HYDROLOGY AND ECOLOGY OF THE APALACHICOLA RIVER, FLORIDA: A SUMMARY OF THE RIVER QUALITY ASSESSMENT

River Quality Assessment of the Apalachicola River Basin, Florida

United States Geological Survey Water-Supply Paper 2196–D

COVER PHOTOGRAPH:

The Landsat image on the cover shows the extent of the flood plain in the Apalachicola River basin, Florida. The dark color of the flood plain is caused by low reflectance from floodwaters. The river (600 feet wide) is barely visible in the center of the flood plain (1-6 miles wide). The Apalachicola River flows from Lake Seminole (at the top), 106 miles south, to Apalachicola Bay (near the bottom of the scene). The numerous white squares near the top of the scene are agricultural fields in Florida and Alabama. The large red area east of the river is a pine forest (Apalachicola National Forest). The faint brown color on the bird's-foot delta at the river mouth depicts marsh grass. The light blue colors near the beaches at the bottom of the scene represent a combination of shallow water and ocean currents that carry high suspended sediment loads.

The false-color composite was obtained on February 6, 1977, by a Landsat multispectral scanner and includes bands 4, 5, and 7. The scene ID is 2746-15190, and more information on this and other satellite images is available through the U.S. Geological Survey, EROS Data Center, Sioux Falls, SD 57101.

Chapter D

HYDROLOGY AND ECOLOGY OF THE APALACHICOLA RIVER, FLORIDA: A SUMMARY OF THE RIVER QUALITY ASSESSMENT

By JOHN F. ELDER, SHERRON D. FLAGG, and HAROLD C. MATTRAW, JR.

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Apalachicola River Quality Assessment

DEPARTMENT OF THE INTERIOR
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PREFACE

The Apalachicola River Quality Assessment was part of a national river quality assessment program of the U.S. Geological Survey. The authors would like to thank the members of the Subcommittee on River Quality Assessment of the Advisory Committee on Water Data for Public Use for their interest and support.

[1]Chairman
[2]Vice Chairman

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By **John F. Elder, Sherron D. Flagg,**
and **Harold C. Mattraw, Jr.**

ABSTRACT

During 1979-81, the U.S. Geological Survey conducted a large-scale study of the Apalachicola River in northwest Florida, the largest and one of the most economically important rivers in the State. Termed the Apalachicola River Quality Assessment, the study emphasized interrelations among hydrodynamics, the flood-plain forest, and the nutrient-detritus flow through the river system to the estuary. This report summarizes major findings of the study. Data on accumulation of toxic substances in sediments and benthic organisms in the river were also collected.

Because of the multiple uses of the Apalachicola River system, there are many difficult management decisions. The river is a waterway for shipping; hence there is an economic incentive for modification to facilitate movement of barge traffic. Such modifications include the proposed construction of dams, levees, bend easings, and training dikes; ditching and draining in the flood plain; and dredging and snagging in the river channel. The river is also recognized as an important supplier of detritus, nutrients, and freshwater to the Apalachicola Bay, which maintains an economically important shellfish industry. The importance of this input to the bay creates an incentive to keep the river basin in a natural state. Other values, such as timber harvesting, recreation, sport hunting, nature appreciation, and wildlife habitat, add even more to the difficulty of selecting management strategies.

Water and nutrient budgets based on data collected during the river assessment study indicate the relative importance of various inputs and outflows in the system. Waterflow is controlled primarily by rainfall in upstream watersheds and is not greatly affected by local precipitation, ground-water exchanges, or evapotranspiration in the basin. On an annual basis, the total nutrient inflow to the system is nearly equal in quantity to total outflow, but there is a difference between inflow and outflow in the chemical and physical forms in which the nutrients are carried. The flood plain tends to be a net importer of soluble inorganic nutrients and a net exporter of particulate organic material.

Analysis of long-term records shows that dam construction in the upstream watersheds and at the Apalachicola headwaters has had little effect on the total annual waterflow but has probably suppressed low-flow extremes. Other effects include riverbed degradation and channelization which have to do with alteration of the habitat for aquatic biota and changes in flood-plain vegetation.

Whatever management decisions are made should take into account the impact on the natural flooding cycle. Flooding is crucial to the present flood-plain plant community and to the production, decomposition, and transport of organic material from that community. Permanent, substantial changes in the natural flooding cycle would be likely to induce concomitant changes in the flood-plain environment and in the nutrient and detritus yield to the estuary.

1.0 BACKGROUND

1.1 Basin Characteristics

The Apalachicola River, the largest river in Florida, flows 106 miles through the northwest Florida Panhandle and empties into the Apalachicola Bay in the Gulf of Mexico (fig. 1.1). Its upstream limit is the Jim Woodruff Dam, 1 mile downstream of the confluence of the Chattahoochee and Flint Rivers. Lake Seminole, the 37,600-acre reservoir impounded by the dam, provides the headwater inflow to the Apalachicola River, but there are no other dams on the river. The Chattahoochee flows about 430 miles from its source in north Georgia to Lake Seminole at the Florida-Georgia State line. The Flint River originates south of Atlanta, Ga., and flows about 370 miles before it joins the Chattahoochee River.

The major tributary to the Apalachicola is the Chipola River. At the time of the Apalachicola River Quality Assessment, the Chipola River was constrained by a weir near Wewahitchka, Fla., to form a pool called Dead Lake. The control gates were removed in 1984 (although the weir remains), allowing the pool to drain to preweir levels. Immediately downstream of the weir, the Chipola is joined by water from the Apalachicola River flowing through the Chipola Cutoff distributary. These waters rejoin the main stem of the Apalachicola 13 miles downstream.

The Brickyard Cutoff, a distributary channel, is located near Sumatra, Fla., at Brickyard Landing and conveys water from the Apalachicola River to the Brothers River. The Brothers River rejoins the Apalachicola 8 miles south of the Brickyard Cutoff. The Apalachicola River then flows 6 miles south, where it connects to the Jackson River and flows southeast into Apalachicola Bay, one of the most productive shellfish areas in the United States.

The entire Apalachicola-Chattahoochee-Flint River drainage basin is 19,600 mi^2 in area and encompasses parts of Georgia, Alabama, and Florida. The part below the dam, which drains directly into the Apalachicola River, has an area of 2,400 mi^2, half of which is the Chipola River subbasin.

Each winter and spring the rising waters of the Apalachicola flood the adjacent wetlands for 3-5 months. The flood plain occupies 175 mi^2 and broadens downstream from 1/2-mile wide just below Lake Seminole to more than 7 miles wide near the mouth. It is heavily forested with cypress, tupelo, and mixed hardwood trees, which thrive on the periodic inundation.

The mean annual flow of the Apalachicola River at its headwaters near Chattahoochee is 22,300 ft^3/s (1928-82). Low flows are generally about 10,000 ft^3/s, and high flows may exceed 100,000 ft^3/s. The flow increases by about 25 percent over the course of the river.

A geologic description of the area by Schnable and Goodell (1968) indicates that the river basin consists primarily of sediments of Holocene age with some late Pleistocene sediments near the mouth of the river. The riverbed is composed primarily of Pleistocene deposits consisting of sand and coarse gravel. Sands and clays have been deposited constantly over time and add to the natural high turbidity of the river. Flood-plain soil has a wide range of textures and colors because it is made up of a variety of sediments deposited under highly variable flow conditions. Near Blountstown and Wewahitchka, Fla., Leitman (1978) found flood-plain soils to be predominantly clay with some silty clay and occasionally clay loam. Sands on point bars were predominantly fine and very fine sands and were of the micaceous type, whereas most Florida sands are siliceous. Cation exchange capacity of flood-plain soils generally ranged from 20 to 50 meq/L, and organic concentration ranged from 1 to 20 percent (higher near the surface). These levels are higher than most Florida soils except peats and mucks. The pH of Apalachicola flood-plain soils ranges from 5.0 to 5.7 (Wharton and others, 1982).

Average annual rainfall in the Apalachicola River basin in Florida is 58 in (1941-70), and mean annual potential evapotranspiration is between 39 and 45 in (U.S. Department of Commerce, 1973). Average annual rainfall in the basin of the Chattahoochee and Flint Rivers in Georgia is 52 in. Georgia rainfall has a greater influence on Apalachicola River flows than does Florida rainfall because only 11 percent of the basin of the Apalachicola, Chattahoochee, and Flint Rivers is in Florida. However, flows in the lower river can be substantially increased by Florida rainfall.

Mean annual air temperature in the Apalachicola River basin in Florida is 66°F. Mean January air temperature is 52 °F, and mean July air temperature is 81 °F (U.S. Department of Commerce, 1973).

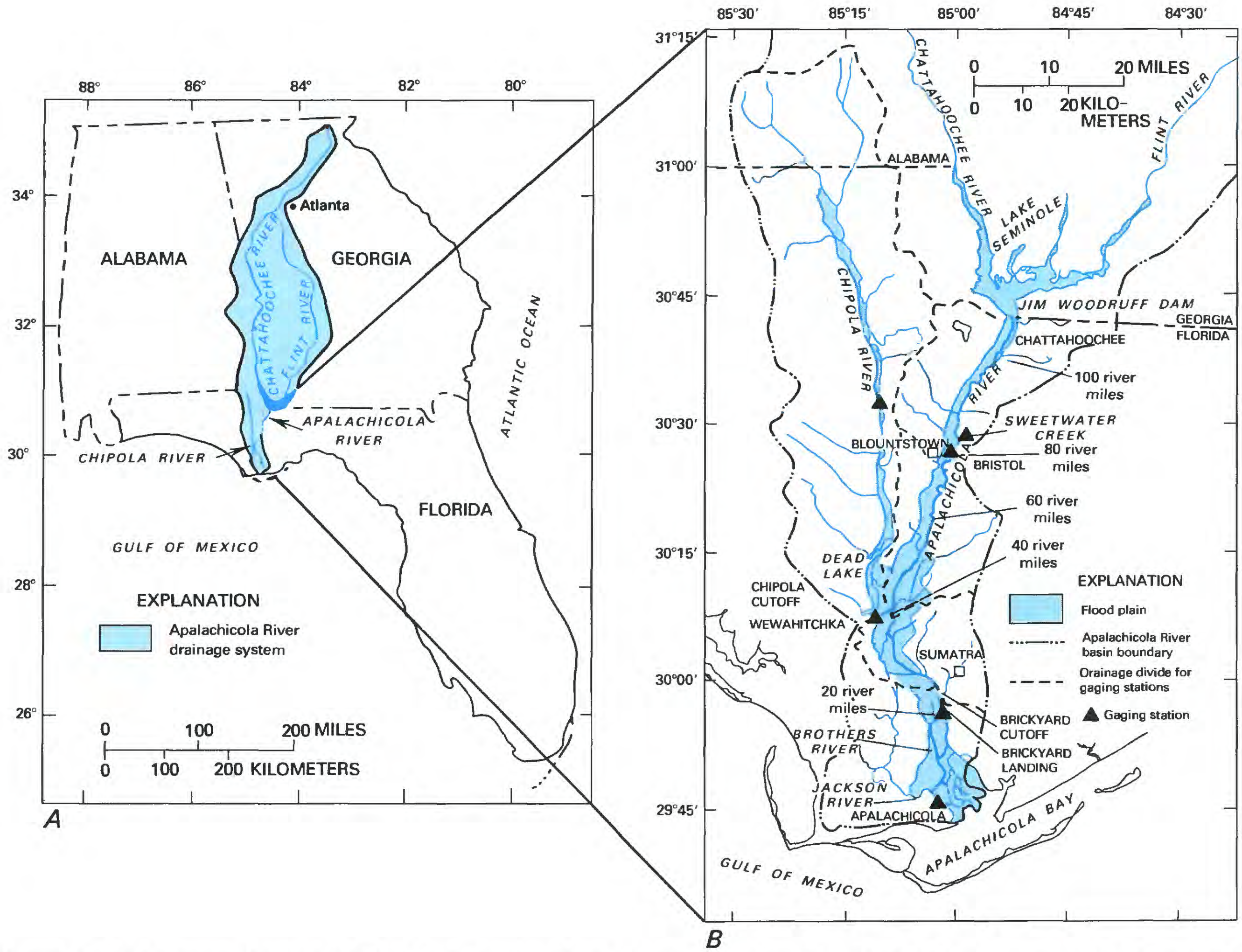


Figure 1.1. The drainage basins of (*A*) the Apalachicola, Chattahoochee, and Flint Rivers in Florida, Georgia, and Alabama and of (*B*) the Apalachicola and Chipola Rivers in Florida.

1.2 Basin History

The Jim Woodruff Dam (fig. 1.2*A*) was constructed by the U.S. Army Corps of Engineers. Construction began in 1950, and filling of the reservoir was accomplished in several stages from May 1954 to February 1957. The primary use of the dam is to improve navigation for barge traffic, with power generation as a secondary benefit. The U.S. Army Corps of Engineers is authorized to maintain a channel 100 ft wide and 9 ft deep. Dredging for the 9-ft depth began in 1956 in preparation of the completion of the Jim Woodruff Dam (Harry Peterson, U.S. Army Corps of Engineers, oral commun., 1980). Including the Jim Woodruff Dam, 16 dams are on the Apalachicola, Chattahoochee, and Flint Rivers (fig. 1.2*B*). Most of the dams were built by local or private organizations for power generation. The oldest dam, the Eagle and Phenix, was built in 1834. Most of the remaining small dams were built near the turn of the century.

The U.S. Army Corps of Engineers made four cutoffs (fig. 1.2*C*) in 1956-57 and three more in 1968-69 to straighten bends in the river that were particularly difficult for barges to navigate. Groins (dikes perpendicular to banks) were installed to improve navigability by creating scour in the channel area of the river (fig. 1.2*D*). There are 29 sets of groins, mostly in the upper river. Constructed of wooden pilings or stone, the groins were installed from 1963 to 1970 (Harry Peterson, U.S. Army Corps of Engineers, oral commun., 1980).

The major land use in the flood plain is forestry. Most areas were first cut between 1870 and 1925 (Clewell, 1977, p. 11) and have been logged once or twice since that time. Other extensive uses are beekeeping for tupelo honey production, commercial and sport fishing, and hunting. A few areas on the flood plain have been cleared for agriculture and residential developments. However, there are no large urban centers, and there is very little industrialization.

With the exception of a cattle ranch south of Wewahitchka, Fla., most of the flood plain in the lower reach of the river (south of river mile 20) is publicly owned. The State of Florida Environmentally Endangered Lands Program purchased 44 mi^2 of flood plain in 1977-78. According to Florida Statutes, land below the "ordinary high waterline" of the river is owned by the State. In addition, as of October 1984, the Apalachicola River was designated by the Florida Department of Environmental Regulation as an "Outstanding Florida Water" (OFW). This designation prohibits development which would significantly degrade water quality and applies to the entire river except for two reaches (near mile 103 and mile 77).

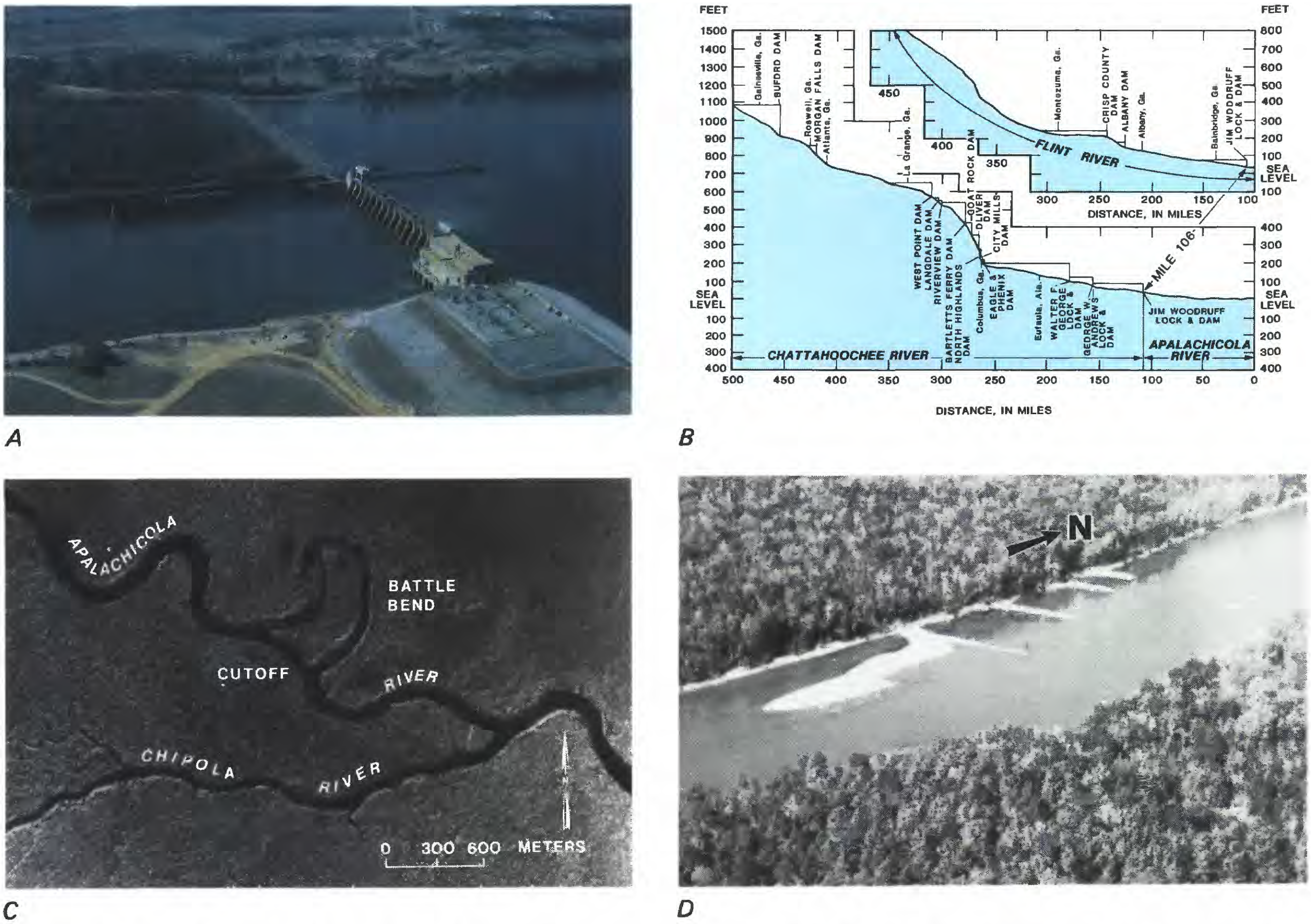


Figure 1.2. Controls on the Apalachicola River: (A) Jim Woodruff Lock and Dam, (*B*) altitudes of the 16 dams on the Apalachicola, Chattahoochee, and Flint Rivers, (C) cutoff of a meander on the Apalachicola River above its confluence with the Chipola River, and (*D*) river training dikes at mile 100 on the Apalachicola River.

1.3 Basin Management and Environmental Concerns

Questions about the most beneficial management strategies for the Apalachicola River result from the diverse values and possible uses of the system. Figure 1.3 shows separate uses and the likely management strategy employed for each use. Some uses call for mechanical or physical alteration of the natural system to maximize utility of the system for commercial benefit. Others benefit by limited intervention in the natural system. Examples of engineered controls are dredging, dam construction, channelization, clearcutting, and road construction. Examples of water utilization are irrigation, water consumption by industry, and discharge of municipal or industrial wastes to the river.

Shellfish harvesting in Apalachicola Bay is a multimillion-dollar industry that provides a major source of income and a way of life for residents of Franklin County, Fla. (Livingston and others, 1974; Prochaska and Mulkey, 1983). This resource could be threatened by disruption of the natural flow of river water and its constituents in the river system (Livingston and others, 1974). The other major use of the system which yields a high economic return is its use as a waterway for freight transport by barges. Barging is the most fuel-efficient means of freight transport (Eastman, 1980), but it requires continual maintenance and navigational improvements in the river channel. Multiple use creates the possibility of a dilemma in developing management strategy: how to enhance the function of the system as a resource of one type without damaging it as a resource of another type.

Besides shipping, uses which may result in some alterations in the natural system include agriculture, timber harvesting, and urban development of the basin. To date, such activities have occurred only on a very limited scale, and most of the basin remains in a relatively natural state. One purpose of the OFW designation is to maintain the natural state of the water system.

Benefits which could result from active utilization of the river basin resources include the possibility of a stimulus to the local economy due to income from agriculture and industry, increased employment, and recreational use of reservoirs which would be impounded by new dam construction. There would also be a probability of increased flood control and decreased impediment to mobility of barges and other large vessels. On the other hand, new problems would also be likely. Altered flooding patterns would probably eliminate large areas of the flood-plain forest and, in general, would decrease its productivity (Leitman and others, 1983). This would in turn have the probable effect of altering the nutrient, detritus, and sediment flows to the bay, resulting in structural changes in the estuarine community and impacting the shellfish industry. There would also be a likely decrease in the diversity of aquatic organisms in the freshwater system after channelization, scouring, and reservoir construction (Smalley and Novak, 1978). New reservoirs would inevitably bring new problems (such as algal blooms and aquatic weeds) that would require costly maintenance. Finally, there is the possibility of contamination by hazardous wastes that could result from the development of agriculture or industry in the basin.

The tradeoffs involved in management decisions may be synthesized in the following general statements:

> It is unlikely that humans, through accident or design, will produce altered systems that behave as efficiently as natural ones which represent the culmination of over 200 million years of evolution and at least 10,000 years of biological acclimatization. Much of the activity of the next decade will be spent attempting to undo environmental damage of the last century and, hopefully, implementing wise protection and management strategies for existing quality environments (Cummins and Spengler, 1978).

> There exists no reason to believe that the current ecological situation represents an unfortunate state that is incapable of improvement through conscientious, intelligent management.... Sound planning should be able to assure that the benefits derived from technology will continue to outweigh its disadvantages (Cairns, 1978).

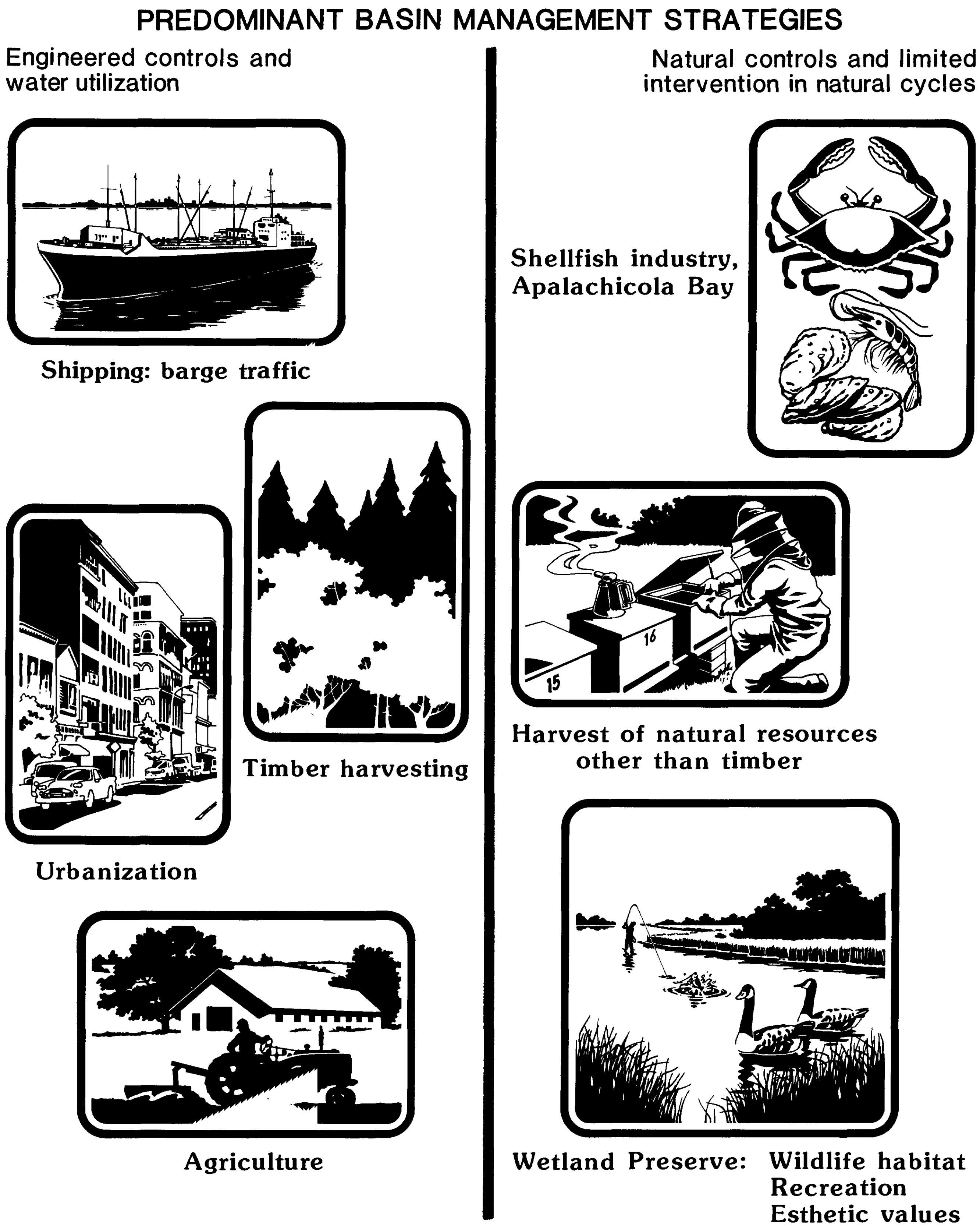


Figure 1.3. Basin uses and associated type of management in the Apalachicola River basin.

1.4 Information Needs

At the time of the initiation of the Apalachicola River Quality Assessment, relatively little was known about the processes controlling the flow of water, sediments, nutrients, or detritus in this large river-wetland system. These types of systems had not been a major focus of ecological study, partly because of the complexities of dealing with two interacting subsystems (river and wetland) and poor documentation of methods. In terms of available information, the Apalachicola River was a kind of missing link between the upstream and the downstream environments, both of which had been under study for several years. Upstream, heavy metals and pesticides were monitored in water, organisms, and sediments of Lake Seminole by the U.S. Army Corps of Engineers (1980). The study also included general hydrologic data about the reservoir and the Chattahoochee and Flint Rivers. Downstream, Apalachicola Bay had been the site of intensive investigation for many years by Livingston and others (1974).

Some of the important information needs for the Apalachicola River basin are outlined in figure 1.4. Information from the three main physiographic units of the basin—the upland areas, the flood plain, and the river—were all needed to understand functions of the system as a whole. Any type of budget estimates would also require information about flows into the Apalachicola system from the upstream watersheds and out of the system to the estuary.

The Apalachicola River Quality Assessment filled some of the information gap about the river basin. In particular, the study produced estimates for water and nutrient budgets, descriptions of hydrologic features of the river and wetland, an assessment of relations between hydrology of the wetland and the forest community, and the measurement of the extent of accumulation of potentially toxic substances in benthic organisms and bottom sediments. It also included some methods development for the collection of data from large rivers and forested wetlands. There is still much to be learned about the system, however, particularly with respect to the variability of water and nutrient budgets from year to year. Furthermore, very little work has been done to describe chemical and biological processes within the river water, flood-plain soils, and vegetation which affect the nutrient and toxicant chemistry of the river water and sediments. Continued fieldwork, supported by laboratory experiments, would be valuable in adding information important for understanding the contribution from the river and the wetlands to estuarine productivity.

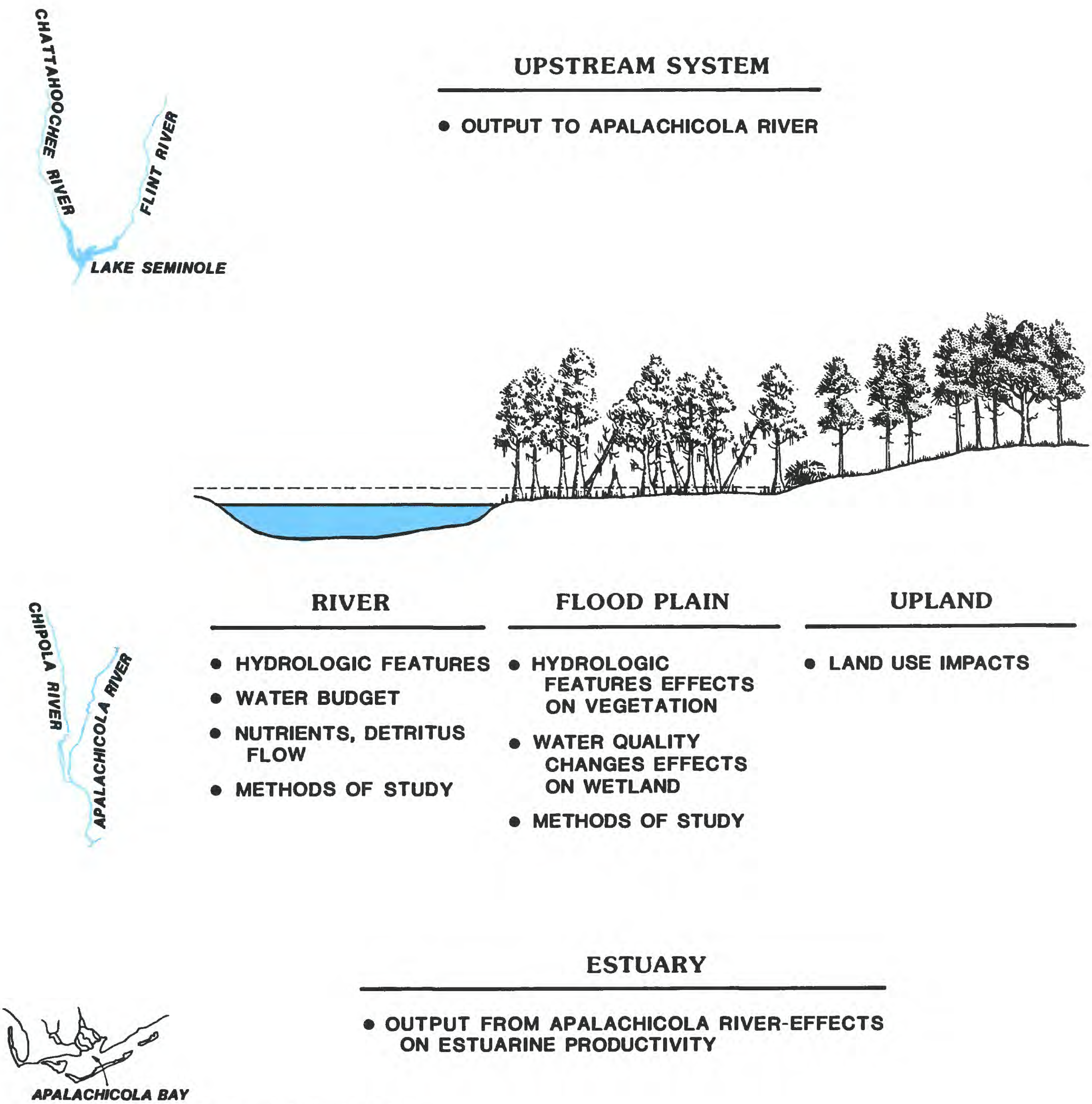


Figure 1.4. Information needs by basin unit.

2.0 APALACHICOLA RIVER QUALITY ASSESSMENT

2.1 Activities

In February 1979, the U.S. Geological Survey began data collection for a 2-year intensive investigation of the Apalachicola River and its associated wetland, a vast flood plain covered with a dense bottom-land hardwood forest. Data collection for the investigation, called the Apalachicola River Quality Assessment, continued until December 1980. Data analysis and interpretation followed, and a series of reports, each addressing a major objective of the study, was published. These reports were "Production and Decomposition of Forest Litter Fall on the Apalachicola River Flood Plain, Florida" (Elder and Cairns, 1982); "Wetland Hydrology and Tree Distribution of the Apalachicola River Flood Plain, Florida" (Leitman and others, 1983); and "Nutrient and Detritus Transport in the Apalachicola River, Florida" (Mattraw and Elder, 1984).

In addition to this report series, other publications focused on specific questions addressed in the investigation. These publications, listed in order of publication date, were "Nutrient Yield of the Apalachicola River Flood Plain, Florida: River-Quality Assessment Plan" (Mattraw and Elder, 1980); "Riverine Transport of Nutrients and Detritus to the Apalachicola Bay Estuary, Florida" (Elder and Mattraw, 1982); "Riverine Transport of Nutrients and Detritus to Apalachicola Bay" (Elder, 1983); "Accumulation of Trace Elements, Pesticides, and Polychlorinated Biphenyls in Sediments and the Clam *Corbicula manilensis* of the Apalachicola River, Florida" (Elder and Mattraw, 1984); "Forest Map and Hydrologic Conditions, Apalachicola River Flood Plain, Florida" (Leitman, 1984); and "Nitrogen and Phosphorus Speciation and Flux in a Large Florida River-Wetland System" (Elder, 1985).

A workshop in Tallahassee, Fla., in April 1982, provided an additional mode of information transfer from the Apalachicola River Quality Assessment. The workshop was cosponsored by the Northwest Florida Water Management District and the U.S. Geological Survey. It included participation by personnel from various local, State, and Federal agencies, local universities and colleges, and private organizations. Information presented at the workshop was collated in a workbook entitled "Apalachicola River Flood-Plain Processes in Nutrient Transport" and distributed to all participants.

This final Apalachicola River Quality Assessment report summarizes the principal results and conclusions of all of the elements of the investigation. The primary purpose of this report is to provide information that will aid those who are involved, either directly or indirectly, in implementing best management practices for the Apalachicola River basin. The rationale for selecting certain management practices may have transfer value to other similar systems in the Southeastern United States. In view of the many values and uses of the Apalachicola River system, some of which are illustrated in figure 2.1, it is clear that management decisions are not easy ones. The more they can be based on scientific knowledge, the more likely such decisions will be beneficial to the stability of the system and to users of this valuable natural resource.

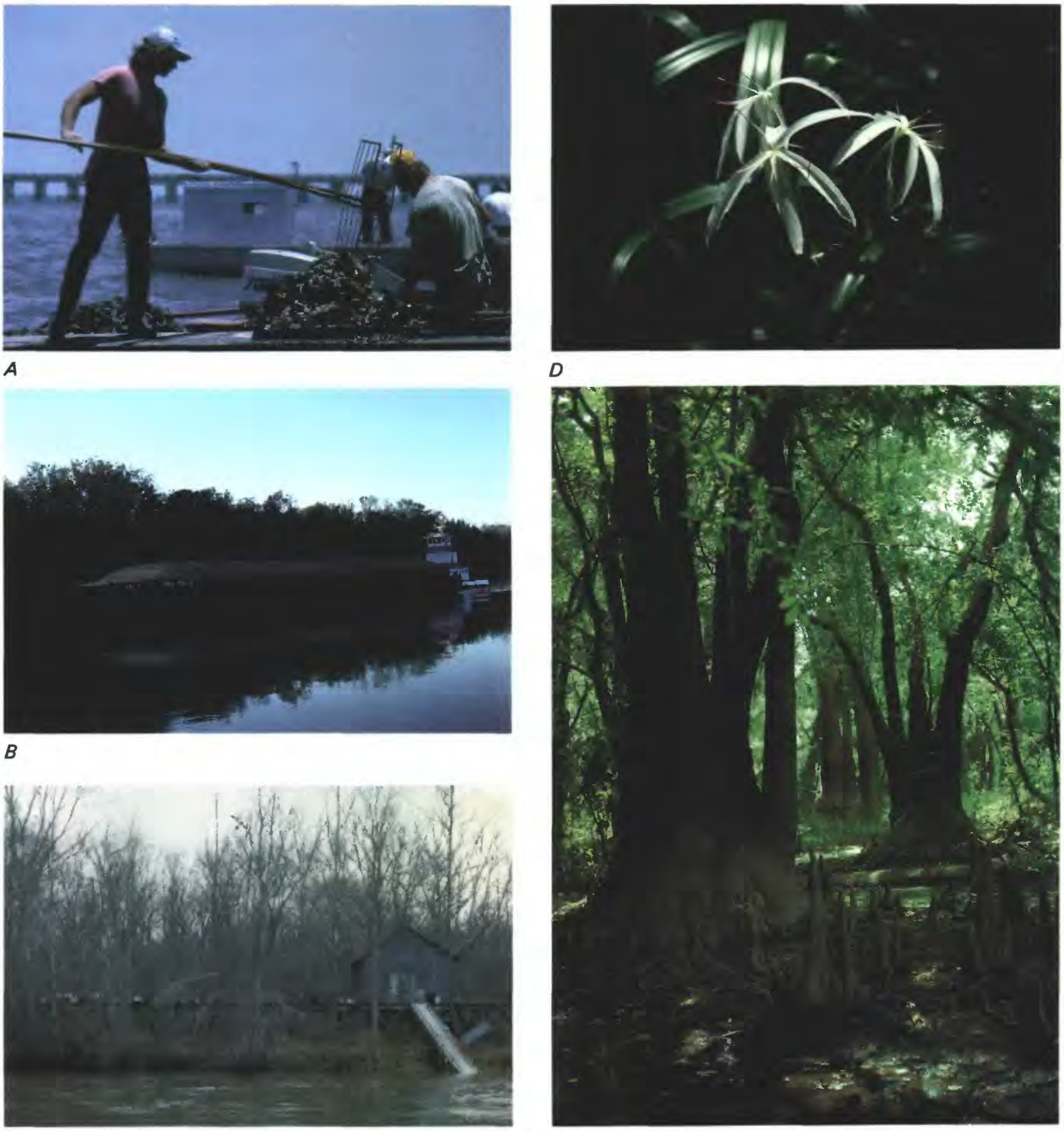


Figure 2.1. Examples of the different uses and values of the Apalachicola River system: (*A*) Oystering in Apalachicola Bay, (*B*) barging on the river, (*C*) beekeeping on the river bank, and (*D*) flood-plain vegetation: swamp lily and (*E*) flood plain forest: Ogeechee tupelos.

2.2 Objectives

The Apalachicola River Quality Assessment was one part of a national river-quality assessment program of the U.S. Geological Survey. The broad objectives of the national program were (1) to define the character, interrelations, and apparent causes of existing river-quality problems and (2) to devise and demonstrate the analytical approaches and the tools and methods that would provide a sound technical basis for planners and managers to use in assessing river-quality problems and evaluating management alternatives (Greeson, 1978).

The specific goals of the Apalachicola River Quality Assessment conformed to these broad program objectives with the modification that the investigation was process oriented rather than problem oriented. The Apalachicola River system supports largely undisturbed forested wetlands on the flood plain and highly productive estuaries at its mouth, the Apalachicola Bay. The overall purpose of this assessment was to investigate river-wetland relations and controlling factors that influence the yield of nutrients and detritus to the bay.

Specific objectives of the study are listed below.

1. To describe how tree distribution on the flood plain is related to the pattern of inundation (duration, level, and frequency).
2. To assess the importance of leaf production and decomposition on the flood plain to detritus and nutrient yields.
3. To identify major sources of nutrients to the river system and to quantify transport of nutrients and organic detritus in various parts of the system.
4. To determine the extent to which potentially toxic trace elements and organic substances accumulate in benthic organisms and sediments.

Figure 2.2 shows diagrammatically the interaction of basin characteristics and processes to produce nutrient and detritus outflow. The relations addressed by the first three objectives of the study are highlighted in red (objective 1), green (objective 2), and blue (objective 3). The fourth objective was quite distinct from the others in that it was not involved with processes that affect the export of nutrients and detritus to the bay. Unlike the rest of the study, this part was oriented more toward monitoring a particular problem or potential problem, and there was little focus on methods development.

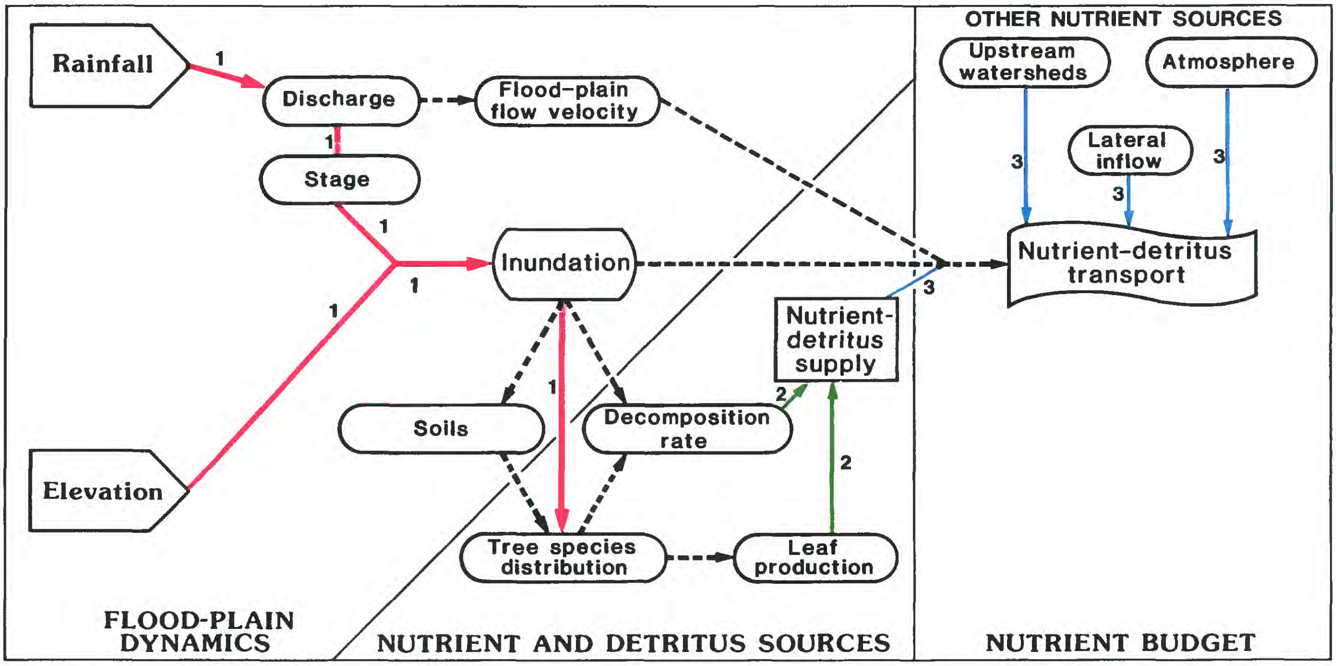


Figure 2.2. The interaction of basin characteristics and processes to produce nutrient and detritus outflow.

2.3 *Flood-Plain Forest*

The forested flood plain of the Apalachicola River, with an area of 175 mi^2, is the largest in Florida. Of the 211 different species of trees growing in the north Florida area, about 60 are found on the Apalachicola River flood plain. It is dominated by the general forest type, oak-gum-cypress, defined by the U.S. Forest Service as bottom-land forest in which 50 percent or more of the stand is tupelo, blackgum, sweetgum, oak, and cypress, singly or in combination (U.S. Forest Service, 1969, p. 9). The oak-gum-cypress type is very common on the flood plains of southeastern alluvial rivers; however, this general forest type has been divided into numerous specific types that various authors define differently from river to river.

Leitman and others (1983) identified 47 tree species in the Apalachicola flood plain. Baldcypress and two species of tupelo (water and Ogeechee) dominate the swamp areas of the flood plain. Together they account for over half of the relative basal area (percentage of the total cross-sectional stem area) of the entire flood-plain tree community. Other common species are Carolina ash, swamp tupelo, sweetgum, overcup oak, planertree, green ash, water hickory, sugarberry, diamond-leaf oak, American elm, and American hornbeam. The nomenclature follows Kurz and Godfrey (1962).

Leitman and others (1983) also defined five major forest types in the Apalachicola River flood plain and listed the composition of each in terms of relative basal area and density for each species. The types were defined on the basis of sampling results from eight transverse transects crossing the flood plain at approximately equally spaced intervals from Jim Woodruff Dam to Apalachicola Bay. The five types defined were type A (sweetgum-sugarberry-water oak); type B (water hickory-green ash-overcup oak-diamond-leaf oak); type C (water tupelo-Ogeechee tupelo-baldcypress); type D (water tupelo-swamp tupelo); and type E (water tupelo-baldcypress). Biomass increased downstream and was greatest with forest types C, D, and E.

Forest types A and B were lumped together (type AB) for mapping (Leitman, 1984) because their color infrared signatures were indistinguishable. Similarly, types D and E were lumped into a single type (DE). In addition, there were three minor forest types that were not sampled by Leitman and others (1983). These were pine (loblolly pine with scattered sweetgum, water oak, American hornbeam, and possumhaw); A/pine (sweetgum, sugarberry, water oak, and loblolly pine); and P (pioneer, dominated by black willow, in sandy soil along river margins). Type M is salt-marsh vegetation found only near the estuary, and type U is unidentified due to alteration by clearing, cultivation, or construction.

Water in the flood plain influences the distribution of trees because the availability of oxygen is severely restricted in saturated and inundated soils. Water-logging tolerance varies with species, environmental conditions, and season (Whitlow and Harris, 1979). Flooding during the dormant season has little or no effect because the oxygen requirements of plants are very low, but as little as 3 days of flooding during the growing season can affect seedlings of certain intolerant species such as yellow poplar (Southeastern Forest Experiment Station, 1958). Seedlings of many species can survive soil saturation without standing water for much longer periods than they can survive complete inundation (Hosner, 1960; Hosner and Boyce, 1962).

Flooding can also influence the many other factors that affect tree distribution, such as seed dispersal and germination, seed consumption by animals, type of soil, availability of nutrients, competition, temperature, salinity, fire, and man's activities. In general, types C, D, and E are commonly found in permanently saturated soils, whereas types A and B are not (Leitman and others, 1983).

Figure 2.3 shows how the relative proportion of cover types changes from upper to lower river. Type AB is the major type in the upper and middle river and decreases in importance downstream of Wewahitchka, nearly disappearing in the tidal reaches of the river from Sumatra to the mouth. The tupelo-dominated types, C and DE, are significant but minor in the upper and middle river and are dominant in the lower river. Marshes dominate the flood plain in the lower 10 miles of the river and are insignificant in the other 97 miles.

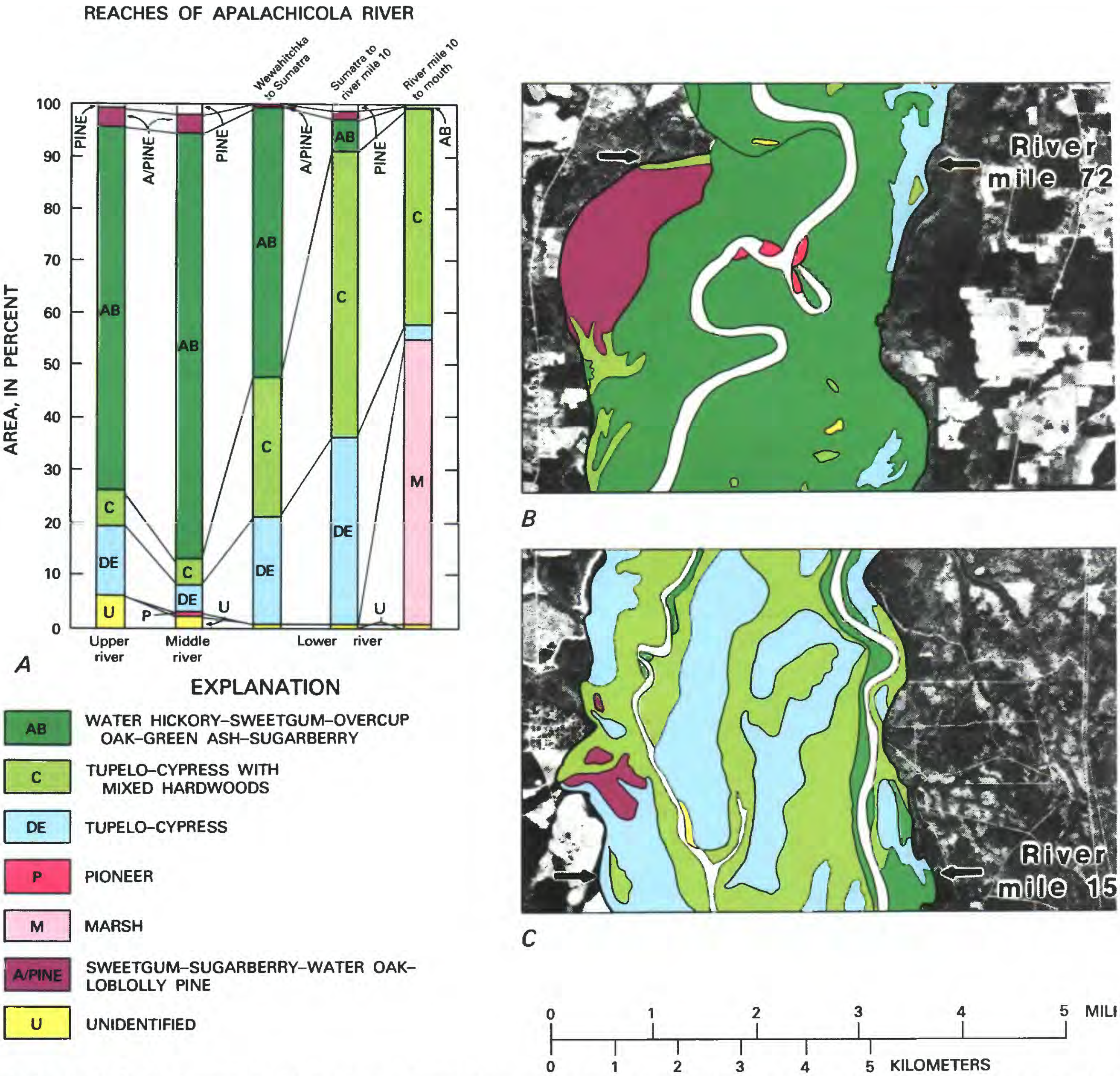


Figure 2.3. Relative proportion of cover type changes from upper to lower river (from Leitman, 1984): (*A*)—Area, in percent, of each mapping category, excluding open water, for five reaches of the Apalachicola River. (*B*) —Upper river flood-plain segment showing distribution of forest cover types. (C)—Lower river flood-plain segment showing distribution of forest cover types.

2.4 Leaf-Litter Production and Decomposition

Litter-fall measurements were made from September 1979 through August 1980 in the Apalachicola River flood plain of northwest Florida. Litter fall was collected monthly from nets located in 16 study plots (fig. 2.4*A*). The plots represented the five forest types in the swamp and levee areas of the Apalachicola River flood plain. The measurements showed that 43 species of trees, vines, and other plants contributed to the total litter fall. Average annual litter fall was determined to be 7,100 lb/acre and resulted in an annual deposition of 4×10^5 tons of organic material in the 175-mi^2 flood plain.

Figure 2.4*B* shows that about half of the litter production was distributed among the major tree types. Slightly less than half was composed of nonleaf material. Tupelo and baldcypress are both swamp species; hence the swamp community accounts for 31 percent of the litter production as leaf material.

Decomposition rates of leaves from five common flood-plain tree species were measured using a standard leaf-bag technique. Leaf decomposition was highly species dependent. Tupelo (*Nyssa* spp.) and sweetgum (*Liquidambar styraciflua*) leaves decomposed completely in 6 months when flooded by river water. Leaves of baldcypress (*Taxodium distichum*) and diamond-leaf oak (*Quercus laurifolia*) were much more resistant. Water hickory (*Carya aquatica*) leaves showed intermediate decomposition rates. Decomposition of all species was greatly reduced in dry environments. Carbon and biomass loss rates from the leaves were nearly linear over a 6-month period, but nitrogen and phosphorus leaching was nearly complete within 1 month.

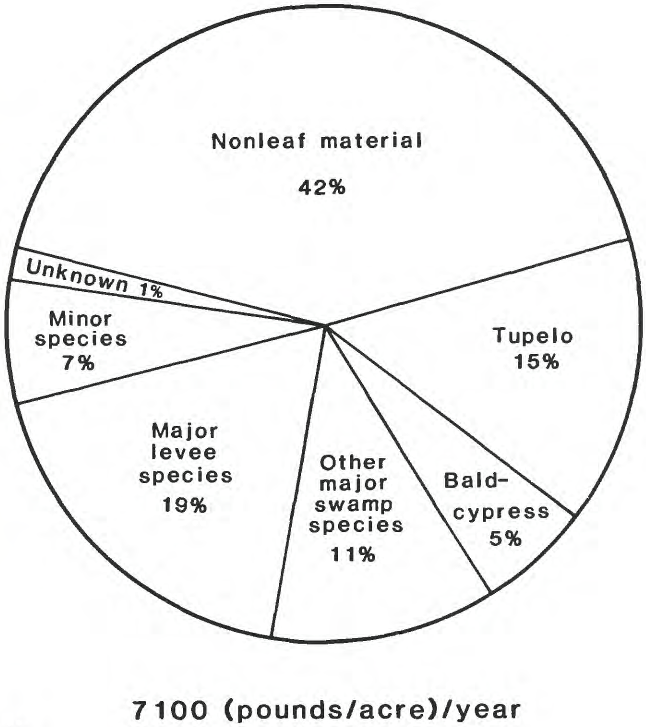
Why is litter fall and decomposition important? It has been estimated (Cummins and Spengler, 1978) that as much as 60 percent of the particulate organic matter in a stream may originate as leaf litter. This material is rapidly colonized by stream micro-organisms—fungi and bacteria. These organisms accelerate the decomposition of the material and release nutrients which are important to the primary productivity of the system. The micro-organism-leaf association also serves as a food supply for consumers in the river and estuary. Micro-organisms and leaf particles are ingested together like "peanut butter on crackers." The "peanut butter" provides most of the nutrition, but the "crackers" are necessary as a substrate (Cummins and Spengler, 1978, p. 4).

If the annual litter production of 4×10^5 tons were totally flushed into the channels, it could produce a mean concentration increase of 7 mg/L of organic carbon. This is not likely to be the case, of course, because of natural recycling within the flood-plain communities. It is nevertheless a major potential source of nutrients and detritus to the river and estuary.

The transport of organic litter from the flood plain to the river depends on flooding. Extensive floods with high flow velocities in the interior of the flood plain can mobilize large amounts of material. The timing of the flood is important. The major annual flood normally occurs several months after the peak litter-fall period. If it occurs earlier, there could be more litter deposited directly on the water surface, but there is less opportunity for decomposition prior to transport.

In comparison with other systems worldwide, the Apalachicola forest annual litter-fall production rate of 7,100 lb/acre is high. It is greater than those of many tropical systems and almost all warm temperate systems. Because most other systems that have been studied are not wetland systems, this comparison adds credence to the suggestion (Odum, 1979) that wetlands are more productive than uplands in comparable latitudes. Leaf decomposition rates in the Apalachicola environment appear to be similar to those found in comparable studies of other systems.

A



B

Figure 2.4. Litter fall in the Apalachicola River flood plain: (*A*) Leaf-litter collection net and (*B*) annual litter fall in the Apalachicola River flood plain.

2.5 *Flooding Hydrology*

If any single characteristic of the Apalachicola River system can be said to be the most critical to its character and function, it is the flooding cycle. In any riverine system, floods are important reset mechanisms, scouring old deposits and growth and redistributing stored organic matter and dried soils. In the Apalachicola, where the forested flood plain occupies 15 percent of the entire basin area, it is especially important. The flood-plain community structure is controlled largely by the annual flooding cycle (Leitman and others, 1983). This community does not exist in its present form in nonflooded areas, and it would not exist if the flooding cycle were to change significantly and permanently.

Discharge in the Apalachicola River generally ranges over about an order of magnitude each year—from 10,000 to 100,000 ft^3/s. High flow periods nearly always occur in late winter or early spring. Hydrographs for 1979-80 at two sites (fig. 2.5*A*) illustrate the flow variability. They also show the discharge above which flooding occurs at both sites. The flooding threshold at the upper site (Chattahoochee) is higher because of more relief and greater channelization. At the downstream site (Sumatra), flooding is evident for several months of the year.

A series of water-level and current-meter discharge measurements at medium and high flood stages were made across two transects during the spring of 1980. One transect was near Sweetwater Creek, 6 miles upstream from Bristol, and the other was at Brickyard Landing, 6 miles south of Sumatra. The distribution of water level, flow, and velocity measured at two stages for each transect are shown in figures 2.5*B* and 2.5*C*.

An analysis of the flow patterns at the Sweetwater intensive transect on March 11 and 18, 1980, shows that instantaneous water levels vary considerably across the flood plain at moderate flood stage (fig. 2.5*B*). The flood plain carried 10 percent of the flow on March 11 and 26.6 percent of the flow at a higher stage on March 18. Velocities increased in the main channel and the east flood plain but decreased in the west flood plain with higher stage.

Flow patterns at the Brickyard transect on March 14 and 19, 1980, show that instantaneous water levels are fairly uniform across the flow corridor at both medium and high flood stages (fig. 2.5*C*). The flood plain at this site has two major channels, Brickyard Cutoff and Brothers River, which convey a high percentage of flow during flooding, especially at lower flood levels. Those two flood-plain channels carried 27.7 and 24.1 percent of the total flow on March 14 and 19, respectively. The remainder of the flood plain, excluding Brickyard Cutoff and Brothers River, carried 35.0 and 44.3 percent of the total flow during medium and high flood stages, respectively. Velocities were higher in most sections of the flood plain at the higher stage.

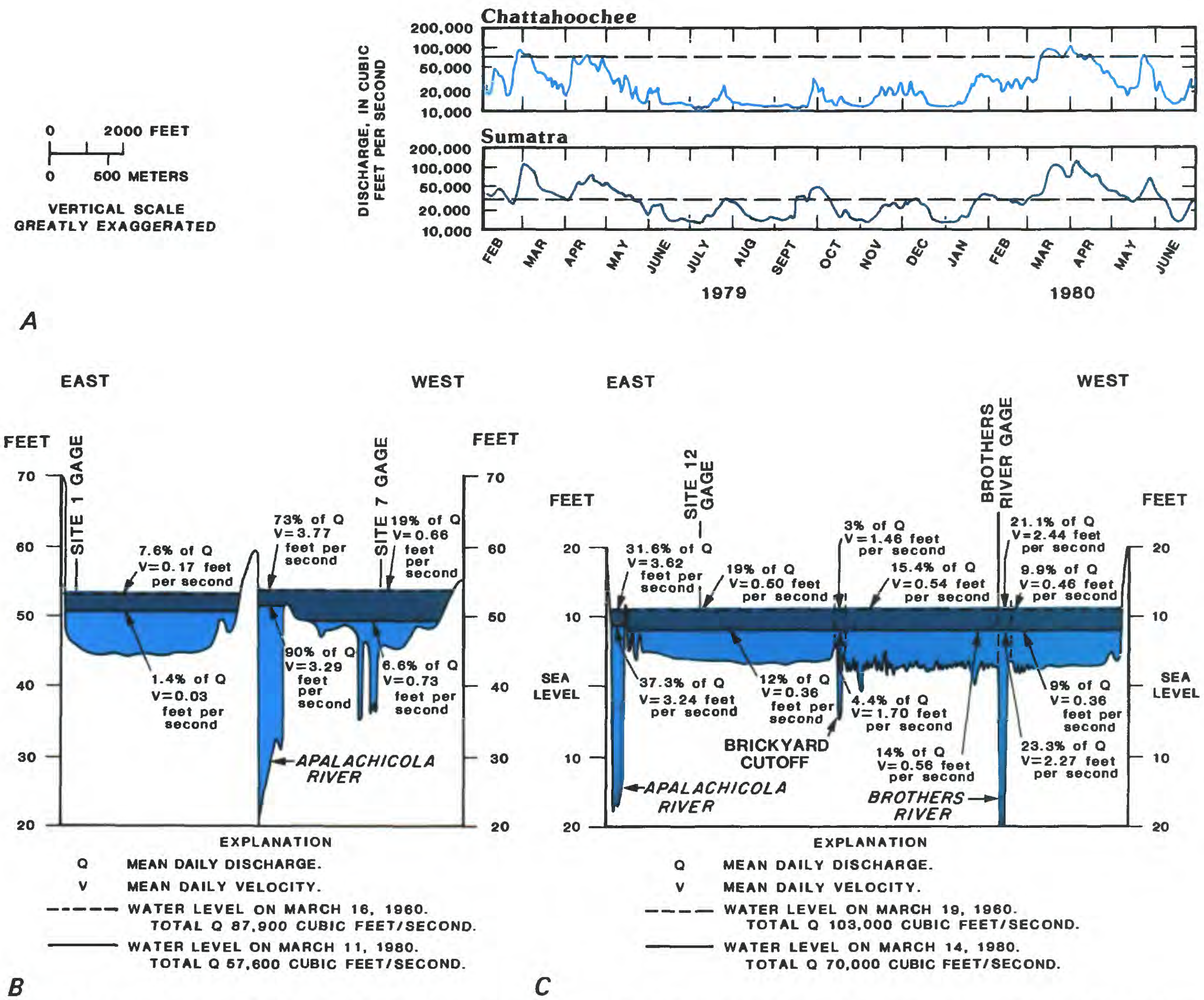


Figure 2.5. Flooding on the Apalachicola River: (*A*) Discharge for Chattahoochee and Sumatra gages, Apalachicola River, February 1979 to June 1980; dashed lines show flooding thresholds. (*B*) flow and velocity distribution at medium and high flood stages at the Sweetwater transect, and (*C*) flow and velocity distribution at medium and high flood stages at the Brickyard transect.

2.6 Water Budget

A water budget for the Apalachicola basin during the 1-year period from June 3, 1979, to June 2, 1980, was described by Mattraw and Elder (1984). Continuous discharge records from gages at each of seven sampling sites on the river and its tributaries, plus rainfall and ground-water-level measurements and evapotranspiration estimates, provided the basis for the calculations.

An equation which expresses the water budget of the Apalachicola River system is

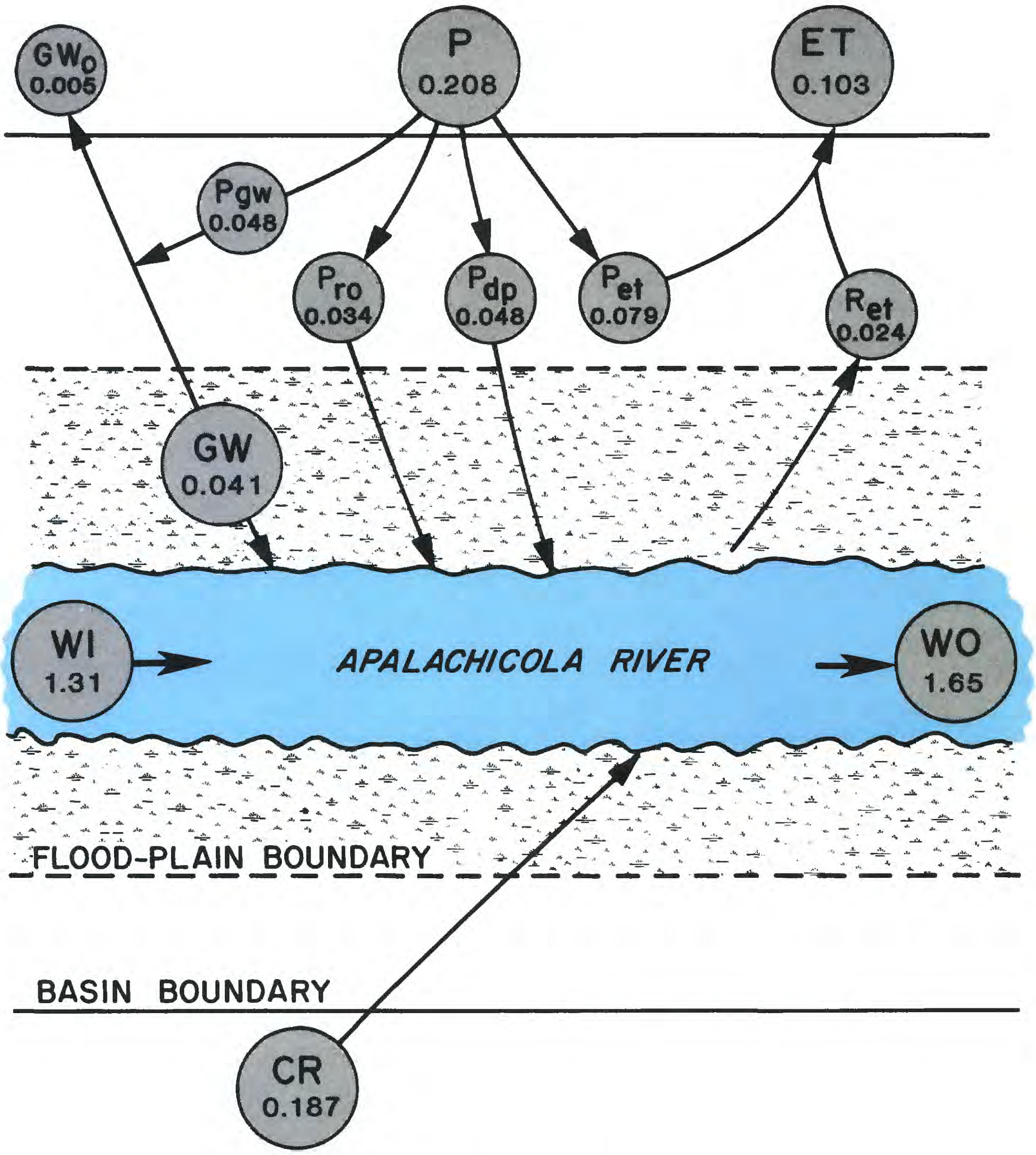
$$WO = WI + P_{ro} + P_{dp} + GW + CR - R_{et} \pm r$$

where all terms represent volumes of water and are defined as follows:

WO = outflow at the downstream limit;
WI = inflow at the upstream limit;
P_{ro} = precipitation runoff;
P_{dp} = direct precipitation in river and flood plain;
GW = ground-water discharge;
CR = input from the mouth of Chipola River;
R_{et} = evapotranspiration of river-derived water; and
r = residual—the amount required to balance the equation (equivalent to an error term and not associated with any known component of the budget).

The water budget described by this equation is depicted diagrammatically in figure 2.6. The numbers shown with each component give overall estimates for the 1979-80 study year; their derivations and seasonal breakdowns are detailed by an earlier report (Mattraw and Elder, 1984). Several of the major components, shown by large circles, can be subdivided into more specific categories. Only the components or subcomponents which provide direct input to or outflow from the river-wetland system are included in the equation.

Inputs exceeded losses, resulting in a 25-percent gain in waterflow from Chattahoochee to Sumatra. More than half of the input was contributed by the Chipola River. The water budget of the Apalachicola basin is heavily streamflow dominated; water volumes involved in precipitation, ground-water flow, surface-water runoff, and evapotranspiration are relatively minor compared to channelized inputs (*WI* and *CR*).



EXPLANATION

WI = Inflow at upstream limit.
WO = Outflow at downstream limit.
CR = Inflow from Chipola River.
GW = Ground water.
GW_O = Ground-water flow out of basin.
ET = Evapotranspiration (total).
R_{et} = Evapotranspiration from riverine and flood-plain storage.

P = Precipitation.
P_{gw} = Precipitation which recharges ground water.
P_{ro} = Precipitation which enters river as surface-water runoff.
P_{dp} = Direct precipitation to river and tributaries.
P_{et} = Precipitation which exits as evapotranspiration.

Values in cubic miles.

Figure 2.6. Apalachicola water budget.

2.7 *Total and Dissolved Carbon Transport*

As in any river system, nutrients are transported by the flowing waters into the estuary in enormous quantities. Thousands of tons of organic carbon, nitrogen, and phosphorus are transported annually into the estuary and supply a critical base for the highly productive estuarine food web. There are two important questions with respect to nutrient transport in the Apalachicola system. How much does flooding and the flood-plain community contribute to or remove from the riverine nutrient flow? If there were no flooding, would the nutrient yield to the estuary be different?

Organic carbon was one of three major nutrients whose transport was studied intensively in the Apalachicola River Quality Assessment. Samples for analysis of both dissolved organic carbon (DOC) and particulate organic carbon (POC) were collected in 1979-80 at the seven sites shown in figure 2.7*A*. The first four sites were on the main river channel; the fifth site was a transect across the lower flood plain, including Brickyard Cutoff and Brothers River; the sixth site was in Little Sweetwater Creek, a small ground-water-fed tributary; and the seventh site was in the Chipola River. Samples were collected monthly during low-flow periods and much more frequently during the flood of March and April 1980.

Organic carbon transport estimates for four sampling dates representing different flow and growth conditions are shown in figure 2.7*B*. The transport rate, in tons per hour, was calculated as the product of concentration and discharge for the day indicated. The data were taken at site 4, the most downstream main-stem site.

Some similarities and some differences in the data for the four dates are immediately obvious. The dissolved fraction predominated over the particulate fraction at all times. Such predominance of DOC over POC is common to many river systems (Naiman and Sibert, 1978). The amount of POC was almost constant on the first three dates, although the total carbon transport dropped substantially in November. Both dissolved and particulate fractions increased in March, during the spring flood.

Factors which may explain the observations shown in figure 2.7*B* include flow variability coupled with biological (photosynthetic) activity which produces organic material. In June 1979, riverflow was quite low, but photosynthetic activity was high; the relatively high carbon transport was primarily a reflection of high DOC concentrations due to the high autotrophic production rate. In November, this production rate was much lower, causing the decrease in DOC. However, litter fall was high, and the flow rate had increased slightly since June, maintaining POC at nearly the same level. In late February, productivity was just beginning to increase, and the flow rate was also higher; a significant increase in DOC flow had occurred. Finally, in March, the very high flow of the spring flood produced a major increase in both POC and DOC transport.

Flooding in March caused an increase in organic carbon transport, but the data indicate that the total increase was not nearly as high as might be expected from the increase in flow. DOC concentrations were lower on March 19 than on February 28 in spite of the flow increase. POC outflow, however, did increase substantially in March and became a much larger fraction of the total load—over 10 percent as opposed to about 5 percent in February. This effect of flooding on POC is examined further in the next section.

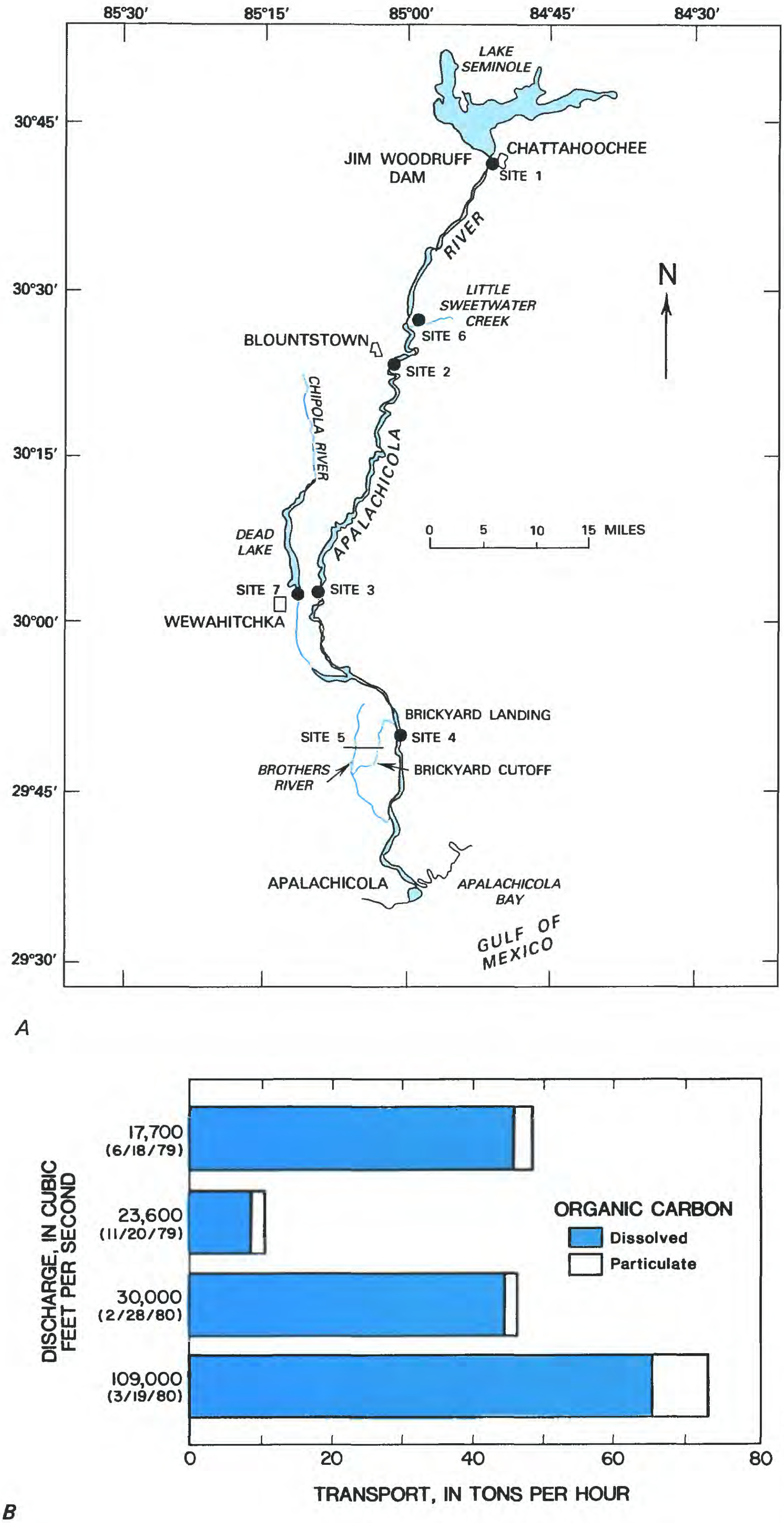


Figure 2.7. (*A*) The Apalachicola-Chipola River subbasin, showing sampling sites, and (*B*) organic carbon transport near Sumatra on four specific dates in 1979 and 1980.

2.8 Particulate Carbon Transport

The particulate organic carbon (POC) fractions shown in figure 2.7*B* are expanded in figure 2.8*A*. The total POC load is divided into four fractions according to particle size and mode of transport. The suspended load, sampled by pumping water through nested sieves and a filter, was separated into (1) the very fine (VF) fraction, with a particle-size range of 0.0000018-0.0024 in; (2) the fine (F) fraction, with a particle-size range of 0.0024-0.04 in; and (3) the coarse (C) fraction, with a particle size greater than 0.04 in. The bottom-load (B) samples were collected with a net of 0.04-in-mesh size held on the bottom at midchannel.

As in nearly all streams and rivers (Naiman and Sedell, 1979), the concentrations of organic carbon decrease as particle size increases. On all of the days represented in figure 2.8*A*, the VFPOC fraction amounted to considerably more than the sum of the other fractions. This feature probably enhances the value of the particulate material as a nutrient source because of the greater surface:volume ratio in finer particles.

The flooding effect on POC, as shown by the data of March 19, was very different than its effect on DOC (fig. 2.7*B*). Total POC transport increased by almost five times from February 28 to March 19, more than the increase in waterflow. Other data collected in the study suggested that this concentration increase in POC during flooding was due to flushing of particles out of the flood plain. Although the flood plain seems to produce very little net increase in dissolved carbon transport, there can be little doubt that it does serve as a source for POC.

The POC transport capacity of the Apalachicola floods is further illustrated by figure 2.8*B*. This graph compares the cumulative transport of all fractions of carbon at Sumatra with the transport curves that would be observed if the rates were constant during the entire year (using January 4, 1980, as the date for determining constant rate). Observed data in the spring months of 1980 were offset considerably from the constant rate curves. On close inspection, the most critical "flushing periods" appear to be quite distinguishable for the different fractions. For example, the principal CPOC surge occurred in April, while the FPOC was released somewhat earlier and had a slower transport rate in April. Bottom-load material (BPOC) showed one of its greatest surges in November, coinciding with the period of heaviest litter fall, and then increased again in winter and spring periods as greater areas became inundated.

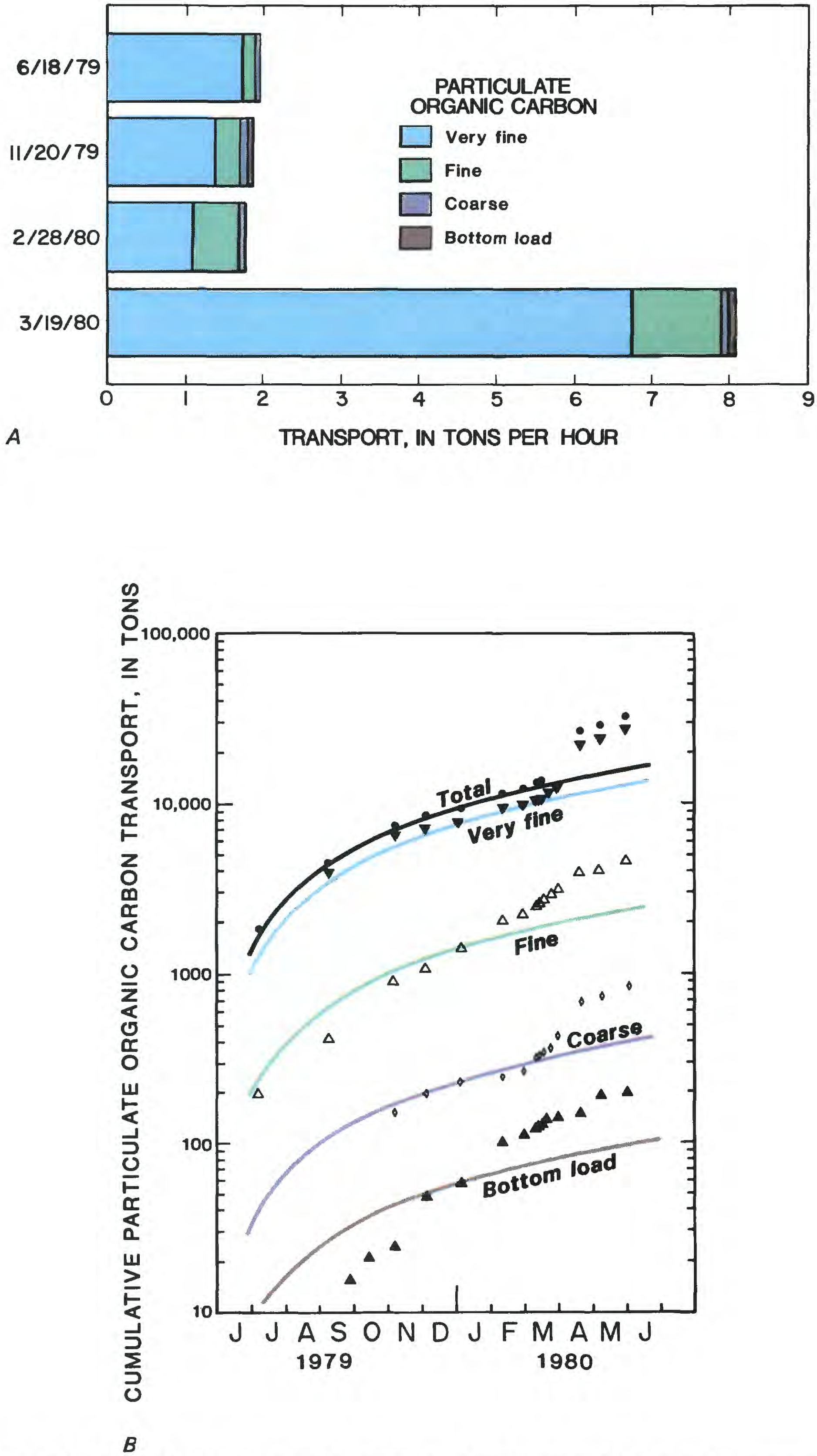


Figure 2.8. Particulate organic carbon transport near Sumatra: (*A*) Particulate organic carbon transport near Sumatra on four specific dates in 1979 and 1980, and (*B*) particulate organic carbon transport for June 1979 to June 1980 (logarithmic vertical scale).

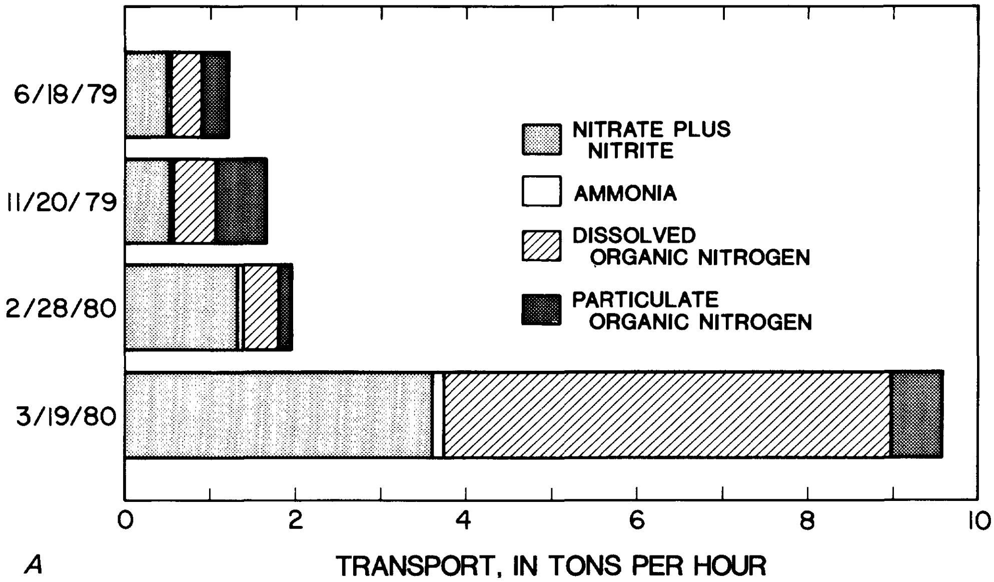
2.9 Nitrogen Transport

The mass of nitrogen transported by the Apalachicola River to its estuary is approximately 10 percent of the mass of organic carbon. The total yield during a 12-month period in 1979-80 was over 23,000 tons. Graphical representations of nitrogen transport on the same four sampling dates that were previously shown for carbon are given in figure 2.9*A*. Nitrogen in aquatic systems is measurable in four principal fractions: (1) oxidized inorganic nitrogen, consisting of dissolved nitrate (NO_3^-) and nitrite (NO_2^-) ions; (2) reduced inorganic nitrogen, consisting of dissolved ammonia (NH_3); (3) dissolved organic nitrogen (DON) associated with various soluble organic compounds; and (4) particulate organic nitrogen (PON) associated with suspended organic material (detritus) such as leaf particles and micro-organisms.

Nitrate and DON tend to predominate in the Apalachicola waters, although PON can occasionally be a major fraction of the total. The November sampling date represents a condition in which the particulate species form a large fraction; the total nitrogen load was relatively low, but litter deposition was occurring at a very fast rate at the time, contributing high amounts of PON.

The March flood coincided with increases in nitrate and DON concentrations, causing an increase in the total nitrogen transport rate which exceeded the relative increase in waterflow. These increases in concentration are probably attributable to two primary causes. The nitrate increase was quite gradual during the winter; this is normal in aquatic systems during nongrowing seasons when biological uptake of nitrate is diminished. The examination of all nitrate data from the study (Elder, 1985) indicated that nitrate concentrations followed a definite seasonal pattern—low in late summer and increasing to maximum levels in late winter. The large increase in DON during the flood (March 19) probably was attributable to flushing of soluble organics from flooded areas throughout the upper basins (Chattahoochee and Flint) as well as from the Apalachicola flood plain.

One of the important characteristics of the inorganic nitrogen data is illustrated in figure 2.9*B*. The data points represent means of all samples collected at a site during the study, and the plots show variation over the course of the river. Ammonia concentrations decreased considerably in a downstream direction, while nitrate concentrations were nearly the same at sites 1 and 4. (Sites 2 and 3 had higher means, but because of the time variability shown by standard error bars, the differences are probably not significant.) As a result, the ratio of ammonia: total inorganic nitrogen decreased in a downstream direction from 0.14 at site 1 to 0.08 at site 4. Mass balance calculations (Elder, 1985) showed that ammonia loss during transport was quite consistent, the result being that the 12-month ammonia export was over 50 percent less than the sum of its imports. The system was clearly a net consumer of ammonia, although it was a net exporter of organic nitrogen and some carbon and phosphorus species.



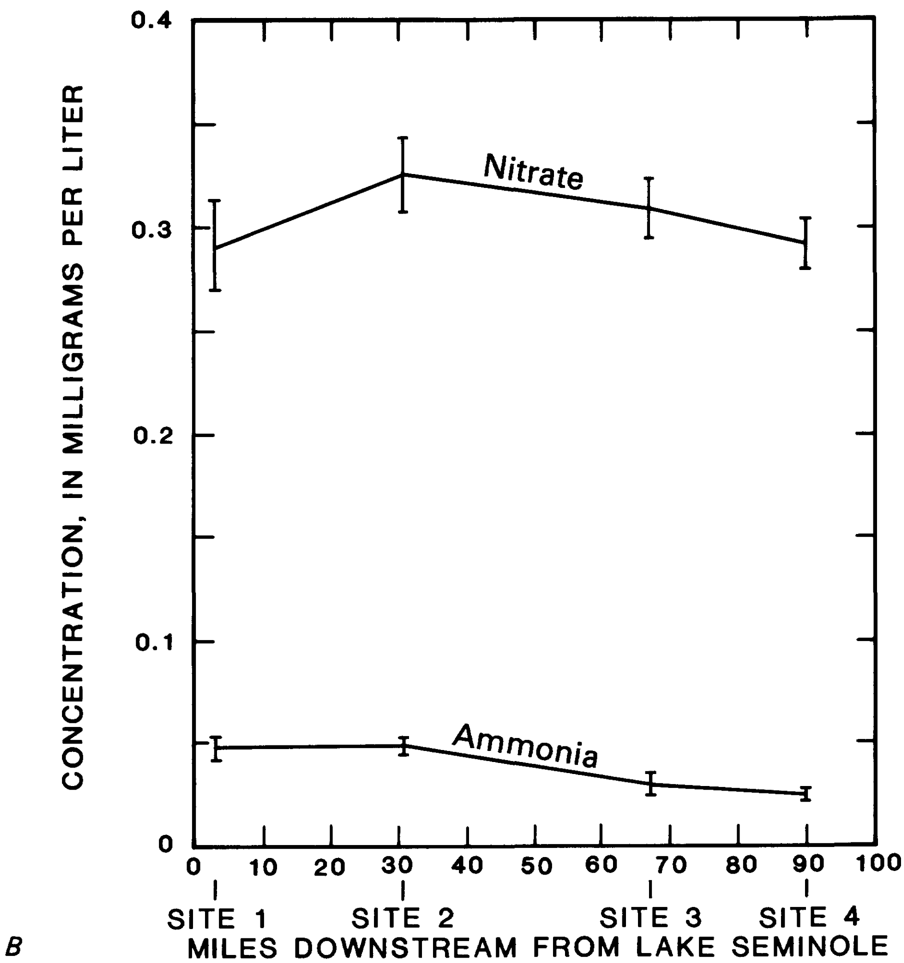


Figure 2.9. (*A*) Nitrogen transport on four specific dates in 1979 and 1980 and (*B*) changes in inorganic nitrogen concentrations with stream location.

2.10 Phosphorus Transport

Primary productivity in Apalachicola Bay is phosphorus limited during summer and autumn each year (Livingston and Loucks, 1979). The ratio of soluble reactive phosphorus (SRP) to dissolved inorganic nitrogen in the Apalachicola River generally ranges from about 1:20 near the headwaters to about 1:40 near the mouth. This suggests an imbalance which can lead to the phosphorus limitation in Apalachicola Bay. It also indicates net consumption of SRP in the flood plain.

Just as ammonia nitrogen became a smaller fraction of dissolved inorganic nitrogen from upstream sites to downstream sites, SRP also became a smaller fraction of total phosphorus (fig. 2.10). At the headwaters, dissolved phosphorus was composed entirely of SRP. Farther downstream, SRP decreased while the total dissolved phosphorus concentration increased slightly, reflecting a downstream increase in dissolved organic phosphorus. At site 4, SRP comprised only about 50 percent of the dissolved phosphorus concentration. There was a small overall downstream increase in total phosphorus concentration, maintained by slightly increasing concentrations of both particulate and dissolved phosphorus.

On an annual time scale, the phosphorus mass balance for the entire river system shows a mixed result similar to that for nitrogen. There was net import of SRP and net export of other dissolved phosphorus and particulate phosphorus.

Unlike nitrogen, phosphorus is relatively insoluble in neutral or alkaline pH conditions. Particulate forms tend to predominate, as is indicated by the difference between total and dissolved phosphorus shown in figure 2.10. Much particulate phosphorus is associated with iron, calcium, and other metals and can sorb to sediments and detritus suspended in the river water. Hence, the pulses of detritus flow during floods, which became evident by analysis of POC, tend to be accompanied by pulses of particulate phosphorus transport. As shown in table 2.10, more than two-thirds of the phosphorus transport in 1979-80 was in particulate form.

Table 2.10-1. Amounts and percentages of phosphorus load at Sumatra (site 4) during 12-month period of 6/3/79-6/2/80.

Phosphorus fraction	Load (tons)	Percent of total
Particulate	1,230	69
Soluble nonreactive	310	17
Soluble reactive	250	14
Total	1,790	

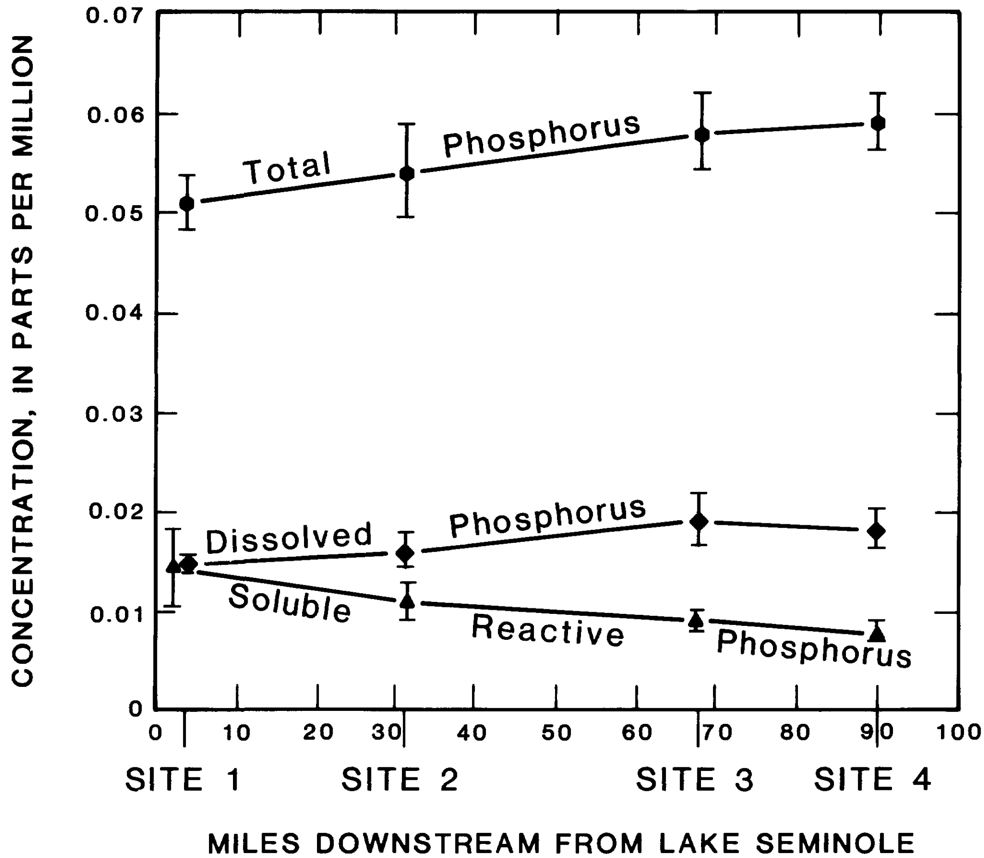


Figure 2.10. Changes of phosphorus concentrations with stream location. Data represent means from 20-41 samples with standard errors as shown by error bars.

3.0 OVERVIEW AND IMPLICATIONS

3.1 Flood-Plain Role in Nutrient Transport

Having examined some of the characteristics of the occurrence and transport of various species of organic carbon, nitrogen, and phosphorus, it becomes quite evident that the flood plain does have an influence on nutrient yield. However, the influence is not as simple as might be implied by viewing wetlands as either sources or sinks for nutrients. The Apalachicola wetland fluctuates between being an importer and being an exporter, depending on numerous variables. As was suggested by de la Cruz (1979), it is more appropriate to depict the wetland as a transformer than either as a source or as a sink.

The transformer role of the flood plain is diagrammatically illustrated in figure 3.1. An amount (X) of a given mix of nutrients (A) is transported into the flood plain. After some processing within the flood plain (incorporation of processes including biological uptake, complexation, oxidation, reduction, sorption, and precipitation), a different mix (B) is output in an amount (Y). Over an annual cycle, the quantities of input and output are not greatly different, hence X is approximately equal to Y. In qualitative terms, however, the output may be very different from the input, hence A is unequal to B. By affecting nutrient chemistry more than total nutrient loads, the river-wetland system plays a critical role in supporting estuarine productivity. The forms of nutrients exported to estuaries are probably of equal or greater importance than are the total amounts (Nixon, 1980).

In the Apalachicola River-wetland system, one effect of the wetland is to transform the nutrient load to one which favors secondary productivity and a detritus-based food web in the estuary. Primary productivity in estuarine systems is likely to be limited by bioavailable species of either nitrogen (Ryther and Dunstan, 1971) or phosphorus (Taft and Taylor, 1976). As was noted earlier, phosphorus would seem to be the more critical nutrient in the Apalachicola River-wetland system because of the shortage of soluble reactive phosphorus relative to inorganic nitrogen. No matter which nutrient is more critical, the inorganic forms of both nitrogen and phosphorus are only sparingly supplied to the estuary by riverine inflow. However, the river transports an abundant supply of detritus from the flood plain (Elder and Mattraw, 1982). The detritus provides an excellent substrate for bacterial growth (Fenchel, 1970) and a base for support of a thriving population of detrital feeders (Darnell, 1961), including many of the economically valuable shellfish species.

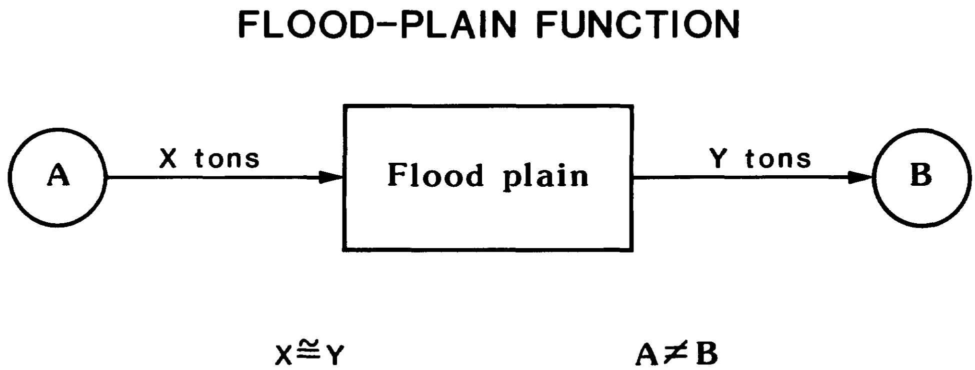


Figure 3.1. Flood-plain function.

3.2 Impact of River and Wetland on Apalachicola Bay

Research conducted for several years by scientists from Florida State University (Livingston, 1983) has shown conclusively that the productivity and general vitality of the Apalachicola Bay estuary is highly dependent on inflow from the river (fig. 3.2). Not only the nutrient and detritus inputs but also the salinity controls by the seasonal fluctuations of riverine input are crucial in maintaining the estuarine community, including the extremely valuable shellfish population.

If there were major changes in the present flooding cycle of the river or if large areas of the flood-plain community were removed, would the river still be able to maintain the estuary the way it does today? Information from the studies of this river basin, as well as others, suggests that there would be at least some appreciable changes in the estuarine community if the river were subject to such major alterations. The importance of the flood plain in propagating nutrient transformations has already been noted. The importance of salinity controls has been extensively described by Livingston (1983). The fluctuating inflows of the river are important in maintaining a community of species that are either euryhaline (tolerant to a wide salinity range) or migratory. Without such pulsations, species with a lower tolerance to salinity variation could immigrate, producing an inevitable change in the community structure.

In addition to the control of nutrient quality by flood-plain processes and to the effects of pulsating riverflow on estuarine salinity, there are other impacts of the river-wetland system on the estuary. One wetland function which may become of greater importance in the Apalachicola basin in future years is the filtration of potentially toxic substances. This process has been shown to be of such efficiency that wetlands can be utilized for wastewater purification (Sloey and others, 1978; Tilton and Kadlec, 1979). Other wetland functions which are less directly related to the estuary are flood detention, aquifer recharge, and utilization as a fish and wildlife habitat.

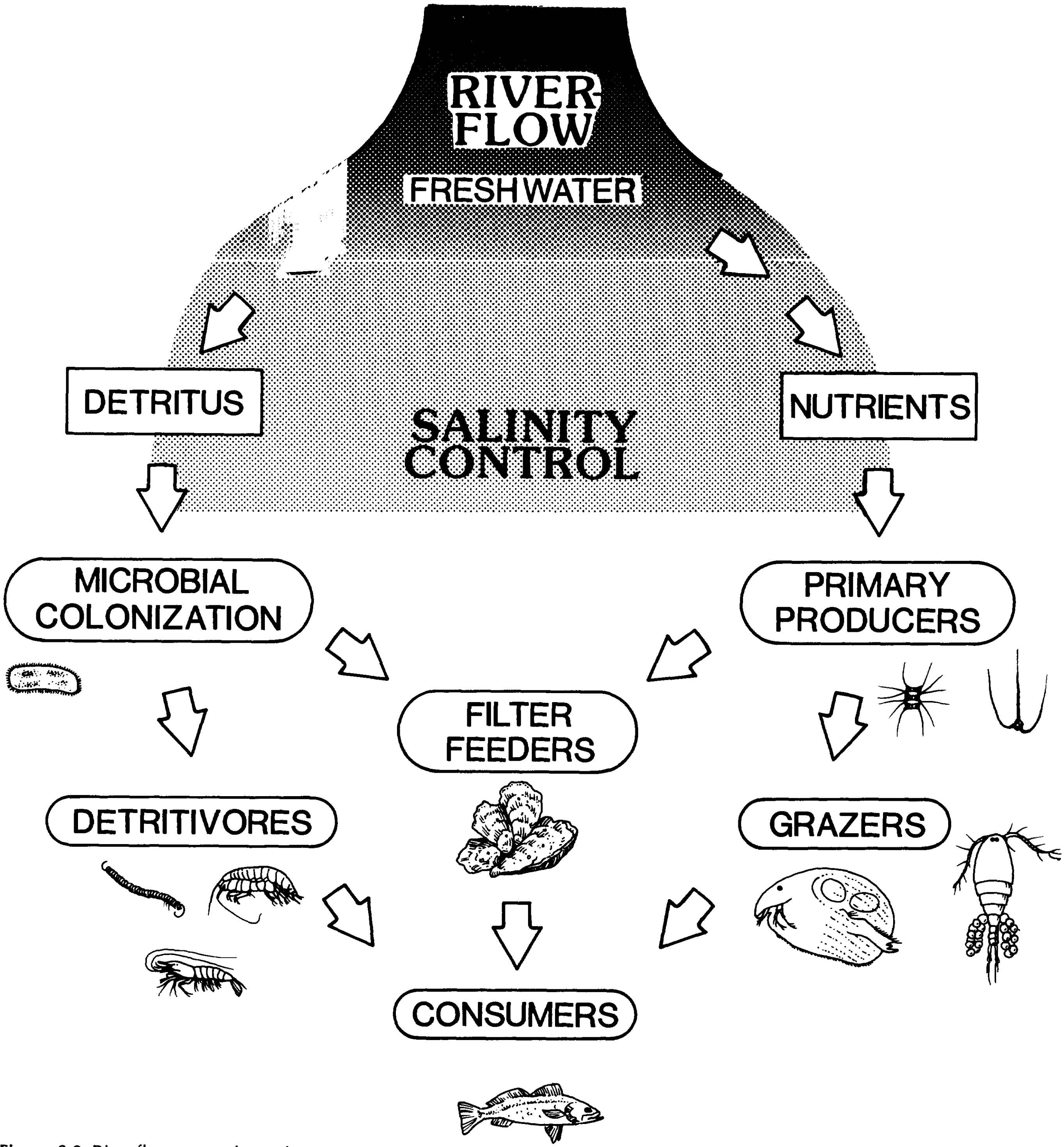


Figure 3.2. Riverflow controls on the estuarine food web.

3.3 *Trace Substances*

The fourth objective of the Apalachicola River Quality Assessment, to determine the accumulation of potentially toxic elements and organic substances in benthic organisms and sediments, was addressed by conducting a survey of trace element and synthetic organic compounds in bottom materials. Data were collected from five sites, all on the main river channel. Four of the sites were the same as sites 1-4 identified earlier, and the fifth site was 6 miles from the river mouth.

Substances analyzed included trace elements (predominantly heavy metals), organochlorine insecticides, organophosphorus insecticides, chlorinated phenoxy-acid herbicides, and polychlorinated biphenyls. Three kinds of materials were surveyed: fine-grained sediments, whole-body tissue of the Asiatic clam *Corbicula manilensis*, and bottom-load organic detritus.

Some of the results of the survey are shown in figure 3.3. The predominant metals and organic compounds are included, although a large number of other substances were analyzed. More details of the study are available in the report by Elder and Mattraw (1984).

The concentrations shown in figure 3.3 do not signify hazardous levels for any of the substances. Concentrations in the fine-grained sediments and clams were generally at least 10 times lower than maximum limits considered safe for biota of aquatic systems (National Academy of Sciences and National Academy of Engineering, 1972; Walsh and others, 1977). Further data analysis did not identify any trends, either with time or from upstream to downstream reaches of the river.

A comparison of trace-substance data from the Apalachicola River with data from Lake Seminole (upstream) and Apalachicola Bay (downstream) showed lower concentrations in riverine clams. Sediment concentrations in all parts of the system were comparable.

The principal use of the results of this survey is as a baseline for comparison with future water quality. At present, there are no major point discharges of these substances in the Apalachicola basin (although there are such sources in the Chattahoochee and Flint basins). If future development were to create additional sources, the impacts of those sources might be assessed on the basis of predevelopment conditions.

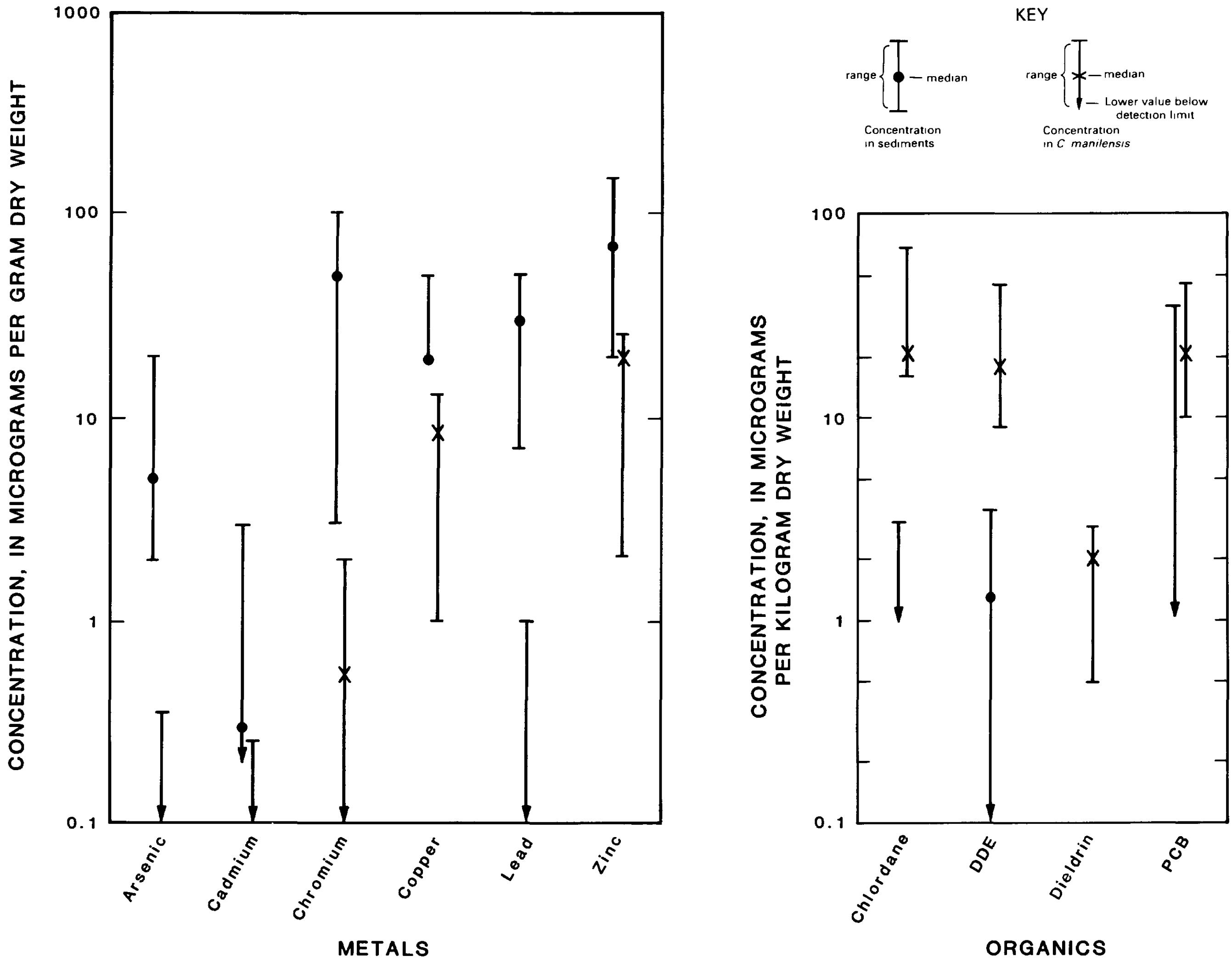


Figure 3.3. Concentration ranges and medians of metals and organic substances in fine-grained sediments and *Corbicula manilensis* in the Apalachicola River, August 1979 through May 1980. Where no median is shown, it was at or below detection limit. Dieldrin in sediments was below detection limit in all samples.

3.4 Influence of Dams

At present, the Apalachicola River flows unimpeded by dams. At the headwaters of the river, however, Jim Woodruff Lock and Dam (fig. 3.4*A*) impounds Lake Seminole, and further upstream, 15 additional dams regulate the flow of the Chattahoochee and Flint Rivers.

Leitman and others (1983) conducted an analysis of long-term stage and discharge records for the Apalachicola River at Chattahoochee. The records represented the period 1929-79. Although the 16 dams on the Apalachicola, Chattahoochee, and Flint Rivers were constructed at various times from 1834 to 1975, filling of both the largest reservoir, Lake Sidney Lanier, and the reservoir closest to the area of investigation, Lake Seminole, was completed in 1957. The second and third largest reservoirs were filled in 1975 and 1963, respectively. Thus, 1929-57 and 1958-79 were the periods of record chosen for comparison.

Figure 3.4*B* shows that the predam and postdam periods were very similar in terms of the distribution of flow through the annual cycle. The principal difference was that the flow of the more recent period was higher. Examination of records from other rivers in north Florida for the same periods showed that the mean annual discharge in all of them was higher from 1958 to 1979 than in the 20 years prior to 1958. This was attributed to higher rainfall over the three-State area during the later period.

A more subtle difference between the two periods is shown in figure 3.4*C*. This graph shows flow duration, or the percentage of time that discharge exceeds any particular level. The curve is somewhat flatter for the period 1958-79 than for 1929-57, indicating that the dams may have had an effect of dampening fluctuations or reducing the amount of time that the flow was at low extremes.

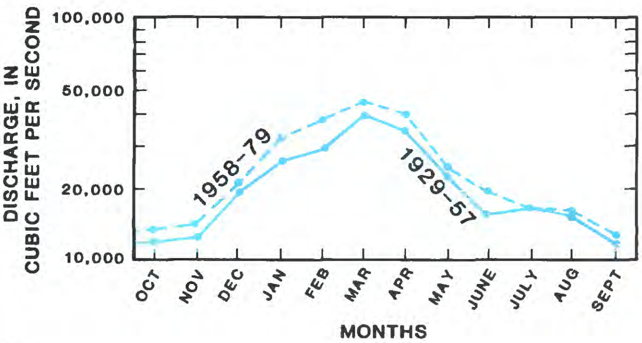
In short, the effect of dams on riverflow is to decrease expection of extreme low flow. There has been very little effect on either the amount or the seasonal distribution of discharge over an annual cycle.

Ecological changes are probably the most notable effects of dam construction. Most ecological changes result from the development of reservoirs in former terrestrial or wetland environments. A system which contains dams and their associated reservoirs is obviously very different than the system before the construction of the dams. Reservoirs, whatever their benefits, bring an entirely new set of management problems, as was previously discussed. Flood-plain area is diminished, and wildlife habitat is altered.

Erosion downstream of a dam can result from the channelized, turbulent flow of relatively clear water below the dam (Taylor, 1978). This could be manifested by degradation of the channel and erosion of streambanks in some reaches, with concomitant aggradation of the channel in others. In the Apalachicola River, scouring just below Jim Woodruff Dam has left the river bottom quite rocky and relatively free of sediments. In general, bank erosion is retarded by the heavy growth of rooted vegetation on the banks.

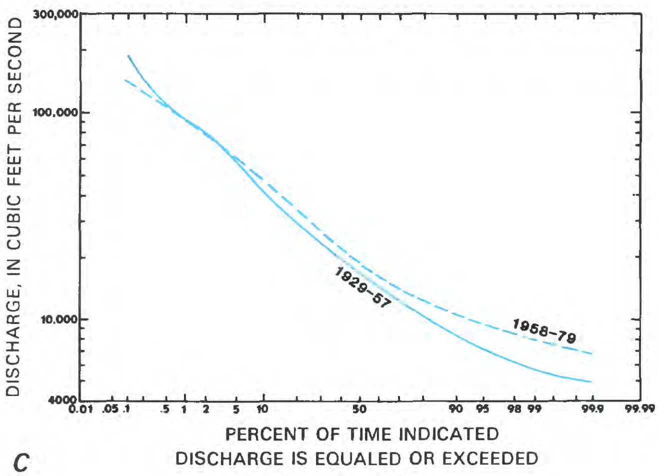
Proposals for the construction of dams on the Apalachicola River to facilitate navigation have been rejected in the past because it was the general consensus of policymakers that the benefits of such dams would be outweighed by losses of existing resources due to alterations to the system. These kinds of decisions are based on the perceived value of the existing conditions; the greater the value of the status quo, the greater the deterrence to introduced changes.

A



B

Figure 3.4. (*A*) Jim Woodruff Lock and Dam and Lake Seminole, (*B*) average monthly flows at Chattahoochee, 1929-57 and 1958-79, and (C) cumulative discharge curve at Chattahoochee, 1929-57 and 1958-79.



C

3.5 *Effects of Channel Modifications*

The amended River and Harbor Act of 1946 authorizes the U.S. Army Corps of Engineers to maintain a channel in the Apalachicola River 100 ft wide and 9 ft deep that is navigable 95 percent of the time from the mouth of the Apalachicola River to Bainbridge, Ga., on the Flint River and to Columbus, Ga., on the Chattahoochee River. The main purpose of the Jim Woodruff Lock and Dam was to help sustain this channel. However, the dam alone is not enough, and channel maintenance requires a considerable amount of dredging (fig. 3.5*A*) and snagging each year. The average annual volume of dredging since 1956 has been 350,000 yd^3/yr. In the past, dredged material was placed at 131 locations along the river (fig. 3.5*B*), many of which were undiked flood-plain disposal sites used on a one-time basis. Most of the 151 disposal sites currently in use are between the banks of the river rather than on the flood plain (Harry Peterson, U.S. Army Corps of Engineers, oral commun., 1980).

In a study of 11 dredged material disposal sites from mile 6.5 to mile 42.5, Eichholz and others (1979) found that deposition on the flood-plain forest averaged 4 acres per disposal area. Dredged material was deposited most often in the mixed bottom-land hardwood forest of the riverbank levee and frequently blocked flood-plain sloughs and creeks. In only one instance was dredged material placed in the tupelo-cypress forest behind the riverbank levee. The depth of deposition ranged from less than 3 ft to over 30 ft. Clewell and McAninch (1977) found that tree vigor was reduced when only 1.5-5 in of fill was deposited on Apalachicola River flood-plain trees. Most trees were killed by 2.5 ft or more of fill.

Dredging of the river might be expected to have some effect on the trace-substance concentrations in bottom materials. Disturbance of bottom sediments due to dredging is likely to cause some resuspension of fine materials, resulting in altered rates of adsorption or release of associated metals and organic substances. It is also likely to change the benthic community and physical environment which is involved in uptake and release of the substances.

Other effects of dredging and snagging have been pointed out by Livingston (1978). The disturbance of the natural habitat for benthic organisms and fish is included among these. If spoils are disposed on banks, destruction of some wildlife habitat will also occur.

Channelization may entail construction of levees which could have a long-term effect of decreasing the extent of the flood plain. The loss of flood-plain area would very likely have an impact on the composition of nutrient and detritus yield to the estuary, as was previously described. A significant amount of channel modification, including construction of levees and cutoffs, ditching, draining, or filling wetlands, could also change the influx of freshwater to the system and therefore change the natural salinity distribution in the estuary.

A

B

Figure 3.5. (*A*) Dredging operation and (*B*) dredge spoil site.

4.0 CONCLUSIONS OF THE APALACHICOLA RIVER QUALITY ASSESSMENT

The essence of the findings of the Apalachicola River Quality Assessment is diagrammatically shown in figure 4.0. The Apalachicola River Quality Assessment dealt with interrelations among hydrodynamics, the flood-plain community and nutrient and detritus flow in the system, and the overall yield to the estuary (fig. 4.0). Important conclusions of the study are as follows:

- Flooding plays a critical role in the combined set of processes which support the existing estuarine productivity. The extent and duration of floods have major influence on the species composition and productivity of the flood-plain plant community. The extent and velocity of floods are important in determining the amount of detritus which can be moved through the system. Leaf-litter decomposition, which produces most of the detritus, is also accelerated by flooding.
- The Apalachicola water budget is heavily streamflow dominated; water volumes involved in precipitation within the basin, ground-water flow, surface-water runoff, and evapotranspiration are relatively minor in comparison with main-stem flow. As is indicated in figure 4.0, however, rainfall in the upper basins of the Chattahoochee and Flint Rivers is the primary control on waterflow in the Apalachicola, especially in the winter when rainfall input is not rapidly taken up by vegetation.
- The flood-plain community is very productive, more so than most warm temperate systems and even more than many tropical systems. Forest-litter fall amounts to about 7,100 lb/acre annually. The fraction of this material that is transported each year to the estuary depends on flooding. In addition to the extent, duration, and velocity of the flood, timing is also important. If the flood occurs very early, more material may be deposited directly on the water surface, but there is less opportunity for decomposition before transport.
- The role of the flood plain in nutrient transport through the system should not be considered as a source or as a sink but more as a transformer. On an annual basis, the quantities of nutrients which enter the headwaters of the Apalachicola are not greatly different from the amounts that exit to the estuary. However, there is a tendency for soluble inorganic nutrients to undergo substantial net import to the flood plain, while there is a net export of particulate organic material. This is important in sustaining a detritivore-based estuarine community.
- Because of the dependence of the forest-community structure on flood characteristics, it should be expected that if the normal flooding cycle is significantly and permanently altered, the flood-plain forest will gradually change in structure and character. This may or may not affect productivity and yield to the estuary, depending on the nature of the change.
- Because of the high litter production of the flood-plain community and the mobilization of litter-generated detritus by inundation, it should be expected that substantial reductions in flood-plain area will result in decreased detritus yield to the estuary.
- Dam construction and other channel modifications cause moderate to severe changes in the aquatic and wetland environments. Analysis of long-term hydrologic records, including periods prior to and following construction of the Jim Woodruff Dam, indicates that dams do not significantly alter the total annual flow or the monthly distribution of flow. However, dams do have an effect of dampening the low-flow extremes. Channelization practices such as dredging and snagging may have a significant effect on benthic organisms and fish by destroying habitats. If dredge spoils are deposited in the flood plain, they will also alter the habitat in that environment. Dredging also causes increased mobilization of substances associated with bottom sediments.
- Toxic substances are present in Apalachicola sediments and benthic organisms, but their concentrations are well below hazardous levels. Future development of industry or agriculture in the basin should be accompanied by monitoring of toxic substances which could be introduced from the new sources.

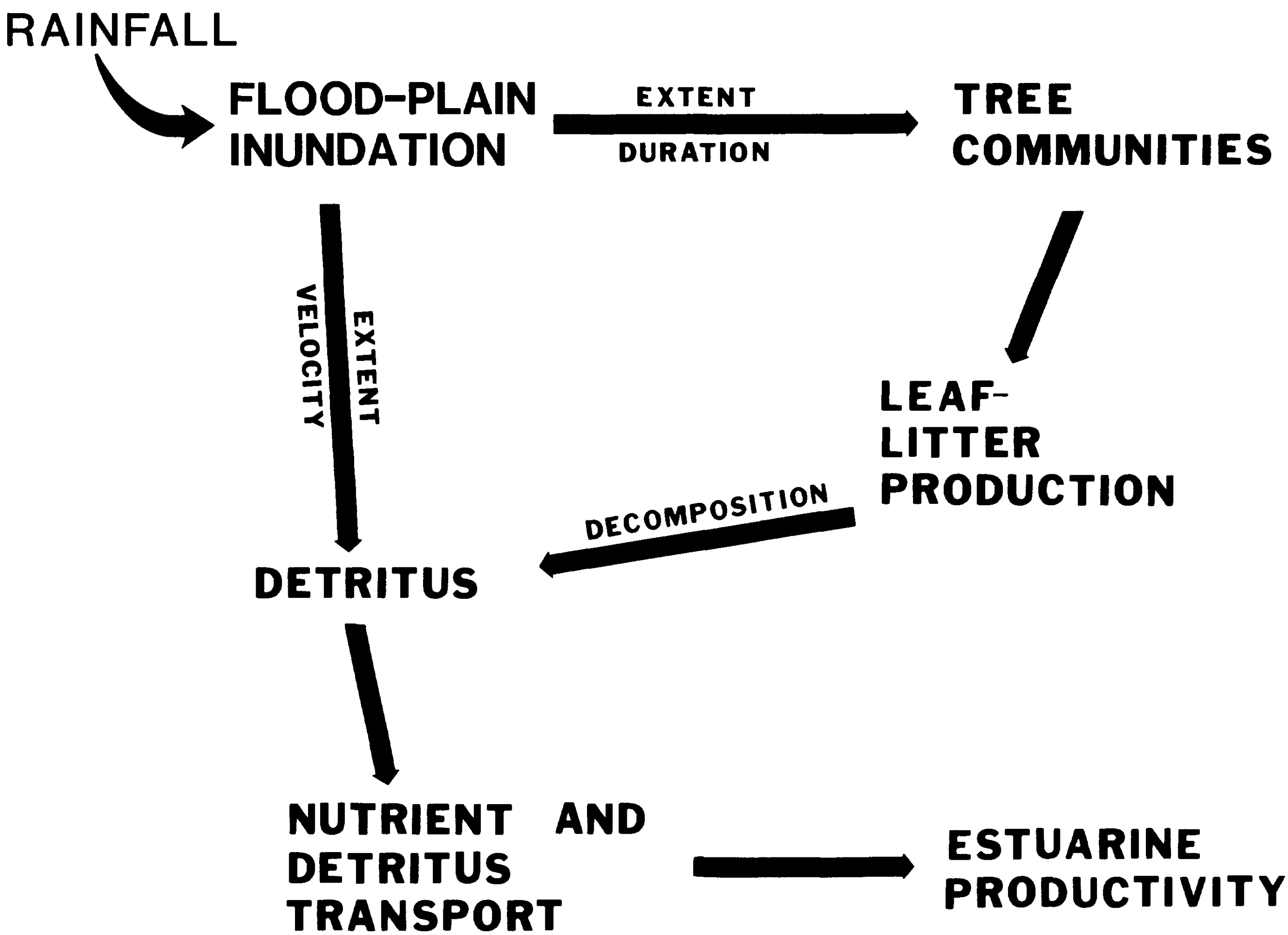


Figure 4.0. Flood-plain processes.

5.0 SUMMARY

During 1979-81, the U.S. Geological Survey conducted a large-scale study of the Apalachicola River in northwest Florida. The Apalachicola River Quality Assessment emphasized the interrelations among hydrodynamics, the flood-plain forest, and the nutrient-detritus flow through the river system to the estuary.

The Apalachicola River is a waterway for shipping; hence, there is an economic incentive for modification to facilitate movement of barge traffic. The river is also recognized as an important supplier of detritus, nutrients, and freshwater to the Apalachicola Bay. The importance of this input to the bay creates an incentive to keep the river basin in a natural state. Questions about the most beneficial management strategies for the Apalachicola River result from these diverse values and possible uses of the system. Some uses call for mechanical or physical alteration of the natural system to maximize utility of the system for commercial benefit. Other uses need limited intervention in the natural system. The benefits are largely controlled by physical, chemical, and biological features of the system, and they can best be maintained by scientific understanding of those features.

The primary purpose of this report is to provide information that will aid those who are involved, either directly or indirectly, in implementing best management practices for the Apalachicola River basin. The more management decisions can be based on scientific knowledge, the more likely such decisions will be beneficial to the stability of the system and to users of this valuable natural resource. The authors hope that the information in this report will help to maximize the possibility that decisions can be made which suit the needs of all users of the river basin.

6.0 SCENES OF THE APALACHICOLA RIVER

"Apalachicola Doin' Time"

When she leaves the dam at Chattahoochee,
Winding in a southern flow,
Easy on her way, another night and day,
She'll finally reach the Gulf of Mexico.

Apalachicola, let her wind;
Apalachicola, flowing fine;
Apalachicola, strong in mind;
Apalachicola, doin' time.

Crider and Crider (1981)




SELECTED REFERENCES

Cairns, J., Jr., 1978, Waterway recovery: Water Spectrum, v. 10, no. 4, p. 26-32.

Clewell, A. F., 1977, Geobotany of the Apalachicola River region: Conference on the Apalachicola drainage system, Gainesville, Florida, April 1976, Proceedings, p. 6-15.

Clewell, A. F., and McAninch, Helen, 1977, Effects of a fill operation on tree vitality in the Apalachicola River floodplain, Florida: Conference on the Apalachicola drainage system, Gainesville, Florida, April 1976, Proceedings, p. 16-19.

Crider, Dale, and Crider, Linda, 1981, Apalachicola doin' time, *in* Crider, Linda, ed., The water song book: Gainesville, Anhinga Roost Music Company, p. 51.

Cummins, K. W., and Spengler, G. L., 1978, Stream ecosystems: Water Spectrum, v. 10, no. 4, p. 1-9.

Darnell, R. M., 1961, Trophic spectrum of an estuarine community based on studies of Lake Pontchartrain, Louisiana: Ecology, v. 43, no. 3, p. 553-568.

de la Cruz, A. A., 1979, Production and transport of detritus in wetlands, *in* Greeson, P.E., Clark, J.R., and Clark, J.E., eds., Wetland functions and values—The state of our understanding: National Symposium on Wetlands, Lake Buena Vista, Florida, 1978, Proceedings, p. 162-174.

Eastman, S. E., 1980, Fuel efficiency in freight transportation: The American Waterways Operators, Inc., Arlington, Va., 17 p.

Eichholz, N. F., Bailey, D. B., and McGehee, A. V., 1979, An investigation of dredged material disposal sites on the lower Apalachicola River: Tallahassee, Fla., Florida Game and Freshwater Fish Commission, Office of Environmental Services, 115 p.

Elder, J. F., 1983, Riverine transport of nutrients and detritus to Apalachicola Bay, *in* Andree, Scott, ed., Apalachicola Oyster Industry Conference: Apalachicola, Fla., October 6-7, 1982, Proceedings, Report No. 57, Florida Sea Grant College, p. 28-30.

——— 1985, Nitrogen and phosphorus speciation and flux in a large Florida river-wetland system: Water Resources Research, v. 21, no. 5, p. 724-732.

Elder, J. F., and Cairns, D. J., 1982, Production and decomposition of forest litter fall on the Apalachicola River flood plain, Florida: U.S. Geological Survey Water-Supply Paper 2196-B, 42 p.

Elder, J. F., and Mattraw, H. C., Jr., 1982, Riverine transport of nutrients and detritus to the Apalachicola Bay estuary, Florida: Water Resources Bulletin, v. 18, no. 5, p. 849-855.

——— 1984, Accumulation of trace elements, pesticides, and polychlorinated biphenyls in sediments and the clam *Corbicula manilensis* of the Apalachicola River, Florida: Archives of Environmental Contamination and Toxicology, v. 13, no. 5, p. 453-469.

Fenchel, Tom, 1970, Studies on the decomposition of organic detritůs derived from the turtle grass *Thallassia testudinum*: Limnology and Oceanography, v. 15, no. 1, p. 14-20.

Greeson, P. E., ed., 1978, River-quality assessments: American Water Resources Association Symposium, Tucson, 1977, Proceedings, 191 p.

Hosner, J. F., 1960, Relative tolerance to complete inundation of fourteen bottomland tree species: Forest Science, v. 6, no. 3, p. 246-251.

Hosner, J. F., and Boyce, S. G., 1962, Tolerance to water saturated soil of various bottomland hardwoods: Forest Science, v. 8, no. 2, p. 180-186.

Kurz, Herman, and Godfrey, R. K., 1962, Trees of northern Florida: Gainesville, University of Florida Press, 311 p.

Leitman, H. M., 1978, Correlation of Apalachicola River floodplain tree communities with water levels, elevation, and soils: Florida State University Master's Thesis, 57 p.

——— 1984, Forest map and hydrologic conditions, Apalachicola River flood plain, Florida: U.S. Geological Survey Hydrologic Investigations Atlas HA-672, 1 sheet.

Leitman, H. M., Sohm, J. E., and Franklin, M. A., 1983, Wetland hydrology and tree distribution of the Apalachicola River flood plain, Florida: U.S. Geological Survey Water-Supply Paper 2196-A, 52 p.

Livingston, R. J., 1978, The Apalachicola dilemma: Wetlands priorities, developmental stress, and management initiatives, *in* U.S. Fish and Wildlife Service, Proceedings of the National Wetland Protection Symposium, Reston, Va., June 6-8, 1977: Biological Services Program FWS/OBS-78/97, p. 163-177.

——— 1983, Resource atlas of the Apalachicola Estuary: Florida Sea Grant Report No. 55, 64 p.

Livingston, R. J., and Loucks, O. L., 1979, Productivity, trophic interactions, and food-web relationships in wetlands and associated systems, *in* Greeson, P.E., Clark, J.R., and Clark, J.E., eds., Wetland functions and values—The state of our understanding: National Symposium on Wetlands, Lake Buena Vista, Florida, 1978, Proceedings, p. 101-119.

Livingston, R. J., Iverson, R. L., Estabrook, R. H., Keys, V. E., and Taylor, John, Jr., 1974, Major features of the Apalachicola Bay system—Physiography, biota, and resource management: Florida Scientist, v. 37, no. 4, p. 245-271.

Mattraw, H. C., Jr., and Elder, J. F., 1980, Nutrient yield of the Apalachicola River flood plain, Florida: River-quality assessment plan: U.S. Geological Survey Water-Resources Investigations 80-51, 21 p.

——— 1984, Nutrient and detritus transport in the Apalachicola River, Florida: U.S. Geological Survey Water-Supply Paper 2196-C, 62 p.

Naiman, R. J., and Sedell, J. R., 1979, Characterization of particulate organic matter transported by some Cascade Mountain streams: Journal of the Fisheries Research Board of Canada, v. 36, no. 1, p. 17-31.

Naiman, R. J., and Sibert, J. R., 1978, Transport of nutrients and carbon from the Nanaimo River to its estuary: Limnology and Oceanography, v. 23, no. 6, p. 1183-1193.

National Academy of Sciences and National Academy of Engineering, 1972, Section III—Freshwater aquatic life and wildlife, water quality criteria: Ecology Research Service Environmental Protection Agency EPA-R3-73-033, Washington, D.C., p. 106-213.

Nixon, S. W., 1980, Between coastal marshes and coastal waters—A review of twenty years of speculation and research on the role of salt marshes in estuarine productivity and water chemistry, *in* Hamilton, P., and MacDonald, K. B., eds., Estuarine and wetland processes: New York, Plenum Press, p. 437-525.

Odum, E. P., 1979, The value of wetlands: A hierarchical approach, *in* Greeson, P.E., Clark, J.R., and Clark, J.E., eds., Wetlands functions and values—The state of our understanding: National Symposium on Wetlands, Lake Buena Vista, Florida, 1978, Proceedings, p. 16-25.

Prochaska, F. J., and Mulkey, David, 1983, The Apalachicola Bay oyster industry: Some economic considerations, *in* Andree, Scott, ed., Apalachicola Oyster Industry Conference: Apalachicola, Fla., October 6-7, 1982, Proceedings, Report No. 57, Florida Sea Grant College, p. 18-20.

Ryther, J. H., and Dunstan, W. M., 1971, Nitrogen, phosphorus, and eutrophication in the coastal marine environment: Science, v. 171, p. 1008-1013.

Schnable, J. E., and Goodell, H. G., 1968, Pleistocene-Recent stratigraphy, evolution, and development of the Apalachicola Coast, Florida: Geological Society of America Special Paper No. 112, 72 p.

Sloey, W. E., Spangler, F. L., and Fetter, C. W., Jr., 1978, Management of freshwater wetlands for nutrient assimilation, *in* Good, R. E., Whigham, D. F., and Simpson, R. L., eds., Freshwater wetlands, ecological processes and management potential: New York, Academic Press, p. 321-340.

Smalley, D. H., and Novak, J. K., 1978, Natural thermal phenomena associated with reservoirs, *in* Chadwick, W. L., and others, eds., Environmental effects of large dams: New York, American Society of Civil Engineers, p. 29-49.

Southeastern Forest Experiment Station, 1958, Annual report 1957: U.S. Department of Agriculture, Forest Service, Asheville, N.C., 75 p.

Taft, J. L., and Taylor, W. R., 1976, Phosphorus dynamics in some coastal plain estuaries, *in* Wiley, M. L., ed., Estuarine processes, v. 1: New York, Academic Press, p. 507-522.

Taylor, K. V., 1978, Erosion downstream of dams, *in* Chadwick, W. L., and others, eds., Environmental effects of large dams: New York, American Society of Civil Engineers, p. 165-186.

Tilton, D. L., and Kadlec, R. H., 1979, The utilization of a fresh-water wetland for nutrient removal from secondarily treated waste water effluent: Journal of Environmental Quality, v. 8, no. 3, p. 328-334.

U.S. Army Corps of Engineers, Mobile District, 1980, 1979 Project maps: Mobile, Ala., 154 maps.

U.S. Department of Commerce, 1973, Monthly normals of temperature, precipitation, and heating and cooling degree days 1941-70—Florida: Climatography of the United States No. 81 (Florida), National Oceanic and Atmospheric Administration, Environmental Data Service, National Climatic Center, Asheville, N.C., 8 p.

U.S. Forest Service, 1969, A forest atlas of the South: Forest Service, 27 p.

Walsh, D. F., Berger, B. L., and Bean, J. R., 1977, Mercury, arsenic, lead, cadmium, and selenium residues in fish, 1971-73, National Pesticide Monitoring Program: Pesticide Monitoring Journal, v. 11, no. 1, p. 5-34.

Wharton, C. H., Kitchens, W. M., Pendleton, E. C., and Sipe, T. W., 1982, The ecology of bottomland hardwood swamps of the southeast—A community profile: U.S. Fish and Wildlife Services FWS/OBS-81/37, Washington, D.C., 133 p.

Whitlow, T. H., and Harris, R. W., 1979, Flood tolerance in plants: A state-of-the-art review: Department of Environmental Horticulture, University of California, Davis, Environmental and water quality operational studies, Technical Report E-79-2, 161 p. plus appendixes and tables.

CONVERSION FACTORS

For those readers who may prefer to use International System (SI) units rather than inch-pound units, the conversion factors for the terms used in this report are listed as follows:

Multiply inch-pound unit	*By*	*To obtain SI unit*
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
square foot (ft^2)	0.09294	square meter (m^2)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
cubic mile (mi^3)	4.168	cubic kilometer (km^3)
ton	0.9072	metric ton
pound (lb)	453.6	gram (g)
ounce (oz)	28.35	gram (g)
	0.0000353	milligram (mg)
parts per million (ppm)	1.0	milligram per liter (mg/L)
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.283	cubic meter per second (m^3/s)
pound per acre per year (lb/acre/yr)	0.1122	gram per square meter per year ($g/m^2/yr$)
pound per acre (lb/acre)	1.1208	kilogram per hectare (kg/ha)
ton per hour (ton/hr)	907.2	kilogram per hour (kg/hr)
parts per billion (ppb)	1.0	microgram per kilogram (ug/kg)
cubic yard per year (yd^3/yr)	0.7646	cubic meter per year (m^3/yr)
°C (degree Celsius)	1.81(+ 32)	°F (degree Fahrenheit)