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UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

A STUDY OF THE FLINT RIVER, MICHIGAN AS IT RELATES TO LOW-FLOW AUGMENTATION

by

Gordon C. Hulbert

Open-file Report

Prepared in Cooperation with
the Genesee County Drain
Commission and the Michigan
Department of Natural Resources

Lansing, Michigan

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ABSTRACT

One of the uses of the Flint River is dilution of waste-water. Population and industrial growth in the Flint area has placed new demands on the stream and emphasized the need for an analysis of the surface water resources of the basin. This report describes selected streamflow characteristics of the Flint River and its tributaries, and presents draft-storage relations for the river basin. Flow characteristics for 17 sites show that the 7-day 2-year low flow ranges from 0 to 0.17 cfs (cubic feet per second) per square mile. Draft-storage relations for the basin show that existing storage, if fully utilized, could, on an average, provide a minimum discharge at Montrose of 160 cfs in 19 out of 20 years. The discharge, in conjunction with water diverted from Lake Huron to the Flint River through the Detroit and Flint water systems (about 60 cfs in 1971), indicates that low flows would seldom be less than about 200 cfs at Montrose. Diversions from the basin for irrigation may reduce low flows by about 12 cfs. Ground-water sources offer small potential for development of large supplies of water for streamflow augmentation, although wells in the glacial deposits may provide a supplemental source of water at some locations.

INTRODUCTION

The Flint River is used in many ways, including recreation, irrigation, water supply and waste dilution. New demands have been placed on Genesee County's waste-treatment facilities as a result of growth in the Flint area. For this reason, a new treatment plant is currently being built at Montrose. Because this expansion of facilities emphasized a need for additional information, the Genesee County Drain Commission requested that the U.S. Geological Survey make a study of the Flint River. This report by the U.S. Geological Survey is the result of that study. The report provides data on flow characteristics and draft-storage relationships of the Flint River. Knowledge of these characteristics and relationships is necessary if water managers are to efficiently use the water resources of the Flint River. The report also provides data on the characteristics of streamflow of streams tributary to the Flint River in the vicinity of Flint. The storage capacities of existing impoundments are given, and the potential benefits of impoundments as they relate to streamflow augmentation are evaluated. The effects of diversions into and out of the basin are discussed. Ground-water resources are also considered for augmentation of flow in the Flint River during periods of low flow.

STREAMFLOW CHARACTERISTICS

The natural flow of streams fluctuates from day to day, season to season, and year to year, reflecting changes in precipitation and weather conditions. In the spring the streams are often swollen with flood waters from snowmelt and rainfall (fig. 1). After the high flows

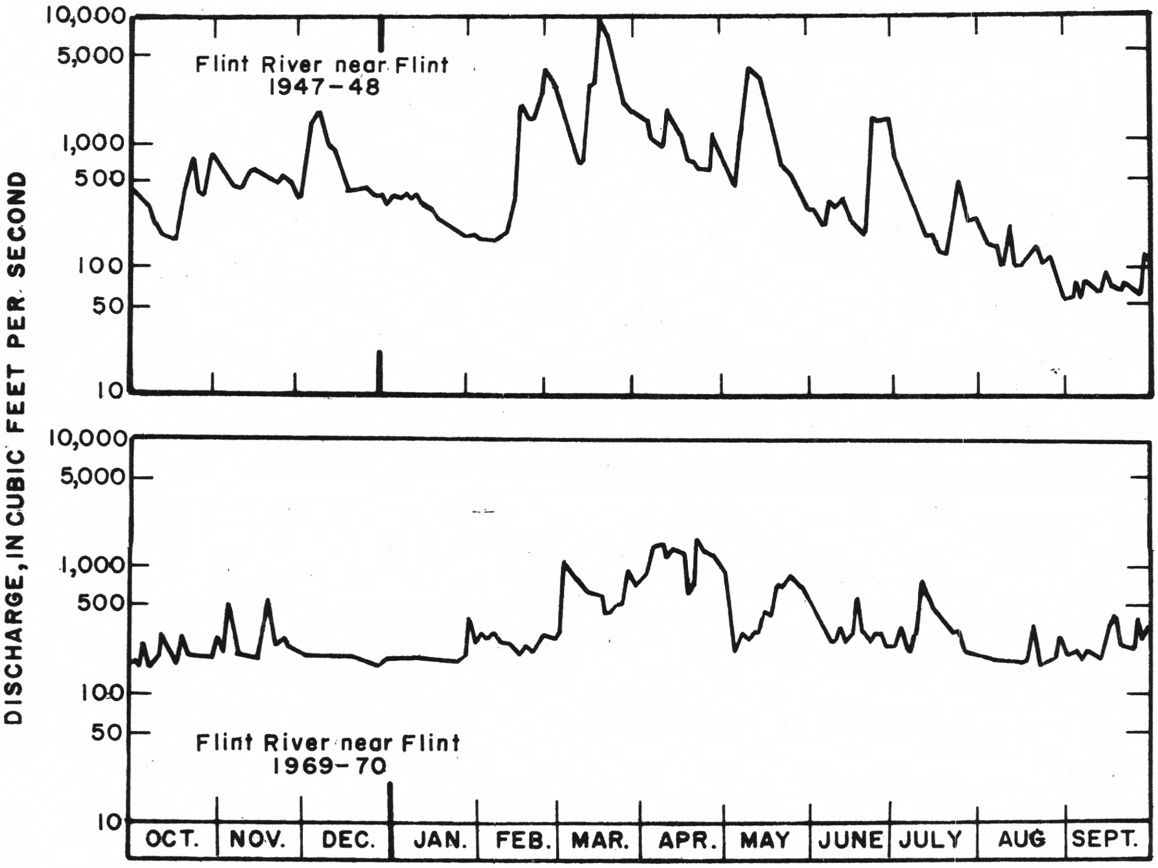

Figure 1.--Snowmelt, spring runoff, and rains are reflected in the shape of discharge hydrographs. The 1947-48 hydrograph reflects streamflow patterns unaffected by appreciable regulation; the 1969-70 hydrograph shows relatively uniform streamflow as affected by regulation.

of the spring, streams gradually recede to annual lows that occur in late summer or early fall. These annual low flows dictate a stream's limitation for waste dilution or other use, provided flow is not affected by storage impoundments.

Frequency and Duration of Flows

The flow characteristics of a stream without storage can be defined by the frequency that streamflow recedes to minimum amounts (frequency distribution of annual low flows), and by the percentage of time specific flows occur (duration of daily flows). Annual minimum flows vary from year to year, from stream to stream, and between different points on the same stream. To determine whether streamflow in the Flint River is adequate to dilute known amounts of treated wastes, an analysis of streamflow data was made to define the streams low-flow characteristics. Figure 2 shows a family of low-flow frequency curves for the Flint River near Flint prior to regulation. For example, the figure shows that the unregulated average flow for 7 consecutive days would be less than 29 cfs (cubic feet per second) at intervals averaging 10 years (7-day Q_{10}). Ten such events would be expected during a 100-year period; the events would not necessarily occur at 10 year intervals, however. Flows equivalent to the 10-year low flow could occur in two or more consecutive years. This possibility should be considered by a water manager in any water-supply development. Table 1 contains tabulation of low-flow frequency data for four sites on the Flint River. Some of these sites, as well as the locations of other data collection sites, are shown on figure 3.

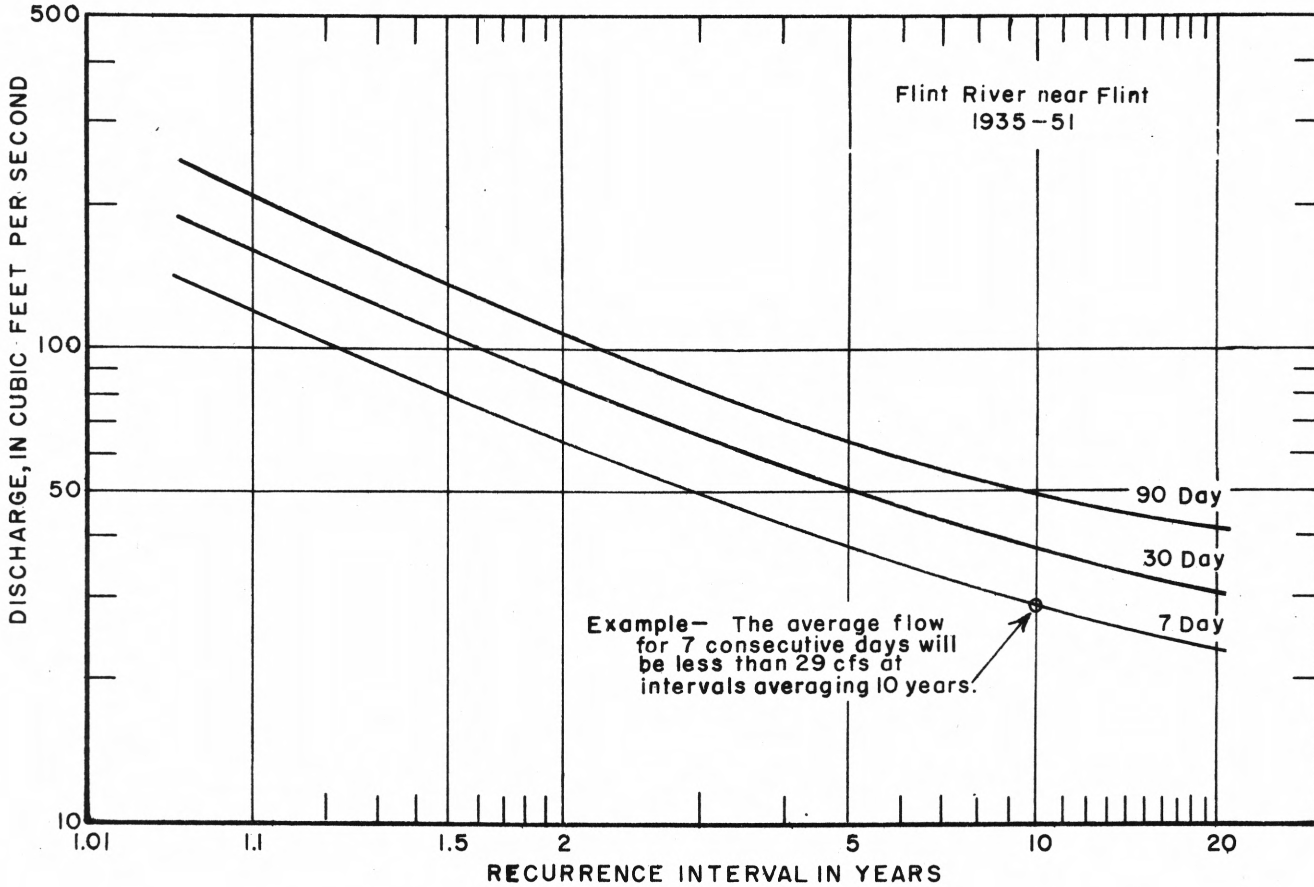

Figure 2.--The magnitude and frequency of low flows for the Flint River near Flint prior to regulation.

Table 1.--Summary of low-flow frequency data, 1933-51.

Values of natural flow shown are in cubic feet per second and, in parentheses, in cubic feet per second per square mile. Locations of sites are shown on figure 3, except station 1490 which is 6 miles north of the Genesee County line.

Station number	Stream	Drainage area (sq mi)	Lowest average discharge for indicated period of consecutive days and for recurrence interval shown					
			7-day			30-day		
			2-year	10-year	20-year	2-year	10-year	20-year
1480	Flint River at Genesee	598	50 (0.084)	25 (0.042)	21 (0.035)	58 (0.097)	31 (0.052)	26 (0.043)
1485	Flint River nr. Flint	954	64 (0.067)	29 (0.030)	24 (0.025)	84 (0.088)	38 (0.040)	31 (0.032)
1487	Flint River at Montrose	1,035	68* (0.066)	29* (0.028)	24* (0.023)	92* (0.089)	46* (0.044)	40* (0.039)
1490	Flint River nr. Fosters	1,120	72 (0.064)	29 (0.026)	24 (0.021)	96 (0.086)	50 (0.045)	41 (0.037)

* Values computed.

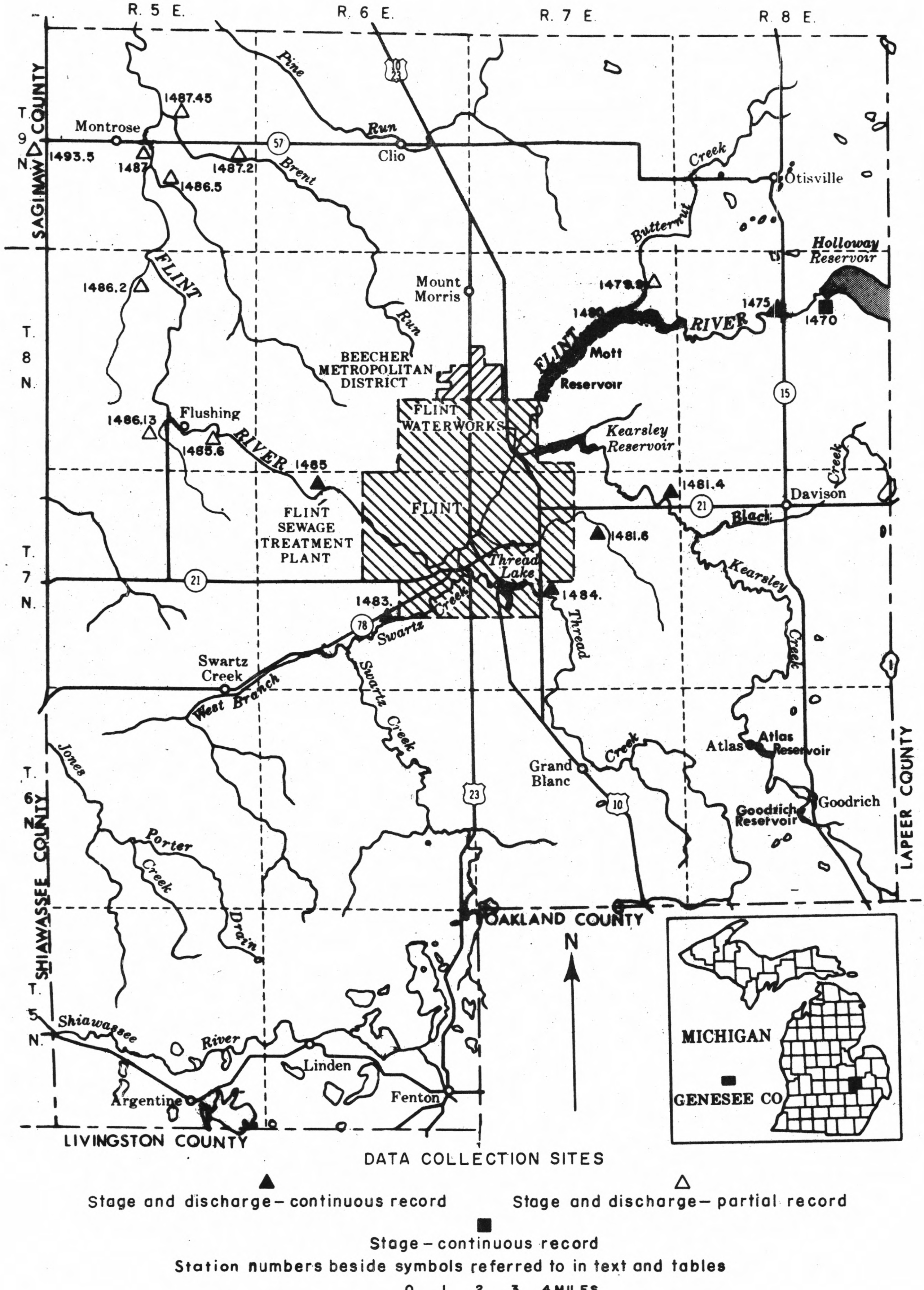

Figure 3.--Map of Genesee County showing locations where data on streamflow and reservoir contents have been collected.

Low-flow frequency characteristics have been determined also for six partial-record stations on tributary streams in the Flint-Montrose area. For these sites, where only a few measurements of low flow have been made, streamflow characteristics have been defined by correlating the measurements with records obtained at long-term gaging stations. Flow characteristics for these and other sites in the Flint River basin are shown in table 2. Because flow characteristics for these sites were based on limited data they are less reliable than flow characteristics for the long-term stations shown in table 1.

Flow duration curves, which show the percentage of time that given flows were equaled or exceeded, also are valuable indexes of dependable flow. These curves afford a convenient means of characterizing the flow of streams by incorporating the entire flow regimen into a single curve. Two duration curves for the Flint River near Flint are shown in figure 4. One of the curves is based on the 1933-51 period, when the flow of the river was not appreciably affected by regulation; the other curve is based on the 1952-67 period, when the flow of the river was regulated. The curve based on unregulated flow conditions shows that the discharge of the Flint River equaled or exceeded 55 cfs about 95 percent of the time, and, conversely, was less than 55 cfs about 5 percent of the time. Table 3 lists flow-duration data for four stations on the Flint River. The table shows five duration percentages that are often used by water managers. Most of the duration data was obtained from a report by Knutilla (1967). Flow-duration data shown in table 3 are based on records collected during a period (1933-51) when man's influence on the flow of the Flint River was negligible. Substantial ground-water

Table 2.--Low-flow characteristics of streams tributary to the Flint River.

Values shown are in cubic feet per second and, in parentheses, in cubic feet per second per square mile. Locations of most sites are shown on figure 3.

Station number	Stream	Drainage area (sq mi)	Low Flow	
			7-day 2-year	30-day 10-year
1460	Farmers Creek near Lapeer (Lapeer County)	55.2	2.4 (0.043)	1.4 (0.025)
1479.9	Butternut Creek near Genesee (Frances Road)	34.5	3.7 (0.107)	2.5 (0.072)
1481.4	Kearsley Creek near Davison (Davison Road)	99.6	5.8 (0.058)	3.2 (0.032)
1481.6	Gilkey Creek near Flint (Arapaho Street)	6.29	* 0 (0)	* .01 (0.002)
1482	Swartz Creek near Holly (Oakland County)	12.0	.58 (0.048)	.23 (0.019)
1483	Swartz Creek at Flint (Ballenger Highway)	115	2.6 (0.023)	1.2 (0.010)
1484	Thread Creek near Flint (Bristol Road)	55.6	2.4 (0.043)	1.4 (0.025)
1485.6	Mud Creek near Flushing (River Road)	8.59	* .16 (0.019)	* .09 (0.010)
1486.13	Cole Creek at Flushing (Pierson Road)	11.6	* .05 (0.004)	* .02 (0.002)
1486.2	Freeman Drain near Montrose (Mt. Morris Road)	8.21	* .10 (0.012)	* .05 (0.006)
1486.5	Armstrong Creek near New Lothrop (McKinley Road)	13.3	* .12 (0.009)	* .05 (0.004)
1487.2	Brent Run near Montrose (Morrish Road)	18.3	*3.1 (0.169)	*3.5 (0.191)
1487.45	Brent Run at Montrose (McKinley Road)	35.4	*2.1 (0.059)	*1.8 (0.051)
1493.5	Mistequay Creek near Montrose (M-57)	97.4	* .94 (0.010)	* .30 (0.003)

*Estimated

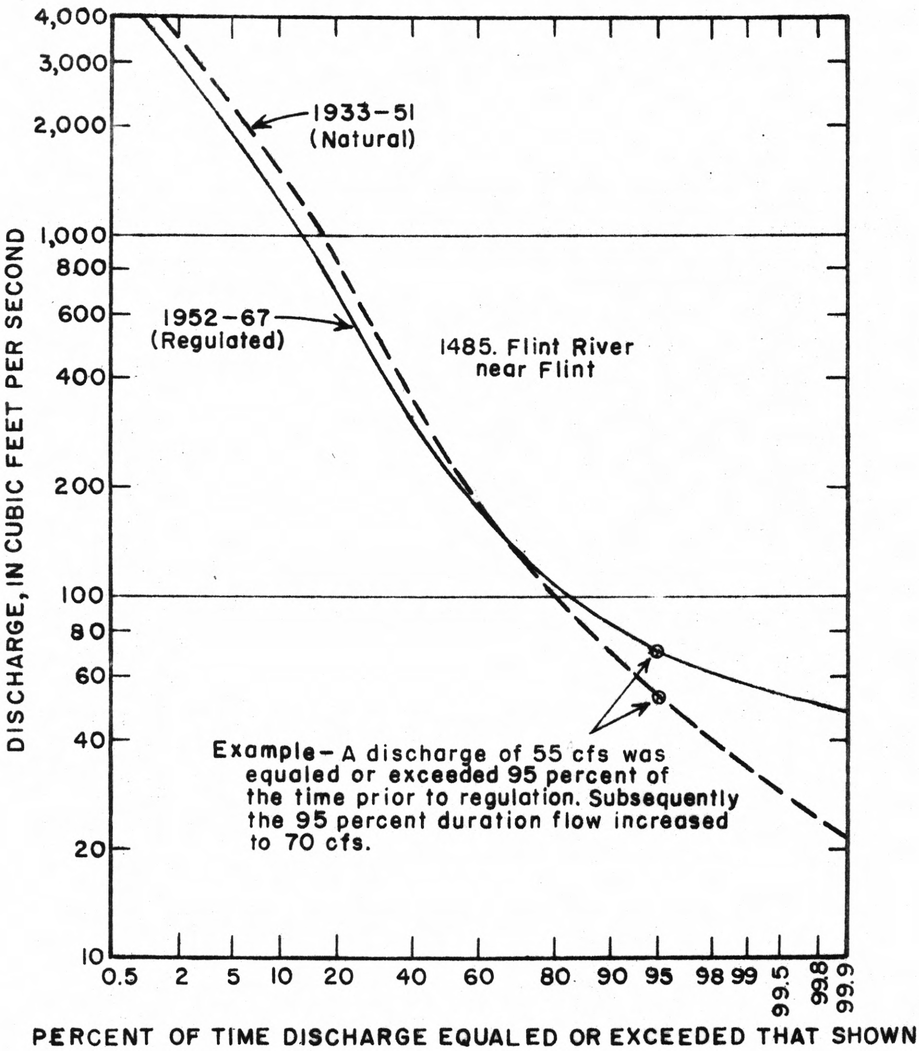

Figure 4.--Duration curves of daily discharge for the Flint River near Flint.

Table 3.--Summary of flow-duration data, 1933-51.

Values of natural flow shown are in cubic feet per second and, in parentheses, in cubic feet per second per square mile. Locations of sites are shown on figure 3, except station 1490 which is 6 miles north of the Genesee County line.

Station number	Stream	Drainage area (sq mi)	Discharge which was equaled or exceeded for indicated percent of time				
			30 percent	50 percent	70 percent	90 percent	95 percent
1480	Flint River at Genesee	598	329 (0.550)	165 (0.276)	94 (0.157)	55 (0.092)	44 (0.074)
1485	Flint River near Flint	954	530 (0.556)	255 (0.267)	140 (0.147)	72 (0.075)	55 (0.058)
1487	Flint River at Montrose	1,035	582* (0.562)	275* (0.266)	150* (0.145)	77* (0.074)	57* (0.055)
1490	Flint River nr. Fosters	1,157	660 (0.570)	305 (0.264)	165 (0.143)	84 (0.073)	60 (0.052)

* Values computed.

development by industry, the construction of Holloway Reservoir, and diversion from Lake Huron had not occurred, and thus natural low flows had not been distorted significantly.

STORAGE FOR AUGMENTING STREAMFLOW

When low-flow frequency and flow-duration data indicate that the discharge of a stream is inadequate to meet demands that might be imposed upon it, storage must be considered for augmentation of streamflow. That is, flood waters may be "captured" and stored for release during low-flow periods.

Regional Draft-Storage Relationship

Several methods, such as the annual mass-curve, mass-curve for period of record, and frequency mass-curve, are available for storage analysis. However, these methods are applicable only to sites where adequate flow data have been collected. Where only limited data have been collected, a regional analysis of discharge data provides a basis for estimating storage needs in relation to anticipated demands. This report defines the regional draft-storage relationship for the Flint River and its tributaries. The method used to define the relationship involves relating the draft-storage relation for gaging stations to a parameter of low flow. In this study, selected values of low-flow frequency and flow duration were evaluated as low-flow indexes. The 7-day 2-year low flow (7-day Q_2) was selected as the most suitable index of low flow. Figures 5 and 6 show draft-storage diagrams that have been developed for the study area. The relationships were developed without considering possible conveyance and evaporation losses.

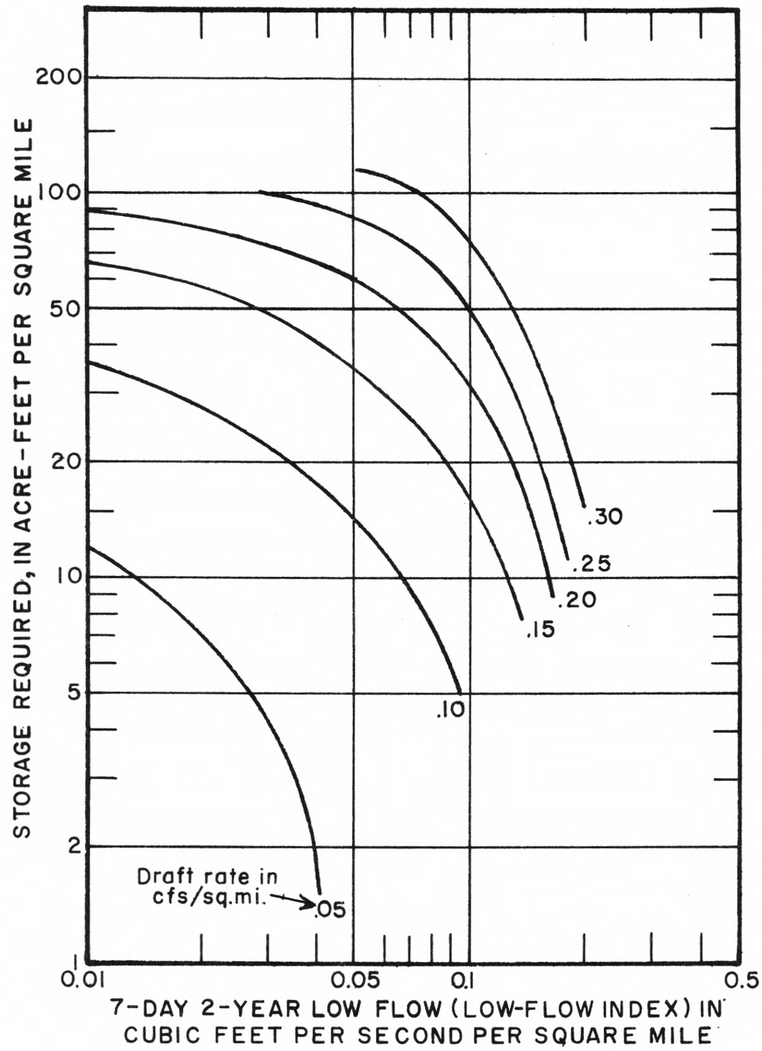

Figure 5.--Regional draft-storage curves for 10-year recurrence interval for the Flint River basin.

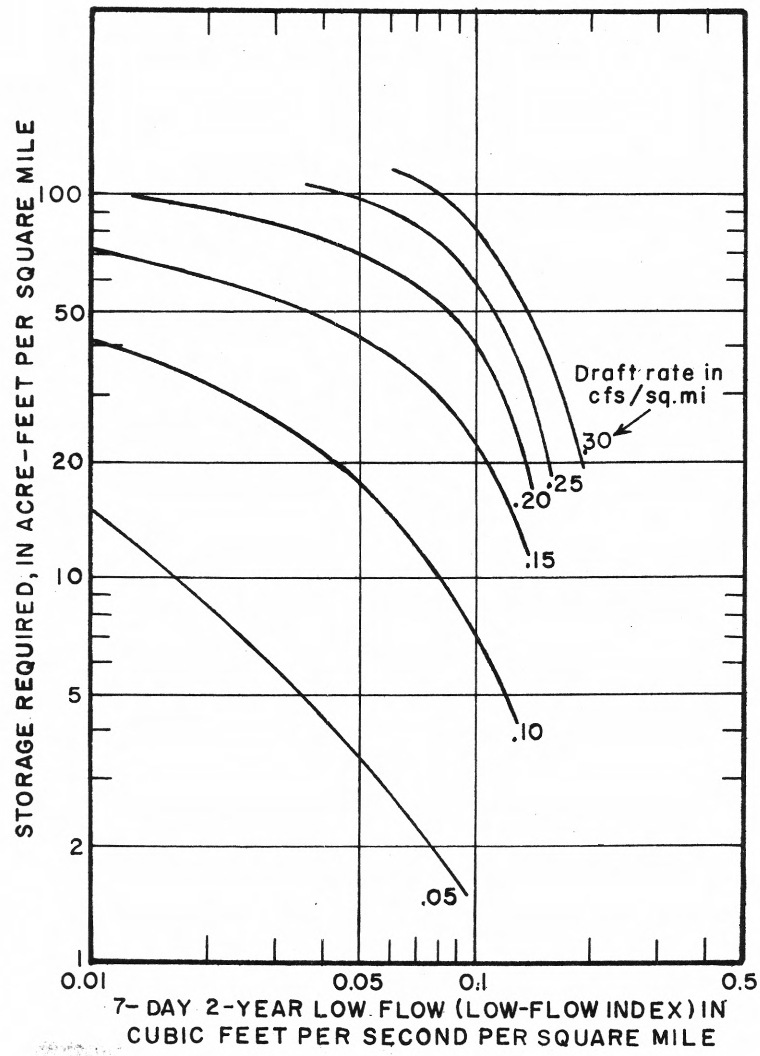

Figure 6.--Regional draft-storage curves for 20-year recurrence interval for the Flint River basin.

Use of Draft-Storage Diagrams

The storage required for a specific draft, with a chance that it will be insufficient on an average of once in 10 or 20 years, can be estimated by using figures 5 or 6, providing the index of low-flow at the site of use is known. For example, assume that a water user on the Flint River near Flint required a minimum of 200 cfs for operational purposes, and that the flow should not drop below this amount more often than once in 10 years on an average. Table 1 shows that the drainage area of the Flint River near Flint is 954 square miles, and that the 7-day 2-year low flow is 64 cfs, or 0.067 cfs per square mile (64 ÷ 954). The draft rate of 200 cfs is equivalent to about 0.20 cfs per square mile (200 ÷ 954). On figure 5 enter the abscissa at 0.067, and move vertically to intersect the 0.20 cfs per square mile draft-rate curve. From the point of intersection move horizontally to the left to determine the storage required. A storage volume of 50 acre-feet per square mile, or about 48,000 acre-feet (50 x 954), is indicated.

Tables 1 and 2 for the Flint River basin provide indexes of low-flow for 18 sites. Only those sites in Genesee County are shown in figure 3. For other stream sites within the basin, provided the streams are free from regulation, the low-flow index usually can be estimated by making a series of low-flow measurements. These measurements may be related to concurrent discharges at one or more nearby stations for which the low-flow index has been defined. The low-flow measurements should be made on different recessions, and in different years, to obtain the best sample for use in correlation. If a user cannot wait to obtain low-flow measurements of a stream, a low-flow index may be estimated by relating the stream to another that has similar physical characteristics (area, slope, natural storage, forest cover, soils, etc.). Estimates may also be made by use of regression models (Bent, 1970). After the low-flow index has been determined, the drainage area for the site must then be determined so that the low-flow index can be converted to runoff per square mile. When these values are determined, figures 5 and 6 may be used as outlined above.

Figures 5 and 6 may be used to define storage needs for a proposed installation or for making comparisons between streams. For example, if it were necessary to divert water from Brent Run or Misteguay Creek to augment streamflow in the Flint River above Montrose, an evaluation of their potential draft, with storage, might be necessary. Table 2 shows that Misteguay Creek near Montrose has a drainage area of 97.4 square miles and a 7-day Q_2 of 0.010 cfs per square mile. By using these values and figure 5, the storage required to maintain a draft of 0.10 cfs per square mile, or about 10 cfs (0.10 x 97.4), can be determined. A storage of 35 acre feet per square mile, or about 3,400 acre-feet, is needed. Brent Run has a drainage area of 35.4 square miles and a low-flow index of 0.059. To maintain a draft rate of 10 cfs (about 0.30 cfs per square mile), the storage required is 110 acre-feet per square mile, or about 3,900 acre-feet. Thus, Brent Run could provide a draft of 10 cfs with only slightly more storage than Misteguay Creek despite its having only about one third the drainage area of Misteguay Creek.

Figures 5 and 6 may be used to define storage requirements for the new treatment plant at Montrose by using a low-flow index of 0.066 (table 1). For convenience, however, draft-storage frequency relations for the Montrose site have been developed from figures 5 and 6 and are shown in figure 7. These curves can be used to define maximum sustained flows that can be realized with full utilization of existing reservoirs. The curves may also be used to define the additional storage that might be needed if existing storage is inadequate to meet projected needs.

USE OF EXISTING STORAGE

The existing reservoirs in the Flint River basin and their storage capacities are as follows:

Reservoir	Drainage Area (sq mi)	Storage Capacity (acre-feet)
Holloway	543	28,834
Kearsley	108	1,800
Thread Lake	31	660
Atlas	50	250
Goodrich	45	200

Mott Reservoir is presently under construction on the Flint River above Flint. When completed, its storage capacity will be 4,400 acre-feet. The total usable storage of the existing reservoirs is about 32,000 acre-feet.

If the existing storage could be fully used for low-flow augmentation the low flow of the Flint River could be substantially increased. For example, using figure 7, and the storage of 32,000 acre-feet, the

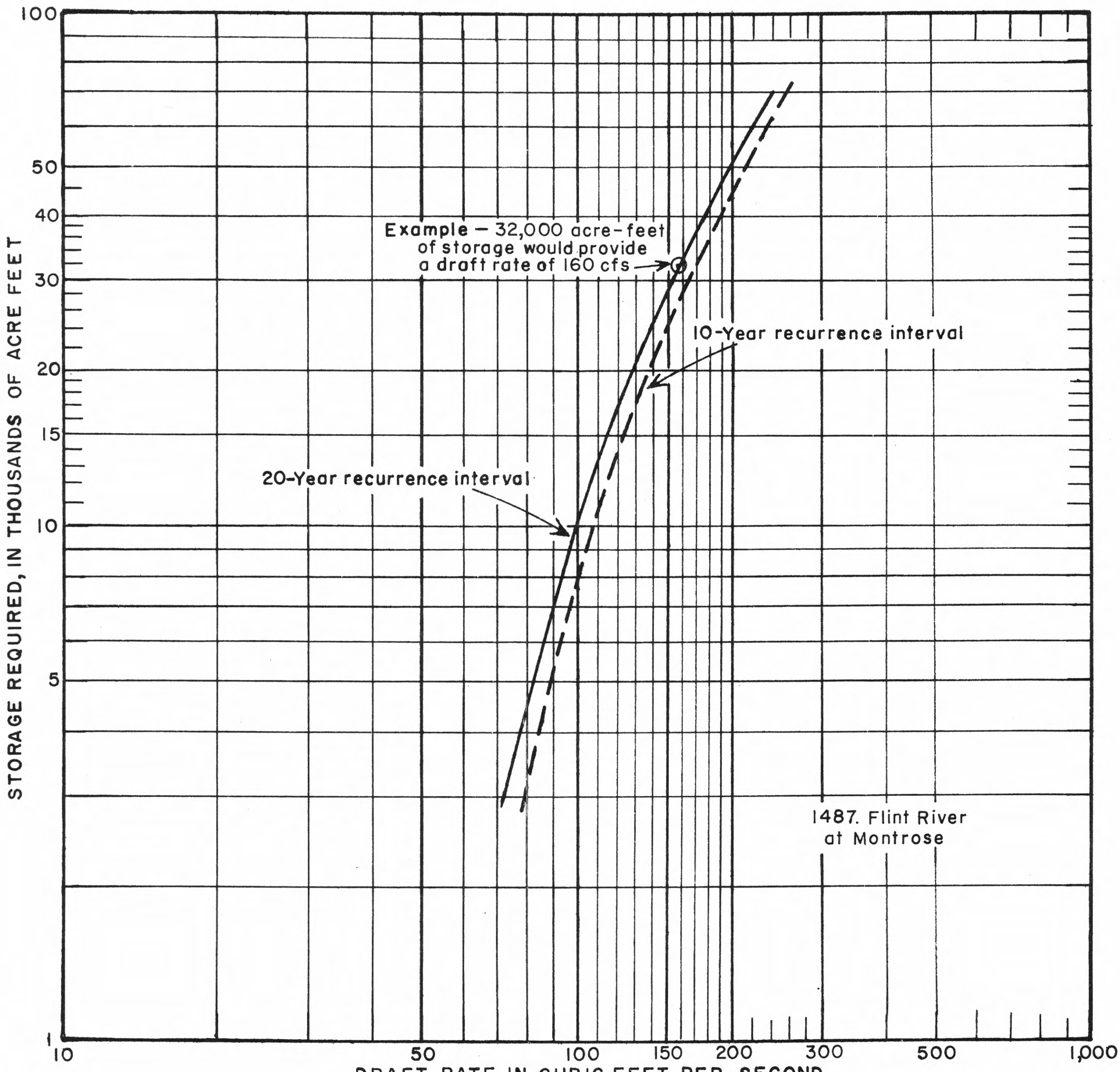

Figure 7.--Draft-storage frequency relations for 10- and 20-year recurrence intervals for the Flint River at Montrose.

20-year recurrence interval curve shows that a draft rate of 160 cfs would be provided. The 10-year curve shows that a draft rate of 170 cfs would be provided. These values show that the Flint River at Montrose could obtain a minimum of 160 cfs from existing storage in 19 out of 20 years on the average, or 170 cfs in 9 out of 10 years on the average. By comparison, data in table 3 shows that natural flows less than these amounts occur more than 30 percent of the time (150 cfs equaled or exceeded 70 percent of the time). If only Kearsley and Holloway Reservoirs could be made available for low-flow augmentation, usable storage would be 30,636 acre-feet. Based on this amount of storage, the 20-year recurrence interval curve shows that the sustained flow of the Flint River at Montrose would be 155 cfs. The 10-year recurrence interval curve shows an allowable draft rate of 165 cfs.

Draft-storage frequency relations may be used also to determine the storage needed to maintain a given draft-rate. Assume that the flow of the Flint River at Montrose must be 230 cfs in order to meet dilution requirements, and that all augmentation of flow must be provided by storage. Based on the 10-year recurrence interval curve of figure 7, the storage necessary to provide the flow would be 55,000 acre-feet. Depending upon the actual draft rate that may be required at Montrose, additional storage might be necessary in the Flint River basin. At least some, and possibly all, of any new storage could be developed on streams tributary to the Flint River.

Although a regional draft-storage analysis is suitable for determining the magnitude of a uniform flow release from a proposed reservoir, some operations may require that releases be varied. In such cases, a storage is usually determined by the methods outlined above. A plan of operation is then tested by varying those factors not evaluated in the regional analyses. On this basis, a non-uniform draft-rate operation can be established.

Application of the draft-storage curves provides reasonable estimates of storage requirements. Analyses made in defining the curves did not include losses in conveyance of water from storage facilities to points of use. Also, losses due to evaporation or seepage are not included. As these losses tend to make the computed amounts of storage requirements lower than they should be, allowances should be made for such losses in any project design.

If the economic and technical feasibility of a new impoundment is questionable, diversions of water from another basin, local ground-water supplies, or a combination of both may be used to augment streamflow. A discussion of existing diversions in and out of the Flint River basin follows.

DIVERSIONS OF WATER AND THEIR EFFECT ON STREAMFLOW

The water supply of the city of Flint and surrounding area is provided by the Detroit water system which obtains water from Lake Huron. In 1971, the city of Flint used from 50 to 60 cfs. Sewage treated during 1971 by the city of Flint also amounted to 50 to 60 cfs. These treated wastes are discharged to the Flint River at Flint and, thus, augment streamflow. If this rate of discharge of treated wastes continues, the low flow at Montrose will be more than that shown in tables 1 and 3 which reflect natural flow characteristics. Using a value of 60 cfs for diversions into the basin and without change of reservoir contents, the flow of the Flint River at Montrose for indicated frequencies and durations will be as shown in the following tables.

Lowest average discharge, in cfs, for indicated period of consecutive days and for recurrence interval shown					
7-day			30-day		
2-year	10-year	20-year	2-year	10-year	20-year
128	89	84	152	106	100

Discharge, in cfs, equaled or exceeded for indicated percent of time				
30%	50%	70%	90%	95%
642	335	210	137	117

Thus, if the available storage in the basin could be fully utilized and 60 cfs continues to be diverted from the Flint water system to the Flint River, the minimum discharge at Montrose would be about 220 cfs in 19 out of 20 years. The discharge would be 230 cfs for a 10 percent chance of being deficient.

Water from the Flint River is withdrawn for irrigation during low-flow periods. According to the Michigan Water Resources Commission (1970), the annual diversion from the Flint River basin is about 1 cfs. If, however, an irrigation season of about three months is assumed, with daily diversion periods of about 8 hours, water withdrawn during the irrigation season will be about 12 cfs. These withdrawals and their locations should be considered when estimating discharges at Montrose or elsewhere on the Flint River and adjustments made.

USE OF GROUND WATER FOR STREAMFLOW AUGMENTATION

The use of ground-water by municipalities and industry has decreased in recent years in Genesee County. Water purchased from the Detroit water system has reduced the demand on ground-water aquifers. Many city wells are now used only for stand-by or supplemental needs. It is possible that these or other wells could be used to augment the flow of the Flint River during drought periods.

The two sources of ground water in Genesee County are the bedrock and the glacial drift aquifers (Krieger and others, 1963). The bedrock formations show little promise for development of large or moderate supplies of water. Most wells yield less than 100 gpm (gallons per minute). In addition, bedrock aquifers may yield water that is too saline to be used for streamflow augmentation or other purposes. If utilization of the bedrock aquifers should be possible or necessary, installation of a number of widely spaced, low capacity wells would be the best method. This would minimize the possibility of severe lowering of the water table and the possibility of saline water migrating upward. Even with spacing of low capacity wells, it is doubtful that sufficient ground water can be obtained in most parts of the county for streamflow augmentation. The most promising area for obtaining sufficient water from bedrock is in the southeast, along the Genesee County-Oakland County line.

The yield of wells tapping glacial deposits differs from place to place. In recent years, most wells have been drilled for domestic supplies. In general, the wells are of small diameter, are relatively undeveloped, and yield less than 20 gpm. Thus, at some locations, the well yields are not indicative of the potential of glacial deposits. Wells that penetrate sands and gravels in buried channels, such as those in the city of Flint, often have large yields. Test drilling may locate new areas where large yields are possible. However, pumping rates as high as 1,000 gpm from individual wells are not common (oral communication, N. Thomas Sheehan, Layne-Northern Company). Several smaller capacity wells might obtain the desired quantities of water.

SUMMARY

Flow characteristics for 18 sites in the Flint River basin show that the 7-day 2-year low flow ranges from 0 to 0.17 cfs per square mile. Existing storage in the basin amounts to 32,000 acre feet. Draft-storage frequency diagrams indicate that this amount of storage would provide a minimum discharge at Montrose of about 160 cfs in 19 out of 20 years on the average. In addition to the natural streamflow the Flint River is augmented by diversions from Lake Huron through the Detroit and Flint water-supply systems. Presently these diversions into the Flint River amount to about 60 cfs. This increases the flow at Montrose to about 220 cfs. Use of water from the Flint River for irrigation above Montrose may amount to as much as 12 cfs during periods of dry weather in the summer. These diversions reduce the flow at downstream sites. The possibility of using ground water for augmenting streamflow is small. Wells finished in glacial deposits that were formerly used by the city of Flint for water supply could provide supplemental sources of water for augmenting streamflow. Elsewhere, glacial deposits yield small supplies of water and offer little potential for streamflow augmentation. Bedrock aquifers, which may yield water of poor quality, offer small potential for development of large supplies of water.

SELECTED REFERENCES

Bent, P. C., 1970, A Proposed Streamflow Data Program for Michigan: U.S. Geol. Survey open-file report.

Knutilla, R. L., 1967, Flow Characteristics of Michigan Streams: U.S. Geol. Survey open-file report.

Krieger, R. A., Vanlier, K. E., and Wiitala, S. W., 1963, Water Resources of the Flint Area, Michigan: U.S. Geol. Survey Water-Supply Paper 1499-E.

Michigan Water Resources Comm., 1970, Irrigation in Michigan: State of Michigan Water Resources Comm., Dept. of Conserv.

U.S. Geological Survey, issued annually, Surface-water supply of the United States, part 4, St. Lawrence River basin: U.S. Geol. Survey Water-Supply Papers and open-file reports.