GEOLOGICAL SURVEY CIRCULAR 174

WATER RESOURCES OF THE LAKE ERIE SHORE REGION IN PENNSYLVANIA

By John W. Mangan, Donald W. Van Tuyl, and Walter F. White, Jr.

UNITED STATES DEPARTMENT OF THE INTERIOR
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GEOLOGICAL SURVEY
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Based on data collected in cooperation with the Pennsylvania Department of Forests and Waters, Pennsylvania Department of Internal Affairs, and Pennsylvania State Planning Board, Department of Commerce

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INTRODUCTION

An abundant supply of water is available to the Lake Erie Shore region in Pennsylvania. Lake Erie furnishes an almost inexhaustible supply of water of satisfactory chemical quality. Small quantities of water are available from small streams in the area and from the ground.

A satisfactory water supply is one of the factors that affect the economic growth of a region. Cities and towns must have adequate amounts of pure water for human consumption. Industries must have suitable water in sufficient quantities for all purposes. In order to assure success and economy, the development of water resources should be based on adequate knowledge of the quantity and quality of the water. As a nation, we can not afford to run the risk of dissipating our resources, especially in times of national emergency, by building projects that are not founded on sound engineering and adequate water-resources information.

The purpose of this report is to summarize and interpret all available water-resources information for the Lake Erie Shore region in Pennsylvania. The report will be useful for initial guidance in the location or expansion of water facilities for defense and nondefense industries and the municipalities upon which they are dependent. It will also be useful in evaluating the adequacy of the Geological Survey's part of the basic research necessary to plan the orderly development of the water resources of the Lake Erie Shore region.

Most of the data contained in this report have been obtained by the U. S. Geological Survey in cooperation with the Pennsylvania Department of Forests and Waters, the Pennsylvania Department of Internal Affairs, and the Pennsylvania State Planning Board, Department of Commerce. The Pennsylvania Department of Health furnished information on water pollution.

The report was prepared in the Water Resources Division of the U. S. Geological Survey by John W. Mangan (Surface Water), Donald W. Van Tuyl (Ground Water), and Walter F. White, Jr. (Quality of Water), under the general direction of C. G. Paulsen, chief hydraulic engineer.

Definition of Terms

The records for quantities of water as presented in this report are in units of both million gallons per day (mgd) and cubic feet per second (cfs). Second-feet was formerly used in Geological Survey reports as an abbreviation of cubic feet per second.

A cubic foot per second is the rate of discharge equivalent to that of a stream whose channel is 1 sq ft in cross-sectional area and whose average velocity is 1 cfs.

Cubic feet per second per square mile (csm) is the average number of cubic feet of water flowing per second from each square mile of area drained, on the assumption that the runoff is distributed uniformly as regards time and area.

1 cfs = 646,317 gpd.
1 mgd = 1.55 cfs.

The results of chemical analyses are reported in parts per million (ppm). One part per million is a unit weight of a constituent present in a million units weight of water.

Population and Land Area

The area covered by this report is a 46-mile strip along Lake Erie averaging about 6 miles in depth (see fig. 1). It lies in Erie County, Pa., extending from the New York border to the Ohio border and contains the highly industrialized city of Eire-Pennsylvania's third largest city. It also contains the rich agricultural lake shore belt which is noted principally for its vineyards and orchards. Seven townships and seven boroughs are included in the area. Data for these political subdivisions are given in table 1.

Physical Features

The region is distinct from others found in Pennsylvania. A steep bluff composed mainly of glacial till overlying bedrock rises abruptly at the shore of Lake Erie to as much as 150 ft above the lake. For a distance of about 2 miles inland from the lake, the surface

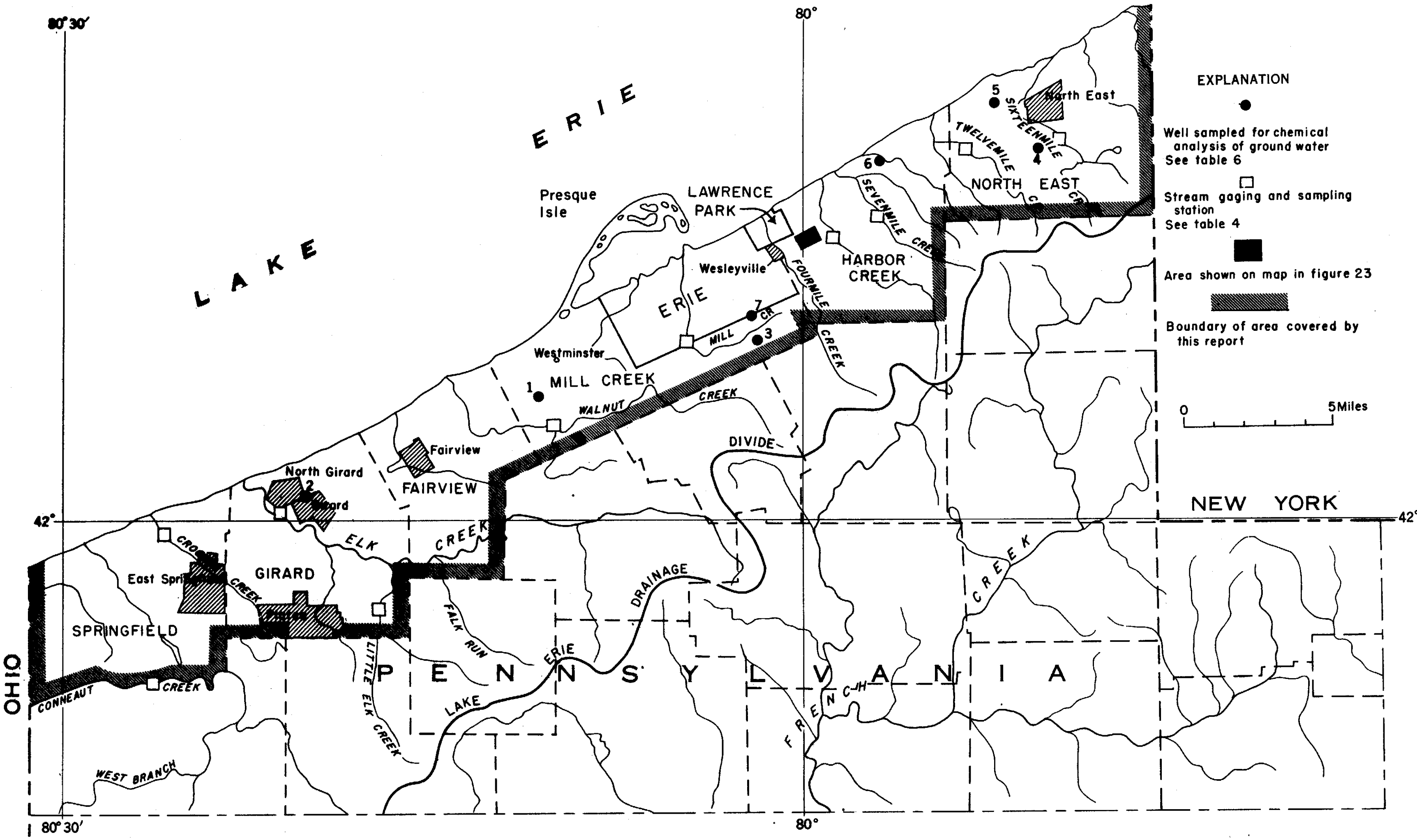

Figure 1. -Map showing sources of water for the Lake Erie Shore region in Pennsylvania.

Table 1. -Area and population of political subdivisions

Subdivision	Population				Land Area	
	1940[a]	1950[a]	Employed in industry[b]	Rural farm[a] 1940	Total square miles[a]	Percent forested[c]
Springfield Township	1,394	1,775	0	850	[d] 34.4	25 (with East Springfield Borough)
East Springfield Borough	415	499	3	160	[d] 3.6	
Girard Township	1,552	2,149	9	985	[d] 34.1	24 (Girard Township through Platea Borough)
Girard Borough	1,732	2,141	1,395	44	1.4	
North Girard Borough	1,108	1,369	475	51	1.3	
Platea Borough	281	290	3	146	[d] 3.4	
Fairview Township	1,479	2,328	1	838	[d] 28.2	20 (with Fairview Borough)
Fairview Borough	555	697	33	37	[d] 1.2	
Mill Creek Township	7,444	17,037	160	687	40.5	24
City of Erie	116,955	130,803	40,377	0	18.0	15
Lawrence Park Township	3,120	4,154	53	8	1.7	8 (with Wesleyville Borough)
Wesleyville Borough	2,918	3,411	0	0	.4	
Harborcreek Township	3,602	7,475	7	647	34.6	23
North East Township	2,400	3,083	0	1,900	42.9	21 (with North East Borough)
North East Borough	3,704	4,247	967	0	1.2	
Total	148,659	180,675	43,483	6,353	246.9	22

a U. S. Census Bureau.
b Thirteenth Industrial Directory of Pennsylvania (1949); Dept. of Internal Affairs.
c Pennsylvania Dept. of Forests and Waters.
d Areas obtained by map measurement in three instances where census data listed area of two civil divisions combined.

is a relatively flat plain. The flatness of the plain is broken by successions of terraces and beach ridges that were formed during the last glacial epoch when the lake stood at higher levels. A steep slope begins from 3 to 4 miles from the lake beyond which the land rises gradually into rolling hills which extend to the watershed divide.

Presque Isle. -Presque Isle peninsula is worthy of special note because it has played and always will play a significant role in the development of the region. Erie Harbor is landlocked by Presque Isle peninsula, thereby making the harbor an important lake port.

The peninsula is a sandy formation 7 miles long and about 1 mile wide. It was formed by sand and gravel washed from the bluffs and accumulated at this point in a recurved sandspit. Sand and gravel washed eastward by waves resulting from the prevailing west wind are extending the shore line of the peninsula eastward at a rate estimated as 1 mile every 200 yr.

Pennsylvania acquired title to the peninsula in 1921 for use as a State park. Presque Isle is used primarily for recreation. It consists of 3,200 acres, much of which is in virgin timber. It contains 11 miles of concrete highways, 15 miles of trails for hiking and horseback riding, and 7 miles of lake shore for bathing, fishing, and boating.

Natural resources. -Except for water, the region is not rich in mineral resources. Although some rock formations that produce oil in counties to the east and south are known to underlie the glacial drift of the region, no oil has been produced from them in Erie County. In a belt about 4 miles wide adjoining the lake front, small natural-gas wells producing 10,000 to 100,000 cu ft per day provide fuel for many farms and households and a few small industries. Extensive deposits of sand and gravel in the old lake terraces have been worked for many years and large reserves still remain. A small amount of sandstone is quarried for building purposes. Some shales have been used successfully for making brick and tile.

Transportation

Erie is noted primarily for its lake commerce. Erie Harbor handled 6,390,612 gross tons of lake shipping in 1949. The commerce consisted principally of iron ore, coke, wheat, and pulpwood. The lake is usually icebound each winter from mid-December to the end of March.

There are good railroad facilities. The east-west main lines of the New York Central and the New York, Chicago, and St. Louis Railroads follow closely along the Lake Erie shore, and traverse the entire region. The Bessemer and Lake Erie and the Pennsylvania Railroads are connecting links with Pittsburgh and the South. Of these railroads, only the Pennsylvania Railroad serves Erie Harbor directly.

U. S. Highway 20 and Pennsylvania State Highway 5 parallel the shore line and cross the region. A good network of improved highways connects all parts of the region to the South.

Although the city of Erie is not served by major transcontinental air routes, daily passenger service is maintained by American and Capital Airlines.

Climate

The climate of the region is greatly influenced by Lake Erie. The temperature of the air during the fall and winter is moderated as the air moves over the warmer waters of the lake (see table 2). This warming effect is most noticeable within 5 miles of the shore line and disappears entirely 10 to 15 miles inland. For this reason vineyards and orchards are concentrated along this narrow strip of lake shore. The slow warming of the lake water surface during the spring delays the start of the growing season, and the warmer water of the lake in late summer prolongs the normal growing season for this latitude. The average date of the first killing frost in autumn is November 1 and the average date of the last killing frost in spring is April 20.

The lake not only retards the beginning and ending of the growing season and moderates extremes of heat and cold throughout the year, but also is responsible for the small daily temperature range. Days with less than 5 degrees temperature range are common during winter. The daily temperature range is seldom more than 10 or 15 degrees during summer. Low cloud formations from late autumn through early spring aid in keeping daily temperature range to a minimum. During periods of clear or partly cloudy weather when wind velocity is light, a northerly lake breeze builds up during the day and prevents high afternoon temperatures. Under such conditions, the highest temperature of the day usually occurs before noon.

The supply of fresh water available to a region determines the degree of cultural and economic development of that region. Fortunately, the water supply of the Lake Erie Shore region is independent of local precipitation owing to adjacent Lake Erie. The average annual precipitation over the Erie region is 37.21 in. compared with 42.16 in. over Pennsylvania as a whole. The average distribution of precipitation and snowfall during the average year is given in table 2. Excesses and deficiencies in precipitation can be expected to occur from time to time in any region. The unusual conditions create floods and droughts. They have occurred in the Lake Erie Shore region but are rarely as severe or as frequent as in many other parts of Pennsylvania.

Floods.–Three major floods have occurred in this area.

August 3, 1915: The most destructive flood of record on Mill Creek at Erie occurred on this date. Twenty-three lives were lost and property damage was estimated at more than two million dollars. The total rainfall was 5.40 in. in less than 24 hr. Elaborate protective structures have been built as a result of this flood. Mill Creek waters are now carried through Erie in closed conduits. The peak discharge during this flood was measured at two sites by the Pennsylvania Department of Forests and Waters. The results are given with the records of Mill Creek on page 18.

March 16, 1942: A local storm occurred in the vicinity of North East. The result of a slope-area measurement of the peak flow of Sixteenmile Creek is given on page 26.

July 22, 1947: The U. S. Weather Bureau reported that 10.42 in. of rain fell in a 19-hr period at their Erie city office. Of this amount, 6.32 in. fell in 3 hr and 8.90 in. in 5 hr. Although the official records show that the total was by far the greatest ever recorded in a 24-hr period at this place, unofficial records indicate that the Weather Bureau office was outside the focal point of the storm. A maximum of 24 in. was measured in a 50-gal oil drum located in Lawrence Park Township on U. S. Highway 20 between Parker Drive and Maple Road. The storm was concentrated over a relatively small area. The rainfall at Port Erie airport 6 miles from the center of Erie was only 3.70 in. and less than 2 in. was recorded beyond a 20-mile radius.

No lives were lost. The severe flooding was confined to the vicinity of lower Sixteenth and Franklin Streets and caused property damage estimated at $250,000. The greatest damages resulted where sewers and drainage structures could not carry the flow. About 6 in. of rain fell on the Mill Creek area near the entrance to the conduit. However, water was confined within the conduit and no damage in that area

Table 2.–Precipitation and temperature at Erie, Pa. (U. S. Weather Bureau)

Month	Precipitation (1874-1950)			Precipitation 1951 (inches)	Average depth of snow (inches)	Average air temperature 1874-1950 (°F)
	Maximum (inches)	Minimum (inches)	Average (inches)			
January	6.25	0.85	2.77	3.59	12.4	28
February	8.50	.33	2.48	3.09	10.5	27
March	7.36	.53	2.74	4.10	7.9	34
April	8.88	.74	2.95	4.28	2.8	45
May	8.05	.55	3.38	2.78	.1	57
June	6.84	.99	3.29	4.17	0	67
July	13.27	.39	3.29	2.13	0	72
August	9.28	.07	3.10	1.26	0	70
September	8.45	.54	3.51	2.93	T	64
October	8.17	.02	3.60	2.25	1.3	54
November	8.93	.40	3.36	4.61	7.2	42
December	6.44	.66	2.74	4.75	12.0	32
Annual	[a] 55.04	[b] 23.84	37.21	39.94	54.2	49

a In 1878 b In 1934 T Trace

was reported. The discharge of Mill Creek during this flood was not measured.

Droughts. -A deficiency in precipitation of about 24 in. accumulated between June 1932 and the summer of 1934. This resulted in serious drought conditions in 1934. Many of the small streams were dry and the ground-water supply was badly depleted. Some crops were seriously damaged or failed completely.

Long periods without rainfall over the region are rare. Usually a heavy shower may be expected every few days. Past records indicate that during the critical growing season protracted dry spells about 3 weeks' duration occur about every 5 yr. On these occasions some crops will suffer and some inconvenience may be caused to the rural population for short periods.

SOURCES OF WATER

The supply of fresh water available is dependent upon precipitation. Water in the lakes, streams and beneath the land surface is moving through a phase of the hydrologic cycle - the path of water from the atmosphere to land and water bodies and back to the atmosphere - mainly from the ocean, through evaporation.

The weathered zone of the earth's surface constitutes a vast regulating reservoir for the water that falls on the land. At times the rate of precipitation exceeds the rate at which water can enter the soil, and a part of the precipitation flows over the ground into the streams. The water that percolates into the ground replenishes the shallow zone of soil water that supports vegetation, and the water not held in this zone continues to move by gravity to the zone of saturation, the upper surface of which is the water table. The ground-water reservoir is not static, but inflow and outflow constantly seek to reach equilibrium - adding more flow to the streams when storage is high, and less flow after periods of little or no infiltration from precipitation.

The water resources available to the region consist of adjacent Lake Erie, several small streams, and ground water. Because of the great volume of water stored in Lake Erie, local precipitation is of less importance in the water supply of the region than in many other localities.

SURFACE WATER

Lake Erie is the major source of water supply for the area and will be the dominant factor in any large-scale water utilization in the future. For practical planning, the lake may be considered an inexhaustible supply of fresh water independent of local precipitation. Many small streams are distributed throughout the region, all tributary to Lake Erie. In contrast to the lake supply, the flow of the streams varies greatly, as the flow is directly related to local precipitation and ground-water discharge.

Lake Erie

In preglacial time a great river flowed east through what is now the Lake Erie basin. When the glaciers came into the area they pushed their way up this valley. They gouged deeply into the soft shales to the east and carved deep grooves in the hard limestone at Sandusky Bay and Kellys Island to the west. Lake Erie and the other Great Lakes were formed by the melting of these continental ice sheets late in the geologic history of North America. Billions of tons of rock and gravel were released and left piled in terminal moraines as much as 500 ft high. As the ice-front retreated from northeastern United States the meltwater ponded against the ice-front, escaping first to the west along the edge of the ice to the Mississippi River and later across New York State to the Hudson River. Lake Erie then began its slow transformation to its present shore lines.

Of the five Great Lakes, Lake Erie is fourth in size. Only Lake Ontario is smaller. Lake Erie is 241 miles long and is 57 miles wide at its widest point. It has a water-surface area of 9, 940 sq mi—about the same size as the State of Maryland. It is the shallowest of the Great Lakes, having a maximum depth of 210 ft as compared with a depth of 1, 290 ft in Lake Superior. The runoff from 34, 680 sq mi of its bordering land drains directly into Lake Erie and at its head it receives the flow of the Detroit River which drains Lakes Superior, Michigan, and Huron. The total drainage area above the head is 230, 415 sq mi. Lake Erie is the one dominating factor in the agricultural and industrial development of the region, its use restricted only by the costly intake and pumping facilities which must be provided.

Erie harbor. -The harbor is located in the bay formed by Presque Isle peninsula and the mainland, with the entrance opening to the east. At the present time, there is an authorized Federal deep-draft navigation project for the maintenance of Erie Harbor. It provides for depth and anchorage facilities for lake carriers loaded to drafts of 24 ft. Complete information on navigation facilities at Erie may be obtained from the Buffalo District, Corps of Engineers.

Beach erosion. -For centuries the waters of Lake Erie have been continually undermining the steep cliffs overlooking almost its entire shore line causing valuable land to crumble into the lake. Erosion as related to Erie Harbor, however, is a particularly serious problem. Within recent years, the harbor has required considerable improvement and maintenance owing to shore erosion processes which have threated to cause a breach in the narrow neck at the west end of Presque Isle peninsula. If this did occur the entrance channel on the eastern end of the peninsula would fill up and result in prohibitive costs for channel maintenance.

The Corps of Engineers, Buffalo District, is now making a beach erosion-control study with recommendations for the permanent protection of Presque Isle. The report when completed will be submitted to Congress with recommendations for or against a Federal-State cooperative project. In the meantime, the

Pennsylvania Department of Forests and Waters is taking emergency measures. During the fall of 1951 it began riprapping 1,700 ft of shore along the neck of the peninsula.

Elevations.-Lake Erie has gone through many stages and has been at various levels since the glacial era. The general trend in level has been a gradual decline. The earliest level may have been 300 ft or more higher than it is today.

Continuous long-term records of the lake elevation at Erie are not available. Records obtained at Cleveland over the 91-yr period (1860-1950) have been furnished by the Buffalo District, Corps of Engineers (see fig. 2).

The maximum monthly elevation recorded was 574.51 ft in June 1876; the minimum monthly elevation was 569.43 ft in February 1936. Normally, the annual fluctuation in lake elevation is about 2 ft. The mean elevation during the period 1860-1950 was 572.30 ft. Elevations are in feet above mean sea level, Sandy Hook datum.

Pollution.-Industrial growth in the Erie area during the past few years has presented a waste-disposal problem. At the present time, waste-treatment

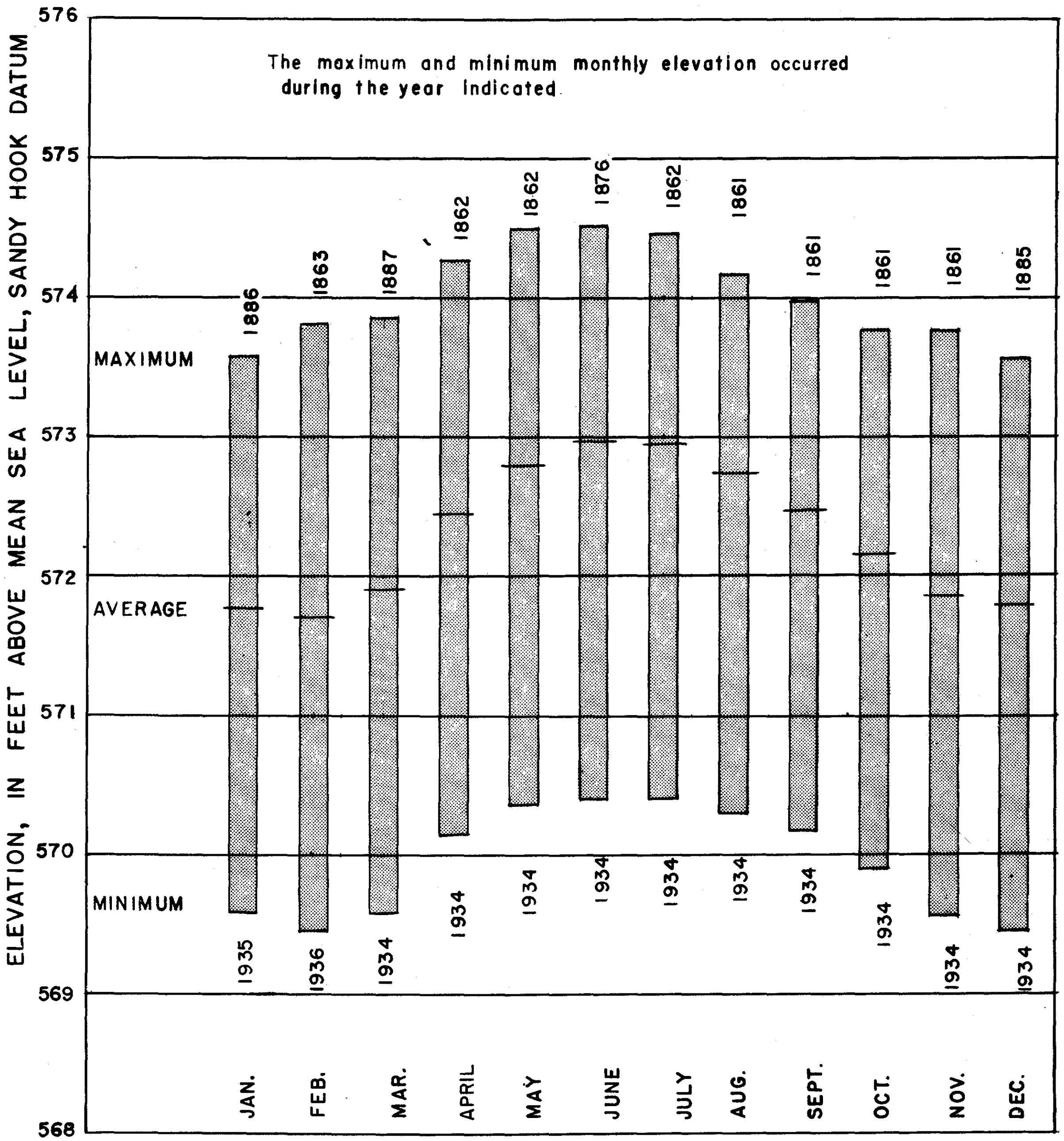

Figure 2.-Average maximum and minimum monthly elevations of Lake Erie at Cleveland, Ohio.

facilities provided by the city of Erie are not adapted to this increased load. Investigations are under way to work out plans for improving the existing system. The city of Erie has a plant for the partial treatment of its sewage and of some received from outside areas. The outfall from the plant extends about 4,800 ft into the lake to the east of Presque Isle Bay. The sewage is chlorinated before being discharged into the lake. This precaution was found necessary because of extensive use now made of the north side of the Presque Isle lake front for bathing purposes.

Three large industries along the lake front in the northeastern section of Erie discharge their wastes into the lake. The treatment now provided by two of the industries is satisfactory. The other plant is now under orders from the Pennsylvania Sanitary Water Board to improve its treatment of waste.

According to the April 1951 interim report of the Ohio Department of Natural Resources, the waters along the shores of Lake Erie in Ohio, notably in the Cleveland area, are seriously contaminated by sewage pollution. Conditions in Ohio at present appear to create no major pollution problems along the lake shore in Pennsylvania although the prevailing movement of the lake water is toward Pennsylvania.

Chemical quality.—Chemical analyses of water from Lake Erie indicate that the chemical character of water is relatively constant. Although increases in concentrations shown for such constituents as sulfate and chloride appear to indicate a slight upward trend, the three analyses are too few for confirmation. See the following tabulation.

	Chemical analyses (ppm) on date indicated		
	March 18, 1934	July 5, 1945	July 26, 1951
Silica (SiO_2)	1.0	1.0	1.5
Iron (Fe)	.01	.01	-
Calcium (Ca)	34	34	37
Magnesium (Mg)	8.0	7.9	8.9
Sodium (Na)	5.7	7.2	9.4
Potassium (K)	1.1	1.1	.6
Carbonate (CO_3)	0	0	0
Bicarbonate (HCO_3)	109	107	108
Sulfate (SO_4)	19	20	24
Chloride (Cl)	14	18	20
Fluoride (F)	-	.1	.0
Nitrate (NO_3)	1.0	1.0	.4
Dissolved solids	147	160	177
Hardness as $CaCO_3$:			
Total	118	117	129
Noncarbonate	28	30	40
Color	-	-	2
pH	-	7.9	7.8
Specific conductance (micromhos at 25 C)	-	271	300
Temperature (°F)	-	-	73

Water temperature.—The following monthly and annual mean temperatures of water from Lake Erie were obtained by the city of Erie Bureau of Water at the Chestnut Street pumping station (1918-50). The water enters the intake about 3 miles from the pumping station, at depths ranging from 20 to 46 ft. The maximum monthly mean recorded was 77 F in August 1938. Maximum daily temperatures of 79 F were observed on July 25, 26, 1935, August 16, 1938, August 12, 1940, and August 11, 1949. The mean annual temperature is 52 F.

Table 3.—Average monthly temperature of raw water from Erie public supply

Month	Temperature (F)	Month	Temperature (F)
January	36	July	70
February	35	August	73
March	36	September	69
April	42	October	60
May	51	November	50
June	62	December	40

Streams

The streams in the region rise in gently rolling hills, flow through valleys cut in glacial drift and alluvial deposits and empty into Lake Erie. Channels become narrow in their lower courses, as they cut through the high cliff near the lake, changing to deep ravines through shale and sandstone as they approach the lake.

A complete list of the streams, tributaries to Lake Erie, with their respective drainage areas within Pennsylvania is shown in table 4.

No permanent gaging stations have been maintained in the area covered by this report. One discharge measurement each year since 1944 has been obtained on Mill and Walnut Creeks. Discharge measurements were obtained at regular intervals at selected sites on ten streams within the region during the summer and fall of 1951. Temporary gages were installed, the stage-discharge relationships established, and daily

Table 4. -Drainage area of streams in the Lake Erie Shore region of Pennsylvania

Stream	Drainage area In Pennsylvania (sq mi)	Drainage area Total (sq mi)
Lake Erie basin:	512	
Ashtabula River	8.5	136
Conneaut Creek	153	191
West Branch Conneaut Creek	30.4	31.4
Turkey Creek	8.99	9.71
Raccoon Creek	8.95	*
Crooked Creek	21.2	*
Elk Creek	101	*
Little Elk Creek	22.0	*
Brandy Run	4.48	*
Trout Run	5.88	*
Walnut Creek	36.1	*
Cascade Creek	8.0	*
Mill Creek	13.6	*
Fourmile Creek	11.5	*
Sixmile Creek	18.2	*
Sevenmile (Ellicott) Creek	8.70	*
Eightmile Creek	7.49	*
Twelvemile Creek	16.9	*
Sixteenmile Creek	18.4	18.9
Twentymile Creek	1.4	36.9

*Total drainage area lies within Pennsylvania.

records of discharge computed for the period June to September 1951 on four of the most important of these streams.

The probable variation in flow during times of low discharge for nine of the ten streams was computed by correlating the miscellaneous discharge measurements or records of daily flow with continuous discharge records for stations on Conneaut Creek at Amboy, Ohio, Cattaraugus Creek at Gowanda, N. Y., or Sugar Creek at Sugarcreek, Pa. The stations at Amboy, Ohio and Gowanda, N. Y. are on streams that also drain the Lake Erie Shore region. Although Sugar Creek is in the Allegheny River basin, the record compares relatively well with many of the records for the Erie region streams. The probable variation in low flow are shown by flow-duration curves (figures 3, 5, 7, 9, 11, 13, 15, 17, and 19) and curves showing discharge available without storage (figures 4, 6, 8, 10, 12, 14, 16, 18, and 20). The flow-duration curves show the percent of time that a specified daily discharge may be expected to be equalled or exceeded. The curves showing discharge available without storage show the longest period of time that the daily discharge may be expected to remain less than a specified amount.

Data for Sixteenmile Creek at North East, Pa., do not correlate well with those for Conneaut Creek, Cattaraugus Creek, or Sugar Creek. This may be caused by diversion from and into the headwaters of this stream for the municipal water-supply system of the borough of North East.

No permanent stations for the collection of temperatures or chemical quality data have been maintained in the area. Complete chemical analyses were made of samples of water obtained from Mill and Conneaut Creeks in February and August 1946. During the summer and fall of 1951 the waters of ten of the region's streams were sampled at regular intervals at selected sites and chemically analyzed. Temperature readings have been made whenever a discharge measurement was made or a water sample collected.

Pertinent data for each of the ten streams follow:

Conneaut Creek

Eight discharge measurements were made during 1946 and 1951, at double-span concrete highway bridge on U. S. Highway 6N, 0.5 mile northwest of Cherry Hill, Erie County, Pa. (lat 41°55'00'', long 80°27'15''). The drainage area at this point is 149 sq mi.

Discharge. -The average discharge for the period 1922-35 was 186 cfs (1.25 csm) estimated from discharge measurements and records for Conneaut Creek at Amboy, Ohio.

No data concerning floods at this site are available. During the period 1922-35 a maximum discharge of 6,160 cfs or 25 csm occurred December 1, 1927 and January 19, 1929 at Amboy, Ohio. The drainage area at Amboy is 178 sq mi.

Minimum discharge measured was 4.68 cfs or 0.031 csm on September 7, 1951. (At Amboy, Ohio, during period 1922-35, a minimum discharge of 0.2 cfs or 0.001 csm occurred on July 31, August 1, 1933; August 1, 2, 1934). Figures 3 and 4 show the low-flow characteristics of the stream.

Chemical quality. -Seven chemical analyses of water were made, two in 1946 and five in 1951. Maximum and minimum concentrations in parts per million are given on page 10.

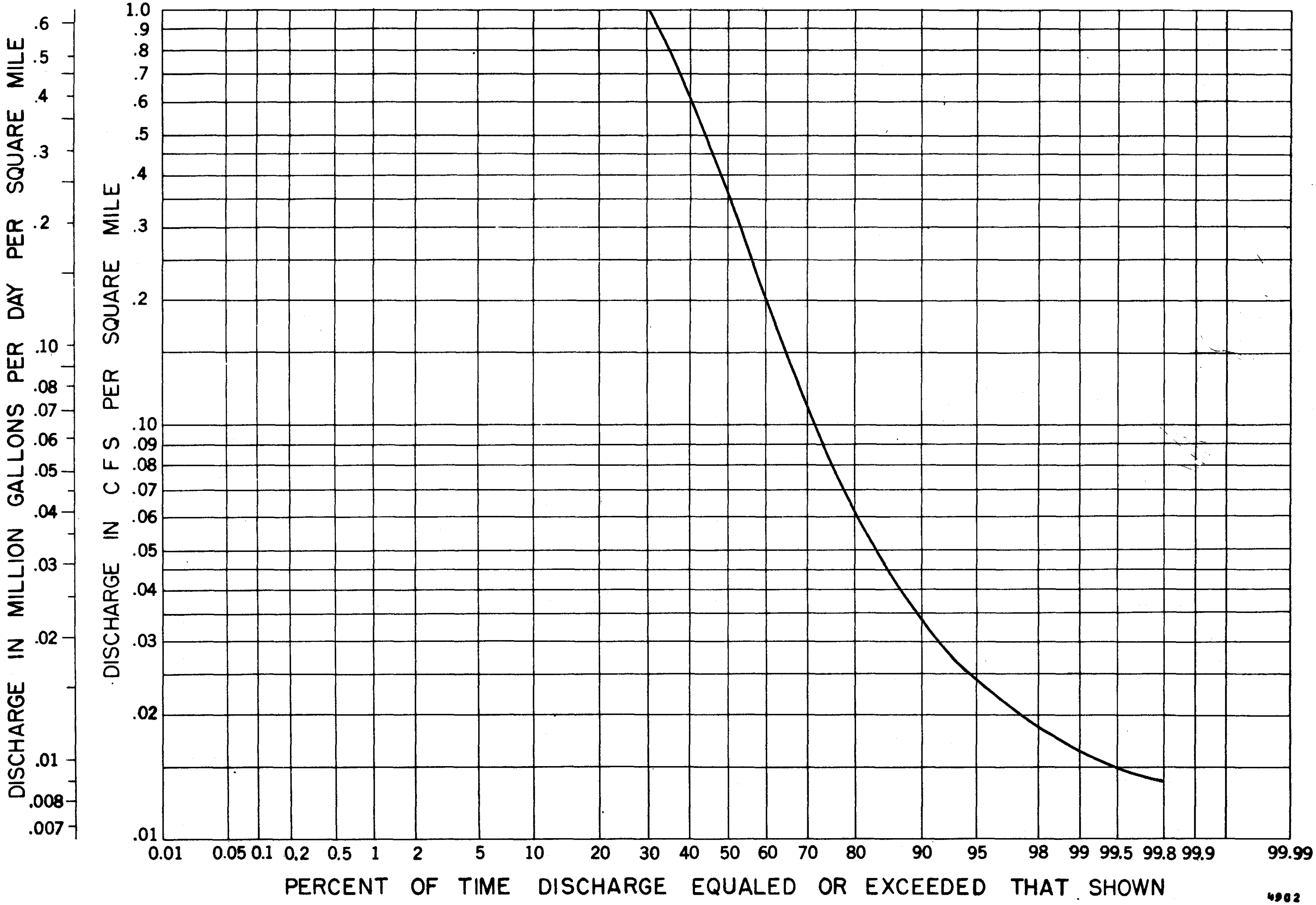

Figure 3.–Flow-duration curve for Conneaut Creek at Cherry Hill.

	Maximum	Minimum
Specific conductance (micromhos at 25 C)	461	142
pH	7.8	6.7
Color	13	4
Hardness as $CaCO_3$	142	56
Bicarbonate	132	32
Sulfate	41	28
Chloride	53	4.6
Nitrate	2.7	.5

Two complete analyses are given in table 5.

Temperature. -The maximum temperature measured was 83 F on July 25, 1951; the minimum was 32 F on February 27, 1946.

Pollution. -There is some pollution caused by the effluent from a pickle plant at Springboro, Crawford County, near the headwaters of Conneaut Creek. A milk plant at Crawford provides complete treatment of its effluent. **The borough of Albion, Erie County, discharges partially treated sewage into East Branch Conneaut Creek.**

Crooked Creek

Six discharge measurements were made during 1951, at the single-span concrete bridge on Pennsylvania Highway 5, at North Springfield, Erie County (lat 41°59'35", long 80°25'15"). The drainage area is 17.3 sq mi at this point.

Discharge. -The average discharge for the period 1932-50 was 26 cfs (1.5 csm) estimated from 6 discharge measurements and records for Sugar Creek at Sugarcreek, Pa. Figures 5 and 6 show the low-flow characteristics of the stream.

Chemical quality. -Five chemical analyses of water were made in 1951. Maximum and minimum concentrations in parts per million are given on page 13.

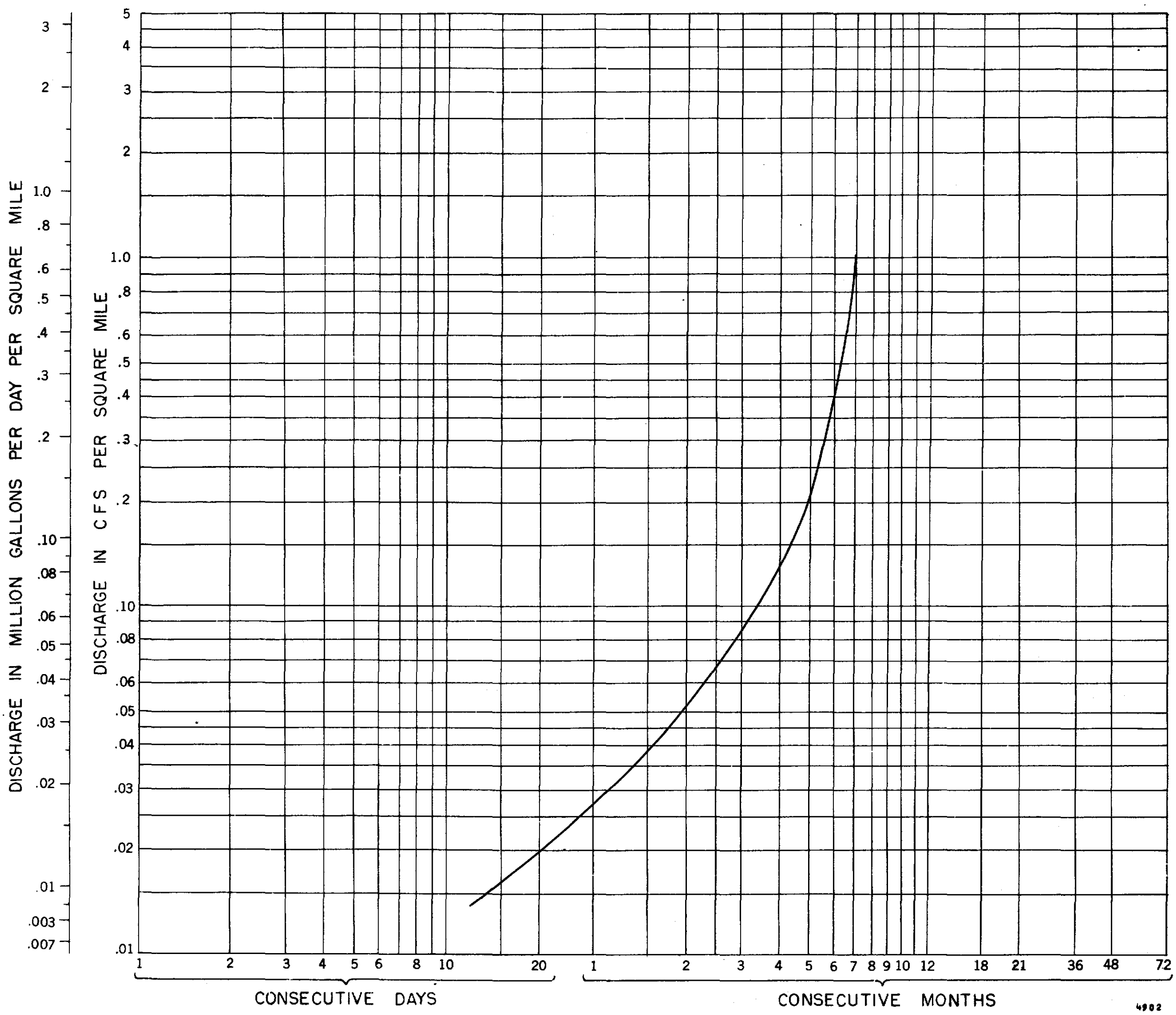

Figure 4. -Discharge available without storage in Conneaut Creek at Cherry Hill.

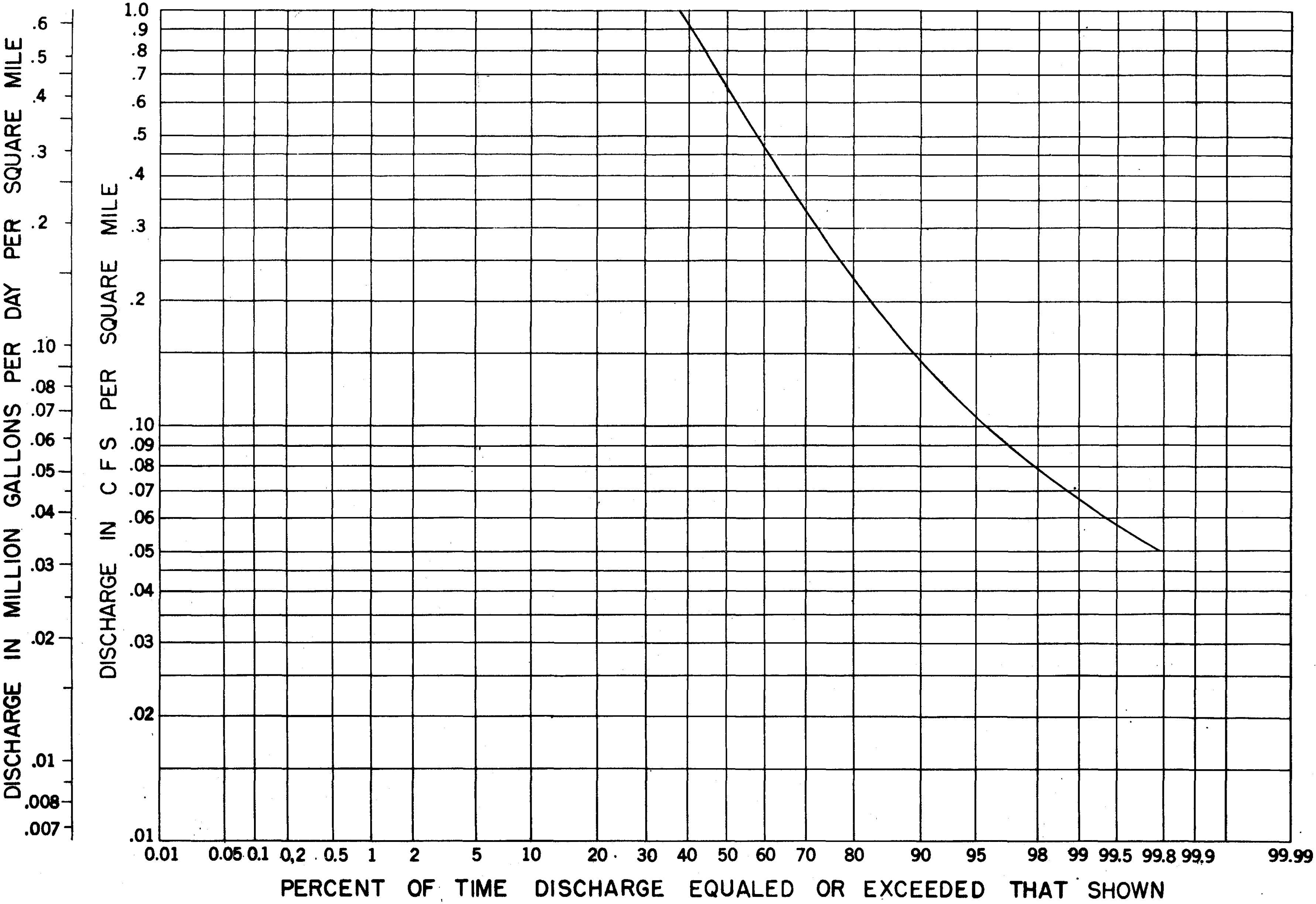

Figure 5. –Flow-duration curve for Crooked Creek at North Springfield.

Table 5. -Chemical analyses of selected surface waters in Lake Erie Shore region, 1951
(parts per million)

	Conneaut Creek at Cherry Hill, Pa.		Crooked Creek at N. Springfield, Pa.		Elk Creek at North Girard, Pa.		Little Elk Creek near Platea, Pa.	
	June 14	Aug. 13	June 14	Aug. 13	June 14	Aug. 13	June 14	Aug. 13
Silica (SiO_2)	4.4	2.1	8.2	7.1	3.9	5.3	3.2	1.6
Iron (Fe)	.03	.04	.37	.04	.02	.06	.05	.08
Calcium (Ca)	36	38	37	47	19	58	12	35
Magnesium (Mg)	8.2	9.9	6.8	8.7	4.0	13	2.6	8.5
Sodium (Na)	15	11	2.8	6.0	3.0	16	1.0	8.9
Potassium (K)	2.1		1.1		1.6		1.4	
Bicarbonate (HCO_3)	111	123	101	118	43	152	25	60
Sulfate (SO_4)	34	41	35	50	27	68	20	69
Chloride (Cl)	24	9.5	5.0	7.5	3.8	24	1.8	14
Fluoride (F)	.1	.1	.1	.1	.1	.1	.1	.1
Nitrate (NO_3)	1.2	1.5	2.4	1.9	2.4	3.2	1.6	.9
Dissolved solids	190	183	168	210	100	287	72	194
Hardness as $CaCO_3$:								
Total	124	136	120	153	64	198	41	122
Noncarbonate	33	35	38	51	29	72	20	73
Color	4	6	3	5	7	0	4	5
pH	7.8	7.8	8.0	8.2	7.5	8.0	7.2	7.7
Specific conductance (micromhos at 25 C)	331	307	262	324	153	459	97.9	298
Temperature (°F)	67	79	60	75	66	77	63	71
Mean discharge (cfs)	177	5.18	26.0	2.94	200	3.01	35.0	.05

	Walnut Creek at Weis Library, Pa.		Raccoon Creek near W. Springfield, Pa.	Trout Run at Avonia, Pa.	Fourmile Creek at Wesleyville, Pa.
	June 14	Aug. 13	Sept. 5	Sept. 5	Sept. 5
Silica (SiO_2)	4.8	2.6	6.8	6.2	2.4
Iron (Fe)	.07	.06	.10	.10	.08
Calcium (Ca)	31	42	49	53	47
Magnesium (Mg)	6.6	10	9.4	11	11
Sodium (Na)	3.9	6.1	3.4	2.3	6.0
Potassium (K)	1.5				
Bicarbonate (HCO_3)	83	123	127	141	103
Sulfate (SO_4)	31	45	53	48	69
Chloride (Cl)	8.8	6.8	5.5	8.0	10
Fluoride (F)	.1	.1	.1	.1	.1
Nitrate (NO_3)	1.4	2.0	1.5	6.7	1.9
Dissolved solids	146	192	208	240	224
Hardness as $CaCO_3$:					
Total	104	146	161	178	162
Noncarbonate	36	45	57	62	75
Color	6	4	7	5	7
pH	7.7	7.9	7.8	7.8	8.0
Specific conductance (micromhos at 25 C)	236	308	319	359	343
Temperature (°F)	64	71	65	64	68
Mean discharge (cfs)	18.6	1.56	.45	2.30	.48

Table 5. -Chemical analyses of selected surface waters in Lake Erie Shore region-Continued

	Mill Creek at Erie, Pa.		Sixmile Creek near Harborcreek, Pa.		Sevenmile Creek near Harborcreek, Pa.	
	June 15	Aug. 13	June 15	Aug. 13	June 15	Aug. 13
Silica (SiO_2)	5.8	4.2	3.0	2.9	5.7	3.6
Iron (Fe)	.08	.06	.03	.08	.04	.06
Calcium (Ca)	41	50	31	38	30	39
Magnesium (Mg)	8.4	11	5.8	7.5	5.4	7.8
Sodium (Na)	5.7	7.1	3.2	6.2	2.4	3.4
Potassium (K)	1.4				2.0	
Bicarbonate (HCO_3)	114	145	89	94	84	108
Sulfate (SO_4)	41	50	29	52	25	36
Chloride (Cl)	7.8	9.0	3.0	5.0	4.8	6.5
Fluoride (F)	.1	.1	.1	.1	.1	.1
Nitrate (NO_3)	2.5	2.0	.8	.7	1.1	1.6
Dissolved solids	186	220	128	172	129	165
Hardness as $CaCO_3$:						
Total	137	170	101	126	97	129
Noncarbonate	43	51	28	49	28	41
Color	6	6	4	3	6	4
pH	8.2	7.8	8.0	7.7	7.9	7.7
Specific conductance (micromhos at 25 C)	300	355	218	279	215	274
Temperature (°F)	67	69	72	74	65	71
Mean discharge (cfs)	4.19	1.06	9.77	0.90	1.43	.21

	Twelvemile Creek at Moorheadville, Pa.		Sixteenmile Creek at Northeast, Pa.		Public Water Supply Erie, Pa. Treated Water from Lake Erie
	June 16	Aug. 13	June 16	Aug. 13	July 26
Silica (SiO_2)	4.2	4.8	3.3	1.0	1.5
Iron (Fe)	.02	.04	.02	.04	-
Calcium (Ca)	17	26	26	23	37
Magnesium (Mg)	3.5	5.1	5.7	5.6	8.9
Sodium (Na)	4.9	3.8	3.9	6.0	9.4
Potassium (K)			2.1		.6
Bicarbonate (HCO_3)	33	46	46	25	108
Sulfate (SO_4)	33	44	50	62	24
Chloride (Cl)	3.5	6.2	5.8	5.5	20
Fluoride (F)	.1	.1	.1	.1	.0
Nitrate (NO_3)	1.0	2.0	2.2	.6	.4
Dissolved solids	93	133	133	127	177
Hardness as $CaCO_3$:					
Total	57	86	88	80	129
Noncarbonate	30	48	51	60	40
Color	4	2	4	5	2
pH	7.5	7.5	7.7	6.6	7.8
Specific conductance (micromhos at 25 C)	144	205	213	203	300
Temperature (°F)	63	68	73	74	73
Mean discharge (cfs)	1.69	0.14	1.36	.69	-

	Maximum	Minimum
Specific conductance (micromhos at 25 C)	328	262
pH	8.2	7.9
Color	16	3
Hardness as $CaCO_3$	158	120
Bicarbonate	132	101
Sulfate	53	35
Chloride	9	4
Nitrate	2.4	1.8

Two complete analyses are given in table 5.

Temperature. -The maximum temperature measured was 75 F on August 13, 1951.

Pollution. -There is no known pollution in this stream.

Elk Creek

Six discharge measurements were made and daily discharges were computed for the period June 15 to September 30, 1951, at single-span steel truss bridge on Elk Park Road, 0.75 mile southwest of North

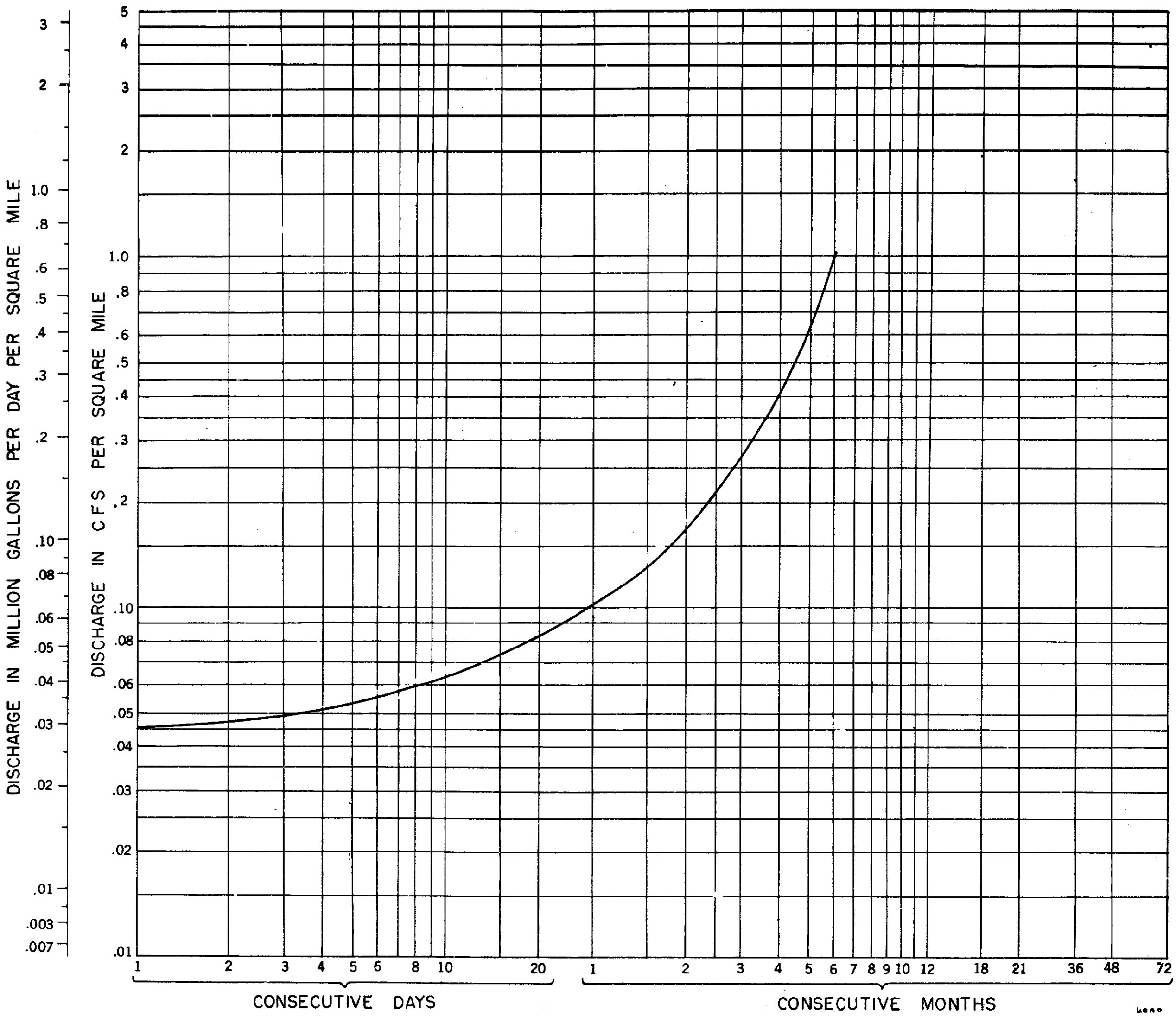

Figure 6.–Discharge available without storage in Crooked Creek at North Springfield.

Girard, Erie County (lat 42°00'20", long 80°21'15"). The drainage area is 96.7 sq mi at this point.

Discharge.–The average discharge for the period 1922-35 was 128 cfs (1.32 csm) estimated by correlating records for period June 15 to September 30, 1951, with records for Conneaut Creek at Amboy, Ohio. Figures 7 and 8 show the low-flow characteristics of the creek.

Chemical quality.–Five chemical analyses of water were made in 1951. Maximum and minimum concentrations in parts per million are given below:

	Maximum	Minimum
Specific conductance (micromhos at 25 C)	528	153
pH	8.4	7.5
Color	12	0
Hardness as $CaCO_3$	210	64
Bicarbonate	169	43
Sulfate	73	27
Chloride	28	3.8
Nitrate	5.4	1.1

Two complete analyses are given in table 5.

Temperature.–The maximum temperature measured was 78 F on July 24, 1951.

Pollution.–There is no known industrial pollution upstream from the mouth of Brandy Run, which enters Elk Creek just upstream from the Girard Borough limits. There is considerable pollution of Brandy Run by tannery waste entering the stream 0.5 mile upstream from the mouth. The tannery waste is untreated, except for settling of the sludge, but studies are being made for plans to remove the objectionable color from the effluent.

The borough of Girard provides complete treatment to sewage before it enters Elk Creek.

Little Elk Creek

Six discharge measurements were made during 1951 at the single-span concrete bridge, 2.5 miles

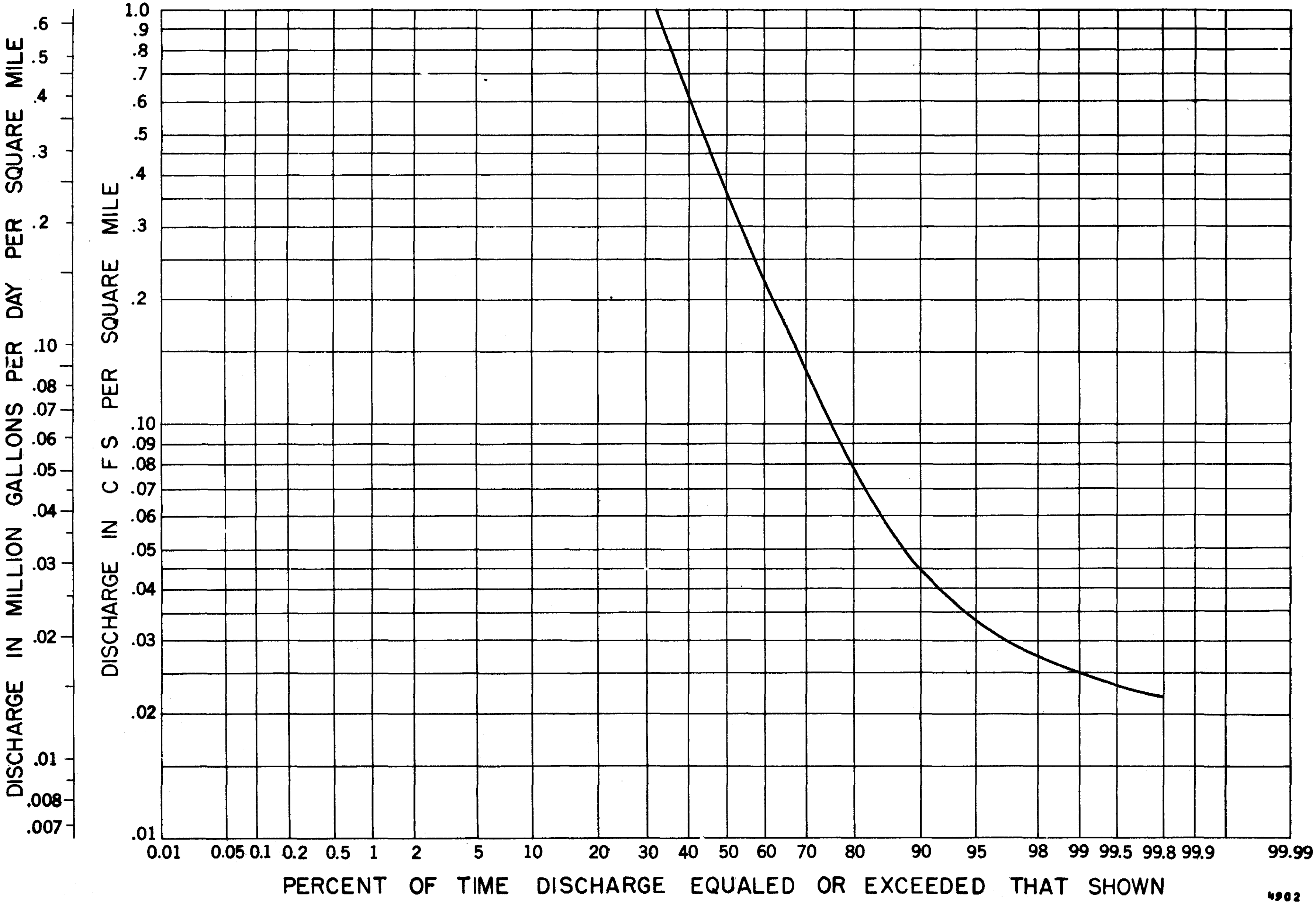

Figure 7.—Flow-duration curve for Elk Creek at North Girard.

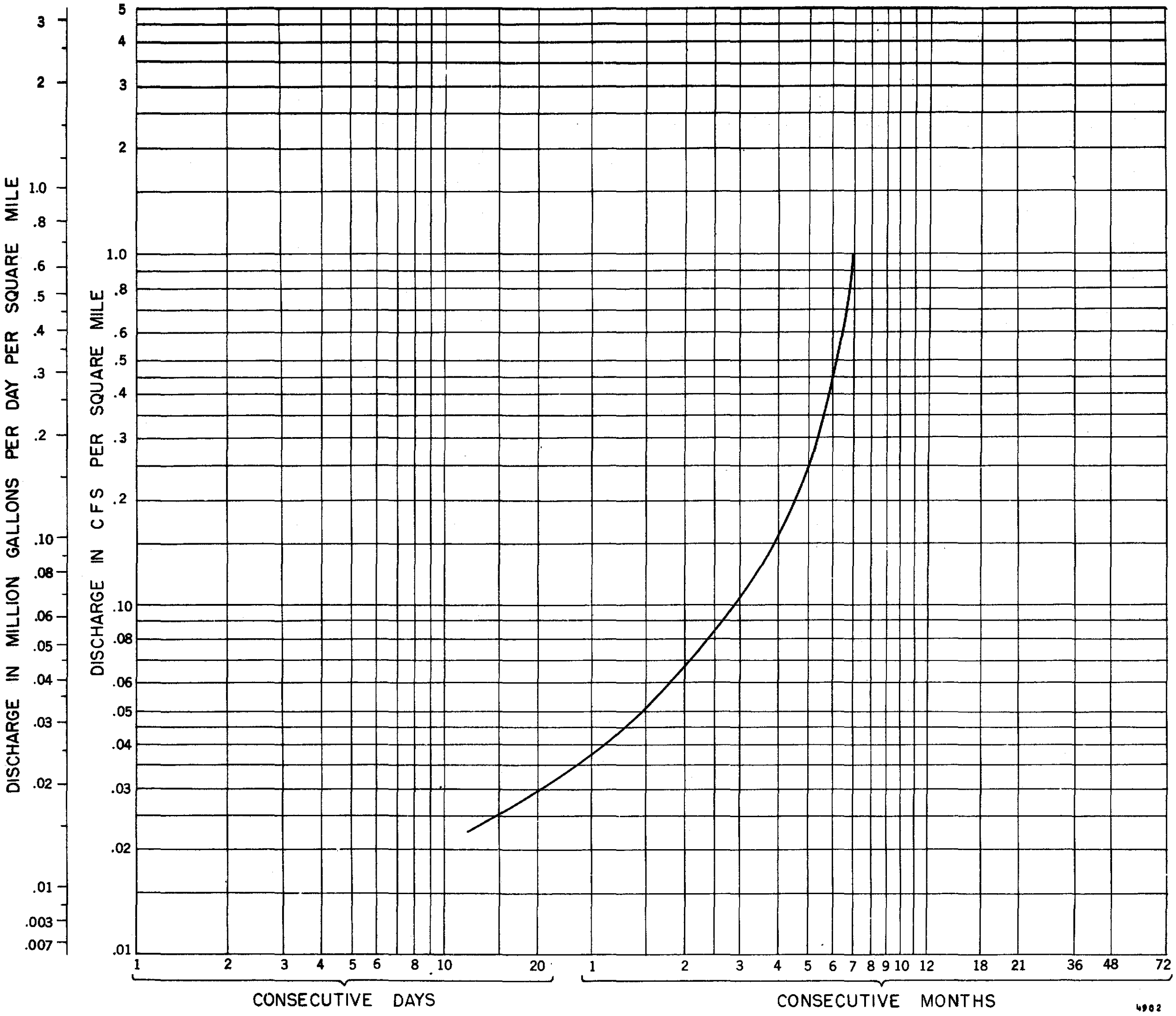

Figure 8. -Discharge available without storage in Elk Creek at North Girard.

northeast of Platea, Erie County (lat 41°57'35", long 80°17'10"). The drainage area at this point is 17.4 sq mi.

Discharge. -The average discharge for the period 1932-50 was 21.8 cfs (1.25 csm) estimated from 6 discharge measurements and records for Sugar Creek at Sugarcreek, Pa. Figures 9 and 10 show the low-flow characteristics of the stream.

Chemical quality. -Five chemical analyses of water were made in 1951. Maximum and minimum concentrations in parts per million are given below:

	Maximum	Minimum
Specific conductance (micromhos at 25 C)	353	97.9
pH	7.8	7.2
Color	15	4
Hardness as $CaCO_3$	136	41
Bicarbonate	62	25
Sulfate	85	20
Chloride	20	1.8
Nitrate	2.4	.6

Two complete analyses are given in table 5.

Temperature. -The maximum temperature measured was 74 F on July 2, 1951.

Pollution. -There is no known pollution in this stream.

Walnut Creek

Fourteen discharge measurements were made during period 1944-51, and daily discharges were computed for the period June 15 to September 30, 1951 at the double-span concrete bridge on State Route 25016, 0.4 mile (by road) northeast of library in village of Weis Library, Erie County (lat 42°03'10"; long 80° 10'05"). The drainage area at this point is 26.9 sq mi.

Discharge. -The average discharge during the period 1932-50 was 29.6 cfs (1.10 csm) estimated by correlating record for period June 15 to September 30, 1951, with record for Sugar Creek at Sugarcreek, Pa. Figures 11 and 12 show the low-flow characteristics of the stream.

Chemical quality.—Five chemical analyses of water were made in 1951. Maximum and minimum concentrations in parts per million are given below:

	Maximum	Minimum
Specific conductance (micromhos at 25 C)	319	236
pH	8.0	7.5
Color	7	4
Hardness as $CaCO_3$	152	104
Bicarbonate	131	83
Sulfate	48	31
Chloride	9	6
Nitrate	2.0	1.1

Two complete analyses are given in table 5.

Temperature.—The maximum temperature measured was 74 F on August 22, 1944 and July 24, 1951; the minimum was 32 F on December 14, 1945.

Pollution.—There is no know industrial pollution in this stream. There may be domestic sewage pollution from the large housing development near Port Erie Airport.

Mill Creek

Sixteen discharge measurements were made during period 1944-51, and daily discharges were computed for the period June 16 to September 30, 1951, at the concrete ledge and small waterfall 0.3 mile upstream

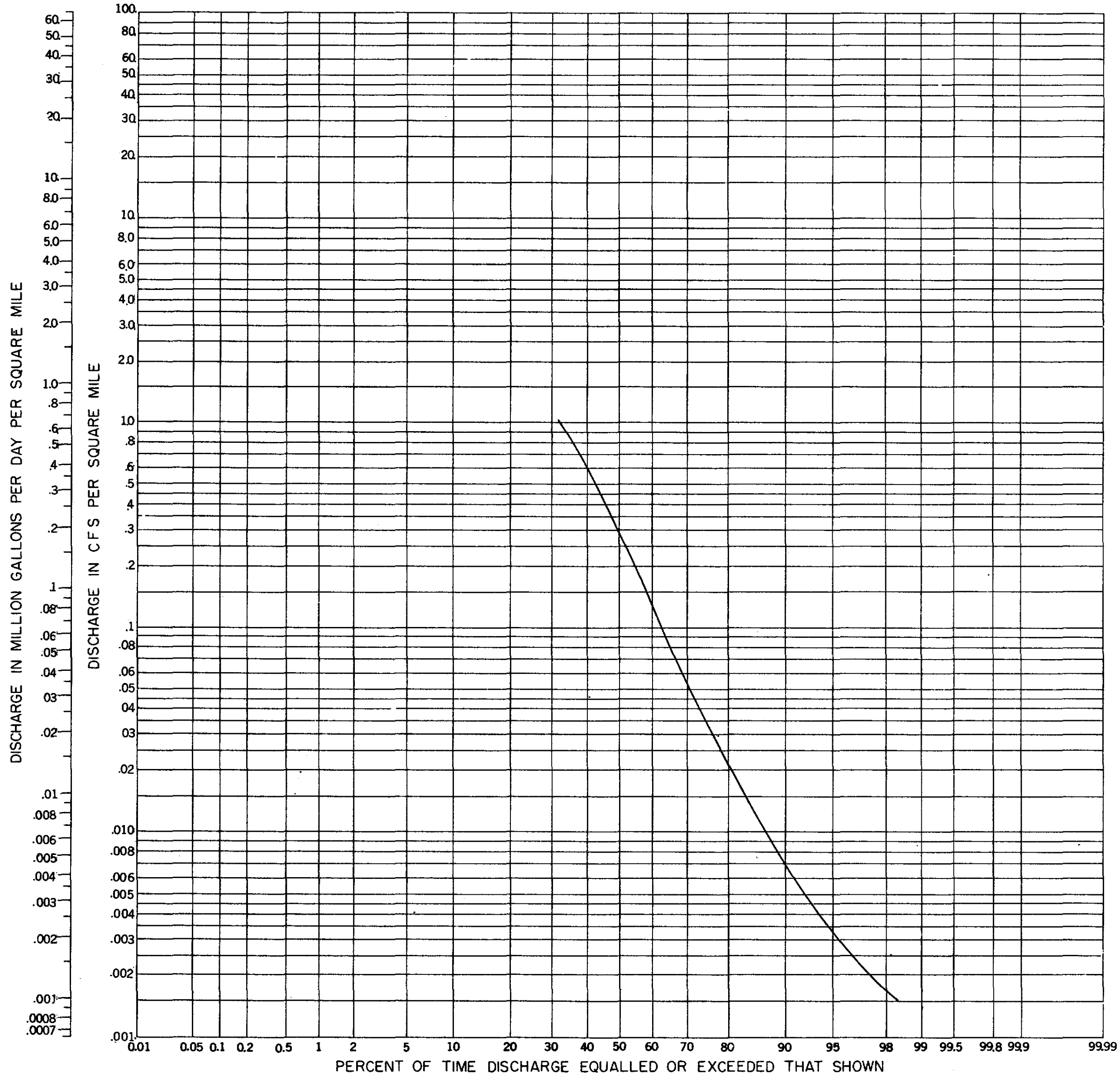

Figure 9.—Flow-duration curve for Little Elk Creek near Platea.

from concrete drift catcher in Glenwood Park at south edge of Erie, 0.6 mile upstream from Glenwood Park Zoo (lat 42°05'40", long 80°04'20"). The drainage area at this point is 9.20 sq mi.

Discharge.-The average discharge for the period 1932-50 was 9.7 cfs (1.05 csm) estimated by correlating record for period June 16 to September 30, 1951 with records for Sugar Creek at Sugarcreek, Pa. Figures 13 and 14 show the low-flow characteristics of the stream.

Results of two slope-area measurements of the flood of August 3, 1915, made by the Pennsylvania Department of Forests and Waters, are tabulated below:

Drainage area (sq mi)	Peak discharge (cfs)	(csm)
9.3	7,500	800
12.9	13,000	1,000

Chemical quality.-Seven chemical analyses of water were made, two in 1946 and five in 1951. Maximum and minimum concentrations in parts per million are given below:

	Maximum	Minimum
Specific conductance (micromhos at 25 C)	375	180
pH	8.2	6.8
Color	14	4
Hardness as $CaCO_3$	186	78
Bicarbonate	145	48
Sulfate	59	37
Chloride	9	3.9
Nitrate	5.3	1.5

Two complete analyses are given in table 5.

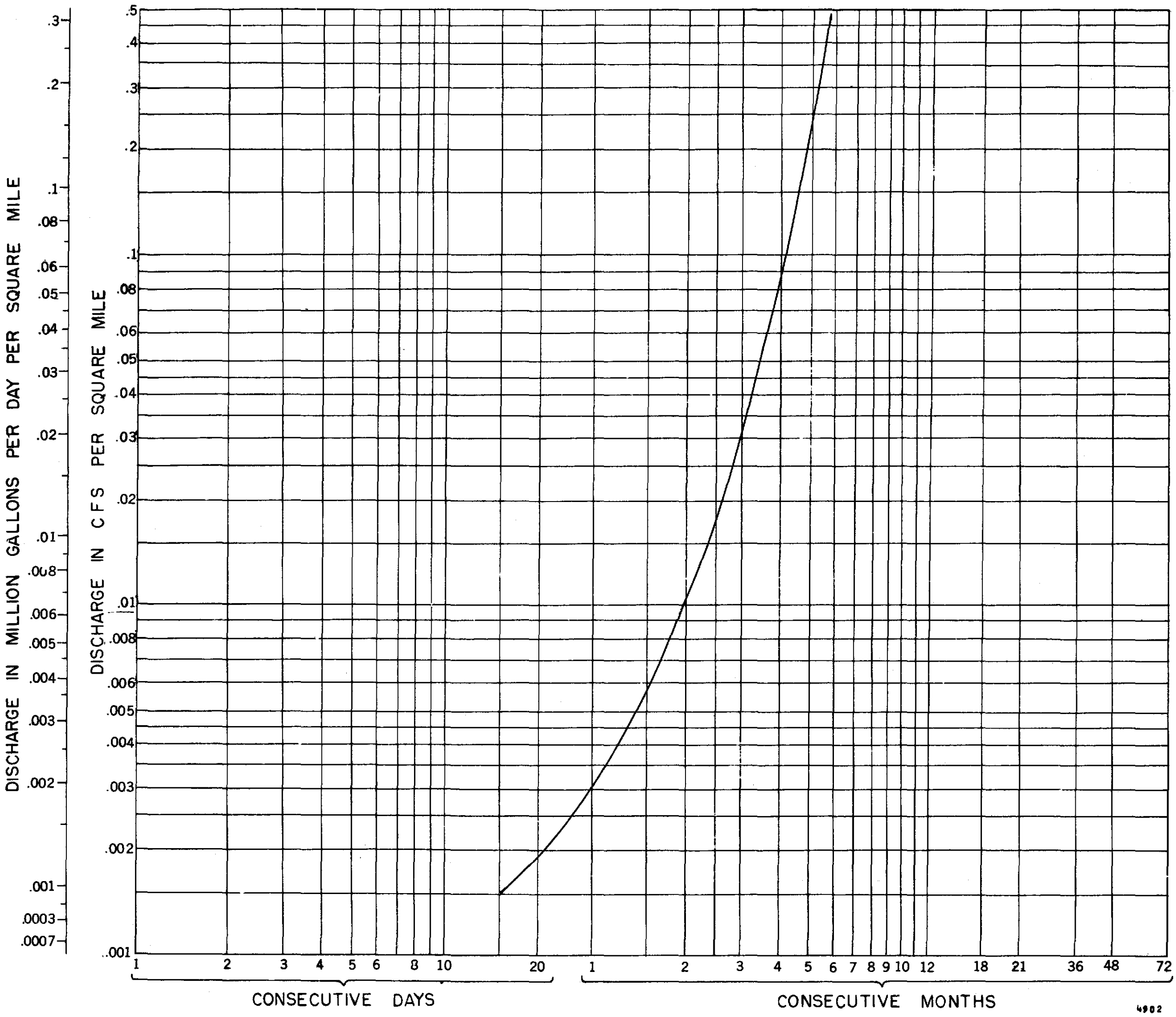

Figure 10.-Discharge available without storage in Little Creek near Platea.

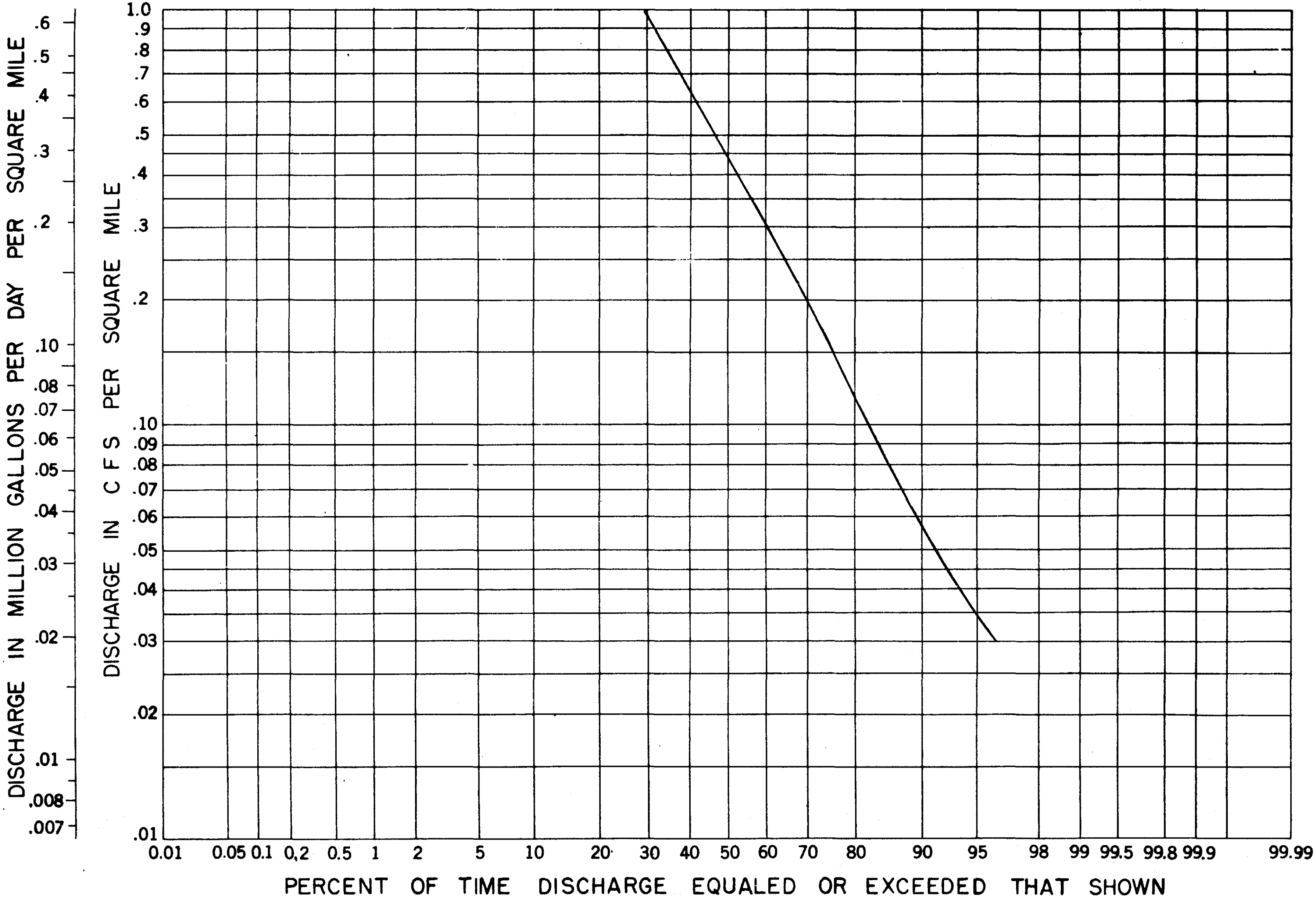

Figure 11.–Flow-duration curve for Walnut Creek at Weis Library.

Temperature. –The maximum temperature measured was 76 F on August 5, 1946 and September 9, 1948; the minimum was 32 F on December 14, and February 27, 1946.

Pollution. –There is no known industrial pollution in this stream. There is a possibility that overflows from septic tanks at home near the upper reaches of the stream may at times enter the stream.

Sixmile Creek

Six discharge measurements were made during 1951, at the single-span steel truss bridge on Clark Road, 1.5 miles southwest of Harborcreek, Erie County, (lat 42°09'15", long 79°58'35"). The drainage area at this point is 15.4 sq mi.

Discharge. –The average discharge for the period 1940-50 was 22.3 cfs (1.45 csm) estimated from 6 discharge measurements and records for Cattaraugus Creek at Gowanda, N. Y. Figures 15 and 16 show the low-flow characteristics of the stream.

Chemical quality. –Five chemical analyses of water were made in 1951. Maximum and minimum concentrations in parts per million are given below and on page 22.

	Maximum	Minimum
Specific conductance (micromhos at 25 C)	289	218

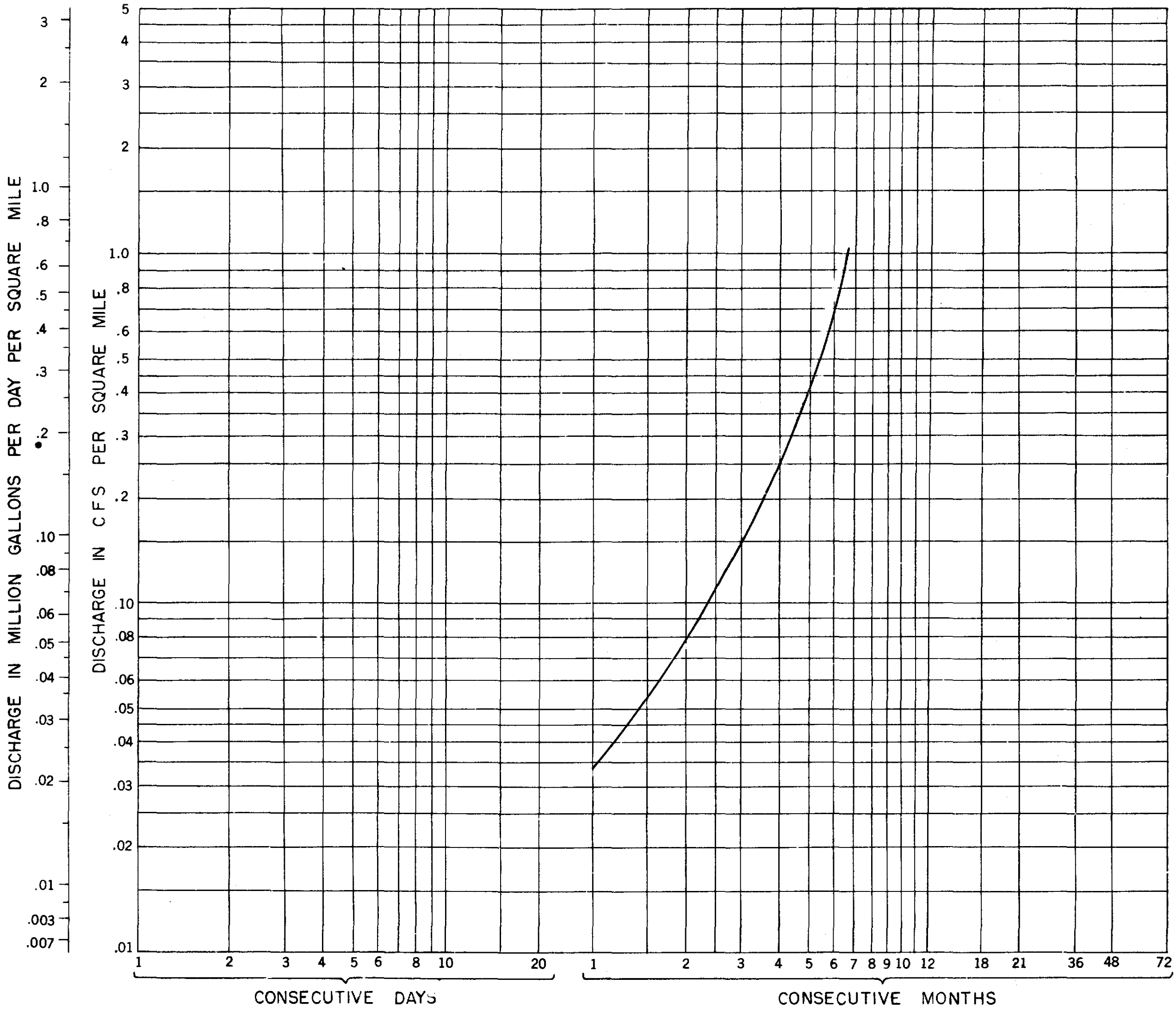

Figure 12. –Discharge available without storage in Walnut Creek at Weis Library.

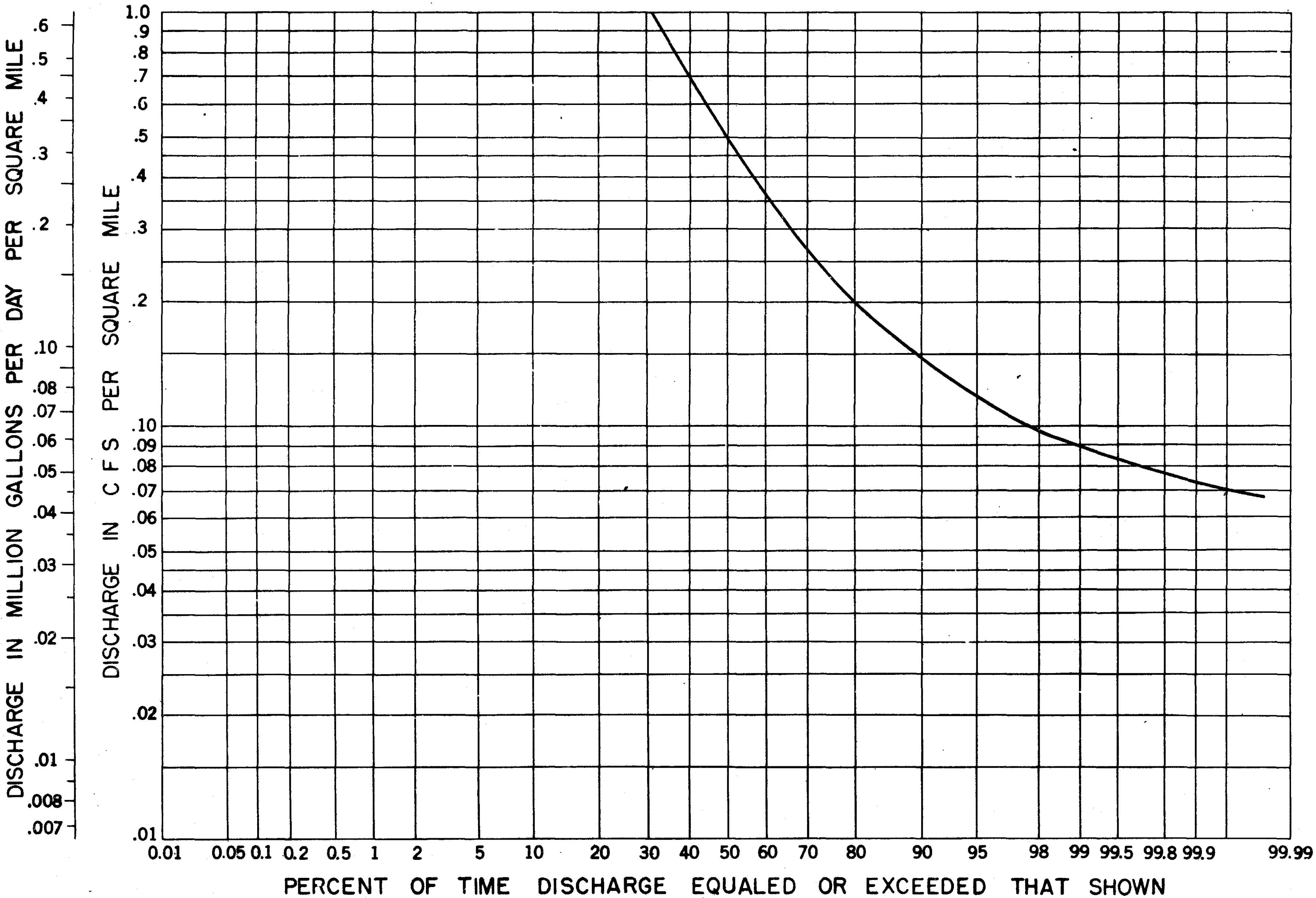

Figure 13. –Flow-duration curve for Mill Creek at Erie.

	Maximum	Minimum
pH	8.2	7.3
Color	12	3
Hardness as $CaCO_3$	137	101
Bicarbonate	108	89
Sulfate	58	29
Chloride	6	3.0
Nitrate	.8	.6

Two complete analyses are given in table 5.

Temperature.—The maximum temperature measured was 72 F on June 15 and August 14, 1951.

Pollution.—There is no known pollution in this stream.

Sevenmile Creek

Six discharge measurements were made and daily discharges were computed for the period June 16 to September 30, 1951, at the single-span bridge on Bell Road, 0.5 mile southeast of U. S. Highway 20 in Harborcreek, Erie County, (lat 42°09'40", long 79°56'55"). The drainage area at this point is 2.85 sq mi.

Discharge.—The average discharge for the period 1932-50 was 3.4 cfs (1.19 csm) estimated by correlation of records for period June 16 to September 30, 1951, with records for Sugar Creek at Sugarcreek, Pa. Figures 17 and 18 show the low-flow characteristics of the stream.

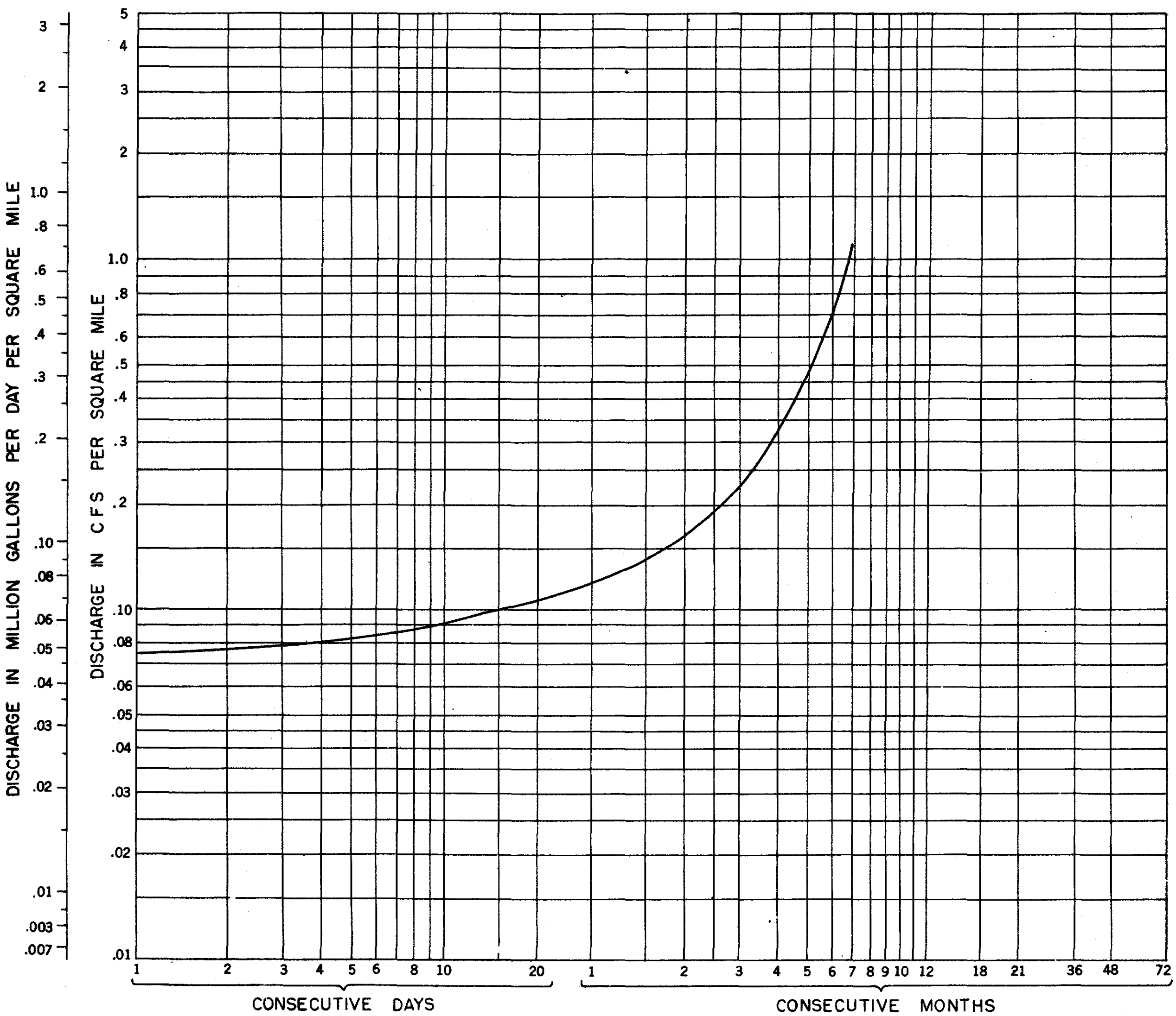

Figure 14.—Discharge available without storage in Mill Creek at Erie.

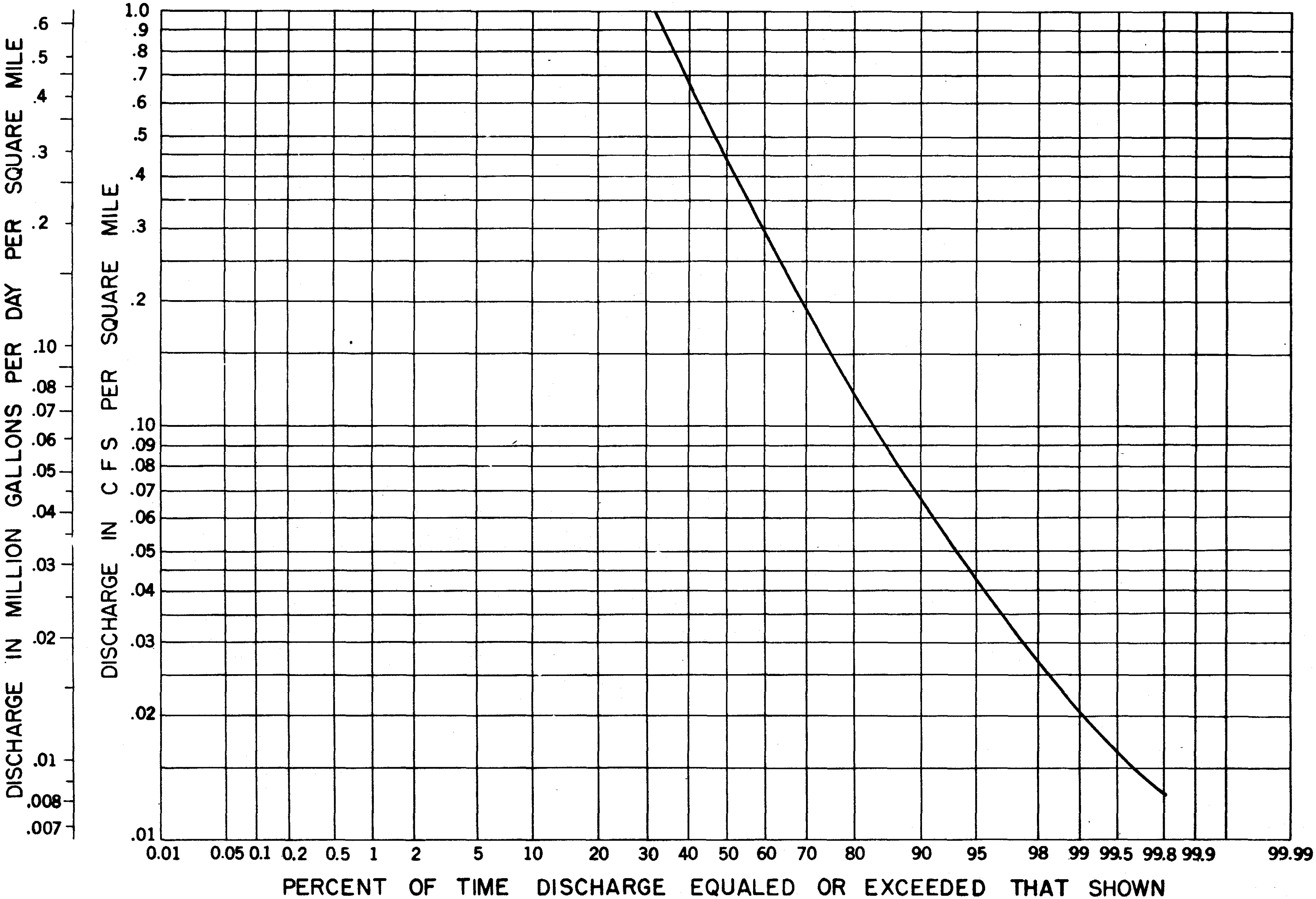

Figure 15. –Flow-duration curve for Sixmile Creek near Harborcreek.

Chemical quality. -Five chemical analyses of water were made. Maximum and minimum concentrations in parts per million are given below:

	Maximum	Minimum
Specific conductance (micromhos at 25 C)	300	215
pH	7.9	7.4
Color	9	2
Hardness as $CaCO_3$	139	97
Bicarbonate	114	84
Sulfate	39	25
Chloride	6.5	4.8
Nitrate	1.6	.4

Two complete analyses are given in table 5.

Temperature. -The maximum temperature measured was 71 F on July 23 and August 14, 1951.

Pollution. -There is no known pollution in this stream.

Twelvemile Creek

Six discharge measurements were made during 1951, at the concrete box culvert on U. S. Highway 20 at Spencer, 1.0 mile east of Moorheadville, Erie County (lat 42°11'40", long 79°53'25"). The drainage area at this point is 6.59 sq mi.

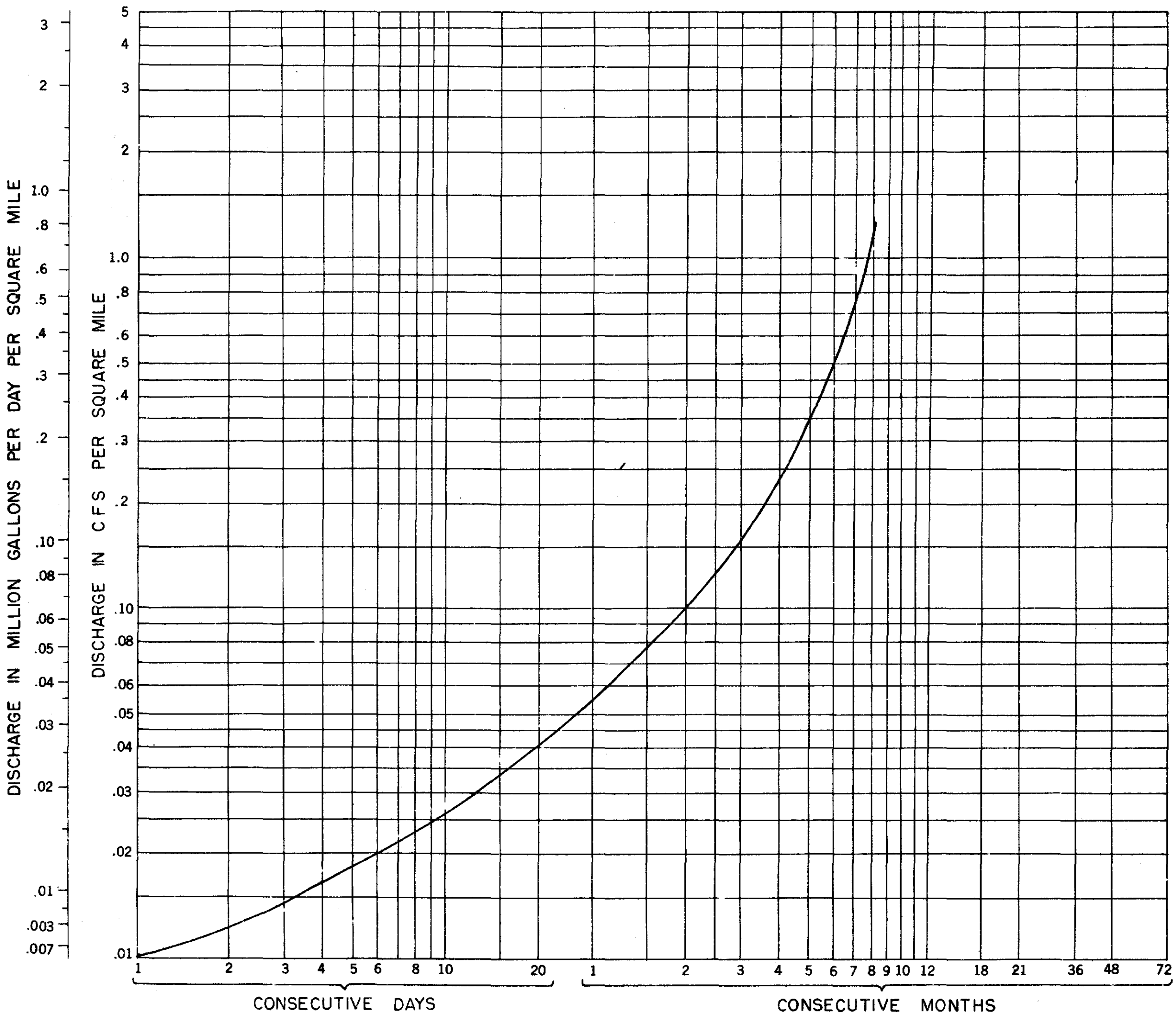

Figure 16. -Discharge available without storage in Sixmile Creek near Harborcreek.

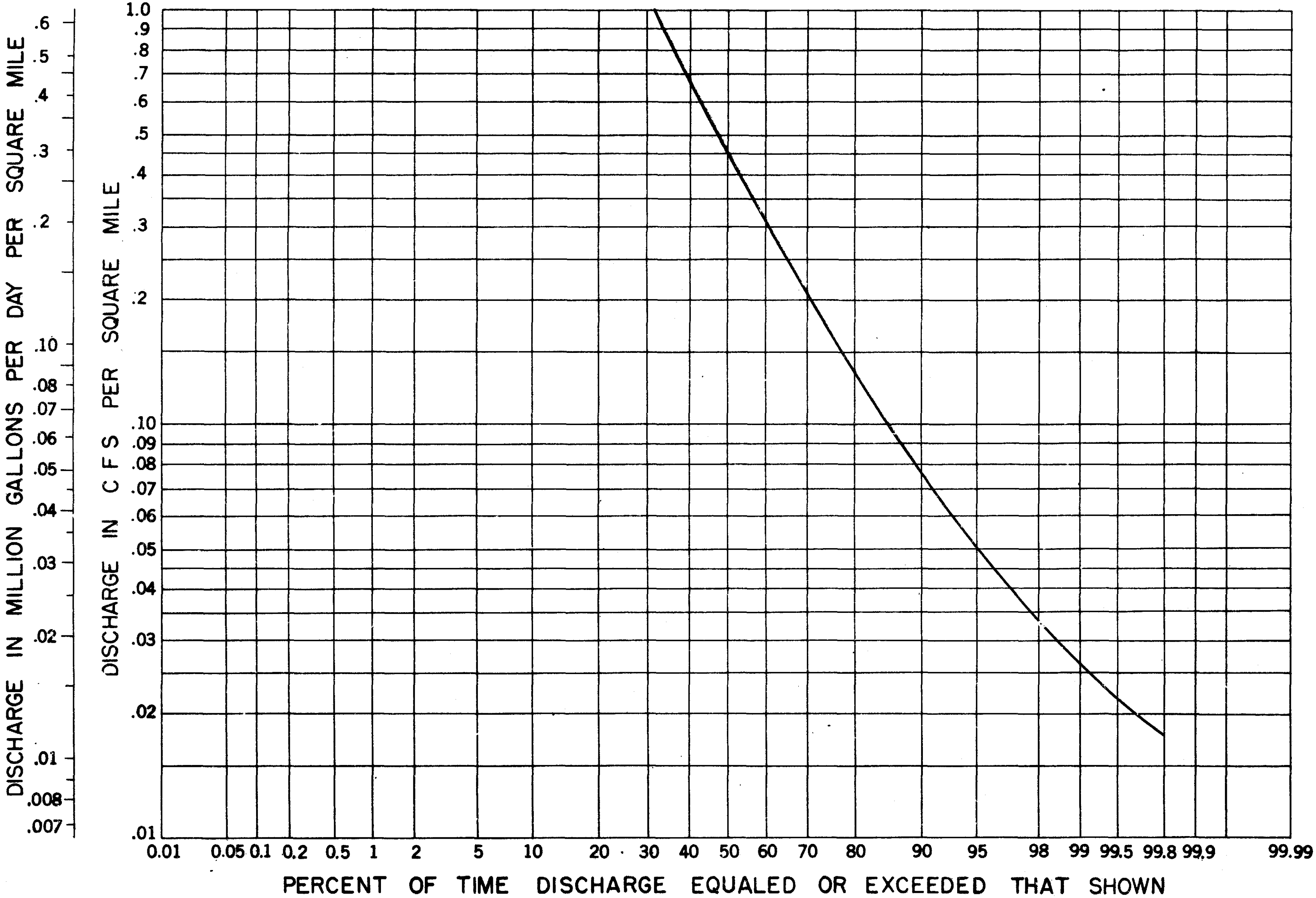

Figure 17. –Flow-duration curve for Sevenmile Creek at Harborcreek.

Discharge. –The average discharge for the period 1932-50 was 9.8 cfs (1.48 csm) estimated from 6 discharge measurements and records for Sugar Creek at Sugarcreek, Pa. Figures 19 and 20 show the low-flow characteristics of the stream.

Chemical quality. –Five chemical analyses of water were made in 1951. Maximum and minimum concentrations in parts per million are given below:

	Maximum	Minimum
Specific conductance (micromhos at 25 C)	239	144
pH	7.5	7.2
Color	7	2
Hardness as $CaCO_3$	86	57
Bicarbonate	53	33
Sulfate	51	33
Chloride	10	3.5
Nitrate	3.5	1.0

Two complete analyses are given in table 5.

Temperature. –The maximum temperature measured was 71 F on July 23 and August 14, 1951.

Pollution. –There is no known pollution in this stream.

Sixteenmile Creek

Six discharge measurements were made during 1951, at the downstream end of the concrete retaining well, 200 ft upstream from single-span bridge on Wellington Street at south edge of North East, Erie County (lat 42°12'40", long 79°50'05"). The drainage area at this point is 9.83 sq mi.

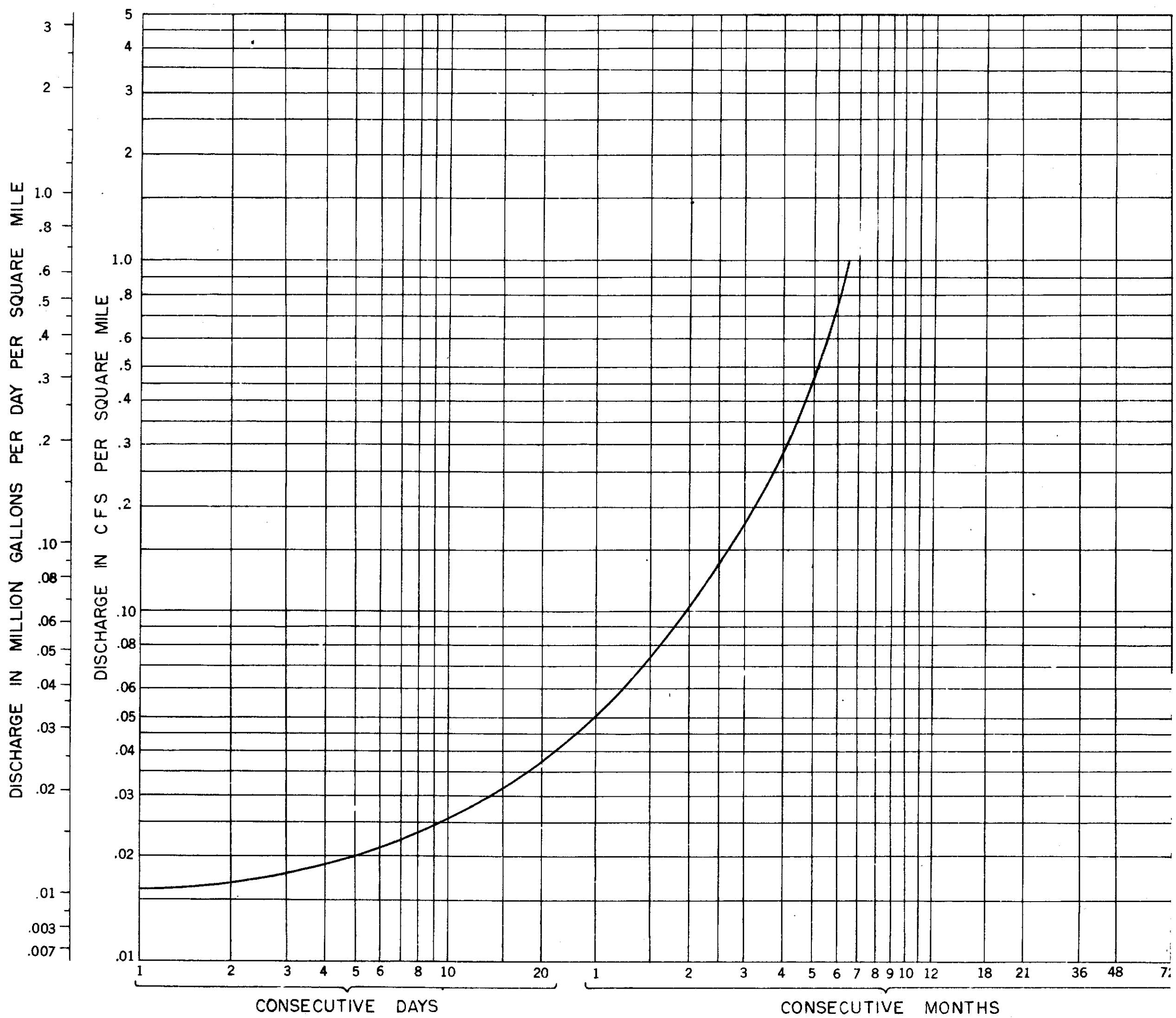

Figure 18. –Discharge available without storage in Sevenmile Creek at Harborcreek.

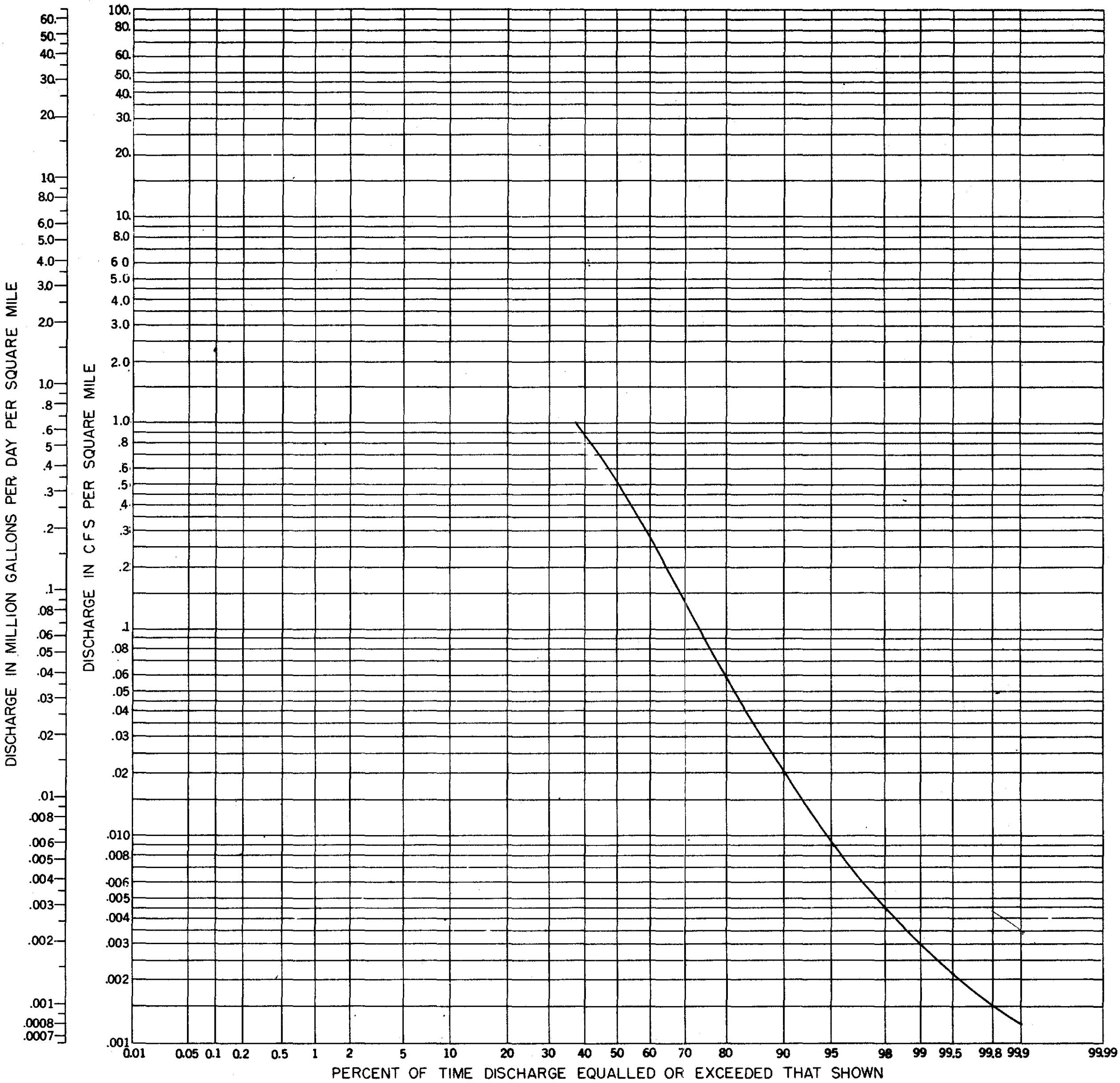

Figure 19. –Flow-duration curve for Twelvemile Creek near Moorheadville.

Discharge. –According to a contracted-opening measurement made by the Pennsylvania Department of Forests and Waters, the peak discharge of the flood of March 16, 1942, was 9,710 cfs or 771 csm at a site where the drainage area is 12.6 sq mi.

The Minimum daily discharge during the period June to September 1951 was 0.2 cfs (0.020 csm) on August 31 and September 1.

Chemical quality. –Five chemical analyses of water were made in 1951. Maximum and minimum concentrations in parts per million are given below:

	Maximum	Minimum
Specific conductance (micromhos at 25 C)	213	160
pH	7.7	6.6
Color	12	3
Hardness as $CaCO_3$	88	68
Bicarbonate	49	25
Sulfate	62	28
Chloride	7	5.5
Nitrate	2.2	.6

Two complete analyses are given in table 5.

Temperature. -The maximum temperature measured was 82 F on August 14, 1951.

Pollution. -The borough of North East has an intermediate sewage treatment plant, the effluent from which enters Sixteenmile Creek. Most of the food-processing plants in the borough give some treatment to their effluent before discharge into the borough sewerage system. However, at times the water below the treatment has a noticeable color.

GROUND WATER

The occurrence of ground water is controlled by the geology, topography, and climate of the region. Although, in the Lake Erie Shore region, rainfall is plentiful and the topography is favorable, the quantities of water obtainable from wells are small. The consolidated sedimentary rocks in the region are covered by unconsolidated glacial drift. With the exception of sand and gravel beds in the drift or in beach ridges, the two types of rock do not contain large or numerous water-bearing openings.

Geology and Hydrology

Erie County was completely covered by the continental ice sheets which reshaped the previous land surface and deposited large quantities of rock debris. Immediately after the retreat of the last glacier, the level of Lake Erie was probably 300 ft or more higher than at present (White, 1881). During the recession of the lake through many thousands of years, wind and wave action caused the formation of many beach ridges and

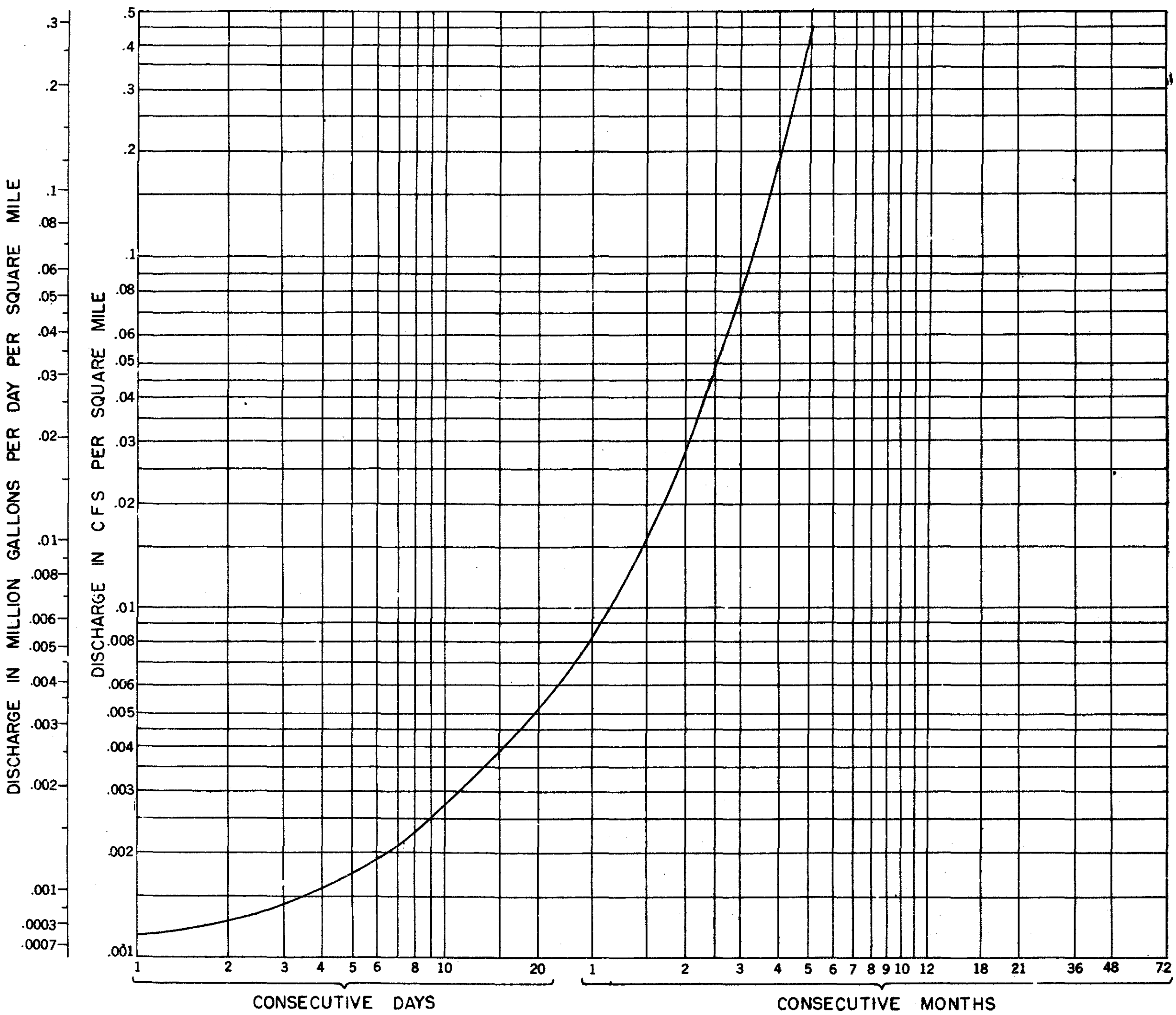

Figure 20. -Discharge available without storage in Twelvemile Creek near Moorheadville

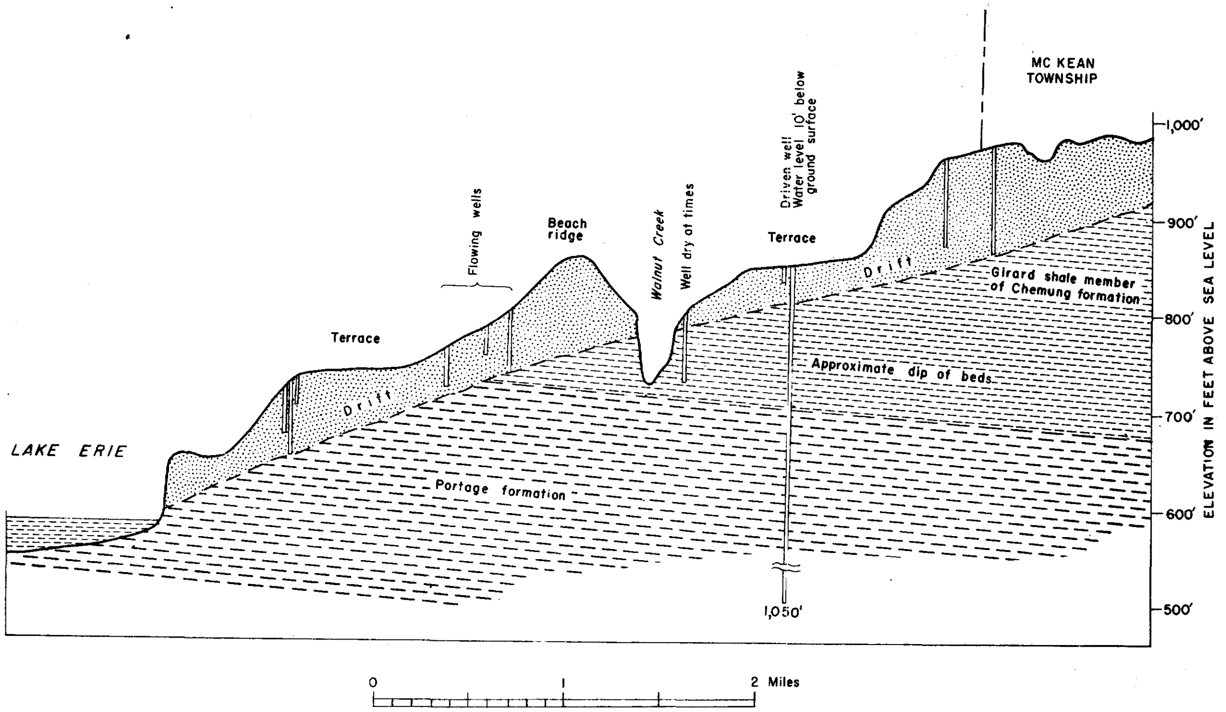

Figure 21. –Geologic section along west side of Mill Creek Township.

terraces by reworking the glacial deposits and bedrock formations exposed along the shore. The unconsolidated materials now lying on the old rock floor are as much as 100 ft thick and average approximately 50 ft thick. These sediments are entirely above the present lake level.

The glacial drift is mostly till (boulder clay) composed of gravel, and clay which was deposited by the melting ice without being sorted by water action. Wells drilled into the poorly sorted till yield little water except from the coarse-grained parts. In some localities in northern Pennsylvania, glacial materials have been sorted by stream action resulting in the deposition of layers of permeable sand and gravel from which large amounts of water can be obtained. It is possible that a similar condition exists in a buried valley under Crooked Creek. This buried valley is believed to be the original outlet of Conneaut Creek which flowed northward directly into Lake Erie. It filled with drift and outwash materials during the glacial epoch (Leggette, 1936). Sufficient geological and well data are not available to evaluate properly the ground-water potential of the valley. However, valley deposits appear to offer better possibilities for development than most of the glacial drift.

The underlying bedrock formations have been exposed in many ravines and on steep hillsides by recent erosion. They are mainly shales and sandstones of sedimentary origin. The dip of the beds is south to southwest, so that a given stratum along the lake bluff is at a lower elevation under the land areas. A typical cross section of the rocks of the shore region is shown in figure 21.

Ground water in the bedrock is contained in the joints and other fractures and along the bedding planes rather than in the pore spaces. Many of the water-bearing openings are imperfectly connected. If these rocks were more permeable, infiltration from Lake Erie could be induced by pumping from wells near the lake. That they do not serve as conduits for recharge from the lake is shown by many gas wells drilled hundreds of feet deep which yielded little water until deep brines were encountered. Five wells drilled for water along the shore about 4 miles from North East were completely dry. One of these was reported to have extended about 90 ft below lake level.

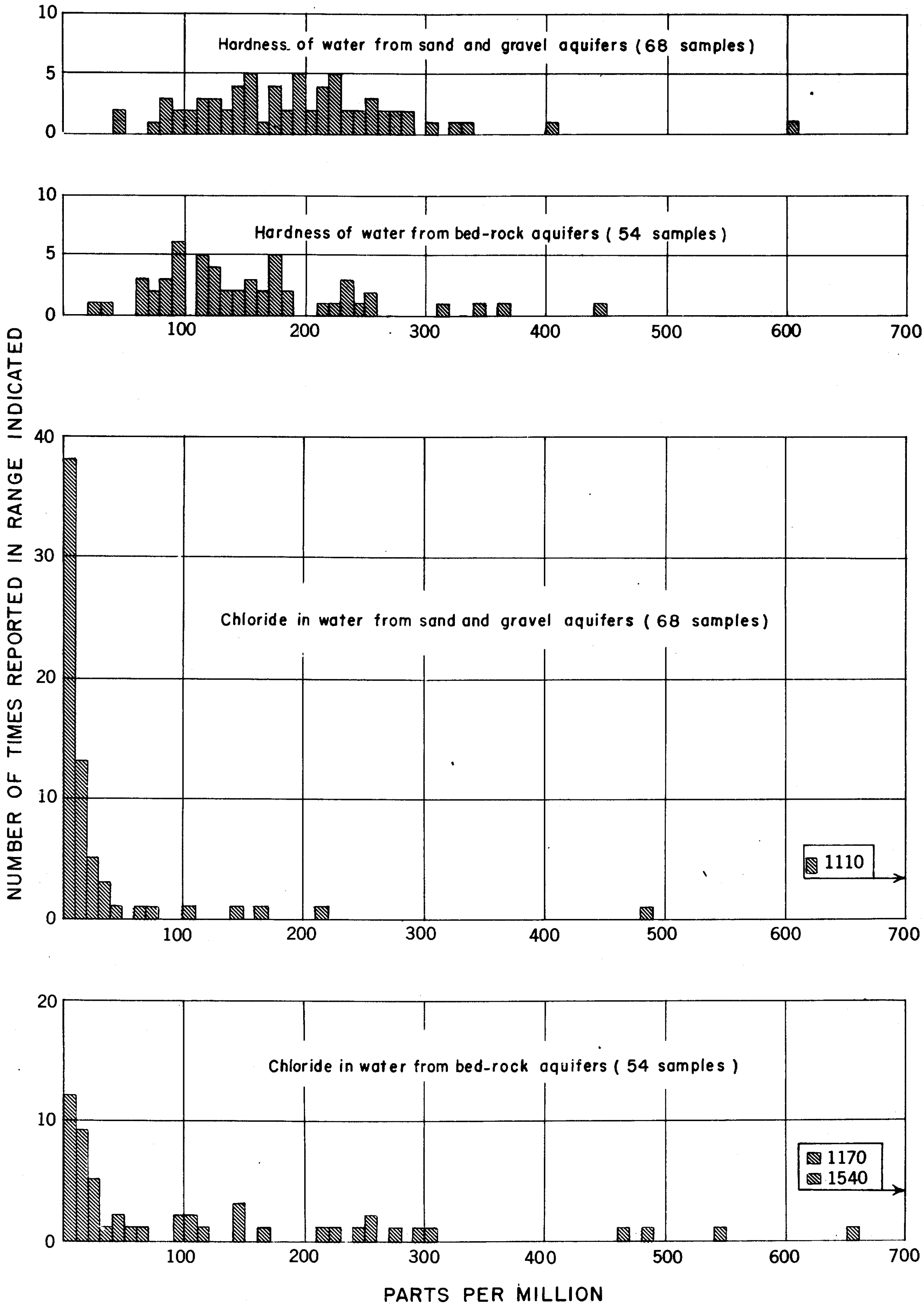

Figure 22. -Distribution graph showing hardness and chloride content of ground water in the Lake Erie Shore region.

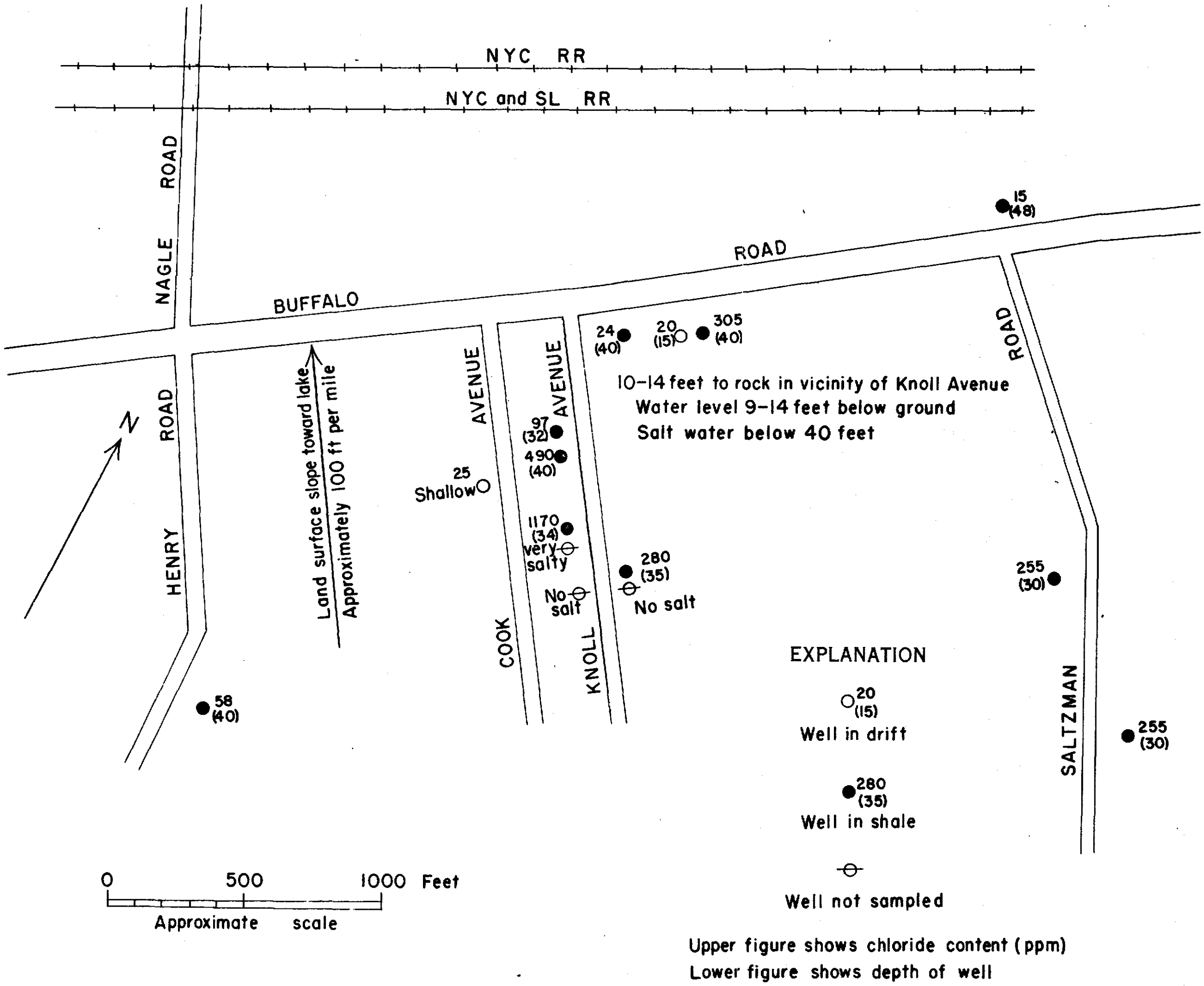

Figure 23.–Map of a section east of Wesleyville showing wells sampled and chloride content of water.

Location and Yield of Wells

Wells in the region are used chiefly for individual domestic supplies. They do not have large yields and no large ground-water supplies have been developed. The wells are dug, drilled, or driven, depending on the location. The newer wells generally have been drilled to depths ranging from 20 to 160 ft. Many of the older wells were dug to depths of about 25 ft. Some small-diameter wells have been driven in sandy areas where the water table is near the land surface.

Outside the areas served by the municipal systems of Erie and North East, nearly every home uses ground water. The area southwest of Erie extending to the Ohio border contains the thickest glacial deposits in the region which generally yield adequate amounts of water for domestic purposes. Some of the best yields are obtained from gravel streaks, either within the glacial drift or lying on the bedrock surface.

Good yields have been reported from municipal wells at Girard and North Girard. These wells are at the foot of an old beach ridge at an elevation about 200 ft higher than the present lake level. The Girard municipal well is 20 ft in diameter and yielded 183 gpm in 1929. In 1949 one of the North Girard municipal wells was drilled to a depth of 36 ft and yielded 110 gpm on test. In this same general area a flowing well (no. 1 on fig. 1), drilled on the beach ridge, was flowing at least 20 gpm in May 1951.

The area immediately east of Erie contains little glacial drift and most wells end in shale from which low yields are common. The hillsides south of this area and farther east are drift-covered and yield moderate supplies of ground water. In general, the area near North East is drift-covered and contains many adequate domestic wells and a few industrial wells. Some of the wells encounter quicksand, which is difficult to control in drilling and in maintaining the yield of the well.

Wells generally are not drilled into bedrock except in the area of thin glacial drift just east of Erie unless a sufficient supply of water cannot be obtained from the overlying glacial deposits. For most of the region, the pattern of bedrock wells is random and there appear to be no clearly defined areas of consistently high or low yield.

Chemical Quality

The quality of ground water in the lake-shore region varies locally but, in general, the well waters have a hardness between 50 and 250 ppm, dissolved solids between 100 and 400 ppm, and pH between 6.5 and 8.0. Although most of the wells sampled had water with a chloride concentration less than 100 ppm, a few had a chloride concentration greater than 1,000 ppm. Throughout the area the water from wells usually was found to be somewhat higher in concentration of most dissolved constituents than the water in Lake Erie or in nearby streams. Chemical-quality data on ground water are given in tables 6 and 7.

Relation to type of aquifer.–Samples of ground water were collected from 122 wells in the region during July 1951. The water was analyzed to determine four chemical characteristics, the results of which are summarized in table 7 and figure 22. The data are considered to be representative of the ground water

Table 6.–Chemical quality of ground water from typical wells in Lake Erie Shore region in Pennsylvania (parts per million)

	1	2	3	4	5	6	7
	5-23-51	5-23-51	5-24-51	5-24-51	5-24-51	5-24-51	5-25-51
Silica (SiO_2)	16	8.6	9.2	6.6	9.2	12	16
Iron (Fe)	.49	.14	.02	.56	.11	.06	.11
Calcium (Ca)	61	85	32	48	68	41	61
Magnesium (Mg)	14	20	12	14	12	20	15
Sodium (Na)	11	4.5	132	7.8	4.2	159	5.4
Potassium (K)	1.9	1.9	4.4	2.1	1.4	5.2	1.8
Carbonate (CO_3)	0	0	0	0	0	0	0
Bicarbonate (HCO_3)	217	230	144	104	182	386	227
Sulfate (SO_4)	37	88	17	80	69	46	30
Chloride (Cl)	9	14	206	18	7	110	4
Fluoride (F)	.2	.1	.3	.2	.1	.2	.1
Nitrate (NO_3)	.5	.2	.2	.3	.2	.2	.5
Dissolved solids	259	348	491	241	268	587	247
Hardness as $CaCO_3$:							
Total	210	294	129	177	219	185	214
Noncarbonate	32	106	11	92	70	0	28
Color	10	5	3	6	6	7	7
pH	8.0	7.8	7.4	7.3	8.0	8.0	8.0
Specific conductance (micromhos at 25 C)	428	559	949	395	434	1020	416
Temperature (°F)	55	52	55	49	55	56	54
Depth of well (feet)	18	36	72	49	52	72	82
Diameter of well (inches	8	8	6	6	4	6	5
Date drilled	1948	1949	1950	1943	1947	1947	1949

1. Well in glacial drift; K. Kallenback, 3127 Asbury Road, Erie.
2. Well in glacial drift; North Girard Borough.
3. Well in shale; C. H. Lyons, Wattsburg Road, Erie.
4. Well in shale; Howard Orton, R. D. 5, North East.
5. Well in glacial drift; L. B. Parmenter, Cemetery Road, North East.
6. Well in glacial drift; C. A. Masso, R. D. 1, Harborcreek.
7. Well in glacial drift; H. W. Zillman, 4705 Wattsburg Road, Erie.

Table 7. -Relation between chemical quality and type of aquifer

Characteristic	Sand and gravel				Bedrock formations			
	Maximum	Minimum	Average	Median	Maximum	Minimum	Average	Median
Depth (feet)	121	15	48	40	160	12	53	46
Specific conductance (micromhos at 25 C)	3,840	146	547	440	5,060	173	838	544
Hydrogen-ion concentration (pH)	8.0	6.2	7.3	7.5	8.4	6.3	7.5	7.6
Hardness as $CaCO_3$ (ppm)	606	46	193	194	444	26	158	139
Chloride (ppm)	1,110	3	46	10	1,540	3	142	40

throughout the region. Of the total number of wells sampled 68 are believed to end in glacial drift (sand and gravel) and 54 in bedrock (shale). Both average and median values are given in table 7 because of the wide range of extremes found in each of the formations. The median is the value that is equalled or exceeded by exactly half the values reported.

The ground water of better quality is usually obtained from sand and gravel aquifers, although the differences in chemical character between water from sand and gravel and water from bedrock in most respects are not great. The water from sand and gravel is slightly harder but contains less chloride than the water from wells in bedrock formations. The principal objection to water from bedrock in this region is the relatively high chloride content in some locations. The sampling program showed that about 40 percent of all rock wells and only 9 percent of all sand and gravel wells had chloride in excess of 100 ppm. Only 2 gravel wells and 11 rock wells of the 122 sampled yielded water with chloride in excess of 250 ppm.

Sources of chemical contamination. -Excessive chloride in the ground water undoubtedly is associated with the bedrock. Local well drillers have reported that a well that is drilled "too deep" will encounter salt water. The 122 analyses for chloride, summarized in table 7, support the contention that the water from bedrock is likely to be more salty than the water from drift. Many drillers tap the bedrock for water only where sufficient glacial drift is not present, or if present, will not yield sufficient water. In some sections, therefore, the choice is bedrock water relatively high in chloride or insufficient water.

Some wells in the drift also yield water of high chloride content. This may be due to the seepage of brines from the underlying rock through natural openings in the rock and through old abandoned gas wells. A report on the geology of Erie County by White (1881) contains many references to the presence of petroleum seeps in the exposed bedrock formations. These occur not only at outcrops along the lake bluff but also at other rock exposures in ravines and hillsides inland from the lake. Natural gas has been reported in "pockets" in both the drift and the bedrock.

Relatively high chloride concentrations were encountered at several places where samples were collected for this study. It is likely that other places also have a similar problem. An area of particularly high chloride concentration just east of Wesleyville was studied in some detail to determine the source and extent of the concentration. The map (fig. 23) shows the location of 12 wells sampled in this area together with the measured chloride content and other notes as reported by well owners.

The highest concentration of chloride in the area shown in figure 23 was 1,170 ppm. The concentration appears to decrease in all directions from this well, indicating a localized source of contamination. An oil seep or an improperly plugged well may be the source of the brine which is contaminating ground water derived from local precipitation. However, the contamination is confined to the bedrock since the chloride in the two wells in the drift is very low.

PRESENT WATER USE

The average daily use of water in the area is at least 58 mgd, of which more than 57 mgd is from surface sources and less than 1 mgd is from ground-water sources. This estimate does not include water used in rural areas or by some small industries. A description of the use of water from the three sources Lake Erie, small streams, and ground water follows:

Lake Erie

Lake Erie is the principal source of water in the area. Most of the water withdrawn from the lake is used for the public supply of the city of Erie, although an appreciable quantity is withdrawn by industry.

Erie public-supply system. -Erie's municipally-owned system served 37.2 mgd to a population of about 150,000 in 1950. Industries and commercial establishments used 21.3 of the 37.2 mgd. The Erie water system furnished water to the city of Erie, Presque Isle State Park, the U. S. Coast Guard Station, and parts of Wesleyville Borough, and Mill Creek, Lawrence Park, and Harborcreek Townships.

Two systems are used for obtaining, treating, and distributing the water. Chestnut Street Plant is supplied through a 60-in. intake 17,641 ft long. The intake extends through the center of Presque Isle Bay and about 5,000 ft into the lake. The intake has a capacity of 36 mgd. The West Plant is supplied through a 72-in. intake 8,745 ft long. It extends through the extreme west end of the bay and into the lake. This intake has a capacity of 70 mgd.

The capacity of the intakes far exceeds the capacity of the two filtration plants. The intakes are capable of delivering 106 mgd, whereas the two filtration plants are capable of delivering only 48 mgd. Even this is far greater than the present demand. The distribution system has not always been adequate. Owing to distribution problems, the city occasionally finds it necessary to prohibit the use of water for lawn sprinkling at times of high draft.

Industrial systems. -Three of the largest water users in Erie have private facilities for obtaining lake water. The Interlake Iron Corp. and Pennsylvania Electric Co. withdraw water from Presque Isle Bay, and the Hammermill Paper Co. withdraws directly from the lake. These companies use a total of 19 mgd.

Small Streams

North East is the only borough obtaining its water supply from streams. The water is withdrawn from tributaries of Sixteenmile Creek and French Creek (French Creek lies outside the area covered by this report). A population of 4,400 is served 1.4 mgd during an average day of which industries use 0.9 mgd. The use during the summer and fall canning season is generally double the average amount owing to the large fruit-processing plants in North East. The present water system has large storage facilities which adequately provide for a future growth in population and industry in that area.

A tannery withdraws an undetermined but small quantity of water from Brandy Run. This water, supplemented during the summer by water from several small springs, has always been adequate for full-time operations.

The use of other small streams for industrial water supply is negligible.

Ground Water

The present use of ground water in the region is widespread but relatively small in the amounts used. For the most part, consumption is confined to domestic use from individual wells.

The public supplies obtained from wells at Fairview and Westminster serve no industries, but some commercial use is made at Girard and North Girard. Two industries in the North East area use ground water to supplement the water supplied by the public system. One industry in North Girard has a large dug well for its water supply. No wells are known to be used for water supply in the city of Erie. Data for public water systems using ground water are given in table 8.

Most domestic wells in the region have been drilled and are 6 in. or less in diameter. Although not tested for yield, they probably would not produce more than 10 to 20 gpm; many wells yield only a few gallons a minute. The use of commercial well screens instead of open end or slotted casing probably would aid substantially in increasing the yields of wells in the glacial drift. The present use is limited in some locations by the poor chemical quality of the water, insufficient quantity, and danger of pollution. An area known as the Fairfield section on East Lake Road, just east of Erie, periodically experiences water shortages affecting about 750 people. Wells in this area are in the bedrock and went dry during the summers of 1950 and 1951. Some areas are not served by sewers so there is danger of the ground water becoming polluted from septic tanks.

Use of ground water for air conditioning in the Erie area has not been reported. Although summer temperatures usually are not oppressive, air conditioning is employed in some Erie buildings. If ground water were more readily available in this area, more of it would be used for air conditioning because of its uniform low temperature (about 50 F) during the summer.

POTENTIALITIES

Owing to the accessibility of Lake Erie, there is not now, nor is there ever likely to be any problem as to amount of water available for municipal and industrial use. Such problems as may arise will stem from problems relating to treatment or distribution.

Table 8. -Public water-supply systems using ground water

[Population and consumption figures from 1949 census of U. S. Public Health Service]

Subdivision	Ownership	Population served	Well data		Consumption (mgd)
			Diameter (inches)	Depth (feet)	
Fairview Borough	Private		8	52	0.03
		555	8	51	
Girard Borough	Municipal	1,730	240	12	.075
North Girard Borough	Municipal	1,100	8	36	.50
			-	20	
Westminster	Private	400	144	26	.05
			96	16	
			72	22	

Streams draining into Lake Erie are small. Conneaut Creek and Elk Creek drain the largest areas. Without storage, Conneaut Creek at U. S. Highway 6 N at Cherry Hill and Elk Creek at North Girard are capable of supplying at least 2 mgd each, for all but one day in an average year. Without storage, Crooked Creek at North Springfield and Mill Creek at the south edge of Erie are capable of supplying at least three-fourths of a million gallons per day each for all but one day per year in an average year. Larger supplies could be obtained if storage were provided.

A major expansion of ground-water use does not appear feasible in the suburban sections of Erie, owing to the smallness of available supplies and low water levels in the summer, danger of organic pollution in areas without sewers, and likelihood of chloride contamination. However, it is probable that many homes near Erie will continue for years to depend on individual water systems, until water service is extended by the municipality. For the Lake Erie Shore region as a whole a future large-scale increase in the use of ground water is unlikely, except in local areas which contain well-sorted sand and gravel deposits.

In general, wells must be shallow to avoid obtaining water high in chloride content. The yield of shallow wells is low because both storage and drawdown are limited. Such additional potable supplies as may be obtained from aquifers in the region will, for the most part, be derived from glacial drift.

In other sections, notably the buried valley under Crooked Creek, additional geological data and further well explorations are needed to determine the possibility of developing higher yields. A ground-water supply recharged by infiltration of the water from Crooked Creek could be large and dependable, provided that the geological conditions are favorable for stream infiltration. The large flow per square mile of Crooked Creek that occurs 80 percent or more of the time (fig. 5) as compared to that of other streams in the area (figs. 3, 7, 9, 11, 13, 15, 17 and 19) indicates that the ground-water-storage capacity of the Crooked Creek drainage basin is relatively large.

WATER LAWS

All public agencies or private interests contemplating development involving Lake Erie or the streams in the region should contact the proper Commonwealth agency at Harrisburg, Pa. The Pennsylvania Department of Forests and Waters and the Water and Power Resources Board have jurisdiction over the construction of dams and other obstructions which in any way might change the course, velocity, or cross-section of any waterway. They are also empowered to allocate all surface waters for public supply. The Pennsylvania Department of Health and the Sanitary Water Board administer surface-water laws which relate to sanitation and pollution.

Lake Erie is classified by the Federal Government as a navigable waterway and all projects involving Lake Erie are subject to the jurisdiction of the Buffalo District, Corps of Engineers.

Pennsylvania has no laws relating to the use or control of its underground waters. The Pennsylvania Department of Health and the Sanitary Water Board, in the interests of pollution abatement, have rules and regulations prohibiting the disposal of wastes into active or abandoned mines, wells, or other underground workings.

SUMMARY

The Lake Erie Shore region has promise of an increasingly important future. Lake Erie will remain the one dominating factor in its development. The lake furnishes an inexhaustible supply of water, provides the link to important lake commerce throughout the Great Lakes system, and aids agriculture by tempering the climate.

The public water department of Erie could extend its services far beyond its present limits. At present, the intakes are delivering only a third of their ultimate capacities. However, water-treatment and distribution facilities have about reached their capacities and must be expanded.

All streams draining into Lake Erie from Pennsylvania are small, mostly less than 25 sq mi in drainage area. The streams are not a major source of water supply; however, supplies of three-fourths to 2 mgd could be developed from Conneaut Creek, Mill Creek, Crooked Creek, and Elk Creek. Larger supplies could be developed if storage were provided. Ground water is not a major source of supply. Although used extensively in homes beyond the Erie and North East water-supply systems, it has been developed by only four small communities and a few industries. In general adequate domestic supplies of ground water can be obtained from both the glacial drift or bedrock, but in most areas, sufficient water of acceptable quality has been found in the glacial drift and the bedrock has not been penetrated. Water in the bedrock is also more likely to be saline than water in the overlying glacial drift.

It appears that wells drilled in the shale to depths below Lake Erie level cannot induce infiltration from Lake Erie.

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Pennsylvania State Planning Board, 1947: Industrial utility of water in Pennsylvania, chemical character of surface water, 1944-46, Pub. 17, 177 pp., 9 figs.

White, I. C., 1881, Geology of Erie and Crawford Counties: Pennsylvania 2d Geol. Survey, Progress Rept. Q4, 354 pp.

SOURCES OF ADDITIONAL INFORMATION

Inquiries relating to current water-resources information may be addressed to the following officers of the U. S. Geological Survey:

Surface water: Harrisburg, District Engineer, 490 Education Building; Pittsburgh 19, Engineer in Charge, 515 Plaza Building.

Ground water: Philadelphia 3, District Geologist, Nineteenth Street and Parkway; Pittsburgh 30, Engineer in Charge, Federal Building.

Quality of water: Philadelphia 6, District Chemist, 1302 U. S. Custom House, Second and Chestnut Streets.

Topographic maps: Washington 25, D. C. Chief of Distribution, Geological Survey.

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