Harmonic Mean Flows for Illinois Streams

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1 INTRODUCTION

State and federal agencies that regulate stream pollution have based their stream water quality standards on a flow condition in a stream specified as the 7-day, 10-year low flow ($Q_{7,10}$). This is defined as the lowest average flow that occurs for a consecutive 7-day period at an average recurrence interval of 10 years. The $Q_{7,10}$ maps for all streams in Illinois and the interstate rivers were first developed by Singh and Stall (1973). The $Q_{7,10}$ values for the Northeastern Illinois region were updated for 1980 conditions by Singh (1984). The $Q_{7,10}$ values for the rest of Illinois were updated for 1984 conditions by Singh et al. (1988a; 1988b).

In calculating dilution flows for substances causing carcinogenic effects in humans, it has been suggested that a low-flow value parameter such as ($Q_{7,10}$) is far too conservative for determining wasteload allocations. The criteria for the carcinogenic substances appearing on the priority pollutant list were derived by the U.S. Environmental Protection Agency (USEPA). The calculations assumed lifetime exposure to the target substances as equivalent to ingesting 2 liters (1) of water and 20 grams (g) of fish each day for 70 years (IEPA, 1990, sec 302.648). The USEPA has suggested using the harmonic mean flow (Q_{HM}) as a design streamflow for wasteload allocations, based on protection of human health from lifetime exposures to carcinogens (IEPA, 1990, sec 302.658). The basic reason for this suggestion is that the average concentration of a carcinogen over a lifetime is a function of the Q_{HM} of the stream. Although Q_{HM} is not a conventionally used flow parameter, it is the most appropriate flow parameter for human health criteria dilution flows from theoretical and practical considerations.

The average daily concentration in milligrams per liter (mg/l) is equal to wasteload (mg/day) divided by average daily flow Q (l/day). The average concentration of the carcinogen (C_{av}) over a lifetime is:

$$C_{av} = \frac{1}{n} \sum_{i=1}^{n} [\frac{wasteload}{Q_i}] \tag{1.1}$$

If we assume that the wasteload is constant, then the C_{av} over a lifetime is:

$$C_{av} = wasteload \times \frac{1}{n} \sum_{i=1}^{n} [\frac{1}{Q_i}] \tag{1.2}$$

If we define the Q_{HM} as:

$$Q_{HM} = \{\frac{1}{n} \sum_{i=1}^{n} [\frac{1}{Q_i}]\}^{-1} \tag{1.3}$$

then we can write equation 1.2 as:

$$C_{av} = [wasteload/Q_{HM}] \tag{1.4}$$

The C_{av} is a function of the wasteload and the flow parameter Q_{HM}. For a target C_{av}, it is therefore possible to allocate the wasteload on the basis of the Q_{HM}s This, of course, assumes that the carcinogenic effects are additive over a lifetime.

1.1   Need for Calculating the Harmonic Mean Flows (Q_{HM})

Attempts have been made by several state agencies to correlate the harmonic mean flows (Q_{HM}) to the mean flow (Q) and the 7-day, 10-year low flow ($Q_{7,10}$). However, all these attempts have indicated poor correlations between Q_{HM} and Q and between Q_{HM} and $Q_{7,10}$. Some of the reasons for the poor correlations are given below.

1. The $Q_{7,10}$ is affected by the quantity of effluents discharged upstream of the point of interest along the stream.

2. The $Q_{7,10}$ is a very low flow. Low flows vary greatly from north to south in Illinois, mostly because of physiography, stream entrenchment, and soil type. The $Q_{7,10}$ may be zero for a drainage area from 5 to 10 square miles (mi^2) in the northern area of the Rock River basin, whereas it may be zero for areas from 200 to 500 mi^2 in southern Illinois.

3. Although the low flows and $Q_{7,10}$ increase as the drainage area increases, the rate of increase of low flows is usually higher than the **rate** of increase of drainage area. There are two basic explanations for this phenomenon: a) as **the** drainage **area** gets larger, the probability of having partial-area storms increases, and b) stream entrenchment increases and results in higher ground-water contribution to the stream.

4. The ratio of Q_{HM} to $Q_{7,10}$ (as well as of $\overline{Q}$ to Q_{HM}) is a function of physiography, drainage area, basin soils, stream entrenchment, ground-water aquifers, wastewater effluent discharges, and land use. An acceptable range for these ratios will be impractical.

5. Many small to medium-sized streams have zero daily flows (Q). For such flows, the inverse of Q is indeterminate. A decision will have to be made whether to neglect such days, to replace zero flow with the minimum nonzero reported flow, or to consider Q_{HM} as zero.

1.1.1 Flow Ratios for Selected Illinois Streams

The three flow parameters ($\overline{Q}$, Q_{HM}, and $Q_{7,10}$) were computed for seven selected gaging stations in Illinois (table 1.1). The Q_{HM} values in table 1.1 may be different than the final values reported because these values have not been adjusted for time trends and changes in effluents.

Table 1.1: Mean Flow, Harmonic Mean Flow, and 7-Day, 10-Year Low Flow Statistics for Selected Gaging Stations in Illinois

Gaging Station	Area (mi^2)	$\overline{Q}$ (cfs)	Q_{HM} (cfs)	$Q_{7,10}$ (cfs)	$Q_{HM}/Q_{7,10}$	$\overline{Q}/Q_{HM}$
Sinsinawa River near Menominee	39.6	28.7	16.4	5.0	3.28	1.75
Kickapoo Creek at Waynesville	227	164	10.1	1.2	8.42	16.2
Salt Creek near Greenview	1804	1293	313	86	3.64	4.13
Salt Fork near St. Joseph	134	117	25	4.1	6.10	4.68
Embarras River near Camargo	186	158	5.49[1]	0.51	10.8	28.8
North Fork Embarras River near Oblong	318	262	4.92[2]	0.17	29.0	53.3
Embarras River at Ste. Marie	1516	1235	116	7.0	16.6	10.7

[1] about 2 percent of the days with zero flows have been neglected
[2] about 1 percent of the days with zero flows have been neglected

The determination of dilution flow parameters to meet established human health criteria is very important. This determination needs to be made using all available information so that industries **that** need to conform to standards for wasteloads are not unduly restricted in their productive ventures. It is therefore imperative for regulatory agencies to determine as accurately as possible Q_{HM} values along all streams in Illinois. This will provide for effective regulation, thereby providing safeguards at reasonable cost. A precise estimation of Q_{HM}s for Illinois streams can only be accomplished by computing them directly using historical daily flow records. The values developed at the gaging stations can be used to

develop regional regression equations. The Q_{HM} values at intermediate points can be determined using the regional regression equations.

1.2   Acknowledgments

2 METHODOLOGY

The objective of this study was to develop the Q_{HM} maps for streams in Illinois for the 1990 conditions of effluent discharges, water withdrawals, and flow regulation. The general procedures used are described briefly. Any special features applicable to a particular region are noted under the relevant map description.

2.1 Development of Hydrologically Homogeneous Regions

Development of hydrologically homogeneous regions for Q_{HM} maps was based on the procedure outlined in Singh and Stall (1973). The following steps are used in preparing a Q_{HM} map for a river basin or region:

1. The drainage area associated with the streams or river system in a particular region is marked on the 2-degree maps of the U.S. Geological Survey (USGS). The maps have a scale of 1 to 250,000 or about 1 inch = 4 miles. Where the elevation contours are not defined well enough to draw the drainage boundary accurately, 15-minute and 7-1/2-minute USGS quadrangle maps are used that have a scale of 1 to 62,500 and 1 to 24,000, respectively. A base map is then prepared showing the drainage boundary, the stream network, all towns that have wastewater treatment plants (WTPs) and lagoons, and county lines. The USGS streamgaging stations on Illinois streams and any bordering rivers are located on the base map from the detailed descriptions of their locations published in USGS Supply Papers and Water Resources Data for Illinois.

2. The locations of the municipal and industrial WTPs are not shown on the maps to reduce clutter. However, whenever significant flows from large treatment plants are present, the Q_{HM} values upstream and downstream of the discharge point are provided.

3. Dams, regulating structures, and lakes (those large enough to be accurately represented on the map) are also located on the base map. Dams and in-channel impoundments for municipal water supply systems are located on various streams from the available information in USGS maps, county plat books, river basin reports, and similar references. All large and medium lakes, and some small ones (natural or man-made) are shown on the maps because of their significant effect on the $Q_{HM}S$.

4. Streams with zero Q_{HM} are defined first. From the natural (excluding the effect of effluents and regulation) low flow versus drainage area graphs, the streams with zero Q_{HM} are determined and shown as dotted-dashed lines on the map. Any WTP effluents entering these intermittent-flow streams are then considered. If the effluent is lost in the dry streambed before reaching the perennial stream, the zero Q_{HM} stream remains as such. But if the effluent is not lost, the stream starts with a Q_{HM} at the outfall equal to the magnitude of the effluent, and this flow is reduced downstream to the point where the natural Q_{HM} flow begins. Downstream, the Q_{HM} equals the reduced effluent flow plus the natural flow.

5. Streams with nonzero $Q_{HM}S$ are mapped next. To natural low flows along such streams are added the effluents from WTPs and lagoons to obtain the Q_{HM} for 1990 conditions. Any withdrawal of water from a stream for a municipal supply or industrial use is shown by a decrease in the Q_{HM} value.

The state was divided into ten regions as shown in figure 2.1 (Singh and Stall, 1973). A Q_{HM} map for 1990 conditions was prepared for each region. Descriptions of these ten maps are given below.
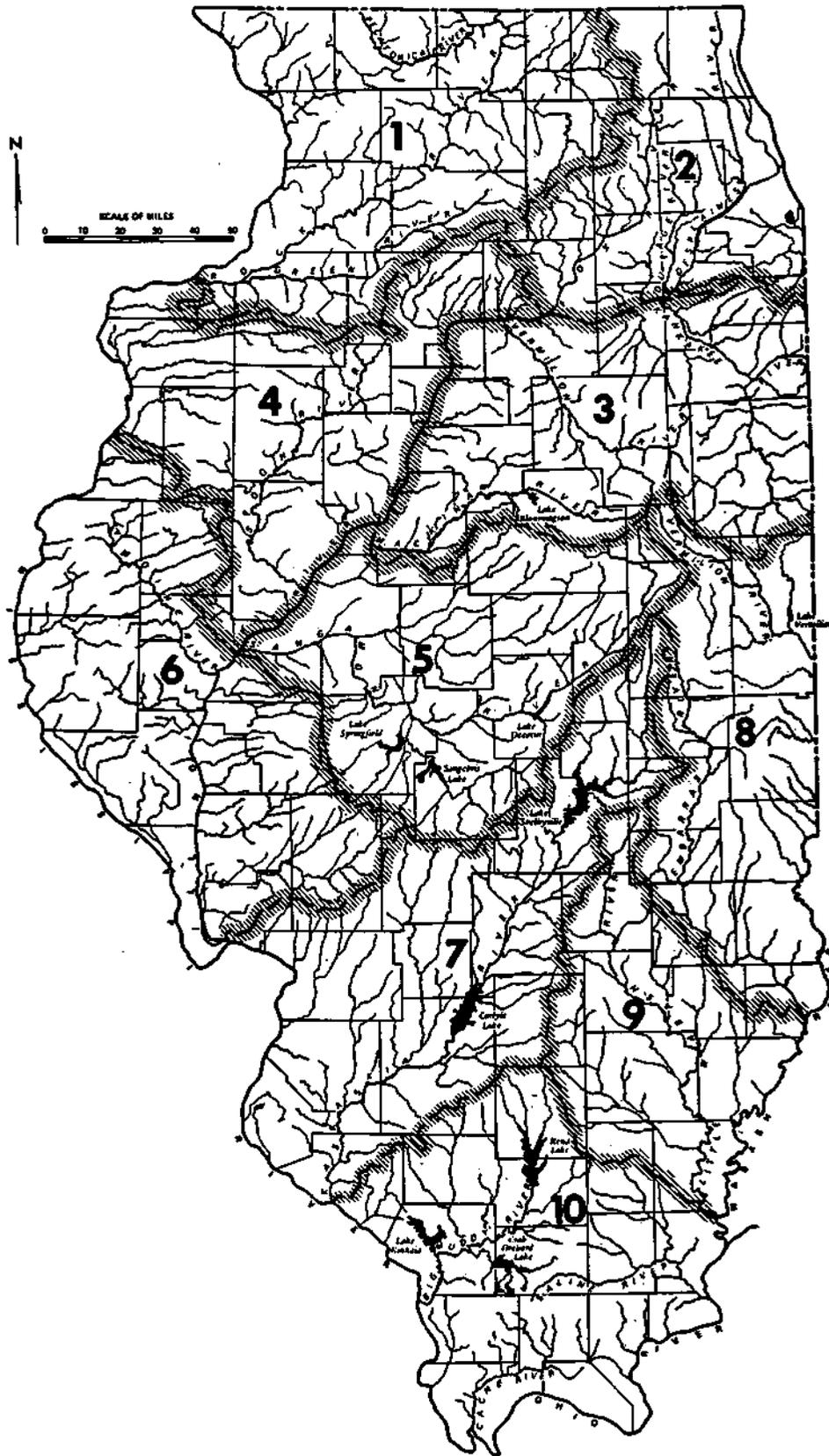
Figure 2.1: Locations of hydrologically homogeneous regions for the development of Harmonic Mean Flow maps

Map 1 Rock River Region: Rock River and Mississippi River drainage upstream of Rock Island

Map 2 Northeastern Illinois Region: Chicago Sanitary and Ship Canal and Chicago, Des Plaines, DuPage, and Fox Rivers

Map 3 Kankakee Region: Kankakee, Mazon, Vermilion, and Mackinaw Rivers, and Illinois River drainage from the east upstream of the Sangamon River

Map 4 Spoon River Region: Bureau Creek, Spoon River, and Mississippi River drainage north of Henderson Creek

Map 5 Sangamon Region: Sangamon River with Salt Creek and other tributaries

Map 6 La Moine River Region: La Moine River, Macoupin Creek, and Mississippi River drainage upstream of the mouth of the Illinois River

Map 7 Kaskaskia Region: Kaskaskia River and Mississippi River drainage between the Illinois and Kaskaskia Rivers

Map 8 Embarras Region: Vermilion and Embarras Rivers, and Wabash River drainage above the Embarras River

Map 9 Little Wabash Region: Little Wabash River and Wabash River drainage between the Embarras and Little Wabash Rivers

Map 10 Southern Region: Saline, Big Muddy, and Cache Rivers, plus direct drainage into the Wabash, Ohio, and Mississippi Rivers

2.2 Q_{HM} at Streamgaging Stations

The primary data used in this study are the daily flow records at the USGS gaging stations on streams in Illinois and the border rivers. These stations are shown on the Q_{HM} maps. Daily-flow data for the period of record up to Water Year 1990 were used for this study. The following procedure was used to compute the Q_{HM} at the gaging stations.

1. Daily-flow data at all gaging stations in Illinois and selected stations in the bordering states of Wisconsin, Iowa, Missouri, Kentucky, and Indiana were obtained from the USGS and stored on the Sun SPARCstation computer disk.

2. A computer program was developed to read the daily flow data for each station and compute the Q_{HM} for each year of record and also for the complete record. Since the Q_{HM} is indeterminate when flow is zero, the the annual Q_{HM} series is computed by neglecting all zero-flow values. The number of zero-flow days in each year is computed at each gaging station and the percentage of zero-flow days for the period of record is determined.

3. The Q_{HM} at a gaging station that has zero-flow days greater than 1 percent was considered to be equal to zero. The 1 percent target for zero flows was based on a comparative analysis of the unadjusted values of Q_{HM} and $Q_{7,10}$ for a sample of gaging stations in Illinois. Gaging stations with zero-flow days very close to 1 percent were checked for any problems with the data or the presence of zero-flow days in recent years. This information was used to decide if the Q_{HM} was zero or nonzero.

4. A five-year moving average series was generated using the annual Q_{HM} for each station. This series was plotted on graph paper to determine any trend in the data. The Q_{HM} value was then adjusted, if necessary.

Out of about 200 streamgaging stations analyzed, about 50 have undergone changes in streamflow regimen because of considerable wastewater effluent flows, diversions, and stream regulation. The Q_{HM}s at these stations were adjusted to conform to the present conditions. A plot of the five-year moving average of the annual Q_{HM} is shown in figure 2.2. The Q_{HM} for the period of record is 32 cubic feet per second (cfs). The adjusted Q_{HM} is 38 cfs.

2.3 Q_{HM} along the Streams

The Q_{HM}s at the gaging stations serve as benchmarks for estimating the Q_{HM} values along the streams and tributaries. Other pertinent information is the location of WTP effluents entering the stream and their effluents during the months in which low flows may occur in the receiving stream. For maximum utility, Q_{HM} values need to be estimated at locations near towns, at junctions with medium and major tributaries, at sizable inflows from WTPs, and at regulation or control works. The Q_{HM} values were estimated at these various points along the streams, but not all of them are shown on the low-flow maps to avoid clutter. The Q_{HM}s along the streams (every 3 to 5 miles) were derived with the use of the following tools, individually or in combination, as dictated by the prevailing conditions in each general area.

2.3.1 Q_{HM} versus Area Curves

The curve for natural Q_{HM} versus drainage area, applicable to the region under consideration, indicates the drainage area (Ao) for which the natural Q_{HM} is zero. The creeks, streams, and tributaries with drainage area less than AQ are shown by dotted-dashed lines on the low-flow maps. When the drainage area equals A_o, the low-flow value is shown as 0.0 and the stream is drawn as a solid line downstream, which means it is then a perennial-flow stream.

The state was divided into hydrologically homogeneous regions to develop significant correlations between Q_{HM} and basin factors (such as drainage area, length, and slope of stream), as well as between Q_{HM} and mean flow. The regional regression equations that were developed were used to calculate Q_{HM} values at various points in the stream system in a hydrologically homogeneous region.

2.3.2   Wastewater Treatment Plant Effluents

The WTP effluents entering the streams pose some problems in estimations $of Q_{HM}$. If these effluents enter streams that have drainage area less than A_o, an estimate has to be made of the losses occurring in the intermittent streams to determine whether these effluents would be absorbed before reaching the natural perennial-flow stream. If the effluent additions are small and enter the stream in the upper reach, generally they are lost in the dry streambed. However, if the effluent additions are considerable, they may contribute to some flow at the stream point with drainage area AQ. The larger the effluent is and the closer it is to the point of entrance to the AQ point, the larger the flow contribution will be. Once the stream has nonzero natural Q_{HM}, any effluent additions simply increase the Q_{HM} by the amount of effluent addition.

2.3.3   Water Withdrawals for Municipal and Industrial Uses

Generally, any town or industry pumping water from a stream returns it to the stream after use in the form of effluents from its WTP. Such use does cause a reduction in the Q_{HM} because the amount of water returned to the stream is always less, though the deficit varies. Adjustments in Q_{HM} values are made for these losses where necessary.

2.3.4   Timing of Flows in Two Major Branches

When two major branches drain sufficiently large areas before joining together, the curves for Q_{HM} versus area that are applicable to these branches may be quite different because of hydrologic, geologic,
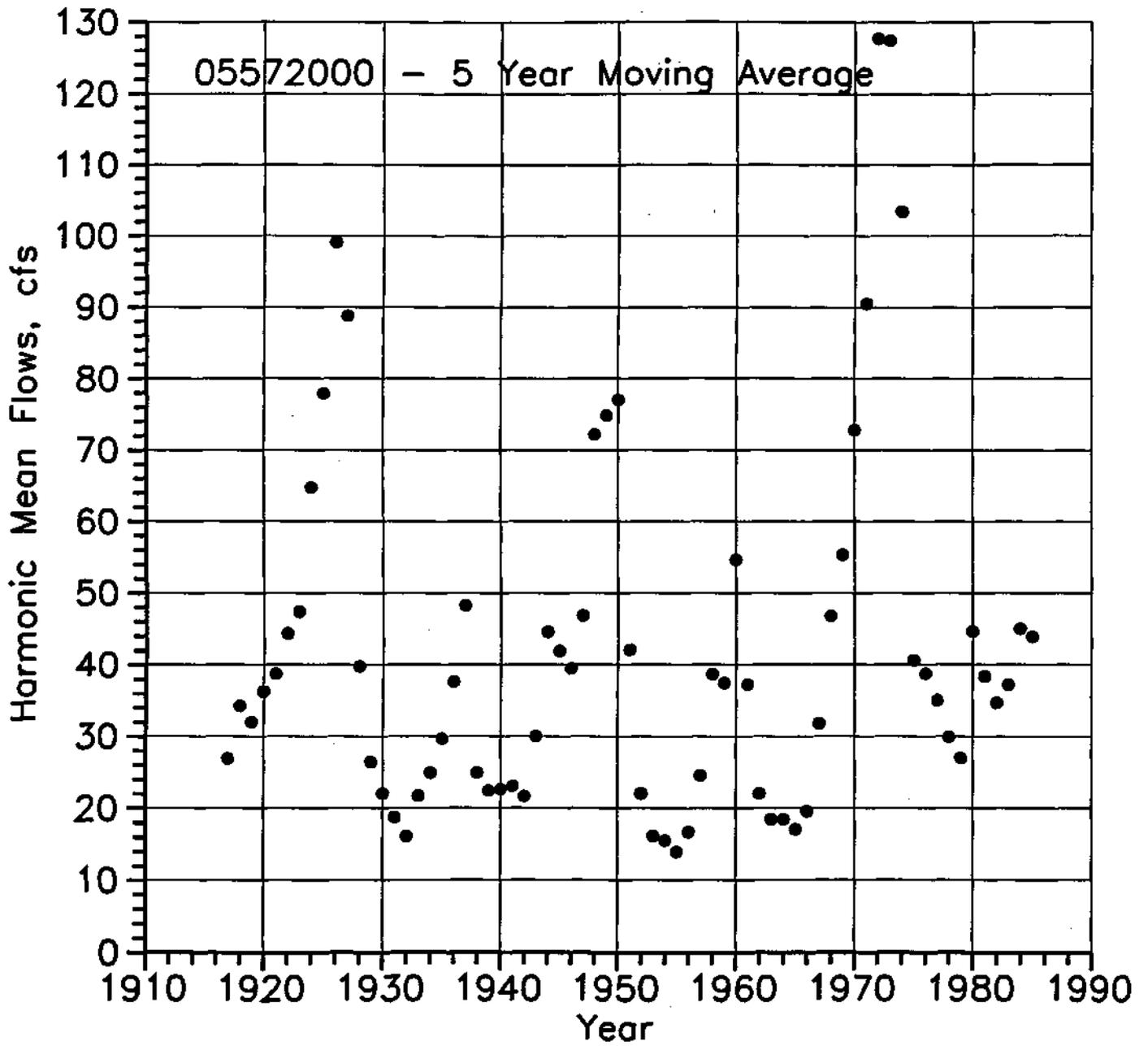
Figure 2.2: Adjustment of trends in determining Q_{HM} : Sangamon River at Monticello

and soil factors. Further, similar flows may not occur during the same month in the two branches. Under such conditions, the Q_{HM} below the junction will be higher than a simple addition of the Q_{HM}s in the two branches.

2.3.5   Modification of Q_{HM} Because of Lakes and Pools

Instream lakes and pools generally reduce the Q_{HM} unless a significant minimum flow release is provided in the project design. Lakes and pools expose considerable water surface areas to evaporation. If the water levels are regulated for recreational or other purposes, the flow needed to maintain lake level combined with evaporation loss may reduce the Q_{HM} at the lake outlet to zero. If no water is released from lakes in order to hold water for municipal or industrial use during critical dry periods, the Q_{HM} below the impounding structure is zero. However, in large multipurpose reservoirs (e.g., Shelbyville, Carlyle, and Rend Lake), some minimum flow release is stipulated downstream of the dam. This low-flow release criterion is used to estimate the Q_{HM} at the outlet.

2.3.6   Flow Regulation for Navigation

Flows in the Illinois River are regulated through a series of locks and dams for navigation purposes. On the Illinois River there are five locks and dams near Dresden, Marseilles, Starved Rock, Peoria, and La Grange, creating pools with very little slope during low-flow conditions. There are three USGS gaging stations on the Illinois River: at Marseilles, at Kingston Mines, and at Meredosia. The observed losses, proportional to water-surface area, are attributed to evaporation and storage as needed for satisfactory flow regulation. Therefore the distribution of losses along the river is found by determining the use of the lake, river, and backwater surface areas at different points along the river.

2.3.7   Ground-Water Accretion to Flow

A stream becomes a gaining stream when ground water flows into it. The amount of this accretion has been shown to be related to the depth of streambed incision or entrenchment (Singh, 1968). The amount of this gain is estimated from the low-flow data at gaging stations along a major stream, streambed conditions, existence of permeable deposits, and other pertinent factors.

2.3.8   Flow Data from Gaging Stations in Adjoining States

For determining Q_{HM}s in the Mississippi River bordering Illinois, the daily-flow data at USGS gaging stations on selected streams in the border states of Wisconsin, Iowa, and Missouri, as well as the Mississippi River, were used. The multistation computer program provided the information on concurrent flows in these rivers and tributaries, both upstream of their junction and below it. These flow series were used in determining the Q_{HM}s. This procedure was also applied in determining the Q_{HM}s on the Wabash and Ohio Rivers.

3 DEVELOPMENT OP REGIONAL HARMONIC MEAN FLOW MAPS

3.1   MAP 1 — ROCK RIVER REGION

The Rock River region includes the Rock River basin in Illinois and areas drained by streams directly entering the Mississippi River upstream of Rock Island. The major tributaries to the Rock River are the Pecatonica, Kishwaukee, and Green Rivers. The Sinsinawa, Galena, Apple, and Plum Rivers drain directly to the Mississippi River. The entire region, with the exception of JoDaviess County and the northwest corner of Carroll County, is covered with Illinoian glacial drift. Streams in the northern part of the region have much more flow during low-flow conditions than do streams in the southern part. The Rock River is navigable for a distance of 15 miles upstream of its confluence with the Mississippi River. There are seven dams on the Rock River, and the average head lies between 7 and 11 feet. These dams (ISPC, 1938a) are: Milan (Sears plant), Sterling (lower plant), Sterling (government dam), Dixon, Oregon, Rockford, and Rockton.

3.1.1 Q_{HM} at Gaging Stations

USGS daily-flow records for 28 gaging stations were analyzed to determine the Q_{HM} values for each year of record at these stations. The Q_{HM} values at each station were determined by following the procedures outlined in chapter 2. The USGS number, stream and gaging station, drainage area, period of record, percent of zero-flow days, and the Q_{HM} are given in table 3.1. The Q_{HM} values at the gaging stations serve as benchmarks for estimating the Q_{HM} values along the streams and tributaries.

3.1.2   Wastewater Treatment Plants and Effluents

The locations of municipal and industrial WTPs and their monthly average effluent discharges for 1987-1990 were compiled from the discharge monitoring reports available from the regional offices of the IEPA. The magnitude of the Q_{HM} from the effluent discharge was estimated by using the ratio of the $Q_{7,10}$ to current mean monthly effluents. Information obtained from telephone conversations with the WTP managers was used in some cases to make an accurate determination of the Q_{HM} for present conditions. Some small towns with lagoon systems have practically no effluent discharge during dry weather conditions. Industrial plants with effluent flows less than 0.1 cfs were not considered. The locations of the municipal and industrial WTPs are not shown on the Q_{HM} map. The Commonwealth Edison Byron Station in Ogle County withdraws water from the Rock River for cooling purposes and returns it after use. In this exchange, a loss of 50 cfs occurs as per communication from Commonwealth Edison.

3.1.3   Illinois and Mississippi Canal

When completed in 1907, the canal was 52 feet wide at its bottom, 80 feet wide at the water line, and had a water depth of 7 feet (Yeater, 1978). It was operated by the U.S. Army Corps of Engineers as a navigable waterway from 1907 to 1951. The navigation was discontinued because of excessive maintenance costs. The State of Illinois assumed full ownership in 1970, and the Illinois Department of Conservation is operating a recreation corridor along the canal, affording a variety of water- and trail-related outdoor recreational opportunities.

A feeder canal diverts water from the Rock River near Sterling in Whiteside County. It flows south about 29 miles where it bifurcates into two branches. The west branch runs about 47 miles to the navigable Rock and Mississippi Rivers, and the east branch travels 28 miles to the Illinois River near the town of Hennepin. At present, about 50 cfs is diverted from the Rock River, and this amount is divided nearly equally between the two branches below the point of bifurcation.

Table 3.1: Map 1 - Gaging Stations and Harmonic Mean Flows

USGS Gage	Stream and Gaging Station	Area (mi²)	Period of Record	Zero-Flow Days (%)	Q_{HM} (cfs)
05414820	Sinsinawa River near Menominee	39.6	20(1968-1987)	0.00	21
05415000	Galena River at Buncombe, WI	125	49(1940-1988)	0.00	60
05415500	East Fork Galena River at Council Hill	20	30(1940-1969)	0.00	6.6
05419000	Apple River near Hanover	247	53(1935-1987)	0.00	92
05420000	Plum River below Carroll Creek near Savanna	230	37(1941-1977)	0.04	70
05420500	Mississippi River at Clinton, IA	86500	88(1901-1988)	0.00	37400
05434500	Pecatonica River at Martintown, WI	1034	49(1940-1988)	0.00	580
05435000	Cedar Creek near Winslow	1.30	20(1952-1971)	34.17	0.0
05435500	Pecatonica River at Freeport	1326	73(1915-1987)	0.00	720
05437000	Pecatonica River at Shirland	2550	19(1940-1958)	0.00	1380
05437500	Rock River at Rockton	6363	48(1940-1987)	0.00	3100
05437695	Keith Creek at Rockford	13.4	7(1980-1986)	0.00	3.0
05438250	Coon Creek at Riley	85.1	21(1962-1982)	0.00	25
05438500	Kishwaukee River at Belvidere	538	48(1940-1987)	0.00	200
05439000	S. Br. Kishwaukee River at DeKalb	77.70	8(1980-1987)	0.00	10
05439500	S. Br. Kishwaukee River near Fairdale	387	48(1940-1987)	0.00	74
05440000	Kishwaukee River near Perryville	1099	48(1940-1987)	0.00	350
05440500	Killbuck Creek near Monroe Center	117	32(1940-1971)	0.00	17
05441000	Leaf River at Leaf River	103	19(1940-1958)	0.00	42
05441500	Rock River at Oregon	8205	10(1940-1949)	0.00	4300
05442000	Kyte River near Flagg Center	116	12(1940-1951)	0.00	22
05443500	Rock River at Como	8755	66(1915-1986)	0.00	4730
05444000	Elkhorn Creek near Penrose	146	48(1940-1987)	0.00	60
05445500	Rock Creek near Morrison	158	16(1943-1958)	0.00	66
05446500	Rock River near Joslin	9551	48(1940-1987)	0.00	5280
05447000	Green River at Amboy	201	19(1940-1958)	0.00	37
05447500	Green River near Geneseo	1003	51(1937-1987)	0.00	275
05448000	Mill Creek at Milan	62.4	45(1942-1986)	0.15	3.0

3.1.4 Determination of Q_{HM}: An Example

The Q_{HM} in the Kyte River near Flagg Center was calculated as 22 cfs under the 1990 effluent flow conditions. The 22 cfs flow comprised 16 cfs natural flow, 5 cfs effluent flow from Rochelle, and 1 cfs effluent from Ashton.

3.2 MAP 2 — NORTHEASTERN ILLINOIS REGION

The Northeastern Illinois region covers the area drained by the Chicago Sanitary and Ship Canal and the Chicago, Des Plaines, Du Page, and Fox Rivers.

3.2.1 Q_{HM} at Gaging Stations

USGS daily-flow records for 44 gaging stations were analyzed to determine the Q_{HM} for each year of record at these stations. The Q_{HM} values at each station were determined by following the procedures outlined in chapter 2. The USGS number, stream and gaging station, drainage area, period of record, percent of zero-flow days, and the Q_{HM} are given in table 3.2.

3.2.2 Wastewater Treatment Plants and Effluents

The Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) operates three major WTPs: Northside, West-Southwest, and Calumet. Since the mid-1970s the MWRDGC has put into operation three new medium-sized plants: Hanover Park, John Egan, and O'Hare. The North Shore Sanitary District (NSSD) also operates two new WTPs.

The monthly operation reports from various towns, cities, and industries were obtained from the IEPA. These reports contain information on the amount of water in gallons per day (gpd) leaving the plant after treatment and any wastewater bypassed during rains in the case of combined sewer systems. The effluent records were analyzed to derive the Q_{HM}s in the year 1990. Some municipal and industrial WTP managers were contacted by phone to verify the information collected from the files.

3.2.3 Fox Chain-of-Lakes

In-stream lakes and pools generally reduce the year low flow. Lakes and pools expose considerable water surface areas to evaporation, thus reducing the natural low flows. The upper part of the Fox River Basin in Illinois has a flat low-lying terrain abounding in lakes, swamps, marshes, and sloughs. Included in this area are the Fox Chain of Lakes with a combined water surface of 13 mi^2. The principal lakes in the chain are Pistakee, Nippersink, Fox, Petite, Channel, and Catherine. There are two dams in the area: the McHenry and Algonquin Dams. The McHenry Dam creates a pool extending upstream to the Pistakee Lake outlet. The surface area of the pool is 403 acres. The Algonquin Dam creates a 16.34-mile-long pool, with a surface area of 849 acres, extending upstream to the McHenry Dam. Gates at the McHenry Dam are operated to maintain the water level in the Chain of Lakes for recreational purposes.

The Q_{HM}S at Wilmot and Algonquin, adjusted for 1990 effluent discharge conditions, are 380 and 625 cfs, respectively.

3.2.4 Flow Regulation for Navigation

Flows in the MWRDGC waterways and in the Illinois River are regulated through a series of locks and dams for navigation purposes. The observed losses are attributed to evaporation, leakage, and storage because of regulation. Because all these losses are proportional to water surface area, the distribution of losses along the river is found by the use of the lake, river, and backwater surface areas at different points along the river.

Table 3.2: Map 2 - Gaging Stations and Harmonic Mean Flows

USGS Gage	Stream and Gaging Station	Area (mi^2)	Period of Record	Zero-Flow Days (%)	Q_{HM} (cfs)
05527500	Kankakee River near Wilmington	5150	72(1916-1987)	0.00	2240
05527800	Des Plaines River at Russell	123	20(1968-1987)	0.07	12
05528000	Des Plaines River near Gurnee	232	19(1969-1987)	0.00	100
05528500	Buffalo Creek near Wheeling	19.6	24(1964-1987)	0.28	2.0
05529000	Des Plaines River near Des Plaines	360	47(1941-1987)	0.36	150
05529500	McDonald Creek near Mount Prospect	7.90	35(1953-1987)	12.67	0.0
05530000	Weller Creek at Des Plaines	13.2	37(1951-1987)	4.58	1.2
05530500	Willow Creek near Park Ridge	19.7	8(1951-1958)	1.68	53
05530990	Salt Creek at Rolling Meadows	30.5	14(1974-1987)	0.59	3.8
05531500	Salt Creek at Western Springs	114	42(1946-1987)	0.00	81
05532000	Addison Creek at Bellwood	17.9	36(1952-1987)	0.01	8.0
05532500	Des Plaines River at Riverside	630	44(1944-1987)	0.01	370
05533000	Flag Creek near Willow Springs	16.5	36(1952-1987)	0.00	15
05534500	N. Br. Chicago River at Deerfield	19.7	35(1953-1987)	4.84	2.0
05535000	Skokie River at Lake Forest	13.0	36(1952-1987)	0.14	3.5
05535070	Skokie River near Highland Park	21.1	20(1968-1987)	0.00	6.4
05535500	W. F. of N. Br. Chicago River at Northbrook	11.5	35(1953-1987)	0.19	7.0
05536000	N. Br. Chicago River at Niles	100	37(1951-1987)	0.00	48
05536195	Little Calumet River at Munster, IN	90.0	30(1959-1988)	0.00	24
05536210	Thorn Creek near Chicago Heights	17.2	16(1965-1980)	6.21	1.5
05536215	Thorn Creek at Glenwood	24.7	38(1950-1987)	0.00	28
05536235	Deer Creek near Chicago Heights	23.1	39(1949-1987)	0.67	2.2
05536255	Butterfield Creek at Flossmoor	23.5	39(1949-1987)	2.11	0.0
05536265	Lansing Ditch near Lansing	8.80	39(1949-1987)	0.84	1.2
05536270	North Creek near Lansing	16.8	32(1949-1980)	3.09	2.7
05536275	Thorn Creek at Thornton	104	39(1949-1987)	0.00	48
05536290	Little Calumet River at South Holland	205	40(1948-1987)	0.00	85
05536340	Midlothian Creek at Oak Forest	12.6	37(1951-1987)	3.11	1.0
05536500	Tinley Creek near Palos Park	11.2	36(1952-1987)	5.95	0.0
05537000	Chicago Sanitary and Ship Canal at Lockport	739	36(1954-1989)	0.00	2900
05537500	Long Run near Lemont	20.9	36(1952-1987)	6.57	1.2
05539000	Hickory Creek at Joliet	107	43(1945-1987)	0.00	19
05539900	W. Br. Du Page River near West Chicago	28.5	26(1962-1987)	0.00	23
05540095	W. Br. Du Page River near Warrenville	90.4	19(1969-1987)	0.00	52
05540500	Du Page River at Shorewood	324	47(1941-1987)	0.00	185

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USGS Gage	Stream and Gaging Station	Area (mi²)	Period of Record	Zero-Flow Days (%)	Q_{HM} (cfs)
05543500	Illinois River at Marseilles	8259	68(1920-1987)	0.00	7200
05546500	Fox River at Wilmot, WI	868	49(1940-1988)	0.00	380
05548280	Nippersink Creek near Spring Grove	192	21(1967-1987)	0.00	95
05549000	Boone Creek near McHenry	15.5	34(1949-1982)	0.00	10
05550000	Fox River at Algonquin	1403	72(1916-1987)	0.00	625
05550500	Poplar Creek at Elgin	35.2	36(1952-1987)	0.00	5.4
05551200	Ferson Creek near St. Charles	51.7	26(1962-1987)	0.00	12
05551700	Blackberry Creek near Yorkville	70.2	27(1961-1987)	0.00	27
05552500	Fox River at Dayton	2642	63(1925-1987)	0.00	1190

3.2.5 Streams in Urbanizing Basins

For streams with a rapidly urbanizing drainage area, the low flows each year exhibit a pronounced upward trend with time. As an example, consider the annual Q_{HM} flows for the Salt Creek at Western Springs (USGS gage 05531500) during the period 1946-1987. The five-year moving average of the Q_{HM}s is plotted in figure 3.1. The best-fit curve shows the trend and yields a Q_{HM} of 81 cfs for the 1990 conditions of inflows to Salt Creek above the gaging station. Various inflows above the gaging station for the years 1940, 1950, 1960, 1970, and 1980 are given below.

Inflows above Station 05531500
Salt Creek at Western Springs

Source	Inflows (cfs)				
	1940	1950	1960	1970	1980
John Egan Plant	.	.	.	.	19.5
Elk Grove Devon	-	-	-	-	0.1
Springbrook	-	0.03	0.42	0.80	1.5
Wood Dale	-	-	0.36	1.1	1.7
Addison	0.08	0.08	0.88	3.8	5.5
Salt Creek S. D.	1.1	1.4	3.4	4.6	2.8
Elmhurst	1.9	2.6	4.8	7.3	10.4
Oakbrook Terrace		.	.	.	0.12
Oak Brook	-	-	0.09	1.6	
TOTAL	3.08	4.11	9.95	19.32	41.5

The total inflow in 1990 was about 60 cfs. Most of the communities in the basin depend on wells for their water supply. Water pumped from the ground or supplied from Lake Michigan is discharged as wastewater effluent. In the southern part of the basin, the glacial drift is thin, and the basal sand and gravel, though too thin to be used as an aquifer, do provide a hydraulic connection between the Salt Creek bed and the dolomite aquifer underlying the sand and gravel. This relationship is **a** critical factor in ground-water recharge in the southern part of the basin. The entire reach of the Salt Creek south
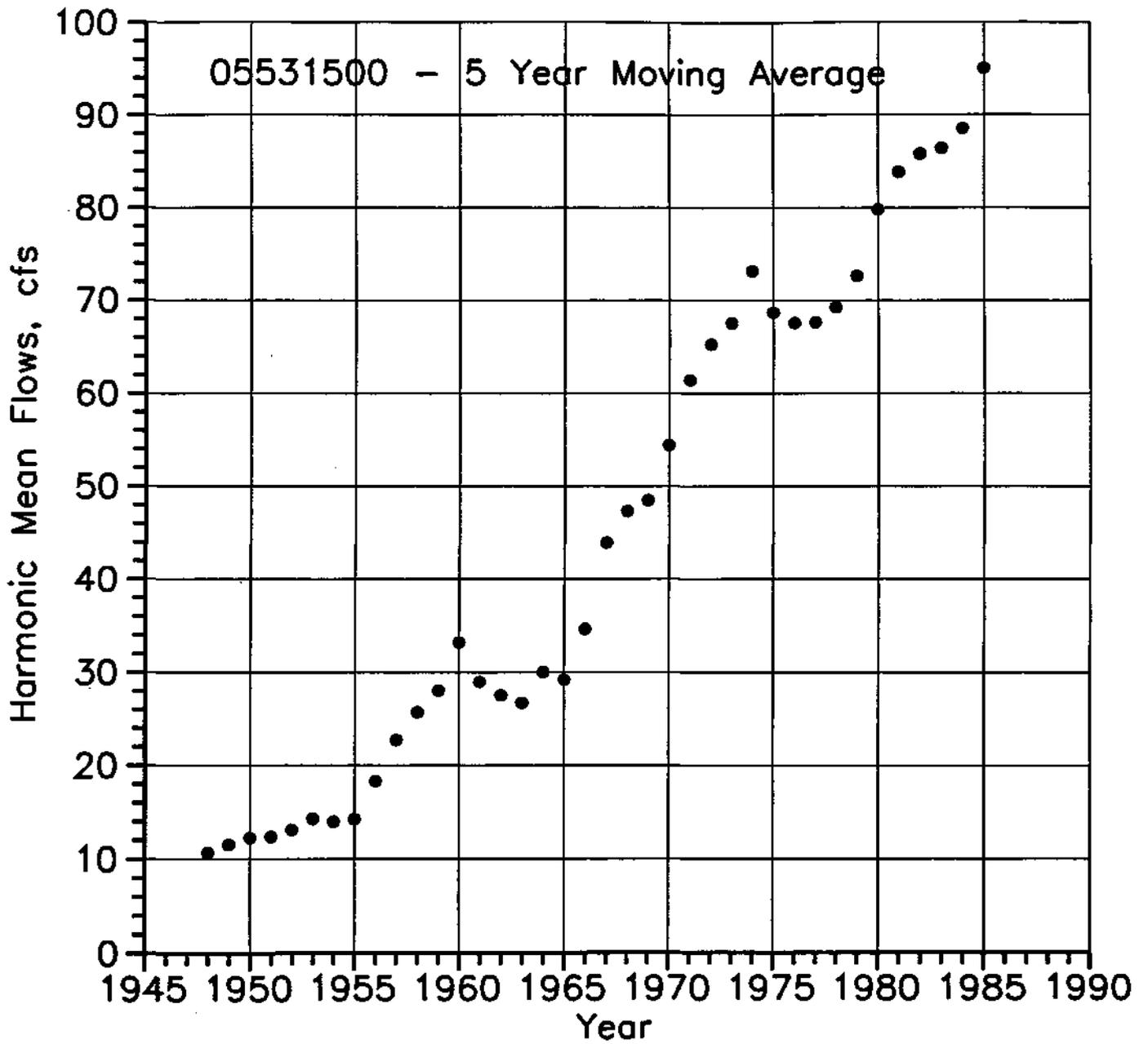
Figure 3.1: Harmonic Mean Flow trends: Salt Creek at Western Springs

and east of Elmhurst is regarded as an area of potential recharge to the shallow aquifers. Favorable conditions for induced recharge exist in the general area near gaging station 05531500 because of an extensive cone of depression caused by ground-water pumping. Induced recharge from the streambed reduces streamflow; this effect will be more pronounced at low flow than at high flow. These losses were used in determining the Q_{HM} flows upstream of the gaging station.

3.2.6 Metropolitan Water Reclamation District of Greater Chicago Waterways

The MWRDGC has three major sewage treatment works (Northside, West-Southwest, and Calumet), which discharge to the North Shore Channel, Chicago Sanitary and Ship Canal, and Calumet-Sag Channel, respectively, of the MWRDGC waterways. These waterways serve a dual purpose. They provide open drainage for effluents from WTPs serving Greater Chicago, and navigation facilities both ways for shipping from Lake Michigan to the Mississippi River via the Illinois River. The water levels in these waterways are controlled primarily for navigation that requires wide and deep waterways.

In the past about 1700 cfs of Lake Michigan water was used by municipalities for water supply. After deductions for storm runoff, pumpage, and lockage and leakage, the remainder allowable diversion or discretionary diversion has been used by the MWRDGC to dilute WTP effluents in the waterways during certain periods.

The northside WTP discharges its effluent to the North Shore Channel, which joins the North Branch Chicago River about 3 miles downstream. The North Branch Chicago River meets the Chicago River, which carries Lake Michigan water coming through the lock facilities at Chicago Harbor. From this junction to Damen Avenue, the channel is known as the South Branch Chicago River. Downstream from Damen Avenue to Lockport, it is the Chicago Sanitary and Ship Canal. The largest MWRDGC WTP, West-Southwest, discharges its effluent to this waterway. The canal is joined by the Calumet-Sag Channel from the east, which carries Lake Michigan water passing through the Calumet River and the O'Brien Lock and Dam, water from the Grand Calumet and Little Calumet Rivers, and the effluent from the Calumet WTP, the MWRDGC's third major WTP. Downstream of the Lockport Lock and Dam, the Chicago Sanitary and Ship Canal joins the Des Plaines River, which later combines with the Kankakee River to form the Illinois River.

3.2.7 Illinois River

The Illinois River basin covers 28,906 miles in northern and central Illinois. The flow in the Illinois River is regulated through a series of locks and dams for navigation purposes. The bed profile, the longitudinal water surface profile during low flows, the five locks and dams (Dresden, Marseilles, Starved Rock, Peoria, and La Grange) and the five pools they create, and the three USGS gaging stations are shown in figure 3.2. The pools have very little surface slope during low-flow conditions. The three gaging stations on the Illinois River and the Q_{HM}S at these locations are:

- 05543500 Illinois River at Marseilles: 7200 cfs

- 05568500 Illinois River at Kingston Mines: 10,900 cfs

- 05585500 Illinois River at Meredosia: 14,490 cfs

The first, second, and third gaging stations are shown in maps 2 and 3, 3-5, and 6 and 7, respectively. The Q_{HM} at the confluence of the Des Plaines and Kankakee Rivers (the start of the Illinois River) was estimated at 7200 cfs from a study of concurrent flows at the following gaging stations:

- 05527500: Kankakee River near Wilmington

- 05532500: Des Plaines River at Riverside

- 05537000: Chicago Sanitary and Ship Canal
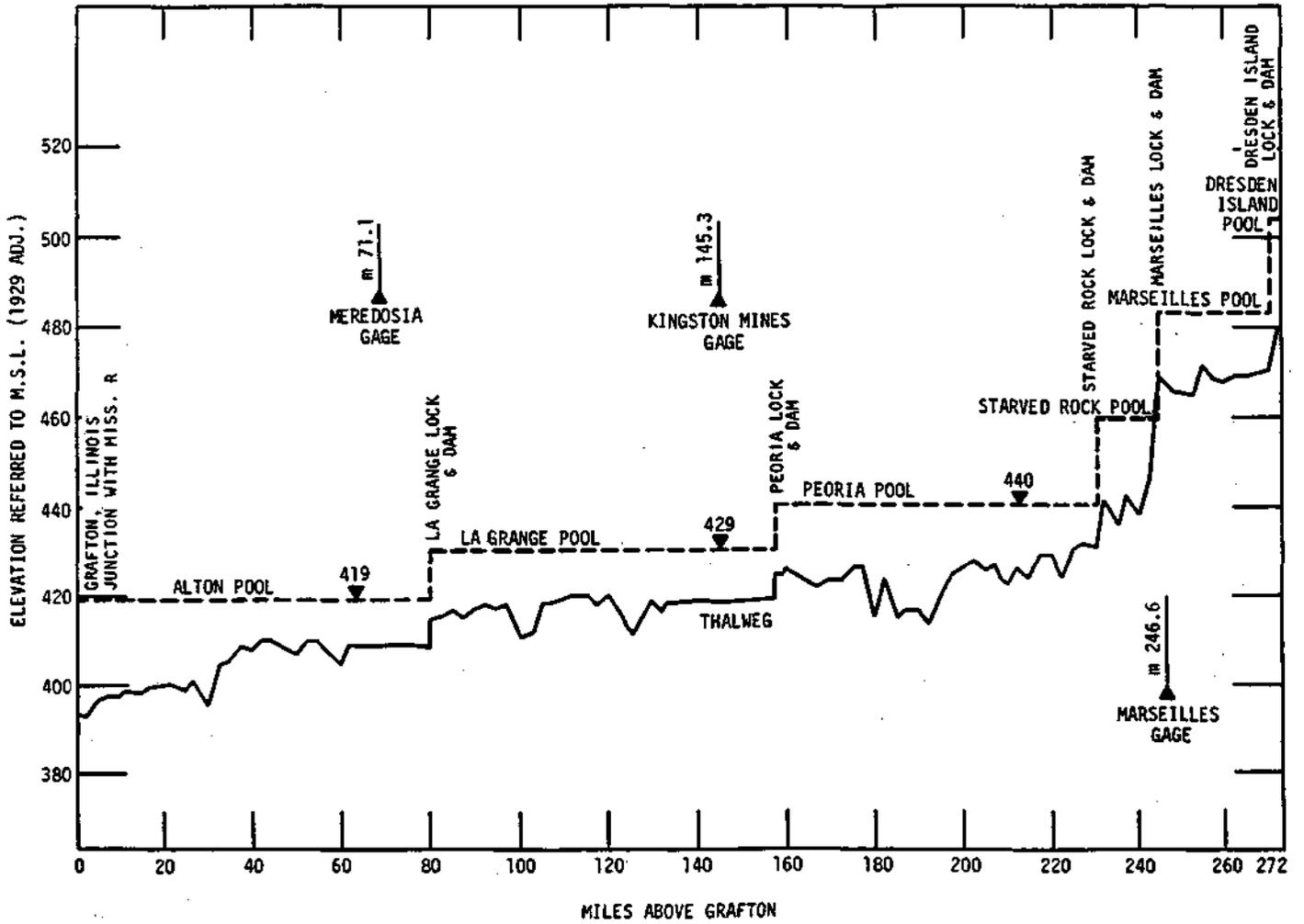
- 05539000: Hickory Creek at Joliet

Figure 3.2: Bed profile and water surface elevations in the various pools of the Illinois River

- 05540500: DuPage River at Shorewood

- 05542000: Mazon River near Coal City

- 05543500: Illinois River at Marseilles

3.3 MAP 3 — KANKAKEE REGION

The Kankakee region includes the Kankakee, Mazon, Vermilion, and Mackinaw Rivers, and the areas drained by streams directly entering the Illinois River from the east, upstream of the Sangamon River.

The Kankakee River flows westward from Indiana into Illinois. The headwaters are near South Bend, IN, and the mouth is at the confluence of the Kankakee and the Des Plaines River where they combine to become the Illinois River. Of the 5165 mi^2 in the Kankakee River drainage basin, 2169 mi^2 are in Illinois. The river has a total length of about 150 miles, with 57 miles in Illinois. There is a very small dam at Momence, a larger dam at Kankakee, and an overflow dam at Wilmington, but most of the river remains a natural, meandering stream. A major tributary to the Kankakee River is the Iroquois River, which joins the Kankakee just below Aroma Park. About one-third of the Iroquois drainage basin lies in Indiana. Singleton Ditch, a channelized tributary with most of its drainage area in Indiana, joins the Kankakee about 6 miles downstream of the Illinois-Indiana border.

The Kankakee River basin is covered with a mantle of glacial deposits (from Kansan, Hlinoian, and Wisconsinan glaciations) overlying Paleozoic bedrock. In Illinois most of the bedrock in the basin is Silurian dolomite; in Indiana much of the bedrock is Devonian shale. The surficial deposits in the Kankakee basin belong to the Wisconsinan glaciation. The morphology of the present-day Kankakee River basin in Indiana is due to channelization (completed in 1918) and dredging over its entire length from South Bend, IN, to the Indiana-Illinois state line. In Illinois the Kankakee River flows as a natural, meandering stream. Between the state line and Momence lies an area commonly called the Momence Wetlands, in which the Kankakee River flows over thick sand deposits. Between Momence and Kankakee, the Kankakee River, for the most part, flows on bedrock.

The Mackinaw River begins in northwestern Ford County and flows in a generally westward course, entering the Illinois River below Pekin in Tazewell County. Two man-made reservoirs, Lake Bloomington on Money Creek and Evergreen Lake on Six Mile Creek, collectively drain an area of 100 mi^2. Physiographically, most of the Mackinaw River basin is located within the Bloomington Ridged Plain except the area near the confluence with the Illinois River, which is located within the Springfield Plain (Leighton et al., 1948).

The Vermilion River is 115 miles long with a drainage area of 1331 mi^2. The river basin is located within the Bloomington Ridged Plain (Leighton et al., 1948) except for the headwaters of the North Fork Vermilion River in northwestern Ford County. The Bloomington Ridged Plain is characterized by low, broad morainic ridges with intervening wide stretches of relatively flat or gently undulatory ground moraine. The glacial deposits are relatively thick throughout the basin. Illinoian and older drift are present below the Wisconsinan in most places. Basin soils mainly comprise soils developed primarily from loess and glacial drift (Fenrenbacher et al., 1967).

3.3.1 Q_{HM} at **Gaging Stations**

USGS daily-flow records for 27 gaging stations were analyzed to determine the Q_{HM} values at each gaging station by following the procedures outlined in chapter 2. The USGS number, stream and gaging station, drainage area, period of record, percent of zero-flow days, and the Q_{HM} are given in table **3.3.**

3.3.2 **Wastewater Treatment Plants and Effluents**

The Commonwealth Edison Dresden and Powerton plants withdraw water from the Illinois River (the Braidwood plant is not in operation at present) for cooling purposes and return it after use. Water loss occurs in this exchange. Net losses also occur in the Kankakee River near Kankakee and the Vermilion

Table 3.3: Map 3 - Gaging Stations and Harmonic Mean Flows

USGS Gage	Stream and Gaging Station	Area (mi^2)	Period of Record	Zero-Flow Days (%)	Q_{HM} (cfs)
05519500	West Creek near Schneider, IN	54.7	18(1955-1972)	0.00	20
05520000	Singleton Ditch at Illinoi	220	33(1945-1977)	0.00	80
05520500	Kankakee River at Momence	2294	72(1916-1987)	0.00	1540
05525000	Iroquois River at Iroquois	686	43(1945-1987)	0.00	130
05525500	Sugar Creek at Milford	446	39(1949-1987)	0.00	40
05526000	Iroquois River near Chebanse	2091	64(1924-1987)	0.00	300
05526500	Terry Creek near Custer Park	12.1	27(1950-1976)	3.98	2.5
05527500	Kankakee River near Wilmington	5150	72(1916-1987)	0.00	2240
05542000	Mazon River near Coal City	455	48(1940-1987)	1.81	21
05543500	Illinois River at Marseilles	8259	68(1920-1987)	0.00	7200
05554000	N. F. Vermilion River near Charlotte	186	20(1943-1962)	1.44	0.0
05554500	Vermilion River at Pontiac	579	45(1943-1987)	0.07	21
05555300	Vermilion River near Leonore	1251	56(1932-1987)	0.00	99
05559500	Crow Creek near Washburn	115	28(1945-1972)	12.27	0.0
05560500	Farm Creek at Farmdale	27.4	39(1949-1987)	4.37	2.2
05561000	Ackerman Creek at Farmdale	11.2	26(1955-1980)	31.45	0.0
05561500	Fondulac Creek near East Peoria	5.54	39(1949-1987)	35.30	0.0
05562000	Farm Creek at East Peoria	61.2	37(1945-1981)	4.22	4.2
05564400	Money Creek near Towanda	49.0	25(1959-1983)	9.70	0.0
05564500	Money Creek near Hudson	53.1	25(1934-1958)	11.35	0.0
05565000	Hickory Creek near Hudson	9.81	20(1939-1958)	27.97	0.0
05566000	E. Br. Panther Creek near Gridley	6.3	11(1950-1960)	33.00	0.0
05566500	E. Br. Panther Creek at El Paso	30.5	34(1950-1983)	7.54	0.0
05567000	Panther Creek near El Paso	93.9	11(1950-1960)	0.55	1.2
05567500	Mackinaw River near Congerville	767	43(1945-1987)	0.00	40
05568000	Mackinaw River near Green Valley	1089	35(1922-1956)	0.00	170
05568500	Illinois River at Kingston Mines	15819	48(1940-1987)	0.00	10900

River near Pontiac and Streator because of water withdrawal for water supply and reduced return flow from the municipal WTPs.

3.3.3   Determination of Q_{HM}: An Example

The Q_{HM} in the Vermilion River at Pontiac was calculated as 21 cfs under the 1990 effluent flow conditions. The 21 cfs flow comprised 24 cfs natural flow minus 3 cfs water withdrawal for Pontiac.

3.4   MAP 4 — SPOON RIVER REGION

The Spoon River region includes the areas drained by the Spoon River, Big Bureau Creek, Edwards River, Pope Creek, and Henderson Creek. Also included are the areas drained by small- to medium-sized streams entering the Illinois River from the west between Ottawa and Beardstown and by streams entering the Mississippi River directly from the east between Rock Island and Lock and Dam No. 18.

The Spoon River, located in west-central Illinois, is 164 miles long and has a drainage area of 1855 mi^2. The river flows in a southwesterly direction up to London Mills, then south up to Seville, and turns southeast thereafter to join the Illinois River near Havana. Except near its confluence with the Illinois River, the river bottom consists mainly of sand and gravel (Evans and Schnepper, 1977).

Physiographically, this river basin is located within the Galesburg Plain (Leighton et al., 1948). It includes the western segment of the Illinoian drift sheet. The plain is level to undulatory with a few morainic ridges and is in a late youthful stage of erosion. The larger valleys are steep-walled, alluviated, and terraced.

Big Bureau Creek, located in the northeast portion of the region, is 75 miles long and has a drainage area of 486 mi^2. The river flows in a southeasterly direction to join the Illinois River near Bureau Junction.

The Edwards River enters the Mississippi River near New Boston. It has a drainage area of 451 mi^2 and is 75 miles long.

Pope Creek is an elongated stream 59 miles long, with a drainage area of 200 mi^2. It flows in an almost westerly direction to enter the Mississippi River near Keithsburg.

Henderson Creek flows in a generally southwesterly direction to join the Mississippi River near Gladstone. It is 68 miles long and has a drainage area of 604 mi^2.

3.4.1 Q_{HM} at Gaging Stations

USGS daily-flow records for 23 gaging stations were analyzed to determine the Q_{HM} values at each station by following the procedure outlined in chapter 2. The USGS number, stream and gaging station, drainage area, period of record, percent of zero-flow days, and the Q_{HM} are given in table 3.4.

3.4.2   Wastewater Treatment Plants and Effluents

Mobil Chemical Corp. in Bureau County, Libbey Owens Ford Co. in La Salle County, and Illinois Power Company in Putnam County withdraw water from the Illinois River and return it after use. In this exchange, some losses occur.

3.4.3   Illinois and Mississippi Canal

The region includes some portion of the east branch of the Illinois and Mississippi Canal in Bureau County. At the present time, 25 cfs flows in this branch from the point of bifurcation to a lock upstream of the junction with Bureau Creek. The canal reach from the lock to the confluence with the Illinois River is not in use. Construction in progress will connect the canal directly to the Illinois River.

Table 3.4: Map 4 - Gaging Stations and Harmonic Mean Flows

USGS Gage	Stream and Gaging Station	Area (mi²)	Period of Record	Zero-Flow Days (%)	Q_{HM} (cfs)
05466000	Edwards River near Orion	155	47(1941-1987)	0.00	17
05466500	Edwards River near New Boston	445	53(1935-1987)	0.00	66
05467000	Pope Creek near Keithsburg	183	52(1935-1986)	0.00	21
05467500	Henderson Creek near Little York	151	18(1941-1958)	0.49	10
05468000	North Henderson Creek near Seaton	67.1	11(1941-1951)	0.70	3.3
05468500	Cedar Creek at Little York	130	32(1941-1972)	3.09	24
05469000	Henderson Creek near Oquawka	432	53(1935-1987)	0.00	58
05469500	South Henderson Creek at Biggsville	82.9	32(1940-1971)	6.81	0.0
05556500	Bureau Creek at Princeton	196	33(1955-1987)	0.00	13
05557000	West Bureau Creek at Wyanet	86.7	30(1937-1966)	5.22	0.0
05557500	East Bureau Creek near Bureau	99.0	30(1937-1966)	11.08	0.0
05558000	Bureau Creek at Bureau	485	11(1941-1951)	0.00	80
05558500	Crow Creek near Henry	56.2	23(1950-1972)	5.70	0.0
05559000	Gimlet Creek at Sparland	5.70	22(1950-1971)	31.39	0.0
05563000	Kickapoo Creek near Kickapoo	119	18(1945-1962)	0.00	9.0
05563500	Kickapoo Creek at Peoria	297	29(1943-1971)	0.00	21
05568500	Illinois River at Kingston Mines	15819	48(1940-1987)	0.00	10900
05568800	Indian Creek near Wyoming	62.7	28(1960-1987)	0.00	7.0
05569500	Spoon River at London Mills	1062	45(1943-1987)	0.00	153
05570000	Spoon River at Seville	1636	73(1915-1987)	0.00	235
05570350	Big Creek at St. David	26.70	13(1973-85)	0.04	10
05570360	Evelyn Branch near Bryant	6.20	15(1973-87)	0.00	2.0
05570370	Big Creek near Bryant	40.30	15(1973-87)	0.00	16

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3.5 MAP 5 — SANGAMON REGION

The Sangamon region includes the Sangamon River and areas drained by small streams directly entering the Illinois River (between miles 147 and 96) from the east. The Sangamon River drains an area of 5419 mi^2 and is 241 miles long. Its major tributaries are the South Fork Sangamon River and Salt Creek, which drain 885 and 1868 mi^2, respectively. The river rises in McLean and Ford Counties and flows southwest for about 110 miles to Lake Decatur Dam. This man-made lake is created by a dam across the river in Decatur for municipal water supply. From Decatur, the Sangamon continues west about 33 miles to a point about 13 miles southeast of Springfield, where it takes a northwesterly course for some 62 miles until joined by Salt Creek about 10 miles north of Petersburg. The river course is marked by **flat** valleys, which vary in width according to the resistance of the drift to erosion. From its confluence with Salt Creek, the river flows westerly about 35 miles, through straightened channels, and then empties into the Illinois River above Beardstown.

The South Fork drains 885 mi^2. It originates in southwestern Macon and northwestern Shelby Counties. It flows southwest up to 5 miles beyond Taylorville and then bends around to flow northwest. It is 88 miles long and joins the Sangamon 2 miles upstream of River ton. Salt Creek rises in the southeast quarter of McLean County and flows southwest about 35 miles through rolling country. It turns west near Lane and continues through typical prairie to its confluence with the Sangamon, some 8 miles southwest of Mason City. For about 5 miles before joining the Sangamon, it flows through straightened channels. Salt Creek is 118 miles long and drains 1868 mi^2.

3.5.1 Q_{HM} at Gaging Stations

USGS daily-flow records for 24 gaging stations were analyzed to determine the Q_{HM} values at each gaging station by following the procedures outlined in chapter 2. The USGS number, stream and gaging station, drainage area, period of record, percent of zero-flow days, and the Q_{HM} are given in table 3.5.

3.5.2 Lake Springfield

Lake Springfield was completed in 1935 by the construction of Spaulding Dam across the valley of Sugar Creek. The dam is 1900 feet long and has a spillway elevation of 560 feet mean sea level (ft msl). The reservoir is approximately 12 miles long, extending south and west from the dam. Its present storage capacity is about 52,000 acre-feet (ac-ft), and its surface area is about 4000 acres. The reservoir is used for the City of Springfield's water supply and also for boiler and cooling water for the city's coal-fired power plant. The city's water treatment and power plants are located along the lakeshore south of the dam. There is no mandatory low-flow release.

3.5.3 Lake Decatur

Lake Decatur was created by a 1900-foot-long dam, built in 1922 across the Sangamon River near Decatur. The pool level is normally maintained at 613.5 ft msl. The lake's present storage capacity is about 19,000 ac-ft and its surface area is about 3000 acres. It is used for the Decatur public water supply and for recreation purposes. There is no mandatory low-flow release.

3.5.4 Clinton Lake

The dam across Salt Creek, about 5 miles east of Clinton, was built in 1977 by the Illinois Power Company to create Clinton Lake. The lake has a storage capacity of about 73,000 ac-ft and its surface area is 5000 acres. The total shoreline is estimated as 130 miles. The **lake** is used primarily for cooling purposes for the nuclear power plant, and for recreation. The mandatory low-flow release is 5.0 cfs.

Table 3.5: Map 5 - Gaging Stations and Harmonic Mean Flows

USGS Gage	Stream and Gaging Station	Area (mi^2)	Period of Record	Zero-Flow Days (%)	Q_{HM} (cfs)
05568500	Illinois River at Kingston Mines	15819	48(1940-1987)	0.00	10900
05570910	Sangamon River at Fisher	240	9(1979-1987)	0.00	11
05571000	Sangamon River at Mahomet	362	30(1949-1978)	0.08	21
05571500	Goose Creek near Deland	47.9	8(1952-1959)	26.01	0.0
05572000	Sangamon River at Monticello	550	73(1915-1987)	0.00	38
05572450	Friends Creek at Argenta	111	16(1967-1982)	0.84	0.7
05573540	Sangamon River at Rt. 48 at Decatur	938	5(1983-1987)	0.00	14
05574000	South F. Sangamon River near Nokomis	11.0	24(1952-1975)	18.82	0.0
05574500	Flat Branch near Taylorville	276	27(1956-1982)	1.16	5.0
05575500	South F. Sangamon River at Kincaid	562	16(1946-1961)	0.00	13
05575800	Horse Creek at Pawnee	52.2	18(1968-1985)	11.60	0.0
05575830	Brush Creek near Divernon	32.4	10(1974-1983)	13.42	0.0
05576000	South F. Sangamon River near Rochester	867	38(1950-1987)	0.03	18
05576500	Sangamon River at Riverton	2618	42(1915-1956)	0.00	200
05577500	Spring Creek at Springfield	107	32(1956-1987)	7.14	0.0
05578500	Salt Creek near Rowell	335	45(1943-1987)	0.00	35
05579500	Lake Fork near Cornland	214	39(1949-1987)	0.00	23
05580000	Kickapoo Creek at Waynesville	227	39(1949-1987)	0.00	13
05580500	Kickapoo Creek near Lincoln	306	27(1945-1971)	0.00	25
05580950	Sugar Creek near Bloomington	34.6	5(1983-1987)	0.00	30
05581500	Sugar Creek near Hartsburg	333	27(1945-1971)	0.00	80
05582000	Salt Creek near Greenview	1804	46(1942-1987)	0.00	370
05582500	Crane Creek near Easton	26.5	26(1950-1975)	0.00	8.0
05583000	Sangamon River near Oakford	5093	48(1940-1987)	0.00	990

3.6 MAP 6 — LA MOINE RIVER REGION

The La Moine River region includes the La Moine River, Macoupin Creek, the area drained by streams directly entering the Mississippi River between Lock and Dam No. 18 and the confluence with the Illinois River, and the area drained by streams directly entering the Illinois River between Beardstown and Grafton.

The La Moine River basin is located in western Illinois. The river drains a total area of 1350 mi^2 that includes nearly all of McDonough County, approximately the western half of Schuyler County, northern Brown County, eastern Hancock County, and small portions of Henderson, Warren, and Adams Counties. The river flows southeasterly along a meandering course approximately 100 miles long, starting from the extreme southeast corner of Henderson County and joining the Illinois River about 5 miles below Beardstown. The average slope of the La Moine is slightly more than 3 feet per mile, but some reaches along the channel have slopes as low as 1 to 1.5 feet per mile. Channel widths are about 100 feet along the middle course of the river and as much as 250 feet near the mouth.

The uppermost surface deposits consist of a layer of Wisconsinan loess ranging from 5 to 20 feet in thickness. The loess is underlain by Hlinoian drift, which in turn overlies Kansan drift or, more commonly, the bedrock.

Macoupin Creek flows in a generally southwest direction to enter the Illinois River near East Hardin. It is 99 miles long and has a drainage area of 961 mi^7.

3.6.1 Q_{HM} at Gaging Stations

USGS daily-flow records for 14 gaging stations were analyzed to determine the Q_{HM} for each year of record at each of the stations. The Q_{HM} values at each station were determined by following the procedure outlined in chapter 2. The USGS number, stream and gaging station, drainage area, period of record, percent of zero-flow days, and the Q_{HM} are given in table 3.6.

3.6.2 Wastewater Treatment Plants and Effluents

The Central Illinois Public Service Company in Morgan County and the Western Illinois Power Company in Pike County withdraw water from the Illinois River for cooling and return it after use. In this exchange, some losses occur.

3.7 MAP 7 — KASKASKIA REGION

The Kaskaskia region includes the Kaskaskia River and the areas drained by other streams directly entering the Mississippi River between its confluences with the Illinois and the Kaskaskia Rivers.

The Kaskaskia River starts from west Champaign, flows in a generally southwesterly direction, and joins the Mississippi River about 8 miles upstream of Chester. Its length is 295 miles, and its total drainage area is 5801 mi^2. This area is rough and hilly in the southwest, but the northeastern part is comparatively level and exceptionally well suited for agriculture.

The 295-mile course of the Kaskaskia is extremely winding and irregular, and the river has a total fall of only about 390 feet. The land on both sides of the river is generally very flat. The soils are deep gray loam, though sandy soils are not uncommon. Of its numerous tributaries, the principal ones are the West Okaw River, East Fork Kaskaskia River, Crooked Creek, Hurricane Creek, Shoal Creek, Sugar Creek, Silver Creek, and Richland Creek. These streams are fairly evenly distributed throughout the basin.

3.7.1 Q_{HM} at Gaging Stations

USGS daily-flow records for 34 gaging stations were analyzed to determine the Q_{HM} values at each station by following the procedure outlined in chapter 2. The USGS number, stream and gaging station, drainage area, period of record, percent of zero-flow days, and the Q_{HM} are given in table 3.7.

Table 3.6: Map 6 - Gaging Stations and Harmonic Mean Flows

USGS Gage	Stream and Gaging Station	Area (mi²)	Period of Record	Zero-Flow Days (%)	Q_{HM} (cfs)
05474500	Mississippi River at Keokuk, IA	119000	88(1901-1988)	0.00	50300
05495500	Bear Creek near Marcelline	3490	22(1966-1987)	0.00	5.0
05502020	Hadley Creek near Barry	40.9	11(1956-1966)	6.35	0.0
05502040	Hadley Creek at Kinderhook	72.7	47(1940-1986)	3.98	0.0
05512500	Bay Creek at Pittsfield	39.4	31(1957-1987)	0.54	1.0
05513000	Bay Creek at Nebo	161	29(1958-1986)	0.11	4.0
05584400	Drowning Fork at Bushnell	26.3	22(1961-1982)	8.09	0.0
05584500	La Moine River at Colmar	655	43(1945-1987)	0.00	34
05585000	La Moine River at Ripley	1293	66(1922-1987)	0.00	100
05585500	Illinois River at Meredosia	26028	49(1939-1987)	0.00	14490
05586000	N. F. Mauvaise Terre Creek near Jacksonville	29.1	25(1951-1975)	15.93	0.0
05586500	Hurricane Creek near Roodhouse	2.30	25(1951-1975)	33.88	0.0
05586800	Otter Creek near Palmyra	61.1	21(1960-1980)	21.11	0.0
05587000	Macoupin Creek near Kane	868	59(1922-1980)	0.04	26

3.7.2 Wastewater Treatment Plants and Effluents

The Illinois Power Company in Randolph County and the U.S. Industrial Chemical Company in Douglas County withdraw water from the Kaskaskia River for cooling purposes and return it after use. Water loss occurs in this exchange. There is also a net loss in the Shoal Creek near Breese because of water withdrawal for water supply.

3.7.3 Carlyle Lake

This multipurpose reservoir was completed by the U.S. Army Corps of Engineers in 1967 by construction of a dam across the Kaskaskia River at mile 94.2 upstream of its confluence with the Mississippi River. Its gross storage at normal pool level is 283,000 ac-ft, and its surface area is 24,600 acres. The reservoir serves many purposes such as flood control, water supply, navigation, and recreation. The mandatory low-flow release is 50 cfs, and the Q_{HM} downstream of the lake is 195 cfs.

3.7.4 Lake Shelbyville

Lake Shelbyville was completed in 1969 by construction of a dam at river mile 197.9. The Shelbyville Dam is located at the edge of the Shelbyville Moraine, which forms the southern boundary of the most recent Wisconsinan glaciation. The valleys are deep, narrow, and steep-sided where the river cuts through the moraine. Thus, Lake Shelbyville is a fairly deep lake in a region where topographic relief is generally small. Its gross storage at normal pool is 210,000 ac-ft, and its surface area is 11,100 acres. This is also a multipurpose reservoir, serving flood control, water supply, navigation, and recreation. A low-flow release of 10 cfs, is mandated, and the Q_{HM} downstream of the lake is 40 cfs.

Table 3.7: Map 7 - Gaging Stations and Harmonic Mean Flows

USGS Gage	Stream and Gaging Station	Area (mi²)	Period of Record	Zero-Flow Days (%)	Q_{HM} (cfs)
05587500	Mississippi River at Alton	171500	47(1940-1986)	0.00	73000
05587900	Cahokia Creek at Edwardsville	212	18(1970-1987)	0.20	4.0
05588000	Indian Creek at Wanda	36.7	47(1941-1987)	13.72	0.0
05589500	Canteen Creek at Caseyville	22.6	43(1940-1982)	0.85	0.5
05590000	Kaskaskia Ditch at Bondville	12.4	38(1950-1987)	0.17	1.1
05590400	Kaskaskia River near Pesotum	109	15(1965-1979)	0.00	26
05590800	Lake Fork at Atwood	149	15(1973-1987)	5.11	0.0
05591200	Kaskaskia River at Cooks Mill	473	17(1971-1987)	0.00	43
05591500	Asa Creek at Sullivan	8.10	33(1951-1983)	21.06	0.0
05591550	Whitley Creek near Allenville	34.6	7(1981-1987)	8.10	0.0
05591700	West Okaw River near Lovington	112	7(1981-1987)	3.83	0.0
05592000	Kaskaskia River at Shelbyville	1054	47(1941-1987)	0.46	40
05592050	Robinson Creek near Shelbyville	93.1	8(1980-1987)	3.15	0.0
05592100	Kaskaskia River near Cowden	1330	17(1971-1987)	0.00	90
05592300	Wolf Creek near Beecher City	47.9	24(1960-1983)	15.95	0.0
05592500	Kaskaskia River at Vandalia	1940	73(1915-1987)	0.00	225
05592800	Hurricane Creek near Mulberry Grove	152	17(1971-1987)	0.00	3.0
05592900	E. F. Kaskaskia River near Sandoval	113	8(1980-1987)	5.92	0.0
05593000	Kaskaskia River at Carlyle	2719	48(1940-1987)	0.00	195
05593520	Crooked Creek near Hoffman	254	13(1975-1987)	0.00	11
05593575	Little Crooked Creek near New Minden	84.3	20(1968-1987)	3.11	0.0
05593600	Blue Grass Creek near Raymond	17.3	23(1961-1983)	18.12	0.0
05593900	E. F. Shoal Creek near Coffeen	55.5	24(1964-1987)	6.63	0.0
05594000	Shoal Creek near Breese	735	42(1946-1987)	0.32	19
05594090	Sugar Creek at Albers	124	10(1973-1982)	0.00	2.7
05594100	Kaskaskia River near Venedy Station	4393	18(1970-1987)	0.00	450
05594330	Mud Creek near Marissa	72.4	12(1971-1982)	12.66	0.0
05594450	Silver Creek near Troy	154	21(1967-1987)	0.44	2.0
05594800	Silver Creek near Freeburg	464	17(1971-1987)	0.00	21
05595000	Kaskaskia River at New Athens	5181	37(1935-1971)	0.00	570
05595200	Richland Creek near Hecker	129	18(1970-1987)	0.00	19
05595270	Plum Creek Tributary near Tilden	0.59	2(1982-1983)	32.74	0.0
07010000	Mississippi River at St. Louis, MO	697000	55(1934-1988)	0.00	142000
07020500	Mississippi River at Chester	708600	46(1943-1988)	0.00	148000

3.7.5   U.S. Industrial Chemical Company

Water is pumped from four wells near Bondville (where the high-yield Mahomet aquifer is located) into the Kaskaskia River. It is later withdrawn from the river about 20 miles downstream for cooling **and** other purposes. Water is returned to the river after use; the return flow is 3 cfs less than the flow withdrawn. The river channel is used to provide an economical means of transporting ground water to the plant site.

3.7.6   Kaskaskia Navigation Canal

The Kaskaskia Navigation Canal was authorized by the River and Harbor Act of 1962, Public Law 87-874. In 1965, the Illinois Department of Transportation was authorized to provide nonfederal sponsorship requirements for the navigation project, restrict water withdrawals, and sell water from the system. The navigation project provides a channel 225 feet wide for barges loaded to a 9-foot draft from the Mississippi River to Fayetteville, 36.2 miles upstream. Traffic in 1984 consisted of 3.2 million tons of coal shipped in 560 tows averaging 4.7 barges per tow. The 84 by 600 foot lock can accommodate six barges in **a** single lockage or ten barges in a double lockage.

3.7.7   Horseshoe Lake

Granite City Steel Company has reduced its discharge to Horseshoe Lake by recycling its cooling water. The annual average discharge is 20 to 22 million gallons per day (mgd). The treatment plant is shut down twice a year for cleanup and repairs. Each shutdown lasts a week during which no discharge is made to Horseshoe Lake.

   Horseshoe Lake is managed by the Metro East Sanitary and Levee District. During high-flow stages in the Mississippi River, the water flows up the Cahokia Canal and enters the lake. There is a low weir to manage flows from the lake to the Cahokia Canal during dry weather conditions. There are periods during which no flow is released from the lake. The Q_{HM} outflow from the lake is considered to be zero.

3.7.8   Baldwin Lake

Illinois Power Company owns Baldwin Lake. Water is pumped into the lake from the Kaskaskia Navigational Canal for cooling and other purposes. The average withdrawal is about 30 mgd in September and October, the low-flow period in the Kaskaskia Navigation Canal. The amount of water returned to the canal is about 6.6 mgd. The loss is determined to be about 50 cfs to the Q_{HM}.

3.7.9   Chain of Rocks Canal

Shipping goes through the Chain of Rocks Canal to avoid dangerous conditions in the portion of **the** Mississippi River from river mile 184.2 to 194.2 (with zero river mile at the confluence of the Mississippi and Ohio Rivers near Cairo, IL). Lock 27 in this canal has two locks: the 1200 by 110 foot main lock, and the 600 by 110 foot auxiliary lock.

3.7.10   Small Lakes

Lake Lou Yaeger, Coffeen Lake, Raccoon Lake, and other small lakes are used primarily for water supply purposes. There are no mandatory low-flow releases from these small lakes during dry periods.

3.8   MAP 8 — EMBARRAS REGION

The Embarras region includes the Vermilion and Embarras Rivers and the areas drained by streams directly entering the Wabash River from the west, upstream of the Embarras River. The Vermilion River drains an area of 1434 mi^2 and is 106 miles long. Major tributaries are the North Fork, Middle Fork, and Salt Fork. The topography of the Vermilion River basin (Barker et al., 1967) varies from

flat throughout most of the area to gently rolling along the morainal ridges. Steep slopes are confined to the valley walls of the larger streams and their tributaries, particularly in the southeastern or lower end of the basin. The parent materials of the Vermilion River basin soils are almost entirely of glacial origin. These materials usually consist of loess on till, outwash, or lakebed deposits. The only soils of postglacial origin are the alluvial, silt loams in the bottomlands of the river.

The Embarras River drains an area of 2440 mi^7 and is 194 miles long. The headwater of the basin is in Champaign County, and the river joins the Wabash River at mile 122 in Lawrence County. At the northern end of the basin, the land is rough and hilly and tributary streams have steep gradients, while at the southern end of the basin lands are generally flatter, and the stream and tributary gradients are quite mild. For a distance of 5 miles upstream of Lawrenceville, the streamflows are affected by backwater from the Wabash River.

The present topography of the entire basin is the result of recent modification of glacial activity during the Wisconsinan and Dlinoian glacial periods. The northern part of the basin lies in the Bloomington Ridged Plain physiographic division (Leighton et al., 1948), which exhibits low and broad morainic ridges of Tazewell age, with intervening wide areas of flat or gently undulatory ground moraines. The central portion of the basin is within the Springfield Plain, which was not subjected to the more recent Wisconsinan glacial activity. The lower portion is within the Mt. Vernon Hill Country physiographic province, where the Dlinoian glacial drift exhibits mature topography with low relief and rather restricted areas of upland between the developed paths of drainage.

3.8.1 Q_{HM} at Gaging Stations

USGS daily-flow records for 25 gaging stations were analyzed to determine the Q_{HM} values at each gaging station by following the procedures outlined in chapter 2. The USGS number, stream and gaging station, drainage area, period of record, percent of zero-flow days, and the Q_{HM} are given in table 3.8.

3.8.2 Wastewater Treatment Plants and Effluents

The Central Illinois Public Service Company in Crawford County and Central Foundry in Vermilion County withdraw water from the river and return it after use. In this exchange, net losses occur.

3.8.3 Wabash River

The Wabash River rises near Celina, OH, flows northwesterly for 67 miles to Huntington, IN; then generally west and southwest 312 miles to its confluence with the White River (its major tributary); and then southwesterly 96 miles to join the Ohio River. The overall length of the Wabash River is about 475 miles and its total drainage area is 33,100 mi^2, of which 319 mi^3 lie in Ohio, 24,218 in Indiana, and 8563 in eastern Illinois (U.S. Army Corps of Engineers, 1967). From Clark County south to a point 10 miles north of Shawneetown, where the river joins the Ohio River, its winding course forms the boundary between Illinois and Indiana. The portion of the Wabash River from river miles 272 to 122 is included in this region.

3.8.4 Lake Vermilion

Lake Vermilion is located northwest of the city of Danville in Vermilion County. The reservoir is owned and operated by Interstate Water Company as a water source for the city. The dam, a 525-foot-long earthfill and concrete structure, was completed in 1925. As of 1976, its surface area at spillway level, 567 ft msl, was 608 acres, and its storage capacity was 4641 ac-ft. There is no mandatory low-flow release during dry conditions.

Table 3.8: Map 8 - Gaging Stations and Harmonic Mean Flows

USGS Gage	Stream and Gaging Station	Area (mi^2)	Period of Record	Zero-Flow Days (%)	Q_{HM} (cfs)
03336000	Wabash River at Covington, IN	8218	50(1940-1989)	0.00	3880
03336500	Bluegrass Creek at Potomac	35.0	23(1950-1972)	9.94	0.00
03336645	M. F. Vermilion River above Oakwood	432	12(1979-1990)	0.00	47
03336900	Salt Fork near St. Joseph	134	29(1959-1987)	0.00	26
03337000	Boneyard Creek at Urbana	4.50	39(1949-1987)	0.00	1.3
03337500	Saline Branch at Urbana	68.0	22(1937-1958)	0.00	9.9
03338000	Salt Fork near Homer	340	14(1945-1958)	0.00	78
03338500	Vermilion River near Catlin	958	19(1940-1958)	0.00	140
03339000	Vermilion River near Danville	1290	59(1929-1987)	0.00	190
03339150	Little Vermilion River near Newport, IN	237	8(1965-1972)	0.14	4.2
03340500	Wabash River at Montezuma, IN	11118	62(1928-1989)	0.00	4810
03341420	Brouilletts Creek near Universal, IN	331	5(1967-1971)	0.00	18
03341500	Wabash River at Terre Haute, IN	12265	61(1928-1988)	0.00	5400
03342000	Wabash River at Riverton, IN	13161	50(1939-1988)	0.00	6080
03343000	Wabash River at Vincennes, IN	13706	60(1930-1989)	0.00	6440
03343400	Embarras River near Camargo	186	27(1961-1987)	2.16	2.0
03344000	Embarras River near Diona	919	13(1971-1983)	7.60	90
03344500	Range Creek near Casey	7.60	33(1951-1983)	35.21	0.0
03345500	Embarras River at Ste. Marie	1516	73(1915-1987)	0.00	150
03346000	North Fork Embarras River near Oblong	319	47(1941-1987)	0.87	4.5

Table 3.9: Map 9 - Gaging Stations and Harmonic Mean Flows

USGS Gage	Stream and Gaging Station	Area (mi²)	Period of Record	Zero-Flow Days (%)	Q_{HM} (cfs)
03343000	Wabash River at Vincennes, IN	13706	60(1930-1989)	0.00	6440
03347500	Wabash River at Mt. Carmel	28635	62(1928-1989)	0.00	13000
03378000	Bonpas Creek at Browns	228	46(1942-1987)	10.02	0.0
03348500	Wabash River at New Harmony	29160	10(1938-1947)	0.00	13340
03378635	Little Wabash River near Effingham	240	21(1967-1987)	9.15	0.0
03378900	Little Wabash River at Louisville	745	17(1966-1982)	0.00	8.0
03379500	Little Wabash River below Clay City	1131	76(1915-1990)	0.06	15
03380350	Skillet Fork near Iuka	208	17(1966-1982)	1.53	0.0
03380475	Horse Creek near Keenes	97.2	28(1960-1987)	9.55	0.0
03380500	Skillet Fork at Wayne City	464	62(1929-1990)	0.73	2.7
03381500	Little Wabash River at Carmi	3102	51(1940-1990)	0.02	90

3.9 MAP 9 — LITTLE WABASH REGION

The Little Wabash region includes the Little Wabash River and areas drained by small streams directly entering the Wabash River between its confluences with the Embarras and the Little Wabash Rivers.

The Little Wabash River, which starts south of Mattoon, drains about 3203 mi^2, is 237 miles long, and flows in a generally southerly direction to join the Wabash River near New Haven. The river is located within the Glacial Plain Region; the northern portion lies in the Springfield Plain and the central and southern portions in Mt. Vernon Hill Country. It flows in a fairly narrow valley and is generally a meandering stream. The average fall of the river below Carmi is about 0.6 feet per mile. The soil in the basin of the Little Wabash is almost entirely gray with a moisture-resisting, noncalcareous subsoil (Illinois State Planning Commission, 1938b). Backwater from both the Ohio and Wabash Rivers affects the lower reaches of the Little Wabash River during high-flow and flood stages. The Skillet Fork, the largest tributary of the Little Wabash River, drains an area of about 1061 mi^2 and is 102 miles long. It joins the Little Wabash River about 39 miles above its confluence with the Wabash River. The topography in the extreme upper reaches is slightly rolling, but it is comparatively flat in most of the remaining area.

3.9.1 Q_{HM} at Gaging Stations

USGS daily-flow records for 11 gaging stations were analyzed to determine the Q_{HM} values at each gaging station by following the procedure outlined in chapter 2. The USGS number, stream and gaging station, drainage area, period of record, percent of zero-flow days, and the Q_{HM} are given in table 3.9.

3.10 MAP 10 — SOUTHERN REGION

The Southern region includes the Saline, Big Muddy, and Cache Rivers, and areas drained by small streams directly entering the Ohio and Mississippi Rivers. The region lies just outside the southern limit of glacial drift in Illinois; the underlying rock strata vary a great deal over the region. The general topography is hilly. A range of hills and high tablelands extends from east to west, separating the valleys

of the Cache River and Big Bay Creek from the valley of the Saline River. The area north of the Saline River is comparatively flat, and the valley of the river itself broadens to several miles in width where it joins the valley of the Ohio River.

The Ohio River forms the Illinois-Kentucky boundary line in this region. It flows into the Mississippi River at Cairo. About 10 miles above Cairo, the valleys of the Ohio and the Mississippi Rivers merge to form a flat, wide delta. This area is periodically flooded by both rivers.

The Saline River is 84 miles long and drains 1177 mi^2. Three major tributaries are the North Fork, Middle Fork, and South Fork Saline River. The North Fork rises in central Hamilton County and flows south through a fiat plain, emptying into the Saline River about 1 mile east of Equality. Rising in the northeast quarter of Williamson County, the Middle Fork flows southeast through a wide, flat valley and joins the Saline about 5 miles below the gaging station near Harrisburg. The South Fork originates in the northern part of Johnson County and flows eastward through the southern portions of Williamson and Saline Counties to its confluence with the Middle Fork. Below the confluence of the Middle Fork and South Fork, the Saline River flows east to a point near Equality, where the North Fork joins, and then turns southeast, emptying into the Ohio River about 10 miles south of Shawneetown. The southern part of the basin is very hilly, but the northern part is generally flat.

The Big Muddy River rises in the northwestern part of Jefferson County, flows southward to the Franklin/Williamson county line, then southwesterly to a point about 5 miles west of Murphysboro, and then southward to its junction with the Mississippi River about 4 miles south of Grand Tower. It is 154 miles long and has a total drainage area of 2387 mi^2. This basin lies mostly in Mt. Vernon Hill Country (Leighton et al., 1948), which is characterized by mature topography of low relief. The present land surface is primarily a bedrock surface of low relief, and it is only slightly modified by a thin mantle of Illinoian drift.

In the Cache River basin, three physiographic provinces (coastal plain, interior low plateaus, and Ozark plateaus) meet and provide the basin with unique, varying physiography (Leighton et al., 1948). The bed of the Cache River upstream of the Post Creek Cutoff is gradually eroding and lowering because of the Cutoff's steep gradient. The flow at the USGS gaging station at Forman has not been affected significantly by the Post Creek Cutoff, about 4 miles downstream.

3.10.1 Q_{HM} at Gaging Stations

USGS daily-flow records for 24 gaging stations were analyzed to determine the Q_{HM} values at each gaging station by following the procedure outlined in chapter 2. The USGS number, stream and gaging station, drainage area, period of record, percent of zero-flow days, and the Q_{HM} are given in table 3.10. Daily-flow data at six special-purpose gaging stations in the Cache River basin were collected by the State Water Survey during the period 1986-1990 (Demissie et al. 1990). The period of record and the estimated Q_{HM} at these stations are given below.

Gaging Station	Record	Q_{HM}
Big Creek at Perks Road	5(1986-1990)	3.2
Cypress Creek at Dongola Road	4(1987-1990)	0.0
Main Ditch at Route 45	3(1986-1988)	1.0
Cache River at Route 46	5(1986-1990)	6.4
Indian Camp Creek at Ulin	2(1987-1988)	6.5
Cache River at Route 51	4(1987-1990)	5.1

The Q_{HM} at these sites were used to update the values for regional analysis.

3.10.2 Wastewater Treatment Plants and Effluents

The Central Illinois Public Service Company in Jackson County and Electric Energy, Inc. in Massac County withdraw water from the river and return it after use. In this exchange, net losses occur.

Table 3.10: Map 10 - Gaging Stations and Harmonic Mean Flows

USGS Gage	Stream and Gaging Station	Area (mi²)	Period of Record	Zero-Flow Days (%)	Q_{HM} (cfs)
03382100	South Fork Saline River near Carrier Mills	147	22(1966-1987)	0.00	13
03382170	Brushy Creek near Harco	13.3	15(1969-1983)	27.66	0.0
03382500	Saline River near Junction	1051	32(1940-1971)	3.02ᵃ	25
03382510	Eagle Creek near Equality	8.51	16(1967-1982)	3.25	0.0
03384450	Lusk Creek near Eddyville	42.9	20(1968-1987)	3.46	0.0
03384500	Ohio River at Dam 51 at Golconda	143900	44(1940-1984)	0.00	66000
03385000	Hayes Creek at Glendale	19.1	27(1950-1976)	21.08	0.0
03385500	Lake Glendale Inlet near Dixon Springs	1.10	9(1955-1963)	37.42	0.0
03386000	Lake Glendale Outlet near Dixon Springs	1.98	9(1955-1963)	63.40	0.0
03386500	Sugar Creek near Dixon Springs	9.70	22(1951-1972)	34.32	0.0
03611500	Ohio River at Metropolis	203000	59(1928-1987)	0.00	141000
03612000	Cache River at Forman	244	63(1925-1987)	1.09	3.8
05595500	Marys River near Sparta	17.8	22(1950-1971)	37.41	0.0
05595730	Rayse Creek near Waltonville	88.0	8(1980-1987)	6.84	0.0
05595800	Sevenmile Creek near Mt. Vernon	21.1	23(1961-1983)	32.58	0.0
05596000	Big Muddy River near Benton	502	25(1946-1970)	0.00	64
05596500	Tilley Creek near West Frankfort	3.87	17(1939-1955)	52.79	0.0
05597000	Big Muddy River at Plumfield	794	73(1915-1987)	0.30	90
05597500	Crab Orchard Creek near Marion	31.7	36(1952-1987)	17.83	0.0
05599000	Beaucoup Creek near Matthews	292	38(1946-1983)	4.54	1.6
05599500	Big Muddy River at Murphysboro	2162	57(1931-1987)	0.46	270
05600000	Big Creek near Wetaug	32.2	32(1941-1972)	3.41	2.6
07020500	Mississippi River at Chester	708600	46(1943-1988)	0.00	148000
07022000	Mississippi River at Thebes	713200	49(1940-1988)	0.00	151500

ᵃ This includes negative flows due to backwater

3.10.3   Rend Lake

Rend Lake, situated in Jefferson and Franklin Counties, was created in 1970 by damming the Big Muddy River. The lake is managed by the U.S. Army Corps of Engineers. Its normal pool elevation is 405 ft msl, its storage capacity is 185,000 ac-ft, and its surface area is 18,900 acres. The lake is used for flood control and water supply as well as for recreational activities. It also serves as a source of public water supply for about 55 communities under the Rend Lake Conservancy District (Illinois State Water Survey, 1978). The mandatory low-flow release during dry conditions is 30 cfs. The Q_{HM} downstream of the lake is equal to 60 cfs.

3.10.4   Crab Orchard Lake

Crab Orchard Lake was completed in 1940. Its original storage capacity was 74,400 ac-ft, and its surface area is 6965 acres. The lake is used for recreational purposes; for conservation of water, soil, and forests; and as a migratory waterfowl refuge. There is no mandatory low-flow release during dry weather.

3.10.5   Lake Egypt

Lake Egypt was completed in 1962 by impoundment of the South Fork of the Saline River. Its storage capacity is 42,550 ac-ft, and its surface area is 2300 acres. The lake, owned by the Southern Illinois Power Cooperative, Marion, IL, is used as a cooling reservoir for the coal-fired power generating station located at the west end of the dam.

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