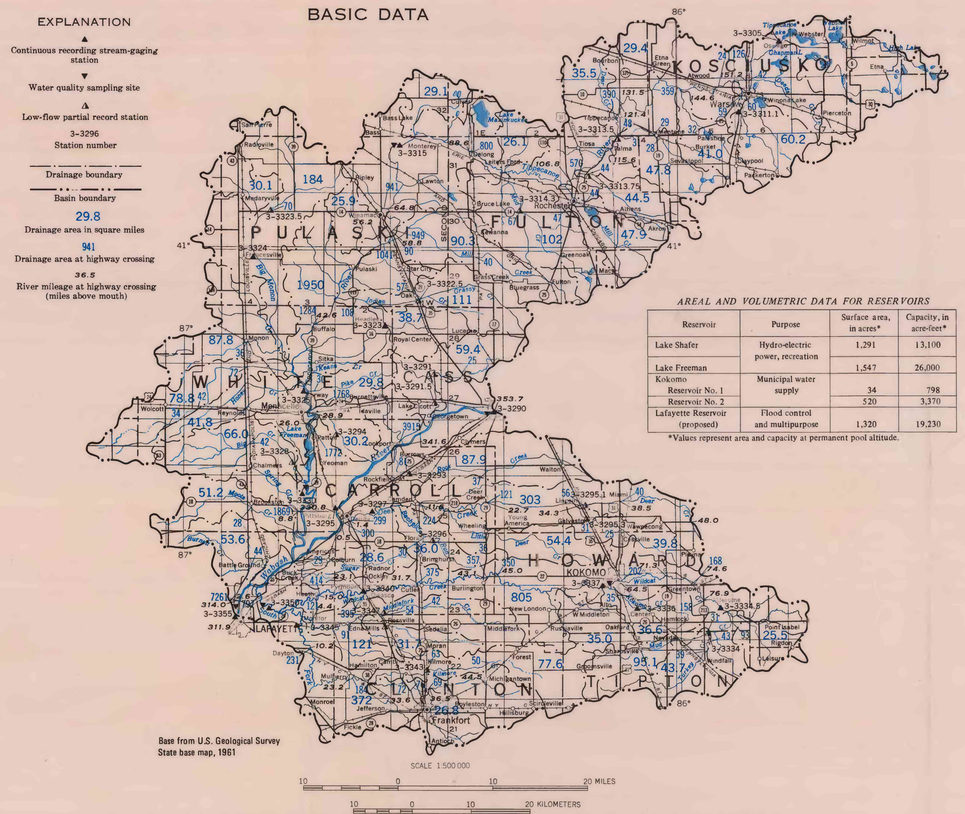
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
INDIANA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER

HYDROLOGIC INVESTIGATIONS
ATLAS HA-508 (SHEET 3 OF 3)

BASIC DATA



RECORDS OF STREAMFLOW ARE BEING COLLECTED AT 18 CONTINUOUS RECORDING STREAM-GAGING STATIONS AND 16 LOW-FLOW PARTIAL-RECORD STATIONS.— *Water-quality information is being collected at six of the continuous recording gaging stations.*

AREAL AND VOLUMETRIC DATA FOR RESERVOIRS

Reservoir	Purpose	Surface area, in acres*	Capacity, in acre-feet*
Lake Shafer	Hydro-electric power, recreation	1,291	13,100
Lake Freeman		1,547	26,000
Kokomo Reservoir No. 1	Municipal water supply	34	798
Reservoir No. 2		520	3,370
Lafayette Reservoir (proposed)	Flood control and multipurpose	1,320	19,230

*Values represent area and capacity at permanent pool altitude.

AVERAGE DISCHARGE

Based on records collected at the continuous recording stream-gaging stations, the average discharge for streams draining areas in excess of 25 square miles can be estimated by:

AVERAGE DISCHARGE = 0.86 × DRAINAGE AREA

The standard error of estimate of the average discharge, using the above relation, is about 9 percent. Drainage areas for many streams are shown on the map. Additional drainage-area data are shown on the principal map in the water-quality section. Drainage areas at gaged sites are listed in the basic-data section, and in the low-flow section of this report. Drainage areas for points other than those given may be determined from standard 7½-minute U.S. Geological Survey topographic maps.

STREAMFLOW DATA AT CONTINUOUS RECORDING GAGING STATIONS

Station No.	Station name	Drainage area (sq mi)	Period of record[1]	Average discharge	Maximum discharge	Minimum discharge
3-3290	Wabash River at Logansport	3,779	1924-70	3,217	89,800	135
3-3294	Rattlesnake Creek near Patton[2]	6.83	1969-70	-----	157	0.43
3-3295	Wabash River at Delphi	4,072	1940-70	3,346	85,300	158
3-3297	Deer Creek near Delphi	274	1944-70	233	14,400	5.6
3-3305	Tippecanoe River at Oswego	113	1955-70	97.1	700	.08
3-3311.1	Walnut Creek near Warsaw[2]	19.6	1970	-----	141	2.4
3-3315	Tippecanoe River near Ora	856	1944-70	782	7,800	86
3-3323	Little Indian Creek near Royal Center	35.0	1965-70	26.7	500	5
3-3324	Big Monon Creek near Francesville	152	1960-70	137	2,750	4.0
3-3325	Tippecanoe River near Monticello	1,733	1932-70	1,463	16,800	103
3-3330	Tippecanoe River near Delphi	1,865	1940-70	1,590	22,600	71.0
3-3334.5	Wildcat Creek near Jerome	146	1962-70	108	4,160	.9
3-3336	Kokomo Creek near Kokomo	24.7	1965-70	17.8	1,040	.11
3-3337	Wildcat Creek at Kokomo	242	1956-70	205	8,100	5.0
3-3340	Wildcat Creek at Owasco	396	1944-70	351	10,200	10
3-3345	South Fork Wildcat Creek near Lafayette	243	1944-70	229	12,600	12
3-3350	Wildcat Creek near Lafayette	794	1955-70	704	25,000	46
3-3355	Wabash River at Lafayette	7,267	1924-70	6,252	131,000	265

[1] Through 1970 water year. [2] See low-flow section. [3] Regulation at dam upstream.

LAKES

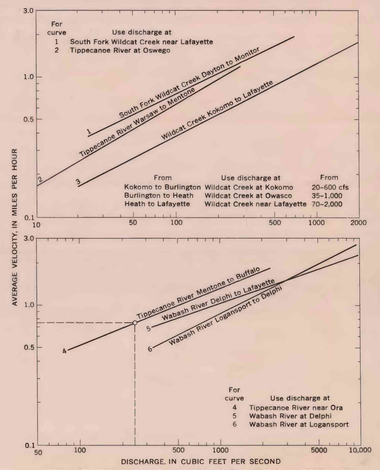
Natural lakes of glacial origin are abundant in Pulaski, Fulton, and Kosciusko Counties. Resort facilities are available at most of the large lakes that have been developed for recreational purposes. Surface-area and capacity data are available for 50 lakes that have been contoured for depth. Some hydrologic data for those lakes having a surface area greater than 500 acres are shown below. Additional information on lakes and their facilities can be obtained from the Indiana Department of Parks and Natural Resources.

Lake	Drainage area (sq mi)	Surface area (acres)	Depth, in feet (max.)	Depth, in feet (average)	Capacity* (million gallons)
Big Chapman Lake	4.17	581	35	10	1,941
Lake Manitou	44.2	631	35	--	----
Lake Maxinkuckee	13.7	1,864	88	24	14,866
Tippecanoe Lake	113	768	123	37	9,247
Webster Lake	49.2	774	45	--	----
Winona Lake	32.1	562	80	30	5,436

*Conversion factor: 1 acre-foot = 325,851 gallons.

SURFACE WATER

TRAVEL TIME OF SOLUTES



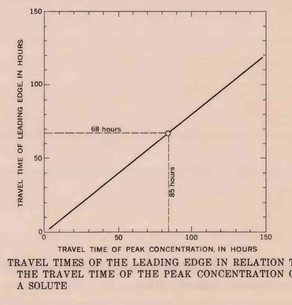
AVERAGE VELOCITY OF SOLUTES IN RELATION TO DISCHARGE

TRAVEL TIMES OF THE PEAK CONCENTRATION AND LEADING EDGE OF A SOLUTE CAN BE ESTIMATED FROM THE GRAPHS PRESENTED IN THIS SECTION

These graphs are based on dye surveys. Each curve shown above represents the relationship between the average velocity of water to discharge for a specific reach of a river, and the discharge is for that gaging station used to define the flow for that reach. These relations should not be used for flows above or below those defined by the curves. Additional data collection would be necessary to determine $t_{1.0}$ at times for flows beyond these limits. As an example of the utility of the above relationships, assume that an accidental spill of a contaminant has occurred on the Tippecanoe River at U.S. Highway 31 north of Rochester. When will the contaminant arrive at State Road 39 in Buffalo (the last bridge above Lake Shafer)? The gaging station used to define the flow for this reach is the Tippecanoe River near Ora, and the discharge there is 250 cfs. From the curve for the Tippecanoe River from Mentone to Buffalo, the average velocity of water at 250 cfs is 0.75 mile per hour (the velocity at which the peak concentration of the contaminant will travel). From the principal map in the basic data section, showing river mileages at highway crossings, the distance between U.S. Highway 31 and State Road 39 is 64.2 miles. Therefore, the travel time for the peak concentration is 64.2 miles or 85 hours.

$$\frac{64.2 \text{ miles}}{0.75 \text{ mph}} = 85 \text{ hours}$$

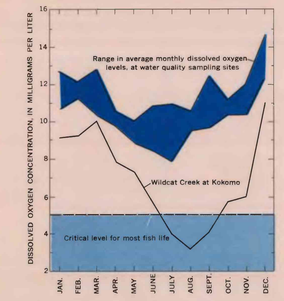
Because the leading edge of the contaminant will arrive at State Road 39 sooner than the peak concentration, its travel time can be estimated from the graph shown below. From the graph, the travel time for the leading edge of the contaminant to reach State Road 39 is 68 hours.



TRAVEL TIMES OF THE LEADING EDGE IN RELATION TO THE TRAVEL TIME OF THE PEAK CONCENTRATION OF A SOLUTE

SURFACE-WATER QUALITY

CHEMICAL AND PHYSICAL PROPERTIES

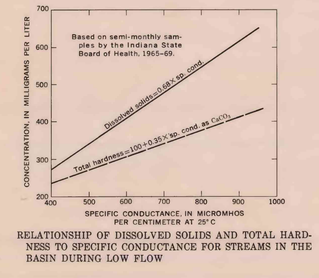


Note: Based on semi-monthly samples by the Indiana State Board of Health, 1965–69.

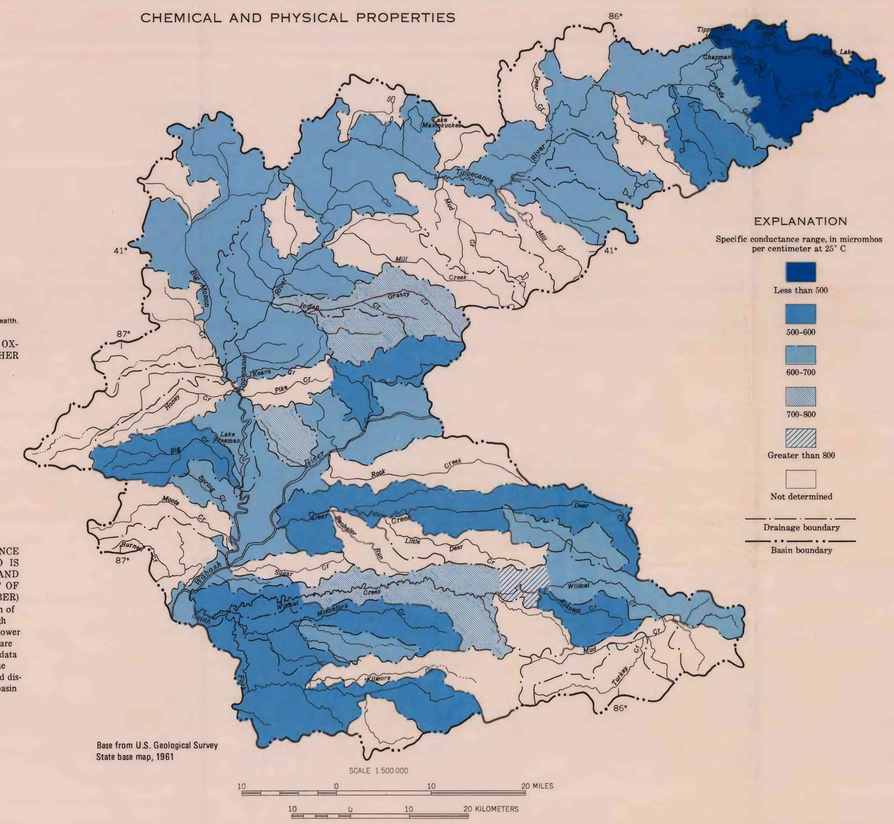
AVERAGE MONTHLY CONCENTRATION OF DISSOLVED OXYGEN FOR WILDCAT CREEK AT KOKOMO AND AT OTHER STREAMS IN THE BASIN

DURING LOW STREAMFLOW THE SPECIFIC CONDUCTANCE OF WATER IN WILDCAT CREEK BELOW KOKOMO IS MUCH HIGHER THAN ELSEWHERE IN THE BASIN, AND THE LEVEL OF DISSOLVED OXYGEN FOR SUPPORT OF FISH LIFE BECOMES CRITICAL (JUNE THRU SEPTEMBER)

As shown in the above graph, the average monthly concentration of dissolved oxygen levels in Wildcat Creek at Kokomo, due to the high volume of municipal and industrial waste discharge there, is much lower than for the other streams in the basin. Specific conductance data are available for all gaged sites in the basin. In addition, water-quality data are collected at the sampling sites shown on the principal map in the basic-data section. By using the graph below, the total hardness and dissolved-solids content of water can be estimated for streams in the basin during low flow.



RELATIONSHIP OF DISSOLVED SOLIDS AND TOTAL HARDNESS TO SPECIFIC CONDUCTANCE FOR STREAMS IN THE BASIN DURING LOW FLOW

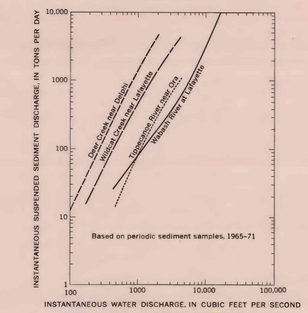


VARIABILITY IN CONCENTRATION OF SELECTED WATER QUALITY PARAMETERS

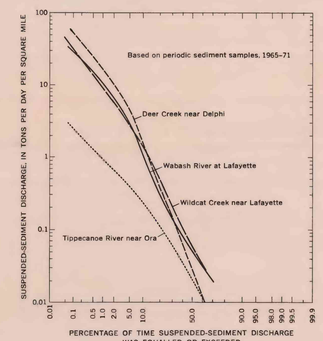
Sampling site	Alkalinity (total) as $CaCO_3$ (mg/l)	Chlorides as Cl (mg/l)	Nitrates as N (mg/l)	pH	Hardness as $CaCO_3$ (mg/l)	Color	Turbidity	BOD (mg/l)
Wabash River at Lafayette	84–260 126–284	9–51 4–40	0.4–9.1 0–9.0	6.6–8.4 7.2–9.1	134–396 214–412	5–40 5–35	5–500 5–80	[1] 0.5–17.0 [2] 2.0–17.0
Tippecanoe River at Delphi	116–232 140–266	10–24 3–34	0.1–9.0 0–3.2	6.6–8.5 7.1–8.7	178–412 232–384	5–50 5–35	5–160 5–20	1.0–8.0 1.2–9.0
Wildcat Creek near Lafayette	60–286 180–324	6–38 3–44	0.1–9.6 0.1–7.3	6.7–8.3 7.2–8.9	94–390 270–428	5–35 5–15	5–2,000 5–110	0.3–7.9 0.9–8.2

[1] Upper figures denote the range in concentration at flows greater than 50 percent duration.
[2] Lower figures denote the range in concentration at flows less than 50 percent duration.

SUSPENDED SEDIMENT



AVERAGE RELATIONS OF SUSPENDED-SEDIMENT DISCHARGE TO WATER DISCHARGE



SUSPENDED-SEDIMENT DURATION CURVES

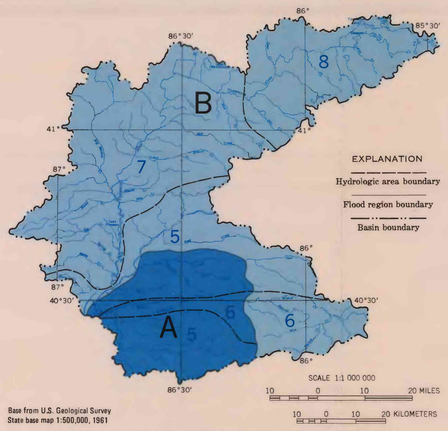
MOST OF THE SUSPENDED SEDIMENT DISCHARGED FROM THE BASIN IS TRANSPORTED BY STREAMS DURING PERIODS OF HIGH FLOW

The sediment-transport curves shown above, are approximate because the ratio of suspended-sediment load to discharge varies considerably with seasonal conditions. Listed below are estimated yearly unit loads of suspended sediment discharged by streams in the basin:

Sampling site	Tons per year per square mile
Deer Creek near Delphi	393
Tippecanoe River near Ora	34.7
Wildcat Creek near Lafayette	227
Wabash River at Lafayette	233

As shown in the suspended sediment duration curves, 90 percent or more of the suspended sediment is discharged at flows exceeding 50-percent duration on Deer Creek, Wildcat Creek, and the Wabash River. About 75 percent of the average yearly suspended-sediment load is discharged at flows exceeding 50-percent duration on the Tippecanoe River. Of the average yearly suspended-sediment load leaving the basin, the greatest amount comes from the southern part of the basin because of higher peak flows and the preponderance of silt and clay materials that are available for removal by surface runoff.

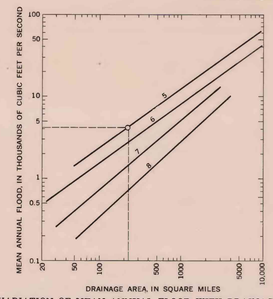
REGIONAL FLOOD FREQUENCY



AN ESTIMATE OF FLOOD DISCHARGES FOR VARIOUS RECURRENCE INTERVALS CAN BE DETERMINED BY USING DATA PRESENTED IN THIS SECTION AND DRAINAGE AREA AT THE SITE OF INTEREST

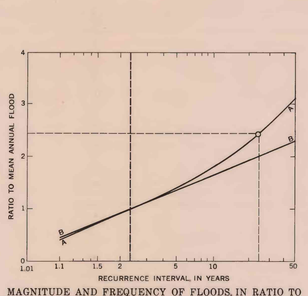
For example, it is proposed to build a new bridge across the South Fork Wildcat Creek on State Road 38 at Dayton that will pass a flood having a 25-year recurrence interval. For what discharge should the opening be designed?

1. Referring to the principal map in the basic data section showing drainage areas at highway crossings, the stream has a drainage area of about 231 sq mi at State Road 38.
2. The above map shows that this site is located in Flood Region A, and hydrologic area 5. From the graph showing the relationship of the mean annual flood to drainage area, the discharge of the mean annual flood for 231 sq. mi. is about 4,200 cfs.
3. Using flood frequency curve A, the ratio of a flood having a 25-year recurrence interval to the mean annual flood is about 2.45. The magnitude of the 25-year flood is 2.45 × 4,200 cfs = 10,300 cfs, the discharge for which the bridge opening should be designed. The equations and curves presented apply to all unregulated streams within the designated areas.



VARIATION OF MEAN ANNUAL FLOOD WITH DRAINAGE AREA FOR STREAMS IN HYDROLOGIC AREAS 5–8

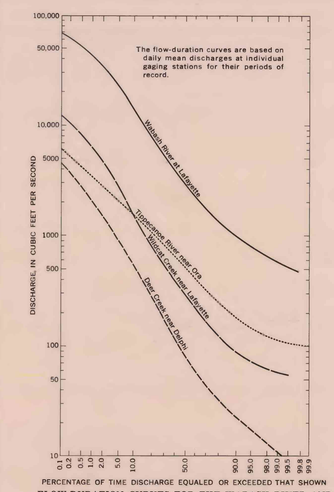
After Speer and Gamble, 1965



MAGNITUDE AND FREQUENCY OF FLOODS, IN RATIO TO THE MEAN ANNUAL FLOOD, FOR STREAMS IN FLOOD REGIONS A AND B

After Speer and Gamble, 1965

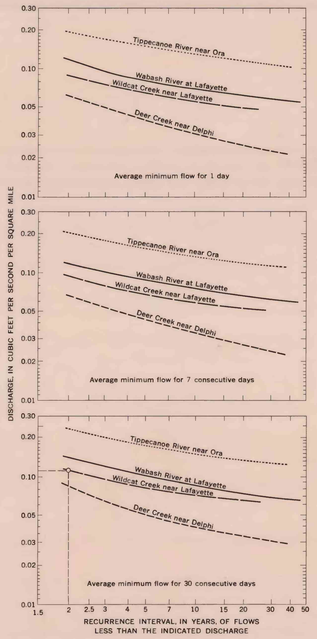
FLOW DURATION



FLOW-DURATION CURVES FOR THE WABASH RIVER AND THREE OF ITS TRIBUTARIES REFLECT THE AREAL VARIATION IN THE NATURE OF RUNOFF, DIFFERENCES IN HYDROLOGIC AND GEOLOGIC CHARACTERISTICS WITHIN THE BASIN, AND THE NATURE OF INTEGRATED FLOWS FROM THE BASIN

The duration curve for the Tippecanoe River has a rather gentle slope compared to curves for Deer Creek and Wildcat Creek. This stream drains an area with many lakefed streams, and is underlain by thick sand and gravel aquifers. Surficial materials overlying this part of the basin have been derived mainly from glacial outwash, and streamflow is characterized by good sustained flow during dry periods and a low to moderate rate of runoff during wet periods. Deer and Wildcat Creeks drain areas underlain by materials derived from glacial moraines; consequently, surface runoff from this part of the basin is rapid during wet periods. Sustained flows during dry periods are variable, but generally low. The duration curve for the Wabash River reflects the combined effect of flow characteristics of all streams within the basin.

STATION FREQUENCY DATA



Note: The low-flow frequency curves, shown above, are based on annual minimum flows at individual gaging stations for their periods of record.

LOW-FLOW DISCHARGES FOR THE WABASH RIVER AND ITS PRINCIPAL TRIBUTARIES CAN BE DETERMINED FROM THE LOW-FLOW FREQUENCY CURVES

The curves provide the average minimum flow at selected frequencies for the indicated number of successive days. For example: if a discharge for the average minimum flow (2-year recurrence interval) for 30 consecutive days were desired for Wildcat Creek near Lafayette, the drainage area times the unit area discharge yields:

794 sq mi × 0.11 cfsm = 87.3 cfs

Average minimum discharges for 7 consecutive days at the 2-year and 10-year recurrence intervals are shown below.

AVERAGE MINIMUM FLOWS FOR 7 CONSECUTIVE DAYS AT THE 2-YEAR RECURRENCE INTERVAL ($M_{7,2}$) AND THE 10-YEAR RECURRENCE INTERVAL ($M_{7,10}$) AT THE CONTINUOUS RECORDING GAGING STATIONS

Station No.	(cfs) $M_{7,2}$	(cfs) $M_{7,10}$	Station No.	(cfs) $M_{7,2}$	(cfs) $M_{7,10}$
3-3290	303	190	3-3330	300	190
3-3295	360	221	3-3334.5	2.2	1.2
3-3297	18	9	3-3336	0.4	0.2
3-3305	6.7	1.9	3-3337	18	10
3-3315	176	116	3-3340	29	19
3-3323	1.6	0.5	3-3345	26	19
3-3324	14	9.1	3-3350	74	47
3-3325	274	171	3-3355	860	560

LOW FLOW

REGIONAL FREQUENCY DATA

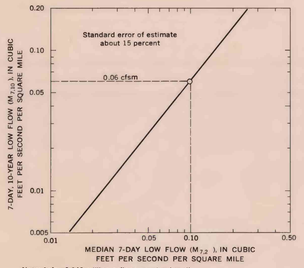
Median 7-day low flows vary from less than 0.01 cubic foot per second per square mile on Wildcat Creek and its tributaries to greater than 0.20 cubic foot per second per square mile on the Tippecanoe River. The ranges in runoff shown on the map are based on low-flow frequency analyses of data from the continuous recording stream-gaging stations, correlation of measurements at low-flow partial-record stations, and correlation of low-flow values with the geology of the surficial materials overlying the basin. A limiting factor of 25 square miles was chosen in regionalizing the data because many streams with drainage areas less than 25 square miles have no flow at the median 7-day index. A regression analysis relating estimates of the median 7-day flow at 22 miscellaneous sites in the basin where low-flow measurements have been made, with estimates at each site by interpolation from the map, provided an accuracy limit of about 75 percent, or a standard error of 25 percent.

Runoff values obtained from the map for ungaged sites are estimates and should not be applied for design purposes without field verification. One or more low-flow measurements should be made at the site and correlated with concurrent flow at a nearby gaging station. The map is intended for use as a preliminary tool by which the planner can select those streams having the most probable chance of providing dependable flow and the approximate magnitude of that flow. An approximate value for the 7-day, 10-year low flow can be determined by using the graph showing the average ratio between the 7-day, 10-year low flow and the median 7-day low flow for streams in the basin.

If an approximation of the median 7-day low flow was desired for Mill Creek at State Road 25 at Rochester (an ungaged site), the unit area discharge (from the map) times the drainage area (from the principal map in the basic data section showing drainage areas at highway crossings) yields:

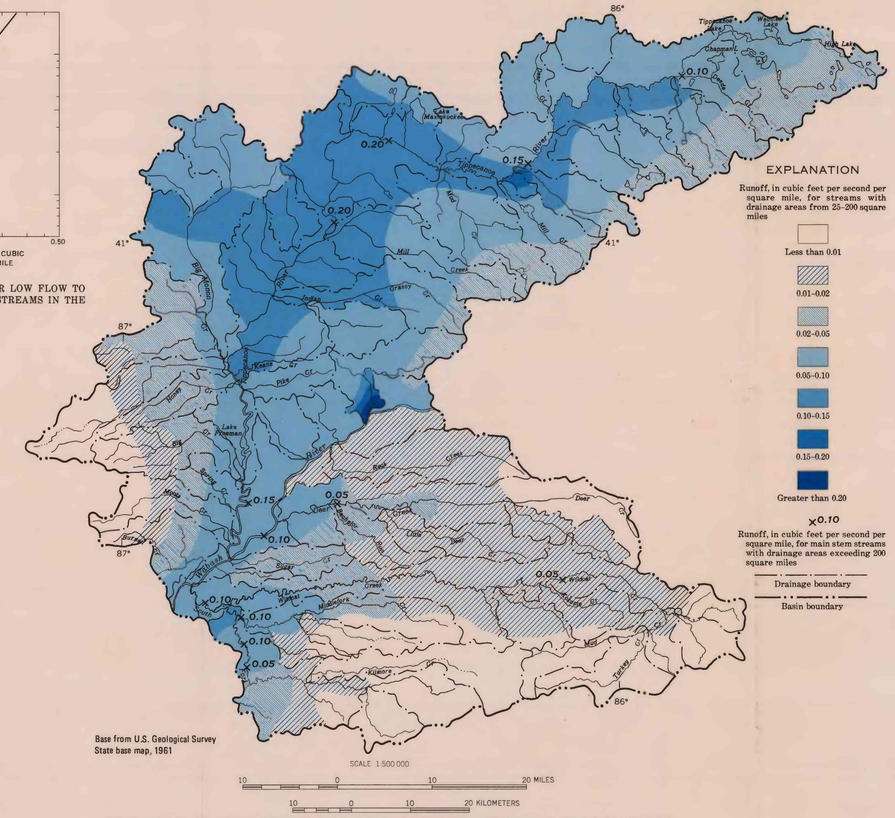
0.10 cfsm × 45.0 sq mi = 4.5 cfs

From the graph, the estimated 7-day, 10-year low flow is 0.06 cfsm or about 2.7 cfs. This is equivalent to about 1.75 million gallons per day.



Note: 1cfs=0.646 million gallons per day (mgd).

AVERAGE RATIO OF THE 7-DAY, 10-YEAR LOW FLOW TO THE MEDIAN 7-DAY LOW FLOW FOR STREAMS IN THE BASIN



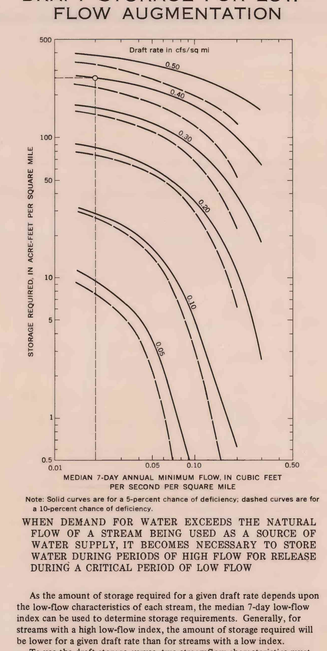
STATION DATA FOR LOW-FLOW PARTIAL RECORD SITES AND FOR CONTINUOUS RECORDING GAGES HAVING LESS THAN 5 YEARS OF RECORD

Station No.	Station name	Drainage area (sq mi)	Period of record	Discharge 1	Discharge 2	Discharge 3
3-3291.0	Crooked Creek near Royal Center	35.9	1968-70	8.90	6.10	4.20
3-3291.5	Crooked Creek near Logansport	54.2	1968-70	22.0	21.0	18.0
3-3293.0	Rock Creek at Rockfield	80.8	1954, 60-66	.89	1.50	.60
3-3294.0	Rattlesnake Creek near Patton	6.83	1969-70	.56	.20	.10
3-3295.1	Deer Creek near Lincoln	56.5	1968-70	1.90	.70	.20
3-3295.3	South Fork Deer Creek at Galveston	31.6	1968-70	1.60	.60	.20
3-3296.0	Bachelor Run near Flora	13.5	1960-66	.56	.30	.20
3-3311.1	Walnut Creek near Warsaw	19.6	1970	3.60	1.30	.50
3-3313.5	Yellow Creek near Mentone	47.8	1969-70	6.20	5.20	3.20
3-3313.75	Chippewanuck Creek near Rochester	43.7	1969-70	9.80	7.60	4.90
3-3314.3	Mud Creek near Bruce Lake	66.9	1960-67	2.20	1.80	1.80
3-3322.5	Indian Creek near Thornhope	56.6	1968-70	12.9	5.10	2.70
3-3323.5	Big Monon Creek near Medaryville	69.6	1969-70	22.3	12.0	7.40
3-3328.0	Big Creek near Monticello	55.3	1968-70	6.60	2.30	1.30
3-3334.0	Mud Creek near Windfall	74.8	1960-64, 67	.40	.90	.40
3-3343.0	Kilmore Creek at Kilmore	62.6	1954, 60-67	0	.20	0
3-3347.0	Middle Fork Wildcat Creek near Rossville	54.0	1969-70	3.64	3.00	1.80
3-3347.5	Campbells Run near Rossville	18.3	1969-70	.56	.30	.10

1. Minimum observed discharge.
2. Median 7 day low-flow (the average minimum discharge for 7 consecutive days having a 50 percent probability of occurrence = 2 year recurrence interval).
3. 7 day, 10 year low-flow (the average minimum discharge for 7 consecutive days having a 10 percent probability of occurrence = 10 year recurrence interval).

ESTIMATES OF THE ANNUAL MINIMUM 7-DAY FLOWS AT THE 2-YEAR (MEDIAN) AND 10-YEAR RECURRENCE INTERVALS CAN BE MADE FOR STREAMS DRAINING AREAS OF 25 SQUARE MILES OR MORE

DRAFT–STORAGE FOR LOW–FLOW AUGMENTATION



Note: Solid curves are for a 5-percent chance of deficiency; dashed curves are for a 10-percent chance of deficiency.

WHEN DEMAND FOR WATER EXCEEDS THE NATURAL FLOW OF A STREAM BEING USED AS A SOURCE OF WATER SUPPLY, IT BECOMES NECESSARY TO STORE WATER DURING PERIODS OF HIGH FLOW FOR RELEASE DURING A CRITICAL PERIOD OF LOW FLOW

As the amount of storage required for a given draft rate depends upon the low-flow characteristics of each stream, the median 7-day low-flow index can be used to determine storage requirements. Generally, for streams with a high low-flow index, the amount of storage required will be lower for a given draft rate than for streams with a low index.

To use the draft-storage curves, two streamflow characteristics must be determined: (1) the drainage area and (2) the median 7-day low flow. These values are available on this sheet for all gaged sites, and can be estimated for ungaged sites by using the two maps showing drainage areas and the map showing the median 7-day low flow. Given these variables, the amount of storage required to maintain a desired draft rate can be estimated from the graph for either a 5-percent or 10-percent chance of deficiency. Allowance for evaporation and seepage losses should be included in the draft rate, or added to the required storage.

Storage requirements obtained from the graph for ungaged sites are estimated, and should not be applied for design purposes without field verification. One or more low-flow measurements should be made at the site and correlated with concurrent flow at a nearby gaging station. The graph is intended for use as a preliminary tool by which a planner can select those sites having the most probable chance of providing dependable flow and the approximate magnitude of storage required to maintain a desired draft rate.

If a dependable flow of 9 million gallons per day is desired at Little Wildcat Creek near Kokomo, the storage requirements for this flow can be estimated by:

1. The drainage area (from the map showing drainage areas for streams and their tributaries) is 35.0 square miles.
2. The median 7-day low flow (from the map showing the median 7-day low flow) is about 0.02 cfsm.
3. The draft rate of 9 million gallons per day is equal to 13.9 cfs or 0.40 cfsm ($\frac{13.9 \text{ cfs}}{35.0 \text{ sq mi}}$).
4. Therefore, from the draft-storage curve, and for a 5-percent chance of deficiency, the storage requirement is 270 acre-feet per square mile or 9,450 acre-feet (270 acre-ft × 35.0 sq mi), without adjustment for evaporation or seepage losses.

WATER RESOURCES OF THE MIDDLE WABASH RIVER BASIN, INDIANA

By

James R. Marie and L. G. Davis

1974

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1974—W77151