discharges recorded at stream gages (table 15) have recurrence intervals greater than 100 years.

For a given flood frequency, a relation between peak discharge and drainage area can be developed to allow the estimation of discharges at ungaged sites within a watershed, or within other watersheds having similar basin characteristics. Figure 32 illustrates the relationship between peak discharge and drainage area for the Kankakee, Yellow and Iroquois Rivers.

The unusually low flood flows on the Kankakee River are evident in figure 32. For example, a site on the Kankakee River with a contributing drainage area of 150 square miles has an estimated 100-year flood discharge of approximately 950 cubic feet per second. At a comparable site on the Yellow River, the 100-year flood is about 2750 cfs. On the Iroquois River, the 100-year flood for this drainage area is about 2075 cfs.

The curves in figure 32 also show that although peak flows on the Yellow River typically exceed those on the Iroquois River for comparable drainage areas, flood discharges increase more rapidly downstream on the Iroquois River. The greater variability of flood peaks on the Iroquois River probably is the result of the more rapid overland runoff from clayey or silty soils, and the limited amount of overbank storage in the Iroquois River valley.

Floodplain management

Since the Kankakee River Basin was first settled in the 1800s, public and private agencies have expended billions of dollars to improve drainage and control flooding. Although most methods of floodplain management historically have involved channelization, ditching, dredging, levee construction, and land-treatment measures, increasing emphasis is being placed on floodplain regulation and non-structural alternatives, such as land-use regulations, flood insurance, floodproofing, flood warning, and flood damage relief.

A report by Grady and Rutledge (1982) describes floodplain management measures and various aspects of land-use planning for Indiana communities. Detailed floodplain management reports and flood insurance studies are available for most counties of the Kankakee River Basin. Most of these reports have been prepared by cooperative efforts of the U.S. Department of Agriculture (Soil Conservation Service), the Federal Emergency Management Agency, the State of Indiana (Department of Natural Resources), soil and water conservation districts, planning commissions, and other local agencies.

Existing floodplain management regulations in Indiana are governed by a combination of statutory laws at both the state and federal levels. In brief, the state establishes minimum standards governing the delineation and regulation of flood hazard areas. Moreover, the 1945 Indiana Flood Control Act (I.C. 13-2-22) prohibits construction, excavation, or the placement of fill in a floodway without prior approval from the Natural Resources Commission.

The Indiana Department of Natural Resources, Division of Water administers the flood control law and also acts as the state coordinator of the National Flood Insurance Program, which further helps to regulate the development of flood-prone lands. According to requirements of the program, new construction in a flood hazard area must be located and built in such a way that the potential for damages and loss of life is minimized.

Under this program, which is administered by the Federal Insurance Administration of the Federal Emergency Management Agency, property owners are eligible to purchase federal flood insurance if their flood-prone community adopts and enforces adequate floodplain management regulations. For properties located in the 100-year floodplain, flood insurance is a mandatory requirement for mortgage loans which are in any way federally connected.

A community can initially enter the **emergency phase** of the flood insurance program by adopting preliminary floodplain management regulations to guide new construction in flood-prone areas, which are approximately delineated on a flood hazard boundary map based on a generalized study. During the initial emergency phase, limited amounts of flood insurance become available to local property owners.

The community can then enter the **regular phase** of the program after a detailed flood insurance rate map is issued following a flood insurance study, and after local officials enact comprehensive regulations that require all new or substantially improved structures to be built in accordance with federal floodplain management criteria. Under the regular program, the full limits of flood insurance coverage become available.

Table 16 shows participation in the National Flood Insurance Program by communities within the Kankakee River Basin as of January 1990. The term "community" refers to both unincorporated and incorporated areas which have a government authority

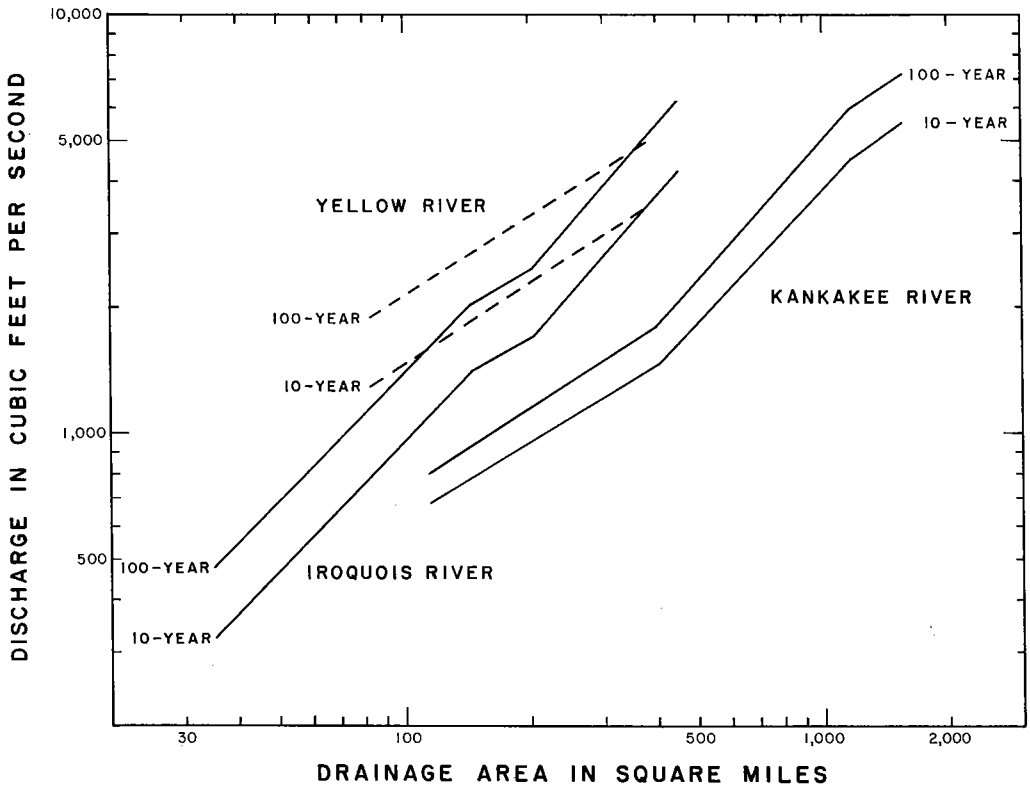

Figure 32. Relation between drainage area and flood discharge for the Kankakee, Yellow and Iroquois Rivers

(Data from Division of Water, 1988e)

Table 16. Community participation in the National Flood Insurance Program for major basin counties

{All communities in regular phase unless indicated as follows: NP, not participating; E, emergency}

County	Community
Benton (NP)	Fowler
Jasper (E)	Remington (E), Rensselaer (E), Demotte
Lake	Lowell, St. John, Schneider, Shelby[1]
LaPorte	LaCrosse, LaPorte (E)
Marshall	Argos, Bremen, Plymouth
Newton	Brook, Goodland, Kentland
Porter	Hebron, Valparaiso
St. Joseph	Lakeville, North Liberty, Walkerton
Starke (NP)	Knox (E), North Judson[2]

[1]Under county
[2]Not applicable

capable of adopting and enforcing floodplain management regulations. By virtue of this definition, an incorporated town is considered independent of unincorporated areas, which are collectively defined as a separate community.

SURFACE-WATER QUALITY

The water quality of rivers, streams and lakes can be an important factor in planning water and land development. The presence of high-quality watercourses can facilitate or enhance development by providing a surface-water source suitable for public water supply, industrial cooling, irrigation, livestock watering, recreation, or aquatic life. In contrast, watercourses containing certain toxic substances can pose a health threat to humans who consume tainted fish taken from the contaminated waters. Moreover, the value of a surface-water source for designated uses can be diminished by bacterial pollution, high levels of

nutrients, or unacceptable concentrations of inorganic and organic chemicals.

Streams

Rivers, streams and ditches in the Kankakee River Basin are used to assimilate wastewater discharged primarily from public supply and industrial facilities. A facility must treat its effluent to maintain the water quality standards established for the receiving watercourse.

The concentrations of polluting materials in these point-source effluents are regulated by the National Pollutant Discharge Elimination System (NPDES) permit program, administered in Indiana by the Department of Environmental Management. The discharge limits set in the permit are designed to protect all designated uses of the receiving watercourse.

Treated effluents discharged into streams normally require dilution to maintain water-quality requirements. Because the volume of water in streams is at a minimum during dry weather, low-flow periods are used as the basis of design for wastewater-treatment facilities.

Table 17 lists most NPDES-permitted municipal, non-municipal, and industrial wastewater-treatment facilities in the Kankakee River Basin. (Some facilities, including motels, mobile home parks, and private businesses, are not listed because of insufficient data.) Figure 29 shows the locations of the tabulated facilities and selected stream-flow characteristics of the receiving streams. The 7-day, 10-year low flow is shown because it determines the level of wastewater treatment needed to meet water-quality standards. The 1-day, 30-year low flow is an indicator of stream-flow dependability, and the average flow is a general measure of water volume in a stream.

Table 17 also shows 1) the reported water use for facilities registered with the IDNR, and 2) the estimated wastewater discharge of facilities having sufficient data. Although wastewater discharges generally approximate total water withdrawals for any given facility, discharges at some municipal facilities exceed withdrawals. In most cases, these facilities receive and treat not only their own wastewater but also wastewater from nearby communities or industries. Stormwater runoff and ground-water infiltration also are probable causes for increased wastewater discharges.

Sources of stream-quality data

The water quality of rivers and streams in Indiana is monitored by several state and federal agencies. Table 18 summarizes the types of data and years of data record for stream- quality stations in the Kankakee River Basin. The location of active and discontinued stream-quality monitoring stations can be determined from figure 29 because stream-quality sites generally are co-located with U.S. Geological Survey stream-flow gaging stations.

The Indiana Department of Environmental Management (IDEM) currently collects monthly, near-surface *grab samples* at two stream-quality monitoring stations on the Kankakee River near Kingsbury and Shelby (see figure 29). Samples are analyzed for physical parameters, chemical constitutents, and the abundance of *fecal coliform*. The IDEM also collects samples of fish tissue and streambed sediment at the two Kankakee River stations for the detection of potential contamination by metals, *polychlorinated biphenyls* (PCBs), and pesticides. In summer 1990, the IDEM conducted chemical and biological surveys of selected streams throughout the Kankakee River Basin.

Data from the IDEM studies generally are summarized in annual and biennial water-quality reports. The data are used primarily to determine water-quality trends, support pollution-abatement activities and enforcement actions, locate potential pollution sources, determine the background levels of chemical constituents, and help document Indiana's progress toward meeting goals of the federal Clean Water Act.

The Illinois Environmental Protection Agency, in cooperation with the U.S. Geological Survey, monitors stream quality at four stations in the Illinois portion of the Kankakee River Basin (table 18). Depth-integrated composite samples are collected at these stations every six weeks, on average. Results of physical, chemical and bacteriological analyses are published annually in U.S. Geological Survey water-resources data reports for Illinois. Data from these stations can be used to supplement the sparse data for the Indiana portion of the basin because most of the drainage area influencing downstream water quality lies in Indiana.

The U.S. Geological Survey is conducting a comprehensive assessment of the surface-water quality of the Upper Illinois River Basin in Illinois, Indiana and Wisconsin as part of a pilot project in the National Water-Quality Assessment Program (Mades, 1987). Some water-quality samples are being collected on the

Table 17. Wastewater discharges and water withdrawals for selected facilities permitted under the National Pollutant Discharge Elimination System

{Data compiled from unpublished files of the IDNR Division of Water and the Indiana Department of Environmental Management.}

Map number: Site locations are shown in figure 29.
Facility type and name: Facilities are municipalities except where indicated as IN, industrial and NM, non-municipal.
Total drainage area: Contributing drainage area is shown in parentheses for watersheds with non-contributing portions.
Wastewater discharge: For 1987 calendar year. Monthly data is incomplete for some facilities.
Water withdrawal: For 1987 calendar year. N/A, data not available (facility is not registered with the IDNR Division of Water).

Map no.	Facility type and site name	Receiving stream	Total drainage area	Wastewater discharge (mgd)	Water withdrawal (mgd)
UPPER KANKAKEE RIVER BASIN					
15	New Carlisle	Niespodziany Ditch	0.0	N/A	0.14
13	LaPorte	Travis Ditch	2.0	3.71	3.40
30	IN Roll Coater	Travis Ditch	10.4	0.08	N/A
8	Kingsbury Utilities[1]	Travis Ditch	53.9 (18.8)	0.29	0.60
9	Kingsford Heights	Porter Ditch	12.3	0.12	0.14
29	IN Packaging Corp of America	Echert Ditch	0	0.01	0.01
23	Westville	Crumpacker Arm	3.55 (2.19)	0.11	0.09
		Forbes Ditch	5.15 (3.77)		
35	IN Westville Correction Center	Crumpacker Arm	4.6	0.37	0.60
36	NM Potato Creek SRA	Potato Creek	11.8[7]	0.01	0.01
17	North Liberty	Potato Creek	27.7	0.18	0.24
22	Walkerton	Pine Creek	36.6 (30.0)	0.21	0.25
5	Hamlet	Donaldson Ditch	3.56	0.09	0.08
16	North Judson	Pine Creek	6.89	0.26	0.17
28	IN Northern Indiana Public Service Company	Kankakee River	1376	3.57	15.58
LOWER KANKAKEE RIVER BASIN					
4	Demotte	Evers Ditch	4.22	0.18	0
31	NM Kankakee Rest Area	UNT DeFries Ditch	0.9	0.01	N/A
34	NM Lincoln Elem. School	Hibler Ditch	1.77	—[2]	N/A
11	Kouts	Plant Township Ditch	2.20	0.18	0.17
6	Hebron	Cobbs Creek	5.12	0.24	0.32
14	Lowell	Cedar Creek	29.6	2.34	0.65
21	Schneider	Brown Ditch	21.0	0.03	0.05
YELLOW RIVER BASIN					
12	Lakeville	Shidler-Hoffman Ditch	4.20	0.09	0.08
2	Bremen	Yellow River	82.2	0.87	0.71
26	IN Del Monte Corporation	Schuh Ditch	3.46	0.07	0.18
18	Plymouth	Yellow River	294	1.37	1.57
1	Argos	UNT Meyers Ditch	0.26	0.12	0.13
		Meyers Ditch	3.6	—	—
10	Knox	Yellow River	435 (384)	0.44	0.43
IROQUOIS RIVER BASIN					
32	NM Little Co/Mary Health Fac.	UNT W. Arm Scholts Ditch	0.04	0.02[3]	N/A
27	IN Rensselaer Stone Co.	Ryan Ditch	46.4	0.81	N/A
24	IN W.C. Babcock Const. Inc.	Iroquois River	203	0.81	1.34
20	Rensselaer	Iroquois River	216	0.86	0.74
25	IN Central Soya	Carpenter Creek	22.3	0.05	N/A
19	Remington	Carpenter Creek	23.5	0.21	0.27
3	Brook	Iroquois River	479	0.07	0.07
7	Kentland	Ditch to Montgomery Ditch	1.23	0.35	0.31
		Montgomery Ditch	35.6	—	—
37	IN Capital Products Corp.	Morrison Ditch #2	4.34	0.07	N/A
33	NM North Newton Jr. & Sr. High School	UNT Beaver Creek	0.05	0.01[4]	0.01

[1]Industrial park; does not serve town of Kingsbury, which has septic system.
[2]Included in discharge of Site 33.
[3]Discharges into Upper Wabash River Basin.
[4]Includes discharge from Site 34.

Table 18. Stream-quality monitoring stations

{Additional water-quality data were collected in St. Joseph, LaPorte and Marshall Counties by Michiana Area Council of Governments (1978), and in Porter County by the U.S. Geological Survey (Bobo and Renn, 1980).}

Station name: Except for the Kingsbury station, all stations are co-located with U.S. Geological Survey stream-gaging sites shown in figure 30.

Agency: USGS, U.S. Geological Survey; IDEM, Indiana Department of Environmental Management; IEPA, Illinois Environmental Protection Agency; NAWQA, National Water-Quality Assessment Program of U.S. Geological Survey

Data type: S, suspended sediment; s, chemical analysis of sediment; P, physical; C, chemical; B, bacteriological; b, biological; f, fish tissue; R, radiological. Parameters analyzed may vary from year to year.

Station name	Agency	Data type	Period of record
Kankakee River			
near North Liberty[1]	USGS	S	1978-81
Kingsbury area[2]	IDEM	P,C,B,f,b,s	1978-
at Shelby[3]	IDEM	P,C,B,f,b,s,R	1957-
at Shelby[1]	USGS	S	1964-79
at Momence, Ill.	IEPA, NAWQA	P,C,B,b,s,S	1959-
Yellow River			
at Plymouth	IDEM	P,C,B	1971-72
at Plymouth[4]	USGS	S	1979-82
at Knox	IDEM	P,C,B,b,s	1957-70
Iroquois River			
at Rosebud[1]	USGS	S	1978-80
near Foresman	IDEM	P,C,B	1957-70
near Foresman	USGS	S	1968-80
at Iroquois, Ill.	IEPA	P,C,B	1972-
near Chebanse, Ill.	IEPA, NAWQA	P,C,B,b,s,S	1959-
Tributaries			
Cobb Ditch near Kouts[1]	USGS	S	1979-80
Singleton Ditch at Schneider[1]	USGS	S	1979-82
Sugar Creek at Milford, Ill.	IEPA	P,C,B	1978-

[1]Partial-record sediment station
[2]In Kingsbury State Fish and Wildlife Area
[3]Gaps occur in years of record
[4]Daily-record sediment station

Kankakee and Iroquois Rivers and Sugar Creek in Indiana, but most sampling sites are located in Illinois.

As part of the initial phase of the Upper Illinois River Basin study, sources of existing water-quality data were compiled and evaluated (Steffeck and Striegl, 1989; Blanchard, 1989). A low-flow synoptic survey of nutrients and dissolved oxygen was performed during drought conditions in the summer of 1988 (Terrio, 1989). The results of additional water-quality sampling projects and special studies are scheduled for publication in the early 1990s.

When complete, the Upper Illinois River Basin study will provide detailed assessments of water quality, including the description of potential water-quality trends and the investigation of relationships among selected water-quality constituents, hydrologic characteristics, and land use. Data collected from the Kankakee River at Momence and the Iroquois River near Chebanse will be compared to determine the effects of geology on the water quality of streams draining similar watersheds (Mades, 1987). This type of data for east-central Illinois should be useful in characterizing and inter-

preting water-quality data for Indiana streams in the Kankakee River Basin.

The U.S. Geological Survey, in cooperation with the U.S. Department of Agriculture's Soil Conservation Service, collected water-quality data for the Porter County portion of the lower Kankakee River watershed in 1978 (Bobo and Renn, 1980). The data were used to determine baseline water quality and evaluate environmental needs for the local watershed.

In 1977, the Michiana Area Council of Governments collected water samples from the Kankakee River and its major tributaries in Laporte and St. Joseph Counties, and from the Yellow River and its major tributaries in Marshall County. The samples were analyzed for physical and chemical parameters, and the results were used in the development of a waste-treatment management plan (Michiana Area Council of Governments, 1978).

From 1964 to 1982, the U.S. Geological Survey, in cooperation with the Indiana Department of Natural Resources, collected suspended sediment data on a periodic basis from the Kankakee and Iroquois Rivers, Cobb Ditch, and Singleton Ditch (table 18, figure 29). Daily records of sediment data were collected on the Yellow River at Plymouth for water years 1979-81. Summaries of the data are included in a report by Crawford and Mansue (1988). Erosion and associated stream sedimentation were discussed previously in the ***Physical Environment*** chapter of this report in the section entitled ***Soils***.

Assessment of stream quality

Stream quality can be evaluated by the degree of compliance with enforceable standards or recommended criteria established by state and federal agencies. Water-quality regulations for Indiana's streams and lakes are developed and administered primarily by the Indiana Department of Environmental Management. Appendix 6 lists either enforceable standards or recommended criteria for public water supply, aquatic life, livestock watering, and irrigation.

Standards for recreation are intended to protect the public from possible health risks from waterborne diseases and to maintain the aesthetic quality of a body of water. Counts of fecal coliform are used to monitor the suitability of surface waters for body-contact recreation such as swimming and wading.

As of early 1990, all streams and lakes in Indiana must meet water-quality standards for whole-body contact recreation. In previous years, most streams in Indiana, including all streams in the Kankakee River Basin, had to meet water-quality standards for partial-body contact recreation. Lakes had to meet more stringent bacterial limits for whole-body contact recreation.

Most streams and lakes in the Kankakee River Basin are designated for support of warmwater fisheries (see box on next page). Worster Lake, Potato Creek, Little Kankakee River, and Crooked Creek are put-and-take trout fisheries and are designated for support of coldwater species. Water-quality requirements to protect fish communities include criteria for pH, temperature, and concentrations of dissolved oxygen, ammonia, and *toxic* substances.

The IDEM periodically assesses potentially fishable and swimmable streams in the Kankakee River Basin to determine their degree of support of designated recreation and aquatic life uses. Assessments are based either on the evaluation of monitored biological or chemical parameters or on the assessment of land use, location of nonpoint-source pollution, and citizen complaints.

Studies by the IDEM in 1986-87 and 1988-89 revealed that roughly 80 percent of the 464 stream miles assessed in the Kankakee River Basin fully supported aquatic-life uses. About 20 percent of the stream miles, including reaches of the mainstem Kankakee River, Travis Ditch, and lower Yellow River, partially supported aquatic-life uses. These impairments were due primarily to low dissolved oxygen and high ammonia concentrations associated with inadequately treated sewage (Indiana Department of Environmental Management, [1988], [1990]). The mainstem Kankakee River did not support whole-body contact recreation uses because of fecal coliform violations (Indiana Department of Environmental Management, [1990]).

The number and frequency of aquatic-life and recreation-use impairments in streams receiving wastewater discharges are expected to decrease in the 1990s as municipalities and industries continue to upgrade existing wastewater-treatment facilities, build new facilities, and improve their treatment operations. However, water-quality problems may continue to occur in some local watersheds, particularly where facilities still do not meet their NPDES discharge limits. Construction projects, maintenance dredging,

Fisheries of the Kankakee River Basin

At least 77 species of fish are believed to exist in lakes and streams of the Kankakee River Basin, according to results of a 1986 sampling project involving 89 stations (Seegert, 1987). Forty-eight species of fish were identified in a 1981 survey of the mainstem Kankakee River (Robertson and Ledet, 1981). Fewer species were identified in a 1989 survey of the Yellow and Iroquois Rivers (Robertson, 1989a, 1989b).

Game fish constitute about 10 percent of the basin's total fish population (Robertson, 1971). Northern pike, walleye, smallmouth bass, rock bass, largemouth bass, channel catfish, bluegill, crappie, yellow perch and other game fish are caught in the basin's streams. The current state-record walleye was caught in the Kankakee River, and the state-record northern pike was taken from the Yellow River in 1983. Large numbers of suckers and redhorse are harvested from some of the basin's streams during spring spawning runs.

The Division of Fish and Wildlife stocks both warmwater and coldwater fish in selected watercourses in the Kankakee River Basin when fish population data indicate that stocked fish have a good chance of improving fishing quality. The division has stocked smallmouth bass, largemouth bass, rock bass, walleye, bluegill, redear sunfish, channel catfish, tiger muskellunge, hybrid striped bass, northern pike and crappie at various locations in the basin. Catchable-size trout are stocked annually in Crooked Creek in Porter County; in the Little Kankakee River in LaPorte County; and in Potato Creek and Worster Lake in St. Joseph County.

J.C. Murphey, Worster, Cedar, Bass, Pine, Stone and Koontz Lakes are among the larger lakes known for their warmwater fisheries. Largemouth bass, bluegill, channel catfish, crappie, redear, walleye and northern pike are popular game fish caught in these and other lakes in the basin. A fish renovation project completed in 1989 at J.C. Murphey Lake should greatly improve the fishery at this large, shallow lake located in Willow Slough Fish and Wildlife Area.

Indiana's only two coldwater fish hatcheries are located in and near the Kankakee River Basin. More than 1 million rainbow trout, mostly migratory steelhead, and coho and chinook salmon are reared annually at Mixsawbah State Fish Hatchery in LaPorte County and at Twin Branch State Fish Hatchery located just east of the basin boundary in St. Joseph County. In addition to raising trout and salmon for a Lake Michigan fishery, these two coldwater hatcheries provide trout for stocking in inland lakes and streams having aquatic habitat and water quality that is adequate to support a put-and-take trout fishery.

A warmwater fish hatchery was operated at Bass Lake in Marshall County from the 1930s to 1988. The facility raised smallmouth bass, channel catfish and other fish for stocking in selected streams and lakes throughout Indiana. Although the Bass Lake facility no longer is used for daily hatchery production, it may be used as a back-up or emergency facility.

bank clearing, and poor agricultural practices are among the activities that may cause localized, short-term sedimentation problems on some streams and ditches.

Mainstem Kankakee River Basin

Water in the mainstem Kankakee River is predominantly of the calcium-bicarbonate type and is characterized by high hardness, high alkalinity, and high concentrations of iron and manganese (figure 33). The river's water quality, as reflected by data from the Kingsbury, Shelby and Momence gages, is similar to the quality of ground water in the hydrologically connected outwash sands and gravels underyling the main valley. A detailed discussion of ground-water quality is presented in the ***Ground-Water Hydrology*** chapter of this report.

Although the Kankakee River is not a source for public water supply, the river's water quality may be compared with drinking-water standards (appendix 6) for descriptive purposes. Data from a selected 10-year period 1978-87 show that iron and manganese concentrations, which are naturally high in ground water, commonly exceeded the secondary *maximum contaminant* levels (figure 33). Concentrations of other constituents such as sulfate, chloride, barium, and trace metals generally were well below the secondary and primary (maximum) contaminant levels (appendices 6, 7).

The water quality of the mainstem Kankakee River usually is suitable for aquatic life, but occasionally high fecal coliform counts at the Kingsbury and Shelby stations impair both partial-body and whole-body contact recreation uses. Because the amount of data is limited, it cannot be determined whether the violations were caused by point sources, *combined sewer overflows*, or runoff associated with agricultural activities (Indiana Department of Environmental Management, [1988]).

The *biochemical oxygen demand* in the Kankakee River is low, indicating a limited presence of oxygen-consuming wastes in the water. Concentrations of dissolved oxygen typically are high enough to support a diverse aquatic biota, including many species of game fish (see box above). The *median* dissolved oxygen concentration of about 8.8 mg/L (milligrams per liter) is well above the 5.0 mg/L critical limit recommended for most fish life.

Fairly well-balanced *benthic* invertebrate communities were found in the mainstem Kankakee River near Hebron during a study of southern Porter County

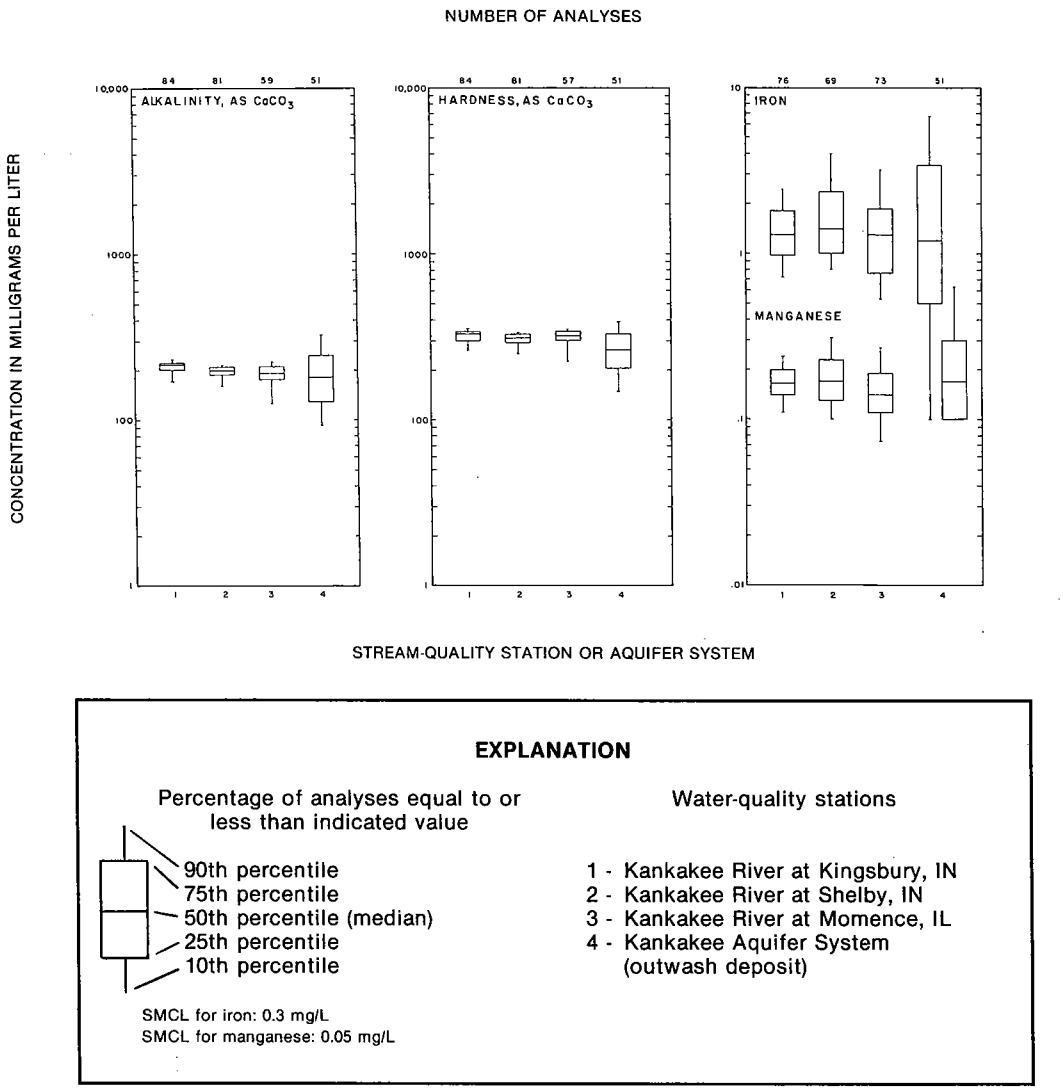

Figure 33. Statistical summary of selected water-quality constituents for stream monitoring stations on the Kankakee River and for the hydrologically connected outwash system

(Bobo and Renn, 1980). The river also supports a unique and diverse population of caddisflies, whose larval stage is completely aquatic and is an important source of fish food.

Concentrations of ammonia and several trace metals in the Kankakee River have rarely exceeded criteria for aquatic life during the period 1978-87 (appendices 6,7). However, lead concentrations in the lower Kankakee River occasionally exceeded the chronic aquatic-life criterion (Indiana Department of Environmental Management, [1990]).

Iron concentrations in the Kankakee River commonly exceeded the aquatic-life criterion during the period 1978-87. Phosphorus concentrations sometimes exceeded the limit (0.1 mg/L) recommended for prevention of nuisance algal growth in flowing water, but excessive algal populations were not reported.

Fish-tissue analyses conducted since 1979 have revealed that metals, PCBs, and pesticide levels in fish from the Kankakee River remain among the lowest in Indiana, and are well below levels that may affect human health (Indiana Stream Pollution Control Board,

1984; Indiana Department of Environmental Management, [1986], [1988], [1990]). Since the monitoring of toxics in fish tissue began in 1979, no samples collected at the Kankakee River station have exceeded *action levels* established by the federal Food and Drug Administration (FDA) for PCBs, chlordane and dieldrin in the edible portions of fish.

As discussed previously in the ***Physical Environment*** chapter of this report in the section entitled ***Soils***, sedimentation and turbidity resulting from soil erosion can adversely affect water quality. Although the Kankakee River frequently is turbid, no reports of water-quality degradation from excessive sedimentation have been documented.

Selected tributaries

Some tributaries of the mainstem Kankakee River frequently do not support aquatic-life uses, primarily as a result of discharges of inadequately treated sewage from municipal and industrial wastewater-treatment facilities. Most stream segments having aquatic-life impairment generally are less than 5 miles in length. Figure 29 shows the general locations of stream reaches where water quality problems have been documented in the last 10 years (Michiana Area Council of Governments, 1978; Indiana Stream Pollution Control Board, 1984; Indiana Department of Environmental Management, [1986], [1988], [1990]).

Perhaps the most serious water-quality problems documented in the upper Kankakee River Basin have occurred in the Travis Ditch watershed in LaPorte County. Travis Ditch receives the effluent of the LaPorte wastewater-treatment facility, the largest point-source discharge of municipal wastewater in the Kankakee River Basin (see table 17). LaPorte's effluent has had demonstrated toxicity problems, possibly due to metals, surfactants, and dissolved solids (Indiana Department of Environmental Management, [1988]). Moreover, equipment failures at the facility recently have resulted in ammonia and copper violations (Indiana Department of Environmental Management, [1990]).

Travis Ditch also receives waste discharges from several industries in the Kingsbury area, one of which has frequently violated its NPDES discharge limits and has produced an effluent with demonstrated toxicity (Indiana Department of Environmental Management, [1986], [1988], [1990]). During the IDEM's 1988-89 survey period, sediments in Travis Ditch were found to contain metal concentrations considerably above background levels (Indiana Department of Environmental Management, [1990]). The recent expansion of the LaPorte municipal sewage-treatment plant and the implementation of enforcement proceedings against the industry are expected to improve local water quality in Travis Ditch.

Another industry located in the Kingsbury area was identified as a potential source of dioxin contamination related to herbicide production. However, extensive soil sampling by the U.S. Environmental Protection Agency in 1984 revealed no traces of dioxin on the property; hence, the risk of dioxin contamination in the Kankakee River from this source is extremely low (Indiana Department of Environmental Management, [1986]).

In the lower Kankakee River Basin, chronic water-quality problems have been documented in the Crooked Creek watershed in Porter and western LaPorte Counties (figure 29). In past years, discharges of inadequately treated sewage were the probable cause of aquatic-life impairments in segments of Crooked Creek and two tributaries, Crumpacker Arm and Forbes Ditch (Indiana Department of Environmental Management, [1988]). Oil spills and inadequate wastewater treatment at a formerly operating oil company created additional water-quality violations in Crumpacker Arm during the 1980s. Moreover, streambed sediments in several parts of the Crooked Creek watershed were found to be contaminated with PCBs and pesticides such as DDT, dieldrin and chlordane (Bobo and Renn, 1980; Indiana Department of Environmental Management, [1986]).

An expanded treatment system at the former oil company, the remedial dredging of contaminated streambed sediments in Crumpacker Arm, and operational changes at the Westville sewage-treatment plant have helped to improve some aspects of the water quality in this local watershed (Indiana Department of Environmental Management, [1986], [1988]). During the IDEM's 1988-89 survey period, Crumpacker Arm, Forbes Ditch and Crooked Creek fully supported aquatic-life uses (Indiana Department of Environmental Management, [1990]).

Low dissolved oxygen and high ammonia concentrations sometimes impaired aquatic-life uses in Cedar Creek downstream of Lowell and Lake Dalecarlia in Lake County during the mid-1980s (Indiana Department of Environmental Management, [1988]).

Undesirably low dissolved oxygen concentrations in Cedar Creek also were documented during an IDNR fisheries survey (Robertson, 1971).

The town of Lowell, which treats its own wastewater in addition to wastewater from the town of Cedar Lake, recently has eliminated raw sewage bypasses into Cedar Creek and has constructed ammonia-removal facilities (Indiana Department of Environmental Management, [1990]). These improvements, plus the recent construction of a new wastewater-treatment facility at Lake Dalecarlia, should help alleviate water-quality problems in the Cedar Creek watershed. In the 1988-89 survey period, Cedar Creek fully supported aquatic-life uses (Indiana Department of Environmental Management, [1990]), indicating an improvement in local water quality since previous surveys.

Yellow River Basin

Although few water-quality problems have been documented on the upper Yellow River in the past 10 years (1978-87), frequent fish kills and other violations of aquatic-life criteria (appendices 6, 7) have occurred on the lower 25 miles of the river. Many water-quality problems on the Yellow River downstream of Plymouth have been attributed to sewage bypasses, combined sewer overflows, and inadequately treated effluents from the municipal wastewater-treatment facility and several major industries that discharge their wastes into the municipal sewer system.

High fecal coliform counts, high concentrations of ammonia and metals, and low concentrations of dissolved oxygen are among the water-quality problems that have been documented downstream of Plymouth (Michiana Area Council of Governments, 1978; Indiana Department of Environmental Management, [1988]). Effluents from several industries and the Plymouth wastewater-treatment plant have contained high oil and grease concentrations, high biochemical oxygen demand, low dissolved oxygen concentrations, occasionally high temperatures, and wide and rapid fluctuations in pH (Indiana Stream Pollution Control Board, 1984).

Although legal actions were taken against Plymouth and the industries during the 1980s for water-quality violations, the recent expansion of the Plymouth sewage-treatment plant, the elimination of eight bypass points, and the continued use of an industrial pretreatment program have alleviated some of the water-quality problems in the lower Yellow River (Indiana Department of Environmental Management, [1988], [1990]).

Eagle Creek, Craigmile Ditch, Wolf Creek, and other tributaries in the Yellow River Basin fully supported designated uses in a 1986-87 study (Indiana Department of Environmental Management, [1988]). In contrast, a portion of Hoffman Ditch, which receives discharge from the Lakeville wastewater-treatment plant in St. Joseph County, is designated as a limited-use stream because instream habitat, physical conditions, and stream flow are insufficient to support well-balanced aquatic communities.

Iroquois River Basin

Because no stream-quality stations currently are operating in the Iroquois River Basin, Indiana, inferences were made from data collected by the Illinois Environmental Protection Agency at two sites in eastern Iroquois County. The general location of these sites is apparent from figure 4.

The two monitoring sites in Illinois are located at the U.S. Geological Survey gaging stations on the Iroquois River at Iroquois, and on Sugar Creek at Milford. Appendix 7 summarizes selected physical and chemical parameters for these stations for the period 1978-87.

The Iroquois River, like the Kankakee and Yellow Rivers, is characterized by high iron and manganese concentrations which frequently exceed secondary maximum contaminant levels for public drinking-water supplies. (Water from the Iroquois River is not used for public supply.) Trace metals generally did not exceed secondary levels or primary standards during the period 1978-87, but occasionally high concentrations of lead have been reported at Iroquois, Illinois.

The Iroquois River, like the Kankakee and Yellow Rivers, frequently is turbid, but no reports of water-quality degradation from excessive sedimentation have been documented. Phosphorus concentrations occasionally exceed recommended limits for flowing waters, but nuisance algal growths have not been reported.

Although NPDES discharge permits occasionally have been violated at Rennsselaer and Foresman, the lower Iroquois River in Indiana fully supported aquatic-life uses in the late 1980s (Indiana Department of Environmental Management, [1988], [1990]). At Iroquois, Illinois, concentrations of ammonia and trace metals generally were below limits recommended for

aquatic life, but iron concentrations commonly exceeded its criterion.

A water sample taken from the Iroquois River near Foresman, Indiana in early 1989 contained concentrations of two pesticides in excess of acceptable limits. In contrast, levels of two herbicides were below health advisory levels (U.S. Geological Survey, 1989).

A study in Illinois (Mitsch and others, 1979) showed that water quality was not as good in the Iroquois River near Chebanse as in the Kankakee River at Momence. Although the drainage areas above the two stations are similar in size, water-quality data for 1975-76 from the Iroquois River showed higher concentrations of total phosphorus, nitrates, and ammonia. Moreover, fecal coliform counts and total dissolved solids concentrations had higher maxima in the Iroquois River than in the Kankakee River. The finer-grained soils, lesser amounts of riparian vegetation, and limited water-storage capability in the Iroquois River watershed may account for some of these water-quality differences (Mitsch and others, 1979).

Sugar Creek, a major tributary of the Iroquois River, fully supported aquatic-life uses in Indiana during 1986-87 (Indiana Department of Environmental Management, [1988]). Data from the Milford, Illinois station, however, show that concentrations of iron and some metals occasionally exceed recommended criteria for aquatic life.

A few tributaries of the Iroquois River in Indiana have segments that in past years only partially supported aquatic-life uses. Low dissolved-oxygen and high ammonia concentrations were the most common problems in these tributary reaches, which are located downstream of municipal and industrial discharge points (see figure 29). Improved NPDES compliance at Morocco and the recent expansion of the treatment facility at Remington have helped reduce water-quality impairments for aquatic life in Beaver Creek and Carpenter Creek (Indiana Department of Environmental Management, [1988], [1990]). The proposed construction of a municipal sewage-treatment plant at Goodland should improve water quality in Hunter Ditch.

A portion of the ditch downstream from the Kentland sewage-treatment plant is designated as a limited-use stream because instream habitat, physical conditions, and stream flow are insufficient to support well-balanced aquatic communities. In nearby Morrison Ditch, aquatic-life uses have been impaired due to high ammonia concentrations in an industrial effluent (Indiana Department of Environmental Management, [1988], [1990]).

Recent improvements in the industry's treatment process have reduced ammonia concentrations in its effluent and are expected to alleviate aquatic-life impairments in the ditch. New sewers and a new treatment plant in Kentland are scheduled for completion in 1990 (Indiana Department of Environmental Management, [1990]).

Lakes

The Kankakee River Basin contains more than 9000 acres (14 square miles) of open water in natural lakes and reservoirs. Because of moderate to high productivity resulting from nutrient inputs from surrounding land uses, many lakes in the basin are vulnerable to accelerated *eutrophication*. Monitoring and management programs have been aimed largely at determining the extent of eutrophy and prescribing measures to control nutrient inputs from point and nonpoint sources. The major programs are identified below.

Sources of lake-quality data

In 1970 the Indiana State Board of Health began sampling public freshwater lakes and reservoirs for physical, chemical and biological data. The goal of the sampling, now coordinated by the IDEM, was to generate a database from which a classification system could be developed for comparing lake quality and establishing a priority system for lake management and restoration. The IDEM uses 10 trophic parameters to derive a composite numerical index scaled from 0 (least eutrophic) to 75 (most eutrophic), which in turn defines a generic four-tiered classification of lakes. The lakes are further grouped by morphometric and trophic similarity into seven major lake management categories. Appendix 5 lists 46 lakes and reservoirs in the Kankakee River Basin, 40 of which have been placed in the IDEM's Indiana Lake Classification System and Management Plan.

In the mid-1980s the IDEM resurveyed a subset of lakes in the Indiana Lake Classification System, including Cedar Lake and Lake of the Woods in the Kankakee River Basin. The primary purpose of this resurvey was to detect apparent lake-quality trends by comparing trophic index numbers determined first in

the mid-1970s then later in the mid-1980s (Indiana Department of Environmental Management, [1988]).

The IDEM also samples fish tissue and sediments to assess the extent of contamination by toxic and bioconcentrating substances in lakes and reservoirs having high recreational use or a potential for contamination (Indiana Department of Environmental Management, [1988]). In the Kankakee River Basin, Cedar Lake and Lake of the Woods are part of this monitoring program.

Lake-quality management programs include the lake-enhancement program, administered by the IDNR Division of Soil Conservation, and the Indiana Clean Lakes Program, administered jointly by the IDEM and the Environmental Systems Application Center at Indiana University. The lake-enhancement program provides technical and financial help to control sediment input and associated nutrient problems in public access lakes, including Koontz Lake in the Kankakee River Basin. The Indiana Clean Lakes Program encourages participation at the local level to refine and implement plans outlined in the IDEM's Indiana Lake Classification System and Management Plan. In the Kankakee River Basin, 14 lakes were monitored in 1989 for nutrient and dissolved oxygen levels, pH, and clarity as part of the Indiana Clean Lakes Program.

Other state programs monitor lake quality for public health, recreational, or fisheries management purposes. The IDNR Division of Engineering samples water from lakes and reservoirs having state-operated public beaches, including Bass Lake, to determine violations of fecal coliform standards for swimming and wading. The IDNR Division of Fish and Wildlife conducts lake surveys in which physical, chemical and fish community data form the basis for fisheries management recommendations. The Division of Fish and Wildlife also conducts aquatic weed control and fish restoration projects to improve game fishing and enhance the recreational value of selected lakes. In the Kankakee River Basin, lake surveys or other fisheries projects have been conducted on J.C. Murphey Lake, Koontz Lake, Lake of the Woods, Riddles Lake, and Bass Lake.

On the federal level, the U.S. Environmental Protection Agency (USEPA) conducted a National Eutrophication Survey in 1973 and 1974 in which 27 Indiana lakes and reservoirs were seasonally sampled. In 1977 Purdue University resurveyed 15 of these lakes to determine changes in trophic condition. In the Kankakee River Basin, only Bass Lake was surveyed (U.S. Environmental Protection Agency, 1976a; Spacie and Bell, 1980).

The USEPA and the State of Indiana (IDNR) cooperatively administer the federal Clean Lakes Program, which provides funds for studies and management activities on publicly-owned freshwater lakes. In 1979 the Environmental Systems Application Center at Indiana University initiated a restoration feasibility study on Cedar Lake which has since come under the federal Clean Lakes Program (Echelberger and Jones, 1979, 1984).

Assessment of lake quality

The 40 major lakes and reservoirs of the Kankakee River Basin which are included in the Indiana Lake Classification System range widely in water-quality characteristics, lake *morphometry*, and management needs. Two-thirds of the lakes and reservoirs that are assigned a trophic class are of either low (Class I) or moderate (Class II) eutrophy and rarely have water quality problems that impair attainable lake uses. About 20 percent of lakes in the basin are highly productive (Class III). These lakes usually support periodic algal blooms and growth of aquatic weeds which impair one or more lake uses.

Four of the lakes in the basin are assigned a Class IV status in the IDEM's Lake Classification System. Class IV lakes have low nutrient profiles, but morphometric characteristics, advanced stages of *senescence* or dense growths of *macrophytes* contribute to an intermediate trophic index. The water quality is generally good and is characterized by high visual clarity, dissolved oxygen to the lake bottom, low *plankton* counts, and rapid nutrient uptake by macrophytes. Attainable uses of Class IV lakes include hunting, fishing, trapping, and wildlife habitat.

Although appendix 5 lists only four Class IV lakes, smaller potential Class IV lakes may exist in the basin. Remnant and oxbow lakes are scattered along the middle and lower reaches of the mainstem Kankakee River and constitute a distinctive feature of the basin. Many of the oxbows, however, are only temporarily or seasonally flooded, and therefore may not be mapped as lakes.

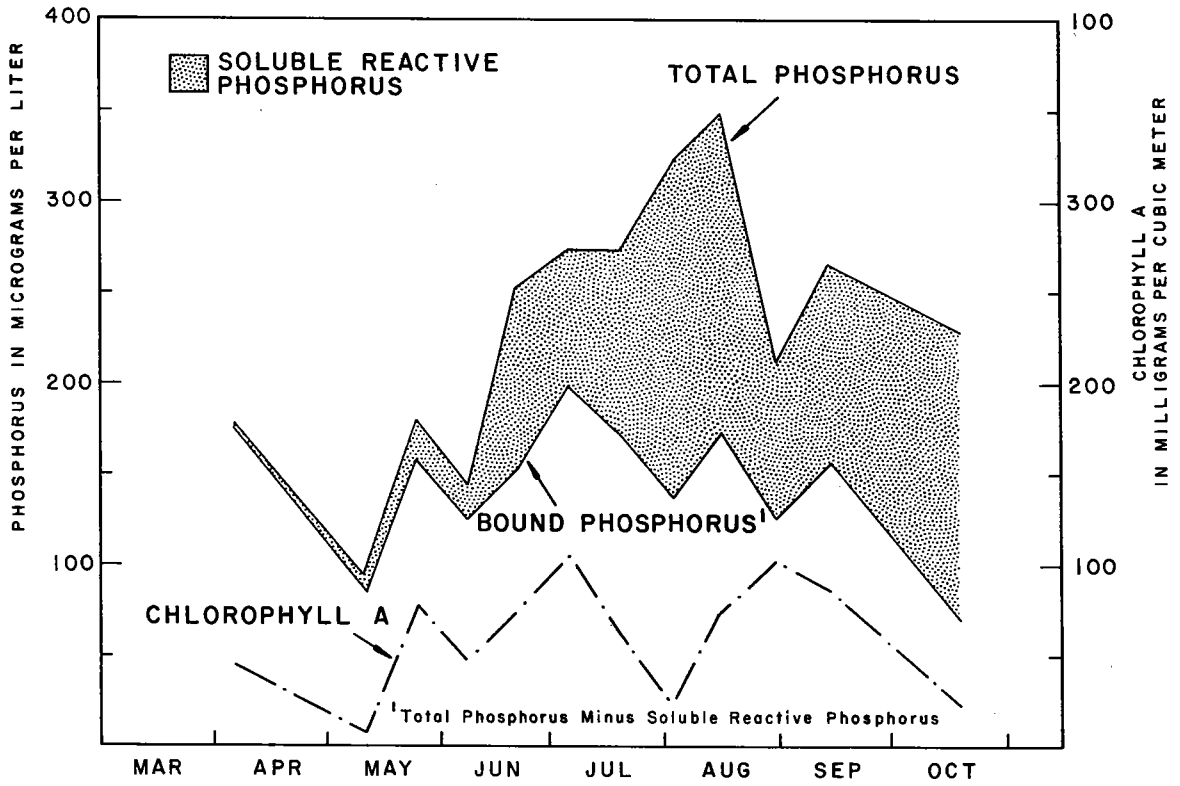

Figure 34. Phosphorus components in averaged samples for Cedar Lake, and the relationship of averaged chlorophyll *a* and bound phosphorus
(Adapted from Echelberger and Jones, 1984)

Mainstem Kankakee River Basin

The mainstem Kankakee River Basin features several lakes of high water quality. Saugany Lake in LaPorte County has unusually high visual clarity (secchi disc depth of nearly 32 feet) and the lowest trophic index (1) of any lake in the Indiana lake classification system. Other high-quality Class I lakes in the basin include Fishtrap, Lower Fish, Pine, and Stone Lakes.

Koontz Lake in Starke County is an intermediate-quality lake characterized by a small surface area and shallow mean depth. In recent years the lake has exhibited symptoms of accelerated eutrophication such as 1) large sediment inputs, especially during peak run off; 2) consequential shoaling in the lake, especially near the inlet of the principal tributary; 3) resuspension of sediments and associated nutrients from boating activity; 4) major expansion of weed beds impairing navigation; and 5) decline in the quality of sport fishing (Earth Plan Consultants, 1987).

In the fall of 1987 the General Assembly appropriated funds for a project on Lawrence Pontius Ditch, a tributary of Koontz Lake, to reduce sediment and nutrient input. The project, which is being coordinated by the IDNR, Division of Soil Conservation includes grade stabilization structures, bank stabilization, a sediment trap, and construction of an artificial wetland to filter nutrients. As of early 1990, the project was partially complete. A lake-enhancement project also is underway at Lake of the Woods in Marshall County.

Cedar Lake in Lake County, one of the most productive natural lakes in the Kankakee River Basin, has experienced deteriorating water quality since the 1940s. Shoreline development and associated wastewater discharges have contributed to large nutrient loadings in the lake.

In 1979 a study was initiated in response to requests by local citizens concerned about Cedar Lake's deteriorating quality (Echelberger and Jones, 1979).

During this restoration feasibility study, it was found that the lake was nitrogen-limited and that high phosphorus concentrations in the water were being maintained by release from sediments. Total phosphorus concentrations were as high as 350 ug/L (micrograms per liter) during late summer (figure 34) compared to 10-50 ug/L for unpolluted lakes. The relationship between *phytoplankton* abundance and levels of non-soluble phosphorus also is apparent in figure 34. The consequences of nutrient enrichment were nuisance algal blooms dominated by blue-green species and a fish community dominated by carp and other bottom feeders. In addition, sediment sampling in 1987 by the IDEM revealed that heptachlor concentrations were well above background levels (Indiana Department of Environmental Management, [1988]), but as yet there is no documentation of water-use impairment from any priority pollutants.

The 1979 study, now administered under the federal Clean Lakes Program, recommended a restoration program that includes a complete fisheries renovation, modification of the lake's outlet structure to prevent rough fish from re-entering, a one-time alum treatment to inactivate nutrients, and a ban on live-bait fishing (Echelberger and Jones, 1984). As of 1990, additional water-quality data is being collected through a state-funded effort.

Yellow River Basin

Myers Lake in Marshall County is a small but moderately deep natural lake. Its high water quality is attributable to high visual clarity, relatively low phosphorus, and lake morphometry. Myers Lake has also been noted for thermally stable vertical zones and for highly oxygenated conditions in intermediate depths (Eberly, 1959).

Bass Lake in Starke County has the largest surface area (1400 acres) of any natural lake in the Kankakee River Basin. Because Bass Lake is quite shallow, it lacks a *thermocline* and is naturally aerated throughout the water column. A state-managed beach provides recreational opportunities such as swimming and wading. Analysis of water samples collected by the IDNR Division of Engineering revealed that there were no fecal coliform violations for whole-body contact recreation within the last three years (1987-1989).

In a 1973-1974 survey by the U.S. Environmental Protection Agency (1976a), Bass Lake was determined to be eutrophic and phosphorus-limited. A Purdue University survey in 1977 (Spacie and Bell, 1980) revealed that Bass Lake remained trophically stable, and that its phosphorus loading was the lowest of 15 Indiana lakes examined. The phosphate ban instituted in 1972 may have helped reduce phosphate loading below levels thought to cause eutrophy.

Lake of the Woods in Marshall County is a moderately productive but trophically stable lake (Indiana Department of Environmental Management, [1988]). Although sediment samples collected by the IDEM contained nearly three times the phosphorus concentration considered acceptable for the prevention of nuisance algal blooms, the actual effects on Lake of the Woods have not yet been determined.

Gilbert Lake in Marshall County is a small, very productive lake which has been assigned the highest trophic index possible (75). The high index is due largely to the water's very low clarity (secchi disc depth of 1 foot) and a phosphorus concentration which is more than eight times the recommended limit for nonflowing water. Fish kills and impairment of most uses were documented in the mid-1980s and were attributed to heavy weed and algal growth. Gilbert Lake has no tributary streams and receives runoff only from the surrounding terrain and effluent from one small wastewater-treatment plant (Indiana Department of Environmental Management, [1988]).

Iroquois River Basin

J.C. Murphey Lake in Newton County is a moderately productive impoundment in the Willow Slough State Fish and Wildlife Area. Several fish eradication and selective restocking projects have been conducted at this lake since the 1960s to improve game fishing. The most recent restoration project, completed in 1989, is expected to produce an excellent fishery by the early 1990s.

Ringneck Lake in the Jasper-Pulaski State Fish and Wildlife Area is the only other major impoundment in the Iroquois River Basin. The shallow lake has a small drainage area of less than 2 square miles and has not been placed in the IDEM's Indiana Lake Classification System.