FOX RIVER

WATERSHED

INVENTORY AND ASSESSMENT

PREPARED BY

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EXECUTIVE SUMMARY

The Fox River basin is a relatively small system of streams which drains 400 square miles in northeastern Missouri and southeastern Iowa upstream of the gage station on Fox River at Wayland, Missouri. Average annual discharge at the gage station is 258 cubic feet per second. The four largest streams in the basin are Fox River (52 miles long in Missouri), Little Fox River (24 miles in Missouri), Honey Creek (36 miles), and Sugar Creek (16 miles). Stream gradients average 3.0 feet per mile on Fox River, 5.0 feet per mile on Little Fox River, 6.7 feet per mile on Honey Creek, and 13.2 feet per mile on Sugar Creek.

Approximately 20% of basin stream mileage is channelized. While the Fox River itself is virtually unaltered, channelized reaches comprise 49% of Little Fox River, 41% of Sugar Creek, and 28% of Honey Creek.

Sedimentation is the only significant form of water pollution in the basin, but it threatens the integrity of the entire ecosystem. In 1984, the watershed was 63% cropland, 16% grassland, and 20% timber. The USDA Soil Conservation Service estimated that annual sediment delivery to the Fox and Wyaconda rivers averaged 3 tons per acre from the 483,780 acres which comprise the combined watersheds; this ranked ninth among 45 Missouri subbasins in rate of sediment delivery to stream channels. This sediment load equates to dumping 100,000 large truck loads of earth fill into these streams annually.

We have documented a reduction in Fox River base flow between the periods 1922-1952 and 1953-1980. Hydrological problems are most probably tied to land use practices which have diminished the moisture retention capacity of basin soils. These net adverse effects have been measurable despite a 5.8% increase in basin timber between 1939 and 1984, indicating that type of vegetative cover alone may not have as significant an effect on basin hydrology as the manner in which cover types are managed. From the 1950s through the 1980s, an increasing dependency on heavy machinery and chemical methods for producing crops has compacted the soil and reduced its organic matter content, thereby reducing its capacity to retain moisture.

The largely agricultural population of Clark County is generally unaware of the adverse effects that channelization, levee construction, riparian corridor clearing, and high-impact agriculture have had on basin streams.

In 1987, a Department of Conservation survey added 16 species to the annotated list of fishes known to the Missouri portion of the Fox River basin, which now number 52. Most fishes in our 1987 samples were widespread, tolerant species.

A statewide telephone survey revealed that 67% of Fox River anglers fished primarily for channel catfish. Our 1987 fish population surveys revealed that most channel catfish (84%) were small (<11 inches). Only 18% of 11-inch-and-larger channel catfish were of "quality" size (16 inches). We suspect that there is insufficient depth and current during much of the year to provide habitat suitable for quality-size channel catfish; they may migrate downstream to the Mississippi River prior to the onset of low-flow conditions. We also feel that migration of adult flathead catfish may significantly influence their density at any point in time. Out 1987 survey yielded only 28 flathead catfish, most small; yet several anglers have reported catching big flatheads during high-flow periods in late spring and early summer. Before we can manage catfish populations in the Fox River basin, we must know whether exploitable stocks are stable or transient. Also, we must learn which methods and times for sampling will provide meaningful information.

Relative to other stream basins in northeastern Missouri, Fox River receives very little attention by anglers or floaters. Boating and canoeing on all tributaries and most of Fox

River is hampered by shallow water, log jams, and low base flow. Even though recreational use of basin streams seems low relative to the availability of public stream frontage, there are some unique habitats which might be enjoyed if they were accessible.

Out 25-year strategic plan for the Fox River basin contains goals for the Fisheries Management Section of the Missouri Department of Conservation to improve aquatic habitat, maintain fish species richness and increase density of large sport fish, and increase appreciation for and accessibility to basin streams.

In order to improve aquatic habitat, we should do our best to prevent additional channelization projects, implement stream corridor management plans on public areas, convince basin farmers to engage in low-input sustainable agriculture and use acceptable methods for managing their riparian corridors, and cooperate with others in maintaining base flow at or above current levels.

In order to approach our goal for fish community integrity, we propose to maintain at least 50 native species of fish and to achieve "balanced" populations of channel and flathead catfish in basin streams. An important first step will be to learn enough about catfish migration patterns and catfish population survey methods to define seasonal parameters which may indicate whether "balance" exists in prairie streams.

In order to increase appreciation for and accessibility to basin streams, we should provide public access to the most unique and scenic reaches of basin streams and ensure that all potential stream anglers and floaters have access to information about recreational opportunities at these areas. To achieve this, we propose to amend the Department of Conservation's Stream Areas Acquisition Plan, develop a brochure, and generally facilitate public awareness and involvement with basin streams.

TABLE OF CONTENTS

List of Figures

List of Tables

LOCATION

Fox River and its largest tributary, the Little Fox River, originate in southeastern Iowa. Both streams travel in a southeasterly direction before they join approximately 2.25 miles northwest of Kahoka, Missouri. In Missouri, the Little Fox River flows through northeastern Scotland County into northwestern Clark County to its confluence with Fox River, which flows through Clark County to its confluence with the Mississippi River approximately 7.5 miles southwest of Keokuk, Iowa. Major tributaries to the lower Fox River are Honey Creek and Sugar Creek. Honey Creek originates in west-central Clark County, flows southeasterly to U.S. Highway 61, then northeast to its confluence with Fox River approximately 2.5 miles southeast of Alexandria, Missouri. Sugar Creek originates near Kahoka and flows southeastward to its confluence with Honey Creek in southeastern Clark County (Figure 1).

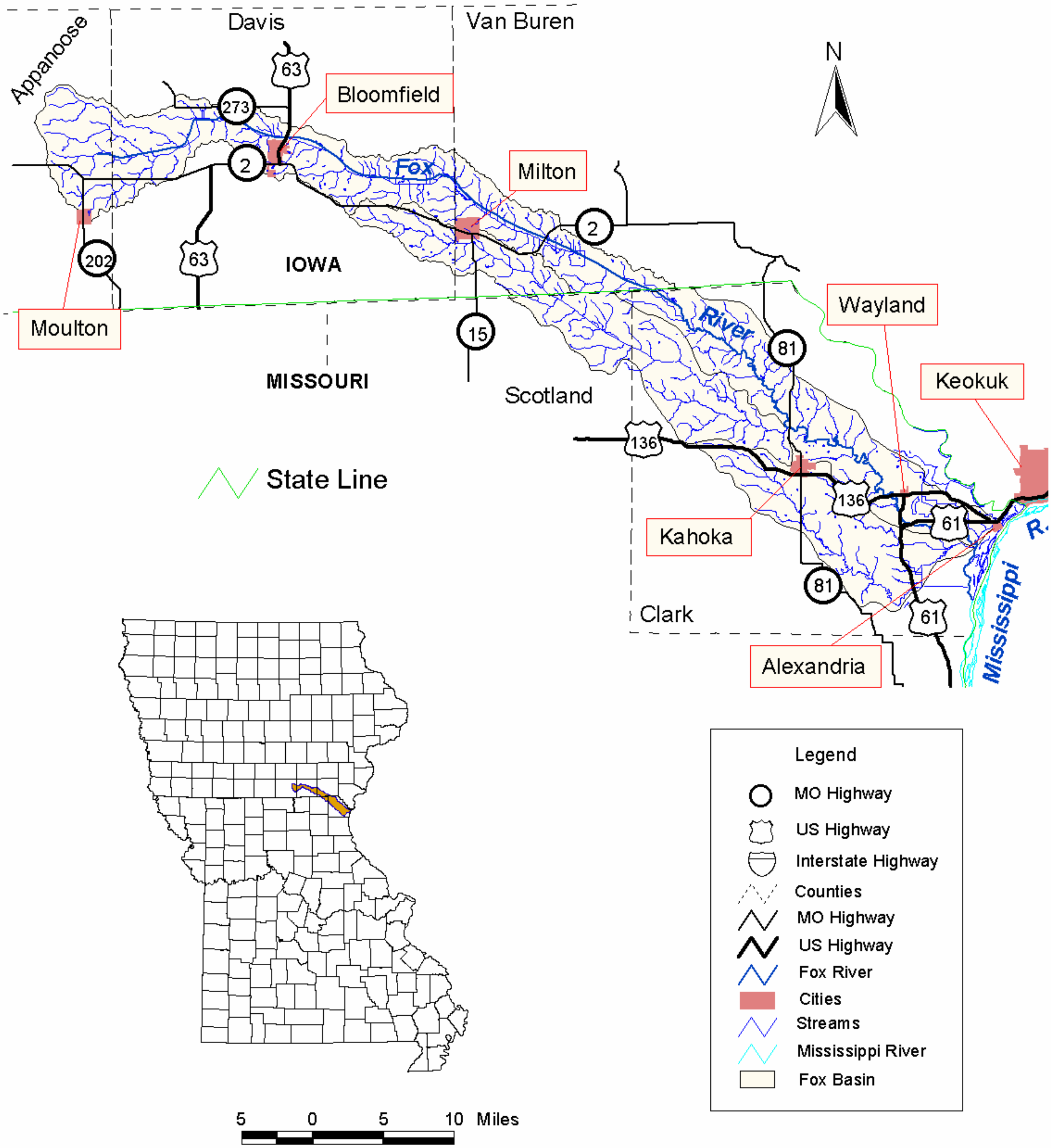


Figure 1. Location of the Fox River watershed, in Missouri and Iowa.

GEOLOGY

Physiographic Region/Geology/Soils

The Fox River basin lies in the Eastern Section of the Glaciated Plains Natural Division (Thom and Wilson 1980) within the Dissected Till Plains physiographic region (Figure nd). This area is composed of rolling to steep glacially deposited hills over Mississippian and/or Pennsylvanian bedrock (Koenig 1961).

Surficial material of the region varies from deep loess and glacial drift in the northwest portion of the watershed, to steep, moderately deep and wooded glacial till slopes in the central and southeastern portions (Figure ge). The Mississippi River floodplain substratum consists of fine alluvium. Loess material is generally greater than 25 feet deep near the Mississippi River bluffs but thins to 4-8 feet at the western edge of the watershed (MDNR 1984, MDNR 1986).

The soils in the basin are generally characterized as a loamy-clay of loess and glacial till parent material with slow permeability and moderate to high erosion potential. Streams in the basin become turbid during intense storms but are moderately clear under normal flows.

For discussion in this plan, the basin was subdivided into physiographic landforms. The Iowa Drift Plain landform has a nearly level to rolling topography. This section of the basin was primarily prairie but has since been converted to agricultural uses. Clay subsoils with low permeability promote rapid runoff. The Kahoka Hills landform is characterized by rolling to rugged, often heavily timbered hills incised into a flat tableland.

Erosive forces have cut steep valleys in the otherwise level topography. This has allowed for a transition zone between Mississippi Valley wooded and prairie habitats. The hills are an expansion of the Mississippi River bluffs that extend along Fox River and the lower Little Fox River to northwest of Kahoka. The side slope soils are generally low in fertility, therefore, support only woodland and pastures. Upland areas, however, are intensely farmed. Streams of this region flow over limestone formations often with gravel or rock substrates. The Mississippi Alluvial Plain landform is essentially the Mississippi River floodplain. The topography is level and the soils are conducive to intensive farming. Streams in this region are of low gradient and are turbid, with sandy or silty substrates.

Stream Order

Stream orders were determined throughout the basin (Figure 3) according to Strahler (1957). Code numbers were assigned to all streams according to Pflieger (1981). Thirty-nine streams were identified in the basin as permanent, intermittent with permanent pools, or ephemeral (Table 1). F ox River is classified as an intermediate size stream at order 5. The Little Fox River and Honey Creek are the only fourth-order streams in the basin. In addition, there are seven third-order and twenty-four second-order streams. Hemp Slough is a former Des Moines/Mississippi River oxbow that empties into Fox River through a network of drainage ditches. It was not assigned a stream order.

Watershed Area

Watershed area was determined by digitizer and the computer program PADPAC for streams fourth-order and larger, and for Sugar Creek, a third-order stream. Upstream from the gage station at Wayland, Missouri, Fox River drains 400 square miles; 278 are in Missouri. Third-order and smaller tributaries draw water from 113 square miles and fourth-order tributaries drain 165 square miles in Missouri. The Honey Creek watershed is 82 square miles in which 21 square miles are drained by Sugar Creek, its largest tributary. The Little Fox River watershed encompasses 83 square miles in Missouri.

Channel Characteristics

Graphs of stream gradient for Fox River and its three largest tributaries were produced from United States Geological Survey 7.5-minute topographic maps (Figures 4a-e). Basin streams were measured and slope determined using a digitizer and the computer program MAPWORK. Average gradient and percent slope data appear in Table 2.

Fox River has a gradient of 4.50 feet/mile from its headwaters to the gage station at Wayland, Missouri. In Missouri, Fox River has an average gradient of 3.00 feet/mile. As a fourth order stream, above its confluence with the Little Fox River, the gradient averages 3.65 feet/mile. Though high gradient areas exist due to local geologic features and channelization, the river is rather uniform in gradient.

In general, Fox River occupies a wide floodplain in the northwestern and southeastern portions of the basin and a somewhat narrow floodplain in the central portion. Channel characteristics are governed by area geomorphology. In the wide floodplain areas, and where channelization has occurred, the channel is characterized by short meanders and long, shallow pools and/or sandy runs. In the Kahoka Hills, where the channel is narrower, large, hairpin meanders occur between long, straight reaches. The river varies with short to long pools separated by short, rocky riffles. Mississippian bedrock is occasionally exposed in this area.

The Little Fox River is characterized by a broad, flat floodplain and a wide sandy channel. The stream typifies an agriculturally converted prairie system with short, shallow pools and cut banks interspersed between long, shallow sandy runs. The overall gradient is higher than Fox River (4.94 feet/mile) which is partially attributable to channelization in the Drift Plain.

Honey Creek and Sugar Creek are relatively high gradient streams for northern Missouri. Both originate near the Kahoka Hills and are characterized by narrow floodplains and channels that align with steep bluffs. Honey Creek emerges on the Drift Plain in a narrow, somewhat straight channel. Oddly, long, sluggish pools with a slough-like appearance characterize that reach. The central portion has entrenched channels with gravel or rock bottoms and approximately a 1:1 pool/riffle ratio. The lower portion of Honey Creek has been channelized. Surface flow usually ceases in this reach as the water infiltrates thick deposits of accreted sand.

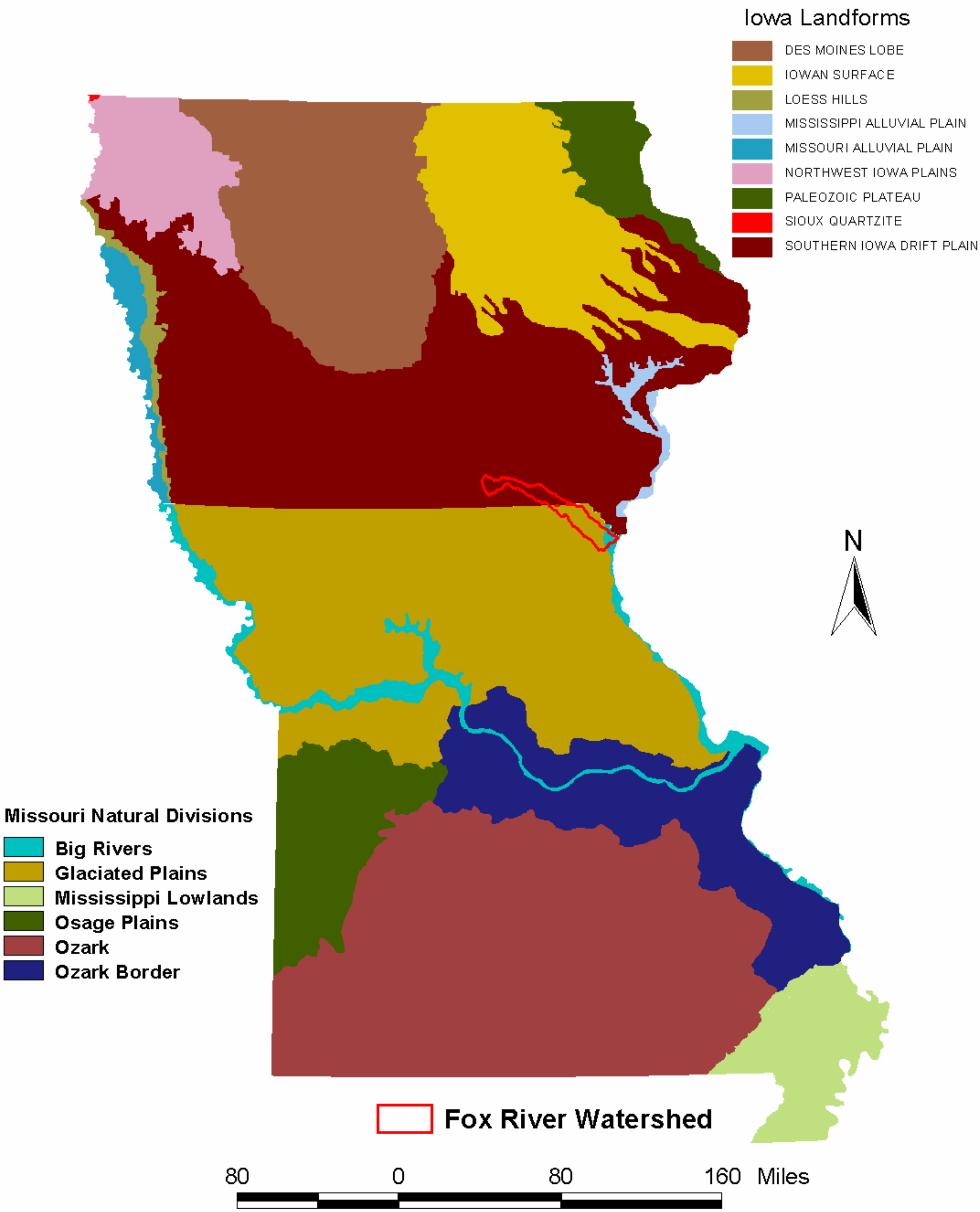


Figure nd. Location of the Fox River Watershed within the natural divisions of Missouri and Iowa.

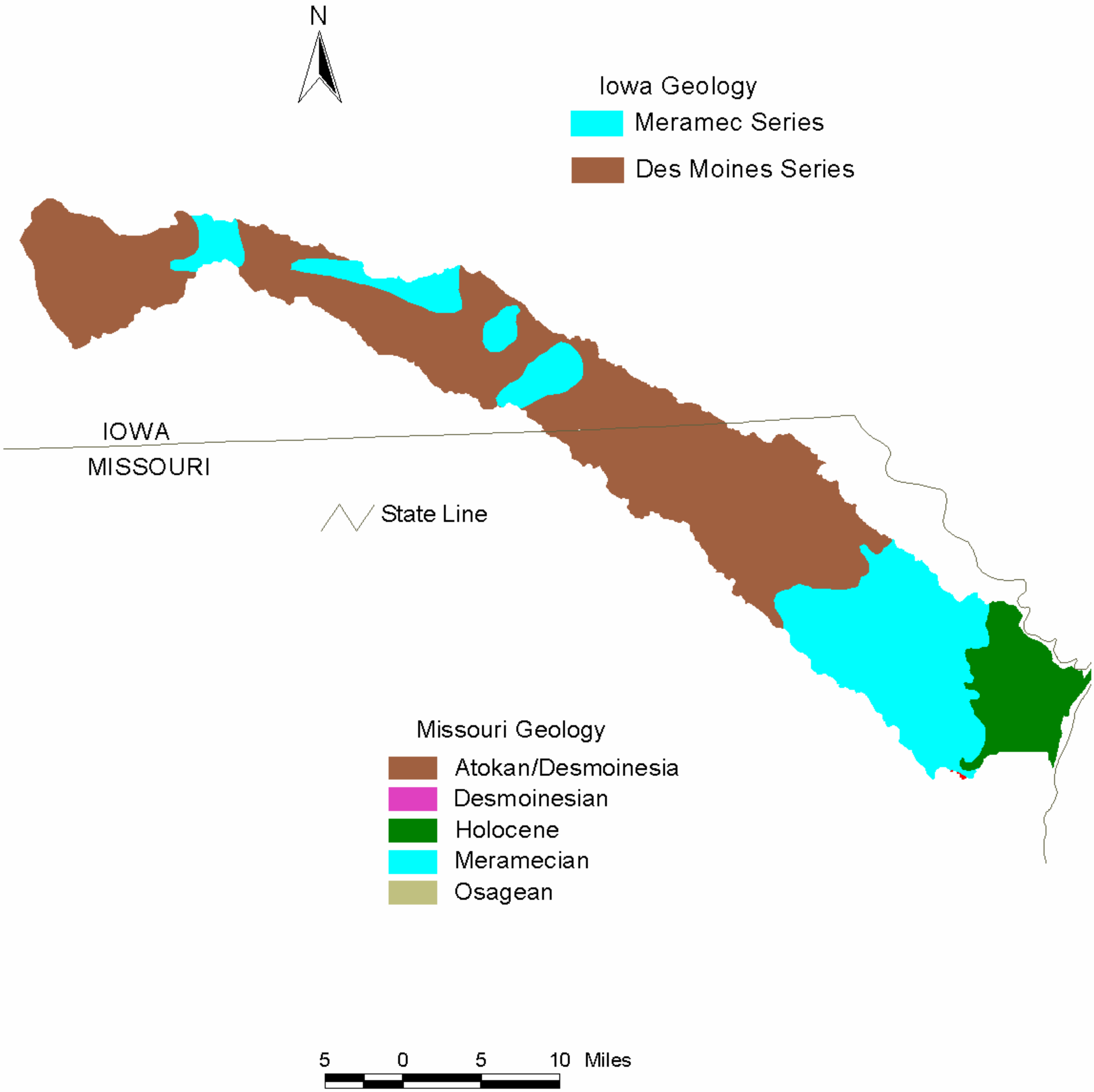


Figure ge. Geology within the Fox River watershed in Missouria and Iowa.

Table 1. Characteristics of stream channels in the Fox River Basin.

Stream Code	Stream Name	Order	County	T-R-S	Area (sq. mi.)	Miles	MiChan*	Miunch*	%Chan
37500000	Fox River	5	Clark	63-05-06	278	52.3	2.5	49.8	05
37511000	Honey Creek	4	Clark	64-05-18	82	35.8	9.9	25.9	28
37511100	Sugar Creek	3	Clark	64-06-14	21	15.7	6.3	9.4	41
37511110	Unnamed	2	Clark	65-07-33	-	1.8	0.9	0.9	50
37511200	Big Branch	2	Clark	64-06-28	-	3.3	2.0	1.3	61
37511300	Unnamed	2	Clark	64-07-36	-	2.0	0.0	2.0	00
37511400	Unnamed	2	Clark	64-07-35	-	3.2	0.1	3.1	04
37511500	Unnamed	2	Clark	64-07-07	-	4.2	0.4	3.8	10
37511600	Unnamed	2	Clark	65-08-35	-	3.7	0.3	3.4	09
37511700	Unnamed	2	Clark	65-08-26	-	2.8	0.3	2.5	11
37511800	Unnamed	2	Clark	65-08-27	-	4.5	0.2	4.3	05
37512000	Hemp Slough	-	Clark	64-05-18	-	10.2	8.6	1.6	85
37513000	Weaver Branch	2	Clark	65-07-24	-	4.7	1.0	3.7	22
37514000	Brush Creek	2	Clark	65-07-15	-	5.1	2.2	2.9	44
37515000	Singleton Branch	1	Clark	65-07-10	-	2.8	0.0	2.8	00
37516000	Ramsey Branch	2	Clark	65-07-09	-	3.1	0.2	2.9	07
37517000	Johnson Branch	2	Clark	65-07-09	-	3.7	1.2	2.5	33
37518000	Wade Branch	2	Clark	65-08-01	-	3.4	1.1	2.3	33
37521000	Little Fox River	4	Clark	65-08-02	83	23.9	11.8	12.1	49
37521100	Linn Creek	3	Clark	65-08-04	-	2.4	0.6	1.8	25
37521110	South Linn Creek	2	Clark	65-08-31	-	3.8	0.0	3.8	00
37521120	North Linn Creek	2	Clark	66-08-31	-	6.5	0.4	6.1	07
37521200	Wolf Branch	2	Clark	66-09-15	-	5.6	0.1	5.5	02
37521300	Pilcher Branch	2	Clark	66-09-08	-	3.0	0.4	2.6	14
37521400	Smith Branch	2	Clark	66-09-07	-	2.8	0.2	2.6	08
37521500	Turkey Branch	1	Scotland	66-10-12	-	2.4	0.2	2.2	09
37521600	Hughes Branch	3	Scotland	66-10-01	-	5.3	0.8	4.5	15
37521700	Jordan Branch	2	Scotland	67-10-35	-	0.9	0.0	0.9	00
37521710	East Fork Jordan	1	Scotland	67-10-35	-	2.2	0.0	2.2	00
37521720	West Fork Jordan	1	Scotland	67-10-35	-	2.2	0.0	2.2	00
37521800	Unnamed	3	Scotland	67-10-19	-	5.5	0.0	5.5	00
37522000	Unnamed	3	Clark	66-08-23	-	3.0	0.0	3.0	00
37523000	Unnamed	3	Clark	66-08-22	-	3.8	0.0	3.8	00
37524000	Kaylor Branch	2	Clark	66-08-21	-	3.3	0.0	3.3	00
37525000	Mantle Branch	2	Clark	66-08-08	-	4.3	0.1	4.2	03
37526000	Nixon Branch	3	Clark	66-08-05	-	4.0	0.0	4.0	00
37527000	Burnt Shirt Br.	2	Clark	67-09-34	-	6.1	0.2	5.9	04
37528000	Unnamed	2	Clark	67-09-22	-	2.2	0.5	1.6	23
37529000	Unnamed	2	Clark	65-08-22	-	2.4	0.0	2.4	00

Figure 4a: Fox River Gradient Plot

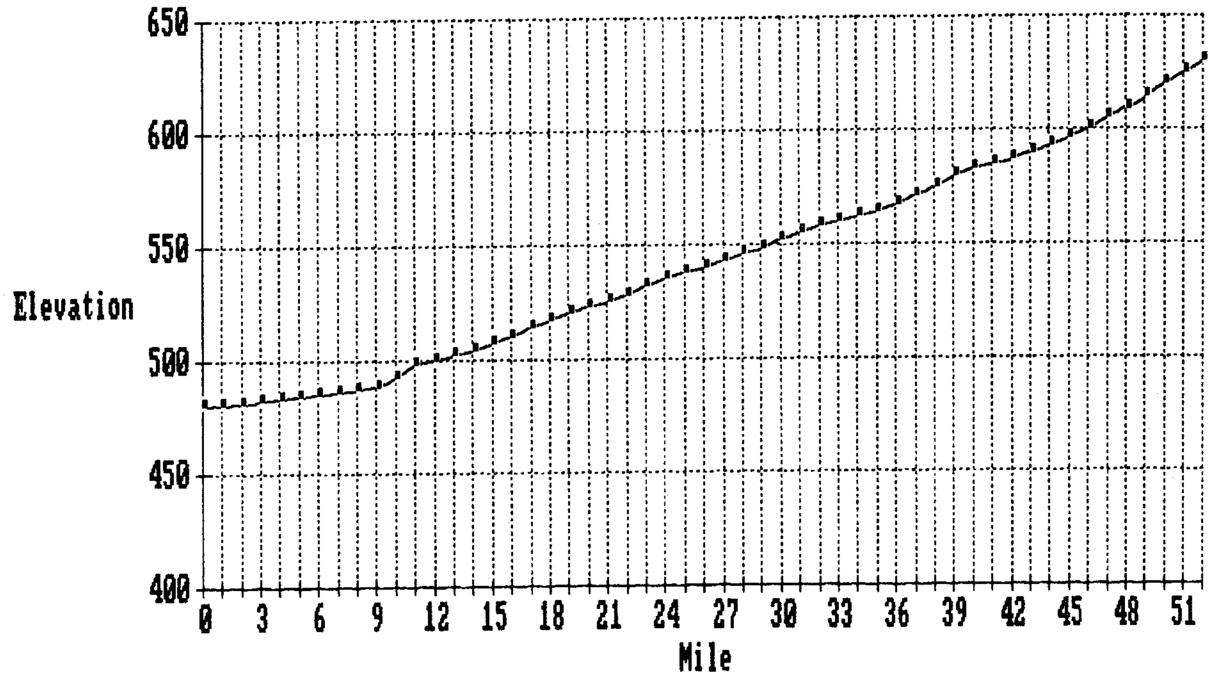
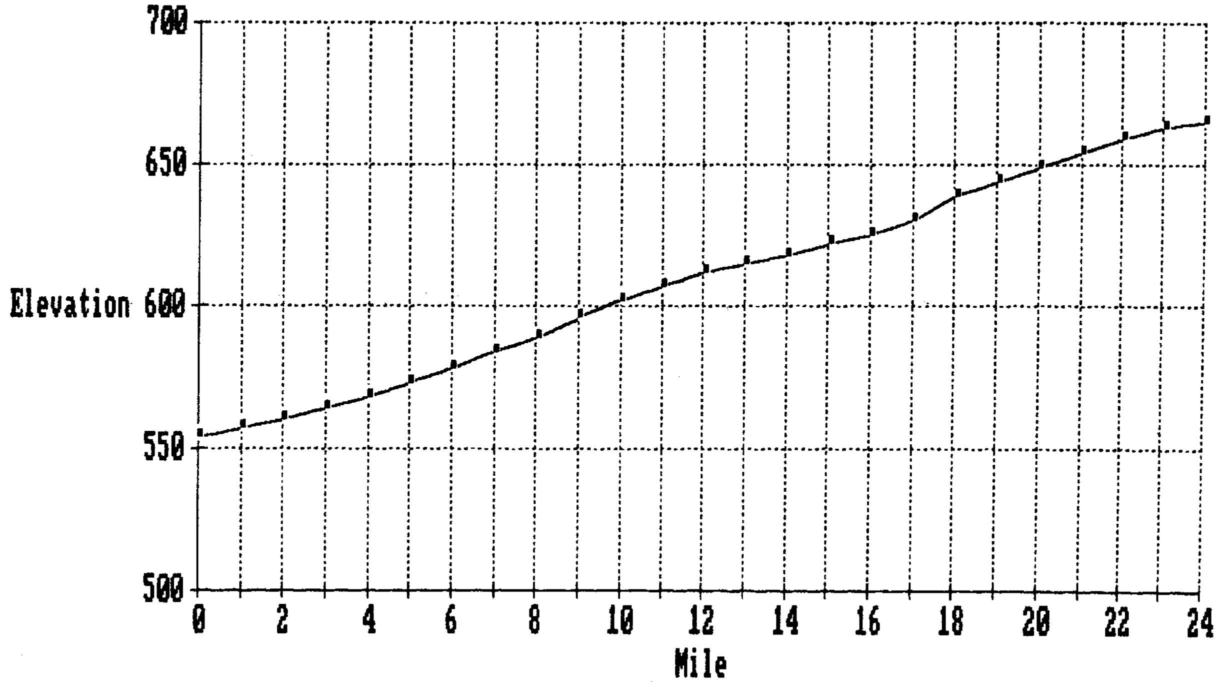


Figure 4b: Little Fox River Gradient Plot



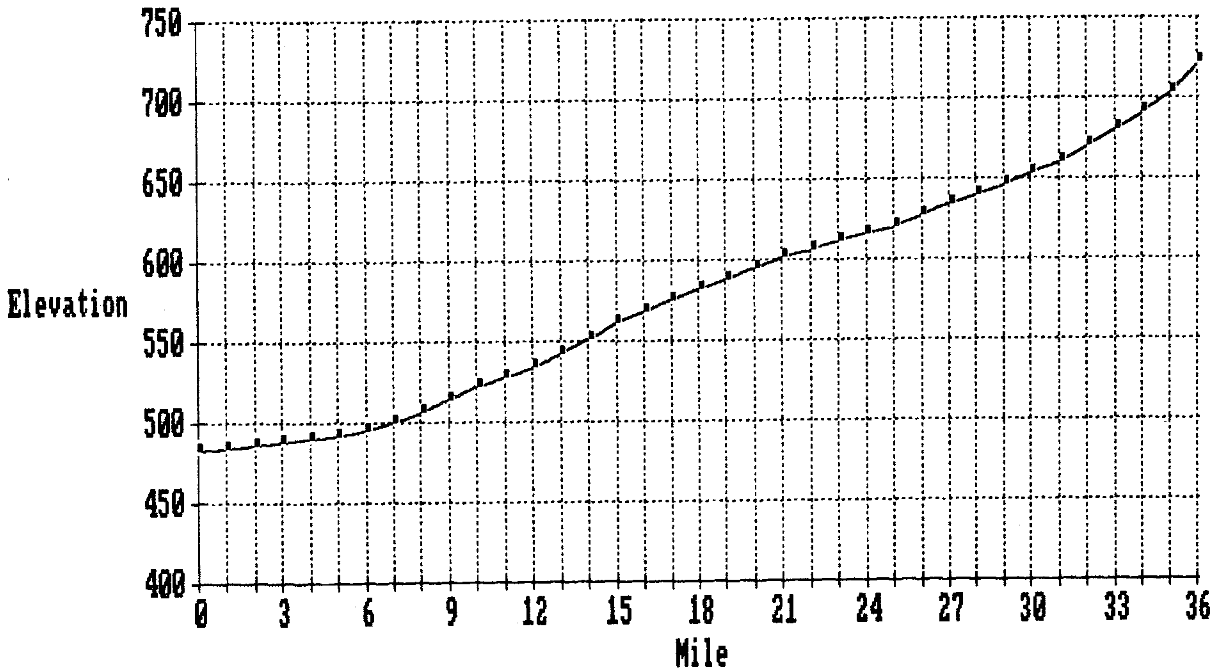


Figure 4c: Honey Creek Gradient Plot

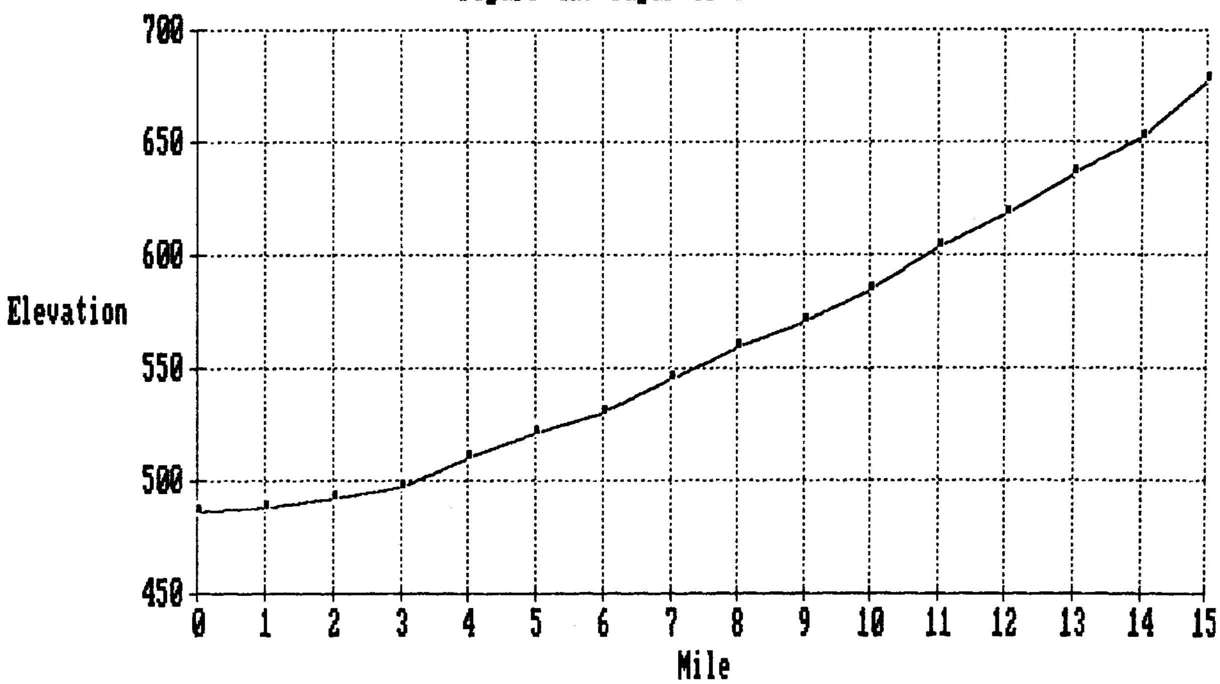


Figure 4d: Sugar Creek Gradient Plot

Figure 4e: Fox River Basin Tributary Relationships and Gradient Plots

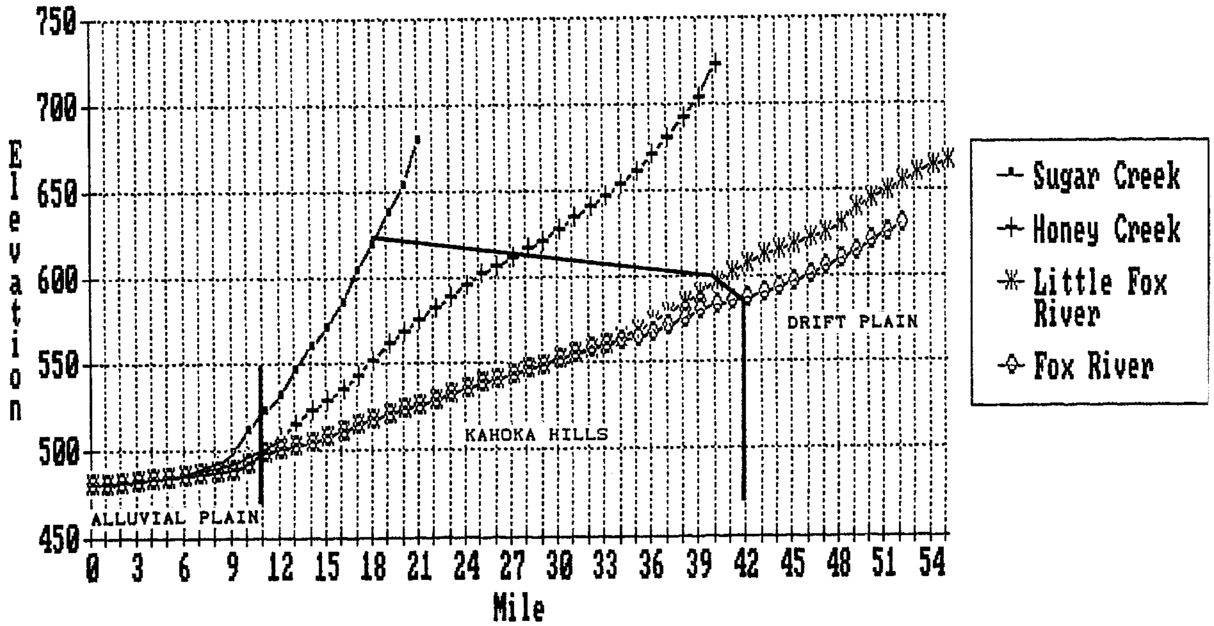


Table 2. Mean Gradient and Slope of Fox River and Its Major Tributaries.

Stream Mile (miles)	Milehead (miles)	Distance (miles)	Elevation (msl)	Stream Order	Gradient (ft/mi)	Percent Slope
FOX RIVER						
0.0	52.3	2.7	470	5	3.00	.057
2.7	49.6	6.8	480	5	1.47	.028
9.5	42.8	2.4	490	5	4.17	.080
11.9	40.4	7.4	500	5	2.70	.052
19.3	33.0	6.6	520	5	3.03	.058
25.9	26.4	6.7	540	5	2.99	.057
32.6	19.7	6.2	560	4	3.23	.062
38.8	1.5	7.3	580	4	2.74	.052
46.1	6.2	4.2	600	4	4.76	.091
50.3	2.0	2.0	620	4	3.50	.069
52.3	0.0	---	627	4	---	---
LITTLE FOX RIVER						
0.0	23.9	1.4	550	4	4.94	.094
1.4	22.5	4.8	560	4	4.17	.080
6.2	17.7	304	580	4	5.88	.112
9.6	14.3	5.0	600	4	4.00	.076
14.6	9.3	3.5	620	4	5.72	.109
18.1	5.8	3.8	640	4	5.26	.100
21.9	2.0	2.0	660	4	4.00	.076
23.9	0.0	---	668	4	---	---
HONEY CREEK						
0.0	35.8	5.2	480	4	6.87	.131
5.2	30.6	1.9	490	3	5.26	.100
7.1	28.7	2.6	500	3	7.69	.147
9.7	26.1	2.9	520	3	6.89	.131
12.6	23.2	2.2	540	3	9.09	.173
14.8	21.0	2.6	560	3	7.69	.147
17.4	18.4	3.0	580	3	6.67	.127
20.4	15.4	4.5	600	3	4.45	.085
24.9	10.9	2.9	620	3	6.89	.131
27.8	8.0	3.2	640	3	6.25	.119
31.0	4.8	2.1	660	1	9.52	.181
33.1	2.7	1.8	680	1	11.11	.211
34.9	0.9	0.7	700	1	28.57	.543
35.6	0.2	0.2	720	1	25.00	.475
35.8	0.0	---	726	1	---	---
SUGAR CREEK						
0.0	15.7	1.6	485	3	13.19	.251
1.6	14.1	2.1	490	3	3.13	.060
3.7	12.0	1.1	500	3	4.76	.091
4.8	10.9	1.9	520	3	18.18	.346
6.7	9.0	1.4	540	3	10.53	.200
8.1	7.6	1.5	560	3	14.29	.272
9.6	6.1	1.5	580	3	13.33	.254
10.7	5.0	1.4	600	3	13.33	.254

Table 2 continued

12.1	3.6	1.2	620	2	14.29	.272
13.3	2.4	1.2	640	2	16.67	.317
14.5	1.2	0.6	660	1	16.67	.317
15.1	0.6	0.6	680	1	33.33	.634
15.7	0.0	---	692	1	20.00	.380

LAND USE

Recent and Historical Land Use

Historically, native vegetation on uplands was dominated by prairie grasses, primarily big and little bluestem, Indian grass, switchgrass and side-oats grama. River slopes and valleys were forested, generally of the oak-hickory type. Now maples, elms, oaks, black walnut and eastern red cedar are abundant.

Detailed land use information exclusive for the Fox River basin was not available prior to the writing of this document. The Soil Conservation Service has published land use and erosion rate data for a combined Fox/Wyaconda rivers hydrological unit (SCS 1978, Figure lu).

Through a joint effort between the Soil Conservation Service and the Missouri Department of Conservation, land use was determined in the Clark County portion of the basin for 1939 an 1984. To facilitate this survey and a future Soil Conservation Service project, the basin was divided into nine subbasins. Aerial photographs taken in 1939 were analyzed for total acres and total acres in timber. Land use data from 1984 were derived from infrared photography; grasslands and permanent pasture could be discerned in addition to timber.

In this investigation, timber was conservatively defined as dense continuous tracts of trees unbroken by fields or disturbances such as grazing. Timbered areas with sparse canopy were not reported as timber because quality was questionable. Sparsely timbered areas were recorded as pasture. All area measurements were determined by digitizer and the computer program PADPAC.

Between 1934 and 1984, timber increased from 14% to 20% of total land use--an increase of 9,000+ acres over 45 years (Table 3). All subbasins except one underwent an increase in timber. The greatest increase occurred in the Central Hills region, particularly in the Middle Fox River, Lower Honey Creek, Lower Little Fox River and Linn Creek subbasins.

In 1984, permanent pasture and other grasslands in the basin totaled 25,813 acres, representing about 16% of the total land area. Urban and industrial areas accounted for less than one percent of the total land area (SCS 1978). Cropland, highways, and rural residential area totaled 101,485 acres (63%).

Throughout the basin, intensive farming accounts for nearly 60% of the upland land use (SCS 1978). The level topography over much of the region is conducive to this activity. By contrast, river slopes, particularly in the Kahoka Hills region and some prairie areas, contain large tracts of permanent pasture and/or continuous meadow.

Erosion data are available for uplands from the combined Fox/Wyaconda rivers hydrological unit (SCS 1978). Croplands lost 12.5 tons/acre/year, accounting for 73% of the gross erosion. Grasslands/pastures lost 9.9 tons/acre/year while grazed forests lost 3.5 tons/acre/year. Human agricultural activities accounted for 99% of all upland erosion. Of the approximately 10.2 tons/acre of eroded land that were lost each year, approximately 3 tons/acre were delivered to the Fox and Wyaconda rivers (SCS 1978). Sheet and gully erosion were responsible for 84 and 12% of the sediment discharged to streams, respectively.

Fox River, Sugar Creek, Honey Creek and several drainage ditches in the Alluvial Plain are leveed. Sugar Creek and Honey Creek are entirely channelized through this region. Drainage in the basin is strictly controlled by the levee system returning water to either Fox River through Hemp Slough or the Mississippi River through pumphouses. The resulting drainage allows for the floodplain areas to be used intensely for agricultural purposes.

Soil Conservation Projects

To date, one soil conservation project has been prepared for the basin under authority of the Watershed Projection and Flood Prevention Act, P.L. 83-566. The project was to treat 55,515 acres in the Honey and Sugar creek subbasins through a series of flood retarding structures. The project became inactive in about 1972 as several of the dams became economically unfeasible. Later, lacking sufficient support for a potable water supply lake for Kahoka, the watershed district abandoned the project.

One Special Area Land Treatment (S.A.L.T) project was initiated in 1984 for the upper Honey Creek drainage southeast of Kahoka. The project was to treat 6,118 acres in the Honey and Sugar Creek watersheds. This was the first attempt in Missouri to implement an accelerated land treatment program (Dwight Snead, SCS, personal communication). The project was abandoned in 1985 due to economics and a general lack of interest by local landowners.

Flood control has often been a source of controversy in the basin. At various times students have been requested or initiated by federal, state, and local agencies to determine the feasibility of water control projects. The first such attempt was made by U.S. Army Corps of Engineers in 1942 (COE 1942). The report emphasized the need for flood control structures and suggested further study to determine their feasibility. However, the requirements of local cooperation could not be met, therefore, no studies were initiated.

In 1951, another report was prepared for Congress by the Corps of Engineers in the interest of flood control and drainage on Fox River, primarily in Iowa. The Chief of Engineers advised against the improvements outlined in the document (COE1951).

In 1958, the Iowa Natural Resources Council prepared an inventory of streams in southern Iowa and commented on their associated water problems (INRC 1958). General recommendations were made in regard to data collection and water control on Fox River. No actions were carried out by that agency.

A seven-year feasibility study was conducted by the U.S. Army Corps of Engineers in the early 1970's to investigate various flood control options (COE 1972). In the original proposal, five dams were considered for Honey and Sugar creeks in addition to channel alterations and extensive levee work on

Fox River and some of its tributaries. After years of deliberation and study, the feasibility report was released in 1979. With the expiration of the notice period, the Board of Engineers for Rivers and Harbors determined the project to be economically unjustified. Since that time, Corps of Engineers involvement in water control has largely been limited to repair of existing levees in the lower Honey and Sugar creek subbasins.

Corps of Engineers Jurisdiction

The Fox River basin is under regulatory jurisdiction of the Rock Island District. The entire Missouri portion of Fox River and the Little Fox River to S15, R9W, T66N, Clark County, were within the jurisdictional boundaries defined by the former Corps of Engineers 5 cfs median flow limitation (Figure 5). The boundary on the Little Fox River has been expanded, however, to now include the entire Missouri portion due to Federal Regulations 33 CFR 320-329 (1977), which provides for Corps of Engineers jurisdiction on the entire length of all streams in the United States.

Public Areas

A total of 5,682 acres in the basin are in public ownership (Figure pa). Stream anglers have access to over ten miles of public frontage (Table 4).

The largest frontage tract available in the basin is at Charlie Heath State Forest and Memorial Wildlife Area which includes 3.85 miles of Fox River. The stream, suitable for bank fishing and wading, provides anglers with the opportunity to fish for several species, primarily channel and flathead catfish.

Recently acquired by the Unites States Fish and Wildlife Service, the Gregory Landing tract was added to the Mark Twain National Wildlife Refuge. Nearly 2.5 miles of Fox River will be available for bank and small craft fishing.

Over 1 ½ miles of frontage are available on Nixon Branch at the Clark State Forest near Chambersburg. Nixon Branch, however, is an intermittent stream that does not support a sport fishery. Slightly more than one mile of stream frontage can be found at the Linn Creek tract. This stream, though considered to have permanent flow, does not support a sport fishery. Nearly one mile of stream frontage is available at Fox Valley State Forest north of Kahoka.

Of two stream access sites identified in the basin (Gann 1989), one has been developed. The Geode Access, completed in 1989, is located west of Wayland off U.S. Highway 136 (NW 1/4, S31, R6W, T65N) encompassing ½ acre of land and less than 1/10th mile frontage on Fox River. A proposed acquisition site is located approximately 14 miles upstream, 2 ½ miles north of Kahoka on Fox River just above its confluence with the Little Fox River (S2, R8W, T65N).

Recreational Use

Because it is small and far from large urban areas, Fox River has a relatively low recreational standing among Missouri watersheds; however, recreational use is expected to increase (Bachant and Martindale 1982).

Stream-related activities in the basin are largely restricted to hunting and fishing. Boating and canoeing on all tributaries and most of Fox River is hampered by shallow water, log jams, insufficient flow, and inaccessibility. Siltation and occasional periods of turbidity discourage swimming.

Fox River receives moderate fishing pressure relative to other Mississippi River tributaries in northeastern Missouri (Table 5). Channel catfish are targeted b 69% of Fox River's anglers; bullheads, carp and crappie are sometimes sought. Channel catfish catch and harvest rates are considered good but rank low compared to other northeastern Missouri streams. Anglers rated the quality of catfishing in Fox River poor (2.6 on a 10 point scale).

Land Use, Habitat, Fishery Corollary

Land use has affected basin hydrology, channel morphology, water quality, habitat and ultimately fish populations. To mitigate for habitat and/or species loss, it is essential to know what has been lost and how the ecosystem formerly functioned. Detailed historical accounts of stream habitat and biota do not exist for Fox River and its tributaries. However, local residents in the basin often recall an era when Fox River was deeper and cleaner, with higher sustained flows and larger fish.

Many changes have occurred in the basin that would seem to support the above observations, most resulting from agricultural activity. The conversion of grasslands to row crops reduced filtration and water retention capacity of the watershed because of topsoil loss, soil compaction, and reduction in soil organic content. Also, from 1939 to 1984 the proportion of forest cover in the watershed increased appreciably, mostly on moderate upland slopes. The original cover type on these slopes was prairie grass, which probably served better as a filter than whatever forest has replaced it.

One consequence of intensive agriculture has been an adversely affected hydrologic regime. Although the average annual flow in Fox River showed no trend toward reduced volume (Figure 7), empirical duration curve data suggest that Fox River has become more susceptible to desiccation (Figure 8c) and perhaps to flash flooding. This is not to say that spates and no-flow periods did not occur historically, but an increasing tendency toward desiccation during late summer probably results from increased evaporation from basin impoundments and from compacted soils which lack the organic matter and overall water retention capacity they possessed prior to intensive agriculture.

Another consequence of agriculture has been the increased rate of stream channel sedimentation. Although some upland erosion and sedimentation rate information exists for the Fox/Wyaconda river basins (SCS 1978), the rate of sediment transport in stream channels has not been determined. Stream upland slopes in the basin were probably forested and subsequently logged, grazed or plowed upon the arrival of mechanized agriculture. By 1939, sediment discharged to Fox River was probably more severe than at any time prior to or since mechanized agriculture. Some problems in the basin today (i.e. shallow water, unstable substrates, low productivity) may be a consequence of land use in the 1930s and 1940s.

Sedimentation coupled with the "flashy" nature of stream flow in the basin have probably increased turbidity and altered water quality parameters important for fish growth and survival. Lack of deep water may partially explain the movement of smallmouth bass from nursery areas in Fox River to the Mississippi River as juveniles. Adult smallmouth bass exhibit a preference for water 3 feet deep (USFWS 1983). The sedimentation of former riffles has destroyed crayfish habitat which may in turn limit smallmouth bass distribution.

Another potential consequence of intensive agriculture is the alternation of fish behavior. Most stream organisms rely upon the cues provided by a somewhat predictable hydrological regime to initiate certain behaviors. If regimes become less predictable, a loss in species diversity could occur over time. The extirpation of the Missouri silvery minnow may have been caused by a change in the hydrological regime. Furthermore, spates and droughts may negatively affect gravel bed habitats like those found in the Kahoka Hills, resulting in lower fish standing crop and shifts in trophic structure (Resh et.al. 1988).

Other anthropogenic disturbances have compounded fishery problems in the basin. Extensive channelization in the Alluvial Plain has resulted in poorer habitat and fish populations than in Kahoka Hills streams. Channelized reaches are characterized by less cover, shallow and warm water, unstable substrate and thin riparian corridors. Fish communities are dominated by omnivores, generalist species; sport fish are few and small.

No clear trend was detected when comparing fish populations in narrow wooded corridors versus wide wooded corridors at unchannelized sites. This suggests that the effects of riparian corridor thickness on fish populations may not be site-specific, even though basin-wide effects may be significant.

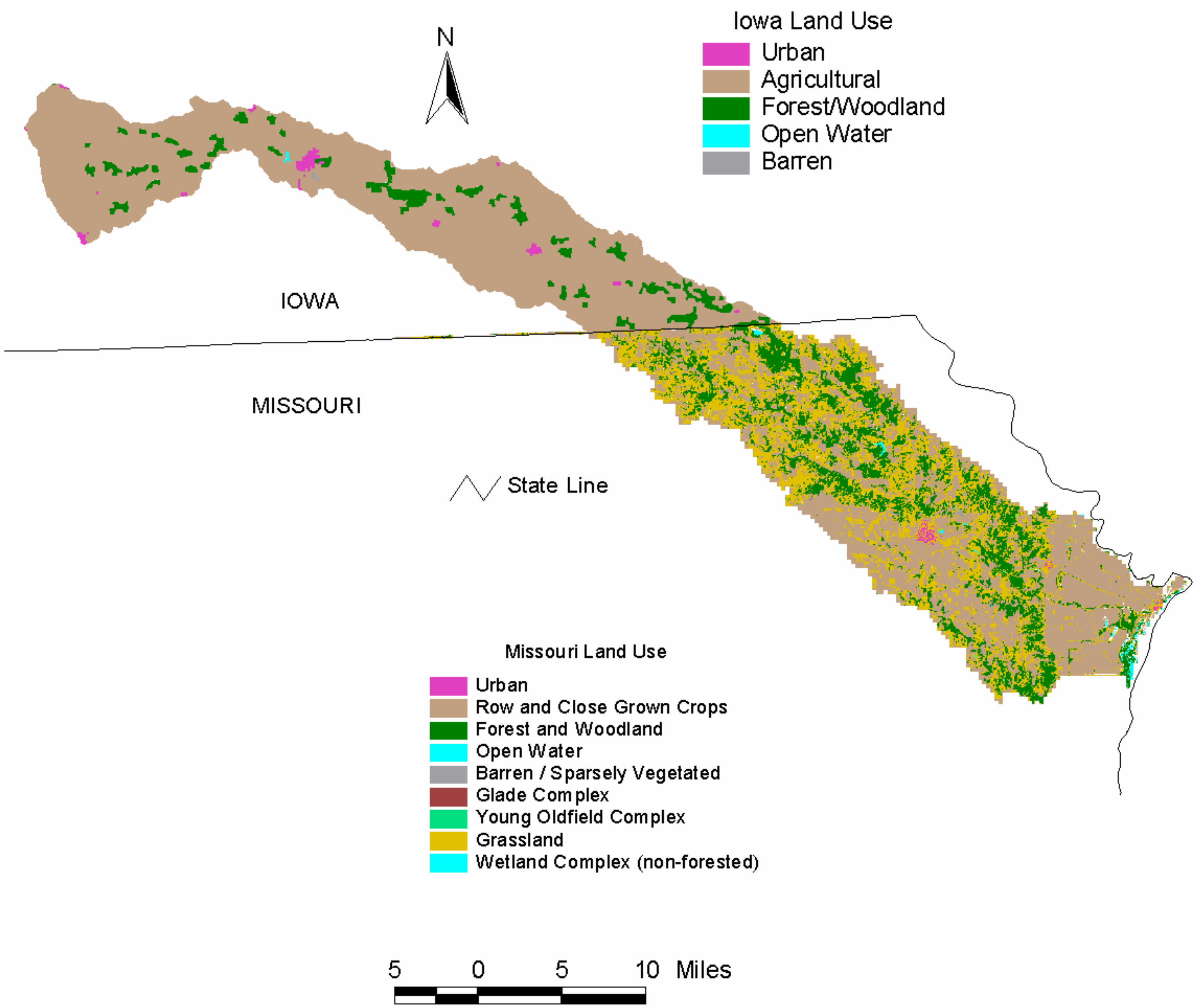


Figure lu. Land use/land cover within the Fox River watershed in Missouri and Iowa (MORAP 1999, preliminary data).

Table 3. Changes in Forest Cover in the Fox River Basin, 1939-84

		Percentage Timber		Percentage Change
Subbasin	**Total Acres**	**1939**	**1984**	
Linn Creek	11,340	12.5	19.2	+6.7
Lower Fox River	20,765	5.8	11.7	+5.9
Lower Honey Creek	21,232	13.9	21.5	+7.6
Lower Little Fox	9,375	28.5	35.3	+6.8
Middle Fox River	31,662	18.3	26.2	+7.9
Sugar Creek	11,431	13.6	17.9	+4.3
Upper Fox River	24,820	22.8	28.7	+5.9
Upper Honey Creek	19,216	2.9	2.7	-0.2
Upper Little Fox	11,641	12.9	18.5	+5.6
Average:		14.4	20.2	+5.8

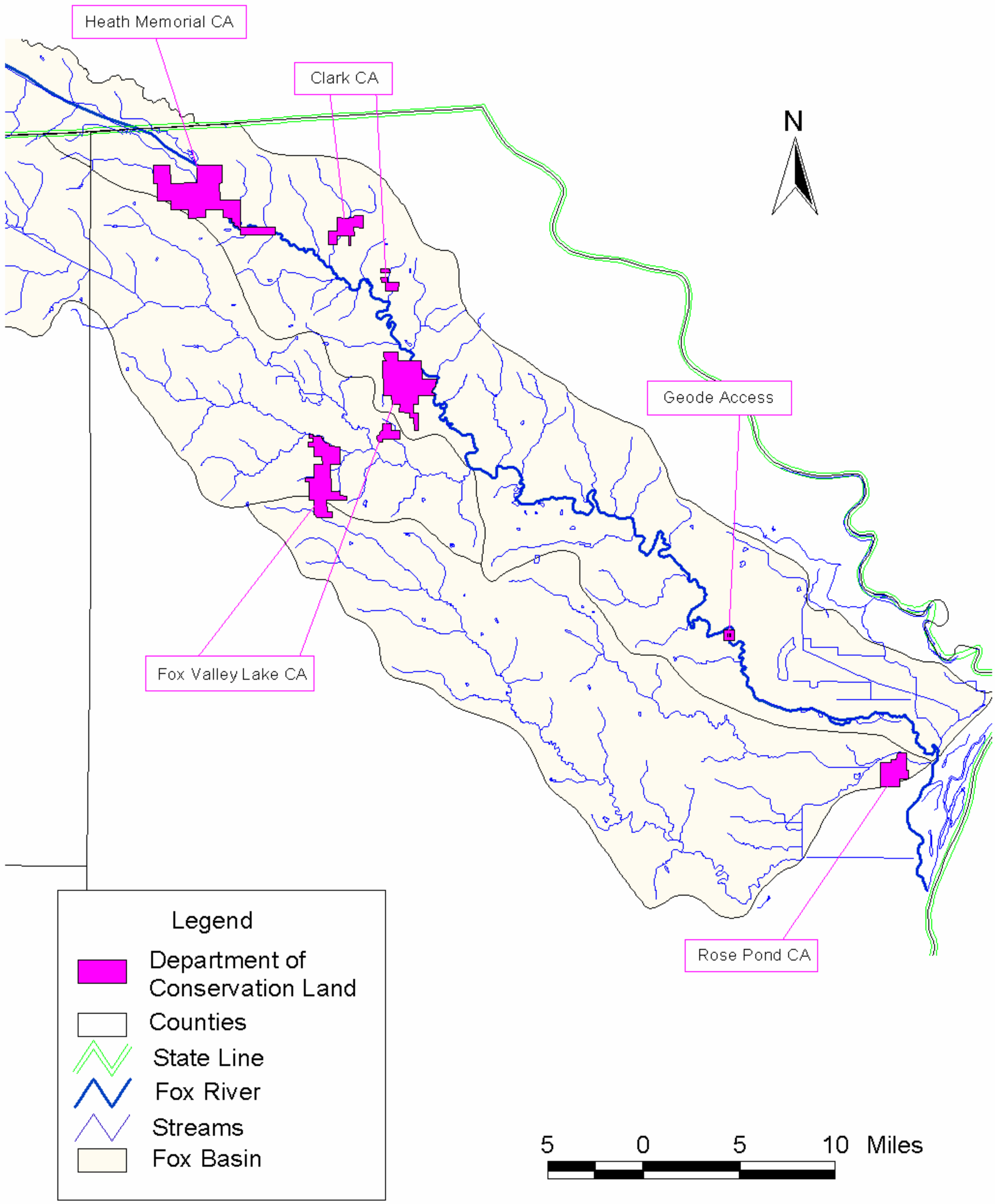


Figure pa. Public areas in the Fox River Basin, in Missouri.
CA = Conservation Area

Table 4. Public Stream Access and Frontage Areas in the Fox River Basin.

Area	Acres	Stream Frontage Miles	Stream
Charlie Heath S.F.	1,530	3.85	Fox River
Clark S.F.	1,167	2.60	Nixon Branch Linn Creek
Fox Valley S.F.	1,568	0.99	Fox River
Mark Twin N.W.R.	1,038	2.47	Fox River
Rose Pond N.H.A.	379	0.37	Honey Creek
Goede Access	<1	<.10	Fox River
Legend: S.F. = State Forest (MDC) N.W.R. = National Wildlife Refuge (USFWS) N.H.A. = Natural History Area (MDC)			

Table 5. Sport Fishery Characteristics of the Fox River and Other Northeastern Missouri Streams, Based Upon a Statewide Angler Telephone Survey, 1983-1986.

River	ANGLERS	PREFCAT	PREFANY	PREFOTR	%PREFCAT	CATCHRT	HARVRT	FISQUAL
Des Moines	58	48	10	0	83	0.98	0.70	5.3
Fabius	86	63	14	9	74	0.85	0.68	4.9
Fox	38	26	3	9	69	0.70	0.29	2.6
North	27	21	4	2	78	0.89	0.78	4.3
Salt	408	292	68	48	72	0.41	0.31	4.3
Wyaconda	13	2	1	10	16	0.75	0.00	2.0

Legend: ANGLERS - Total number of anglers who fished each river.
PREFCAT - Total number of anglers who fished for catfish.
PREFANY - Total number of anglers who fished for anything.
PREFOTR - Total number of anglers who fished for other species.
%PREFCAT - Percent of total anglers who fished for catfish.
CATCHRT - Catfish catch rate by anglers who fished for them.
HARVRT - Catfish harvest rate by anglers who fished for them.
FISQUAL - Survey participants evaluation of the quality of their catfishing trip.

HYDROLOGY

Precipitation

Precipitation averages 35.3 inches annually at Wayland, Missouri (Gann et.al. 1971). The greatest amount of precipitation occurs during the months of June, July, and August, which produce 34% of the total annual precipitation (MDNR 1986). Snowfall averages 22 inches per year and average annual evaporation is approximately 4.8 inches at Wayland.

Average annual run-off at Wayland is 7.3 inches (Figure 6). Based on average annual precipitation and average annual run-off data, approximately 21% of the average annual precipitation appears as streamflow and the remaining 79% is lost primarily to evapo-transpiration.

U.S.G.S. Gaging Station

One gaging station occurs in the Fox River basin (05495000). It is located at 40 23' latitude and 91 35' longitude in the NE 1/4 of the NW 1/4 of S31, R6W, T65N approximately ½ mile west of Wayland, Missouri (Figure gs). Two "type A" wire-weight gates are located on the downstream side of the U.S. Highway 136 bridge, one on the east side and one on the west side of the bridge handrail. The period of record is from 1921 to present.

Permanent/Intermittent Streams

The basin has numerous intermittent streams and ephemeral ditches (Figure 3, Table 1). A total of 39 streams were identified in the basin, seven of which support permanent pools: Fox River, Little Fox River, Honey Creek from approximately RM-20 to its confluence with Fox River, Sugar Creek from approximately RM-10 to its confluence with Honey Creek, Linn Creek from the junction of North and South Linn creeks to its confluence with the Little Fox River, and the entire length of Brush Creek, its flow being augmented by treated wastewater release from the City of Kahoka.

There are no sizeable springs in the basin. Because the surface stream network accounts for most of the water movement in the drainage, base flow is low. All streams in the basin are subject to no-flow periods.

Streamflow Characteristics

Average annual discharge in Fox River for a 66-year period ending in 1988 was 258 cubic feet per second (USGS 1988). The cumulative mean annual discharge is plotted in Figure 7. High flows in the 1920s were followed by a relatively long period of lower but stable flows until the late 1970s and early 1980s when higher flows returned. The Q2 seven-day low flow is 1.3 cfs; Q10 and Q20 seven-day low flows are 0 cfs. The slope index, therefore, cannot be computed.

The 63-year flow duration curve for Fox River shows that high flows often result in flash floods while groundwater contribution to discharge is low, resulting in zero flow during dry periods (Figure 8a).

From the duration table of daily flows, data were compared to determine if Fox River has become more or less susceptible to flooding and/or drying in recent years. Figure 8b depicts duration flows from 1922 through 1952 and 1953 through 1980. During each time period, an equal number of high and low flow periods occurred and the median flow of each period was within 6 cfs. The computer-generated plotting points were too few to make meaningful comparisons of high-flow intensity, but low-flow duration could be compared. The graph suggests that extremely low base flows were more frequent during 1953-1980 than during the early time period. However, visual differences were not examined statistically. Note that data for each time period were similar in the graph's middle section.

Over a period of time, high- and low-flow effects tend to cancel one another, making it necessary to have many years of data to detect rends in flow duration. To negate this, flows during two four-year time periods were selected within each of the original two periods. Criteria for selection were: 1) high run-off periods to establish duration curves emphasizing changes in the middle section of the curve; and 2) similar flows over an equal time period, in this case four years. The periods analyzed were 1926-1929, 1945-1948, 1958-1961 and 1977-1980. For clarity, only two of the four curves are shown in Figure 8c, although the omitted curves fit within the curves shown. Note the disparity between the two curves, suggesting greater maintenance of base flow during 1926-1929. This is consistent with casual observations that streams in northeastern Missouri flood and dry up with greater frequency today than in years past.

The 90:10 ratio, determined by computer-generated flow data ending in 1985, is 2.2 cfs:539 cfs or 1:245. This is a relatively low ratio, indicating great variance in flow. Flood frequency data show the 2, 5, 10, 25, 50 and 100 year floods to be 6,000, 9,950, 12,600, 15,800, 18,200 and 20,400 cubic feet per second, respectively (Hauth 1974).

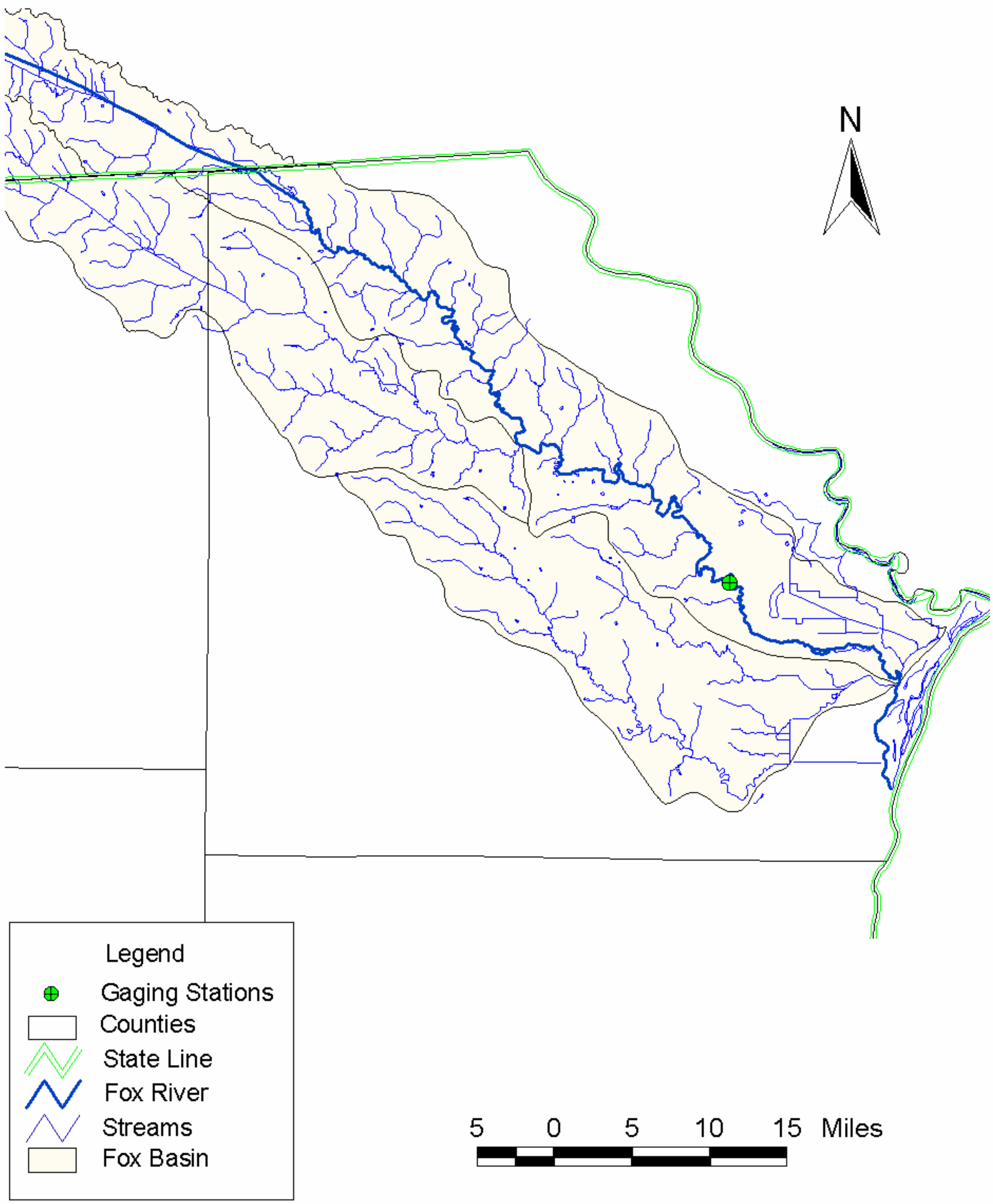


Figure gs. Gaging stations in the Fox River Basin, in Missouri.

Figure 6. Relationship of precipitation to streamflow in the Fox River (from Gann, et. al. 1971). Precipitation during the summer months, when evapotranspiration and soil-moisture requirements are greatest, is seen to have less effect on streamflow and the water table than does precipitation during the spring.

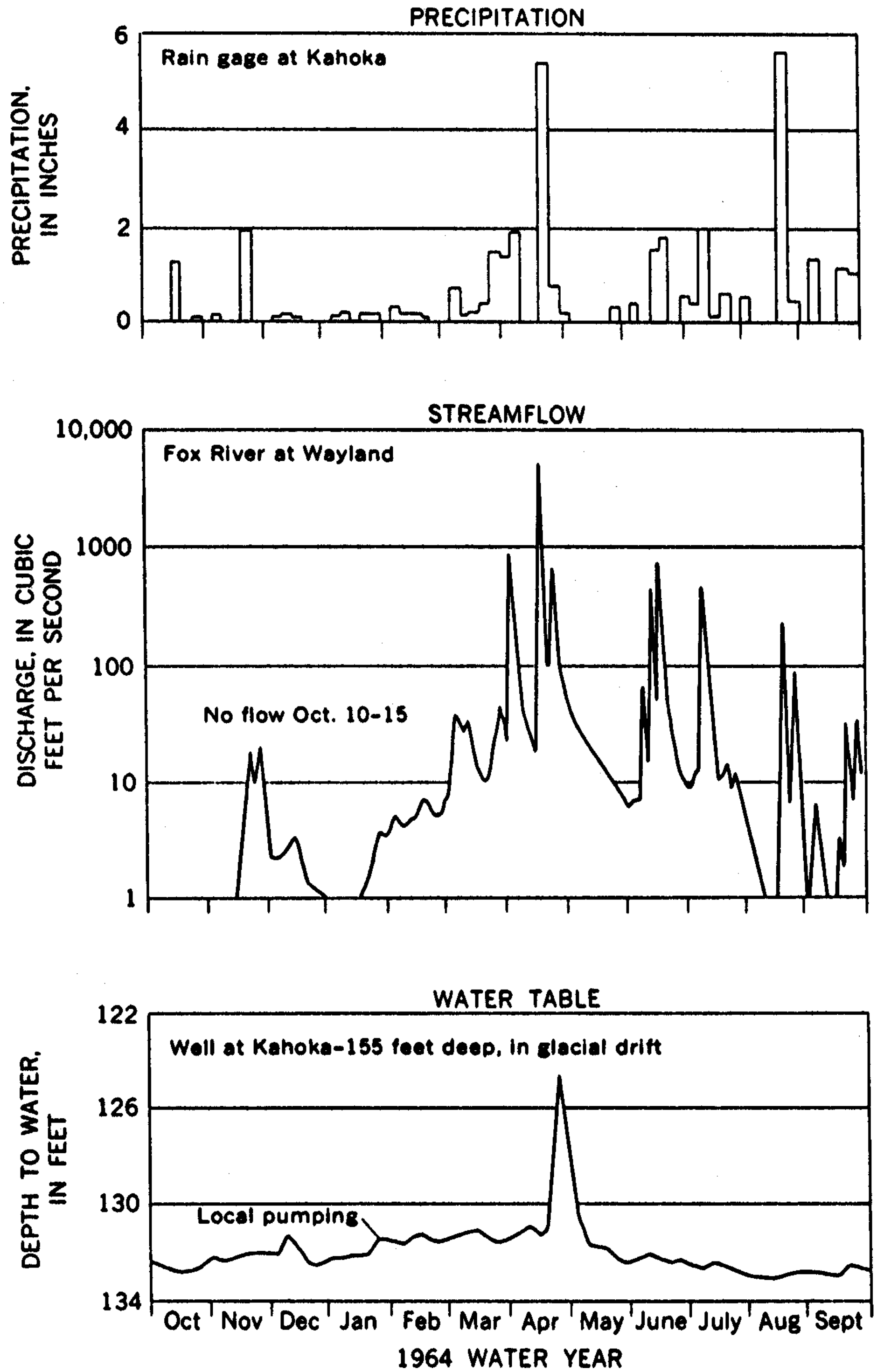


Figure 7. Cumulative average flow of the Fox River, 1922-1988.

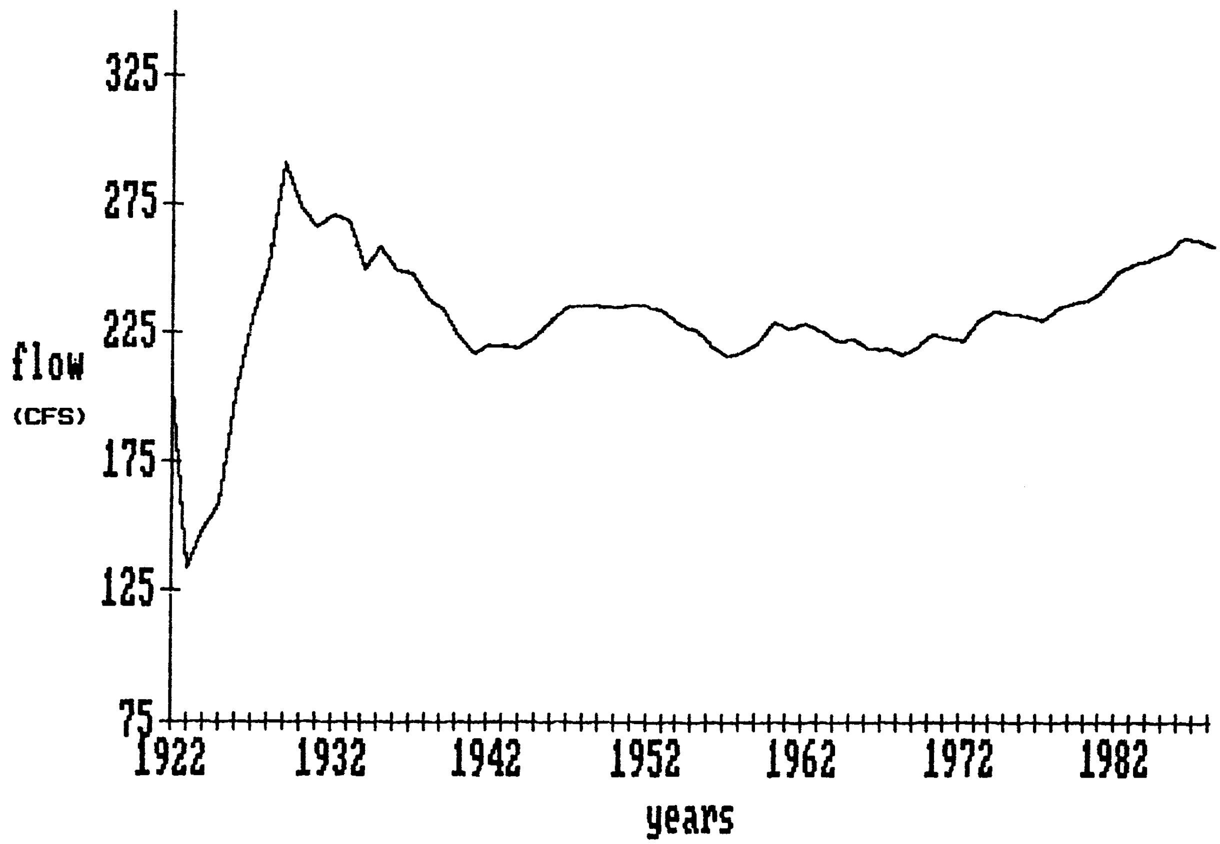


Figure 8a. Fox River duration curve

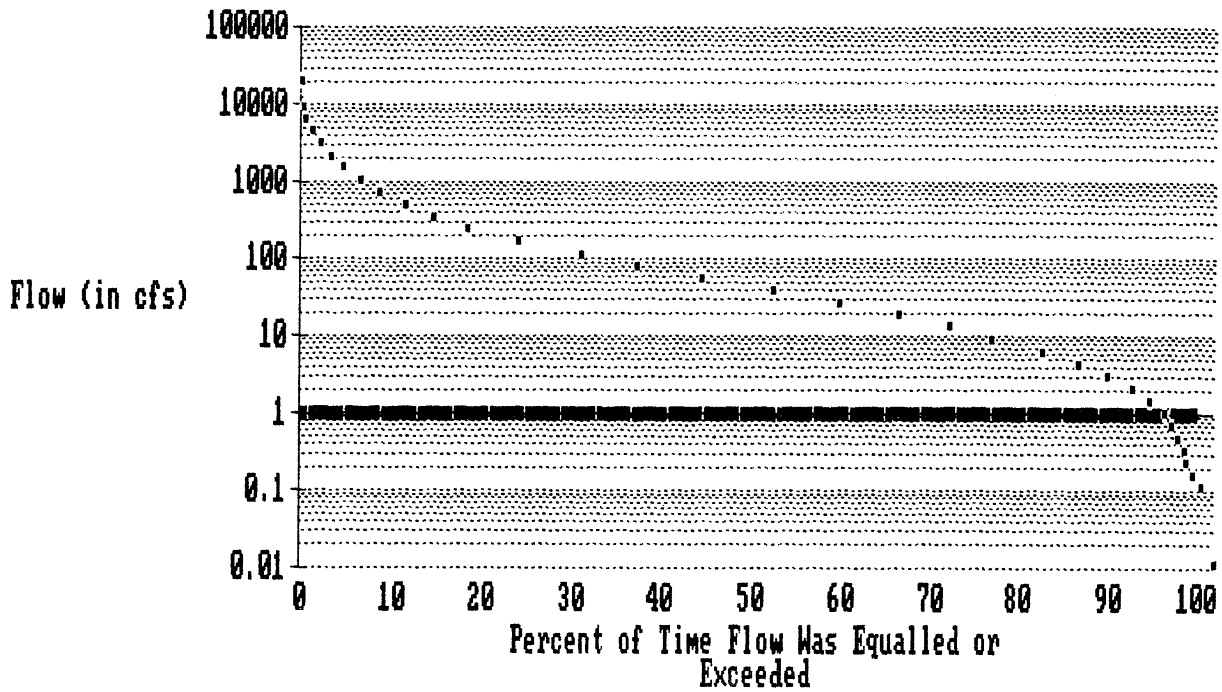
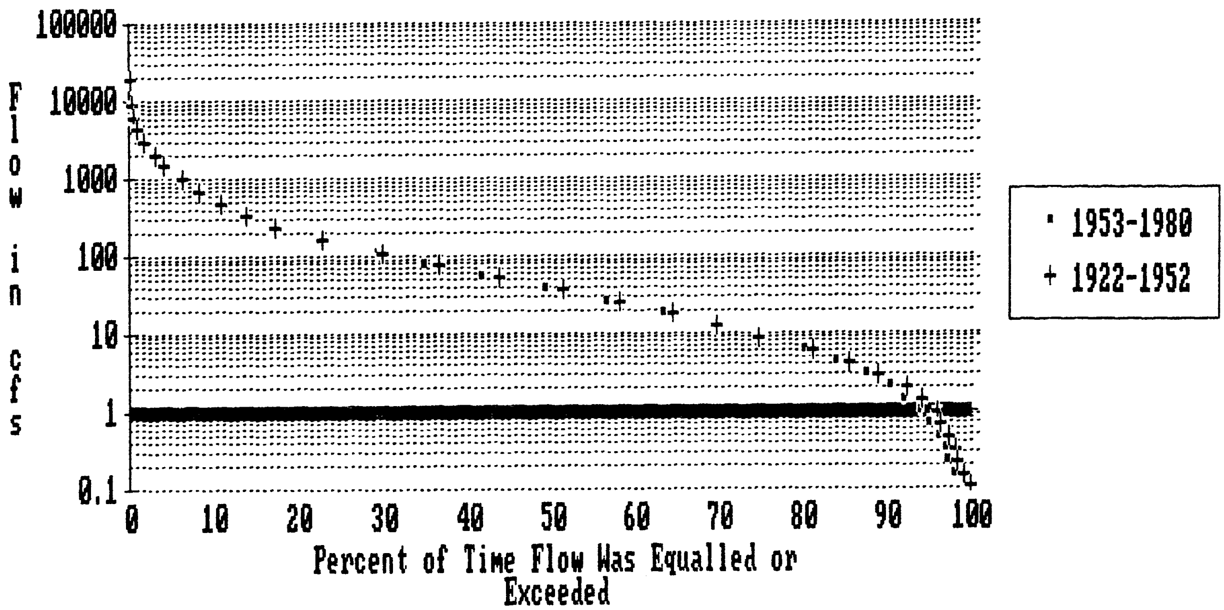


Figure 8b. Comparison of duration curves from two time periods in the Fox River basin.



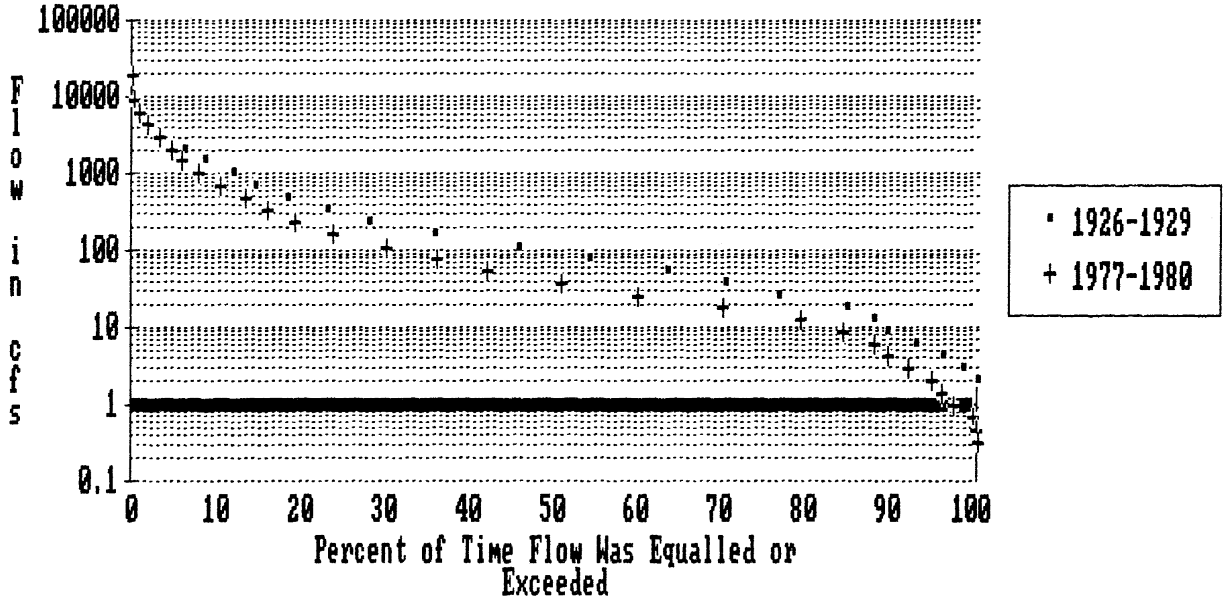


Figure 8c. Comparison of duration curves from two, four year high flow periods in the Fox River basin.

WATER QUALITY AND USE

Contaminants and Fish Kills

The U.S. Geological Survey does not maintain water quality records at the Wayland, Missouri gate station. In 1987, Missouri Department of Conservation personnel conducting faunal surveys in the Fox River Basin recorded various water quality parameters at selected sample sites (Table 6). All parameters measured were within acceptable standards for protection of aquatic life (MDNR 1987), and fish growth (Boyd and Lichtkoppler 1979). The only acute water quality problems known to the basin are low dissolved oxygen and high ammonia levels. Due to low base flow and nutrient loading from adjacent farmland, algal densities become elevated, often resulting in oxygen depletion when algae die. Ammonia problems may occur simultaneously due to organic waste input from livestock. Water temperature in many of these streams becomes unacceptably high from some species of fish, thereby limiting their distribution in the basin.

Only six pollution incidents have been recorded since 1969. Four incidents produced fish mortality, none of which were the result of natural causes. However, reports periodically surface detailing minor fish kills in localized areas. These episodes usually cease before the cause and extent of mortality can be determined.

Dumping of raw materials appears to have been the primary cause of fish loss in the last twenty years. The largest fish kill on record occurred in 1988 when an estimated 2,898 fish perished because liquid manure was pumped from a lagoon into a tributary of Honey Creek.
To date, no attempt has been made by the Environmental Protection Agency, Missouri Department of Natural Resources or the Missouri Department of Conservation to collect fish flesh samples for pesticide or heavy metal testing.

Point-Source Pollution

Point-source pollution moderately affects four streams in the basin (Figure ps). Effluents from sewage treatment lagoons are released from the cities of Kahoka and Wayland into tributaries of Brush Creek and Fox River, respectively. The Kahoka facility (S19, T65N, R7W) degrades approximately four miles of Brush Creek through discoloration under extended dry conditions (MDNR 1984). The Wayland facility (S30, T65N, R6W) impacts five miles of an unnamed tributary through discoloration, and the effluent ditch may pose a potential health hazard (MDNR 1984).

Water quality data collected from Brush Creek by Missouri Department of Conservation personnel detected no problems at that time (Table 6). Historically, severe pollution problems have occurred in the stream due in part to discharges from area dairy processors. In a statewide stream pollution survey conducted in 1968 (MDC memo, W.L. Redmon to J. R. Whitley, October 30, 1970), two dairy processing plants were discharging milk wastes and starch into the Kahoka sewage lagoon in excess of its capacity. Brush Creek at this time was reported to be "grossly polluted" and supported a dense growth of *Sphaerotilus spp*. Fish kills occurred in Brush Creek in 1968 and 1969 and Fox River in

1971 when cheese whey was discarded at the Kahoka City Dump (which drains into Brush Creek) and later at a lagoon near Fox River. Improvements made at the Kahoka treatment facility and the closing of the dairy processing plants have improved conditions in Brush Creek.

Two non-municipal discharges also occur in the basin. One discharges sewage from a lagoon into Wade Branch and another employs an aeration system before discharging directly into Fox River. Impacts from these discharges are considered slight as only .013 MGD (million gallons daily) of sewage is released on the average (MDNR 1984).

Point source originating in Iowa are not believed to adversely impact the Missouri portion of the Fox or Little Fox rivers (MDNR 1984). There are currently no known industrial discharges.

Non-Point Pollution

Sedimentation and inorganic turbidity are chronic and severe water quality problems. The Fox/Wyaconda basin delivers approximately 3 tons/acre of sediment to receiving streams annually and is ranked as the 9th worst subbasin of 45 subbasins in the state (SCS 1978).

Approximately 84% of the sediment originates from sheet erosion. Gully erosion problems are considered to be severe (SCS 1978), but have improved in the past 45 years as evidenced by fewer deep gullies observed on aerial photographs. No data are available on streambed or streambank erosion.

Table 6. Water Quality Parameters From Selected Sites in the Fox River Basin.

Stream Code	Stream Name	Sample Station	Date	Water Temp (F)	Cond. (umnos)	pH	TDS (mg/1)	Hard. (mg/1)	D.O. (mg/1)	NH3 (mg/1)	NO (mg/1)	Secchi (in)
37521000	Little Fox	01	08-12-87	79								
37521000	Little Fox	02	08-12-87	82	290	9.4	189	239	13.0	.5	.1	8
37521000	Little Fox	04	08-17-87	90	540	9.2	351	239	10.0			8
37521000	Little Fox	08	08-18-87	83	530	9.3	345	171	9.0			10
37500000	Fox	10	08-19-87	80		9.3		239	11.0	.05	0	12
37500000	Fox	11	08-19-87	80		9.6		222	11.0			13
37500000	Fox	12	08-20-87	83		9.3		239	8.0			8
37500000	Fox	16	08-20-87	82		9.4		222	14.0			8
37514000	Brush Creek	17	08-26-87	63		9.0		307				18
37500000	Fox	19	08-26-87	72								12
37500000	Fox	20	09-01-87	77		9.3		273	13.0			10
37500000	Fox	22	09-02-87	71	450		275					
37511000	Honey Creek	27	08-04-87	76	500	8.7	325	205	6.0	.05	0	6
37511000	Honey Creek	28	08-04-87	84	490	9.6	319	188	10.0			17
37511000	Honey Creek	29	08-05-87	73		9.3		342	8.0			
37511000	Honey Creek	31	08-05-87	85		9.2		239	10.0			

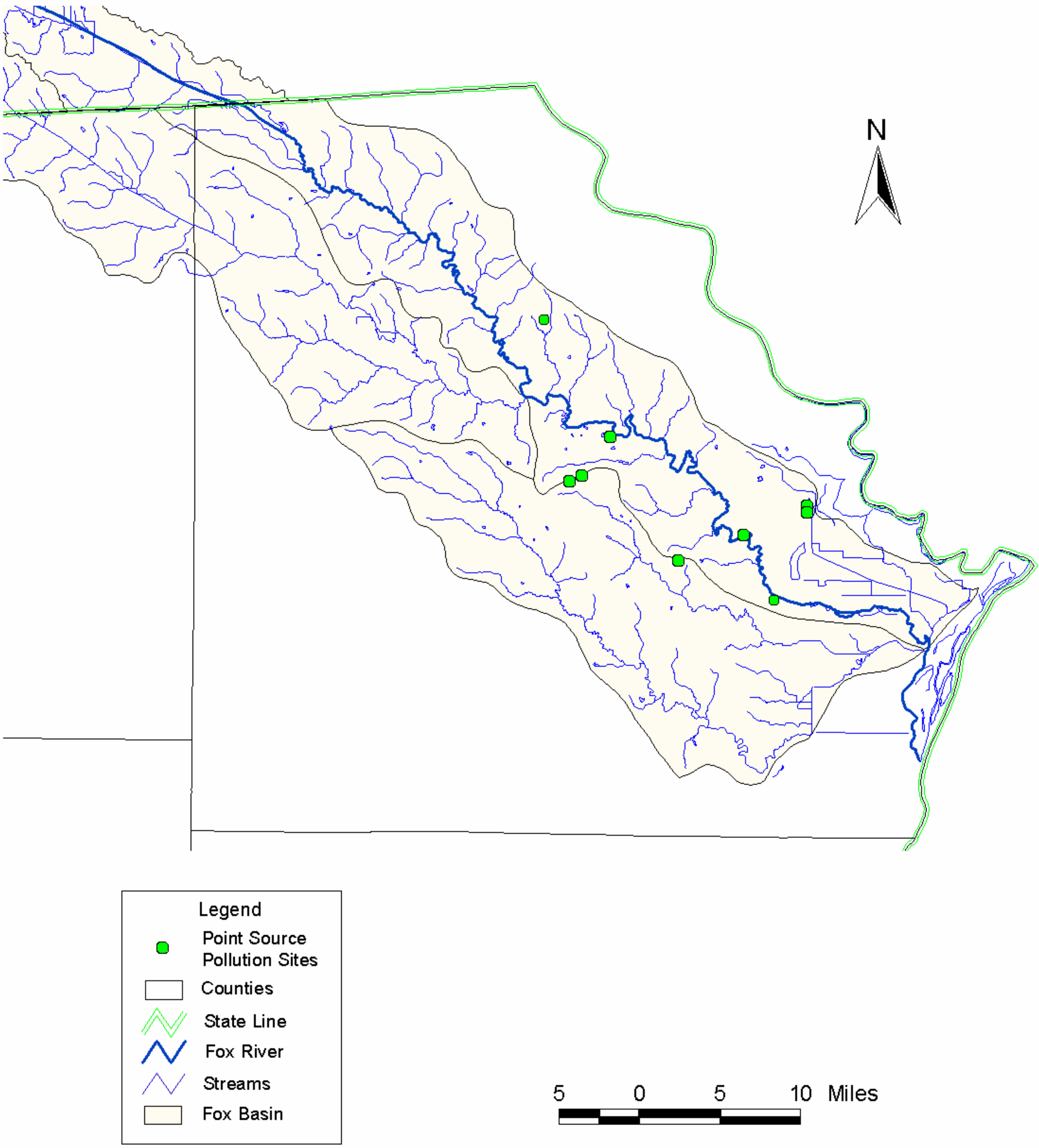


Figure ps. Point source pollution locations within the Fox River Basin, in Missouri.

HABITAT CONDITIONS

Channel Alterations

The Missouri portion of the Fox River basin supports 257.9 miles of permanent and intermittent streams (Table 1, contact authors for Table 1 information). At present, 205.3 miles, or 80%, are unchannelized. Extensive modifications, however, have taken place on a number of streams in the basin. Hemp Slough has been converted into a drainage ditch, and is 85% channelized. Many small streams of the Alluvial Plain have been altered in an attempt to facilitate drainage. For example, Big Branch is 61% channelized. Larger streams of the basin have also suffered. The Little Fox River is 49 percent, Sugar Creek is 41 percent and Honey Creek is 28 percent channelized. Insufficient information existed prior to channelization to determine the total miles of stream lost to modification.

Perhaps the most significant alteration that has occurred in the basin involved Honey Creek. Historically, Honey Creek was never a tributary of Fox River. The stream currently flows northeasterly after leaving the Kahoka Hills (Figure 1, contact authors for Figure 1 information). However, prior to its alteration, it flowed southeasterly, entering the Mississippi River in northern Lewis County. The alteration occurred in 1912 by the newly formed Gregory Drainage District (Mr. F.G. Neumann, personal communication). Two levees were constructed that diverted flow into the channelized portion of Sugar Creek (which occurred before 1900). Flow was diverted by first using straw bales, then later through additional levee work. Honey Creek, therefore, was never originally channelized but simply diverted between two levees. This explains why Honey Creek presently ceases to flow as it enters the Alluvial Plain. The channel bed is several feet above the normal contour of the land. Lost mileage for Honey Creek is not exactly known. It seems, however, that the stream was at least 12 miles longer than it is today.

By contrast, Fox River has undergone very little channel modification in the State of Missouri. At present, it flows freely for a distance of 49.8 miles; only 2.5 miles are channelized. Channelization occurred in the Upper Fox and Little Fox rivers in the late 1910s and early 1920s. Information derived from old topographic maps shows that Fox River flowed for 55.8 miles before modification.

The upper Fox River has been subjected to numerous channel modifications and dredging activities. Channelization first took place in 1917 and 1918, originating in the state of Iowa and continuing into Missouri for approximately 1.5 miles.

Channelization efforts ceased near the current northern boundary of Charlie Heath State Forest. Water velocity decreases at the point where the downstream end of a channelization reach meets the upstream end of an unchannelized reach. The downstream end of the channelized portion of Fox River quickly filled with sand; it was subsequently dredged in 1940-41, 1961 and again in 1974. However, by the mid-1970s, the channel was filled with sand and debris for approximately 0.7 mile. In response, the river formed a new channel, flowing south and then southeast before rejoining an old channel in Charlie Heath State Forest. The new channel is considerably narrower and somewhat straighter than the old channel. Consequently, flood frequency and severity have increased along this stretch of the river. In addition, Fox River in Charlie Heath State Forest was shortened by approximately 0.5 mile.

Many streams in the Alluvial Plain have been leveed. Much of this activity occurred early in this century. Fox River's lower 11 miles, 7.2 miles of Honey Creek and 2.8 miles of Sugar Creek have been leveed.

Unique Habitats

Despite intense agricultural development, a few natural communities of local and statewide significance can still be found in the basin. Most notable is the privately owned wetland known as Goose Pond (Figure hb). This area is thought to have been a former channel of the Des Moines River. As the Des Moines migrated away from this location, it left an oxbow that has undergone succession and is today classified as a deep fresh marsh (Alexander 1983). A network of drainage ditches and levees now surround the marsh and flow into the Fox River watershed. Goose Pond is approximately 320 acres located in S32 and 33, T65N, R6W and S4 and 5, T64N, R6W in Clark County.

Goose Pond is of statewide significance because of its diversity of wetland flora and fauna. Three Missouri endangered species are known to the marsh, the Illinois mud turtle (*Kinosternon flavescens*), Blanding's turtle (*Emydoideablandingii*) and the central mudminnow (*Umbra limi*). The Illinois mud turtle and the central mudminnow are restricted to the Fox River basin in Missouri. Indeed, ecosystems of this type, with their unique species assemblages, have largely been eliminated from the Fox River basin.

One unique ecosystem was known as Britton Prairie, located on Honey Creek in S21, 22, 27, 28 and 33, T64N, R6W. This area, drained and leveed beginning in the 1910s, undoubtedly supported a rich diversity of hydrophilic life, perhaps similar to what exists today at Goose Pond and the Rose Pond Natural History Area (NHA). According to Mr. F.G. Neumann (personal communication), the area encompasses over 1,000 acres of native wet prairie. Apparently, it was a haven for waterfowl. During dry periods large prairie fires broke out. Today, only about 5 acres remain.

Rose Pond NHA (Figure hb), obtained by the Missouri Department of Conservation in 1983, supports two endangered species—the Blanding's turtle and the Illinois mud turtle—in addition to unique wetland flora. Rose Pond, like Britton Prairie, was a marsh and has undergone extensive leveeing and dredging that lowered its water table in the early 1970s.

The Waterloo Cemetery (Figure hb) overlooks Fox River at S9, T65N, R7W, northeast of Kahoka. Approximately one acre of undisturbed natural prairie may be found on an unused portion of the cemetery.

Alexander (1983) listed the Fox River from Missouri State Highway 81 to U.S. Highway 136, a distance of approximately 15 miles, as a "significant aquatic area." Dr. William L. Pflieger selected this stretch of Fox River to represent "some of the best remaining stream habitat in northeast Missouri." To qualify for this distinction, the streams must be unchannelized and support a diversity of aquatic life.

Based upon habitat and fish surveys in the basin, there do not seem to be any habitat or fish assemblages that are unique to Fox River or northeastern Missouri. There are, however, a few species of fish that are rather distinctive of this region (see account under stream biota). Interesting geological features are present in the basin and offer a diversity of habitats, leading to a somewhat rich assemblage of stream fishes.

One of these interesting geological areas occurs on Fix River near the town of Chambersburg at the southern ½ of S9, T66N, R8W. Here, a large outcrop of bedrock has been exposed forming an isolated area in the Drift Plain more characteristic of the Kahoka Hills region (Figure hb). Expansive pools are separated by short cobble and rubble riffles. The substrate is exclusively bedrock, often covered with silt, sand and gravel. A 1:1 pool/riffle ratio, relatively deep water and diversity of habitat promote high species richness for a stream of this size. At no other location in the basin did we observe such pronounced bedrock exposure and sharp contrast in adjoining habitats (prairie and woodland).

Exposed geode deposits are common in the basin and in northeastern Missouri in general. However, the largest deposit known to the basin and perhaps to northwestern Missouri was documented during the 1987 survey (Figure 10). Located in the northeastern 1/4 of S23, T65N, R7W, this deposit spans the width of the river bottom and continues outward from each bank for several hundred feet. Goedes in diameters greater than two feet were found. Commonplace were geodes 6 to 12 inches in diameter. Riffles were composed entirely of broken and intact geodes. Benthic fishes were particularly abundant in this reach.

Upstream from the geode deposit, approximately 1.5 miles, is yet another unusual geological formation (Figure hb). Here a natural bridge spans the width of a small tributary to Fox River in the northeast 1/4 of S14, T65N, R7W. The opening is large enough to walk through. It may be the only such geological phenomenon in northeastern Missouri.

Honey Creek from river mile 22 to river mile 8 flows through the heart of the Kahoka Hills region (Figure 3, contact authors for Figure 3 information). This region characterized by steep bluffs of limestone, forms a rather unique stream habitat. The pool/riffle ratio approaches 1:1 and the substrate is composed chiefly of gravel and rubble. Steep wooded bluffs combined with the limestone outcrops, rocky bottoms, somewhat clear water, and increased species richness is more reminiscent of habitat found in the lower Fabius River system in Marion County (Hrabik, unpublished data and personal observations). Despite some degradation due to siltation and channel alteration, this reach of Honey Creek represents some of the finest stream habitat remaining in the basin and is deemed significant.

Improved Projects

To date, no projects have been initiated specifically to improve fish habitat, perpetuate rare and/or endangered species or to enhance the quality of fishing in any streams in this basin.

One bank stabilization project was completed in 1980. The U.S. Army Corps of Engineers laid a blanket of rip-rap on an eroding bank of the Fox River in S25, T65N, R7W at river mile 17.5. The bank was graded to a 2:1 slope and an 18-inch blanket of rip-rap was laid for a distance of 1,000 feet. The purpose of the project was to protect a county road in danger of becoming undermined. An inspection of this site in 1987 revealed that the project had halted erosion in the meander.

Sample Site Selection

Thirty-one sites in the Fox River basin were selected for habitat assessment during the summer of 1987. Due to drought conditions, only 19 sites were sampled (Table 7).

Stream order was determined for all streams in the basin to demarcate major sampling boundaries. Representative reaches within a given stream order were then determined. First gradient plots were constructed. Local variation in slope was used to divide a gradient plot into blocks. Within each gradient block, habitats, based on riparian corridor conditions, channel morphology, surrounding topography, land use, unique geological features and substrate type were stratified into segments. All habitat parameters could be determined by aerial photography or topographic maps with the exception of substrate type. Substrate type was often inferred based on surrounding topography, land use and channel morphology.

Similar habitat segments were grouped and, using a stratified random approach, sample sites were selected as "representative reaches" within a stream segment of a gradient block. (See Appendix A for clarification). Representative reaches with access were given preference.

Habitat Evaluation Methods

Habitat quality was determined by the Missouri Department of Conservation's in-house Stream Habitat Assessment Device (SHAD, Version 1) which ranks ten parameters from best to worst. SHAD was derived and modified from the Stream Habitat Evaluation Procedure (SHEP, Fajen and Wehnes 1981). Numerical scores were assigned to categories within each parameter being evaluated. All assessments were subjective and reflected inter-site comparisons and the experience of the evaluator. For purposes of discussion in this report, a reach of stream having a SHAD score of less than .70 out of a possible score of 1.00 is considered degraded and in need of habitat improvement.

Average scores derived from SHAD are site specific; and because site selection was not entirely random, they do not represent habitat quality of entire subbasins. Furthermore, scores indicative of quality habitat (greater than .70) may combine high scores for several parameters with a low score for one or more parameters, thereby masking degradation that may affect fish populations.
Habitat evaluations were based upon total length of stream sampled for fish population information (Table 8). This was done in order to establish meaningful relationships between habitat and fish population data.

Various habitat parameters were measured or estimated and recorded on a standardized data sheet (Appendix B, contact authors for Appendix B information). Substrate composition was estimated by the points sampling method (Wright et.al. 1981) in which particle size within standardized areas (points) of a grid system is visually determined, tallied and converted into percent coverage. Substrate particle size followed that of Cummins (1962) and the modified Wentworth classification. The one deviation from the modified Wentworth scale was the recognition of rubble size material (250-450 mm in diameter), thereby elevating the size of boulder material to be greater than 450 mm in diameter. Percent shading was estimated visually by observing the shaded portion of the stream when the sun was at its highest point over the channel. An average shading figure was approximated over the entire reach and was reported as percent shading.

The description of the ecological area and erosion potential were subjective evaluations based on historical land use and the erosiveness of streambank soils. Ecological areas were divided into prairie, prairie/woodland integrade, and woodland ecotones. Erosion potential was separated into slight, moderate and substantial categories. Erosion potential was also addressed in SHAD not only by estimating the erosiveness of bank materials, but also taking into account man-induced influences. Each bank was evaluated when using SHAD. The erosion potential determination recorded on the standardized data sheet attempts to account for soil erosiveness, but without considering man's impact.

Using information collected for SHAD analysis, each sample site was categorized into one of four broad habitat classes: unchannelized with a wide riparian corridor where both banks had an average riparian corridor width close to or exceeding 100 feet (UW), unchannelized with a narrow riparian corridor where both banks had an average riparian corridor width less than 100 feet (UN), channelized, wide corridor (CW) and channelized, narrow corridor (CN). No sites were sampled in the CW category.

Habitat Evaluation

A total of 15,417 feet (2.92 miles) of Fox River and its major tributaries were evaluated in 1987 for habitat quality and fish population characteristics (Table 8).

Habitat quality can be characterized by physiographic landform within the basin. Streams originating in the Drift Plain region were small, shallow and had somewhat narrow channels. Pool depth averaged 1.7 feet and rarely exceeded 4 feet. Substrates were mostly sand-silt; however, gravel and limestone outcrops occurred locally. Channels were generally quite sinuous where channelization had not occurred. Riffles were uncommon or non-existent in most streams of the region, occurring only in rare areas of gravel deposit and/or bedrock outcrop. There was some evidence of embedded riffles in the upper Fox River.

Instream cover was particularly limiting to fish populations. At most sample sites, instream cover (root wads, snags, etc.) was embedded or of insufficient size to provide adequate habitat. Erosion potential of uplands and streambanks was classified as moderate to high. The average SHAD score 0.73 did not indicate major stream habitat problems in this region. However, the score did indicate that some habitat parameters were borderline degraded and in need of improvement.

Reasons for degradation in the Drift Plain are many. Channelization has adversely affected approximately one-half of the Little Fox River. Though most of the small streams (orders 1-3) of the reg are unchannelized, some have been altered at least 20 percent (Table 1). As a result of channelization a few streams, and in particular the Little Fox River, have suffered head cutting, widened channels and sand deposition. However, because channelization occurred over 70 years ago, banks were fairly stable and the quality of the narrow riparian corridors was surprisingly good.

Steams originating in or flowing through the Kahoka Hills region contained higher quality fish habitat than those originating in the Drift Plain. These stream channels were generally straight and narrow. Pool depth averaged 1.9 feet and rarely exceeded 6 feet. Many small streams originate in the Kahoka Hills but most are intermittent, so stream beds were often covered with vegetation over substrates of sand and silt. Permanent streams were characterized by a variety of instream habitat and substrate types. Cobble and rubble size substrate material was found over the entire region, and were occasionally predominant substrate types. However, the substrate in most permanent streams of the Kahoka Hills region was sand-gravel or sand-cobble.

Unlike streams in the Drift Plain, streams in the Kahoka Hills had lots of riffle habitat. Pool/riffle ratios of 1.5:1 were typical. Channels typically had long, straight, narrow pools often with hairpin turns as the stream meandered between adjacent bluffs. Riffles separated most pools with frequent interspersion of shallow sandy or gravelly runs. Instream cover was abundant in the Kahoka Hills. In some areas, rootwads in excess of two feet in diameter numbered 15-20 in a 1/4-mile stretch of stream. Log jams seemed to be less frequent in this region than in the Drift Plain. Erosion potential ranged from low to high depending upon streambank materials. In general, banks were more stable than in the Drift Plain because soils were less erosive and riparian corridor quality was higher. The average SHAD score, however, was slightly lower in the Kahoka Hills region than in the Drift Plain, due primarily to poor elevations given to Brush Creek, degraded by domestic discharge from the City of Kahoka, and lower Honey Creek, where flow subsided into unconsolidated streambed materials. The average SHAD score of .70 indicates that streams of the region need improvement.

Excessive bedload was the primary habitat problem in streams of the Kahoka Hills region. Many of the streams were much too shallow for their size and order. Although rocky substrates were exposed in riffle or run areas, pools which may have historically consisted of bedrock or rocky substrates were often covered with a layer of silt or sand now functioning as the streambed. The main cause of excessive bedload was probably intensive grazing of the uplands and riparian corridors.

Almost all streams flowing through the Alluvial Plains were channelized and/or converted into drainage ditches. The streams were very shallow (<2 feet deep, except for lower Fox River at its confluence with the Mississippi River), and often ceased to flow during dry seasons. Substrates were sand, silt and to a lesser degree, gravel. There were no riffles, but gravelly runs could be found in Fox River. Due to channelization and levees, most streams in the region had straight and narrow channels. There was very little fish habitat in most streams of the region, however, lower Honey Creek and Fox River had tree stumps and brush piles of sufficient size to provide cover for many species of sport fish.

All streams entering the Alluvial Plain had moderate to high erosion potential due to channelization and erosive soils. Erosion potential was much less in lower Honey Creek and Fox River near the confluence of the Mississippi River because of high quality riparian corridors. Elsewhere in the ion, riparian corridors were in extremely poor condition. Average SHAD score was .68, the lowest of any physiographic region.

Channelization was the primary reason for degradation in streams of the Alluvial Plain, resulting in heavy bedload and limited fish populations. In addition, in-stream cover was rare except in lower Honey Creek and Fox River.

Fox River had the highest average SHAD score (.81) in the basin. This was due to several factors: 1) water quality was very good; 2) riparian corridors were generally of good width and quality; and 3) only five percent of the river has been channelized. The subbasin is not without problems, however. Insufficient pool depth and lack of instream cover reduces habitat suitability for large fish.

The Little Fox River had a much lower average SHAD score (0.70) than Fox River primarily because of extensive channelization. However, altered portions of the river have not been maintained, so the channel has developed a "natural" appearance. Although many riparian corridors were narrow, they were generally in good condition. Therefore, streambanks were usually stable even in channelized sections. As in the Fox River subbasin, depth was poor, bedload (sand and silty-sand) was heavy and instream cover was inadequate.

Sugar Creek scored 0.68 using SHAD at one locality. Riparian corridor quality was similar to other reaches in the Kahoka Hills region. Streambank soils were only slightly erosive and water quality problems were infrequent. However, Sugar Creek was marred by shallow pools filled with unconsolidated sediment (usually sand). Instream cover was nonexistent. Sugar Creek was 100% channelized in the Alluvial Plain where flow often subsides after it leaves the Kahoka Hills.

Honey Creek was characterized by the most interesting and the worst habitat in the basin. The average SHAD score was 0.62, lowest among the three major Fox River tributaries. Habitats throughout much of the Drift Plain and Kahoka Hills were in good condition. Riparian corridors were often narrow but usually of high quality. Sedimentation did not s to be excessive, although most pools showed signs of deposition. Instream cover, such as crevice habitat and root wads, as more abundant than in other subbasins. The diversity of substrate and microhabitats increased species richness and diversity. However, an abrupt transformation occurred as the stream left the Kahoka Hills and entered the Alluvial Plain. Sediment rapidly deposits as gradient levels off near the lower end of the Kahoka Hills. Almost all of lower Honey Creek in the Alluvial Plain was channelized. Pools were shallow, instream cover nonexistent, and riparian corridors were of unacceptable width and quality. The SHAD scores assigned to these lower stations were the poorest in the basin.

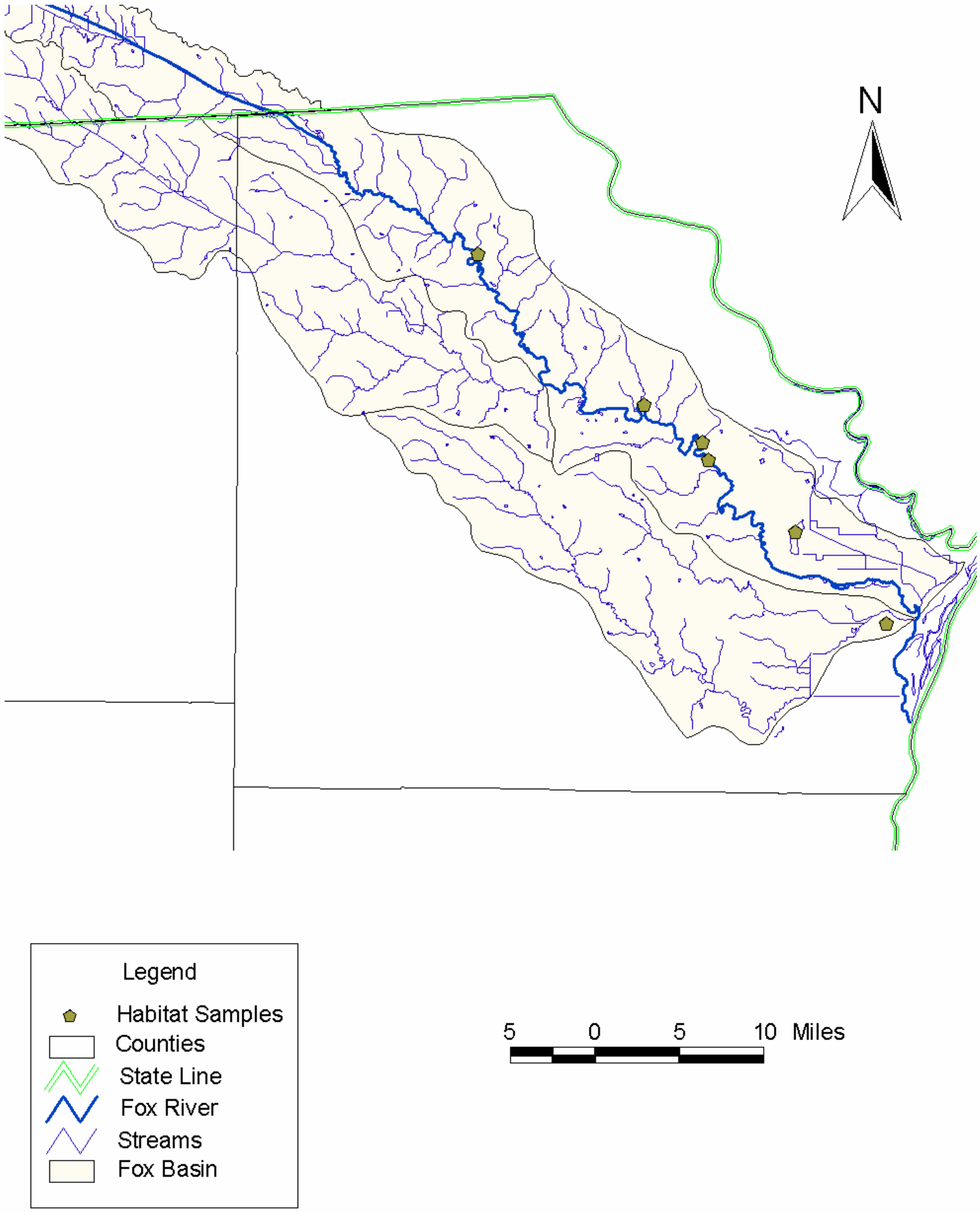


Figure hb. Habitat sample sites in the Fox River Basin, in Missouri.

Table 7. Stream Habitat and Fish Sample Sites in the Fox River Basin, 1987.

Stream Code/Name	Site	Order	River Mile	Location Township-Range-Section	Topographic Map	Survey Date
37521000 - Little Fox River	1	3	22.9	67N-10W-19	Azen	08-12
37521000 - Little Fox River	2	3	14.6	66N-09W-08	Mount Sterling	08-12
37521000 - Little Fox River	4	4	3.7	65N-08W-04	Medill	08-17
37521000 - Little Fox River	8	4	0.0	65N-08W-22	Kahoka	08-18
37500000 - Fox River	10	4	44.0	66N-08W-06	Anson	08-19
37500000 - Fox River	11	4	38.7	66N-08W-16	Anson	08-19
37500000 - Fox River	12	4	35.0	66N-08W-27	Medill	08-20
37500000 - Fox River	16	5	24.6	65N-07W-09	Kahoka	08-20
37514000 - Brush Creek	17	2	1.4	65N-07W-16	Kahoka	08-26
37500000 - Fox River	19	5	19.2	65N-07W-23	Kahoka	08-26
37500000 - Fox River	20	5	10.6	64N-06W-19	Kahoka S.E.	09-01
37500000 - Fox River	22	5	4.0	64N-06W-18	Warsaw	09-02
37512000 - Hemp Slough	23	-	4.8	65N-06W-35	Wayland	09-01
37511100 - Sugar Creek	26	3	4.6	64N-06W-07	Kahoka S.E.	08-06
37511000 - Honey Creek	27	3	21.6	64N-07W-17	St. Patrick	0804
37511000 - Honey Creek	28	3	14.1	64N-07W-26	St. Patrick	08-04
37511000 - Honey Creek	29	3	12.3	64N-07W-36	Kahoka S.E.	08-05
37511000 - Honey Creek	30	3	5.8	64N-06W-28	Kahoka S.E.	08-06
37511000 - Honey Creek	31	4	1.8	64N-06W-14	Kahoka S.E.	08-05

Table 8. Habitat Parameters in the Fox River Basin, 1987.

Streamcode/Name	Site #	Sample Length (ft)	Average Channel Width (ft)	Average Depth Pools (ft)	Substrate Composition**	Pool/ Riffle Ratio	Ecological Area Land Use	Erosion Potential	SHAD	Habitat Class
37521000-Little Fox River	1	200	10	.84	SA70, SL30	---	prairie-meadow/row crop	moderate	.55	CN
37521000-Little Fox River	2	370	10	1.00	SA70, SL30	---	rolling prairie/row crop	moderate	.80	UN
37521000-Little Fox River	4	800	15	2.00	SA80, SL20	---	floodplain prairie/row crop	moderate	.82	UN
37521000-Little Fox River	8	1850	25	2.40	SA90, SL10	---	floodplain prairie/row crop	high	.61	UN
37500000-Fox River	10	655	20	2.17	SA60,SL40	---	rolling prairie pasture/row crop	moderate	.76	UN
37500000-Fox River	11	750	40	2.00	BD45,SL20, SA15, CB15, RB5	1:1	prairie/woodland timber/row crop	low	.88	UW
37500000-Fox River	12	710	35	2.00	SA50, SL50	---	rolling prairie/row crop	moderate-high	.82	UN
37500000-Fox River	16	1152	40	2.50	SA40, SL30, RB20, CB10	---	prairie/woodland timber/row crop	moderate	.84	UW
37514000-Brush Creek	17	450	10	2.00	SA40, SL30, GR25, CB10	1:1	prairie/urban/row crop	moderate	.67	UN
37500000-Fox River	19	1700	40	2.00	CB30, BD20, RB20, SL10, SA7.5, GR7.5, BL5	1.5:1	prairie/woodland pasture/row crop	low-moderate	.79	UW
37500000-Fox River	20	1850	40	2.00	SA45, SL35, GR20	---	floodplain timber/row crop	moerate-high	.71	CN
37500000-Fox Creek	22	1550	40	6.00	SA50, SL50	---	floodplain woodland/row crop	low moderate	.88	UW
37512000-Hemp Slough	23	140	30	3.00	SL100	---	floodplain prairie/row crop	low	--	CN
37511100-Sugar Creek	26	50	10	0.84	SA80, SL20	---	woodland/row crop	moderate	.68	UW
37511000-Honey Creek	27	490	18	1.50	SA50, SL40, GR1	---	prairie pasture/row crop	moderate	.71	UW
37511000-Honey Creek	28	1100	23	2.00	RB70, GR15,SA15	1.5:1	woodland/row crop	low-moderate	.73	UW
37511000-Honey Creek	29	250	12	1.00	SA90, SL10	---	woodland/row crop	moderate-high	.47	UN
37511000-Honey Creek	30	150	30	2.50	SA50, SL50	---	prairie/marsh/row crop	high	.47	CN
37511000-Honey Creek	31	1200	18	1.50	SA50, SL50	---	floodplain woodland/woodland	low	.68	UW

***SA=sand, SL=silt, BD=bedrock, GR=gravel, CB=cobble, RB=rubble, BL=boulder**
***CN=channelized, narrow corridor; UN=unchannelized, narrow corridor; UW=unchannelized, wide corridor**

BIOTIC COMMUNITIES

Sample Site Selection

Thirty-one sites in the Fox River basin were selected for habitat and biological assessment during the summer of 1987 (Figure fs). Due to drought conditions, only 19 sites were sampled (Table 7, contact authors for Table 7 information).

Fisheries Evaluation Methods

Nearly three miles of Fox River and its tributaries were sampled during summer 1987. The minimum sample area per station was one pool and two riffles, runs or glide habitats. Usually, three pools and three riffles, runs or glides were considered to be adequate. Fish were collected primarily by seine measuring 25'x6'x1/8" mesh. Riffles were sampled using kick seine methods. Pools were usually surveyed in a downstream direction. The number of seine hauls varied, but usually consecutive hauls were made until the number of fish captured approached zero or were substantially fewer than in preceding hauls. Large, deep pools were "walked" downstream with one person stationary near the bank and the other sweeping 180 degrees around the pivot. Where possible, a boat mounted direct current electrofishing rig was used to sample deep pools. Large fishes were weighed, measured and returned to the water on site. Spines or scales were taken from selected species for age analysis. Small fishes were preserved on site with 10% formaline and later identified and enumerated in the laboratory. Voucher specimens were deposited at the University of Nebraska State Museum. Analyses of fish community data followed Pflieger (1971) for geographical affinity and Pflieger (1989) for ecological affinity within Missouri. Trophic guild assignments followed Karr, et. al. (1986) and were occasionally amended at the discretion of the investigator in order to reflect knowledge of local fish ecology.

Fishery Evaluation

A total of 52 species of fishes are known to the Fox River basin in Missouri, representing 14 families (Table 9). The 1987 survey yielded 19,582 fish, 47 species and one hybrid, adding 16 species to the annotated list. Five species recorded from the basin prior to 1987 were not collected. In general, the number of species collected per station increased with an increase in stream order (Figure 12, contact authors for Figure 12 information).

In general, the Fox River basin was dominated by ubiquitous, wide ranging or large river species. As classified by Pflieger (1971), wide ranging types accounted 35% of all species collected. Other faunal groups were almost evenly represented; prairie species accounted for `8%, while the river, lowland, and Ozark-prairie faunal groups each contributed 14% to the total. Ozark species (four) comprised 8% of all species known to the basin.

Dominant fish families were minnow (Cyprinidae-15 species), sucker (Catostomidae-8 species), catfish (Ictaluridae-7 species), sunfish (Centrarchidae-7 species) and perch (percidae-5 species).

The most collected fish was the omnivorous red shiner which comprised 31% of the total sample and occurred at 95% of the 1987 sample sites (Table 10). The bluntnose minnow, also an omnivore, was the second-most sampled fish, totaling 23% of all collected specimens and occurring at 84% of the sample sites. Other frequently sampled species include the central stoneroller, channel catfish, mosquitofish, green sunfish, and johnny darter. All of these species occurred in at least 60% of the collection sites.

Species associated in the Fox River basin seemed to be limited to physicochemical parameters—often the case in prairie stream systems (Matthews 1988). The typical headwater species in this basin were tolerant types able to withstand environmental extremes. This typifies mid- and southern-plains streams, which differ from the northern plains where species associated in headwaters, due to more stable groundwater flow, consist of more intolerant types (Matthews 1988, Hrabik 1989). Common headwater species in the Fox River basin were the golden shiner, flathead minnow, creek chub, white sucker, black bullhead, green sunfish and johnny darter. These fish are insectivorous and omnivorous generalists.

Creek and small river habitats (e.g. Honey Creek, Little Fox River and the upper Fox River) support a richer fish fauna than the headwaters. The most common species were the central stoneroller, red shiner, bigmouth shiner, sand shiner, suckermouth minnow, bluntnose minnow, quillback, shorthead redhorse, channel catfish, mosquitofish, orangespotted sunfish, smallmouth bass and slenderhead darter. This species association consists of more specialized foragers and predators. Conspicuously absent from this assemblage, however, was the redfin shiner (*Notropis umbratilis*). This fish is widespread over most of northeastern Missouri (Pflieger 1975) and is dominant in some drainages (Hrabik, unpublished data). Its absence from Fox River, despite suitable habitat, poses an interesting zoogeographic question concerning the distribution of fishes in northeastern Missouri.

Fishes occurring in the lower Fox River were primarily specialized insectivores and predators. They included gar, common carp, silver chub, emerald shiner, river carpsucker, buffalo, flathead catfish, channel catfish, white bass, white crappie, sauger, walleye and freshwater drum.

The fishes of the Fox River basin can be characterized as widespread, tolerant, prairie-Ozark types. However, four species in the basin have been identified by Karr et.al. (1986) to be intolerant types. They are the Mississippi silvery minnow, slender madtom, tadpole madtom, and slenderhead darter.

The slender madtom, an Ozark species, has particular habitat and water quality requirements, and would be a good indicator of environmental perturbation. However, its preferred habitat is limited in the basin, making it too uncommon a resident of Fox River to serve as a water quality indicator.

The slenderhead darter was surprisingly abundant in the basin, reaching its greatest diversity in the middle section of Fox River. The upper Mississippi River drainage seems to be a stronghold for this species in Missouri (Pflieger, personal communication). Its habitat requirements and distribution abroad (Lee et.al. 1980) suggest a preference for clear, cool water. However, it was more widespread than the slender madtom in the Fox River basin and seemed to tolerate moderate sedimentation.

The tadpole madtom is an insectivore found in small, sluggist streams reach in organic debris. It seems tolerant of high turbidity and silt, particularly in the western plains (Hrabik, unpublished data). In northeastern Missouri, tadpole madtoms are found in low gradient, murky streams, some of which have been channelized (Hrabik, unpublished data). For these reasons, it is not considered to be an intolerant species in the Fox River basin.

The Mississippi silvery minnow has abruptly declined in the pooled portion of the Mississippi River (Pflieger 1975, Grace and Pflieger 1985) and was last collected from Fox River in 1941. Similar declines have occurred elsewhere in its range particularly in Tennessee (Etnier 1979). Apparently, free flowing water is required for certain aspects of its life history, but reasons for its decline are not understood. The Mississippi silvery minnow has been recommended for listing as a Watch List species in Missouri because of its probable extirpation in northeastern Missouri streams, including the upper Mississippi River.

The only other species that may have inhabited the upper Fox River basin in Missouri was the Topeka shiner, *Notropis tristis* (formerly *N. topeka*). It was collected in Fox River in Iowa prior to 1948 and more recently in tributaries to the lower Des Moines River in Lee County, Iowa (adjacent to Clark County, Missouri) and in Cedar Creek, Clark County (Harlan and Speaker 1987, Hrabik, unpublished data). Its former distribution may have included other tributaries to the Des Moines River in Iowa and Missouri as well as the upper Fox and Wyaconda Rivers to the Chariton River basin, where it may still be found (Pflieger 1975).

Other unusual or rare species collected in the basin were northern pike, golden redhorse, orangethroat darter, warmouth, black buffalo and central mudminnow. No attempt was made to sample mudminnows in basin wetlands during the 1987 survey.

Northern pike were collected in lower Honey Creek near the confluence of Fox River. Apparently, a self-sustaining, low density population inhabits the Alluvial Plain as occasional reports of pike have come from the area. Pike have been sampled in Mississippi River floodplain ditches when flooded (Gordon Farabee, personal communication). Pike are sometimes captured as far south as Salt River in northeastern Missouri (Hrabik, unpublished data). They are currently under consideration for listing as rare in Missouri.

Golden redhorse and orangethroat darters are Ozark species in Missouri. We collected only one golden redhorse in the basin (Honey Creek). Orangethroat darters exhibited a wider but habitat-specific distribution. Before these collections, orangethroat darters were not known to occur north of the North River basin in Marion County. Subsequent surveys (Hrabik, unpublished data) have documented its occurrence in all major tributaries to the upper Mississippi River in northeastern Missouri.

Warmouth and black buffalo are peripheral to the basin. One warmouth was sampled in Fox River near the confluence of the Mississippi River in 1987. Warmouth are taken occasionally by anglers in the upper Mississippi River but are most abundant in the Bootheel area in Missouri. Although black buffalo are widespread in Missouri, they are rare in the upper Mississippi River where its frequency of occurrence declines south to north. One black buffalo was sampled from Fox River in 1941.

Mosquitofish and quillback were not collected by previous investigators, but they were widespread and abundant in 1987. Mosquitofish were not known to northeastern Missouri 15 years ago (Pflieger 1975). Today, this species is found in every major basin in northeastern Missouri (Hrabik, unpublished data). Similar range extensions have occurred in other Midwestern plains streams particularly after introduction (Brow 1987, Lynch 1988). The ecological consequences of introducing this species, and its rapid rate of colonization, are being argued by ecologists. In the Fox River basin and elsewhere in northeastern Missouri, mosquitofish seem to thrive in disturbed areas but are generally excluded in better quality streams (Hrabik, unpublished data).

Quillback were the most frequently collected sucker in the Fox River basin. This fish has probably always been abundant and widespread in the basin and may have been overlooked or misidentified by previous researchers.

Game fishes were well represented in the basin. Most intriguing, however, were the 116 smallmouth bass sampled in the middle section of Fox River. Similar to quillback, smallmouth bass were not recorded from Fox River prior to 1987. Smallmouth bass size structure was poor; the largest individual measured 8.9 inches (age-1+). Young-of-the-year averaged 4.6 inches (N=56) in August. Pflieger (1975) reported age-1 smallmouth bass at 3.5 inches from Ozark populations. The lack of older and larger smallmouth bass was puzzling. Apparently, reproductive habitat is available in the middle portion of Fox River but the fish move out as yearlings, presumably to the Mississippi River. If so, this eliminates smallmouth bass from consideration as the keystone predator in the system.

Channel catfish are the most important game species in the basin. They were collected at 63% of all sample sites and constituted 2.7% of all fishes collected. Substock size fish (<11 inches) dominated the sample, accounting for 84% of the 540 channel catfish captured in 1987 (Figure 13). Although sampling gear may have skewed the length frequency histogram somewhat towards smaller fish, the representation of size structure seems accurate for a mid-summer sample.

While the Fox River contained a high number of small channel catfish, its importance as a nursery area for the Mississippi River channel catfish population is unknown. In general, the relationship between channel catfish stocks in the Mississippi River and its tributaries is not well understood. For example, the Fox River channel catfish population is dominated by small fish in mid-summer, even in habitats which seem suitable for large fish. A pressing question is whether this is a static characteristic, or whether seasonal movements of adult channel catfish to and from the Mississippi River are so dramatic that catfish size structure in Fox River and other tributaries is strongly seasonal.

Mean length of 164 channel catfish ages 1-7 were 2.0, 4.8, 7.3, 9.7, 12.1, 14.2 and 16.9 inches, respectively (Table 11). This age structure seems consistent with that reported for another northeastern Missouri stream (Purkett 1958).

Only 28 flathead catfish were captured during the 1987 survey, 14 of which were marked with Floy anchor tags and released; there have been no returns. The low number of flathead catfish captured is probably not indicative of its true density in Fox River. Distribution and size structure may be better described by using multiple collection methods at various times of year. A few anglers report good catches of flathead catfish each year from the Kahoka Hills region.

Twenty-four flathead catfish were aged (Table 11). Mean length at age 4 was 10.1 inches in Fox River compared to 11.8 inches in Salt River (Purkett 1958). However, the small Fox River sample was inadequate to describe flathead catfish age structure. Fox River may function as a nursery area for the Mississippi River flathead catfish population. It is quite possible among the fish we aged that some of their growth occurred in the Mississippi.

White crappie were usually present in small numbers in pool habitats with cover. However, numerous white crappie from the Mississippi River utilize lower Fox River at various times—often a high proportion of 10-inch and larger fish. Fifty white crappie were collected during the 1987 survey; 82% were 9 inches long. Age 1-4 white crappie averaged 3.9, 8.2, 10.3, and 11.8 inches, respectively, suggesting rapid growth.

Aquatic Invertebrates

No detailed surveys of aquatic invertebrates, including freshwater mussels or clams, have been conducted in the Fox River basin to date. Although invertebrate sampling was beyond the scope of the 1987 survey, mussels encountered inadvertently were noted (Table 12).

The winged mapleleaf, *Quadrula frigosa*, is a candidate for Federal protection. Three specimens were collected by Charles Nelson in Fox River at T65N, R6W, Clark County, probably in the 1920s or 1930s (Dr. David H. Stansberry, Ohio State University, personal communication). This is the only known collection of this species in Missouri. The winged mapleleaf superficially resembles the mapleleaf (*Q. quadrula*), and may have easily been overlooked in 1987 if it still existed.

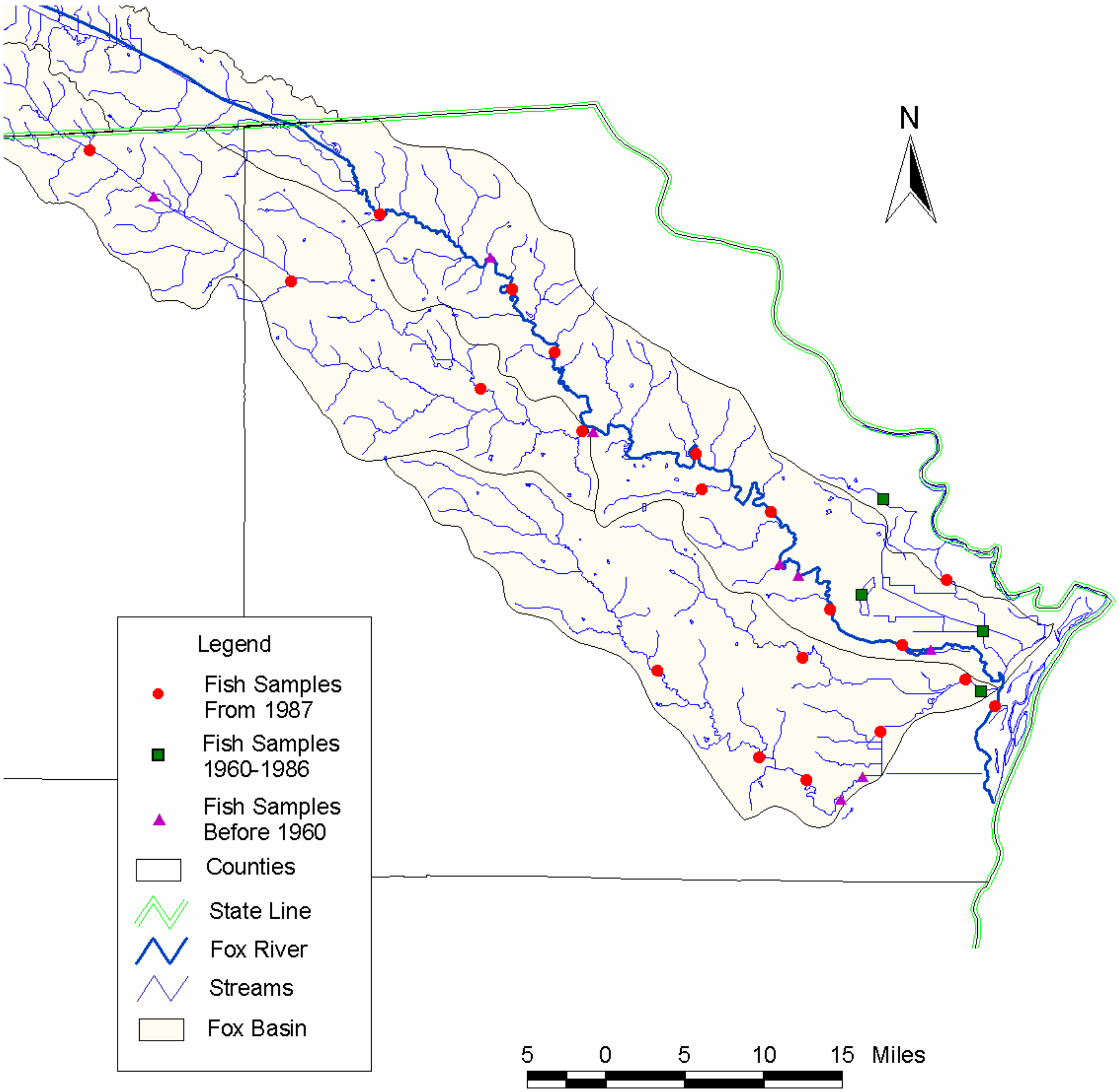


Figure fs. Fish sample locations in the Fox River Basin, in Missouri.

Table 9. Annotated List and Status of Fishes Known to the Fox River Basin, Including Trophic, Geographical, and Ecological Affinities.

Species	Coll. 1987 Survey	Coll. Prior Surveys	Trophic[1] Guild	Status[2]	Geographic[3] Affinity	Ecological [4] Affinity
Longnose Gar (*Lepisosteus osseus*)	X		P	LA	W	L-LR
Shortnose Gar (*Lepisosteus platostomus*)	X		P	LA	R	L-LR
Bowfin (*Amia calva*)	X	X	P	U	L	L-LR
Goldeye (*Hiodon alosoides*)	X		P	U	W	L-LR
Gizzard Shad (*Dorosoma cepedianum*)	X	X	O	LA	W	L-LR,LA
Central Stoneroller (*Campostoma anomalum*)	X	X	H	C	O-P	N-CR
Red Shiner (*Cyprinella lutrensis*)	X	X	O	C	P	N-CR,SR
Common Carp (*Cyprinus carpio*)	X	X	O	C	W	L-SR, LR
Mississippi Silvery Minnow (*Hyboqnathus nuchalis*)		X	H*	E	L	N-LR
Silver Chub (*Hybopsis storeriana*)	X	X	I	LA	R	N-LR
Golden Shiner (*Notemiqonus crysoleucas*)	X	X	O	LA	W	N-HS
Emerald Shiner (*Notropis atherinoides*)	X	X	I	LA	R	N-LR
River Shiner (*Notropis blennius*)	X		I	U	R	N-LR
Bigmouth Shiner (*Notropis dorsalis*)	X	X	I	C	P	N-CR
Sand Shiner (Notropis ludibundus)	X	X	O	C	P	N-CR,SR
Suckermouth Minnow (*Phenacobius mirabilis*)	X	X	I	C	P	B-SR,LR
Bluntnose Minnow (*Pimephales notatus*)	X	X	O	C	W	N-CR,SR
Flathead Minnow (*Pimephales promelad*)	X	X	O	LA	P	N-HS
Bullhead Minnow (*Pimephales viqilax*)	X	X	I	U	L	N-SR,LR
Creek Chub (*Semotilus atromaculatus*)	X	X	I	C	O-P	N-CR,HS
River Carpsucker (*Carpiodes carpio*)	X	X	O	C	P	L-SR,LR
Quillback (*Carpiodes cyprinus*)	X		O	C	P	L-SR
White Sucker (*Catostomus commersoni*)	X	X	I	LA	O-P	L-HS,SR
Smallmouth Buffalo (*Ictiobus bubalus*)	X		I	LA	W	L-LR
Bigmouth Buffalo (*Ictiobus cyprinellus*)	X		I\P	LA	W	L-LR
Black Buffalo (*Ictiobus nigeru*)		X	I	R	W	L-LR
Golden Redhorse (*Moxostoma erythrurum*)	X		I	R	O	L-SR,CR
Shorthead Redhorse (*Moxostoma macrolepidotum*)	X	X	I	C	O-P	L-SR
Black Bullhead (*Ameiurus melas*)	X	X	I	LA	W	L-CR,HS
Yellow Bullhead (*Ameiurus natalis*)	X	X	I	LA	W	L-CR,SR
Channel Catfish (*Ictalurus punctatus*)	X	X	I/P	C	W	L-SR,LR
Slender Madtom (*Noturus exilis*)	X		I*	U	O	B-SR
Tadpole Madtom (*Noturus gyrinus*)	X	X	I	U	O	B-CR
Freckled Madtom (*Noturus nocturnus*)		X	I	U	L	B-LR
Flathead Catfish (*Pylodictus olivaris*)	X	X	P	LA	W	L-SR,LR
Northern Pike (*Esox lucius*)	X		P	R	O-P	L-LR,LA
Central Mudminnow (*Umbra limi*)		X	O	R	P	N-LA
Mosquitofish (*Gambusia affinis*)	X	X	I	C	L	N-SR,LR
White Bass (*Morone chrysops*)	X		I/P	LA	R	L-LR
Green Sunfish (*Lepomis cyanellus*)	X	X	I/P	C	W	L-HS,SR
Warmouth (*Lepomis gulosus*)	X		I/P	R	L	L-LR
Orangespotted Sunfish (*Lepomis humilis*)	X	X	I	C	P	L-CR
Bluegill (*Lepomis macrochirus*)	X	X	I	LA	W	L-SR
Smallmouth Bass (*Micropterus dolomieui*)	X		I/P	C	O	L-SR
Largemouth Bass (*Micropterus salmoides*)	X	X	I/P	LA	W	L-SR
White Crappie (*Pomoxis annularis*)	X	X	I/P	LA	W	L-LR

Table 9 continued

Black Crappie (*Pomoxis nigromaculatus*)	X	X	I/P	LA	W	L-LR
Johnny Darter (*Etheostoma nigrum*)	X	X	I	C	O-P	B-HS,CR
Orangethroat Darter (*Etheostoma spectabile*)	X		I	U	O	B-HS,CR
Slenderhead Darter (*Percina phoxocephala*)	X	X	I*	C	O-P	B-SR,LR
Sauger (*Stizostedion canadense*)	X		P	LA	R	L-LR
Walleye (*Stizostedion vitreum*)		X	P	LA	W	L-LR
Freshwater Drum (*Aplodinotus grunniens*)	X		I/P	C	R	L-LR

[1] - H=Herbivore, I=Insectivore, O=Omnivore, P=Piscivore, *=Intolerant Species

[2] - C=Common, E=Extirpated, LA=Locally Abundant, R=Rare, U=Uncommon

[3] - L=Lowland, O=Ozark, P=Prairie, R=Big River, W=Wide Ranging

[4] - B=Benthic, L=Large Species, N=Nektonic, CR=Creek, HS=Headwater Stream, LA=Lake/Marsh, LR=Large River, SR=Small River

Table 10. Percentage Composition Within Sample Sites and Frequency of Occurrence Among All Sites of Fish Species Collected in the Fox River Basin, 1987 (*Denotes <0.5% Composition).

Species	1	2	4	8	10	11	12	16	17	19	20	22	23	26	27	28	29	30	31	Total % Comp	Total % Occr
Longnose Gar																			*	*	5
Shortnose Gar											`	*								*	5
Bowfin												*								*	5
Goldeye										*										*	5
Gizzard Shad											2	32						9	5	3	21
Central Stoneroller	1	*	*	*	*	*	*		5	*				10	1	11	9			2	68
Red Shiner	7	39	35	30	31	35	34	28	2	42	60	2		2	44	44	25	6	23	31	95
Common Carp					*			*				22	100					1	*	2	32
Silver Chub											*	*								*	11
Golden Shiner		*	*	*					3						2	*			2	*	37
Emerald Shiner				*								6							6	1	16
River Shiner												*								*	5
Bigmouth Shiner	70	17	9	17	10		4	*	2	*	1			39	3	5	6	1		10	79
Sand Shiner	1	12	6	2	2		2	3		2	1	*		6	3	2	5		*	2	79
Suckermouth Minnow	*	1		2	1		5	1	*		2	1		*	*	*	2		1	1	74
Bluntnose Minnow	2	11	20	13	31	38	46	45	18	37	14			7	17	22	38	1	14	23	84
Flathead Minnow	1	1	1	*			1	28			*				*				*	1	47
Bullhead MInnow											*									*	5
Creek Chub	12	3	1	3	1				18					13	4	2	1	1		2	58
River Carpsucker			1	2	5	*	1	4		1	4	2						1		1	53
Quillback	*	*	8	5	3	1	3	3		2	2	1		1	*	*	3	4	4	2	89
White Sucker	1	*	1	*			*		4					1	5	1	*	*		1	58
Smallmouth Buffalo												1							2	*	11
Bigmouth Buffalo												*							*	*	11
Golden Redhorse																			*	*	5
Shorthead Redhorse			1	2	1	2	1	1		*	1	*						*	*	1	58
Black				*	*		*		3			1			*	*	1	1	1	1	53

Table 10 continued

Bullhead																					
Yellow Bullhead		1				*			1						*		*	2		*	32
Channel Catfish			*	9	5	1	1	2		2	9	10				*		1	1	3	63
Slender Madtom						*				*						*				*	16
Tadpole Madtom																		*	*	*	11
Flathead Catfish					*	*		*		*	*	1								*	32
Northern Pike																			*	*	5
Mosquito-fish			*	9		1	1	1		1	2	1		2		2	8	55	16	3	68
White Bass												2							*	*	11
Green Sunfish		3	5	1	3	4	1	3	14	*	*	1		*	9	7	*	10		3	84
Warmouth												*								*	5
Orange-spotted Sunfish			*	*	*	*	1	2		1		9				*		1	1	1	58
Bluegill				*	*	*			1			2				*		1	10	*	42
Smallmouth Bass			1	2		1	1	2		2	*	*								1	42
Largemouth Bass				*								*			*			2	1	*	26
White Crappie			*	*	*	*		*				3							1	*	37
Black Crappie		*										1							1	*	16
Johnny Darter	3	7	7	2	5	4	3	2		*	*			15	10	3	2	1	1	3	84
Orange-throat Darter						*		*	*	*				2		1	*			*	37
Slenderhead Darter			1	*	1	8	*	3		6	*									1	42
Sauger												*								*	5
Freshwater Drum					*					*		2						3	5	*	26

Table 11. Age Structure of Channel and Flathead Catfish Collected from the Fox River Basin in 1987.

	Calculated Mean Length at Annulus						
	I	II	III	IV	V	VI	VII
Channel Catfish	2.0	4.8	7.3	9.7	12.1	14.2	16.9
Number Aged	44	14	19	50	18	4	15
Flathead Catfish	2.3	5.3	7.2	10.1	11.8	15.7	16.6
Number Aged	10	4	4	3	1	0	2

Table 12.Annotated List of Freshwater Mussels Sampled From the Fox River Basin in Missouri.

Giant floater	***Anodonta grandis grandis***
White heelsplitter	***Lasmigona complanata***
Fragile papershell	***Leptodea fragilis***
Pink heelsplitter	***Potamilus alatus***
Pink papershell	***Potamilus ohiensis***
Three ridge	***Amblema plicata plicata***
Fatmucket	***Lampsilis radiate***
Pondmussel	***Liqumia subrostrata***
Winged mapleleaf	***Quadrula frigosa***
Mapleleaf	***Quadrula quadrula***

MANAGEMENT PROBLEMS AND OPPORTUNITIES

Management Activities

Fish Introductions
To date, no attempt has been made to introduce exotic species or augment native populations through fish stocking. The possibility of transplanting endangered central mudminnows from Goose Pond to suitable locations in the basin has been discussed, but no formal plans have been written.

Sport Fishing/Harvest Regulations
Statewide creel and size limits are in effect.

Strategic Plan for the Fox River Basin

The following planning portion of this document is structured around the fundamental premise that there are three basic components to any fishery: 1) the habitat, which by definition includes water quality; 2) the aquatic biota, which include sport fish; and 3) recreational use and other interactions among people, habitat, and biota. The plan includes only the desired outcomes and actions which district staff of the Fisheries Management Section of the Missouri Department of Conservation can reasonably expect to achieve or influence during the next 25 years. The goals are of equal importance, but objectives and tasks are listed in priority order whenever possible.

GOAL I: Improve aquatic habitat conditions in the Fox River Basin so that all life stages of native fish species may thrive.

Perspective: In 1987, average Stream Habitat Assessment Device (SHAD) scores in three physiographic regions ranged between .68 and .73, indicating borderline stream habitat degradation throughout the basin. Approximately 20% of basin stream mileage was channelized. While the Fox River itself was virtually unaltered, the Little Fox River, Sugar Creek, and Honey Creek were channelized extensively 28-49%). Sedimentation is the only significant form of water pollution in the basin, but it threatens the integrity of the entire stream ecosystem. The Soil Conservation Service (1978) estimated that sediment delivery to the Fox and Wyaconda rivers averaged 3 tons/acre/year from the 483,780 acres which comprise the combined watersheds; this ranked ninth among 45 Missouri subbasins in rate of sediment delivery to stream channels. This sediment load equates to dumping 100,000 large truck loads of earth fill into these streams annually.

We have documented a reduction in Fox River base flow between the periods 1922-1952 and 1953-1980. A 90:10 ratio of 1:245 further indicates "flashy" streamflow. These hydrological problems are most probably tied to land use practices which have diminished the moisture retention capacity of basin soils. These net adverse effects have been measurable despite a 5.8%

increase in basin timber between 1939 and 1984, indicating that type of vegetative cover along may not have as significant an effect on basin hydrology as the manner in which cover types are managed. From the 1950s through the 1980s, an increasing dependence on monoculture, heavy machinery and chemical methods for producing crops has compacted the soil and reduced its organic matter content, thereby reducing its capacity to retain moisture.

The largely agricultural population of Clark County is generally unaware of the adverse effects that channelization, levee construction, riparian corridor clearing, and high-input agriculture have had on basin streams. Most are also in a poor position financially to act favorably upon any sense of stream stewardship which they may possess. It may be possible during the next 25 years to provide enough information and inspiration to begin reversing the trend toward stream habitat degradation, but it will require frequent interaction with school-age children, influential landowners, and the media. It will also require that aquatic resource managers acquire a working knowledge of the concepts and techniques of low-input sustainable agriculture. Significant change cannot occur without widespread adoption of this technology by basin landowners.

Objective 1.1: No additional channelization projects or levee construction projects which may damage basin stream channels.

Strategy: Preventing stream channel destruction will require a combination of watchdog activity in order to facilitate enforcement of current laws and education in order to build a consensus in thinking that will minimize the need for law enforcement action. To accomplish this, we should:

* Bring unpermitted wetland fill projects to the attention of the U.S. Army Corps of Engineers and comment on all basin applications for wetland fill projects which fall under the jurisdiction of Section 404 of the Clean Water Act.
* Make classroom presentations on stream conservation to Clark County sixty graders, including demonstration of the artificial stream whenever possible.
* Prepare news releases for the Kahoka newspaper, "The Media," which describe problems associated with channelization and levee construction projects.

Objective 1.2: Stream Corridor Plans developed and implemented as part of Area Plans for Charlie Heath SF and Fox Valley SF.

Strategy: The time of completion of Stream Corridor Plans will depend upon inter-divisional priorities for planning Department of Conservation areas. Even though streambank erosion and riparian corridor problems on these areas are not serious or widespread, implementation of Stream Corridor Plans, once written, should proceed with relative dispatch. To start the process, we should:

* Participate in area planning committees at time of formation by the managing MDC division.
* Ensure that Stream Corridor Plans include restoration of badly eroded streambanks and conservation of wooded corridors which extend at least 100 feet from the top of banks on all order-3-and-larger streams.

Objective 1.3: A majority of basin farmers engaging in low-input, sustainable agriculture.

Strategy: The Department of Conservation lacks a survey system which will allow us to track the number of Fox River basin farmers who are using low-input, sustainable production methods. Because of this, and because we do not know if agricultural agencies can provide the data for evaluation, we must first:

* Work with the National Center for Appropriate Technology, agricultural agencies, and the Department of Conservation's Biometrics Unit, Stream Unit, and Planning Section in order to develop an effective and efficient survey system.
Once a survey system is operational, we should begin educational efforts which will help us to approach the objectives, such as:
* Educate ourselves and our audiences by reading and sharing information contained in the following sources:
- ATTRAnews, the newsletter of Appropriate Technology Transfer for Rural Areas which is funded by a grant from the U.S. Fish and Wildlife Service.
- project summaries of the USDA Sustainable Agriculture Research and Education Program, which include USDA project summaries and reports of the EPA-USDA "Agriculture in Concert with the Environment" (ACE) program (in Folio InfoBase format).
* Prepare news releases for the Kahoka newspaper, "The Media," and the local SWCD newsletter which describe the economic and ecological advantages of low-input, sustainable crop production methods.
* Seek invitations to speak to groups of landowners or business people about the potential benefits to streams of altering the prevailing approach to agriculture.

Objective 1.4: A majority of basin landowners who use acceptable methods for managing their riparian corridors.

Strategy: The Department of Conservation lacks a survey system which will allow us to track the number of Fox River basin farmers who are using acceptable methods for managing their riparian corridors. Because of this, we must first:

* Work with agricultural agencies and the Department of Conservation's Biometrics Unit, Stream Unit, and Planning Section in order to develop an effective and efficient survey system.
Once a survey system is operational, we should begin educational efforts which will help us to approach the objective, such as:
* Implement a Landowner Cooperative Project in Clark County if a suitable opportunity presents itself. LCP development will be dependent upon site accessibility, landowner attitude, and probability of successfully solving a problem by using biotechnical methods on a reach of stream which has unique habitat or supports unique or exploitable fish populations.
* Prepare news releases for the Kahoka newspaper, "The Media," and the local SWCD newsletter which describe the economic and ecological advantages of stream corridor conservation.
* Provide technical advice on stream management to all basin landowners who ask for help. Conduct on-site visits and follow up with written recommendations which facilitate action, but only in cases where the problem is approachable by using biotechnical methods and the

landowner seems likely to implement recommendations.
Objective 1.5: Maintenance of Fox River base flow at or above current levels within the constraints imposed by seasonal variation in precipitation.

Strategy: We will have to work closely with agricultural agencies in order to ensure that conflicting objectives do not send mixed messages and produce mixed results. In doing so, we should:

* Encourage the Soil Conservation Service to use low-flow augmentation structures in any water retention structures (e.g., PL-566 impoundments) in upland portions of the watershed. Such structures may trap sediment and buffer the effects of high flow, but they can also reduce runoff in summer when basin streams need flow to maintain adequate depth and water quality.
* Support development of a Missouri water law which would restrict irrigation projects on basin streams during times of low flow.

Objective 1.6: A Stream Corridor Plan developed and implemented for 2.5 miles of Fox River within the recently acquired Mark Twain National Wildlife Refuge.

Strategy: Such a plan must first be considered desirable by the U.S. Fish and Wildlife Service, who must also demonstrate a commitment to implementation. In order to determine this and begin the process, we should:

* Share a copy of this Plan with the USFWS Refuge Manager, and seek a response which will indicate Federal commitment.
* If USFWS desires MDC planning assistance, draft a Corridor Plan which involves implementation by USFWS and offers technical advice from MDC.

GOAL II: Maintain fish species richness at current level or greater while increasing the number of large sport fish which inhabit Fox River and its major tributaries throughout the year.

Perspective: In 1987, we added 16 species to the annotated list of fishes known to the Missouri portion of the Fox River basin, which now number 52. Five species reported by previous investigators eluded our gear in 1987: black buffalo, freckled madtom, walleye, Mississippi silvery minnow, and central mudminnow (no sample at Goose Pond). Most fishes in our 1987 samples were widespread, tolerant species. However, the intolerant slenderhead darter was surprisingly abundant; and slender madtoms, while limited to a couple areas, were indicative of satisfactory water quality. The absence of intolerant Mississippi silvery minnows in 1987 samples is cause for concern, as is the status of central mudminnows in the aftermath of the 1988 drought.

Our 1987 samples contained 540 channel catfish, of which 84% were sub-stock size (<11 inches). Only 18% of stock size and larger channel catfish were quality size (16 inches). We can only speculate why so few large channel catfish were captured, but we suspect that there is insufficient depth and current during much of the year to provide habitat suitable for quality-size channel catfish; they may migrate downstream to the Mississippi River prior to the onset of low-flow conditions. Similar questions about downstream migration of adults exist for flathead catfish and smallmouth bass. Our 1987 survey yielded only 28 flathead catfish, most small; yet several anglers have reported catching big flatheads during high-flow periods in late spring and early summer. Of the 116 smallmouth bass captured in the Kahoka Hills area of Fox River, all were less than 9 inches long. Either recruitment to quality size is low or emigration to the Mississippi River is high.

We know virtually nothing about the migratory habits of quality-size sport fish in Fox River and other northeastern Missouri stream basins. Before we can manage these fisheries, we mush know whether the exploitable stocks are stable or transient. Also, we must learn which methods and times of sampling will provide meaningful information. And it may be important to know if exploitable fish stocks in the Fox River basin contain tissue contaminants that might concern consumptive anglers; however, results of a contamination would be clouded by the unknown factor of fish movement into and out of the system. None of these information needs are specific to the Fox River basin; they exist for most tributaries to the upper Mississippi.

Objective 2.1: At least 50 native species of fish (common carp excluded) in basin streams or associated wetlands, including central mudminnow.

Strategy: We must assume that achieving basin habitat objectives will ensure maintenance of fish species richness. In order to know whether this objective has been achieved, three of the five species which were not collected in 1987 surveys must be found to still exist in the basin. This will require periodic surveys, with some effort directed toward capturing species not common within the basin. It will also require protection of existing central mudminnow habitat and location of additional waters suitable for mudminnows. Our approach should be:

* Conduct fish population surveys at ten-year intervals at ten randomly selected 1987 sample sites and additional sites thought to harbor species not common within the basin.
* With permission from the current landowner, determine current status of central mudminnows in Goose Pond. If central mudminnows are still present, purchase the property (approximately 320 acres in S32/33, T65N, R6W and S4/5, T64N, R6W); manage primarily for central mudminnows.
* Seek one additional wetland area where central mudminnows may thrive; purchase the property and introduce central mudminnows from the assumed Goose Pond population.

Objective 2.2: Balanced populations of channel catfish and flathead catfish, and a balanced fish community (conditions not yet defined for warmwater streams).

Strategy: We must establish fish population and community parameters which reflect a desired state of balance, but cannot do so until we learn more about sport fish migration patterns and seasonal variability in fish population survey results. In order to empower managers with the methods they need to set measurable objectives, we must first:

* Initiate the process of determining the degree to which quality-size channel catfish and flathead

catfish migrate between the Fox River and the upper Mississippi River by proposing that the Fisheries Research Section conduct a broad investigation of catfish movement between the upper Mississippi River and its major tributaries.
* Initiate the process of determining satisfactory times, locations, and methods for assessing the status of exploitable fish stocks in the Fox River basin by proposing that the Fisheries Research Section conduct a broad investigation that will lead to efficient and reliable methods for assessing exploitable fish stocks (primarily channel and flathead catfish) in prairie streams.
If results from these prerequisite investigations satisfy our need for information, we should amend this plan by adding parameter-based objectives which define specifically what we mean by balanced catfish populations and a balanced stream fish community. Regulatory strategies for achieving balance should be thoroughly considered at that time.

GOAL III: Increase appreciation for the accessibility to streams within the Fox River Basin which are capable of supporting more recreational use without degration of unique habitats or native fish populations.

Perspective: Relative to other stream basins in northeastern Missouri, Fox River receives very little attention by anglers or floaters. Boating and canoeing on all tributaries and most of Fox River is hampered by shallow water, log jams, and low base flow. Over two-thirds of Fox River anglers prefer to fish for channel catfish over other species, probably from shore or by wading. ublic areas containing a total of 10 miles of stream frontage in the basin. Charlie Heath State Forest alone includes 3.9 miles of wadable, fishable Fox River. Gann (1989) identified two additional sites within the basin for stream access development. Goede Access on Fox River was developed in 1989. The second site would provide access to Fox River upstream of its confluence with Little Fox River approximately 2.5 miles north of Kahoka.

Even though recreational use of basin streams seems low relative to the availability of public stream frontage, there are some unique habitats which might be enjoyed if they are accessible. A 15-mile reach of Fox River from Missouri State Highway 81 to U.S. Highway 136 has been classified as a "significant aquatic area."

Within this reach, a one-acre natural prairie at the Waterloo Cemetery would be an interesting site near a potential access at a county road just downstream from the mouth of Ramsey Branch. Locating an access at this point would allow floaters to travel past a very large geode deposit and a natural rock bridge on their way to Goede Access, and might therefore be more desirable than the second site identified by Gann.

Other sites which may be worth considering for public ownership include frontage to Honey Creek somewhere between Missouri State Highway 81 and 61, and frontage to Fox River in the vicinity of Chambersburg. The Honey Creek segment is characterized by steep wooded bluffs, limestone outcrops, rocky streambed, relatively clear water, and high fish species richness. The Chambersburg site on Fox River is characterized by large bedrock outcroppings with expansive bedrock pools separated by short cobble and rubble riffles, leading to high fish species richness.

Objective 3.1: Public access to the most unique and scenic reaches of basin streams.

Strategy: We should propose modification of the Department of Conservation's Stream Areas Acquisition Plan (Gann 1989) to reflect current knowledge of opportunities for public use and appreciation. Our proposal should include recommendations to:

* Replace the currently proposed access on Fox River at S2, T8W, T65N with a proposed access near the Waterloo Cemetery at S9, R7W, T65N.
* Purchase additional stream frontage on Honey Creek between Missouri State Highway 81 and 61, and on the Fox River near Chambersburg (S9, R8W, T60N).

Objective 3.2: All potential stream anglers and floaters having access to information and an appreciation for stream recreational opportunities within the Fox River basin.

Strategy: We assume that not all potential anglers and floaters of Fox River basin streams know about existing recreational opportunities. Publicity should increase use and appreciation of these resources without risk of degradation, and it may help to create private sector advocates for basin streams. In order to effectively disseminate information, we should:

* Develop an attractive brochure which describes points of access and interest along basin streams and provides information on fishing and floating. We should schedule publication to occur when most anticipated public access acquisition and development is completed.
* Make classroom presentations on stream conservation to Clark County sixth graders, including information on points of interest in the Fox River basin.
* Facilitate the development and activity of Stream Teams or other groups interested in adopting or otherwise promoting stewardship and enjoyment of basin streams.

LITERATURE CITED

REFERENCES

Alexander, J. 1983. Addition to the eight-county natural features inventory. Missouri Department of Conservation. Jefferson City. 47 pages.

Bachant, J.P. and J.D. Martindale. 1982. Ranking the recreational values and associated problems of Missouri's major watersheds. Reference document for the Regional Watershed Assessment Plan. 76 pages.

Boyd, C.E. and F. Lichtkoppler. 1979. Water quality management in pond fish culture. Research and development series number 22. Agricultural Experiment Station. Auburn University. Auburn, AL. 30 pages.

Brown, K.L. 1987. Colonization by mosquitofish (Gambusiaaffinis) of a Great Plains river basin. Copeia 1987: 336-351.

COE. 1942. Preliminary examination for flood control, Fox River, and its tributaries, Missouri, and dam at northern end of Fox Island, Clark County, Missouri. United States Department of the Army, Corps of Engineers. Washington, D.C.

COE. 1951. Review of reports for flood control on the Fox River, Iowa and Missouri. United States Department of the Army, Corps of Engineers, Washington, D.C.

COE. 1972. Fox River, Iowa and Missouri, review of reports for flood control plan of survey. United States Department of the Army, Corps of Engineers. Washington, D.C. 27 pages.

Cummins, K.W. 1962. An evaluation of some techniques for the collection and analysis of benthic samples with special emphasis on lotic waters. American Midland Naturalist 67: 477-504.

Etnier, D.A., W.C. Starnes and B.H. Bauer. 1979. Whatever happened to the silvery minnow (Hybognathus nuchalis) in the Tennessee River? Southeastern Fishes Council Proceedings. Volume 2, Number 3.

Fajen, O.F. and R.E. Wehnes. 1981. Missouri's method of evaluating stream habitat. Pages 117-123 in N.B. Armantrout, editor. Acquisition and utilization of aquatic habitat inventory information symposium. American Fisheries Society. Bethesda, MD.

Gann, E.E., E.J. Harvey, H.G. Jeffery and D.L. Fuller. 1971. Water resources of northeastern Missouri. Hydrologic investigations atlas HA-372. Department of the Interior, United States Geological Survey. Washington, D.C.

Gann, L.W. 1989. Stream Areas Acquisition Plan. Missouri Department of Conservation. Jefferson City.

Grace, T.B. and W.L. Pflieger. 1985. The status and distribution of commercial and forage fish in the Missouri River and their utilization of selected habitats. Job 1. Fish survey of the Missouri and Mississippi rivers. National Marine Fisheries Service. Program 2-363-R. Project IV. June 1985.

Harlan, J.R. and E.B. Speaker. 1987. Iowa fish and fishing. Iowa Department of Natural Resources. Des Moines. 323 pages.

Hauth, L.D. 1974. Technique for estimating the magnitude and frequency of Missouri floods. United States Department of the Interior Geological Survey open file report. 19 pages.

Hrabik, R.A. 1989. Fishes. Pages 143-154 in A. Bleed and C. Flowerday, editors. An atlas of the Sand Hills. Resources atlas number 5/1989. Conservation and Survey Division. Institute of Agriculture and Natural Resources. University of Nebraska. Lincoln.

INRC. 1958. An inventory of water resources and water problems, southern Iowa river basins. Iowa Natural Resources Council.

Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant and I.J. Schlosser, 1986. Assessing biological integrity in running waters: A method and its rationale. Illinois Natural History Survey. Special Publication 5. Champaign. 28 pages.

Koenig, J.W. (ed.), 1961. The stratigraphic succession of Missouri. Geological Survey and Water Resources. Rolla.

Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister and J.R. Stauffer, Jr. 1980. Atlas of North American Freshwater Fishes. Publication 1980-12. North Carolina Biological Survey. North Carolina State Museum of Natural History. Raleigh. 854 pages.

Lynch, J.D. 1988. Introduction, establishment and dispersal of western mosquitofish in Nebraska (Actinoptergii: Poeciliidae). Prairie Naturalist 20(4): 203-216.

Matthews, W.J. 1988. North American prairie streams as systems for ecological study. Journal of the North American Benthological Society 7(4): 387-409.

MDNR. 1984. Missouri water quality basin plans. Volume 1. Des Moines, Fox, Wyaconda, Fabius, North, Salt, Cuivre and Upper Mississippi rivers, Peruque and Dardenne creeks. Missouri Department of Natural Resources. Jefferson City.

MDNR. 1986. Missouri water atlas. Missouri Department of Natural Resources. Jefferson City. 97 pages.

MDNR. 1987. Missouri water quality standards (10 CSR 20-7.031). Rules of Department of Natural Resources Division 20-Clean Water Commission, effective December 12, 1987. Missouri Department of Natural Resources. Jefferson City. 79 pages.

Pflieger, W.L. 1971. A distributional study of Missouri fishes. University of Kansas Publications, Museum of Natural History. Volume 20, Number 3. Pages 225-570.

Pflieger, W.L. 1975. The fishes of Missouri. Missouri Department of Conservation. Jefferson City. 343 pages.

Pflieger, W.L. 1989. Aquatic community classification system for Missouri. Aquatic series number 19. Missouri Department of Conservation. Jefferson City. 70 pages + supplement.

Pflieger, W.L., P.S. Haverland and M.A. Schene, Jr. 1981. Missouri's system for storage retrieval and analysis of stream resource data. Pages 284-290 in N.B. Armantrout, editor. Acquisition and utilization of aquatic habitat inventory information symposium. American Fisheries Society. Bethesda, MD.

Purkett, C.A. 1959. Growth of fishes in the Salt River, Missouri. Transactions of the American Fisheries Society 87 (1957): 116-131.

Resh, V.H., A.V. Brown, A.P. Covich, M.E. Gurtz, H.W. Li, G.W. Minshall, S.E. Reice, A.L. Sheldon, J.B. Wallace and R.C. Wissmar. The role of disturbance in stream ecology. North American Benthological Society 7(4): 433-455.

SCS. 1978. Erosion inventory. United States Department of Agriculture, Soil Conservation Service. Columbia, MO. 30 pages.

SCS. 1979. Missouri general soils map and soil association descriptions. United States Department of Agriculture, Soil Conservation Service. Columbia, MO. 74 pages.

Strahler, A.N. 1957. Quantitative analysis of watershed geomorphology. Transactions of the American Geopysical Union 38: 913-920.

Thom, Richard H. and James H. Wilson. 1980. The natural divisions of Missouri. Transactions of the Missouri Academy of Science 14: 9-23.

USGS. 1988. Water resources data for Missouri, water year 1988. U.S. Geological Survey Water-Data Report MO-88-1. 282 pages.

USFWS. 1983. Habitat suitability information: smallmouth bass. United States Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/10.36. September 1983.

Wright, J.F., P.D. Hiley, S.F. Ham and A.D. Berrie. 1981. Comparison of three mapping procedures developed for river macrophytes. Freshwater Biology 11: 369-380.

GLOSSARY

Alluvial soil Soil deposits resulting directly or indirectly from the sediment transport of streams, deposited in river beds, flood plains, and lakes.
Aquifer An underground layer of porous, water-bearing rock, gravel, or sand.
Benthic Bottom-dwelling; describes organisms which reside in or on any substrate.
Benthic macroinvertebrate Bottom-dwelling (benthic) animals without backbones (invertebrate) that are visible with the naked eye (macro).
Biota The animal and plant life of a region.
Biocriteria monitoring The use of organisms to assess or monitor environmental conditions.
Channelization The mechanical alteration of a stream which includes straightening or dredging of the existing channel, or creating a new channel to which the stream is diverted.
Concentrated animal feeding operation (CAFO) Large livestock (ie.cattle, chickens, turkeys, or hogs) production facilities that are considered a point source pollution, larger operations are regulated by the MDNR. Most CAFOs confine animals in large enclosed buildings, or feedlots and store liquid waste in closed lagoons or pits, or store dry manure in sheds. In many cases manure, both wet and dry, is broadcast overland.
Confining rock layer A geologic layer through which water cannot easily move.
Chert Hard sedimentary rock composed of microcrystalline quartz, usually light in color, common in the Springfield Plateau in gravel deposits. Resistance to chemical decay enables it to survive rough treatment from streams and other erosive forces.
Cubic feet per second (cfs) A measure of the amount of water (cubic feet) traveling past a known point for a given amount of time (one second), used to determine discharge.
Discharge Volume of water flowing in a given stream at a given place and within a given period of time, usually expressed as cubic feet per second.
Disjunct Separated or disjoined populations of organisms. Populations are said to be disjunct when they are geographically isolated from their main range.
Dissolved oxygen The concentration of oxygen dissolved in water, expressed in milligrams per liter or as percent.
Dolomite A magnesium rich, carbonate, sedimentary rock consisting mainly (more than 50% by weight) of the mineral dolomite ($CaMg(CO_3)_2$).
Endangered In danger of becoming extinct.
Endemic Found only in, or limited to, a particular geographic region or locality.
Environmental Protection Agency (EPA) A Federal organization, housed under the Executive branch, charged with protecting human health and safeguarding the natural environment — air, water, and land — upon which life depends.
Epilimnion The upper layer of water in a lake that is characterized by a temperature gradient of less than 1^{o} Celsius per meter of depth.
Eutrophication The nutrient (nitrogen and phosphorus) enrichment of an aquatic ecosystem that promotes biological productivity.
Extirpated Exterminated on a local basis, political or geographic portion of the range.
Faunal The animals of a specified region or time.
Fecal coliform A type of bacterium occurring in the guts of mammals. The degree of its presence in a lake or stream is used as an index of contamination from human or livestock waste.

Flow duration curve A graphic representation of the number of times given quantities of flow are equaled or exceeded during a certain period of record.
Fragipans A natural subsurface soil horizon seemingly cemented when dry, but when moist showing moderate to weak brittleness, usually low in organic matter, and very slow to permeate water.
Gage stations The site on a stream or lake where hydrologic data is collected.
Gradient plots A graph representing the gradient of a specified reach of stream. Elevation is represented on the Y-axis and length of channel is represented on the X- axis.
Hydropeaking Rapid and frequent fluctuations in flow resulting from power generation by a hydroelectric dam's need to meet peak electrical demands.
Hydrologic unit (HUC) A subdivision of watersheds, generally 40,000-50,000 acres or less, created by the USGS. Hydrologic units do not represent true subwatersheds.
Hypolemnion The region of a body of water that extends from the thermocline to the bottom and is essentially removed from major surface influences during periods of thermal stratification.
Incised Deep, well defined channel with narrow width to depth ration, and limited or no lateral movement. Often newly formed, and as a result of rapid down-cutting in the substrate
Intermittent stream One that has intervals of flow interspersed with intervals of no flow. A stream that ceases to flow for a time.
Karst topography An area of limestone formations marked by sinkholes, caves, springs, and underground streams.
Loess Loamy soils deposited by wind, often quite erodible.
Low flow The lowest discharge recorded over a specified period of time.
Missouri Department of Conservation (MDC) Missouri agency charged with: protecting and managing the fish, forest, and wildlife resources of the state; serving the public and facilitating their participation in resource management activities; and providing opportunity for all citizens to use, enjoy, and learn about fish, forest, and wildlife resources.
Missouri Department of Natural Resources (MDNR) Missouri agency charged with preserving and protecting the state's natural, cultural, and energy resources and inspiring their enjoyment and responsible use for present and future generations.
Mean monthly flow Arithmetic mean of the individual daily mean discharge of a stream for the given month.
Mean sea level (MSL) A measure of the surface of the Earth, usually represented in feet above mean sea level. MSL for conservation pool at Pomme de Terre Lake is 839 ft. MSL and Truman Lake conservation pool is 706 ft. MSL.
Necktonic Organisms that live in the open water areas (mid and upper) of waterbodies and streams.
Non-point source Source of pollution in which wastes are not released at a specific, identifiable point, but from numerous points that are spread out and difficult to identify and control, as compared to point sources.
National Pollution Discharge Elimination System (NPDES) Permits required under The Federal Clean Water Act authorizing point source discharges into waters of the United States in an effort to protect public health and the nation's waters.
Nutrification Increased inputs, viewed as a pollutant, such as phosphorous or nitrogen, that fuel abnormally high organic growth in aquatic systems.
Optimal flow Flow regime designed to maximize fishery potential.

Perennial streams Streams fed continuously by a shallow water table.
pH Numeric value that describes the intensity of the acid or basic (alkaline) conditions of a solution. The pH scale is from 0 to 14, with the neutral point at 7.0. Values lower than 7 indicate the presence of acids and greater than 7.0 the presence of alkalis (bases).
Point source Source of pollution that involves discharge of wastes from an identifiable point, such as a smokestack or sewage treatment plant.
Recurrence interval The inverse probability that a certain flow will occur. It represents a mean time interval based on the distribution of flows over a period of record. A 2-year recurrence interval means that the flow event is expected, on average, once every two years.
Residuum Unconsolidated and partially weathered mineral materials accumulated by disintegration of consolidated rock in place.
Riparian Pertaining to, situated, or dwelling on the margin of a river or other body of water.
Riparian corridor The parcel of land that includes the channel and an adjoining strip of the floodplain, generally considered to be 100 feet on each side of the channel.
7-day Q^{10} Lowest 7-day flow that occurs an average of every ten years.
7-day Q^{2} Lowest 7-day flow that occurs an average of every two years.
Solum The upper and most weathered portion of the soil profile.
Special Area Land Treatment project (SALT) Small, state funded watershed programs overseen by MDNR and administered by local Soil and Water Conservation Districts. Salt projects are implemented in an attempt to slow or stop soil erosion.
Stream Habitat Annotation Device (SHAD) Qualitative method of describing stream corridor and instream habitat using a set of selected parameters and descriptors.
Stream gradient The change of a stream in vertical elevation per unit of horizontal distance.
Stream order A hierarchical ordering of streams based on the degree of branching. A first order stream is an unbranched or unforked stream. Two first order streams flow together to make a second order stream; two second order streams combine to make a third order stream. Stream order is often determined from 7.5 minute topographic maps.
Substrate The mineral and/or organic material forming the bottom of a waterway or waterbody.
Thermocline The plane or surface of maximum rate of decrease of temperature with respect to depth in a waterbody.
Threatened A species likely to become endangered within the foreseeable future if certain conditions continue to deteriorate.
United States Army Corps of Engineers (USACE) Federal agency under control of the Army, responsible for certain regulation of water courses, some dams, wetlands, and flood control projects.
United States Geological Survey (USGS) Federal agency charged with providing reliable information to: describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect the quality of life.
Watershed The total land area that water runs over or under when draining to a stream, river, pond, or lake.
Waste water treatment facility (WWTF) Facilities that store and process municipal sewage, before release. These facilities are under the regulation of the Missouri Department of Natural Resources.