INDIANA
Floods and Droughts

Precipitation in Indiana is determined by weather systems that originate in the Pacific and Atlantic Oceans and the Gulf of Mexico. Precipitation patterns in Indiana vary gradually, both geographically and seasonally. Annual precipitation is about 40 inches. Lake Michigan adds to the quantity of moisture available for precipitation in parts of northern and northwestern Indiana. Widespread flooding is caused by frontal systems from the Pacific Ocean, and local flooding is caused by convective storms. Floods generally occur when continental weather patterns slow the passage of a storm. Similar weather patterns can also cause droughts if moisture from the Gulf of Mexico is prevented from entering the State and cyclonic storms are diverted.

The March 1913 flood was the worst in Indiana history. Rainfall of 5-9 inches accompanied turbulent weather. At least 90 lives were lost, and damage was estimated to be $15 million. The flood of January-February 1937 may have been the most severe in hundreds of years in the Ohio River basin. During the summer of 1979, three storms caused widespread flooding in southern Indiana and damage of about $50 million. Rapid melting of a snowpack containing 2 to 6 inches of water equivalent coincided with moderate rainfall in March 1982 to cause major flooding across northern Indiana. In one county, damage estimates were $5 1 million.

Droughts of varied severity and duration have occurred in Indiana since 1930. The drought from April 1952 to March 1957 was prolonged, although northern Indiana had a major flood in October 1954, halfway through the drought. Conditions were similar about a decade later when flooding in March 1963 and March 1964 occurred within the drought of April 1962 to November 1966. The same weather patterns that caused the droughts also slowed the passage of storms and thereby caused the floods.

The State of Indiana manages its water resources through a comprehensive regulatory program. The 1945 Indiana Flood Control Act prohibits new residential construction in floodway areas and requires prior approval for nonresidential construction and other activities in floodway areas. Flood-warning mechanisms are limited mostly to flood-stage and weather forecasts provided by the National Weather Service. The 1983 Water Resources Management Act contains provisions for establishment of minimum streamflows and ground-water levels, inventory of water use, and assessment of the availability of water resources.

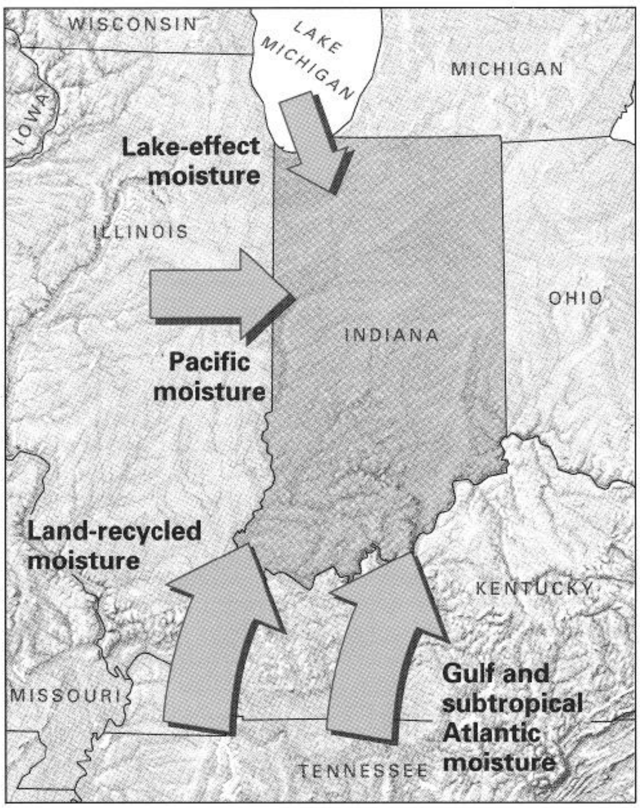


Figure 1. Principal sources and patterns of delivery of moisture into Indiana. Size of arrow implies relative contribution of moisture from source shown. (Source: Data from Douglas R. Clark and Andrea Lage, Wisconsin Geological and Natural History Survey.)

GENERAL CLIMATOLOGY

Indiana has a distinctly seasonal climate. The summers are hot and humid, and the winters are cold and damp. The transitional seasons of spring and fall have daily changes in weather. A well-defined, north-south climatic gradient across Indiana results in a cool, temperate, continental climate in the north and a warm, temperate, continental climate in the south.

Precipitation patterns in Indiana vary gradually, both geographically and seasonally. Precipitation, which is greatest from March through July, is received each month of the year. Average annual precipitation and temperature values for each of the nine climatological districts in Indiana are northwest (37 inches, 50 °F [degrees Fahrenheit]), north central (37 inches, 50 °F), northeast (36 inches, 50 "F), west central (39 inches, 52 °F), central (39 inches, 51 °F), east central (38 inches, 50 °F), southwest (43 inches, 55 °F), south central (44 inches, 54 °F), and southeast (43 inches, 54 "F). These data are based on the period of record 1951-80 (U.S. Weather Bureau, 195 l-69; National Oceanic and Atmospheric Administration, 1970–80). Losses from evapotranspiration are relatively uniform across the State and average 28 inches per year (Clark, 1980).

Indiana's climate is affected by six airmasses during the annual cycle of seasonal changes. The principal moisture-producing airmasses and their origin are shown in figure 1.

Tropical maritime airmasses dominate Indiana's climate during late spring, summer, and early fall. The source of moisture is the Gulf of Mexico and the subtropical Atlantic Ocean (fig. 1). Cyclonic or convective thunderstorms from this source produce about 65 percent of Indiana's annual precipitation.

Polar continental airmasses dominate in late fall, winter, and early spring. Frontal systems form over Alberta, Canada, and move southeastward. Arctic airmasses also cross into Indiana at times during the winter. Polar continental and arctic airmasses result in little precipitation. However, moisture from Lake Michigan increases the quantity of precipitation in parts of northern and northwestern Indiana.

Polar maritime airmasses that affect Indiana's climate originate in the North Pacific and North Atlantic Oceans and provide about 15 percent of the State's annual precipitation. Polar maritime airmasses from the North Pacific lose most of their moisture as they cross the mountain ranges of western North America.

Tropical continental and subsidence airmasses do not provide moisture to Indiana. About 20 percent of Indiana's annual precipitation comes from regional sources. The main regional source is the Great Lakes, particularly Lake Michigan (fig. 1).

In addition to the oceans, important moisture sources include local and upwind land surfaces, as well as lakes and reservoirs, from which moisture evaporates into the atmosphere. Typically, as a moisture-laden ocean airmass moves inland, it is modified to include some water that has been recycled one or more times through the land-vegetation-air interface.

The most widespread floods in Indiana are caused by excessive late-winter rainfall, sometimes in conjunction with snowmelt, delivered in frontal systems. Frozen or saturated ground can increase the runoff to streams. Intense rainfall associated with the remnants of cyclones, including hurricanes, that track their way across Indiana also has caused widespread floods. Summer floods that result from thunderstorms generally are more localized than those resulting from cyclonic storms.

Droughts lasting months and years can be attributed to two causes. First, the high-pressure cell called the Bermuda High, which normally forms over the Gulf of Mexico or the adjacent Atlantic Ocean, can strengthen and move northwestward over the Southeastern United States. This high-pressure cell prevents moisture in the Gulf of Mexico from reaching Indiana and diverts cyclonic storms north of the State. Second, persistent northwesterly winds aloft might keep moisture in the Gulf of Mexico from entering Indiana. The high-pressure cell tends to form in spring and summer, whereas the northwesterly winds are more common in winter.

MAJOR FLOODS AND DROUGHTS

Major floods and droughts discussed herein are those that were areally extensive and have significant recurrence intervals greater than 25 years for floods and greater than 10 years for droughts, or are currently ongoing. These major events, and those of a more local nature, are listed chronologically in table 1; rivers and cities are shown in figure 2. Floods (fig. 3) and droughts (fig. 4) in Indiana are depicted by use of records from six streamflow-gaging stations that were selected from more than 175 gaging stations in the statewide network. The selection of these six gaging stations was based on criteria that included wide area1 distribution, diverse basin size, long period of record, and active status in 1988. Additionally, the basin upstream from a gaging station must have lacked substantial regulation. The resulting six-station network provides a representation of hydrologic conditions in the various regions of Indiana. Streamflow data are collected, stored, and reported by water year (a water year is the 12-month period from October 1 through September 30 and is identified by the calendar year in which it ends).

FLOODS

Relatively little information is available to document major floods in Indiana before 19 13. The March 19 13 flood in Indiana is well documented because of its magnitude and area1 extent. When major floods occur, additional information usually is collected on historic floods for the purpose of comparison. Information on pre- 19 13 floods in Indiana is available in the documentation of the March 1913 flood (Horton and Jackson, 1913; Bybee and Malott, 1914).

Five major floods are discussed in this section: 1913, 1937, 1957, 1979, and 1982. These floods are among the most severe in Indiana's history in terms of magnitude, area1 extent, loss of life, or property damage. Data from 24 gaging stations were used to map the area1 extent and severity of each of the five floods (fig. 3). Annual-peak-discharge data for six selected gaging stations, the

Figure 2. Selected geographic features, Indiana.

corresponding theoretical discharge having 10- and 100-year recurrence intervals, the location of each of the six gaging stations, and the associated drainage-area boundaries are also shown in figure 3.

The flood of March 1913 was caused by substantial rainfall over a large area from two storms that occurred March 23-27. The ground was saturated by moderate rainfall from previous storms but was not frozen. Rainfall quantities during March 23-27 ranged from 5 to 9 inches across the State. On March 25 alone, more than 6 inches of rain was recorded at Elliston and Shoals in southwestern Indiana. The rainfall patterns are described in detail by Horton and Jackson (1913) and Bybee and Malott (1914). In Indiana, at least 90 lives were lost, and damage was estimated to be $15 million (Horton and Jackson, 1913). The death toll included 25 people killed in Terre Haute by a tornado spawned by the storms on March 23.

The March 1913 flood was the most severe in Indiana history because of the exceptional magnitude and intensity of the storms that caused it, the high flood stages reached at many locations, and the extensive damage. Many high-water marks for the 19 13 flood' were identified, and, for some locations, the associated discharge for the flood has been estimated. The recurrence intervals for most flood-peak discharges are greater than 100 years. At many gaging stations installed later on the White, East Fork White, Whitewater, and Wabash Rivers, the peak stage of the 1913 flood remains as the greatest of record. For example, the maximum stage and discharge on the Wabash River at Mount Carmel, Ill. (fig. 3, site 4), for 1875–1988 occurred in March 1913.

The magnitude of the flood of January-February 1937 possibly has not been paralleled in hundreds of years in the Ohio River basin (Grover, 1938). The floods were the result of continued light but widespread rainfall followed by intense rainfall. From December 26 to January 25, rainfall of as much as 20 inches was recorded in southern Indiana, mostly in basins draining directly into the Ohio River. As much as 10 inches of this total was received January 20-25. Other Ohio River tributaries in Pennsylvania, Ohio, and Ken-

Table 1. Chronology of major and other memorable floods and droughts in Indiana, 1828-1988

[Recurrence Interval The average interval of time within which streamflow will be greater than a particular value for floods or less than a particular value for droughts Symbol. >, greater than Sources Recurrence Intervals calculated from US Geological Survey data, other information from US Geological Survey, State and local reports, and newspapers]

Flood or drought	Date	Area affected (fig. 2)	Recurrence interval (years)	Remarks
Flood	1828	White and Wabash Rivers.	Unknown	Considered by old settlers to be the greatest known. Stages on part of Wabash River exceeded those of 1913.
Flood	July-Aug. 1875	White, East Fork White, and Wabash Rivers.	Unknown	Produced by intense rainfall. Extensive agricultural damage.
Flood	Mar. 1913	Statewide	25 to >100	Worst in Indiana history. Multistate flood. Lives lost, at least 90; damage, $15 million.
Drought	Mar. 1930–Aug. 1931	Statewide	10 to 20	8egan decade of low-flow conditions. Streamflow generally greater than 7-day, lo-year value in central and northern Indiana.
Drought	June 1933–Sept. 1936	Statewide	25 to 60	Streamflow less than 7-day, 10-year value in central and northern Indiana.
Flood.	Jan.-Feb. 1937	Wabash, White, East Fork White, Ohio, Whitewater, and Patoka Rivers.	IO to >100	Caused by widespread rainfall. Ohio River flooded many towns. Multistate. Lives lost, 77.
Drought	May 1939–Jan. 1942	Statewide	20 to 60	Central Indiana severely affected. Most streams had flow less than 7-day, IO-year value.
Flood.	May 1943	White and Wabash Rivers.	5 to >100	Greatest crop-season flood since 1875. Levees' failed on Wabash River. Lives lost, 10; damage, $23 million.
Drought	Apr. 1952–Mar. 1957	Statewide	10 to 60	Streamflow less than 7-day, lo-year value. Broken in northern Indiana in Oct. 1954 by floods.
Flood	Oct. 1954	Calumet and Kankakee Rivers.	5 to >100	Intense rainfall caused prolonged inundation. Drought preceded flood.
Flood.	June-July 1957	White and Wabash Rivers.	5 to >100	Intense rains from remnants of hurricane. Worst in Eagle Creek and Raccoon Creek basins. Lives lost, 6.
Flood.	June 1958	Wabash, White, and Kankakee Rivers.	5 to 250	Worst in north-central Indiana. Levees failed along Wabash River. One million acres of crops flooded.
Flood.	Jan.-Feb. 1959	Wabash, East Fork White, Whitewater, Ohio, Maumee, and Patoka Rivers.	5 to >50	Caused by runoff from rainfall on frozen ground during two storms. Ice jams on larger rivers. Lives lost, 3.
Drought.	Apr. 1962–Nov. 1966	Statewide	20 to 60	Streamflow less than 7-day, IO-year value. Floods occurred in 1963 and 1964 in central and southern Indiana.
Flood	Mar. 1963	White, East Fork White, and Whitewater Rivers.	5 to >50	Intense rains falling on deeply frozen ground covered by snow. Lives lost, at least 2. Widespread damage.
Flood	Mar. 1964	Patoka, Ohio, and East Fork White Rivers.	5 to >50	Caused by torrential rainfall.
Flood	Mar. 1978	Maumee River.	5 to >50	Rainfall and melting snow from the "Blizzard of 1978." Extensive damage in Fort Wayne. Damage, $11 million.
Flood	June-Aug. 1979	Whitewater, Ohio, East Fork White, Wabash, Patoka, and White Rivers.	5 to >100	Three storms in central and southern Indiana. July storms remnants of hurricanes. Damage, $50 million.
Flood	Mar. 1982	Wabash, St. Joseph, Kankakee, and Maumee River basins.	5 to >100	Rapid melting of dense snowpack and rainfall. Kankakee River levee broke. Damage in Fort Wayne, $51 million.
Drought.	Dec. 1986–present	Statewide	Unknown	Ongoing. Nationwide attention. Affecting agriculture, water supply, and electric-power generation.

tucky also contributed large quantities of runoff. Seventy-seven people lost their lives, and more than 200,000 were forced to evacuate their homes as a result of the January-February 1937 flood. Problems of shelter, food, and drinking water were critical. Martial law was declared for the first time in the State's history throughout southern Indiana to control and systemize the work of rescue and relief.

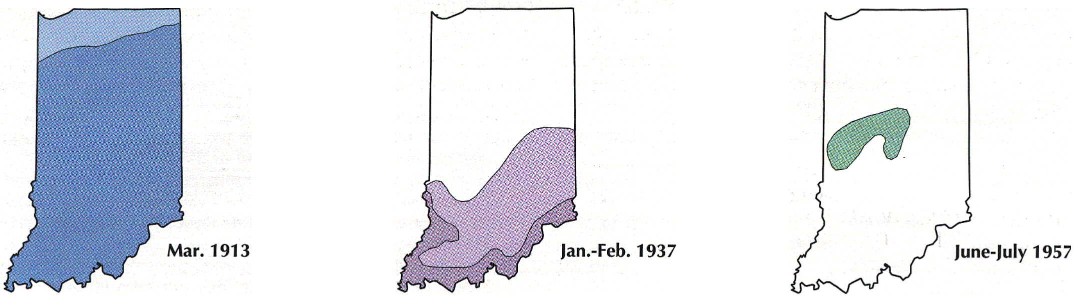
Lawrenceburg was completely inundated by the flood, and many houses were destroyed and industrial plants damaged. Most of the 6,000 residents were evacuated. Jeffersonville also suffered severe loss. Most of the city was submerged, and many buildings collapsed or were overturned. Damage also was great at smaller towns along the Ohio River. After the flood, Leavenworth was rebuilt as a new town on higher ground, and the former site was abandoned. Water began flowing into the low-lying parts of Evansville on January 20. By the time the flood crested on January 31, one-half of the city was under water. A number of business buildings and residences collapsed or were greatly damaged. Drinking water was imported following failure of the water filtration plant.

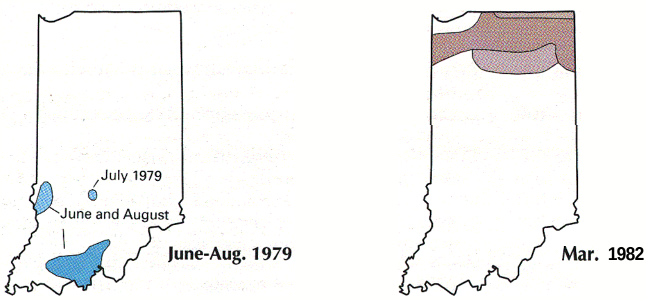
The flood on the main stem of the Ohio River was so severe that it overshadowed other flooding in January 1937; however, the Wabash, White, East Fork White, and Patoka River basins, as well as Ohio River tributaries, also experienced extreme flooding. For example, the maximum flood stage on the Blue River near White Cloud (fig. 3, site 2) exceeded that of March 1913. In the Wabash River basin, flooding damaged towns, highways, and farm property. On the White River and East Fork White River, maximum flood stages were somewhat below those of the 1913 flood, although the 1937 flooding was more prolonged. The Patoka River reached a flood stage equal to that of 19 13 at some locations.

The floods of June-July 1957 exceeded those previously known on some tributaries to the White and Wabash Rivers. Intense rains of as much as 10 inches on June 27-28 were produced when remnants of Hurricane Audrey reached a weather front located across central Indiana. Especially affected were the Eagle Creek and Raccoon Creek basins. For example, Whitestown in the Eagle Creek basin received almost 8 inches of rain in 12 hours. The June-July 1957 floods resulted in 6 lives lost, 1,282 dwellings damaged, dozens of highway and railroad bridges washed out, and 125 businesses and a million acres of cropland flooded (Schoppenhorst, 1958).

Most tributary streams in the central White and Wabash River basins flooded during June-July 1957. Flooding was especially severe in the Eagle Creek basin, which drains western Indianapolis. The peak flood stage on Eagle Creek at Indianapolis was 0.4 foot higher than that of the flood of 1913. The peak discharge of the 1957 flood had a recurrence interval greater than 100 years. As a result of the flood, Eagle Creek Reservoir was constructed in 1969 to prevent or decrease future flood damage in the basin. On Raccoon Creek,

Areal Extent of Floods





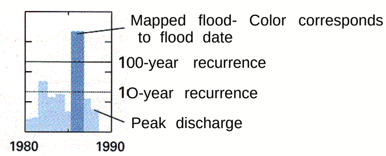
EXPLANATION

Areal extent of major flood

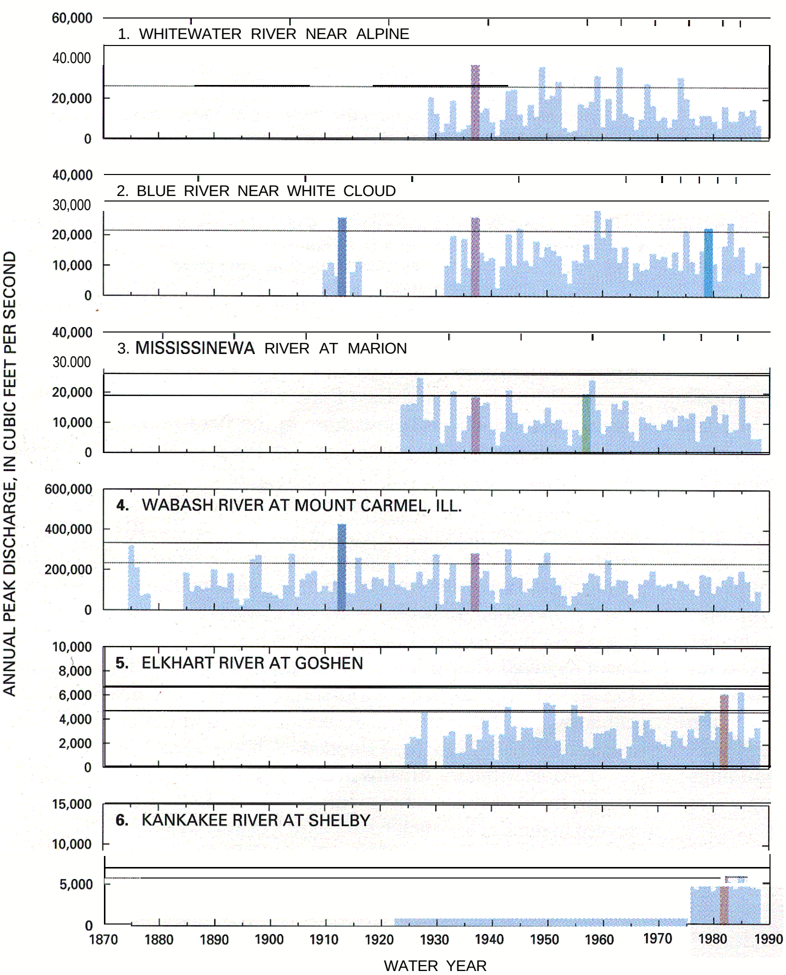
Recurrence interval, in years

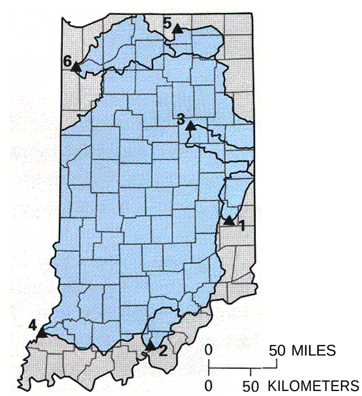
25 to 50	More than 50	
		Mar. 1913 (water year 1913)
		Jan.-Feb. 1937 (water year 1937)
NONE		June-July 1957 (water year 1957)
		June-Aug. 1979 (water year 1979)
		Mar. 1982 (water year 1982)

Annual stream peak discharge



Peak Discharge





U.S. Geological Survey streamflow-gaging stations and corresponding drainage basins — Numbers refer to graphs

Figure 3. Areal extent of major floods with a recurrence interval of 25 years or more in Indiana, and annual peak discharge for selected sites, water years 1875-1988. (Source: Data from U.S. Geological Survey files.)

the flood stage at Mansfield was 0.3 foot higher than that of the July–August 1875 flood, according to local residents. The peak discharge during the 1957 flood on Raccoon Creek had a recurrence interval of greater than 100 years. Construction of a flood-control project on Raccoon Creek (Cecil M. Harden Lake) had been started in September 1956, but because it was unfinished at the time of the flood, the project had little effect on the flood peak.

Major flooding resulted from three storms during June-August 1979—one in June and two in July-centered primarily in central and southern Indiana. State Civil Defense authorities estimated damage at $50 million (Gold and Wolcott, 1980).

The first storm, during June 8-9, 1979, resulted from a cold front that extended from central Illinois, through northwestern Indiana, and into central Michigan. Total precipitation from thunderstorms June 8-9 was in excess of 10 inches in parts of southwestern Indiana, particularly in the Patoka River basin. In general, the annual maximum discharge for most streams in the area was not during June 1979, although several small towns were flooded. The saturated condition of the soil following the June flood, however, contributed to the extreme flooding in July and August.

Rain from the remnants of Hurricane Bob resulted in the second major storm during the summer of 1979. Rainfall in southern Indiana began during the early morning of July 12 and continued throughout the day. As the low-pressure storm center associated with the downgraded hurricane tracked along the southern boundary of Indiana, moderate rain continued. Rainfall was more than 5 inches July 12-14 in parts of southwestern, central, and eastern Indiana. Localized flooding resulted from the excessive precipitation, particularly on small streams near Bloomington and Indianapolis.

The third and most destructive storm in the summer of 1979 resulted from the combined effect of a stationary weather front and the remnants of Hurricane Claudette. A line of thunderstorms produced intense rainfall that caused flash floods in three counties in southwestern Indiana. Total rainfall of as much as 9 inches was recorded at many locations. Flooding associated with the July 25–28 storm was greatest in the Busseron Creek and Patoka River basins and on Ohio River tributaries downstream from Louisville, Ky. Most affected were the towns of English, Marengo, and Milltown, where more than 500 people were evacuated. The recurrence interval of the maximum discharge during the 1979 floods on most small streams in this area was greater than 100 years.

In March 1982, rapid melting of a snowpack containing 2 to 6 inches of water equivalent, coupled with moderate rainfall, caused major flooding across northern Indiana (Glatfelter and Chin, 1988). Major tributary and main-stem flooding occurred in the Wabash, St. Joseph, Kankakee, and Maumee River basins. Peak discharges in March 1982 on streams in each of these basins had recurrence intervals of 100 years or greater. Five counties were declared Federal disaster areas. In Fort Wayne, flooding of the Maumee River and its tributaries damaged 1,500 homes and 100 businesses, forced the evacuation of 9,000 people, and caused $51 million in damage (Glatfelter and Chin, 1988). Flooding of the Kankakee River and its principal tributary, the Yellow River, caused considerable damage in three counties in northwestern Indiana. Breaks in the levees and backwater on tributaries flooded thousands of acres of cropland.

The March 1982 flooding in the Wabash River basin was confined to major tributaries draining from the north: the Little, Eel, and Tippecanoe Rivers. Recurrence intervals for the floods on these rivers ranged from 20 to 100 years.

The stage or discharge in March 1982 on many streams in the St. Joseph River basin exceeded that of the flood of April 1950, which was the largest flood in this basin for the period of record. For example, the highest stage and largest discharge on the Elkhart River at Goshen (fig. 3, site 5) for 1932-82 were recorded in March 1982. About 1,100 lakefront properties in northeastern Indiana were flooded in March 1982 by lake levels in the Pigeon Creek chain of lakes that were l-2 feet higher than those in April 1950.

The March 1982 flooding in the Maumee River basin was the worst since the historic flood of March 1913, particularly on the St. Joseph River and its principal tributary, Cedar Creek, which drain the northern one-half of the basin. Peak discharges on both streams had recurrence intervals of 50 to greater than 100 years. The St. Marys River, which drains the southern one-half of the basin, joins the St. Joseph River at Fort Wayne to form the Maumee River. Flooding on the Maumee River downstream from the confluence was caused not only by the magnitude of the peak stage and discharge on the St. Marys River, Cedar Creek, and the St. Joseph River, but also by the timing of the peaks. The peak flood stage on the Maumee River at Fort Wayne in March 1982 was only 0.2 foot lower than during the flood of March 1913. The flooding was compounded because the river remained above flood stage from March 12 through March 26. This prolonged high stage saturated and strained the levees protecting Fort Wayne.

Flooding in March 1982 also was widespread on the Kankakee River and its major tributary, the Yellow River. Damage caused by flooding on the Yellow River was extensive, particularly in the community of Plymouth. Peak discharges on the Yellow River had recurrence intervals greater than 100 years and have been exceeded during the period of record only by the flood of October 1954 (table 1). In March 1982, the Kankakee River rose slowly but steadily along the entire reach bordered by levees. Recurrence intervals of 100 years or more have been estimated for the peak discharges at most locations. For example, the highest stage and discharge on the Kankakee River at Shelby (fig. 3, site 6) for 1923-88 were recorded in March 1982. Although high flood stages on the Kankakee River and the associated backwater flooding on tributaries caused serious problems, flooding became most severe after breaks developed in the levees along the river and its tributaries. Floodwaters flowing through the breaks inundated roads and farmland and damaged homes in many communities.

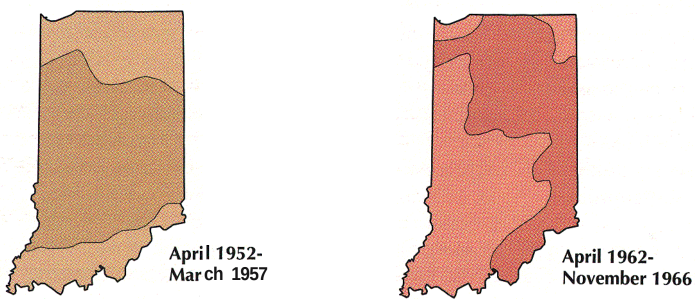
DROUGHTS

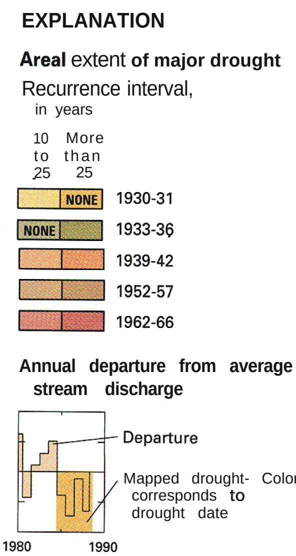
Dry-weather periods that are characteristic of Indiana summers can have adverse effects on the agricultural economy of the State. These periods can last from a few weeks to many months. Data from 24 gaging stations were used to map the extent, duration, and severity of five droughts in Indiana (fig. 4). Graphs of departure from average streamflow and the location of the drainage basin for six selected gaging stations also are shown in figure 4. Of the many droughts that are evident throughout the period of record, six are described in this section.

The drought of March 1930–August 193 1 marked the beginning of a decade of low-flow conditions. The recurrence interval of this drought ranged from 10 to 20 years. The 7-day, lo-year discharge was reached during the drought at only one of the six selected gaging stations-the Whitewater River near Alpine (fig. 4, site 1). The 7-day, lo-year discharge is an annual minimum 7-consecutive-day discharge which, on average, will not be exceeded more than once in every 10 years at a particular gaging station. It is indicative of very low streamflow.

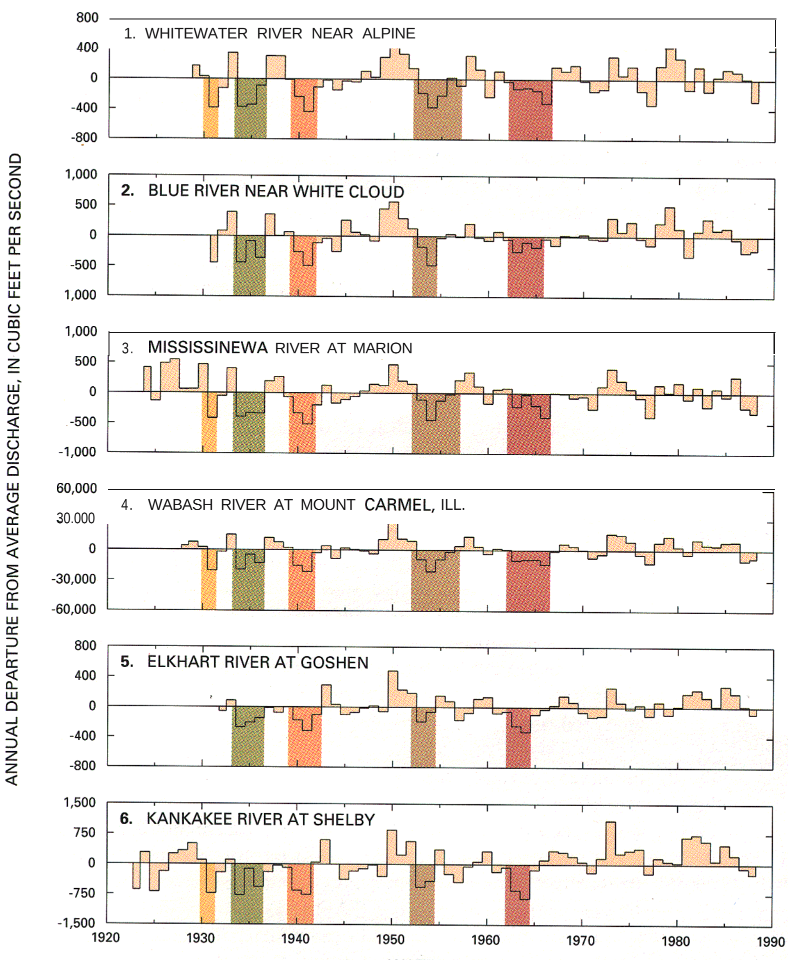
The drought of June 1933–September 1936 had a recurrence interval that ranged from 25 to 60 years. For the 24 gaging stations analyzed, the 3.3-year drought of 1933-36 was the most severe or second-most severe for the period of record. In northern Indiana, the breaks between the 1930–31, 1933-36, and 1939-42 droughts are difficult to discern. For example, annual-departure data for the Kankakee River at Shelby (fig. 4, site 6) indicate only 1 year between 1930 and 1942 (water year 1933) having greater than normal streamflow. Seven-day average discharges less than the 7-day, lo-year value were recorded during the drought on the Whitewater River near Alpine (fig. 4, site 1), the Wabash River at Mount Carmel, Ill. (fig. 4, site 4), the Elkhart River at Goshen (fig. 4, site 5), and the Kankakee River at Shelby (fig. 4, site 6).

Areal Extent of Droughts





Annual Departure



U.S. Geological Survey streamflow-gaging stations and corresponding drainage basins — Numbers refer to graphs

Figure 4. Areal extent of major droughts with a recurrence interval of 10 years or more in Indiana, and annual departure from average stream discharge for selected sites for water years 1923-88. (Source: Data from U.S. Geological Survey files.)

The drought of May 1939–January 1942 was particularly severe in central Indiana. The recurrence interval of the drought was about 60 years, on the basis of data from the Wabash River at Mount Carmel, Ill. (fig. 4, site 4), which drains this part of the State. In southeastern and extreme northern Indiana, the drought had a recurrence interval of about 20 years. All six gaging stations recorded a 7-day average discharge during the drought equal to or less than the 7-day, 20-year value.

A prolonged drought occurred April 1952–March 1957. Ironically, northern Indiana was affected by a major flood in October 1954, halfway through the drought. After the flood, precipitation was sufficient to maintain normal streamflow and effectively overcome the drought in northern Indiana. Annual-departure data for the Elkhart River at Goshen (fig. 4, site 5) and the Kankakee River at Shelby (fig. 4, site 6) show the effect of the October 1954 (water year 1955) flood as greater than normal streamflow in 1955. The annual-departure data for the Blue River near White Cloud (fig. 4, site 2) show that streamflow in extreme southern Indiana also increased during this period. However, less than normal streamflow continued in the rest of Indiana until 1957. Seven-day average discharges less than the 7-day, lo-year value were recorded at least once during the first 3 years of this drought at five of the six gaging stations. Only the Mississinewa River at Marion (fig. 4, site 3) did not have a 7-day average discharge less than the 7-day, IO-year value. Data for the Blue River near White Cloud (fig. 4, site 2) show the occurrence of this low-flow condition for 3 consecutive years.

The most severe statewide drought in Indiana was that of April 1962–November 1966 (water year 1967). This drought was particularly severe in parts of northern Indiana, although it eased somewhat from January 1965 through November 1966. Annual-departure data for the Elkhart River at Goshen (fig. 4, site 5) and the Kankakee River at Shelby (fig. 4, site 6) show that the severity of the drought in northern Indiana decreased following 1964. Annual-departure data for the Wabash River at Mount Carmel, Ill. (fig. 4, site 4), show no years of greater than normal streamflow during the drought. Seven-day average discharges less than or equal to the 7-day, lo-year value were recorded in 2 separate years during the drought on the Blue River near White Cloud (fig. 4, site 2), the Elkhart River at Goshen (fig. 4, site 5), and the Kankakee River at Shelby (fig. 4, site 6) and once at the Wabash River at Mount Carmel, Ill. (fig. 4, site 4). Severe flooding occurred in March 1963, March 1964, and April 1964 in central and southern Indiana, as the same weather patterns that caused the drought also slowed the passage of storms.

A combination of less than normal precipitation and greater than normal temperature caused a drought beginning in December 1986 in Indiana and other Midwestern States that has received nationwide attention. Because the drought is ongoing (1988). a recurrence interval cannot be determined. Seven-day average discharges at the six gaging stations did not reach the 7-day, lo-year value during 1988, but annual streamflow was less than normal in 1988 at all six gaging stations (fig. 4). Major water users who were particularly affected by the drought included public water-supply systems, power-generating stations, and farmers.

WATER MANAGEMENT

Indiana manages its water resources through a comprehensive regulatory program. The responsibility for administration of this program rests with the Natural Resources Commission, the Water and Mineral Resources Council, and the Department of Natural Resources, Division of Water. Through this program, the State ensures that its water resources are used for the maximum benefit of its citizens, both now and in the future.

Flood-Plain Management.-Flood-plain management is a major component of the regulatory program. Goals include a decrease in the risk to life, property, and general welfare from flooding and the conservation and protection of the unique natural resources found in and along the State's rivers, lakes, and streams. To achieve this goal, Indiana has enacted several regulations.

The cornerstone of the flood-plain-management program is the 1945 Indiana Flood Control Act. This law prohibits new residential construction in floodway areas and requires prior Natural Resources Commission approval for nonresidential construction, excavation, or filling projects in floodway areas, as well as approval for all flood-control projects. To be acceptable, a project must be designed so that it will not adversely affect or unduly restrict the floodway, will not be unsafe to life and property, and will not be unreasonably detrimental to fish, wildlife, or botanical resources.

The Indiana Flood Control Act gives the Natural Resources Commission authority to establish minimum standards for local flood-plain ordinances. Local flood-plain ordinances have been adopted in about 300 flood-prone communities around the State.

Flood-Warning Systems.-River Forecast Centers in Cincinnati, Ohio, and Minneapolis, Minn., develop and disseminate flood forecasts for most of Indiana. Other responsibilities include providing information such as general river forecasts, reservoir-inflow forecasts, water-supply outlooks, spring-flood outlooks, and various types of flash-flood guidance for navigation, water supply, and other interests. The major objectives of the program are to protect lives, to decrease property damage, and to contribute to the maximum use of water resources.

Flood forecasts are developed by a hydrologic-forecast computer model on the basis of river stage and discharge and observed and forecasted rainfall, snow, and temperature data. The time and height of flood crests at forecast points on large streams (drainage areas greater than 100 square miles) and general small-stream flood watches and warnings are issued to the general public on radio and television.

Water-Use Management During Droughts.-With the enactment of the Water Resources Management Act in 1983, Indiana has one of the most comprehensive water-management programs in the region; however, the issue of droughts has not been explicitly addressed in the Act. The provisions of the law call for establishment of minimum streamflow and ground-water levels, inventory of significant users of surface and ground water, and assessment of the availability of the State's water resources. An additional regulation, adopted in 1985, addresses the problem of excessive water-level drawdown caused by large-capacity wells. This regulation protects nearby domestic wells by the declaration of temporary ground-water emergencies.

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