm of nitrate (NO <sub>3</sub> ) may cause a type of methemoglobinemia in infants, sometimes fatal. Water of high nitrate content should not be used in baby feeding (Maxcy, 1950, p. 265, App. D). 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.
Dissolved solids .....	Chiefly mineral constituents dissolved from rocks and soils. Includes any organic matter and some water of crystallization.	Federal drinking water standards recommend that the dissolved solids should not exceed 500 ppm. Waters containing more than 1,000 ppm of dissolved solids are unsuitable for many purposes.
Hardness as CaCO <sub>3</sub> .....	In most waters nearly all the hardness is due to calcium and magnesium.	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 non-carbonate hardness. Waters of hardness as much as 60 ppm are considered soft; 61 to 120 ppm, moderately hard; 121 to 200 ppm, hard; more than 200 ppm, very hard.
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 electric 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.

## The Quality of the Water from Wells

Ground water in Van Buren County generally is hard to very hard and contains undesirable amounts of iron, but with standard treatment it can be made suitable for most uses. Chemical analyses of samples of water from wells are listed by townships in table 4. The dissolved materials reported in this table include all the major elements normally in solution in natural waters, but only a few of these are likely to cause trouble to the water user. In addition to the laboratory analyses, field analyses of iron, hardness, and chlorides are given in the tables of well data that adjoin each of the township water availability maps in appendix A. Most of these were made in the field, and the quantities reported are subject to greater error than those determined in the laboratory.

In Van Buren County the dissolved materials in ground water that cause most problems are calcium and magnesium (major source of hardness), iron, chlorides, and nitrates. Let us consider each of these in some detail.

### Hardness

Hardness of water is a problem that is common to most drift wells in Van Buren County. All but a very few wells in Van Buren County produce water that is hard to very hard, and as a result, water-softeners are in rather general use. The range in hardness of water from wells is shown on the map, figure 20. There are several areas where most wells produce water with hardness greater than 300 ppm. Most of these wells are in or near moraines, but some are in till plains, outwash plains, and lake plains and drainageways. There appears to be no correlation of hardness with depth of well.

### Iron

Iron is another problem in water obtained from most drift wells in Van Buren County. About two-thirds of the water samples from wells in Van Buren County contained more than 0.3 ppm of iron and a few contained more than 2 ppm. Most of the iron determinations were made with field equipment at the well site and are listed in the tables of wells. Figure 21 shows areas where water samples containing more than 1 ppm of iron were collected. The occurrence of iron appears to be unpredictable, and high iron concentrations may be found almost anywhere in the county. Neither is there any apparent correlation of iron content with depth of well. Fortunately, iron is relatively easy to remove from water, and iron-removal conditioners for domestic use are available on the market.

Table 4.--Chemical analyses of water from wells.

Analyses in parts per million except for specific conductance and pH values.  
Conductance is in micromhos at 25° Centigrade.

Analyst: MDH - Michigan Department of Health; USGS - U. S. Geological Survey

Location T & sec.	Owner	Depth (feet)	Diam (inches)	Use	Month and year sampled	Analyst	Silica	Iron	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride	Dissolved solids	Hardness (as calcium carbonate)	Specific conductance	pH
ANTWERP TOWNSHIP																			
SW NW 13	Glaser-Grandall Co.	119	10	Ind	11-62	USGS			42	15	2.8	0.6	174	23	4.0	186	167	323	7.8
SW SE 29	Lawton Village	105	12	Mun	12-58	MDH	10	0.8	62	26	6	1.2	258	53	6	290	260	500	7.3
SE SW 29	Lawton Village	125	36	Mun	3-62	MDH	12	.5	70	26	13	1.4	248	75	18	350	280	600	7.6
SW NE 29	E. Sanders	31	2	Dom	10-63	USGS	6.6		11	2.0	1.3	.8	31	12	2.5	54	36	83	7.0
NW SE 32	Lawton Village	110	12	Mun	6-58	MDH	11	0	60	23	3.0	.5	268	35	0	262	245	450	8.0
NW NE 32	Do.	39	18		6-58	MDH	4	0	62	21	5.8	5.5	254	35	7	298	240	500	7.5
NW NE 32	Do.	39	24	Mun	12-42	MDH	8.8	tr	61	18		(8.3)	220	42	15	270	228		
ARLINGTON TOWNSHIP																			
SE SE 1	K. Smidt	86	2	Dom	10-63	USGS			62	20	6.7	1.3	232	48	11	265	237	550	
NW NW 7	Du-Well Metal Prod. Inc.	80	8	Ind	10-63	USGS	12		62	20	6.7	1.3	232	48	11	265	237	482	6.9
NE SW 7	Village of Bangor	64	8	Mun	12-58	MDH	8	.25	55	24	2.3	.6	232	38	2	252	235	450	7.6
NE SW 7	Village of Bangor	60	12	Mun	11-62	MDH			64	24	3.7	1.1	265	38	7	294	260	475	7.6
NW SW 13	J. Zirbel	30		Dom, Stk	11-63	USGS		0.73	64	22	9.5	1.6	318	7.0	16	269	250	513	7.3
SW NW 24	F. Gurnsey	118		Dom, Stk	11-63	USGS	15		79	25	4.2	.8	330	38	7.0	316	300	556	6.9
SW NW 29	G. Mahr	85	2	Dom, Stk	11-63	USGS	15		105	57	9.6	2.0	530	67	9.0	516	497	900	6.8
SW NW 31	Donavan Lake Farms	112	2	Dom	11-63	USGS	13		71	30	5.2	1.0	360	27	1.0	312	301	567	6.8
NE SE 33	F. Nicholas	60		Dom	11-63	USGS	15		86	38	7.1	1.5	424	40	1.0	388	371	683	6.9
BANGOR TOWNSHIP																			
NE SE 1	Village of Bangor	75	12	Mun	6-58	MDH	13	.5	54	19	17	.9	244	22	18	266	215	460	7.9
NW SE 11	R. Funk (1)	64	2	Dom, Stk	12-63	USGS			61	27	3.5	1.6	250	41	6.2	284	263	506	7.1
NE SE 12	Village of Bangor (2)	60	8	Mun	6-58	MDH	10	0	74	22	8.3	3.0	266	55	12	350	275	560	7.9
SW SW 14	H. Watkins	38	2	Dom, Stk	12-63	USGS			78	49	35	5.4	295	174	52	573	396	877	7.5
SE NE 17	P. Overton (3)	40	2	Dom, Stk	11-63	USGS		.8	187	59	48	51	560	97	141	996	710	1,680	6.9
SW SE 24	P. Hardin	35	2	Dom, Stk	12-63	USGS			88	41	6.4	1.1	425	50	5.0	427	388	716	6.9
BLOOMINGDALE TOWNSHIP																			
NE NW 12	V. Healy	20	1k	Dom	10-63	USGS			92	31	14	1.3	212	37	136	465	357	808	7.2
NE SE 14	Mrs. J. Vavrina	90	2	Dom	10-63	USGS	12		114	31	100	1.2	294	13	282	708	412	1,320	6.8
SW SE 15	D. Greenhouse	140	8	Irrig	10-63	USGS			65	20	3.5	.7	287	18	8.0	280	244	472	7.2
SE NE 15	R. Esler	30	2	Dom	10-63	USGS	11		60	16	17	.8	226	40	38	281	216	532	6.9
SW NW 16	Bloomington High Sch.	127	6	Pub	10-63	USGS	15		106	36	74	2.2	300	13	238	604	413	1,200	6.9
NE NW 19	R. Schendel	187	2	Dom	10-63	USGS	16		26	28	20	1.4	220	14	30	220	180	429	7.6
SE SW 20	J. Kopterski	75	2	Dom	10-63	USGS	17		78	49	6.5	1.6	472	31	1.0	376	396	722	7.0
COLUMBIA TOWNSHIP																			
SE SW 3	B. Graney	44	2	Pub	10-63	USGS			24	10	2.3	.5	92	21	3.0	104	101	196	7.5
SE SE 9	Covey	30		Dom	10-63	USGS			85	34	16	.7	364	47	38	416	352	720	6.8
NE NE 11	H. Lucas	68		Dom	10-63	USGS			71	25	11	.9	332	26	16	336	280	581	7.0
NE NW 26	H. Ashbrook	110		Dom	10-63	USGS			64	29	8.4	1.1	356	12	1.0	307	279	542	7.1
SW SW 33	D. Palmer	70		Dom	10-63	USGS			68	33	6.4	1.1	360	31	2.0	341	305	582	7.0
DECATUR TOWNSHIP																			
SE NW 3	P. Hoffman	57	2	Dom	8-63	USGS			35	13	2.4	.6	150	14	2.5	152	141	271	7.6
NW SW 14	Mroczek	25	2	Dom	8-63	USGS			171	62	6.8	1.5	308	413	8.0	904	682	1,130	7.4
NE NW 17	E. Knoska	56	2	Dom	8-63	USGS			75	32	7.6	4.5	292	63	23	369	319	628	7.3
NE NW 19	Decatur Village	111	12	Mun	6-58	MDH	10	.0	52	17	6.4	.9	192	47	4	262	200	420	7.8
NW NW 20	Decatur Village	120	12	Mun	12-58	MDH	7	1.6	48	20	4.6	.9	200	35	4	222	200	400	7.7
SW SW 29	J. Feenstra	135	2	Dom, Stk	8-63	USGS			45	24	25	1.8	280	1.6	22	272	211	494	7.4
SW SW 29	J. Feenstra	35	1k	Dom	8-63	USGS			144	51	18	2.0	288	324	18	770	570	1,030	7.2
GENEVA TOWNSHIP																			
NW SE 1	I. Lewis	30	2	Dom	11-63	USGS			127	41	12	1.2	375	129	64	558	486	960	7.0
SW SE 17	I. Bennett	43	4	Irrig	11-63	USGS			73	42	18	1.8	478	5.2	3.8	385	355	718	7.0
SE SW 20	S. Sollitt	180	4	Dom, Stk	11-63	USGS			79	28	513	10	220	32	870	1,640	312	3,060	6.8
NW NE 24	E. Empson	22	1k	Dom	11-63	USGS			36	6.8	18	4.0	38	100	29	218	118	386	6.7
SE SW 33	D. Funk	50	2	Dom, Ind	11-63	USGS			110	44	12	1.4	300	203	29	558	456	869	7.3
HAMILTON TOWNSHIP																			
SW NW 4	H. Fassett	97	2	Dom	8-63	USGS			48	23	5.8	.7	268	9.6	3.0	231	215	423	7.4
NW SW 31	Urlick	34	1k	Dom	8-63	USGS			60	22	2.5	.2	294	2.0	.5	273	240	444	7.1
HARTFORD TOWNSHIP																			
SE SE 2	P. Evans	150	2		7-63	USGS			79	38	3.8	8.3	382	44	6.0	393	353	680	7.4
SW SW 3	D. Childs	60		Ind	7-63	USGS			77	36	5.0	.7	346	65	2.0	390	340	628	7.4
NW NW 5	W. Knebel	10		Dom	10-63	USGS			34	22	4.0	.7	176	38	4.0	204	176	344	7.3
NE NE 6	G. Bessler	65	4	Pub	7-63	USGS			75	36	3.2	.8	340	62	5.0	366	335	615	7.5
NE NW 10	V. Kaucher	18	2	Dom, Spr	7-63	USGS			56	26	2.7	.4	265	32	1.0	260	247	464	7.3
NE SE 16	Hartford	95	12	Mun	7-58	MDH	12	.8	62	23	6.7	2.0	254	45	5	314	250	500	7.6
NE SE 16	Hartford	93	12	Mun	7-58	MDH	14	.8	64	24	11	1.1	293	18	8	312	260	525	7.6
SE SE 16	Hartford	108	12		7-58	MDH	15	1.2	68	24	10	.9	332	12	7	288	270	540	7.8
SE SW 30	N. Smith				7-63	USGS			73	34	5.7	.9	350	43	5.0	358	322	604	7.5
SE SW 34	D. Rittase			Dom	7-63	USGS			67	31	4.3	.6	325	39	4.0	320	295	552	7.4
KEELER TOWNSHIP																			
SW SW 22	Burnette Farms Pack. Co.	127	10	Ind	7-63	USGS			56	25	3.8	.7	262	30	6.0	263	243	465	7.6
NW NW 27	G. Van Tyne	65	2		7-63	USGS			21	5.8	3.3	1.0	98	1.6	3.0	106	76	162	7.4
LAWRENCE TOWNSHIP																			
SE SE 9	Lawrence	74	12		11-55	MDH	11	.65	61	24.4		(7.3)	280	31	7	296	252	520	7.7
SE SE 9	Lawrence Village	74	12		7-58	MDH	13	.7	64	22	9.0	.8	283	33	5	286	250	500	7.7
SE SE 13	M. Reynolds	73	2	Dom	7-63	USGS			69	19	2.0	1.1	300	4.4	2.0	259	250	446	7.6
SE NE 15	C. Sill	56	3	Dom, Stk	7-63	USGS			65	25	3.9	1.4	324	7.2	1.5	277	265	481	7.3
SE SE 17	Dolce Brothers	58	2	Dom, Spr	7-63	USGS			74	30	7.0	1.5	296	41	20	341	308	586	7.2

Table 4.--Chemical analyses of water from wells.--Continued.

Location ¼ ¼ sec.	Owner	Depth (feet)	Diam (inches)	Use	Month and year sampled	Analyst	Silica	Iron	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride	Dissolved solids	Hardness (as calcium carbonate)	Specific conductance	pH
PAW PAW TOWNSHIP																			
SW SW 12	Village of Paw Paw	95	12	Mun	3-62	MDH	10	.8	62	22	4.6	1.4	254	38	5	278	245	500	7.6
NE SE 11	Village of Paw Paw	110	34	Mun	3-62	MDH	13	1.4	60	22	13	.8	275	24	10	280	240	500	7.6
SW SW 12	Village of Paw Paw	108	16	Mun	6-58	MDH	13	.2	56	17	10	1.0	229	30	11	264	210	450	7.6
SW SW 12	Village of Paw Paw	62	34	Mun	6-58	MDH	13	.3	58	21	13	.9	256	24	15	286	230	490	7.6
NE NE 28	G. Ampey	46	2	Dom	7-63	USGS		0.11	86	32	4.5	1.4	296	28	9.0	393	346	667	7.1
NE SE 30	M. Hood	60	3	Dom	7-63	USGS		1.8	91	35	3.6	8.4	380	63	6.0	426	371	680	7.2
NW SE 32	C. Lachtman	100	2	Dom	7-63	USGS		2.9	62	24	3.0	1.1	276	27	2.0	284	253	466	7.2
NE NW 33	N. Hood	70	3	Dom,Stk	7-63	USGS		1.8	53	20	3.0	1.4	220	35	3.0	242	214	404	7.3
NW SE 36	J. Nagy	27	1½	Dom	7-63	USGS		5.2	99	33	5.2	3.4	304	129	8.0	460	383	698	7.3
PINE GROVE TOWNSHIP																			
SE NE 6	H. Siegrist	90		Dom	10-63	USGS			71	23	6.8	.9	328	13	4.0	295	272	513	6.8
SW SE 14	H. Bricker	52		Dom,Stk	10-63	USGS			103	36	14	3.3	410	55	18	473	405	791	6.9
NW NW 30	City of Gobles # 1	105	8	Mun	8-39	MDH	7.2		63	29			271	36	10	292	272		
NW NW 30	City of Gobles # 2	124½		Mun	12-58	MDH	8	.2	52	26	3.2	.5	228	43	5	244	235	450	7.9
NW NW 30	City of Gobles # 3	110	10	Mun	12-58	MDH	9	.0	66	30	8	.8	273	50	8	350	290	560	7.5
SW SW 31	C. Stratton	36		Dom,Spr	10-63	USGS			45	14	14	4.8	136	49	9.0	261	170	423	6.9
SW SW 35	F. Nash	23		Dom	10-63	USGS			97	42	23	7.3	345	30	39	520	415	895	6.9
SE NW 36	Mentha Plantation Inc.	90		Ind	10-63	USGS	12	.46	64	27	6.5	.9	298	38	8.0	304	271	530	7.0
PORTER TOWNSHIP																			
NW NE 26	M. Wellburn	73	2	Dom,Stk	7-63	USGS			96	36	12	1.7	364	40	18	449	388	759	7.2
SOUTH HAVEN TOWNSHIP																			
NW SE 3	Mich. Fruit Cannery(4)	36-42	8	Ind	12-63	USGS			81	26	22	2.2	300	70	31	399	309	661	6.9
NE NW 13	A. Servatius	90		Dom,Ind	12-63	USGS			26	6.1	51	1.2	242	1.4	1.2	213	90	376	7.0
WAVERLY TOWNSHIP																			
SW SW 10	P. Groth	60		Dom,Stk	10-63	USGS			75	31	14	.9	376	34	5.0	353	315	622	6.8
SE SE 12	L. Ringle	184		Dom	10-63	USGS			58	19	8.0	.8	258	25	7.0	264	223	450	6.9
SW SE 13	C. Janosek			Dom	10-63	USGS			73	30	22	79	254	89	50	611	306	929	6.8
NW NW 32	W. Fleeman	48		Dom	10-63	USGS			53	20	10	.7	264	16	10	257	214	446	6.9
NE NW 36	E. Millek	35		Dom	10-63	USGS			35	9.0	2.8	.5	128	23	3.0	156	125	256	6.7

- (1) Nitrate - 14 ppm  
(2) Nitrate - 2  
(3) Nitrate - 179  
(4) Composite sample of 3 production wells

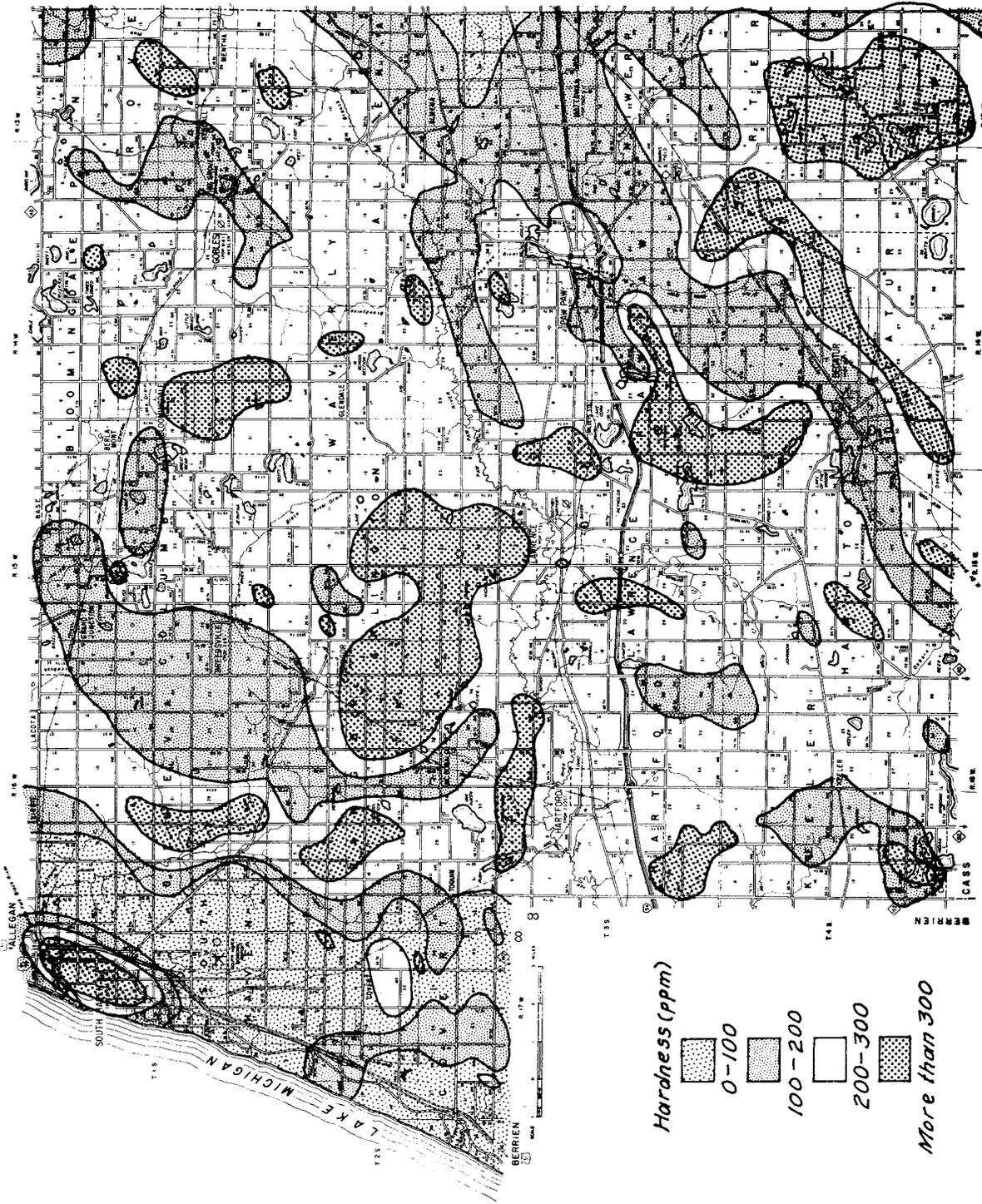


FIGURE 20.--MAP SHOWING DISTRIBUTION OF HARDNESS IN GROUND WATER.

Most of the ground water in the county is hard to very hard except in the northwestern part.



## Chlorides

Concentrations of chlorides in water from drift wells in Van Buren County are high enough in a few places to cause the water to taste "flat" or "salty". Areas where chlorides in ground water may be greater than 250 ppm are shown on the map, figure 22. These areas are small and generally are attributed to local contamination from oil field operations or industrial wastes. The occurrence of salty water is by no means uniform even in contaminated areas, and one well may produce water too salty for use while another nearby may produce fresh water. It should be kept in mind that salty water may be encountered anywhere in the county in the bedrock underlying the drift. Most drift wells in Van Buren County produce water containing less than 20 ppm of chlorides, but there are several areas where chlorides in well water are greater than 30 ppm (fig. 22). Water containing chlorides in the range 30 to 250 ppm is satisfactory for domestic use if other quality requirements are met. Nevertheless, chloride over 30 ppm from shallow wells may serve as a warning of contamination from oil field operations, industrial wastes, or from sewage.

## Nitrates

A few wells in Van Buren County have produced water containing concentrations of nitrate great enough to cause illness of infants; at least one case has occurred in the county. Fortunately the cause was determined before serious harm was done to the child. The wells where nitrate concentrations are greater than the local average are shown on the map, figure 23. Most wells in these areas produce water that is satisfactory, but an occasional check of nitrate content and sanitary quality is recommended. Generally the shallower wells are more likely to produce water high in nitrates than the deeper wells.

### The Quality of the Water From Streams

During periods of base flow the water in the streams of Van Buren County is very similar in quality to the water from wells. This is to be expected because at base flow all the water in the streams comes from ground-water discharge. Analyses of 35 samples taken at base flow are listed in table 5. Like the ground water, the stream water at base flow is hard to very hard with calcium, magnesium, and bicarbonate making up most of the dissolved materials. The range in concentration of dissolved substances is less in the stream-water samples than in the ground-water samples. This is attributed to the mixing of ground-water discharge from various sources in the stream channel. The few samples of stream water that contained high concentrations of chlorides are attributed to saline water associated with oil production.

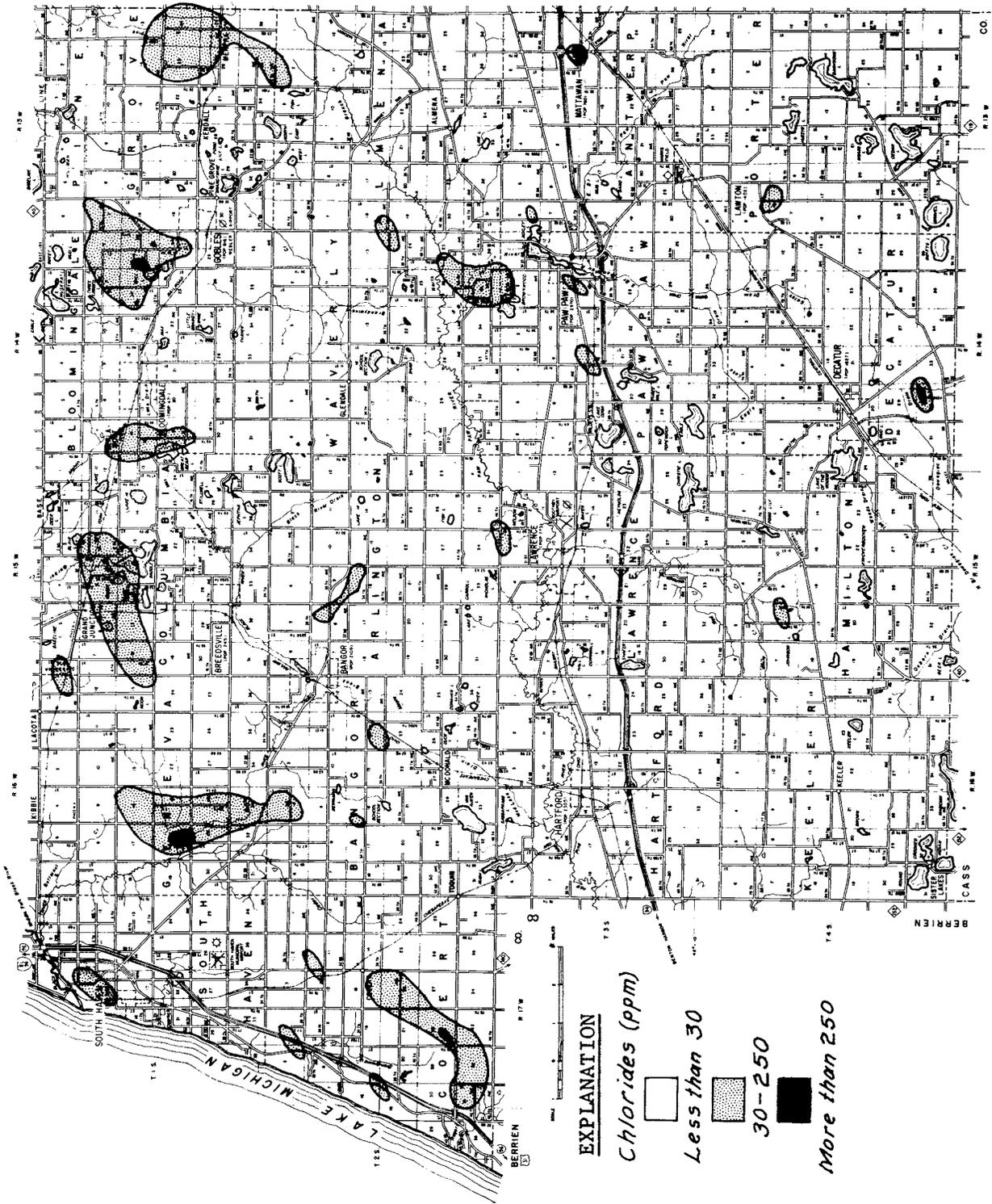


FIGURE 22.--MAP SHOWING DISTRIBUTION OF CHLORIDE IN GROUND WATER.

Chloride is a problem only in localized areas and is mostly the result of contamination from oil wells, industrial wastes, and mineralized water from the bedrock underlying the drift.



Table 5.--Chemical analyses of water from streams.

Field number	Date of collection	Temperature (°F)	Silica (SiO <sub>2</sub> )	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO <sub>3</sub> )	Carbonate (CO <sub>3</sub> )	Sulfate (SO <sub>4</sub> )	Chloride (Cl)	Fluoride (F)	Nitrate (NO <sub>3</sub> )	Dissolved solids (residue at 180° C)	Hardness as CaCO <sub>3</sub>		Specific conductance (micro-mhos at 25° C)	pH
																	Ca, Mg	Non-carbonate		
Dowagiac drain at Decatur, Mich.																				
1	July 8, 1963..	70				69	28	6.8	0.9	258		84				345	287	76	552	7.4
Lake of the Woods drain near Decatur, Mich.																				
2	July 8, 1963..	70				65	23	6.3	1.6	210		81				317	257	84	497	7.2
Osborn drain near Keeler, Mich.																				
3	July 8, 1963..	67				48	18	3.7	1.0	202		27				216	194	28	377	7.2
Gates drain near Lawton, Mich.																				
4	July 8, 1963..	--				70	30	8.3	1.3	252		81		18		361	298	92	574	7.9
Eagle Lake drain near Lawton, Mich.																				
5	July 8, 1963..	--				59	22	5.3	.6	258		34		6.0		277	238	26	458	7.8
South Branch Paw Paw River near Paw Paw, Mich.																				
6	July 8, 1963..	--				67	26	7.3	.9	260		56		11		333	274	61	528	8.0
East Branch Paw Paw River near Lawton, Mich.																				
7	July 8, 1963..	72				52	24	3.7	.9	258		26		2.0		248	228	16	432	7.2
East Branch Paw Paw River at Paw Paw, Mich.																				
8	July 8, 1963..	--				44	19	5.2	.7	212		22		6.0		207	188	14	371	7.3
South Branch Paw Paw River near Paw Paw, Mich.																				
8-a	July 8, 1963..	--				54	23	7.3	1.1	205		12		12		274	229	41	448	8.6
North Branch near Gobles, Mich.																				
9	July 9, 1963..	62				45	18	4.4	.4	215		18		5.0		209	186	10	374	7.2
North Branch near Paw Paw, Mich. (Below bridge)																				
9-a	Feb. 6, 1963..	--				56	19	6.7	.9	226		34		7.0		256	218	32	434	7.2
North Branch near Paw Paw, Mich. (at center)																				
10	July 8, 1963..	--				46	18	5.1	.7	212		22		6.0		215	189	15	375	7.4
Brandywine Creek near Gobles, Mich. (At bridge)																				
11	July 9, 1963	--				51	21	2.7	.4	231		28		2.0		232	214	24	398	7.6
Brandywine Creek near Gobles, Mich. (200 ft. above gage)																				
12	July 9, 1963	--				65	26	4.4	.9	282		41		5.0		296	269	38	491	7.5

Table 5.--Chemical analyses of water from streams.--Continued.

(Chemical analyses, in parts per million)

Field number	Date of collection	Temperature (*F)	Silica (SiO <sub>2</sub> )	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO <sub>3</sub> )	Carbonate (CO <sub>3</sub> )	Sulfate (SO <sub>4</sub> )	Chloride (Cl)	Fluoride (F)	Nitrate (NO <sub>3</sub> )	Dissolved solids (residue at 180° C)	Hardness as CaCO <sub>3</sub>		Specific conductance (micro-mhos at 25° C)	pH
																	Ca, Mg	Non-carbonate		
13	July 9, 1963..	55				55	22	4.8	0.7	248		30	7.0			252	228	24	438	7.4
Brandywine Creek near Paw Paw, Mich.																				
Paw Paw River near Lawrence, Mich.																				
13-a	July 8, 1963..	--				52	21	6.1	1.1	222		39	9.0			268	216	34	431	7.7
Brush Creek at Lawrence, Mich. (At center 72nd Ave.)																				
14	July 9, 1963..	54				43	18	4.5	.9	200		22	6.0			216	181	17	360	7.9
Red Creek at Lawrence, Mich.																				
15	July 9, 1963..	58				63	25	4.8	1.5	282		32	4.5			296	260	29	488	7.8
Brush Creek at Lawrence, Mich. (At bridge on Hwy. 12)																				
16	July 8, 1963..	64				49	20	6.0	.7	238		19	6.0			242	204	9	404	8.0
Paw Paw River at Lawrence, Mich. (At bridge on 54th St.)																				
16-a	July 8, 1963..	68				52	23	6.7	1.1	230		34	10			258	224	36	441	7.8
Paw Paw River near Hartford, Mich.																				
16-b	July 8, 1963..	71				54	22	6.3	.9	232		38	10			267	225	35	444	7.8
Paw Paw River at Hartford, Mich.																				
16-c	July 8, 1963..	--				52	23	7.0	1.2	232		38	10			288	224	34	446	8.0
Mud Lake drain near Hartford, Mich.																				
17	July 8, 1963..	--				60	26	7.1	1.0	248		58	8.0			324	257	54	494	8.0
Pine Creek near Hartford, Mich.																				
17-a	May 2, 1963...	58				72	21	6.2	.6	232		60	14			315	266	76	508	8.2
Pine Creek at Hartford, Mich.																				
18	July 8, 1963..	68				52	22	4.8	1.2	238		35	6.0			282	220	25	432	7.9
Mill Creek near Hartford, Mich.																				
18-a	May 2, 1963...	59				50	16	6.2	.5	198		20	9.5			217	191	29	368	7.9
Mill Creek at Hartford, Mich.																				
19	July 8, 1963..	66				36	20	3.3	.8	185		23	4.0			219	172	20	335	8.2
Brandywine Creek near Covert, Mich.																				
20	July 8, 1963..	62				25	7.8	3.5	1.2	95		18	5.0			164	94	16	205	7.9

Table 5.--Chemical analyses of water from streams.--Continued.

(Chemical analyses, in parts per million)

Field number	Date of collection	Temperature (* F)	Silica (SiO <sub>2</sub> )	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO <sub>3</sub> )	Carbonate (CO <sub>3</sub> )	Sulfate (SO <sub>4</sub> )	Chloride (Cl)	Fluoride (F)	Nitrate (NO <sub>3</sub> )	Dissolved solids (residue at 180°C)	Hardness as CaCO <sub>3</sub>		Specific conductance (micro-mhos at 25°C)	pH
																	Ca	Mg		
21	July 8, 1963..	62				60	23	19	2.8	272		29	26			311	244	21	542	7.4
Deerlick Creek near South Haven, Mich.																				
22	July 8, 1963..	59				57	30	16	1.2	312		19	20			311	266	10	552	7.7
Black River drain near Bangor, Mich.																				
22-a	Oct. 24, 1963.	--				68	26	28	1.4	310		15	58			369	277	22	669	7.1
Haven and Max Lake drain at Bloomingdale, Mich.																				
23	July 8, 1963..	73				58	32	106	2.4	200		29	215			552	276	111	1,070	7.5
Haven and Max Lake drain near Bangor, Mich.																				
24	July 8, 1963..	72				50	26	25	1.8	250		20	40			306	232	27	555	7.4
Black River at Bangor, Mich.																				
25	July 8, 1963..	66				62	28	9.4	1.4	282		37	12			315	270	38	531	7.7
Maple Brook at Bangor, Mich.																				
26	July 9, 1963..	53				64	30	18	1.3	295		38	26			354	283	41	598	7.6
Black River tributary No. 1, near Bangor, Mich.																				
27	July 9, 1963..	64				52	26	20	1.5	250	15	24	34			309	237	23	523	8.4
Black River near South Haven, Mich. (At bridge on 16th Ave.)																				
28	July 9, 1963..	62				47	21	10	.9	238		15	11			249	204	8	420	7.7
Black River tributary No. 2, near South Haven, Mich.																				
29	July 9, 1963..	--				40	16	7.2	1.1	182		23	11			204	166	17	353	7.8
Cedar Creek near South Haven, Mich.																				
30	July 9, 1963..	53				39	13	6.1	1.3	132		45	11			209	151	43	330	8.0
Butternut Creek near South Haven, Mich.																				
31	July 9, 1963..	62				50	23	17	1.5	218	10	26	28			282	220	24	476	8.3
Black River near South Haven, Mich. (At 70th Street)																				
31-a	Oct. 25, 1963.	--										38	480							2,020
Melvin Creek at Bloomingdale, Mich. (At county road 665)																				
31-b	Oct. 24, 1963.	--										637	27,000							60,700
Melvin Creek at Bloomingdale, Mich. (At 44th Street)																				

Table 5.--Chemical analyses of water from streams.--Continued.

Field number	Date of collection	Temperature (° F)	Silica (SiO <sub>2</sub> )	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO <sub>3</sub> )	Carbonate (CO <sub>3</sub> )	Sulfate (SO <sub>4</sub> )	Chloride (Cl)	Fluoride (F)	Nitrate (NO <sub>3</sub> )	Dissolved solids (residue at 180°C)	Hardness as CaCO <sub>3</sub>		Specific conductance (micro-mhos at 25°C)	pH
																	Ca	Non-carbonate		
Melvin Creek near Bloomingdale, Mich. (County road 688)																				
31-c	Oct. 24, 1963.	--				219	74	510	8.0	320	80	1,200				2,540	852	590	4,180	6.8
Melvin Creek near Bloomingdale, Mich. (At bridge on 47th Street)																				
32	July 9, 1963..	58				56	32	38	1.5	278	24	72				396	271	45	680	7.9
Barber Creek near Grand Junction, Mich.																				
33	July 9, 1963..	54				32	12	10	.9	142	15	17				179	130	13	310	7.4
Clear Lake outlet near Kendall, Mich.																				
34	July 9, 1963..	--				36	18	7.0	.9	162	26	16				211	164	31	346	7.4

No samples of stream water were obtained during periods of high surface runoff in Van Buren County. Records from other areas suggest that the water is lower in total concentration of dissolved substances at high flows than at low flows, but the relative amounts of the different materials are nearly the same.

A summary of the analyses of stream water is listed below. The summary does not include the high-chloride samples from the oil-production area near Bloomingdale.

Constituent or property	Maximum (Results in parts per million, except pH)	Minimum	Median
Sulfate (SO <sub>4</sub> )	84	15	35
Chloride (Cl)	215	2	10
Dissolved solids	552	164	260
Hardness (as CaCO <sub>3</sub> )	298	94	240
pH	7.1	8.6	7.8

#### The Quality of the Water From Inland Lakes

The water from inland lakes in the county is of two general types--the relatively soft water from lakes having no surface inlet or outlet and the relatively hard water from lakes having inlets, outlets, or both. The ranges in hardness in the two types of lakes are listed below (lakes contaminated with oil field brines not included).

Type of Lake	Hardness (ppm)	
	Maximum	Minimum
Lakes without inlets or outlets (land-locked lakes).	135	15
Lakes with inlets or outlets or both.	236	137

Water from most lakes is similar to that from wells and streams in that calcium, magnesium, and bicarbonate are the major dissolved materials. However, a few of the very soft waters from land-locked lakes contained little or no bicarbonate (table 6).

Table 6.--Chemical analyses of water from lakes.

Analyses are in parts per million, except specific conductance and pH.  
Specific conductance is in micromhos at 25° C.

Name	Month and year sampled	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride	Dissolved solids	Hardness (as calcium carbonate)	Specific conductance	pH
ALMENA TOWNSHIP												
Wolf Lake	2-63	47	16	2.6	0.8	190	21	3.5	198	183	348	7.8
Fish Lake	5-63	45	17	5.7	.8	218	10	7.0	212	182	362	8.1
Do.	10-63	49	14	6.3	.7	222	7.2	10	227	180	364	6.8
Do.	7-63	38	18	5.8	.3	200	8.0	7.5	182	169	339	7.6
North Lake	10-63	17	5.4	1.7	.9	75	6.0	1.5	88	64	139	6.5
ARLINGTON TOWNSHIP												
Lower Jeptha Lake	10-63	41	13	3.3	.7	163	29	3.0	188	156	321	6.8
North Scott Lake	10-63	43	14	3.7	1.5	160	36	5.0	194	165	335	6.8
South Scott Lake	10-63	39	15	3.7	1.7	138	48	5.0	200	159	323	6.9
BANGOR TOWNSHIP												
Donavan Lake	10-63	26	14	2.3	1.5	138	10	4.0	136	123	245	6.7
Duck Lake	10-63	37	23	2.9	1.0	142	77	1.0	196	187	378	7.0
Dyer Lake	10-63	24	6.3	2.3	2.7	91	13	2.0	108	86	180	6.7
Merrimans Lake	10-63	53	20	19	1.5	203	44	34	294	214	492	6.9
School Section Lake	10-63	50	17	44	1.7	169	35	86	372	195	593	6.6
Southard Lake	10-63	6.4	1.9	1.1	1.2	20	7.6	1.0	43	24	58	6.1
Van Auken Lake	10-63	41	19	31	2.0	150	42	64	314	180	518	7.0
BLOOMINGDALE TOWNSHIP												
Eagle Lake	10-63	27	16	6.4	1.3	160	10	8.0	154	134	294	7.0
Great Bear Lake	10-63	40	20	18	1.7	180	8.4	36	247	182	438	7.1
Little Brandywine L.	10-63	18	8.0	2.7	1.4	79	18	2.0	114	78	177	6.9
Max Lake	10-63	53	18	30	1.5	166	39	71	38	206	561	6.7
Mill Lake	10-63	8.2	4.7	8.2	1.1	28	9.6	19	87	40	137	6.2
Muskrat Lake	10-63	25	16	9.4	1.2	138	11	18	163	129	303	6.8
Sweet Lake	10-63	34	16	39	1.8	91	9.2	112	284	151	533	6.8
Thayer Lake	10-63	40	11	4.7	1.3	130	42	2.0	223	145	298	6.5
Three Legged Lake	10-63	67	34	79	2.1	200	42	196	542	307	1,010	7.1
Twin Lakes	10-63	8.6	5.4	.9	1.7	36	13	1.0	74	44	103	6.4
COLUMBIA TOWNSHIP												
Base Line Lake	10-63	30	9.9	1.8	.6	128	11	1.0	143	116	229	6.7
Coffee Lake	10-63	22	5.6	2.7	.4	78	12	2.0	106	78	160	6.6
Deer Lake	10-63	102	40	195	3.4	232	42	430	994	419	1,790	7.1
Jeptha Lake	10-63	40	15	4.2	.9	162	28	5.0	200	162	319	6.9
Lake Eleven	10-63	45	18	38	1.9	164	33	79	310	186	574	6.9
Lake Fourteen	10-63	26	18	27	1.0	126	13	60	248	139	441	6.9
Lake Moriah	10-63	65	36	114	2.5	230	37	238	626	310	1,160	7.4
Little Bear Lake	10-63	32	11	26	.7	119	12	49	204	125	372	6.7
Munson Lake	10-63	3.2	2.3	.9	.4	12	8.4	1.0	32	18	49	6.0
North Lake	10-63	23	8.4	2.7	.5	98	12	1.5	113	92	194	6.8
Saddle Lake	10-63	34	14	6.8	1.1	165	12	11	181	143	298	7.3
Silver Lake	10-63	16	8.8	3.6	1.5	57	24	6.2	103	76	178	6.7
Stillwell Lake	10-63	23	10	7.4	2.5	106	9.6	14	139	98	232	6.6
Upper Jeptha Lake	10-63	43	16	3.8	.8	185	27	5.5	208	173	341	7.7
Do.	10-63	43	16	4.2	1.1	188	25	5.0	206	173	347	7.0
DECATUR TOWNSHIP												
Cedar Lake	2-64	31	11	2.3	1.1	143	8.0	3.0	134	123	244	6.9
Lake-of-the-Woods	10-63	48	21	3.9	1.0	183	59	6.0	238	207	409	6.7
Swift Lake	10-63	5.4	1.7	1.2	.3	22	1.8	2.0	18	20	50	6.1
GENEVA TOWNSHIP												
Moon Lake	10-63	22	5.2	2.3	1.6	78	13	2.5	108	76	168	6.5
Pitcher Lake	10-63	38	10	4.2	1.4	152	15	4.5	177	136	281	6.8
HAMILTON TOWNSHIP												
Knickerbocker Lake	10-63	4.6	1.4	1.2	0.2	2	16	2.0	24	18	56	6.6

Table 6.--Chemical analyses of water from lakes.--Continued.

Name	Month and year sampled	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride	Dissolved solids	Hardness (as calcium carbonate)	Specific conductance	pH
HARTFORD TOWNSHIP Rush Lake	10-63	34	21	3.5	1.5	148	56	4.0	206	172	343	7.2
KEELER TOWNSHIP Crooked Lake	10-63	25	7.8	2.3	.5	105	6.8	6.5	116	94	192	6.9
Indian Lake	10-63	15	3.9	1.7	.2	56	6.4	3.5	62	54	110	6.7
Keeler Lake	2-64	4.3	1.1	1.8	1.2	5	10	3.8	30	15	54	5.8
Do.	5-63	5.4	.8	3.3	.5	0	11	6.0	30	17	64	4.45
Round Lake	10-63	7.6	2.1	2.3	1.0	24	10	3.0	41	28	78	6.2
LAWRENCE TOWNSHIP Christie Lake (1)	8-63	19	14	2.2	.5	116	12	1.5	109	105	214	7.1
Do.	10-63	22	13	2.4	.5	122	12	3.0	118	109	221	6.7
Hall Lake	10-63	32	15	2.5	1.2	163	17	2.0	164	142	283	7.3
Lake No. 2	10-63	17	6.7	6.5	1.5	80	3.8	13	108	70	171	7.1
Lower Reynolds Lake	10-63	20	8.0	2.0	.8	87	12	4.0	100	83	175	7.0
Shafer Lake	10-63	29	14	2.9	1.7	149	16	3.0	143	130	267	7.1
Do (2)	10-63	26	14	2.8	1.5	136	16	4.0	140	123	256	7.5
Do	2-64	32	12	3.6	1.8	139	16	5.5	144	130	262	7.0
Upper Reynolds Lake	10-63	17	7.0	1.7	.6	74	11	2.5	84	72	151	6.6
PAW PAW TOWNSHIP Ackley Lake	10-63	48	20	7.0	1.1	198	43	10	236	202	418	7.2
Brownwood Lake	10-63	25	11	3.4	.5	120	14	5.0	123	108	227	6.8
Eagle Lake	10-63	22	9.0	2.1	.7	108	6.4	2.0	100	92	185	6.7
Lake Cora	10-63	24	11	2.3	.3	124	6.8	2.0	107	105	211	6.9
Thre Mile Lake (3)	8-63	7.3	3.6	1.6	.7	32	6.8	2.0	46	33	79	6.6
Do.	10-63	9.2	2.7	1.4	.5	32	7.6	2.0	48	34	81	6.4
PINE GROVE TOWNSHIP Brandywine Lake	10-63	8.2	1.8	1.7	1.1	21	9.6	2.5	68	28	69	6.1
Clear Lake	10-63	35	16	7.4	1.1	162	23	18	211	154	335	7.3
Story Lake	10-63	6.7	3.3	5.7	.9	9	17	14	84	30	109	5.6
PORTER TOWNSHIP Banksons Lake	10-63	16	8.6	1.8	0.1	82	11	1.0	88	76	158	6.6
Cedar Lake	5-63	31	14	1.9	.6	150	12	1.0	137	135	254	7.6
Do.	7-63	19	12	2.1	.6	110	10	2.0	106	97	201	7.2
Gravel Lake	10-63	25	13	3.8	.7	139	7.8	3.0	122	116	236	6.6
Huzzy Lake	10-63	17	7.8	1.5	.4	89	5.4	1.0	88	74	155	6.5
Little Cedar Lake	10-63	15	9.7	1.8	.3	84	9.8	2.0	96	78	159	6.5
SOUTH HAVEN TOWNSHIP Lake Michigan intake at South Haven (4)	3-64	40	10	5.1	.9	130	27	10	170	140	300	7.4
WAVERLY TOWNSHIP School Section Lake	10-63	35	12	4.0	1.8	148	17	6.0	161	137	281	6.7
Shaw Lake	10-63	43	15	5.0	2.9	178	25	6.0	213	169	349	6.6

(1) Nitrate 0.8

(2) Nitrate 0.9

(3) Nitrate 1.0

(4) Nitrate 1.0; Fluoride 1.0; Analysis by Mich. Dept. of Health

The "soft-water" lakes probably receive little recharge from the more mineralized ground waters and must receive most of their water directly from rainfall and direct surface runoff which contain only small amounts of dissolved materials. Another possible cause of the softness of water in these "closed" lakes is the removal of calcium-carbonate from the water by living plants and animals.

The lakes with natural or man-made outlets are similar in chemical character to the streams.

Although water from inland lakes is little used in the county except for recreation and, to some extent, for irrigation, it is of satisfactory chemical quality for domestic use, public supply, or other common uses of water. From the standpoint of hardness, water from some of the lakes is superior to all other known sources in the county.

#### The Quality of Water From Lake Michigan

Water from Lake Michigan is harder than the water from all land-locked lakes in the county, but it is softer than the water from most of the inland lakes having inlets or outlets (table 6). The Lake Michigan water generally is of satisfactory quality for all normal use of water.

#### Are Pesticides Contaminating the Water Supplies of the County?

Although very minor amounts of pesticides have been detected in water from some of the streams in the county, pesticide contamination does not appear to be a serious problem at this time. The pesticides used in Van Buren County consist mostly of chlorinated hydrocarbons, organophosphates, and related materials.

A sample collected in May 1963 from Keeler Lake and another from Pine Creek in the fruit belt in the western part of the county showed chlorinated hydrocarbons in estimated amounts of less than 1 part per billion (ppb). A sample from Mill Creek in the same area showed an estimated 5 ppb of chlorinated hydrocarbons. A sample collected in April from a shallow-driven well in an orchard was negative in both hydrocarbons and organophosphates. A summary of the 1963 results of analysis for pesticides is given below. All samples from surface sources were collected at base flow periods when the stream was fed entirely by ground water. Samples collected during periods of surface runoff may show higher concentrations.

The quantities of pesticides shown in the summary must be considered tentative until checked by further sampling and analysis. Additional samples were obtained during the spring of 1964; the results of these analyses are not yet available.

Analyses of Pesticides in Van Buren County Waters  
(Results in ppb - parts per billion\*)

Sampling Site	Date Sampled	Chlorinated hydrocarbons (ppb)	Organophosphates (ppb)
Keeler Lake	5- 2-63	1.	Neg.
Keeler Lake	7- 9-63	0.1	0.1 <sup>±</sup>
Pine Creek	5- 2-63	1.	Neg.
Pine Creek	7- 8-63	Neg.	0.1 <sup>±</sup>
Mill Creek	5- 2-63	5.	Neg.
Bisnett Well	4-18-63	Neg.	Neg.
Cedar Creek	7- 9-63	Neg.	0.1 <sup>±</sup>
Black River			
Tributary No. 1	7- 9-63	0.3 <sup>±</sup>	0.1 <sup>±</sup>
Brandywine Creek	7- 8-63	Neg.	0.1 <sup>±</sup>

\* All reported quantities are estimates only,  
and the order of accuracy is not known.

## HOW THE WATER IS PRESENTLY OBTAINED AND USED

Almost all the water now used in the county is obtained from wells and farm ponds. Exceptions are the city of South Haven that obtains its municipal supply from Lake Michigan, and the few irrigation supplies that are obtained from streams and lakes, and in some areas from ditches. For small supplies it is generally more economical to drill a well than to install an intake and pipeline to tap a lake or a stream.

Thus, thousands of wells are in use throughout the county. These vary from the small domestic wells ranging in diameter from  $1\frac{1}{2}$  to 4 inches to the larger municipal, irrigation, and industrial wells of from 6 to 36 inches in diameter. Depths of wells inventoried ranged from as shallow as 8 feet to as deep as 294 feet.

Water management in the county is not a large-scale practice at present but is more or less on an individual basis by municipalities, industries, irrigators, and public and private well owners. Thus, it is important that these individuals should know how their use of water can affect other users.

At the request of county officials, information on the relative efficiency of various screen lengths and diameters has been included in the appendix of this report (Appendix C).

### By Cities and Villages

Except for South Haven, all cities and villages having a municipal supply obtain water from large-diameter wells in the glacial drift.

Municipalities in the county use water to supply the usual public and industrial needs, for fire protection, and for irrigation of public lands.

The water is stored in elevated towers or ground tanks or reservoirs for use during high-demand periods and to maintain pressure in the distribution systems. Water pressure is maintained by either personal supervision or automatic control devices. In the event of large fires additional well pumps may have to be turned on to maintain high pressure.

In general municipal well field operation and management involves some or all of the following:

1. Water levels in the wells are measured by air line readings under static conditions and at known pumpage rates to avoid overpumping an area. Pumpage is distributed among the wells in order to equalize lifts, and in some cases to reduce the effects of water from a well with inferior quality such as high iron, chlorides or hardness.

2. An observation well or wells may be maintained to measure or automatically record water levels in the well field, to observe trends in water levels, and to help determine if additional wells could be added to the present field without excessive interference or lowering of the water table or artesian head.

3. Meters are maintained at well discharge lines to measure the amount of water produced. Metered consumer use is compared to the amount of water pumped to determine losses and possible major leaks in distribution systems or faulty meters at pumps or at the consumer end.

4. The records of pumping and water levels are used to determine the efficiency and production of the wells.

5. If maximum water demand taxes the capacity of well production and storage facilities, resulting in below normal water pressure, new wells may be added to the system. If the present field is estimated to be unable to supply more water without excessive interference between wells, test drilling to locate a new well field may be necessary.

6. Auxiliary engines may be installed and maintained to provide means for pumping water during periods of electric power failure.

7. Samples of water are taken from individual wells or from some point on the distribution line for bacteriological analysis at monthly intervals.

8. At least every 5 years a sample of water from each well is analyzed for its chemical constituents, with more frequent partial analyses for iron, chlorides, etc., if these constitute a problem.

9. If well yields decline and pumping levels increase because of incrustation of the well screen, a program of screen cleaning or replacement may be undertaken.

10. Softening and/or iron removal may be necessary to provide better water for public needs. Chlorination of the water is required if there is danger of bacterial contamination. Fluoridation may be applied to the water for public consumption to help reduce tooth decay.

11. Hydrants are flushed periodically, especially if iron is a problem.

12. Extension or enlargement of mains to new subdivisions may be necessary.

Listed on the following page are reported pumpage of water by several communities in 1963. South Haven uses water from Lake Michigan and the others use ground water. Records of pumpage by other communities were not available.

<u>Community</u>	<u>Population</u> (1960)	<u>Pumpage</u> (in million gallons-1963)	<u>Average</u> daily use <u>per capita</u>
City of Bangor	2,109	138	179
Village of Hartford	2,305	90	107
Village of Lawton	1,402	277	541
Village of Paw Paw	2,970	255	235
City of South Haven	6,149	550	245

Where use of municipal water by food-processing industries creates a heavy seasonal demand, peak loads and daily per capita use may be much higher than in other cities or villages of comparable size. For example, the Village of Lawton which supplies several industries used about 37 million gallons (mg) in October 1963 as compared to 24 mg in September and 16 mg in November. The maximum daily use reported was 1.8 mg, the minimum was 0.3 mg, and the average daily use for the year was 0.8 mg. The wide variations in daily per capita use by the various communities are the result of this industrial use. Where industries use water from their own wells, the per-capita use is correspondingly lower.

A description of the various municipal supplies in the county is contained in Appendix A.

#### By Agriculture

Water for irrigation and pesticide spraying in the county is obtained from wells and farm ponds, and a few supplies are pumped from lakes, streams and drainage ditches. Reported yields of some 60 large-diameter irrigation wells ranged from 50 to 1,250 gpm. About 3/4 to 1-1/2 inches of irrigation water are used on crops at each application during the growing season. The number of applications depends, of course, on the amount of rainfall during the growing season. Most of the irrigation is for vegetable and fruit crops although some water is also used to irrigate mint crops, pastures, and flower and nursery tracts. One of the most critical uses of irrigation water is for frost protection of fruit in the spring.

Most of the water used for spraying of crops with pesticides is obtained from small diameter (1-1/4 to 4-inch) wells. The water is usually pumped into overhead storage tanks where spraying equipment can then be filled by gravity. The amount of water needed is not usually large at any one time, and the tanks can be filled at a rate of 10-15 gpm or less by small-capacity wells. Many of the wells used to supply water for spraying serve a multi-purpose -- they may be primarily domestic wells for household use and may also be used for watering livestock.

Where small-diameter wells are used for "spraying water", the long period of pumping necessary to fill storage tanks or spraying equipment may lower water levels in the well sufficiently to expose the screen. This hastens the clogging of the screen by deposition of lime from the water. In such cases a slower rate of pumping or the use of two or more wells offers a solution. Overpumping may also cause the clogging of the screen by pulling fine sands into the screen openings if the well had not been properly developed at the time it was drilled, and the formation contains fine sands. Most wells inventoried, however, were found to produce sufficient water for spraying purposes even where they were also used for domestic and stock purposes.

#### By Industry

Industrial supplies in the county are obtained from ground-water sources except for those industries in South Haven that obtain Lake Michigan water from the City of South Haven. Because of the general availability of ground water in most of the county, most industries use privately-owned wells even in areas where municipal supplies are at hand.

Water for processing agricultural products constitutes a major water demand in the county. The use is largely seasonal. The heaviest use is during the summer and early fall when various vegetables, berries, and fruits are processed. Wells supplying this demand are generally pumped very little, if any, during the winter and spring months. The seasonal industries require large-diameter, high-capacity wells usually equipped with turbine or submersible pumps. Although water levels are drawn down in the area by the heavy pumping, the seasonal use allows for long periods of recovery.

A few industries in the county, such as dairies and manufacturers of auto equipment, use water on a year-around basis.

Industrial plants usually have two wells in order to avoid water shortages due to breakdowns at critical periods of demand; this is especially true for food processing plants. If the industry is located where a municipal supply is available, a connection to the municipal supply may also be made to be used in emergency. In industries where seasonal use is the rule, an advantage is that repair of pumping equipment and screens, etc., can be made during the long periods when the wells are not in use.

The following tabulation gives the total reported daily ground-water use in 1962 by some industries in the county (Water Resources Commission, 1964):

	<u>Thousands of gallons per day</u>	
	<u>Municipal</u>	<u>Private</u>
<u>Village of Hartford</u>		
Hartford Metal Protection Co.	59	--
Auto Specialties Mfg. Co.	--	71
<u>Keeler (unincorporated)</u>		
*Burnette Packing Co.	--	75
*Frigid Foods	--	50
Bronte Wine	--	12
<u>Village of Lawrence</u>		
Michigan Quality Frozen Foods	--	864
*Lawrence Packing Co.	5	100
<u>Village of Lawton</u>		
Welch Grape Juice Co.	560	--
*HoneeBear Packing Co.	--	300
Eaton Mfg. Co.	160	--
<u>Village of Mattawan</u>		
*Glaser-Crandall Co.	--	32
<u>Village of Paw Paw</u>		
Murch, A. F. & Co.	--	100
Michigan Wineries, Inc.	16	80
Paw Paw Plating, Inc.	80	--
St. Julian Wine Co., Inc.	--	7
Frontenac Wine Co.	--	5

\* Seasonal use

#### By Public Establishments other than Municipal

Small-diameter wells of from 2- to 4-inches are generally used to supply schools, small industries, restaurants, motels, resorts, migrant worker camps, trailer camps, and small subdivisions where municipal supplies are not available. The proper construction of the wells to prevent pollution, the minimum amount of water required for each person served, and the sanitary quality of the water is safeguarded by periodic inspection by County Health Department personnel. Ordinarily the small amount of water required for these installations presents no great problem except in heavy clay and water-poor areas such as parts of South Haven and Covert Townships (figs. 34 and 44 in Appendix A). In these areas the availability of water should be investigated before public installations are built.

### For Power

Very little water is used for power production in Van Buren County. The only reservoir with any appreciable storage capacity is on the South Branch Paw Paw River at Paw Paw. It has a normal operating head of 16 feet; the reservoir, Maple Lake, has an estimated area of 300 acres.

### For Domestic and Stock Supplies

Wells are used for all domestic supplies and for most stock supplies. Farm ponds and streams also provide water for stock. Nearly all the wells inventoried in the field were reported to produce adequate supplies for these needs. Many farms have several wells -- one for domestic use and others for stock, especially where wells can be obtained at shallow depth. Almost all these wells use electric pumps; most windmill pumps have been abandoned although they are still in evidence in the countryside.

Because of the hardness of the water, and in some cases, the iron content in many parts of the county, water softeners are in quite general use for domestic supplies. Most softeners are hooked up to hot water lines only, or some cold water lines are left out of the system to provide better drinking water at the tap. Also, most outdoor taps are not connected as it is needlessly expensive to use soft water for watering lawns.

Most of the difficulty with domestic and stock wells seemed to be with "liming" or encrustation of the well screen. This may have been aggravated by low water levels caused by the recent relatively dry weather, or from overpumping, resulting in exposure of the screen to air and hastening its clogging by lime.

Thus, most of the difficulties with domestic and stock wells involves the replacement of well screens when they become clogged. Also involved is the substitution of deep-well for shallow-well pumps, perhaps because of current lower ground-water levels, but more likely because of the increasing use of water in the home and around the farm. The increased heavy use temporarily lowers the water level in the well pipe below suction lift of the shallow-well pumps. This probably leads many people to declare that water levels are falling when they are really only lowered locally by heavy demands for short periods of time.

### By the Public for Recreation

Van Buren County has abundant water resources suitable for recreation, including 14 miles of shoreline along Lake Michigan, more than 100 inland lakes, and 150 miles of streams. Recreational use of water generally

does not deplete the resource, but may restrict its use for other purposes because the best recreational use requires clean water in ample supply.

### Inland Lakes

Swimming, fishing, boating, water-skiing and summer cottage living are the major recreational attractions on the inland lakes of the county. Twelve public fishing sites are maintained on inland lakes by the Michigan Department of Conservation. Several of the lakes are stocked with trout, and almost all have a good natural population of bass and panfish. The sandy beaches and gently sloping sandy bottom on most lakes provide excellent swimming sites. There are a few summer resorts and youth camps on inland lakes in the county.

Despite the many cottages on the lakes, the shorelines are not generally overcrowded at present (1964). Up to the present the abundance of lakes perhaps protects them from excessive use.

### Farm Ponds

The larger farm ponds can be used for fishing, boating, canoeing, and swimming. One farm pond even had an island where family picnics could be held.

### Lake Michigan

The county's shoreline along Lake Michigan with its many fine sandy beaches and interesting sand dunes is a highly-valued recreational asset. There are many summer resorts on Lake Michigan in and near South Haven, and many more private cottages along the waterfront in the county. Public access to the lake is limited to a few public beaches and one county park.

### Streams

The streams in the county provide good fishing, including some trout fishing, but streams are not used for recreation nearly as much as the lakes. The Paw Paw River is listed as one of the canoe trails in "Canoe Trails of Michigan" (1964), but there is very little canoe traffic on this river. The Paw Paw lacks the swift current and interesting rapids that make some of the northern rivers so popular with canoeists. However, the river traverses areas of beautiful hardwood groves and is especially attractive when the leaves are turning in the fall. Canoeing could become popular if encouraged by canoe liveries, prepared camp sites, and removal of fallen trees and other obstructions from the river.

The recreational values of Van Buren County streams are largely dependent on a relatively high base flow and relative freedom from contamination by sewage and other wastes. A high base flow is usually associated with cool water in summer and with resultant high dissolved oxygen content essential for trout habitat. The ground water discharged to the stream contains little or no dissolved oxygen, but the relatively low temperature of the ground water permits a relatively high dissolved oxygen content when the water is aerated. A high base flow is also essential to dilute the waste materials discharged to the river. Large withdrawals of water directly from the streams or indirectly from wells could seriously damage the trout populations in some of the smaller streams of the county. Increase in discharge of sewage and other organic wastes could also deplete the dissolved oxygen and damage the trout.

## HOW PRESENT WATER PROBLEMS CAN BE SOLVED

Most of the water problems of the county can be solved by more fully utilizing and conserving known sources, exploring for additional sources, and guarding against contamination of the water.

### Ground Water

The township maps (figs. 28-45, Appendix B) show the availability and depth of ground water in all parts of the county. In using these maps it should be remembered that "generally" does not mean "invariably". It is characteristic of glacial formations that they vary greatly over short distances. There is a certain amount of risk in drilling a well anywhere in the county. The availability maps tell whether the odds are favorable or unfavorable at any particular site.

Well tables (tables 7-24, Appendix B) and well logs (table 1) provide additional information on availability of ground water at specific locations. Examples of how these tables can be used together with the availability maps to provide the needed information are presented in the introduction of this report.

Can enough water for a domestic supply be obtained everywhere in the county?

Obtaining enough water for domestic, stock, or spraying supplies is not a problem in most of the county, although it may be necessary to drill more than one well in order to find a water-yielding bed of sand or gravel. The one area in the county where it is generally difficult to obtain a domestic supply from wells is in the western parts of South Haven and Covert Townships. Even in this area there are deep bedrock valleys in places that may yield moderate to large supplies of water.

Can additional large supplies of ground water be developed?

Large reservoirs of ground water, especially in the outwash plains, can provide several times the amount of water now used, but large withdrawals of ground water may eventually lower the levels of nearby lakes or diminish the flow of nearby streams. There is no evidence that current withdrawals of groundwater have caused a serious decline in lake levels or streamflow, but water-level records should be obtained wherever large quantities of ground water are pumped so that the long-term effects of pumping can be determined. In general, the farther a well is from a lake or stream, the less the immediate effect of well discharge on lake levels or streamflow.

What can be done to minimize the possible future lowering of the water table in the irrigated areas?

Records of water levels in the irrigated areas (fig 8) are too brief to show whether water levels are progressively falling as a result of ground-water withdrawals. It is impossible to pump water from a well without lowering the water table near the well, but the water level begins to recover as soon as the pump is shut off. Probably the lowering of water levels in the vicinity of the pumped wells during the irrigation season is largely restored by recharge during the remainder of the year. If a longer record should indicate that water levels are showing a long-term decline as a result of increased irrigation, then a decision must be made either to accept the decline of water level in wells and lakes as a necessary condition for crop production or to take steps to halt the downward trend.

Lowering of the water table could be minimized by restricting ground-water pumpage, by intercepting ground-water discharge, or by increasing the recharge to the aquifer. However, the irrigated areas generally are located far from perennial streams, and interception of discharge or increase of recharge from the streams cannot be accomplished without costly importation of water from distant sources.

Parts of the irrigated areas are located near swamps and it is possible that an increase of the water pumped in these areas would intercept water that normally would discharge to the swamps. This would lower the water level in the swamps, thus impairing the value of these wet lands as wildlife habitat. A decision would then have to be made as to whether the irrigation value would be of greater importance than the preservation of the wetlands.

Can surface-water impoundments increase the amount of ground-water storage?

Surface-water impoundments raise the ground-water table in the vicinity of the impoundments and increase the saturated thickness of ground-water reservoirs. This is most effective in areas where highly-permeable materials occur above the original water table adjacent to the stream. Under these conditions the increased ground-water storage may be larger than the amount of surface water stored in the impoundment.

Are water levels dropping in the vicinity of municipal and industrial wells?

Records of water levels in most municipal and industrial wells do not indicate a serious decline. Many of the municipal and industrial wells

in the county are located near streams, and drawdown of water levels in such wells generally is much less than in wells located far from streams. Pumping of these wells reduces the ground-water discharge to the stream or, in some cases, induces flow from the stream to the well. The problem of excessive drawdown in the wells is avoided, and the reduction in streamflow in most instances is not enough to cause serious problems.

Pumpage of ground water at the present time is very small in comparison to the flow of the major streams, even in late summer when streamflow is likely to be relatively low. For example, pumpage at the Village of Hartford in 1963 averaged about one-third of a cubic foot per second. This is only two-tenths of one percent of the minimum recorded flow of the Paw Paw River at Riverside. Furthermore, much of the water pumped for public supplies and for industries is returned to the stream.

How can ground-water recharge be increased?

Ground-water recharge can be increased in some areas by constructing recharge channels and recharge ponds to intercept and divert surface water to ground-water storage. The permeable surface formations in some parts of the county (such as the sandy lake beds along the Paw Paw River) would be suitable for this type of recharge, provided that the well fields are near the streams. The efficiency of such systems has been tested and proved by the city of Kalamazoo where millions of gallons of water have been pumped for years without appreciable lowering of levels that can be attributed to the withdrawals by wells (Deutsch and others, 1960).

Another method of increasing ground-water recharge is by direct recharge into the aquifer, through return wells, of river water that has been filtered and chlorinated. The water is recharged during the winter and spring when the water is cold and relatively abundant in the streams. The advantage of the uniform temperature of ground water is thus retained. This method, however, is usually more expensive than recharging by infiltration from ponds.

Can large supplies of ground water be developed  
in the South Haven area?

Well logs and geophysical prospecting indicate deep bedrock valleys filled with glacial drift in the South Haven area (fig. 24). These deep valleys are favorable sites for test-drilling for large quantities of ground water. Other things being equal, the greater the thickness of glacial drift the better the chances of penetrating permeable material. Test wells should be drilled to bedrock unless salt water is found in the deeper glacial deposits. Samples should be collected at five-foot intervals or at each noticeable change of formation, and a careful log of the materials penetrated should be prepared. If sufficient sand and gravel is found to encourage the drilling of

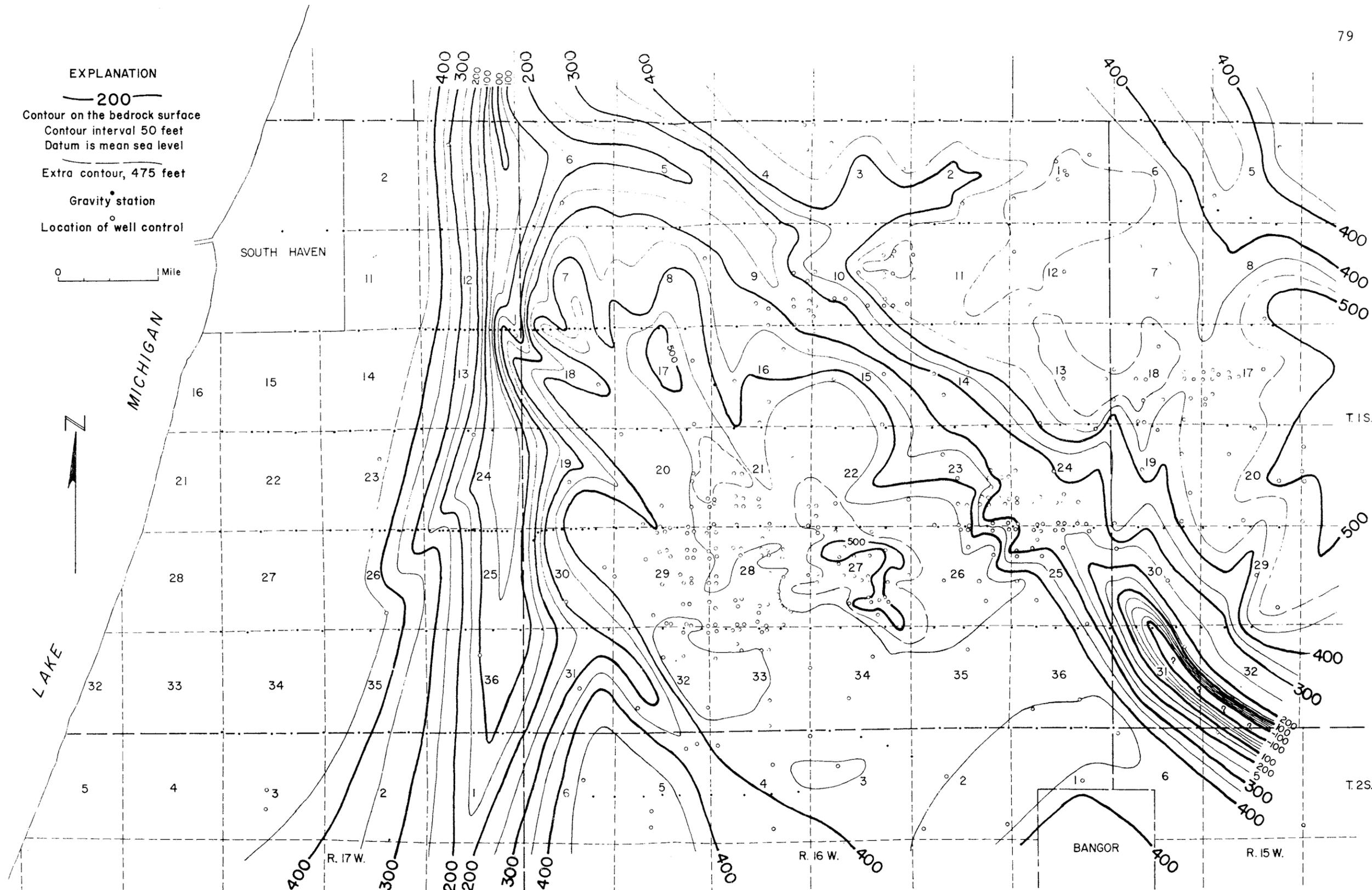


FIGURE 24.--MAP SHOWING BURIED BEDROCK VALLEYS IN THE SOUTH HAVEN AREA. (after Kiasner, 1964)

Gravity and seismic surveys in this area indicate deep drift-filled bedrock valleys where large supplies of ground water may be available.

a large-diameter production well, the well log should be used to determine the proper setting of the well screen or screens.

Deep bedrock valleys also underlie other parts of the county (fig. 25), although these are not so well-defined as those near South Haven. These bedrock valleys also may be favorable sites for exploration for large supplies of ground water. Because productive aquifers generally are available at relatively shallow depth in these areas, the bedrock valleys are not so important here as they are in the western part of the county.

### Surface Water

Can streams furnish large quantities of water?

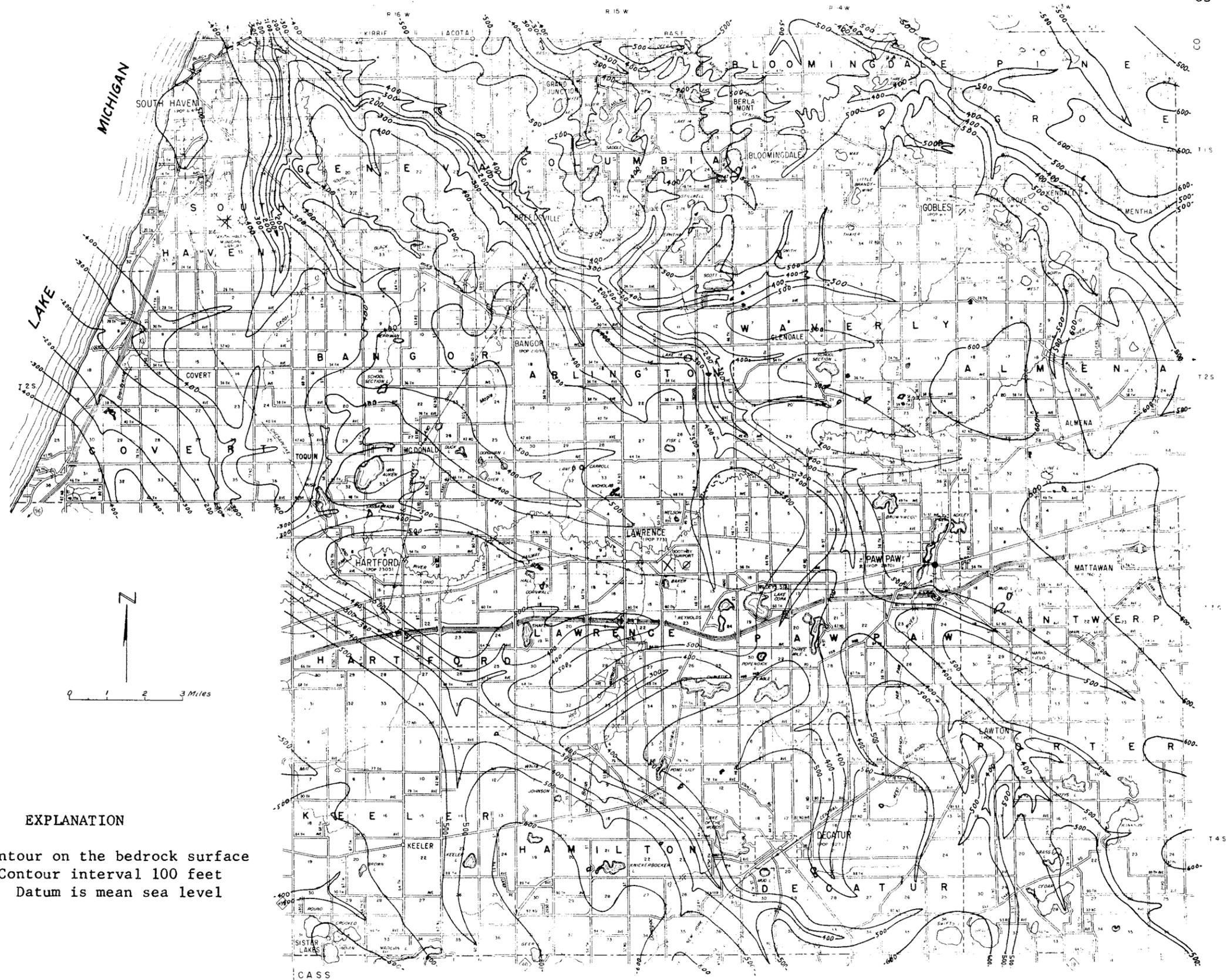
The major streams of the county can furnish very large quantities of water, but large withdrawals of water would diminish the waste-assimilating capacity of the streams. Most cities and villages in the county discharge their treated sewage and industrial effluents into streams. As population and industry increases, both water withdrawals and waste treatment needs will increase.

Can surface impoundments be used to increase  
the low flow of streams?

Surface impoundments can be used to augment the low flow of streams by storing flood flows.

The topography and soils of the county are not generally favorable for large reservoir sites. Some otherwise favorable sites do not possess the refill potential necessary to function as units to supply water for annual low flow augmentation. However, such sites may have important possibilities for development primarily as recreational water areas, and also provide an emergency reserve for low flow augmentation during droughts. Backwaters created by dams on streams raise the ground-water table in nearby areas, thus increasing the amount of water stored in underground reservoirs. To be suitable for reservoir development a site must meet certain requirements as follows:

1. Damsite -- This requires a topographic constriction or bottleneck in the stream valley.
2. Storage area -- The valley upstream from the dam must be sufficiently wide and deep to store significant volumes of water without flooding unreasonably large areas of land and without overflowing into other drainage areas.
3. Catchment area -- Sufficient area must contribute flow to the stream above the damsite to ensure that the reservoir can be filled and maintained by minimum rates of runoff.



EXPLANATION

Contour on the bedrock surface  
 Contour interval 100 feet  
 Datum is mean sea level

FIGURE 25.--MAP SHOWING LOCATION OF BURIED BEDROCK VALLEYS IN THE COUNTY.  
 (after Terwilliger)

The thick drift in these bedrock valleys is a potential source of large supplies of ground water.

4. **Geology** -- The type and cost of a dam are dependent to some extent on the soils and the subsurface geology at the damsite and reservoir area. The soils and glacial drift of the impoundment area must be sufficiently tight to prevent large losses of surface water to the ground.

The probable relative merit of surface formations for reservoir sites is as follows: till plains; lake plains and drainageways; moraine; outwash.

In addition to the physical requirements, the reservoir site must be available at reasonable cost, and its use for water storage must not inflict unreasonable damages on other present or potential values.

Figure 26 shows 4 possible reservoir sites in the county, with information pertinent to each. Information on the Paw Paw River site at Hartford, Brush Creek site and the East Branch Paw Paw River site was obtained from a Michigan Water Resources Commission report (1964). Information on the Haven and Max Lake Drain site was prepared for this report.

#### What can be done about falling lake levels?

Falling levels in most inland lakes during periods of drought are inevitable. Most, if not all the lakes in the county are at water-table level, and the lakes fall with declining water table. The decline is greater in land-locked lakes (fig. 11) than in lakes having outlets (fig. 12). This decline in land-locked lakes caused by drought generally cannot be avoided without prohibitive cost. Pumping of water from a stream into the lake is often suggested, but most of the land-locked lakes are not located near streams. Pumping of ground-water from a deep aquifer into the lake is another frequently suggested remedy for falling lake levels. The theory is that the deep aquifer is separated from the lake by impermeable beds, and water pumped from this aquifer will be replaced by recharge at considerable distance from the lake. Unfortunately, even the clay and till in the glacial deposits are slightly permeable, and much of the water pumped from the deep aquifer will be replaced by water from the lake.

Decline of water levels in lakes having outlets can be partially controlled by constructing regulating dams at the outlets. This can be accomplished under the procedure for "STABILIZING INLAND LAKE LEVELS" Act 146, Public Acts, 1961, of the State of Michigan. If the water level in the lake should fall below the level of the natural lake outlet, the control obviously is no longer effective.

If long-term water-level records show a continuous decline in lake levels caused by withdrawals of ground and surface water, then control of such withdrawals may be the only feasible solution.

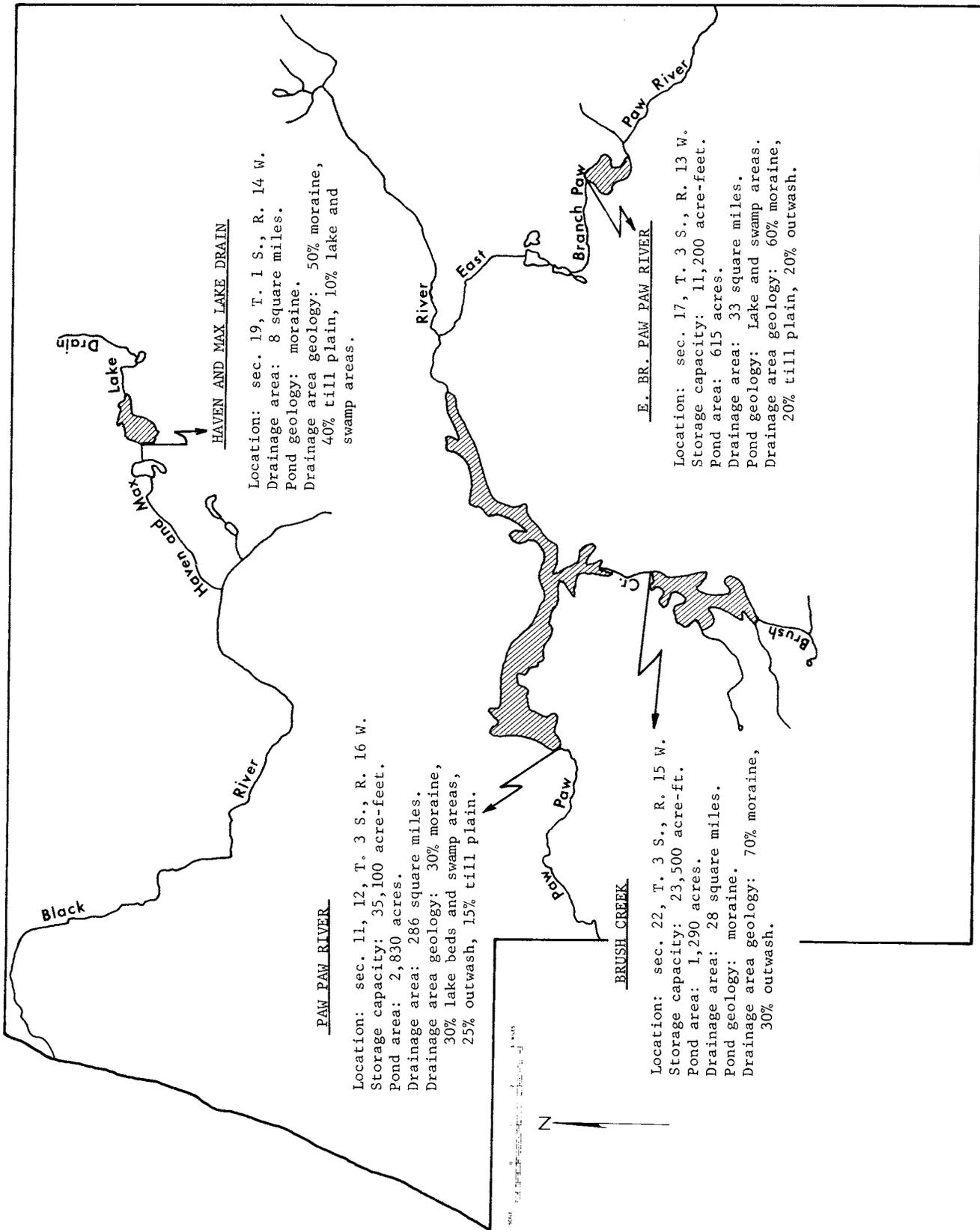


FIGURE 26.--POSSIBLE RESERVOIR SITES IN THE COUNTY.

A frequently-suggested alternative to maintaining lake levels is to provide the desirable depth of water by dredging the lake bottom. This has been done in many lakes in Michigan. The material removed is commonly used to build up low swampy areas along the lake thus adding to the amount of lakeshore available for cabin development. Such dredging and filling tends to artificialize the lake and to destroy fish and wildlife habitat. Thus, the advantages of deeper water and additional developed shoreline in the dredged lake must be balanced against the sacrifice of natural beauty and of fish and wildlife habitat. Again, it should be remembered that once natural conditions are destroyed they can never be entirely restored.

### Quality of Water

What can be done about the salty water in some wells?

If the salty water is attributed to contamination from surface sources, elimination of the source of contamination generally will improve the quality of water in time. Although the efforts of state and local agencies have successfully eliminated most sources of contamination, there are areas in the county, such as near Bloomingdale, where brines associated with oil production in the past have contaminated ground-water supplies. Contamination by sewage or animal wastes usually causes an increase in the chloride content of the water. Accordingly, it is suggested that owners of shallow wells producing water containing more than 30 ppm of chloride should have their water checked for possible bacterial contamination. Even if the source of the chlorides is sewage wastes, it is possible that no bacterial contamination may be found because of the filtering action of the glacial materials. If the chlorides do not come from sewage or animal wastes, the contamination probably is from oil field operations or from industrial wastes. If repeated analyses show that chloride content is increasing in the well, the assistance of local and state agencies should be obtained to eliminate the source of contamination. Even after the source has been eliminated a number of years may be required to bring the water back to near-natural conditions.

Another possible means of avoiding salt water from surface contamination is to drill to a deeper aquifer that is separated from the source of contamination by relatively impermeable beds. However, if the source of the salt water is leakage at depth from improperly plugged and abandoned oil well or brine disposal well, the deeper wells may yield water higher in chlorides than the water from shallow wells.

If the salt water is naturally-occurring from the brines in the bedrock, a shallower well may yield water of better quality.

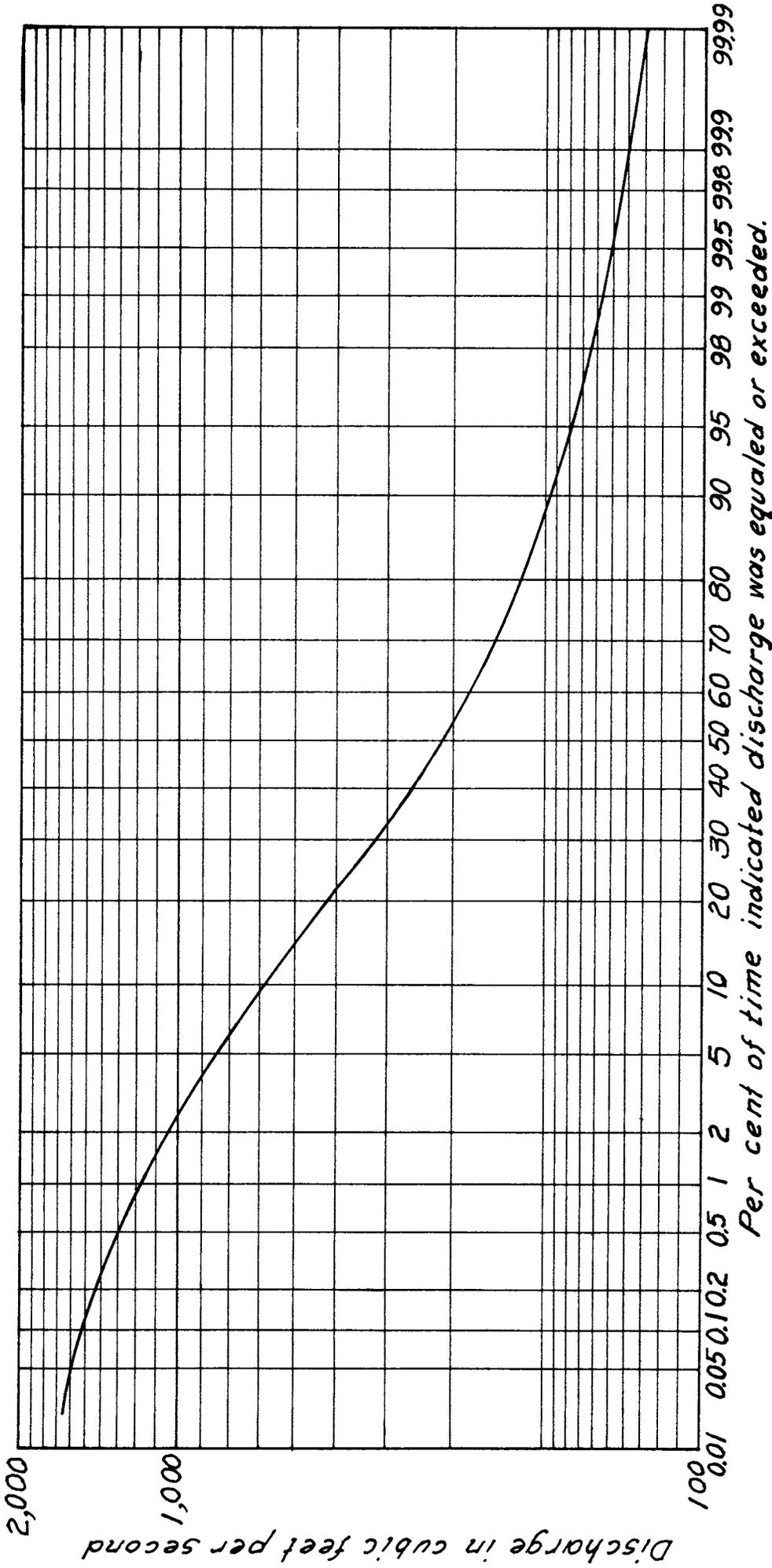


FIGURE 27.--GRAPH SHOWING DURATION CURVE OF DAILY DISCHARGES FOR THE PAW PAW RIVER, AT RIVERSIDE, 1963.

The graph shows that for example during the period 1952-63, the flow of the river was equal to or greater than 200 cubic feet per second for 90 percent of the time.

What can be done about hard water and water high in iron obtained from most wells in the county?

Standard water treatment seems to be the most practical solution to problems of hardness and high iron content. There is no apparent correlation of either hardness or iron content with depth of wells, so it may be futile to drill shallower or deeper wells in the hope of obtaining better water.

What can be done about the high nitrate content of water from some wells?

Because the most common sources of high nitrates are decaying organic matter and commercial fertilizers, it is to be expected that shallower wells are more likely to yield water high in nitrates than deeper wells. If a shallow well yields water containing objectionable amounts of nitrates, a second well tapping a deeper aquifer should be tried.

What can be done about contamination of streams by sewage and other wastes?

Contamination of streams can best be detected by periodic sampling and analysis of the water. If contamination is found to exceed tolerable limits, the State Water Resources Commission should be informed.

Knowledge of the flow of streams is essential in the determination of the amount of wastes a stream can assimilate safely. If a stream is overloaded, additional waste treatment must be provided, another disposal site found, or low flows augmented by reservoirs.

The flow characteristics of the Paw Paw River at Riverside are shown on the flow-duration curve (fig. 27). This information, along with that of frequency of low flow, give a sound basis for planning and design of treatment facilities. Such records are also useful beyond the planning and design stage, because they provide a basis for efficient operation in waste treatment and disposal.

## HOW FUTURE WATER PROBLEMS CAN BE SOLVED

Solution of future water problems will require an understanding of the hydrologic environment that controls the occurrence of water along with records of the changes and trends in ground-water levels, lake levels, streamflow, and water quality. This report describes the water environment of the county, but the two years of study was not long enough to determine the probable ranges and trends in the hydrologic variables. To obtain meaningful information on these variables a longer period of recorded data is needed. Recording stations must be selected with care so that the information obtained will be truly representative of the problem area or condition. The study of the county just completed provided the information needed for the selection of these stations.

### Surface Water

In order to expand the present knowledge of surface-water resources and document future trends and occurrences, the following steps are recommended: (a) establishment of stream-gaging stations on the Black River and on at least one of the major tributaries of the Paw Paw River, (b) establishment of a pesticide sampling station on a small stream, (c) continuation of selected low-flow partial-record stations, (d) establishment of high-flow partial-record stations to provide data on flood peaks. The location and number of the above stations would be dependent on the needs and desires of county officials.

Records of fluctuations of lake levels in the county also should be obtained. Greatest fluctuations in levels generally occur in lakes having no surface outlets, so most records should be obtained from such lakes. As a minimum sampling, records should be obtained on one lake in each township of the county.

### Ground Water

Observation wells should be established in areas where man-made influences, such as pumping wells, may affect water levels and in areas away from man's influence, to record the natural fluctuations of the water table. The natural fluctuations must be determined in order to evaluate those fluctuations caused by the works of man.

At least one observation well should be established in every community using ground water for the municipal supply. This is necessary in order to determine the long-term effects of pumping the municipal wells. The observation well should be located near the center of pumping but should not be so close to a pumping well that the long-term fluctuations are masked by the large changes caused by turning the pumping well on and off. Because large variations in water levels in a short period of time may occur, these observation wells should be equipped with continuous recording instruments.

One or more observation wells should also be established in areas where large quantities of ground water are pumped for irrigation or for industrial use. These wells also should be equipped with continuous recorders.

Finally, a network of observation wells should be established in unpumped areas to record the natural fluctuations in the water table. These should be selected to sample each geologic and topographic situation in the county. For example, at least one observation well should be established in the lake plains area in the western part of the county, one in the outwash plains in the south, one in the till plains area in the central part, and one in the high moraine area in the southeast. Observation wells in unpumped areas could be measured monthly. Continuous recording instruments probably would not be needed.

### Quality of Water

Samples should be collected at regular intervals from representative wells, streams, and lakes to determine short term changes and long term trends in quality of water. Samples should also be collected from streams to determine fluctuations in the sediment load.

### Using the Recorded Information

It seems superfluous to point out that records of water levels, streamflow, and quality of water are of no value unless they are used. Yet too often records are obtained over a period of years, faithfully recorded, and carefully filed, but never looked at until a problem arises. The recorded information may help to solve the problem, but the problem might have been avoided if the information had been studied earlier.

The present report summarizes what is known about the water resources of Van Buren County at this time. It is suggested that the report be kept up to date by adding a brief yearly progress report summarizing and interpreting the data that were obtained during that year. At five-year intervals a more comprehensive progress report could be prepared. Thus the people of Van Buren County would always have available an up-to-date evaluation of their water resources.

## SUMMARY

1. The glacial drift is the only known source of fresh ground water in the county. All the glacial deposits are capable of yielding some water to wells, but the sand and gravel outwash deposits yield the largest quantities.
2. Large reservoirs of ground water, especially in the outwash plains, can provide several times the amount of water now used, but large withdrawals of ground water may lower the levels of inland lakes or reduce the flow of nearby streams.
3. Streams in the southeastern two-thirds of the county are characterized by relatively high base flows owing to the permeable character of the soils and drift; streams in the northwestern part have lower base flows because soils and drift are not so permeable.
4. The major streams of the county can provide very large quantities of water, but large withdrawals will reduce the waste-assimilating capacity of these streams.
5. Floods are not a major problem in the county, but information on the size and frequency of floods is essential to the efficient design of bridges and drainage structures. A method for estimating size and frequency of floods in the county is described in the report.
6. The chemical character of water from most wells, streams, and lakes is satisfactory for most uses. Water from streams generally is hard, and water from wells is both hard and high in iron content, but hardness and iron can be removed by standard treatment. Water from some inland lakes is very soft.
7. The deficient rainfall during the period of this study (October 1962 to June 1964) resulted in falling ground-water levels and lake levels and low base flow in streams, but a few wet years could reverse this trend.
8. Water levels in land-locked lakes declined much more during this dry period than levels in lakes having surface outlets.
9. More than 300 farm ponds provide large quantities of water for irrigation and stock supplies, and some of the larger ones are used for fishing and swimming.
10. Well logs and geophysical surveys indicate deep bedrock valleys filled with glacial drift in the South Haven area. These bedrock valleys are favorable sites for test drilling for large quantities of ground water.

11. Although very minor amounts of pesticides have been detected in water from some of the streams in the county, pesticide contamination does not appear to be a serious problem at this time.
12. The availability of ground water, the base flow of streams, and the chemical character of water in the county are summarized in maps and tables in this report.
13. A program of continuing records of water levels in wells and lakes, streamflow, and water quality is essential to provide information needed to solve and avoid future water problems.

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## APPENDIX A. - Description of municipal supplies in the county

Village of Bangor

## Present Supply

To supply the population of 2,100, water is obtained from 5 wells finished in glacial drift at depths of from 60 to 75 feet. The storage facilities are elevated and have a 50,000 gallon capacity. The water is hard and contains excessive iron in wells No. 1, 2, and 3. No water treatment is used.

No. 1 and No. 2 wells are 60 feet deep, have 8-inch diameters, and are located at Exchange and Depot Streets in a 15-foot deep pit. The wells are pumped together by a centrifugal pump at a combined rate of 400 gpm. They were reportedly drilled in 1903 when the municipal system began. They tap 10 feet of gravel at 50 to 60 feet which is overlain by 40 feet of blue clay.

No. 3 is a 12-inch diameter well, 75 feet deep, drilled in 1948, and located at North and Second Streets. It taps sand and gravel and its turbine pump produces about 350 gpm. It has a reported specific capacity of  $15\frac{1}{2}$  gpm/per foot of drawdown. (Specific capacity is the yield of the well, in gallons per minute, per foot of drawdown.)

No. 4 and 5 wells, which were drilled in 1958, are located at the east edge of Bangor, in section 7, Arlington Township. No. 4 is a 12-inch diameter well, 60 feet deep. It taps coarse and fine sand from 33 to 60 feet which is overlain by 19 feet of blue clay. The well is equipped with a turbine pump and produces about 225 gpm with a specific capacity of about 9 gpm per foot of drawdown.

No. 5 is an 8-inch diameter well, 64 feet deep. It taps coarse and fine sand from 43 to 64 feet, which is overlain by 33 feet of blue clay. Its turbine pump produces 175 gpm with a specific capacity of about  $5\frac{1}{2}$  gpm/per foot of drawdown.

Village of Decatur

## Present Supply

The village has a population of 1,800 that is supplied with water from wells called Nos. 1, 2, and 3. All are equipped with turbine pumps. No. 1, or East well (at Ely and School Streets), was drilled about 1927.

It is a 12-inch diameter well 120 feet deep. It taps sand and gravel at about 95-120 feet. It produces an estimated 250 gpm.

No. 2, or West well (also at Ely and School Street), was drilled in 1929. It is a 12-inch diameter well 116 feet deep. It taps sand and gravel at 95-116 feet. It also produces about 250 gpm. The specific capacity is low -- about 6 gpm/per foot of drawdown.

No. 3 well at Phelps and Cedar Streets (school grounds) was drilled in 1952. It is 111 feet deep, has a 12-inch diameter, and taps fine to medium sand from 55 to 111 feet. The well is equipped with an auxiliary gasoline engine for use in case of power failure. It pumps an estimated 250 gpm. At a test pumping rate of 790 gpm the specific capacity was reported as 13 gpm/per foot of drawdown. This is about double the capacity of No. 1 and 2 wells. As No. 1 and 2 wells are about 100 feet apart, and the specific capacities are low (6 gpm/per foot of drawdown), there is probably a great deal of interference between the two when both are pumped at the same time. Pumping levels in each well are about 80 feet below land surface. Thus, if both wells are pumped at the same time, this would cause lowering of water levels from mutual interference. This should conceivably draw levels down below the top of the screens after a long period of pumping. Close proximity of wells generally should be avoided wherever possible.

The elevated 50,000-gallon storage tank is located adjacent to No. 1 and 2 wells at the Water Works Building. No treatment is used. The municipal water is very hard and also contains objectionable amounts of iron at wells 1 and 2.

### History of Water Works

About 1895 the water supply was obtained from two wells at the site of the present Water Works Building. The wells had a reported combined yield of 1,000 gpm with a lift of 5 to 10 feet. The construction of these wells consisted of a pit 18 feet in diameter and 28 feet deep, lined with brick. Two 6-inch wells were drilled in the pit to a depth of 117 feet. Materials penetrated were reported as 39 feet of sand and gravel, 30 feet of clay, and 48 feet of sand and gravel. Apparently the water entered the pit from both the lower and upper water-bearing materials and was pumped from the pit.

A report indicated that later, in 1928, the Village was supplied by three wells located at the Water Works site: No. 1 -- 10 inches in diameter, 116 feet deep, drilled in 1918; No. 2 -- 12 inches in diameter, 116 feet deep, drilled in 1925; and No. 3 -- 12 inches in diameter, 123 feet deep, drilled in 1927. Reportedly, Nos. 1 and 2 were plugged in 1957, and No. 3 is probably the present day No. 1 well.

## City of Gobles

### Present Supply

The population of 816 is supplied by two municipal wells, Nos. 2 and 3, which are equipped with turbine pumps. The wells are located on the east side of the City in Pinegrove Township. No. 1 well, drilled in 1917, was abandoned and plugged in September, 1963.

No. 2 well is an 8-inch well, is 124 feet deep, and has a reported capacity of 340 gpm -- it is pumped at about 140 gpm. The reported specific capacity of the well is 2.3 gpm/per foot of drawdown. No log of the materials penetrated was available.

No. 3 well is a 10-inch well, is 110 feet deep, and taps sand and gravel from 95 to 110 feet. The well has a reported specific capacity of about 13 gpm/per foot of drawdown.

The City has an elevated storage tank with a 25,000-gallon capacity. No water treatment is used. The water is very hard, but otherwise is of good quality.

## Village of Hartford

### Present Supply

The Village has a population of 2,300 served by three wells using turbine pumps and has elevated storage of 250,000 gallons. No treatment is used. The water is hard and contains objectionable amounts of iron.

The 3 wells now supplying the Village are No. 1 (N. Parking Lot well), No. 2 (Ely Park well) and No. 3 (Mary Street well).

No. 1 well is located at Center and Main Streets. It is a 12-inch well, is 95 feet deep, and was drilled in 1939. It taps coarse sand from 56 to 89, which is overlain by 9 feet of clay, and has 20 feet of .025 slot screen. This well has a reported specific capacity of 50 gpm/per foot of drawdown at a test pumping rate of 200 gpm.

No. 2 well is located at Franklin and Main Streets, in Ely Park. It is a 12-inch well, is 93 feet deep, and was drilled in 1947. It taps fine to coarse sand and gravel from 66 to 93 feet, which is overlain by 17 feet of clay, and has 20 feet of .020 slot screen. It is equipped with a 25 HP turbine pump and an auxiliary gasoline engine for emergency use in case of power failure. It is pumped at 375 gpm. The well has a reported specific capacity of about 13 gpm/per foot of drawdown at a test pumping rate of 450 gpm.

No. 3 well is a 12-inch well, is 107 feet deep, and was drilled in 1956; it is located in the southwest part of the Village at Mary and Beachwood Streets. The log shows fine sand (dirty) to 44 feet and sand and gravel from 44 to 107 feet. The well screen is 25 feet long, with 15 feet of .060 and 10 feet of .032 slot. The well is pumped at the rate of about 470 gpm. At a test-pumping rate of 940 gpm, the reported specific capacity was about 39 gpm/foot of drawdown. The well is equipped with an auxiliary gasoline engine for emergency use.

### History of Waterworks

The first water supply at Hartford was a system of six wells; all of 6-inch diameter and varying in depth from 26 to 43 feet. These wells were a mile southeast of the center of Hartford and built in a semicircle around a reservoir. The water flowed into the reservoir and then was pumped through wooden mains to the Village. This system was probably abandoned in 1939 when No. 1 (N. Parking Lot) well was installed.

In 1929 a 10-inch well 60 feet deep was constructed at the old water works station at Linden and Center Streets. This well had a reported specific capacity of 7 gpm/foot of drawdown at a rate of 350 gpm. This well has since been abandoned and plugged.

### Village of Lawrence

#### Present Supply

The Village has a population of 770 served by two wells named the East and the West well. The wells are located 100 feet apart at James and South Paw Paw Streets. Storage consists of two pressure surface tanks, with a total capacity of 18,000 gallons. Pumps are 20 HP turbines with an auxiliary gasoline pump for emergency on the East well. Water is very hard and rather high in iron. No water treatment is used.

The East well, or No. 1, is a 12-inch well, 74 feet deep, tapping gravel at about 45 to 74 feet. The gravel is overlain by 27 feet of blue clay. The screen is 10 feet long, with 7 feet of .034 slot and 3 feet of .018 slot. The well has a specific capacity of about 20 gpm/foot of drawdown at a test pumping rate of 625 gpm.

The West well, or No. 2, is a 12-inch well, 80 feet deep, tapping sand and gravel at about 50-80 feet. This material is overlain by 38 feet of blue clay. The screen consists of 15 feet of .015 slot. The well is reportedly pumped at about 400 gpm. No specific capacity test was of record.

## History of Water Works

In 1913 three 6-inch driven wells 55, 65, and 75 feet deep, tapping fine gravel were used reportedly for public supply. Total production of about 250 gpm was reported. A 12-inch well 106 feet deep was installed in 1927, followed by two 6-inch wells 96 feet and 93 feet deep. Later, two 4-inch wells and one 12-inch well were installed in the SE  $\frac{1}{4}$  of the NE  $\frac{1}{4}$  of section 9 near the Paw Paw River. All these wells have since been abandoned and plugged.

### Village of Lawton

#### Present Supply

The population of 1,400 is supplied by four wells equipped with turbine pumps. A pressure ground storage tank of 36,000 and elevated storage of 250,000 gallons is used. Water is in the "very hard" category and iron is a problem in No. 3 and 5 wells. No treatment is employed.

No. 2 well is located at James Street and Highway M-119. It is a Kelly concrete well 24 inches in diameter, and is 39 feet deep. It was installed in 1928. It has a 21-foot long screen with gravel pack of 42-inch diameter. The log lists fine sand, and fine sand with clay balls opposite the screen. It is pumped at about 200 gpm. At a 250 gpm rate it had a reported specific capacity of 12- $\frac{1}{2}$  gpm/per foot of drawdown.

No. 3 well, at White Oak Street and Highway M-119, was drilled in 1946. It is a 12-inch well, is 105 feet deep and has 27 feet of .010 slot screen. Sand and gravel was reported from the surface to the bottom of the well. The well is pumped with a 30 HP turbine at a rate of about 300 gpm. It had a reported specific capacity of about 16 gpm/per foot of drawdown at a test pumping rate of 655 gpm.

No. 4 well, located at Dunkel and Main Streets, was drilled in 1953. It is a 12-inch well, is 110 feet deep, and has 20 feet of .030 and .014 slot screen. The water is obtained from sand and gravel at 82 to 110 feet; the sand and gravel is overlain by 27 feet of blue clay. A 30 HP turbine pumps at about 500 gpm, and a gasoline auxiliary engine is available in the event of power failure. The well had a specific capacity of about 15  $\frac{1}{2}$  gpm/per foot of drawdown at a pumping rate of 930 gpm after 5 hours.

No. 5 well, which is located at Walker and White Oak Streets about 600 feet west of No. 3, was drilled in 1961. It is a 12-inch well, is 125 feet deep, and has 36 feet of .035 slot screen. It is equipped with a 75 HP turbine that pumps about 1,000 gpm. It had a specific capacity of 22 gpm/per foot of drawdown at 1,000 gpm rate.

## History of Water Supply

In 1913 it was reported that the village supply was from three 6-inch wells 103, 45 and 45 feet deep. The deeper well was equipped with a 20-foot Cook Strainer screen, while the 45-foot wells had 10 feet of strainer. These wells were probably at the site of the present Kelly well (No. 2) at James Street and M-119.

No. 1 well, at M-119 and James Street, was a Kelly concrete well drilled in 1924 -- 18-inch inside diameter with a 24-inch strainer 20 feet long with gravel pack. It was pumped at 150 gpm with specific capacity of about 16 gpm/foot of drawdown. All these wells are now abandoned.

### Village of Paw Paw

#### Present Wells

The Village population of 3,000 is supplied by 4 wells equipped with turbine pumps; elevated storage capacity is 65,000 gallons. The water is very hard, but iron is within the recommended limits.

No. 1 well is located at the east end of the bridge over the Paw Paw River just north of Michigan Avenue. It has a 12-inch diameter, and is 95 feet deep. No screen information or specific capacity was available. It had a reported yield of 420 gpm at time of drilling, but in 1962 the yield was reported as only 100 gpm with a 10 HP turbine pump.

No. 2 well is located 50 feet North and 430 feet East of the Michigan Avenue bridge. This well is 16 inches in diameter, 108 feet deep, and gravel packed. When drilled in 1950, it was equipped with 30 feet of 8-inch bronze shutter No. 5 opening screen. In 1952 the screen was changed to 20 feet of 8-inch screen. The well was drilled through 28 feet of clay to tap sand and a little gravel from 46 to 108 feet. A 30 HP turbine pumps at a rate of about 300 gpm. It has a gasoline auxiliary motor for emergency use. Specific capacity was originally reported as about 13 gpm/foot of drawdown. However, in 1962 production had fallen to about 5 gpm/foot of drawdown. In late 1963 the well screen was acidized and cleaned with phosphate and production came up to 9 gpm/foot of drawdown at a test pumping rate of 576 gpm for 30 minutes.

No. 3 well is located between the south and east branches of the Paw Paw River at the west end of Berrien Street. It was drilled in 1949 to a depth of 62 feet. The well is equipped with a 20 HP turbine which pumps at a rate of about 120 gpm. Twenty feet of bronze shutter screen was installed in a gravel pack 34 inches in diameter. The well taps medium to coarse sand from 32 to 62 feet which is overlain by 18 feet of hard sandy clay.

No. 4 well is located 750 feet north of Michigan Avenue, between Harris and Miller Streets. The well was drilled in 1961 and is a 12-inch gravel pack, 110 feet deep, equipped with 30 feet of .020 slot screen. The well taps medium sand and gravel from 68 to 110 feet overlain by sandy and gravelly clay. The 50 HP turbine is pumped at a rate of 400 gpm. When the well was drilled a specific capacity of 15 gpm/per foot of drawdown was reported at a test pumping rate of 820 gpm.

#### History of the Water Works

In 1914, two wells were used--a dug well 20 feet in diameter and 18 feet deep and a drilled, 14-inch diameter well that was 20 feet deep. Reportedly, water was produced from gravelly clay. Although no location was given, these wells were probably at the old water works station just south of the Paw Paw River and west of Kalamazoo Street.

In 1923 5 wells were used--all 85 feet deep-- one 8-inches, two 10-inches, and two 12-inches. These wells reportedly encountered "good coarse gravel" from 20-85 feet below 10 feet of tough clay. The "natural overflow" was reported as 400 gpm.

In 1933 two wells were reported in use. No. 1, with a 10-inch diameter and 100 feet deep was drilled about 1918 and No. 2, 8-inches in diameter and 90 feet deep was drilled in 1928. Gravel and sand was reported from the 15-foot depth down with an overburden of about 7 feet of clay. These two wells were pumped at a rate of 400 gpm each. All these wells have been abandoned.

#### City of South Haven

South Haven and some of its suburban area (population about 6,200), is supplied by water from Lake Michigan. Water enters through a 24-inch intake pipe, 40 feet below the lake surface. It is then piped about a mile to the treatment plant. Here, the water is fluoridated and given "Standard Filtration", which indicates at least chlorination, chemical coagulation, and rapid sand filtration. The finished water falls into the "hard" classification. A standpipe gives elevated storage of 1.5 million gallons.

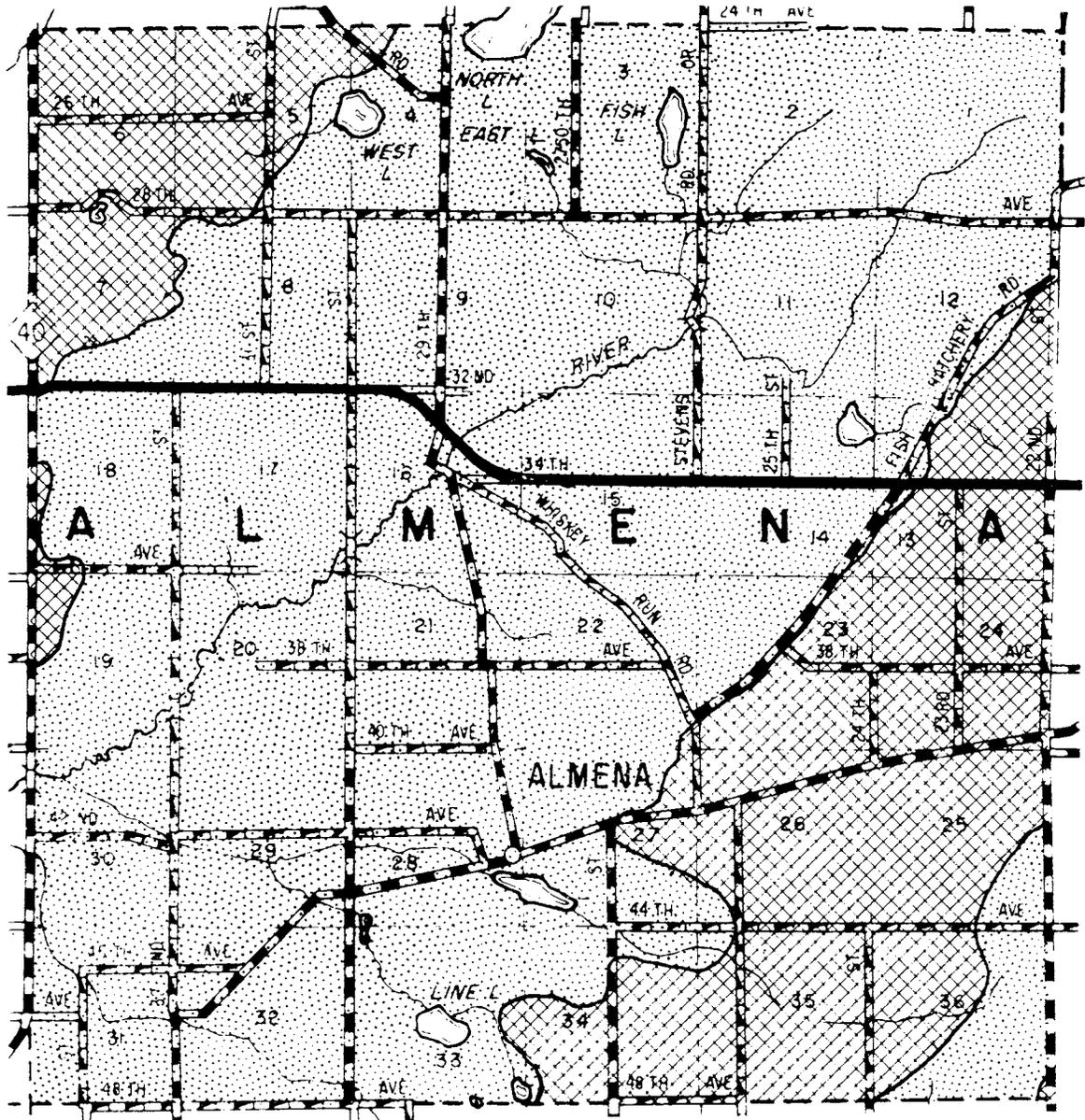
Test wells were drilled in 1932 in an effort to obtain water from wells for the city. However, these tests failed to locate any adequate ground-water sources.

APPENDIX B.--Ground water availability maps and tables of wells  
(alphabetically by townships)

Table 7.--Records of selected wells in Alma Township (T. 2S, R. 13W.)

Explanation: e -- estimated; Analyst--Field, not accurate to laboratory standards; USGS, U. S. Geological Survey; MDH, Michigan Dept. of Health; REMARKS--LOG, record of materials penetrated on file; ANML, also see table of chemical analyses of ground water.

Location T. R. sec	Owner	Driller	Year drilled	Depth (in ft.)	Diam (in inches)	Water level (in feet)	Month and year measured	Field (in gpm)	Use	Screen openings (inches)	Pump	Water- bearing materials	Altitude (in ml)	Quality of Water				Remarks
														Iron (as Fe)	Hardness (as CaCO <sub>3</sub> )	Chloride (Cl)	Analyst	
NW 2	Co. Rd. Commission	USGS	1963	23	1 1/4	17.12	4-53		Obs	Drive ft	Piston	Sand	730					Used as observation well
SW 4	G. Stoughton	W. Goble	1939	36	2	24	5-39		Dom	.007	Piston	Gravel	760	tr	240	5	Field	
SW 5	E. Bergren			60	3	50	-50		Dom		Jet	Sand, gravel	790	2.5	250	5	Field	
SE 10	B. Penny	Ormer	1963	38	1 1/2	+3	10-53		Dom	.007	Jet	Sand, gravel	720	0.6	220	10	Field	Through clay at 33'
SW 12	G. Vander Molen	B. Sanders	1958	46	2	e-1	-58	55	Dom		Jet	Sand, gravel	760	0.4	200	10	Field	LOG
NW SW 13	Wolf Lake Fish Hatch.	T. Newman	1948	60	4	2.3	-48		Pub	.014	Jet	Sand	770				Field	100
SE 14	Wolf Lake Fish Hatch.	L. Sanders		60	4	flows			Pub		Jet	Sand, gravel	720	1.0	220	20	Field	1/2 gpm flow; hydrogen sulfide odor reported
NW SW 15	G. Cox	D. Waite	1962	45	2	3	8-62		Dom		Jet	Sand, gravel	720	0.8	220	10	Field	Restaurant supply
NW 16	O. Ketchum			110	2	40-60	-61		Dom		Piston	Sand, gravel	760	0.5	220	10	Field	Has 2 wells
NE 18	C. Leonard	E. Brindley	1962	85	2				Dom		Jet	Sand, gravel	722	0.4	220	10	Field	
SE NW 21	H. Livingston		1953	e-35	2				Dom		Jet	Sand, gravel	735	0.8	180	10	Field	
NE 22	E. Wertsler		1958	15	2				Dom		Jet	Sand, gravel	810	tr	180	5	Field	
SE NE 23	R. Overacker	E. Sanders	1936	72	2				Dom, Stk		Jet	Sand, gravel	840	0.2	170	5	Field	
NE 24	R. Williams	Rice	1938	73	2				Dom		Piston	Gravel	820	0.4	200	10	Field	May use for Irrigation
NE 26	M. Vandersalm	E. Sanders	1959	86	3	e-6	-59		Dom		Jet	Gravel	840	0.4	200	10	Field	
SE 27	E. Ritter	R. Sanders	1958	60	2				Dom		Jet	Gravel	820	0.1	200	200	Field	
NE 28	L. Howard	E. Sanders		25	2				Dom		Jet	Gravel	760				Field	
SE 28	V. Miller	E. Sanders	1963	40	2	11	7-53		Dom		Jet	Gravel	710				Field	
SW 29	F. Beyer			18	2				Dom, Stk		Jet	Gravel	710				Field	
SW 31	P. Churchill	Ormer	1940	22	1 1/2	15	-40		Dom		Centr	Sand	720				Field	
SW 32	M. Fallanus	Ormer	1959	22	1 1/2	16	-59		Dom		Jet	Sand	730				Field	Also has well 57' deep
SE 36	H. Boven	L. Nolan	1963	44	2	e-30	9-53	10	Dom	.005	Jet	Sand	850				Field	



**AREA I.** Enough water for domestic, stock, and spraying supplies (up to 10 gpm) generally can be obtained from wells less than 75 feet deep. Water in the well usually is less than 30 feet below land surface. Enough water for irrigation, municipal, or industrial supplies (more than 100 gpm) generally can be obtained from deeper, large-diameter wells (more than 6 inches in diameter and 100 to 200 feet deep).

**AREA II.** Enough water for domestic, stock, or spraying supplies generally can be obtained from wells less than 125 feet deep. Depth to water in about half the wells is more than 30 feet below land surface. Large-diameter wells less than 200 feet deep generally yield enough water for irrigation, municipal, and industrial supplies.

**AREA III.** Enough water for domestic, stock, or spraying supplies generally can be obtained from wells less than 200 feet deep. Wells for irrigation, industrial, or municipal supplies generally would have to be drilled to depths greater than 150 feet, and probably less than half of these would be successful.

**AREA IV.** Enough water for domestic, stock, and spraying supplies generally can be obtained from wells less than 75 feet deep. Water in the well generally is less than 30 feet below land surface. Exploratory drilling would be needed to determine where large supplies can be obtained.

**AREA V.** It is difficult to obtain enough potable water for domestic supplies in this area. It may be necessary to drill several wells before a successful domestic well is obtained. Chances of obtaining large supplies are poor.

**AREA VI.** Similar to surrounding areas except that thick glacial drift in deep bedrock valleys may yield moderate to large supplies of water (50 to more than 100 gpm). Exploratory drilling would be needed to determine where large supplies are available. Test wells should be drilled to bedrock unless salt water is found at shallower depths. Bedrock may be more than 500 feet deep in places.

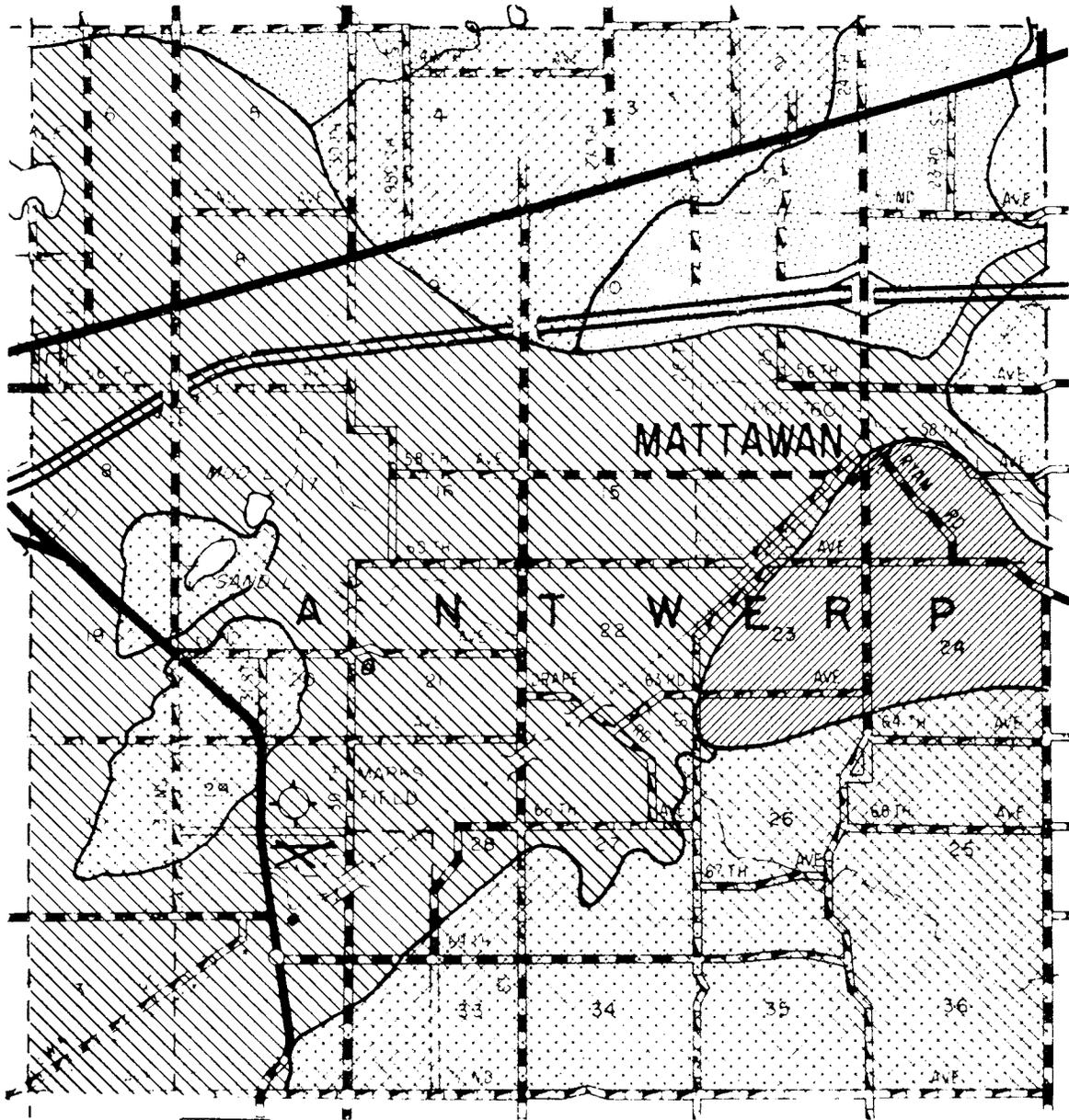
Swamps and marshes

FIGURE 28.--MAP OF ALMENA TOWNSHIP SHOWING THE GENERAL AVAILABILITY OF GROUND WATER TO WELLS.

Table 8.--Records of selected wells in Antwerp Township (T. 3S., R. 13W.)

Explanation: e - estimated; Analyst--Field, not accurate to laboratory standards; USGS, U. S. Geological Survey; MDH, Michigan Dept. of Health; Remarks--LOG, record of materials penetrated on file; ANAL, also see table of chemical analyses of ground water.

Location T. R. Sec	Owner	Driller	Year drilled	Depth (in ft)	Diam (in inches)	Water level (in feet)	Month and year measured	Yield (in gpm)	Use	Screen openings (inches)	Pump	Water- bearing material	Altitude (in msl)	Quality of Water				Remarks
														Iron (as Fe)	Hardness (as CaCO <sub>3</sub> )	Chloride (Cl)	Analyst	
SE NE 1	R. Boven	E. Sanders	1962	50	2	OK	6-62	9	Dom,Irrig	.010	Jet	Sand	850					Used for greenhouse
NW SW 2	L. DeLeeuw	Do.	1948	50	2	e 57	-45	e 5	Dom,Stk		Jet	Sand, gravel	770	1.50	10	Field		Also used for spraying
NW SW 4	R. Areaux	Do.	1945	157	2				Dom,Stk		Jet	Sand, gravel	800	300	25	Field		NO <sub>3</sub> 31.5 ppm (MDH)
NW SE 6	A. Oranich	Owner	1943	30	14	e 30	-59	15	Irrig	.012	Jet	Sand	770	200	15	Field		SO <sub>4</sub> 34; pH 7.8
SE NE 7	A. Stinao	E. Sanders	1959	62	4	e 36	5-60	20	Dom	.010	Jet	Sand, gravel	760	200	15	Field		
SW NE 7	F. Henningsen	G. Tinker	1960	50	2	e 36	9-62	20	Dom	.008	Jet	Sand, gravel	750	170	5	Field		
SE NE 7	G. Eadnington		1943	100	2	e 40-50	4-3		Dom,Spray	.015-.030	Jet	Gravel	820	0	5	Field		LOG
SW NW 10	A. Gladysz	Bogart	1962	87	6	e 26	11-62	120	Pub,Ind	.070	Subm	Gravel	840	1.50	5	Field		LOG; Anal. by driller
NW SW 12	Internat. Research	A. Wealer	1961	119	10	e 65.15	11-62	400	Pub,Ind		Turb	Sand, gravel	880	0.4	4.0	USGS		Water level 67.1 Nov. '62(recently pumped);
SW NW 13	Glaser-Chandall Co. Do # 2	Ohio Drilling Co. Layne-Northern Co.	1937	114	10	e 61.1	7-37	250	Pub,Ind		Turb	Sand, gravel	875	0.4	4.0	USGS		ANAL
NW NE 14	Mattawan High Sch. Carpenter	Layne-Northern Co.	1958	70	6				Pub		Turb	Sand	830	.05	2	Field		
NE NE 14	H. Bevoe	Val's Pump Serv.	1955	45	4	e 40			Pub		Jet	Sand	830	0	10	Field		Trailer Park
SE SE 16	H. Davis	E. Sanders	1955	80	4				Dom	.010	Jet	Sand	793	0.3	5	Field		
SE SE 18	G. Davis	E. Sanders	1963	54	3	e 33	7-63	30	Dom,Spray		Piston	Sand	780	tr	200	Field		Use 2,000 gals per day when spraying
SW SW 20	D. Angel	E. Sanders	1961	28	2	e 86			Dom	.012	Jet	Sand	800	1.0	14.0	Field		"Hardpan" rept. at 20 feet
SW SW 21	L. Brown	E. Sanders	1956	116	3	e 52	4-63	200	Dom,Spray	.012	Jet	Sand	800	0.0	150	Field		
NW NW 24	V. Shultz	J. Newman	1963	147	8	e 52			Irrig	.008-.010	Turb	Sand, gravel	920	tr	250	Field		Has 2-inch test 5 ft. from well
NW NW 24	Do.	H. Dibble	1922	104	2	e 30			Dom,Spray		Jet	Sand	880	tr	170	Field		
SW SE 29	S. Twarog	Owner	1948	31	2	e 19	-61	6	Dom	.010	Centr	Sand	790	tr	36	Field		ANAL
SW SE 29	E. Sanders	Ind-Mich Water Co	1946	105	12	e 6.5	4-46	655	Mun	.010	Turb	Sand	780	0.8	260	Field		LOG; ANAL
SE SW 29	Village of Lawton #3	Dunbar Drig. Co.	1961	125	36	e 5.8	11-62	1,000	Mun	.035	Turb	Sand	780	0.5	280	Field		ANAL; LOG
SE SW 29	Do.	Kelly Well Co.	1928	39	24	e 4.5	6-28	250	Mun		Turb	Sand	785	0	240	Field		LOG; ANAL; Concrete well
NW NE 32	Do.	Do.	1924	44	24	e 6.5	7-24	500	Mun		Turb	Sand	785	1.4	240	Field		Abandoned well; 9 1/2' water level 1942; LOG
NW NE 32	Do.	Do.	1924	44	24	e 6.5	7-24	500	Mun		Turb	Sand	785	1.4	240	Field		LOG; ANAL
SW SE 32	Do.	Ind-Mich Water Co	1953	110	12	e 27.15	11-62	930	Dom,Spray	.014-.030	Turb	Sand	785	1.4	240	Field		
SW SE 33	J. Gladings	A. Elmop	1940	100	2	e 70			Dom,Stk		Jet	Gravel	920	tr	200	Field		
SW NE 34	E. Elum	E. Sanders	1960	105	3				Dom,Stk		Jet	Gravel	920	tr	200	Field		
SE SE 35	D. Abbott	E. Sanders	1960	84	2				Dom,Stk	.010	Jet	Gravel	965	0	10	Field		



**AREA I.** Enough water for domestic, stock, and spraying supplies (up to 10 gpm) generally can be obtained from wells less than 75 feet deep. Water in the well usually is less than 30 feet below land surface. Enough water for irrigation, municipal, or industrial supplies (more than 100 gpm) generally can be obtained from deeper, large-diameter wells (more than 6 inches in diameter and 100 to 200 feet deep).

**AREA IV.** Enough water for domestic, stock, and spraying supplies generally can be obtained from wells less than 75 feet deep. Water in the well generally is less than 30 feet below land surface. Exploratory drilling would be needed to determine where large supplies can be obtained.

**AREA II.** Enough water for domestic, stock, or spraying supplies generally can be obtained from wells less than 125 feet deep. Depth to water in about half the wells is more than 30 feet below land surface. Large-diameter wells less than 200 feet deep generally yield enough water for irrigation, municipal, and industrial supplies.

**AREA V.** It is difficult to obtain enough potable water for domestic supplies in this area. It may be necessary to drill several wells before a successful domestic well is obtained. Chances of obtaining large supplies are poor.

**AREA III.** Enough water for domestic, stock, or spraying supplies generally can be obtained from wells less than 200 feet deep. Wells for irrigation, industrial, or municipal supplies generally would have to be drilled to depths greater than 150 feet, and probably less than half of these would be successful.

**AREA VI.** Similar to surrounding areas except that thick glacial drift in deep bedrock valleys may yield moderate to large supplies of water (50 to more than 100 gpm). Exploratory drilling would be needed to determine where large supplies are available. Test wells should be drilled to bedrock unless salt water is found at shallower depths. Bedrock may be more than 500 feet deep in places.

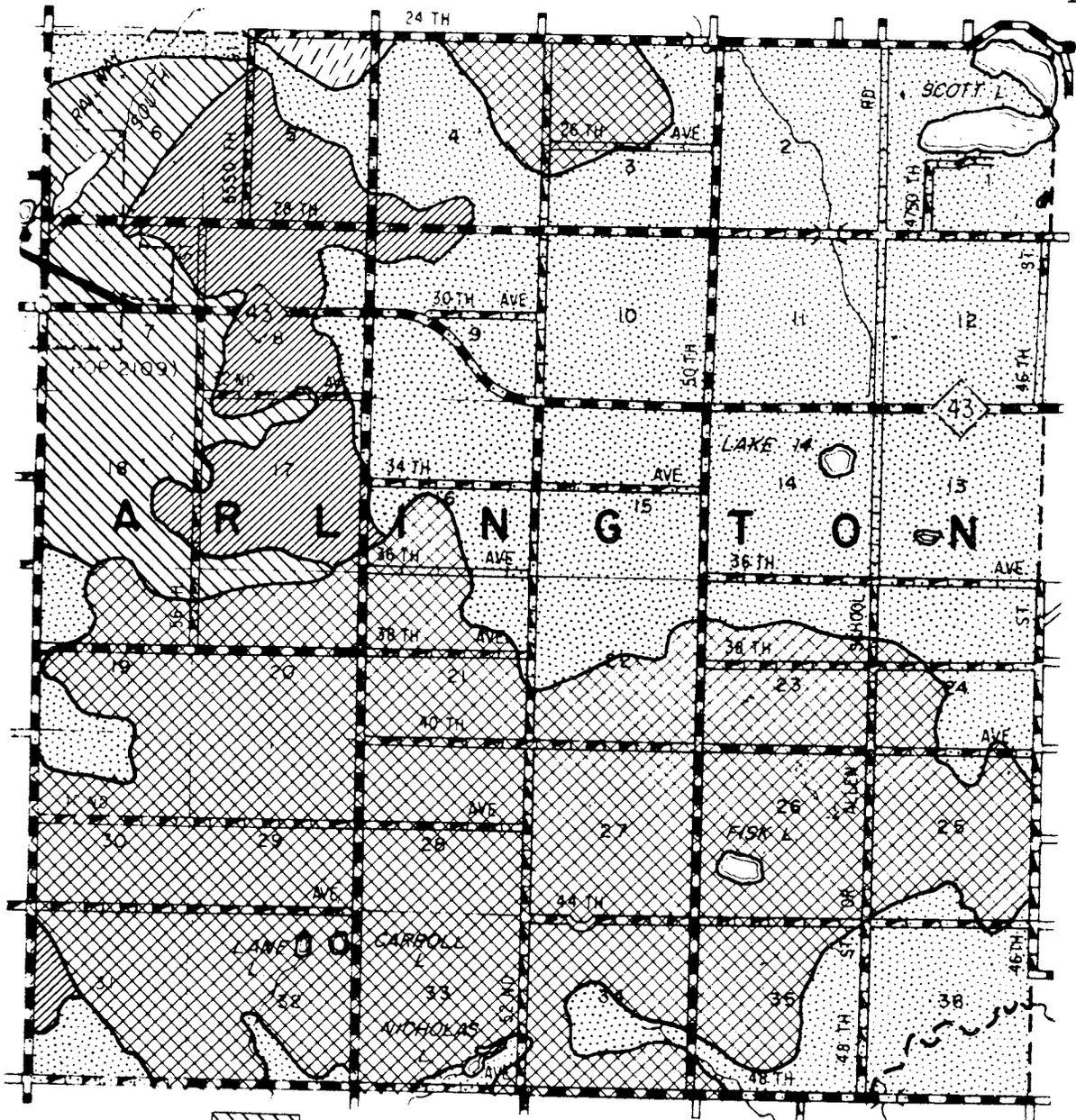
Swamps and marshes

FIGURE 29.--MAP OF ANTWERP TOWNSHIP SHOWING THE GENERAL AVAILABILITY OF GROUND WATER TO WELLS.

Table 9.--Records of selected wells in Arlington Township (T. 2S., R. 15W.)

Explanation: e - estimated; Analyt--Field, not accurate to laboratory standards; USGS, U. S. Geological Survey; MDH, Michigan Dept. of Health; ~~Remarks~~--LOG, record of materials penetrated on files; MAI, also see table of chemical analyses of ground water.

Location T. R. S. E.	Owner	Driller	Year drilled	Depth (in ft.)	Diam (in ft.)	Water level (in feet)	Month and year measured	Yield (in gpm)	Use	Screen openings (inches)	Pump	Water- bearing materials	Altitude (in feet)	Quality of Water			Analyt	Remarks
														Iron (as Fe)	Hardness (as CaCO <sub>3</sub> )	Chloride (Cl)		
SE SE 1	K. Smith	U. S. G. S.	1963	86	2	22.30	5-63		Dom		Jet	Sand	688	1.5	240	10	Field	Sulfate 12
NW SW 3	Co. Rd. Commission			37	1 1/2				Obs		Jet	Sand	689		220	10	Field	Auger hole used as observation well; LOG
SE SE 3	N. Mayer			26	2	60	-61		Dom		Piston	Sand, gravel	750	1.5	220	10	Field	LOG
SW SW 5	L. and M. Sealey			180	8			125	Test			Sand, gravel	660		237	11	USGS	Water temp 52.7°F
SW SW 6	Village of Bangor	Godfrey Oil Co.	1947	80	8	14	2-62	350	Ind	.014	Turb	Gravel	658	0.2	260	7	MDH	LOG
NW NW 7	Du-Well Metal Products	G. Cole	1962	60	12	15.80	11-62	250	Mun	.020	Turb	Sand	660	0.25	235	2	MDH	LOG
NE SW 7	Village of Bangor #4	Ind.-Mich Water Co.	1958	64	8	-18.37	11-62	225	Mun	.010	Turb	Sand	680	0.2	240	15	Field	LOG; at west edge of cemetery
SW NE 7	Village of Bangor	J. Taylor	1963	54	2	e 4	10-63	20	Dom		None	Sand	680				Field	LOG; at west edge of cemetery
NE NW 7	Village of Bangor	Ind.-Mich Water Co. Owner	1958	130	6				Test	Open bott	Jet	Sand	710	1.5	135	40	Field	Former school well
SE SE 8	O. Hildebrandt			70	2	3	-43		Dom		Jet	Sand	720	2	170	10	Field	Bailed 20 gpm (by driller); LOG
SE SE 8	M. Pickenhain			16	30				Dom		Jet	Sand	710	2	170	10	Field	
SE NE 8	E. Root	Dunbar Drig. Co.	1949	86	5	40	1-49		Spray	.020	Turb	Sand	720	0.2	340	35	Field	
NE NE 9	K. Drake	R. Sanders	1962	70	2	18	-62		Dom,Stk		Jet	Gravel	705	1.0	200	5	Field	
NW NW 10	G. Hasty	H. Starbeck	1938	67	2	29	-61		Dom		Jet	Gravel	700	0.3	200	10	MDH	
NW NE 14	J. Zirbel	J. Taylor	1963	30	4	2	7-63	40	Dom,Stk		Jet	Gravel	690	0.73	250	16	USGS	
NW NE 14	A. Duda	R. Sanders	1957	46	2				Dom,Stk		Piston	Gravel	680	1.5	270	15	Field	Water temp. 51.3
SE NE 16	S. Baker	Owmer	1938	25	11	e20	-51	400	Dom,Stk	.010	Piston	Sand	720				Field	Oil well on this farm years ago.
SE NE 17	B. Hills	J. Taylor	1963	88	7	30	6-63		Irrig	.010	Subm	Gravel	660				Field	Former 160' well was abandoned
SE SE 20	W. Hoyer	R. Sanders	1954	212	4				Dom	.010	Subm	Sand	800	1.0	260	5	Field	
SE SE 22	A. Bregger	E. Sanders	1954	126	2				Dom		Jet	Sand	710	1.5	375	5	Field	ph 7.1
SE SE 22	K. Judd	R. Sanders	1941	290	3-2			9	Dom,Spray		Piston	Sand	800	1.2	250	5	Field	
SW SE 24	F. Tomcala	H. Starbeck	1959	100	2	60	-61		Dom	.010	Piston	Sand	760	0.5	300	1.0	USGS	ph 7.2 Supply for 2 houses and stock
SW NW 24	F. Gurnsey	C. Raymond	1903	118	2	52			Dom,Spray		Piston	Sand	760	0.5	300	5	Field	Iron not all in solution
SW SE 26	H. Hutchins	E. Richtcreek	1951	132	2				Dom,Stk		Piston	Sand	780	5	400	5	Field	35' of screen; LOG
SW NW 27	M. Blum	A. Bishop	1976	170	4			540	Irrig,	.012-.030	Piston	Sand	780				Field	Supply 2 houses, 50 stock; pH 7.2
NW SW 28	H. Wakeman	Dunbar Drig. Co.	1961	215	12	100	8-61		Spray		Turb	Sand, gravel	780	0.1	497	9	USGS	
SW NW 29	G. Mahr	E. Sanders	1955	85	2	e70	-61		Dom,Stk		Jet	Sand	720	1.5	340	5	Field	
SW NW 30	F. Hay	H. Starbeck	1962	112	2	e85	4-62	8	Dom,Stk	.006	Jet	Sand	750	1.0	301	1	USGS	
SW NW 31	Donovan Lake Farms	D. Rose	1962	54	2	e25	11-62	12	Dom	.010	Jet	Sand	680				Field	
SW SW 32	W. Jordan	E. Sanders	1962	54	2	e28	-57		Dom		Jet	Sand	710				Field	
NE SE 33	F. Nicholas	E. Sanders	1977	60	2	86	11-63		Dom		Piston	Sand	760				Field	Have 3 wells 40' & 102'; Analysis of 40' well
SW SE 34	H. Harris	E. Richtcreek	1963	126	2				Dom		Jet	Sand	680	0.2	200	10	Field	Barn well 22' deep
SE SW 36	G. Richardson	E. Richtcreek	1963	36	2				Dom		Jet	Sand	680				Field	



**AREA I.** Enough water for domestic, stock, and spraying supplies (up to 10 gpm) generally can be obtained from wells less than 75 feet deep. Water in the well usually is less than 30 feet below land surface. Enough water for irrigation, municipal, or industrial supplies (more than 100 gpm) generally can be obtained from deeper, large-diameter wells (more than 6 inches in diameter and 100 to 200 feet deep).

**AREA II.** Enough water for domestic, stock, or spraying supplies generally can be obtained from wells less than 125 feet deep. Depth to water in about half the wells is more than 30 feet below land surface. Large-diameter wells less than 200 feet deep generally yield enough water for irrigation, municipal, and industrial supplies.

**AREA III.** Enough water for domestic, stock, or spraying supplies generally can be obtained from wells less than 200 feet deep. Wells for irrigation, industrial, or municipal supplies generally would have to be drilled to depths greater than 150 feet, and probably less than half of these would be successful.

**AREA IV.** Enough water for domestic, stock, and spraying supplies generally can be obtained from wells less than 75 feet deep. Water in the well generally is less than 30 feet below land surface. Exploratory drilling would be needed to determine where large supplies can be obtained.

**AREA V.** It is difficult to obtain enough potable water for domestic supplies in this area. It may be necessary to drill several wells before a successful domestic well is obtained. Chances of obtaining large supplies are poor.

**AREA VI.** Similar to surrounding areas except that thick glacial drift in deep bedrock valleys may yield moderate to large supplies of water (50 to more than 100 gpm). Exploratory drilling would be needed to determine where large supplies are available. Test wells should be drilled to bedrock unless salt water is found at shallower depths. Bedrock may be more than 500 feet deep in places.

Swamps and marshes

FIGURE 30.--MAP OF ARLINGTON TOWNSHIP SHOWING THE GENERAL AVAILABILITY OF GROUND WATER TO WELLS.

Table 10.--Records of selected wells in Bangor Township (T. 2S, R. 16W.)

Explanation: Analyst--Field, not accurate to laboratory standards; USGS, U. S. Geological Survey; MDH, Michigan Dept. of Health; Remarks--LOG, record of materials penetrated on file; ANAL, also see table of chemical analyses of ground water.

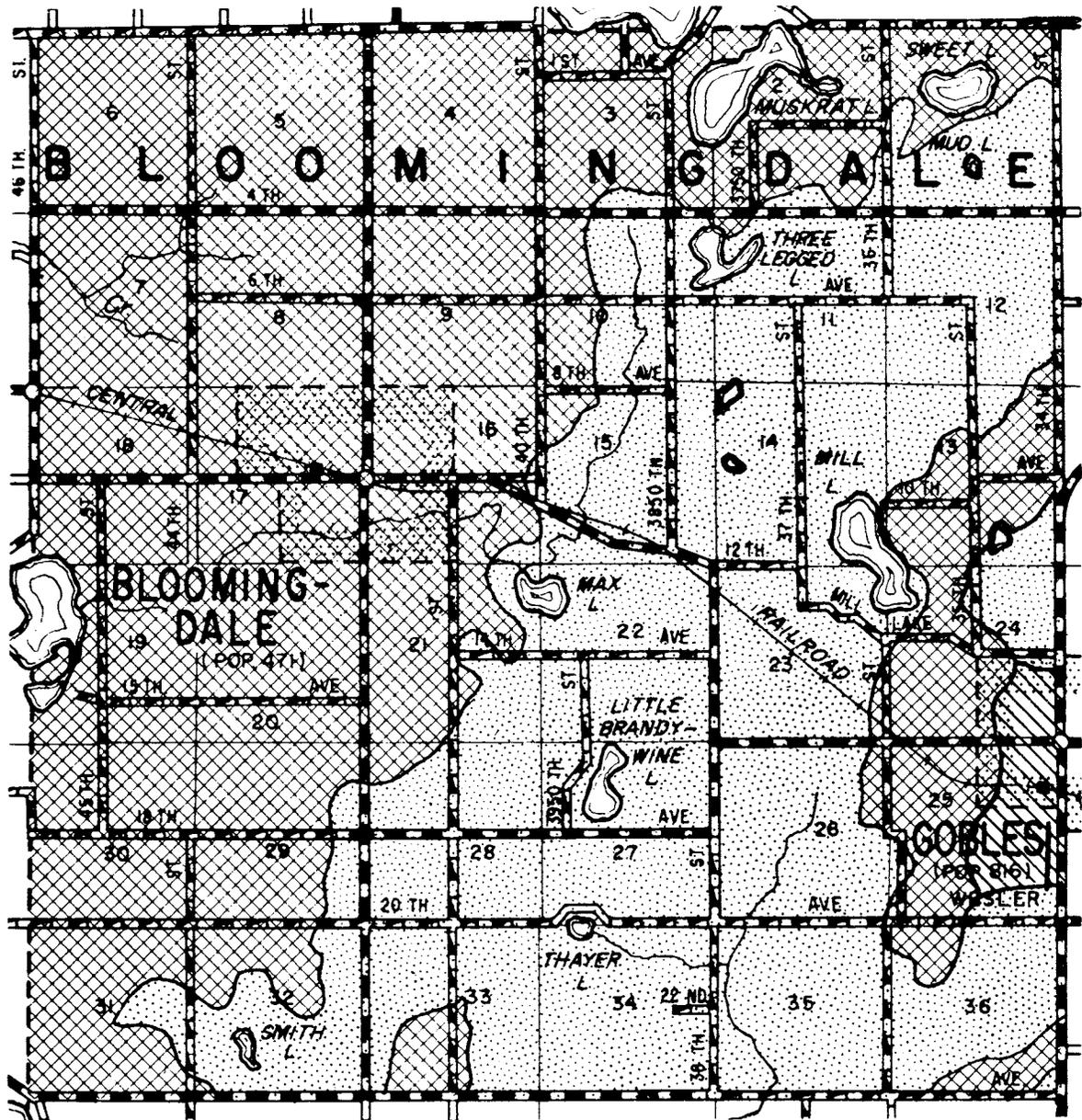
Location T. 2S, R. 16W.	Owner	Driller	Year drilled	Depth (in ft.)	Diam (in inches)	Water level (in feet)	Month and year measured	Yield (in gpm)	Use	Screen openings (inches)	Pump	Water-bearing materials	Altitude (in msl)	Quality of Water				Remarks
														Iron (as Fe)	Hardness (as CaCO <sub>3</sub> )	Chloride (Cl)	Analyst	
NE SE 1	Village of Bangor #3	Dunbar Drilg. Co.	1948	75	12	15.15	11-62	350	Mun	.020-.080	Turb.	Gravel, Sand	660	0.5	215	18	MPH	LOG, ANAL 5 wells total
NE SE 3	Triple S (Stein)	Calay, H.	80-1203	4	2	30	4-63	c/15	Dom, Stk	.010	Piston	Sand	650	1.2	140	40	Field	Cond. 550; Specific Conductance 550
NE SE 4	E. Hessey	J. Taylor	1963	65	2	30	4-59		Dom, Stk	.006	Jet	Sand	640	0.4	240	5	Field	Specific Cond. 440; LOG
NE SE 5	A. Debest		1961	42-50	14	6			Dom, Stk		Jet	Sand	660	1.0	290	10	Field	Specific Conductance 370
NE SE 6	M. Weber	J. Taylor	1944	75	2				Dom, Stk		Jet	Sand	660	1.0	290	10	Field	Specific Conductance 440
NE SE 8	D. Watkins	R. Sanders	1953	64	2				Dom, Stk		Jet	Sand	660	1.0	263	6.2	Field	Specific Conductance 420
NE SE 9	R. Dillman	H. Starbeck	1975	150	10	30	5-56	1,100	Irrig.	.010-.045	Turb.	Sand, Gravel	670			USGS	ANAL LOG	
NE SE 11	R. Funk	Dunbar Drilg. Co.	1976	150	10	30			Test		Centr.	Gravel	660			MDH	LOG; ANAL; both wells pumped together, 440 each	
NE SE 12	Village of Bangor do #1 & 2	Godfrey Oil Co.	1947	158	8	16		400	Mun		Jet	Gravel	660	1.5	425	20	Field	pH 7.2
NE SE 13	A. Sciele	E. Saunders	90	30	2				Dom, Stk		Jet	Gravel	675	1.5	395	52	Field	ANAL
NE SE 14	H. Watkins	C. Jones	1960	38	2			44	Dom, Stk	.005-.007	Piston	Sand	680	1.5	395	52	USGS	ANAL
NE SE 17	F. Overton	E. Saunders	1962	40	2				Dom, Stk		Jet	Sand	700	0.08	710	141	USGS	ANAL
NE SE 18	J. Handolph	Vanderbooth	1948	35	2				Dom, Stk		Jet	Sand	680					
NE SE 19	U. Watkins	D. Nose	1962	52	2	35 e	6-62	6	Dom	.010	Jet	Sand	693	0.9	180	10	Field	pH 7.2
NE NW 22	I. Westcott	do	1962	40	2	20 e	4-62	12	Dom, Stk	.010	Jet	Sand	700	None	185	10	Field	
NE SE 24	P. Harlin	do	1962	35	2	30 e	4-62	5	Dom, Stk		Suct	Sand	600	0.5	388	5.0	Field	ANAL
NE SE 28	I. Westcott	D. Nose	1963	108	2	30 e	-63	5	Dom, Stk		Jet	Sand	690				Field	Specific conductance 420; also has 2 wells 105 ft
NE NW 29	W. Nutting	Owner	1946	18	14	5	-46	40	Dom		Piston	Gravel	670	tr	275	15	Field	Rept Clay to 105 ft
NE NE 29	R. Jackson	R. Sanders	1956	21	2	10		10	Irrig.		Piston	Sand	671				Field	14 ft of clay above gravel
NE SE 31	Mrs. E. Kemp	D. Rose	1963	38	2	10 e	8-62	12	Dom	.010	Jet	Sand	650	0.6	240		Field	3 wells pumped together; same depth at Rush Lake
SE SW 33	D. Moore	do	1962	49	2	10 e	6-62	10	Dom		Jet	Sand	660	3.0	280	10		
SE NE 33	C. Drake	do	1962	97	2	52	6-62	10	Dom, Spray	.007	Jet	Sand	700					
SE SW 34	T. Robinson	do	1962	54	2	45	10-62	8	Dom	.006	Jet	Sand	720					
SE SW 35	K. Coon	Owner	1972	24	14	5	-52		Dom		Jet	Gravel	740	0	150	2	Field	pH 7.4; Springs in area
SE SW 36	J. Mulholland	C. Griffens	1977	15	16	flows	-63		Pub.		Centr.	Sand	680	tr	250	5	Field	pH 7.3; Dug well w/open bottom



Table 11.--Records of selected wells in Bloomingdale Township (T. 1S., R. 14W.)

Explanation: e - estimated; Analyz--Field, not accurate to laboratory standards; USGS, U. S. Geological Survey; MDH, Michigan Dept. of Health; Remarks--LOG, record of materials penetrated on file; ANML, also see table of chemical analyses of ground water.

Location T. R. sec	Owner	Driller	Year drilled	Depth (in ft.)	Diam (in inches)	Water level (in feet)	Month and year measured	Yield (in gpm)	Use	Screen opening (inches)	Pump	Water bearing materials	Altitude (in feet)	Quality of Water			T Remarks
														Iron (as Fe)	Hardness (as CaCO <sub>3</sub> )	Chloride (Cl)	
SE SE 1	L. Healey	E. Brindley	1962	85	2	2			Dom,Stk	.015	Jet	Gravel	754	200	15	Field	
SW NW 3	W. Van Horn			125	2	65			Dom,Stk		Jet		780	190	10	Field	
SW SW 5	G. Greiffendorf			87	2	40			Dom,Stk		Jet	Sand	780	270	20	Field	
SE NE 5	C. Pearson			45	2	20			Dom,Stk		Piston		780	200	15	Field	
SW SW 7	D. English	E. Brindley		60	2	e			Dom		Jet		700	290	20	Field	
SW SW 7	P. & J. Staassek	Do.		75	2	e			Dom,Stk	.010	Jet	Sand	700	290	20	Field	
NE SE 8	H. Kugel			60	2	e			Dom,Stk		Jet		700	290	20	Field	Supply reported inadequate
SE SE 10	R. Stone	E. Brindley	1962	115	2	e			Dom,Stk		Jet	Sand	775	240	15	Field	
NW NW 10	E. Harris			100	2	e			Dom,Stk		Jet		760	240	15	Field	
NW NW 11	E. Brindley			84	3	45			Dom	.018	Hand		784	220	10	Field	
NW SW 13	J. Lindquist	Owner		20	2	e			Dom		Hand		770	357	136	USGS	Also used for spraying pumped 30 gpm w/drilling machine ANML; water temp 52.9°F Oil wells nearby
SW SE 14	Mrs. H. Valako			85	2	e			Dom		Jet		780	170	75	Field	
SW SE 14	E. Brindley			92	2	e			Dom		Jet		766	130	25	Field	
SW SE 15	Mrs. J. Vavrina	C. Waite	1963	90-100	2	e			Dom		Jet		770	410	28	Field	Supply for resort cottage ANML.
SE NE 15	Dickerson Greenhouse	Cole & Lynch	1956	140	8	30		500	Dom	.030	Turb	Sand	770	214	38	USGS	ANML; have 3 shallow and 2 deep wells
SE NE 15	R. Esler			30	2	5			Dom		Hand		770	214	38	USGS	
SW NW 16	Bloomingdale High Sch.	J. Newman	1962	127	6	2			Pub	.050-.025	Subm		710	413	238	USGS	
SE NW 16	V. Ferguson	E. Brindley	1954	89	2	16			Dom	.007	Piston		720	313	4	MDH	Field Anal '63: Fe 4.0; Cl 1.5; Hdness 320
SW NW 16	Vic's Cut Rate	Do.		42	2	e			Pub	.020	Jet		720	313	4	MDH	Field Anal '63: Fe 1.2; Cl 4.0; Hdness 270
SW NW 16	Thomas Oil Co.	Do.		67	2	32		10	Ind	.020	Jet		760	200	20	Field	Field 20 gpm by driller Used for restaurant
SW NW 16	R. Brush	C. Cooley	1963	36	2	2			Dom		Jet		720	270	22	Field	
SW NW 17	L. Page	Do.		60	2	2			Dom		Jet		680	180	15	Field	Flow rept. 2 gpm; ANML; clay at top-1/8 ft.
NE NW 19	R. Schendel	Do.		137	2	Flows			Dom	.007	Centr		680	180	15	Field	
SE SW 20	J. Kopterski	A. Wealer	1946	75	2	35			Dom		Jet		760	386	10	Field	*Field w/drilling machine pump *Trace of iron
SE NE 21	G. Kridler	E. Brindley	1958	50	2	2			Dom,Stk		Jet		790	270	25	Field	
NE NE 23	J. Cusack	Do.		108	2	57		*25	Dom	.012	Jet		760	270	25	Field	
SW SW 24	J. Rosenberg	Do.		50	2	2			Dom,Stk		Jet		790	270	25	Field	
NE NE 24	G. Sutton	E. Brindley	1962	115	4	60		850	Dom,Stk	.015	Subm		825	240	15	Field	
SW SE 27	T. Gibbons	E. Sanders		82	2	56			Dom		Jet		795	310	15	Field	Have other well 68' deep; and tile dug well 12' not used
SW NW 28	A. Shaw	H. Starbeck	1956	68	2	2			Dom		Jet		760	270	10	Field	
SW SW 29	W. Hendricks	Do.		90	2	2			Dom,Stk		Jet		800	300	10	Field	
SW NW 30	J. Eifner	Owner		26	1 1/2	1 1/2			Dom		Centr		680	290	20	Field	Springs on property flow into Irrig. pond; 170 hardness; Cl 10
SW SW 31	J. Abernathy	H. Starbeck	1950	116	2	70			Dom,Stk		Jet		700	280	20	Field	
SE SE 34	C. Doney	E. Brindley	1954	54	2	6		R 5	Dom		Centr		710	260	10	Field	Alternating layers of clay
NW NW 34	A. Jones			60	2	e			Dom,Stk		Jet		790	210	10	Field	
NE NE 35	W. Frits	E. Brindley		42	2	15			Dom,Stk		Jet		770	170	10	Field	
NW NE 36	R. Baxter	Do.	1948	60	2	22			Dom		Jet		800	220	20	Field	
NW NW 6	R. Austin	E. Brindley	1962	31	2	20		*30	Dom	.015	Piston		717				*Field w/drilling machine pump
NE NW 2	Shannon	Do.		112	2	7		8-62 9-62	Dom	.020	Jet		760				



**AREA I.** Enough water for domestic, stock, and spraying supplies (up to 10 gpm) generally can be obtained from wells less than 75 feet deep. Water in the well usually is less than 30 feet below land surface. Enough water for irrigation, municipal, or industrial supplies (more than 100 gpm) generally can be obtained from deeper, large-diameter wells (more than 6 inches in diameter and 100 to 200 feet deep).

**AREA II.** Enough water for domestic, stock, or spraying supplies generally can be obtained from wells less than 125 feet deep. Depth to water in about half the wells is more than 30 feet below land surface. Large-diameter wells less than 200 feet deep generally yield enough water for irrigation, municipal, and industrial supplies.

**AREA III.** Enough water for domestic, stock, or spraying supplies generally can be obtained from wells less than 200 feet deep. Wells for irrigation, industrial, or municipal supplies generally would have to be drilled to depths greater than 150 feet, and probably less than half of these would be successful.

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**AREA V.** It is difficult to obtain enough potable water for domestic supplies in this area. It may be necessary to drill several wells before a successful domestic well is obtained. Chances of obtaining large supplies are poor.

**AREA VI.** Similar to surrounding areas except that thick glacial drift in deep bedrock valleys may yield moderate to large supplies of water (50 to more than 100 gpm). Exploratory drilling would be needed to determine where large supplies are available. Test wells should be drilled to bedrock unless salt water is found at shallower depths. Bedrock may be more than 500 feet deep in places.

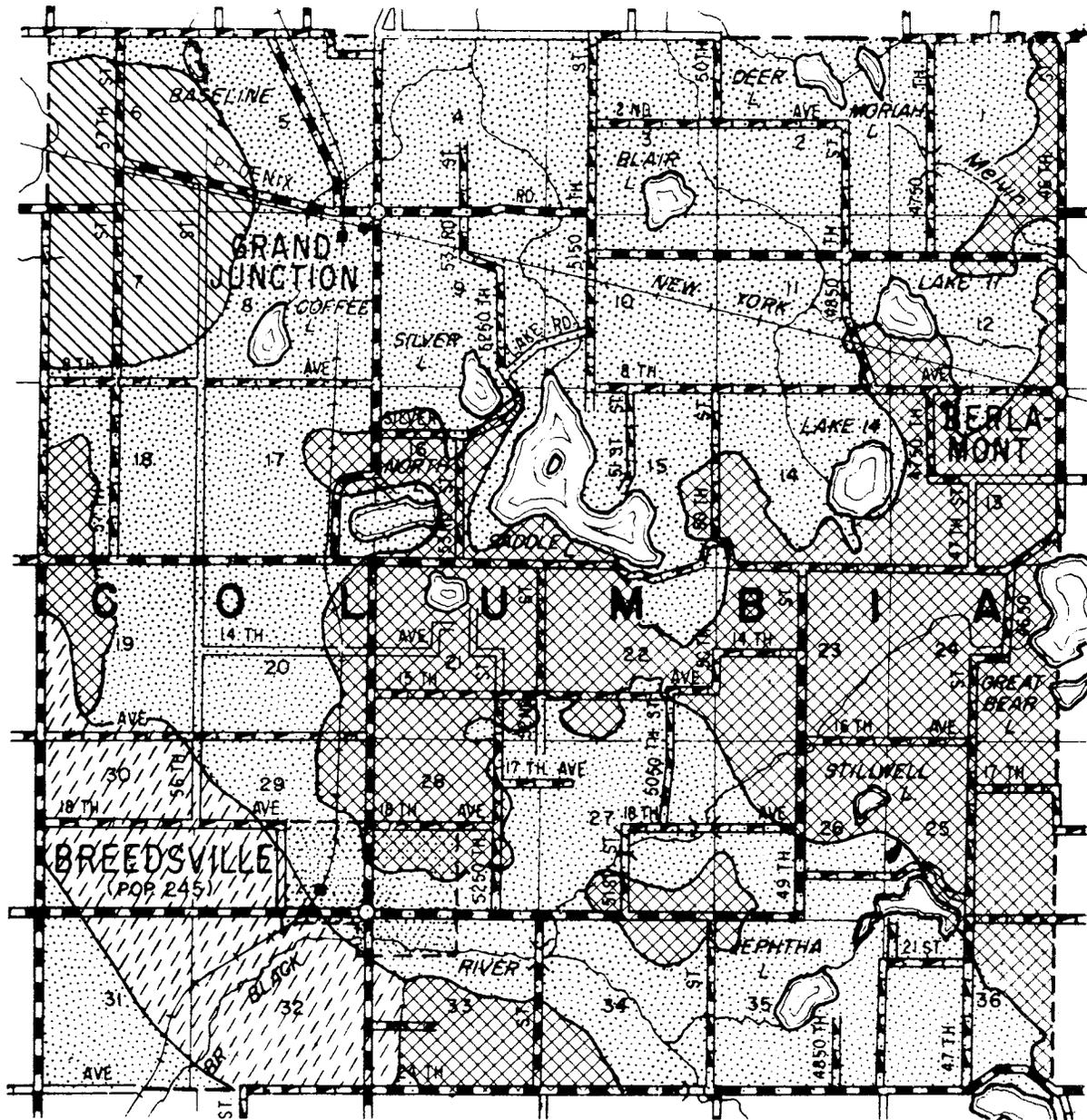
Swamps and marshes

FIGURE 32.--MAP OF BLOOMINGDALE TOWNSHIP SHOWING THE GENERAL AVAILABILITY OF GROUND WATER TO WELLS.

Table 12.--Records of selected wells in Columbia Township (T. 1S., R. 15W.)

Explanation: e - estimated; Analyst--Field, not accurate to laboratory standards; USGS, U. S. Geological Survey; MDH, Michigan Dept. of Health; Remarks--LOG, record of materials penetrated on file; ANAL, also see table of chemical analyses of ground water.

Location T. R. sec	Owner	Driller	Year drilled	Depth (in ft.)	Diam (in inches)	Water level (in feet)	Month and year measured	Field (in gpm)	Use	Screen openings (inches)	Pump	Water- bearing materials	Altitude (in msl)	Quality of Water			Remarks
														Iron (as Fe)	Hardness (as CaCO <sub>3</sub> )	Chloride (Cl)	
SE SW 3	R. Grady		1954	44	2	7-8			Pub Dom	.007	Jet	Sand	670	101	3.0	USGS	at Little Bear Lake; ANAL
SW SW 4	C. Krueger		1922	25	11						Jet	Sand	680				
NW NE 5	G. Burns	Sanders	1937	100-	2				Dom, Spray		Jet						
SW SW 6	W. Warner	H. Starbeck	1955	120	2			125	Irrig		Jet		675	200	15		
SW SW 6	W. Warner	H. Starbeck	1955	77	4				Dom		Jet		670				
SE 8	A. Thomas	Dunbar Drig. Co.	1917	37	2	5	8-47	325	Irrig	.008	Jet		670	180	10	Field	pH 7.5
SE 17	N. Lake Blueberry Fm.	Regler Drig. Co.	1926	90	8			285	Irrig		Turb	Sand	680				
SE 17	N. Lake Blueberry Fm.	Dunbar Drig. Co.	1925	170	6	8		500	Irrig		Turb		680				
NW SW 9	Jones Bros.		1915	170	6			50	Irrig				680				
SE SE 9	Covey	H. Starbeck	1939	70	11				Dom		Jet	Sand	685	352	38	USGS	3 wells hooked together
SW SW 11	M. Korpak, Jr.		1939	70	11				Dom, Stk		Piston	Sand	680			USGS	ANAL; clay above sand
NE NE 11	H. Lucas	Sanders	1960	68	2	e 10	8-52		Dom			Sand	700	280	16	USGS	ANAL
SE SE 12	A. Harris	E. Brindley	1962	68	2	e 20	-50	16	Dom	.012	Jet	Sand	675	130	10	Field	pH 7.5
NW SE 15	L. Puccio	Owner	1990	28	1 1/2	5-6			Dom		Jet	Sand	690	220	30	Field	
NE SE 17	J. Davids	Owner	1952	40	1 1/2				Dom		Jet	Sand	690	100	10	Field	pH 7.0
NE NE 18	K. Thys	Owner	1963	25	1 1/2	e 10	-53		Dom, Stk		Piston	Sand	640	220	3	MDH	NO <sub>3</sub> -1.6
NE NE 19	O. Cummins	Owner	1963	30	2				Dom		Hand	Sand	760	210	5	Field	
NE NW 21	M. Meyer		1900	100	2				Dom		Jet		700				
NE NE 23	C. Cooley	H. Starbeck	1948	36	2	30	-48	9	Dom	.010	Jet	Sand	685	280	0.7		wells in area 100' and 180' deep
SW NE 24	A. Boler	Owner	1958	105	1 1/2	4-5			Dom		Jet	Sand	680	279	1.0	USGS	ANAL
NW SE 25	A. Gackowald	H. Starbeck	1958	110	2	90			Dom, Stk		Piston	Sand, gravel	710				
NE NW 26	H. Ashbrook		1958	110	2				Dom		Jet		670				
SE NW 28	E. Carlson	J. Taylor	1963	55	1 1/2	12	8-52	15	Irrig	.012-.015	Jet	Gravel	690	0			6 ft of screen
SW SE 29	J. Lehardt	E. Brindley	1962	104	2		10-53		Dom		Jet		690	0			
SW SW 30	T. Ruck	H. Starbeck	1930	60	1 1/2	e 35			Dom, Spray		Jet		690	1.5		USGS	ANAL
SW SW 33	D. Palmer	H. Starbeck	1930	70	2				Dom, Spray		Jet		700				
NE NE 34	P. Bunker		1960	80	2				Dom		Jet	Gravel	695				
SE SW 36	C. Schlofmer	Kelly	1960	80	2				Dom		Jet						



**AREA I.** Enough water for domestic, stock, and spraying supplies (up to 10 gpm) generally can be obtained from wells less than 75 feet deep. Water in the well usually is less than 30 feet below land surface. Enough water for irrigation, municipal, or industrial supplies (more than 100 gpm) generally can be obtained from deeper, large-diameter wells (more than 6 inches in diameter and 100 to 200 feet deep).

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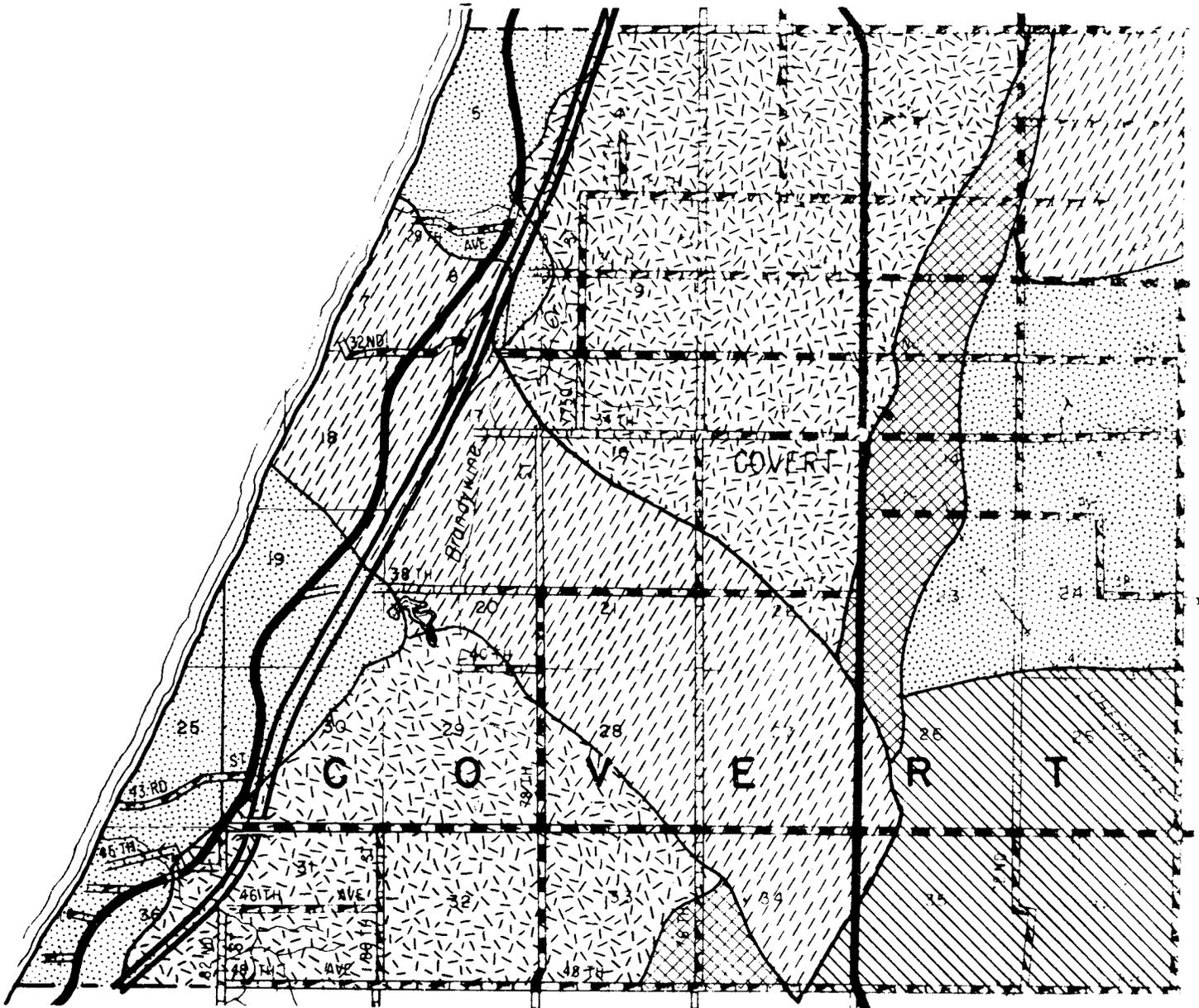
Swamps and marshes

FIGURE 33.--MAP OF COLUMBIA TOWNSHIP SHOWING THE GENERAL AVAILABILITY OF GROUND WATER TO WELLS.

Table 13.--Records of selected wells in Covert Township (T. 1S, R. 17 & 18W.)

Explanation: e - estimated; Analyst--Field, not accurate to laboratory standards; USGS, U. S. Geological Survey; MDH, Michigan Dept. of Health; Remarks--LOG, record of materials penetrated on file; AMH, also see table of chemical analyses of ground water.

Location T. R. S.	Owner	Driller	Year drilled	Depth (in ft)	Diam (in inches)	Water level (in feet)	Month and year measured	Yield (in gpm)	Use	Screen openings (inches)	Pump	Water- bearing materials	Altitude (in msl)	Iron (as Fe)	Hardness (as CaCO <sub>3</sub> )	Chloride (Cl)	Analyst	Remarks
NE SW 1	V. Gudzevic	A. Vanderbough	1958	150	2	35	9-62	20	Dom,Skk	.010	Piston	Sand	710	0.3	50	5	Field	Specific Conductance 320
NE NW 2	A. Lloyd	J. Taylor	1962	172	2	35	9-62	20	Dom		Jet	Sand	683	0.2	70	15	Field	Specific Conductance 170, pH 6.8; LOG
NE SE 3	E. Anderson	Owner	1961	18	2	2	5-64		Dom		Jet	Sand	640	0.1	50	10	Field	Specific Conductance 75, pH 6.8
SE SE 3	W. Krasinski	Owner	1961	8	2	2	5-64		Dom		Jet	Sand	655	0.2	90	10	Field	Specific Conductance 200, pH 7.5; Dug well
SE SE 7	F. Podgorny	Eicherek	1952	65	16	32	4-52		Dom	.019	Piston	Sand	610	4.0	70	50	Field	Specific Conductance 360, pH 7.0
SW SW 7	Layne-Northern Co.	G. Thompson	1957	55	2	8	4-52		Dom, Pub		Centr	Sand	622	1.30	10	Field	Specific Conductance 300, pH 7.2; LOG	
SE SW 9	P. Frakes	Owner	1957	113	1	8			Dom		Jet	Sand	611	2.0	50	10	Field	Sand dune topography
SE NE 10	F. Williams	Owner	1954	118	2	45	5-64	4.5	Dom, Spr	.007	Jet	Sand	655	0.1	70	65	Field	Specific Conductance 140, pH 6.5
NW SE 11	P. Reed	D. Rose	1956	85	2	45	5-64		Dom, Spr	.007	Jet	Sand	736	0.8	340	5	Field	Specific Conductance 790, pH 7.2
NW NW 13	C. Spellman	D. Rose	1956	96	2	45	5-64		Dom, Spr	.007	Jet	Sand	736	0.8	340	5	Field	2 wells are 40' apart; LOG
SW NW 14	Covert School	Owner	1956	220	2	12	-56	60	Pub.		Jet	Sand	661	3.0	190	5	Field	Specific Conductance 550; Springs in area rept.
SE NE 15	Mrs. B. Mitchell	A. Vanderbough	1953	128	2	45.6	2-55	40	Dom	.025	Turb	Sand	700	2.0	220	5	Field	Pulled back to 200 feet (not used)
SE NW 16	T. Shivers	Owner	1943	102	2	26			Dom		Piston	Sand	680	0.3	70	5	Field	Specific Conductance 435, pH 7.8; bottomed in clay
NW NW 17	I. Hanson	Owner	1954	50	2	at surf			Dom		Jet	Sand	640	1.0	100	5	Field	Specific Conductance 170, pH 7.0
NW SE 19	E. Dalen	Owner	1942	25	2	7.5	-63		Dom		Jet	Sand	615	0.3	50	30	Field	Sand dune topography, iron present
NE SE 20	Mrs. M. Bralisher	Owner	1963	30	12	5			Dom		Jet	Sand	630	2.5	115	5	Field	Specific Conductance 88, pH 6.2
SW NE 21	R. DePriest	Owner	1953	17	12	5			Dom		Jet	Sand	655	0.2	275	55	Field	Specific Conductance 235, pH 7.2
SE NW 23	Mrs. J. Pitchford	Owner	1953	17	12	5			Dom		Jet	Sand	705	0.75	245	5	Field	Specific Conductance 600, pH 7.2
SE SE 24	F. Thar	Leach & Cole	1956	110	8				Dom		Subm	Sand	690	0.2	245	5	Field	Specific Conductance 430, pH 7.5
SE SE 24	Do	Do	1964	80	8				Irrig		Turb	Sand	680	0.2	85	20	Field	Specific Conductance 225
SW SE 24	Do	Do	1964	80	8				Irrig		Turb	Sand	680	0.2	85	20	Field	Specific Conductance 345
Center of 24	Do	Do	1961	100	8				Irrig		Subm	Sand	665	0.2	85	20	Field	Specific Conductance 225
SW NE 24	Do	Do	1944	120	8				Irrig		Turb	Sand	665	0.2	85	20	Field	Specific Conductance 345
SW NE 24	Do	Do	1940	90	8				Irrig		Turb	Sand	665	0.2	85	20	Field	Specific Conductance 225
SE NW 24	Do	Do	1940	110	8				Irrig		Turb	Sand	665	0.2	85	20	Field	Specific Conductance 345
NE SE 24	Do	Do	1943	95	8				Irrig		Turb	Sand	660	0.2	85	20	Field	Specific Conductance 225
NE SE 24	Do	Do	1943	95	8				Irrig		Turb	Sand	660	0.2	85	20	Field	Specific Conductance 345
NE SE 24	Do	Do	1943	55	6				Irrig		Turb	Sand	660	0.2	85	20	Field	Specific Conductance 225
NE SE 24	Do	Do	1943	55	6				Irrig		Turb	Sand	660	0.2	85	20	Field	Specific Conductance 345
NE SE 24	C. Wadlick	Dunbar Drilg Co.	1967	49	6	2	2-60	155	Irrig	.010-.012	Turb	Sand	690	Tr.	160	10	Field	Not adequate for Irrigi; to be pulled
Chr. E. Line 24	Do	Do	1967	115	8	15	9-57	94	Irrig	.006-.008	Subm	Sand	690	Tr.	160	10	Field	pH 7.2; LOG; 3 test wells--one 300 ft unproductive
NW SW 25	Pocahontas Farm	Do	1950	282	8	10	9-50	280	Irrig	.008-.010	Subm	Sand	660	0.9	345	6	Field	Abandoned--Inadequate; LOG
NW NW 25	Do	Do	1950	204	8	10	5-50	135	Irrig	.008-.010	Subm	Sand	660	0.9	345	6	Field	Shale at 314 ft; was drilled to 322
NW NW 26	A. Marsala	Do	1962	44	2	20			Dom		Centr	Sand	708	0.05	125	7	Field	Shale rept at 228 ft; screened in 2 stratas
SE SE 26	H. Smith	A. Vanderbough	1962	235	0	2			Dom, Pub		Centr	Sand	705	2.1	950	7	Field	Analysis by MDH
SE SE 28	J. Sweaty	G. Cole	1956	13	14	5			Dom		Jet	Sand	665	0.1	85	5	Field	Analysis by MDH; NO <sub>3</sub> =5-10
SE SE 28	G. Stearny	Owner	1961	13	14	2			Dom		Jet	Sand	678	0.1	85	5	Field	Specific Conductance 230, pH 6.9
SE SE 28	F. Seabury	Owner	1961	18	14	2	2-3		Dom		Piston	Sand	670	0.1	105	30	Field	Specific Conductance 495, pH 6.0
NE NE 29	J. Nicklson	Owner	1961	12	14	2			Dom		Centr	Sand	635	Tr.	120	10	Field	Specific Conductance 162, pH 7.3
SE NW 30	C. Griegrett	O'Leary	1912	36	14	6			Dom		Jet	Sand	620	0.2	35	10	Field	Specific Conductance 95, pH 6
SE NW 31	A. Stiver	Owner	1918	12	14	6			Dom		Piston	Sand	640	0.2	35	10	Field	Specific Conductance 715, pH 7.3
SE SE 31	J. Thurber	Owner	1918	95	12	12			Dom		Jet	Sand	640	0.2	35	10	Field	Specific Conductance 215, pH 7.3
SE SE 32	H. Williams	Owner	1945	40	2	12	5-64		Dom		Jet	Sand	642	0.4	105	5	Field	Specific Conductance 530, pH 7.1
SE SE 32	S. Di Stefano	Owner	1954	121	2	12	5-64		Dom		Jet	Sand	668	0.1	190	55	Field	Dug well
SE SE 32	W. Cook	Strong	1954	144	2	12	5-64		Dom		Jet	Sand	658	0.1	190	55	Field	Specific Conductance 475, pH 7.5
NW NW 34	H. Leonard	Owner	1954	180	2	3	5-64		Dom		Jet	Sand	690	0.2	103	5	Field	Specific Conductance 525, pH 7.4
NW NW 34	H. Thomas	Owner	1954	180	2	3	5-64		Dom		Jet	Sand	690	0.2	103	5	Field	Specific Conductance 475, pH 7.7
NW NW 34	J. Turmas	Owner	1954	180	2	3	5-64		Dom		Jet	Sand	664	1.5	103	5	Field	Specific Conductance 245, pH 7.5,
NE NE 35	M. Goldring	Vanderbough	1961	30	14	2			Dom		Jet	Sand	664	1.5	103	5	Field	3 shallow wells
SW SW 36	L. Conci	Owner	1945	40	2	12			Dom		Jet	Sand	660	0.05	189	5	Field	Specific Conductance 405, pH 7.8
NE NW 36	M. Casco	Dunbar Drilg Co.	1954	145	2	5	4-54	120	Irrig	.006	Turb	Sand	660	0.05	189	5	Field	Blueberry farm; LOG
NE NW 36	F. Appengren	Dunbar Drilg Co.	1956	200	6	11.5	4-64	80	Irrig	.006	Turb	Sand	664	0.05	189	5	Field	Pumped into Irrigi, pond; LOG
NE NW 36	Do	Do	1956	280	6	12-36	4-64	80	Test		None	Sand	664	0.05	189	5	Field	Rept dry hole, bed rock elev, 423 ft
NE NW 36	Do	Do	1956	36	2	2	12-36		Dom		None	Sand	670	1.5	52	10	Field	Specific Conductance 195, pH 6.0
NE NW 36	Do	Do	1956	30	14	2			Dom		Hand	Sand	665	0.8	52	15	Field	Specific Conductance 195, pH 5.9
NE NE 36	Rendell Bros.	J. Burros	1954	45	2	e 30			Dom, Pub		Jet	Sand, gravel	e6.0	120	10	Field	Iron very high	
NE NE 36	Rendell Bros.	J. Burros	1954	45	2	e 30	5-64		Dom, Pub		Jet	Sand, gravel	e6.0	120	10	Field	Iron very high; did not originally flow	
NE NE 36	Rendell Bros.	G. Thompson	1945	45	2	e 30	5-64		Dom, Pub		Jet	Sand, gravel	e6.0	120	10	Field	Iron very high; did not originally flow	



**AREA I.** Enough water for domestic, stock, and spraying supplies (up to 10 gpm) generally can be obtained from wells less than 75 feet deep. Water in the well usually is less than 30 feet below land surface. Enough water for irrigation, municipal, or industrial supplies (more than 100 gpm) generally can be obtained from deeper, large-diameter wells (more than 6 inches in diameter and 100 to 200 feet deep).

**AREA II.** Enough water for domestic, stock, or spraying supplies generally can be obtained from wells less than 125 feet deep. Depth to water in about half the wells is more than 30 feet below land surface. Large-diameter wells less than 200 feet deep generally yield enough water for irrigation, municipal, and industrial supplies.

**AREA III.** Enough water for domestic, stock, or spraying supplies generally can be obtained from wells less than 200 feet deep. Wells for irrigation, industrial, or municipal supplies generally would have to be drilled to depths greater than 150 feet, and probably less than half of these would be successful.

**AREA IV.** Enough water for domestic, stock, and spraying supplies generally can be obtained from wells less than 75 feet deep. Water in the well generally is less than 30 feet below land surface. Exploratory drilling would be needed to determine where large supplies can be obtained.

**AREA V.** It is difficult to obtain enough potable water for domestic supplies in this area. It may be necessary to drill several wells before a successful domestic well is obtained. Chances of obtaining large supplies are poor.

**AREA VI.** Similar to surrounding areas except that thick glacial drift in deep bedrock valleys may yield moderate to large supplies of water (50 to more than 100 gpm). Exploratory drilling would be needed to determine where large supplies are available. Test wells should be drilled to bedrock unless salt water is found at shallower depths. Bedrock may be more than 500 feet deep in places.

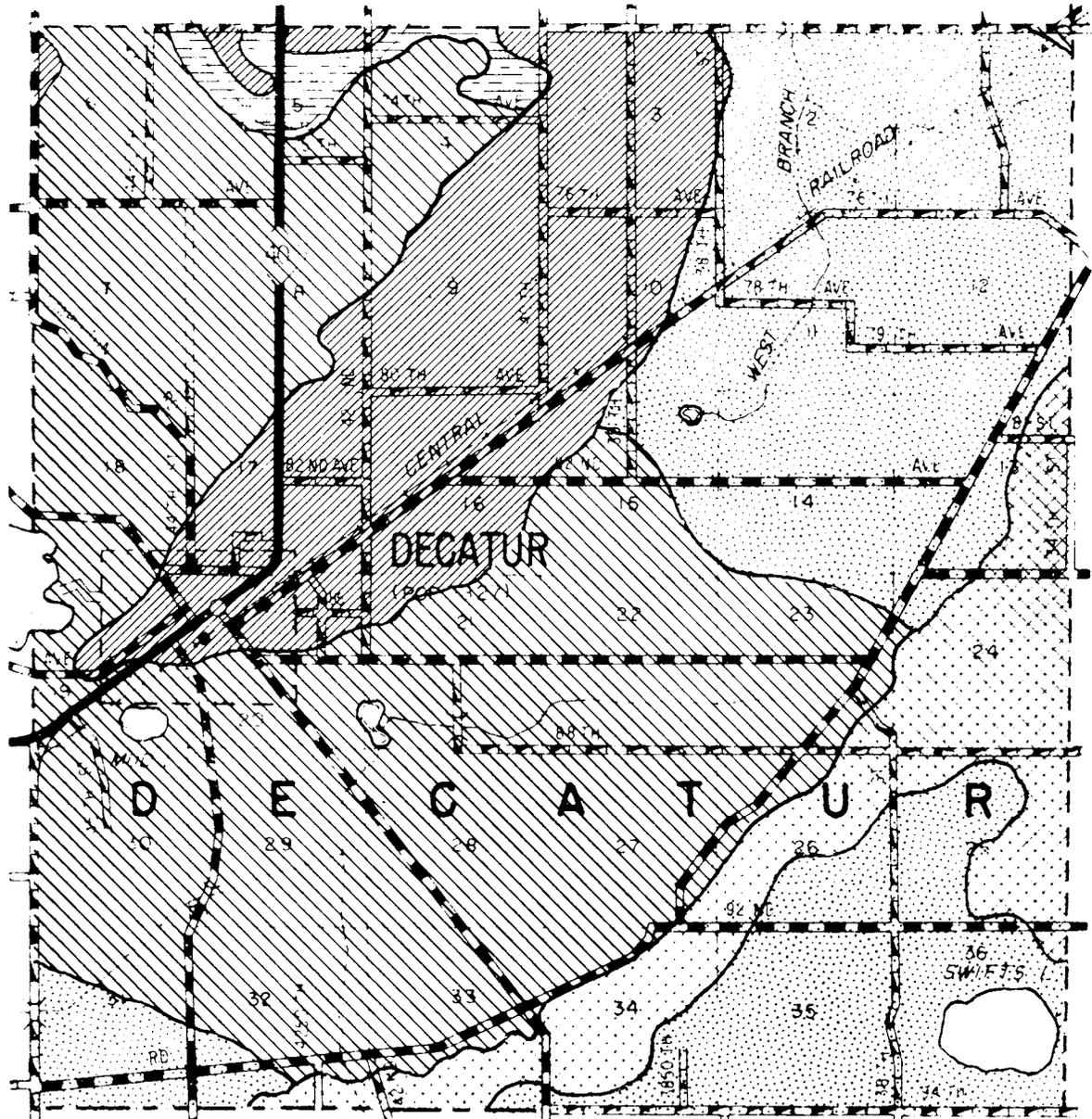
Swamps and marshes

FIGURE 34.--MAP OF COVERT TOWNSHIP SHOWING THE GENERAL AVAILABILITY OF GROUND WATER TO WELLS.

Table 14.--Records of selected wells in Decatur Township (T. 4S., R. 14W.)

Explanation: e - estimated; Analyst--Field, not accurate to laboratory standards; USGS, U. S. Geological Survey; MDH, Michigan Dept. of Health; Remarks--LOG, record of materials penetrated on file; ANML, also see table of chemical analyses of ground water.

Location	Owner	Driller	Year drilled	Depth (in ft)	Diam (in inches)	Water level (in feet)	Month and year measured	Yield (in gpm)	Use	Screen openings (inches)	Pump	Water-bearing materials	Altitude (in feet)	Quality of water			Remarks
														Iron (as Fe)	Hardness (as CaCO <sub>3</sub> )	Chloride (Cl)	
SE NW 3	P. Hoffman	E. Sanders	1963	57	2	32	8-63	10	Dom		Jet	Gravel	780	141	2.5	USGS	ANML.
SE SE 4	E. Blake		1922	52	2	8	8-63		Dom,Stk		Jet	Gravel	780	200	15	Field	Water yellowish; well near dried-up swamp Blue clay below 32 feet
SW SE 5	S. Nemeth	Owner	1961	45	2	22	8-63	7	Stk		Jet	Sand, gravel	775	200	10	Field	
SE NE 6	G. Orr	E. Sanders	1943	50	2	17			Dom,Stk		Jet	Sand, gravel	775	135	15	Field	
NW SW 11	G. Kusmack	J. Brigham	1936	50	1 1/2				Dom		Jet	Sand, gravel	745	255	15	Field	Neighbor has flowing well at 80 feet inadequate supply water yellowish
SE SE 12	J. Motyczkar	R. Smith	1960	62	2	21		10 1/2	Dom	.010	Jet	Sand	840			USGS	ANML; muckland area
SW SE 13	N. White	G. Tinker	1959	71	2	61	10-59		Dom		Jet	Sand	750	682	8.0	USGS	
NW SW 14	S. W. Forbes	Owner	1961	53	2	e35		9	Dom,Stk		Jet	Sand	775	319	23	USGS	ANML.
NW SW 16	H. Mroczek	C. Lewis	1948	77	2	21	-59	14	Dom		Jet	Sand, gravel	775	200	4	MDH	Seasonal use ANML.
NE NW 17	E. Knoska	G. Tinker	1959	56	2	41	3-53	12	Dom	.010	Jet	Sand, gravel	770	1.6		MDH	LOG; ANML.
SE NE 17	G. Tinker	G. Tinker	1963	55	2	22.04	5-29	255	Ind	.030	Turb	Sand, gravel	790	200	4	MDH	LOG; ANML.
S 3	Koops Storage	R. Kersey	1961	90	2	5	3-63	790	Mun	.020	Turb	Sand, gravel	790	0		MDH	Have 5 wells--4 are 10', 1 is 150' deep. Complete anal by Brookside Labs (2 wells, same pump)
NW NW 20	Do.	Ind-Mich Water Co	1929	120	12	5		9	Dom,Ind		Piston	Sand	750	0.35	1.3	Field	
NW NE 19	Village of Decatur	Owner	1929	116	12	5			Dom,Ind			Sand	750	338		Field	
NE SW 21	Do.	Do.	1952	111	11	4			Dom,Ind			Sand	750	270	15	Field	Rept. springs in area See hydrograph; LOG
SE NE 22	A. Houtman	J. Lewis	1961	40	2	18	6-59		Dom	.010	Jet	Gravel	780	340	20	Field	Top of aquifer not used--capped LOG
SW SE 23	E. Lozier Greenhouse	G. Tinker	1969	55	2	25.28	3-63		Dom	.010	Jet	Sand	900			Field	
NW NW 24	R. Martinez	U. S. G. S.	1963	75	1 1/2			500	Obs		Jet	Sand	900			Field	
SW NW 25	L. Parker	G. Lewis	1958	75	2			1,000	Dom		Centr	Gravel, sand	900	255	15	Field	
SW NW 25	T. Ackellar	Do.	1958	158	6	54	5-60		Irrig	.012	Turb	Gravel, sand	900			Field	
SW NW 25	C. Henderson	Dunbar Drig. Co.	1960	166	12	32	7-59	10	Dom,Stk	.010	Jet	Gravel, sand	900			Field	
NE NE 25	C. Henderson	Do.	1953	108	2	32	8-56		Dom	.010	Jet	Sand	700			Field	
NE NE 25	K. Schur	G. Tinker	1953	87	2	22		13	Dom	.010	Jet	Gravel	700			Field	
NW NE 26	Mrs. J. Mroczek	Do.	1956	54	1 1/2	10		12	Dom,Spn		Jet	Sand	750			Field	
SW NE 26	F. Magyar	J. Brigham	1956	24	1 1/2				not used		Jet	Sand	750			Field	
SW NW 27	J. Miller	Do.	1945	43	2	Flows	8-63		Dom		Jet	Sand, gravel	750	211	22	USGS	Many flowing wells in area use for celery washing springs less at present; ANML
NW SW 28	H. Mroczek	A. Jacobs	1952	132	1 1/2	6-7		575	Dom	.100	Jet	Sand, gravel	770	570	18	USGS	ANML.
SW SW 29	J. Feunstra	Owner	1955	132	1 1/2	17	8-49		Dom		Turb	Gravel, sand	800	255	10	Field	Rept. many springs in area
NW SW 29	J. Feunstra	Dunbar Drig. Co.	1949	123	8	e38	-59		Dom		Jet	Gravel, sand	780	550	2.550	MDH	ANML; Finished in blue rock 394-400 ft.
SE SE 32	E. Kraus	Owner	1937	36	2	flowed			Dom		Jet	Gravel, sand	900	285	10	Field	Also have 2' x 100' well for stock
SE NE 34	Dr. C. Reading	C. Lewis	1931e	400	10				Dom,Stk		Jet	Gravel, sand	900			Field	
SW SE 36	C. Kern	H. Riegel	1961	20	2				Dom,Stk		Jet	Gravel, sand	900			Field	



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**AREA I.** Enough water for domestic, stock, and spraying supplies (up to 10 gpm) generally can be obtained from wells less than 75 feet deep. Water in the well usually is less than 30 feet below land surface. Enough water for irrigation, municipal, or industrial supplies (more than 100 gpm) generally can be obtained from deeper, large-diameter wells (more than 6 inches in diameter and 100 to 200 feet deep).
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**AREA II.** Enough water for domestic, stock, or spraying supplies generally can be obtained from wells less than 125 feet deep. Depth to water in about half the wells is more than 30 feet below land surface. Large-diameter wells less than 200 feet deep generally yield enough water for irrigation, municipal, and industrial supplies.
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**AREA III.** Enough water for domestic, stock, or spraying supplies generally can be obtained from wells less than 200 feet deep. Wells for irrigation, industrial, or municipal supplies generally would have to be drilled to depths greater than 150 feet, and probably less than half of these would be successful.
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**AREA IV.** Enough water for domestic, stock, and spraying supplies generally can be obtained from wells less than 75 feet deep. Water in the well generally is less than 30 feet below land surface. Exploratory drilling would be needed to determine where large supplies can be obtained.
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**AREA V.** It is difficult to obtain enough potable water for domestic supplies in this area. It may be necessary to drill several wells before a successful domestic well is obtained. Chances of obtaining large supplies are poor.
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**AREA VI.** Similar to surrounding areas except that thick glacial drift in deep bedrock valleys may yield moderate to large supplies of water (50 to more than 100 gpm). Exploratory drilling would be needed to determine where large supplies are available. Test wells should be drilled to bedrock unless salt water is found at shallower depths. Bedrock may be more than 500 feet deep in places.
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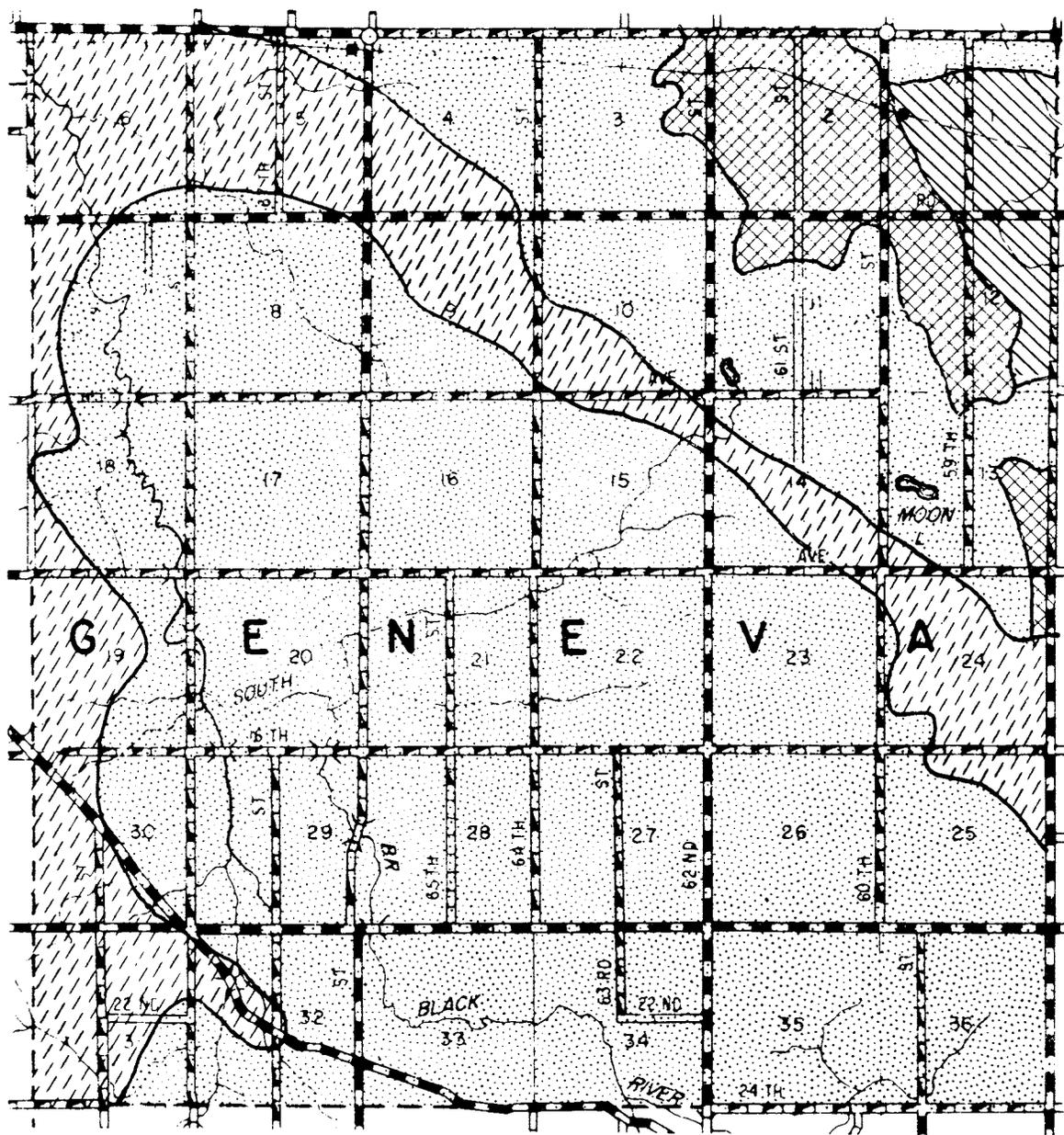
Swamps and marshes

FIGURE 35.--MAP OF DECATUR TOWNSHIP SHOWING THE GENERAL AVAILABILITY OF GROUND WATER TO WELLS.

Table 15.--Records of selected wells in Geneva Township (T. 1S., R. 16W.)

Explanation: e - estimated; Analyst--Field, not accurate to laboratory standards; USGS, U. S. Geological Survey; MDH, Michigan Dept. of Health; Borelog--LOG, record of materials penetrated on file; Abld, also see table of chemical analyses of ground water.

Location T. R. sec	Owner	Driller	Year drilled	Depth (In ft.)	Diam (Inches)	Water level (In feet)	Month and year measured	Yield (In gpm)	Use	Screen openings (Inches)	Pump	Water- bearing materials	Altitude (In msl)	Quality of Water			Remarks	
														Iron (as Fe)	Hardness (as CaCO <sub>3</sub> )	Chloride (Cl)		Analyst
NW SE 1	I. Lewis	J. Taylor	1943	30	2	18	9-53		Dom	.006	Jet	Sand	640	486	64	USGS	ANAL	
SW NE 1	J. Brown		1928	33	2	23	11-53		Dom		Hand	Sand	625					
SW NE 2	M. Stein		1953	90	2				Dom		Jet	Sand	690					
SE NE 2	C. Kraenen		1955	50	2	e10	9-53	9	Dom,Stk		Jet	Sand	655				Flowing springs 1/2 mile North	
SE NE 3	A. Retberg	J. Taylor	1947	33	2			20	Dom,Stk		Jet	Sand	640			Field	3 other wells 50' deep	
SW SW 3	A. Hope	Sanders	1960	75	3			e12	Dom		Jet	Gravel	620			Field	Specific Conductance - 240'	
NW SW 4	G. Winkler	H. Haney	1954	18	2 1/2	8	-46		Dom		Jet	Sand	620					
SE NE 6	J. Stephenson		1946	28	2 1/2			7	Dom		Jet	Sand	620					
E4 SE 7	L. Banaszak	H. Starbeck	1960	28-35	3	28		10	Dom,Stk		Suct	Sand	640			Field	Specific Conductance - 120'; 2 wells same depth	
S4 SE 9	M. Kinney	H. Starbeck	1958	42	2	50	11-53	300	Dom,Spray		Jet	Sand	700				Specific Conductance - 490	
NE NE 11	M. Stein		1956	120	2	16			Dom		Turb	Sand	690				Spec. Cond. 440; 4 other wells 2" x 60'	
SE NE 14	E. Hartman	R. Sanders	1938	50	2	25	-61		Dom	.010	Suct	Sand	680				Specific Conductance - 330	
SE NE 15	H. Putnam	H. Starbeck	1958	60	2	25	11-53	e250	Dom	None	Jet	Sand	670			USGS	Springs along river valley rept.	
SE NE 15	Tolles estate		1905	30	3/8	25-58			Dom	.006	Jet	Sand	640				House well 2" x 4 1/2'	
SW SE 17	I. Bennett	H. Haney	1956	43	4	20-25			Dom		Jet	Sand	630					
SW SE 18	M. Stein		1958	45	2				Dom		Jet	Sand	670					
SE SW 18	S. Reznick	R. Sanders	1954	38-40	2				Dom		Jet	Sand	630			Field	Spec. Cond. 360; several wells	
SE SW 20	S. Sollitt	R. Sanders	1928	180	4				Dom,Stk		Jet	Sand	630			USGS	Also 9 driven wells 20' deep	
SW SE 21	F. Reimer	H. Haney	1963	79	2 1/2	18-50	11-53		Dom,Stk		Hand	Sand	650			Field	Rept good supply at 160' fr oil wells	
NW NE 22	A. Fellows	H. Brown	1963	79	2	e16	11-53		Dom	.006	Hand	Sand	660			USGS	Clay to 30 ft.	
NE SE 23	M. Woods	J. Taylor	1962	48	2	15	8-52	20	Dom	.010	Piston	Sand, gravel	670				Clay to 4 1/2'; salty	
NW NE 24	E. Empson	Omer	1947	22	1 1/2				Dom		Jet	Sand	690			USGS	Sand to 22'; then clay	
SW SE 25	S. Scoggins	H. Starbeck	e48	2					Dom		Jet	Sand	670					
NE NW 26	Z. White	Dunbar Drilg. Co.	1953	148	8	25	7-53	125	Dom	.015	Turb	Sand	665				LOG; was drilled to shale at 185'	
SW SE 28	M. Listiak		1963	95	2	5	11-53	e20	Irrig	.010	Jet	Sand	640			MDH	Rept by MDH	
SE SE 29	F. Reimer	J. Taylor	1947	80	2	40			Dom		Piston	Sand	620				Clay to 48'	
NW SE 30	G. Heine	R. Sanders	1963	121	2	50	9-53	4	Dom,Stk		Jet	Sand	630			Field	Springs in creek; Specific cond. 340	
NE SE 32	V. Selvidge	D. Rose	1962	50	2	e30	9-52	e10	Dom,Ind		Jet	Gravel	657					
SE SW 33	D. Funk Packing		1962	50	2				Dom		Cent	Sand	665			USGS	ANAL	
SE SW 34	M. Stein	R. Sanders	1952	75	5	30		45	Dom,Irr		Cent	Sand	670				Have 2 wells	
SW NW 35	R. White	H. Starbeck		58	3			5	Dom,Stk		Jet	Sand	665				25' of sand; 10' of screen	
SW SW 36	J. Rainey																	
N4 NE 12	A. Bagalla (4 wells)	H. Starbeck & Barnes		54-64	2-4	e4			Dom,Irrig		Cent	Gravel	680			Field	Specific conductance 460; drilled 1940-55	



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**AREA IV.** Enough water for domestic, stock, and spraying supplies generally can be obtained from wells less than 75 feet deep. Water in the well generally is less than 30 feet below land surface. Exploratory drilling would be needed to determine where large supplies can be obtained.
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**AREA V.** It is difficult to obtain enough potable water for domestic supplies in this area. It may be necessary to drill several wells before a successful domestic well is obtained. Chances of obtaining large supplies are poor.
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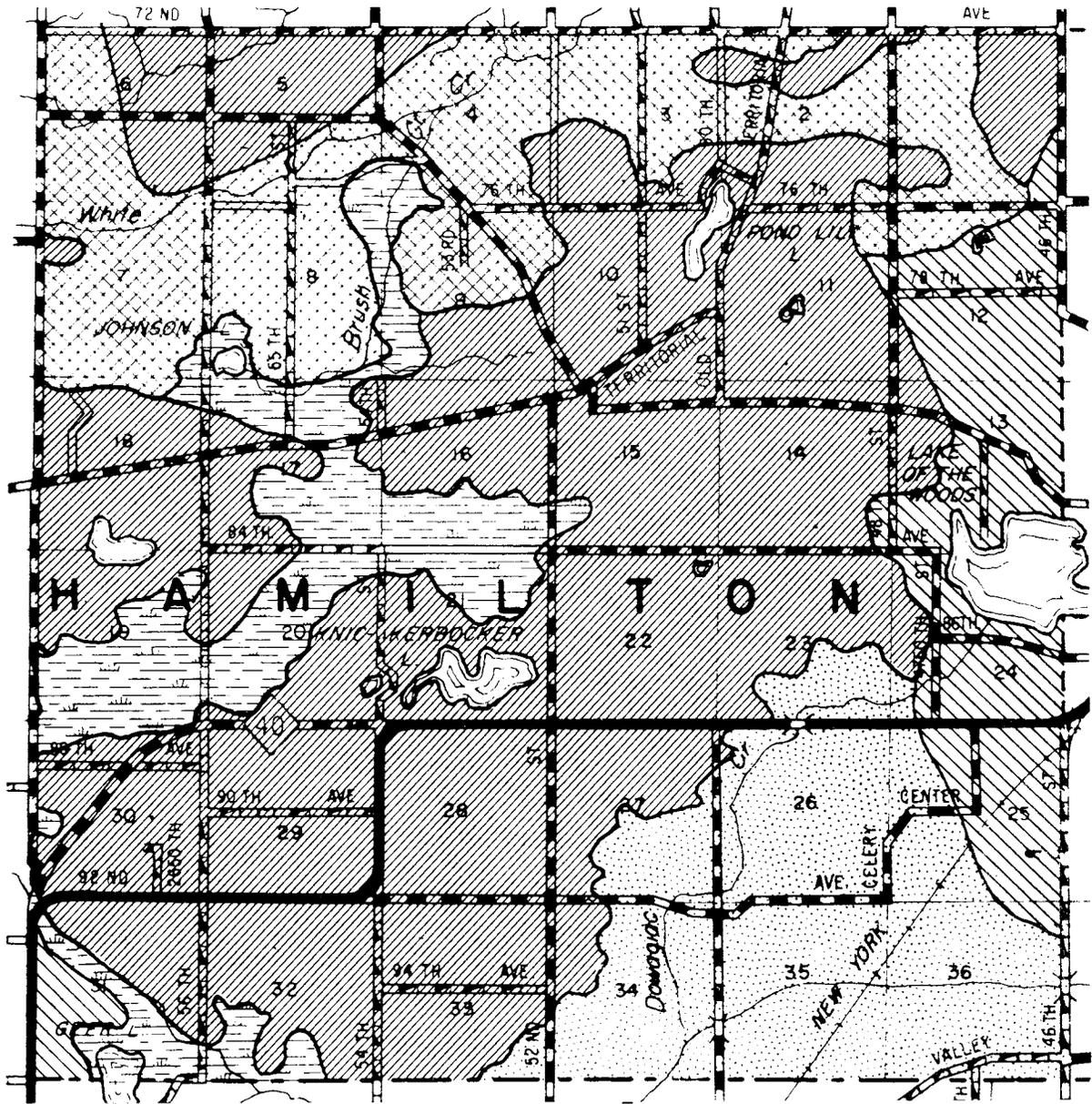
**AREA VI.** Similar to surrounding areas except that thick glacial drift in deep bedrock valleys may yield moderate to large supplies of water (50 to more than 100 gpm). Exploratory drilling would be needed to determine where large supplies are available. Test wells should be drilled to bedrock unless salt water is found at shallower depths. Bedrock may be more than 500 feet deep in places.
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 Swamps and marshes

FIGURE 36.--MAP OF GENEVA TOWNSHIP SHOWING THE GENERAL AVAILABILITY OF GROUND WATER TO WELLS.

Table 16.--Records of selected wells in Hamilton Township (T. 4S., R. 15W.)

Explanation: e - estimated; Analyst--Field, not accurate to laboratory standards; USGS, U. S. Geological Survey; MDH, Michigan Dept. of Health; Remarks--LOG, record of materials penetrated on file; ANAL, also see table of chemical analyses of ground water.

Location T. R. sec	Owner	Driller	Year drilled	Depth (In ft)	Diam (Inches)	Water level (In feet)	Month and year measured	Yield (in gpm)	Use	Screen openings (Inches)	Pump	Water- bearing materials	Altitude (In msl)	Quality of Water			Remarks
														Iron (as Fe)	Hardness (as CaCO <sub>3</sub> )	Chloride (Cl)	
SE SE 1	O. Gotbard	G. Tinker	1958	56 2	2	33	8-58	15	Dom	.010	Jet	Gravel	780	340	15		"Hardpan" at 50 feet
NE NW 2	F. Kloeka	G. Tinker	1949	54 2	2	46	-49		Dom		Jet	Sand	790				Some iron reported
NW SE 3	E. Barrett	M. Lacey	1975	109 2	2	17		10	Dom	.010	Jet	Gravel	795				
SW NW 4	H. Barrett	G. Tinker	1960	98 2	2	17			Dom		Jet	Gravel	760	215	3-0	USGS	Springs in nearby creek; ANAL
SE NW 5	E. Weston	E. Sanders	1962	97 2	2	70			Dom,Stk		Jet	Sand, gravel	780	180	10	Field	33' well went dry in 1958
SE NW 6	H. Dersch	G. Tinker	1958	130 2	2	70			Dom,Stk		Jet	Sand, gravel	780				Supply two homes
SE NW 7	J. Graham	E. Richcreek	1977	125 3	3	11	-48	7	Dom		Piston	Gravel	770	250	30		Foxloam soil
SW SE 8	A. Hanson	H. Calay	1946	91 2	2	11			Dom,Stk		Centr	Gravel	780				Well was deepened 10 ft.
SE NE 9	J. Gaborik	Lewis Bros.	1948	74 2	2	12	-48		Dom		Jet	Gravel	780				Swamps in vicinity
SE NE 10	J. Gaborich	G. Tinker	1956	65 2	2	28	8-56	10	Dom	.010	Jet	Gravel	780				Edge of bog area
NW NW 11	J. Kluch	Penning	1959	60 2	2	30			Dom		Jet	Gravel	780				Swampy area
NW NE 12	J. Haucite	G. Tinker	1958	67 2	2	9.37	8-63	10	Dom		Turb	Sand	780				LOG
SE NE 13	S. Lewandowski	Leach & Cole	1963	112 10	10	8	-61	10	Dom		Jet	Gravel	770				Lakeside; not adequate supply
NE SW 14	H. Proeknutzen	E. Lewis	1961	47 2	2	8			Dom		Turb	Gravel	780				6" test hole drilled to 200'; LOG
NE SE 15	H. Haltep Orchards	Dunbar Drig. Co.	1963	103 4	4	20	-63	90	Irrig	.012	Turb	Sand	760				LOG
NW SE 16	B. Thomas	R. Smith	1959	67 2	2	39.5	5-59	10	Dom		Subm	Sand	760				LOG
NW NW 17	J. Korovich Cabins	G. Tinker	1956	104 14	14	20	3-56	1,100	Pub	.007	Hand	Sand, gravel	790				LOG
NW SE 18	J. Bessie	Dunbar Drig. Co.	1975	184 12	12	35	9-55	1,200	Irrig	.008-.080	Turb	Sand, gravel	805				LOG
SE SE 19	H. Negoy Bros.	Dunbar Drig. Co.	1948	215 10	10	31	7-48	407	Irrig	.060	Turb	Sand, gravel	800				LOG
SE NW 20	H. Baudry Nursery	Dunbar Drig. Co.	1956	155 12	12	25	3-56	1,000	Irrig	.070, .018	Turb	Sand, gravel	790				LOG
SE NW 21	C. Gochrich	G. Tinker	1958	135 2	2	28	11-58	15	Dom,Stk		Jet	Sand, gravel	790	120	15		LOG
SE SW 22	D. Zochel	Dunbar Drig. Co.	1950	134 8	8	9	12-50	400	Irrig	.100	Jet	Sand, gravel	790				Replaced by 12" well; LOG
SE SE 23	E. Froehlich	Dunbar Drig. Co.	1956	102 16	16	10	4-56	1,000	Irrig	.100	Turb	Sand, gravel	790				LOG
SE SE 24	E. Froehlich	Dunbar Drig. Co.	1946	102 12	12	13	5-48	300	Irrig	.100	Turb	Sand, gravel	790				Replaced by 12" well; LOG
SE NW 25	D. Adams	Dunbar Drig. Co.	1956	102 12	12	13	8-63	1,030	Irrig	.100	Turb	Sand, gravel	790				Replaced 8" well
SE SE 26	W. Cady	Thomas Plumbing	1962	101 3	3	17	11-62		Dom		Jet	Sand, gravel	790				Have 30' well not used
SE SE 27	E. Cady	Owner	1960	25 11	11				Dom,Stk		Subm	Sand, gravel	780	370	24	MDH	
SE SE 28	F. Kupp	E. Lewis	1960	32 2	2				Dom		Hand	Sand, gravel	780				*Flowed when drilled
SE SE 29	J. Puhf	Owner	1960	27 11	11	*3		8-9	Dom		Jet	Sand, gravel	780	200	25	Field	60 feet of clay, then sand
SE SE 30	A. Erolin	E. Richcreek	1961	40 2	2			70	Dom,Stk		Jet	Sand, gravel	760				Has 3 shallow wells
NE SE 31	L. Robert Farm	Inc-Mich. Water Co.	1945	115 18	18	8	5-43		Dom,Stk		Jet	Sand, gravel	760				Flowed when drilled
NE SE 32	F. Matias	Owner	1957	18 11	11	7	-57	10	Dom		Jet	Gravel	760				
SE NW 33	F. Baris	E. Lewis	1953	46 2	2		-53		Dom		Jet	Gravel	760				
SE NW 34	F. Corven	R. Smith	1959	26 11	11	e17	12-59	10	Dom		Jet	Sand, gravel	760	200	15	Field	
SW NW 35	F. Wetzel	G. Tinker	1959	45 2	2				Dom		Jet	Sand, gravel	780	240	25	Field	Has 3 other wells
SW NW 36	K. L. Kern	E. Richcreek	1959	48 2	2	35	-61	12	Dom,Stk		Jet	Gravel	780				ANAL
SW NW 37	L. Osborne	E. Richcreek	1959	48 2	2			25	Dom		Jet	Gravel	780				
SW NW 38	L. Osborne	E. Richcreek	1959	65 2	2				Dom		Jet	Gravel	780				
SW NW 39	J. Orick	Owner	1962	34 11	11				Dom		Jet	Gravel	770	250	10	Field	
SW NW 40	E. Lewis	E. Lewis	1961	43 2	2	6	-61		Dom		Hand	Sand	770	3.5	0.5	USGS	
SW NW 41	J. Madright	Owner	1953	21 11	11	22	-53	25	Dom		Jet	Gravel	750	135	15	Field	
SW NW 42	Stoll	Stimpson	1959	106 12	12	22			Dom,Stk		Jet	Sand	770	325	15	Field	
SW NW 43	A. Ruff	Penning	1959	25 11	11	e8			Dom,Stk		Jet	Gravel	760	170	10	Field	
SW NW 44	J. Haverman	Owner	1900	22 11	11				Dom		Jet	Gravel	760	210	3	MDH	
SE SE 45	C. Gray	Owner	1900	22 11	11				Dom		Jet	Gravel	780	310	15	Field	



**AREA I.** Enough water for domestic, stock, and spraying supplies (up to 10 gpm) generally can be obtained from wells less than 75 feet deep. Water in the well usually is less than 30 feet below land surface. Enough water for irrigation, municipal, or industrial supplies (more than 100 gpm) generally can be obtained from deeper, large-diameter wells (more than 6 inches in diameter and 100 to 200 feet deep).

**AREA II.** Enough water for domestic, stock, or spraying supplies generally can be obtained from wells less than 125 feet deep. Depth to water in about half the wells is more than 30 feet below land surface. Large-diameter wells less than 200 feet deep generally yield enough water for irrigation, municipal, and industrial supplies.

**AREA III.** Enough water for domestic, stock, or spraying supplies generally can be obtained from wells less than 200 feet deep. Wells for irrigation, industrial, or municipal supplies generally would have to be drilled to depths greater than 150 feet, and probably less than half of these would be successful.

**AREA IV.** Enough water for domestic, stock, and spraying supplies generally can be obtained from wells less than 75 feet deep. Water in the well generally is less than 30 feet below land surface. Exploratory drilling would be needed to determine where large supplies can be obtained.

**AREA V.** It is difficult to obtain enough potable water for domestic supplies in this area. It may be necessary to drill several wells before a successful domestic well is obtained. Chances of obtaining large supplies are poor.

**AREA VI.** Similar to surrounding areas except that thick glacial drift in deep bedrock valleys may yield moderate to large supplies of water (50 to more than 100 gpm). Exploratory drilling would be needed to determine where large supplies are available. Test wells should be drilled to bedrock unless salt water is found at shallower depths. Bedrock may be more than 500 feet deep in places.

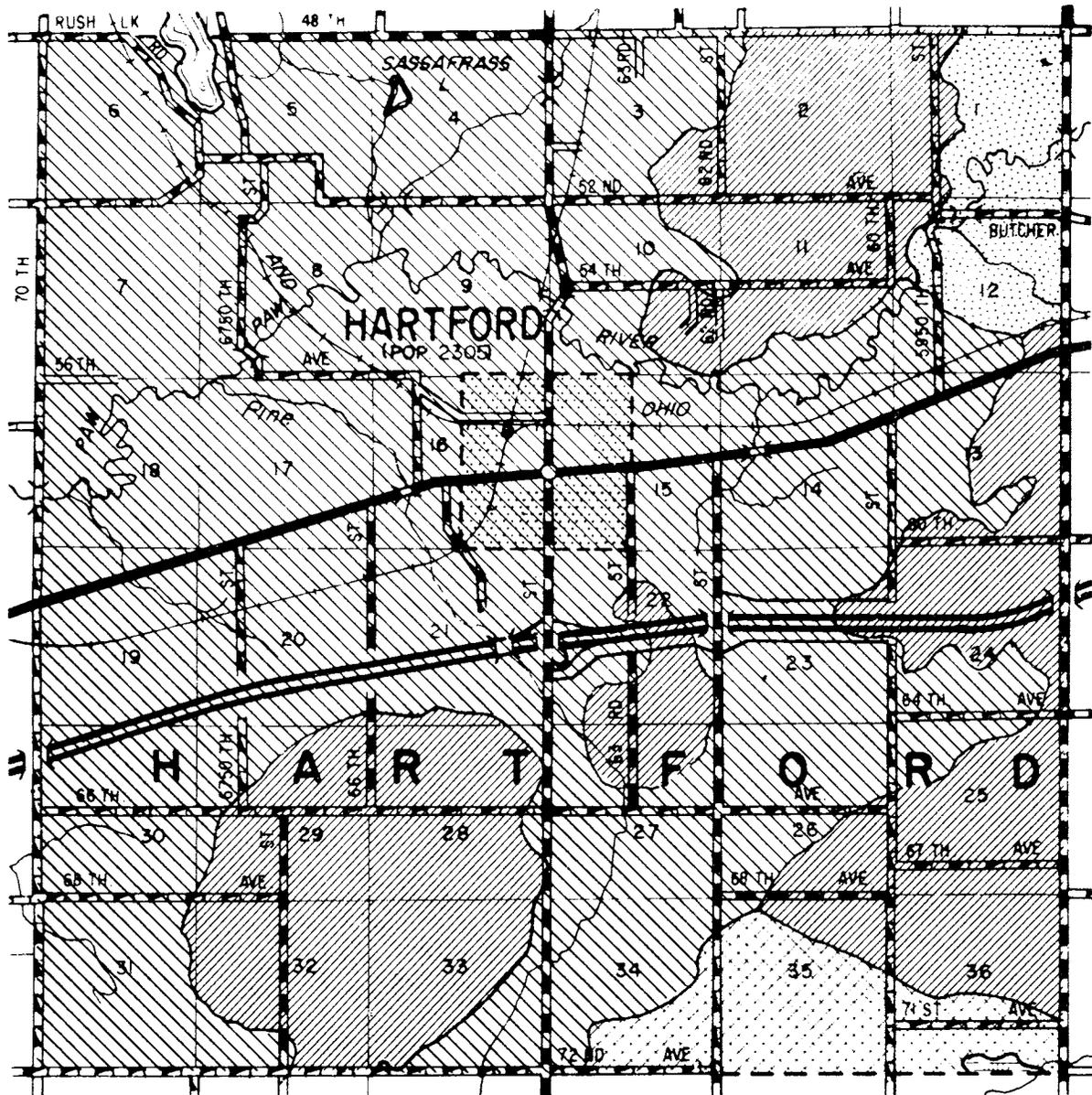
Swamps and marshes

FIGURE 37.--MAP OF HAMILTON TOWNSHIP SHOWING THE GENERAL AVAILABILITY OF GROUND WATER TO WELLS.

Table 17.--Records of selected wells in Hartford Township (T. 3S., R. 16W.)

Explanation: e - estimated; Analyst--Field, not accurate to laboratory standards; USGS, U. S. Geological Survey; MDH, Michigan Dept. of Health; Remarks--LOG, record of materials penetrated on file; ANAL, also see table of chemical analyses of ground water.

Location T. R. Sec	Owner	Driller	Year drilled	Depth (In ft.)	Diam (In inches)	Water level (In feet)	Month and year measured	Yield (In gpm)	Use	Screen openings (Inches)	Pump	Water- bearing materials	Altitude (In feet)	Quality of Water			Remarks
														Iron (as Fe)	Hardness (as CaCO <sub>3</sub> )	Chloride (Cl) (10)	
NE SW 1	Hilltop Orchards	G. Tinker	1961	58	2	25	10-61	10	Dom	.010	Jet	Gravel	690				
SE NE 1	C. Jackson	D. Rose	1961	47	2	21			Dom	.010	Jet	Sand	670				
SE SE 1	B. Clausell	Owner		36					Dom								
SE SE 2	P. Evans			190	2	18	10-62	50	Ind	.010	Subm	Sand	660	353	6.0	USGS	ANAL
SW SW 3	D. Childs Garage	D. Rose	1962	50	4	e10	8-62	12	Dom	.010	Jet		660	340	2.0	USGS	ANAL
NW NW 5	W. Rice	Owner	1961	10	1 1/2	Flow	10-63	400	Dom		Subm		645	176	4.0	USGS	ANAL
NW NW 6	G. Hessler	C. Kreitner		65	4				Pub		Turb		660	335	5.0	USGS	ANAL
NE NW 7	E. Kerlikowsky	C. Claspaddle		85	4				Irr		Jet		680				
SW NE 10	D. Carny	D. Rose	1962	64	2			4	Dom	.010	Jet	Sand, gravel	680				Inadequate supply
NE SE 10	V. Kaucher	Do		100	3			12	Dom		Jet	Sand, gravel	680	247	1.0	USGS	Well in gravel pit
NE NW 11	C. Dreke	D. Rose	1962	140	70	92	9-62	12	Dom	.010	Jet	Sand, gravel	700				Well in gravel pit
NW SW 12	W. King, Jr.	Do		70	3	e20			Dom		Subm	Gravel	770				Springs reprot. nearby
NW NE 12	H. Hany	D. Rose	1962	31	1 1/2	64	5-62	12	Dom	.010	Jet	Gravel	660				Springs reprot. nearby
SE SE 13	Hilltop Orchards	Owner	1920	35	1 1/2		4-59	18	Dom	.010	Jet	Gravel	660				Springs reprot. nearby
SE SE 14	Hartford Farm Supply	G. Tinker	1959	99	8	15	7-63	e-1000	Dom		Jet	Gravel	760				Seasonal use
SE NW 14	Springdale Manor	C. Cole	1962	44	2	e18	10-62	12	Dom	.018	Turb	Gravel	660				Screen stripped to allow flow
SE SW 14	Springdale Manor	D. Rose	1962	24	2	Flow	7-62	65	Dom	.010	Jet	Sand	640				Seasonal use; 2nd well same depth
SE SW 14	W. Schickel	D. Rose	1963	55	3	10	7-63	40	Ind	.010	Jet	Gravel	665				2 wells in pit; ANAL; LOG
SW NE 14	Shafers Lake Farms	Hendy Bros.	1929	61	4	18	7-63	100	Ind	.020	Subm	Sand	665				
SE NE 15	Village of Hartford	Ind-Mich Water Co.	1956	60	10	28	4-56	1,300	Mun	.060-.080	Turb	Sand, gravel	660	tr	14	MDH	
SE NE 15	J. Fahlstetter	Dunbar Drig. Co.	1956	167	14	28			Irr		Turb		660				
NE SE 16	Mrs. B. Peters	Do		89	2	15.82	3-63	200	Mun	.025	Turb	Sand	660	1.0	210	MDH	ANAL; LOG
NE SE 16	Village of Hartford	Do	1947	93	12	10	7-47	375	Mun	.020	Turb	Sand, gravel	660	0.8	5	MDH	ANAL; LOG
SE SE 16	Do	Do	1956	108	12	10	2-56	940	Mun	.060-.036	Turb	Sand, gravel	660	0.8	260	MDH	ANAL; LOG
SW NE 16	Do	Do	1954	140	6	18	10-54	550	Test			Sand, gravel	660	1.2	270	MDH	ANAL; LOG
SW SE 17	F. Williams	D. Rose	1962	105	2	e15	9-62		Dom	.010	Jet	Sand, gravel	660				LOG
NW SW 19	V. Drake	D. Rose	1963	50	3	30	7-63	20	Pub		Jet	Sand, gravel	675				Large use for Motel, Pool
NW NW 20	C & O RR	Layne Northern Co.	1915	125	8	35	6-59	700	Ind		None	Sand	660				Abandoned R.R. well; LOG
NW NW 20	Do	Do	1968	143	12	33	9-58	170	Ind		Turb	Sand, gravel	670				
SE NE 21	H. Foker	Do	1916	144	12	31.50	7-63	700	Ind		Turb	Sand, gravel	670				
SW NW 22	Auto Specialties West	R. Sanders	1960	55	4				Pub		Jet	Sand, gravel	675				Restaurant & gas station use
NW NW 22	East 12th	E. Richtrek	1955	46	4				Irr	.010	Jet	Sand, gravel	675				Pumped into surface pond
NW NW 23	Village of Hartford	Do		26	4	Flow	50-100		Pub		Jet	Sand, gravel	675				6 wells now abandoned
NE NE 25	A. Dowd	Do	1955	46	4				Mun		Jet	Sand, gravel	670				
SE NE 26	F. Hillah	G. Tinker	1956	89	3	15	8-56	12	Dom,Stk	.010	Jet	Sand, gravel	720				Was drilled to 166'; LOG
SE SE 27	L. Page	D. Rose	1963	163	4	47.82	7-63	67	Dom	.012	Subm	Sand	745				ANAL
SE NE 28	J. Johnson	D. Rose	1962	97	2	Flows	7-62		Spray	.010	Jet	Sand	805				20 ft screen, fine gauze; LOG
SE NE 28	J. Johnson	D. Rose	1962	94	2	e90	7-62	12	Dom	.010	Jet	Sand, gravel	700				Dry hole - abandoned; LOG
SE NE 28	J. Johnson	D. Rose	1962	52	2	e90	7-62	12	Dom	.010	Jet	Gravel	695				
SW SE 29	L. Kling	D. Rose	1963	85	2	60	7-62	12	Dom	.010	Jet	Sand	695				
SE SW 30	N. Smith	Dunbar Drig. Co.	1949	44	6	63	7-49	235	Irr	.010-.020	Turb	Sand	770				
NW SW 31	C. Hathaway	Do		69	2	e15	-63	15	Dom	.010	Jet	Sand	690	322	5.0	USGS	ANAL
SE SW 31	G. Geisler	D. Strong	1942	69	4	38	11-45	180	Spray	.010	Jet	Sand, gravel	700				
NW SW 31	Layne-Northern Co.	Layne-Northern Co.	1945	63	8				Irr		Turb	Sand, gravel	720				
NW SW 31	C. Kreitner	Layne-Northern Co.	1945	77	8-6				Dom		Subm	Sand, gravel	720				
SE NW 32	L. Fisher	C. Kreitner	1953	42	2			7	Spray		Subm	Sand, gravel	740				
SE SW 32	H. Reichman	Ind-Mich Water Co.	1940	159	10	40			Dom		Hand	Sand, gravel	700				
SE SW 32	D. Bittase	Do		80	4				Irr	.010	Jet	Sand, gravel	750				
SE SW 36	E. Phillips	E. Richtrek	1956	50	1 1/2				Dom,Stk		Jet	Sand, gravel	780				



**AREA I.** Enough water for domestic, stock, and spraying supplies (up to 10 gpm) generally can be obtained from wells less than 75 feet deep. Water in the well usually is less than 30 feet below land surface. Enough water for irrigation, municipal, or industrial supplies (more than 100 gpm) generally can be obtained from deeper, large-diameter wells (more than 6 inches in diameter and 100 to 200 feet deep).

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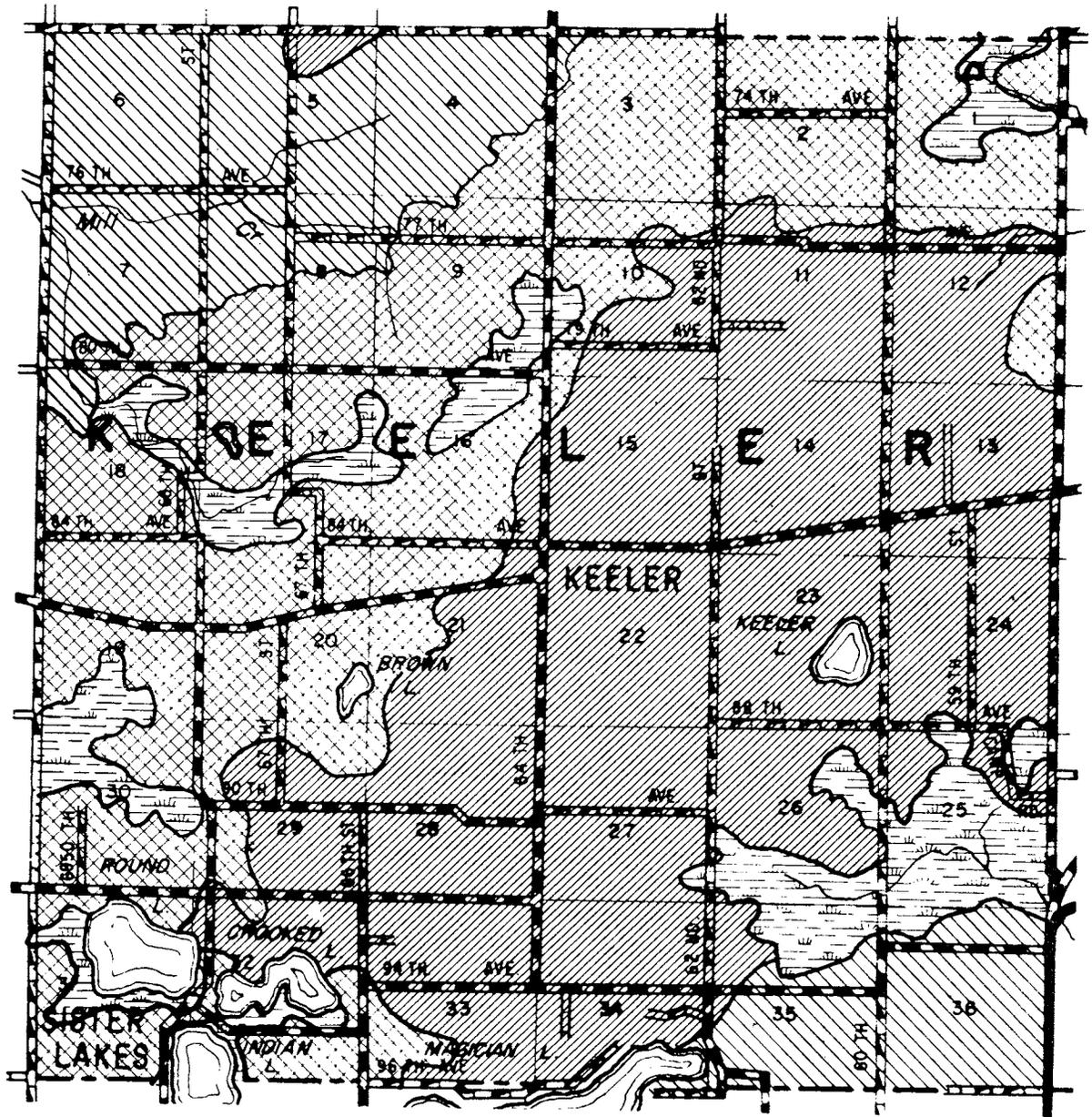
Swamps and marshes

FIGURE 38.--MAP OF HARTFORD TOWNSHIP SHOWING THE GENERAL AVAILABILITY OF GROUND WATER TO WELLS.

Table 18.--Records of selected wells in Keeler Township (T. 4S., R. 16W.)

Explanation: e - estimated; Analyst--Field, not accurate to laboratory standards; USGS, U. S. Geological Survey; MOH, Michigan Dept. of Health; Remarks--LOG, record of materials penetrated on file; AMAL, also see table of chemical analyses of ground water.

Location	Owner	Driller	Year drilled	Depth (in ft)	Diam (in inches)	Water level (in feet)	Month and year measured	Yield (in gpm)	Use	Screen openings (inches)	Pump	Water-bearing materials	Altitude (in msl)	QUALITY OF WATER				Remarks
														Iron (as Fe)	Hardness (as CaCO <sub>3</sub> )	Chloride (Cl)	Analyst	
SE SE 1	J. Thar	Ind-Mich Water Co.	1945	156	10	34	7-43	180	Irrig	.007	Turb	Sand	800	0.1	150	10	Field	Water level 35' in 1945; pumps sand; LOG
SE SE 2	G. Stagers	E. Richcreek	1942	151	2			50	Irrig	.010	Subm	Sand	790	0.2	250	15	Field	For 4 acres of blueberries Water temp. 52.7°F.
SE SE 4	J. Babcock	E. Richcreek	1960	126	4	17.25	7-63	300	Dom	.006	Turb	Sand, gravel	820				Field	
SE NE 6	G. & S. Gaiser	Layne-Northern Co.	1937	77	8	36.1	7-63	500	Irrig		Turb	Sand, gravel	700				Field	
NW NW 6	D. Sabadin	Ind-Mich Water Co.	1935	90	10	flow		500-700	Irrig		Turb	Sand, gravel	720				Field	
NE SE 7	E. Zirk	D. Fredenhagen	1050	88	2	6	-63	700	Dom, Stk		Turb	Sand	705				Field	Flowed at 55'-95'; Small flow 1963; Oil test pH 7.2
NW NW 8	E. Klett	Dunbar Dr.-g. Co.	225	8	2	flow		200	Irrig		Jet	Sand	740				Field	
NW NW 9	L. Kolberg	E. Richcreek	225	8	2	flow		10	Dom, Stk		Jet	Sand	740				Field	Flowed 10 gpm when drilled
NW NW 10	C. Kolberg	E. Richcreek	1961	62	2	+12	-61	600	Dom, Stk		Jet	Sand	730				Field	Flows 10 gpm to creek; screen only 12' down
NW NW 10	A. Falkner	Godfrey (Bangor)	1946	165	8		4-56	1180	Irrig	.080-.060	Turb	Sand, gravel	800				Field	
NW NW 11	J. Falkner	Dunbar Dr.-g. Co.	1956	157	14	28		450	Irrig	.007	Jet	Sand	800				Field	LOG pH 7.1
NW NE 11	C. Garfield	J. C. Newman	1950	182	8	26	-56	el, 100	Irrig		Subm	Sand	800				Field	
SE NE 11	C. Johnson	E. Richcreek	1956	128	4		4-63	2,000	Irrig	.200	Turb	Gravel	800				Field	LOG
SE SW 13	R. Johnson	Dunbar Dr.-g. Co.	1956	185	8		6-58	1,000	Irrig	.016-.020	Turb	Gravel	790				Field	LOG
SE SW 13	T. Roosevelt	Dunbar Dr.-g. Co.	1961	147	12-		4-55	460	Obs	.040, .016, .018	Turb	Sand, gravel	800				Field	LOG; used as observation well
SE NE 14	M. Seel	Do.	1958	181	10	22	2-55	660	Irrig	.018	Turb	Sand, gravel	800				Field	Water temp. 52.0; LOG; pH 7.3
SE SW 14	O. Klett	Do.	1955	170	14	19	1-59	900	Irrig	.020-.015	Turb	Sand	800				Field	60' of blue clay above sand and gravel
SE SW 14	O. Klett	J. Newman	1955	135	8	19	-46	900	PS, Ind	.008	Turb	Sand	810				Field	Seasonal use; pH 7.5
NW NW 14	M. Poland	Dunbar Dr.-g. Co.	1955	193	12	34	6-48	500	Irrig	.010	Jet	Sand, gravel	805				Field	Well abandoned
NW NW 15	H. Anthony	J. Newman	1946	200	8	40	8-56	500	Irrig	.040, .016, .125	Turb	Sand, gravel	805				Field	Well abandoned
NW NW 15	Bronte Champagne Co.	Lewis & Sons	1962	172	4	37	7-63	1225	Aband.	.040	Turb	Sand, gravel	805				Field	Sample 25 gal for Pest. 6/18/63; Temp. 51.5; LOG
NW NW 15	Bronte Champagne Co.	Dunbar Dr.-g. Co.	1944	72	4	24	2-55	615	Ind	.030	Turb	Sand, gravel	800				Field	Used as Observation well; LOG
NW NW 15	Bronte Champagne Co.	Dunbar Dr.-g. Co.	1956	134	10	24	3-56	750	Irrig	.016, .030, .040	Turb	Sand, gravel	800				Field	Water temp 54; LOG; AMAL
NW NW 15	Bronte Champagne Co.	Dunbar Dr.-g. Co.	1956	134	10	24	3-56	750	Irrig	.016, .030, .040	Turb	Sand, gravel	800				Field	LOG
NW NW 22	Do. Drillers # 2	Do.	1953	135	10	25.46	7-63	1225	Aband.	.005, .020, .030, .060	Hand	Sand, gravel	805				Field	Also used as observation well
SW SW 22	Burnette Farms Packing	Ind-Mich Water Co.	1955	127	10	32	2-55	615	Ind	.060	Turb	Sand, gravel	805				Field	Used as Observation well; LOG
SW SW 22	Do.	Do.	1952	123	10	28	6-52	400	Ind	.030	Turb	Sand, gravel	800				Field	Water temp 54; LOG; AMAL
SW SW 22	Do.	J. Newman	1950	el25	8	32	7-50	400	Ind	.016, .030, .040	Turb	Sand, gravel	800				Field	LOG
SE SE 23	M. Delmorrow	Dunbar Dr.-g. Co.	1956	160	10	30	7-63	750	Irrig	.005, .020, .030, .060	Jet	Sand, gravel	805				Field	LOG
SE NE 24	Adams	Owner	1956	25	11	6	2-55	1300	Irrig	.005, .020, .030, .060	Jet	Sand	790				Field	Also used as observation well
SE NE 27	R. Blannett	Dunbar Dr.-g. Co.	1955	135	10	25	2-55	1300	Irrig	.005, .020, .030, .060	Jet	Sand	790				Field	Also used as observation well
SE NE 27	R. Blannett	Do.	28	2	2		6-54	780	Dom	.060	Turb	Gravel	800				Field	Pesticide sample taken
NW SW 27	G. Kays	Do.	1954	139	12	33	6-54	700	Irrig		Turb	Gravel	800				Field	LOG
SW SE 28	J. Shyer	B. J. Lewis & Sons	1956	173	8			650	Irrig		Turb	Gravel	807				Field	
SW SW 29	M. Seel	Do.	1954	167	10			650	Irrig		Turb	Gravel	805				Field	
NW NE 30	H. Utrup	Do.	1954	65	2			650	Dom, Stk		Jet	Sand, gravel	820				Field	
NW NW 31	Fun & Sun Resort	Fun & Sun Resort		65	2			650	Pub		Jet	Sand, gravel	780				Field	
NW NE 31	Rays Cabins	Do.	1962	69	14	21	5-62		Pub		Jet	Sand, gravel	780				Field	
NW NE 31	Do.	Do.	1962	69	14	21	5-62		Pub		Centr	Sand, gravel	780				Field	Supplies 6 cottages
NW SW 32	Mclabb Cottages	Do.	1962	50	2			600	Pub		Jet	Sand, gravel	800				Field	
NW SW 34	L. Scherer	B. J. Lewis & Sons	1954	50	2			400	Irrig	.080	Turb	Gravel	800				Field	Supplies 8 cottages; pH 7.2
NW SW 34	H. Krohn	Dunbar Dr.-g. Co.	1948	89	8	20	-48	400	Irrig		Turb	Sand, gravel	800				Field	
SW SW 35	Bob's Harbor Resort	Pritchard	1949	43	2	10	-49		Dom		Jet	Sand, gravel	780				Field	
SW NW 35	L. Parquette	Owner	1956	26	11	2			Dom		Jet	Sand, gravel	780				Field	
SE NW 36	C. Carter	Owner	1956	26	11	2			Dom		Jet	Sand, gravel	780				Field	Shallow wells in area; sand below hardpan
NW SW 36	C. Moulton	F. Joime	1961	32	2	20	-61		Dom		Jet	Sand	781				Field	

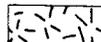


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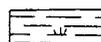
**AREA I.** Enough water for domestic, stock, and spraying supplies (up to 10 gpm) generally can be obtained from wells less than 75 feet deep. Water in the well usually is less than 30 feet below land surface. Enough water for irrigation, municipal, or industrial supplies (more than 100 gpm) generally can be obtained from deeper, large-diameter wells (more than 6 inches in diameter and 100 to 200 feet deep).
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**AREA IV.** Enough water for domestic, stock, and spraying supplies generally can be obtained from wells less than 75 feet deep. Water in the well generally is less than 30 feet below land surface. Exploratory drilling would be needed to determine where large supplies can be obtained.
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**AREA II.** Enough water for domestic, stock, or spraying supplies generally can be obtained from wells less than 125 feet deep. Depth to water in about half the wells is more than 30 feet below land surface. Large-diameter wells less than 200 feet deep generally yield enough water for irrigation, municipal, and industrial supplies.
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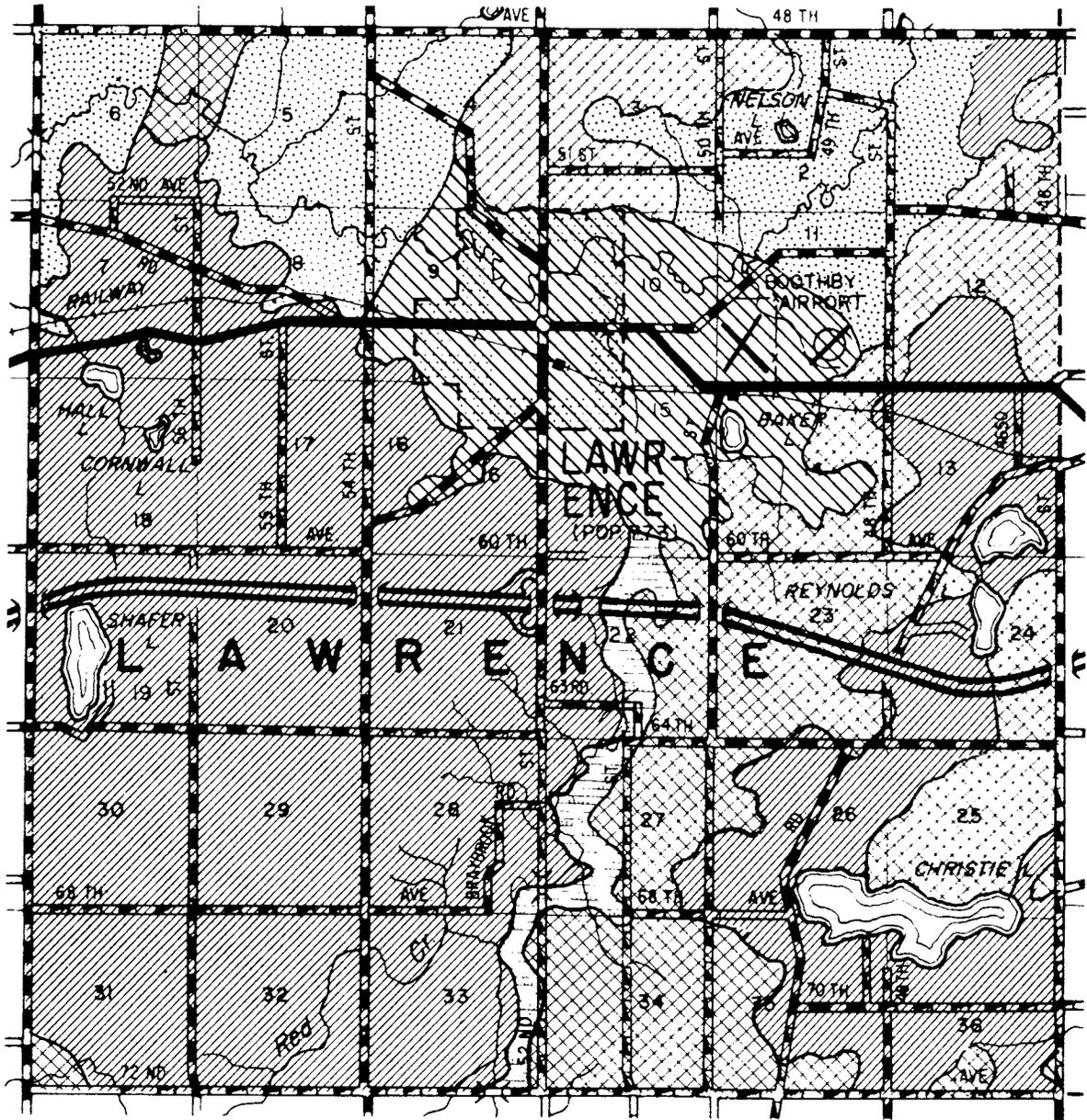
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**AREA VI.** Similar to surrounding areas except that thick glacial drift in deep bedrock valleys may yield moderate to large supplies of water (50 to more than 100 gpm). Exploratory drilling would be needed to determine where large supplies are available. Test wells should be drilled to bedrock unless salt water is found at shallower depths. Bedrock may be more than 500 feet deep in places.
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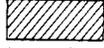
Swamps and marshes

FIGURE 39.--MAP OF KEELER TOWNSHIP SHOWING THE GENERAL AVAILABILITY OF GROUND WATER TO WELLS.



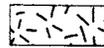


 **AREA I.** Enough water for domestic, stock, and spraying supplies (up to 10 gpm) generally can be obtained from wells less than 75 feet deep. Water in the well usually is less than 30 feet below land surface. Enough water for irrigation, municipal, or industrial supplies (more than 100 gpm) generally can be obtained from deeper, large-diameter wells (more than 6 inches in diameter and 100 to 200 feet deep).

 **AREA II.** Enough water for domestic, stock, or spraying supplies generally can be obtained from wells less than 125 feet deep. Depth to water in about half the wells is more than 30 feet below land surface. Large-diameter wells less than 200 feet deep generally yield enough water for irrigation, municipal, and industrial supplies.

 **AREA III.** Enough water for domestic, stock, or spraying supplies generally can be obtained from wells less than 200 feet deep. Wells for irrigation, industrial, or municipal supplies generally would have to be drilled to depths greater than 150 feet, and probably less than half of these would be successful.

 **AREA IV.** Enough water for domestic, stock, and spraying supplies generally can be obtained from wells less than 75 feet deep. Water in the well generally is less than 30 feet below land surface. Exploratory drilling would be needed to determine where large supplies can be obtained.

 **AREA V.** It is difficult to obtain enough potable water for domestic supplies in this area. It may be necessary to drill several wells before a successful domestic well is obtained. Chances of obtaining large supplies are poor.

 **AREA VI.** Similar to surrounding areas except that thick glacial drift in deep bedrock valleys may yield moderate to large supplies of water (50 to more than 100 gpm). Exploratory drilling would be needed to determine where large supplies are available. Test wells should be drilled to bedrock unless salt water is found at shallower depths. Bedrock may be more than 500 feet deep in places.

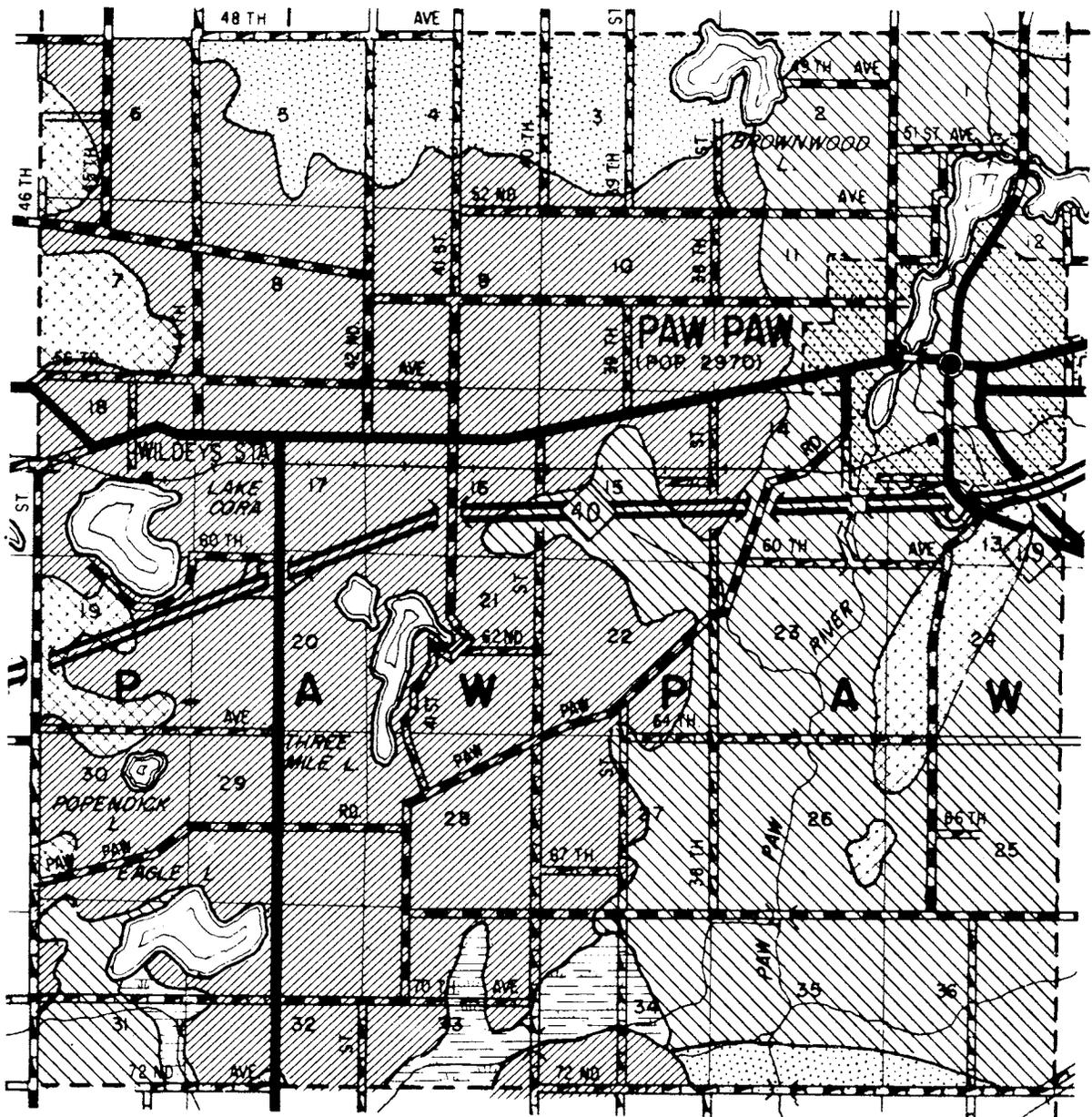
 Swamps and marshes

FIGURE 40.--MAP OF LAWRENCE TOWNSHIP SHOWING THE GENERAL AVAILABILITY OF GROUND WATER TO WELLS.

Table 20.--Records of selected wells in Paw Paw Township (T. 3S., R. 14W.)

Explanation: e - estimated; Analyzed--Field, not accurate to laboratory standards; USGS, U. S. Geological Survey; MDH, Michigan Dept. of Health; Remarks--LOG, record of materials penetrated on file; ANAL, also see table of chemical analyses of ground water.

Location T. R. Sec	Owner	Driller	Year drilled	Depth (In ft)	Diam (Inches)	Water level (In feet)	Month and Year	Yield (In gpm)	Use	Screen opening (Inches)	Pump	Water bearing materials	Altitude (In msl)	Quality of water			Remarks
														Hardness (as CaCO <sub>3</sub> )	Chloride (In ppm)	Iron (as Fe)	
SE NW 1	G. C. Cole	G. Tinker	1960	56	2	31	9-60	10	Dom	.010	Jet	Gravel	800	700	250	Field	MO <sub>3</sub> - 4.0; NO <sub>2</sub> - 0.00
NE NW 2	J. Cutler	E. Sanders	1948	80	2	12	-62		Dom,Stk	.010	Piston	Sand	703	230	10	Field	
SE NW 3	M. Wojciechowski	Do.	1947	85	2	12	-63		Dom,Stk	.010	Jet	Sand	725	250	10	Field	
SW NW 4	A. Panozzo	Do.	1917	75	1 1/2	11-43	5-63		Obs.	.010	Subm	Sand	740	170	10	Field	See fig. ---
NE NW 5	R. Martin	U. S. G. S.	1963	59	1 1/2	11-43	3-63	55	Irrig.	.015	Turb	Sand	795	260	10	Field	Sand entire depth
NE NW 6	C. Pervanger	Dunbar Drig. Co.	1961	122	4	66	8-59-05	350	Dom,Stk	.125	Jet	Sand & gravel	800	240	10	Field	Water level 53 ft in 1948; LOG
NE NW 7	F. Pervanger	Do.	1948	149	8	59-05	-60	25				Gravel	731			Field	Well abandoned; LOG
NE NW 8	H. J. Webb	Do.	1960	83	3	33	2-46					Gravel	740			Field	Well not in use
NE NW 9	H. J. Webb	Do.	1946	51	4	14						Gravel	740			Field	pH 8.0
SW SE 10	Maple Dairy Co. # 1	B. J. Lewis	1957	116	4	14			Ind		Turb	Sand	740	260	40	Field	1362 yield 100 gpm; LOG; ANAL
SW SE 11	Maple Dairy Co. # 2	Do.	1942	95	12	13-55	11-62	420	Mun	.105	Turb	Sand	720	245	5	Field	LOG; ANAL
SW SE 12	Village of Paw Paw # 1	F. Chapman	1946	108	16	3	5-49	576	Mun	.105	Turb	Sand	720	210	11	Field	LOG; ANAL
SW SE 13	Village of Paw Paw # 2	Do.	1949	62	34	10-83	11-62	120	Mun	.105	Turb	Sand	720	230	15	Field	LOG; ANAL
SW SE 14	Village of Paw Paw # 3	Layne-Northern	1951	110	34	15-53	6-49	400	Mun	.105	Turb	Sand	730	240	10	Field	LOG; ANAL
NE SE 11	Village of Paw Paw # 4	Do.	1942	152	8	6-3	1-42	7	Test			Sand	720			Field	LOG; Test for # 4 well
NE SE 12	Village of Paw Paw	Do.	1942	155	8	7	11-45		Test			Sand	720			Field	LOG; Test for # 2 well
NE SE 13	Village of Paw Paw	Do.	1945	112	6	11	7-28		Test			Sand	720			Field	LOG; Test for # 2 well
NE NW 14	Village of Paw Paw	F. Chapman	1928	100	2	2-5		75	Ind		Jet	Sand & gravel	750	250	10	Field	Rept. flow of 115 gpm
NE NW 15	Village of Paw Paw	E. Sanders	1942	112	2	14	8-63		Ind			Sand & gravel	730			Field	Have 5 wells 20 ft deep
NE NW 16	St. Julian Mine Co. # 1	A. Mesler	1921	92	6	10-37	8-63	50	Ind		Jet	Sand	730			Field	Used seasonally
NE NW 17	St. Julian Mine Co. # 2	Do.	1911	110	8	10-73	8-63	50	Ind		Jet	Sand	730			Field	Used seasonally
NE NW 18	Dwan Canning Co. # 1	E. Sanders, Sr.	1950	110	8			350	Ind		Turb	Gravel	730	165	6.0	MDH	Used seasonally
NE NW 19	Dwan Canning Co. # 2	J. C. Newman	1940	88	8			150	Ind		Turb	Gravel	730			Field	Used seasonally
NE NW 20	Michigan Winerites # 1	Do.	1940	80	8			150	Ind		Turb	Gravel	730			Field	Used seasonally
NE NW 21	Michigan Winerites # 2	Dunbar Drig. Co.	1961	80	10	18	5-61	450	Ind	.018	Turb	Sand	760			Field	Used seasonally; LOG
NE NW 22	Frontenac Mine Co. # 1	Do.	1961	87	6			450	Ind		Turb	Sand	760			Field	Used seasonally
NE NW 23	Frontenac Mine Co. # 2	Do.	1961	87	4			450	Ind		Turb	Sand	760			Field	Used seasonally
NE NW 24	A. F. Murch Co. (East)	Dunbar Drig. Co.	1957	130	12	40-02	4-63	250	Ind	.010-.040	Turb	Sand & gravel	765	190	10	Field	Water level 38 ft 5-57; LOG
NE NW 25	A. F. Murch Co. (West)	Do.	1957	120	8	37	6-57	385	Ind	.012-.035	Turb	Sand & gravel	765	200	10	Field	Water temp 52-7, 4-63; LOG
NE NW 26	A. F. Murch Co. (Tin)	J. C. Newman	1953	110	8			250	Ind		Turb	Sand & gravel	765			Field	Originally drilled to 162 ft; LOG
NE NW 27	A. F. Murch Co. (Inside)	Dunbar Drig. Co.	1952	105	8	31	3-52	300	Ind	.012	Turb	Sand	765			Field	
NE NW 28	A. F. Murch Co. (South)	Do.	1952	130	12	25-33	4-63	600	Pub	.033	Turb	Sand	765			Field	
NE NW 29	Pioneer Motel	Do.	1962	67	2			600	Pub		Jet	Sand & gravel	770	290	35	Field	
NE NW 30	Lake Cora Golf Course	G. Tinker	1960	46	2	8	8-60	20	Pub	.010	Hand	Sand & gravel	790			Field	
SE SE 20	J. G. Woodman	Dunbar Drig. Co.	1948	106	10	20-21	3-63	1,100	Irr	.010	Turb	Sand & gravel	770			MDH	LOG
SE SE 21	W. J. Blessing	B. Lewis & Sons	1957	57	4	13	5-57	1,100	Irr	.200	Jet	Sand & gravel	760			MDH	LOG; Water Temp 52.6
SE SE 22	J. Mandigo	Dunbar Drig. Co.	1947	76	10	7-14	4-63	1,300	Dom		Turb	Gravel	760			MDH	LOG; Water Temp 52.6
SE SE 23	H. Cutler	Owner	1947	45	2	10		1,300	Dom		Turb	Gravel	760			MDH	LOG; Water Temp 52.6
SE SE 24	R. Brockway	Owner	1947	45	2	10		1,300	Dom		Turb	Gravel	760			MDH	LOG; Water Temp 52.6
SE SE 25	C. Costello	Owner	1947	18	2	10		1,300	Dom		Jet	Sand	767			Field	
SE SE 26	G. Ampey	Owner	1947	45	1 1/2			15	Dom	.010	Piston	Sand	771	170	10	Field	
SE NW 27	K. Lyle	E. Richcreek	1958	82	2	30	11-58	15	Dom		Jet	Sand	777	346	9.0	USGS	ANAL
SE NW 28	M. Hood	Do.	1945	60	3			16	Dom		Jet	Sand & gravel	772			USGS	Also 4 wells 32-75 ft deep
SE NW 29	E. Goens	Owner	1949	44	1 1/2			16	Dom		Jet	Sand & gravel	780	371	6	Field	ANAL
NE NW 30	C. Lichtman	Owner	1949	60	3			16	Dom		Jet	Sand & gravel	780	325	2	Field	ANAL
NE NW 31	N. Hood	Dunbar Drig. Co.	1953	100	2			450	Dom	.100	Turb	Sand & gravel	765	253	2	USGS	ANAL; also has 20 ft well
NE NW 32	N. Hood	Do.	1953	77	2			450	Dom		Turb	Sand & gravel	770	214	3	USGS	LOG
NE NW 33	N. Hood	E. Sanders	1949	70	3			3 1/2	Dom		None	Sand & gravel	775	155	10	USGS	ANAL
NE NW 34	McGrew	Do.	1949	52	3	flows		3 1/2	Dom		Hand	Sand & gravel	740	155	10	Field	2 other wells 28-32 ft
NE NW 35	T. Wasylecki	Do.	1963	30	1 1/2	19			Dom		Jet	Sand	750			USGS	ANAL; also has 18 ft well
NE NW 36	J. Nagy	R. Sanders	1963	27	1 1/2	19			Dom		Jet	Sand	750	383	8	USGS	ANAL; also has 18 ft well



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**AREA III.** Enough water for domestic, stock, or spraying supplies generally can be obtained from wells less than 200 feet deep. Wells for irrigation, industrial, or municipal supplies generally would have to be drilled to depths greater than 150 feet, and probably less than half of these would be successful.
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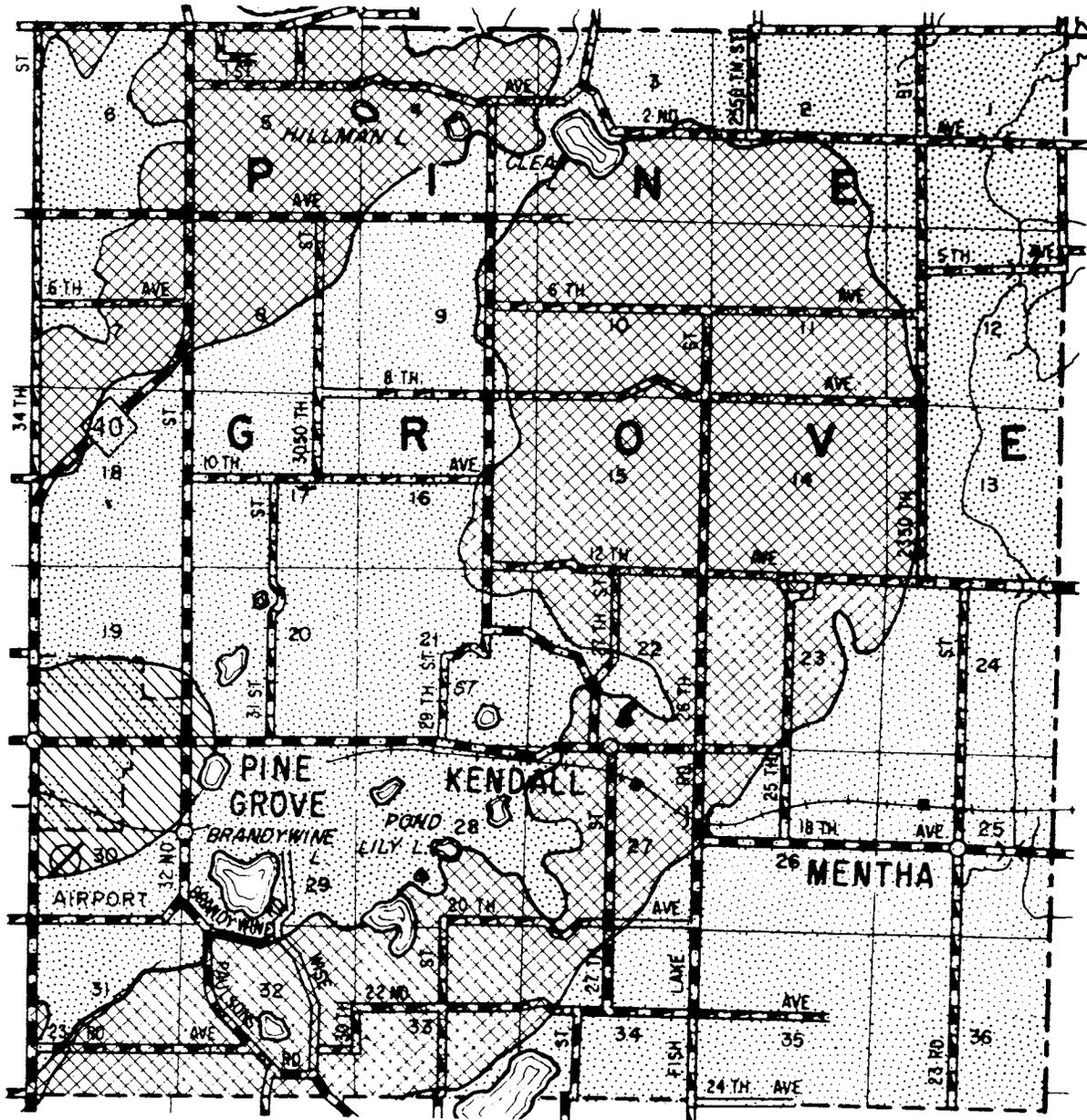
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Swamps and marshes

FIGURE 41.--MAP OF PAW PAW TOWNSHIP SHOWING THE GENERAL AVAILABILITY OF GROUND WATER TO WELLS.





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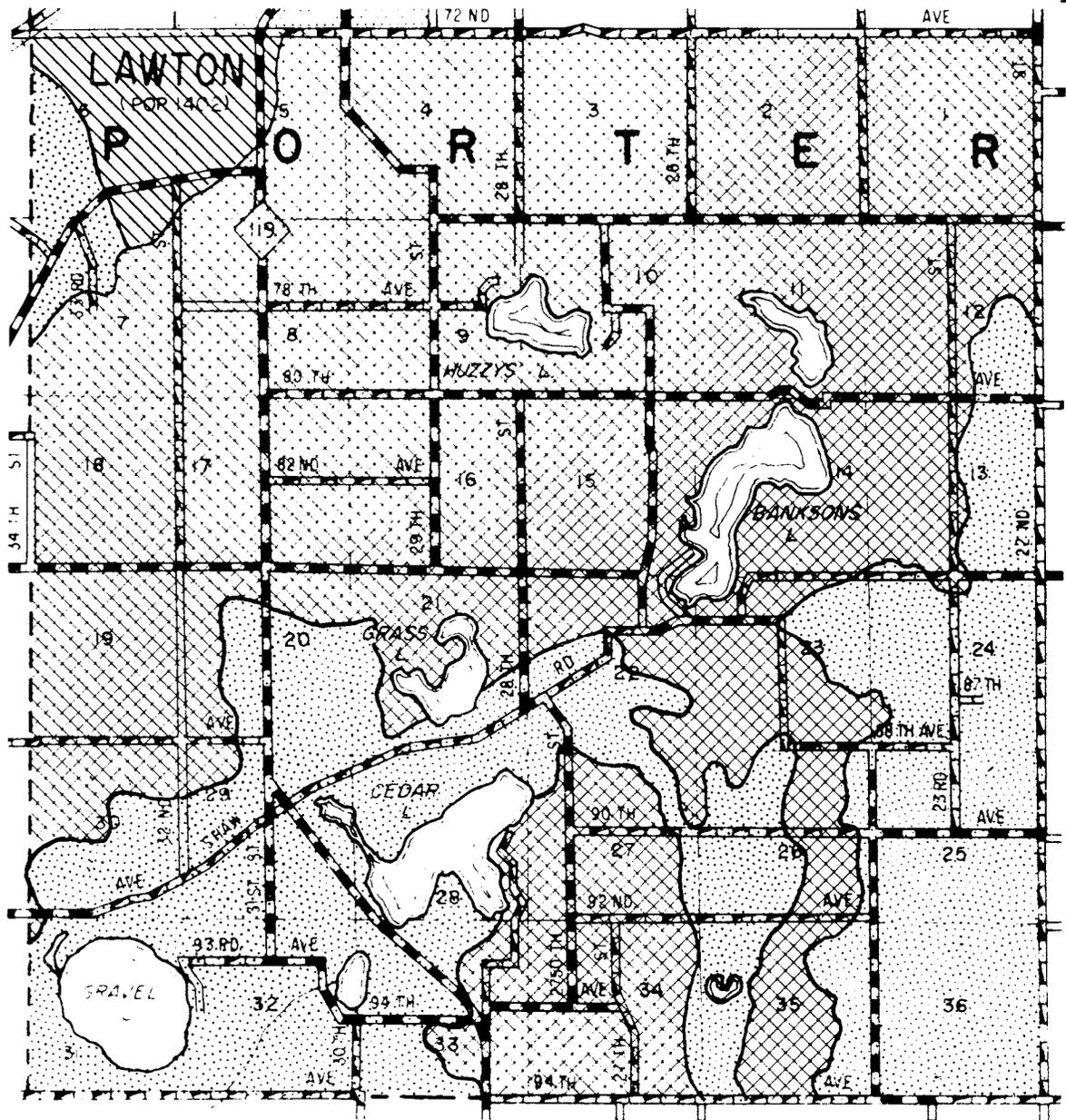
  
Swamps and marshes

FIGURE 42.--MAP OF PINE GROVE TOWNSHIP SHOWING THE GENERAL AVAILABILITY OF GROUND WATER TO WELLS.

Table 22.--Records of selected wells in Porter Township (T. 4S., R. 13W.)

Explanation: e - estimated; Analyst--Field, not accurate to laboratory standards; USGS, U. S. Geological Survey; MDH, Michigan Dept. of Health; Remarks--LOG, record of materials penetrated on file; WMI, also see table of chemical analyses of ground water.

Location	Owner	Driller	Year drilled	Depth (in ft)	Diam (in inches)	Water level (in feet)	Month and year measured	Yield (in gpm)	Use	Screen openings (inches)	Pump	Water bearing materials	Altitude (in ms)	Iron (as Fe)	Hardness (as CaCO <sub>3</sub> )	Chloride (Cl)	Analyst	Remarks
SE SE 2	L. Turner & Sons	E. Sanders	1962	78	2	e 59	-62	10	Dom,Stk	.010	Jet	Sand	960	tr	270	5	Field	pH 7.2
SE NE 3	M. Shoemaker	E. Sanders, Val's Pump Serv.		176	2	120	7-61		Dom,Spry	.010	Centr	Sandy clay	1,000		200	5	Field	uses spray clay
SE SW 5	D. Gibson	E. Sanders	1951	85	2	61	-48	10	Dom,Spry	.010	Jet	Sand	830	0	300	10	Field	pH 7.2
NE NW 5	Honeybear Packing Co.	Layne-Northern	1886	74	2	22	-58	164	Dom	.010	Jet	Sand	790	tr	250	15	Field	LOG
NE NW 5	Honeybear Packing Co.	E. Sanders & others	1958	109	8	9			Pub,Ind	.010 & .015	Turb	Sand, gravel	790	tr	205	15	Field	16 20 wells (incl. 1-4") 27-37 ft deep.
SE SE 6	R. Franks	E. Sanders & others	30-37	30-37	2				Dom	.012, .010	Suct	Sand, gravel	780	0.4	325	25	Field	pH 7.5
SE SE 7	D. Perkins	Owner	1959	29	2				Dom		Jet	Sand, gravel	900				Field	
NE NW 8	R. Rife	E. Sanders	1961	115	2	126	-50		Dom,Stk	.010	Piston	Sand, gravel	820	0.4	390	25	Field	pH 7.2
NE NW 9	W. Cummings	E. Sanders	1961	132	2	85	-61		Dom,Spry	.010	Jet	Sand, gravel	953	tr	250	5	Field	pH 7.5; supply inadequate
NE NW 10	R. Cornish	E. Sanders	1978	87	2	e 118	-55		Dom	.010	Jet	Sand, gravel	950		290	15	Field	uses sand for spray water
NE NW 11	C. Finch	E. Sanders	1978	67	2	75	-60		Dom	.010	Jet	Sand, gravel	953				Field	Had dug well w/60' of pipe for 80 yrs.
SE NW 13	Girl Scouts SW Mich	E. Sanders	1978e	e 80	2	50	-63		Dom	.010	Piston	Sand, gravel	942	tr	200	5	Field	6 wells at cam
SE SE 15	L. Dalley	U. S. G. S.	1963	83	1 1/2	47.15	5-63		Dom	.010	Piston	Sand	940		340	10	Field	Old windmill well
SE NW 16	Porter Township	U. S. G. S.	1880	67	2	59			unused		None	Sand	926		360	10	Field	LOG; see hydrographs
NE NW 16	H. Mohney	U. S. G. S.	1956	72	3	e 59			Dom,Spry	.010	Jet	Sand	940		390	10	Field	Old windmill well
NE NW 20	J. Thompson	E. Sanders	1956	108	2				Dom,Spry	.010	Jet	Sand	926		220	5	Field	pH 7.5
NE NE 21	F. & G. Nesbitt	E. Sanders	1953	65	2	51	-63		Dom,Spry	.010	Jet	Sand	940		410	10	Field	Have 2 wells same depth
SE NE 24	R. Alexander	Owner	1944	21	1 1/2	14	-63		Dom,Stk	.010	Suct	Gravel	910		410	10	Field	Have 3 wells same depth
NE SW 25	E. Copenhaver	Owner	1944	e 30	2	67	-59		Dom		Jet	Gravel	915	tr	300	10	Field	pH 7.1; have 2 wells
NE NE 26	M. McIlburn	E. Sanders	1943e	73	2	e 45	-63		Dom,Stk		Jet	Sand	920		388	18	USGS	ANAL.
SW NW 27	E. Shugars	E. Sanders	1943e	75	2	e 45	-63	10	Dom,Stk		Jet	Sand	920				Field	
NE NW 28	L. Cornish	E. Sanders	1962	73	2	53	-62		Spry	.010	Jet	Sand, gravel	910		270	5	Field	Have total of 4 wells - 2-48', 1-113'
NE NW 29	E. Cornish	E. Sanders	1958	82	2	e 48	-58		Dom,Stk	.010	Jet	Sand, gravel	930	2.5			Field	
N. NE 30	J. Turner	E. Sanders	1956	45	3			ell	Dom		Jet	Sand	920				Field	
NE NW 31	C. Allett	E. Sanders	1961	45	4	11		75	Spry	.010	Jet	Gravel	905				Field	Trailer Court
NE NW 33	A. Bays	E. Sanders	1945	65	2	e 27			Pub	.010	Jet	Gravel	890				Field	Cabins at lake edge
NE SE 34	S. Green	E. Sanders	1945	65	2	e 27			Pub	.010	Jet	Gravel	900				Field	
SE SE 36	E. Abernathy	E. Sanders	1948	e 25	2				Dom,Stk		Jet	Gravel	880	tr	350	5	Field	
SW NW 36	E. Stratton	E. Sanders	1948	28	2	22			Dom,Stk		Jet	Gravel	895		230	10	Field	pH 7.2



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**AREA III.** Enough water for domestic, stock, or spraying supplies generally can be obtained from wells less than 200 feet deep. Wells for irrigation, industrial, or municipal supplies generally would have to be drilled to depths greater than 150 feet, and probably less than half of these would be successful.

**AREA IV.** Enough water for domestic, stock, and spraying supplies generally can be obtained from wells less than 75 feet deep. Water in the well generally is less than 30 feet below land surface. Exploratory drilling would be needed to determine where large supplies can be obtained.

**AREA V.** It is difficult to obtain enough potable water for domestic supplies in this area. It may be necessary to drill several wells before a successful domestic well is obtained. Chances of obtaining large supplies are poor.

**AREA VI.** Similar to surrounding areas except that thick glacial drift in deep bedrock valleys may yield moderate to large supplies of water (50 to more than 100 gpm). Exploratory drilling would be needed to determine where large supplies are available. Test wells should be drilled to bedrock unless salt water is found at shallower depths. Bedrock may be more than 500 feet deep in places.

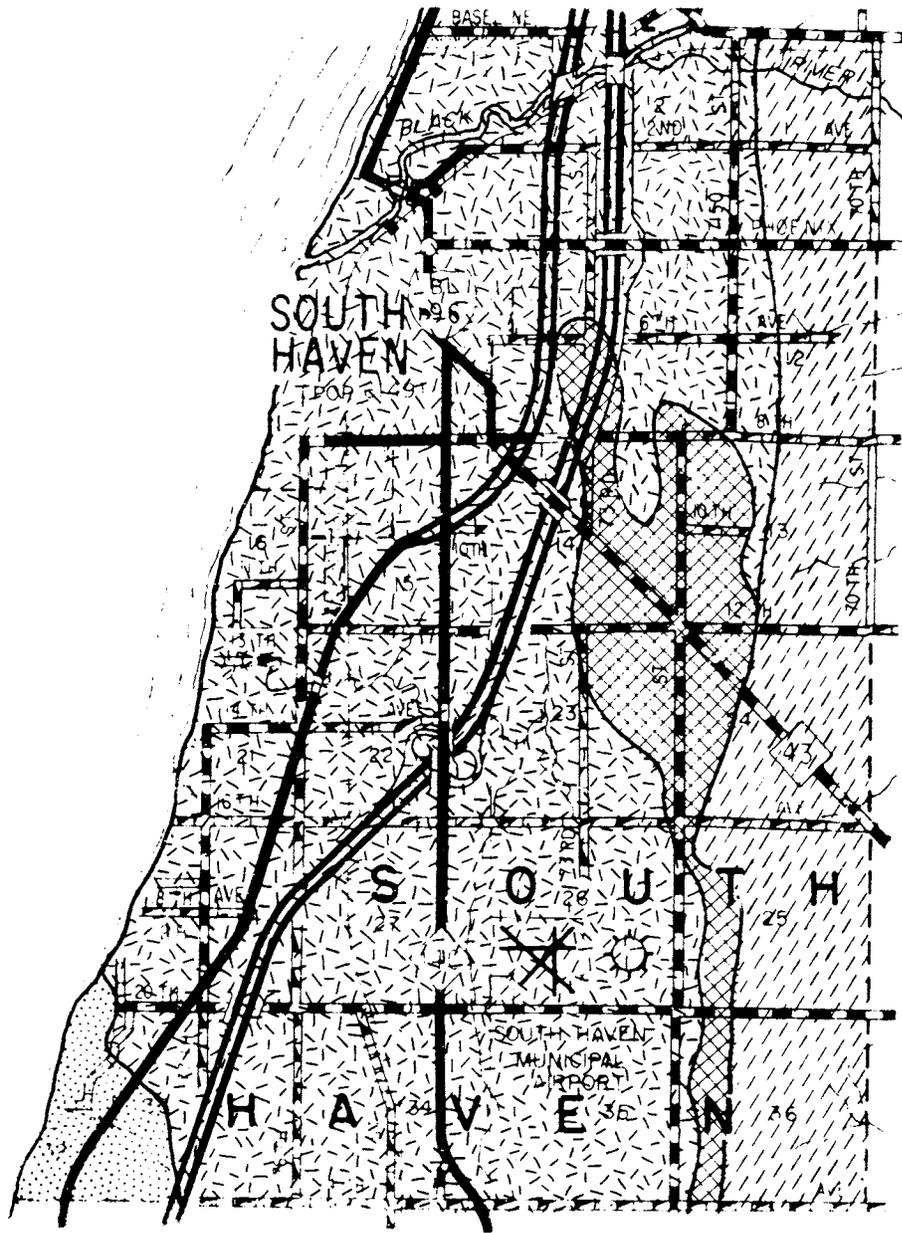
Swamps and marshes

FIGURE 43.--MAP OF PORTER TOWNSHIP SHOWING THE GENERAL AVAILABILITY OF GROUND WATER TO WELLS.

Table 23.--Records of selected wells in South Haven Township (T. 1S., R. 17W.)

Explanation: e - estimated; Analyst--Field, not accurate to laboratory standards; USGS, U. S. Geological Survey; MDH, Michigan Dept. of Health; Remarks--LOG, record of materials penetrated on file; AMM, also see table of chemical analyses of ground water.

Location	Owner	Driller	Year drilled	Depth (in ft)	Diam (in inches)	Water level (in feet)	Month and year measured	Yield (in gpm)	Use	Screen openings (inches)	Pump	Water-bearing materials	Altitude (in msl)	Quality of Water				Remarks	
														Iron (as Fe)	Hardness (as CaCO <sub>3</sub> )	Chloride (Cl)	Analyst		
SW SE 1	A. Stogiera			e 80	2				Dom		Piston	Sand	635						
SW SE 1	E. Dyksta		1949	e 80	2				Dom		Jet	Sand	630	0.5	190	30	Field	Specific Conductance 440	
SE SE 2	Sherman Dairy		1929	96	8			60	Ind	.007	Subm	Sand	630	0.6	310	5	Field	Specific Conductance 700	
SE SE 2	Do.		1963	145	4			25	Ind	.007	Subm	Sand	639						
SE SE 2	Do.		1937	36	38			90	Stk	.018	Subm	Gravel	637						
NW SE 3	Mich Fruit Can Co # 1	J. Taylor	1938	42	12	3	6-37	150	Ind	.155	Subm	Sand	580						
NW SE 3	Do.	Layne-Northern	1951	42	12	6	1-38	250	Ind		Subm	Sand	580						
NW SE 3	Do.	Do.	1951	42	12	5	3-51	140	Ind		Subm	Sand	580						
NW SE 3	Do.	H. Geer	1927	1715	10	55		75	Unused		Turb	Gravel	625	1.	240	30	Field	Drilled 7 test wells; LOGS; # 1 gravel packed	
NW NE 10	Aldo Hotel			193	6				Ind		None		625	0.1	37,000	103,700	Field	LOG; Gravel packed	
SW SW 10	Everett Piano Co.	Layne-Northern	1932	186	2	45	5-32		Test		Jet		630	2.5	240	99	MDH	Specific Conductance 680; LOG; gravel packed	
NE SE 11	City of South Haven	R. Sanders	1963	96	2				Dom		Jet	Sand	635	2.5	290	26	MDH	LOG; Anal. on file; Mineral Water	
NE SE 11	J. Gordon		1963	84	2				Dom		Jet	Sand	660	0.5	170	Tr	Field	LOG; Anal. on file; Mineral Water	
NE SE 12	T. Gordon		1953	84	2				Dom		Jet	Sand	660	0.5	170	Tr	Field	LOG; Anal. on file; Mineral Water	
NE SE 12	R. Bailey	Owner		30	1 1/2				Dom	.007	Jet	Sand	630						
NE NE 12	J. Stacimik			80	2				Dom	.007	Jet	Sand	630						
NE NE 12	T. Gency	J. Taylor		50	2				Stk, Dom	.007	Jet	Sand	630						
NE NW 13	A. Sevatus	C. Jones	1943	90	2	30	-63	3	Ind, Dom	.006	Jet	Sand	670						
SW SW 13	I. Stein		1952	100	2				Dom, Sprng		Turb	Sand	685						
NW NW 14	Mich. State Highway	J. Newman	1941	e 100	4				Pub		Jet	Sand	640	0.2	140	20	Field	Specific Conductance 380; for greenhouse	
NE SE 15	Lambert Subdivision	Do.		87	6				Pub		Jet	Sand	630						
NE SE 15	Do.			86	2				Pub		Jet	Sand	630						
SW SW 15	M. Steive		1940	180	2				Dom		Jet	Sand	620						
SW SW 21	C. Jones	H. Starbeck	1962	38	1 1/2				Stk, Dom		Jet	Sand	620	0.2	86	Tr	Field	LOG; Abandoned well	
SE SW 21	E. Cooper		1922	80	1 1/2				Dom		Piston	Sand	620	0.7	241	35	Field	Specific Conductance 200	
SW NE 22	Phillips Gas Station			78	2				Dom			Gravel	645						
SW NE 22	Stevie Bros.			80	2				Stk, Dom			Gravel	645						
SW NE 22	Phillips Gas Station			78	2				Dom	.010		Gravel	645						
SE SW 23	R. Nelson	G. Taylor	1963	132	4	55	8-63	5	Obs	.010	Jet	Sand	640	4.	172	590	Field	LOG; see hydrographs	
NE SE 25	T. Nuoffer	J. Taylor	1960	286	2	30	9-63	40	Dom	.010	Jet	Sand	645	0.7	138	5	Field	LOG	
NE SE 27	J. Jakubs	Thomson	1948	68	2	10	-63	20	Dom, Ind	e .006	Jet	Sand	650	1.0	172	360	Field	Specific Conductance 440	
NW NE 33	Black River Orchids		1955	91	2				Dom		Jet	Sand	645	1.7	120	30	Field	Specific Conductance 1,000	
NW NW 36	J. Mucha	H. Starbeck	1957	143	2				Dom	.010	Jet	Sand	620	0.4	121	370	Field	Have 10 # allow well	
NW NW 36				143	2				Dom		Jet	Sand	680						



**AREA I.** Enough water for domestic, stock, and spraying supplies (up to 10 gpm) generally can be obtained from wells less than 75 feet deep. Water in the well usually is less than 30 feet below land surface. Enough water for irrigation, municipal, or industrial supplies (more than 100 gpm) generally can be obtained from deeper, large-diameter wells (more than 6 inches in diameter and 100 to 200 feet deep).



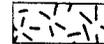
**AREA II.** Enough water for domestic, stock, or spraying supplies generally can be obtained from wells less than 125 feet deep. Depth to water in about half the wells is more than 30 feet below land surface. Large-diameter wells less than 200 feet deep generally yield enough water for irrigation, municipal, and industrial supplies.



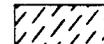
**AREA III.** Enough water for domestic, stock, or spraying supplies generally can be obtained from wells less than 200 feet deep. Wells for irrigation, industrial, or municipal supplies generally would have to be drilled to depths greater than 150 feet, and probably less than half of these would be successful.



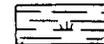
**AREA IV.** Enough water for domestic, stock, and spraying supplies generally can be obtained from wells less than 75 feet deep. Water in the well generally is less than 30 feet below land surface. Exploratory drilling would be needed to determine where large supplies can be obtained.



**AREA V.** It is difficult to obtain enough potable water for domestic supplies in this area. It may be necessary to drill several wells before a successful domestic well is obtained. Chances of obtaining large supplies are poor.



**AREA VI.** Similar to surrounding areas except that thick glacial drift in deep bedrock valleys may yield moderate to large supplies of water (50 to more than 100 gpm). Exploratory drilling would be needed to determine where large supplies are available. Test wells should be drilled to bedrock unless salt water is found at shallower depths. Bedrock may be more than 500 feet deep in places.



Swamps and marshes

FIGURE 44.--MAP OF SOUTH HAVEN TOWNSHIP SHOWING THE GENERAL AVAILABILITY OF GROUND WATER TO WELLS.

Table 24.--Records of selected wells in Waverly Township (T. 2S., R. 14W.)

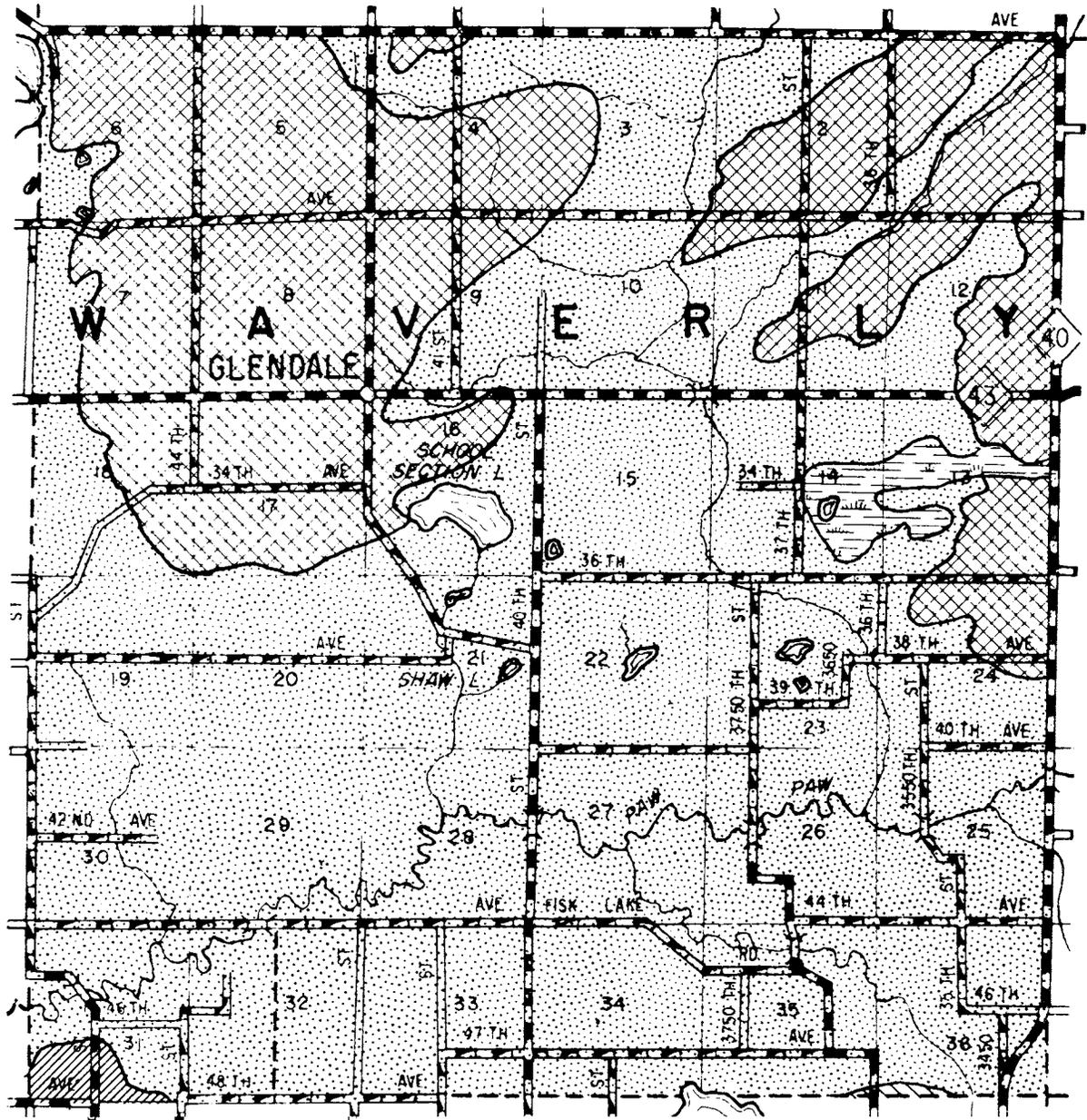
Explanation: e - estimated; Analyst--Field, not accurate to laboratory standards; USGS, U. S. Geological Survey; MDH, Michigan Dept. of Health; Remarks--LOG, record of materials penetrated on file; ANAL, also see table of chemical analyses of ground water.

Location T. R. Sec	Owner	Driller	Year drilled	Depth (in ft)	Diam (in inches)	Water level (in feet)	Month and year measured	Yield (in gpm)	Use	Screen (inches)	Pump	Water bearing materials	Altitude (in msl)	Quality of Water				Remarks	
														Iron (as Fe)	Hardness (as CaCO <sub>3</sub> )	Chloride (Cl)	Analyst		
SW SE 1	V. Johnson	E. Brindley	1953	35	3	30	-53		Dom,Stk	.010	Jet	Sand, gravel	770	tr	240	15	Field		
SW SE 2	R. Leedy	Do.	1955	e 50	3	62	-55	15	Dom		Jet	Sand	770	0.4	240	10	Field		
SW SE 4	T. Kiefer	C. Cooley	1933	120	2				Dom		Jet	Sand	760	0.6	255	10	Field		
NE NE 5	M. Founie	R. Sanders	1945	85	2				Dom,Stk		Piston	Gravel	750	0.1	255	10	Field		
SW NW 7	C. Zantello	J. Newman	1961	184	3				Dom	.010	Jet	Sand	780	0.4	223	7	USGS	ANAL	
SE SE 12	C. Ringel			35	2				Dom		Jet	Sand	770	0	306	50	USGS	ANAL	
SW SE 13	L. Janosek			28	14	29	-62		Dom,Stk		Jet	Sand	700	0.4	240	10	Field		
SW SE 14	M. Anthony	E. Sanders	1946	35	14	80	-46		Dom,Stk		Piston	Gravel	780	0.7	240	15	Field		
NE NW 17	G. McKnight			e 30	2				Dom,Stk	.010	Jet	Gravel	710	1.5	270	10	Field		
NE SW 20	N. Trull			28	14	10	-60		Dom,Stk		Jet	Gravel	700	2.5	275	10	Field		
NE NW 21	L. Chase	O. Owner	1950	54	2	29	-58		Dom,Stk		Jet	Gravel	720	2.5	230	10	Field		
SE SW 22	B. Donora	E. Brindley	1963	46	2	20	-63		Dom,Stk		Jet	Sand	710	0	190	25	Field		
NE NE 22	F. Keater			27	2				Dom,Stk		Piston	Gravel	690	0.6	170	15	Field		
NE NE 25	L. Peacock			18	14	16	-60	e16	Dom		Jet	Gravel	639	0.5	190	20	Field		
SW SE 27	W. Lala	G. Tinker	1953	18	14	4	-59		Dom	.010	Jet	Gravel	695	0	280	20	Field		
SW SE 28	W. Fyckyk			64	2	16	-60		Dom,Stk		Piston	Gravel	680	0.4	214	10	USGS	LOG	
SW NW 30	M. Mills	C. Tinker	1958	65	2	4	-59		Dom	.010	Jet	Sand	690	0.6	180	85	Field	Flow 1/2 gal a minute; ANAL	
SW NW 31	Sermatinger	O. Owner	1959	48	14	7.05	-63		Obs.		Piston	Sand	700	0.6	125	3	USGS	See hydrograph; Drilled to 82'-pulled back	
NE NW 32	W. Fleeman	U.S.G.S.	1963	12	14				Obs.		Piston	Sand					USGS	See USGS anal.	
NE NW 35	Co. Rd. Comm.		1918	35	14				Dom		Piston	Sand							
NE NW 36	E. Willek																		

Table . Records of selected wells in Alma Township (T. 2 S., R. 13 W.)

Explanation: e - estimated; Analyst--Field, not accurate to laboratory standards; USGS, U. S. Geological Survey; MDH, Michigan Dept. of Health; Remarks--LOG, record of materials penetrated on file; ANAL, also see table of chemical analyses of ground water.

Location T. R. Sec	Owner	Driller	Year drilled	Depth (in ft)	Diam (in inches)	Water level (in feet)	Month and year measured	Yield (in gpm)	Use	Screen (inches)	Pump	Water bearing materials	Altitude (in msl)	Quality of Water				Remarks
														Iron (as Fe)	Hardness (as CaCO <sub>3</sub> )	Chloride (Cl)	Analyst	
NW NW 2	Co. Rd. Commission	USGS	1963	23	1 1/2	17.12	4-63		Obs	Drive Pt	Piston	Sand	730	tr	240	5	Field	Used as observation well
SW SE 4	C. Shoughton	W. Goble	1939	e 36	2	24	5-39		Dom	.007	Piston	Gravel	760	2.5	250	5	Field	
SE NE 5	B. Bergren		1963	46	2	3	10-63		Dom	.007	Jet	Sand,gravel	720	0.6	220	10	Field	Through clay at 33'
SW NE 10	P. Penny	O. Owner	1948	28	1 1/2	e 1	-58	55	Dom		Jet	Sand,gravel	760	0.4	200	10	Field	LOG
SW NE 12	C. Vander Molan	P. Sanders	1948	46	2	2.3	-48		Pub	.014	Jet	Sand	770				Field	1 gpm flow; hydrogen sulfide odor reported
SW NE 13	Wolf Lake Fish Hatch.	T. Newman		60	2	Flows			Pub		Jet	Sand,gravel	810	0.8	180	5	Field	Restaurant supply
SE NE 14	Wolf Lake Fish Hatch.	L. Sanders	1962	60	2	Flows	-48		Pub		Jet	Sand,gravel	810	0.8	180	5	Field	
NW NW 15	G. Cox	D. Helle	1962	45	2	7	8-62		Pub		Jet	Sand,gravel	840	0.2	170	5	Field	
NW NE 16	G. Keckum		1962	45	2	40-60	-61		Pub		Piston	Sand,gravel	840	0.4	200	10	Field	
NE NE 18	C. Leonard	E. Brindley	1953	e 32	2				Dom		Jet	Sand,gravel	720	1.0	220	20	Field	
SE NW 21	H. Livingston		1938	72	2				Dom		Jet	Sand,gravel	760	0.8	230	10	Field	
SE NE 22	E. Wersaler	O. Owner	1938	72	2				Dom		Jet	Sand,gravel	722	0.1	220	10	Field	
SE NE 23	E. Wersaler	E. Sanders	1938	72	2				Dom		Jet	Sand,gravel	722	0.1	220	10	Field	
SE NE 24	H. Williams	E. Sanders	1939	86	2	e16	-59		Dom,Stk		Jet	Sand,gravel	810	0.8	180	5	Field	
SE NE 26	M. Yandersala	E. Sanders	1939	86	2				Dom		Jet	Sand,gravel	840	0.2	170	5	Field	
SE SE 27	E. Ritter	E. Sanders	1938	65	2				Dom		Jet	Gravel	840	0.4	200	10	Field	
SE SE 28	L. Howard	E. Sanders	1938	25	2				Dom		Jet	Gravel	830	0.1	200	10	Field	
SE SE 29	V. Miller	E. Sanders	1963	48	2	11	7-63		Dom		Jet	Gravel	760	0.1	180	10	Field	May use for Irrigation
NW NW 29	F. Meyer		1940	22	14	15	-40		Dom,Stk		Jet	Gravel	710	170	200	10	Field	
SW NE 31	F. Churchill	O. Owner	1939	22	14	15	-40		Dom		Jet	Gravel	720	200	200	10	Field	
NW SW 32	M. Fallanus		1939	22	14	16	-59		Dom		Jet	Sand	730	180	180	10	Field	
SE SE 36	H. Bowen	L. Nolan	1963	44	2	e 30	9-63	10	Spray	.005	Jet	Sand	860	200	200	10	Field	Also has well 57' deep



**AREA I.** Enough water for domestic, stock, and spraying supplies (up to 10 gpm) generally can be obtained from wells less than 75 feet deep. Water in the well usually is less than 30 feet below land surface. Enough water for irrigation, municipal, or industrial supplies (more than 100 gpm) generally can be obtained from deeper, large-diameter wells (more than 6 inches in diameter and 100 to 200 feet deep).

**AREA II.** Enough water for domestic, stock, or spraying supplies generally can be obtained from wells less than 125 feet deep. Depth to water in about half the wells is more than 30 feet below land surface. Large-diameter wells less than 200 feet deep generally yield enough water for irrigation, municipal, and industrial supplies.

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Swamps and marshes

FIGURE 45.--MAP OF WAVERLY TOWNSHIP SHOWING THE GENERAL AVAILABILITY OF GROUND WATER TO WELLS.

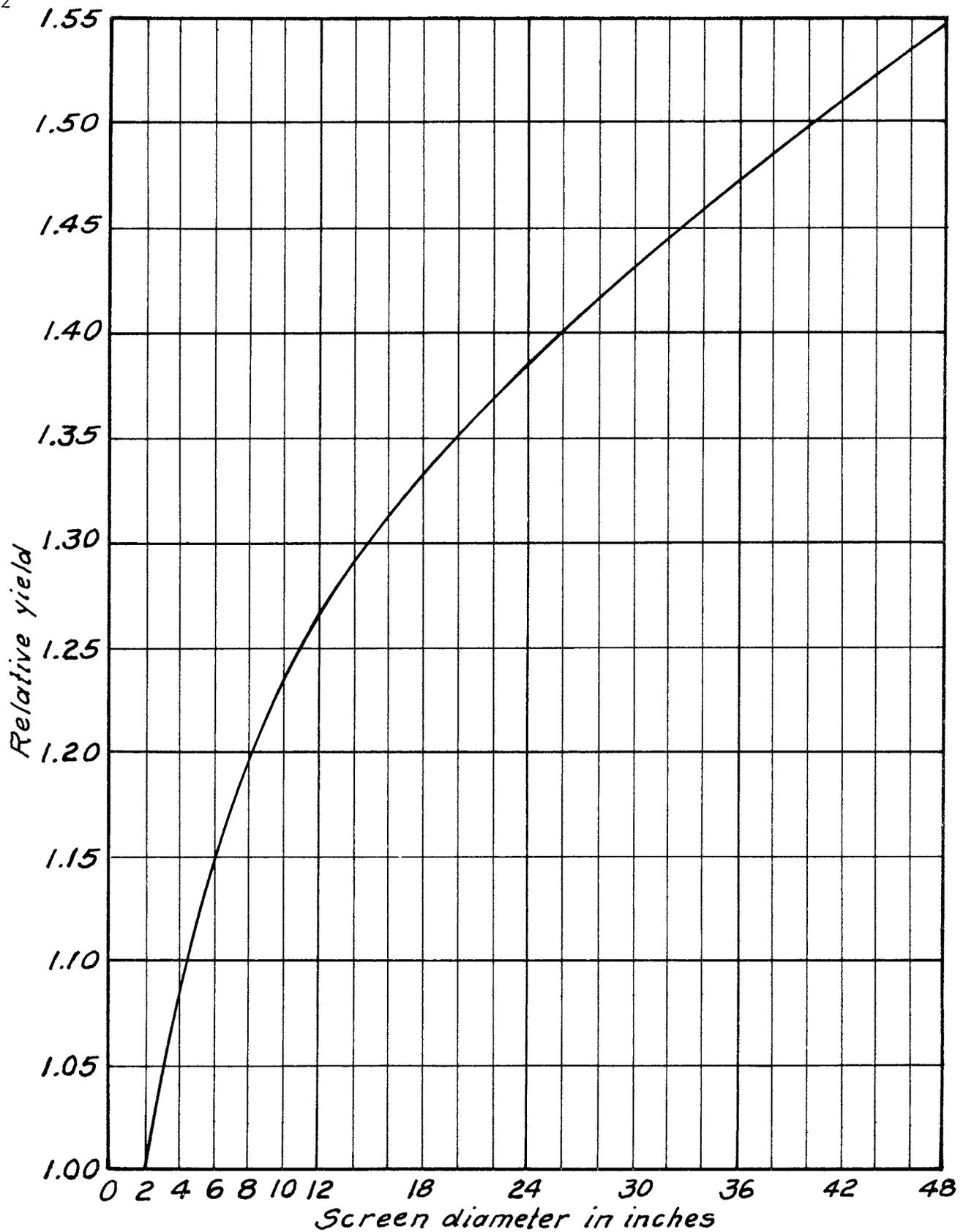


FIGURE 46.--CURVE SHOWING RELATION BETWEEN DIAMETER AND YIELD IN WELLS HAVING SAME DEPTH, SAME SCREENS, AND IN SAME FORMATION (after Theis, C. V., 1953).

The relative yield of a 12-inch and a 24-inch diameter well is 1.27 and 1.38, or an advantage in yield of only 10 percent in the 24-inch well.

## APPENDIX C - RELATION BETWEEN DIAMETER AND YIELD IN WELLS

Assuming identical construction of a well, (in general) increasing only the diameter of a well does not increase the yield proportionally. Figure 46 gives a general comparison of size versus yield. For example, increasing the well diameter from 12 to 24 inches increases yield only about 10%.

Most domestic wells in the county are 10 to 100 feet deep, but municipal, industrial, and irrigation wells are more than 200 feet deep in places. Because almost all water wells in the county are finished in the glacial drift they are equipped with well screens and cased from land surface to the screen.

The screen permits water to enter the well easily through closely-spaced openings. As the screen determines the efficiency of the well to produce water, the size of the screen opening must be selected carefully. The opening should preferably allow about 2/3 of the finer materials around the screen to pass through when the well is developed. This then retains the coarser 1/3 around the screen. If the water-bearing formation consists of various strata of different sizes of sands and gravels, several gradations of screens may need to be installed at the various depths. If artificial gravel packing is used, slot openings should be determined by the gravel size used. Openings to retain 3/4 to 9/10 of the gravel pack should be used. Thus, only a little of the gravel particles will be pumped out when the well is developed by pumping.

The length of screen is determined by the thickness of the water-bearing materials penetrated. For a thin layer the length should be approximately equal to the thickness of the water-bearing formation. For a thick formation the screen should be about equal to 1/2 the total thickness of the sand or gravel for best performance or the screen should be set in the coarsest strata of the material.

The diameter of the screen is usually the same as the well casing. Providing room for the pumping equipment is usually the determining factor in the size of the well casing. The yield or capacity of a well increases with an increase in screen diameter, other factors remaining the same. However, doubling the screen diameter will as a rule only increase the capacity of the well by around 20 percent. However, large-diameter screens may have to be used if the water-bearing formation is thin. If a thick aquifer is available, the yield will be increased more by increased screen length than increased diameter.

Various types of screens are used. Most screens are described as slotted, gauze, or shutter. The relative sizes of the openings in these screens are listed on the following page:

## Relative sizes of openings in well screens

<u>Slot number</u>	<u>Gauze number</u>	<u>Opening size in inches</u>
5	100	.005
6	90	.006
8	70	.008
10	60	.010
12	50	.012
18	40	.018
25	30	.025
35	20	.035
50	12	.050
100	1/10 inch	.100
250	1/4 inch	.250

## Width of shutter openings

No. 1	.205 inches	5	.105 inches
2	.180	6	.080
3	.155	7	.055
4	.130	8	.030

The opening size in inches of the well screens are included in the tables of wells in the appendix.