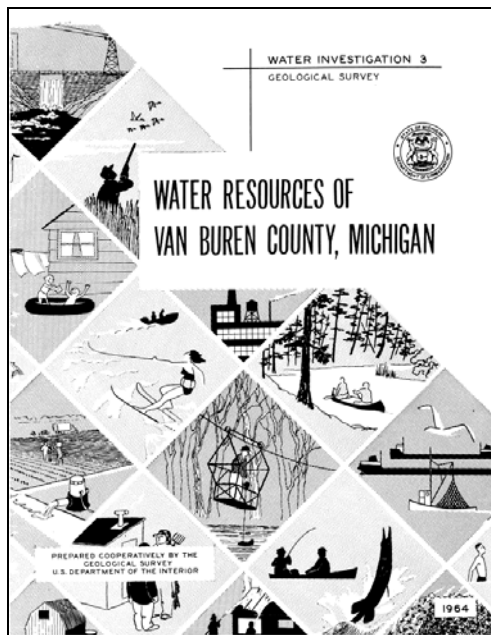




STATE OF MICHIGAN
DEPARTMENT OF CONSERVATION
GEOLOGICAL SURVEY DIVISION

WATER INVESTIGATION 3 WATER RESOURCES OF VAN BUREN COUNTY, MICHIGAN

by
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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.

INTRODUCTION

Why 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).

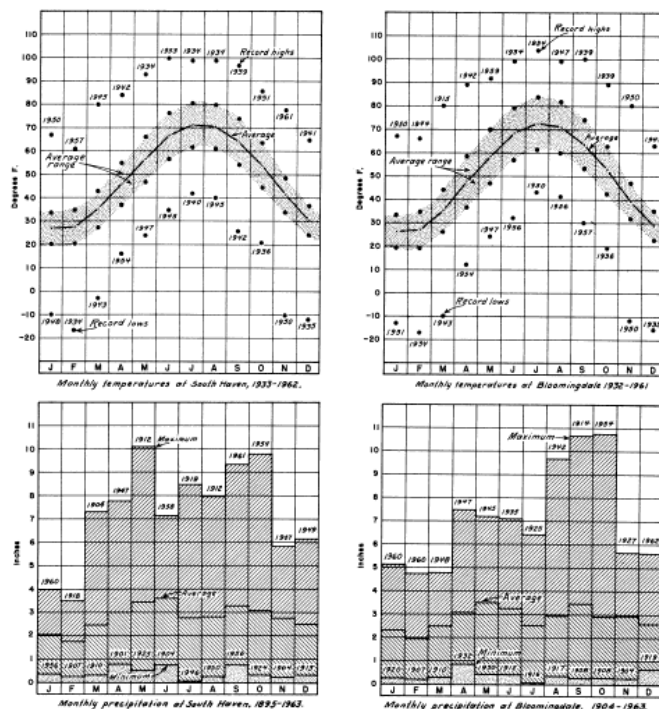


Figure 1. Graphs showing monthly ranges of temperature and precipitation.

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.

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 bottomed 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 ¼ 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.

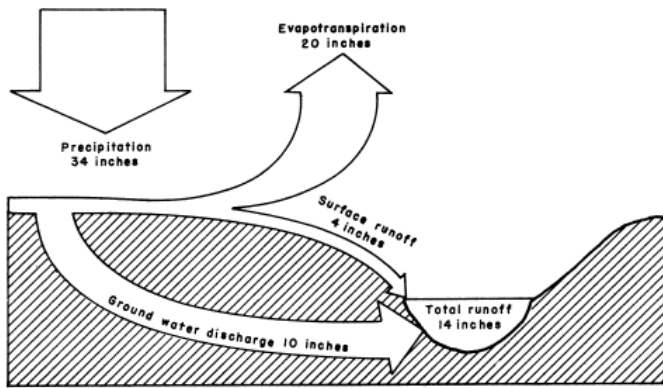


Figure 2. Diagram showing the annual hydrologic cycle in the county.

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 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.

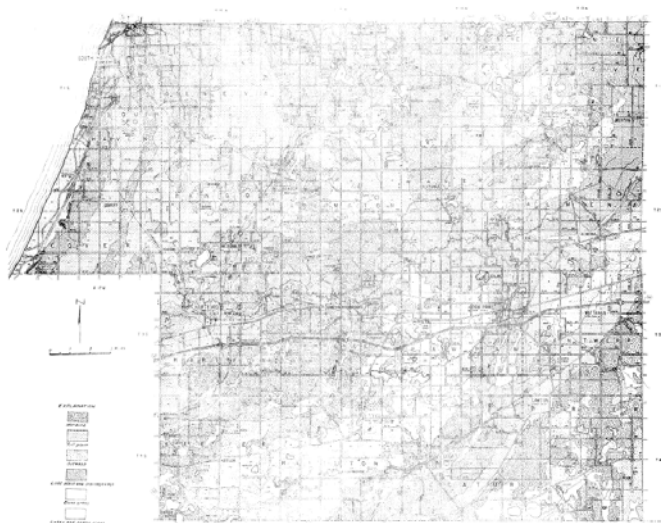


Figure 3. Map showing the surface geology (after Terwilliger).

The outwash materials yield the largest quantities of ground water.

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 drawdown 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 out-wash 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.

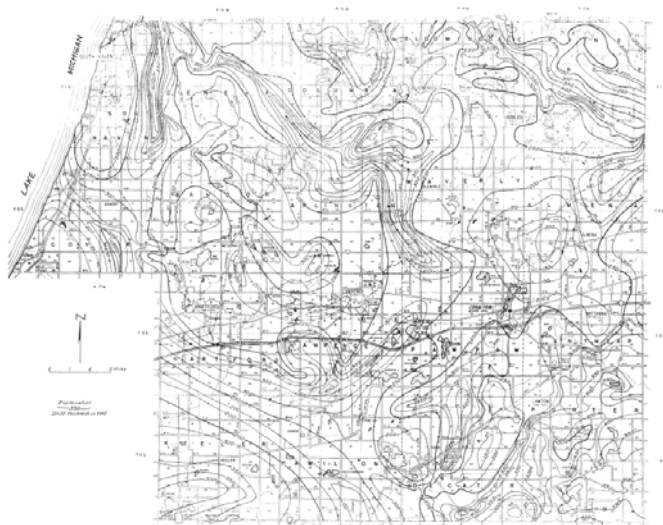


Figure 4. Map showing glacial drift thickness.

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

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 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.

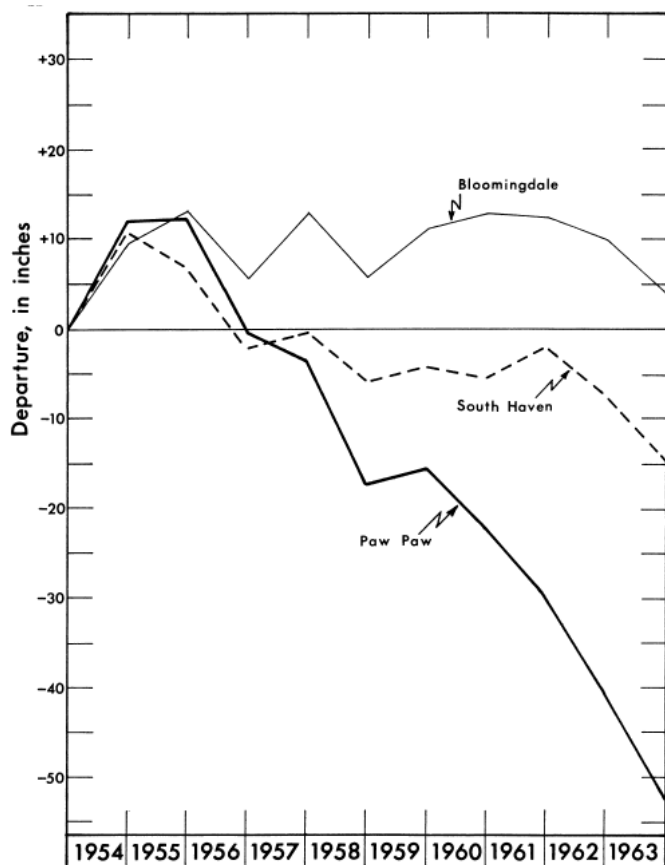


Figure 5. Graph showing cumulative departure of precipitation from long-term average, 1954-63.

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.

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.

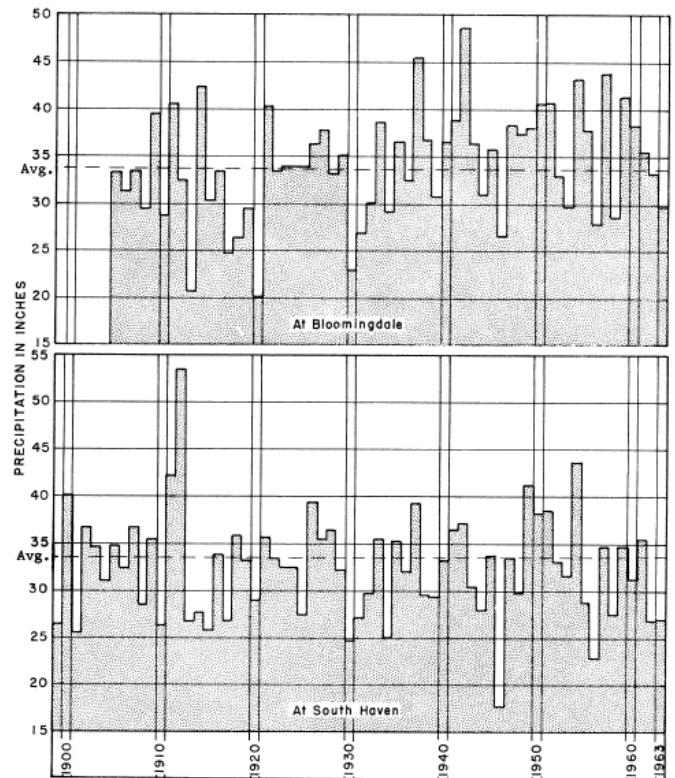


Figure 6. Bar graphs showing annual precipitation, 1899-1963.

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

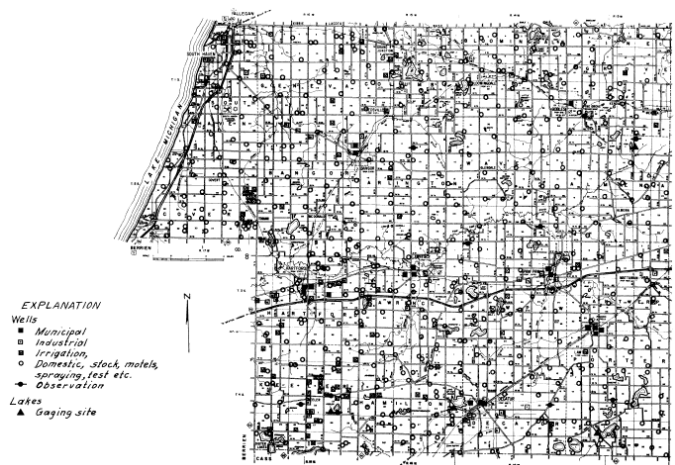


Figure 7. Map showing location of well and lake data collection sites.

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".

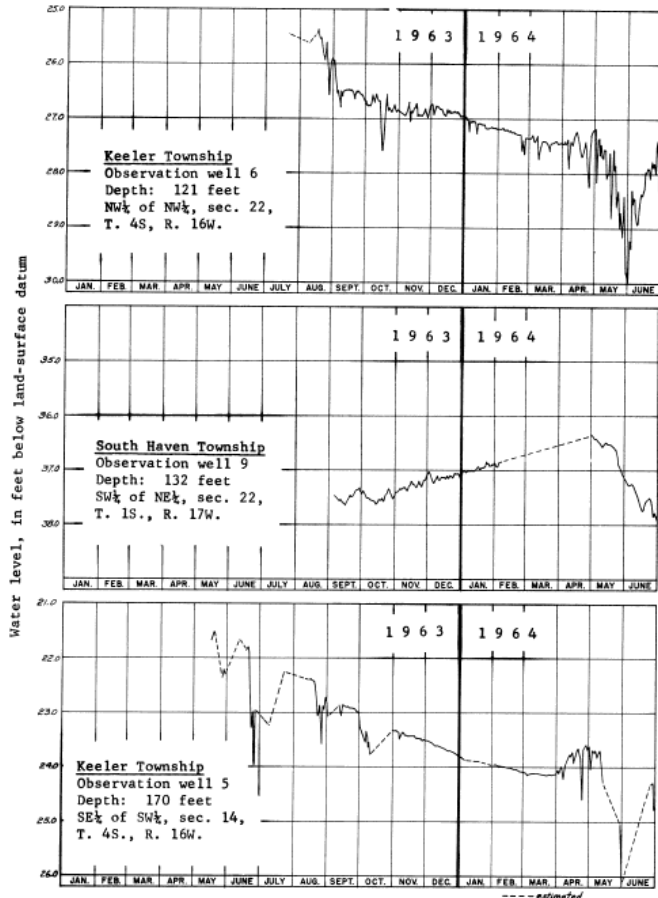


Figure 8. Graphs of water levels showing effects of pumping and barometric pressure, 1963-64.

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

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.

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.

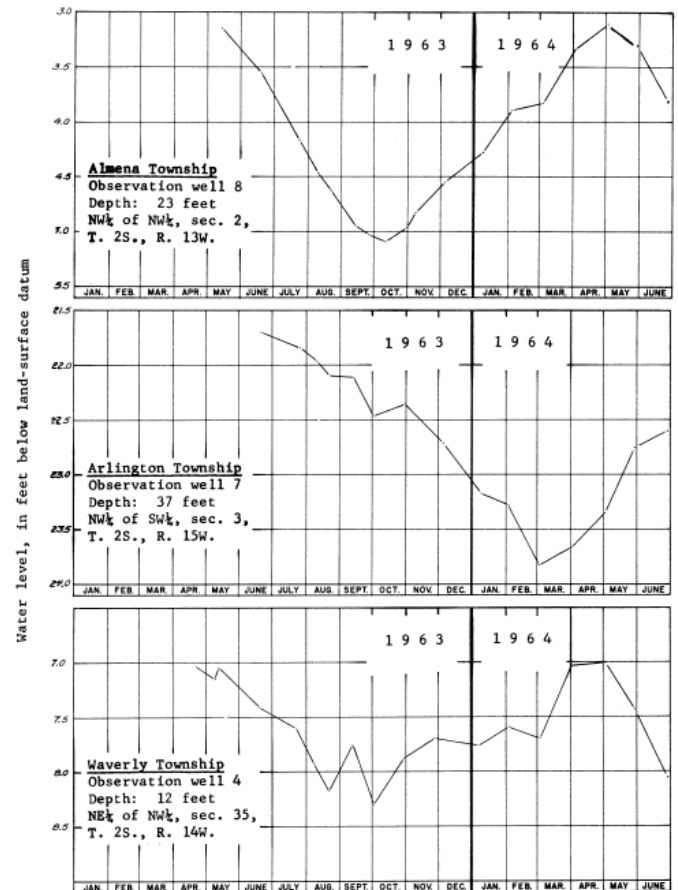


Figure 9. Graphs of water levels showing seasonal trends, 1963-64.

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.

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.

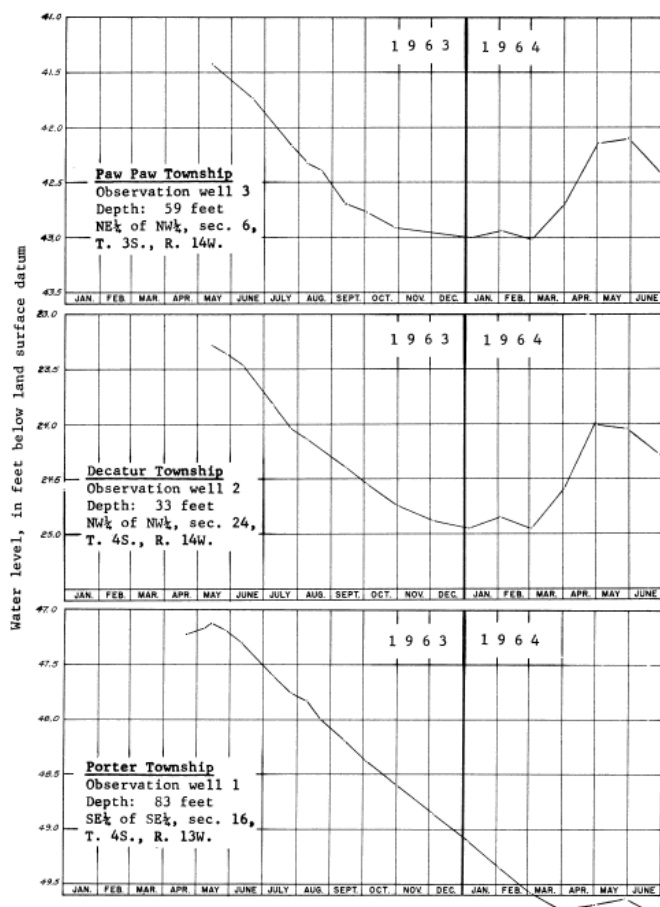


Figure 10. Graphs of water levels showing net declines, 1963-64.

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

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.

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.

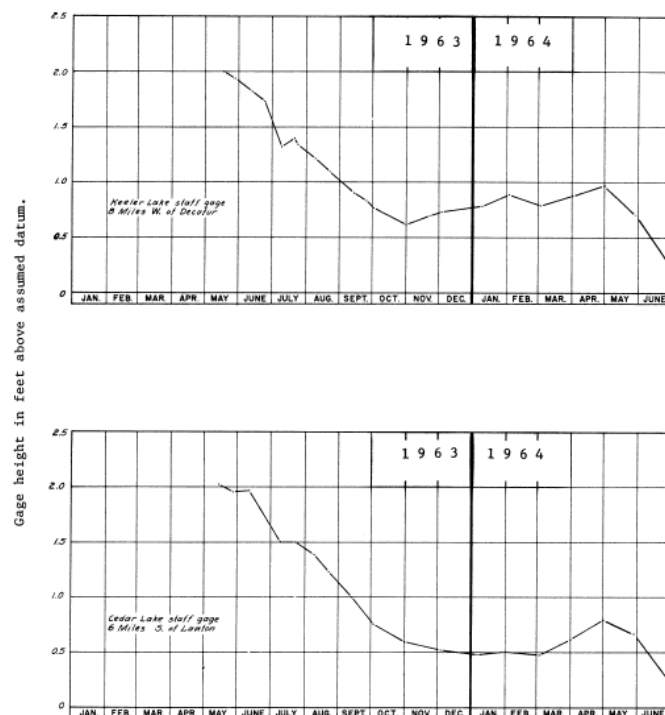


Figure 11. Graphs of water levels of land-locked inland lakes, 1963-64.

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.

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).

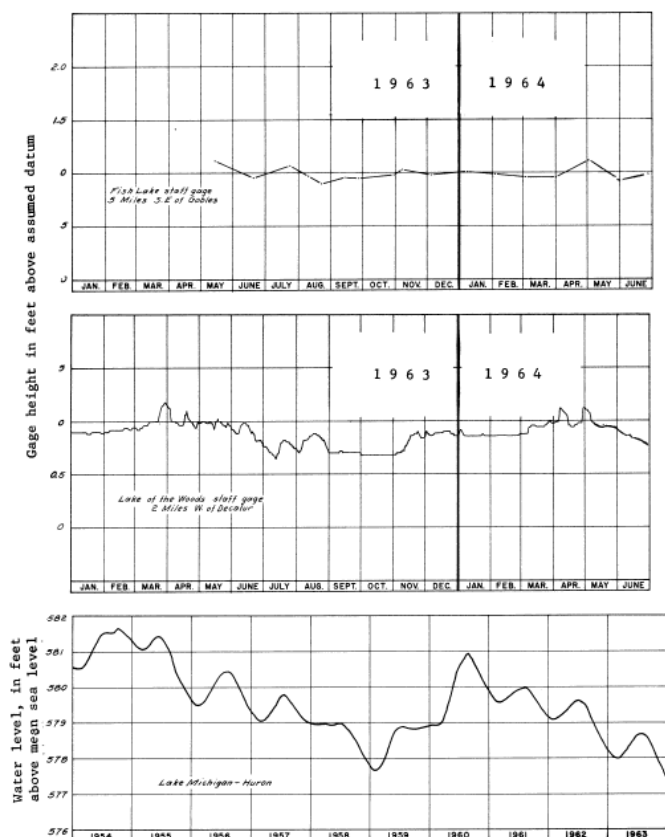


Figure 12. Graphs of water levels of lakes with outlets, 1963-64, and of Lakes Michigan-Huron, 1954-63.

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.

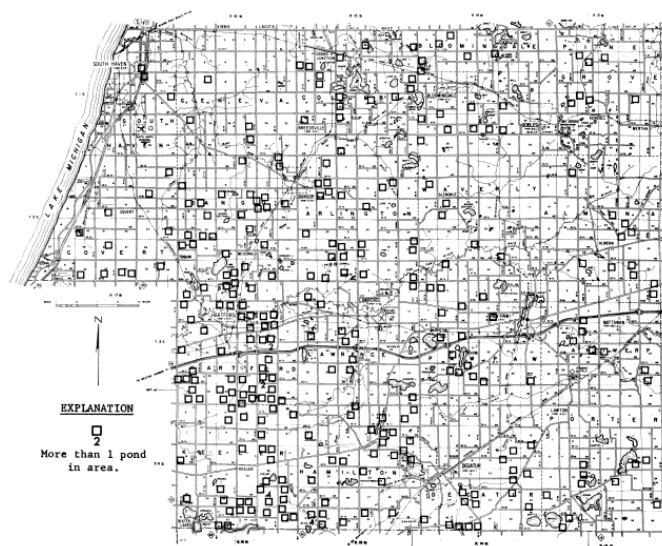


Figure 13. Map showing distribution of farm ponds.

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

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.

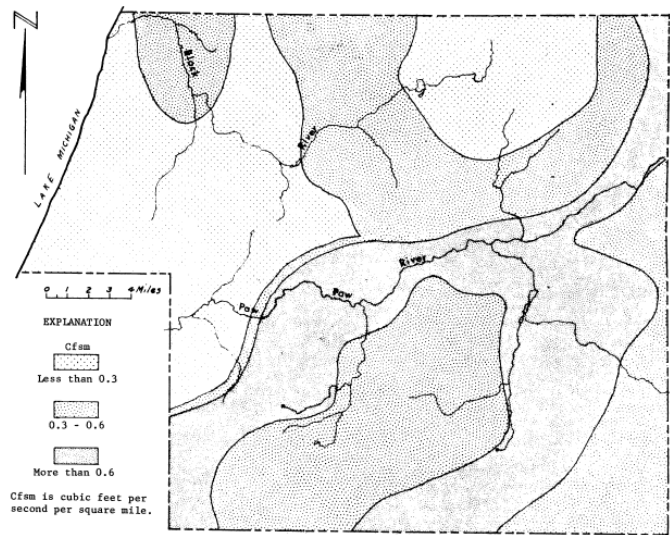


Figure 14. Generalized map of ground-water contribution to dry-weather flow of streams.

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

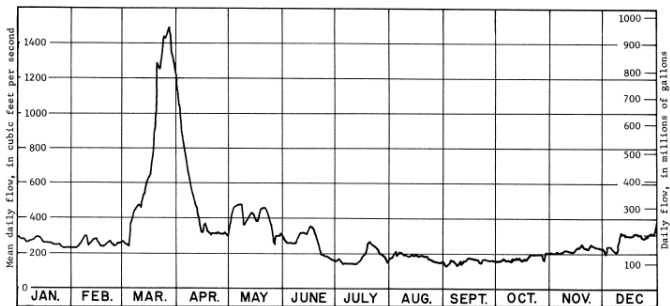


Figure 15. Graph of daily flow of the Paw Paw River at Riverside, 1963.

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 602 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.

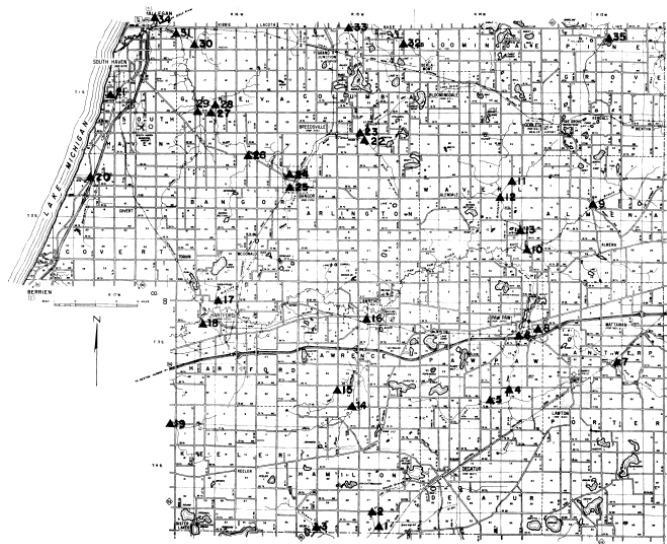


Figure 16. Map showing base-flow measurement sites.

Data for each site numbered is contained in table 3.

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.

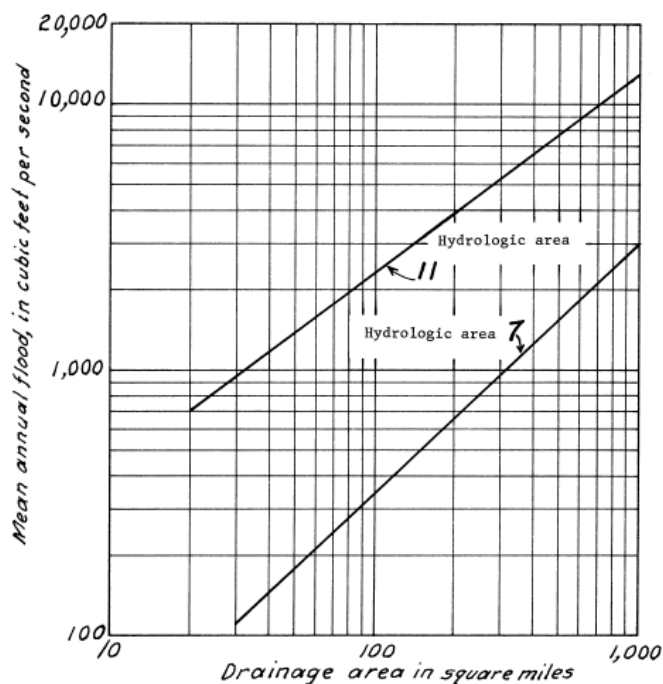


Figure 17. Graph showing variation of mean annual flood with drainage area. (see figure 19 for map of flood regions.)

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

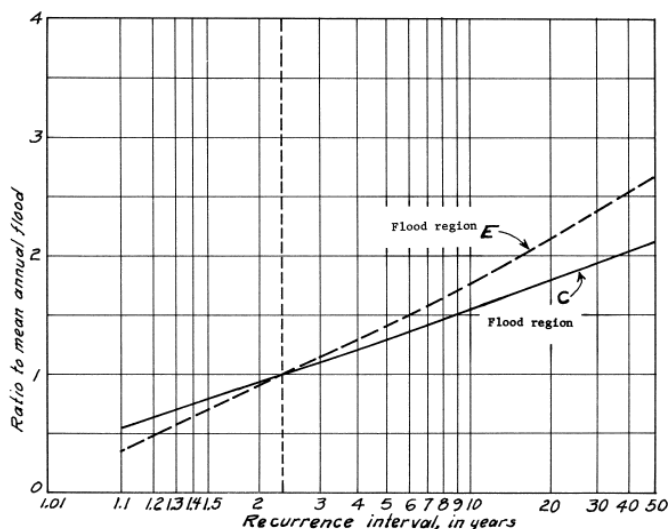


Figure 18. Graph showing frequency of annual floods.

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.

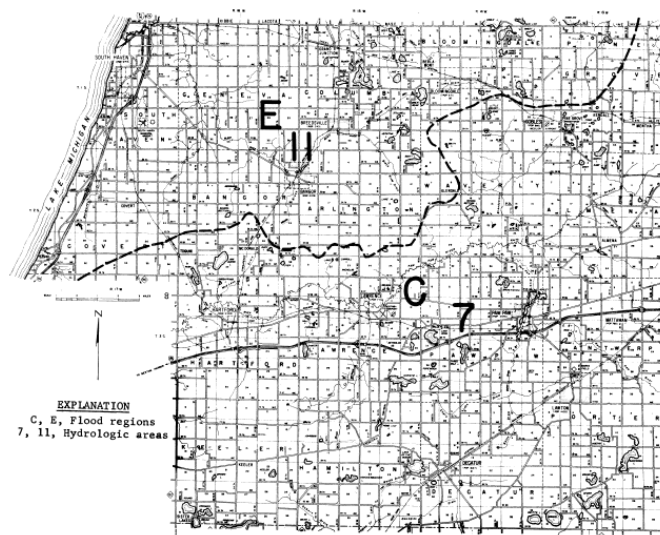


Figure 19. Map showing flood regions and hydrologic areas.

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 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.

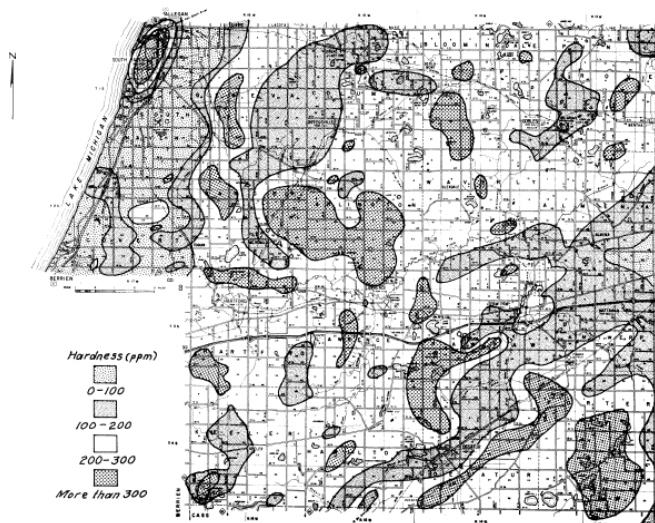


Figure 20. Map showing distribution of hardness in ground water.

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

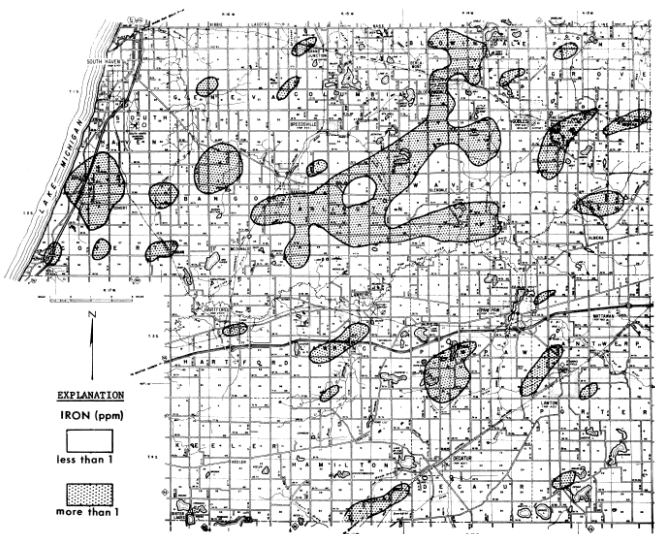


Figure 21. Map showing areas where ground water contains more than 1 part per million of iron.

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.

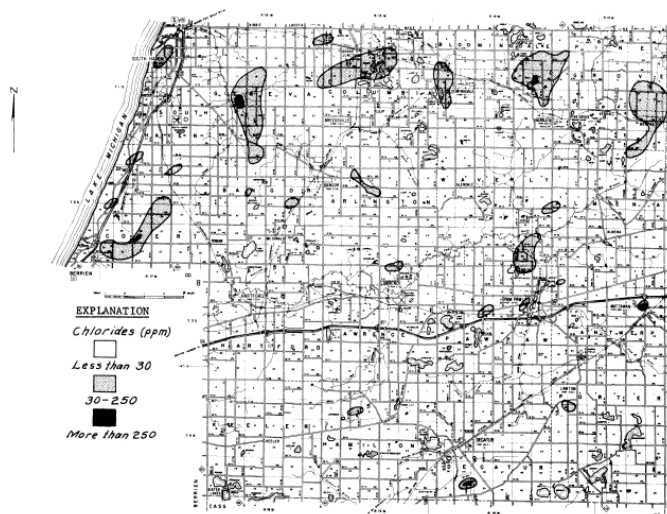


Figure 22. Map showing distribution of chloride in ground water.

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.

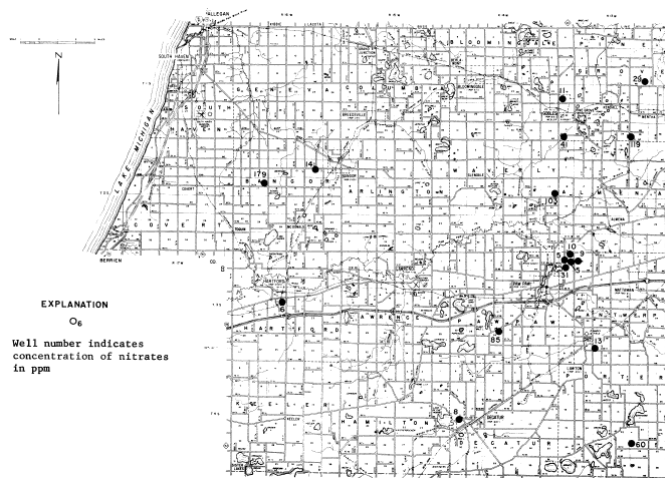


Figure 23. Map showing wells where concentration of nitrates in ground water exceeded 4 ppm.

Some local contamination by nitrates was found. High nitrate in water is a hazard to infants.

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	Minimum	Median
(Results in parts per million, except pH)			
Sulfate (SO ₄)	84	15	35
Chloride (Cl)	215	2	10
Dissolved solids	552	164	260

Hardness (as CaCO ₃)	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).

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 landlocked 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 Water
(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±
Pine Creek	5- 2-63	1.	Neg.
Pine Creek	7- 8-63	Neg.	0.1±
Mill Creek	5- 2-63	5.	Neg.
Bisnett Well	4-18-63	Neg.	Neg.
Cedar Creek	7- 9-63	Neg.	0.1±
Black River Tributary No. 1	7- 9-63	0.3±	0.1±
Brandywine Creek	7- 8-63	Neg.	0.1±

* 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 1¼ 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> <u>daily use</u> <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 multipurpose -- 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 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.



Figure 24. Map showing buried bedrock valleys in the South Haven area. (after Klasner, 1964.)

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

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.

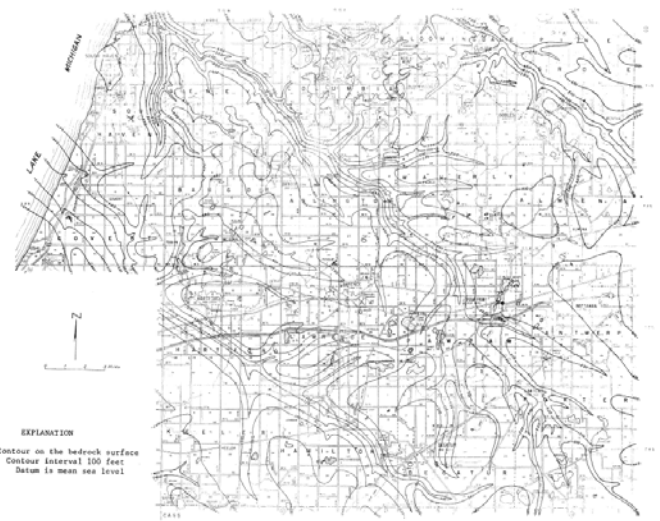


Figure 25. Map showing location of buried bedrock valleys in the county. (after Terwilliger)

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

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.
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.

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.

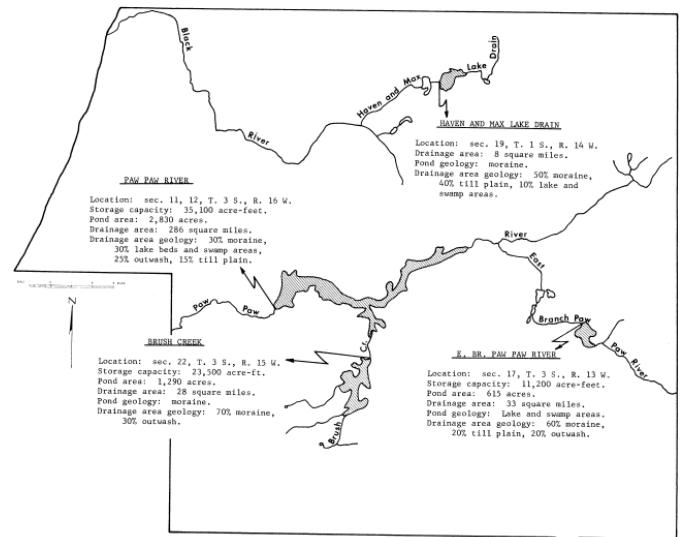


Figure 26. Possible reservoir sites in the county.

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.

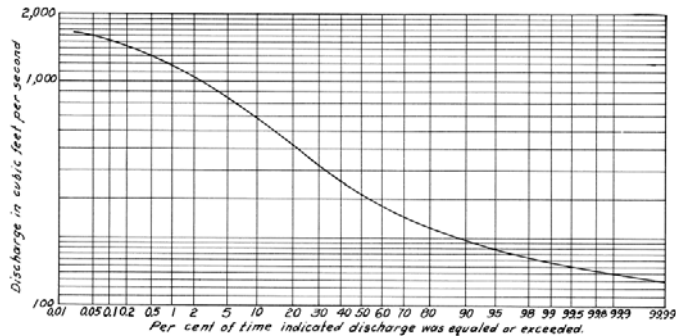


Figure 27. Graph showing duration curve of daily discharges for the Paw Paw River, at Riverside, 1963.

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 15½ 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 5½ 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 sites 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/per 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/per 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/per 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 ¼ of the NE ¼ 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 12-½ 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 ½ 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/per 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/per foot of drawdown. However, in 1962 production had fallen to about 5 gpm/per foot of drawdown. In late 1963 the well screen was acidized and cleaned with phosphate and production came up to 9 gpm/per 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 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.