RC. 183

GEOLOGICAL SURVEY CIRCULAR 183

DEPARTMENT OF THE INTERIOR
March 3, 1849

WATER RESOURCES OF THE DETROIT AREA MICHIGAN

By C. O. Wisler, G. J. Stramel, and L. B. Laird

UNITED STATES DEPARTMENT OF THE INTERIOR
Oscar L. Chapman, Secretary

GEOLOGICAL SURVEY
W. E. Wrather, Director

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Washington, D. C., 1952

Free on application to the Geological Survey, Washington 25, D. C.

PREFACE

This report was prepared in the Water Resources Division of the U. S. Geological Survey under the general supervision of C. G. Paulsen, chief hydraulic engineer, and under the direct supervision of A. D. Ash, district engineer (Surface Water), J. G. Ferris, district engineer (Ground Water), and W. L. Lamar, district chemist (Quality of Water).

The authors are deeply indebted to many persons who generously contributed information and material and otherwise aided in the preparation of this report.

Some of the basic water-resources data in this report have been collected by the U. S. Geological Survey in cooperation with agencies of the State of Michigan. Other data and information have been taken from technical reports and other sources. The data on pollution are from a report on Pollution of boundary waters, by the International Joint Commission (1951). Most of the chemical analyses were made by the U. S. Geological Survey; others were made by the Michigan Department of Health. Data and chemical analyses for the Detroit public water supply were obtained from the Detroit Department of Water Supply.

Records and information were obtained through courtesy and cooperation of the following agencies:
Michigan Water Resources Commission, Milton P. Adams, executive secretary.
Michigan Department of Conservation, G. E. Eddy, director.
Detroit Metropolitan Area Regional Planning Commission, T. Ledyard Blakeman, executive director.
Detroit Department of Water Supply, Laurence G. Lenhardt, general manager.
Detroit Board of Commerce, Harvey Campbell, executive vice president.
State Highway Department, Charles M. Ziegler, commissioner.
Corps of Engineers, Detroit District, John D. Bristor, Colonel, district engineer.
Wayne County Road Commission, Leroy C. Smith, county highway engineer.
Michigan Department of Health, Albert E. Heustis, M. D., commissioner.
Michigan Department of Economic Development, Don C. Weeks, director.
The Detroit Edison Company, Walter T. Cisler, president and general manager.
Detroit Department of Public Works, G. R. Thompson, city engineer.
City of Dearborn, DeWitt M. Coburn, city engineer.
Huron-Clinton Metropolitan Authority, Kenneth L. Hollenbeck, director.
U. S. Department of Commerce, Weather Bureau, A. H. Eichmeier, section director.

Special acknowledgment is due Laurence G. Lenhardt, Detroit Department of Water Supply; T. Ledyard Blakeman, William P. Edmonson, Paul M. Reid, and Robert D. Carpenter of the Detroit Metropolitan Area Regional Planning Commission; John R. Stewart, Detroit Board of Commerce; Louis D. Kirshner, U. S. Lake Survey; John G. Rulison, Michigan Geological Survey; and L. F. Oeming and Norman Billings, Michigan Water Resources Commission.

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WATER RESOURCES OF THE DETROIT AREA, MICHIGAN

ABSTRACT

The water used for all purposes in the Detroit area is obtained from three sources: Lake St. Clair and the Detroit River, their tributary streams and inland lakes, and ground water. During 1950 Lake St. Clair and the Detroit River provided 2,896 million gallons per day (mgd), or 98.3 percent of the total usage of 2,949 mgd. Tributary streams and inland lakes supplied about 10 mgd, or 0.3 percent, and ground water contributed 43 mgd, or 1.4 percent of the total. These rates of use represent the following percentages of the total supply available from esch source: From Lake St. Clair and Detroit River, 2.5 percent; from tributary streams, 1.2 percent; from ground water, probably about 15 percent.

Of the above total usage, about 2,500 mgd was raw water that was drawn directly from the Detroit River by adjacent industrial plants, used for cooling, processing, and other similar purposes, and immediately returned to the river. Of the remaining 449 mgd, 383 mgd was drawn from Lake St. Clair by the Detroit Department of Water Supply and, after purification, was distributed for domestic and commercial use throughout Detroit and its environs; 23 mgd was obtained from additional surface stream supplies; and 43 mgd waa derived from wells.

An abundant supply of raw water may be obtained from the Detroit River. The practicability of its utilization at any particular site is beyond the scope of this report.

The Detroit Department of Water Supply can supply potable water of good quality and in any reasonable quantity anywhere in the area which it serves. Throughout the remainder of the Detroit area the Detroit Department of Water Supply can supply any normal demand, if distribution and storage facilities are provided. In outlying areas where the main source of supply is ground water and tributary streams, the water is hard and contains greater amounts of dissolved solids.

There will be no serious shortage of water supplies at their source in the foreseeable future although local shortages owing to lack of adequate distribution systems will occur.

INTRODUCTION

The purpose of this report is to provide such information on the water resources of the Detroit area as may be useful for initial guidance in the location or expansion of water facilities for defense and nondefense industries and for the municipalities upon which they are dependent. The authors hope that it may also prove of value to municipalities or other agencies that have water supply or pollution problems. For two reasons this report is not expected to provide the final answer to every question which may arise in connection with the water resources of the area. First, sufficient data are not at hand from which it would be possible to determine the amount of ground water that could be obtained in any particular locality. Second, the conditions which affect the availability of a satisfactory supply of water at various places throughout the suburban areas are so rapidly changing, because of the advent of new industries, shifts in population, and extensions in distribution facilities, that information which would be correct today might be very misleading tomorrow. Therefore, only such general basic information pertaining to the water resources of the area as will be of relatively permanent value is included. Special investigation will be required to determine the local availability of any given supply.

Industrial development and new processes increase the demand for water of a particular quality to meet specific uses; these uses may at the same time depreciate the water quality by pollution from industrial activity and concentration of population. In general, Lake St. Clair and the Detroit River are sources of water of good quality. However, in some small areas the water is polluted by industrial wastes and sewage. Therefore, an evaluation of the water quality in the area is also presented in the report.

Description of Area

The area considered in this report has no definite political boundaries. It includes the city of Detroit and those environs into which industry and its allied activities have overflowed. This area includes all of Wayne County, the three eastern tiers of townships in Washtenaw County, and the three southern rows of townships in Oakland and Macomb Counties (see pl. 1).

The Detroit area is one of the most important industrial centers in the entire United States and is the world center of the automobile industry. It has an area of 1,832 sq miles and, according to the 1950 census, has a population of about 3,100,000. In addition to scores of smaller municipalities and rapidly growing communities it includes the following major cities:

City	Population (1950)	City	Population (1950)
Highland Park	46,393	Detroit	1,849,568
Hamtramck	43,355	Dearborn	94,994
Wyandotte	36,846	Pontiac	73,681
Ferndale	29,675	Ann Arbor	48,251
Lincoln Park	29,310	Royal Oak	46,898

The population of selected political subdivisions from 1910 through 1950 is shown in figure 1. This graph shows a continuous growth in population in all areas throughout these 40 yrs. The largest percentage increase has been in the subdivisions outside of Detroit.

The total population and manufacturing employment in the Detroit area is shown in figure 2. The manufacturing employment data and the projections of total population and manufacturing employment to 1970 are estimates based on trends ascertained by the Detroit Metropolitan Area Regional Planning Commission for a slightly different area with nearly the same population.

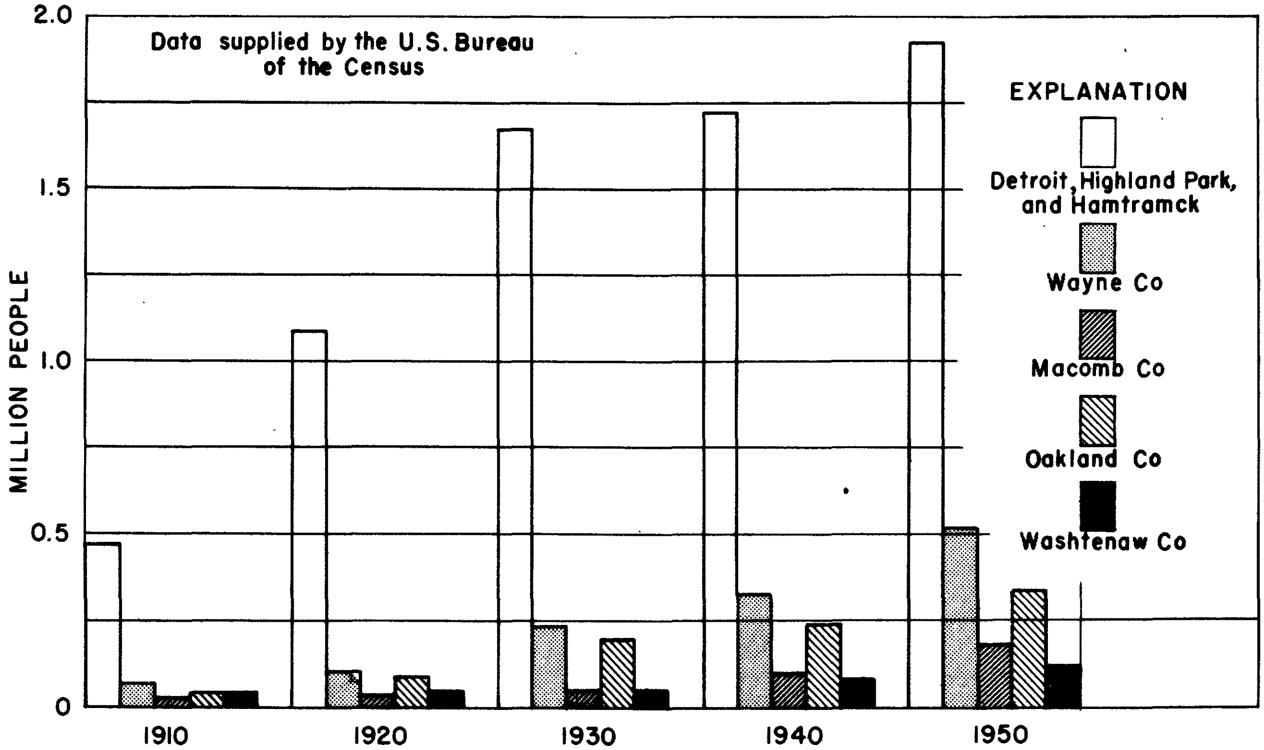


Figure 1.-Growth in population of selected subdivisions of the Detroit area.

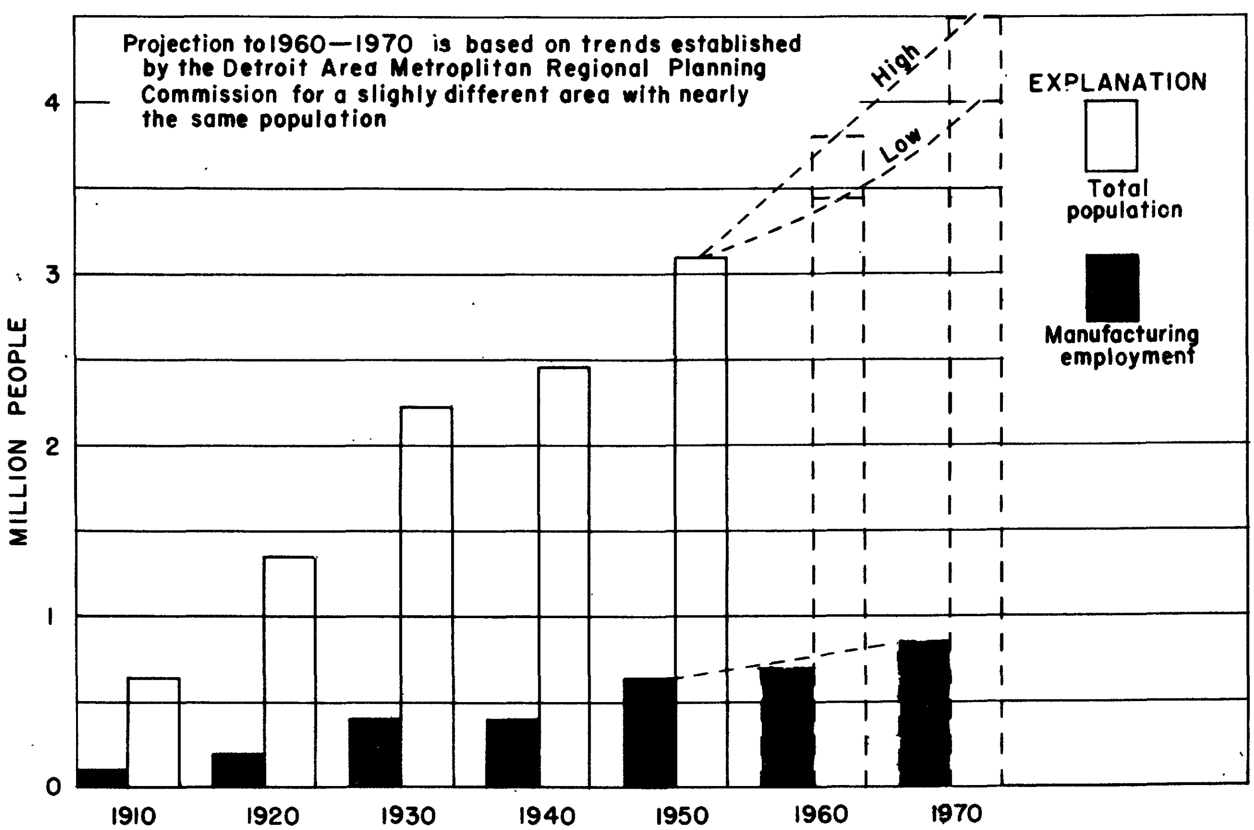


Figure 2.-Growth in population and manufacturing employment in the Detroit area.

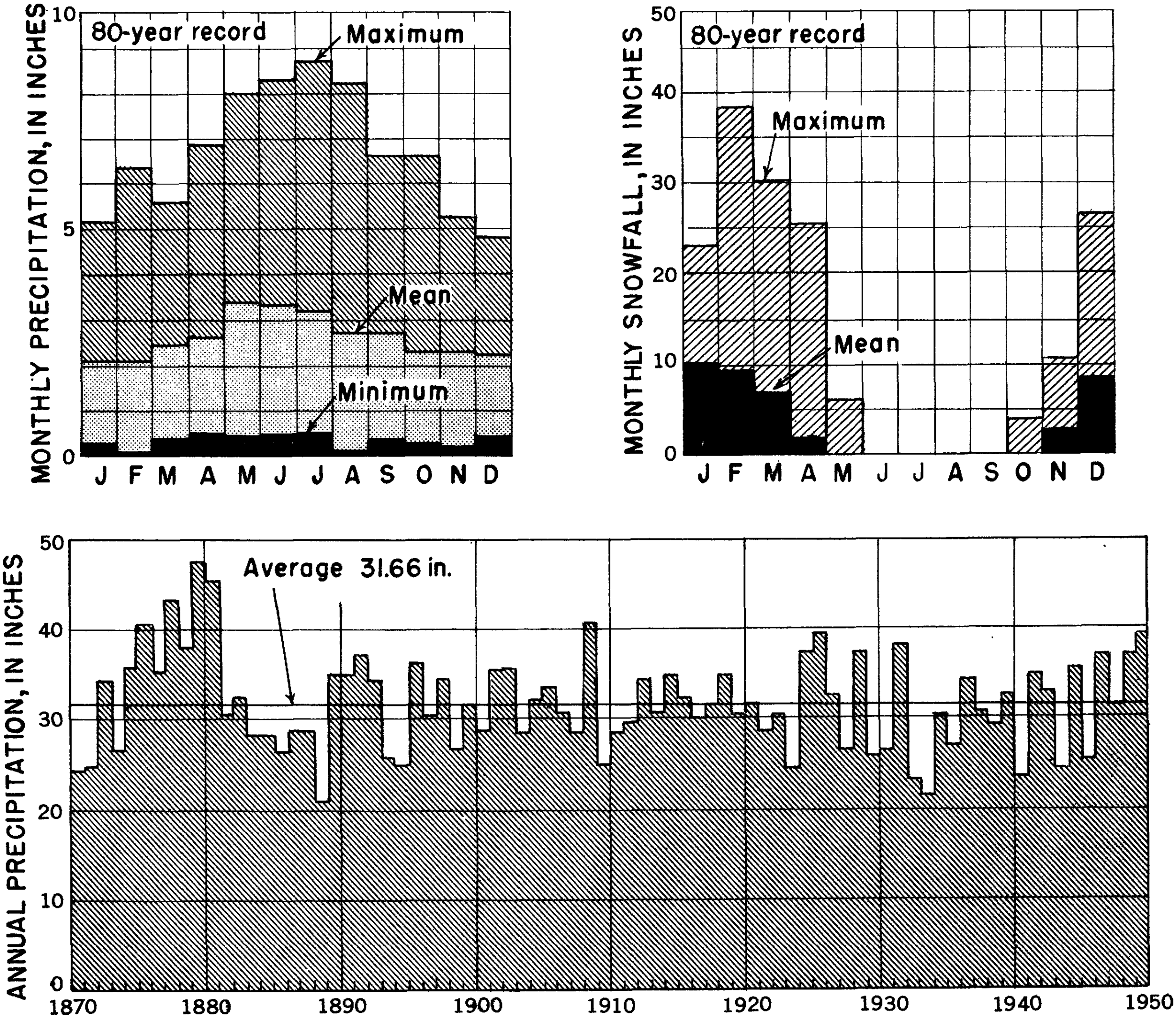


Figure 3.—Precipitation at Detroit.

The area is served by a large network of transportation facilities which include many good railroads, Federal, State, and county highways, water transportation on the Detroit River and Great Lakes, and 17 municipal and private airports. The importance of water transportation is illustrated by the fact that the tonnage transported through the Detroit River is greater than that past any other port in the world. Transportation facilities are shown on plate 1.

Climate

Michigan is situated in the heart of the Great Lakes region and is under the climatic influence of these large bodies of water. Because of the stabilizing influence of the Great Lakes, extreme temperatures occur rather infrequently in the Detroit area. Records from the U. S. Weather Bureau station in Detroit indicate that temperatures of 100 F or more occur about once in every 4 yr, and subzero temperatures occur on only about 4 days each winter. The mean annual temperature at Detroit is about 48 F.

The average date of the last killing frost in spring is April 27, with the latest on record being May 31. The average date of the first killing frost in autumn is October 16, with the earliest on record being September 20. The growing season, which is defined as being the length of period between these dates, has ranged from 122 days to 208 days, the average being 171 days.

The average annual precipitation at Detroit is 31.66 in. (see fig. 3). Variations in monthly precipitation and in snowfall are shown in the same figure. Short and irregular periods of drought occur from time to time, but long periods of drought are rare.

The annual average number of days with dense fog at Detroit is 10, with no more than 2 days of fog in any one month. In general, dense fog occurs in autumn and winter, with none reported in May, June, July, and August.

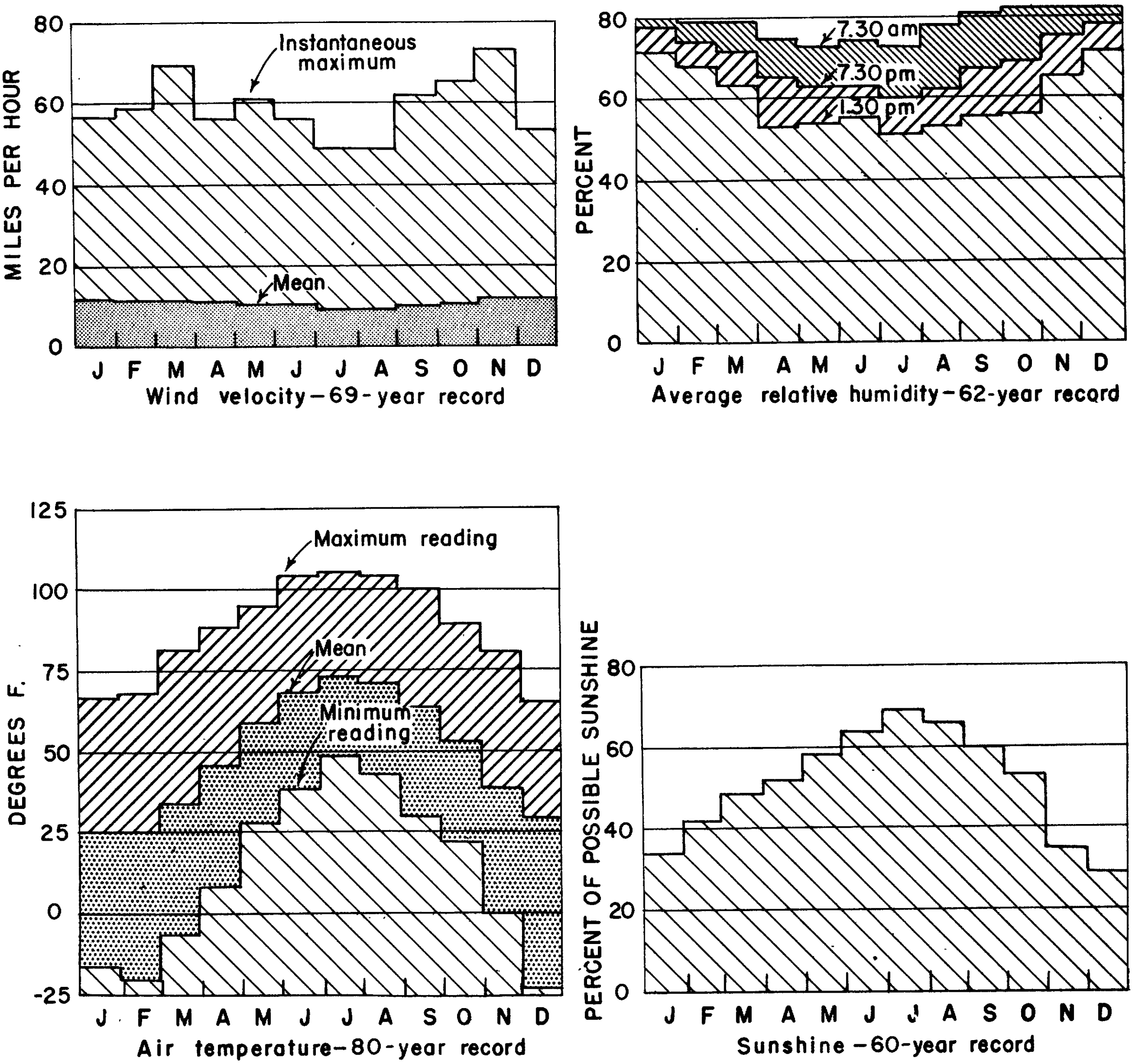


Figure 4.–Climatological data for Detroit.

Winters are marked by cloudiness and frequent snow flurries; summers have plentiful sunshine without extreme heat.

Prevailing winds are from the southwest, with winds from the northwest being next in frequency of occurrence. The average wind velocity is about 14 mph. Violent windstorms are infrequent; tornadoes have struck the Detroit area five times in the past 75 yr.

Figure 4 presents the climatological data on percent of possible sunshine, maximum and mean wind velocity, relative humidity, and temperature.

SOURCES OF WATER

Precipitation is the original source of all our water supplies. At Detroit the average annual precipitation throughout the period of record is 31.66 in. Most of the precipitation soaks into the ground and either drains to wet-weather seeps, percolates down to the water table, or is evaporated or transpired. The water that reaches the water table may slowly flow to a discharge area where it becomes part of the streamflow or is evaporated. The part of the precipitation that does not soak into the ground becomes overland flow and provides the major part of all flood flows.

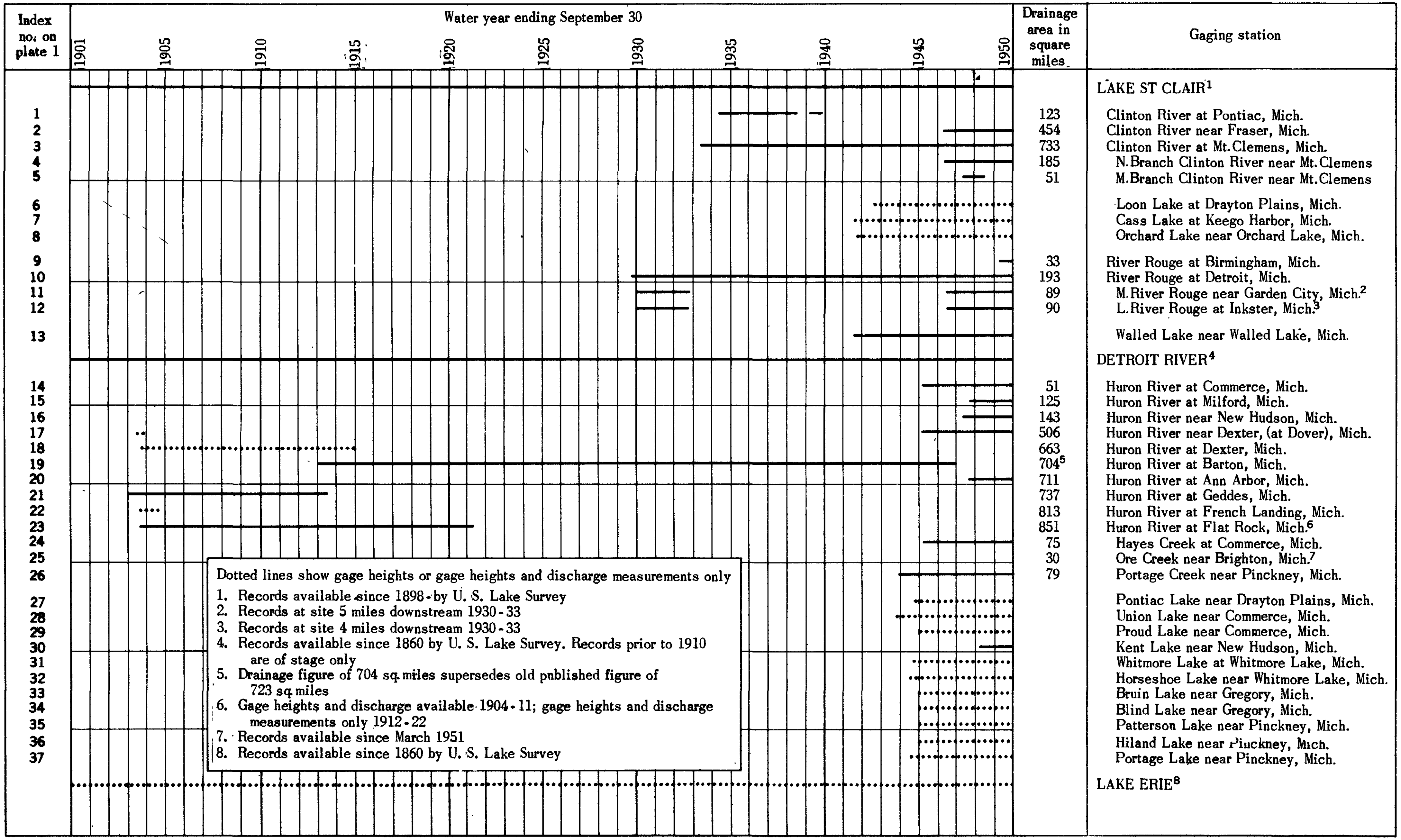


Figure 5. —Duration of records at gaging stations in the Detroit area.

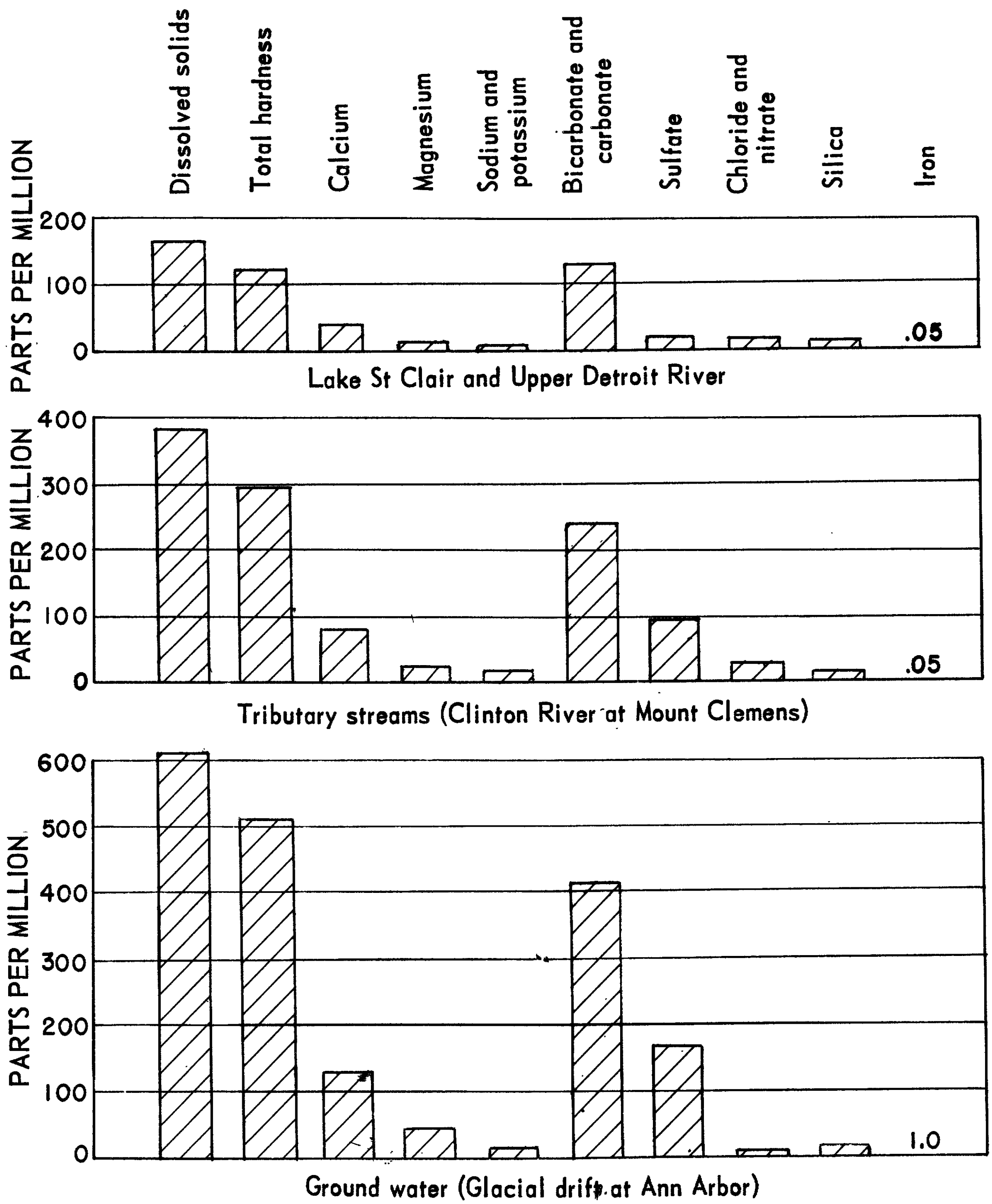


Figure 6.--Comparison of the quality of water from the three major sources in the Detroit area.

A little less than 25 percent of the total precipitation runs off in the streams.

In areas of finely textured and well compacted soils the permeability is low, and as a result the major part of the flood-producing rains flow directly over the surface to the streams and only a small amount enters the ground and later becomes available as ground-water flow to the streams or wells. In general the old lake bed (see pl. 2) in the southeast part of the area has a low permeability, whereas the part northwest of line AA' is permeable to greater depths and is more productive of ground-water supplies.

The direct sources of water supply for the Detroit area are Lake St. Clair, Detroit River, Clinton River, River Rouge, Huron River, inland lakes, and ground water. Of these the first two are by far the most important. Plate 1 shows the streams and lakes of the area. Figure 5 shows the periods in which surface-water data have been collected at the various sites in the Detroit area.

Inland lakes in the Detroit area are of relatively little importance as a source of water supply because all of them are in headwater areas and are fed by small drainage areas. Nor do these lakes, unlike many lakes elsewhere, provide much recharge to ground-water supplies. Thus, the rate of water supply that can be continuously obtained from lakes in this area is generally limited to their outflow rates and the total of these is relatively small.

Although ground water occurs throughout the area, the amount available locally is of very uncertain quantity and quality. The few records available are wholly inadequate to serve as a basis for an appraisal of the ground-water resources of the area.

Lake St. Clair and the upper Detroit River are abundant sources of water of good quality. Their tributary streams contain water that is higher in dissolved solids and harder, and pollution is a factor in some areas. The ground water is generally hard, being principally a calcium and magnesium barcarbonate water, and contains varying amounts of iron and sulfate, and often contains hydrogen sulfide or methane gas. Figure 6 shows the chemical character of these three major sources of water.

SURFACE WATER

The chemical quality of surface waters varies with precipitation, soil, vegetation, and water usage in the drainage basin. However, Lake St. Clair and most of the Detroit River are abundant sources of water of relatively unvarying good quality but with noticeable pollution in the lower reach of the Detroit River. Other streams in the area are higher in mineral content and have varying degrees of pollution.

Inasmuch as surface waters provide the major part of the water supply for this area, each of these several sources will be briefly discussed.

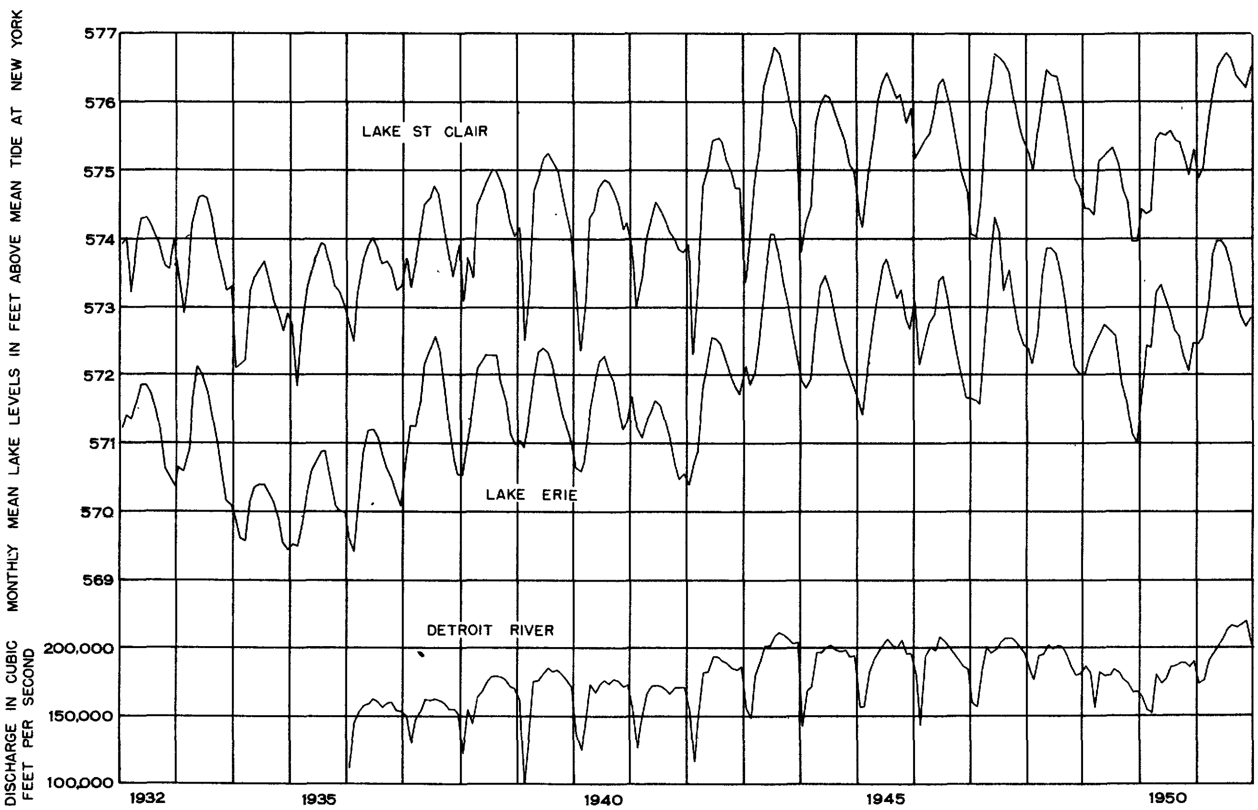


Figure 7. -Monthly mean water levels of Lake St. Clair and Lake Erie, and monthly discharge of the Detroit River.

Table 1. -Chemical quality of Detroit River water

[From the Annual summary of mineral analyses, monthly water samples, July 1, 1949, through June 30, 1951, Department of Water Supply, Detroit, Mich.]

(Chemical results in parts per million)

	July 1949 through June 1950			July 1950 through June 1951		
	Maximum	Minimum	Average	Maximum	Minimum	Average
Temperature (°F)	74	33	50	72	36	51
ph value	8.2	8.0	8.1	8.4	8.0	8.1
Silica (SiO_2)	3.1	.4	1.7	1.8	.3	.9
Iron (Fe)	.34	.01	.11	.14	.04	.08
Aluminum (Al)	.9	.1	.4	.8	.2	.4
Calcium (Ca)	27	26	26	27	26	27
Magnesium (Mg)	8	7	8	8	7	8
Sodium (Na)	4	1	2	5	1	2
Carbonate (CO_3)	1	1	1	2	1	1
Bicarbonate (HCO_3)	84	79	81	83	79	81
Sulfate (SO_4)	15	11	13	15	12	13
Chloride (Cl)	8	6	7	9	7	8
Nitrate (NO_3)	.30	.18	.22	.40	.17	.26
Total solids	140	114	129	135	126	130
Hardness (as $CaCO_3$):						
Total	100	95	98	100	95	100
Noncarbonate	20	12	16	19	12	18
Total Alkalinity	85	80	82	84	80	82
Oxygen Consumed	2.1	.8	1.5	1.8	1.2	1.6
Dissolved Oxygen	13.4	7.6	10.7	13.6	8.1	11.0
Turbidity	40	4	15	35	7	18

Lake St. Clair and Detroit River

Lake St. Clair at its normal stage of 574.7 ft above mean sea level has an area of 430 sq miles. It is shallow, has low marshy shores, a gently sloping bed, and a maximum depth of 25 ft. It has a dredged navigation channel 25 ft deep and 700 to 800 ft wide, extending from the mouth of the St. Clair River to the head of the Detroit River. Its stage, unaffected by winds, varies from a minimum of about 571.5 ft to a maximum of about 578.0 ft with an average annual variation of about 1.6 ft. The minimum stage usually occurs in January or February and the maximum in July. Figure 7 shows the monthly mean water levels since 1932.

The Detroit River is the outlet for Lake St. Clair. It flows southwestward about 30 miles and empties into Lake Erie. It normally has a fall of about 2.8 ft throughout its length and an average width of 2,500 ft. It contains a number of islands, the most important of which are Belle Isle, near the upper end, and Fighting Island and Grosse Isle, near the lower end. The Detroit River is a natural harbor and has many docking facilities throughout most of its length.

Its flow is exceptionally steady. Because of the tremendous storage provided by Lakes Superior, Huron, and Michigan, it is excelled in this respect by few if any rivers in the world. A hydrograph of the Detroit River since January 1936 is shown in figure 7. Stage records have been kept since 1860. Discharge records since 1910 exist, but those obtained since 1936 are more reliable than preceding ones.

Figure 7 is based upon mean monthly discharges. For most rivers average monthly measurements do not reveal the great fluctuations that ordinarily occur from day to day. However, available records of daily discharge of the Detroit River indicate that for any month under normal conditions the extreme high or low daily discharges do not depart by more than about 5 percent from the average monthly discharge. Consequently, a hydrograph of the Detroit River based upon monthly averages may for practical purposes be considered as representing the actual variations in flow.

The average discharge of the Detroit River for the 16-yr period, January 1936 to December 1951, was about 177,000 cfs (114,000 mgd). The monthly averages range from 100,000 cubic feet per second (cfs), or 65,000 mgd to 219,000 cfs (142,000 mgd). These extremes were probably affected by winds or sudden changes in barometric pressure.

In general, the higher the stage of a river, the greater its flow. However, because of the small differences in level between Lake St. Clair and Lake Erie, the relationship between stage and discharge for this river is not easily determined. It is affected by several factors: first, by dredging operations that are carried on from time to time for the improvement of navigation through certain reaches of the river; second, by differences in level between Lake Erie and Lake St. Clair which are caused by varying rates of inflow from their respective drainage areas; and third, by winds or changes in barometric pressure usually occurring over a part of Lake Erie and causing abnormally high or low elevations of water level at the outlet of the Detroit River.

Table 2.–Summary of analyses showing pollution of Lake St. Clair and Detroit River at public water supply intakes

[From Report of the International Joint Commission, United States and Canada, on the Pollution of Boundary Waters, 1951]

Municipality		Coliforms (mpn[1] per 100 ml)	Chloride (ppm)	Phenols (ppm)	Dissolved oxygen (ppm)	BOD[2] 5-day (ppm)	pH	Alkalinity (ppm)
Mt. Clemens	Median	930	...	...	...	...	...	...
	Average	...	9.4	0.008	11.1	1.4	7.6	94
	Maximum	18,000	32	.264	13.3	13.0	8.7	130
	Minimum	32	5.1	.000	6.2	.1	6.6	46
	Number of samples	183	72	97	58	62	72	72
Grosse Pte. Farms	Median	92	...	...	...	...	...	...
	Average	...	8.0	.002	11.3	1.8	7.[illegible]	85
	Maximum	16,000	16	.022	13.8	2.6	8.[illegible]	99
	Minimum	1.9	5.0	.000	6.0	.3	7.[illegible]	76
	Number of samples	144	34	49	28	28	35	36
Detroit	Median	4.5	...	...	...	...	...	...
	Average	...	7.3	.001	11.0	.63	7.6	83
	Maximum	2,400	27	.030	13.8	2.2	8.5	100
	Minimum	0.63	4.7	.000	5.8	0	7.3	74
	Number of samples	441	73	98	76	77	73	73
Wyandotte	Median	15,000	...	...	...	...	...	...
	Average	...	19	.006	10.9	2.0	7.6	82
	Maximum	163,000	90	.050	13.14	8.0	8.0	100
	Minimum	4,300	5.9	.000	6.1	0	7.3	80
	Number of samples	220	55	75	58	62	47	47
Trenton	Median	15,000	...	...	...	...	...	...
	Average	...	69	.033	12.0	6.6	8.3	93
	Maximum	46,000	96	.076	13.5	9.1	9.2	110
	Minimum	910	26	.000	9.2	2.2	7.5	84
	Number of samples	35	12	12	11	12	12	12

1/ Most probable number.
2/ Biochemical oxygen demand.

Although the third factor has some effect most of the time, it is seldom that the effect is large. When it is, winds or changes in barometric pressure cause the water to pile up at the western end of Lake Erie to an elevation above that of Lake St. Clair and, as a result, the flow of the Detroit River may actually reverse its direction. At other times the water level at the lower end of the river may suddenly drop, causing a great increase in discharge for any particular stage. As an illustration, on January 31, 1914 the elevation of the water surface at Amherstburg, Ontario, dropped more than 6 ft in 10 hr. This phenomenon resulted from a severe storm over Lake Erie. Although these sudden changes are infrequent, they should nevertheless be considered in constructing an intake if it is important that the water supply be continuous.

The water from Lake St. Clair and the upper Detroit River is of better quality than water from any other major source in the Detroit area. It is moderately low in dissolved solids and very low in suspended solids. A 25-yr record shows an average hardness of 97 parts per million (ppm). The mineral content of the water does not vary appreciably and the water is suitable for many industrial purposes with little or no treatment (see table 1). The water in the lower Detroit River is so polluted from industrial wastes and sewage that it is undesirable for some purposes.

Varying degrees of pollution are found in Lake St. Clair and the Detroit River (International Joint Commission, 1951). The pollution in Lake St. Clair was relatively low, the median coliform count ranging from 2 to 2,400 mpn per 100 ml (most probable number per 100 milliliters). The greatest pollution was near the mouth of the Clinton River and the least in the central area of the lake. Table 2 shows the amount and variation of pollution as determined at various water-supply intakes from Mount Clemens to Trenton. At Mount Clemens the median coliform count was 930 mpn per 100 ml. This is due to the discharge from the Clinton River greatly increasing the pollution of the lake in this area. The pollution decreased toward the outlet of the lake beyond which it again increases owing to the discharge of sewage and industrial wastes into the Detroit River. The River Rouge, which

Table 3. -Chemical quality of water from selected streams in the Detroit area

[Chemical results in parts per million]

	Detroit River at Belle Isle	Detroit River at Wyandotte	Clinton River at Mt. Clemons	Clinton River near Fraser	North Branch Clinton River near Mt. Clemens	River Rouge at Detroit	Lower River Rouge at Inkster	Middle River Rouge near Garden City	Huron River at Flat Rock	Huron River at Ann Arbor
Sample no. a/	1	2	3	4	5	6	7	8	9	10
Date of collection	June 1951	Aug. 17, 1951	Nov. 16, 1951	Nov. 16, 1951	Nov. 16, 1951	Nov. 15, 1951	Nov. 15, 1951	Nov. 15, 1951	Nov. 15, 1951	Nov. 15, 1951
Discharge...cfs	...	...	928	512	288	312	207	234	1,450	354
ph value	8.0	8.3	7.9	7.5	8.2	8.0	8.0	8.0	8.0	7.8
Specific conductance micromhos at 25°C	...	218	463	519	439	498	456	562	442	429
Silica (SiO_2)	1.8	2.9	7.8	9.4	8.3	8.2	7.3	7.9	3.7	6.6
Iron (Fe)	.08	.02	.05	.05	.05	.04	.05	.05	.03	.02
Calcium (Ca)	27	27	62	66	61	70	65	80	60	61
Magnesium (Mg)	7	7	18	20	18	18	14	21	19	20
Sodium (Na)	1	6.7	9.0	19	7.4	13	10	14	10	5.6
Potassium (K)	...	2.2	4.1	3.9	4.2	3.8	4.1	3.8	2.4	1.1
Carbonate (CO_3)	1	6	...	...	...	...	...	...	...	...
Bicarbonate (HCO_3)	74	100	192	232	186	212	156	250	230	244
Sulfate (SO_4)	13	14	68	58	66	62	76	66	45	32
Chloride (Cl)	1	9	16	22	14	24	24	30	12	6.8
Fluoride (F)	...	.1	.5	.4	.4	.4	.4	.4	.2	.4
Nitrate (NO_3)	.2	.6	5.4	6.6	4.7	4.6	4.7	2.4	2.9	1.5
Dissolved solids	129	120	302	331	292	321	298	361	278	263
Hardness as $CaCO_3$:										
Total	97	98	232	248	228	250	218	286	228	234
Noncarbonate	16	15	71	57	74	75	92	81	39	34

a/ Numbers refer to sample on figure 11.

receives the discharge from the Detroit sewage treatment plant, increases appreciably the pollution in the Detroit River. At Wyandotte and Trenton the median coliform count was 15,000 mpn per 100 ml. The bacterial count increased 300 times as the water passed through the Detroit River, most of this increase occurring in the lower reach.

Industrial wastes are the chief source of chemical pollution and are objectionable because they contain oils, toxic substances, or taste- and odor-producing compounds. There is little difference in the chemical quality of the lake and the section of the Detroit River above Wyandotte (see table 3). However, below Wyandotte industrial pollution is much more pronounced. Monguagon Creek, a source of considerable industrial wastes, had a mean phenol content of 3.49 ppm and a chloride content of 300 ppm. The daily discharge of some of the principal industrial wastes is given in table 4.

The Department of Water Supply of Detroit has maintained temperature records of the water at the Belle Isle intake for over 25 yr. These records show an average temperature of 50 F with a maximum of 76 F and a minimum of 33 F. The water temperature varies with the seasons, reaching a maximum in July and August and falling to a minimum in January and February.

Tributary Streams

The Clinton River, River Rouge, and Huron River are the only tributary streams of importance in the area. Of these three, the Huron River has the most uniform flow and the River Rouge has the least uniform.

Clinton River

The Clinton River rises in central Oakland County and flows eastward to empty into Lake St. Clair in the vicinity of Mount Clemens. It has a drainage area of 760 sq miles. The upper two-thirds of the basin is fairly rugged and contains areas having altitudes greater than 1,000 ft. The lower part is an old lake bed and is relatively flat. The many lakes in its headwaters provide excellent natural storage.

Records of stage and flow have been collected in the Clinton River basin at five sites (fig. 5). The record for Clinton River at Mount Clemons covers the longest period. The drainage area at this site is 733 sq miles. The datum of the gage is 570.43 ft above mean sea level, datum of 1929. The average discharge for the 16-yr period 1934-50 was 486 cfs (314 mgd). The hydrograph for a median water year shows the flow characteristics of the river (fig. 8).

Table 4.–Summary of industrial wastes discharged daily

[From report of the International Joint Commission, United States and Canada, on the Pollution of boundary waters, 1951]

Area	Total flow (mgd)	Phenols (lb)	Cyanides (lb)	Ammonium compounds (lb)	Oils, etc. (gal)	Suspended solids (lb)
Lake St. Clair.........	16	1,230	1	40	0	2,900
Detroit River............	1,257	4,890	3,692	11,570	16,240	2,209,300
Total..................	1,273	6,120	3,693	11,610	16,240	2,212,200

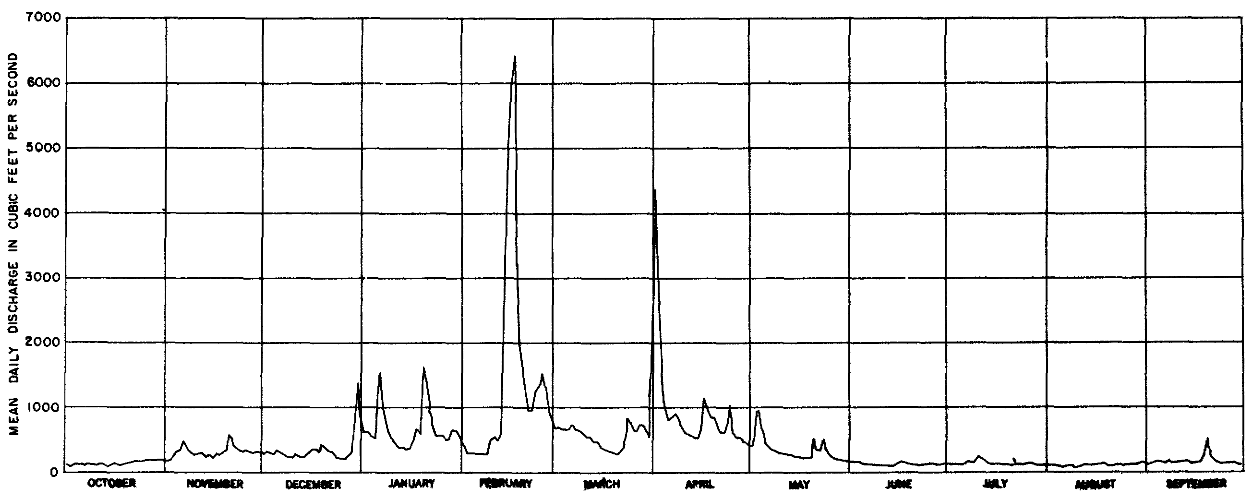


Figure 8.–Hydrograph of Clinton River at Mount Clemens for a median year.

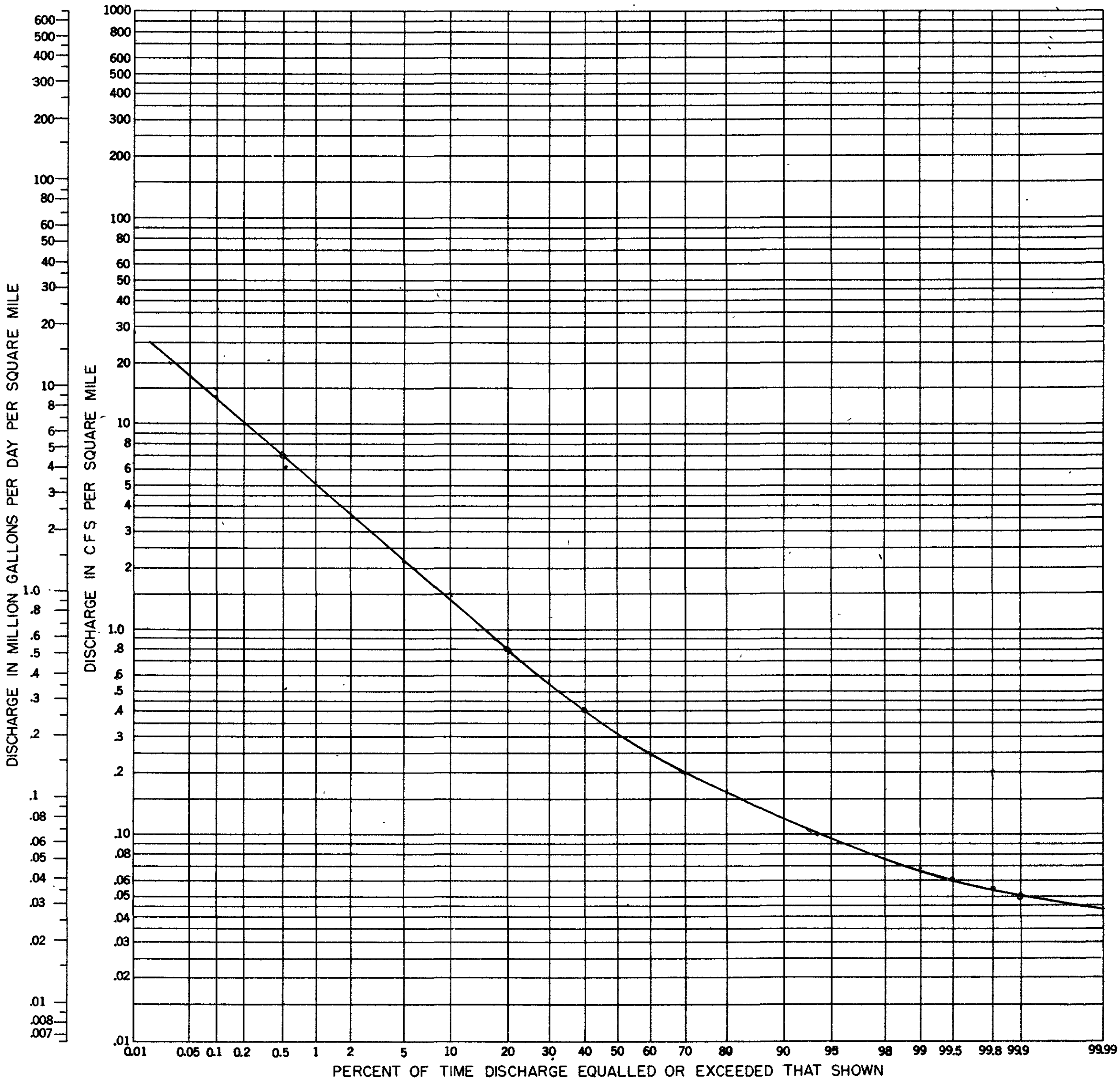


Figure 9. -Flow-duration curve for Clinton River at Mount Clemens.

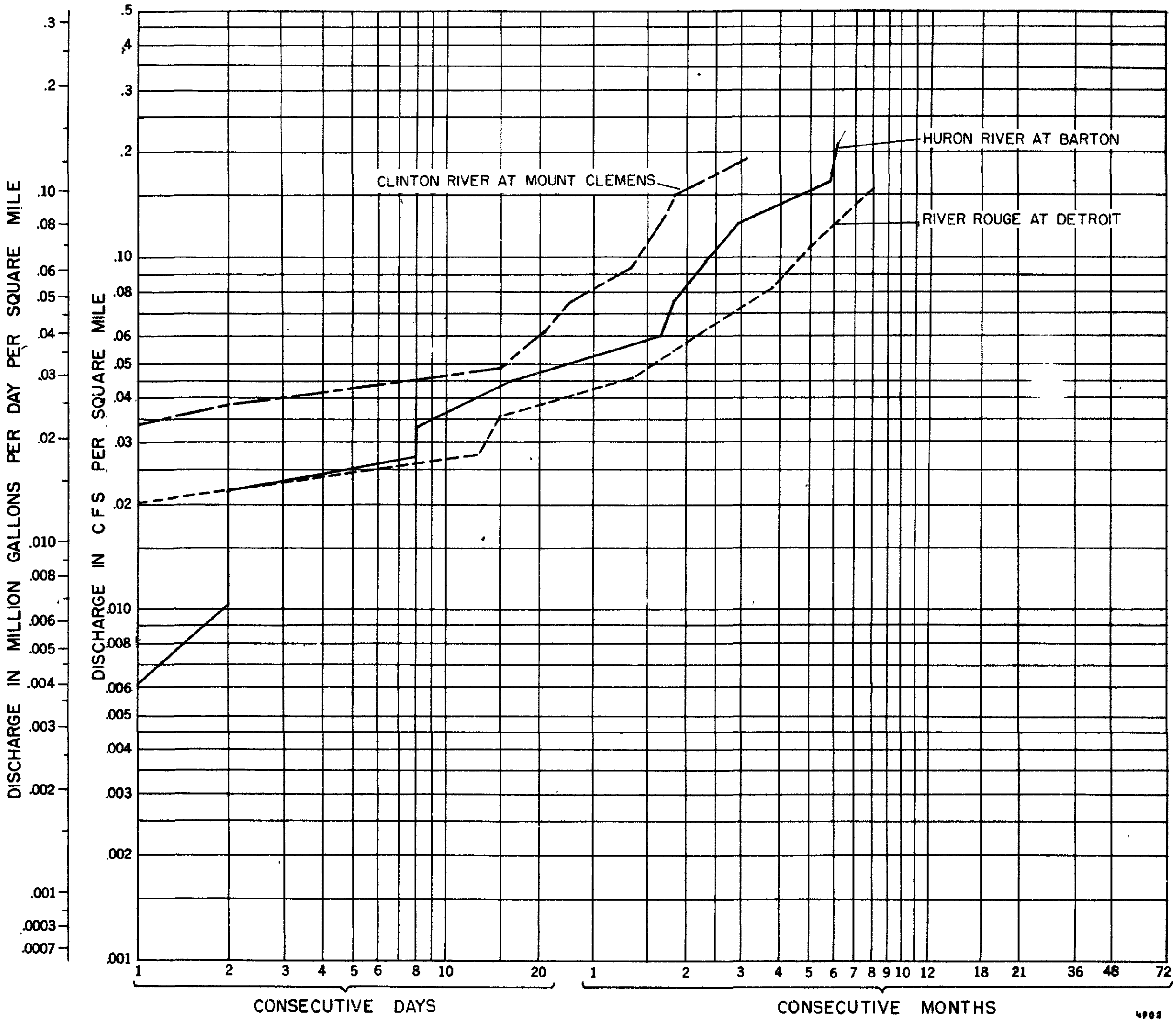


Figure 10. -Maximum period of deficient discharge of Clinton River at Mount Clemens, River Rouge at Detroit, and Huron River at Barton.

Floods. -The maximum flow recorded since the gage was established at Mount Clemens in 1934 is 21,200 cfs on April 6, 1947. Floods of this magnitude have a recurrence interval of approximately once in 20 yr.

Low flows. -The minimum daily discharge recorded since May 1934 is 25 cfs (16 mgd) on August 24, 1934. The flow-duration curve (fig. 9) shows the flow characteristics of the river. This curve shows the percentage of time that the flow exceeds any given quantity. For example, the flow at Mount Clemens exceeds 0.075 cfs per sq mile (55 cfs) during 98 percent of the time. During an average year the flow would be less than 55 cfs only 7 days. The maximum period of deficient discharge for the Clinton River at Mount Clemens is shown in figure 10. This curve shows that even in unusual years, the flow of the Clinton River at Mount Clemens may be expected to be less than 55 cfs for not more than 25 consecutive days.

Quality. -Three chemical analyses of water from the Clinton River basin were made during 1951 (see table 3). These analyses show that the water is very hard, with dissolved solids ranging from 292 to 331 ppm. Figure 11 shows that calcium bicarbonate is the principal mineral constituent of this water.

The Clinton River carries varying amounts of pollution. It had an average coliform count of 2,400 mpn per 100 ml at its mouth and because of sewage discharge from municipalities upstream higher counts in other reaches. The Clinton River basin is not highly developed industrially, and therefore the pollution is largely from sewage rather than industrial wastes.

River Rouge

The River Rouge rises in Oakland County and flows southeastward, emptying into the Detroit River below Dearborn near Ecorse. It has two tributaries, the

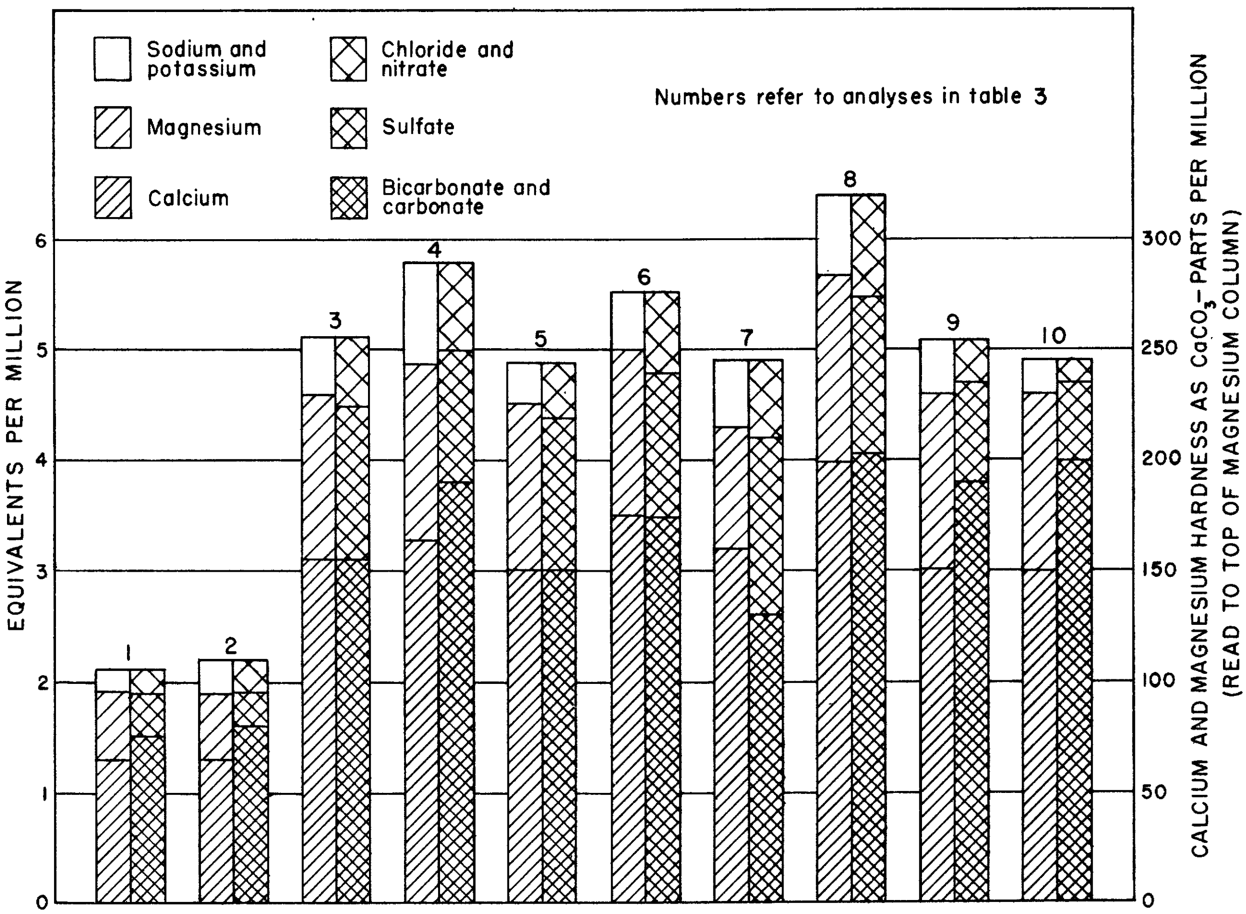


Figure 11. -Composition of selected surface water in the Detroit area.

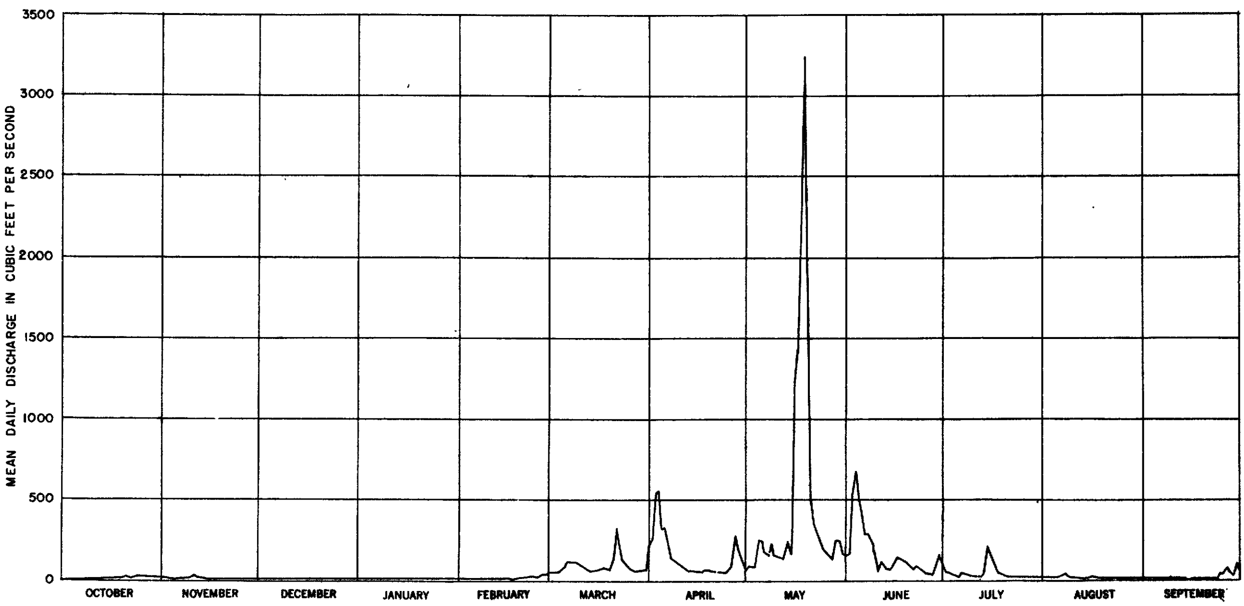


Figure 12. -Hydrograph of River Rouge at Detroit for a median year.

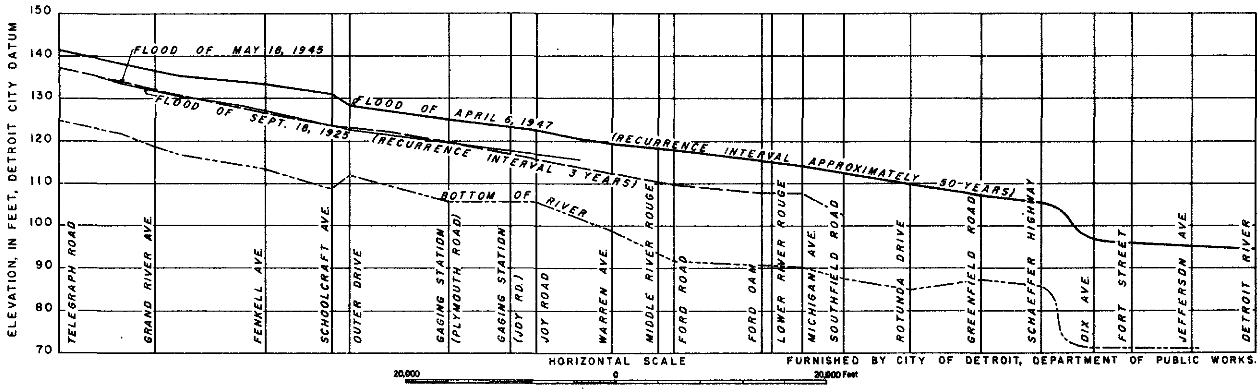


Figure 13.—Flood profile of River Rouge, Telegraph Road to mouth. Flood of April 6, 1947: Maximum elevation 94.3 at Detroit River was furnished by U. S. Lake Survey; maximum elevation 95.9 at Fort Street bridge was furnished by the Wayne County Road Commission; all other elevations shown were ascertained by Survey Division, Detroit Department of Public Works. Flood of May 18, 1945: From data furnished by Survey Division, Detroit Department of Public Works. Flood of September 18, 1925: From data furnished by Hubbell, Hartgering, and Roth, consulting engineers. Horizontal intervals on profile are approximate only, being scaled distances of meanders of the River Rouge. All elevations shown hereon are referred to the Detroit city datum which is 480.30 ft above the Government datum generally used before 1936 (Lake Survey) and 479.79 ft above the U. S. Coast and Geodedic Survey datum.

Middle and Lower branches, and drains an area of about 440 sq miles. Its basin lies almost entirely in the old lake bed and as a result, except perhaps for the upper fringe, it is relatively flat and impervious. It has practically no natural surface storage.

Records of stage and flow have been collected in the River Rouge basin at four sites (fig. 5). The record for River Rouge at Detroit covers the longest period. The drainage area at this site is 193 sq miles. The datum of the gage is 584.00 ft above mean sea level. The average discharge for the 20-yr period 1930-50 was 107 cfs (69 mgd). The hydrograph for a median year shows the flow characteristics of the river (fig. 12).

Floods.—The maximum flow recorded since the gage was established in 1930 is 13,000 cfs on April 5, 1947; maximum gage height 23.0 ft April 6, 1947. The maximum flow for the same flood at Michigan Avenue where the drainage area is 410 sq miles was 28,000 cfs. Floods of this magnitude have a recurrence interval of about 50 years. Figure 13 is a flood profile for the lower part of the River Rouge. The upper profile is the flood of April 6, 1947 and the lower profile is the flood of September 18, 1925. The peak flow during the 1925 flood was 3,000 cfs at the present gaging station site. Floods of this size occur about once in every three years. By plotting these profiles on a topographic map the areas that would be flooded under the above conditions may be estimated.

Low flow.—The minimum flow observed since the gage was established in 1930 is 2.7 cfs (1.7 mgd) on August 11, 1934. The flow-duration curve (fig. 14) shows the flow characteristics of the river. The maximum period of deficient discharge for River Rouge at Detroit is shown in figure 10.

Quality.—The water in the River Rouge is very hard and in the lower reach it is polluted by both sewage and industrial wastes. Three chemical analyses of water from the River Rouge basin were made during 1951 (see table 3). The principal mineral constituent of these waters is calcium bicarbonate (fig. 11).

Many wastes are discharged into the river in the highly industrialized area near the mouth. In 1946-48, the river had a median coliform count of 43,000 mpn per 100 ml and an average phenol concentration of 0.079 ppm at its mouth (International Joint Commission, 1951).

Huron River

The Huron River rises in Oakland County, flows southwestward across the southeastern corner of Livingston County into Washtenaw County and thence southeastward, emptying into Lake Erie near the mouth of the Detroit River. Its drainage basin has the shape of a mallet with the handle providing the outlet. The drainage area above Ann Arbor is 711 sq miles. Most of the upper portion is hilly and contains many lakes which provide much natural storage.

Several hydroelectric plants have a dual effect on the natural flow of the Huron River. When a water-powered plant is suddenly shut down, the flow downstream is reduced, but this reduction is temporary and continues only until the pond is refilled. The other effect is to reduce flood flows by storing water. The extent of each of these effects depends upon the size of the pond, although both are certain to occur even though the pond is filled. Because of the small size of the ponds created by the plants on the Huron River, the flow is not greatly affected, except for short periods.

Records of stage and flow have been collected in the Huron River basin at 13 sites (fig. 5). The record for Huron River at Barton covers the longest period. The drainage area at the site is 704 sq miles. Based in part on unpublished records, the average discharge for the 33-yr period 1914-47 was 451 cfs (291 mgd). The hydrograph for a median year shows the flow characteristics of the river (fig. 15).

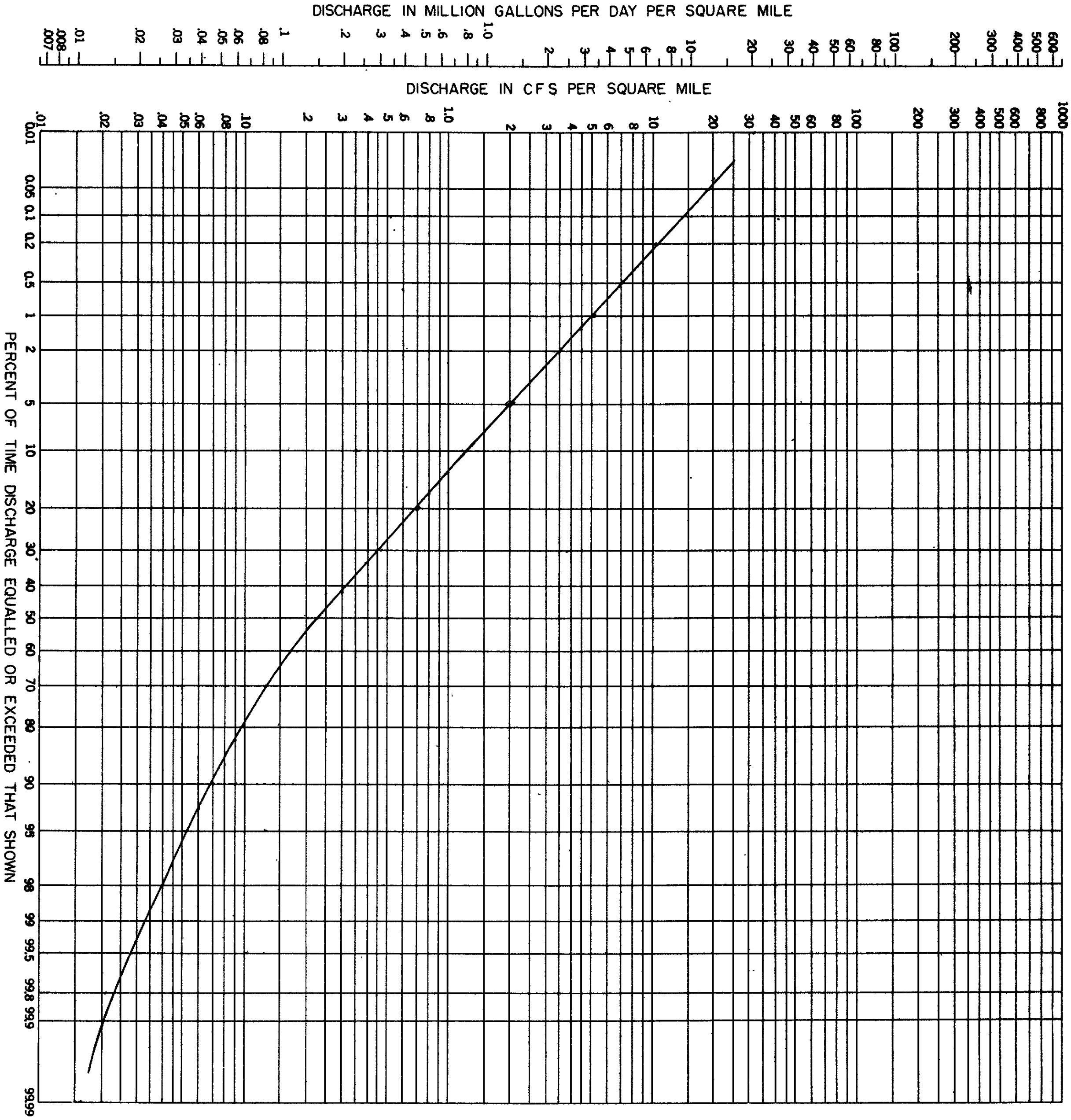


Figure 14. -Flow-duration curve for River Rouge at Detroit.

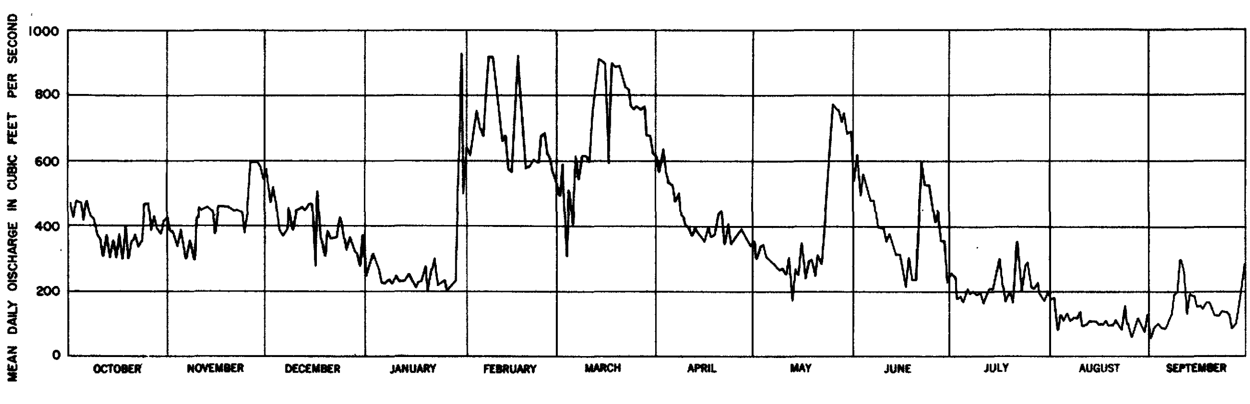


Figure 15.-Hydrograph of Huron River at Barton for a median year.

Floods.-The maximum daily flow recorded at Barton during the period of record was 5,840 cfs on March 14, 1918. A flood of 5,000 cfs at Ann Arbor and 6,000 cfs at Flat Rock will occur on the average once in 20 yr.

Low flow.-The minimum daily flow at Barton during the period of record is 4 cfs (2.6 mgd) on February 11, 1931. Flow duration curve (fig. 16) shows the low flow characteristics of the river. The maximum period of deficient discharge for the Huron River at Barton is shown in figure 10.

Quality.-Two chemical analyses of water from the Huron River were made in 1951 (see table 3). The principal mineral constituent of these waters is calcium bicarbonate (fig. 11). These analyses show the water to be very hard with dissolved solids of 263 ppm at Ann Arbor and 278 ppm at Flat Rock.

GROUND WATER

Occurrence

The rocks comprising the earth's crust contain many openings that vary widely in shape and size. The size of the openings range from minute pores to huge caverns. Generally, they are connected so that water can move from one opening to another. It is these openings which form the receptacles for storage and conduits for ground-water flow. Formations containing these receptacles and conduits are called aquifers.

Ground water in the Detroit area is derived almost entirely from precipitation that falls within the area and percolates to the water table. The amount of ground water that can be withdrawn depends on the permeability of the water-bearing formations, the amount of water in storage, and the rate of replenishment by precipitation. If the quantity of water withdrawn exceeds the quantity recharged, the difference is supplied from storage. Withdrawals in excess of the rate of replenishment can continue only as long as water in storage is available.

Generally, ground water is moving slowly from areas of intake to points of discharge. The movement may range from a few feet a year to a few feet a day, except at points of concentrated discharge. Ground water occurs under either water-table or artesian conditions (see fig. 17). Under water-table conditions it is unconfined and the upper surface of the saturated zone is called the water table. Under artesian conditions it is confined under pressure beneath an impermeable bed. This hydrostatic pressure is due to the weight of water that stands at higher levels between a given artesian well and the area of outcrop. If the pressure in an artesian aquifer is sufficient to raise the water level above the land surface, as it does in certain parts of the Detroit area, water will flow from the wells without pumping.

In the glacial drift of the Detroit area ground water occurs under both water-table and artesian conditions. In general, the drift consists of irregular beds of sand, silt, gravel, and clay which grade into each other laterally and vertically in relatively short distances. Figure 18 shows two vertical sections through the Detroit area. It shows that the glacial drift thickens to the northwest and that the area south and east of the old glacial-lake shore line (see pl. 2, line AA') is predominatly clay with isolated terraces, beaches, and lenses of sand and gravel. Except for alluvial deposits along streams there is little hope for developing large supplies of ground water in the old lake bed. To the north and west of line AA' the drift contains thick sections of permeable sand and gravel, and it is in this area that large supplies of potable ground water have been developed. These broad differences in the ground-water yield of the glacial drift deposits are shown in figure 19.

The influence of clays and sandy clays in confining ground water in underlying sands and gravels and thereby developing artesian conditions is shown by figure 18. From the comparison of plate 2 and figure 18 it is evident that there may be little or no indication on the surface of the presence of these deeper beds of highly permeable sands and gravels. Thus it is of the utmost importance that the development of these water-bearing formations be preceded by a carefully planned

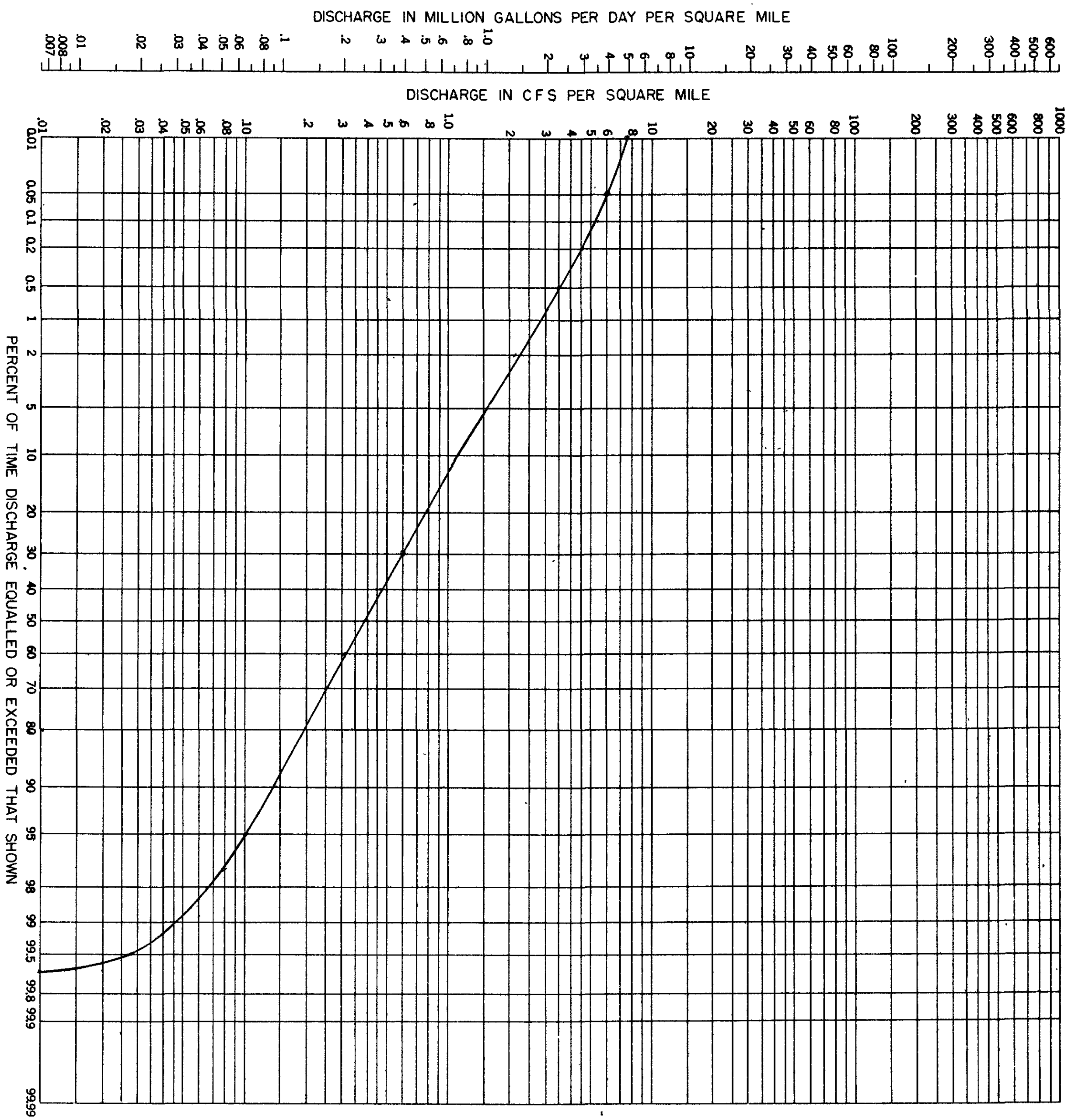


Figure 16.—Flow-duration curve for Huron River at Barton.

Table 5. –Water-bearing properties of the principal formations in the Detroit area

System	Series	Formation	Lithology	Approximate thickness (feet)	Water-bearing properties
Quarternary.	Recent and Pleistocene (?).	Alluvium.	Fine to coarse sand and gravel, clay, silt.	0-87	Yields few large supplies along Huron and River Rouge Valleys.
	Pleistocene.	Drift.	Sand, gravel, clay, silt.	0-330	Yields small to large supplies of water of good quality and is the source of water for nearly all the wells in the area.
Carboniferous.	Mississippian.	Coldwater shale.	Blue, green, and gray shales and lenses of sandstone.	0-890	Locally the sandstone lenses may yield small supplies of fresh water to wells.
		Sunbury shale.	Brown to black shale.	0-38	Yields no water to wells.
		Berea sandstone.	White and gray to yellowish coarse sandstone. Contains lenses of hard blue shale.	0-155	Generally yields small supplies of highly mineralized water. Domestic supplies of relatively fresh water have been obtained locally.
		Bedford shale.	Gray limy shale.	0-135	Yields no water to wells.
Carboniferous and Devonian.	Mississippian (lower) and Upper Devonian.	Antrim shale.	Black carbonaceous shale; thin gray shale members in lower part.	0-294	Yields moderate supply of fresh water in the Belleville area. Generally, water is mineralized.
Devonian.	Middle Devonian.	Traverse formation.	Gray to bluish calcareous shale and thin-bedded limestone.	0-515	Yields moderate supplies of highly mineralized water.
		Dundee limestone.	Buff to light-brown cherty limestone and dolomitic limestone.	0-320	Yields moderate supplies of highly mineralized water.
		Detroit River dolomite.	Fine-grained, gray to buff, thin-bedded dolomite; some limestone, anhydrite, salt, and sandstone.	0-485	Yields moderate supplies of highly mineralized water.
		Sylvania sandstone.	White friable sandstone and sandy dolomite. Some sandy limestones are present.	80-350	Locally yields small supplies of fresh water to shallow wells in the extreme southeast part of the Detroit area. Generally yields large supplies of highly mineralized water.

Table 6. –Chemical quality of selected ground waters in the Detroit area

[Chemical analyses in parts per million]

	Near Ann Arbor[a]	Pontiac[a]	Birmingham[b]	Berkley[b]	Ypsilanti[b]	Taylor[b] Twp.	Royal Oak[a]
Sample no.[c]	1	2	3	4	5	6	7
Source of water	Glacial drift	Glacial drift	Glacial drift	Glacial drift	Glacial drift	Bedrock	Glacial drift
Late of collection	Nov. 2, 1951	June 26, 1951	Oct. 1947	Mar. 16, 1944	....	....	Aug. 23, 1951
ph value	7.5	7.4	....	....	....	6.8	7.6
Specific conductance micromhos at 25°C	718	676	....	....	....	....	789
Silica (SiO_2)	13	20	15	13	9	....	14
Iron (Fe)	.05	1.4	1.7	.5	1.5	....	.35
Calcium (Ca)	104	80	78	45	111	308	34
Magnesium (Mg)	35	30	27	27	29	89	20
Sodium (Na)	7.1	25	37	64		276	106
Potassium (K)	2.3	3.0	....	....	....	....	3.2
Carbonate (CO_3)	0	0	....	....	....	....	8
Bicarbonate (HCO_3)	335	390	395	342	346	808	339
Sulfate (SO_4)	132	32	10	5.2	113	730	1.8
Chloride (Cl)	7.8	22	37	55	17	200	84
Fluoride (F)	.2	.5	....	.8	....	....	1.0
Nitrate (NO_3)	.5	2.5	....	....	....	....	.2
Dissolved solids	491	408	406	378	498	2,240	440
Hardness (as $CaCO_3$):							
Total	404	324	308	224	397	769	169
Noncarbonate	129	3	0	0	113	106	0

a/ Analyzed by U. S. Geological Survey.
b/ Analyzed by Michigan Department of Health.
c/ Numbers refer to sample locations on figure 21.

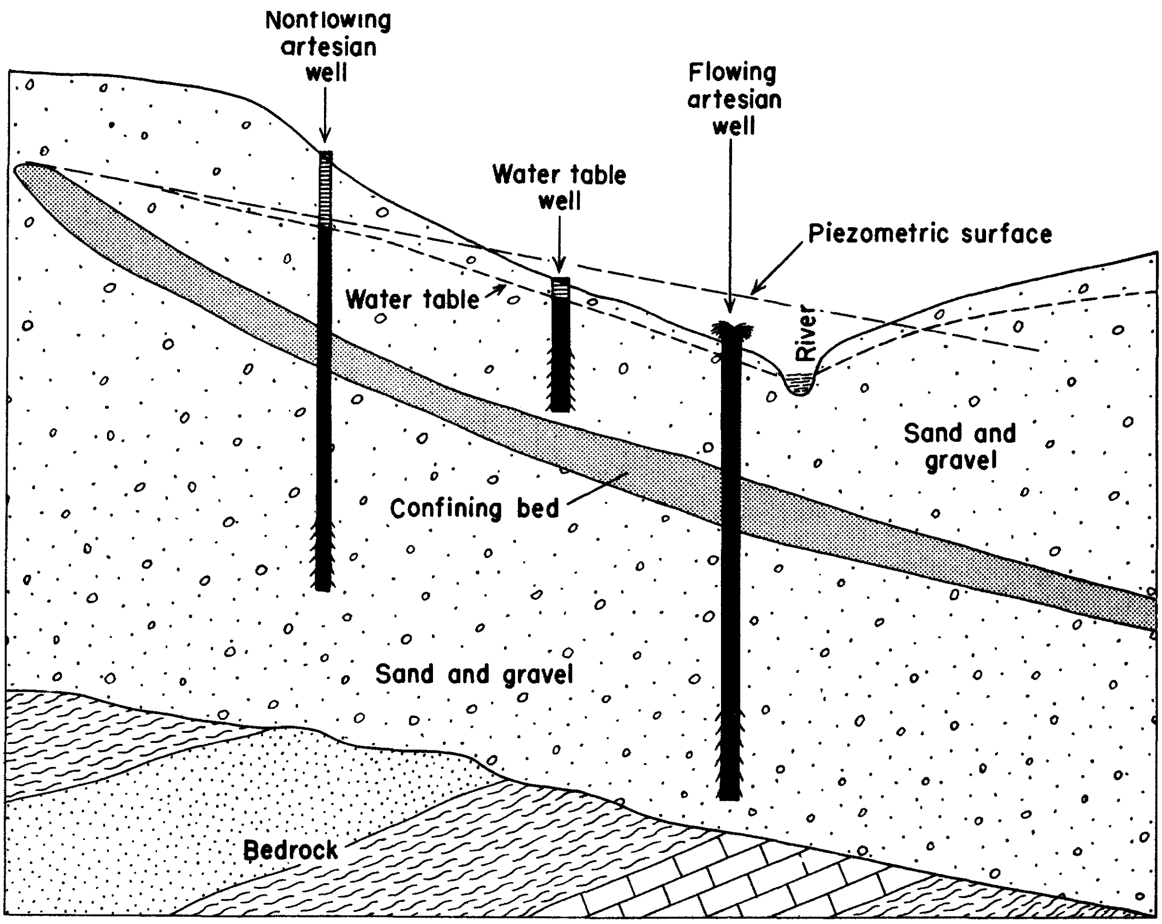


Figure 17. –Generalized section showing occurrence of ground water under water-table and artesian conditions.

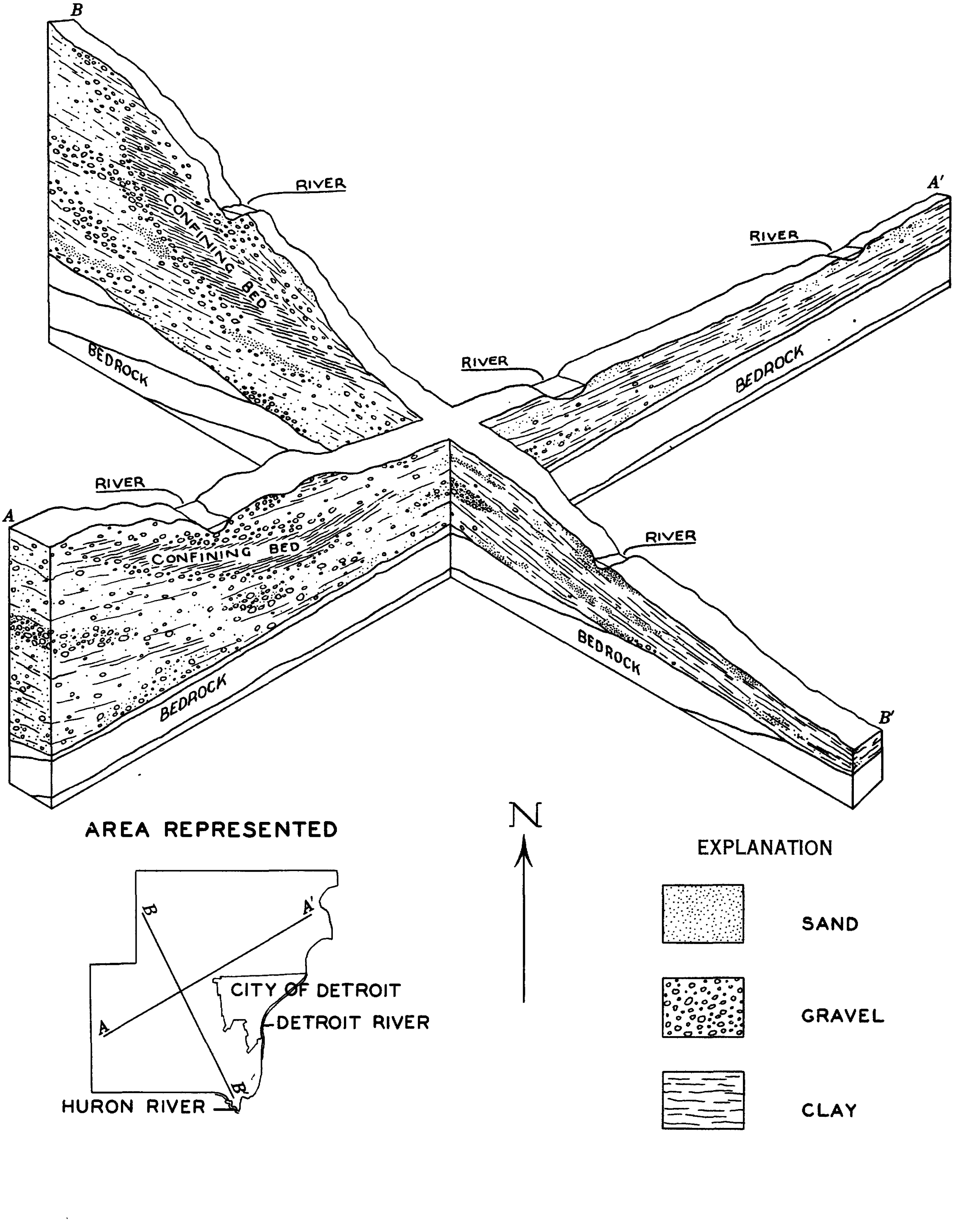


Figure 18.–Generalized sectional diagram showing geological features of the Detroit area.

Table 7. -Maximum, minimum, and median concentration of chemical constituents of ground water from glacial drift, based on 36 analyses

[Chemical analyses in parts per million]

	Maximum	Minimum	Median
pH value	7.9	6.6	7.1
Specific conductance .... micromhos at 25°C	3,120	292	702
Iron (Fe)	45	.04	.44
Calcium (Ca)	504	9.6	76
Magnesium (Mg)	194	8.7	24
Carbonate (CO_3)	0	0	0
Bicarbonate (HCO_3)	504	54	280
Sulfate (SO_4)[a/]	1,800	1	28
Chloride (Cl)	800	2.5	50
Nitrate (NO_3)	1,040	0	.9
Total hardness as $CaCO_3$	2,060	88	292

a/ By turbidity test.

program of test drilling and other exploratory studies.

Where a river is freely connected with an aquifer, as shown on figure 20, it is often possible to induce infiltration from the river by pumping from adjacent wells tapping the aquifer. This type of well development has large potentialities in certain parts of the Detroit area and is perhaps best examplified at the former Willow Run bomber plant, where wells have been developed having yields as high as 4,000 gpm.

Water-Bearing Formations

The three types of water-bearing formations in the Detroit area are bedrock, glacial deposits, and valley alluvium.

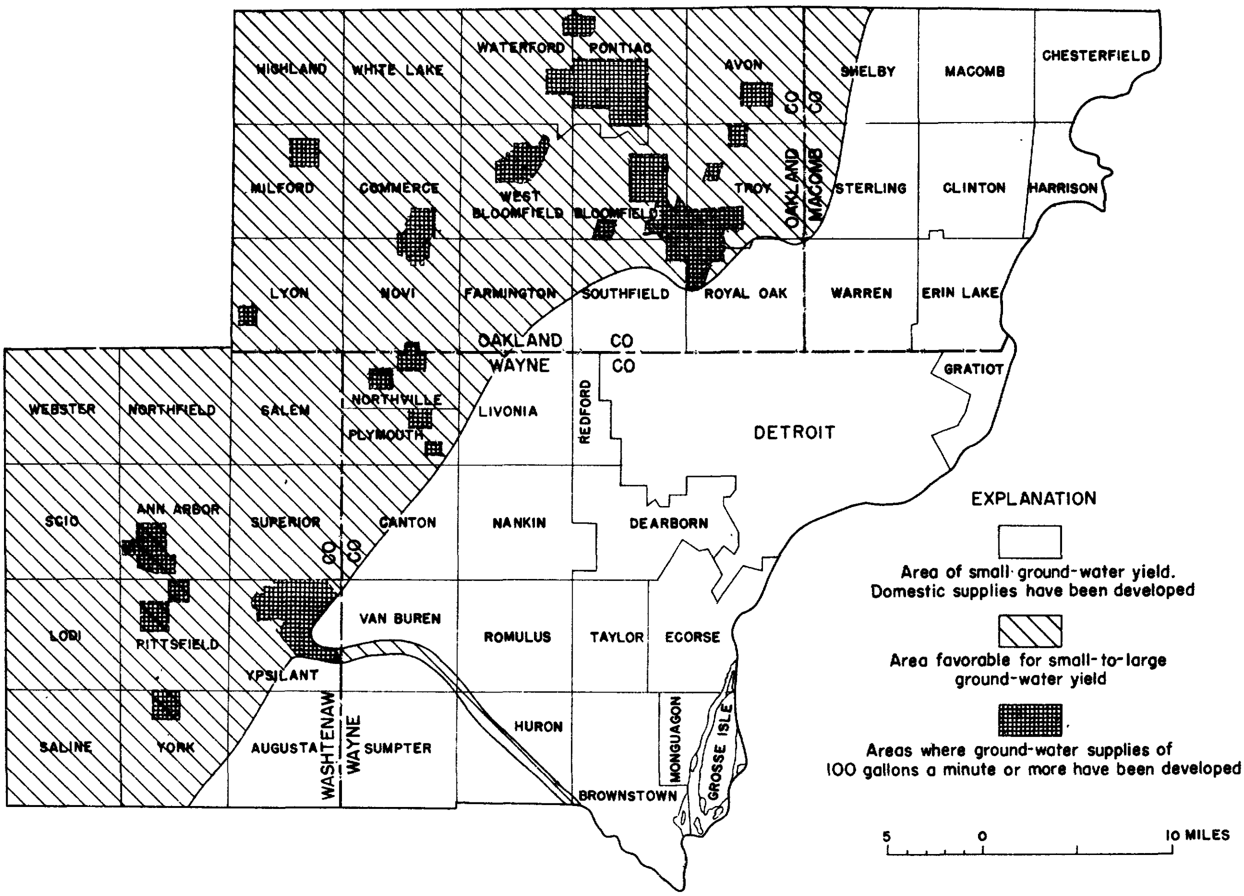


Figure 19. -Map of Detroit area showing potential yield of ground water from glacial drift.

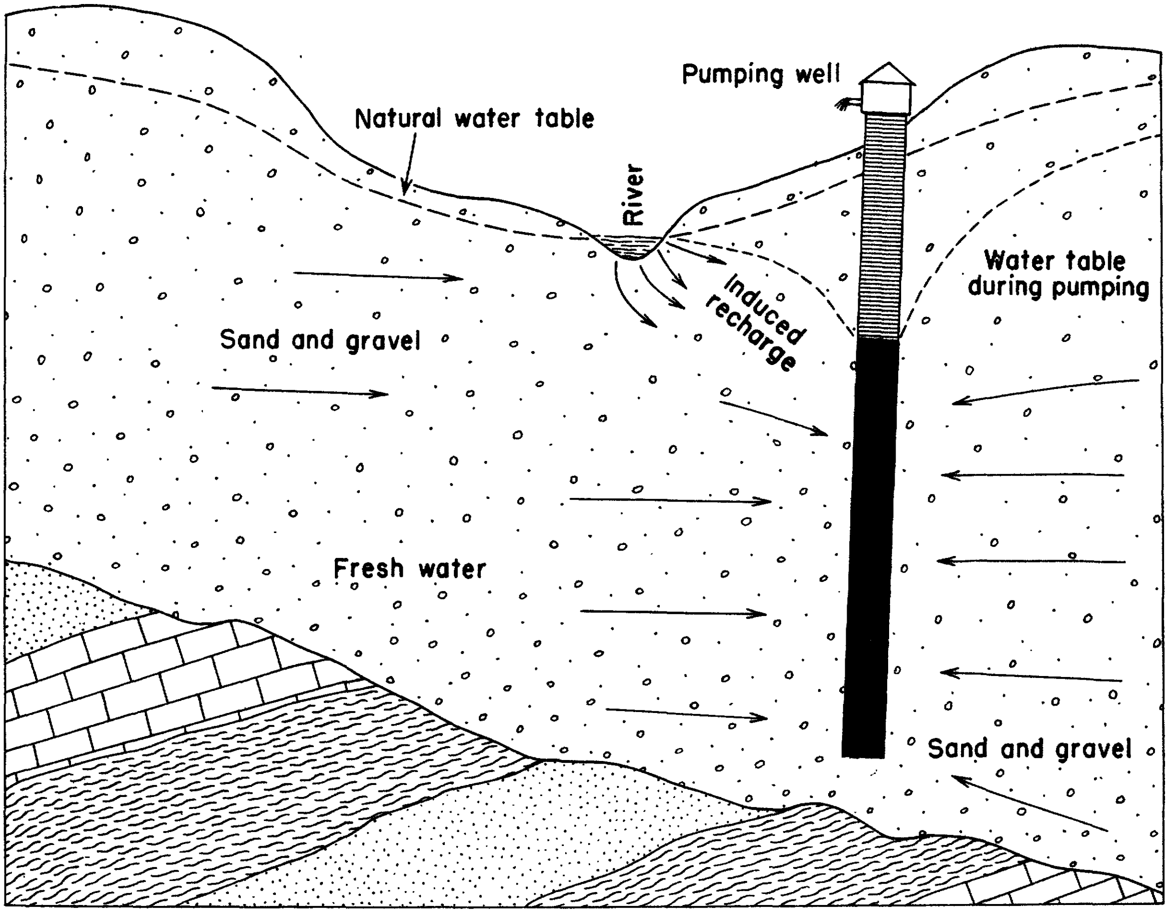


Figure 20.–Generalized diagram showing movement of fresh water from a river to a well.

Bedrock

The bedrock formations immediately underlying the glacial deposits in the Detroit area consist of several hundred feet of sedimentary rocks deposited in ancient inland seas. They range in age from early Mississippian to early Devonian (see table 5). Older sedimentary formations underlie the Devonian rocks. However, these older rocks in the Detroit area contain highly mineralized water and will not be considered in this report. The rocks of Mississippian and Devonian age consist of shale, sandstone, limestone, dolomite, and salt. The only place that any of the bedrock formations crop out is near the mouth of the Huron River. The regional dip is northwest at about 30 ft to the mile.

Wells drilled into the bedrock formations usually yield water that is too highly mineralized for most uses. In those areas where good water is found the formations are relatively thin and the yield of wells is small. In the extreme southeast part of the Detroit area, small domestic supplies of moderately mineralized water can be obtained from shallow wells tapping the bedrock.

Belleville, on the Huron River downstream from Ypsilanti, is the only municipality in the area which now derives its water supply from the bedrock. While the upper weathered zone of the Antrim shale yields moderate supplies of fresh water in the Belleville area, it seldom yields similar supplies in other parts of the Detroit area.

During past years large supplies of highly mineralized water have been developed in the bedrock formations underlying the Detroit area. Although highly mineralized, this water can be used for cooling purposes and for air conditioning. After use it is usually emptied into the sewer system. The temperature is uniform throughout the year and averages about 53 F. The so-called Swan well on Grosse Isle has the highest yield of any well known to tap the bedrock in the area. It is a flowing well drilled to a depth of 2,375 ft. When completed in 1904, it discharged highly mineralized water at a rate of 3,000 gpm. McGuinness, Poindexter, and Otton (1949) summed up the water-bearing properties of the bedrock very well when they stated, "Thus, although the Swan well shows that large supplies of water can be obtained from the bedrock under favorable conditions, it offers no

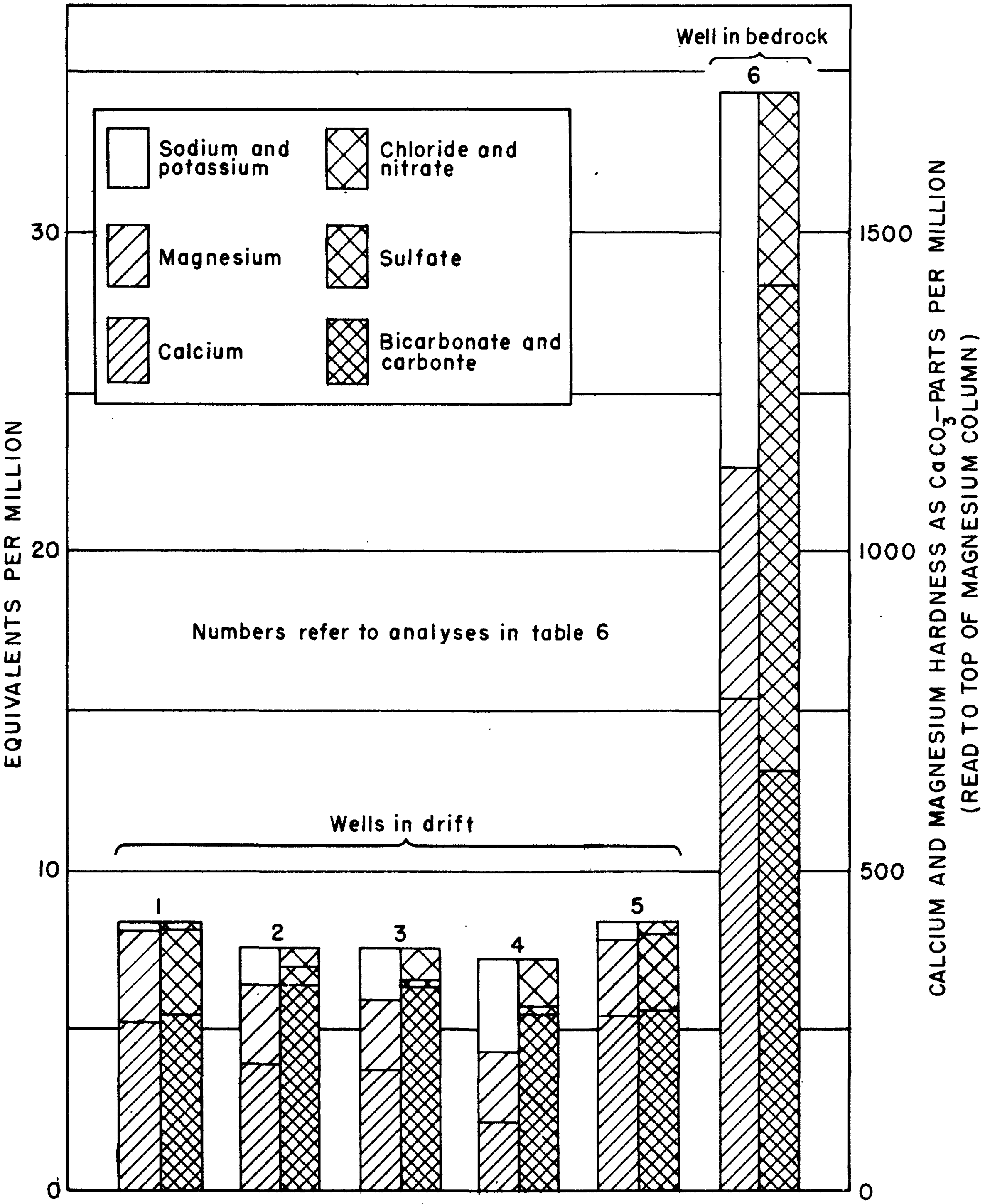


Figure 21. -Composition of selected ground waters in the Detroit area.

encouragement with regard to the availability of water of good quality."

Table 6 gives a chemical analysis of water from a well ending in bedrock, and figure 21 shows the composition of the water as compared to water from wells ending in glacial drift. For the most part the water in the bedrock formations is of variable quality, containing large amounts of calcium, bicarbonate, sulfate, and considerable quantities of sodium chloride. The water from the bedrock in a large part of the Detroit area is also contaminated with varying amounts of hydrogen sulfide gas and is often noticeably high in iron content.

Glacial Drift

A layer of glacial drift ranging in thickness from a few feet to as much as 330 ft overlies the bedrock. These deposits cover all the Detroit area, except for a few small outcrops of bedrock in the southeastern part. The glacial deposits are thinnest near the mouth of the Detroit River and in general thicken gradually toward the west and more rapidly toward the northwest (see fig. 15 and pl. 3).

The continental glaciers picked up the mantle of soil and loose rock at the earth surface and, with additional material gouged from the bedrock, incorporated it into the lower part of the ice. This material was later deposited in various forms by the melting ice. For the purpose of this report, these glacial deposits will be treated in three sections as follows: glacial-lake clays and sands, moraines and till plains, and outwash deposits.

Lake clays and sands. -The old glacial-lake bed is a clay plain (pl. 2). A series of hills and ridges composed of sand and gravel as much as 25 or 30 ft high rest on the clay plain. These hills and ridges were formed as beaches, terraces, and river deltas by wind, waves, and stream action during the closing part of the glacial epoch. They are very porous and readily absorb a large percentage of the precipitation that falls upon them. Normally the water seeps downward to the water table, where it moves transversely above a layer of impervious clay toward points of discharge.

The water absorbed by these sand and gravel deposits in the old glacial-lake bed is available to wells and the supply is generally sufficient for domestic purposes, but it is unlikely that large supplies can be obtained from them. The supply may fail entirely during prolonged droughts because of the small storage available. The water table is relatively near the surface and fluctuated with the seasons. The water escapes as seepage along the margins of the sandy surface deposits where they are cut by streams. The flow may be slight and merely moisten the surface, or it may be concentrated into a single flow of greater volume to form a spring. In parts of this area some of the springs may be used for domestic supply.

A relatively thick layer of lake clays with interbedded deposits of sand and gravel underlies the old lake bed. Small to moderate supplies of ground water may be developed from the interbedded sand and gravel. Because of the irregularity of these deposits, it is possible to determine their areal extent only by means of intensive geologic study and test drilling, thus making the development of an adequate water supply difficult and uncertain.

Moraine and till plains. -Northwest of the line showing the limit of the lake clays (see pl. 2) the glacial till identified as moraines and till plains was deposited without stratification or assortment of materials according to size by the melting ice. The till has low permeability owing to its compactness and heterogenous composition and does not yield water freely to wells. However, it should be recognized that the surface geology as shown by plate 2 represents only the materials deposited during the last phase of the Wisconsin stage of glaciation and does not necessarily reflect the nature of the underlying materials deposited during the earlier stages of glaciation. Large supplies of ground water can often be obtained from the underlying sands and gravels, the location of which requires test drilling. For example, test drilling in the Pontiac area revealed permeable deposits that yielded more than 750 gpm to wells about 175 ft deep.

Outwash deposits. -The outwash deposits consist of partially sorted and stratified sands and gravels of highly variable thickness that overlie the till plains in certain areas northwest of line AA' (pl. 2). They form valuable catchment areas for the interception and storage of large quantities of precipitation. These deposits serve as ground-water reservoirs that maintain streamflow during periods of no precipitation and recharge deeper aquifers. Where the outwash is thick and the water table is at shallow depth, wells may be expected to yield as much as several hundred gallons per minute. Again, test drilling generally is required to determine the areas where large supplies are available.

Chemical quality of water from glacial drift. -Knowledge of the chemical quality of the ground water in the glacial drift in the Detroit area has been determined by analyses of water from municipal and industrial wells and from 36 privately-owned wells. The location of these wells are shown in plate 1.

The composition of water from several municipal wells is shown in figure 21 and the chemical analyses given in table 6. The maximum, minimum, and median concentration of some chemical constituents in 36 samples of water from glacial drift are given in table 7. These glacial drift wells usually produce calcium magnesium bicarbonate water. The median concentration of iron is 0.44 ppm and that of total hardness is 292 ppm. The ranges of concentration are rather wide; that is, nitrate ranges from practically none to 1,040 ppm, chloride from 2.5 to 800, and calcium from 9.6 to 504 ppm. In some wells these wide ranges are probably caused by contamination of water from the surface or by highly mineralized water from the bedrock. Should a well end too close to the bedrock, it is possible to induce enough highly mineralized water to flow into the zone of fresh water to make the well useless as a source of fresh water (see fig. 22). Some water obtained from the drift in this area contains hydrogen sulfide and natural gas which tend greatly to restrict its usefulness.

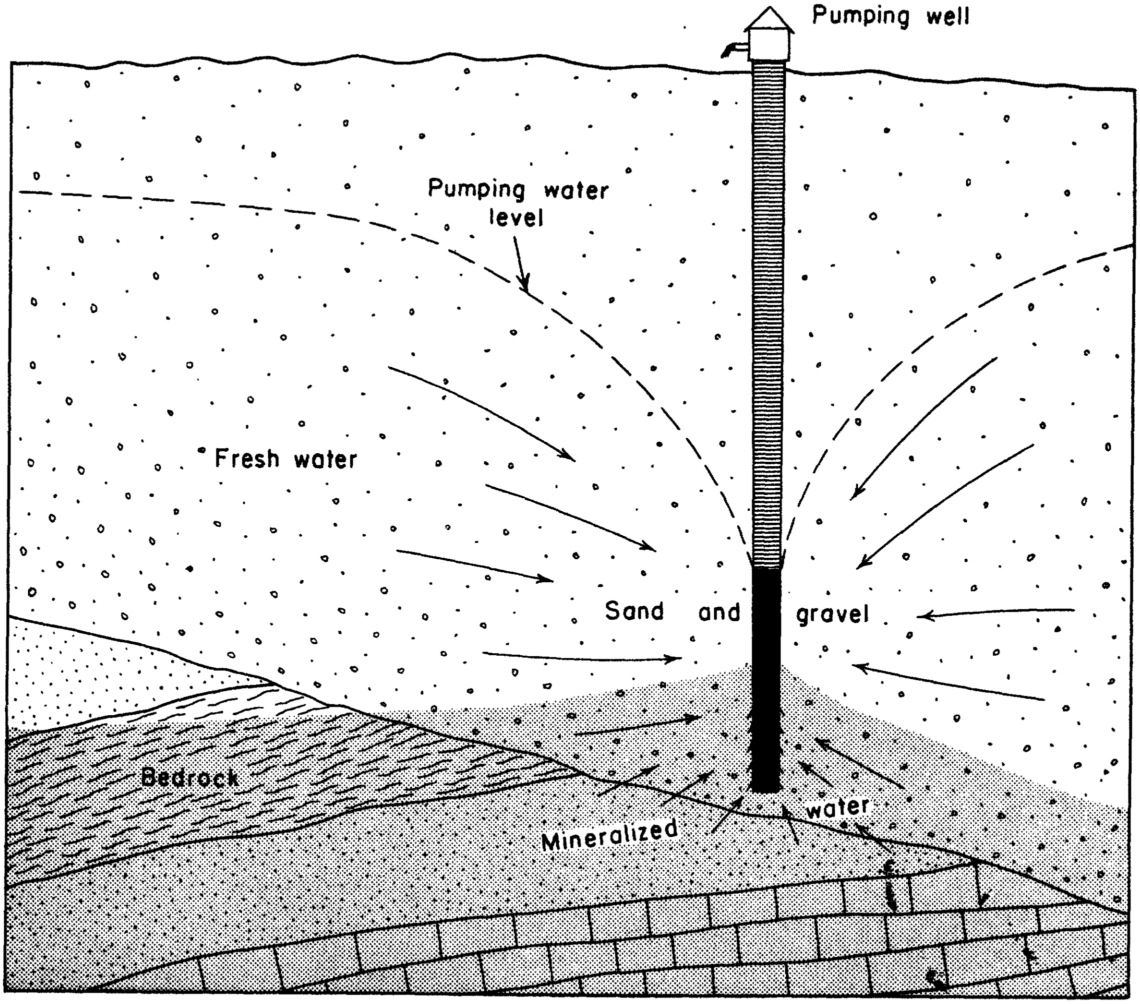
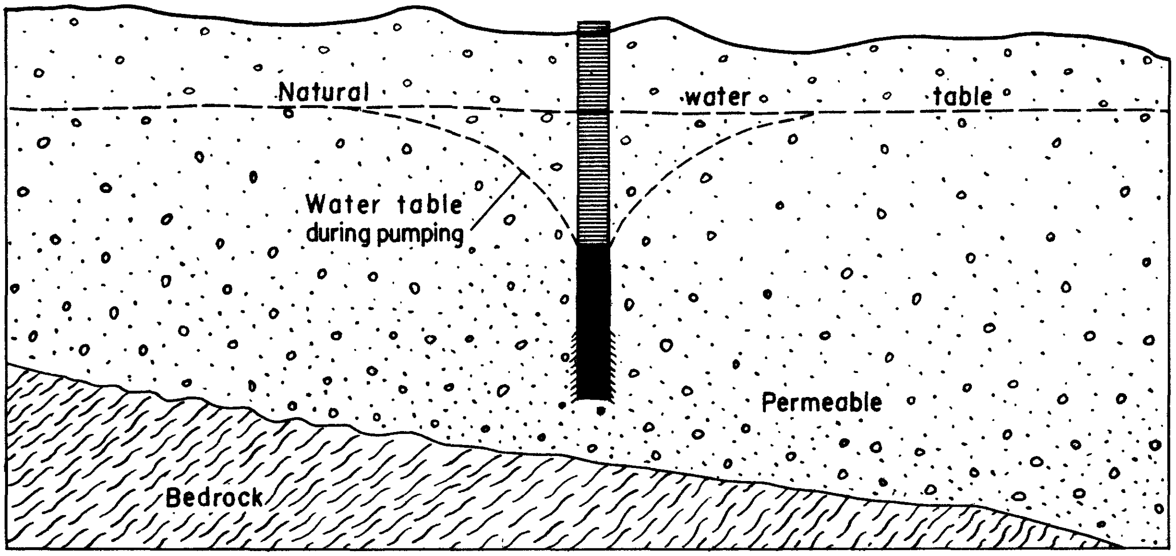


Figure 22.–Generalized diagram showing how a fresh-water well may be contaminated by highly mineralized water from underlying rocks.

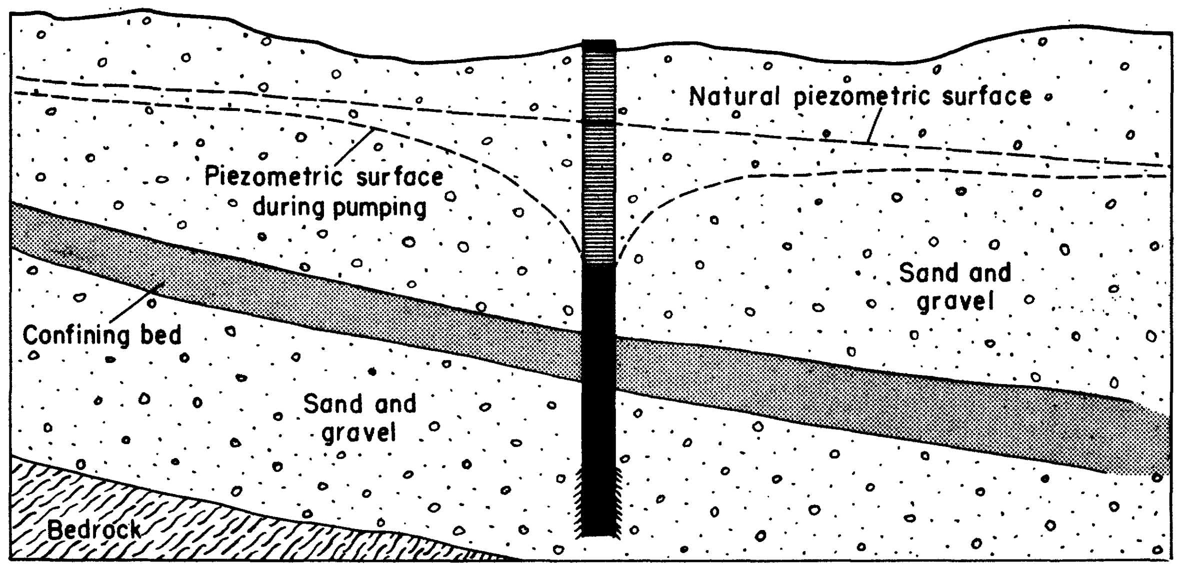
Valley alluvium.–Alluvial deposits consisting of silt, sand, and gravel are present chiefly along the Huron River and the River Rouge and their main tributaries. The upper part of these deposits is of Recent age and the lower part may be Pleistocene. Where these deposits are permeable and of appreciable thickness, large supplies of water may be obtained. Wherever such deposits border a perennial stream and are freely connected with it, large ground-water supplies can be developed by lowering the water table below the level in the river and thereby inducing infiltration from the stream (see fig. 20).

The supply at the former Willow Run bomber plant is an excellent example of induced infiltration from a river. This supply was developed in 1942 and is now used by the Ypsilanti Township Water Department. It is described in detail by McGuinness, Poindexter, and Otton (1949). The wells, which are 24 to 26 in. in diameter, are finished in medium to coarse gravel and range in depth from 81 to 87 ft. Individual yields during tests were as high as 4,000 gpm. Induced infiltration augments the public supplies of Ypsilanti and New Boston and a few large industrial supplies along the Huron River in the Ypsilanti area and along the River Rouge in the Plymouth and Northville areas. Ordinarily the supplies have been obtained from one or two wells. Although the wells are closely spaced, the average yield per well when two wells were operating (Willow Run area) ranged from about 2,650 to 3,500 gpm. The performance of these wells is ample evidence of the large potential that exists wherever highly permeable material is connected to a plentiful source of recharge.

In very shallow wells the water temperature will fluctuate in response to seasonal changes in air temperature but will be more moderate in range. The maximum observed temperature is about 60 F. The temperature of water from deeper wells is much more uniform, varying only little throughout the year. The average temperature of the ground water from the glacial drift in the Detroit area is about 52 F. Where ground water is induced to flow from streams to wells, the temperature of the ground water will vary with the stream temperature but to a lesser degree, and with a time lag that depends on the distance from the stream.



Water-table conditions



Artesian conditions

Figure 23. –Generalized diagram showing position of the water level and piezometric surface under natural and pumping conditions.

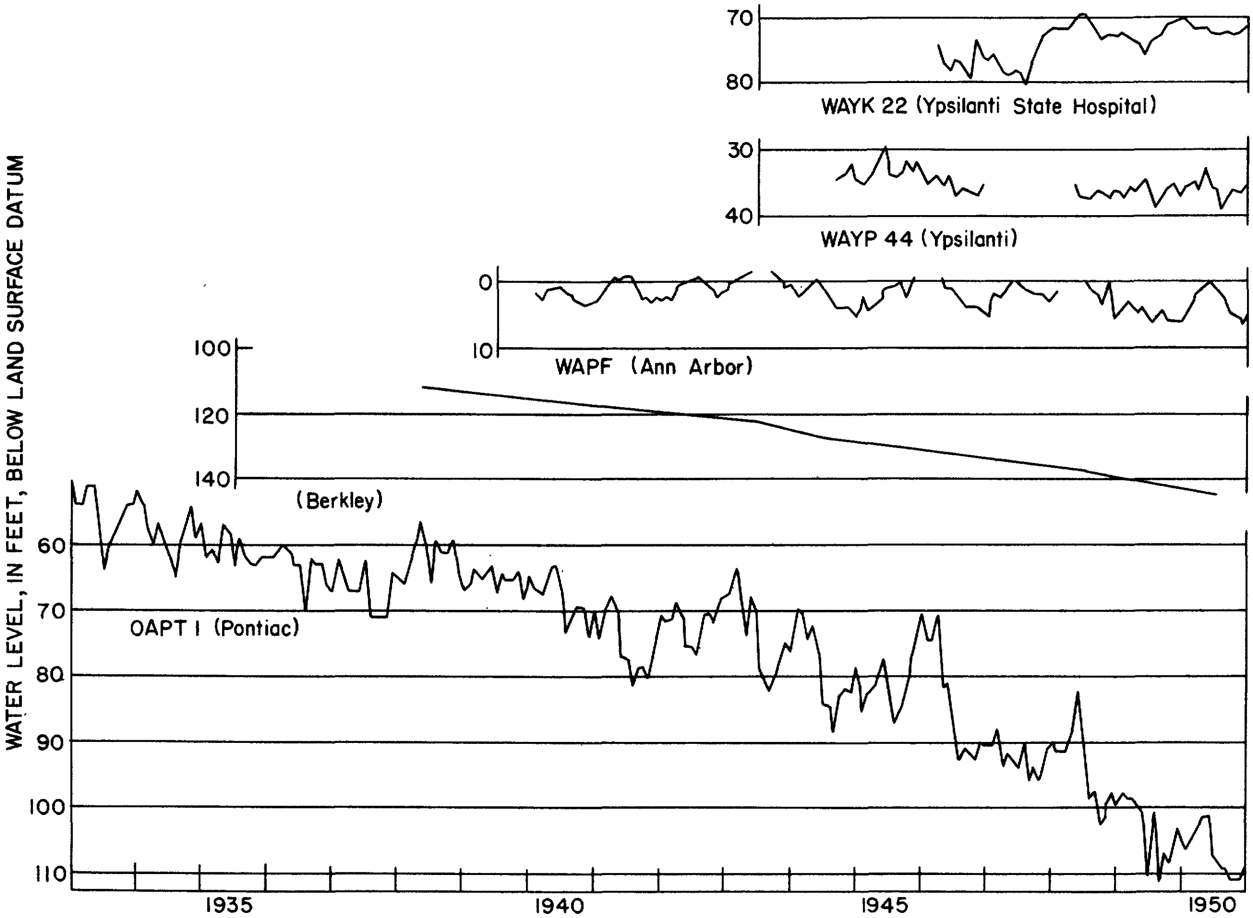


Figure 24. –Typical hydrographs of water levels in the Detroit area. Well designations are those of the Michigan identification system.

Changes in Ground-Water Levels

The water level in wells does not remain constant but rises and falls in response to changes in the rates of recharge and discharge. Thus, if more water is recharged than is withdrawn, the water level will rise, and if the withdrawal of water exceeds that recharged, then by necessity the water level must decline.

When water is removed from a well the water level or pressure surface at the well is lowered and water flows radially toward the well from the outer regions of the reservoir (see fig. 23). As the water level is lowered around the well the water surface takes a shape somewhat similar to an inverted cone, called the cone of depression. If the rate of pumping exceeds the available recharge, the cone of depression continues to broaden and deepen, because the excess pumpage must be drawn from storage. As pumping continues, this cone will continue to expand until the rate of flow into the area of drainage equals the rate of withdrawal. However, it does not necessarily follow that a long-extended lowering of the water-table is evidence of regional overdraft. Furthermore, it should be pointed out that ground water cannot be obtained without a corresponding decline in the ground-water level. This decline is necessary to cause water to flow toward the well, and in itself is not sufficient evidence to determine whether there has been overdevelopment.

Ground-water recharge in Michigan occurs principally during the nongrowing period; during the growing season most of the precipitation is required to meet evapotranspiration needs. The most favorable areas for recharge are those northwest of line AA' shown on plate 2. The principal sources are the shallow deposits of sand and gravel. The water level in these formations fluctuates in response to periods of heavy precipitation or drought.

The water level in wells in the Detroit area ranges from about 110 ft below the surface to several feet above. Over most of the area it is at relatively shallow depth except where there has been concentrated pumping.

There has been no widespread decline of water levels in the area.

Figure 24 presents a number of typical hydrographs showing the fluctuations of water level in selected areas. In general, the data in the Ypsilanti and Ann Arbor areas show only slight progressive decline. The available information suggests that existing withdrawals have been stabilized. In contrast, the hydrographs for wells at Pontiac and Berkley show that a progressive decline has taken place at least locally in the southeastern part of Oakland County. Although there is no indication that this recession

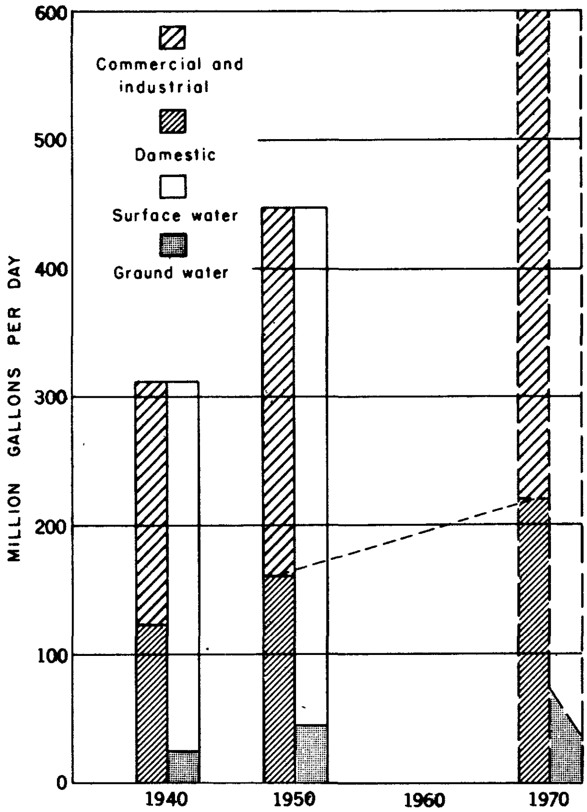


Figure 25.-Source and use of water in the Detroit area exclusive of raw industrial water from the Detroit River.

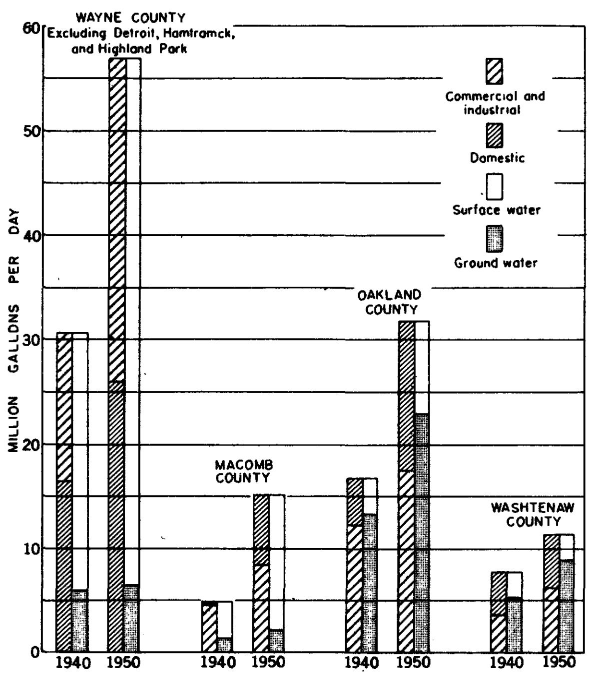


Figure 26.-Source and use of water in suburban areas.

will cease in the immediate future, it does not follow that the supply will soon be depleted. A large part of this decline may be attributed to the continuing increase of ground-water use in this area. Whether overdevelopment has occurred or is in prospect can be determined only by means of a comprehensive survey.

WATER SUPPLIES

During 1950 the daily use of water in the Detroit area averaged 2,949 mgd of which about 2,500 million gal was raw water taken from the Detroit River by industry, used, and immediately returned to the river. The remaining 449 million gal was used for commercial, industrial, and domestic purposes (see fig. 25). Figure 25 also shows the quantity of water used in 1940 and the estimated requirements in 1970, exclusive of the raw water used by industry from the Detroit River. Figure 26 shows the use and source of all water except raw water used by industry from the Detroit River and water used from the public water supply systems in Detroit, Hamtramck, and Highland Park.

The quantities of water used in Detroit, Hamtramck, and Highland Park are shown in figure 27 for each year from 1901 to 1950. Beginning with 1935 the total use is divided according to type of use, domestic, commercial, industrial and other uses.

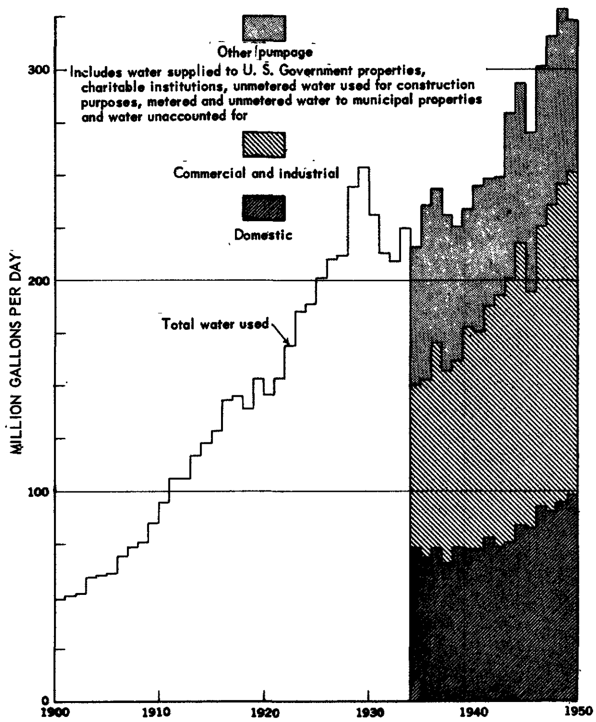


Figure 27.-Use of treated water in Detroit, Hamtramck, and Highland Park.

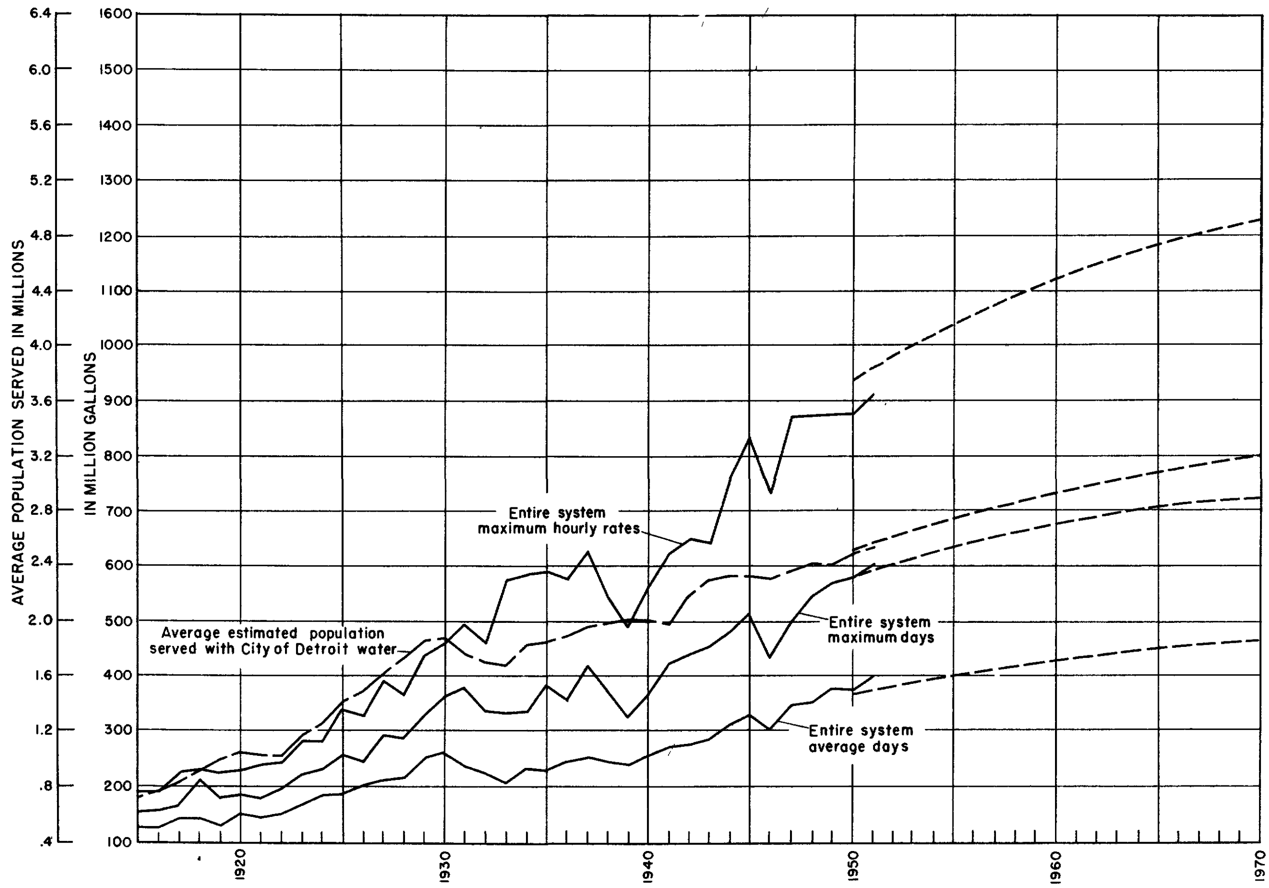


Figure 28. –Water pumped and population served by the Detroit Department of Water Supply.

Public Water Supplies

The demand for water is increasing rapidly in certain parts of the Detroit area. Within the present city limits of Detroit the population is approaching the point of saturation. As a result, industry is moving to the suburbs and population naturally follows it. Information provided by the Detroit Area Regional Planning Commission shows that in 1920 only 17 percent of the total population of this area lived outside Detroit, Hamtramck, and Highland Park. In 1930 this percentage increased to 24, and in 1950 it was 37. According to the best judgment of the Detroit Regional Planning Commission, half the population of this area will be suburban by 1960. This rapid shift in population has presented serious problems to those in charge of water supply.

Detroit public water-supply system

The Detroit Department of Water Supply provides Detroit and the adjacent area with an abundant supply of excellent water. This water is obtained from the Detroit River, and after purification, is distributed throughout the city and its environs.

The City of Detroit was formerly prevented by charter from extending the water mains beyond its limits; however, it has had the right to sell and deliver water at any point on its boundary. Charter limitations were removed by the exigencies of World War II. Figure 28 was supplied by the Detroit Department of Water Supply and shows the population served and water pumped, by fiscal years, from 1915 through 1951. The Department of Water Supply has extended the curves to show conditions in 1970, which are being anticipated by the construction of a new plant to supply the demand then. The area presently being served by the Detroit Department of Water Supply is shown on plate 4.

The Wayne County Board of Supervisors recognized the urgent need for water at various points throughout the suburban area and, in 1939, authorized the Board of Road Commissioners to construct and operate sewage and water supply facilities throughout the outlying districts of Wayne County. As a result of this action the Wayne County Board of Road Commissioners has constructed three distribution systems, one extending down river, another out Michigan Avenue, and a third to Livonia. Through these systems water purchased from the Detroit Department of Water Supply is supplied to the following customers:

Village of Wayne
Village of Riverview
Village of Trenton
Village of Allen Park
Garden City
Livonia City
Nankin Township

Table 8. -Summary of public water supplies in the Detroit area

	Population served 1950	Source of supply	Treatment	Other areas served	Average use 1950 (gal per day)
Ann Arbor	50,000	Glacial drift and Huron River. About 50 percent from river	Coagulation, Filtration, Softening, Chlorination	None	6,200,000
Belleville	1,700	Bedrock	Chlorination	None	170,000
Berkley	20,000	Glacial drift	Chlorination	None	1,200,000
Birmingham	15,370	Glacial drift	None	None	1,680,000
Center Line	7,640	Glacial drift	None	None	160,000
Clawson	5,180	Glacial drift	None	None	460,000
Detroit	2,497,371	Detroit River	Coagulation, Filtration, Chlorination	39 adjoining communities	383,000,000
Farmington	2,320	Glacial drift	None	None	139,000
Flat Rock	4,000	Huron River	Filtration, Softening, Chlorination	City of Rockwood	700,000
Fraser	1,000	Glacial drift	None	None	64,000
Grosse Pointe Farms	15,350	Lake St. Clair	Coagulation, Filtration, Chlorination	Grosse Pointe and Grosse Pointe Shores	1,456,000
Highland Park	46,390	Lake St. Clair	Coagulation, Filtration, Chlorination	None	10,900,000
Milford	1,900	Glacial drift	None	None	80,000
Mt. Clemens	24,000	Lake St. Clair	Coagulation, Filtration, Chlorination, Fluorination	Selfridge Field, also part of Harrison and Clinton Township	2,517,000
New Baltimore	2,040	Lake St. Clair	Coagulation, Filtration, Chlorination	None	270,000
Northville	3,220	Glacial drift	Iron removal	None	250,000
Plymouth	7,000	Glacial drift	None	None	816,000
Pontiac	80,000	Glacial drift	Chlorination	None	12,232,000
Rochester	4,280	Glacial drift	None	None	500,000
Royal Oak	46,900	Glacial drift and 75 percent of total use from city of Detroit	Well supply is chlorinated	Interconnection with a number of surrounding water agencies	2,300,000
South Lyon	1,320	Glacial drift	None	None	100,000
Utica	1,200	Clinton River	Filtration Chlorination	None	300,000
Warren	730	Glacial drift	None	None	36,000
Wyandotte	40,000	Detroit River	Coagulation, Filtration, Fluorination	South part of Lincoln Park city	4,710,000
Ypsilanti	18,000	Glacial drift	Softening, Chlorination	None	2,190,000

Ecorse Township
Grosse Ile Township
Taylor Township
Romulus Township
Brownstown Township
Wayne County General Hospital
Wayne County Training School
Detroit House of Correction

Plans are now being developed to extend all these systems to meet future needs. To the north, the Detroit Department of Water Supply is also serving Royal Oak, Ferndale, Hazel Park, and a number of other municipalities in Oakland County and Macomb County.

Other Public Water-Supply Systems

Most of the cities and towns that do not obtain their water from the Detroit Department of Water Supply use ground water, although a few obtain their supply from surface sources. Table 8 is a summary of public water supplies in the Detroit area showing quantity of water used, population served, source, and treatment.

Chemical Quality

The public supplies drawn from Lake St. Clair and the Detroit River are of good chemical quality (table 9). Records for 25-yr show that in the Detroit public

Table 9. -Chemical quality of water from selected public water supply systems in the Detroit area

[Chemical analyses in parts per million]

	Ann Arbor[a]	Berkley[b]	Detroit[c]	Highland Park[a]	Mt. Clemens[a]	Plymouth[b]	Pontiac[a]	Royal Oak[a]	Wyandotte[a]	Ypsilanti[b]
Date of collection	11/2/51	3/44	6/50	11/5/51	8/27/51	8/41	6/26/51	8/23/51	8/17/51	11/43
Color	2	...	...	0	3	...	0	3	2	...
pH value	9.4	...	7.6	7.6	7.6	...	7.7	7.7	7.5	...
Specific conductance .. micromhos at 25°C	246	...	...	215	248	...	635	1000	225	...
Silica (SiO_2)	9.4	13	.2	3.5	2.3	7.6	20	11	2.4	7.2
Iron (Fe)	.11	.50	.02	.07	.17	1.10	1.2	.23	.10	...
Calcium (Ca)	17	45	27	26	28	84	71	36	27	14
Magnesium (Mg)	9.2	27	7	8.0	7.8	23	28	17	6.8	8.8
Sodium (Na)	12	64	3	4.2	6.9	83	26	150	4.9	40
Potassium (K)	2.2			1.2	1.0		3.7	2.6	1.1	
Carbonate (CO_3)	5	...	0	0	0	...	0	12	0	17
Bicarbonate (HCO_3)	16	342	93	92	99	312	340	248	88	8.5
Sulfate (SO_4)	71	5.2	19	20	16	54	28	.4	17	102
Chloride (Cl)	10	5.5	7	8.0	13	6.0	28	182	10	12
Fluoride (F)	.2	.8	...	.1	1.3	...	.6	1.0	1.4	.3
Nitrate (NO_3)	.4	...	.15	.9	.3	...	1.0	.2	4	...
Dissolved solids	153	378	132	126	135	340	375	537	126	212
Hardness (as $CaCO_3$):										
Total	80	224	98	98	102	302	292	162	96	70
Noncarbonate	59	0	22	22	21	46	14	0	23	63

a/ Analysis by U. S. Geological Survey.
b/ Analysis by Michigan Department of Health.
c/ Analysis by Detroit Department of Water Supply; includes all areas supplied by Detroit and Wayne County Board of Road Commissioners.

supply water the dissolved solids ranged from 107 to 145 ppm, calcium from 25 to 30 ppm, bicarbonate from 65 to 88 ppm, and hardness ranged from 88 to 113 ppm.

Some cities and towns in the area use ground water with little or no treatment. This water is hard and for the most part it contains troublesome quantities of iron. An analysis of the water supplied by Pontiac showed a hardness of 292 parts ppm, an iron content of 1.2 ppm, and a bicarbonate concentration of 340 ppm. Several municipalities use treated ground water. The water is softened and objectionable quantities of iron are removed. An analysis of the treated ground water from Ypsilanti shows dissolved solids to be 212 ppm, total hardness 70 ppm, and sulfate 102 ppm. The chemical quality of water delivered to the public by the larger municipalities in the Detroit area is shown in table 9, and the chemical quality of the water delivered in the major cities in the area is shown on plate 4.

Private Industrial Supplies

Essentially all the water supply for private industrial use in the Detroit area is obtained from the Detroit River. This use of raw water from the river is shown in figure 29. The quantities for 1940 and 1950 include industrial uses for processing, steam power, and cooling. They do not include the water withdrawn for public supplies. Most of this industrial water is returned directly to the Detroit River. The extension of this water use curve to 1970 is based primarily on studies of industrial employment made by the Detroit Metropolitan Area Regional Planning Commission. These data are contained in their reports on population and manufacturing employment in the Detroit region.

A few large industries in the Pontiac, Northville, Plymouth, and Ann Arbor areas have developed ground-water supplies. The quantity of ground water used by any one plant seldom if ever exceeds 2,000,000 gal per day.

Irrigation and Rural Supplies

A relatively small amount of water is used for irrigation in this area. Some is used for lawn and garden sprinkling; some for commercial truck gardening; and some for watering the greens and fairways of the many golf courses in the area. The total truck garden acreage irrigated in 1950 was only about 600 acres. From the best information available about 13 mgd are used during three months in the summer for irrigation of golf courses.

Rural uses are almost entirely unmetered. An estimated 16 mgd are used for domestic purposes outside of areas served by public water supply systems, assuming a per capita use of 50 gal per day. Almost all rural supplies are obtained from wells.

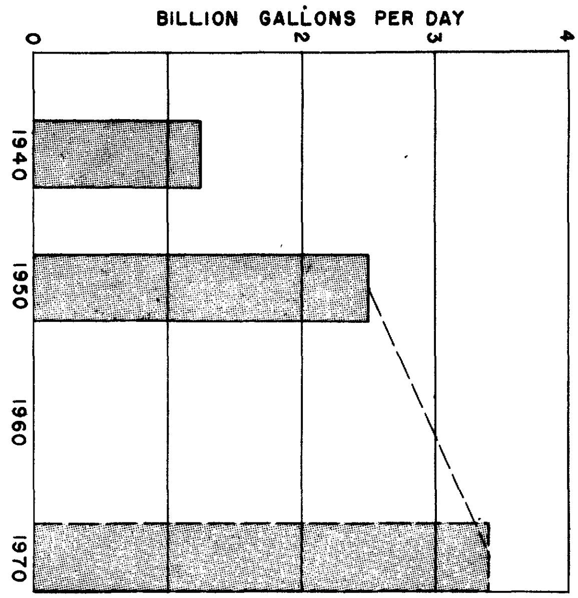


Figure 29.—Industrial use of raw water from the Detroit River.

Fluctuations in Water Use

Practically all of the water use data presented in this report are expressed as average use in gallons per day. The use actually fluctuates with the seasons. For example, the average daily pumpage for the city of Detroit for the fiscal year 1950 was 372,842,466 gal. The maximum daily pumpage was 575,400,400 gal, which is about 54 percent greater than the average daily use. The minimum daily pumpage was 254,800,000 gal, which is about 68 percent of the average daily use.

Normally, the largest use will occur in the summer and the smallest in the winter. The maximum and minimum monthly uses in the Detroit area during 1950 ranged from one-fourth to more than twice the average. Such variations in use depend upon type of industries, water temperature, cost of water, delivery pressure, climate, and many other factors. During the summer large quantities of water are used for cooling and refrigeration and for sprinkling lawns and small gardens.

Fluctuations in water use are also noted from year to year. In general, the use of water in the Detroit area has increased. However, there are years or periods in which there has been noticeable decreases in water use (see fig. 27). In 1931 there was a decline in annual water use in Detroit, Hamtramck, and Highland Park resulting from wide-spread shutdown of industrial plants. This decline persisted until about 1935 and then resumed its upward trend. However, it was not until 1940 that the rate of use again equaled that of the 1920's. The rising trend of water use in

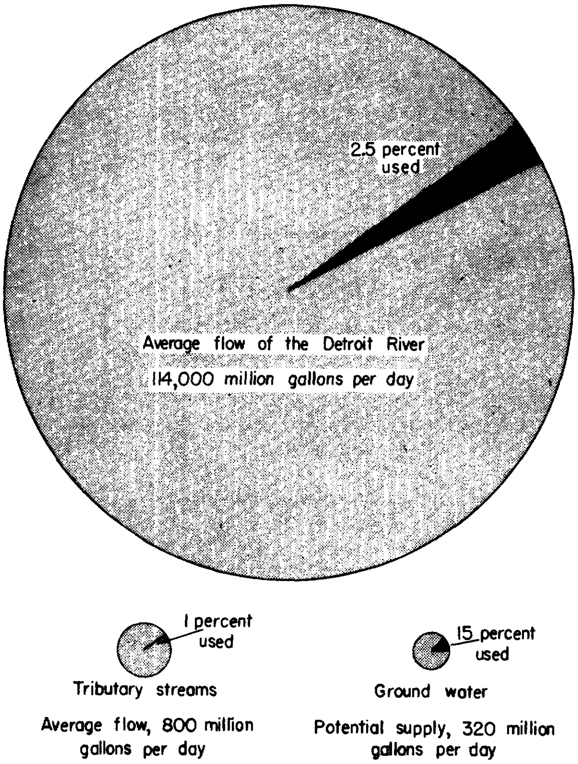


Figure 30. -Potential supply and present use of water in the Detroit area.

the 1920's has again been paralleled in the 1940's and from the present indications it will continue.

POTENTIALITIES

The potential water supply of the Detroit area is almost unlimited. This is clearly shown by figure 30, in which the present (1950) use is contrasted to the total available supply.

Lake St. Clair and Detroit River

Lake St. Clair and the Detroit River are unusual as sources of water supply because they are subject to much less variation in quantity and quality than most other streams and lakes outside of the Great Lakes system. These sources alone provide a potential water supply of good quality that is far in excess of the foreseeable needs of the Detroit area.

The average flow of the Detroit River for the last 16-yrs, during which time the records are believed to be the most reliable, was 177,000 cfs (114,000 mgd) but only 2.5 percent of this flow is being used. Furthermore most of the water that is being used is almost immediately returned to the river and becomes available for reuse. The quality of the water in Lake St. Clair and the upper reaches of the Detroit River is good. The water in the lower reaches is less desirable because of pollution. The utilization of this source of supply throughout the area is limited only by economic considerations.

Tributary Streams

Of the tributary streams in the Detroit area, the Huron River offers a better potential source of water that the River Rouge or the Clinton River. Water from these three tributary streams has a higher mineral concentration than does water from Lake St. Clair and the Detroit River

Clinton River. -The Clinton River at Mount Clemens is a potential source of at least 70 cfs (45 mgd) for 95 percent of the time (fig. 9). Even in unusual years the discharge at Mount Clemens may be expected to be less than 70 cfs for not more than 40 consecutive days (fig. 10).

River Rouge. -The River Rouge differs from the Clinton and Huron Rivers in that it has but little natural storage and, consequently, greater fluctuations in flow (see fig. 8). The River Rouge at Detroit is a potential source of at least 10 cfs (6.5 mgd) for 95 percent of the time (fig. 14). In unusual years the discharge of the River Rouge at Detroit may be expected to be less than 12 cfs not more than $2\frac{1}{4}$ consecutive months (fig. 10). It has the smallest water-supply potential of any of the three major tributary streams. Furthermore, because of unfavorable topography this low flow cannot be appreciably increased by storage.

Huron River. -The Huron River has the largest water-supply potential of the three major tributary streams because of the shape of its basin, the natural storage in its headwater areas, and the storage provided by hydroelectric plants. It is therefore the most widely utilized of the three streams. The Huron River at Barton is a potential source of 74 cfs (48 mgd) for 95 percent of the time (fig. 16). In unusual years the discharge at Barton may be expected to be less than 74 cfs not more than $2\frac{1}{2}$ consecutive months, (fig. 10).

Inland lakes. -Although the inland lakes of this area are not of any great importance as potential sources of water supplies, nevertheless they are important for recreation and storage. Any contemplated use of these waters should therefore take these values into consideration.

Ground Water

The supply of ground water potentially available to the Detroit area is difficult to determine because of differences in character of the water-bearing materials from place to place and the lack of reliable hydrologic data. From indirect evidence, the quantity of ground water believed to be perennially available is approximately 320 mgd. The known use of ground water is about 43 mgd or about 15 percent of the total. High mineral concentrations in the ground water, inadequate supplies of ground water in the heavily populated part of the area, and the lack of knowledge about the occurrence of large supplies north and west of the old lake shore account in part for the small development of this resource.

Figure 25 shows the use of ground water in the Detroit area. In general, it appears that as the area develops, it will become more and more dependent on the Detroit public water supply, and as a result, the total ground-water use may decline. However, there are many factors that could change this trend. With the improvement of techniques in well development and in testing procedures, it is possible that large supplies of ground water may be developed. Artificial recharge of ground water may permit an increase in pumping in some heavily pumped areas. Finally, economic considerations will determine whether the use of ground water in this area will increase or decrease.

It is probable that the most favorable areas for greater ground-water development are parts of the alluvial-filled valley of the Huron River. Although small in total area, these valley deposits may yield large supplies to wells that can induce infiltration from adjacent streams. For instance, yields as large as 4,000 gpm per well have been developed in permeable valley alluvium.

Another area of potential ground-water development lies north and west of line AA' limiting the lake clays, as shown on plate 2. In this area the highly productive sands and gravels are erraticly distributed. Moderate yields may be obtained in the upper parts of the drift or from permeable deposits buried beneath layers of impermeable till. Yields of 2,000 gpm or more have been developed. It is possible that many additional supplies of ground water might be developed from these sources.

The large area underlain by lake clay, as shown on plate 2, is relatively unfavorable for more than rural and domestic supplies except at places where the thicker portions of the beach sands overlie the lake clay. These sandy deposits are generally thin and not dependable as perennial sources of supply.

The differences in ground-water yield for the general areas shown in figure 19 correlate closely with the occurrence of the several types of the glacial deposits described. Locally these differences may be modified because of variations in the permeable nature of the deposits.

The bedrock aquifers are not favorable as potential sources of supply because they contain water of poor chemical quality throughout almost all the Detroit area. Further, the rocks generally yield small quantities of water to wells and therefore are not favorable sources for cooling water which is generally required in large volumes.

WATER LAWS

Water laws applicable to the area deal mostly with pollution and obstructions to navigation. However, Michigan has a law restricting unreasonable waste from flowing wells.

The control of pollution is divided among the Federal governments of the United States and Canada, the State government of Michigan, the Provincial government of Ontario, and municipalities. The United States laws prohibit the deposition of "any refuse matter of any kind or description whatever other than that flowing from streets and sewers and passing therefrom in a liquid state, into any navigable water of the United States or any tributary of any water from which the same shall float or be washed into such navigable water." However, in certain restricted areas dumping of certain kinds of materials can be authorized by permit from the Corps of Engineers, Department of the Army.

The Michigan Water Resources Commission has control over the pollution of any water of the State. Section 8B of the act creating the Michigan Water Resources Commission states, "***it shall be the duty of any person *** requiring a new or substantial increase over and above the present use now made of the waters of the state for sewage or waste disposal purposes, to file with the Commission a written statement setting forth the nature of the enterprise or development contemplated, the amount of water required to be used, its source, the proposed point of discharge of said wastes into the waters of the state, the estimated amount so to be discharged, and a fair statement setting forth the expected bacterial, physical, chemical, and other known characteristics of said wastes." For a more complete discussion of the laws governing pollution of boundary waters reference is here made to the report of the International Joint Commission on the Pollution of Boundary Waters, 1951, pages 54-56.

The laws concerning navigation are both federal and state. The Federal laws are intended to prevent any possible obstruction to navigation in waters that are declared navigable by the Department of the Army and require the approval of that Department before any such construction can be made. The State laws require only the approval of the county board of supervisors before any dam or other obstruction is built in waters not controlled by the Department of the Army. The navigable waters in this area as recognized by the Department are Lake St. Clair, Detroit River, a portion of the Clinton River below Mt. Clemens, and the River Rouge to the upper limits of the turning basin.

The only State law dealing with the use of ground waters is Act 107, P. A. 1905, which provides for the restriction of "unreasonable" waste flows from artesian or flowing wells, which damage other wells supplied from the same head or reservoir. The difficulty of defining what is unreasonable in any case, and of proving that any particular waste flow is responsible for the damage seems to render the law unworkable. No case is known in which Act 107 has been utilized.

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