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The 7-Day 10-Year Low Flows of Illinois Streams

by KRISHAN P. SINGH and JOHN B. STALL

The flow values shown on the maps accompanying this report have been adopted for official use by the Illinois Environmental Protection Agency for calculating in-stream dilution ratios applicable to all waste water effluents discharged into Illinois streams.

Title: The 7-Day 10-Year Low Flows of Illinois Streams.

Abstract: The 11 separate maps provided show all the rivers and streams in Illinois. Flow values in cfs for the lowest flow expected for a 7-day period at a recurrence interval of 10 years are shown at intervals along the course of each stream. These flows are useful for calculating the in-stream dilution available for waste water effluents. The report describes the hydrologic methodology used to derive the flow values. Flow records from 266 stream gaging stations were the primary data used. Effluent waste water flow during low-flow periods was obtained for about 300 treatment plants now discharging into Illinois streams. These locations and flow amounts are shown on the maps. The hydrologic effects of natural lakes, man-made lakes, gaining streams, losing streams, navigation dams, and evaporation from the river surface are considered. The timing, or season, of the 7-day 10-year low flows is described. The special cases of the controlled waterways within the Metropolitan Sanitary District of Greater Chicago, the Illinois River, the Mississippi River, and the Ohio River are also described.

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Indexing Terms: evaporation, Illinois River, intermittent streams, lakes, low flow, Mississippi River, Ohio River, regulated flow, rivers, runoff, sewage effluents, streamflow, Wabash River, waste water.

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8

CONTENTS

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ABSTRACT

The 11 separate maps provided with this report show all the rivers and streams in Illinois. Flow values in cubic feet per second (cfs) for the lowest flow expected for a 7-day period at a recurrence interval of 10 years are given at intervals along the course of each stream. These flows are useful for calculating the in-stream dilution available for waste water effluents.

The report describes the hydrologic methodology used to derive the flow values. Flow records from 266 stream gaging stations were the primary data used. The amount of effluent waste water flow during low-flow periods was obtained for about 300 existing waste water treatment plants now discharging into Illinois streams. These locations and flow amounts are shown on the maps. The hydrologic effects of natural lakes, man-made lakes, gains and losses from groundwater, navigation dams, and evaporation from the river surface are considered.

The timing, or season, of the 7-day 10-year low flows is described. The special cases of the controlled waterways within the Metropolitan Sanitary District of Greater Chicago, the Illinois River, the Mississippi River, and the Ohio River are also described.

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. This is defined as the lowest average flow that occurs for a consecutive 7-day period at a recurrence interval of 10 years. That is, over a long period of years, the *average* time interval between 7-day low flows of this severity will be 10 years.

Accompanying this report are 11 maps covering all the streams in Illinois, showing the amounts of flow during this prescribed 7-day 10-year low flow condition. The preparation of these maps is described briefly in the paragraphs that follow. The remainder of this report explains the methods used in compiling the 7-day 10-year low flows for the maps.

Preparation of Maps

Figure 1 shows the state of Illinois and the rivers that are included on each of the 11 separate maps, and table 1 lists the rivers and drainage for each map. The various steps that went into preparation of these maps are described briefly.

Table 1. Rivers Included on the 11 Separate Maps

Map number (fig. 1)	Rivers
1	*Rock River Region* — Rock River and Mississippi River drainage upstream of Rock Island
2	*Northeast Region* — Chicago Sanitary and Ship Canal and Chicago, Des Plaines, Du Page, and Fox Rivers
3	*Kankakee Region* — Kankakee, Mazon, Vermilion, and Mackinaw Rivers, and Illinois River drainage from the east upstream of the Sangamon River
4	*Spoon River Region* — Bureau Creek, Spoon River, and Mississippi River drainage north of Henderson Creek
5	*Sangamon Region* — Sangamon River with Salt Creek and other tributaries
6	*La Maine River Region* — La Moine River, Macoupin Creek, and Mississippi River drainage upstream of mouth of Illinois River
7	*Kaskaskia Region* — Kaskaskia River and Mississippi River drainage between the Illinois and Kaskaskia
8	*Embarras Region* — Vermilion and Embarras Rivers, and Wabash River drainage above Embarras River
9	*Little Wabash Region* — Little Wabash River and Wabash River drainage between the Embarras and Little Wabash
10	*Southern Region*— Saline, Big Muddy, and Cache Rivers, plus direct drainage into Wabash, Ohio, and Mississippi Rivers
11	*Border Rivers* — Main stem only of Mississippi, Wabash, and Ohio Rivers along Illinois boundary and the Illinois River

Base maps were first prepared. The drainage area covered by the stream or river system in a particular region was marked on the 2-degree maps of the U.S. Geological Survey. These maps have a scale of 1 to 250,000 or about 1 inch = 4 miles. Where the contours were not defined well enough to draw the drainage boundary accurately, use was made of the 15-minute USGS quadrangle maps that have a scale of about 1 inch = 1 mile. A base map was then prepared showing the drainage boundary, the stream network, all towns having waste water treatment plants discharging to the streams, and county lines. The

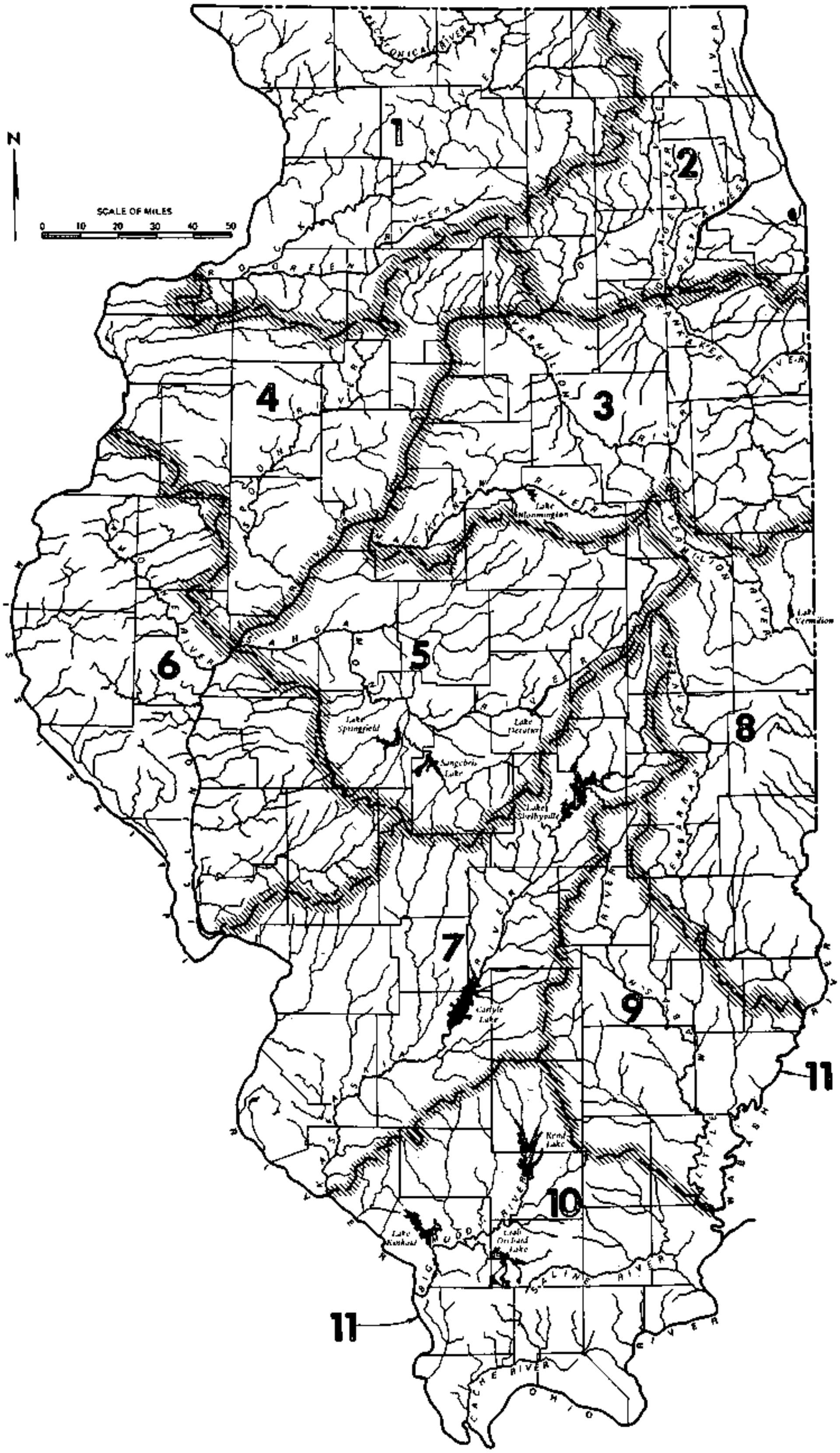

Figure 1. Rivers and other drainage included in the 11 separate maps

USGS stream gaging stations on Illinois streams and bordering rivers were located on the base maps from the detailed description of their location published in U.S. Geological Survey Water Supply Papers and Water Resources Data for Illinois.

The locations of waste water effluent outfalls to streams were obtained from the USGS 7½-minute and 15-minute quadrangle maps or from the Illinois Environmental Protection Agency office in terms of latitude and longitude, or section, township, and range, or in some cases by direct telephone inquiries. Arrows were drawn on the base map to indicate the effluent outfall to a stream. The magnitude of 7-day low flow effluents from municipal and industrial waste water treatment plants was determined, as described later in this report, from: 1) the data collected from operation reports available at the regional Environmental Protection Agency offices, 2) the applicable curves of effluent flow versus population where plant effluent data were not available, and 3) telephone and written inquiries made to some municipalities and industries. The amounts of waste water effluents that are indicated on the maps represent the 1970 effluents entering the receiving stream during the 7-day 10-year low flow condition.

Dams, regulating structures, and lakes were also located on the base maps. The locations of locks and dams, given in river miles for the Illinois, Ohio, and Mississippi Rivers were obtained from the navigation charts published by the U.S. Army Corps of Engineers. These locations were checked with those on the 2-degree USGS maps to insure that all such structures built to the year 1970 were shown on the low flow maps. The dams, fords, and in-channel impoundments for municipal water supply were located on the various streams from the available information in USGS maps, county plat books, highway maps, river basin reports, and similar references. In addition, all large and medium lakes, and some small ones, natural or man-made, were shown on the maps because of their significant effect on the 7-day 10-year low flows.

Streams with zero 7-day 10-year low flow were designated first. From the natural low flow versus drainage area graphs, described later, the streams with zero 7-day 10-year low flow were determined and shown as dot-dash lines (figure 2) on the maps. Any waste water plant effluents entering these intermittent-flow streams were then considered. If the effluent is lost in the dry streambed before reaching the perennial stream, the zero 7-day 10-year low flow stream remains as such. But, if the effluent is not lost, the stream starts with a 7-day 10-year low flow at the outfall equal to the magnitude of the effluent, and this flow is reduced in a downstream direction to the point where the natural 7-day 10-year low flow begins. Here the 7-day 10-year low flow is then equal to the reduced effluent value plus the natural value.

Streams with nonzero 7-day 10-year low flow were mapped next. To natural 7-day 10-year low flows along such streams are added the effluents from waste water plants to obtain the 7-day 10-year low flows for 1970 conditions. Any removal of water from a stream for a municipal supply or industrial use is shown by a decrease in the 7-day 10-year low flow (note net loss symbols in figure 2).

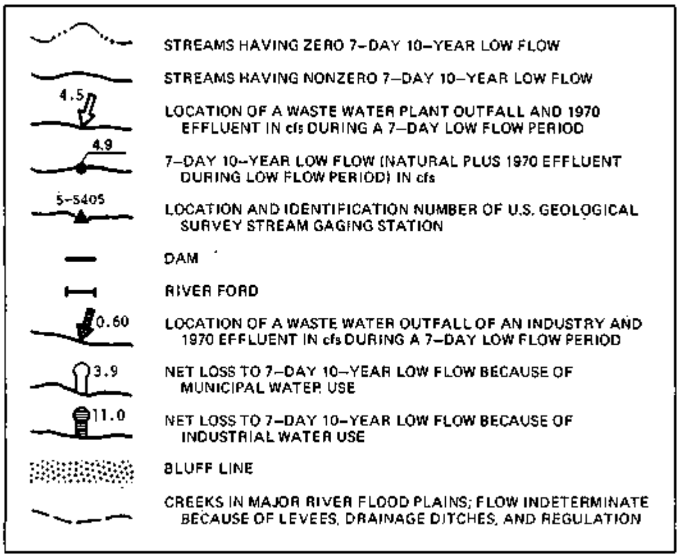

Figure 2. Symbols used on the low flow maps

Acknowledgments

This study was carried out by the authors as a part of their regular work in the Hydrology Section of the Illinois State Water Survey. The project was initiated by Dr. William C. Ackermann, Chief, and carried out under his supervision. Many other Water Survey personnel contributed. Computer programs were written by Robert A. Sinclair, Systems Analyst. Mrs. J. Loreena Ivens, Technical Editor, edited the report. Farook Kolanda, part-time Engineering Assistant, assisted greatly in data handling, drawing, revising, and checking the maps. William Motherway Jr. of the Graphic Arts Section drew the working base maps and the final maps for publication. Linda Riggin of the Graphic Arts Section prepared the drawings used in the text.

This project was carried out as an aid to the Illinois Environmental Protection Agency. Many EPA persons aided the project. Principal coordination of the project was carried out by John J. Forneris, Head, and Ronald Barganz of the Surveillance Section of the Water Pollution Control Division in Springfield. A great deal of help and cooperation was extended to the authors by engineers of the Surveillance Section in field offices of the EPA as follows: Edward Marek, Aurora; Benn Leland, Chicago; James Frost, Springfield; Paul Barry, Rockford; Robert L. Schleuger, Collinsville; Keith Weeber and Kenneth Merideth, Peoria; Kenneth L. Baumann, Champaign; and Murl G. Teske and Robert R. Gates, Marion.

Data, help, and cooperation in conducting this project were provided by officials of the Metropolitan Sanitary

District of Greater Chicago, including William A. Eyre, Head, and Tom Edwards and Don Vogeli, of the Waterways Control Section.

Computer analysis was carried out on the IBM 360/75 of the Department of Computer Science, University of Illinois.

METHODOLOGY

Flows at Stream Gaging Stations

The primary data used in this study are the measured flows at 201 USGS gaging stations on streams in Illinois and at 15 stations on the Mississippi, Ohio, and Wabash Rivers bordering the state. These stations are shown on the eleven 7-day 10-year low flow maps and are listed in table 2. Daily flow data were available for an average of 25 years at these stations. The flow data were brought up-to-date to the year 1970 and stored on disks for quick computer processing. Low flows in Illinois streams occur most often in the fall months and do not occur in March or April, which are months of high spring flows, snowmelt, and high water table. Therefore, the water year selected for low flow analysis was taken to begin April 1 and end March 31 of the following year.

A computer program was written in Fortran to compute the lowest 7-day flow of each low-flow year of the available record for each station, and to print the year, the flow value, and the beginning day of the 7-day period. The

Table 2. 7-Day 10-Year Low Flows Adjusted for 1970 Effluent Conditions at USGS Gaging Stations

USGS number	Station	Drainage area (sq mi)	7-da 10-yr low flow (cfs)
Map 1 — Rock River Region			
5-4150	Galena River at Buncombe, Wis.	128	11.7
5-4155	East Fork Galena River at Council Hill	20.1	2.3
5-4190	Apple River near Hanover	244	20.1
5-4200	Plum River below Carroll Creek, near Savanna	231	10.7
5-4205	Mississippi River at Clinton, Iowa	85,600	13,970
5-4345	Pecatonica River at Martintown, Wis.	1,040	153
5-4350	Cedar Creek near Winslow	1.29	0.0
5-4355	Pecatonica River at Freeport	1,330	181
5-4370	Pecatonica River at Shirland	2,540	393
5-4375	Rock River at Rockton	6,290	795
5-4382.50	Coon Creek at Riley	85.3	2.6
5-4385	Kishwaukee River at Belvidere	525	34.3
5-4390	South Branch Kishwaukee River at De Kalb	70.0	0.10
5-4395	South Branch Kishwaukee River near Fairdale	386	9.9
5-4400	Kishwaukee River near Perryville	1,090	62.3
5-4405	Killbuck Creek near Monroe Center	114	3.1
5-4410	Leaf River at Leaf River	102	8.4
5-4415	Rock River at Oregon	8,120	1,100
5-4420	Kyte River near Flagg Center	125	3.3
5-4435	Rock River at Como	8,700	1,097
5-4440	Elkhorn Creek near Penrose	153	15.5
5-4455	Rock Creek near Morrison	143	13.6
5-4465	Rock River near Joslin	9,520	1,306
5-4470	Green River at Amboy	199	4.9
5-4475	Green River near Geneseo	958	49.2
5-4480	Mill Creek at Milan	62.5	0.10
Map 2 — Northeast Illinois			
4-0876	Little Calumet River at Munster, Ind.		5.7
4-0879.50	Thorn Creek near Chicago Heights	17.1	0.50
4-0880	Thorn Creek at Glenwood	24.6	14.0
4-0885	Deer Creek near Chicago Heights	23.2	3.0
4-0890	Butterfield Creek at Flossmoor	23.4	1.0
4-0895	Lansing Ditch near Lansing	8.7	0.0
4-0900	North Creek near Lansing	16.7	0.05
4-0905	Thorn Creek at Thornton	104	21.3
4-0910	Little Calumet River at South Holland		34.0
4-0920	Midlothian Creek at Oak Forest	12.6	0.0
5-5275	Kankakee River near Wilmington	5,250	451
5-5278	Des Plaines River at Russell	124	0.0
5-5280	Des Plaines River near Gurnee	230	0.05
5-5285	Buffalo Creek near Wheeling	19.4	0.21
5-5290	Des Plaines River near Des Plaines	359	4.3
5-5295	McDonald Creek near Mount Prospect	7.52	0.0
5-5300	Weller Creek at Des Plaines	13.1	0.0
5-5305	Willow Creek near Park Ridge	19.6	0.0
5-5310	Salt Creek near Arlington Heights	32.5	0.0
5-5315	Salt Creek at Western Springs	114	14.9
5-5320	Addison Creek at Bellwood	18.2	1.8
5-5325	Des Plaines River at Riverside	635	18.4
5-5330	Flag Creek near Willow Springs	16.2	2.5
5-5335	Des Plaines River at Lemont	657	24.8
5-5345	North Branch Chicago River at Deerfield	20.7	0.0
5-5350	Skokie River at Lake Forest	12.8	1.3
5-5350.70	Skokie River near Highland Park	21.0	1.3
5-5355	West Fork of North Branch Chicago River at Northbrook	11.5	1.4
5-5360	North Branch Chicago River at Niles	102	7.6
5-5365	Tinley Creek near Palos Park	11.3	0.0
5-5370	Chicago Sanitary and Ship Canal at Lockport		1,700
5-5375	Long Run near Lemont	20.8	0.0
5-5390	Hickory Creek at Joliet	107	1.9
5-5399	West Branch Du Page River near West Chicago	27.5	3.2
5-5400.95	West Branch Du Page River near Warrenville	88.5	13.6
5-5405	Du Page River at Shorewood	325	45.0
5-5435	Illinois River at Marseilles	7,640	3,240
5-5465	Fox River at Wilmot, Wis.	880	62.0
5-5482.80	Nippersink Creek near Spring Grove	193	18.6
5-5490	Boone Creek near McHenry	15.3	3.7
5-5500	Fox River at Algonquin	1,253	51.0

Table 2 (Continued)

USGS number	Station	Drainage area (sq mi)	7-da 10-yr low flow (cfs)
5-5505	Poplar Creek at Elgin	36.3	0.96
5-5512	Ferson Creek near St. Charles	51.6	0.23
5-5517	Blackberry Creek near Yorkville	69.4	2.5
5-5525	Fox River at Dayton	2,570	198

Map 3—Kankakee Region

USGS number	Station	Drainage area (sq mi)	7-da 10-yr low flow (cfs)
5-5195	West Creek near Schneider, Ind.	54.7	4.4
5-5200	Singleton Ditch at Illinois	220	12.7
5-5205	Kankakee River at Momence	2,340	411
5-5250	Iroquois River at Iroquois	686	9.1
5-5255	Sugar Creek at Milford	430	3.5
5-5260	Iroquois River near Chebanse	2,120	16.6
5-5265	Terry Creek near Custer Park	12.0	0.03
5-5275	Kankakee River near Wilmington	5,250	451
5-5420	Mazon River near Coal City	470	0.0
5-5435	Illinois River at Marseilles	7,640	3,240
5-5540	North Fork Vermilion River near Charlotte	184	0.0
5-5545	Vermilion River at Pontiac	568	0.20
5-5555	Vermilion River at Lowell	1,230	7.3
5-5595	Crow Creek near Washburn	123	0.0
5-5605	Farm Creek at Farmdale	27.6	0.0
5-5610	Ackerman Creek at Farmdale	11.8	0.0
5-5615	Fondulac Creek near East Peoria	5.47	0.0
5-5620	Farm Creek at East Peoria	60.9	0.0
5-5644	Money Creek near Towanda	47.9	0.0
5-5645	Money Creek above Lake Bloomington	51.9	0.0
5-5650	Hickory Creek above Lake Bloomington	10.1	0.0
5-5660	East Branch Panther Creek near Gridley	6.3	0.0
5-5665	East Branch Panther Creek at El Paso	28.8	0.0
5-5670	Panther Creek near El Paso	95.0	0.0
5-5675	Mackinaw River near Congerville	764	0.54
5-5680	Mackinaw River near Green Valley	1,100	25.5
5-5685	Illinois River at Kingston Mines	15,200	3,000

Map 4—Spoon River Region

USGS number	Station	Drainage area (sq mi)	7-da 10-yr low flow (cfs)
5-4660	Edwards River near Orion	163	1.7
5-4665	Edwards River near New Boston	434	6.8
5-4670	Pope Creek near Keithsburg	171	1.9
5-4675	Henderson Creek near Little York	151	0.03
5-4680	North Henderson Creek near Seaton	66.4	0.0
5-4685	Cedar Creek at Little York	128	7.4
5-4690	Henderson Creek near Oquawka	428	7.8
5-4695	South Henderson Creek at Biggsville	81.4	0.0
5-5565	Bureau Creek at Princeton	186	0.92
5-5570	West Bureau Creek at Wyanet	83.3	0.0
5-5575	East Bureau Creek near Bureau	101	0.0
5-5580	Bureau Creek at Bureau	481	16.9
5-5585	Crow Creek (West) near Henry	55.3	0.0
5-5590	Gimlet Creek at Sparland	5.42	0.0
5-5630	Kickapoo Creek near Kickapoo	120	0.53
5-5635	Kickapoo Creek at Peoria	296	1.0
5-5685	Illinois River at Kingston Mines	15,200	3,000
5-5688	Indian Creek near Wyoming	62.9	0.12
5-5695	Spoon River at London Mills	1,070	9.8
5-5700	Spoon River at Seville	1,600	19.0

Map 5—Sangamon Region

USGS number	Station	Drainage area (sq mi)	7-da 10-yr low flow (cfs)
5-5685	Illinois River at Kingston Mines	15,200	3,000
5-5710	Sangamon River at Mahomet	356	0.29
5-5715	Goose Creek near DeLand	47.3	0.0
5-5720	Sangamon River at Monticello	550	2.1
5-5724.50	Friends Creek at Argenta	111	0.0
5-5740	South Fork Sangamon River near Nokomis	10.8	0.0
5-5745	Flat Branch near Taylorville	279	0.0
5-5755	South Fork Sangamon River at Kincaid	510	0.79
5-5758	Horse Creek at Pawnee	53.0	0.0
5-5760	South Fork Sangamon River near Rochester	869	0.84
5-5765	Sangamon River at Riverton	2,560	37.2
5-5775	Spring Creek at Springfield	107	0.0
5-5785	Salt Creek near Rowell	334	2.2
5-5795	Lake Fork near Cornland	207	2.0
5-5800	Kickapoo Creek at Waynesville	227	0.48
5-5805	Kickapoo Creek near Lincoln	306	2.5
5-5815	Sugar Creek near Hartsburg	333	11.9
5-5820	Salt Creek near Greenview	1,800	68.6
5-5825	Crane Creek near Easton	28.7	0.89
5-5830	Sangamon River near Oakford	5,120	206

Map 6—La Moine River Region

USGS number	Station	Drainage area (sq mi)	7-da 10-yr low flow (cfs)
5-4745	Mississippi River at Keokuk, Iowa	119,000	15,170
5-4955	Bear Creek near Marcelline	348	0.0
5-5100	Hadley Creek near Barry	40.6	0.0
5-5105	Hadley Creek at Kinderhook	72.7	0.0
5-5125	Bay Creek at Pittsfield	39.6	0.0
5-5130	Bay Creek at Nebo	162	0.0
5-5844	Drowning Fork at Bushnell	25.9	0.0
5-5845	La Moine River at Colmar	655	0.78
5-5850	La Moine River at Ripley	1,310	9.0
5-5855	Illinois River at Meredosia	25,300	3,500
5-5860	North Fork Mauvaise Terre Creek near Jacksonville	30.0	0.0
5-5865	Hurricane Creek near Roodhouse	2.33	0.0
5-5868	Otter Creek near Palmyra	61.6	0.0
5-5870	Macoupin Creek near Kane	875	2.0

Map 7—Kaskaskia Region

USGS number	Station	Drainage area (sq mi)	7-da 10-yr low flow (cfs)
5-5875	Mississippi River at Alton	171,500	21,470
5-5880	Indian Creek at Wanda	37.0	0.0
5-5895	Canteen Creek at Caseyville	22.5	0.06
5-5900	Kaskaskia Ditch at Bondville	12.3	0.05
5-5905	Kaskaskia River at Ficklin	127	0.70
5-5915	Asa Creek at Sullivan	7.93	0.0
5-5920	Kaskaskia River at Shelbyville	1,030	10.0
5-5923	Wolf Creek near Beecher City	48.0	0.0
5-5925	Kaskaskia River at Vandalia	1,980	25.7
5-5930	Kaskaskia River at Carlyle	2,680	50.0
5-5935.75	Little Crooked Creek near New Minden	84.2	0.0
5-5936	Blue Grass Creek near Raymond	17.2	0.0
5-5939	East Fork Shoal Creek near Coffeen	55.4	0.0
5-5940	Shoal Creek near Breese	760	0.20
5-5944.50	Silver Creek near Troy	148	0.0
5-5950	Kaskaskia River at New Athens	5,220	93.0
7-0100	Mississippi River at St. Louis, Mo.	701,000	45,970

Map 8—Embarras Region

USGS number	Station	Drainage area (sq mi)	7-da 10-yr low flow (cfs)
3-3360	Wabash River at Covington, Ind.	8,208	723
3-3365	Bluegrass Creek at Potomac	34.8	0.0
3-3369	Salt Creek near St. Joseph	134	3.6
3-3370	Boneyard Creek at Urbana	4.70	0.70
3-3375	Saline Branch at Urbana	68.1	1.0
3-3380	Salt Fork near Homer	340	13.5
3-3385	Vermilion River near Catlin	959	19.0
3-3390	Vermilion River near Danville	1,279	33.0

Table 2 (Concluded)

USGS number	Station	Drainage area (sq mi)	7-da 10-yr low flow (cfs)
3-3391.50	Little Vermilion River near Newport, Ind.	240	0.0
3-3405	Wabash River at Montezuma, Ind.	11,100	886
3-3414.20	Brouilletts Creek near Universal, Ind.	331	1.1
3-3415	Wabash River at Terre Haute, Ind.	12,200	1,008
3-3420	Wabash River at Riverton, Ind.	13,100	1,249
3-3430	Wabash River at Vincennes, Ind.	13,700	1,326
3-3434	Embarras River near Camargo	185	0.0
3-3435	Embarras River near Oakland	518	0.08
3-3440	Embarras River near Diona	919	3.2
3-3445	Range Creek near Casey	7.60	0.0
3-3450	Embarras River at Newton	1,392	13.2
3-3455	Embarras River at Ste. Marie	1,513	16.6
3-3460	North Fork Embarras River near Oblong	319	0.0
3-3465	Embarras River at Lawrenceville	2,333	35.0
Map 9 — Little Wabash Region			
3-3430	Wabash River at Vincennes, Ind.	13,700	1,326
3-3775	Wabash River at Mt. Carmel	28,600	2,490
3-3780	Bonpas Creek at Browns	228	0.0
3-3785	Wabash River at New Harmony, Ind.	29,160	2,620
3-3786.35	Little Wabash River near Effingham	240	0.0
3-3789	Little Wabash River at Louisville	747	0.0
3-3795	Little Wabash River below Clay City	1,134	0.47
3-3803.50	Skillet Fork near Iuka	208	0.0
3-3804.75	Horse Creek near Keenes	97.2	0.0
3-3805	Skillet Fork at Wayne City	464	0.0
3-3815	Little Wabash River at Carmi	3,111	5.7
Map 10 — Southern Region			
3-3820	Middle Fork Saline River near Harrisburg	198	1.1
3-3821	South Fork Saline River near Carrier Mills	148	0.50
3-3821.70	Brushy Creek near Harco	13.3	0.0
3-3823.50	North Fork Saline River near Ridgeway	426	0.0
3-3825	Saline River near Junction	1,040	2.4
3-3825.10	Eagle Creek near Equality	8.50	0.0
3-3844.50	Lusk Creek near Eddyville	42.6	0.0
3-3845	Ohio River at Golconda	143,900	12,610
3-3850	Hayes Creek at Glendale	18.9	0.0
3-3855	Lake Glendale Inlet near Dixon Springs	1.04	0.0
3-3860	Lake Glendale Outlet near Dixon Springs	2.11	0.0
3-3865	Sugar Creek near Dixon Springs	9.70	0.0
3-6115	Ohio River at Metropolis	203,000	44,820
3-6120	Cache River at Forman	243	0.0
5-5955	Marys River near Sparta	17.8	0.0
5-5958	Sevenmile Creek near Mt. Vernon	21.5	0.0
5-5960	Big Muddy River near Benton	498	30.6
5-5965	Tilley Creek near West Frankfort	4.03	0.0
5-5970	Big Muddy River at Plumfield	753	31.0
5-5975	Crab Orchard Creek near Marion	31.9	0.0
5-5985	Beaucoup Creek near Pinckneyville	227	0.0
5-5990	Beaucoup Creek near Matthews	291	0.0
5-5995	Big Muddy River at Murphysboro	2,170	35.2
5-6000	Big Creek near Wetang	32.2	0.0
7-0205	Mississippi River at Chester	712,600	46,840
7-0220	Mississippi River at Thebes	717,200	47,810
Map 11 — Border Rivers (and Illinois River)			
3-3360	Wabash River at Covington, Ind.	8,208	723
3-3405	Wabash River at Montezuma, Ind.	11,100	886
3-3415	Wabash River at Terre Haute, Ind.	12,200	1,008
3-3420	Wabash River at Riverton, Ind.	13,100	1,249
3-3430	Wabash River at Vincennes, Ind.	13,700	1,326
3-3775	Wabash River at Mt. Carmel	28,600	2,490
3-3785	Wabash River at New Harmony, Ind.	29,160	2,620
3-3845	Ohio River at Golconda	143,900	12,610
3-6115	Ohio River at Metropolis	203,000	44,820
5-4205	Mississippi River at Clinton, Iowa	85,000	13,970
5-4745	Mississippi River at Keokuk, Iowa	119,000	15,170
5-5875	Mississippi River at Alton	171,500	21,470
7-0100	Mississippi River at St. Louis, Mo.	701,000	45,970
7-0205	Mississippi River at Chester	712,600	46,840
7-0220	Mississippi River at Thebes	717,200	47,810
5-5370	Chicago Sanitary and Ship Canal at Lockport		1,700
5-5435	Illinois River at Marseilles	7,640	3,240
5-5685	Illinois River at Kingston Mines	15,200	3,000
5-5855	Illinois River at Meredosia	25,300	3,500

computer program also ranks these low flows in ascending order of magnitude and computes the corresponding percent probability and recurrence interval in years from

$$p_m = \frac{m}{n+1} \times 100$$

and

$$T_m = \frac{n+1}{m}$$

in which m is the rank of 7-day low flow, $m = 1, 2, \ldots, n$; n denotes the total number of years; p_m represents percent probability of the low flow being equal to or less than mth low flow; and T_m is the average recurrence interval, in years, for the mth flow. A typical computer output is shown in table 3 for Pope Creek near Keithsburg in the Spoon River Region, USGS gaging station 5-4670, which has a drainage area of 171 square miles. The 7-day low flows are given for 35 years.

The first four lowest 7-day flows in Pope Creek, shown in Part B of table 3, are 1.66, 1.71, 1.79, and 1.87 cfs and occurred, as shown in Part A, during the years 1964, 1949, 1940, and 1963 and in the months December, September, October, and October, respectively. These low flows do not exhibit any trend of increase or decrease over the 35-year period. There are no waste water treatment plants discharging effluents that affect the flow at this gage. The 7-day low flow for a 10-year recurrence interval is obtained by interpolating between the 9-year and 12-year low flow values shown in table 3, which indicates a 7-day 10-year low flow of 1.85 cfs at this station.

Table 3. Typical Computer Output

Pope Creek near Keithsburg, USGS gaging station 5-4670
Drainage area 171 square miles

Part A					Part B		
		Beginning of 7-day low flow period					
Low-flow year	7-da 10-yr low flow (*cfs*)	Days from Apr 1	Month	Date	Probability, *p* (%)	*T* (*years*)	7-da 10-yr low flow (*cfs*)
1935	11.57	169	9	16	2.78	36.00	1.66
1936	2.57	133	8	11	5.56	18.00	1.71
1937	2.00	169	9	16	8.33	12.00	1.79
1938	13.29	152	8	30	11.11	9.00	1.87
1939	4.00	296	1	21	13.89	7.20	2.00
1940	1.79	184	10	1	16.67	6.00	2.09
1941	3.11	151	8	29	19.44	5.14	2.57
1942	10.43	199	10	16	22.22	4.50	3.00
1943	5.74	188	10	5	25.00	4.00	3.11
1944	5.43	279	1	4	27.78	3.60	3.60
1945	6.29	214	10	31	30.56	3.27	3.76
1946	8.51	187	10	4	33.33	3.00	3.83
1947	6.57	296	1	21	36.11	2.77	3.91
1948	5.39	201	10	18	38.89	2.57	4.00
1949	1.71	181	9	28	41.67	2.40	4.07
1950	3.91	270	12	26	44.44	2.25	4.17
1951	27.43	183	9	30	47.22	2.12	4.30
1952	4.30	191	10	8	50.00	2.00	4.30
1953	3.60	297	1	22	52.78	1.89	4.53
1954	4.53	174	9	21	55.56	1.80	5.39
1955	4.07	306	1	31	58.33	1.71	5.43
1956	2.09	213	10	30	61.11	1.64	5.57
1957	3.00	190	10	7	63.89	1.57	5.74
1958	4.17	256	12	12	66.67	1.50	5.90
1959	5.90	163	9	10	69.44	1.44	6.29
1960	6.86	299	1	24	72.22	1.38	6.57
1961	3.83	158	9	5	75.00	1.33	6.86
1962	5.57	173	9	20	77.78	1.29	8.51
1963	1.87	193	10	10	80.56	1.24	8.63
1964	1.66	258	12	14	83.33	1.20	10.43
1965	18.71	119	7	28	86.11	1.16	11.57
1966	4.30	188	10	5	88.89	1.13	13.29
1967	8.63	161	9	8	91.67	1.09	14.00
1968	3.76	214	10	31	94.44	1.06	18.71
1969	14.00	186	10	3	97.22	1.03	27.43

The 7-day 10-year low flow values at some stations do indicate a trend for increase in low flow when the drainage area upstream of the gaging station is slowly or rapidly urbanizing, and thus discharging more and more waste water effluents to the stream. Usually the source of water supply is groundwater from deep wells. These two situations are discussed in detail in later sections.

Flows along the Streams

The 7-day 10-year low flows at the gaging stations serve as control points for estimating these low flow values along the streams and their tributaries. Other pertinent information is the location of waste water treatment plant effluents entering the stream and their 7-day low flow effluents. For maximum utility, 7-day 10-year values need to be estimated at locations near towns, at junctions with medium and major tributaries, at sizeable inflows from waste water treatment plants, and at regulation or control works. The 7-day 10-year low flows were estimated at these various points along the streams, but not all of them were shown on the low flow maps to avoid overcrowding the maps.

The 7-day 10-year low flows along the stream were derived with the use of the following tools, singly or in combination, as dictated by the prevailing conditions in each general area.

Low Flow vs Area Curves. The 7-day 10-year low flow versus drainage area curve, applicable to the area under consideration, indicates the drainage area A_o for which the 7-day 10-year low flow is zero. The creeks, streams, and tributaries with drainage area less than A_o are shown by dot-dash lines on the low flow maps. When the drainage area equals A_o, the low flow value is shown as 0.00 and the stream is drawn as a solid line downstream which means it is then a perennial-flow stream.

Waste Water Treatment Plant Effluents. The waste water effluents entering the streams pose some problems in estimating low flows. If these effluents enter streams that have drainage areas 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 would be 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 A_o. The flow contribution will increase the larger the effluent and the closer its point of entrance to the A_o point. Once the stream has nonzero natural 7-day 10-year low flow, any effluent additions simply increase the 7-day 10-year flow by the amount of effluent addition.

Water from Streams for Municipal and Industrial Use. Generally any town or industry pumping water from a stream returns it to the stream after use in the form of effluents from its waste water treatment plant. Such use does cause reduction in the 7-day 10-year low flow because the return water is always less, though the deficit will vary. Adjustments in 7-day 10-year values are made for these losses where necessary. Some examples are the loss of 3.9 cfs to the 7-day 10-year low flow in the Illinois River because of the Peoria water supply, and the loss of 28.0 cfs to the low flow value for the Chicago Sanitary and Ship Canal because of water use by the Corn Products Company.

Timing of Low Flows in Two Major Branches. When two major branches drain sufficiently large areas before joining together, the 7-day 10-year low flow versus area curves applicable to these branches may be quite different because of hydrologic, geologic, and soil factors. Further, the low flows may not occur during the same month. Under such conditions, the 7-day 10-year flow below the junction will be much more than a simple addition of 7-day 10-year low flows in the two branches.

For example, the 7-day 10-year flow for the Pecatonica River at its mouth (drainage area 2647 sq mi) is 412 cfs, and that for the Rock River just upstream of its junction with the Pecatonica (drainage area 3640 sq mi) is 240 cfs. At the USGS gaging station at Rockton on the Rock River, ¾ mile below its confluence with the Pecatonica, the 7-day

10-year low flow is 795 cfs, which is much more than the sum of the two low flows above the junction (652 cfs). Flows in the range of the 7-day 10-year low flow in the Pecatonica occur during the months of July, December, or January, whereas they occur during August or September in the Rock River above the confluence. Such flows at Rockton occur during August or October, and the concurrent low flows during these two months yield the 7-day 10-year low flow of 795 cfs for the Rock River at Rockton. Another example is the 7-day 10-year low flows at the confluence of the Des Plaines and Kankakee Rivers where they form the Illinois River downstream, as shown below.

River	7-da 10-yr low flow (*cfs*)	Months
Des Plaines	1926	December, March
Kankakee	455	September
Illinois	3181	October, January

Modification of Low Flow because of Lakes and Pools. In-stream lakes and pools generally reduce the 7-day 10-year low flow unless a significant minimum flow release is provided in the project design. Lakes and pools expose considerable water surface areas to evaporation, thus reducing the natural low flows. If the water levels are regulated for recreational or other purposes, the flow needed to maintain the lake level combined with evaporation loss may reduce the 7-day 10-year low flow 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 7-day 10-year low flow below the impounding structure would be zero. However, in large multipurpose reservoirs as discussed in a later section, some minimum flow release is stipulated downstream of the dam and this can be taken as the 7-day 10-year low flow at the outlet.

Flow Regulation for Navigation. Flows in the waterways of the Metropolitan Sanitary District of Greater Chicago (MSDGG), and 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 7-day 10-year low flow conditions. There are three USGS gaging stations on the Illinois River, at Marseilles, Kingston Mines, and Meredosia. The observed losses are attributed to evaporation, leakage, and storage because of regulation. Because all these 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. A detailed description is given later.

Groundwater Accretion to Low Flow. A stream becomes a *gaining stream* when groundwater flows into the stream. The amount of this accretion has been shown (Singh, 1968) to be related to the depth of streambed incision or entrenchment. 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.

Backwater Effects from Ohio and Mississippi Rivers. The flows in the river reaches from a confluence to a variable distance upstream of the Ohio and Mississippi Rivers can be reversed because of backwater effects. Such backflow occurs in the Saline River and to a smaller extent in the Big Muddy River. The water backs up into the small rivers when their flows are low to moderate while flows in the Ohio and Mississippi Rivers are high. Because these backwater conditions last only a few days, are not easily predictable, affect only a small downstream length of the river, and depend to a large extent on the flood flow regulation in the Ohio and Mississippi Rivers, the 7-day 10-year low flows to the mouth have been processed under an assumption of no interference from backwater.

Flow Data from Gaging Stations in Adjoining States. For determining 7-day 10-year low flows in the Wabash, Ohio, and Mississippi Rivers bordering Illinois, the daily flow data at 50 USGS gaging stations in the neighboring states of Indiana, Kentucky, Missouri, Iowa, and Wisconsin were used in addition to 15 stations on the bordering rivers. The multistation computer program provided the information on concurrent flows. With the exception of the timing problem for low flows in the Missouri-Mississippi Rivers and Tennessee-Ohio Rivers at their respective confluences, the period of low flows was primarily decided by low flows in the Wabash, Ohio, or Mississippi Rivers. In one case on the Mississippi River, concurrent low flows had to be considered at 16 main stem and tributary stations.

Other Considerations. Some other assumptions have been made in deriving 7-day 10-year low flows along the streams and showing them on the low flow maps.

1) Effluents from waste water treatment plants serving schools have not been considered because these would be practically zero during school closure in July and August — the usual months of low flow in streams. Therefore, these are not shown on the 7-day 10-year low flow maps.
2) Effluents from waste water treatment plants serving trailer parks or recreational areas have not been considered because such flows are not only small but also transitory and seasonal. In intermittent streams, all such effluents would be lost before reaching the perennial stream. For similar reasons, effluents in the range of 0.02 cfs or less from some small towns are not shown.
3) Any local conditions that are atypical of the general area were not considered. For example, flow from a local spring was not considered unless springs were distributed over the general area.
4) The 7-day 10-year low flows for the 1970 condition of effluents may need adjustment in later years with increases in effluent flows because of increased population. The impact of such increases may be relatively more in streams having small natural low flow.

Waste Water Treatment Plants

All cities operating waste water treatment plants are required by the Illinois Environmental Protection Agency to submit monthly operation reports. These reports contain information on the amount of water in gallons per day leaving the plant after treatment, any waste water bypassed during rains in the case of combined sewer systems, and quality parameters such as BOD and concentration of suspended solids. These operation reports are on file in the field offices of the Illinois EPA in Chicago, Rockford, Aurora, Kankakee, Peoria, Champaign, Springfield, Collinsville, and Marion. The information from these reports varies in quality but is generally useful in understanding the variability of the effluent.

The EPA field offices were visited to collect the information on effluent flow for the year 1970, as well as for a few earlier years where available. The relevant information was noted in a format specifically prepared for this study. An example of this information for the city of McHenry in the Fox River basin is shown in table 4. The 7-day 10-year low flow in the receiving stream, the Fox River, occurs during the months of July through October.

Table 4. Effluent Flow Data from Waste Water Treatment Plant at McHenry for 1970

Month	Flow (*mgd*) Average	Flow (*mgd*) Minimum day
January	0.66	0.59
February	0.65	0.60
March	0.73	0.59
April	0.94	0.81
May	1.07	0.80
June	1.41	0.94
July	0.90	0.73
August	0.79	0.60
September	1.11	0.70
October	0.96	0.83
November	0.95	0.82
December	0.81	0.66
Mean	0.915	

7-day low flow = 0.721 mgd
= 1.11 cfs
1970 population = 6772

Note: 7-day 10-year low flow in Fox River occurs during July-October

Daily flow in August for computing 7-day low flow during dry season

Date	Flow (*mgd*)
1	0.92
2	0.83
3	0.91
4	0.82
5	0.82
6	0.82
7	0.87
8	0.75
9	0.72
10	0.92
11	0.86
12	0.88
13	0.79
14	0.90
15	0.73
Begin lowest 7 days	
16	0.65
17	0.77
18	0.70
19	0.85
20	0.77
21	0.71
22	0.60
7-day mean	*0.721 mgd*
23	0.77
24	0.80
25	0.75
26	0.74
27	0.91
28	0.77
29	0.76
30	0.67
31	0.73

With the exception of the Fox River and the northern part of the Rock River basin, the 7-day low flow effluent from waste water treatment plants in Illinois occurs about the same time as the 7-day 10-year low flow in the receiving stream. For these special cases in which the effluent from the plant and the low flow in the stream are not in phase and the effluent is a small part of the total low flow in the stream, the 7-day low flow effluent must be determined for the period of low flow in the receiving stream.

As shown in table 4, the average monthly effluent flow and the minimum day flow in each month were noted from the operation reports. During the months of July through October 1970, the minimum day effluent flow occurred in August and the average monthly flow for August was also the lowest in the four-month period. A cursory inspection of the operation report confirmed that the lowest 7-day flow occurred in August. Therefore, the daily flows were copied for the month of August (table 4). The lowest 7-day flow was for the period August 16-22, 1970, and this flow averaged 0.721 mgd, or 1.11 cfs. Similar low flow information was processed from the available records for as many towns as possible in a river basin or region.

The relation between the 7-day low flow effluent, E_7, and population, P, was defined by plotting information such as that from table 4 on loglog paper. One such plot for 32 plants in the Fox River basin is shown in figure 3. The average relation is typified by the principal curve:

$$E_7 = 26 P^{1.15} \times 10^{-6}$$

in which E_7 is the lowest 7-day waste water effluent, in mgd, during the usual period of low flows in the receiving stream, and P is the population served. Values of low flow effluents from waste water treatment plants, in gallons per capita per day (gpcd), for various populations as obtained from the average curve are given below.

Population served	Low flow effluent (*gpcd*)
500	66
1,000	73
5,000	93
10,000	104
50,000	132
100,000	146

For individual towns, curves were drawn parallel to the average curve to obtain 7-day low flow effluents for populations in other years, which were needed for towns in rapidly urbanizing basins. The low flow effluents for towns that had no effluent data were estimated from figure 3 on the basis of the 1970 population, general location, comparison with other towns having plotted data, and the character of the town, whether residential or lightly or considerably industrialized.

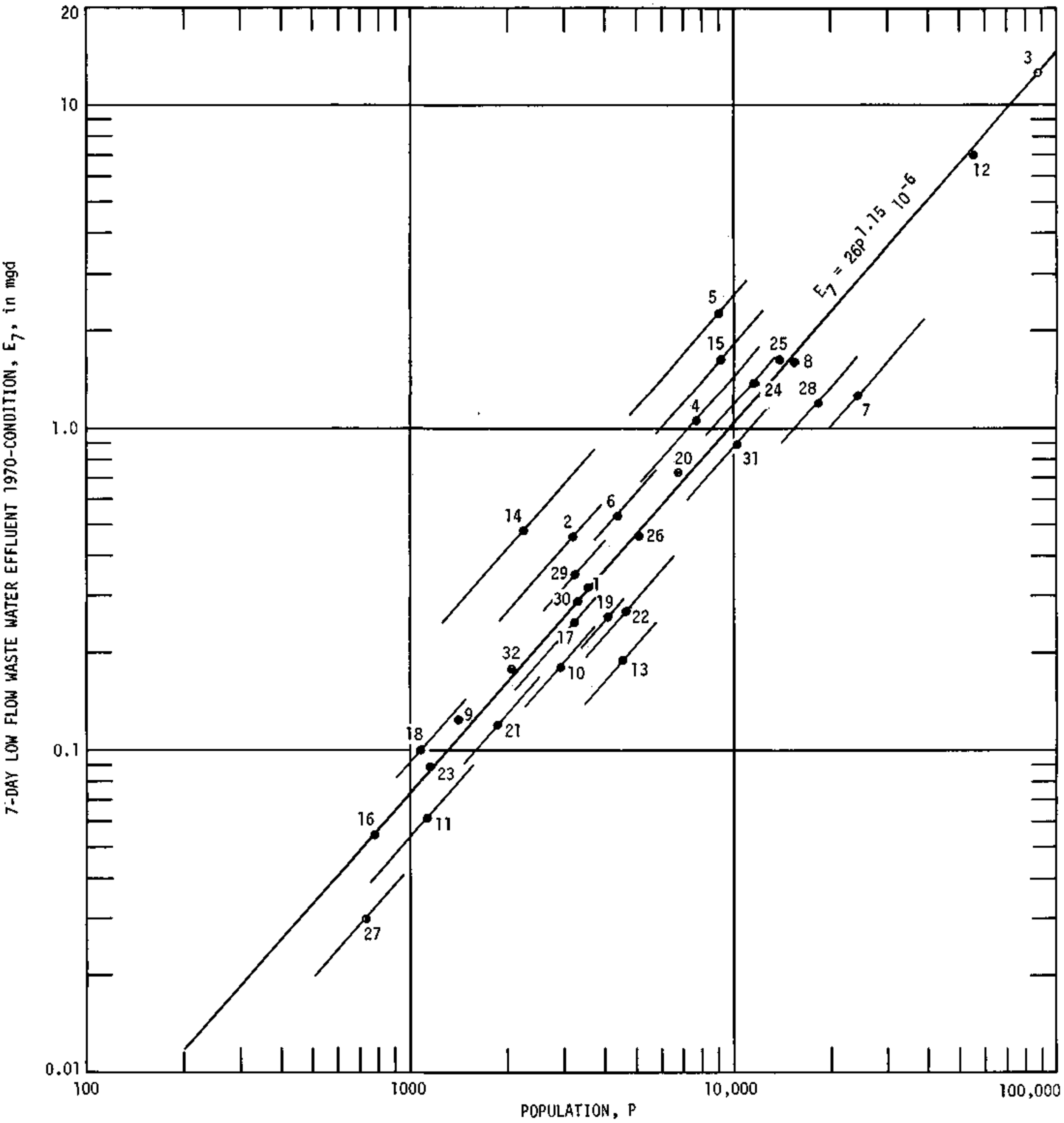

Figure 3. 7-day low flow waste water plant effluent in 1970 as related to population served, for cities in the Fox River basin

Intermittent Streams

Intermittent streams at times have zero flow. To illustrate the losses in intermittent-flow streams that have significant inflows from sewage treatment plants, we will consider the Sangamon River basin in general. The basin lies in the Springfield Plain physiographic division (Leighton et al., 1948) which is the level portion of Illinoian drift sheet in central Illinois and has shallow entrenchment of streams. From a study of streamflow variability and flow duration curves for streams in Illinois, Singh (1971) divided the state into 14 hydrologic divisions and an area 'a' of Wisconsinan sand deposits. The Sangamon River basin has portions of hydrologic divisions 5, 6, and 10, and area 'a' as shown in figure 4.

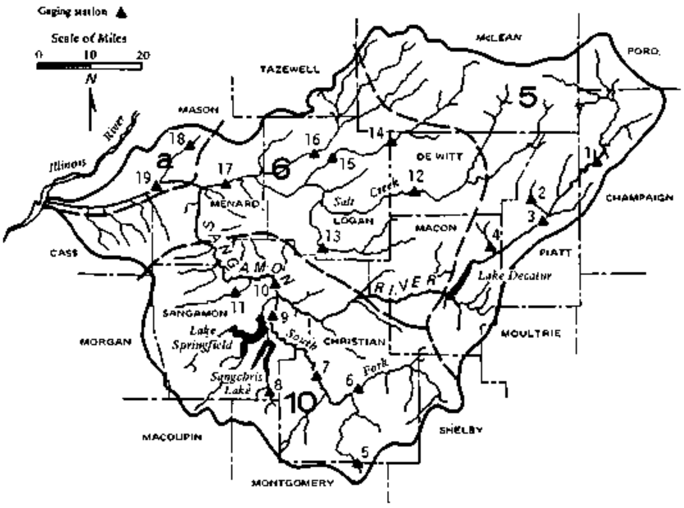

Figure 4. Sangamon River basin showing stream gaging stations and hydrologic divisions 5, 6, 10, and a

There are 19 gaging stations in the basin. Table 5 shows the drainage areas, the natural 7-day 10-year low flows, and the 1970-condition low flows as described earlier. The natural 7-day 10-year low flow is obtained by subtracting the waste water effluent contributions from the 7-day low flows. If after subtraction, the flows are negative, they are put equal to zero. Natural values are plotted against respective drainage areas in figure 5. There are four distinct curves for the four hydrologic divisions, and three intermediate curves for drainage areas covered by two or more of these divisions. These curves show that the natural 7-day 10-year low flow would be zero for drainage areas less than 1, 60, 230, and 600 square miles within the hydrologic divisions 'a', 6, 5, and 10, respectively.

For some streams, the 1970-condition 7-day 10-year low flow is zero even when some effluents are being discharged to the stream in its upper reach. This occurs when the natural 7-day 10-year value is zero and the drainage area at the gaging station is small. During low flow periods, such streams lose water to groundwater storage, and are called *losing streams.* For example, in 1964 the 7-day low flow for Flat Branch near Taylorville (station 5-5745, drainage area 279 sq mi) was zero even though the effluent contribution from the town of Macon, upstream of Taylorville, amounted to 0.15 cfs.

Table 5. 7-Day 10-Year Low Flows at Gaging Stations in the Sangamon River Basin

Map number (*fig. 4*)	USGS number	Station	Drainage area (*sq mi*)	7-da 10-yr low flow: 1970 condition (*cfs*)	7-da 10-yr low flow: Natural (*cfs*)	Hydrologic Div.
1	5–5710	Sangamon River at Mahomet	356	0.29	0.11	5
2	5–5715	Goose Creek near DeLand	47.3	0.00	0.00	5
3	5–5720	Sangamon River at Monticello	550	2.1	0.71	5
4	5–5724.5	Friends Creek at Argenta	111	0.00	0.00	5
5	5–5740	South Fork Sangamon River near Nokomis	10.8	0.00	0.00	10
6	5–5745	Flat Branch near Taylorville	279	0.00	0.00	10
7	5–5755	South Fork Sangamon River near Kincaid	510	0.79	0.00	10
8	5–5758	Horse Creek at Pawnee	53.0	0.00	0.00	10
9	5–5760	South Fork Sangamon River near Rochester	869	0.84	0.15	10
10	5–5765	Sangamon River at Riverton	2560	37.2	11.9	5,10
11	5–5775	Spring Creek near Springfield	107	0.00	0.00	10
12	5–5785	Salt Creek near Rowell	334	2.2	1.5	5,6
13	5–5795	Lake Fork near Cornland	207	2.0	2.0	6
14	5–5800	Kickapoo Creek at Waynesville	227	0.48	0.48	5,6
15	5–5805	Kickapoo Creek near Lincoln	306	2.5	2.5	5,6
16	5–5815	Sugar Creek near Hartsburg	333	11.9	2.7	5.6
17	5–5820	Salt Creek near Greenview	1800	68.6	56.9	5,6
18	5–5825	Crane Creek near Easton	28.7	0.89	0.89	a
19	5–5830	Sangamon River near Oakford	5120	206	144	5,6,10,a

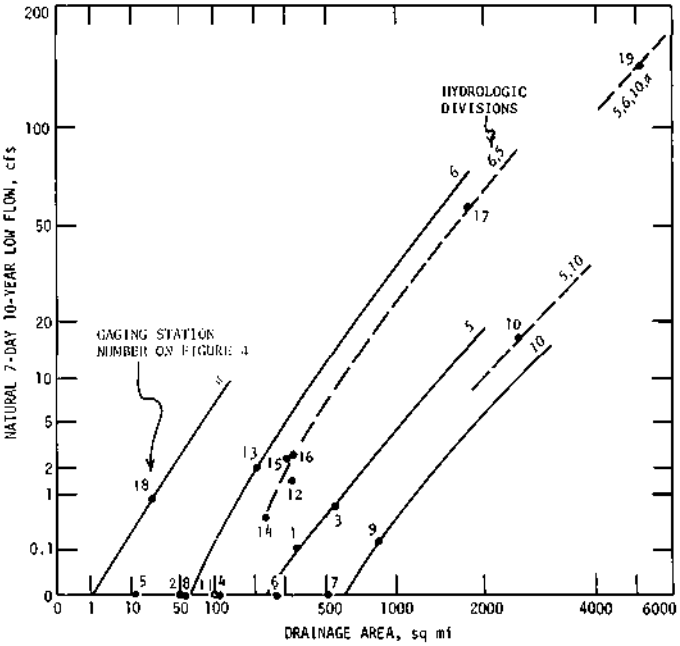

Figure 5. 7-day 10-year low flows as related to drainage area, Sangamon River basin

When the effluent discharge is considerable, only part of it will be lost as it flows down the dry streambed. Sugar Creek near Hartsburg (station 5-5815, drainage 333 sq mi) had a 7-day 10-year low flow of 6.8 cfs for the 1950 condition of effluents. At that time the Bloomington-Normal plant discharged an effluent of 6.0 cfs to the stream in its upper reach. The adjacent stream, Kickapoo Creek near Lincoln (station 5-5805, drainage 306 sq mi), had an observed 7-day 10-year low flow of 2.5 cfs, had no effluent contributions for the period of record, and therefore had a natural low flow equal to its observed low flow, or 2.5 cfs. The natural low flow at Hartsburg was estimated at 2.7 cfs on the basis of drainage area and similar basin and channel characteristics for the two streams. Thus, the effluent loss was 1.9 cfs [6.0 + 2.7 - 6.8] out of a total of 6.0 cfs.

For streams in which the natural 7-day 10-year low flow is not zero, the 1970-condition 7-day 10-year low flow is the sum of the natural low flow and the sewage treatment plant effluents discharged to the stream when low flow conditions prevail.

The philosophy of modification of natural low flow by sewage treatment plant effluents is briefly described below.

1) A small amount of effluent discharge to a stream will not add to the natural low flow in the stream, un-

less the stream is near to having or has some natural 7-day 10-year low flow.

2) A medium amount of effluent discharge, if it is added to the uppermost reach of a stream, will slightly increase the low flow. However, the flow increase will tend to equal the amount of effluent discharge for effluent locations closer to the stream section where the natural 7-day 10-year low flow is not zero.
3) A large amount of effluent discharge will contribute to streamflow downstream, but the contribution will decrease with distance until the stream is no longer intermittent.

The derived natural 7-day 10-year low flow at the 19 gaging stations are given in table 5. These low flow values serve as control values for interpreting, interpolating, and extrapolating natural low flows along the entire stream network consistent with pertinent physical, geologic, hydrologic, and soil information for the basin.

Streams in Slowly Urbanizing Basins

For streams draining a slowly urbanizing drainage area, the lowest 7-day flows show minor changes from increased effluents but do not exhibit any significant upward trend with time. As an example we will consider the low flows occurring in various streams in the Rock River region. Here the differences in low flow are primarily related to the natural hydrology. This basin is shown in figure 6, and table 6 lists the 28 gaging stations in this basin, their drainage areas, and the 7-day 10-year low flows corrected to 1970 conditions of waste water effluent inflows. The lowest 7-day flows each year at these stations do not exhibit any significant time trend. The 7-day 10-year values derived from the lowest 7-day flows for the available record (1941-1969) needed adjustment at 8 gaging stations (Nos. 11, 14, 16, 17, 20, 21, 22, and 25) to allow for increased effluents from municipal and industrial plants, and for an artificial flow reduction instituted in the Illinois and Mississippi Canal. Values before adjustment for these stations are also shown in table 6.

For the Kyte River near Flagg Center, the 7-day 10-year value from the lowest 7-day flows recorded up to 1950 is 2.8 cfs. Rochelle and Ashton discharge effluents from their treatment plants to the Kyte River and its tributary, respectively. The effluent from the Rochelle waste water plant has increased by 0.40 cfs from 1950 to 1970, and that from Ashton makes an effective contribution of 0.10 cfs to the

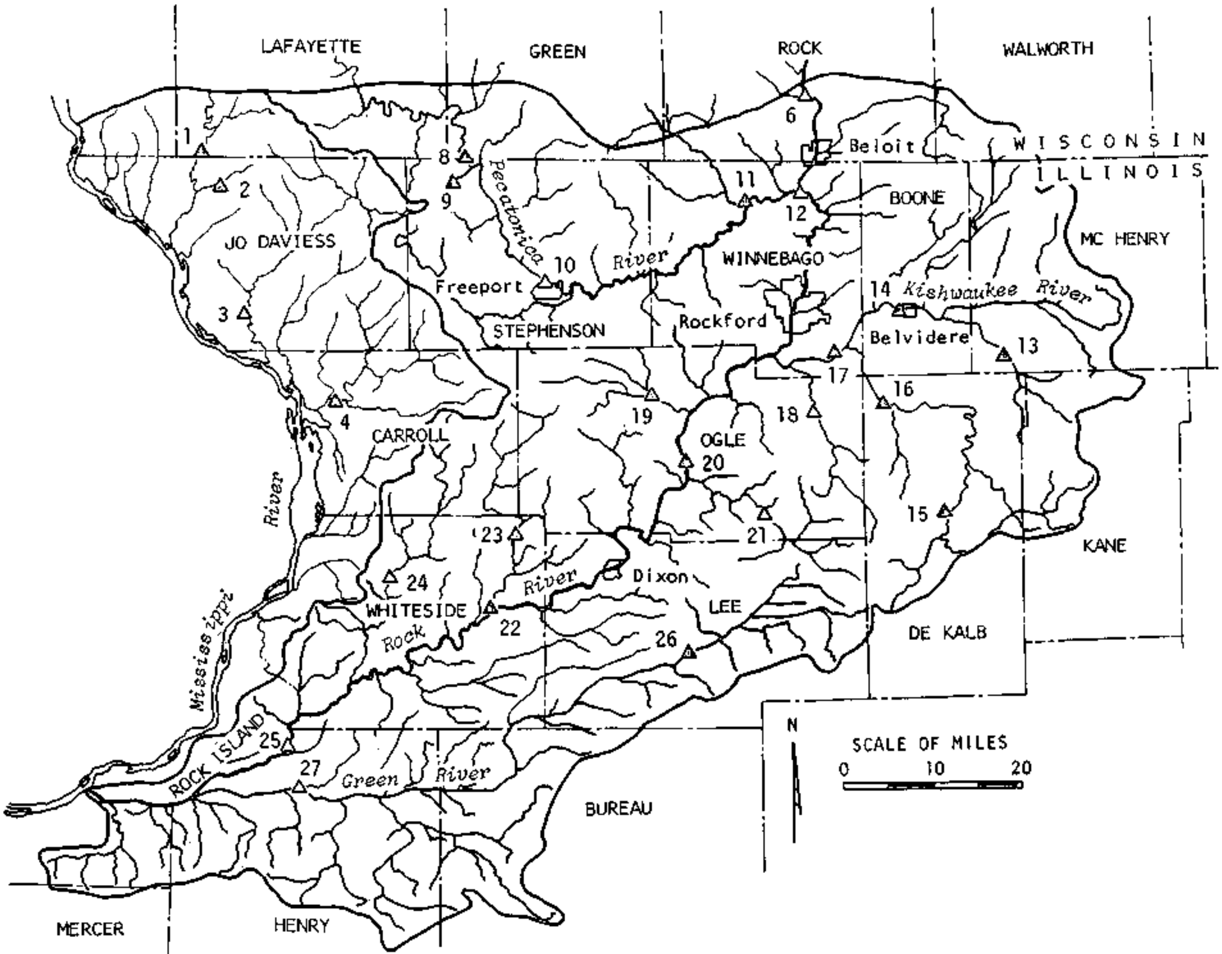

Figure 6. Rock River basin showing stream gaging stations

Table 6. 7-Day 10-Year Low Flows at Gaging Stations in the Rock River Region, 1970 Conditions

Map number (*fig. 6*)	USGS number	Station	Drainage area (*sq mi*)	7-da 10-yr low flow (*cfs*)	
1	5–4150	Galena River at Buncombe, Wis.	128	11.7	
2	5–4155	East Fork Galena River at Council Hill	20.1	2.3	
3	5–4190	Apple River near Hanover	244	20.1	
4	5–4200	Plum River below Carroll Creek, near Savanna	231	10.7	
5	5–4255	Rock River at Watertown, Wis.	971	8.4	
6	5–4305	Rock River at Afton, Wis.	3300	180	
7	5–4325	Pecatonica River at Darlington, Wis.	274	30.6	
8	5–4345	Pecatonica River at Martintown, Wis.	1040	153	
9	5–4350	Cedar Creek near Winslow	1.29	0.0	
10	5–4355	Pecatonica River at Freeport	1330	181	
11	5–4370	Pecatonica River at Shirland	2540	393	(391)*
12	5–4375	Rock River at Rockton	6290	795	
13	5–4382.5	Coon Creek at Riley	85.3	2.6	
14	5–4385	Kishwaukee River at Belvidere	525	34.3	(32.3)
15	5–4390	S. Br. Kishwaukee River at De Kalb	70.0	0.10	
16	5–4395	S. Br. Kishwaukee River near Fairdale	386	9.9	(8.8)
17	5–4400	Kishwaukee River near Perryville	1090	62.3	(59.4)
18	5–4405	Killbuck Creek near Monroe Center	114	3.1	
19	5–4410	Leaf River at Leaf River	102	8.4	
20	5–4415	Rock River at Oregon	8120	1100	(1090)
21	5–4420	Kyte River near Flagg Center	125	3.3	(2.8)
22	5–4435	Rock River at Como	8700	1097	(1063)
23	5–4440	Elkhorn Creek near Penrose	153	15.5	
24	5–4455	Rock Creek near Morrison	143	13.6	
25	5–4465	Rock River near Joslin	9520	1306	(1276)
26	5–4470	Green River at Amboy	199	4.9	
27	5–4475	Green River near Geneseo	958	49.2	
28	5–4480	Mill Creek at Milan	62.5	0.10	

* *7-day 10-year low values before adjustment are shown in parentheses*

low flows. Thus, the 7-day 10-year low flow for the Kyte River near Flagg Center is adjusted to 3.3 cfs [2.8 + 0.40 + 0.10] to correct for the 1970 conditions of effluent inflows.

In figure 7 the 7-day 10-year values for all 28 stations are plotted against drainage area, on cube-root paper. Six curves are drawn representing 7-day 10-year low flow versus area relationships for the Pecatonica River, Rock River above Pecatonica River, Kishwaukee River (north), Kishwaukee River (south), Green River, and Rock River below Rockton. For other streams, such as the Galena (station 1), Apple (3), Plum (4), and Leaf (19) Rivers, curves can be drawn through the relevant flow-area point following the configuration of the nearest curves. It is evident from figures 6 and 7 that:

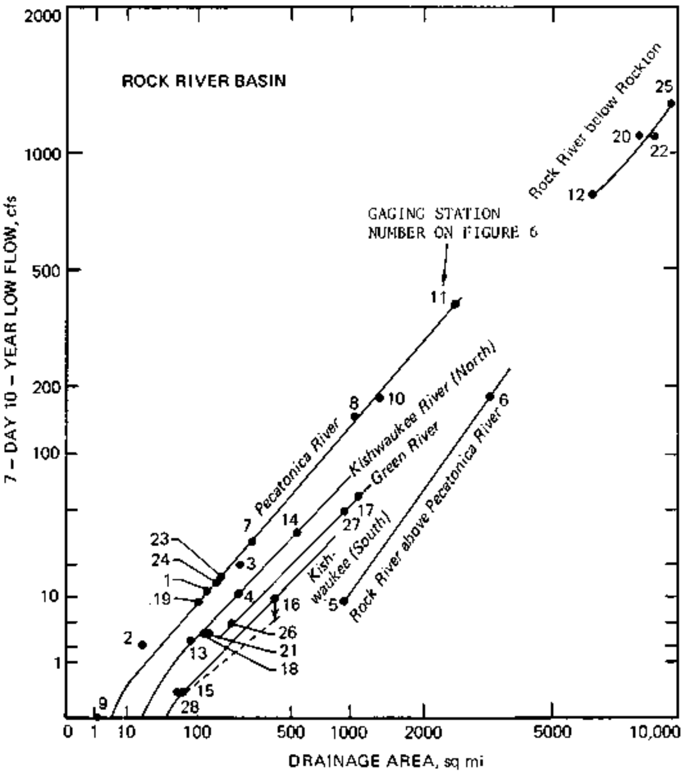

Figure 7. 7-day 10-year low flows as related to drainage area. Rock River basin

1) The Pecatonica River curve would be applicable to the Pecatonica River and at least up to the gaging stations on the Galena and Leaf Rivers and on Elkhorn (23) and Rock (24) Creeks. Thus, about 25 percent or more of the Rock River basin in Illinois follows the Pecatonica curve, which represents the highest 7-day 10-year low flow for a given drainage area within the basin.
2) The Kishwaukee River basin in the eastern part of the Rock River basin, displays two distinct curves — one for the northern portion draining to the Kishwaukee River, and the other for the southern portion draining to the South Branch of the Kishwaukee River. Both northern and southern curves yield much lower 7-day 10-year flows than the Pecatonica curve, but the southern curve indicates much drier conditions than the northern one. The dashed southern curve shows natural 7-day 10-year low flows obtained after subtracting effluents.
3) The Green River curve lies between the Kishwaukee north and south curves and has on it the Kishwaukee River near Perryville (located below the confluence of the two streams draining the north and south portions).
4) For minor tributaries flowing into the Rock River, the 7-day 10-year low flow versus area curves will lie between the curves for areas surrounding them.
5) For the Rock River basin in Illinois, the drainage area for zero 7-day 10-year low flow varies from 5 square miles in the Pecatonica basin to 60 square miles in the South Branch Kishwaukee River basin.

The Rock River basin is not homogeneous so far as 7-day 10-year low flows are concerned. However, the basin can be parcelled out into separate entities and some intermediate categories for defining the relation between 7-day 10-year low flow and the drainage area.

Streams in Rapidly Urbanizing Basins

For streams with a rapidly urbanizing drainage area the lowest 7-day flows each year exhibit a pronounced upward trend with time. As an example we will consider the lowest 7-day flows observed in the Salt Creek at Western Springs (station 5-5315, drainage 114 sq mi) during the years 1946-1969, plotted in figure 8. The lowest 7-day curve typifies the trend and yields a 7-day 10-year low flow of

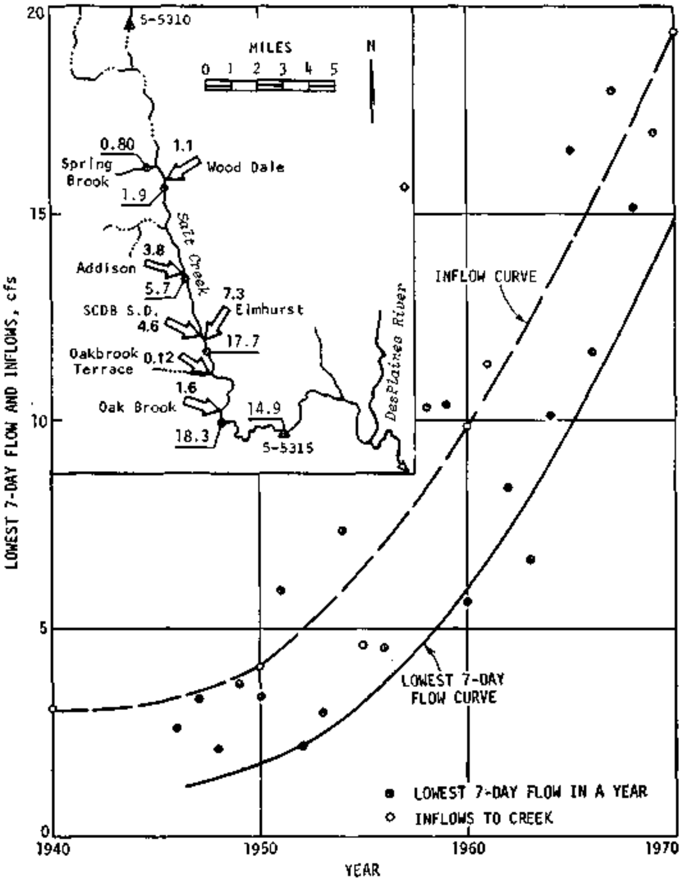

Figure 8. Lowest 7-day flows observed at gaging station 5-5315, Salt Creek at Western Springs, and inflows to stream from waste water plant effluents, 1940-1970; inset map shows location and amount of inflows to Salt Creek

14.9 cfs for the 1970 conditions of inflows to Salt Creek above the gaging station.

The inflows from waste water treatment plants to Salt Creek for four decade years are given in table 7 and reflect the rapid urbanization of the area. Since the total inflow in 1970 was 19.32 cfs, the loss in the stream channel amounts to 4.42 cfs [19.32 — 14.90]. It remains to be determined how this loss is distributed in various reaches.

Salt Creek basin, in general, is poorly drained. Most of the area is covered by moderately fine textured silty clay loam derived from glacial till as much as 200 feet thick which covers a dolomite aquifer. The soil is moderately slow to slowly permeable. Land use has been changing steadily from rural to urban with the increase in population. Most of the communities in the basin depend on wells for their water supplies. Water pumped from the ground is returned to the stream as waste water 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, does 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 groundwater recharge in the southern part of the basin. The entire reach of the Salt Creek south and east of Elmhurst can be regarded as an area of potential recharge to the shallow aquifers.

Table 7. Inflows from Waste Water Treatment Plants above Station 5-5315, Salt Creek at Western Springs

	Inflow *(cfs)*			
Source	1940	1950	1960	1970
Spring Brook (effluent flow from west)		0.03	0.42	0.80
Wood Dale			0.36	1.1
Addison	0.08	0.08	0.88	3.8
Salt Creek Drainage Basin Sanitary District	1.1	1.4	3.4	4.6
Elmhurst	1.9	2.6	4.8	7.3
Oakbrook Terrace				0.12
Oak Brook			0.09	1.6
Total	3.08	4.11	9.95	19.32

Favorable conditions for induced recharge exist in the general area near gaging station 5-5315 because of an extensive cone of depression caused by groundwater pumping. Induced recharge from the streambed reduces streamflow; this effect will be more pronounced at low flow than at high flow. From a study (Spieker, 1970) of seepage runs made by the U.S. Geological Survey in 1965 and 1966, the losses of streamflow from induced recharge were determined for the various reaches. These losses were used in determining the 7-day 10-year low flows upstream of the gaging station that are shown in figure 8.

Natural Lakes

An example showing the effect of natural lakes on 7-day 10-year low flow is for the upper part of the Fox River basin in Illinois (figure 9). The Fox River drains a total

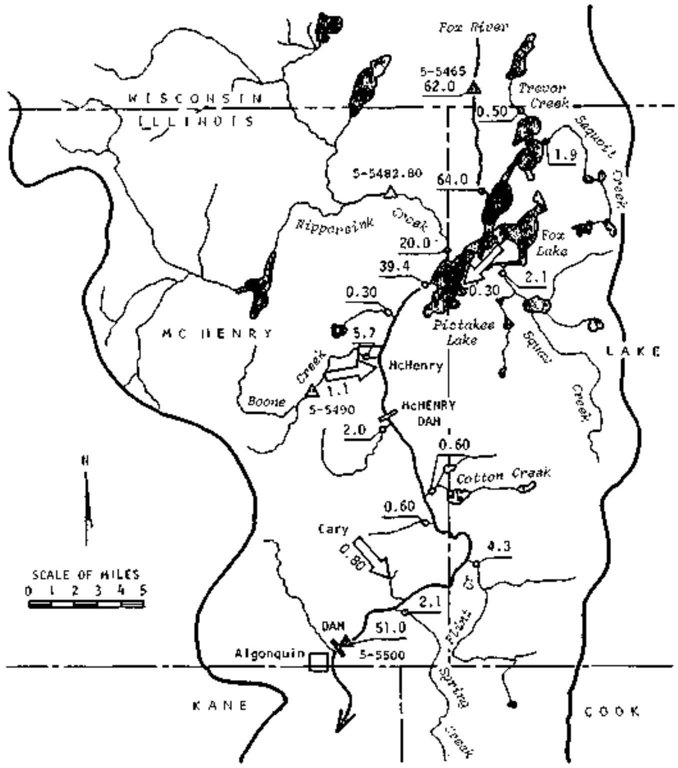

Figure 9. 7-day 10-year low flows in the upper Fox River basin

of 2580 square miles of which 1640 square miles lie in Illinois. The upper portion of this basin, from the state line to the city of Algonquin 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 square miles.

The principal lakes in the chain are: Pistakee, Nippersink, Fox, Petite, Grass, Marie, Channel, and Catherine. There are two dams in the area, McHenry and Algonquin Dams. McHenry Dam is 282 feet long and 6.5 feet high, with a crest elevation at 736.7 feet. It is gated and creates a pool extending upstream to the Pistakee Lake outlet. The surface area of the pool is 403 acres. Algonquin Dam is a broad-crested weir, 308 feet long and 9.0 feet high, with a crest elevation at 730.3 feet. The length of the pool is 16.34 miles extending upstream to McHenry Dam, and the pool has a surface area of 849 acres. Gates at the McHenry Dam are operated to maintain the water level in the Chain-of-Lakes for recreational purposes.

On the main river, at the upper and lower ends of the area, the USGS operates two gaging stations, one at Wilmot, Wisconsin, and the other at Algonquin, Illinois; the respective drainage areas at these stations are 880 and 1402 square miles. Nippersink Creek is the major tributary draining a total of 234 square miles. There is a gaging station near Spring Grove (drainage 193 sq mi), and another on Boone Creek near McHenry (drainage 15.3 sq mi).

The observed lowest 7-day flows at Wilmot for 1941-1969 show no trend and yield a 7-day 10-year value of 62.0 cfs. Low flows in this range occur during the months of July through October, but mostly in September. The 7-day 10-year low flow in the Fox River at Algonquin, adjusted for the 1970 condition of effluents from waste water treatment plants, is 51.0 cfs. Thus, the 7-day 10-year low flow decreases by 11.0 cfs from Wilmot to Algonquin, whereas the drainage area increases by 522 square miles. The various tributaries, groundwater accretion, and waste water effluents from Wilmot to Algonquin add 44.3 cfs of flow (table 8 and figure 10). Hence, the losses in the Fox Chain-of-Lakes and the two pools created by McHenry and Algonquin Dams are 62.0 + 44.3 - 51.0, or 55.3 cfs. Distribution of these losses will now be considered.

The following figures apply to evaporation from lake surfaces (Roberts and Stall, 1967) for the area under consideration during July to October.

Month	Lake evaporation (*inches*)	Lake evaporation (*cfs/sq mi*)
July	5.60	4.86
August	4.50	3.90
September	3.10	2.78
October	2.05	1.78

Table 8. Contributions from Tributaries and Effluents to Upper Fox River

Tributary	1970-condition 7-da 10-yr low flow (*cfs*)
Trevor Creek at Channel Lake outlet	0.5
Fox Lake (effluent)	0.3
Sequoit Creek	1.9
Squaw Creek	2.1
Nippersink Creek	20.0
Fox River (groundwater accretion)	2.0
Total at Pistakee Lake outlet	26.8
Unnamed Creek	0.3
Boone Creek	5.7
McHenry (effluent)	1.1
Unnamed Creek	2.0
Cotton Creek	0.6
Unnamed Creek	0.6
Flint Creek	4.3
Cary (effluent)	0.8
Spring Creek	2.1
Total to Algonquin	44.3

Lowest 7-day flows usually occur during September or late August. Thus, an evaporation loss of 3 cfs per square mile of lake surface can be applied. For the two pools created by Algonquin and McHenry Dams, the evaporation loss becomes 3.0 X [(403 + 849)/640], or 5.9 cfs. The 7-day 10-year low flow in the Fox River at the outlet of Pistakee Lake is

$$= 51.0 - [(44.3 - 26.8) - 5.9]$$
$$= 39.4 \text{ cfs}$$

Losses in the Fox Chain-of-Lakes are

$$= 62.0 + 26.8 - 39.4$$
$$= 49.4 \text{ cfs}$$

For a water surface area of 13 square miles, the loss amounts to 3.8 cfs per square mile. This figure is higher than the 3.0 cfs for the pool areas created by the in-channel

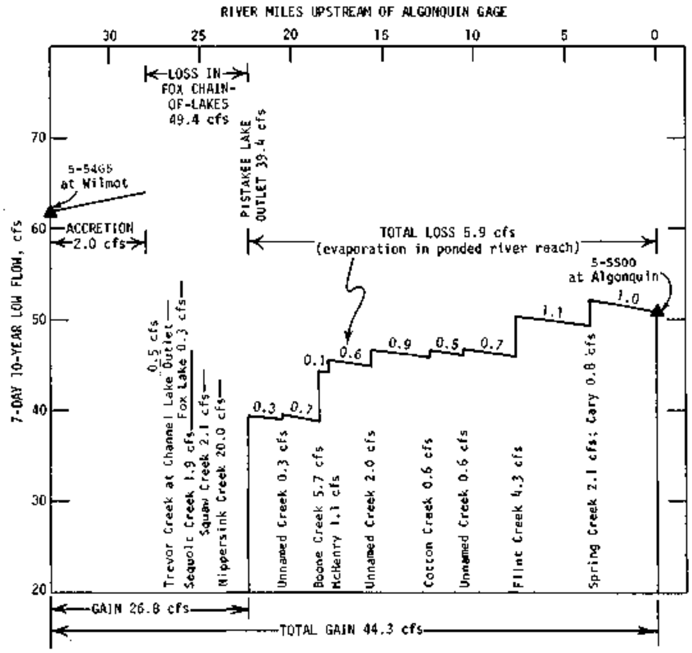

Figure 10. 7-day 10-year low flows in the upper Fox River showing losses and gains in the 35-mile reach from Wilmot, Wisconsin, to Algonquin, Illinois

dams because of more wind effects in the lake area and some inhibition of groundwater accretion. Low flow analyses from Algonquin to the mouth of the Fox River and the losses from the pools created by 10 in-channel dams downstream of Algonquin Dam indicate that the loss of 3.0 cfs per square mile of water surface from such pools is satisfactory.

As indicated by the values of 7-day 10-year low flows along the Fox River from Wilmot to Algonquin shown in figures 9 and 10, losses in large natural lakes used for recreation can reduce 7-day 10-year low flows very significantly.

Man-Made Lakes

Rivers and streams are dammed to impound water for various uses such as water supply for towns and industries, flood control, low flow augmentation, and recreation. In Illinois, small reservoirs and lakes have been designed primarily for a single purpose, municipal water supply. Examples are Lake Decatur, Lake Vermilion, Lake Charleston, and Lake Mattoon. During severe droughts the water supply from these reservoirs becomes critical and practically no water is allowed to flow through the sluices or openings. Thus the 7-day 10-year low flow downstream of dams at such lakes would be zero. The streams flowing into these lakes have natural 7-day 10-year low flows equal or close to zero except in the case of the Sangamon River near Decatur. There are other small water impoundments for which the low flow of the inflowing stream may not be zero, but it may be small enough to be absorbed by evaporation from the lake surface, so that the 7-day 10-year low flow downstream of the impounding structure is zero.

The state has three large multipurpose reservoirs — Lake Shelbyville, Carlyle Lake, and Rend Lake. The first two are on the Kaskaskia River and the third is on the Big Muddy River. As designed and constructed by the U.S. Army Corps of Engineers, these lakes provide minimum releases that can be taken as the 7-day 10-year low flows at their outlets. These minimum releases can be compared with the 7-day 10-year low flows that would have existed if these lakes had not been constructed, as follows:

	Present 7-da 10-yr low flow (*cfs*)	7-da 10-yr low flow without lakes (*cfs*)
Shelbyville	10	0.9
Carlyle	50	20.1
Rend	30	0.2

Some towns such as Breese in Clinton County and Pontiac in Livingston County pump water from in-stream impoundments. Breese pumps 0.40 cfs from Shoal Creek during low flow conditions, reducing the 7-day 10-year low flow from 0.60 to 0.20 cfs at gaging station 5-5940. The effluent from its waste water treatment plant is discharged to an intermittent tributary, and thus is lost to Shoal Creek under 7-day 10-year low flow conditions. Pontiac pumps 1.8 cfs from the Vermilion River, reducing the 7-day 10-year low flow at gaging station 5-5545 to 0.20 cfs. However, the effluent from the Pontiac waste water plant enters the river a little distance downstream of the gage and therefore does not affect the low flows farther downstream.

Use of large quantities of river water and its return later to the river in the form of effluents from the waste water plant does involve some loss during dry weather conditions. The loss is attributed to such things as consumptive water use, watering of lawns, or leakage from sewer systems. For the city of Peoria using Illinois River water, the net loss to 7-day 10-year low flow in the river is estimated at 3.9 cfs.

LOW FLOWS IN THE ILLINOIS WATERWAY

MSDGC Waterways

The Metropolitan Sanitary District of Greater Chicago's three major sewage treatment works and the combined storm-sanitary sewers discharge to a system of waterways that are tributary to the Des Plaines River. Lock and dam facilities prevent the backflow of these contaminated waters into Lake Michigan during high flows that occur during heavy rains. The dam at Lockport at the downstream end of this waterway system is so operated as to lower the water level in the waterways, thus providing greater water surface slope to increase the conveyance capacity in the system. A few bypasses in the lower reach of the system help in diverting part of the flood flows to the Des Plaines River and other streams. The MSDGC waterways are shown in figure 11 together with the locations of diversions from Lake Michigan.

The MSDGC waterways serve a dual purpose. They provide open drainage for effluents from sewage treatment works 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 which requires wide and deep waterways. Diversions from Lake Michigan are restricted to a 1500-cfs average over the year, but much more water is diverted in summer than in winter because greater dilution is needed in summer to maintain certain minimum dissolved oxygen levels in the waterways. With limited flow during low flow conditions the water surface has a very small slope. The velocities during 7-day 10-year low conditions may range from a minimum of less than 0.1 to a maximum of 0.7 foot per second in these waterways.

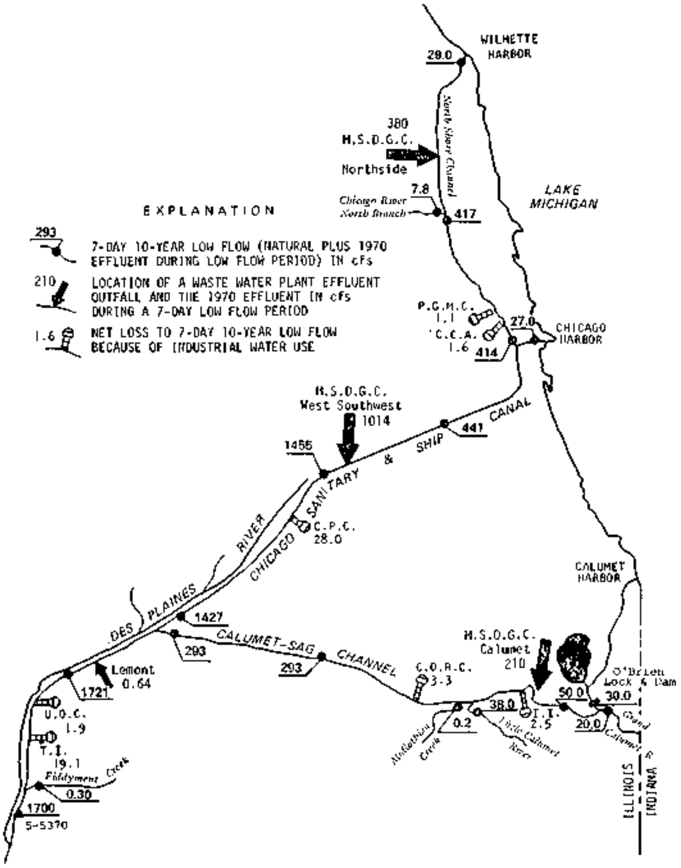

Figure 11. 7-day 10-year low flows for principal waterways of the Metropolitan Sanitary District of Greater Chicago

The three major MSDGG sewage treatment works (STW) are the Northside, West Southwest, and Calumet. Northside STW 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 of Damen Avenue to Lockport, it is named the Chicago Sanitary and Ship Canal. The largest MSDGC sewage treatment works, 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 effluent from the Calumet STW, the third major MSDGC sewage treatment works. 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.

An analysis of daily diversions from Lake Michigan to the North Shore Channel at Sheridan Road, to the Chicago River at Outer Drive, and to the Calumet River at O'Brien Lock and Dam, as obtained from the MSDGC office for the period May 1968 to March 1972, yielded the lowest 7-day diversions that are shown in table 9.

Table 9. Minimum 7-Day Diversions from Lake Michigan

(Amounts in cubic feet per second)

Month	North Shore Channel	Chicago River	Calumet	Total
March	31.0	26.3	29.4	86.7
January	21.3	27.3	33.0	81.6
March	38.0	25.1	26.5	89.6
December	29.4	32.9	27.9	90.2
February	26.0	22.4	35.3	83.7
Average	29	27	30	86

Thus, the diversions from Lake Michigan during low flow months, which are January and March for the Chicago Sanitary and Ship Canal at Lockport, may be taken as 29, 27, and 30 cfs at Wilmette, Chicago Harbor, and O'Brien Lock and Dam, respectively. The 7-day 10-year low flow at Lockport, gaging station 5-5370, is estimated at 1700 cfs from the daily flow data for the years 1939-1970.

Rivers and creeks entering the Chicago Sanitary and Ship Canal and the Calumet-Sag Channel add flows amounting to ~ 152 cfs to the 7-day 10-year low flows in these waterways (table 10). The balance of 1548 cfs [1700 — 152] is made up by the effluents from the MSDGC sewage treatment works and a number of industrial plants.

Visits were made to the Environmental Protection Agency office in Springfield to collect data on the use of water by industries along the Chicago Sanitary and Ship Canal, Calumet-Sag Channel, and Des Plaines River including any addition to flows by industries using groundwater but discharging effluents to the waterways, and any loss to flow by industries using water from these waterways and either not discharging it back or discharging a smaller amount because of consumptive use in plant processing or cooling. Many industries were contacted by telephone to gather the required information or to verify the available information regarding their use of water. Additions to flow from groundwater in this area were small, and such small

Table 10. Balance of Gains and Losses to 7-Day 10-Year Low Flows in MSDGC Waterways

Flow Additions

	Gain (cfs)
North Branch Chicago River	7.8
Grand Calumet River	20.0
Little Calumet River	38.0
Midlothian Creek	0.2
Fiddyment Creek	0.3
Total	66.3
Diversions from Lake Michigan	86.0
Total	152.3

Losses to Industrial Use

	Loss (cfs)
Proctor and Gamble Mfg. Co. (P.G.M.C.)	1.1
Container Corp. of America (C.C.A.)	1.6
Corn Products Co. (C.P.C.)	28.0
Interlake Inc. (I.I.)	2.5
Clark Oil and Refining Corp. (C.O.R.C.)	3.3
Union Oil Co. (U.O.C.)	1.9
Texaco Inc. (T.I.)	19.1
Total	57.5

Balance of Flows

	(cfs)
Flow from tributary streams including lake diversions	152
Effluent from MSDGC Northside STW	380
Effluent from MSDGC West Southwest STW	1014
Effluent from MSDGC Calumet STW	210
Miscellaneous	1
Total	1757
Less water loss from industrial use	57
7-day 10-year low flow at Lockport	1700

additions or losses to flow (less than 1 cfs) were neglected because of the high order of flows in the waterways. The information on industrial use of water (December to March) in MSDGC waterways to Lockport is given in table 10. This excludes the Calumet River from Calumet Harbor to O'Brien Lock and Dam because this reach is directly connected to Lake Michigan and its flows are controlled by the dam.

A balance of flows in the MSDGC waterways, also shown in table 10, yields a 7-day 10-year low flow of 1700 cfs in the Chicago Sanitary and Ship Canal at Lockport. The 7-day 10-year low flows in the MSDGC waterways up to the junction with the Des Plaines River are shown on figure 11.

Illinois River

Flow in the Illinois River is regulated through a series of locks and dams for navigation purposes. Figure 12 shows the bed profile, the longitudinal water surface profile during low flows, the five locks and dams near Dresden, Marseilles, Starved Rock, Peoria, and La Grange and the five pools they create, and the three USGS gaging stations. The five pools have very little surface slope during 7-day 10-year low flow conditions. The gaging stations and their 7-day 10-year low flows are: station 5-5435, Illinois River at Marseilles, 3240 cfs; station 5-5685, Illinois River at Kingston Mines, 3000 cfs; and station 5-5855, Illinois River at Meredosia, 3500 cfs.

The 7-day 10-year low flow at the beginning of the Illinois River at the confluence of Des Plaines and Kankakee Rivers has been estimated at 3181 cfs from a study of concurrent flows at the following gaging stations:

5-5275 — Kankakee River near Wilmington
5-5325 — Des Plaines River at Riverside
5-5370 — Chicago Sanitary and Ship Canal
5-5390 — Hickory Creek at Joliet
5-5405 — Du Page River at Shorewood
5-5420 — Mazon River near Coal City
5-5435 — Illinois River at Marseilles

The groundwater accretion to flow during 7-day 10-year low flow conditions in the reach above Marseilles is estimated at 2.25 cfs per mile on the basis of balancing the inflows from the tributaries and the flows in the Illinois River.

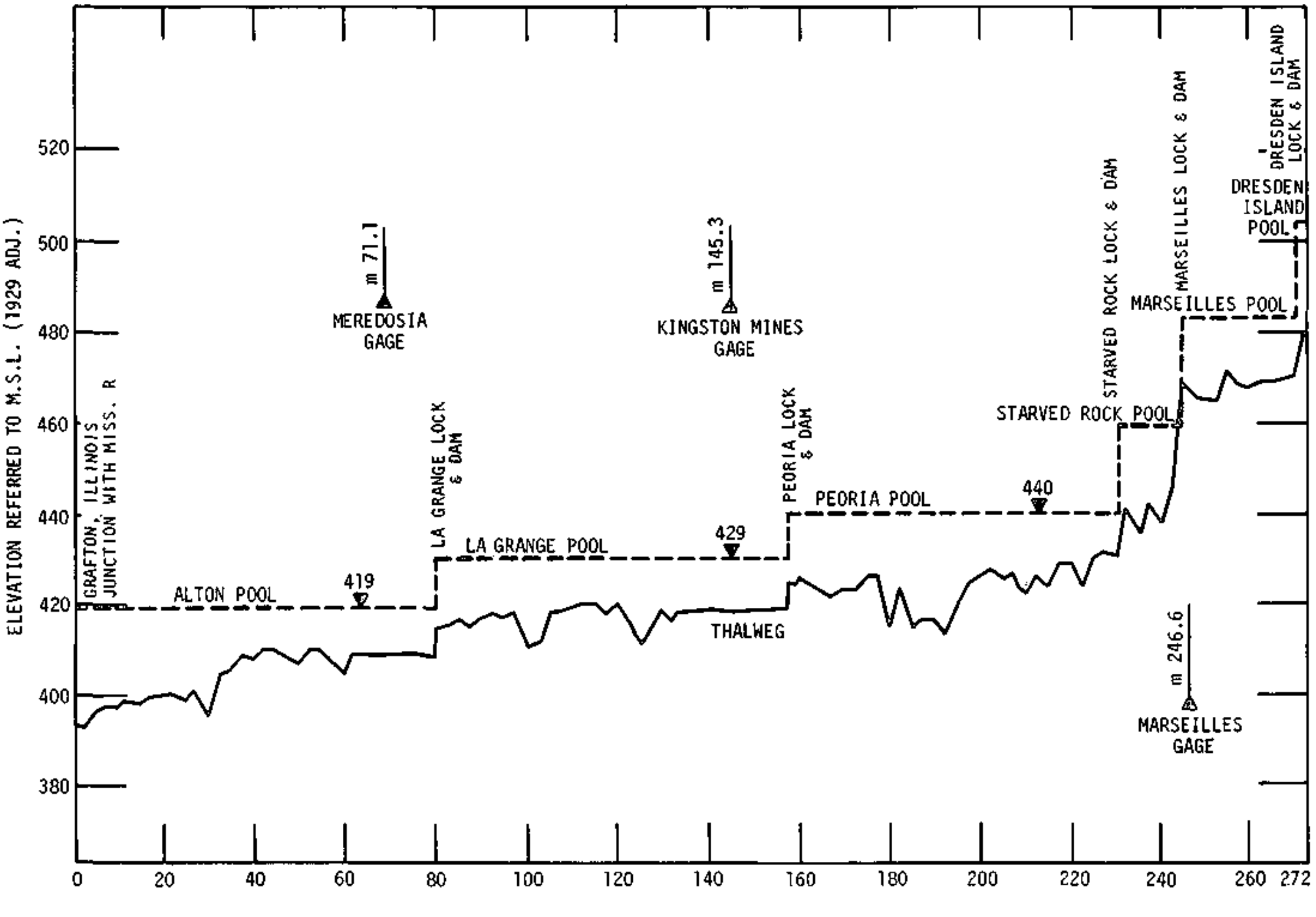

Figure 12. Bed profile and water surface elevations in the various pools of the Illinois River

Between the gaging stations at Marseilles and Kingston Mines, river mile 246.6 to 145.3, the main tributaries are the Fox and Vermilion Rivers, Big Bureau Creek, and the Mackinaw River. The low flows in the range of the 7-day 10-year low flow at Kingston Mines occur during August through October or in January, compared with October or January at Marseilles. The addition of August and September to the low flow period at Kingston Mines underscores the reduction of the impact of low flows from the Chicago Sanitary and Ship Canal, which occur mostly in January or March. A brief balance of flows between Marseilles and Kingston Mines is given in table 11.

Loss of 698 cfs in 7-day 10-year low flow in the river reach between Marseilles and Kingston Mines is attributed to evaporation losses from river, lake, and backwater areas, and to regulation of water levels for navigation. Modification of low flow because of these two factors depends on the extent of water surface area. These areas were calculated from USGS quadrangle maps and maps of Illinois River backwater areas (Department of Public Works and Buildings, 1969). The total water surface area during low flow conditions from mile 246.6 to mile 145.3 of the Illinois River was calculated at 40,257 acres, yielding a loss to 7-day 10-year low flow of 0.0173 cfs per acre or 11.1 cfs per square mile. The loss will vary from mile to mile depending on the additional water surface area.

The 7-day 10-year low flow increases from 3000 cfs at Kingston Mines, mile 145.3, to 3500 cfs at Meredosia, mile 71.1. Low flows in the range of the 7-day 10-year low flow occur during September through October or in January at Meredosia, and therefore are concurrent with the low flow periods at Kingston Mines. The main tributaries between the two stations are Quiver Creek and the Spoon, Sangamon, and La Moine Rivers, which together contribute 399 cfs to the 7-day 10-year low flow in this reach as listed in table 11.

An area covered by Wisconsinan sand deposits lies along this reach, and is a source of considerable groundwater recharge (Walker et al., 1965) to the river from mile 145.3 to 89.0, though the recharge per mile varies depending on the extent of Wisconsinan deposits in the Havana Lowland portion. The accretion to river flow during 7-day 10-year low flow conditions is estimated at 0.6 cfs per square mile of the Havana Lowland area, and 0.5 cfs per square mile of the other permeable low-lying areas. The total accretion from groundwater to flow in the Illinois River is 309 cfs.

Table 11. Gains and Losses to 7-Day 10-Year Low Flows in Illinois River, Marseilles to Meredosia

Marseilles to Kingston Mines

	(cfs)
7-day 10-year low flow at Marseilles	3240
Net 1970 effluent flow	18
Fox River	330
Vermilion River	11
Illinois and Mississippi Canal	25
Big Bureau Creek	19
Mackinaw River	50
Other tributaries	5
Total	3698
7-day 10-year low flow at Kingston Mines	3000
Evaporation-regulation loss	698

Kingston Mines to Meredosia

7-day 10-year low flow at Kingston Mines	3000
Quiver Creek	14
Spoon River	39
Sangamon River	324
La Moine River	22
Minor tributaries and effluents	2
Flow accretion from lowland area	309
Total	3710
7-day 10-year low flow at Meredosia	3500
Evaporation-regulation loss	210

The water surface area of the river, lakes, and backwater areas under low flow conditions from Kingston Mines to Meredosia is 22,016 acres. Therefore, the loss in this reach because of evaporation and regulation is 0.0095 cfs per acre, or 6.1 cfs per square mile.

From Meredosia to the mouth of the Illinois River, the permeable lowland area is estimated to yield a flow of 99 cfs to the river during low flow conditions. Flow additions from Mauvaise Terre and Macoupin Creeks and from waste water treatment plants add another 10 cfs to the river low flow. Many of the lakes, for example Stump and Gilbert Lakes, have no direct connection with the Illinois River during low flow conditions. A loss of 9 cfs is allowed for Swan Lake. This brings the 7-day 10-year low flow at the mouth of the Illinois River to 3600 cfs [3500 + 99 + 10 — 9]. The water level in the Alton pool extending from mile 80.2 to the mouth of the river is governed by the operation of the Lock and Dam at Alton, on the Mississippi River.

The 7-day 10-year low flows at various river miles along the Illinois River are given in table 12 together with a description of each location.

Table 12. 7-Day 10-Year Low Flows in Illinois River

River mile	7-da 10-yr low flow *(cfs)*	Location
271.5	3181	Dresden Island Lock and Dam
268.3	3188	Downstream of Aux Sable Creek
263.2	3201	Downstream of Mazon River
258.0	3214	0.6 mi downstream of Grist Island Light
252.0	3228	0.2 mi upstream of Spring Brook Light
246.6	3240	Marseilles gaging station
242.0	3235	0.5 mi upstream of Bulls Island Bend Light
240.0	3232	0.2 mi downstream of Scherer Island
239.0	3563	0.7 mi downstream of Fox River
235.0	3557	0.5 mi upstream of Delbridge Island Head Light
231.0	3533	Starved Rock Lock and Dam
226.0	3525	0.5 mi upstream of Vermilion River
225.0	3535	0.5 mi downstream of Vermilion River
220.4	3533	La Salle/Bureau/Putnam County line

Table 12 (Continued)

River mile	7-da 10-yr low flow (cfs)	Location
215.0	3525	Marquette Bar Light
211.0	3519	0.2 mi upstream of DePue Lake outlet
210.2	3504	Upstream of Illinois and Mississippi Canal
207.0	3543	Downstream of Big Bureau Creek
204.0	3539	2 mi downstream of Bureau/Putnam County line (west)
201.0	3533	Willow Point Light and Day Mark
199.5	3525	0.2 mi upstream of Putnam/Marshall County line
197.5	3424	Senachwine Lake
195.5	3409	Putnam/Marshall County line (east)
193.0	3403	Upstream of Billsbach Lake outlet
190.0	3378	Billsbach Lake
187.0	3349	Goose Lake
182.5	3287	Marshall County conservation area
181.0	3284	Marshall/Woodford County line
167.8	2998	Upper Peoria Lake, Woodford/Tazewell County line
162.3	2964	End of Peoria Lake
157.7	2961	Peoria Lock and Dam
153.0	2955	Peoria and Pekin Union Railroad Bridge
148.0	2954	0.3 mi upstream of Mackinaw River
145.3	3000	Kingston Mines gaging station
139.6	3016	Peoria/Fulton County line
136.5	3030	Downstream of Copperas Creek
133.3	3044	Tazewell/Mason County line
130.0	3029	Downstream of Clear Lake
125.0	3055	1 mi downstream of Big Sister Creek
121.0	3085	0.5 mi upstream of Spoon River
120.0	3125	0.5 mi downstream of Spoon River
115.0	3141	Upstream of Mantanzas Lake outlet
113.5	3150	Upstream of Bath Chute
106.5	3157	0.1 mi downstream of Bath Chute
103.0	3141	0.2 mi upstream of Elm Creek
99.0	3132	0.2 mi upstream of Elm Island
95.0	3130	0.6 mi upstream of Sugar Creek
90.0	3128	1 mi upstream of Sangamon River
87.0	3441	2 mi downstream of Sangamon River
84.0	3449	0.2 mi upstream of La Moine River
83.0	3475	0.8 mi downstream of La Moine River
80.0	3485	0.2 mi downstream of La Grange Lock and Dam
74.8	3502	Cass/Morgan County line
71.1	3500	Meredosia gaging station
68.0	3512	Morgan/Scott County line
66.6	3516	At McGee Creek
63.2	3524	Upstream of Mauvaise Terre Creek
61.4	3529	At Flint Creek
58.1	3534	At Big Blue Creek
54.0	3541	At Little Blue Creek
50.0	3546	At Sandy Creek
47.9	3549	Scott/Greene County line
43.1	3557	At Hurricane Creek
38.8	3563	Pike/Calhoun County line
34.6	3571	At Woods Creek
30.6	3577	0.3 mi downstream of Crawford Creek
25.7	3583	End of Hurricane Island
22.9	3591	0.3 mi downstream of Macoupin Creek
19.5	3595	Beginning of Mortland Island
14.0	3601	Beginning of Twelve Mile Island
9.6	3602	0.3 mi upstream of Day Mark and Blooms Landing Light
5.2	3599	0.4 mi downstream of Cherokee Light Bend
0	3600	Junction with Mississippi River

LOW FLOWS IN BORDER RIVERS

The Wabash, Ohio, and Mississippi Rivers bordering Illinois originate far away, and drain areas in two or more other states. In the river reaches bordering Illinois, they receive tributary rivers from Indiana, Kentucky, Tennessee, Iowa, and Missouri. The 7-day 10-year low flows in these rivers are discussed here for the Wabash, Ohio, and Mississippi Rivers, in that order.

Wabash River

The Wabash River originates in Mercer County, Ohio, about 15 miles east of the Indiana-Ohio state line. The river drains a total of 33,100 square miles. The largest tributary is the White River in Indiana, draining an area of 11,402 square miles. The major tributaries from Illinois are the Vermilion, Embarras, and Little Wabash Rivers. The 7-day 10-year low flows in the Wabash River at the USGS gaging stations, as obtained from an analysis of available daily flow data, are given in table 13.

Tributaries between the Covington and Montezuma gaging stations are the Vermilion River, Coal Creek, Little Vermilion River, Sugar Mill Creek, and Sugar Creek with drainage areas at their mouth of 1520, 264, 242, 76, and 811 square miles, respectively, which practically account for the increase in drainage area from Covington to Montezuma. From the multistation computer program, the flows from these tributaries to the Wabash River during 7-day 10-year low flow conditions (usually in September) are 70.0, 8.0, 0.4, 1.6, and 34.0 cfs, respectively, making a total of 114 cfs. The difference of 49 cfs [886 — 723 — 114] is distributed along the river from Covington to Montezuma gages, that is, over 31.1 miles from miles 271.1 to 240.0.

Practically all the drainage area between the gages at Montezuma and Terre Haute is supplied by Big Raccoon and Brouilletts Creeks, which add 38 and 2 cfs respectively to the 7-day 10-year low flow in the river. Thus there is a

Table 13. 7-Day 10-Year Low Flows at USGS Gaging Stations on the Wabash River

USGS number	Station	River mile	Drainage area (sq mi)	7-da 10-yr low flow (cfs)
3-3360	Wabash River at Covington, Indiana	271.1	8,208	723
3-3405	Wabash River at Montezuma, Indiana	240.0	11,100	886
3-3415	Wabash River at Terre Haute, Indiana	214.4	12,200	1008
3-3420	Wabash River at Riverton, Indiana	162.0	13,100	1249
3-3430	Wabash River at Vincennes, Indiana	129.8	13,700	1326
3-3775	Wabash River at Mt. Carmel, Illinois	94.5	28,600	2490
3-3785	Wabash River at New Harmony, Indiana	51.5	29,160	2620

groundwater accretion of 82 cfs [1008 — 886 — 40] in this 25.6-mile reach of the river.

From Terre Haute to Riverton, the tributaries are Sugar, Big, and Mill Creeks with 94, 107, and 120 square miles of drainage area, respectively. These tributaries do not add any flow to the Wabash River during 7-day 10-year low flow conditions. Therefore, the 241 cfs increase in 7-day 10-year low flow is distributed along the river reach of 52.4 miles. In the next reach, Riverton to Vincennes, the only major tributary is Sugar Creek which adds 3.2 cfs to the 7-day 10-year low flow in the river. In this reach of 32.2 miles, the flow accretion from groundwater is 2.3 cfs per mile [(1326 - 1249 - 3.2)/32.2].

The three major tributaries to the Wabash River from Vincennes to Mt. Carmel add 1046 cfs to the 7-day 10-year low flow of the river as follows: Embarras River (drainage 2438 sq mi), 45 cfs; White River (drainage 11,402 sq mi), 994 cfs; and Patoka River (drainage 862 sq mi), 7 cfs.

There is only 1 chance in 3 that low flows in the range of the 7-day 10-year low flow will occur near the same time in the Wabash River at Vincennes and at Mt. Carmel. The reason is the large flow from the White River; its drainage area combined with that of the Embarras River is practically of the same order as that of the Wabash River. The 7-day 10-year low flow in the White River at its mouth is estimated at 790 cfs, but its addition to the 7-day 10-year low flow in the Wabash River is 994 cfs because of the usual nonconcurrency of low flows. The groundwater accretion to flow along the river reach of 35.3 miles is 118 cfs [2490 - 1326 - 1046].

From Mt. Carmel to New Harmony, a distance of 43 miles along the Wabash River, the drainage area increases by 560 square miles, about half of which is contributed by Bonpas Creek. However, it does not add any flow to the river during the 7-day 10-year low flow conditions. The difference in 7-day 10-year low flows between New Harmony and Mt. Carmel gages, that is, 130 cfs, is provided by groundwater accretion along the river reach of 43 miles. This means an increase of 3.03 cfs per mile of river length.

In the last reach of the river from New Harmony to the confluence with the Ohio River, the major tributary is the Little Wabash River draining an area of 3209 square miles and adding 9.0 cfs to the 7-day 10-year low flow in the Wabash River. The present river length is 43.5 miles as measured from USGS topographic maps; this reach was shortened from the 51.5 miles shown in table 13 by construction of a new channel which cut off one large meander.

The accretion rate along the Wabash River increases from Covington to Terre Haute, but then decreases probably because of changed hydrogeologic conditions as indicated by comparatively lower 7-day 10-year low flows in the tributary rivers. From New Harmony to the mouth of the Wabash River, the major tributary (Little Wabash River) has a much lower 7-day 10-year low flow than either the Embarras or Vermilion River. The accretion rate in this 43.5 mile reach can be expected to be lower than that in the previous reach, and is taken as 2.5 cfs per mile. The 7-day 10-year low flow at the mouth of the Wabash River is 2738 cfs [2620 + 9 + 43.5(2.5)].

Ohio River

The Allegheny and Monongahela Rivers collecting runoff from the western slopes of the Appalachian Mountains merge together at Pittsburgh, Pennsylvania, to form the Ohio River. From its source the Ohio winds a meandering course southwest for 981 miles to join the Mississippi River at Cairo, Illinois. Over the years the river has been canalized throughout its entire course. The successive construction of 46 locks and dams has converted the river into a series of elongated pools with a minimum channel depth of 9 feet (Cleary, 1967). From Pittsburgh to Cairo, the boats are lowered by 430 feet over the entire length.

The portion of the Ohio River pertinent to this 7-day 10-year low flow study for Illinois streams extends from the confluence with the Wabash River to where it meets the Mississippi River, that is, mile 848 to 981. There are four locks and dams — 50, 51, 52, and 53 at river mile 876.8, 903.1, 938.9, and 962.6, respectively. The 7-day 10-year low flows in the Ohio River at the USGS stations, as obtained from an analysis of available daily flow data, are given in table 14.

The 7-day 10-year low flows occur during the months of September and October at both Evansville and Golconda, and their periods of occurrence are practically concurrent. Major tributaries are the Wabash, Saline, and Tradewater Rivers, draining 33,100, 1130, and 970 square miles and adding 2850, 5, and 5 cfs, respectively, to the 7-day 10-year low flows in the Ohio River. The area draining directly and through small tributaries into the Ohio River is 1700 square miles [143,900 - (107,000 + 33,100 + 1130 + 970)]. The 7-day 10-year low flow generated along the river equals 1040 cfs [12,610 - (8710 + 2850 + 5 + 5)] over a length of 110.8 miles. This yields an accretion rate of 9.4 cfs per mile. The values of 7-day 10-year low flow were calculated and are shown on the low flow maps starting from Lock and Dam 49 at mile 845.

In the river reach from Golconda to Metropolis, mile 903.1 to 944.0, the two major rivers that add a large amount of flow to the 7-day 10-year low flow in the Ohio River are the Cumberland and Tennessee Rivers. Their drainage areas are 17,850 and 40,330 square miles, and

Table 14. 7-Day 10-Year Low Flows and Average Flows for the Ohio and Tennessee Rivers

USGS number	Station	Drainage area *(sq mi)*	7-da 10-yr low flow *(cfs)*	Average flow *(cfs)*
3-3220	Ohio River at Evansville, Ind. (mi 799.3)	107,000	8,710	133,000
3-3845	Ohio River at Golconda, Ill. (mi 903.1)	143,900	12,610	181,000
3-6095	Tennessee River near Paducah, Ky.	40,200	27,640	64,000
3-6115	Ohio River at Metropolis, Ill. (mi 944.0) (includes Tennessee River)	203,000	44,820	258,000

their flow additions as derived from the multistation computer program are 3200 and 28,580 cfs, respectively. A smaller tributary, Clarks River, drains an area of 480 square miles and adds 20 cfs to the low flow in the river. The area accounted for by small tributaries and direct drainage is 440 square miles [203,000 - (143,900 + 17,850 + 40,330 + 480)]. The contribution to 7-day 10-year low flow by flow accretion along the river is 410 cfs [44,820 — (12,610 + 3200 + 28,580 + 20)]. This means an accretion of 10 cfs per mile, a little more than the 9.4 cfs per mile in the previous reach. It is interesting to note that the flow in the Tennessee River is now almost completely regulated. A comparison (table 14) of 7-day 10-year low flow with the average discharge at some gaging stations emphasizes this point.

From Metropolis to Cairo at its confluence with the Mississippi River, a distance of 37 miles, there is no major or medium tributary except the Cache River, which together with small effluent flows from towns contributes only 2 or 3 cfs to the 7-day 10-year low flow in the Ohio River. Therefore, an accretion rate of 10 cfs per mile, as in the reach from Golconda to Metropolis, was adopted for the last reach. The 7-day 10-year low flow in the Ohio River just upstream of the junction with the Mississippi River is 45,190 cfs [44,820 + (37 X 10)].

Mississippi River

The Mississippi River originates at Lake Itasca in central Minnesota and flows southerly toward the Gulf of Mexico. The river length bordering Illinois stretches from mile 580.7 at the Wisconsin-Illinois line to mile zero at the confluence with the Ohio River. The creation of the 9-foot navigation channel in the Upper Mississippi River has converted the river above St. Louis into essentially a series of pools during periods of low and normal flows. To evaluate the 7-day 10-year low flows along the river, the daily flow data at the USGS gaging stations (table 15) on the Mississippi River were run on the low flow program.

The increments to the 7-day 10-year low flow in the Mississippi River from the tributary rivers and streams were derived by applying the multistation computer program to river reaches between two successive gaging stations as listed in table 15. Table 16 lists the tributary rivers, their drainage areas, the river mileage where they meet the Mississippi, their 7-day 10-year low flows, and their flow additions to the Mississippi River flow during its 7-day 10-year low flow condition. Brief descriptions of low flows for river reaches between the gaging stations on the Mississippi River follow.

Table 15. 7-Day 10-Year Low Flows at USGS Gaging Stations on the Mississippi River

USGS number	Station	River mile	Drainage area (sq mi)	7-da 10-yr low flow (cfs)
5-3895	Mississippi River at McGregor, Iowa	633.4	67,500	9,276
5-4205	Mississippi River at Clinton, Iowa	511.8	85,600	13,970
5-4745	Mississippi River at Keokuk, Iowa	364.2	119,000	15,170
5-5875	Mississippi River at Alton, Illinois	202.7	171,500	21,470
7-0100	Mississippi River at St. Louis, Missouri	180.0	701,000	45,970
7-0205	Mississippi River at Chester, Illinois	109.9	712,600	46,840
7-0220	Mississippi River at Thebes, Illinois	43.7	717,200	47,810
7-0320	Mississippi River at Memphis, Tennessee		932,800	110,000

Table 16. Tributary Rivers to the Mississippi River from McGregor, Iowa, to Thebes, Illinois

Tributary	Drainage area (sq mi)	Miss. R. mile	7-da 10-yr low flow (cfs)	Flow addition to Miss. R. low flow (cfs)
McGregor to Clinton, Iowa				
Wisconsin River, Wis.	11,705	630.7	3,000	3,500
Turkey River, Iowa	1,696	608.0	100	113
Grant River, Wis.	320	593.0	44	66
Platte River, Wis.	340	588.5	54	81
Little Maquoketa River, Iowa	136	586.5	7	14
Menominee River, Ill.	31	574.4	3.8	5
Little Menominee River, Ill.	15	570.6	2	3
Sinsinawa River, Ill.	48	568.8	5.5	7
Galena River, Ill.	208	564.9	18	33
Smallpox Creek, Ill.	32	563.0	4	6
Maquoketa River, Iowa	1,903	548.6	212	366
Apple River, Ill.	259	545.1	22	34
Rush Creek, Ill.	74	541.0	5	6
Plum River, Ill.	303	537.0	13	28
Johnson Creek, Ill.	24	522.0	2	3
Total	17,094		3,492.3	4,265
Clinton to Keokuk, Iowa				
Wapsipinicon River, Iowa	2,563	506.8	120	226
Rock River, Ill.	10,850	479.0	1,466	1,555
Iowa River, Iowa	12,640	433.6	805	902
Edwards River, Ill.	440	431.3	7	21
Pope Creek, Ill.	175	427.7	2	8
Henderson Creek, Ill.	595	409.9	9	15
Skunk River, Iowa	4,325	395.9	22	110
Total	31,588		2,431	2,837
Keokuk, Iowa, to Alton, Illinois				
Des Moines River, Iowa	14,540	361.3	130	390
Fox River, Mo.	502	353.5	1	1
Bear Creek, Ill.	380	341.0	0	0
Wyaconda River, Mo.	458	337.3	0	1
Fabius River, Mo.	1,570	323.4	2	4
North River, Mo.	379	321.1	0	2
Salt River, Mo.	2,920	284.0	3	8
Cuivre River, Mo.	1,230	238.2	1	3
Illinois River, Ill.	29,010	218.0	3,600	4,060
Total	50,989		3,737	4,469
Alton, Illinois, to St. Louis, Missouri				
Missouri River, Mo.	529,800	194.3	11,820	15,300
St. Louis, Missouri, to Chester, Illinois				
Meramec River, Mo.	3,980	160.7	300	550
Kaskaskia River, Ill.	5,840	118.1	147	296
Total	9,820		447	846
Chester to Thebes, Illinois				
Big Muddy River, Ill.	2,360	75.5	36	80

McGregor to Clinton, Iowa. The station at McGregor, Iowa, is 52.7 miles upstream from the Illinois-Wisconsin state line. The tributaries in the McGregor to Clinton reach drain an area of 17,094 square miles and add 4265 cfs of flow to the 7-day 10-year low flow in the Mississippi River. In this reach of 121.6 miles, there are three locks and dams— 11, 12, and 13 at mile 583.1, 556.7, and 522.6. The flows in the range of the 7-day 10-year low flow at McGregor occur during August through October or in January, whereas they occur during August through November or in February at Clinton. From the multistation computer program, the concurrent low flow at McGregor for the 7-day 10-year low flow condition at Clinton was estimated at 9700 cfs. Unexplained flow additions between McGregor and Clinton come to 5 cfs [13,970 - (9700 + 4265)]. This accretion is assumed to occur above the Wisconsin-Illinois state line. The 7-day 10-year low flow at this line was calculated as 13,477 cfs. The 7-day 10-year low flows along the Mississippi River downstream to Clinton, Iowa, are shown on the low flow maps.

Clinton to Keokuk, Iowa. In this river reach of 147.6 miles, from mile 511.8 to 364.2, there are six locks and dams—14, 15, 16, 17, 18, and 19 at mile 493.4, 482.9, 457.2, 437.1, 410.4, and 364.3 of the Mississippi River. The total area drained by the tributaries shown in table 16 is 31,588 square miles leaving 1812 square miles to lateral drainage and minor tributaries. There is a loss of 1637 cfs [13,970 + 2837 — 15,170] over this reach, or a loss of 11.1 cfs per mile. This loss is caused by such factors as flow regulation for navigation and evaporation.

Keokuk, Iowa, to Alton, Illinois. In the river reach from Keokuk to Alton, the drainage area increases by 52,500 square miles and the 7-day 10-year low flow by 6300 cfs. The drainage area supplied by the tributaries in table 16 is 50,989 square miles and the flow accretion is 4469 cfs. Thus, 1511 square miles are accounted for by lateral drainage and minor tributaries. The accretion to flow in this reach is 1831 cfs [21,470- (15,170 + 4469)] over 161.5 miles length, which yields an accretion rate of 11.3 cfs per mile. This reach lies in a rather drier area compared with the previous reach. The flow accretion, instead of loss as in the previous reach, is attributed to flow regulation combined with the timing and magnitude of tributary low flows. The 7-day 10-year low flows in the Mississippi River are shown on the low flow maps. There are six locks and dams—20, 21, 22, 24, 25, and 26 at river mile 343.2, 324.9, 301.2, 273.5, 241.5, and 202.9, respectively.

Alton, Illinois, to St. Louis, Missouri. This reach extends from mile 202.7 to 180.0, a distance of 22.7 miles. The last dam, No. 27, on the Mississippi River is located at mile 190.3 in this reach. The dominant tributary is the Missouri River draining an area of 529,800 square miles. The 7-day 10-year low flow at its mouth is 11,820 cfs and this usually occurs in December or January. The 7-day 10-year low flow at Alton occurs mostly in October, whereas it occurs in January at St. Louis, 14.3 miles downstream of the confluence with the Missouri River. The shift in the low flow timing in the Mississippi River is caused by the Missouri River low flow, which is of the same order as that for the Mississippi upstream of the confluence but occurs two or three months later. The concurrent low flows under the 7-day 10-year low flow conditions at the confluence are 30,540 and 15,300 cfs for the Mississippi and Missouri Rivers, respectively. Granite City Steel takes 100 cfs from the Chain of Rocks Canal. Therefore the accretion of flow along the reach equals 230 cfs [45,970 - (30,540 + 15,300 — 100)] distributed over 14.3 miles. Lateral drainage and minor tributaries contribute 700 square miles to the drainage area.

St. Louis, Missouri, to Chester, Illinois. The Mississippi River flows for a length of 70.1 miles in this reach, gaining a drainage area of 11,600 square miles out of which 9820 square miles is contributed by the Meramec and Kaskaskia Rivers. A total of 870 cfs is added to the 7-day 10-year low flow. The Meramec and Kaskaskia Rivers together contribute 846 cfs and the waste water effluents from St. Louis and industries from mile 180 to 170 discharge about 122 cfs. The loss in this river reach amounts to 98 cfs, or 1.4 cfs per mile.

Chester to Thebes, Illinois. The Big Muddy River joins the Mississippi River at mile 75.5, and adds 80 cfs to its 7-day 10-year low flow. The area covered by lateral drainage and minor tributaries is 2240 square miles. Flow of 890 cfs [47,810 - 46,840 - 80] is distributed over this reach of 66.2 miles, giving an accretion rate of 13.4 cfs per mile.

Thebes, Illinois, to Confluence with Ohio River. There are only minor tributaries in this reach of 43.7 miles. The hydrologic conditions in this reach are similar to those in the reach from Chester to Thebes. A flow accretion of 13.4 cfs per mile was adopted, giving a 7-day 10-year low flow of 48,390 cfs ½ mile upstream of the confluence with the Ohio River.

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