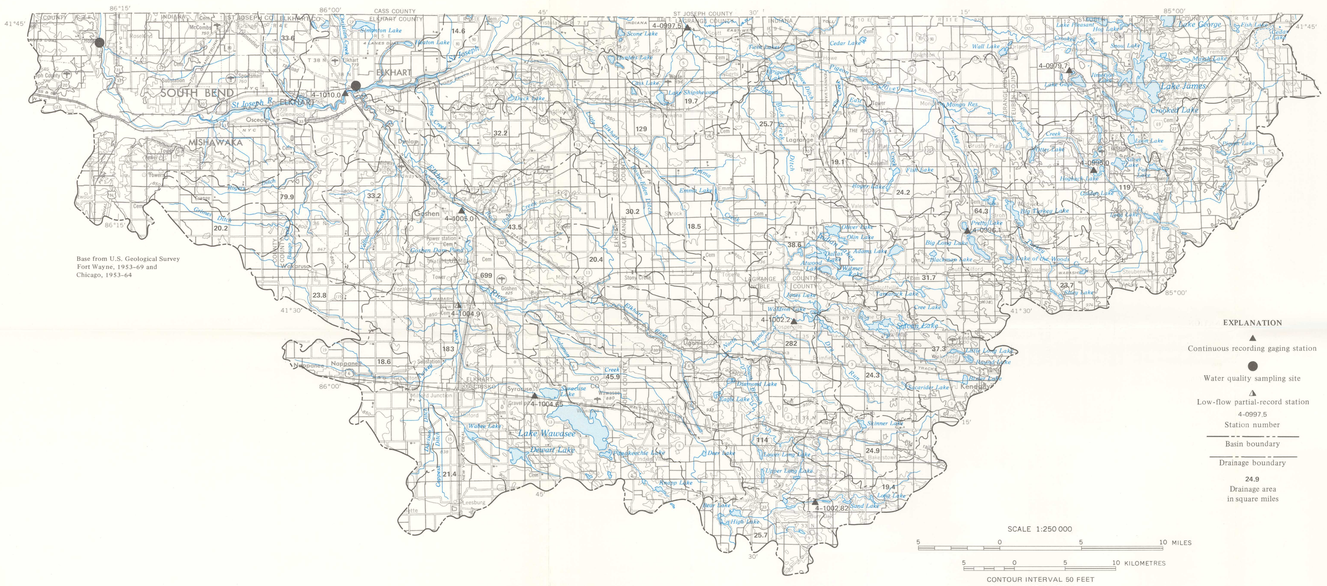
SURFACE WATER

BASIC DATA



STREAMFLOW RECORDS ARE BEING COLLECTED AT NINE CONTINUOUS RECORDING GAGING STATIONS AND ONE LOW-FLOW PARTIAL-RECORD STATION

AVERAGE DISCHARGE

On the basis of records collected at the continuous recording gaging stations, the average discharge of streams draining more than 25 sq mi (square miles) can be estimated by multiplying the drainage area by 0.86. The standard error of estimate of the average discharge obtained by this method is 12 percent. Drainage areas of many streams are shown on the above map. Additional drainage-area data are shown in the table and on the map in the surface-water-quality section.

STREAMFLOW DATA AT CONTINUOUS RECORDING GAGING STATIONS

Station No.	Station name	Drainage area (sq mi)	Period of record (water years)	Average discharge (cfs)	Maximum discharge (cfs)	Minimum discharge (cfs)
4–0979.7	Lime Lake Outlet at Panama	17.5	1970	.....	26	0.50
4–0995.0	Pigeon Creek at Hogback Lake Outlet near Angola	102	1946–70	72.8	744	3.4
4–0996.1	Pretty Lake Inlet near Stroh	1.96	1964–70	.47	21	0
4–0997.5	Pigeon River near Scott	373	1969–70	.....	1,450	85
4–1002.2	North Branch Elkhart River near Cosperville	133	1951–70	107	717	2.2
4–1002.52	Forker Creek near Burr Oak	19.2	1970	.....	999	.36
4–1004.65	Turkey Creek at Syracuse	43.8	1970	.....	114	3.2
4–1005.0	Elkhart River at Goshen	580	1932–70	498	5,440	*6.6
4–1010.0	St. Joseph River at Elkhart	3,339	1948–70	3,014	18,400	**336

*Result of regulation.
**Minimum daily discharge.

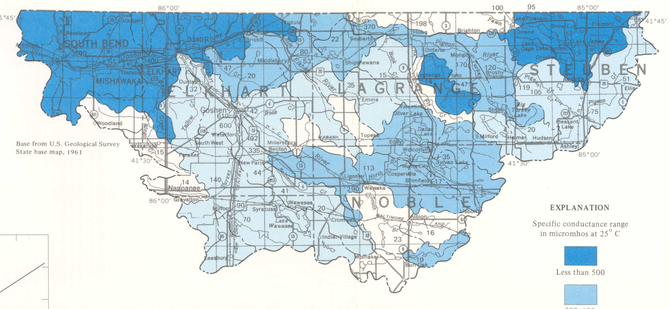
LAKES

Natural lakes are abundant in the area and are a possible source of water supply. Lakes act as temporary storage reservoirs for excess runoff during peak-flow periods and could be developed for water supplies. Resort facilities are available at most of the large lakes, and it is expected that lakes will continue to be used primarily for their recreative and esthetic value. Surface-area and capacity data are available for 82 lakes. Hydrologic data for lakes having surface areas greater than 500 acres are shown below. Additional information on lakes can be obtained from the Indiana Department of Parks and Natural Resources.

Name	Drainage area (sq mi)	Surface area (acres)	Depth (feet) maximum	Depth (feet) average	Capacity* (million gallons)
Lake James	43.0	1,034	-----	-----	----------
Crooked Lake	11.9	733	-----	-----	----------
Sylvan Lake	31.5	575	-----	-----	----------
Wawasee Lake	36.1	3,060	77	22	21,900
Dewart Lake	7.88	551	82	16	2,933

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

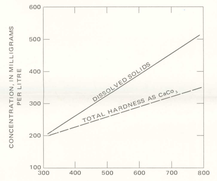
WATER QUALITY



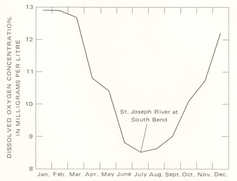
EXPLANATION

Specific conductance range in micromhos at 25° C

- Less than 500
- 500–600
- 600–700
- Not determined
- Basin boundary
- Drainage boundary
- 30 Drainage area at highway crossing, in square miles



RELATIONSHIP OF DISSOLVED SOLIDS AND HARDNESS TO SPECIFIC CONDUCTANCE FOR STREAMS IN THE BASIN DURING LOW FLOW BASED ON TWICE-MONTHLY SAMPLES BY THE INDIANA STATE BOARD OF HEALTH, 1958–69. – *Specific-conductance data for all gaged sites in the basin, as well as for additional sites, are shown on the principal map in the basic-data section. By using the graph above, the hardness and dissolved-solids content of water can be estimated for streams in the basin during low flow.*



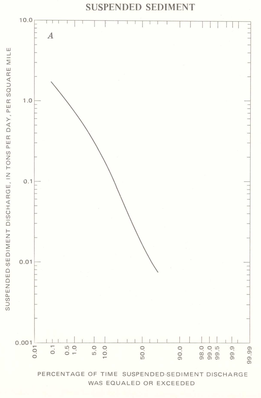
AVERAGE MONTHLY CONCENTRATION OF DISSOLVED OXYGEN FOR ST. JOSEPH RIVER AT SOUTH BEND BASED ON TWICE-MONTHLY SAMPLES BY THE INDIANA STATE BOARD OF HEALTH, 1958–69. – *As shown in the above graph, the dissolved oxygen content of water in the St. Joseph River at South Bend is more than 5 mg/l (milligrams per litre), a critical amount for most fish life.*

SPECIFIC CONDUCTANCE DURING PERIODS OF LOW STREAMFLOW RANGES FROM ABOUT 400 TO 700 MICROMHOS

VARIATION OF CONCENTRATION OF SELECTED WATER-QUALITY PARAMETERS
(Data from Indiana State Board of Health)

Sampling site	Alkalinity (total) as $CaCO_3$ (mg/l)	Chloride as Cl (mg/l)	Nitrate as N (mg/l)	pH	Hardness as $CaCO_3$ (mg/l)	Color	Turbidity	BOD (mg/l)
St. Joseph River at South Bend	66–316 72–234	9–29 10–34	0.1–6.3 0.3–3.0	6.6–8.4 7.0–8.5	210–340 134–306	5–35 5–35	0–160 5–30	0.9–6.0 1.0–8.0
St. Joseph River at Elkhart	82–108 114–248	6–21 7–15	0.3–9.4 0.0–2.0	6.2–8.5 6.8–8.3	182–510 135–288	5–35 0–25	0–20 0–20	0.3–4.1 0.8–3.8

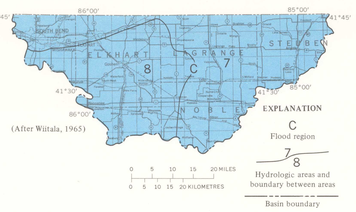
Upper figures denote the values at flows greater than those that were equaled or exceeded 50 percent of the time. Lower figures denote the values at flows less than those that were equaled or exceeded 50 percent of the time.



A. SUSPENDED SEDIMENT DURATION CURVE
B AVERAGE RELATIONSHIP OF SUSPENDED-SEDIMENT DISCHARGE TO WATER DISCHARGE

MOST OF THE SUSPENDED SEDIMENT DISCHARGE FROM THE BASIN IS TRANSPORTED BY STREAMS DURING HIGH FLOW. – *The sediment-transport curves shown above are approximate because the ratio of suspended-sediment load to discharge varies seasonally. Based on periodic sediment samples, 1966–68, the yearly load of suspended sediment for Elkhart River at Goshen was estimated to be 12.4 tons per year per sq mi. As shown on the suspended-sediment duration curve, 65 percent of the average yearly suspended-sediment load is discharged at flows greater than 50-percent flow duration on the Elkhart River at Goshen.*

REGIONAL FLOOD FREQUENCY

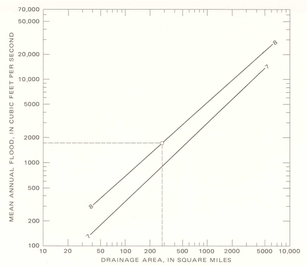


FLOOD DISCHARGES FOR VARIOUS RECURRENCE INTERVALS CAN BE ESTIMATED FROM REGIONAL FLOOD-FREQUENCY CURVES. – *For example, suppose a new bridge is necessary on the Elkhart River at State Route 5 at Ligonier and that the bridge must pass a flood having a 25-year recurrence interval. For what discharge should the bridge opening be designed?*

1. From the map in the surface-water-quality section, which shows drainage areas at selected highway crossings, the drainage area at Ligonier is found to be 290 sq mi.

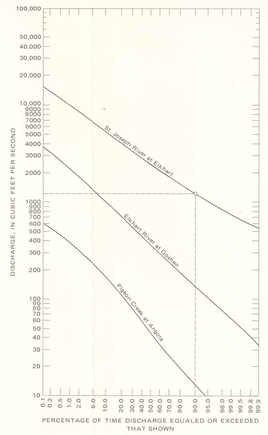
2. The above map shows that Ligonier is in flood region C and hydrologic area 8. From the graph showing the relationship of the mean annual flood to drainage area, the mean annual flood for 290 sq mi is seen to be about 1,800 cfs (cubic feet per second).

3. Using flood-frequency curve C, the ratio of the flood having a 25-year recurrence interval to the mean annual flood is 1.9. The magnitude of the 25-year flood is 1.9 × 1,800 or about 3,400 cfs, the design discharge. The curves apply to all unregulated streams within the designated areas.



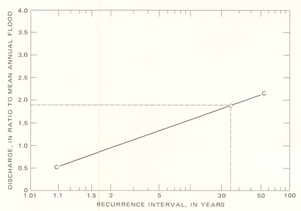
VARIATION OF MEAN ANNUAL FLOOD WITH DRAINAGE AREA FOR STREAMS IN HYDROLOGIC AREAS 7 AND 8. (After Wiitala, 1965).

FLOW DURATION



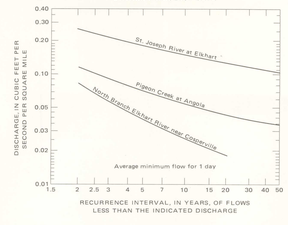
FLOW-DURATION CURVES SHOW THE MAGNITUDE OF FLOW THAT CAN BE EXPECTED TO BE EQUALED OR EXCEEDED. – *For example, suppose a power plant is planned for the St. Joseph River near Elkhart that will require water for cooling. The 90-percent duration discharge is used as the minimum design discharge. From the above graph, a discharge of at least 1,300 cfs can be expected 90 percent of the time.*

Note. – Flow-duration curves shown above are based on daily mean discharges at each gaging station for their periods of record.



MAGNITUDE AND FREQUENCY OF FLOODS, IN RATIO TO THE MEAN ANNUAL FLOOD, FOR STREAMS IN FLOOD REGION C. (After Wiitala, 1965).

LOW-FLOW



KNOWLEDGE OF LOW-FLOW DISCHARGES IS NECESSARY FOR DESIGN OF RESERVOIRS AND WATER-SUPPLY AND SEWAGE-TREATMENT FACILITIES. – *The above curves show the average minimum flow at selected sites for periods of 1, 7, and 30 consecutive days. For example, the average minimum flow for 7 consecutive days (at the 10-year recurrence interval) for the St. Joseph River at Elkhart is:*

0.225 cfs per sq mi × 3,399 sq mi = 786 cfs

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

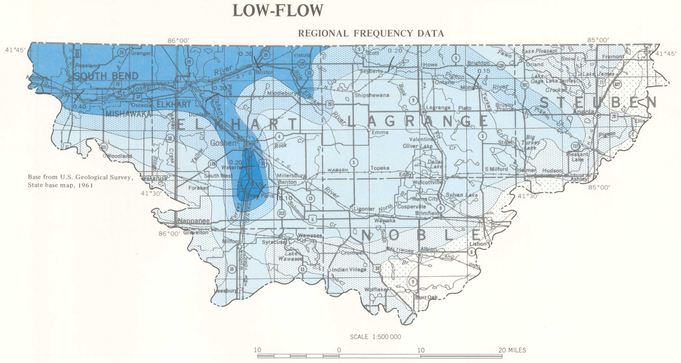
Note. – The low-flow frequency curves shown above are based on annual minimum flows at each gaging station for their periods of record. The 1-day frequency curve for Elkhart River at Goshen is omitted because of the river's regulation.

REGIONAL LOW–FLOW FREQUENCY

Median average 7-day low flows range from less than 0.01 cfs per sq mi on South Branch Elkhart River and its tributaries to more than 0.40 cfs per sq mi on the St. Joseph River. The ranges in runoff shown on the map are based on low-flow-frequency analysis of data from the continuous record gaging stations, measurements at low-flow partial-record stations, and correlation of low-flow discharges with surficial geology. In regionalizing the data, 25 square miles was chosen as the minimum drainage area because smaller streams provide no median average 7-day index flow. A regression analysis comparing estimates of the median average 7-day low flow at 24 miscellaneous sites, where low-flow measurements have been made, with estimates made by interpolating from the map shows an accuracy limit of about 52 percent, or a standard error of 48 percent.

AVERAGE MINIMUM DISCHARGE FOR 7 CONSECUTIVE DAYS AT THE 2–YEAR RECURRENCE INTERVAL ($M_{7,2}$) AND THE 10–YEAR RECURRENCE INTERVAL ($M_{7,10}$) AT CONTINUOUS RECORDING AND LOW-FLOW PARTIAL-RECORD STATIONS

Station No.	Discharge (cfs) $M_{7,2}$	Discharge (cfs) $M_{7,10}$	Station No.	Discharge (cfs) $M_{7,2}$	Discharge (cfs) $M_{7,10}$
4–0995.0	13	6.0	4–1004.65	2.4	1.0
4–0996.1	0	0	(PR)4–1004.9	34	18
4–0997.5	95	55	4–1005.0	129	76
4–1002.2	12	4.5	4–1010.0	1,150	760
4–1002.52	.1	0			



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

EXPLANATION

Median average 7-day low flow, in cubic feet per second per square mile, for streams with drainage areas ranging from 25–200 square miles

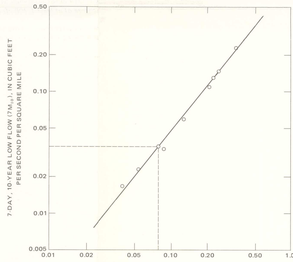
- Less than 0.01
- 0.01–0.02
- 0.02–0.05
- 0.05–0.10
- 0.10–0.15
- 0.15–0.20
- Greater than 0.20
- 0.10 Line of equal median average 7-day low flow, in cubic feet per second per square mile, for streams having drainage areas of more than 200 square miles
- Basin boundary

Estimates of median annual 7-day low flow obtained from the map used for design purposes without field verification is not advisable. Several discharge measurements at base flow, correlated with concurrent discharge at nearby gaging stations, would be necessary for verification. The map is intended to provide a preliminary tool by which planners can select streams having the best potential for providing dependable discharge.

An approximate value for the average 7-day 10-year low flow can be determined from the graph showing the ratio between the average 7-day 10-year low flow and the average 7-day 2-year low flow. For example, if an estimate of the median average 7-day low flow is needed for Turkey Creek at State Route 15 at Milford (an ungaged site), the unit-area discharge from the map times the drainage area taken from the map in the surface-water-quality section showing drainage area above selected highway crossings yields:

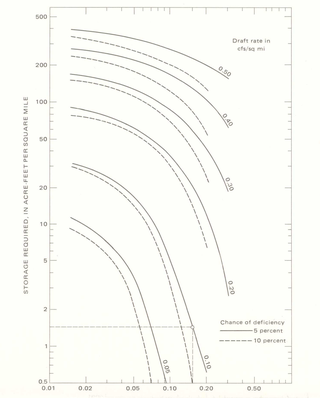
$$(\frac{0.05 + 0.10}{2}) \text{ cfs per sq mi} \times 90 \text{ sq mi} = 7.2 \text{ cfs}$$

From the graph, the estimated average 7-day 10-year low flow is 0.035 cfs per sq mi or about 3.2 cfs. This is equivalent to 2.1 mgd.



RATIO OF THE AVERAGE 7-DAY 10-YEAR LOW FLOW TO THE AVERAGE 7-DAY 2-YEAR LOW FLOW.
Note. – 1 cfs = 0.646 mgd

DRAFT-STORAGE FOR LOW-FLOW AUGMENTATION



WHEN THE DEMAND FOR WATER EXCEEDS THE NATURAL FLOW OF A STREAM, IT IS NECESSARY TO STORE WATER DURING PERIODS OF HIGH FLOW FOR USE DURING PERIODS OF LOW FLOW. – *Because the amount of storage required to maintain a given draft rate depends on the low-flow characteristics of the stream, the median 7-day low flow can be used as an index to determine storage requirements*

To use the draft-storage curves, the drainage area and the median average 7-day low flow must be known. Values for these variables can be obtained or estimated, as explained elsewhere on this sheet. Using 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 curves for ungaged sites need field verification for application. The graph is intended for planners to use as a preliminary tool in selection of sites having the most probable chance of maintaining a desired draft rate.

If a dependable discharge of 11 mgd is desired at a site on the Pigeon River at Mongo, what are the storage requirements for this discharge?

1. The drainage area is 170 sq mi.

2. The median average 7-day low flow is 0.15 cfs per sq mi.

3. The draft rate of 11 mgd is equal to 17 cfs, or 0.10 cfs per sq mi.

4. For a 5-percent chance of deficiency, the storage requirement is 1.4 acre-feet per sq mi, or 238 acre-feet (1.4 × 170), without adjustment for evaporation or seepage.

Interior–Geological Survey, Reston, Va.–1975

WATER RESOURCES OF THE ST. JOSEPH RIVER BASIN IN INDIANA

By

J. P. Reussow and P. B. Rohne, Jr.

1975