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Aquatic Habitats in Relation to River Flow in the Apalachicola River Floodplain, Florida

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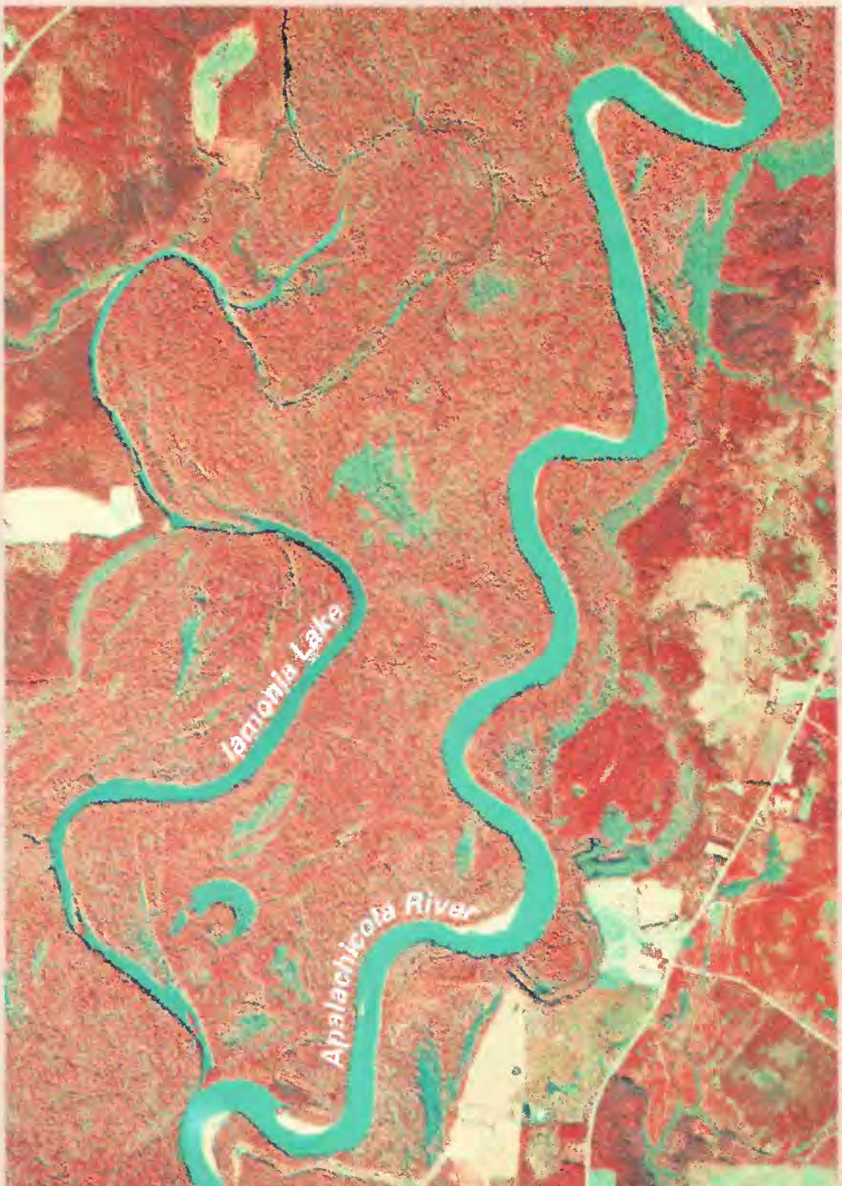
Prepared in cooperation with the
Northwest Florida Water Management District



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Aquatic Habitats in Relation to River Flow in the Apalachicola River Floodplain, Florida

By Helen M. Light, Melanie R. Darst, *and* J.W. Grubbs

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1594

Prepared in cooperation with the
NORTHWEST FLORIDA WATER
MANAGEMENT DISTRICT

The research described in this document was conducted as part of the Apalachicola River and Bay Freshwater Needs Assessment developed by the States of Florida, Alabama, and Georgia, and the U.S. Army Corps of Engineers for the Alabama-Coosa-Tallapoosa/Apalachicola-Chattahoochee-Flint River Basins Comprehensive Study.

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CONVERSION FACTORS, SEA LEVEL DATA, AND ACRONYMS

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square foot (ft^2)	929.0	square centimeter
cubic foot (ft^3)	0.02832	cubic meter
foot per second (ft/s)	0.3048	meter per second
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
square mile (mi^2)	2.590	square kilometer
acre	0.4047	hectare
part per million (ppm)	1.0	milligram per liter

Sea Level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called "Sea Level Datum of 1929."

Acronyms:

ACF = Apalachicola-Chattahoochee-Flint
ARQA = Apalachicola River Quality Assessment
FGFWFC = Florida Game and Fresh Water Fish Commission
GIS = Geographic Information System
NWS = National Weather Service
NWFWMD = Northwest Florida Water Management District
USACE = U.S. Army Corps of Engineers
USFWS = U.S. Fish and Wildlife Service
USGS = U.S. Geological Survey

LIST OF COMMON NAMES USED AND SCIENTIFIC EQUIVALENTS

FISHES

[Nomenclature follows Lee and others (1980) unless otherwise indicated]

Common names	Scientific names
Alabama shad	*Alosa alabamae* Jordan and Evermann
American eel	*Anguilla rostrata* (Lesueur)
Atlantic needlefish	*Strongylura marina* (Walbaum)
banded pygmy sunfish	*Elassoma zonatum* Jordan
banded sunfish	*Enneacanthus obesus* (Girard)
banded topminnow	*Fundulus cingulatus* Valenciennes
bandfin shiner	*Notropis zonistius* (Jordan)
bannerfin shiner	*Notropis leedsi* Fowler
black crappie	*Pomoxis nigromaculatus* (Lesueur)
black madtom	*Noturus funebris* Gilbert and Swain
blackbanded darter	*Percina nigrofasciata* (Agassiz)
blackspotted topminnow	*Fundulus olivaceous* (Storer)
blacktail shiner	*Notropis venustus* (Girard)
bluefin killifish	*Lucania goodei* Jordan
bluegill	*Lepomis macrochirus* Rafinesque
bluenose shiner	*Notropis welaka* Evermann and Kendall
bluespotted sunfish	*Enneacanthus gloriosus* (Holbrook)
bluestripe shiner	*Notropis callitaenia* Bailey and Gibbs
bowfin	*Amia calva* Linnaeus
brook silverside	*Labidesthes sicculus* (Cope)
brown bullhead	*Ictalurus nebulosus* (Lesueur)
brown darter	*Etheostoma edwini* (Hubbs and Cannon)
chain pickerel	*Esox niger* Lesueur
channel catfish	*Ictalurus punctatus* (Rafinesque)
clear chub	*Hybopsis winchelli* (Girard)
coastal shiner	*Notropis petersoni* Fowler
common carp	*Cyprinus carpio* Linnaeus
creek chub	*Semotilus atromaculatus* (Mitchill)
dollar sunfish	*Lepomis marginatus* (Holbrook)
dusky shiner	*Notropis cummingsae* Myers
eastern starhead topminnow	*Fundulus escambiae* (Bollman)
Everglades pygmy sunfish	*Elassoma evergladei* Jordan
flagfin shiner	*Notropis signipinnis* Bailey and Suttkus
flathead catfish	*Pylodictis olivaris* (Rafinesque)
flier	*Centrarchus macropterus* (Lacepede)
Florida sand darter	*Ammocrypta bifascia* Williams
gizzard shad	*Dorosoma cepedianum* (Lesueur)
golden shiner	*Notemigonus crysoleucas* (Mitchill)
golden topminnow	*Fundulus chrysotus* (Gunther)
goldstripe darter	*Etheostoma parvipinne* Gilbert and Swain
grayfin redhorse	*Moxostoma n.sp.*
green sunfish	*Lepomis cyanellus* Rafinesque
Gulf darter	*Etheostoma swaini* (Jordan)
Gulf of Mexico sturgeon	*Acipenser oxyrhynchus desotoi* Vladykov and Greeley
hogchoker	*Trinectes maculatus* (Bloch and Schneider)
ironcolor shiner	*Notropis chalybaeus* (Cope)

FISHES—Continued

[Nomenclature follows Lee and others (1980) unless otherwise indicated]

Common names	Scientific names
lake chubsucker	*Erimyzon sucetta* (Lacepede)
largemouth bass	*Micropterus salmoides* (Lacepede)
least killifish	*Heterandria formosa* Agassiz
longnose gar	*Lepisosteus osseus* Linnaeus
longnose shiner	*Notropis longirostris* (Hay)
mosquitofish	*Gambusia affinis* (Baird and Girard)
mountain mullet	*Agonostomus monticola* (Bancroft)
Okefenokee pygmy sunfish	*Elassoma okefenokee* Bohlke
orangespotted sunfish	*Lepomis humilis* (Girard)
pirate perch	*Aphredoderus sayanus* (Gilliams)
pugnose minnow	*Notropis emiliae* (Hay)
pygmy killifish	*Leptolucania ommata* (Jordan)
quillback	*Carpiodes cyprinus* (Lesueur)
redbreast sunfish	*Lepomis auritus* (Linnaeus)
redear sunfish	*Lepomis microlophus* (Gunther)
redeye chub	*Notropis harperi* Fowler
redfin pickerel	*Esox americanus americanus* Gmelin
sailfin shiner	*Notropis hypselopterus* (Gunther)
sauger	*Stizostedion canadense* (Smith)
shadow bass	*Ambloplites ariommus* Viosca
shoal bass	*Micropterus n.sp. cf coosae*
silverjaw minnow	*Ericymba buccata* Cope
skipjack herring	*Alosa chrysochloris* (Rafinesque)
snail bullhead	*Ictalurus brunneus* (Jordan)
southern brook lamprey	*Ichthyomyzon gagei* Hubbs and Trautman
southern flounder	*Paralichthys lethostigma* Jordan and Gilbert
speckled madtom	*Noturus leptacanthus* Jordan
spotted bass	*Micropterus punctulatus* (Rafinesque)
spotted bullhead	*Ictalurus serracanthus* Yerger and Relyea
spotted gar	*Lepisosteus oculatus* Winchell
spotted sucker	*Minytrema melanops* (Rafinesque)
spotted sunfish	*Lepomis punctatus* (Valenciennes)
striped bass	*Morone saxatilis* (Walbaum)
striped mullet	*Mugil cephalus* Linnaeus
sunshine bass	*Morone* hybrid: *chrysops X saxatilis*[1]
swamp darter	*Etheostoma fusiforme* (Girard)
tadpole madtom	*Noturus gyrinus* (Mitchill)
taillight shiner	*Notropis maculatus* (Hay)
threadfin shad	*Dorosoma petenense* (Gunther)
warmouth	*Lepomis gulosus* (Cuvier)
weed shiner	*Notropis texanus* (Girard)
white bass	*Morone chrysops* (Rafinesque)
white catfish	*Ictalurus catus* (Linnaeus)
yellow bullhead	*Ictalurus natalis* (Lesueur)
yellow perch	*Perca flavescens* (Mitchill)

[1]Ager and others (1985)

PLANTS

[Nomenclature for plants follows Godfrey (1988)]

Common names	Scientific names
cypress	*Taxodium distichum* (L.) L.C. Rich.
green ash	*Fraxinus pennsylvanica* Marsh.
overcup oak	*Quercus lyrata* Walt.
sugarberry	*Celtis laevigata* Nutt.
swamp laurel oak	*Quercus laurifolia* Michx.
sweetgum	*Liquidambar styraciflua* L.
tupelo	*Nyssa aquatica* L. and *Nyssa ogeche* Bartr. ex Marsh
water hickory	*Carya aquatica* (Michx. f.) Nutt.
water oak	*Quercus nigra* L.

Aquatic Habitats in Relation to River Flow in the Apalachicola River Floodplain, Florida

By Helen M. Light, Melanie R. Darst, *and* J.W. Grubbs

Abstract

Increasing demands for water in the Apalachicola-Chattahoochee-Flint River Basin have resulted in conflicts among water user groups, the States of Georgia, Alabama, and Florida, and various Federal agencies, particularly during periods of regional drought. A study of aquatic habitats in the floodplain in relation to river flow was conducted in the nontidal reach of the Apalachicola River in north Florida from 1992 to 1996. The study was conducted by the U.S. Geological Survey, in cooperation with the Northwest Florida Water Management District, as part of a larger effort to identify freshwater needs throughout the region and develop a mechanism for basinwide water management. The primary results of this report are quantitative estimates of the amount of aquatic habitat in the floodplain in relation to river flow. The report also includes plates showing streams, lakes, and floodplain forests connected to the main river channel at selected flows; an analysis of long-term flow record in the Apalachicola River; a review of the literature regarding fishes in floodplains of the Apalachicola River and other rivers of the eastern United States; and examples showing how this report can be used to assess impacts of flow alterations on aquatic habitats and fishes. The study area consists of about 82,200 acres of floodplain that is predominantly wetlands, according to the U.S. Fish and Wildlife classification system.

Very low flows in the Apalachicola River, defined as flows less than 6,000 cubic feet per second (ft^3/s) at Chattahoochee, Florida, occurred in 15 of the 74 years of record from 1922 to 1995. At a river flow of 5,000 ft^3/s, an estimated 260 acres of floodplain streams and lakes is connected to the main river channel. Most of these areas have shallow waters with no flow and are located in the middle and nontidal lower reaches of the river. These connected aquatic habitats comprise a very small percentage (0.3 percent) of the entire floodplain at very low flows, yet they serve as important refuges for fishes from the deep, swiftly flowing waters of the main channel. In the upper reach of the river, entrenchment that occurred after construction of Jim Woodruff Dam lowered bed elevations and river levels. Many perennial streams in the upper reach that were accessible to main channel fishes at low and very low flows prior to entrenchment are now inaccessible because of waterfalls or very shallow water at their mouths. About 4,000 acres of isolated aquatic habitat, mostly tupelo-cypress swamps with standing water less than 3 feet deep, is also present in the floodplain at very low flows. A review of the literature indicates that many species of fishes inhabit the quiet, shallow waters typically found in isolated swamps.

Low flows (6,000-10,000 ft^3/s at Chattahoochee, Florida) occur in most years. The median annual 1-day low flow for the period of record is 8,490 ft^3/s. About 740 acres of aquatic habitat in the floodplain is connected to the main channel at a river flow of 8,000 ft^3/s. Most of these areas are tributary

lakes, which are open bodies of water having a linear conformation and little or no flow except during floods. Large tributary lakes in the middle and lower reaches of the river, such as Iamonia Lake and River Styx, support diverse fish communities. In a previous study, 44 fish species were collected by the Florida Game and Fresh Water Fish Commission in tributary lakes during low flows.

Medium flows (10,000-20,000 ft^3/s at Chattahoochee, Florida) occur every year. At the median flow for the period of record, which is 16,400 ft^3/s, approximately 8,300 acres (10 percent of the floodplain) is connected aquatic habitat. Most of these areas are tupelo-cypress swamps bordering streams and lakes in the middle and nontidal lower reaches that are inundated by backwater from the main channel. Flowing-water habitats in more than 200 miles of streams and lakes are also connected to the main channel at the median flow. The amount of vegetative structure in connected aquatic habitats is much greater during medium flows than during low flows, because water is no longer contained in the beds of floodplain streams, but is covering vegetation and woody debris on streambanks and in adjacent swamps. Vegetative structure in aquatic habitats provides food sources, protective cover, and reproductive sites for fishes.

Medium-high flows (20,000-50,000 ft^3/s at Chattahoochee, Florida) occur every year. An estimated 40,700 acres, which is approximately one-half of the floodplain, is connected aquatic habitat at 32,000 ft^3/s. Nearly all aquatic habitat in tupelo-cypress swamps that is isolated at lower flows is connected to the main channel between flows of 20,000 and 40,000 ft^3/s. High flows (greater than 50,000 ft^3/s) occur in most years. At the median annual 1-day high flow of 86,200 ft^3/s, about 78,000 acres (95 percent of the floodplain) is connected aquatic habitat. During high flows, water is moving through most of the floodplain in a general downstream direction. Many main channel fishes migrate into flooded forests where greatly increased food sources and abundant vegetative structure are available to them. Eighty percent, or 73 of the 91 fish species known to inhabit the Apalachicola River have been collected in river floodplains of the eastern United States and are probably present in the Apalachicola River floodplain during medium-high and high flows.

In evaluating the impacts of flow alterations, it is important to determine types and extent of habitat affected, address impacts on biotic communities, and make comparisons of altered to historical flows. In an example, effects on habitat as a result of flow regulation to create a navigation window for barge traffic in the fall of 1990 were examined. For 19 days during this period, there was approximately 590 fewer acres of connected aquatic habitat than there would have been if the navigation window had not been implemented. Effects of reduced aquatic habitat on fishes include reductions in the amount of food, protective cover, and spawning sites. A hydrologic event with flows similar to this period of reduced flows occurred once every 10 years on average (1922-95) and probably would not have occurred in 1990 if navigation windows had not been implemented.

INTRODUCTION

In the coastal plain of the southeastern United States, large rivers have extensive forested floodplains that contain a diverse assortment of aquatic and wetland habitats (Wharton and others, 1982; Mitsch and Gosselink, 1986). Streams, sloughs, ponds, lakes, and swamps in these floodplains are alternately connected and disconnected from the main river channel as river levels fluctuate. Complex relationships exist between biological communities in floodplain habitats and river flow, with floral and faunal distributions varying spatially, seasonally, and annually (Welcomme, 1979; Bayley, 1995; Power and others, 1995). During low-flow periods, shallow, quiet waters in the floodplain provide refuges for fishes from the deep, swiftly flowing waters of the main channel (Kwak, 1988; Baker and others, 1991; Leitman and others, 1991). During flood events, fishes use inundated floodplain forests for food, protective cover, spawning sites and nursery grounds (Guillory, 1979;

Wharton and others, 1981, 1982; Ross and Baker, 1983; Walker and Sniffen, 1985; Finger and Stewart, 1987; Knight and others, 1991).

Increased demands for water in the Apalachicola-Chattahoochee-Flint (ACF) River Basin have resulted in conflicts among water user groups, the States of Georgia, Alabama, and Florida, and various Federal agencies, particularly during periods of regional drought. "As a result, widespread concern has been expressed regarding the need to properly manage the water resources so that regional economies may continue to be supported within the bounds of the environmental conditions that exist within the river systems" (Alabama, Florida, Georgia, and the U.S. Army Corps of Engineers, 1991, p. 1). In the early 1990's, Congress funded a study to determine water requirements in the ACF River Basin (and an adjacent basin) and to recommend an interstate mechanism for resolving issues from a regional perspective. As a part of this study, the Northwest Florida Water Management District (NWFWMD) initiated a freshwater needs assessment for the Apalachicola River and Bay. Water requirements of the Apalachicola River are addressed in this report, which presents information on the area and characteristics of aquatic habitats in the floodplain in relation to river flow. Results of this investigation can be used to evaluate potential impacts of flow alterations (such as increased upstream water withdrawals or modified water delivery schedules from storage reservoirs) on floodplain habitat.

Purpose and Scope

This report presents the final results of an investigation relating aquatic habitats in the floodplain to flow in the Apalachicola River. This report includes:

(1) Duration and frequency statistics of the long-term flow record of the Apalachicola River based on monthly, annual, and multiple-year periods of analysis.

(2) A description of the major types of streams, lakes, and forests in the Apalachicola River floodplain and the changes that occur in those habitats with changes in river flow.

(3) Estimates of the area of aquatic habitat in the floodplain that exist at specific Apalachicola River flows ranging from very low to very high. Estimates of area include total areas of aquatic habitat in the floodplain for each major reach of the river and for the entire study area, and areas of particular types of aquatic habitats in the floodplain having characteristics that are important to fishes.

(4) A list of the species of fishes collected in the Apalachicola River floodplain, and a list of additional species that probably inhabit the Apalachicola River floodplain, based on a summary of the literature on floodplain fishes of the eastern United States.

(5) Examples showing how the results of this investigation can be used to assess impacts of flow alterations on aquatic habitat and fishes in the Apalachicola River floodplain.

The study area addressed in this report is the floodplain of the nontidal Apalachicola River from the Georgia-Florida State line to the upper limit of tidal influence about 20 mi upstream of Apalachicola Bay (fig. 1). The freshwater tidal floodplain is not included in the study area. Data collection was conducted from 1992 to 1995 and data analysis was completed in 1996. Two interim progress reports describing preliminary methods and results were published during the data-collection period (Light and others, 1993; Light and others, 1995).

Acknowledgments

This project, jointly funded by the NWFWMD and the U.S. Geological Survey (USGS), is part of the Apalachicola River and Bay Freshwater Needs Assessment as developed by the States of Florida, Alabama, and Georgia and the U.S. Army Corps of Engineers (USACE) for the Alabama-Coosa-Tallapoosa/Apalachicola-Chattahoochee-Flint Comprehensive Study. The authors wish to acknowledge F. Graham Lewis III, NWFWMD, for technical and administrative guidance throughout the project. Partial funding was received from USACE for two related investigations that contributed data to this report. Appreciation is extended to Mary M. Davis, USACE, Waterways Experiment Station, Vicksburg, Miss., and Joanne U. Brandt, USACE, Mobile District, Ala., for technical and administrative guidance in those two studies. Leslie L. Batts, formerly with the USGS, is acknowledged for his invaluable support with field work. Appreciation is also extended to Michael J. Hill, Charles L. Mesing, and D. Gray Bass, Jr., Florida Game and Fresh Water Fish Commission (FGFWFC), for assistance in assembling and interpreting fish data for the Apalachicola River

Base from U.S. Geological Survey digital data, 1972
Albers Equal-Area Conic projection
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

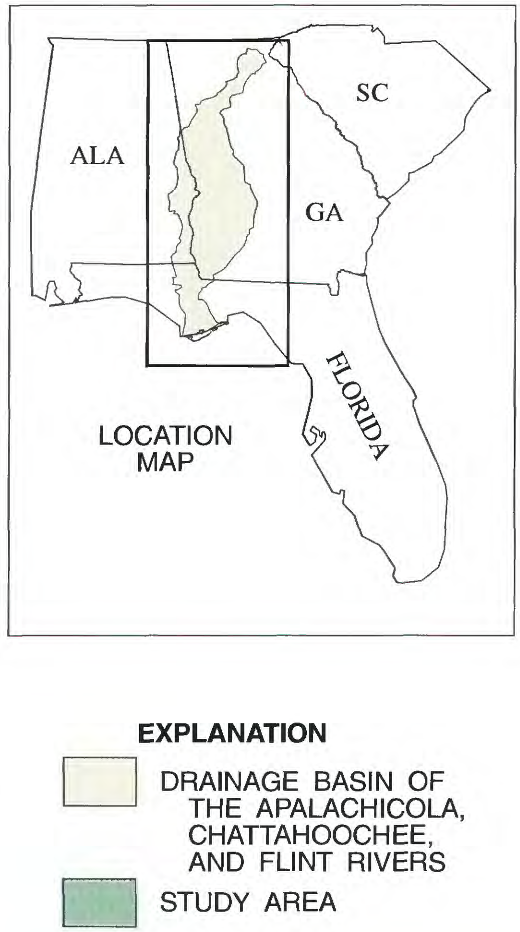


Figure 1. Drainage basin of the Apalachicola, Chattahoochee, and Flint Rivers in Florida, Georgia, and Alabama.

floodplain; Steven E. Ovenden, formerly with the USGS, for help with organizing and interpreting background literature; and Wade L. Bryant, USGS, for technical assistance in report preparation. Appreciation for field assistance is extended to William I. Stinson III and K. Maureen Karns, formerly with the USGS; F. Graham Lewis III, NWFWMD; Jerry W. Ziewitz, U.S. Fish and Wildlife Service (USFWS); Theodore S. Hoehn, FGFWFC; Beth A. Gaza, formerly with Florida State University; and Duncan T. Johnson, volunteer.

Background and Terminology

The Apalachicola River is a large alluvial river formed by the confluence of the Chattahoochee and Flint Rivers (fig. 1). The three rivers drain 19,600 mi^2 in Florida, Georgia, and Alabama. The Chattahoochee flows about 400 mi from its source in north Georgia to Lake Seminole at the Florida-Georgia State line. The Flint River originates just south of Atlanta, Ga., and flows about 350 mi before it joins the Chattahoochee River. The Apalachicola River is 106 mi long and falls about 40 ft from the Georgia-Florida State line to the Apalachicola Bay in the Gulf of Mexico. The Apalachicola River downstream of Lake Seminole drains 2,400 mi^2, approximately 50 percent of which is drained by its largest tributary, the Chipola River.

The drainage basin of the Apalachicola, Chattahoochee, and Flint Rivers lies within three major physiographic provinces of the southeastern United States (Clark and Zisa, 1976). Less than 1 percent of the basin in the northernmost part contains mountains and ridges of the Blue Ridge Province. The remainder of the upper basin north of Columbus, Ga., lies in the rolling hills of the Piedmont Province. The entire lower basin south of Columbus, Ga., is in the Coastal Plain Province, which is hilly in the northernmost part, karstic in the central part, and contains low lying coastal flats in the southernmost part (Couch and others, 1996).

The Apalachicola River is the largest river in Florida and ranks 21st in magnitude of discharge among the rivers of the conterminous United States. Mean annual flow at Chattahoochee, Fla. (fig. 2) from 1922 to 1995 was 22,300 ft^3/s. Peak floods are most likely to occur in January, February, March, or April of each year. Low flow generally occurs in September, October, and November. Flood patterns vary greatly from year to year and may not conform to these seasonal trends in any given year. In this report, **very low flows** are less than 6,000 ft^3/s, **low flows** are 6,000 to 10,000 ft^3/s, **medium flows** are 10,000 to 20,000 ft^3/s, **medium-high flows** are 20,000 to 50,000 ft^3/s, and **high flows** are greater than 50,000 ft^3/s. All flow values refer to flow in the Apalachicola River at the USGS gage at Chattahoochee, Fla., unless otherwise indicated.

There are 16 dams on the Apalachicola, Chattahoochee, and Flint Rivers. The most downstream dam, Jim Woodruff Dam, impounds Lake Seminole at the head of the Apalachicola River where the Chattahoochee and Flint Rivers join. Construction began on Jim Woodruff Dam in 1950, and filling of the reservoir was accomplished from 1954 to 1957. Congressional authorization for navigational improvements was approved in 1874 and dredging was sporadically conducted from 1874 to 1956. Dredging to construct the modern 9- by 100-ft navigation channel began in 1956, with maintenance dredging since that time usually conducted on an annual basis. Rock removal in the upper reach of the river was conducted in 1957, 1963, 1968, and 1983-84. Twenty-nine sets of groins made of wooden pilings or stone were installed from 1963 to 1970, most of which are in the upper reach of the river. Six cutoffs, which were made from 1956 to 1969 to improve navigation by straightening bends in the lower reach of the river, have shortened the total length of the river by approximately 2 mi (U.S. Army Corps of Engineers, 1986). **Entrenchment** is riverbed degradation that has lowered the elevation of the riverbed in the upper reach of the Apalachicola River since the construction of Jim Woodruff Dam. In an analysis of the effects of a variety of navigational improvements on riverbed elevation, it was concluded that entrenchment "appears to be directly related to the presence of the dam" (Simons, Li, and Associates, 1985, p. 100). Dredging, groins, cutoffs, and rock removal appear to have primarily local effects on bed degradation that are not associated with the overall trend of entrenchment. The USACE implements **navigation windows** by regulating flows in the Apalachicola River to improve navigation during periods when channel depths are insufficient to allow barge traffic. Immediately prior to each navigation window, water is stored in upstream reservoirs for 2 to 3 weeks during a **prewindow period**. Flows are increased rapidly during a short **transition period** of 1 or 2 days, and then water is released in a **window period** of 10 days to 2 weeks to raise water levels for barge navigation on the river.

Aquatic habitats of the main channel of the Apalachicola River have been surveyed by the FGFWFC. Sandbars are relatively unproductive with regard to fishes and invertebrates, whereas habitats such as dike fields, gently sloping natural banks, and steep natural banks with snags and other submerged structures are significantly more productive (Ager and others,

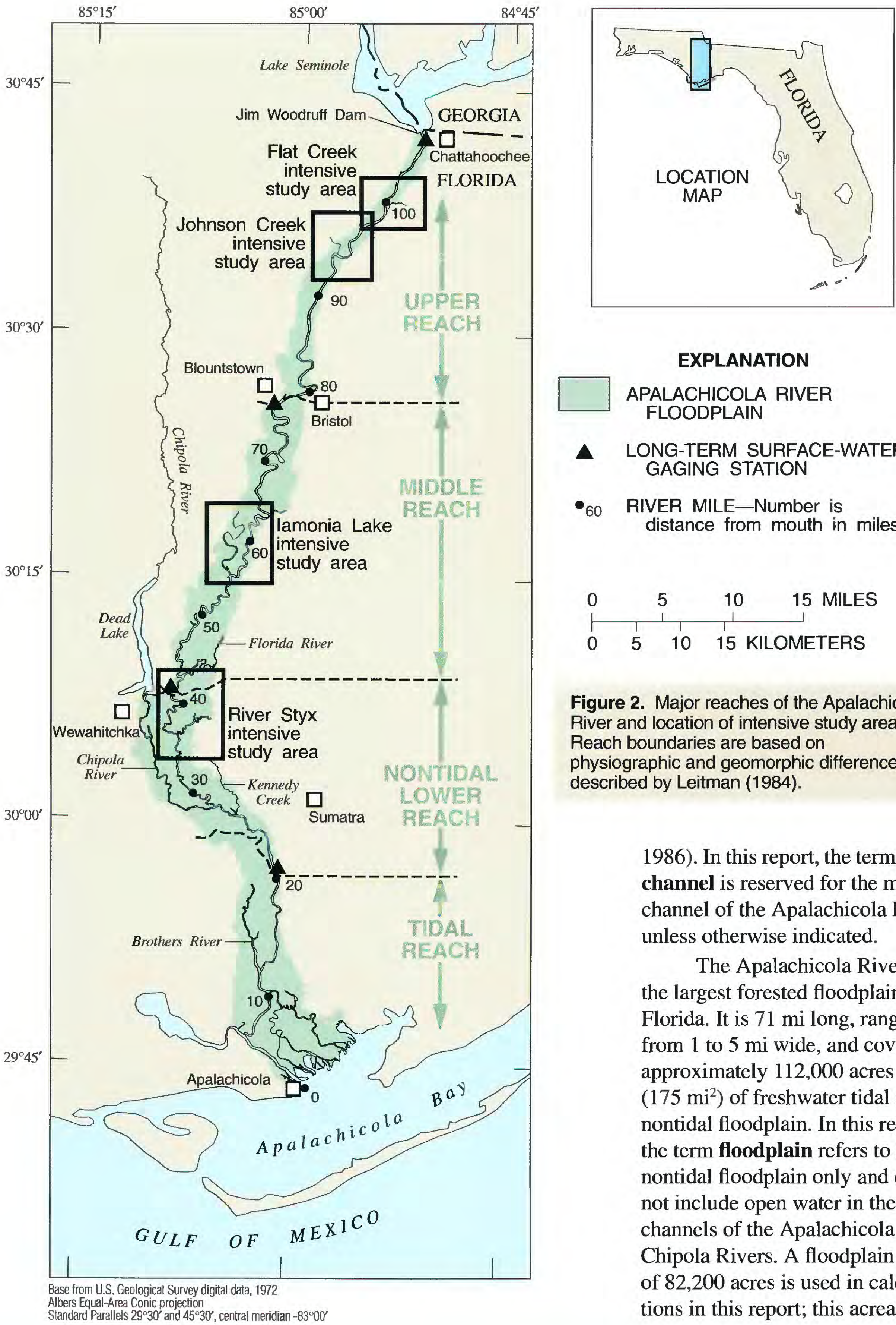


Figure 2. Major reaches of the Apalachicola River and location of intensive study areas. Reach boundaries are based on physiographic and geomorphic differences described by Leitman (1984).

1986). In this report, the term **main channel** is reserved for the main channel of the Apalachicola River unless otherwise indicated.

The Apalachicola River has the largest forested floodplain in Florida. It is 71 mi long, ranges from 1 to 5 mi wide, and covers approximately 112,000 acres (175 mi^2) of freshwater tidal and nontidal floodplain. In this report, the term **floodplain** refers to the nontidal floodplain only and does not include open water in the main channels of the Apalachicola and Chipola Rivers. A floodplain area of 82,200 acres is used in calculations in this report; this acreage represents approximately 92 percent of the total area that is shown within the nontidal floodplain boundary as mapped by Leitman (1984). The remaining 8 percent of floodplain in nontidal reaches consists of land areas within the floodplain boundary that are higher than most annual floods or have been converted to nonforested uses. Floodplains as defined in this report are predominantly wetlands according to the wetland classification system of the USFWS (Cowardin and others, 1979; Reed, 1988). However, the percentage of this area that would be classified as jurisdictional wetlands meeting criteria in State and Federal wetland regulations is not known. Most of the floodplain would be classified by the USFWS as wetlands in the palustrine system, but the floodplain also includes some areas classified as both wetlands and deepwater habitats in the riverine and lacustrine system (Cowardin and others, 1979; Brinson and others, 1981).

About 60 species of trees occur in the bottomland forest of the Apalachicola River floodplain (Leitman and others, 1983). **Mixed bottomland hardwoods** are dominated by water hickory, sweetgum, overcup oak, green ash, and sugarberry, and grow in the areas of higher elevation in the floodplain (levees, ridges, and flats). **Tupelo-cypress swamps**, also called **swamps** in this report, grow in depressions and areas of lower elevation. Some of these swamps are covered with standing water year-round; others are inundated much of the year but lack standing water during the driest months of September, October, and November.

Alluvial rivers contain a variety of **aquatic habitats** that occur outside the main channel of the river but within the floodplain. In this report, any part of the floodplain is considered to be aquatic habitat when it is inundated; thus, the amount of aquatic habitat in the floodplain is very low during droughts and very high during floods. **Connected aquatic habitat** is inundated and connected to the main channel with a 2-way connection. In a **2-way connection**, a level or near-level water passageway exists between a floodplain water body and the main channel, allowing fish passage in both directions. **One-way connections** are waterfalls or very shallow water dropping into the main channel at the mouths of streams. One-way connections block access for main channel fishes to enter streams, but allow stream fishes to enter the main channel. **Isolated aquatic habitat** has no water passageways connecting it to the main channel. During the dry season, many isolated aquatic habitats hold water at levels that are higher than stages in the main channel. A **sill**, or **controlling sill**, is that part of a streambed that determines the elevation of the water connection between the upstream and downstream parts of a stream, or between a stream and the main channel. **Still-water habitat** is any aquatic habitat with nonflowing water.

A **floodplain stream** is any conduit of periodically or continuously moving water in the floodplain that is of sufficient size and development to have a recognizable channel with bed and banks. **Perennial streams** flow continuously and **intermittent streams** flow only during part of the year. When intermittent streams are not flowing, their streambeds may be filled with water, may be partially exposed with isolated pools remaining in parts of the bed, or may completely lack any surface water. **Loop streams** (which can be perennial or intermittent) are fed by flow diverted from the main channel that flows for a few miles through the floodplain and then back into the river farther downstream. A **floodplain lake** is an open body of water that is not flowing except during floods when river water is moving through the floodplain in a general downstream direction. **Tributary lakes** are open bodies of water in the floodplain that have characteristics of both streams and lakes. They usually have little or no flow during very low, low, and medium river flows. Most tributary lakes are connected to the main channel during low river flows. The linear conformations of tributary lakes suggest that they may be abandoned main channel courses of the Apalachicola River. One of the larger examples of a tributary lake is Iamonia Lake (cover of this report; fig. 2) which is approximately 5 mi in length and is nearly as wide and deep as the main river channel in some places. Tributary lake systems often have **connector streams** that divert flow from the main channel into the tributary lake. Tributary lakes and many other streams and lakes are affected at times by **backwater**, which means that either river water has moved into the stream or lake from the main channel, or flowing water in the stream or lake is retarded in its course by water in the main channel.

METHODS OF STUDY

The primary results of the study are quantitative estimates of the amount of aquatic habitat in the floodplain in relation to the full range of river flows. These estimates can be used by water managers to determine changes in habitat that may result from flow alterations. Flow reductions during droughts are of particular concern; they can decrease availability of aquatic habitat in the floodplain at a time when the amount of habitat is already at a minimum. During low and very low flows, aquatic habitats in the floodplain that are most affected by changes in river flows are streams and lakes. Most forested areas are not inundated except during higher flows. In an effort to address concerns about impacts during droughts, field data collection in this investigation was designed to focus on streams and lakes.

Estimates of the amount of aquatic habitat in relation to flow were made for every stream and lake that is connected to the main channel of the Apalachicola River during very low, low, and medium flows. The areal extent of aquatic habitat in floodplain forests was also quantified in this investigation, but with less specific methods than those used for streams and lakes. Representative floodplain forest data were generalized for each major reach of the river, rather than calculated with site specific estimates. Most of the floodplain forest data used in this report were collected in previous studies (Leitman, 1978, 1984; Leitman and others, 1983; Mattraw and Elder, 1984; Light and Darst, 1997).

Intensive Study Areas and General Survey Sites

Data collection in this study focused on floodplain streams and lakes that were connected to the main channel of the Apalachicola River at low and medium flows. Measurements and observations were made at intensive sites many times throughout the study period, but usually only once at general survey sites.

Four intensive study areas were selected to represent major types of floodplain streams in the upper, middle, and nontidal lower reaches of the river (fig. 2). In the floodplain of the upper reach, which extends from river mile 77.4 to 106.3, there are many perennial and intermittent streams that receive water from upland streams. Intensive study areas were selected in the upper reach at Flat Creek to represent perennial streams and at Johnson Creek to represent intermittent streams. Flat Creek has a drainage area of 52 mi^2 (Foose, 1981) most of which lies east of the floodplain of the Apalachicola River. For its most downstream 2 mi, Flat Creek flows through the river floodplain and joins the Apalachicola River at river mile 99.6. Johnson Creek receives intermittent drainage from upland streams west of the Apalachicola River floodplain. For its most downstream 1.5 mi, Johnson Creek lies in the river floodplain, joining with the intermittent drainage of another smaller unnamed stream before it joins the Apalachicola River at river mile 94.0.

Large tributary lakes affected by backwater from the Apalachicola River are the most prominent hydrologic features in the floodplain of the middle reach (river mile 42 to 77.4) and lower reach (river mile 20.6 to 42). Iamonia Lake (mouth at river mile 55.8) and its associated tributaries were selected as an intensive study area to represent tributary lake systems in the middle reach. River Styx (mouth at river mile 35.3) and its associated tributaries were selected as an intensive study area to represent tributary lake systems in the nontidal lower reach. During low river flows, both Iamonia Lake and River Styx receive little water from upland drainage (probably less than 1 ft^3/s).

Approximately 300 general survey sites were located at the mouths of most floodplain streams that met at least one of the following criteria: (1) streams were shown on USGS 7.5-minute quadrangle maps; (2) streams were apparent on 1:65,000 scale color infrared aerial photographs taken November 1979 by National Oceanic and Atmospheric Administration; or (3) streams were observed in the field to have streambed elevations low enough to be connected to the main river channel during very low, low, or medium flows. Most general survey sites were located at mouths of streams tributary to the Apalachicola River; however, some sites were located at mouths of streams tributary to the lower Chipola River and a few of the large tributary lakes, such as Florida River and Kennedy Creek (fig. 2).

Hydrologic Data Collection and Analysis

Hydrologic data for the study were obtained from four long-term surface-water gaging stations located on the Apalachicola River (fig. 2) at Chattahoochee (station number 02358000), near Blountstown (station number 02358700), near Wewahitchka (station number 02358754), and near Sumatra (station number 02359170). At the Chattahoochee gage, nearly-continuous daily stage data were collected by the National Weather Service (NWS) from October 1921 until September 1928, and daily stage and flow data have been collected by the USGS from October 1928 to the present (1995). A regression relation between daily stages measured at the Blountstown gage and 1-day lagged daily stages at the Chattahoochee gage was used to estimate stages at the Chattahoochee gage for missing NWS stage data prior to 1929. Daily discharge data were estimated for the period 1922-28 using the NWS stage data and a composite pre-entrenchment stage-discharge rating for Chattahoochee based on 190 discharge measurements made from 1929 to 1951 (Light and others, 1993). Daily stage data for the Apalachicola River near Blountstown were collected by the NWS from 1920 to 1957 and by the USACE (Mobile District) from 1957 to the present. Missing data at the Blountstown gage were estimated using the Chattahoochee-Blountstown regression relation. Daily stage data for the Apalachicola River near Wewahitchka were collected by the USACE from October 1955 to September 1957 and October 1965 to the present. Daily stage and flow data for the Apalachicola River near Sumatra were collected by the USGS from September 1977 to the present. Flows below 15,000 ft^3/s at the Sumatra gage (river mile 20.6) are generally affected by tides. Tidal fluctuation is approximately 0.5 ft at very low flows. Tidal effects do not occur at river mile 36 or at the Wewahitchka gage (river mile 42). In this report, the lower reach of the study area was considered to be nontidal because tidal effects are minor at the downstream end of the reach and absent in the upper part of the reach.

Records at the Chattahoochee gage were selected for analysis of long-term flow because of the location of the gage at the head of the Apalachicola River, the long period of record available (1922-95), and the continuity of the data. A variety of monthly, annual, and multiple-year duration tables of daily mean flows for the period of record were generated. Nonexceedance durations (durations that flows were below given flow values) were calculated for flows of 4,000 to 16,000 ft^3/s. Exceedance durations (durations that flows were above given flow values) were calculated for flows of 16,000 to 200,000 ft^3/s. Annual and multiple-year durations calculated for flows of 4,000 to 16,000 ft^3/s were based on climatic years from April 1 to March 31 to avoid splitting low flow periods that typically occur in summer and fall. Annual durations calculated for flows of 16,000 to 200,000 ft^3/s were based on water years from October 1 to September 30 to avoid splitting high flow periods that typically occur in winter and spring. Annual nonexceedance durations for flows of 4,000 to 16,000 ft^3/s were calculated two ways: (1) greatest number of consecutive days per year, and (2) total number of days per year that flows were below given flow values. All remaining durations were calculated based on total number of days per year (which are not necessarily consecutive). Statistical analyses of duration tables were conducted to generate frequency information (medians and percentiles).

Stage-discharge ratings reflecting channel conditions prior to entrenchment and present (entrenched) channel conditions were developed at both the Chattahoochee and Blountstown gages. The composite pre-entrenchment stage-discharge rating for 1929-51 (described previously) was used at Chattahoochee. The pre-entrenchment stage-discharge rating for Blountstown was based on pre-entrenchment stage at Blountstown from 1929 to 1951 in relation to 1-day lagged flow at Chattahoochee. For present conditions at Chattahoochee, the 1995 stage-discharge rating was used. For present conditions at Blountstown, unit values at Blountstown were plotted in relation to flow at Chattahoochee using a variety of lag times. The plot with the least amount of scatter (17 hours) was selected and a rating representing average conditions was developed from a hand-fitted line drawn through the points on the plot.

Water-level measurements at intensive study areas were made periodically at a total of 56 reference point (RP) locations: 23 in the upper reach (8 on Flat Creek, 3 on the main channel near Flat Creek, 2 in an isolated swamp near Flat Creek, and 10 on Johnson Creek), 14 in the middle reach (10 on Iamonia Lake and associated tributaries, 3 on the main channel near Iamonia Lake, and 1 on a pond near Iamonia Lake), 19 in the nontidal lower reach (14 on River Styx and associated tributaries, 4 on the main channel near River Styx, and 1 in an isolated swamp near River

Styx). RP locations are identified on maps of the intensive study areas in a previous report (Light and others, 1995, figs. 2-5). Nails in trees were used as the fixed point from which water levels were measured with a tape and weight. A total of 471 water-level measurements were made at RP locations from June 1993 to September 1994. Most of the RP measurements were made during very low, low, or medium flows; however, a few measurements were made at higher flows to establish an approximate elevation relative to sea level for each RP. Visual observations of the movement of floating debris were used to estimate velocity (to nearest 0.2 ft/s) at floodplain RPs at the same time that most water-level measurements were taken.

Daily or hourly stage and flow data and stage-discharge ratings at all four long-term gages and an additional gage at river mile 36 (station number 023587547, approximately 8 mi downstream of the Wewahitchka gage) were used in conjunction with water-level measurements at the RP locations to determine relations between flow at the Chattahoochee gage and stage at intensive study areas. For streams and lakes at the general survey sites, stage-discharge ratings relating stage at representative locations in each major reach of the river to flow at Chattahoochee were developed by interpolation between gages. The representative rating for the upper reach was selected at river mile 94.1 (mouth of Johnson Creek) and for the middle reach at river mile 58.7 (near Iamonia Lake). Two ratings were chosen for the nontidal lower reach, one at river mile 35.2 (mouth of River Styx) for the upstream half of the lower reach, and one at river mile 26.0 (mouth of Kennedy Creek) for the downstream half of the lower reach. A representative rating for pre-entrenchment conditions in the upper reach at river mile 94.1 (mouth of Johnson Creek) was developed by interpolation between pre-entrenchment ratings at the Chattahoochee and Blountstown gages. Previously published ratings (Leitman and others, 1983, fig. 16) were used for some of the floodplain forest data in the upper reach. Ratings were developed by interpolation between gages for all other forest data.

The flow at Chattahoochee at which each floodplain stream and lake was connected to the main channel was estimated from field observations by the following method. A single field visit was made to each of the 300 general survey sites to determine the difference between the water level of the Apalachicola River and the elevation of the streambed (or controlling sill if present). An elevation for the river level at each observation site was determined by calculating lagged flow at Chattahoochee at the time of the observation. This flow was converted to stage using the representative rating for the appropriate reach of the river. For streams connected to the river at the time of the observation, depths were determined by poling with a graduated rod in shallower areas and with a depth sounder in deeper areas. For streams not connected at the time of observation, visual estimates of the elevation (to nearest 0.5 ft) of the streambed or controlling sill above the river level were made at most sites. A hand level and graduated rod were used when the sill was too far from the river to estimate visually. An example of a general survey site, at which the connecting flow was determined by adding the elevation of the streambed to the connecting stage, is shown in figure 3.

Field observations at most general survey sites were used in conjunction with lagged discharge at the Chattahoochee gage at the time of the field visit to determine Chattahoochee flows at which streams were connected to the main channel. A variation of this method was required in the downstream half of the nontidal lower reach because of variability introduced by the greater distance from Chattahoochee and the input from the Chipola River. Relations between flow at Chattahoochee and stage at the Sumatra gage were determined for average conditions by drawing a hand-fitted line through a scatter plot of Sumatra daily mean stages for the period of record in relation to lagged Chattahoochee flow. Stages at the Sumatra gage at the time of field observations in the downstream half of the nontidal lower reach were converted to average Chattahoochee flows using this rating. All field observations for this part of the lower reach were made during periods when stages at the Sumatra gage were not showing tidal fluctuations.

Characterization of Floodplain Habitats

Characterization data of floodplain habitats included widths and lengths (or areas) of floodplain features, land surface elevations, general soil type, and amount of live or dead vegetative structure. Methods used to characterize streams and lakes were different than those used to characterize forests.

Floodplain streams and lakes.--Characterization data were collected at 27 cross-section locations in the intensive study areas. Cross-section locations were selected to represent the most common types of floodplain streams (based on stream width and general forest type bordering the stream) in each major reach of the river, as determined from color infrared aerial photographs and USGS quadrangle maps. Of the 27 cross sections, there were 6 in the upper reach (3 on Flat Creek and 3 on Johnson Creek), 9 in the middle reach (3 on Iamonia Lake and 6 on tributaries of Iamonia Lake), and 12 in the nontidal lower reach (6 on River Styx and 6 on tributaries of River Styx). Cross-section locations are identified on maps of the intensive study areas in a previous report (Light and others, 1995, figs. 2-5).

Most of the cross sections established on floodplain streams were perpendicular to the channel, with end points at recognizable top-of-bank elevations on either side of the channel (fig. 4). In some cases where streambanks were very low, cross sections included several hundred feet of low forest adjacent to the stream. Surveyed cross sections ranged in length from 50 to 1,300 ft. Length of all 27 cross sections totaled approximately 7,000 ft.

At the time of the survey, cross sections were divided into segments based on breaks in slope, or relatively homogeneous soil type or vegetative structure (fig. 4). The horizontal length of each segment was measured with a fiberglass measuring tape. Vertical elevation in relation to the water level was determined at the endpoints of each segment with a

Figure 3. Example of general survey site with floodplain stream disconnected from the Apalachicola River at the time of observation. This unnamed stream at river mile 59.7 in the middle reach of the river had a streambed approximately 3.5 feet above the water level of the river when lagged flow was 9,600 cubic feet per second at the Chattahoochee gage. Using a stage-discharge rating representative of the middle reach of the river, the flow at the Chattahoochee gage at which this stream would be connected to the main channel was determined to be about 16,000 cubic feet per second.

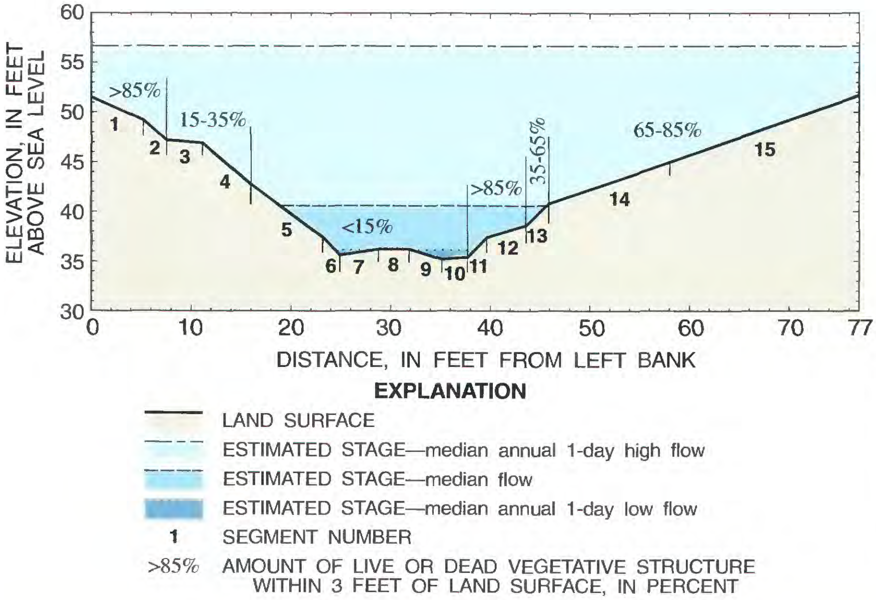


Figure 4. Example of cross section divided into segments based on breaks in slope and relatively homogeneous vegetative structure. Soil type is silt-clay in all segments of the cross section. The estimated stages shown for the cross section were based on long-term flow statistics at the Chattahoochee gage (1922-95) and were determined by interpolation between gages. An adjustment was made to the estimated stage for the median annual 1-day low flow to reflect the lowest observed water level at the cross section. The cross section is located 1,450 feet upstream of mouth of Johnson Creek in the upper reach of the Apalachicola River.

tripod-mounted level and graduated rod. Elevations of the two endpoints of each segment were averaged to determine the segment elevation that was used in data analysis. General soil type in each segment was classified as silt/clay, sandy, or organic. The amount of vegetative structure was visually estimated for each segment from the percent of the segment length that intersected live vegetation, woody debris, or other vegetative matter within 3 ft of the ground. Vegetative structure was recorded in the following categories: less than 15 percent, 15 to 35 percent, 35 to 65 percent, 65 to 85 percent, and greater than 85 percent.

Observations at other locations in intensive study areas and at most general survey sites included visual estimates (to nearest 1 ft) of the width of the streambed (segment numbers 7-10 in fig. 4), width of the remaining channel to top of banks (segment numbers 1-6 and 11-15 in fig. 4), heights of banks, and presence or absence of water in the streambed.

Widths of the larger streams, lengths of all streams, and surface areas of all lakes were determined using map coverages and digital image data in GIS files. Other types of information such as drainage basin configuration and extent, and adjacent forest types were obtained from GIS files when needed to characterize parts of streams that were not observed in the field. GIS files contained digital image data consisting of 1979 color infrared aerial photography scanned at a resolution having a pixel size of 5.9 ft on the ground, and map coverages consisting of USGS 7.5-minute quadrangle maps and a forest map of the Apalachicola River floodplain (Leitman, 1984).

Floodplain forests.--Most of the floodplain forest data used in this report were collected during a USGS study from 1979 to 1982 known as the Apalachicola River Quality Assessment (ARQA). Results of this previous study included land surface elevations and forest types at 223 sample points located on 7 line transects crossing the Apalachicola River floodplain (Leitman and others, 1983, fig. 34) and a map showing areal extent of forest types (Leitman, 1984). Major floodplain forest types in these reports were mixed bottomland hardwoods and tupelo-cypress. Other sources of forest data used to supplement the ARQA data were land surface elevations, general soil type, vegetative structure, and forest types on the forested parts of 5 of the 27 cross sections at the intensive study areas (in the present study); land surface elevations, vegetative structure, and forest type on 21 circular plots located at the intensive study areas (Light and Darst, 1997); and land surface elevations, soil type, and forest types at 2 belt transects located near the Blountstown and Wewahitchka gages (Leitman, 1978).

Land surface elevations, soil type, and vegetative structure for each forest type in each major reach of the river were summarized from the various sources of data listed above. Estimates of soil type by forest type were made using soils data reported by Leitman (1978), sediment grain size data for ARQA sites (Mattraw and Elder, 1984, p. 61), and general soil type observations collected on the forested parts of the cross sections at the intensive study areas (in the present study). Estimates of percent cover of vegetative structure by forest type were made using structure data collected on the forested parts of the cross sections at the intensive study areas and at forest plots described by Light and Darst (1997).

The previously published map of forest types (Leitman, 1984) was digitized for use in GIS. Minor corrections to polygon boundaries were made to adapt the map to the more detailed scale used in GIS coverages in this study. Areas of each forest type in each reach were computed from the new GIS version of the map.

Computations of Amount of Aquatic Habitat in Relation to River Flow

Final products of this investigation consisted of amounts of aquatic habitat in relation to river flow presented in a variety of formats (fig. 5). These products were generated by combining habitat

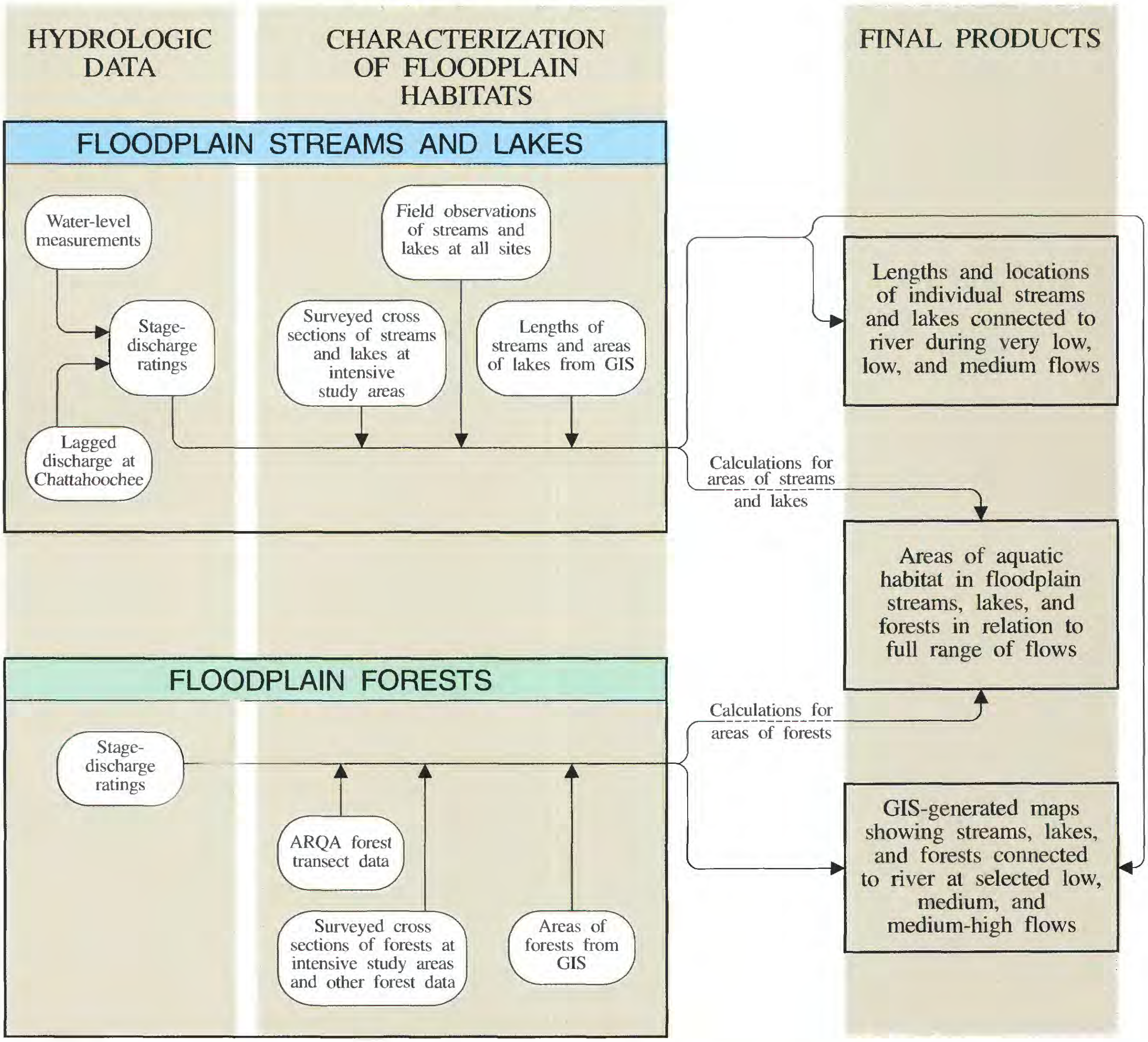


Figure 5. Flowchart for determining amount of aquatic habitat in floodplain streams, lakes, and forests in relation to flows in the Apalachicola River. (ARQA, Apalachicola River Quality Assessment; GIS, Geographic Information System)

characterization with hydrologic data.

Final results are expressed in relation to river flow rather than stage, although stage is more directly related to hydrologic conditions in floodplain habitats than flow. River stages decline as the river flows downstream from the upper to lower end of the study area, and range in stage decreases as the floodplain gets wider and flatter near the coast. Thus, relations of floodplain habitats to river stage cannot be easily compared between sites on the river and cannot be summarized by reach or for the entire river. Flow, on the other hand, is relatively consistent throughout much of the river and flow relationships can be established between reaches. Additionally, expressing results in terms of flow at the head of the river makes the results directly usable for water managers in determining releases from Jim Woodruff Dam and other upstream reservoirs. In this report, elevations of floodplain habitats were initially related to stage and then stage was converted to flow to allow comparisons and summaries of data from different sites.

Area of aquatic habitat was calculated for 36 discrete flow values which were selected to provide greater detail at very low, low, and medium flows, and lesser detail at higher flows. Flow values used in this analysis were set at intervals of 1,000 ft^3/s, from 2,000 to 23,000 ft^3/s. Intervals gradually increased with increasing flows; remaining flow values were set at 25,000, 27,000, 29,000, 31,000, 33,000, 35,000, 40,000, 45,000, 55,000, 65,000, 75,000, 100,000, 140,000, and 200,000 ft^3/s. This set of flow values represents the full range of flows in the Apalachicola River from extreme low to extreme high. The lowest daily mean flow at the Chattahoochee gage in the 74-year period of record was 3,900 ft^3/s (Nov. 15-16, 1987) and the lowest instantaneous flow was 2,570 ft^3/s (Aug. 6, 1986). Extremely low flows of 2,000 ft^3/s are included to provide habitat data in the event that a decreasing trend in flows occurs in the future.

Three variables were chosen to characterize hydrologic conditions in aquatic habitats in relation to river flow because of their importance to fish and aquatic invertebrate populations: depth, connection depth, water velocity, general soil type, and vegetative structure. Depth indicates average water depth of the habitat, whereas connection depth is the depth of the water at the shallowest control point along the connecting passageway from the habitat to the main river channel. For many habitats, depth and connection depth have the same value, but in isolated pools and ponds at low flows, depths are sometimes 1 to 3 ft when connection depth is zero. Depths and connection depths were grouped into five categories for analysis: 0.01 to 0.49, 0.50 to 0.99, 1.00 to 2.99, 3 to 6, and greater than 6 ft. Two additional categories were used for connection depth: 1-way connection (preventing access for fishes from river to floodplain) and no connection. There were three categories for water velocity: 0, 0.1 to 0.5, and greater than 0.5 ft/s.

Floodplain streams and lakes.--All floodplain streams and lakes connected to the main channel at very low, low, and medium flows were divided into reaches that were relatively homogeneous with regard to channel width and thalweg depth. One of the cross sections from an intensive study area in the same major reach of the river was selected and modified to represent each homogeneous stream reach. Modifications included changes in elevation, channel width, thalweg depth, bank heights, soil type, or vegetative structure. Most floodplain lakes were linear in shape, allowing cross sections from large streams to be used, with modifications, to represent lakes. Dimensions and characteristics for many reaches were determined by field observations. For each stream reach that was not observed in the field, a known reach that appeared similar to the unknown reach on aerial photos and maps was identified, and a cross section from the known reach was applied.

Using the representative ratings for each major reach of the river, and the flow at Chattahoochee at which each floodplain stream and lake was connected to the main channel (described in the section entitled "Hydrologic data collection and analysis"), cross-section elevations were related to flow at Chattahoochee. When river flows exceeded the connecting flow for a stream or lake, depths were calculated for each individual segment of the cross section by comparing the segment elevation to stages in the representative rating. Similarly, connection depths were calculated for cross-section segments by comparing the controlling sill elevation to stages in the rating. When river flows were below the connecting flow, all cross-section segments were disconnected from the main river channel. For each cross section, the area and depth of isolated pools (if any) when the stream or lake was disconnected was estimated based on observations of that stream reach or similar reaches. Velocities were estimated for each stream reach and for each flow value based on field observations of that stream reach or similar reaches.

For each segment of the cross section, the segment width was multiplied by the length of the stream reach to determine the area in acres. All area data were summarized for each major reach of the river, and the resulting data file contained the area in acres of many different aquatic stream and lake habitats, each with a unique combination of characteristics (soil type, vegetative structure, depth, connection depth, and velocity) at each of the 36 flow values.

Floodplain forests.--Each forest transect had a stage-discharge rating relating stage at the transect with flow at Chattahoochee. Transects were divided into segments based on elevations that corresponded to stages in the rating for each of the 36 flow intervals. The flow at which each segment of the transect was inundated and connected to the main channel was determined using the appropriate rating. When river flows exceeded the connecting flow for a transect segment, depths were calculated for the segment by comparing the segment elevations to stages in the rating. When river levels were below the connecting flow, the segment was considered to be nonaquatic, unless the transect had been observed (either in this study or in previous studies) to have isolated pools of standing water during the dry season.

Water velocities were estimated for each forest type and for each flow value based on field observations of velocities in that forest type in this or previous studies. Estimates of soil type and vegetative cover were determined for each forest type using methods described previously.

For each major reach of the river, lengths of inundated transect segments of each forest type in each elevation category were summarized and then converted to the percentage of the total transect length in that forest type. Percentages were then multiplied by the total area of each forest type in each major reach of the river. The resulting data file contained the area, in acres, of many different aquatic forest habitats, each with a unique combination of characteristics (soil type, vegetative structure, depth, connection depth, and velocity) at each of the 36 flow values.

Analysis of combined data for streams, lakes, and forests.--Areal data for streams and lakes were merged with areal data for forests for each major reach of the river and for the nontidal river as a whole. Analyses of the data were conducted to generate final products in three different formats (fig. 5): (1) a list of lengths and locations of individual streams and lakes connected at very low, low, and medium flows; (2) flow-area curves showing the area of aquatic habitat in relation to the full range of flows at Chattahoochee for a variety of habitat characteristics; and (3) maps generated from GIS coverages for each major reach of the river showing streams, lakes, and forests connected to the main river channel at selected low, medium, and medium-high flows.

FLOW AND STAGE CHARACTERISTICS OF THE APALACHICOLA RIVER, 1922-95

Hydrologic conditions are a primary factor in the creation and maintenance of river floodplains. River flow builds floodplain features such as levees and ridges by depositing sediments during a flood. Floodplain streams and lakes are created from old river channels when the river changes course. River flow erodes the banks and beds of floodplain streams when velocities are high enough to scour sediments and carry them downstream. Changes in river stage alternately connect and disconnect floodplain water bodies, changing the conditions for fishes and aquatic invertebrates, as well as for vegetation and other biota. In this section of the report, duration and frequency statistics of the long-term flow record of the Apalachicola River based on monthly, annual, and multiple-year periods of analysis are presented. This information is important in assessing impacts of flow alterations because it can be used to make comparisons between altered flows and historical flows. This section ends with a discussion of altered stages that have occurred as a result of entrenchment in the upper river.

All statistical analyses were based on daily mean flows of the 74-year period of record at Chattahoochee, Fla., from 1922 to 1995. Previous hydrologic analyses conducted on flow records through the year 1980 compared flows before and after construction of Jim Woodruff Dam, and concluded that climatic fluctuations were primarily responsible for higher flows after construction of the dam (Maristany, 1981; Leitman and others, 1983). The river experienced periods of severe drought immediately following those analyses; annual low flows in 1981, 1986, 1987, and 1988 were lower than in all previous years for the period of record. This raises the possibility that flows are exhibiting a slightly decreasing trend over time;

Table 1. Basic flow characteristics of Apalachicola River at Chattahoochee, Florida, 1922-95

[Median annual 1-day low flow is based on annual periods using climatic years of April 1–March 31 to avoid splitting low flow periods that typically occur in summer and fall. Median annual 1-day high flow is based on annual periods using water years of October 1–September 30 to avoid splitting high flow periods that typically occur in winter and spring]

Flow descriptor	Flow value, in cubic feet per second (with dates of lowest and highest flows)		Flow records used in analysis	
			Number of years	Period analyzed
Lowest 1-day flow	3,900	(November 15-16, 1987)	74.5	October 1921–March 1996
Median annual 1-day low flow	8,490		74	April 1922–March 1996
Median flow	16,400		74.5	October 1921–March 1996
Median annual 1-day high flow	86,200		74	October 1921–September 1995
Highest 1-day flow	291,000	(March 20, 1929)	74.5	October 1921–March 1996

however, low flows during the 1950's drought were of longer duration than in the 1980's. Comparisons of the two drought periods will be discussed later in this section. Trend analysis with an examination of associated climatic differences is needed to determine if a trend exists. In the absence of a documented trend, the entire period of record was preferred for analysis of flow characteristics.

Because of both the possible trend in the record and the flow regulation that has occurred since construction of Jim Woodruff Dam, the use of predictive frequency statistics such as recurrence intervals was avoided in this study. Frequency information is instead described in terms of median and percentiles of flows that have occurred during the 74-year period of record. In unregulated streams having long-term record with no trends, the median flow is approximately equivalent to the 2-year recurrence interval flow, and the 10th, 25th, 75th, and 90th percentile flows are approximately equivalent to the 10-, 4-, 1.33-, and 1.11-year recurrence interval flows, respectively.

River flow fluctuates greatly from low-water to high-water periods within each year as well as from one year to the next. In the 74-year period of record the median flow of the Apalachicola River at Chattahoochee was approximately 16,400 ft^3/s, with a typical annual range of flows from 8,490 to 86,200 ft^3/s (table 1). The lowest daily mean flow in the period of record was 3,900 ft^3/s in November 1987, and the highest was 291,000 ft^3/s in March 1929.

Very Low to Medium Flows

The greatest number of consecutive days and total number of days per year that flows were below given flow values (annual nonexceedance durations) of 4,000 to 16,000 ft^3/s for the period 1922-95 are presented in table 2. The durations that occurred under normal or typical conditions are represented by the median durations. Durations in drier years are represented by the 10th- and 25th-percentile durations, and in wetter years by the 75th- and 90th-percentile duration. The greatest number of consecutive days and total number of days in each individual year from 1922 to 1995 are presented in appendix IA and IB, respectively.

In a typical year, daily mean flows less than 8,000 ft^3/s did not occur in the Apalachicola River at Chattahoochee. Flows less than 9,000 ft^3/s occurred in a typical year with a duration of 6 consecutive days or 13 total days. Flows less than 16,000 ft^3/s occurred for 93 consecutive days or 179 total days (approximately half of the year).

Flows less than 8,000 ft^3/s occurred in 34 of the 74 years of record (app. I). Flows less than 8,000 ft^3/s occurred with a duration of 64 consecutive days at the 10th percentile, and 20 consecutive days at the 25th percentile (table 2). Flows less than 6,000 ft^3/s occurred in 15 years of the period of record. Flows under 5,000 ft^3/s were rare, occurring in only 4 years in the 74-year period of record (1981, 1986, 1987, and 1988). Flows under 4,000 ft^3/s were exceptionally rare and occurred for only 3 days in 1987 (table 2; app. I).

In 19 of the 74 years of record, flows less than 10,000 ft^3/s did not occur (app. I). In the two wettest years (1948 and 1975), the lowest daily mean flow was 12,400 ft^3/s.

Normal and extreme flows must be defined to understand known limits of hydrologic conditions that have been experienced by biological communities in the system. For example, some streams are continuously connected and flowing under normal and even drier than normal conditions, but are disconnected and become a series of stagnant, isolated pools during severe droughts. Fish and aquatic invertebrate populations that require flowing, oxygenated water are greatly reduced during droughts and may not be fully restored for years, depending upon the resiliency of individual species, the proximity of aquatic habitat that might provide a source for restocking, and the amount of recovery time before the next drought (Starrett, 1951; Larimore and others, 1959; Taylor, 1983).

Year-to-year variability is an important aspect of hydrologic fluctuation that affects the opportunity for recovery between droughts. The year-to-year variability of lower flows is graphically depicted in figure 6, which shows the lowest 5 percent of daily mean

Table 2. Greatest number of consecutive days and total number of days per year that flow was below given flow values from 4,000 to 16,000 cubic feet per second in the Apalachicola River at Chattahoochee, Florida

[Period of record analyzed is 1922-95. Analysis is based on climatic years of April 1–March 31 to avoid splitting low-flow periods that typically occur in summer and fall. In each column, durations are expressed first (in bold) in greatest number of consecutive days per year, and second (in italics) in total number of days per year, which are not necessarily consecutive. Percentiles indicate frequency of durations over 74-year period of record]

Flow value, in cubic feet per second	**Greatest number of consecutive days** and *total number of days* per year that flow was below given flow value for indicated percentile													
	Extreme (dry)		10th percentile		25th percentile		Median (50th percentile)		75th percentile		90th percentile		Extreme (wet)	
4,000	**3**	*3*	**0**	*0*	**0**	*0*	**0**	*0*	**0**	*0*	**0**	*0*	**0**	*0*
5,000	**20**	*29*	**0**	*0*	**0**	*0*	**0**	*0*	**0**	*0*	**0**	*0*	**0**	*0*
6,000	**64**	*67*	**12**	*14*	**0**	*0*	**0**	*0*	**0**	*0*	**0**	*0*	**0**	*0*
7,000	**80**	*115*	**49**	*68*	**5**	*8*	**0**	*0*	**0**	*0*	**0**	*0*	**0**	*0*
8,000	**122**	*166*	**64**	*96*	**20**	*36*	**0**	*0*	**0**	*0*	**0**	*0*	**0**	*0*
9,000	**144**	*208*	**81**	*137*	**45**	*63*	**6**	*13*	**0**	*0*	**0**	*0*	**0**	*0*
10,000	**192**	*227*	**98**	*157*	**60**	*95*	**19**	*37*	**0**	*0*	**0**	*0*	**0**	*0*
11,000	**241**	*241*	**110**	*182*	**76**	*133*	**29**	*65*	**9**	*15*	**0**	*0*	**0**	*0*
12,000	**244**	*261*	**138**	*205*	**105**	*155*	**52**	*92*	**19**	*46*	**7**	*13*	**0**	*0*
13,000	**256**	*283*	**163**	*227*	**109**	*178*	**61**	*120*	**27**	*72*	**16**	*27*	**2**	*5*
14,000	**286**	*291*	**179**	*242*	**123**	*197*	**71**	*139*	**36**	*93*	**27**	*41*	**3**	*11*
15,000	**292**	*303*	**205**	*259*	**129**	*214*	**82**	*160*	**52**	*115*	**32**	*76*	**5**	*17*
16,000	**293**	*308*	**211**	*267*	**138**	*229*	**93**	*179*	**57**	*130*	**39**	*89*	**8**	*31*

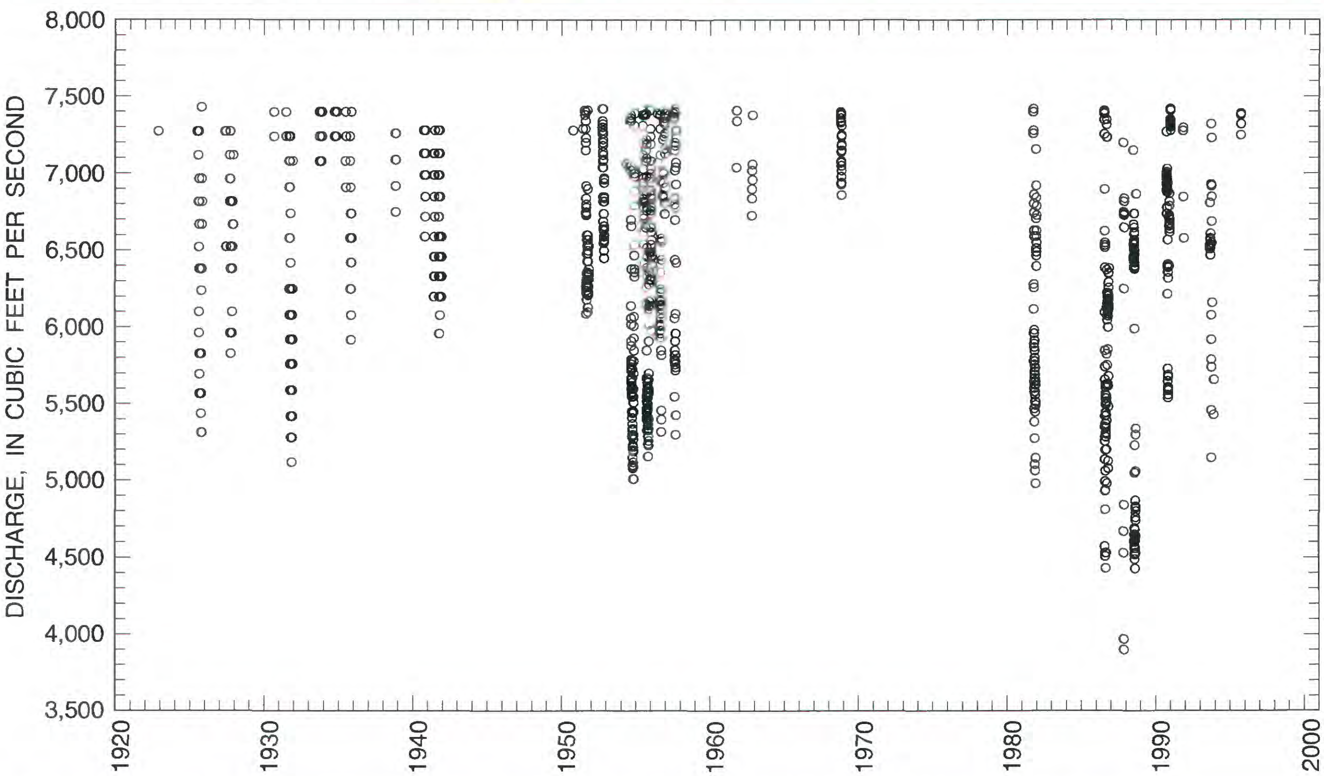


Figure 6. Lowest 5 percent of daily mean flows in the Apalachicola River at Chattahoochee, Florida, 1922-95. The 1,350 daily mean flows depicted in this graph were not affected by filling of the reservoir at Lake Seminole except for 2 days with daily means of 7,060 ft³/s in 1954. Almost all reservoir filling occurred during periods when flows were greater than 8,000 ft³/s (U.S. Army Corps of Engineers, 1985).

Table 3. Number of days per year for multiple-year periods that flow was below given flow values from 4,000 to 16,000 cubic feet per second in the Apalachicola River at Chattahoochee, Florida

[Period of record analyzed is 1922-95. Analysis is based on climatic years of April 1–March 31 to avoid splitting low flow periods that typically occur in summer and fall. Durations are expressed in total number of days per year, which are not necessarily consecutive]

Flow value, in cubic feet per second	Median duration in which flow was below given flow value, in number of days per year for multiple-year period			
	Two consecutive years	Three consecutive years	Four consecutive years	Five consecutive years
4,000	0	0	0	0
5,000	0	0	0	0
6,000	0	0	0	0
7,000	0	0	0	0
8,000	0	0	0	0
9,000	0	0	0	0
10,000	6	0	0	0
11,000	26	11	4	3
12,000	52	38	16	12
13,000	76	62	58	48
14,000	105	92	85	83
15,000	120	114	111	92
16,000	136	129	125	104

Flow value, in cubic feet per second	Maximum duration in which flow was below given flow value, in number of days per year for multiple-year period			
	Two consecutive years	Three consecutive years	Four consecutive years	Five consecutive years
4,000	0	0	0	0
5,000	6	6	0	0
6,000	54	11	11	0
7,000	83	42	23	0
8,000	114	101	53	4
9,000	145	139	80	31
10,000	190	177	99	63
11,000	208	199	117	83
12,000	227	214	142	122
13,000	257	248	167	138
14,000	271	258	182	160
15,000	278	268	202	174
16,000	292	273	223	182

flows in relation to time. Nonexceedance durations for multiple-year periods of 2 to 5 years are shown in table 3. The upper part of table 3 shows median durations and the lower part shows maximum durations for all multiple-year periods in the 74-year period of record. For example, flows less than 9,000 ft^3/s occurred for a total of 13 days in a typical single year (table 2), but typically did not occur for two consecutive years (upper part of table 3). Flows less than 10,000 ft^3/s occurred for a total of 37 days in a typical single year and 6 days per year for two consecutive years under normal conditions, but typically did not occur for three consecutive years. All possible combinations of 2, 3, 4, or 5 years were used to determine the durations in table 3. Appendix IB gives the durations for each individual year that were used to develop this table.

The droughts of the 1980's were the most severe in terms of single-year low flow durations; however, the 1950's drought was drier in terms of multiple-year durations (fig. 6; app. IB). More than three-quarters of the maximum multiple-year flow durations shown in the lower part of table 3 occurred in the extended drought period of 1954-58; most of the remaining durations occurred during 1984-88. Very low flows occurred at other times from 1922-95, but typically occurred in a single year with flows that were not as low as in the 1950's or 1980's and with a return to more normal flows the following year.

Seasonal fluctuation is another characteristic of river flow that has important effects on biological processes. Many fishes require spawning sites in spring and summer, and structural cover for juveniles following spawning (Lee and others, 1980; Savino and Stein, 1982). Availability of additional food sources in inundated forests helps fishes meet increased energetic needs for reproduction and growth (Killgore and Baker, 1996). Timing of floods affects the delivery of detrital material from forested areas to stream channels of the floodplain and to the main river channel as well as to downstream estuarine habitats, affecting the seasonal food supply of riverine and estuarine detritivores (Mattraw and Elder, 1984).

Seasonal variability is described with monthly durations for flows from 4,000 to 16,000 ft³/s in table 4. The upper part of table 4 shows median flow durations and the lower part shows maximum flow durations for the 74-year period of record. September, October, and November are typically the driest months, with flows less than 10,000 ft³/s for durations of 4 to 10 days of the month. February, March, and April are the wettest months and typically do not have flows less than 16,000 ft³/s. Flows during some months such as January and August are highly variable. January is among the wettest months with respect to its median flow duration, but has maximum flow durations that are considerably drier. Maximum duration of flows less than 5,000 ft³/s for August were much longer than for any other month.

Table 4. Number of days per month that flow was below given flow values from 4,000 to 16,000 cubic feet per second in the Apalachicola River at Chattahoochee, Florida

[Period of record analyzed is 1922-95. Durations are expressed in total number of days per month, which are not necessarily consecutive]

Flow value, in cubic feet per second	Median number of days per month that flow was below given flow value											
	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
4,000	0	0	0	0	0	0	0	0	0	0	0	0
5,000	0	0	0	0	0	0	0	0	0	0	0	0
6,000	0	0	0	0	0	0	0	0	0	0	0	0
7,000	0	0	0	0	0	0	0	0	0	0	0	0
8,000	0	0	0	0	0	0	0	0	0	0	0	0
9,000	0	0	0	0	0	0	0	0	0	0	0	0
10,000	0	0	0	0	0	4	10	6	0	0	0	0
11,000	0	0	0	0	0	10	18	16	0	0	0	0
12,000	0	0	2	6	6	18	23	23	4	0	0	0
13,000	0	1	8	11	13	23	29	26	10	0	0	0
14.000	0	3	11	16	17	26	31	29	14	0	0	0
15,000	0	5	15	18	22	29	31	30	15	0	0	0
16,000	0	6	19	21	24	30	31	30	19	2	0	0

Flow value, in cubic feet per second	Maximum number of days per month flow was below given flow value											
	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
4,000	0	0	0	0	0	0	0	3	0	0	0	0
5,000	0	0	0	0	25	4	0	6	0	0	0	0
6,000	0	0	0	1	31	30	31	30	6	1	0	0
7,000	0	1	15	31	31	30	31	30	23	20	0	0
8,000	0	5	28	31	31	30	31	30	24	24	0	0
9,000	0	20	30	31	31	30	31	30	26	26	7	0
10.000	2	26	30	31	31	30	31	30	31	31	10	0
11,000	7	31	30	31	31	30	31	30	31	31	23	0
12,000	12	31	30	31	31	30	31	30	31	31	26	4
13,000	15	31	30	31	31	30	31	30	31	31	28	22
14,000	18	31	30	31	31	30	31	30	31	31	28	26
15,000	26	31	30	31	31	30	31	30	31	31	28	31
16,000	27	31	30	31	31	30	31	30	31	31	28	31

Table 5. Number of days per year that flow was above given flow values from 16,000 to 200,000 cubic feet per second in the Apalachicola River at Chattahoochee, Florida

[Period of record analyzed is 1922-95. Analysis is based on water years of October 1–September 30 to avoid splitting high-flow periods that typically occur in winter and spring. Durations are expressed in total number of days per year, which are not necessarily consecutive. Percentiles indicate frequency of durations over 74-year period of record]

Flow value, in cubic feet per second	Number of days per year that flow was above given flow value for indicated percentile				
	Extreme (wet)	25th percentile	Median (50th percentile)	75th percentile	Extreme (dry)
200,000	9	0	0	0	0
140,000	21	0	0	0	0
100,000	27	3	0	0	0
75,000	32	10	3	0	0
65,000	46	19	6	1	0
55,000	79	33	14	4	0
45,000	100	48	30	12	0
40,000	123	60	42	18	0
35,000	151	78	61	24	0
33,000	168	88	68	29	0
31,000	177	96	75	36	0
29,000	192	110	84	38	0
27,000	205	126	95	44	0
25,000	215	141	103	53	0
23,000	241	152	113	61	1
22,000	265	164	122	74	4
21,000	287	173	132	87	16
20,000	298	178	142	91	21
19,000	312	190	154	105	29
18,000	328	205	165	125	31
17,000	331	218	176	135	38
16,000	338	240	193	143	41

Medium to High Flows

The total number of days per year that flows were above given flow values (annual exceedance durations) of 16,000 to 200,000 ft^3/s for the period 1922-95 are presented in table 5. Median durations represent typical conditions. Wet and dry ends of the range are reversed compared to the nonexceedance durations of table 2. Durations in wetter years are represented by the 25th-percentile durations in table 5, and in drier years by the 75th-percentile duration.

In a typical year, daily mean flows did not exceed 100,000 ft^3/s. Typical annual duration was 3 days for flows greater than 75,000 ft^3/s, and 6 days for flows greater than 65,000 ft^3/s. Flows greater than 16,000 ft^3/s occurred approximately half of the time in a normal year.

Short periods during which flows were above 100,000 ft^3/s occurred in 25 of the 74 years of record. Duration of flows exceeding 100,000 ft^3/s at the 25th percentile was 3 days (table 5). Flows above 140,000 ft^3/s occurred in 12 years of the period of record. Flows above 200,000 ft^3/s were rare, occurring in only 3 years (1925, 1929, and 1994). The 1929 flood holds the record not only for the highest flow (291,000 ft^3/s) (table 1), but also for the longest duration of any flood exceeding 100,000 ft^3/s (27 days).

In drier years, flows did not exceed 75,000 ft^3/s. There were 9 years in the period of record in which the highest flows for the year did not exceed 55,000 ft^3/s. The lowest annual 1-day high flow was 24,300 ft^3/s in 1941.

Effects of Entrenchment on Stage in the Upper Reach

Entrenchment or riverbed degradation is a typical process that occurs downstream of dams in the first 1 to 3 decades after dam construction (Galay, 1983; Ligon and others, 1995). Coarse sediments carried downstream along the riverbed are trapped in the reservoir behind the dam. Water lacking coarse sediments is released below the dam and tends to erode the riverbed, lowering the elevation of the bed. The rate of entrenchment of the Apalachicola River at Chattahoochee was greatest from 1954 to the late 1960's (fig. 7). An additional decrease in

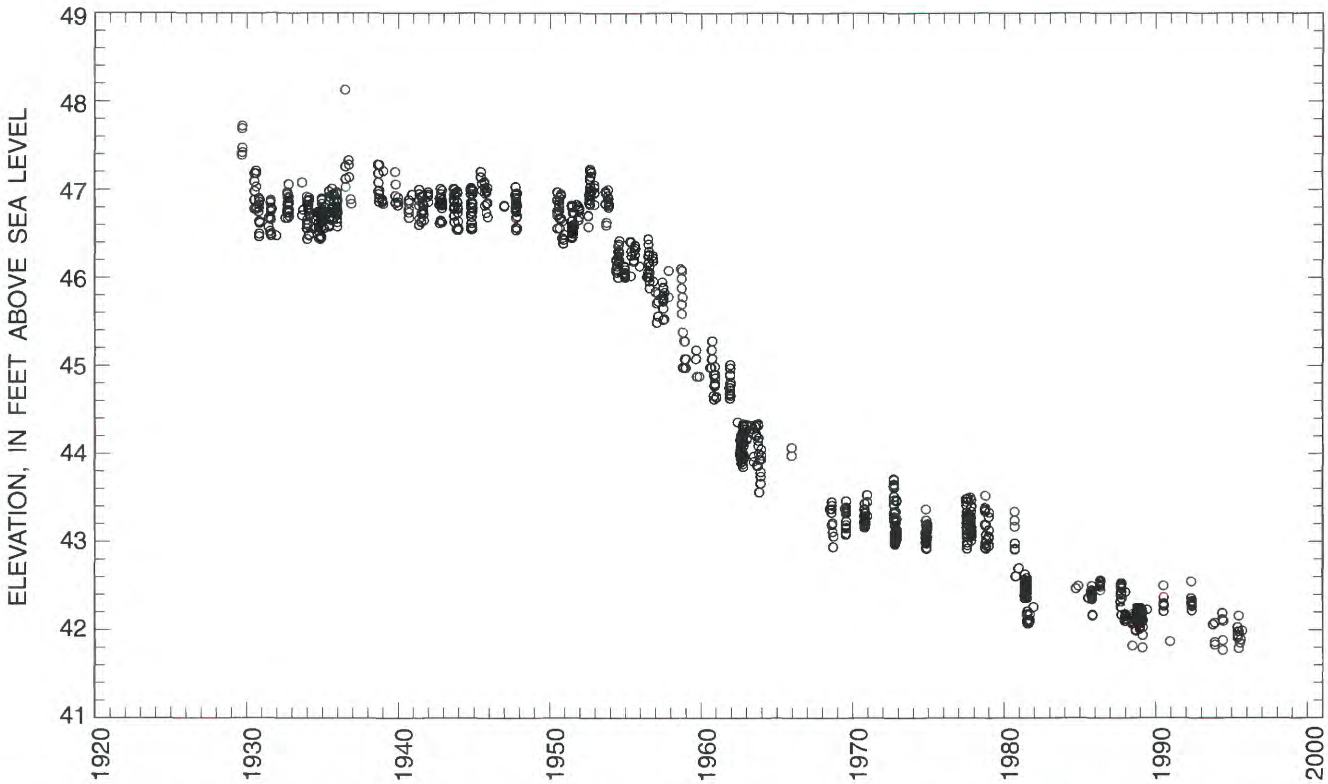


Figure 7. River stages during low flows in the Apalachicola River at Chattahoochee, Florida, 1929-95. Data points shown include all daily mean stages in the 67-year period that have corresponding flow values between 9,500 and 10,500 cubic feet per second using the stage-discharge rating in effect at the time. Data prior to 1929 are not shown because no discharge measurements were made prior to 1929.

stage of approximately 1 ft occurred around 1981. Entrenchment appears to have stabilized since then, as no additional decrease in stage is apparent from 1981 to 1995. This agrees with a previous analysis conducted by Simons, Li and Associates, Inc. (1985), except that an aggradational trend since 1981 noted by those authors is not apparent in the more recent analysis depicted in figure 7.

Effects of entrenchment decrease with increasing flow and with distance downstream of the dam (table 6). Decreases in stage as a result of entrenchment averaged 4.8 ft at the Chattahoochee gage, and 1.9 ft at the Blountstown gage at low and medium flows. Effects of entrenchment appear to be restricted to the

Table 6. Decrease in stage in upper reach of Apalachicola River as a result of entrenchment

[Chattahoochee gage is at the upstream end and Blountstown gage is at the downstream end of upper reach. Decrease in stage represents the amount that stages have dropped for a given flow from pre-entrenchment conditions existing prior to 1954 to present (1995) conditions. Values were computed from stage-discharge ratings for pre-entrenchment and current conditions at each gage]

Flow range, in cubic feet per second	Decrease in stage as a result of entrenchment, in feet	
	At Chattahoochee gage	At Blountstown gage
4,000 to 15,000	4.8	1.9
16,000 to 35,000	4.7	1.9
36,000 to 75,000	4.0	1.5
76,000 to 100,000	3.3	1.0
101,000 to 150,000	2.2	0.6
Greater than 150,000	<1.5	<0.6

upper reach of the river. Downstream of the Blountstown gage, the river channel thalweg reflects alternating cycles of aggradation and degradation but there are no consistent decreasing trends in stage (Simons, Li, and Associates, Inc., 1985, p. 100 and fig. 5.2).

FLOODPLAIN STREAMS, LAKES, AND FORESTS IN RELATION TO RIVER FLOW

This section of the report describes the major types of streams, lakes, and forests of the floodplain by river reach, and the changes that occur in these features with changes in river flow. Detailed maps and descriptions are provided for streams and lakes at the intensive study areas. Streams, lakes, and forests described in this section are illustrated on plates depicting connected aquatic habitat in the upper reach (pl. 1), middle reach (pl. 2), and nontidal lower reach (pl. 3) at specific flow values selected to represent low, medium, and medium-high river flows. The specific flow values used to represent low flows (8,000 ft^3/s) and medium flows (16,000 ft^3/s) are the same on all three plates. The specific flow value representing medium-high flows on the plates varies with the reach and approximates the minimum river flow at which at least 70 percent of the total area of tupelo-cypress swamps in the reach is inundated and connected to the main channel. These specific flow values are 31,000 ft^3/s for the upper reach (pl. 1C), 27,000 ft^3/s for the middle reach (pl. 2C), and 23,000 ft^3/s for the nontidal lower reach (pl. 3C). Lengths and locations of individual streams connected to the main channel at selected flows are listed in appendix II and summarized in table 7.

Table 7. Lengths of floodplain streams and lakes in upper, middle, and nontidal lower reaches of the Apalachicola River that are connected to the main river channel at flows ranging from 4,000 to 19,000 cubic feet per second

["Connected" means that approximately level water passageways exist between floodplain water bodies and the main river channel, allowing 2-way access for fishes to move from river to floodplain as well as from floodplain to river. Individual stream locations and lengths are given in appendix II. Not included in this table are the main channel of the nontidal Apalachicola River which is 86 miles in length, and main channels of the lower Chipola River and Chipola Cutoff which total 17 miles in length]

Flow at Chattahoochee gage, in cubic feet per second	Length of streams and lakes connected to main channel at or below given flow values, in miles			
	Upper reach	Middle reach	Nontidal lower reach	Total
4,000	0.8	5.2	12.7	18.7
5,000	2.6	6.3	26.0	34.9
6,000	5.3	8.8	39.7	53.8
7,000	5.3	11.9	50.3	67.5
8,000	8.3	29.4	55.4	93.1
9,000	9.0	32.0	65.2	106.2
10,000	14.4	32.2	75.2	121.8
11,000	20.3	42.0	77.7	140.0
12,000	20.5	57.7	83.7	161.9
13,000	20.5	63.0	88.3	171.8
14,000	20.6	71.4	96.3	188.3
15,000	20.9	79.3	98.9	199.1
16,000	20.9	86.7	100.6	208.2
17,000	21.0	88.8	101.3	211.1
18,000	24.6	93.8	104.1	222.5
19,000	24.6	101.5	104.1	230.2

Upper Reach

Flat Creek, an intensive study area in the upper reach, is a perennial stream draining an upland area of 52 mi^2 (figs. 8 and 9). During very low flows, water in the mouth of Flat Creek is very shallow (less than 3 in. deep) and drops into the main channel across a sandy delta. Lowered stages in the main channel as a result of entrenchment appear to have altered the mouth of this stream since the 1950's, making aquatic habitat in the Flat Creek drainage inaccessible to main channel fishes. Prior to construction of Jim Woodruff Dam, the mouth of Flat Creek was deep enough during very low flows for fish and boat access (J.M. Barkuloo, retired, USFWS, oral commun., 1997). When the river rises higher than the mouth of Flat Creek in its present condition, river water enters the downstream reach of the stream creating an area of backwater with very sluggish flow; but farther upstream, Flat Creek is still flowing swiftly. During high flows, the banks of Flat Creek are under water and water flows across forests and streams in the

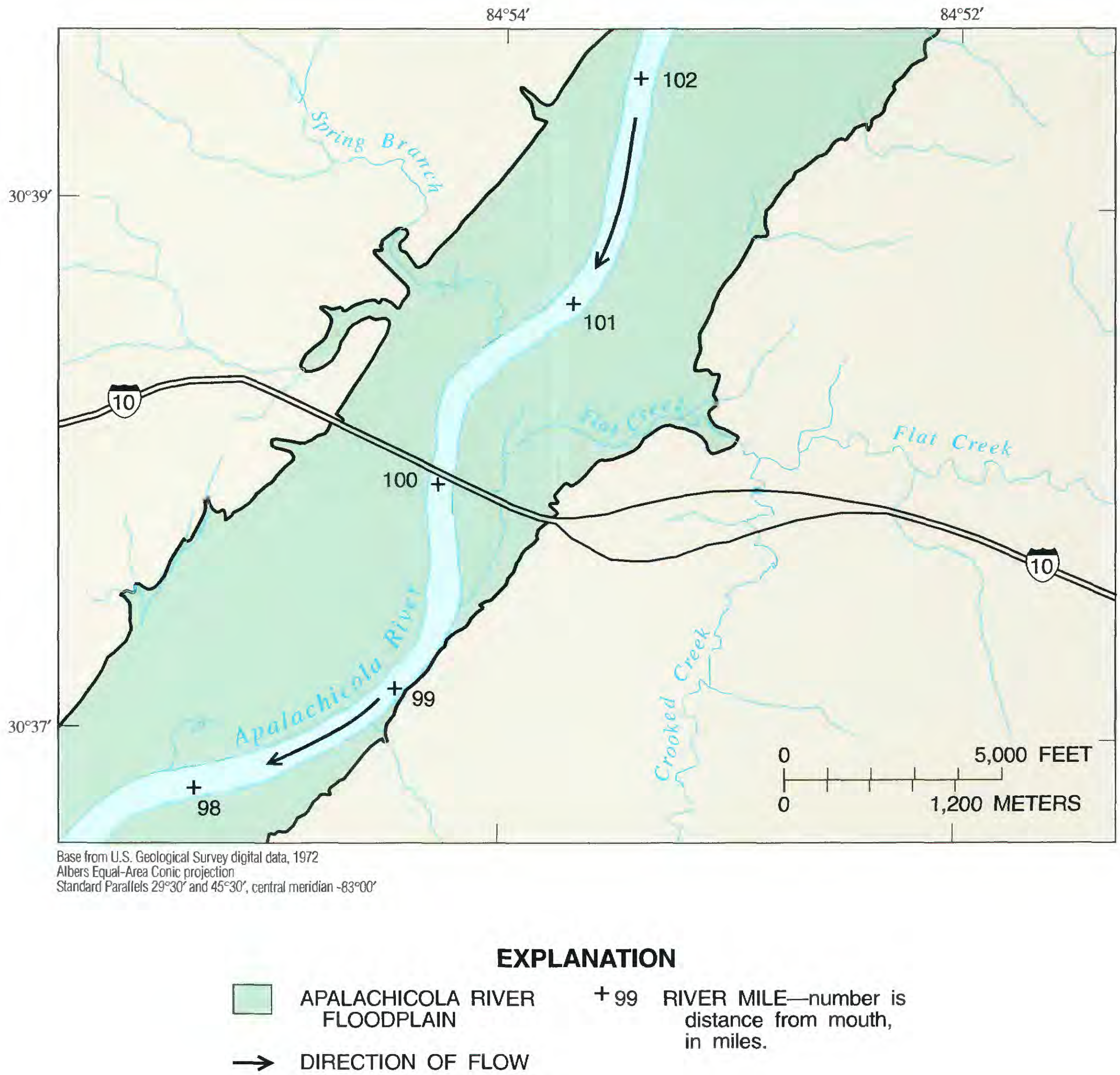


Figure 8. Flat Creek intensive study area.

Figure 9. Flat Creek during low flow about 1,500 feet upstream of its mouth on the Apalachicola River. Perennial streams with sandy bottoms that originate in steep ravines east of the floodplain are unique to the upper reach of the river.

general direction of river flow (fig. 10).

Mosquito Creek is the largest tributary in the upper reach of the river with regard to discharge. It is a perennial stream with an upland drainage area of 90 mi^2 which lies east of the river (pl. 1A). Entrenchment can move upstream into tributaries (Galay, 1983) and appears to have progressed approximately 100 ft into the mouth of this creek to a bridge, where rock and concrete rubble have been deposited in the bed and along the banks. The spillway created by this rock and rubble probably prevented bed degradation from progressing farther upstream. It also makes the entire upstream drainage inaccessible to fish in the main channel during very low flows.

Perennial streams in the floodplain originating from the upland are features that are common in the upper reach of the river but relatively rare in the middle and lower reaches. Streams draining steep ravines which dissect the upland on the east side of the river include Sweetwater Creek, Rock Creek, Beaverdam Creek, Little Sweetwater Creek, and Kelley Branch. Spring-fed streams on the west side of the river are Spring Branch and Blue Spring run (pl. 1B). At a river flow of 8,000 ft^3/s, most of these perennial streams are waterfalls, allowing no access for fish in the main channel (pl. 1A, app. II). Vertical drop of waterfalls at this flow varies with the stream and can be 2 ft or more.

Johnson Creek, a second intensive study area in the upper reach, is fed by small intermittent streams draining the upland west of the river (fig. 11). A sill at the mouth disconnects Johnson Creek from the main channel during very low flows. During low and medium flows, the first half mile of Johnson Creek is still-water habitat connected to the main channel (fig. 12) and the remaining upstream reaches are a series of isolated pools. Sometimes the entire stream flows swiftly in response to local rains, but then returns to its still-water condition shortly afterwards. Consistent flow in Johnson Creek does not occur until high flows, when the river is flowing through both forests and streams of the floodplain in a general downstream direction.

Other streams in the upper reach that are usually connected to the main channel by backwater are Ocheesee Creek, Graves Creek, and The Bayou (pl. 1C). The Bayou and its tributaries are the longest stream system (approximately 9 mi) in the upper reach of the floodplain. During low flows, the most downstream 4,000 ft of The Bayou is still-water habitat connected to the main channel. The Bayou is disconnected during low flows upstream of that reach by a rubble spillway in the vicinity of a small bridge used for logging access. Upstream from this point to the head of The Bayou on the main channel at river mile 85.7, the stream is a steep-sided and

Figure 10. Flooded swamp near Flat Creek during high flow. During floods, turbid river water moves slowly downstream through the floodplain forest at velocities of approximately 0.5 foot per second.

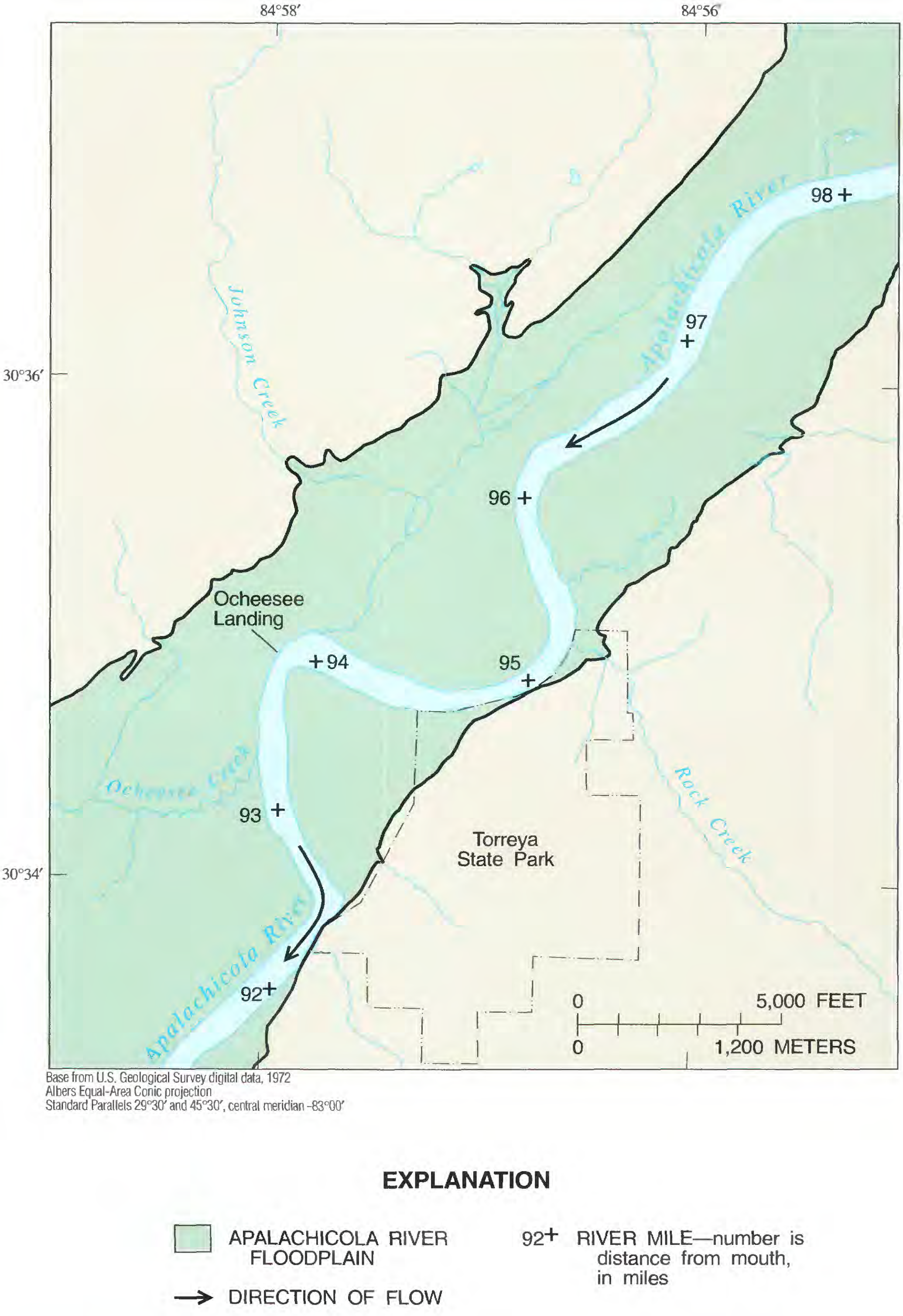


Figure 11. Johnson Creek intensive study area.

relatively narrow channel with water pooled in the deeper parts of the streambed (fig. 13). During medium flows, flow from Stafford Creek and rising backwater from the mouth connect the most downstream 4 mi of The Bayou to the main channel (pl. 1B). During medium-high flows the remaining reach of The Bayou, from its upstream head on the main channel at river mile 85.7 to the mouth of Stafford Creek, is connected and flowing, creating a complete loop that serves as an alternate flow path for river water from the main channel (pl. 1C). When streams of this type are connected, velocity increases to speeds that are relatively fast for floodplain streams (1-3 ft/s).

Sutton Lake is still-water habitat with a connection to the main channel that is deep enough for access by larger fishes, even during very low flows. It is the largest area of aquatic floodplain habitat that is connected to the main channel during low flows in the upper reach (pl. 1A).

About 72 percent of all tupelo-cypress swamps in the upper reach of the river is connected aquatic habitat at a flow of 31,000 ft^3/s (pl. 1C). Large tupelo-cypress swamps with semi-permanent standing water are a prominent feature of the upper reach (fig. 14). Many of these swamps are fed by groundwater seepage from the steep upland bluffs bordering the eastern edge of the floodplain. Hydrologic fluctuations in a large swamp with semi-permanent standing water in the vicinity of Beaverdam Creek were measured in the ARQA study (Leitman and others, 1983,

Figure 12. Johnson Creek during low flow about 2,000 feet upstream of its mouth on the Apalachicola River. Johnson Creek receives a small amount of intermittent runoff from upland drainages. During low and medium flows, the lower reach of Johnson Creek, shown here, is a still-water habitat connected to the river, and the upper reach is a series of isolated pools.

Figure 13. The Bayou during medium flow about 5 miles upstream of its mouth on the Apalachicola River. Water in the stream was isolated from the main river channel and not flowing at the time this photograph was taken; however, the narrow, steep-sided channel is evidence of the relatively high velocities that occur when the stream is connected and flowing.

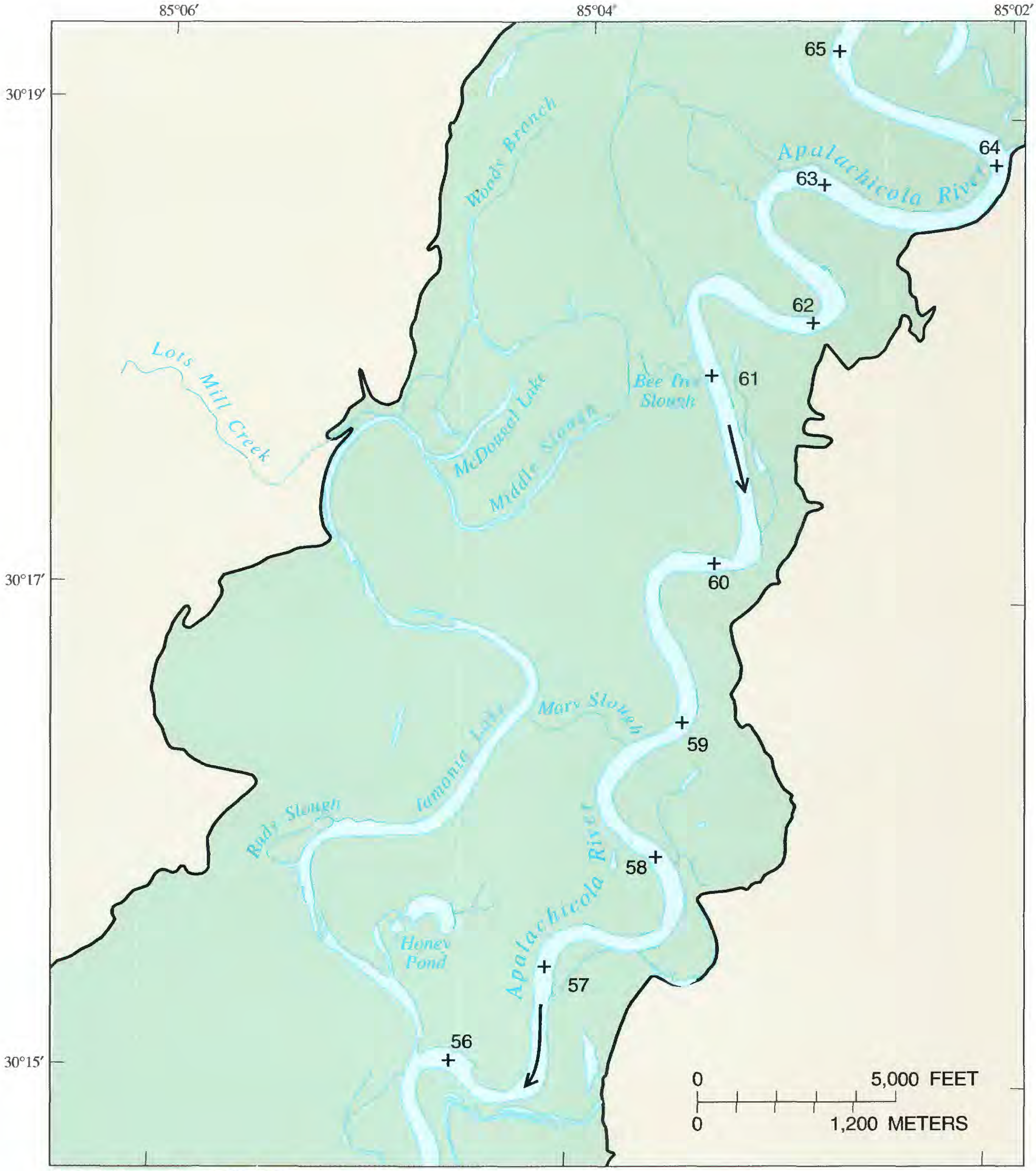
fig. 23). The pond level in that swamp was perched approximately 12 ft above the elevation of the water surface of the river at median low flow, and water in the swamp was not connected to the main channel until flows exceeded about 30,000 ft^3/s.

Middle Reach

Iamonia Lake and its tributaries, the intensive study area in the middle reach of the river, is a tributary lake system that receives little runoff from upland drainage (cover illustration, fig. 15, fig. 16). In some of its wider reaches, Iamonia Lake is as deep and wide as the Apalachicola River; yet under most conditions, Iamonia Lake has little or no flow. During flows less than 8,000 ft^3/s, a sill near the mouth of Iamonia Lake disconnects it from the main river channel (app. II). During low and medium flows above 8,000 ft^3/s, Iamonia Lake has a nearly level water surface for the entire 5 mi of its length, with an elevation equal to the level of the river at the downstream connection at river mile 55.8. During high flows, river water enters the upper and middle reaches of Iamonia Lake through many small connector streams and the main body of the lake is flowing and sloped in a downstream direction.

Figure 14. Tupelo-cypress swamp with semi-permanent standing water in the floodplain of the Apalachicola River just north of Flat Creek. Ground-water seepage from steep upland bluffs bordering the eastern edge of the floodplain provides a source of water for extensive areas of semi-permanently wet swamps in the upper reach of the river. The water level in these swamps is perched several feet above the low water level of the river.

Figure 15. Iamonia Lake about 2 miles upstream of its mouth on the Apalachicola River. With a channel width of 400 feet and depths of 20 to 30 feet, Iamonia Lake looks similar to the main channel of the Apalachicola River. Tributary lakes such as this are probably old river channels that were abandoned when the river changed course.



Base from U.S. Geological Survey digital data, 1972
Albers Equal-Area Conic projection
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

EXPLANATION

APALACHICOLA RIVER FLOODPLAIN

DIRECTION OF FLOW

+56 RIVER MILE—number is distance from mouth, in miles

Figure 16. Iamonia Lake intensive study area.

The two largest connector streams in the Iamonia Lake system are the Middle Slough-Bee Tree Slough passageway and Mary Slough (fig. 16). During low flows, Middle Slough is disconnected and most of its streambed is dry (fig. 17A). Bee Tree Slough is also disconnected but has a series of isolated pools in its bed, some of which are 5 to 6 ft deep. The controlling sill for the Middle Slough-Bee Tree Slough passageway is in Middle Slough, about 3,000 ft upstream of its mouth on Iamonia Lake. During river flows of 11,000 ft^3/s and higher, water flows from higher elevations in the Apalachicola River through Bee Tree Slough and Middle Slough to lower elevations in the upper end of Iamonia Lake (fig. 17B). Relatively high velocities (1.5-2 ft/s) were observed in these

A

B

Figure 17. Middle Slough about 2,700 feet from its mouth on Iamonia Lake (A) partially dry and disconnected during low flow and (B) flowing with shallow water during medium flow. When connected, Middle Slough carries water from the Apalachicola River by way of Bee Tree Slough to the upper end of Iamonia Lake. Relatively high velocities of 1.5 to 2 feet per second occur in Middle Slough during higher flows.

Figure 18. Outside Lake during medium flow about 1 mile upstream of its mouth on the Apalachicola River. This tributary lake is probably a very old river channel that has nearly filled with sediment. Much of Outside Lake during medium river flow is a shallowly flooded tupelo-cypress swamp with a slightly deeper open channel in the center.

connector streams at a river flow of 20,000 ft^3/s. Mary Slough is another connector stream near the middle of Iamonia Lake. During low flows, the west end of Mary Slough is connected by backwater to Iamonia Lake; its east end is higher in elevation than the water surface in the lake and is a series of isolated pools during low flows. Water flows from the main channel through Mary Slough to Iamonia Lake at a river flow of 13,000 ft^3/s and higher.

McDougal Lake (fig. 16) is shallower than Iamonia Lake; however, the two lakes are connected with a level water surface even during very low flows. Honey Pond (fig. 16) is a shallow flood-plain lake with scattered tupelo and cypress trees that is isolated from Iamonia Lake during low flows. During medium flows, Honey Pond is connected and accessible from Iamonia Lake by small boats.

Florida River is a large tributary lake in the middle reach that is connected to the main channel during very low flows. The mouth of Florida River has a relatively deep connection to the main channel, connecting almost 5 mi of still-water habitat to the main channel during very low flows with an additional 3 mi connected during low flows (pl. 2A, app. II). About 25 more miles of streams in this system are connected during medium flows. During medium flows, water from the Apalachicola River flows through the lower reach of Equaloxic Creek and Finns Slough into the upper Florida River (pl. 2B). During medium-high flows, water from the Apalachicola River flows through Dog Slough into the lower Florida River (pl. 2C).

Outside Lake has a very shallow channel about 400 to 500 ft wide that is forested with mature tupelo and cypress trees except for about 150 ft in the center of the channel (fig. 18). Since the channel of Outside Lake is nearly filled with sediment, it may be a former river channel that is older than either Iamonia Lake or Florida River. During low flows, the first mile of Outside Lake upstream of its mouth is 3 to 4 ft deep and connected to the main channel. Upstream of the first mile, Outside Lake is very shallow,

Figure 19. Sand Slough about 500 feet from its mouth on the Apalachicola River. Dry streambeds are typical of higher elevation streams when they are disconnected from the river.

and 2 mi upstream of the mouth the lake is a series of shallow isolated ponds. As the Apalachicola River rises, water from the river moves farther up into the lake. During medium flows the lake is also connected to the Apalachicola River at its upper end through a small stream flowing from Dead River (pl. 2B).

Old River and its tributary, Baker Branch, are narrow, steep-sided streams that receive small amounts of flow from two upland streams during low flows. During medium flows, water from the Apalachicola River enters Old River at its upstream end and flows back into the main channel at the downstream end of Baker Branch (pl. 2).

Equaloxic Creek receives runoff from Big Gully Creek, a stream draining a relatively large area of flatwoods and acid swamps east of the floodplain (drainage area undetermined, probably greater than 20 mi^2). During low flow, water sampled about 3 mi upstream of the mouth of Equaloxic Creek had a pH of 2.5 (Michael J. Hill, Florida Game and Fresh Water Fish Commission, oral commun., 1993). Water in the main channel of the Apalachicola River usually has a pH between 7 and 8. At a river flow of 7,500 ft^3/s, water in the mouth of Equaloxic Creek was observed to be tannin stained, with no turbidity, indicating that water in the creek originated from the acidic upland stream rather than from turbid backwater from the main channel. Water from the river moves into the channel of Equaloxic Creek during medium flows and connects to the upper Florida River through Finns Slough.

Many more streams in the middle reach are connected to the main channel during medium and medium-high flows. At a river flow of 19,000 ft^3/s, the middle reach has 4 times as many miles of streams as the upper reach (table 7). Higher elevation streams that are connected to the river during medium or higher flows usually have dry streambeds when disconnected from the river (figs. 3 and 19). Lower elevation streams that are connected to the river during low flows contain isolated pools of water when they are disconnected from the river.

At a river flow of 27,000 ft^3/s, about 74 percent of tupelo-cypress swamps and 25 percent of mixed bottomland hardwood forests in the middle reach are inundated and connected to the main channel (pl. 2C). Tupelo-cypress swamps are mostly located near the outside edges of the floodplain but some swamps are located along stream channels, such as those on the Florida River and Outside Lake. Unlike some of the swamps in the upper reach, most middle reach swamps have little or no standing water in the dry season. At a river flow of 27,000 ft^3/s (pl. 2C), connected aquatic habitats in mixed bottomland hardwoods probably consist of areas with land surface elevations similar to, or only slightly higher than, tupelo-cypress swamps. These areas are forested with some tupelo and cypress in a mixture of water hickory, overcup oak, swamp laurel oak, and green ash.

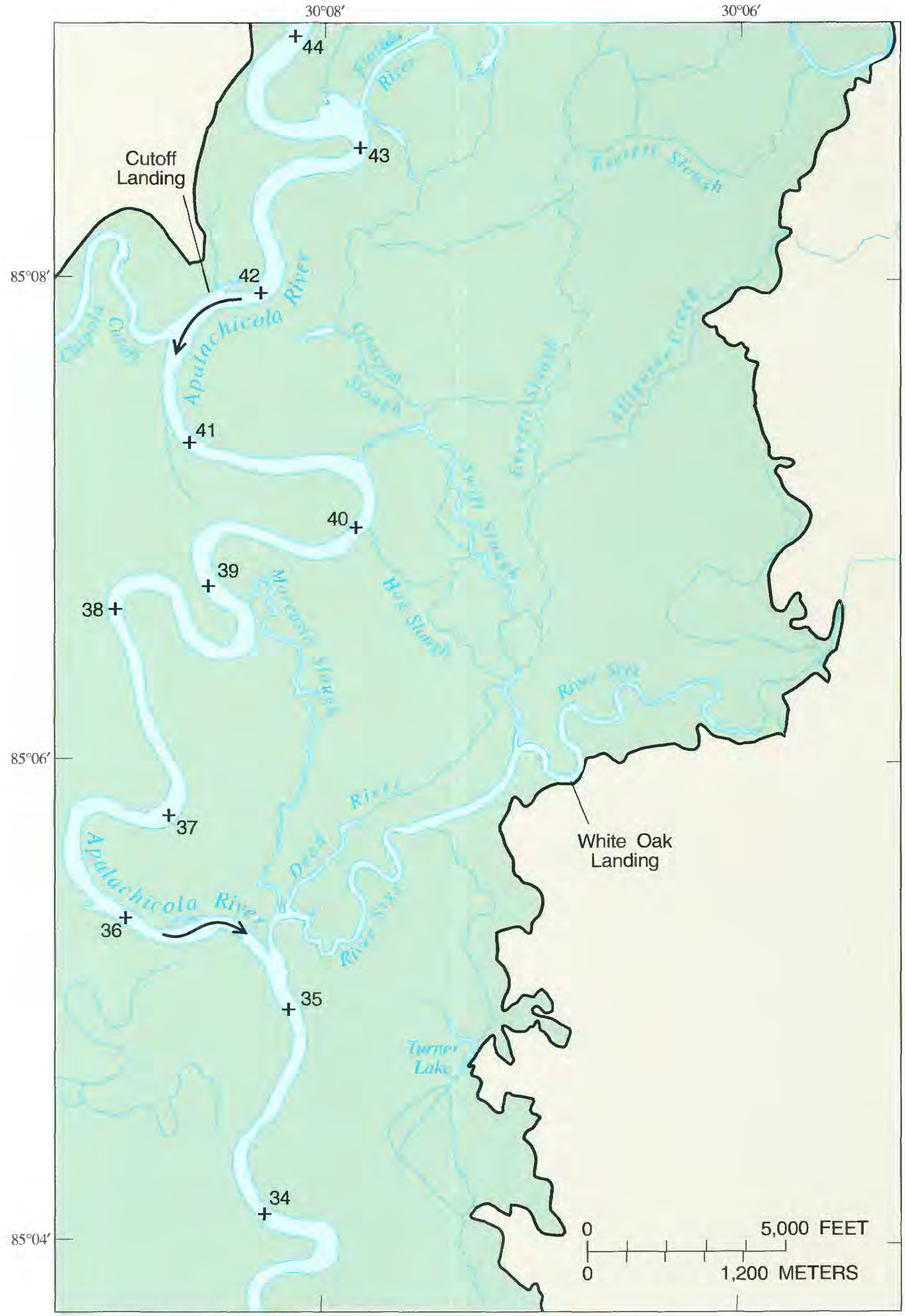
Nontidal Lower Reach

River Styx and its tributaries, the intensive study area in the nontidal lower reach of the river, is a tributary lake system that receives very little runoff from upland drainage (fig. 20). Over 4 mi of still-water stream habitat in River Styx is connected to the main channel during low flows (fig. 21). Depths in River Styx are highly variable. In the first 1,300 ft from the mouth, the channel ranges from 15 to 30 ft in depth. Elevation of the water surface at the mouth of River Styx at low water is about 7 ft above sea level; thus, the elevation of the streambed in the deeper locations is 10 to 20 ft below sea level. About 1,400 ft from the mouth, a shallow, sandy sill across the river disconnects all upstream reaches of River Styx during very low flows (fig. 22). Very deep reaches continue to alternate with very shallow reaches upstream to approximately 4 mi from the mouth, where the River Styx at low water is consistently narrow with shallow water and low banks. Seven miles upstream of the mouth of River Styx, there is a wide swamp corridor with occasional isolated pools and no recognizable streambed. As the river rises from low to medium flows, water from the Apalachicola River backs up into the mouth of River Styx. During medium-high flows, water from the river enters at points upstream (Florida River and Equaloxic Creek) and moves through the swamp corridor as sheet-flow. When this occurs, the entire River Styx system is flowing toward its mouth on the Apalachicola River.

The two largest connector streams in the River Styx system are Swift Slough and Moccasin Slough (fig. 20). Both are relatively high velocity streams (1-2 ft/s) that carry water from the main channel down to the River Styx during low flows. Moccasin Slough empties into the River Styx close to its mouth on the Apalachicola River (fig. 20). Swift Slough ends about 2.5 mi from the mouth of River Styx. At flows of less than 17,000 ft^3/s in the Apalachicola River, the River Styx downstream of the mouth of Swift Slough has little flow. At flows of greater than 17,000 ft^3/s in the Apalachicola River, the lower 2 mi of River Styx begins to flow more swiftly because additional connector streams, such as Hog Slough, Grayson Slough, and Everett Slough, are connected by rising water and the River Styx receives a significant amount of flow from the main channel (pls. 2C and 3C).

The parts of Kennedy Creek and Owl Creek that lie within the Apalachicola River floodplain are tributary lakes connected during very low flows (app. II, pl. 3A). Both streams originate in flatwoods and acid swamps in the upland east of the floodplain (similar to Equaloxic Creek in the middle reach) and both streams usually have sluggish flow.

Kennedy Creek is deep (15-20 ft during low water) and relatively wide (100-200 ft) for much of its length (fig. 23). The still-water habitat in Kennedy Creek and its tributaries that are connected to the river during low flows is extensive, totalling about 9 mi of streams (4 mi of the mainstem of Kennedy Creek and an additional 5 mi of connected still-water streams). During low and medium flows, water in the most downstream 1 mi of Kennedy Creek is flowing into a stream that connects to the upper end of the wide part of Brushy Creek (pl. 3A). The wide part of Brushy Creek is very deep (20-30 ft) at its mouth on the main channel and throughout its entire length.



Base from U.S. Geological Survey digital data, 1972
Albers Equal-Area Conic projection
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

EXPLANATION

APALACHICOLA RIVER FLOODPLAIN

+34 RIVER MILE—number is distance from mouth, in miles

→ DIRECTION OF FLOW

Figure 20. River Styx intensive study area.

Figure 21. River Styx during low flow about 2.5 miles upstream of its mouth on the Apalachicola River. River Styx is 200 feet wide and 25 feet deep at this location. More than 4 miles of still-water stream habitat in River Styx are connected to the Apalachicola River during low flows.

Figure 22. Main channel of River Styx during low flow about 1,400 feet from its mouth on the Apalachicola River. The sandy streambed is partly exposed at this location. Maximum depths of 1.1 feet were measured at the controlling sill; lagged flow at Chattahoochee at that time was 6,100 cubic feet per second. Many miles of River Styx upstream of this sill are disconnected during very low flows of 5,000 cubic feet per second or less.

During medium flows, Kennedy Creek is connected to River Styx by Shepard Slough and other unnamed streams (pl. 3B). Most of the tributaries of Kennedy Creek, including Shepard Slough and the connector to Brushy Creek, are narrow watercourses with shallow beds and low forests on the banks. These streams are usually too shallow to navigate during low flows, and during medium flows the low banks and surrounding forest are inundated and the channel becomes difficult to follow. In some reaches, the stream channel disappears into a diffuse network of streams that flow around tree hummocks (fig. 24).

The Chipola River is the largest tributary of the Apalachicola River, draining approximately 1,200 mi^2 in Florida and Alabama (Foose, 1981). The lower Chipola River below Dead Lakes receives approximately 70 percent of its flow from the main channel of the Apalachicola River by way of the Chipola Cutoff during low flows, and approximately 75 percent during medium flows (USACE, written commun., 1994). The remaining 25 to 30 percent of the flow is from the Chipola River upstream of the mouth of Dead Lakes. Two streams, Corley Slough and Virginia Cut, that previously connected the lower Chipola River with the Apalachicola River near the mouth of River Styx, have been altered by dredge spoil deposition and no longer serve as connector streams during low and medium flows (pl. 3). Near its mouth, the lower Chipola is connected to the Apalachicola River during low water by way of Douglas Slough and its tributaries. Douglas Slough also is a loop stream during very

Figure 23. Kennedy Creek during medium flow about 7,500 feet upstream of its mouth on the Apalachicola River. This tributary lake is quite deep (15-20 feet) and relatively wide (100-200 feet) for much of its length. At the time this photograph was taken, lagged flow at the Chattahoochee gage was 13,000 cubic feet per second, and most of the low banks and swamps adjacent to this stream were underwater.

Figure 24. Tree hummock in a tributary of Kennedy Creek. During medium flows, the channels of small streams in the vicinity of Kennedy Creek are very difficult to follow when they branch out into a diffuse network of streams flowing around tree hummocks.

low flows, with both ends connected to the lower Chipola River. Several other streams, including Maddox Slough, Roberts Slough, and Burgess Creek, have both ends connected to the lower Chipola during medium flows. Lockey Lake is deep (10-20 ft) and connected during very low flows. At a river flow of 14,000 ft^3/s, Spiders Cut and other streams on the south side of the lower Chipola near its mouth were observed flowing south into the floodplain, probably to the upper end of Brothers River, which is a large tributary system that begins in the floodplain a few miles downstream of the mouth of the lower Chipola River (fig. 2).

During low flows, the nontidal lower reach has many more miles of connected streams than both the upper and middle reach combined (table 7). In the middle reach, almost all connected aquatic habitat during low flows is in a few large stream systems. However, in the lower reach, connected aquatic habitat during low flow is located in many small streams that have low sills and low, flat streambeds. At a river flow of 19,000 ft^3/s, the lower reach has about the same number of miles of streams connected to the main channel as the middle reach.

About 25 percent of tupelo-cypress swamps in the lower reach is inundated and connected to the main channel at a river flow of 16,000 ft^3/s (pl. 3B). About 74 percent of tupelo-cypress swamps in the lower reach is inundated and connected to the main channel at a river flow of 23,000 ft^3/s (pl. 3C). Tupelo-cypress swamps cover most of the floodplain in the lower half of the lower reach and contain many small isolated pools of water even during low flows. Many tupelo-cypress swamps of the lower half of the lower reach have irregular ground surfaces with trees growing on hummocks or small tree islands (fig. 24).

AREA OF AQUATIC HABITATS IN THE FLOODPLAIN IN RELATION TO RIVER FLOW

In the first part of this section, estimated areas of three types of floodplain habitats are described in relation to river flow: (1) aquatic habitat connected to the main river channel, (2) aquatic habitat isolated from the main channel, and (3) nonaquatic habitat. The remainder of this section relates estimated areas of different types of connected aquatic habitats to river flow. Connected aquatic habitats are primarily floodplain streams and lakes during low flows and flooded forests during high flows. Connected aquatic habitats in different reaches of the river respond differently to increases in flow. Depths of controlling sills between the main channel and aquatic habitats in the floodplain affect fish diversity by controlling access between diverse habitats. Water velocity, soil type, and vegetative structure are additional factors affecting the composition of fish and invertebrate populations.

Connected Aquatic Habitat Compared to Isolated Aquatic and Nonaquatic Habitats

At a river flow of 5,000 ft^3/s, the total area of connected aquatic habitat, estimated to be about 260 acres, is relatively small, comprising only 0.3 percent of the total floodplain area (fig. 25). However, aquatic habitats that are connected to the main channel at very low flows are of crucial importance to fishes and invertebrates of the floodplain. Connected aquatic habitats provide shallow, quiet waters in floodplain streams and lakes as refuges from the deep, swiftly flowing waters of the main channel.

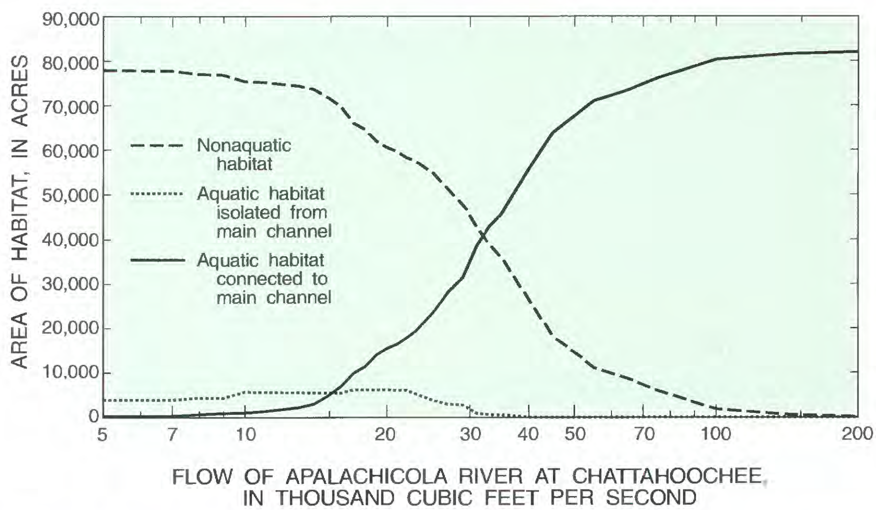


Figure 25. Area of connected aquatic, isolated aquatic, and nonaquatic habitat in the nontidal Apalachicola River floodplain in relation to flows ranging from 5,000 to 200,000 cubic feet per second.

Acreage of connected aquatic habitat increases rapidly with increases in flow above 14,000 ft^3/s. At the median river flow of 16,400 ft^3/s, about 8,200 acres (10 percent of the floodplain) is connected aquatic habitat. Most of these areas are tupelo-cypress swamps bordering floodplain streams and lakes. When river flow reaches 32,000 ft^3/s, an estimated 40,700 acres (approximately one-half of the floodplain) is connected aquatic habitat. At 86,200 ft^3/s, the median annual 1-day high flow, about 78,000 acres (95 percent of floodplain) is connected aquatic habitat.

At a river flow of 5,000 ft^3/s, approximately 4,000 acres (5 percent of the floodplain), is isolated aquatic habitat (fig. 25). Most of these areas are swamps with standing water typically less than 1 ft deep and rarely deeper than 3 ft in the dry season (fig. 14). The area of isolated swamps increases to about 5,800 acres at the median river flow of 16,400 ft^3/s. This increase is a result of the increase in local precipitation that typically accompanies increases in river flow. Rainfall collects in swamps, expanding existing pools and creating new isolated aquatic habitats. As the river continues to rise, isolated swamps are eventually flooded by the river and become connected to the main channel. Flow required to flood isolated swamps decreases downstream, with river flows of 30,000 to 35,000 ft^3/s required to flood most isolated swamps in the upper reach, and 20,000 to 25,000 ft^3/s required in the lower reach.

At a river flow of 5,000 ft^3/s, about 77,900 acres (95 percent of the floodplain) is forest habitat with no surface water present. These areas include levees, high flats and ridges with forests dominated by sweetgum, sugarberry, and water oak; low flats with water hickory, green ash, overcup oak, and swamp laurel oak; and tupelo-cypress swamps with damp or saturated soils (Leitman and others, 1983). At 86,200 ft^3/s, the median annual 1-day high flow, about 4,200 acres of the floodplain is dry and exposed. Floodplain areas that are exposed during high flows areas are mostly high levees adjacent to the main channel with a few levees bordering streams in the interior of the floodplain. Levees of this height are created by flood waters with high velocities capable of carrying a large amount of coarse sediments.

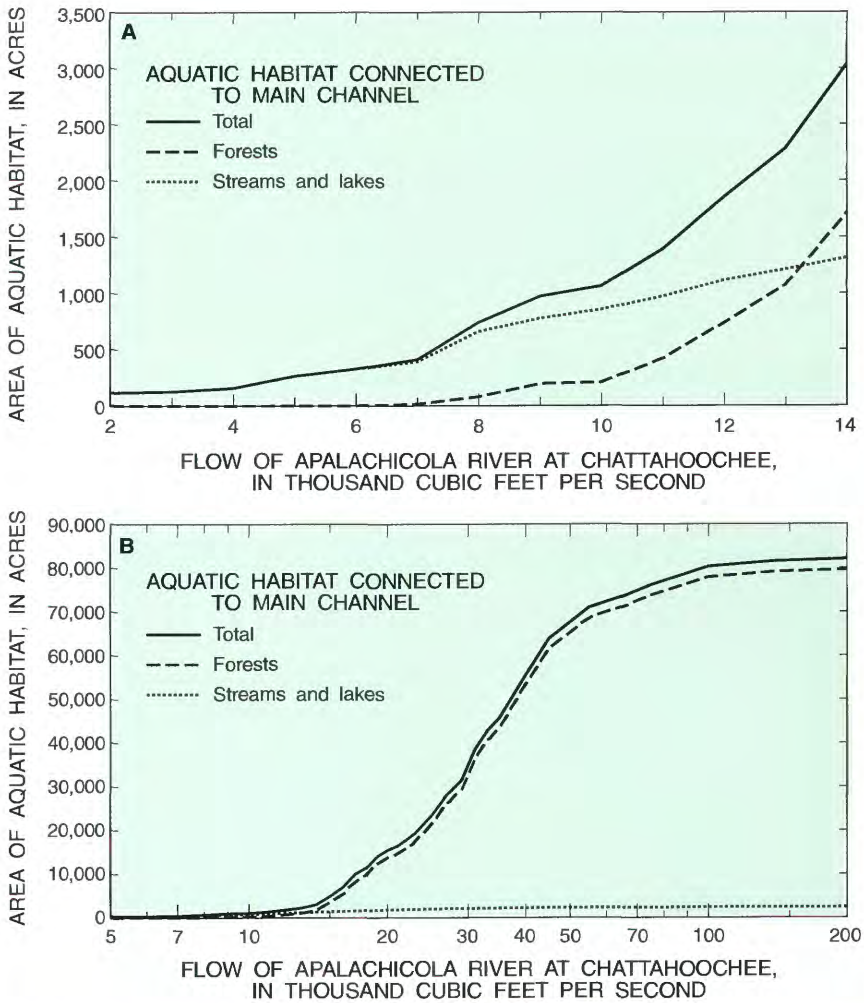


Figure 26. Area of connected aquatic habitat in forests compared to streams and lakes of the nontidal Apalachicola River floodplain in relation to flows ranging from (A) 2,000 to 14,000 cubic feet per second and (B) 5,000 to 200,000 cubic feet per second.

Connected Aquatic Habitat in Forests Compared to Streams and Lakes

At river flows of 7,000 ft^3/s or lower, nearly 100 percent of the connected aquatic habitat in the floodplain is streams and lakes (fig. 26A). At these low flows, floodplain forests are almost com-

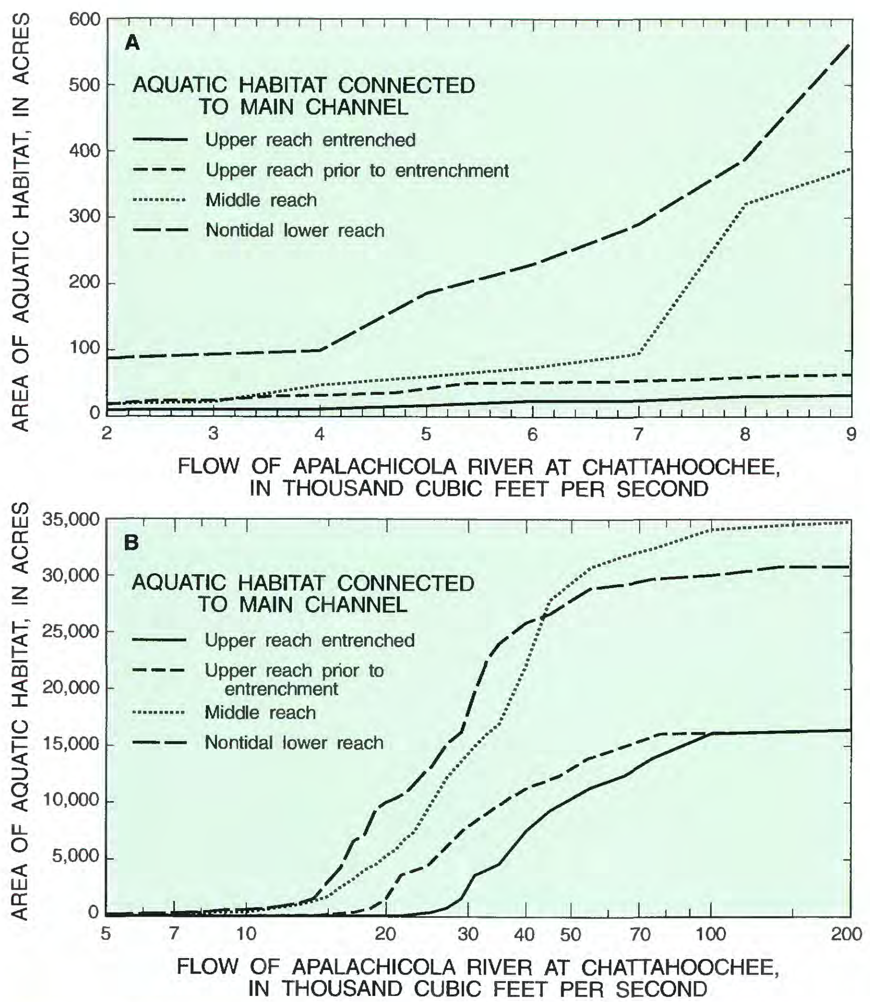


Figure 27. Area of connected aquatic habitat in the upper, middle, and nontidal lower reaches of the Apalachicola River floodplain in relation to flows ranging from (A) 2,000 to 9,000 cubic feet per second and (B) 5,000 to 200,000 cubic feet per second.

pletely drained of standing water except for the isolated swamps indicated in figure 25. At a flow of 10,000 ft^3/s, streams and lakes still constitute most of the connected aquatic habitat (860 acres), but about 210 acres of forest is flooded and connected to the main channel. Above a flow of 10,000 ft^3/s, the area of connected aquatic habitat increases more rapidly in forests than in streams and lakes (fig. 26A). At the median flow of 16,400 ft^3/s, more than 80 percent of connected aquatic habitat is flooded forests (fig. 26B). As the river continues to rise above median flow, the area of flooded forests increases rapidly, but the area of streams and lakes shows little increase because nearly all of them were flooded at lower flows.

The different horizontal scales in the two graphs in figure 26 depict different processes at work in the floodplain. In figure 26A, increases in habitat are shown on the order of hundreds of acres as the river moves into previously isolated streams or dry channels. This information is obscured with the scale used in figure 26B, which shows increases in aquatic habitat on the order of thousands of acres as flow increases and the river moves into large areas of the floodplain forest.

Figure 26A and several other figures in this section include flows of 2,000 ft^3/s to provide habitat data in the event that a decreasing trend in flows occurs in the future. The full range of river flows shown in figures 25 and 26B include flows of 200,000 ft^3/s. Increases in area of aquatic habitat with flow are relatively minor above the median annual 1-day high flow of 86,200 ft^3/s.

Connected Aquatic Habitat in the Upper, Middle, and Nontidal Lower Reaches

Connected aquatic habitat depicted in figures 25 and 26 represents habitat in the entire nontidal floodplain. Connected aquatic habitat in each of the three reaches of the river responds differently to increases in flow (fig. 27).

At flows ranging from 2,000 to 9,000 ft^3/s (fig. 27A), the nontidal lower reach has the greatest amount of connected aquatic habitat and the upper reach has the least. The lower reach has many deep streams and lakes, such as Brushy Creek, Owl Creek, and Lockey Lake, that have bottom elevations below sea level and deep connections to the main channel. About 100 acres of aquatic habitat in the lower reach is connected at flows below 3,900 ft^3/s, the lowest recorded daily mean flow, compared to about 45 acres in the middle reach (mostly in the Florida River), and about 11 acres in the upper reach (Sutton Lake). At flows ranging from 4,000 to 9,000 ft^3/s, the lower reach continues to have the most connected aquatic habitat as large parts of the River Styx and Kennedy Creek systems become connected. In the middle reach, the biggest increase in connected aquatic habitat during low flows occurs between 7,000 and 8,000 ft^3/s, when the amount of habitat more than triples as Iamonia Lake becomes connected. The increase in flow from 2,000 to 9,000 ft^3/s causes a three-fold increase in connected aquatic habitat in the upper reach, from about 10 to 33 acres. Prior to entrenchment, about twice as much aquatic habitat was connected in the upper reach during low flows than is connected in its present entrenched condition.

Area of aquatic habitat increases greatly at river flows of 14,000 ft^3/s in the nontidal lower reach and 15,000 ft^3/s in the middle reach (fig. 27B). In the upper reach this large increase in aquatic habitat does not occur until river flow reaches 29,000 ft^3/s. Some of this difference is attributable to physiographic changes that occur from the upper to the lower reach. Topographic relief and land surface elevations in floodplains decrease in coastal plain rivers as they approach the sea. However, most of this difference is a result of entrenchment that has occurred in the upper reach since construction of Jim Woodruff Dam. The flow associated with a large increase in connected aquatic habitat in the upper reach was about 19,000 ft^3/s prior to entrenchment compared to 29,000 ft^3/s in its present entrenched condition (fig. 27B).

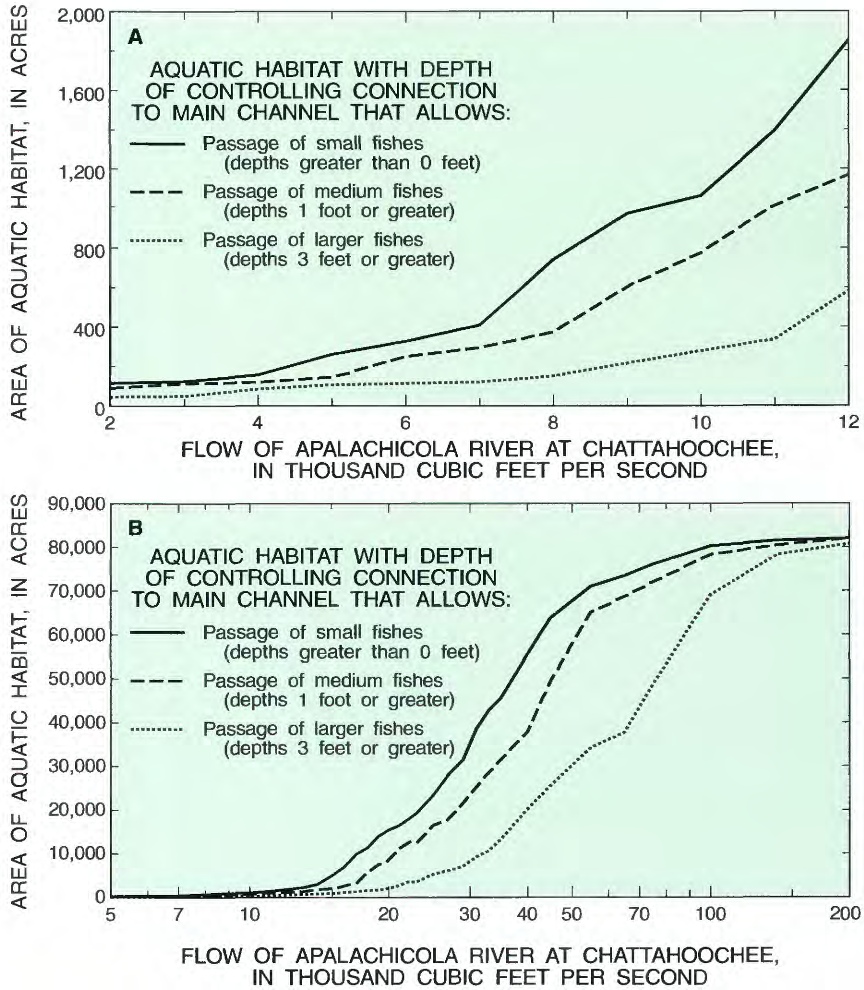


Figure 28. Area of aquatic habitat with controlling connections that allow passage of small, medium, and large fishes in the nontidal Apalachicola River floodplain in relation to flows ranging from (A) 2,000 to 12,000 cubic feet per second and (B) 5,000 to 200,000 cubic feet per second.

Connection Depths

Connected aquatic habitat addressed in the preceding figures and discussion represent habitat that is connected at any depth. The connection depth is very shallow for some habitats, allowing passage for small fishes but blocking access for medium-sized fishes such as adult bluegill or redear sunfish, or large fishes such as striped bass or Gulf of Mexico sturgeon. Generally, the area of aquatic habitat that is accessible to medium and large fishes is considerably less than that accessible to small fishes (fig. 28). The connected aquatic habitat that allows passage of small fishes, as shown in the two graphs in figure 28, represents aquatic habitat in all nontidal reaches that is connected at any depth greater than zero. The other curves in these graphs represent aquatic habitat that will allow passage of medium fishes (connection depth of 1 ft or greater) and large fishes (connection depth of 3 ft or greater).

Accessible habitat is available at different flows for fishes of different sizes. For example, 260 acres of habitat is accessible to small fishes at river flows of 5,000 ft^3/s, but this same amount of habitat is not available to large fishes until flows of about 10,000 ft^3/s (fig. 28A). Large

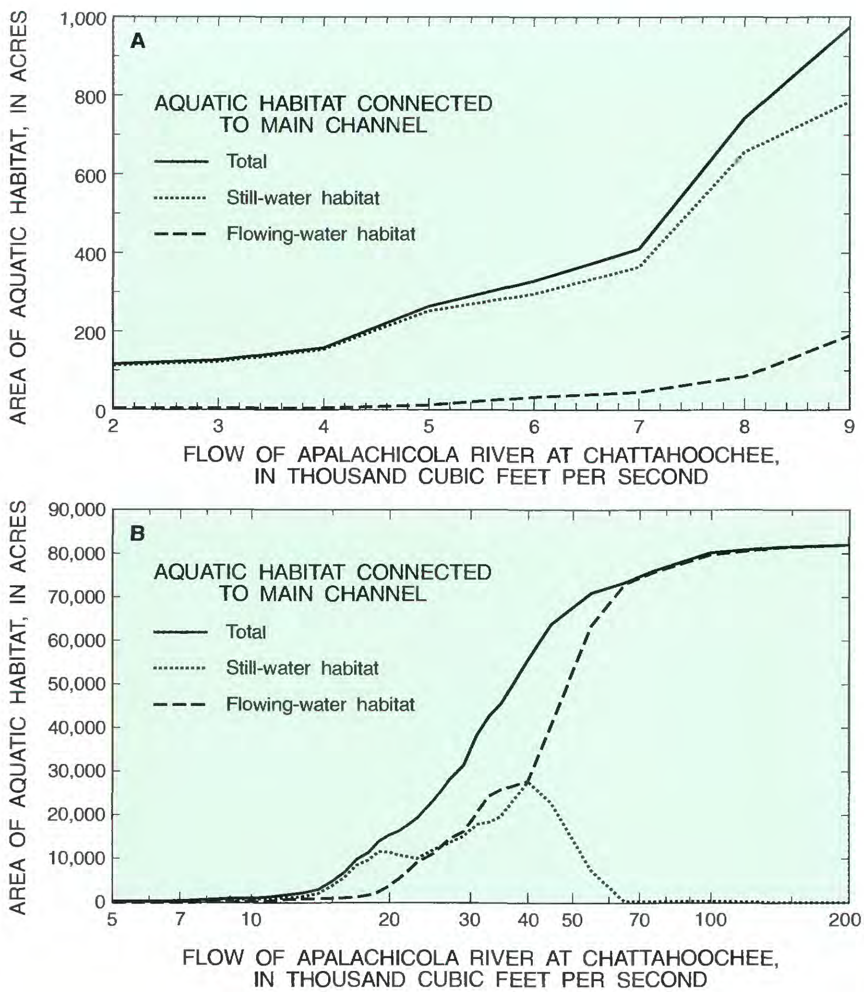


Figure 29. Area of still-water and flowing-water habitat in the nontidal Apalachicola River floodplain connected to the main channel in relation to flows ranging from (A) 2,000 to 9,000 cubic feet per second and (B) 5,000 to 200,000 cubic feet per second.

increases in area of connected aquatic habitat occur above flows of 14,000 ft^3/s for small fishes, above flows of 17,000 ft^3/s for medium-sized fishes, and between flows of 20,000 and 30,000 ft^3/s for large fishes (fig. 28B).

Water Velocities in Connected Aquatic Habitats

Both still-water and flowing-water habitats in shallow floodplain water bodies provide refuges for fishes from the deeper and more swiftly flowing waters in the main channel. Some fishes, such as redfin pickerel, taillight shiner, flier, and warmouth, primarily reside in still-water habitats of the floodplain and rarely enter the main channel (Leitman and others, 1991). Other fishes, such as darters, prefer flowing-water habitats in small floodplain streams.

Water velocities in the main channel are usually between 1 and 4 ft/s. Velocities observed in most aquatic habitats in the floodplain are much lower (0 - 1 ft/s), with the exception of loop and connector streams that carry river water along a steeper course than the main channel. Velocities of 2 to 3 ft/s were observed in the connector streams Bee Tree Slough and Swift Slough.

Changes in area of connected still-water and flowing-water habitat in the floodplain in relation to river flow is illustrated in figure 29. At a river flow of 5,000 ft^3/s, still-water habitat covers about 250 acres and flowing-water habitat covers 12 acres (fig. 29A). At a river flow of 9,000 ft^3/s, about 790 acres of still-water habitat exists compared to 190 acres of flowing-water habitat. Area of still-water habitat continues to greatly exceed area of flowing-water habitat until river flows reach about 20,000 ft^3/s (fig. 29B). At this river flow, water in connected aquatic habitats is flowing in most streams and lakes, but not flowing in forests. At river flows less than 20,000 ft^3/s, the opportunity for flow-through is limited because the water is not high enough to break over levees and ridges that control connections between different parts of the floodplain. At river flows greater than 20,000 ft^3/s, flow-through in the floodplain increases and water begins to move through large areas of floodplain forest. Flowing-water and still-water habitats continue to increase in area until river flows are about 40,000 ft^3/s. When flows exceed 40,000 ft^3/s, still waters are rapidly converted to flowing waters as the rising water connects more and more of the floodplain into a flow-through corridor. When flows reach 65,000 ft^3/s, more than 99 percent of the connected aquatic habitat in the floodplain is flowing.

In the upper reach, there are a number of streams such as Flat Creek and Mosquito Creek that drain relatively large areas in the uplands adjacent to the river. The source of water for these streams is not dependent upon flows in the Apalachicola River, and the streams continue to flow during low and very low flows. However, their connections to the river during low flows do not allow 2-way access for fishes because of waterfalls or very shallow water dropping into the main channel. Small fishes can move from the streams into the main channel of the river but cannot swim back the other way. Streams with 1-way connections cover relatively small areas (less than 35 acres), exist primarily at flows less than 11,000 ft^3/s, and are found only in the upper reach.

The area of flowing-water habitat with both 1-way and 2-way connections in the upper reach under present entrenched conditions is shown in figure 30A and under pre-entrenchment conditions is shown in figure 30B. At river flow of 3,900 ft^3/s, the lowest daily mean flow on record, all flowing waters in the floodplain of the entrenched upper reach have 1-way connections to the main channel. At this same river flow, prior to entrenchment, about half of the flowing-water habitat had 2-way connections to the main channel, and half had 1-way connections. Under present entrenched conditions, it is not until flows are about 11,000 ft^3/s that nearly all streams in the upper reach have 2-way connections to the main channel.

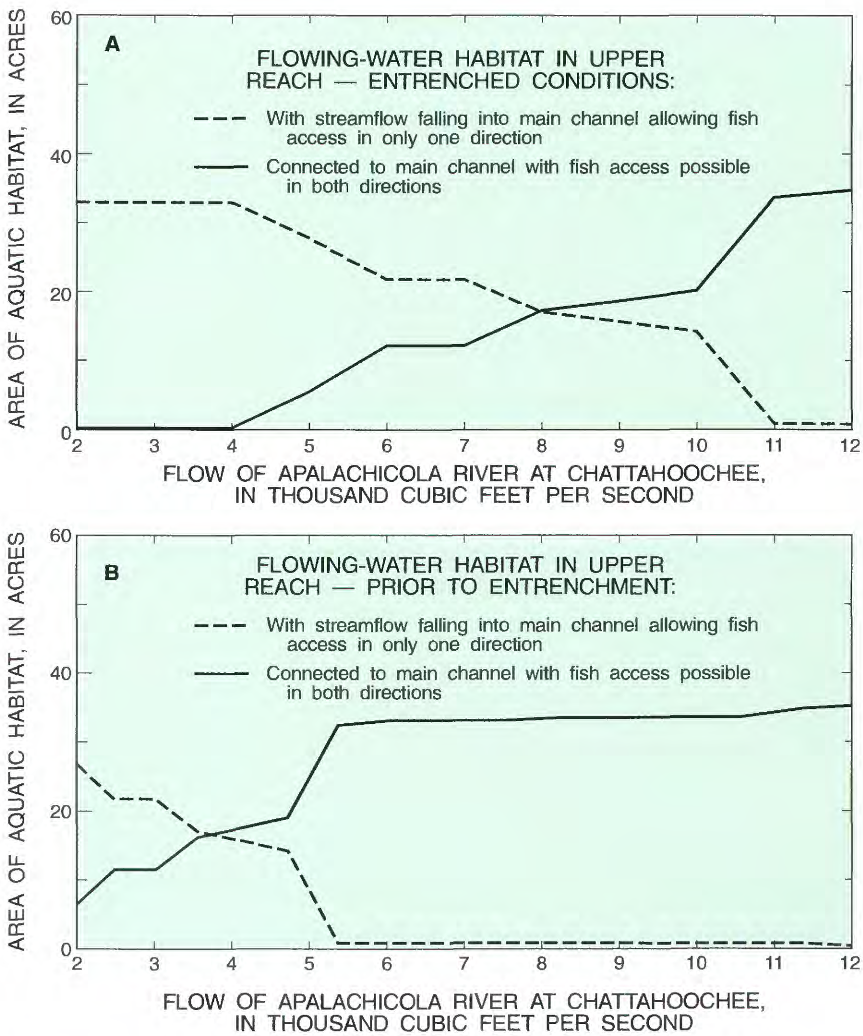


Figure 30. Area of flowing-water habitat in the floodplain with 1-way and 2-way connections to the main channel in relation to flows ranging from 2,000 to 12,000 cubic feet per second in the upper reach of the Apalachicola River (A) under present (1995) entrenched conditions and (B) prior to entrenchment.

Soils of Floodplain Habitats

Variety in soil types affects diversity of floodplain fishes because many fishes have substrate preferences for either sandy or muddy bottoms (Lee and others, 1980). Three major types of surface soils were found in the Apalachicola River floodplain: silt-clays, sandy soils, and organic soils. Approximately 90 percent of the floodplain has silt-clay surface soils. Silt-clays predominate on alluvial rivers because large amounts of fine-grain sediments are carried long distances and deposited on the floodplain during overbank flows. The percentage of connected aquatic habitat with silt-clay soils varies with river flow but is always relatively high, ranging from 85 to 98 percent of the total area for any given flow (fig. 31).

Sandy soils are found on about 6,400 acres (8 percent of the floodplain). Most of the sandy soils in the floodplain are found on levees that are flooded only at

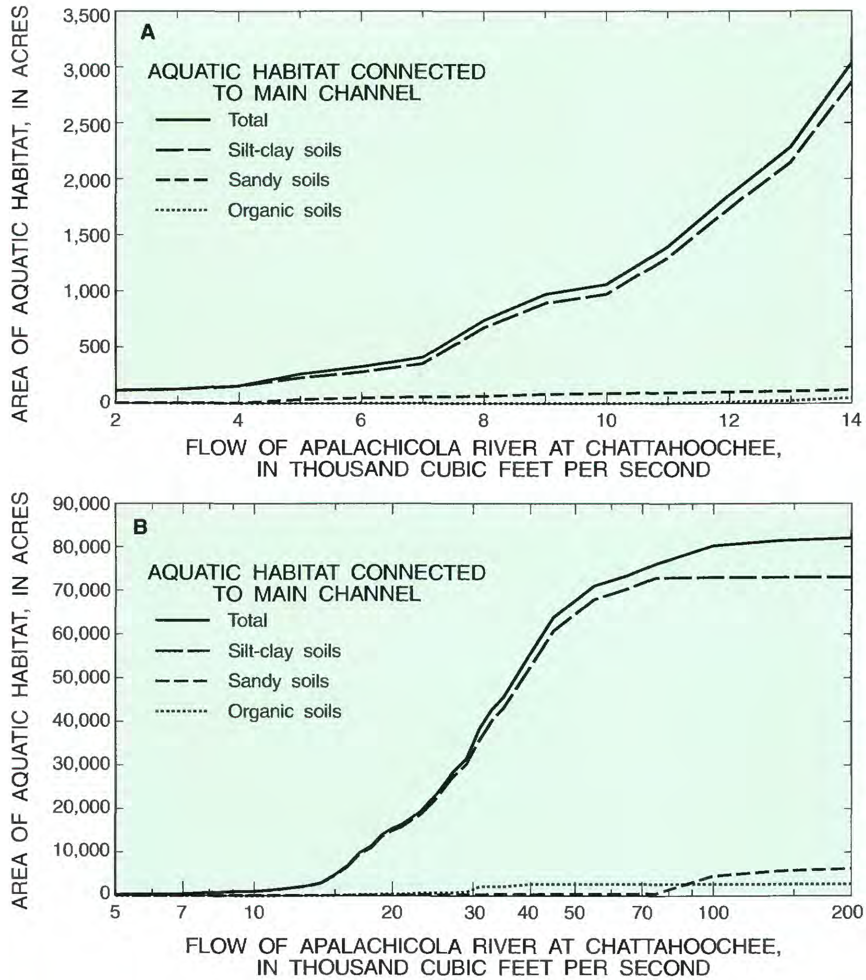


Figure 31. Area of connected aquatic habitat with silt-clay, sandy, and organic soils in the nontidal Apalachicola River floodplain in relation to flows ranging from (A) 2,000 to 14,000 cubic feet per second and (B) 5,000 to 200,000 cubic feet per second.

flows greater than 80,000 ft^3/s (fig. 31B). Formation of these high levees occurs when alluvial flow of relatively high velocity leaves the main channel and enters the floodplain. The water slows down quickly as it enters the forest and immediately drops the coarse-grain component of its sediment load, forming a sandy levee adjacent to the main river channel. Sandy levees also border a few of the larger floodplain streams with high flow velocities.

In addition to riverbank and streambank levees, an estimated 500 acres of sandy soils is found in the beds of some floodplain streams. Streams observed in this study that had relatively high velocities (1 ft/s or greater) during low or medium flows, had 30 to 100 percent of their beds composed of sandy soils. Streams with little or no velocity during low and medium flows had silt-clay beds with no sand either in the beds or along their banks. The flows at which streams with sandy streambeds are connected to the main river channel vary greatly. About 50 acres of sandy-bottom streams, such as Flat Creek and Swift Slough, is connected at a river flow of 6,000 ft^3/s (fig. 31A). Some streams, like Sand Slough (fig. 19) are dry during low flows and do not become connected and flowing until medium or higher flows.

Organic soils are found on about 2,700 acres (3 percent of the floodplain). Most of the organic soils in the floodplain are found in large tupelo-cypress swamps in the upper reach. These areas are (1) isolated from the river at very low, low, and medium flows, (2) connected to the main channel when flows reach 30,000 to 40,000 ft^3/s (fig. 31B), and (3) do not experience high velocities even during floods. When these swamps are isolated from the main channel, rate of litter decomposition in still-water ponds decreases as the amount of oxygen in the stagnant water decreases. The result is a build-up of organic matter. During floods, these areas do not have velocities high enough to scour the floor of the swamp and remove the organic build-up. This lower velocity may be due to their large, flat basin-like shape or their location outside of the higher velocity corridors of flow in the floodplain.

The large tupelo-cypress swamp in the vicinity of Beaverdam Creek in the upper reach is an example of a wet depression with organic soils that is pooled and isolated from the main channel during low and medium flows. Flows of about 31,000 ft^3/s are required to connect this swamp to the main channel. At a flow of 57,800 ft^3/s, the average velocity in this swamp was 0.03 ft/s; at 87,900 ft^3/s, the average velocity was still quite low at 0.17 ft/s (Leitman and others, 1983, fig. 25).

Amount of Vegetative Structure

Vegetative structure in aquatic habitat provides food sources, protective cover, and reproductive sites for fishes and aquatic invertebrates. Generally, floodplain habitat that is terrestrial most of the time, such as mixed bottomland hardwoods, has more vegetative structure than habitat that is primarily aquatic. When floodplain forests are inundated, large amounts of vegetative structure become available to aquatic organisms.

The amount of vegetative structure measured in floodplain forests and on the sloping banks of floodplain streams in this study was moderate to high (greater than 15 percent) compared to that of floodplain streambeds which was usually low (less than 15 percent). However, in one-tenth of the total length of streambed cross sections, vegetative structure was moderate to high. Low velocities in floodplain streams allow woody debris to collect in parts of streambeds (figs. 9, 12, and 13), and live vegetation such as tupelo and cypress trees sometimes grow in floodplain streambeds (fig. 18). Comparable measurements of vegetative structure in the bed of the main channel were not made in this study; however, because water velocities are considerably higher in the main channel than in most floodplain streams, vegetative structure in the bed of the main channel is probably lower than that in streambeds in the floodplain. In a study of large river-floodplain systems by Power and others (1995), main channel structure was estimated to be 5 percent at low flow, decreasing at higher flows as debris was dislodged and washed away.

At river flows less than 9,000 ft^3/s, most of the connected aquatic habitat is confined to streambeds and is consequently low in structure (fig. 32A). When water levels in floodplain streams rise out of their beds onto the sloping banks and into bordering swamp forests, the amount of vegetative structure in connected aquatic habitat increases greatly. This increase in structure in connected aquatic habitat begins at flows greater than 10,000 ft^3/s; and at 16,000 ft^3/s, about 3,800 acres of aquatic habitat with moderate to high structure is connected to the main channel (fig. 32B). As the river continues to rise, the amount of vegetative structure available to aquatic organisms increases greatly as large areas of floodplain forest are inundated (fig. 32C).

FISHES IN RIVER FLOODPLAINS OF THE EASTERN UNITED STATES: LITERATURE REVIEW

In the preceding sections, aquatic habitat in the Apalachicola River was described and quantified in relation to river flow for the purpose of determining changes in habitat that may result from flow alterations. Effects of these habitat changes on biological communities are also important to address in the impact evaluation process. Of the wide array of organisms that depend on aquatic habitat, fishes are probably the most well-known group. Fish species that have been collected in the floodplain of the Apalachicola River are listed in this section of the report. A review of the literature of fishes in the river floodplains of the eastern United States was conducted to identify additional species that probably inhabit the Apalachicola River floodplain.

A total of 131 species of freshwater and estuarine fishes have been found in the freshwaters of the Apalachicola River or the lower Chipola River downstream of Dead Lakes (Livingston and others, 1977; Yerger, 1977; Bass, 1983; Ager and Land, 1984; Ager and others, 1985; Edmiston and Tuck, 1987; Hill and others, 1990; Light and others, 1993). Of this total, 40 species are euryhaline estuarine fishes that have been found only in the freshwater tidal part of the lower Apalachicola River and its distributaries. These 40 species are not addressed in this report. The remaining 91 species are known to inhabit the nontidal Apalachicola or lower Chipola Rivers. Of these 91 species, 65 are freshwater species that are strictly intolerant of salt water, and 26 species are either freshwater species that can tolerate some salt water or euryhaline estuarine species that occur in the nontidal river (Yerger, 1977).

Eighty percent, or 73 of the 91 species collected in the Apalachicola River, are known to occur in river floodplains of the eastern United States (table 8). Fifty-one of these species have been collected in the Apalachicola River floodplain (22 common or abundant, 29 collected in low numbers), and an additional 22 species have been found in other river floodplains of the eastern United States. Collections of Apalachicola River floodplain fishes have been conducted primarily in one type of habitat (connected streams with sluggish flow) using one collection method (electrofishing).

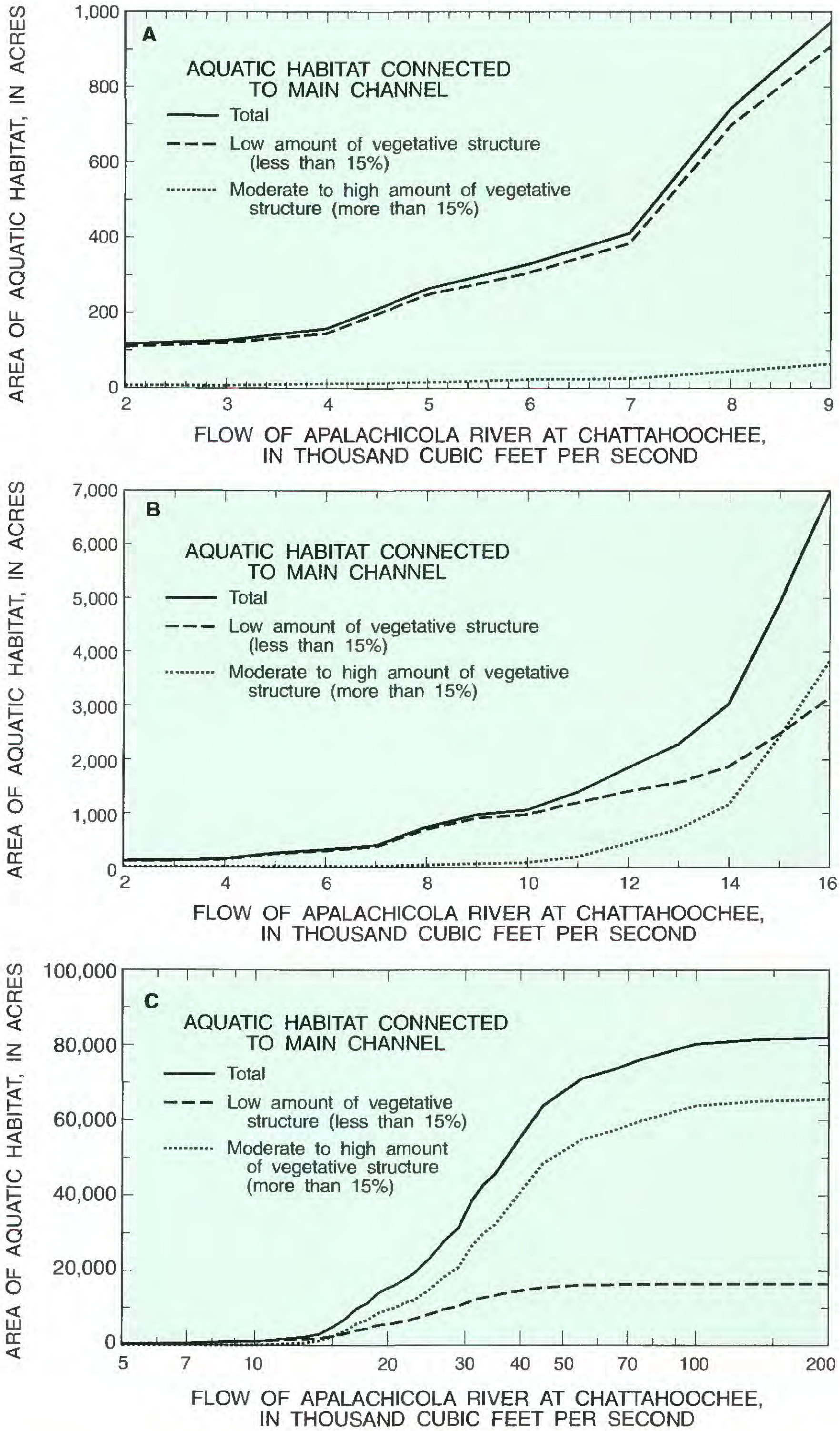


Figure 32. Area of connected aquatic habitat with low and moderate to high amounts of vegetative structure in the nontidal Apalachicola River floodplain in relation to flows ranging from (A) 2,000 to 9,000 cubic feet per second; (B) 2,000 to 16,000 cubic feet per second; and (C) 5,000 to 200,000 cubic feet per second.

Table 8. Occurrence of Apalachicola River fish species in river floodplains of the eastern United States

[Sources include Baker and others, 1991; Bass and Hitt, 1973; Beecher and others, 1977; Finger and Stewart, 1987; Foster and others, 1988; Guillory, 1979; Holder, 1971b; Killgore and Baker, 1996; Knight and others, 1991; Kwak, 1988; Leitman and others, 1991; Light and others, 1995; Ross and Baker, 1983; Walker and Sniffen, 1985. Excludes estuarine species that are restricted to the lower Apalachicola River. Excludes tidal floodplain habitats. Common or abundant, 1 percent or greater by number; low numbers, less than 1 percent by number]

Occurrence in floodplain of Apalachicola or other rivers of eastern United States	Species of fishes known to inhabit the Apalachicola River			Number of species
Common or abundant in Apalachicola floodplain collections	Spotted gar[1,2] Bowfin[1,2] American eel Gizzard shad[2] Threadfin shad[2] Common carp[2] Golden shiner[1,2] Bluestripe shiner	Taillight shiner[1,2] Blacktail shiner[2] Spotted sucker[1,2] Pirate perch[1,2] Mosquitofish[1,2] Brook silverside[1,2] Okefenokee pygmy sunfish[1]	Redbreast sunfish Warmouth[1,2] Bluegill[1,2] Redear sunfish[1,2] Spotted sunfish[1] Largemouth bass[1,2] Black crappie[1,2]	22
Collected in low numbers in Apalachicola floodplain	Longnose gar[1,2] Skipjack herring Redfin pickerel[1,2] Chain pickerel[1] Pugnose minnow[1,2] Redeye chub Coastal shiner Weed shiner Bandfin shiner Lake chubsucker[2] Grayfin redhorse	Snail bullhead Yellow bullhead[1,2] Brown bullhead[1,2] Channel catfish[2] Spotted bullhead Atlantic needlefish Eastern starhead topminnow Blackspotted topminnow[1,2]	Bluefin killifish[1] Least killifish[1,2] Sunshine bass Flier[1,2] Everglades pygmy sunfish Orangespotted sunfish[1] Dollar sunfish Blackbanded darter[2] Striped mullet Hogchoker	29
Present in floodplains of other rivers of eastern United States; presence in Apalachicola floodplain probable	Silverjaw minnow Bannerfin shiner Bluenose shiner Quillback White catfish Black madtom Tadpole madtom[1,2]	Speckled madtom Flathead catfish Golden topminnow[1] Pygmy killifish White bass[2] Striped bass Banded pygmy sunfish[1,2]	Bluespotted sunfish[1,2] Banded sunfish Green sunfish[1] Spotted bass Brown darter Swamp darter Gulf darter[2] Sauger	22
No documented occurrences in floodplains of other rivers of eastern United States; presence in Apalachicola floodplain uncertain	Southern brook lamprey Gulf of Mexico sturgeon Alabama shad Clear chub Ironcolor shiner	Dusky shiner Sailfin shiner Longnose shiner Flagfin shiner Creek chub Banded topminow Shadow bass	Shoal bass Florida sand darter Goldstripe darter Yellow perch Mountain mullet Southern flounder	18
	Number of species known to inhabit the Apalachicola River			91

[1]Collected in isolated water bodies in river floodplains of eastern United States (from Light and others, 1995, app. III).

[2]Evidence of use of floodplain habitats for reproduction (spawning, larval, or young-of-the-year fishes collected) in river floodplains of eastern United States (from Light and others, 1995, app. III; and Killgore and Baker, 1996).

Most of the 22 additional species in table 8 that were present in other river floodplains would probably be found in the Apalachicola River floodplain if more comprehensive sampling was conducted in other types of habitat using a variety of collection methods. For example, in other river floodplains, white catfish, three species of madtoms (black, tadpole, and speckled), and small centrarchids such as banded pygmy sunfish and bluespotted sunfish were frequently collected with seines, dip nets, traps, and rotenone (Holder, 1971; Ross and Baker, 1983; Walker and Sniffen, 1985; Finger and Stewart, 1987; Kwak, 1988; Baker and others, 1991; Knight and others, 1991; Leitman and others, 1991). Information on river floodplain fishes in the eastern United States in table 8 was summarized from 14 sources, one of which (Baker and others, 1991) summarized floodplain collections in the lower Mississippi River from more than 70 sources of information.

The fish communities of relatively large streams with sluggish flow in the Apalachicola River floodplain have been well-documented by the Florida Game and Fresh Water Fish Commission. Forty-four species were collected during low flows in the following six floodplain streams when they were connected to the main channel: Iamonia Lake, Equaloxic Creek, Florida River, River Styx, Kennedy Creek, and Owl Creek (Hill and others, 1990; Light and others, 1995, app. II). The most frequently collected species (in order from most to least common) were bluegill, brook silverside, bowfin, largemouth bass, spotted gar, redear sunfish, spotted sucker, warmouth, American eel, and redbreast sunfish.

More swiftly flowing streams such as Flat Creek, Middle Slough (connected to Iamonia Lake), and Swift Creek (connected to River Styx) probably support common Apalachicola River species such as gizzard shad, threadfin shad, weed shiner, blacktail shiner, spotted sucker, bluegill, largemouth bass, redear sunfish, and redbreast sunfish, as well as fishes that prefer smaller streams such as flagfin shiner, bandfin shiner, and Gulf darter (Lee and others, 1980). The fish communities of these streams are relatively undocumented, with the notable exception of striped bass. The Apalachicola River system harbors the last remaining native population of Gulf race striped bass in the Southeast (Wooley and Crateau, 1983). Flowing streams in the floodplain that have cool water from springs or ground-water seepage are thermal refuges that are critical to the survival in summer of adult striped bass, which cannot tolerate the warmer waters of the main channel (Moss, 1985; Coutant, 1987; Van Den Avyle and Evans, 1990). Sampling efforts by the Florida Game and Fresh Water Fish Commission confirm that striped bass use more than a dozen flowing streams in the upper reach of the Apalachicola River floodplain as thermal refuges (Charles Mesing, FGFWFC, written commun., 1995). Entrenchment in the upper reach of the river has lowered river stages and greatly decreased fish access to these flowing streams during low flows (fig. 30).

Isolated water bodies in the floodplain are primarily still-water habitats with shallow waters (less than 3 ft deep) that support fish communities distinctly different from deep, flowing waters of the main channel (Baker and others, 1991). A total of 31 species, identified on table 8, are known to inhabit isolated aquatic habitat in river floodplains of the eastern United States, the most common being redfin pickerel, golden shiner, taillight shiner, yellow bullhead, pirate perch, mosquitofish, least killifish, flier, banded pygmy sunfish, warmouth, bluegill, and black crappie (Kwak, 1988; Baker and others, 1991; Leitman and others, 1991; Light and others, 1995). Most or all of these species would probably be found in the Apalachicola River floodplain with expanded collection efforts. A few of these species may be almost entirely dependent on floodplain habitats, residing year-round in still-water habitats of the floodplain and rarely entering the main channel. Species that primarily inhabit isolated aquatic habitats in the floodplain have been known to tolerate dissolved oxygen concentrations less than 1 ppm (Leitman and others, 1991).

Many main channel fishes exploit inundated floodplain habitats during high flows; these habitats are primarily flooded forests, with a relatively small percentage of the total area being flooded streams and lakes. All 73 species that have been collected in the river floodplains of the eastern United States under various hydrologic conditions (table 8), are probably present on those floodplains during floods. (A total of 64 species have been collected on inundated floodplains during high water (Light and others, 1995, app. III); the remaining 9 species found in connected streams and isolated ponds probably remain on the floodplain during floods, but have not yet been collected there at high water.) The extent of flood exploitation was similar on the adjacent Ochlockonee

River (fig. 1) where 75 percent of the known main channel species was collected in the floodplain during floods (Leitman and others, 1991).

Fishes use floodplains to fulfill basic needs for food, shelter from predators, and reproduction (Baker and others, 1991; Wharton and others, 1981, 1982). Several studies of southeastern rivers reviewed by Wharton and others (1981) have documented feeding on floodplains as evidenced by terrestrial invertebrates in the stomachs of fishes collected on inundated floodplains. The abundant vegetative structure in floodplain habitat such as snags, stumps, debris, grasses, and shrubs provide excellent shelter from predators (Aggus and Elliott, 1975; Savino and Stein, 1982; Benke and others, 1985; Harmon and others, 1986). Evidence of reproduction on other river floodplains indicate that at least 33 Apalachicola River species (identified on table 8) may use floodplain habitats for spawning or nursery grounds (Guillory, 1979; Finger and Stewart, 1987; Leitman and others, 1991; Killgore and Baker, 1996).

APPLICATION OF STUDY RESULTS

Reduced flows in the Apalachicola River may result from increased use of water upstream in the Chattahoochee and Flint River Basins or when flows are regulated for navigation. Understanding the impacts of these flow alterations is important in long-term maintenance of wetland functions in the floodplain. The results of this study can be used to assess the effects of flow alterations on the area of various types of aquatic habitats in the floodplain of the Apalachicola River. Changes in the types and amount of aquatic habitats are widely known to produce changes in biotic communities (Gorman and Karr, 1978; Baker and others, 1991). Habitat-based evaluations are frequently used to assess environmental impacts (Bovee, 1982).

Flow reductions that occur when flows are less than 16,000 ft^3/s will result in a decrease in area of most types of connected aquatic habitat in the floodplain in most reaches of the river (table 9).

Table 9. Summary of areas of aquatic habitat in the floodplain that are connected to the main channel of the Apalachicola River in relation to flows ranging from 4,000 to 16,000 cubic feet per second

[These data are presented in graphical form for a wider range of flows in figures 25-32; <, less than; >, greater than; ≥, greater than or equal to; ft, feet; %, percent]

Flow at Chattahoochee gage, in cubic feet per second	Area of aquatic habitat in the floodplain that is connected to the main river channel at or above given flow value, in acres																
	Upper reach under entrenched conditions (and prior to entrenchment)	Middle reach	Non-tidal lower reach	Entire non-tidal river	Forests	Streams and lakes	Allowing passage of: Small fishes (depths >0 ft)	Allowing passage of: Medium fishes (depths ≥1 ft)	Allowing passage of: Large fishes (depths ≥3 ft)	Still water	Flowing water	Flowing water with 2-way connection in upper reach under entrenched conditions (and prior to entrenchment)	General soil type: Silt-clay	General soil type: Sandy	General soil type: Organic	Vegetative structure: Low (<15%)	Vegetative structure: Moderate to high (>15%)
4,000	12 (32)	47	100	160	0	158	160	120	87	150	4.3	0.3 (17)	150	3.7	0	150	13
5,000	17 (43)	61	190	260	0	263	260	150	110	250	12	5.5 (25)	230	36	0	250	15
6,000	24 (52)	75	230	330	0	329	330	250	110	300	33	12 (33)	280	50	0	310	24
7,000	24 (55)	96	290	410	17	394	410	300	120	370	46	12 (33)	350	57	0	380	26
8,000	31 (60)	320	390	740	81	661	740	380	150	660	86	17 (33)	680	67	0	700	45
9,000	33 (63)	380	570	970	200	778	970	600	220	780	190	19 (33)	890	83	0	910	65
10,000	36 (70)	400	630	1,100	210	856	1,100	780	280	810	250	20 (34)	970	90	0	980	87
11,000	51 (83)	620	720	1,400	420	974	1,400	1,000	340	950	450	34 (34)	1,300	97	3.2	1,200	190
12,000	52 (91)	850	950	1,900	740	1,120	1,900	1,200	580	1,100	770	35 (35)	1,700	100	14	1,400	450
13,000	54 (99)	1,100	1,200	2,300	1,100	1,210	2,300	1,300	680	1,400	870	36 (43)	2,100	110	26	1,600	710
14,000	56 (110)	1,400	1,600	3,000	1,700	1,320	3,000	1,800	810	2,100	950	36 (53)	2,900	120	49	1,900	1,200
15,000	62 (200)	1,800	3,100	4,900	3,500	1,420	4,900	2,000	880	3,800	1,100	42 (63)	4,700	130	100	2,500	2,400
16,000	63 (290)	2,600	4,300	7,000	5,500	1,510	7,000	2,600	1,100	5,800	1,200	42 (66)	6,700	130	170	3,200	3,800

However, the specific effects of flow reductions vary with the range of flows at which the reduction occurs. For example, a flow reduction of 1,000 ft^3/s will decrease the area of aquatic habitat connected to the main channel in the entire nontidal river about 105 acres if the reduction is from 5,000 to 4,000 ft^3/s; about 331 acres if the reduction is from 8,000 to 7,000 ft^3/s; and about 2,090 acres if the reduction is from 16,000 to 15,000 ft^3/s. Generally, when flows are between 4,000 and 16,000 ft^3/s, much larger areas of connected aquatic habitat are affected by flow reductions occurring at higher flows within that range than at lower flows. However, it would be misleading to conclude from this statement that flow alterations occurring at lower flows have less impact than those occurring at higher flows. Decrease in total area of aquatic habitat is an important measure of the impact of flow alterations; however, relatively small decreases in a particular type of habitat can be important to certain species, especially at low flows when that type of habitat is already scarce. For example, cool-water streams in the floodplain of the upper reach of the Apalachicola River are important thermal refuges for striped bass. Entrenchment in the upper reach of the river has lowered river stages and greatly decreased 2-way access for fishes to flowing streams in the upper reach during low water periods (table 9), many of which are thermal refuges for striped bass. The amount of these habitats remaining at low flows is already low; thus, even relatively minor flow reductions during low flows may have a large impact on striped bass if cool-water streams used for thermal refuges are affected.

A few other examples from table 9 illustrate how the specific effects of flow reductions will vary with the range of flows at which the flow reduction occurs. Flow reductions that occur when flows are less than 5,000 ft^3/s will nearly eliminate aquatic habitat having sandy soils in the floodplain that is connected to the main channel. Flow reductions that occur when flows are between 6,000 and 9,000 ft^3/s will reduce the area of connected aquatic habitat in forests when the area of that habitat is already less than 200 acres. Flow reductions that occur when flows are between 10,000 and 16,000 ft^3/s will greatly reduce the number of acres of connected aquatic habitat with moderate to high vegetative structure.

Flow alterations that occurred in the Apalachicola River during 1990-95 are used in the following discussion as examples to show how the results of this investigation can be used to determine the effects of flow alterations on habitat area. The USACE regulated flows to create 16 navigation windows from 1990 to 1995 to increase the amount of time that barge traffic could navigate on the Apalachicola River (app. III). Immediately prior to each navigation window was a prewindow period in which water was stored in several of the upstream USACE reservoirs for an average of 15 days. During the navigation window, stored water was released at a consistent rate sufficient to support navigation by barges. The transition period between the prewindow and window was typically a 1-day period of rapidly increasing flow. The effects of flow augmentation have not been taken into account with regard to the average flows in appendix III; these flows were averaged from actual flows that occurred on the dates indicated.

Flows during the period October 23-November 24, 1990, which included one prewindow period and its corresponding window, were selected for use as a specific example in this discussion and are shown in the green shaded area in table 10. The prewindow period included in this example has the lowest average flow of all prewindow periods (app. III). Flows during the previous window and subsequent prewindow are shown outside the shaded area. The area of connected aquatic habitat in the floodplain was reduced by about 1,700 acres in a 3-day period (October 20-23) as the previous window ended and the prewindow period began. After the 19-day prewindow period ended on November 10, the area of connected aquatic habitat increased by about 1,900 acres in a 2-day transition period. After the 13-day window period ended on November 24, the area of connected aquatic habitat decreased again by about 1,800 acres in a 2-day period as the next prewindow period began. If the window had not been implemented, the area of aquatic habitat connected to the main channel for the prewindow and window period from October 23 to November 24 would have averaged about 910 acres (based on the average flow for that 33-day period). As a result of this flow alteration, there was about 590 fewer acres of connected aquatic habitat during the prewindow period than there would have been if the window had not been implemented. Also there was about 1,300 more acres of connected aquatic habitat during the window than there would have been if the window had not been implemented.

Table 10. Area of aquatic habitat in the floodplain that is connected to the main channel of the Apalachicola River at flows preceding, during, and after a navigation window and at estimated flows if the window had not been implemented

[Green shaded rows give data for the period October 23–November 24, 1990, which is used as an example in the text. Data for the transition period of 1 day are not shown. Average flow for the total period (in italics) represents the estimated flow that may have occurred during the prewindow, transition, and window periods if the window had not been implemented. Nonshaded rows give data for the previous window and and the next prewindow. Dates and flows for all periods were determined from daily mean flows at the Chattahoochee gage]

Period	Dates	Average flow at Chattahoochee gage during indicated period, in cubic feet per second	Area of aquatic habitat in floodplain that is connected to main channel at or above indicated flow value, in acres
Previous window (water release period)	Oct. 15–20, 1990	12,300	2,000
Prewindow (water storage period)	Oct. 23 – Nov. 10, 1990	5,900	320
Total period (prewindow, transition, and window periods combined)	*Oct. 23 – Nov. 24, 1990*	*8,720*	*910*
Window (water release period)	Nov. 12–24, 1990	12,900	2,200
Next prewindow (water storage period)	Nov. 26 – Dec. 11, 1990	6,690	390

Documenting the impacts of flow alterations on biota involves diverse and complex investigations that are beyond the scope of this study. However, some possible impacts on fishes are described in the following discussion and might serve as a basis for further research. Probably 80 percent of fish species known to inhabit the Apalachicola River use floodplain habitats as a source of food, shelter, or reproductive sites. In addition to 590 fewer acres for 19 days from October 23 to November 10, two other prewindow periods occurred in the fall of 1990, resulting in a total of 54 days in which there was an average of 540 fewer acres of connected aquatic habitat available to main channel fishes than if the windows had not been implemented (19 additional days with 400 fewer acres, and 16 additional days with 650 fewer acres, as interpolated from table 9 using flows from appendix III). A reduction in habitat of this magnitude and duration means that food sources were reduced for many main channel fishes in 1990, which may have affected both the survival rate of some fishes as well as spawning success for certain species the following winter and spring. Protection from predation was probably compromised also; fishes were concentrated into less space during prewindows which may have affected survival rates for many juvenile fishes. Most fishes spawn in late winter, spring, or summer; however, a few species such as redfin pickerel and chain pickerel sometimes spawn in the fall (Lee and others, 1980). For those species, reduced habitat during prewindows meant that area available for spawning was reduced in 1990. Nine of the 16 prewindows from 1990 to 1995 (app. III) occurred in spring or summer, and probably affected the availability of spawning sites as well as the survival rate of larval fishes for many species that are spring or summer spawners.

Of the 590 fewer acres of connected aquatic habitat available to main channel fishes during the prewindow, an estimated 60 percent was habitat that was drained of all standing water and eliminated as aquatic habitat for fishes. Drained areas with no standing water included low forest areas, dry streambeds, and the exposed parts of streambeds that were partially dry and partially covered with isolated pools in streams such as Johnson Creek (fig. 12), Old River, and Moccasin Slough. The remaining 40 percent was aquatic habitat that was disconnected from the main channel and no longer accessible to main channel fishes. These disconnected aquatic habitats include large isolated bodies of water such as Iamonia Lake (fig. 15) and Kennedy Slough (a tributary of Kennedy Creek), as well as many small isolated pools in partially dry streambeds. Field observations made by the authors in this and a previous study (Leitman and others, 1991) indicate that fishes are frequently trapped in isolated pools that can develop stagnant conditions shortly after they are disconnected. Oxygen demand exceeds oxygen supply when organisms are trapped and concentrated into small areas; the result can be very low dissolved oxygen concentrations, especially during hot weather.

During November 24-26, 1990, river levels at the end of a navigation window and the start of the next prewindow period dropped very rapidly, with flows decreasing by 6,210 ft^3/s in a 2-day period. Species such as taillight shiner, flier, and warmouth that are known to inhabit isolated pools, may not be adversely affected by being trapped during prewindows because they are adapted to low dissolved oxygen concentrations. Many other species use the floodplain that may either prefer flowing waters or be sensitive to low dissolved oxygen concentrations, such as redbreast sunfish, Gulf darter, and blackbanded darter. Less tolerant species are also likely to be trapped in isolated pools, especially if river levels were consistently higher in a previous window, and then drop rapidly to very low levels. Many fishes may succumb to the adverse conditions, or they may be stressed by crowding, low dissolved oxygen, and high temperatures and become vulnerable to infection. Columnaris, a disease of fishes that was implicated in a fish kill that occurred in summer 1995 in the Apalachicola River (Charles Mesing, FGFWFC, written commun., 1995), is caused by a ubiquitous bacterial organism that is common in the water, soil, and even on the skin of healthy fish. Columnaris disease "is thought to result more from stress factors which adversely affect the fishes' natural defense mechanisms, than from the presence of the bacteria" (Francis-Floyd, 1988).

Assessing impacts of flow alterations is complicated by the fact that large and sometimes rapid fluctuations in flow occur naturally in the Apalachicola River. Low flows are a relatively common occurrence in summer and fall under unregulated conditions, and frequent storms at that time of year may cause rapid increases and decreases in river flow. Determining how river level fluctuations when flows are regulated for navigation windows differ from the fluctuations that might have occurred if the windows had not been implemented is an important component in evaluating the impacts of this flow alteration. The 19-day prewindow from October 23 to November 10, 1990, shown in table 10 included 12 consecutive days in which the flow was less than 6,000 ft^3/s. In that climatic year (March 1, 1990–April 30, 1991) flows below 6,000 ft^3/s occurred only during prewindow periods. Flows below 6,000 ft^3/s for a duration of 12 consecutive days have occurred in only 10 percent of the years 1922-95 (table 2) which in unregulated streams would be equivalent to once every 10 years on average. Thus a low-flow event of this type is relatively infrequent in the period of record, and would probably not have occurred in 1990 if navigation windows had not been implemented. If flow regulation to provide navigation windows for barge traffic continues to be used in dry years, the durations presented in table 2 will likely change for low and very low flows. Multiple-year and monthly flow characteristics also will probably change. Flows below 6,000 ft^3/s for a duration of 12 consecutive days have never occurred each year for more than 2 consecutive years (table 3), and have never occurred in the months of December through July (table 4). Continued use of navigation windows may change other characteristics of the flow record that were not analyzed in this report, such as the number of times in the driest months of September, October, and November that flows increase or decrease by 6,000 ft^3/s in a period of 0 to 3 days.

As the preceding discussion implies, a thorough evaluation of the impacts of navigation windows or of any other type of flow alteration would require additional study which is beyond the scope of this investigation. One particular navigation window was used as an example in table 10; other navigation windows and other types of flow alterations would result in different effects. This report provides detailed information for determining the effects of altered flows on types and extent of aquatic habitat. Other important components of impact analysis include studies addressing effects of altered flows on biotic communities and comparisons of altered to historical flows.

SUMMARY AND CONCLUSIONS

The Apalachicola River is a large alluvial river in northern Florida formed by the confluence of the Chattahoochee and Flint Rivers in Georgia and Alabama. Increasing demands for water in the three States have resulted in conflicts, particularly during droughts. Water requirements of the Apalachicola River are addressed in this report, which presents information on aquatic habitat in the floodplain in relation to river flow. Results of this investigation can be used to evaluate potential impacts of flow alterations on floodplain habitat. Specific items covered in this report are (1) an analysis of long-term flow record in the Apalachicola River, (2) a description of the major types of floodplain streams, lakes, and swamps in relation to river flow, (3) estimates of the area of several different types of floodplain habitat in relation to river flow, (4) information about the species of fishes that occur in the floodplain, and (5) examples showing how these results can be used to assess impacts of flow alterations on aquatic habitats and fishes in the Apalachicola River floodplain. The study was conducted from 1992 to 1996 in the nontidal floodplain of the Apalachicola River. Hydrologic analyses were based on 74 years of river stage and flow records (1922-95) at Chattahoochee, Fla. All flows in the following summary refer to flows at the Chattahoochee gage.

Principal conclusions relating to the first four items are grouped by the following general flow ranges:

Very low flows (less than 6,000 ft^3/s)

- Very low flows occurred in 15 of the 74 years of record. Flows less than 5,000 ft^3/s occurred in only 4 years (1981, 1986, 1987, and 1988). The lowest mean daily flow in the period of record was 3,900 ft^3/s in November 1987. The droughts of the 1980's were the most severe in terms of low-flow durations in a single year; however, the 1950's drought was drier in terms of multiple-year low-flow durations.
- At a river flow of 5,000 ft^3/s, an estimated 260 acres of floodplain streams and lakes is aquatic habitat connected to the main channel, most of which is still-water habitat in the nontidal lower reach. The lower reach has many streams and lakes, such as Owl Creek and Lockey Lake, with bottom elevations below sea level and deep connections to the main channel at very low flows.
- In the upper reach, entrenchment that occurred after construction of Jim Woodruff Dam lowered bed elevations and river stages and altered connections between floodplain streams and the main channel. Many perennial streams in the upper reach, such as Flat Creek and Mosquito Creek, which were accessible to main channel fishes at low and very low flows prior to entrenchment, are now inaccessible because of waterfalls or very shallow water at their mouths.
- At a river flow of 5,000 ft^3/s, about 77,900 acres (95 percent of the floodplain) is forest habitat with no surface water present. Major forest types are tupelo-cypress and mixed bottomland hardwoods; surface soils are predominantly silt-clays.
- At a river flow of 5,000 ft^3/s, about 4,000 acres (5 percent of the floodplain) is isolated aquatic habitat. Most of these areas are tupelo-cypress swamps with standing water less than 3 ft deep. The pond level in some isolated swamps in the upper reach can be perched as much as 12 ft above the elevation of the low-water surface of the river.
- About one-third of the 91 fish species known to inhabit the Apalachicola River have been collected in isolated aquatic habitat in river floodplains of the eastern United States; the most common being redfin pickerel, golden shiner, taillight shiner, yellow bullhead, pirate perch, mosquitofish, least killifish, flier, banded pygmy sunfish, warmouth, bluegill, and black crappie.

Low flows (6,000–10,000 ft^3/s)

- Low flows occur in most years. The median annual 1-day low flow for the period of record is 8,490 ft^3/s. Flows less than 8,000 ft^3/s occurred in 34 of the 74 years of record. Low flows typically occur in September, October, and November.
- At a river flow of 8,000 ft^3/s, the estimated area of connected aquatic habitat in the floodplain is 740 acres. Most of this area is located in tributary lakes, which are open bodies of water with little or no flow that are affected by backwater from the main river channel. The largest tributary lakes are Iamonia Lake, Outside Lake, and Florida River in the middle reach, and River Styx and Kennedy Creek in the nontidal lower reach.
- At a river flow of 8,000 ft^3/s, the area of still-water habitat (660 acres) greatly exceeds the area of flowing water habitat (86 acres). Both still-water and flowing-water habitats in shallow floodplain water bodies provide refuges for fishes from the deeper and more swiftly flowing waters in the main channel.
- At low flows, most of the connected aquatic habitat is confined to streambeds in which the amount of vegetative structure is lower than in other floodplain habitat, but probably higher than in the main channel.
- Forty-four fish species were collected in connected aquatic habitat in the Apalachicola River floodplain during low flows, the most common being bluegill, brook silverside, bowfin, largemouth bass, spotted gar, redear sunfish, spotted sucker, warmouth, American eel, and redbreast sunfish. These collections were made in a previous study by the Florida Game and Fresh Water Fish Commission, primarily in large tributary lakes connected to the main channel in the middle and lower reaches of the river.

Medium flows (10,000–20,000 ft^3/s)

- Medium flows occur every year. The median flow for the period of record is 16,400 ft^3/s. Flows less than 16,000 ft^3/s do not normally occur in the wettest months of February, March, and April; flows greater than 16,000 ft^3/s do not normally occur in the driest months of September, October, and November.
- At river flows above 10,000 ft^3/s, the area of connected aquatic habitat increases more rapidly in forests than in streams and lakes. At the median flow of 16,400 ft^3/s, approximately 8,200 acres (10 percent of the floodplain) is connected aquatic habitat. Most of these areas are tupelo-cypress swamps bordering streams and lakes in the middle and nontidal lower reaches that are inundated by backwater from the main channel.
- During medium flows, water in most of the connected aquatic habitat in forests is not flowing. Opportunities for water to flow through floodplain forests are limited because the water is not yet high enough to break over levees and ridges that control connections between different parts of floodplain.
- At a river flow of 19,000 ft^3/s, most of the 230 miles of streams and lakes that are connected to the main channel is flowing. Tributary lakes of the middle and lower reach are still affected by backwater at this flow, but are slowly flowing because a considerable amount of water from the main channel is being diverted into them by way of connector streams. Bee Tree Slough and Mary Slough are examples of connector streams flowing from the main channel into Iamonia Lake during medium river flows. Connector streams also carry water from one tributary lake to another, such as Shepard Slough, which flows from River Styx to Kennedy Creek. Loop streams such as Old River are fed by flow diverted from the main channel that flows for a few miles through the floodplain and then back into the river farther downstream.
- The amount of vegetative structure in connected aquatic habitat is much greater during medium flows than during low flows. This is because water is no longer contained in the beds of floodplain streams, but is covering vegetation and woody debris on streambanks and in adjacent swamps. Flooded vegetative structure provides cover for prey refuges, food sources, and reproductive sites for fishes and aquatic invertebrates.

Medium-high flows (20,000–50,000 ft^3/s)

- Medium-high flows occur every year. In a typical year of the period of record, flows exceeded 20,000 ft^3/s for a total duration of 142 days and exceeded 45,000 ft^3/s for 30 days. The lowest annual 1-day high flow was 24,300 ft^3/s in 1941.
- As flows increase from 20,000 to 50,000 ft^3/s, the area of connected aquatic habitat increases from about 19 to 82 percent of the floodplain. An estimated 40,700 acres, which is approximately one-half of the floodplain, is connected aquatic habitat at a river flow of 32,000 ft^3/s.
- At flows from 23,000 to 40,000 ft^3/s, the area of flowing-water habitat is roughly equal to the area of still-water habitat. Water velocities observed in most flowing-water habitats in the floodplain (less than 1 ft/s) are much lower than velocities in the main channel (1-4 ft/s), with the exception of loop and connector streams that carry river water at a relatively high velocity along a steeper course than the main channel.
- Nearly all aquatic habitat in tupelo-cypress swamps that is isolated at lower flows is connected to the main channel between flows of 20,000 to 40,000 ft^3/s. The flow required to flood isolated swamps decreases downstream, with river flows of 30,000 to 35,000 ft^3/s required to flood most isolated swamps in the upper reach, and 20,000 to 25,000 ft^3/s required in the nontidal lower reach. Large areas of organic soils in isolated swamps, which comprise about 3 percent of the floodplain, are connected to the main channel at medium-high flows.

High flows (greater than 50,000 ft^3/s)

- High flows occur in most years. The median annual 1-day high flow for the period of record was 86,200 ft^3/s. Flows above 100,000 ft^3/s occurred in 25 of the 74 years of record. The highest mean daily flow was 291,000 ft^3/s in March 1929.
- At the median annual 1-day high flow of 86,200 ft^3/s, about 78,000 acres (95 percent of the floodplain) is connected aquatic habitat. The remaining 4,200 acres of floodplain that is still dry and exposed at this flow is mostly high levees adjacent to the main channel. Most of the 6,400 acres of sandy soils in the floodplain are found on high levees.
- During high flows, water is moving through most of the floodplain in a general downstream direction. At a flow of 65,000 ft^3/s, more than 99 percent of the aquatic habitat in the floodplain is flowing.
- Many main channel fishes migrate into inundated floodplain forests where greatly increased food sources and abundant vegetative structure are available to them. Eighty percent, or 73 of the 91 species known to inhabit the Apalachicola River have been collected in river floodplains of the eastern United States under various hydrologic conditions and are probably present in floodplains during floods.

The following are principal conclusions relating to the last item, application of study results to assess impacts of flow alterations on aquatic habitats and fishes in the Apalachicola River floodplain:

- Flow reductions that occur when flows are less than 16,000 ft^3/s will result in a decrease in area of most types of connected aquatic habitat in the floodplain in most reaches of the river. Specific effects of flow reductions vary with the range of flows at which the reduction occurs.
- Generally, when flows are between 4,000 and 16,000 ft^3/s, much larger areas of connected aquatic habitat are affected by flow reductions occurring at higher flows within that range than at lower flows. However, relatively small decreases in a particular type of habitat can be extremely important to certain species, especially during low flows when that type of habitat is already scarce. For example, the amount of flowing-water habitat in streams of the upper reach is extremely small during low flows. Relatively minor flow reductions

during low flows may have a large impact on striped bass if cool-water streams used for thermal refuges are affected.

- Flow regulation to create navigation windows for barge traffic during the period October 23-November 24, 1990, was selected for use as an example period of altered flows. Flows decreased rapidly by 6,400 ft^3/s immediately prior to the prewindow period, flows increased rapidly by 7,000 ft^3/s just prior to the window period, and flows decreased rapidly again by 6,210 ft^3/s immediately after the window. As a result of this flow alteration, there was about 590 fewer acres of connected aquatic habitat during the prewindow period than there would have been if the window had not been implemented. Also there was about 1,300 more acres of connected aquatic habitat during the window than there would have been if the window had not been implemented.
- Although detailing the effects of flow alterations on biota was beyond the scope of this study, some possible impacts on fishes were described to provide suggestions for further evaluation and research. Reduced aquatic habitat in the floodplain limits the amount of food, protective cover, and spawning sites for many species of fishes that utilize these areas. When flows are reduced, some areas are drained of all standing water and eliminated as aquatic habitat for fishes. Other habitat remains aquatic after flows decrease, but is disconnected from the main channel and can no longer be accessed by main channel fishes. Fishes are likely to be trapped in isolated pools, especially if river levels drop rapidly, and may be subjected to crowded conditions and low dissolved oxygen concentrations. Many fishes may succumb to the adverse conditions, or they may be stressed and become vulnerable to infection.
- Assessing impacts of flow alterations is complicated by the fact that large and sometimes rapid fluctuations in flow occur naturally in the Apalachicola River. A low-flow event of the type that occurred in the period of flow regulation used as an example in this report occurred once every 10 years on average in the 74-year period of record, and would probably not have occurred that year if navigation windows had not been implemented. Continued use of navigation windows in dry years will likely change low flow characteristics of the river and potentially affect biotic communities in the floodplain.
- To thoroughly evaluate the impacts of navigation windows or of any other type of flow alteration, it is important to determine the types and extent of habitat affected, address impacts on biotic communities, and make comparisons of altered to historical flows.

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Appendixes

Appendix I. Greatest number of consecutive days and total number of days in each year from 1922 to 1995 that flow was below given flow values from 4,000 to 16,000 cubic feet per second in the Apalachicola River at Chattahoochee, Florida

A. GREATEST NUMBER OF CONSECUTIVE DAYS

[Analysis is based on climatic years of April 1–March 31 to avoid splitting low-flow periods that typically occur in summer and fall]

Year	Greatest number of consecutive days in indicated year that flow was below given flow value												
	4,000	5,000	6,000	7,000	8,000	9,000	10,000	11,000	12,000	13,000	14,000	15,000	16,000
1922	0	0	0	0	7	19	46	49	106	107	109	119	120
1923	0	0	0	0	0	0	8	28	31	36	36	60	75
1924	0	0	0	0	0	5	7	23	35	35	35	35	35
1925	0	0	57	63	98	101	104	106	156	156	164	208	210
1926	0	0	0	0	0	0	6	19	36	37	43	43	44
1927	0	0	3	66	88	97	98	99	107	109	109	111	118
1928	0	0	0	0	0	0	0	0	2	6	11	30	33
1929	0	0	0	0	0	0	4	6	14	26	28	33	34
1930	0	0	0	0	3	12	19	20	32	34	39	47	52
1931	0	0	32	58	95	101	103	106	109	109	111	205	207
1932	0	0	0	0	0	11	19	31	45	46	51	52	52
1933	0	0	0	0	6	43	84	110	121	163	166	192	217
1934	0	0	0	0	4	14	32	44	68	84	86	86	87
1935	0	0	5	30	39	46	49	54	57	60	61	62	111
1936	0	0	0	0	0	0	2	3	10	31	37	50	51
1937	0	0	0	0	0	0	0	3	6	18	32	33	47
1938	0	0	0	6	30	52	96	116	138	148	169	173	174
1939	0	0	0	0	0	10	57	62	73	79	80	83	85
1940	0	0	0	9	44	47	60	66	67	68	106	117	125
1941	0	0	1	40	52	89	96	104	120	121	123	128	128
1942	0	0	0	0	0	0	2	12	24	54	63	64	66
1943	0	0	0	0	2	30	43	45	78	79	128	129	132
1944	0	0	0	0	0	3	25	49	58	60	74	77	110
1945	0	0	0	0	0	0	2	9	10	24	27	28	56
1946	0	0	0	0	0	0	0	3	7	24	33	81	94
1947	0	0	0	0	0	0	4	12	37	61	67	70	70
1948	0	0	0	0	0	0	0	0	0	8	10	13	16
1949	0	0	0	0	0	0	0	0	2	19	36	37	39
1950	0	0	0	0	10	20	40	42	48	50	90	91	105
1951	0	0	0	28	36	51	54	77	78	80	81	225	226
1952	0	0	0	24	52	67	71	76	116	117	179	180	200
1953	0	0	0	0	0	0	6	12	22	38	53	54	55
1954	0	0	64	80	105	128	155	157	158	185	192	195	208
1955	0	0	53	70	85	93	170	175	177	178	183	183	189
1956	0	0	7	35	41	50	64	68	70	134	135	135	135

Year	Greatest number of consecutive days in indicated year that flow was below given flow value												
	4,000	5,000	6,000	7,000	8,000	9,000	10,000	11,000	12,000	13,000	14,000	15,000	16,000
1957	0	0	4	5	34	45	52	53	77	79	86	87	87
1958	0	0	0	0	2	7	24	55	66	107	109	128	134
1959	0	0	0	0	0	4	14	14	21	26	31	32	42
1960	0	0	0	0	0	2	8	11	35	43	109	111	112
1961	0	0	0	0	6	16	49	57	82	83	83	91	92
1962	0	0	0	2	5	16	32	43	105	131	136	137	138
1963	0	0	0	0	3	16	41	116	117	117	125	125	126
1964	0	0	0	0	0	0	0	0	1	2	3	5	8
1965	0	0	0	0	0	0	0	2	8	23	28	32	40
1966	0	0	0	0	0	0	0	2	24	34	59	59	60
1967	0	0	0	0	0	0	0	0	5	14	30	49	60
1968	0	0	0	3	30	57	76	76	161	166	210	210	211
1969	0	0	0	0	0	0	3	13	55	65	66	68	68
1970	0	0	0	0	0	0	4	13	33	49	54	57	57
1971	0	0	0	0	0	0	0	3	21	27	33	65	66
1972	0	0	0	0	0	0	34	72	93	113	116	117	122
1973	0	0	0	0	0	0	0	22	38	45	59	66	67
1974	0	0	0	0	0	0	0	29	73	73	77	77	78
1975	0	0	0	0	0	0	0	0	0	3	4	5	9
1976	0	0	0	0	0	0	0	0	8	16	35	41	64
1977	0	0	0	0	0	0	19	40	58	65	68	92	92
1978	0	0	0	0	0	36	80	97	112	118	131	131	137
1979	0	0	0	0	0	0	0	4	27	50	57	58	59
1980	0	0	0	0	0	6	153	162	177	208	209	209	220
1981	0	1	40	49	64	76	174	241	244	256	261	261	262
1982	0	0	0	0	0	0	0	0	10	49	61	75	96
1983	0	0	0	0	0	0	0	2	7	16	30	63	106
1984	0	0	0	0	0	0	0	26	65	80	81	88	143
1985	0	0	0	0	0	6	44	60	61	78	105	110	216
1986	0	2	41	50	122	144	192	208	209	212	213	234	236
1987	3	6	6	14	15	49	90	97	132	140	169	184	188
1988	0	20	35	68	73	81	83	95	128	232	286	292	293
1989	0	0	0	0	0	0	0	3	7	14	15	28	40
1990	0	0	12	20	22	46	89	103	105	105	136	168	200
1991	0	0	0	1	20	23	23	23	24	35	41	55	111
1992	0	0	0	0	3	3	11	15	15	18	53	71	72
1993	0	0	3	12	14	17	22	22	23	74	74	112	147
1994	0	0	0	0	1	1	3	9	9	10	18	18	18
1995	0	0	0	0	13	15	19	19	19	19	20	82	87

Appendix I.Greatest number of consecutive days and total number of days in each year from 1922 to 1995 that flow was below given flow values from 4,000 to 16,000 cubic feet per second in the Apalachicola River at Chattahoochee, Florida--Continued

B. TOTAL NUMBER OF DAYS

[Analysis is based on climatic years of April 1–March 31 to avoid splitting low-flow periods that typically occur in summer and fall]

Year	Total number of days in indicated year that flow was below given flow value												
	4,000	5,000	6,000	7,000	8,000	9,000	10,000	11,000	12,000	13,000	14,000	15,000	16,000
1922	0	0	0	0	27	63	85	98	106	110	122	137	149
1923	0	0	0	0	0	0	18	43	52	58	64	76	84
1924	0	0	0	0	0	14	31	71	88	101	118	124	129
1925	0	0	57	82	104	137	161	182	205	216	233	249	254
1926	0	0	0	0	0	0	6	42	84	122	153	177	197
1927	0	0	5	75	96	144	157	179	226	244	261	277	291
1928	0	0	0	0	0	0	0	0	2	12	41	59	70
1929	0	0	0	0	0	0	6	9	15	27	30	36	44
1930	0	0	0	0	6	20	40	65	87	100	115	135	148
1931	0	0	45	79	102	144	161	173	180	189	197	205	207
1932	0	0	0	0	0	15	33	46	58	84	109	141	161
1933	0	0	0	0	36	91	111	138	170	215	242	259	267
1934	0	0	0	0	12	40	71	110	146	178	195	214	231
1935	0	0	5	31	53	79	119	150	166	188	203	222	235
1936	0	0	0	0	0	0	3	15	47	91	115	131	135
1937	0	0	0	0	0	0	0	3	16	55	85	112	156
1938	0	0	0	8	38	83	119	137	155	181	199	217	225
1939	0	0	0	0	0	18	57	65	74	95	115	131	140
1940	0	0	0	14	44	52	60	72	110	149	182	208	232
1941	0	0	1	79	115	140	156	187	203	212	221	232	242
1942	0	0	0	0	0	0	6	32	52	75	100	117	146
1943	0	0	0	0	5	47	75	103	117	125	130	146	174
1944	0	0	0	0	0	7	29	49	67	85	108	146	183
1945	0	0	0	0	0	0	2	27	55	91	114	136	168
1946	0	0	0	0	0	0	0	4	24	59	92	115	124
1947	0	0	0	0	0	0	7	29	49	63	72	82	89
1948	0	0	0	0	0	0	0	0	0	10	25	35	51
1949	0	0	0	0	0	0	0	0	5	23	59	90	114
1950	0	0	0	0	11	59	89	111	139	176	226	252	269
1951	0	0	0	52	75	104	134	161	180	201	216	230	235
1952	0	0	0	27	62	101	132	152	167	178	186	193	204
1953	0	0	0	0	0	0	6	33	64	81	101	114	126
1954	0	0	67	83	114	145	190	208	227	257	272	290	303
1955	0	0	54	115	166	208	227	239	250	264	271	278	292
1956	0	0	11	42	101	139	177	199	214	248	258	268	273

Year	Total number of days in indicated year that flow was below given flow value												
	4,000	5,000	6,000	7,000	8,000	9,000	10,000	11,000	12,000	13,000	14,000	15,000	16,000
1957	0	0	14	23	53	80	99	117	127	138	143	150	152
1958	0	0	0	0	4	31	63	83	122	149	161	177	192
1959	0	0	0	0	0	11	19	26	51	62	92	114	130
1960	0	0	0	0	0	7	33	64	105	178	215	230	244
1961	0	0	0	0	15	47	67	77	87	101	110	123	129
1962	0	0	0	4	12	32	81	133	156	171	187	206	220
1963	0	0	0	0	3	40	106	136	153	163	173	178	188
1964	0	0	0	0	0	0	0	0	1	5	11	17	31
1965	0	0	0	0	0	0	0	4	44	75	104	125	142
1966	0	0	0	0	0	0	0	7	52	74	93	111	136
1967	0	0	0	0	0	0	0	0	13	76	122	154	178
1968	0	0	0	5	38	67	83	122	176	230	263	273	288
1969	0	0	0	0	0	0	5	25	134	169	186	204	217
1970	0	0	0	0	0	0	10	38	91	117	137	168	190
1971	0	0	0	0	0	0	0	6	42	61	84	92	104
1972	0	0	0	0	0	0	54	72	113	163	179	188	194
1973	0	0	0	0	0	0	0	27	42	65	83	99	112
1974	0	0	0	0	0	0	0	60	120	128	142	162	173
1975	0	0	0	0	0	0	0	0	0	5	18	31	39
1976	0	0	0	0	0	0	0	0	20	69	84	98	107
1977	0	0	0	0	0	0	45	84	138	165	171	182	189
1978	0	0	0	0	0	40	86	105	140	160	177	190	207
1979	0	0	0	0	0	0	0	11	92	133	160	168	179
1980	0	0	0	0	0	27	153	162	193	227	241	250	255
1981	0	1	40	65	81	101	175	241	244	257	261	261	264
1982	0	0	0	0	0	0	0	0	10	94	133	153	156
1983	0	0	0	0	0	0	0	5	34	48	105	122	134
1984	0	0	0	0	0	0	0	53	65	89	150	174	182
1985	0	0	0	0	0	6	77	130	142	177	204	224	229
1986	0	10	54	96	123	182	192	208	209	212	215	234	238
1987	3	6	6	14	19	58	92	116	144	167	182	202	223
1988	0	29	35	68	73	81	95	190	261	283	291	303	308
1989	0	0	0	0	0	0	0	3	8	14	18	63	102
1990	0	0	12	52	76	133	148	159	163	181	194	198	210
1991	0	0	0	2	21	23	23	23	29	38	41	80	123
1992	0	0	0	0	4	5	15	18	46	72	138	169	175
1993	0	0	7	26	33	40	82	94	107	132	140	158	189
1994	0	0	0	0	1	1	3	12	13	17	29	29	33
1995	0	0	0	0	26	56	69	76	76	79	89	134	153

Appendix II. Lengths of floodplain streams and lakes connected to main channel of the nontidal Apalachicola River at flows ranging from 4,000 to 19,000 cubic feet per second

["Connected" means that approximately level water passageways exist between floodplain water bodies and the river, allowing 2-way fish access from river to floodplain and floodplain to river. rm, river mile; RB, right bank (looking downstream) of Apalachicola River; LB, left bank of Apalachicola River; RBC, right bank of lower Chipola River; LBC, left bank of lower Chipola River; Chip10,000 (and other similar Chip numbers), notation to describe location of stream in number of feet upstream of mouth of lower Chipola River (which is located at rm 27.9 on the Apalachicola River); ft^3/s, cubic feet per second; ft, feet; inc, including; trib, tributary; conf, confluence; approx, approximately; R, river]

Flow at Chattahoochee gage[1], in ft^3/s	Streams and lakes connected at or above and isolated below given flow value[2] Name (description of connected reach) and location[4]	Length[5], in ft
4,000[3]	Graves Creek (from mouth at rm 88.8 to 1,960 ft upstream)--RB	1,960
	Sutton Lake--rm 78.1--RB	2,520
	unnamed cutoff from rm 50.7 to rm 49.7--RB	2,300
	Porter Lake (from mouth at rm 48.2 to 590 ft upstream)--RB	590
	Florida R (from mouth at rm 43.2 to to downstream connection of Larkin Slu)--LB	25,010
	R Styx (from mouth at rm 35.3 to 1,300 ft upstream)--LB	1,300
	Dead R (from mouth located 1,200 ft upstream of mouth of R Styx to approx 3,000 ft upstream)--LB	3,000
	unnamed stream at lower end of Battle Bend (from mouth at rm 28.6 to 320 ft upstream)--LB	320
	unnamed stream--rm 27.1--RB	1,670
	unnamed stream--rm 27.0--RB	1,170
	unnamed stream--rm 26.6--RB	1,980
	unnamed stream--rm 24.8--RB	1,230
	unnamed stream--rm 24.75--RB	1,320
	Brushy Creek (from mouth at rm 24.0 to head at rm 25.7)--LB	8,520
	unnamed stream connecting Brushy Creek to Kennedy Creek (from mouth approx 6,400 ft upstream of mouth of Brushy Creek to 2,800 ft upstream)--LB	4,290
	unnamed stream--rm 23.5--LB	1,460
	Scott Creek--rm 23.3--LB	2,230
	Owl Creek--rm 22.1--LB[6]	9,190
	Devon Creek (mouth approx 3,400 ft upstream of mouth of Owl Creek)--LB[6]	780
	unnamed stream--rm 21.8--RB	2,350
	unnamed stream--rm 21.55--RB	840
	unnamed stream--rm 21.3--RB	1,330
	Brickyard Creek (from mouth at rm 20.6 to 1,600 ft upstream) inc 1 trib--LB	6,580
	White R (from mouth at Chip49,900 to 5,790 ft upstream)--LBC	5,790
	unnamed trib of White R (mouth approx 600 ft upstream of mouth of White R at Chip49,900)--LBC	3,670
	Lockey Lake inc unnamed trib--Chip19,500--RBC	4,440
	Douglas Slough (from mouth at Chip8,200 to 3,810 ft upstream)--LBC	3,810
4,000	Subtotal	99,650

Flow at Chattahoochee gage[1], in ft^3/s	Streams and lakes connected at or above and isolated below given flow value[2] Name (description of connected reach) and location[4]	Length[5], in ft
5,000	Sweetwater Creek inc 1 trib--rm 89.3--LB	5,220
	Bayou (from mouth on Sutton Lake to US 20)--rm 78.1-RB	4,250
	unnamed stream (from mouth at rm 50.7 going north towards Brown Lake to 3,050 ft upstream)--RB	3,050
	Outside Lake (from mouth at rm 63.9 to 2,900 ft upstream)--LB	2,900
	Swift Slu (from mouth on R Styx to 2,400 ft upstream)--LB	2,400
	Moccasin Slough (from mouth on R Styx to 1,100 ft upstream)--LB	1,100
	R Styx (from 1,300 ft upstream of mouth at rm 35.3 to approx 18,200 ft upstream)--LB	16,900
	unnamed stream inc 1 trib--rm 30.05--RB	5,120
	Kennedy Creek (from mouth at rm 26.0 to 26,670 ft upstream)--LB	26,670
	unnamed trib of Kennedy Creek (from mouth 800 ft upstream of mouth of Kennedy Creek to 2,900 ft upstream) inc 1 trib--LB	3,680
	unnamed trib of Kennedy Creek (from mouth 15,800 ft upstream of mouth of Kennedy Creek to 600 ft upstream)--LB	600
	3 unnamed tribs of Lockey Lake (mouths 1,600, 2,400, and 2,410 ft upstream of mouth of Lockey Lake)--RBC[7]	7,170
	Douglas Slough (from 3,810 ft upstream of mouth at Chip8,200 to head at Chip12,700)--LBC[7]	2,300
	unnamed stream--Chip3,400--RBC	2,740
	unnamed stream--Chip1,500--RBC	1,500
5,000	Subtotal	85,600
6,000	unnamed stream--rm 101.1--LB	160
	Flat Creek inc 2 tribs--rm 99.5--LB	14,140
	Equaloxic Creek (from mouth at rm 51.9 to 6,000 ft upstream)--LB	6,000
	Iola Lake--rm 45.2--RB	1,100
	old channel loop of Florida R (connected at approx 2,600 and 3,500 ft upstream of mouth of Florida R)--LB	5,000
	Swift Slough (from 2,000 ft upstream of mouth on R Styx to head at rm 40.3)--LB	11,870
	2 unnamed streams inc connection to Douglas Slu--rm 30.3 and rm 30.08--RB	7,550
	unnamed stream--rm 26.25--RB	890
	unnamed trib of Kennedy Creek (mouth approx 9,000 ft upstream of mouth of Kennedy Creek)--LB	3,630
	unnamed trib of Kennedy Creek (from 600 ft upstream of mouth 15,800 ft upstream of mouth of Kennedy Creek to 760 ft upstream)--LB	160
	unnamed trib (mouth 2,400 ft upstream of mouth of unnamed trib 800 ft upstream of mouth of Kennedy Creek)--LB	1,410
	Kennedy Slough (from mouth 1,800 ft upstream of mouth of Kennedy Creek to 7,550 ft upstream) inc 2 tribs--LB	9,790
	Shepard Slough (from mouth on Kennedy Creek to approx 3,500 ft upstream) inc 1 trib--LB	9,420
	unnamed stream connecting Brushy Creek to Kennedy Creek (from approx 2,800 ft upstream of mouth on Brushy Creek to head at Kennedy Creek)--LB	2,970
	unnamed stream--rm 22.05--RB	360
	unnamed stream--Chip64,500--LBC	4,650

Flow at Chatta-hoochee gage[1], in ft³/s	Streams and lakes connected at or above and isolated below given flow value[2] Name (description of connected reach) and location[4]	Length[5], in ft
6,000	Gum Drift Slough (from head at Chip52,500 to 6,090 ft downstream)--RB	6,090
	unnamed stream (from mouth at Chip42,800 to 2,860 ft upstream) inc alternate head at Chip45,700--LBC[7]	3,300
	unnamed stream--Chip40,800--LBC	1,210
	unnamed stream--Chip18,600--RBC	1,650
	2 unnamed tribs of Douglas Slough and connecting stream (mouths at 100 and 500 ft upstream of mouth of Douglas Slough at Chip8,200)--LBC	2,950
	Spiders Cut--Chip2,400--RBC	4,600
6,000	Subtotal	98,900
7,000	Equaloxic Creek (from approx 6,000 ft upstream of mouth at rm 51.9 to 12,010 ft)--LB	6,010
	unnamed stream (from mouth at rm 50.7 to south end of Brown Lake)--RB	3,000
	Kentucky Lake--rm 43.8--RB	1,830
	Larkin Slu (from mouth on Florida R approx 22,400 ft upstream of mouth of Florida R to Gregory Mill Creek)--LB	5,980
	2 unnamed tribs of R Styx (from their mouths 5,600 and 7,000 ft upstream of mouth of R Styx to approx 100 ft upstream)--LB	200
	unnamed stream--rm 26.15--RB	1,050
	2 unnamed tribs of Kennedy Creek (mouths at 1,350 and 1,450 ft upstream of mouth of Kennedy Creek)--LB	1,600
	unnamed trib of Kennedy Creek (mouth 22,900 ft upstream of mouth of Kennedy Creek)--LB	3,340
	unnamed trib of Kennedy Creek (from 2,900 ft upstream of mouth on Kennedy Creek at approx 800 ft upstream of mouth of Kennedy Creek to 3,560 ft upstream) inc 1 trib--LB	1,460
	unnamed trib of Kennedy Slough (from 1,000 ft upstream of mouth at 3,000 ft upstream of mouth of Kennedy Slough to 1,500 ft upstream)--LB	500
	Shepard Slough (from approx 3,500 ft upstream of mouth on Kennedy Creek to 7,000 ft upstream)--LB	3,480
	unnamed stream--rm 23.35--RB	750
	Maddox Slough (from mouth at Chip53,600 following westward course to floodplain edge 1,750 ft upstream)--RBC	1,750
	White R (from approx 5,800 ft upstream of mouth at Chip49,900 to 10,800 ft upstream)--LBC	4,980
	unnamed stream connecting trib of White R (mouth 600 ft upstream of mouth of White R) to Corley Slough inc Corley Slough to conf with Virginia Cut--LBC[7]	4,470
	unnamed stream inc 2 tribs--Chip46,100--LBC[7]	5,130
	Virginia Cut (from mouth at Chip37,300 to 12,790 ft upstream)--LBC	12,790
	Burgess Creek (from mouth at Chip35,900 to 8,050 ft upstream) inc 3 tribs--RBC[7]	12,590
	2 unnamed tribs of unnnamed stream (mouths 200 and 600 ft upstream of mouth of unnamed stream at Chip3,400)--RBC	1,710
7,000	Subtotal	72,620
8,000	Mosquito Creek inc 1 trib--rm 105.1--LB	8,580
	unnamed stream--rm 95.5--LB[6]	5,110
	Johnson Creek (from mouth at rm 93.9 to 1,810 ft upstream)--RB	1,810
	Old R (from rm 77.0 to north end of Baker Branch), Baker Branch, Sutton Creek, and Hicks Creek--RB	33,880

Flow at Chatta-hoochee gage[1], in ft³/s	Streams and lakes connected at or above and isolated below given flow value[2] Name (description of connected reach) and location[4]	Length[5], in ft
8,000	Dead R (at Poloway Point)--rm 71.4--LB	6,600
	Iamonia Lake (from mouth at rm 55.8 to 26,180 ft upstream) inc McDougal Lake, Rudy Slough, and Lots Mill Creek --RB	33,780
	Equaloxic Creek inc 2 tribs (from 12,010 ft upstream of mouth at rm 51.9 to Big Gully Creek)--LB	12,010
	Porter Lake (from 590 ft upstream of mouth at rm 48.2 to north end)--RB	1,060
	Florida R (from downstream connection of Larkin Slu to 26,000 ft upstream of mouth at rm 43.2) inc lower end of Dog Slough (from mouth on Florida R to 890 ft upstream)--LB	5,890
	R Styx (from approx 18,200 ft upstream of mouth at rm 35.3 to 20,200 ft upstream)--LB	2,000
	unnamed stream--rm 26.3--RB	690
	Shepard Slough (from approx 7,000 ft upstream of mouth on Kennedy Creek to 11,000 ft upstream) inc 1 trib--LB	8,580
	unnamed stream inc trib--Chip70,000--RBC	1,360
	Magnolia Slough--Chip56,100--LBC	1,320
	unnamed stream--Chip45,000--LBC[7]	90
	Roberts Slough (from mouth at Chip40,900 to 1,830 ft upstream)--RBC[7]	1,830
	Burgess Creek (from 8,050 ft upstream of mouth at Chip35,900 to conf with Roberts Slough)--RBC[7]	2,730
	Piney Reach Slough--Chip22,500--LBC	4,800
	unnamed stream--Chip10,400--RBC	2,630
	unnamed stream--Chip7,900--RBC	720
8,000	Subtotal	134,470
9,000	Rock Creek--rm 95.2--LB[6]	1,090
	unnamed stream inc 2 tribs--rm 88.5--LB	2,760
	Outside Lake (from 2,900 ft upstream of mouth at rm 63.9 to 9,000 ft)--LB	6,100
	Bee Tree Slough (from mouth at rm 61.1 to 1,320 ft upstream)--RB	1,320
	Mary Slough (from mouth on Iamonia Lake to 1,210 ft upstream)--RB	1,210
	Middle Slough (from mouth on Iamonia Lake to 1,900 ft upstream)--RB	1,900
	unnamed stream--rm 51.6--LB	2,400
	Brown Lake--RB	790
	Moccasin Slough (from 1,100 ft upstream of mouth on R Styx to head at rm 38.8)--LB	11,880
	unnamed trib of Dead R (mouth approx 3,200 ft upstream of mouth of Dead R on R Styx)--LB	960
	unnamed stream at downstream end of Battle Bend (from 320 upstream of mouth at rm 28.6 to approx 4,430 ft upstream)--LB	4,430
	unnamed trib of Kennedy Creek (mouth approx 18,000 ft upstream of mouth of Kennedy Creek at rm 26.0)--LB	700
	Shepard Slough (from approx 11,000 ft upstream of mouth on Kennedy Creek to 14,600 ft upstream) inc 2 tribs--LB	6,860
	unnamed stream--rm 24.4--LB	480
	unnamed stream--rm 22.1--RB	2,160
	unnamed stream--rm 22.0--RB	500

Flow at Chatta-hoochee gage[1], in ft³/s	Streams and lakes connected at or above and isolated below given flow value[2]	
	Name (description of connected reach) and location[4]	Length[5], in ft
9,000	unnamed stream--Chip65,900--LBC	2,170
	Gum Drift Slough (from approx 6,100 ft downstream of head at Chip52,500 to conf with Roberts Slough)--RBC[7]	6,090
	Roberts Slough (from 1,830 ft upstream of mouth at Chip40,900 to approx 9,400 ft upstream) inc 2 tribs--RBC[7]	8,930
	unnamed trib of White R (mouth approx 6,500 ft upstream of mouth of White R at Chip49,900)--LBC	2,320
	unnamed stream--Chip44,600--LBC[7]	220
	Van Horn Slough--Chip31,200--LBC	1,310
	2 unnamed tribs of Piney Reach Slough (mouths 500 and 3,000 ft upstream of mouth of Piney Reach Slough at Chip22,500)--LBC[7]	2,510
9,000	Subtotal	69,090
10,000	Spring Branch inc 2 tribs--rm 100.6--RB	6,620
	Ocheesee Creek inc tribs--rm 93.3--RB	15,880
	unnamed stream at Caraway Landing inc trib--rm 90.6--RB	3,990
	Little Sweetwater Creek--rm 84.4--LB	2,000
	Bee Tree Slough (from 1,320 ft from mouth at rm 61.1 to conf with Middle Slough)--RB	1,320
	3 unnamed tribs of Swift Slough (mouths 2,000, 6,400, and 6,600 ft upstream of mouth of Swift Slough on R Styx)--LB	4,400
	Hog Slough (from head at rm 40.0 to mouth on Swift Slough)--LB	8,060
	unnamed stream--rm 30.12--RB	1,740
	Shepard Slough (from approx 14,600 ft upstream of mouth on Kennedy Creek to approx 18,100 ft upstream)--LB	3,480
	unnamed stream--rm 25.9--RB	210
	Maddox Slough (fr[illegible]prox 1,300 downstream of head at Chip53,600 to conf with Tom Smith Branch)--RBC[7]	6,740
	2 unnamed tribs o[illegible]e R (mouths 1,200 and 1,900 ft upstream of mouth of White R at Chip49,900)--LBC[7]	1,460
	Tom Smith Branch (from conf with Roberts Slough to floodplain edge)--RBC[7]	8,010
	unnamed stream--Chip39,800--LBC[7]	1,230
	Virginia Cut (from 12,790 ft upstream of mouth at Chip37,300 to head approx 24,390 ft upstream) inc 1 trib--LBC[7]	13,190
	unnamed stream--Chip37,250--LBC[7]	1,470
	unnamed stream--Chip26,800--LBC	1,250
	unnamed stream--Chip26,700--LBC[7]	1,560
10,000	Subtotal	82,610
11,000	Blue Spring run and spring (before restoration)--rm 98.0--RB[6]	1,880
	Johnson Creek (from 1,810 ft upstream of mouth at rm 93.9 to 2,530 ft)--RB	720
	Beaverdam Creek--rm 84.5--LB	7,960
	Bayou (from US Highway 20 to 18,790 ft upstream of mouth on Sutton Lake) inc Stafford Creek--RB	20,370
	unnamed trib of Dead R (mouth approx. 3,400 ft from mouth of Dead R at rm 71.4)--LB	1,870
	Outside Lake (from approx 9,000 ft upstream of mouth at rm 63.9 to 17,700 ft upstream) inc Johnson Mill Creek--LB	11,010

Flow at Chatta-hoochee gage[1], in ft³/s	Streams and lakes connected at or above and isolated below given flow value[2] Name (description of connected reach) and location[4]	Length[5], in ft
11,000	unnamed slu to Muscogee Lake (from mouth at rm 60.2 to 1,940 ft upstream)--LB	1,940
	Middle Slough (from 1,900 ft upstream of mouth on Iamonia Lake to Bee Tree Slu)--RB	7,090
	unnamed slu to Miller Lake--rm 57.9--LB	3,080
	Mary Slough (from 1,210 ft upstream of mouth on Iamonia Lake to 2,420 ft)--rm 55.8--RB	1,210
	unnamed slu to Queen City Lake--rm 51.4--RB	1,160
	unnamed stream--rm 48.4--LB	1,450
	unnamed trib of Porter Lake--rm 48.2--RB	1,850
	unnamed trib of Florida R (mouth approx 100 ft upstream of mouth of Florida R at rm 43.2)--LB	2,690
	unnamed trib of Florida R (mouth approx 12,400 ft upstream of mouth of Florida R at rm 43.2)--LB	1,200
	unnamed trib of Florida R (mouth approx 16,400 ft upstream of mouth of Florida R at rm 43.2)--LB	5,540
	unnamed trib of Florida R (mouth approx 16,600 ft upstream of mouth of Florida R at rm 43.2)--LB	860
	unnamed trib of loop of Florida R (mouth approx 2,400 ft from upstream end of loop at 3,500 ft upstream of mouth of Florida R at rm 43.2)--LB	4,050
	Everett Slough (from head on Larkin Slu 2,800 ft upstream of mouth of Larkin Slu on Florida R to 6,910 ft downstream)--LB	6,910
	Grayson Slough (from mouth on Swift Slough to 2,300 ft upstream)--LB	2,300
	R Styx (from approx 20,200 ft upstream of mouth at rm 35.3 to 22,500 ft upstream)--LB	2,300
	unnamed trib of Dead R (mouth approx 3,600 ft upstream of mouth of Dead R on R Styx)--LB	860
	unnamed stream--rm 30.65--RB	790
	Shepard Slough (from approx 18,100 ft upstream of mouth on Kennedy Creek to approx 21,520 ft upstream)--LB	3,420
	2 unnamed tribs of White R (mouths 200 and 1,300 ft upsteam of mouth of White R at Chip49,900)--LBC[7]	2,070
	unnamed stream--Chip33,000--RBC[7]	1,380
11,000	Subtotal	95,960
12,000	unnamed trib of Blue Spring run--RB[6]	290
	trib of unnamed stream at rm 88.5 -- LB	310
	Kelley Branch (from mouth at rm 81.4 to 350 ft upstream)--LB	350
	unnamed stream--rm 69.6--RB	1,840
	Outside Lake (from approx 17,700 ft upstream of mouth to north end) inc 5 tribs and Landy Lake)--rm 63.9--LB	29,880
	unnamed trib of McDougal Lake--rm 55.8--RB	1,340
	Honey Pond and slu connecting to Iamonia Lake--rm 55.8--RB	3,890
	unnamed stream--rm 55.0--RB	6,800
	unnamed stream--rm 54.2--LB	2,350
	2 unnamed tribs of cutoff at rm 50.7--RB	4,060
	Finns Slough--LB	7,540
	Florida R (from approx 26,000 ft upstream of mouth at rm 43.2 to 39,800 ft upstream) inc Bill's Arm and 2 tribs--LB	25,060

Flow at Chatta-hoochee gage[1], in ft³/s	Streams and lakes connected at or above and isolated below given flow value[2] Name (description of connected reach) and location[4]	Length[5], in ft
12,000	Everett Slough (from mouth on Swift Slough to 4,430 ft upstream)--LB	4,430
	unnamed stream--rm 39.9--LB	1,070
	unnamed stream--rm 27.2--RB	1,450
	Shepard Slough (from approx 21,520 ft upstream of mouth on Kennedy Creek to 25,050 ft upstream) inc 1 trib--LB	7,410
	unnamed stream inc 1 trib--rm 22.8--RB	3,830
	unnamed stream--Chip48,200--LBC[7]	1,100
	unnamed stream--Chip46,400--LBC[7]	2,620
	unnamed stream inc alternate mouth at Chip34,600--Chip35,200--RBC[7]	3,770
	unnamed trib of unnamed trib of Douglas Slough (mouth 800 ft upstream of mouth of unnamed trib with mouth 1,400 ft upstream of mouth of Douglas Slough at Chip8,200)--LBC	890
12,000	Subtotal	110,280
13,000	unnamed trib of Dead R (located approx 4,700 ft from mouth of Dead R at rm 71.4)--LB	4,890
	Woods Slu (from conf with Bee Tree Slu to approx 4,790 ft upstream)--RB	4,790
	unnamed stream--rm 60.9--RB	1,490
	Mary Slough (first 1,210 ft from rm 58.7 going towards Iamonia Lake)--RB	1,210
	unnamed trib of Rudy Slough--RB	1,170
	unnamed stream--rm 53.3--RB	3,680
	Dog Slough (from approx 890 ft upstream of mouth on Florida R to south end of Greenback Lake)--LB	7,760
	unnamed stream--rm 49.9--LB	1,000
	unnamed stream--rm 47.3--LB	1,850
	R Styx (from approx 22,500 ft upstream of mouth at rm 35.3 to 25,900 ft upstream)--LB	3,400
	unnamed trib of R Styx (from 3,480 ft downstream of head located 9,300 ft upstream of mouth of R Styx to conf with Shepard Slough 700 ft downstream)--LB	700
	unnamed stream--rm 35.1--LB	2,490
	unnamed stream--rm 30.7--LB	2,010
	unnamed stream--rm 27.7--LB	700
	Shepard Slough (from approx 25,050 ft upstream of mouth on Kennedy Creek to conf with 2 tribs of R Styx 27,830 ft upstream) inc 2 tribs--LB	9,270
	unnamed stream--rm 22.15--RB	500
	unnamed stream--Chip75,800--RBC	380
	unnamed stream--Chip30,400--RBC	1,240
	unnamed stream--Chip32,900--LBC	1,100
	unnamed stream--Chip5,800--RBC	770
	unnamed stream--Chip5,000--RBC	1,600
13,000	Subtotal	52,000

Flow at Chatta-hoochee gage[1], in ft³/s	Streams and lakes connected at or above and isolated below given flow value[2]	
	Name (description of connected reach) and location[4]	Length[5], in ft
14,000	Johnson Creek (from 2,530 ft upstream of mouth at rm 93.9 to 3,240 ft)--RB	710
	unnamed stream--rm 62.0--LB	510
	unnamed tribs of McDougal Lake and Iamonia Lake--RB	6,560
	Muscogee Lake--LB	590
	Miller Lake--LB	660
	unnamed stream--rm 56.2--LB	440
	unnamed trib of Honey Pond--RB	2,020
	unnamed stream--rm 55.6--LB	1,150
	unnamed stream--rm 55.4--RB	640
	unnamed stream--rm 53.4--RB	1,970
	Queen City Lake and smaller pond--LB	440
	unnamed stream-rm 47.1--LB	1,240
	Florida R (from approx 39,800 ft upstream of mouth at rm 43.2 to Equaloxic Creek) inc part of Larkin Slu (from approx 6,200 ft upstream of downstream mouth on Florida R to reconnection with Florida R), Gregory Mill Creek, and 4 tribs--rm 43.2--LB	24,380
	unnamed trib of Larkin Slu (mouth approx 1,700 ft upstream of mouth of Larkin Slu on Florida R)--LB	960
	Grayson Slough (from 2,300 ft upstream of mouth on Swift Slough to approx 5,100 ft upstream) inc Greenback Lake and part of Silver Lake--LB	2,800
	unnamed stream connecting Grayson and Everett Sloughs--LB	3,300
	Everett Slough (from 4,420 ft upstream of mouth on Swift Slough to 11,060 ft upstream)--LB	6,640
	unnamed stream (from head 3,800 ft upstream of mouth of R Styx to 2,270 ft downstream)--LB	2,270
	2 unnamed tribs of R Styx (from 100 ft upstream of their mouths at 5,600 and 7,000 ft upstream of mouth of R Styx to ends)--LB	1,200
	unnamed stream (from head 9,300 ft upstream of mouth of R Styx to 3,480 ft downstream)--LB	3,480
	unnamed stream inc 1 trib--rm 34.75--LB	4,100
	unnamed stream connected by 2 mouths--rm 33.7 and rm 33.62--LB	3,110
	unnamed stream--rm 32.15--LB	1,810
	Kennedy Slough (from mouth 1,400 ft upstream of mouth of Kennedy Creek to 470 ft upstream)--LB	470
	unnamed stream--rm 25.4--RB	1,060
	2 unnamed tribs of Virginia Cut (mouths 11,800 and 14,300 ft upstream of mouth of Virginia Cut at Chip37,300)--LBC[7]	11,480
	unnamed stream--Chip34,400--RBC	720
	unnamed stream--Chip6,700--RBC	890
	unnamed trib of Spider Cut (mouth approx 800 ft downstream of mouth of Spider Cut at Chip2,400)--RBC	1,570
14,000	Subtotal	87,170

Flow at Chatta-hoochee gage[1], in ft³/s	Streams and lakes connected at or above and isolated below given flow value[2]	
	Name (description of connected reach) and location[4]	Length[5], in ft
15,000	unnamed stream (from mouth at rm103.6 to 890 ft upstream) --LB	890
	unnamed stream--rm 98.9--LB[6]	470
	unnamed stream--rm 90.3--LB	250
	Old R (from north end of Baker Branch to rm 72.9)--RB	8,520
	James Slough and Dirt Bridge Slu--RB	15,110
	unnamed stream--rm 62.8--RB	4,860
	Dog Slough (from rm 50.15 to south end of split channel) --LB	8,450
	unnamed stream--rm 49.2--RB	2,190
	Greenback Lake on Dog Slough--LB	2,790
	unnamed trib of Hog Slough (mouth approx 900 ft upstream of mouth of Hog Slough on Swift Slough)--LB	1,400
	unnamed trib of Moccasin Slough (mouth approx 1,400 ft upstream of mouth of Moccasin Slough on R Styx)--LB	910
	Dead R (from approx 3,400 ft upstream of mouth on R Styx to end on Swift Slough)--LB	5,910
	unnamed stream (from head 3,800 ft upstream of mouth of R Styx to 2,270 ft downstream)--LB	2,270
	unnamed trib of R Styx (mouth 4,200 ft upstream of mouth of R Styx)--LB	410
	unnamed stream (from head 9,300 ft upstream of mouth of R Styx to 3,480 ft downstream)--LB	3,480
	unnamed trib of R Styx (mouth 23,400 ft upstream of mouth of R Styx)--LB	70
	unnamed stream--rm 39.3--RB	1,430
	unnamed stream--rm 31.2--RB	1,920
	unnamed stream--rm 26.4--RB	1,210
15,000	Subtotal	62,540
16,000	unnamed stream--rm 64.9--LB	1,210
	unnamed stream--rm 59.9--LB	880
	unnamed stream--rm 59.5--RB	1,520
	unnamed stream--rm 57.5--RB	4,690
	unnamed stream--rm 53.6--LB	910
	unnamed stream--rm 52.8--LB	1,420
	unnamed stream--rm 51.2--RB	770
	unnamed stream--rm 47.31--RB	1,210
	2 unnamed tribs of Outside Lake (at approx 14,200 and 17,300 ft upstream of mouth at rm 43.2)--LB	3,380
	unnamed stream--rm 41.9--RB	2,830
	unnamed trib of Florida R (mouth approx 22,100 ft upstream of mouth of Florida R at rm 43.2)--LB	6,630
	unnamed trib of Larking Slu (mouth 400 ft upstream of mouth of Larkin Slu on Florida R)--LB	600
	Everett Slough (from approx 10,840 ft upstream of mouth on Swift Slough to 13,980 ft)--LB	3,140

Flow at Chattahoochee gage[1], in ft^3/s	Streams and lakes connected at or above and isolated below given flow value[2] Name (description of connected reach) and location[4]	Length[5], in ft
16,000	Grayson Slough (from approx 5,100 ft upstream of mouth on Swift Creek to 9,110 ft upstream)--LB	4,010
	unnamed stream connecting Grayson Slough to Everett Slough--LB	5,990
	unnamed trib of R Styx (mouth approx 4,600 ft upstream of mouth of R Styx at rm 35.3)--LB	740
	unnamed trib of Dead R (mouth approx 3,500 ft upstream of mouth of Dead R on R Styx)--LB	350
	unnamed stream--rm 41.1--RB	1,020
	unnamed stream--rm 41.08--RB	1,670
	unnamed stream--rm 31.8--RB	1,400
	unnamed stream--rm 22.3--RB	1,550
	unnamed stream--Chip67,200--LBC	1,350
	unnamed trib of White R (mouth 8,000 ft upstream of mouth of White R at Chip49,900)--LBC	1,060
16,000	Subtotal	48,330
17,000	Kelley Branch (from approx 350 ft upstream of mouth at rm 81.4 to 1,020 ft)--LB	670
	unnamed stream--rm 73.2--LB	870
	Gin House Lake--rm 71.0--RBL	1,190
	unnamed streams at rm 66.3 and rm 66.25--RB	2,900
	unnamed stream--rm 62.6--RB	3,720
	unnamed slu to Muscogee Lake (from approx 1,940 ft upstream of mouth at rm 60.2 to Acorn Lake)--LB	1,940
	unnamed stream--rm 31.1--LB	1,190
	unnamed stream--Chip72,000--LBC	1,060
	unnamed stream--Chip68,600--LBC	770
	unnamed stream--Chip27,700--RBC	850
17,000	Subtotal	15,160
18,000	unnamed stream (from 890 ft upstream of mouth at rm 103.6 to 1,770 ft)--LB	880
	Johnson Creek (from 3,240 ft upstream of mouth at rm 93.9 to floodplain boundary), secondary channel starting 3,200 ft upstream of mouth, inc 1 trib--RB	15,310
	2 tribs of Bayou (from their mouths on Bayou to 1,410 and 1,150 ft upstream)--rm 79.1--RB	2560
	3 unnamed tribs of Middle Slu--RB	8,750
	unnamed stream--rm 54.3--LB	1,270
	unnamed stream--rm52.7--LB	3,120
	unnamed stream--rm 52.1--RB	2,310
	Acorn Lake (connected to Florida R approx 23,000 ft upstream of mouth)--LB	830
	Alligator Creek (mouth approx 4,800 ft upstream of mouth of Everett Slough on Swift Creek)--LB	10,490
	R Styx (from approx 25,900 ft upstream of mouth at rm 35.3 to 32,900 ft upstream)--LB	7,000
	unnamed stream--rm 41.4--RB	900

Flow at Chatta-hoochee gage[1], in ft^3/s	Streams and lakes connected at or above and isolated below given flow value[2] Name (description of connected reach) and location[4]	Length[5], in ft
18,000	unnamed stream--rm 34.1--RB	3,170
	unnamed stream at Double Points--rm 31.4--LB	1,250
	unnamed stream--rm 28.25--LB	640
	unnamed stream--rm 27.3--RB	1,240
	unnamed stream--Chip4,800--RBC	570
18,000	Subtotal	60,290
19,000	unnamed stream--rm 75.2--LB	1,390
	Acorn Lake (connected to Muscogee Lake)--LB	320
	unnamed stream--rm 52.6--LB	750
	Dog Slough (from north end of Greenback Lake to south end of split channel)--LB	6,370
	unnamed stream--rm 44.7--LB	9,100
	Elsie Lake, unnamed lake, and connected tribs of Florida R--LB	19,390
	Everett Slough (from 6,910 ft downstream of head on Larkin Slu to 10,360 ft downstream)--LB	3,450
	unnamed trib of R Styx (mouth 25,700 ft upstream of mouth of R Styx at rm 35.3)--LB	310
	unnamed trib of Moccasin Slough (mouth 3,100 ft upstream of mouth of Moccasin Slough on R Styx)--LB	220
19,000	Subtotal	41,300
TOTAL	318 entries (a single entry represents a single stream, one of a number of partial reaches of a long stream, or multiple streams and lakes)	230 miles

[1] Flows at which streams are connected were determined from lagged Chattahoocheee flows at the time of field observations.

[2] The accuracy of these estimates is greatest for the intensive study sites (Flat Creek, Johnson Creek, Iamonia Lake system, River Styx system) because those areas were visited many times under a variety of hydrologic conditions. Estimates on most other streams were based on one-time field observations, and those estimates should be used as an approximate guide.

[3] Most of the streams and lakes listed for 4,000 ft^3/s have deep connections to the main river channel and have not been isolated at any time from 1922 to 1995.

[4] Order of streams and lakes is from most upstream location to most downstream in river floodplain. Location within river reach is indicated by colors: beige, upper river; light green, middle river; dark green, lower river. Additional description of location is given for features not named on USGS 7.5 minute quadrangle maps and named features when necessary.

[5] Actual stream lengths may be longer than shown. In most cases, they are derived from lengths that appear on USGS quadrangle maps or infrared aerial photography, whichever is longer.

[6] These streams on the Apalachicola River were not measured to determine the depth of the connection. An estimate of connection depth was made based on the size of the stream, stream velocity, connecting streams, characteristics of drainage basin on aerial photos and maps, and other relevant field observations.

[7] These streams on the lower Chipola were observed to be connected to the main channel when flow at Chattahoochee was approximately 14,500 ft^3/s, but were not measured to determine the depth of that connection. In each case, an estimate of connection depth was made based on field observations of stream size and velocity and characteristics of connecting streams and drainage basin on aerial photos and maps. In some cases the entry includes a combination of measured and unmeasured streams.

Appendix III.-- Average flows preceding and during 16 navigation windows in the Apalachicola River, 1990-95

[Data shown in green for the period October 23-November 24, 1990, is used as an example in the text and table 10. Dates and flows for all periods were determined from daily mean flows at the Chattahoochee gage. ft^3/s, cubic feet per second; na; not applicable because transition period was too short to be reflected in daily mean flows; nd, not determined]

Pre-window (water storage period)			Transition (period of increasing flow)			Corresponding window (water release period)			Average flow for total period[1], in ft^3/s
Dates	Number of days	Average flow, in ft^3/s	Dates	Number of days	Average flow, in ft^3/s	Dates	Number of days	Average flow, in ft^3/s	
Sept 25-Oct 13, 1990	19	6,930	Oct 14, 1990	1	9,450	Oct 15-20, 1990	6	12,300	8,270
Oct 23-Nov 10, 1990	19	5,900	Nov 11, 1990	1	8,110	Nov 12-24, 1990	13	12,900	8,720
Nov 26-Dec 11, 1990	15	6,690	Dec 12, 1990	1	10,200	Dec 13-24, 1990	12	13,400	9,680
Dec 27, 1990-Jan 8, 1991	13	7,370	Jan 9-10, 1991	2	10,800	Jan 11-22, 1991	12	16,300	11,600
Oct 28-Nov 18, 1991	22	7,620	na	0	0	Nov 19-29, 1991	11	13,500	9,570
May 10-24, 1992	15	9,520	May 25, 1992	1	12,600	May 26-June 6, 1992	12	13,500	11,300
June 15-July 1, 1993	17	9,440	July 2-3, 1993	2	11,600	July 4-14, 1993	11	15,400	11,800
July 16-Aug 6, 1993	22	9,490	Aug 7, 1993	2	11,500	Aug 8-21, 1993	14	14,000	11,300
Aug 26-Sep 6, 1993	12	6,560	Sep 7, 1993	2	7,450	Sep 8-22, 1993	15	12,200	9,630
Sep 25-Oct 10, 1993	16	6,670	Oct 11-12, 1993	2	10,900	Oct 13-24, 1993	12	12,100	9,110
Nov 17-26, 1993	10	9,040	Nov 27, 1993	1	11,700	Nov 28-Dec 9, 1993	12	14,900	12,200
May 23-31, 1994	9	9,970	na	0	0	June 1-12, 1994	12	17,500	14,300
May 24-29, 1995	6	9,970	na	0	0	May 30-June 15, 1995	17	19,200	16,800
June 20-July 4, 1995	15	8,590	July 5, 1995	1	13,600	July 6-17, 1995	12	15,600	11,800
July 20-Aug 5, 1995	17	8,620	Aug 6, 1995	1	9,950	Aug 7-22, 1995	16	14,400	11,400
Aug 25-Sep 8, 1995	15	7,790	Sep 9, 1995	1	10,100	Sep 10-20, 1995	11	14,100	10,400
			AVERAGES FOR ALL PERIODS[2]						
	15	8,000		1	nd		12	14,600	11,000

[1] Total period is pre-window, transition, and window periods combined.

[2] Average flows for all periods were determined by multiplying the average flow for each period by the number of days in the period, adding the products together for all periods, and dividing the sum by the total number of days for all periods.