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VOLUME 5
OF THE
LOWER ST. JOHNS RIVER BASIN RECONNAISSANCE

SEDIMENT CHARACTERISTICS AND QUALITY

by

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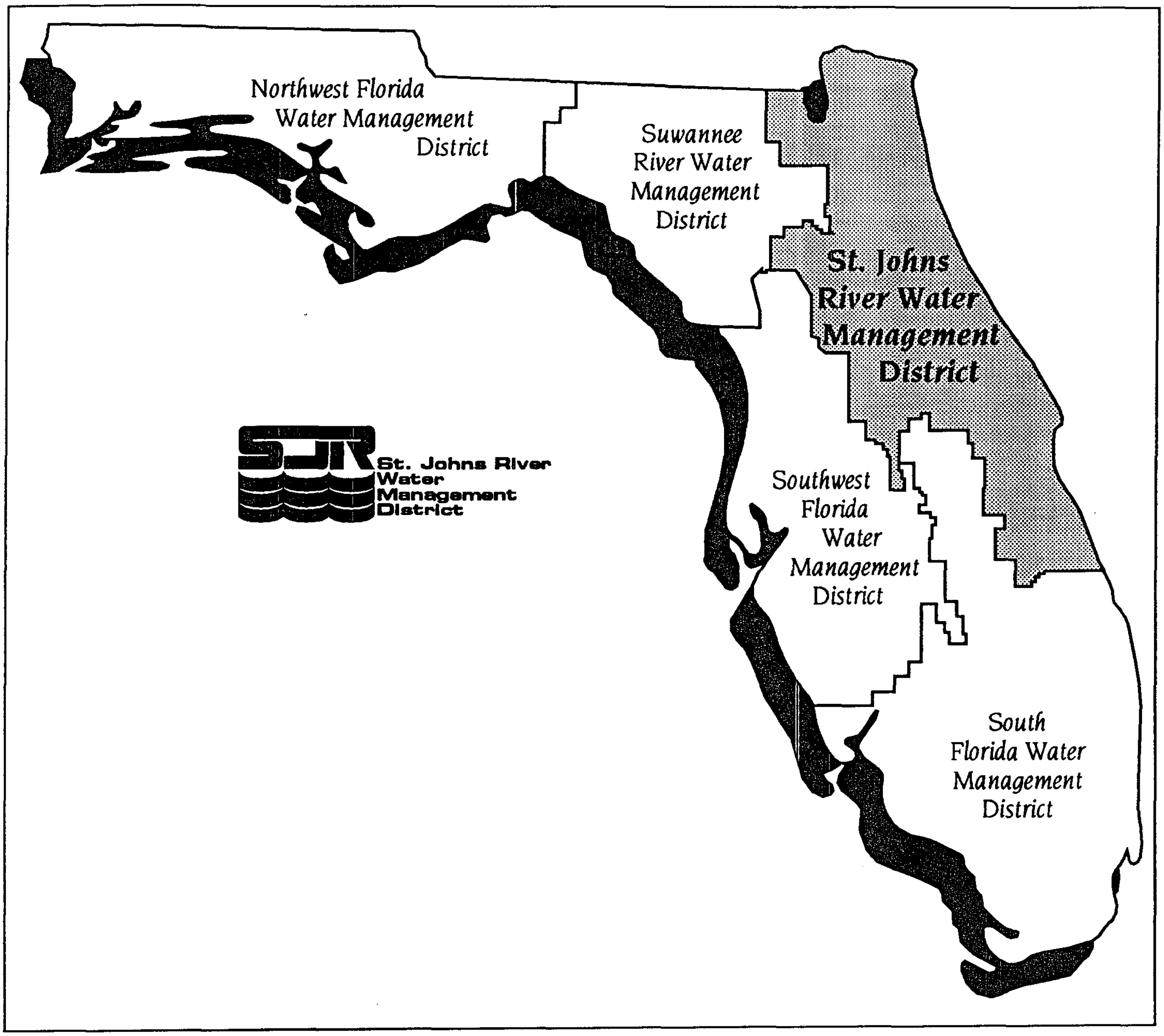

The **St. Johns River Water Management District** (SJRWMD) was created by the Florida Legislature in 1972 to be one of five water management districts in Florida. It includes all or part of 19 counties in northeast Florida. The mission of SJRWMD is to manage water resources to ensure their continued availability while maximizing environmental and economic benefits. It accomplishes its mission through regulation; applied research; assistance to federal, state, and local governments; operation and maintenance of water control works; and land acquisition and management.

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ABSTRACT

This report is Volume 5 in a series of reconnaissance reports about the lower St. Johns River surface water drainage basin. The lower St. Johns River is the northern part of the St. Johns River from the mouth of the Ocklawaha River in Putnam County to the inlet at the Atlantic Ocean in Duval County. The drainage basin includes parts of nine counties in northeast Florida. The reconnaissance reports compile information and make recommendations to help resource managers identify priority needs for research into and management of the Lower St. Johns River Basin (LSJRB). These reports are part of the research funded under the Surface Water Improvement and Management Act of 1987 (Sections 373.451-373.4595, *Florida Statutes*).

The lower St. Johns River is a shallow tidal estuary which was formed by wind and tidal action of an ancient sea, followed by inundation with fresh water as the sea receded. The most important factors affecting sedimentation processes are tidal currents, river inflow, river traffic, dredging, and the density contrast between fresh and salt water. At the freshwater-saltwater interface, flocs are formed that result in increased sedimentation of organic contaminants and precipitation of dissolved metals. The majority of sediments from the St. Johns River are fine-textured silts and clays, dark in color, high in percent moisture, and poorly sorted. The tributaries of the river contain sediments with high organic content, particularly in low-energy fringing areas. No apparent spatial relationship exists between the distance upstream and either sediment particle size or organic content. Industrial and residential activities in LSJRB have resulted in the accumulation of sediments from a number of toxic pollutants including heavy metals, aromatic hydrocarbons, chlorinated pesticides, and polychlorinated biphenyls. A complete understanding of the complexity of the system's dynamic nature is hindered by a paucity of information on sedimentation processes and sediment characteristics of the St. Johns River.

INTRODUCTION

This report is Volume 5 in a series of reconnaissance reports about the Lower St. Johns River Basin (LSJRB). This compilation of information and recommendations should provide resource managers with a basis for identifying priority needs for future research and actions regarding LSJRB. The reconnaissance reports are part of the research funded under the Surface Water Improvement and Management (SWIM) Act of 1987 (Sections 373.451-373.4595, *Florida Statutes*).

The SWIM Act declares that many natural surface water systems in Florida have been or are in danger of becoming degraded from point and nonpoint sources of pollution and from the destruction of natural systems. The state's five water management districts, in cooperation with state agencies and local governments, were directed to set priorities for waterbodies of regional or statewide significance and to design plans for surface water improvement and management. Six waterbodies were named for immediate action, including LSJRB.

LSJRB is one of ten surface water basins of the St. Johns River Water Management District (SJRWMD) (Figure 1). The basin is located in northeast Florida and represents about 22 percent of the area within the boundaries of SJRWMD. LSJRB extends from the City of De Land, in the south, to the inlet of the St. Johns River at the Atlantic Ocean. LSJRB includes parts of nine counties including Clay, Duval, Flagler, Putnam, St. Johns, Volusia, Alachua, Baker, and Bradford counties (Figure 2).

Landscape features within LSJRB are relatively low and flat. Three ridge systems border the drainage area. Surface elevations range from sea level at the inlet to greater than 61 meters (m) (200 feet [ft]) in the western part of the basin.

The St. Johns River is an elongated, shallow estuary with an extensive floodplain. The elevation of the St. Johns River at the mouth of the Ocklawaha River is less than 3.0 m (10 ft) above

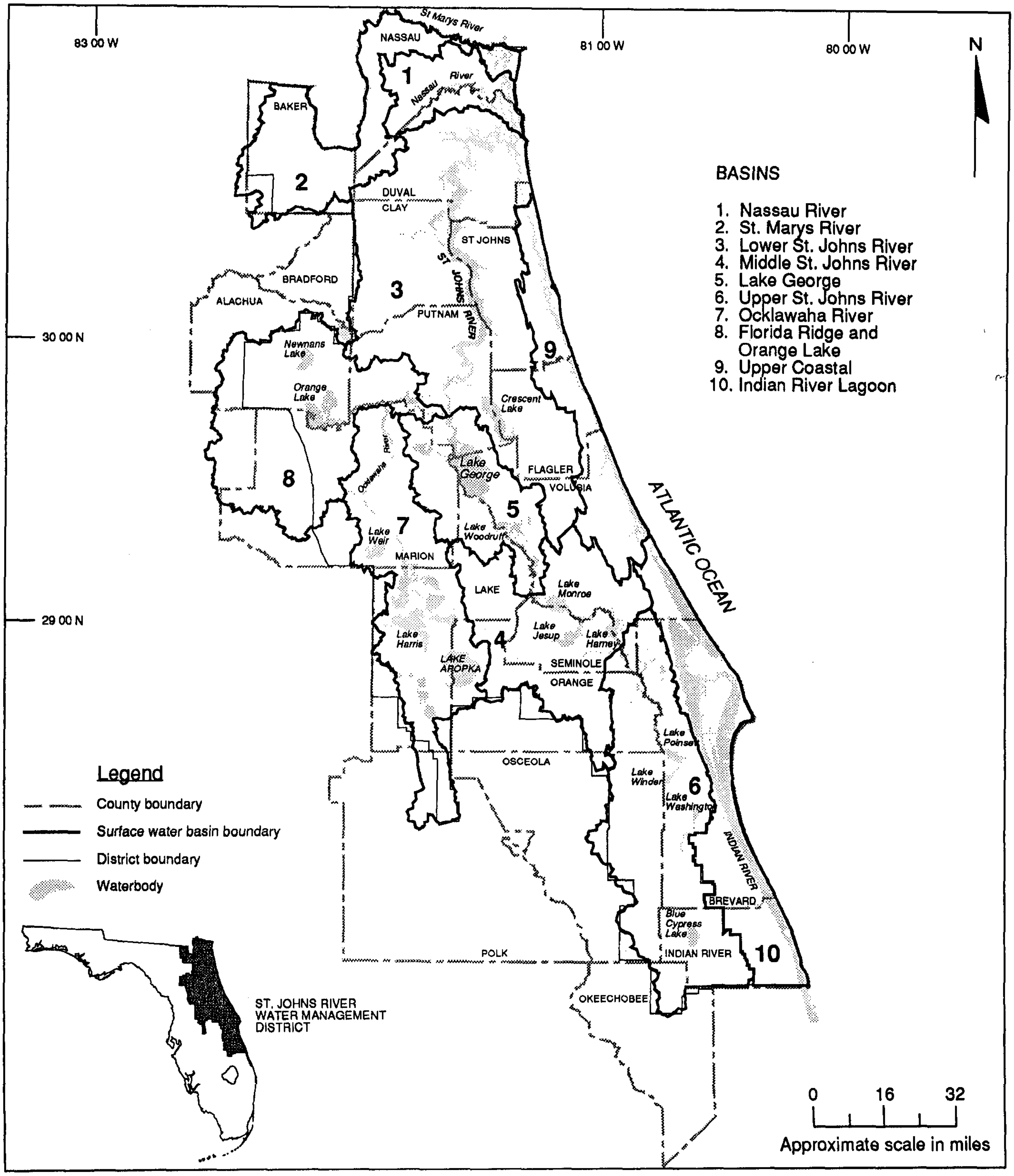


Figure 1. **Major surface water basins within the St. Johns River Water Management District**

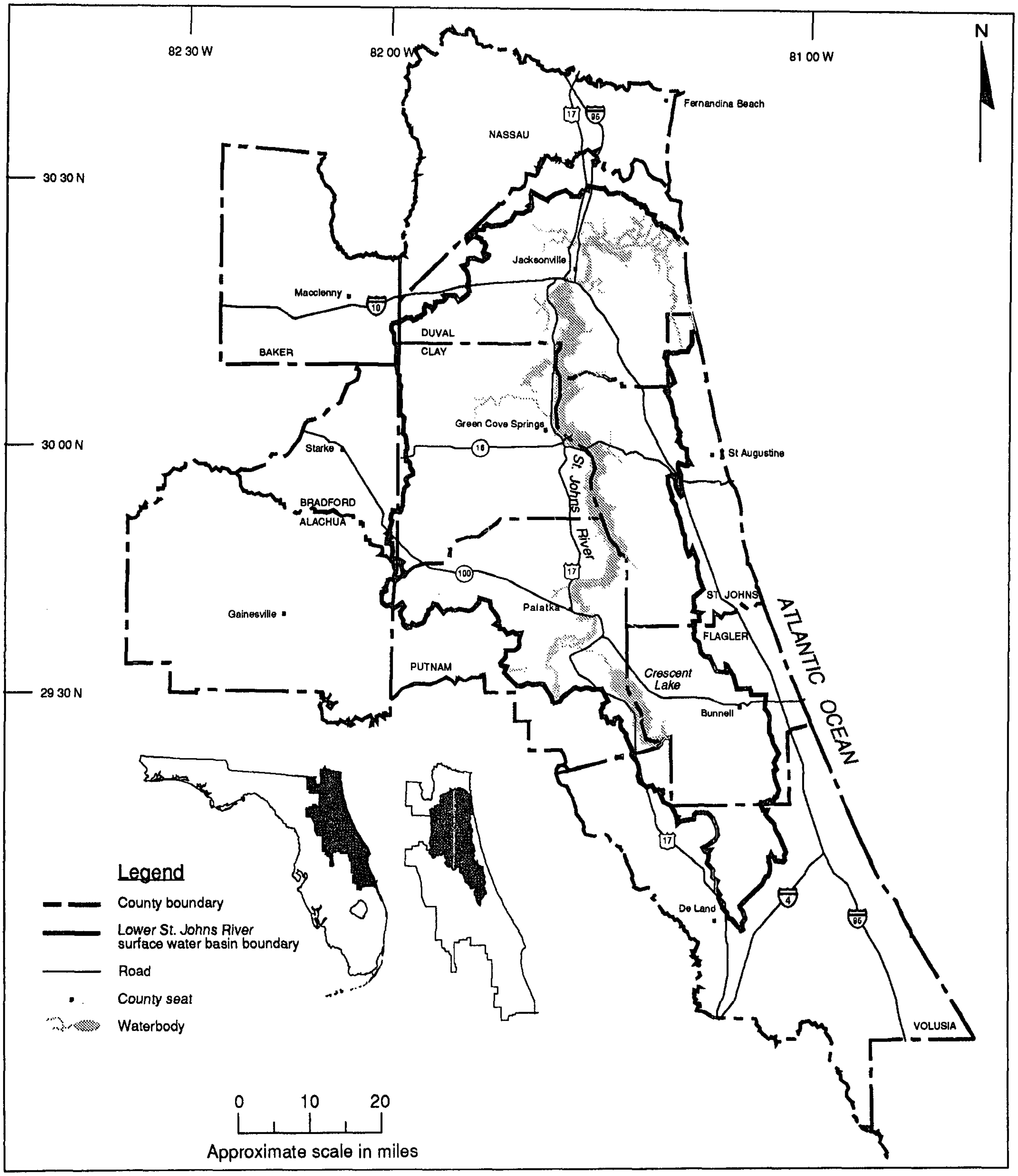


Figure 2. Lower St. Johns River surface water basin

sea level, and the average gradient of the main river channel is only 0.022 meters per kilometer (m/km) (0.1 ft per mile). Average annual tidal amplitude is 1.5 m (4.9 ft) at the ocean inlet and varies unequally upstream because of channel morphology. However, due to the low gradient of the river, tides affect the entire LSJRB along with the lower reaches of its tributaries. The mixing of salt water and fresh water has an influence on water quality as well as on the quantity and characteristics of sediments deposited in the basin. Water quality conditions for LSJRB range from good in the sparsely populated southern end of the basin to poor in the urban reaches of Jacksonville (Hand and Paulic 1992).

The basin is drained by 12 major tributaries. The drainage basins of the tributaries are called tributary basins (Figure 3), and each bears the name of the major tributary flowing through it. A thirteenth tributary basin (the St. Johns River tributary basin) represents the minor tributaries draining directly into the St. Johns River.

The *Lower St. Johns River Basin reconnaissance report* provides a synthesis of what is known about the condition of the lower St. Johns River and its tributaries from three perspectives: hydrologic, environmental, and socioeconomic. Volume 1, *Basin hydrogeology,* presents information on the ground water system in the basin and its connection to surface waterbodies. Volume 2, *Surface water hydrology,* discusses the surface water system, including hydrologic and hydraulic data collection networks. Volume 3, *Hydrodynamics and salinity of surface water,* describes relationships between river water levels, velocity, flow, storage, and salinity and reviews previous hydrodynamic modeling studies. Volume 4, *Surface water quality,* and Volume 5, *Sediment characteristics and quality,* present details on the levels and trends of chemical contaminants present in the water column and in the bottom sediments. Volume 6, *Biological resources,* describes plant communities and fish, shellfish, and marine animal communities. Volume 7, *Population, land use, and water use,* ties population estimates and projections to land use and residential, commercial, industrial, and agricultural water use. Volume 8, *Economic*

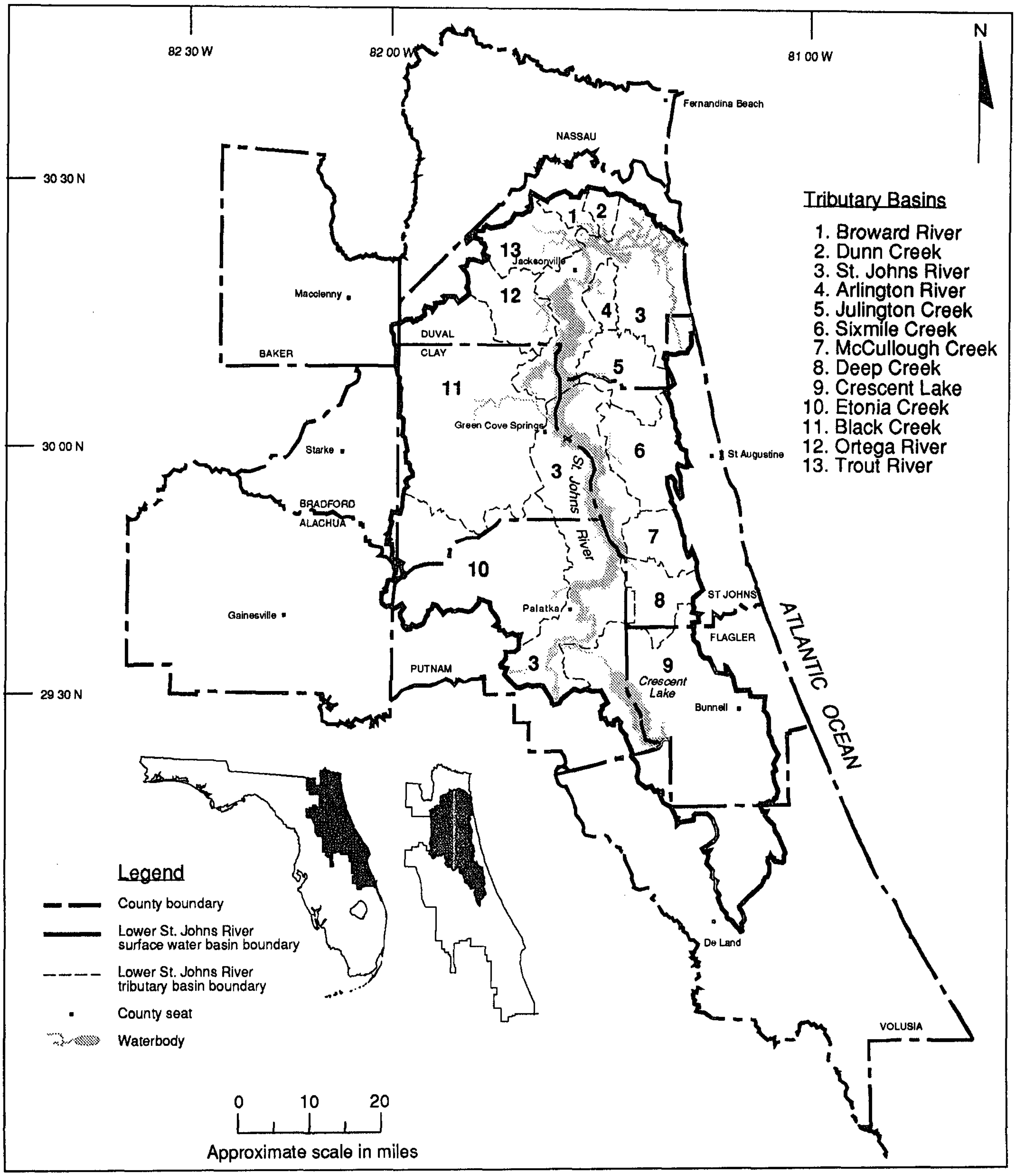


Figure 3. **Lower St. Johns River surface water tributary basins**

values, discusses the commercial, recreational, and aesthetic assets of the river. Finally, Volume 9, *Intergovernmental management,* discusses jurisdictional boundaries, regulatory authorities, and management efforts of governmental agencies, offices, and commissions involved in restoration or protection of water quality and habitat.

This volume, *Sediment characteristics and quality,* describes the characteristics and quality of river sediments as well as the processes that affect sediment formation. This volume also provides a review of the published information on levels of toxic chemicals present in LSJRB sediments, and it provides an evaluation of the potential impact on biota of these chemicals. Volume 5 presents recommendations for future research programs that will address current informational needs.

GEOLOGICAL HISTORY OF THE RIVER BASIN

Since its formation, the Florida peninsula has been subjected to periodic marine inundations alternating with re-emergences of dry land. Fluctuations in sea level occurred during the Pleistocene epoch (1.8 million to 10,000 years B.P.), forming barrier beaches and terraces that are evident today in the topography of the state (McLane 1955). The accumulation and wasting of continental ice sheets produced fluctuations of greater than 400 ft in sea level, so that during each glacial stage, much of the Florida plateau was dry land, whereas interglacial stages submerged large areas (Struthers 1981).

The St. Johns River valley was formed by a combination of erosion, fluctuating sea levels, and the work of winds, waves, and currents. The river valley probably originated during a geologic period (100,000 years B.P.) when sea level was 42 ft above its current level (Talbot shoreline) and most of peninsular Florida was inundated (Figure 5.1). During this time, a broad, deep (20 ft) lagoon, separated from the ocean by barrier islands and land bars, occupied much of what is now central Duval and western St. Johns counties (Struthers 1981). Tidal and wind action began to define the lagoon. A period of glaciation followed, which lowered sea level to 60 ft below its present elevation (Pre-pamlico shore). This exposed the former lagoon to wind, rain, and other erosional forces. Next came an interglacial period, during which time sea level rose again to 25 ft above the present level, and the Atlantic seashore (Pamlico shore) was 25 to 30 miles (mi) west of its current position (Cooke 1939). Ten to 15 mi offshore, a number of large islands once again enclosed a large bay and lagoon now partly occupied by the St. Johns River (Figure 5.1). Slow regression of the sea defined the basin and resulted in the formation of major topographical features from which developed the stream systems that currently drain the area (Burgess and Franz 1978). Today, the action of weather, tides, currents, ship traffic, and dredging continues to sculpt the river and its valley.

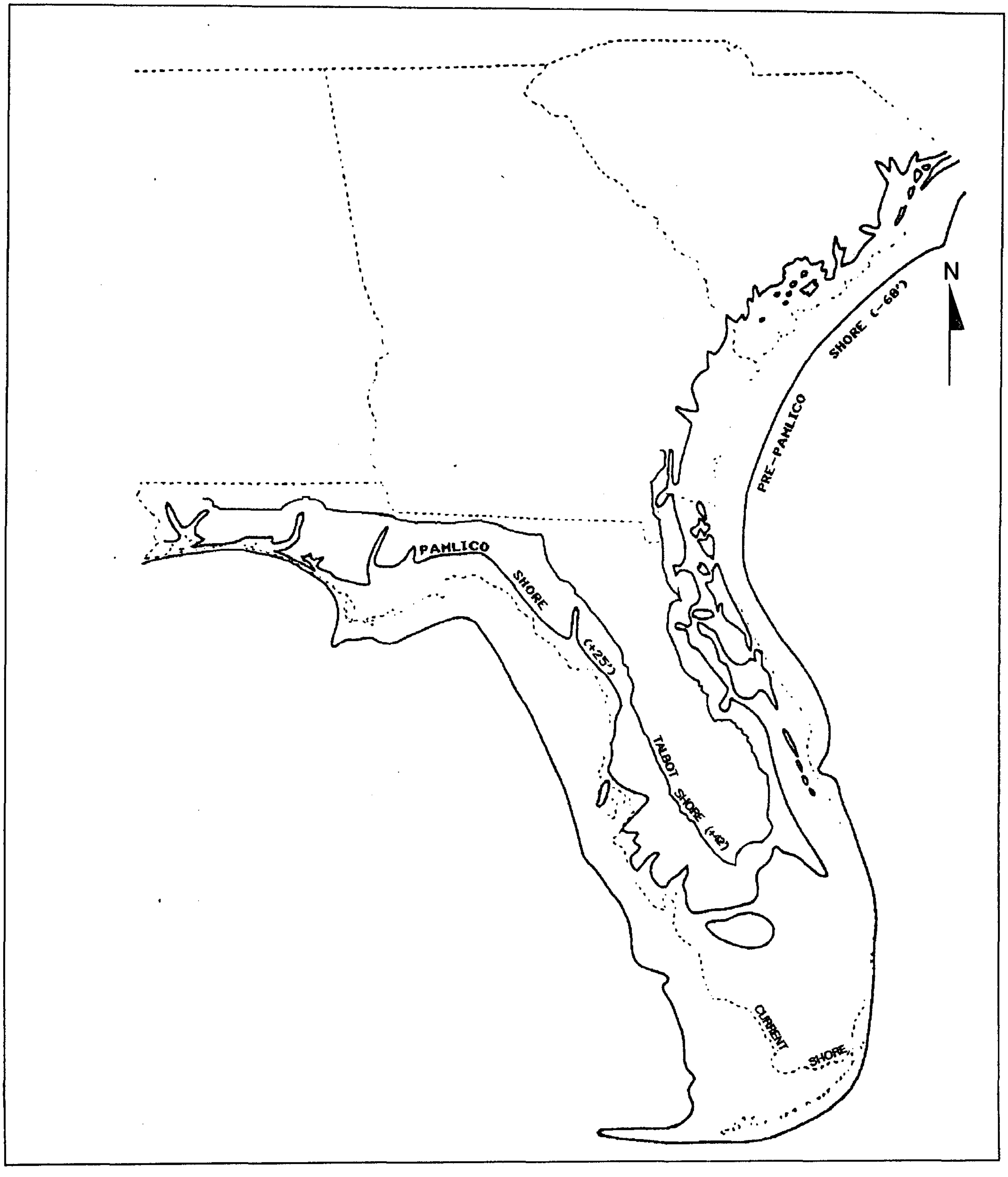


Figure 5.1 **The Talbot, Pamlico, and pre-Pamlico shorelines of Florida, indicating the historic basin of the present St. Johns River**

Source: Cooke 1939 (modified)

CHARACTERISTICS OF RIVER SEDIMENTS

Several characteristics of river sediments are important in determining the transport potential of the sediments and in indicating the likelihood of the sediments serving as sinks for contaminants. Geology of and activities in the watershed are important in determining the general characteristics of a river's sediments. Particle size (Table 5.1), particle distribution (skewedness), and total organic carbon (TOC) content are also important in a river's sediments. Contaminants are attracted to fine-grained sediments with high TOC (greater than 2 percent). In addition, enrichment of sediments with nitrogen and phosphorus (nutrients) can increase benthic algal and microbial production, which can lead to low oxygen levels. When anoxia occurs at the sediment-water interface, metals become more soluble and can enter the water column.

GENERAL SEDIMENT CHARACTERISTICS

Sediment analyses reported by the Mote Marine Laboratory (Pierce et al. 1988) indicated that the river bottom was composed primarily of fine-grained sediment. In addition, the majority of the sediments were dark in color, high in percent moisture, and poorly sorted (Pierce et al. 1988; Dames and Moore 1983). At a specific station, sediments were uniform in size, shape, organic content, etc.; however, sediment appearance varied widely among sample stations, ranging from a gelatinous, highly organic mousse to a relatively coarse shell hash (Pierce et al. 1988).

Pierce et al. (1988) also reported that in the upstream areas, a large fraction of the fine sediments was composed of organic materials, although there was no correlation between the distance upstream and increasing sediment organic content, as might be expected. While mud deposits occurred in low-energy fringe areas (shorelines, shallows, and areas protected from currents), the sediments in mid-channel were slightly coarser than those in fringe areas. This was expected, because water flow is generally

Table 5.1 Wentworth particle-size scale

Limiting Particle Diameter			Size Class		
Millimeters	Phi (ϕ) Units	Micrometers			
2048	-11		Very large	Boulders	GRAVEL
1024	-10		Large		
512	-9		Medium		
256	-8		Small		
128	-7		Large	Cobbles	
64	-6		Small		
32	-5		Very coarse	Pebbles	
16	-4		Coarse		
8	-3		Medium		
4	-2		Fine		
2	-1		Very fine	Granules	
1	0		Very course	Sand	
1/2	+1	500	Coarse		
1/4	+2	250	Medium		
1/8	+3	125	Fine		
1/16	+4	62	Very fine		
1/32	+5	31	Very coarse	Silt	MUD
1/64	+6	16	Coarse		
1/128	+7	8	Medium		
1/256	+8	4	Fine		
1/512	+9	2	Very fine		
				Clay	

Source: Barth and Starks 1985

greater in the channel and, therefore, flushes fine particles downstream.

PARTICLE SIZE AND DISTRIBUTION

Median particle size ranged from 0.25 millimeter (mm) to less than 0.063 mm at all Mote Marine Laboratory sample stations (Pierce et al. 1988). "The maximum percentages of fine sediments (less than 0.063 mm in diameter) were observed in the Cedar River...where over 75 percent of the sample by dry weight was silt-clay" (Pierce et al. 1988, p. 25). The median particle size for samples taken primarily from the mainstream of the river averaged 0.135 mm (May and September 1987). Geographical features of LSJRB used in this report are shown on Figure 5.2.

In a subsequent sampling effort (by Mote Marine Laboratory) with emphasis on tributary locations, the median particle size was 0.110 mm (March 1988). Smaller sized particles would be expected to accumulate in more depositional environments than where the samples were collected in 1987. While the sediments exhibited a substantial range of particle sizes (0.25 mm to 0.063 mm), there was no apparent spatial relationship between particle size and distance of the station from the mouth of the St. Johns River (Pierce et al. 1988). However, particle size appeared to be somewhat smaller at the tributary stations.

Sediment samples collected from LSJRB by Pierce et al. (1988) had an asymmetrical particle size distribution (skewedness) dominated by fine (silt-clay) or flocculent material. The coarsest sediments were found near the river's edge where wave action erodes sandy bluffs (Struthers 1981) and at the mouth of the St. Johns River where ocean forces carry marine sediments landward (Pierce et al. 1988).

TOTAL ORGANIC CARBON CONTENT

Sediment organic content is derived from plankton, microorganisms, benthic organisms, macrophytes, and

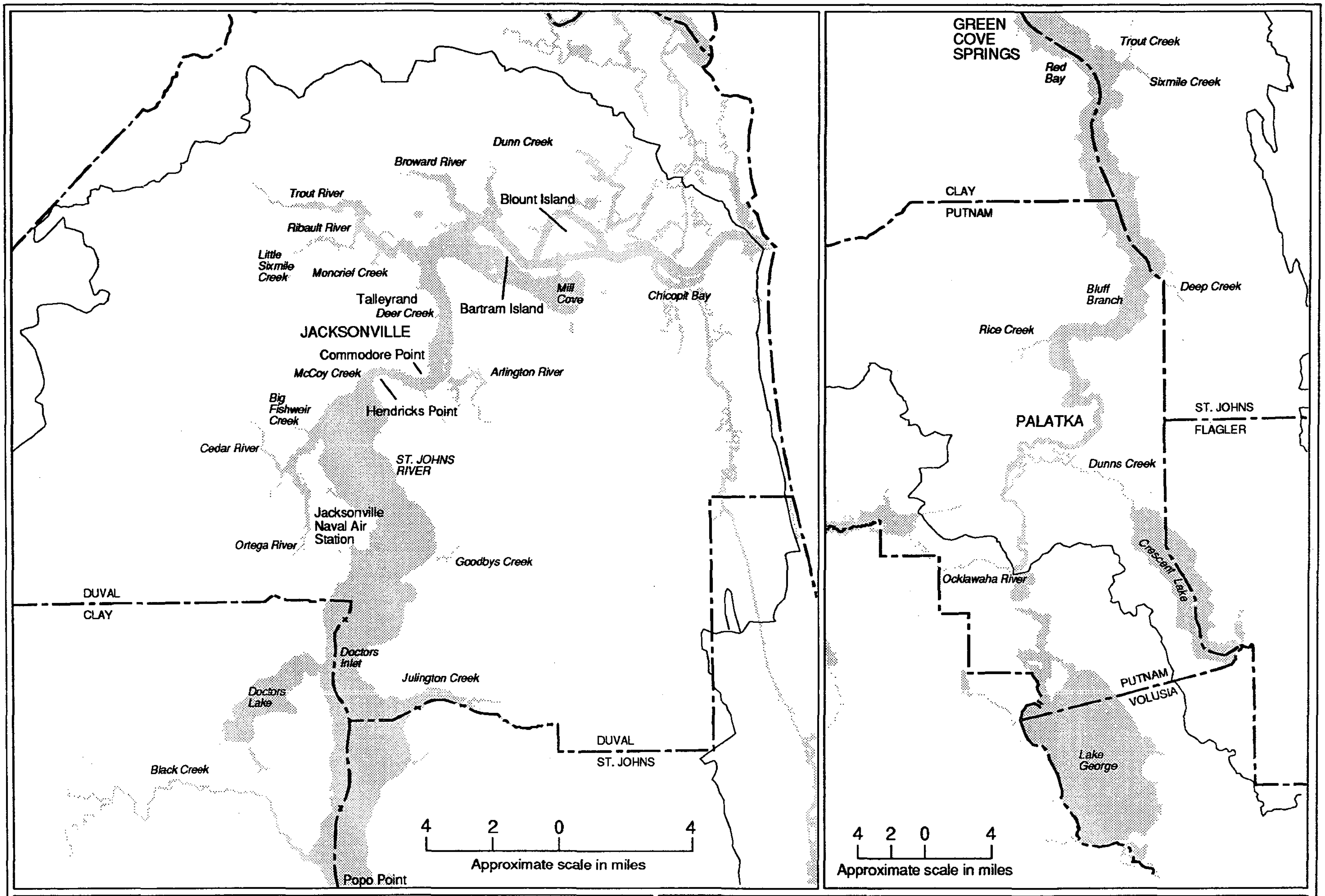


Figure 5.2 Location of geographical features referenced in the discussion on the characteristics and quality of sediments in the Lower St. Johns River Basin

allochthonous matter. Fine-grained sediments from the tributaries generally contain more organic carbon than do those from mainstream areas. This is due to the runoff of humus-rich soil from surrounding land, input from riparian vegetation, and the lower flow in the tributaries that allows sediment to accumulate. The National Status and Trends Program report (NOAA 1988) listed the sediments of the lower St. Johns River among the 20 highest in TOC content for the coastal United States. Values ranged from a low of 0.03 percent TOC to a high of 15 percent, based on dry weights (Pierce et al. 1988). Other southeastern estuaries had comparably high TOC levels. However, 25 sediment samples collected by SJRWMD from sites between the Ribault River and Julington Creek ranged from 2 percent TOC to 35 percent TOC.

Carbon attracts (adsorbs) contaminants, thereby making the contaminants unavailable to organisms. TOC may compete with biota for uptake of contaminants and thereby reduce the bioavailability of the contaminants in the water column. Sediments with high TOC serve as a sink for contaminants by chemically attracting them. Thus, pelagic biota are less likely to take up the contaminants. Organisms that live directly in benthos or consume sediments may be impacted adversely by contaminated sediments.

NUTRIENTS

Nutrients can have a significant effect on sediment quality. Sediments bind nitrogen and phosphorus that enter the river from sewage treatment plants, landscape fertilizers, agricultural sources, and decomposition of riparian vegetation (International Joint Commission 1988). Growth of benthic algae and bacteria can be stimulated by nutrients. This can lead to changes in redox potential of the sediment-water interface as the algae generate oxygen and then both the algae and bacteria use oxygen in respiration. When the sediment-water interface becomes anoxic, nutrients are released to the water column. More importantly, perhaps, sediment-bound metals also can be released from the sediment. This changing benthic environment has a direct impact on both water quality and biological colonization of the area.

Sediment concentrations of total Kjeldahl nitrogen and total phosphorus for LSJRB ranged from 20 to 19,000 milligrams per kilogram (mg/kg) and 9.7 to 2,570 mg/kg sediment dry weight, respectively (Pierce et al. 1988; Dames and Moore 1983; Savannah Laboratories and Environmental Services 1988). The higher values are representative of highly enriched conditions, while the lower concentrations indicate sediments that are nutrient-poor. Samples were taken from both tributary and mainstream areas, providing a wide range of values.

SOURCES, DISTRIBUTION, AND DEPOSITION OF SEDIMENTS

Estuaries have four basic elements in common which affect the characteristics and transport of materials that make up an estuary bottom. According to Pritchard (1967), "an estuary is a waterbody that is coastal and semi-enclosed, freely connected to the open sea, influenced by tidal action, and characterized by seawater measurably diluted with fresh water derived from land drainage."

Sedimentation processes in large estuaries are dependent on a number of complex and interacting factors. Unlike inland rivers, estuaries are strongly influenced by factors such as tidal action and wind, as well as by downstream flow. The lower St. Johns River is a shallow, slightly graded (less than 0.02 m/km) tidal estuary formed by wind and tidal action of an ancient sea. Because the river has large areas with shallow depths, winds can have a major influence on mixing and currents. Also as a result of the basin topography, tidal effects are found many miles upstream, with the mixing of fresh and salt water occurring over a wide area. This mixing of salt water with fresh water has a profound influence on the quantity and characteristics of sediments deposited in the basin.

Although general physical and hydrological principles affecting sediment formation and movement are applicable to LSJRB, a sediment management program requires the use of empirical data that is basin specific. The movement and fate of sediments within a river may be understood best through a detailed description of flow patterns. Due to the combined effects of wind, tide, water chemistry, and basin morphology, this type of understanding can only be obtained by the development and application of a basinwide hydrodynamic model, which is the subject of volume 3 of this reconnaissance series.

SEDIMENT SOURCES

In terms of sediment sources and movements, estuaries are very complex environments. The four major sources of estuarine sediments are adjacent watersheds and their drainage systems, the ocean, the lower slopes of the lands bordering the estuary (river banks), and the river as bedload or as resuspended sediment. These sources produce sediments that differ in particle size, organic content, density, and other parameters (Schultz and Simmons 1957). The major sources of sediments in LSJRB include erosion of sand and clay from the adjacent watersheds and production of organic sediments (e.g., flocculent and muck sediments).

Bedload is defined as "the part of the total stream load that is moved on or immediately above the streambed such as larger or heavier particles" (Bates and Jackson 1980). Sand is contributed mainly by erosion of the river banks and the ocean floor, and it enters the system as bedload sediment. In contrast, most of the clay is delivered from the remaining sources mentioned above (Schultz and Simmons 1957), and this fine sediment enters the estuary as suspended load (Struthers 1981). In a low-gradient system like the St. Johns River, transport of bedload is low due to the lack of strong downstream currents. Large amounts of sand are moved in and out of the river at its mouth, where strong ocean and tidal currents are capable of moving heavier particles.

The source of clays found in river sediments upstream of Jacksonville appears to be the inland drainage system (Struthers 1981), whereas downstream of Jacksonville the primary source of sediments is bedload. If large amounts of clay were being introduced by ocean flood currents, then chlorite would be a component of the bottom sediment. Chlorite is a major component of the Atlantic Seaboard clay suite which is carried south by drift. No traces of chlorite were found, however, in the bottom sediments near Julington Creek or at Doctors Inlet.

Although a number of different types of sediments are formed as a result of distinctive chemical and physical processes, flocculent and muck sediments may be qualitatively the most important in LSJRB. Since both types of sediment are fine grained, they are easily resuspended, causing increased biological oxygen demand and increased exposure of the water column to sediment-bound contaminants. Flocculent and muck sediments are poor habitats both for growth of rooted aquatic vegetation and for colonization by benthic organisms.

Flocculent Sediment

One of the unique qualities of an estuarine system is that the mixing of fresh and salt water increases the formation of flocculent sediments. Flocs are formed when clay particles agglomerate (Struthers 1981). Clay minerals entering the river have a plate-like structure, which provides a large amount of surface area per unit weight (Mehta and Partheniades 1975). When these particles are suspended in water, they carry electrostatic charges, usually negative. In fresh water, the mutual repulsion caused by the negative poles of adsorbed water layers on adjacent mineral particles prevents the particles from adhering to one another, and they remain in a dispersed state. However, as salinity increases, the electrostatic charges on the particles and on their adsorbed water layer are neutralized by the dissolved salts. The result is that some particles become mutually attractive and form flocs (McDowell and Connor 1977). Flocs will settle relatively quickly due to their increased mass (Partheniades 1964). The large fraction of suspended silt-clay present in the lower St. Johns River flocculates, then settles during slack tides, forming mud deposits that cover the river bottom in low-energy fringe areas.

Muck Sediment

Muck is black, fine-grained sediment with a high water content, composed of partly decomposed organic matter with a considerable amount of silt and clay material (Trefry et al. 1990). This high organic content increases the adsorption of organic contaminants (polychlorinated biphenyls [PCBs], polycyclic aromatic hydrocarbons [PAHs], dichlorodiphenyltrichloroethane

[DDT], etc.) to muck. Muck is not the natural bottom in most estuarine areas; rather, it results mainly from soil runoff due to development and poor soil conservation practices. Muck can be easily resuspended and greatly increases the turbidity of the water (Trefry et al. 1990).

Poor soil management practices in the last century or so have resulted in the addition of muck sediments to the river's sediment profile. Pierce et al. (1988) indicated that muck deposits occur in a number of tributaries of the St. Johns River, including the Ortega River tributary basin (Figure 3), Trout River, Deep Creek, and Rice Creek (Figure 5.2).

SEDIMENT DISTRIBUTION

An important cause of local sediment distribution is the reentrainment of existing bedload via dredging, tides, and boat traffic (U.S. Army Corps of Engineers 1989). New sediment may be coming from immediately adjacent lands (the lower slopes of the lands bordering the estuary), but due to the low terrain and drainage characteristics of LSJRB, this source is likely to be less important in localized areas than sedimentation resulting from reentrainment via dredging, boat traffic, and tides.

The U.S. Army Corps of Engineers maintains a navigation channel in the St. Johns River. The channel is 38 ft deep at mean low water and 400-1,200 ft wide from the ocean to about 20 mi upstream, 34 ft deep to Commodore Point, and 30 ft deep to the Florida East Coast Railroad Bridge at Hendricks Point in Jacksonville. From Hendricks Point to Palatka, the channel is maintained at 13 ft deep by 100 ft wide; from Palatka to the Ocklawaha River it is 12 ft deep and 100 ft wide.

The farther a harbor or shipping channel is from an ocean-disposal site, the more economical it is to dispose of dredge spoil in the water and on land adjacent to the navigation channel (U.S. Army Corps of Engineers 1989). Thus, for areas from the Talleyrand area to Blount Island, dredge spoil has been deposited on nearby land or in the water. Both Blount and Bartram islands were formed exclusively from this spoil material. Dredging will continue, but as disposal areas are filled to capacity, new options will be needed. The U.S. Army Corps of Engineers (1989) published a reconnaissance report which discusses in detail the issues that need to be considered in the development of new disposal options for dredge material. The report examines alternate spoil sites, the effect of these spoil sites on water quality, and the development of alternate uses for filled spoil sites.

SEDIMENT DEPOSITION

Deposition of the suspended load entering the system depends on both physical and chemical processes of the river. In a tidal estuary like the lower St. Johns River, the major physical influence is tidal current. Because the river has an extremely low gradient, tidal effects are evident as far as Lake George, some 106 mi upstream (Anderson and Goolsby 1973). In the absence of strong downstream flow, sediment is transported landward (upstream) when flood tides predominate. The flood tides are capable of carrying large amounts of suspended ocean material, as well as some resuspended bedload, several miles upstream (McDowell and Connor 1977).

In addition to tidal current, another important mechanism for the movement of sediment is the salt wedge that exists near the seaward end of the estuary. A salt wedge forms because of density differences between salt and fresh water. Since salt water is more dense than fresh water, an upstream moving tidal current is generated on the bottom of the river channel. In contrast, the less dense fresh water floats on the salt water and forms a seaward moving surface water layer. As suspended sediments carried in fresh water approach the saltwater boundary, the flow slows, allowing more time for fine particles to settle (sedimentation).

In the St. Johns River, the salt wedge can remain intact as far as 40 mi upstream to near the Duval-Clay county line, where the river becomes a well-mixed estuary. Palatka, about 80 mi upstream of the river's mouth, is considered to be the upper limit of tidal influence because ocean water reaches that point only during extended droughts (Struthers 1981).

SEDIMENT CONTAMINATION

Human activity in the river's watershed has increased dramatically during the last 50 years. Land use has changed from predominantly low density housing in rural areas to increasingly dense urban development with industrial components. Between 1980 and 1990, the population of Duval County increased 15 percent, from 571,300 to 673,000 (Shermyen et al. 1991). Even though water reuse is being encouraged and the number of permitted discharges is decreasing, over 380 permitted industrial and wastewater treatment plants in Duval County alone discharge into LSJRB (City of Jacksonville 1985). This increase in population and human activities and the physical and chemical characteristics of LSJRB have resulted in the accumulation of significant levels of toxic chemicals in the sediments. In the past, river sediments were thought to protect the water column by removing pollutants. Now, this storage and concentration of pollutants is viewed as harmful to the biota (especially benthic), because of long-term exposure of the biota to the toxic substances.

During the past 10 years, nine studies have evaluated the degree of contamination of LSJRB sediments (Dames and Moore 1983; Boehnke et al. 1983; Pierce et al. 1988; Savannah Laboratory and Environmental Services 1988; FDER 1988; City of Jacksonville 1990; Delfino et al. 1991; Hanson and Evans 1991; SJRWMD 1993). Although that number of studies is higher than the number of studies done for most other Florida estuaries, few of the LSJRB area studies were comprehensive. As a result, the extent of the contamination of the river basin is not well defined, nor is the biological significance of contamination understood.

The three most comprehensive studies on sediment quality in the lower St. Johns River were the Dames and Moore (1983) maintenance dredging study, the Mote Marine Laboratory Report (Pierce et al. 1988), and a Florida Department of Environmental Regulation (FDER) program in 1988 (FDER 1988). All three studies included analyses of both metal and organic pollutants.

Dames and Moore (1983) analyzed samples taken from the main channel of the river near downtown Jacksonville. Within a 2-year period, the Mote Marine Laboratory (Mote) and FDER analyzed sediments from over 120 different sites in LSJRB. Mote personnel sampled sites both in the main channel and in many of the major tributaries, including the Arlington River, the Ortega and Cedar rivers, Goodbys Creek, Doctors Lake, Julington Creek, and Rice Creek (Figures 5.3 and 5.4). The FDER project focused mainly on the main channel of the river.

Four other studies are noteworthy. Five sites in LSJRB were included in a study of metal contamination in 19 southeast Atlantic Coast and Gulf of Mexico estuaries by the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) (Hanson and Evans 1991). Delfino et al. (1991) completed a statewide survey of sediment organic contaminants, including four sites in LSJRB. Boehnke et al. (1983) sampled sediments at 30 locations extending from Julington Creek to the mouth of the St. Johns River and performed analyses of hydrocarbon content. The City of Jacksonville and SJRWMD analyzed sediment samples from a number of tributaries for metal and organic pollutants.

Each of the nine investigations was designed to locate contaminated areas rather than to determine the extent of the contamination or to assess the potential environmental risk. The size of the contaminated area (as well as the sediment toxicity and its potential for biological impact must be known) prior to the development of any remediation plan.

Although a variety of anthropogenic chemicals and other compounds enter LSJRB, the sediments act as a sink or reservoir for two important classes of toxic pollutants: heavy metals and organic contaminants.

HEAVY METALS

Metals entering the lower St. Johns River from upstream can remain in the water column adsorbed to suspended solids and be

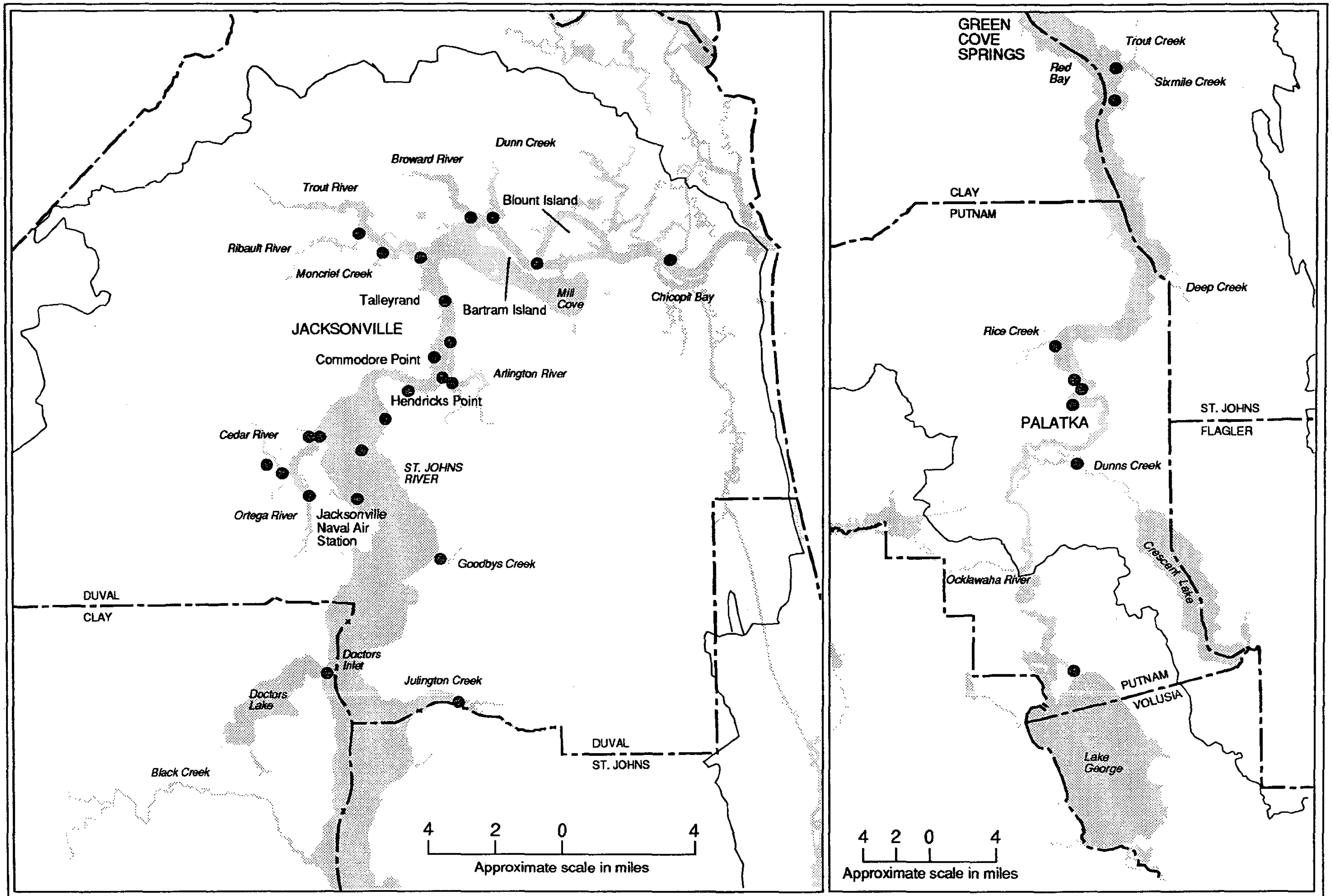


Figure 5.3 **Sediment sampling stations used by Mote Marine Laboratory in 1987**

Source: Pierce et al. 1988

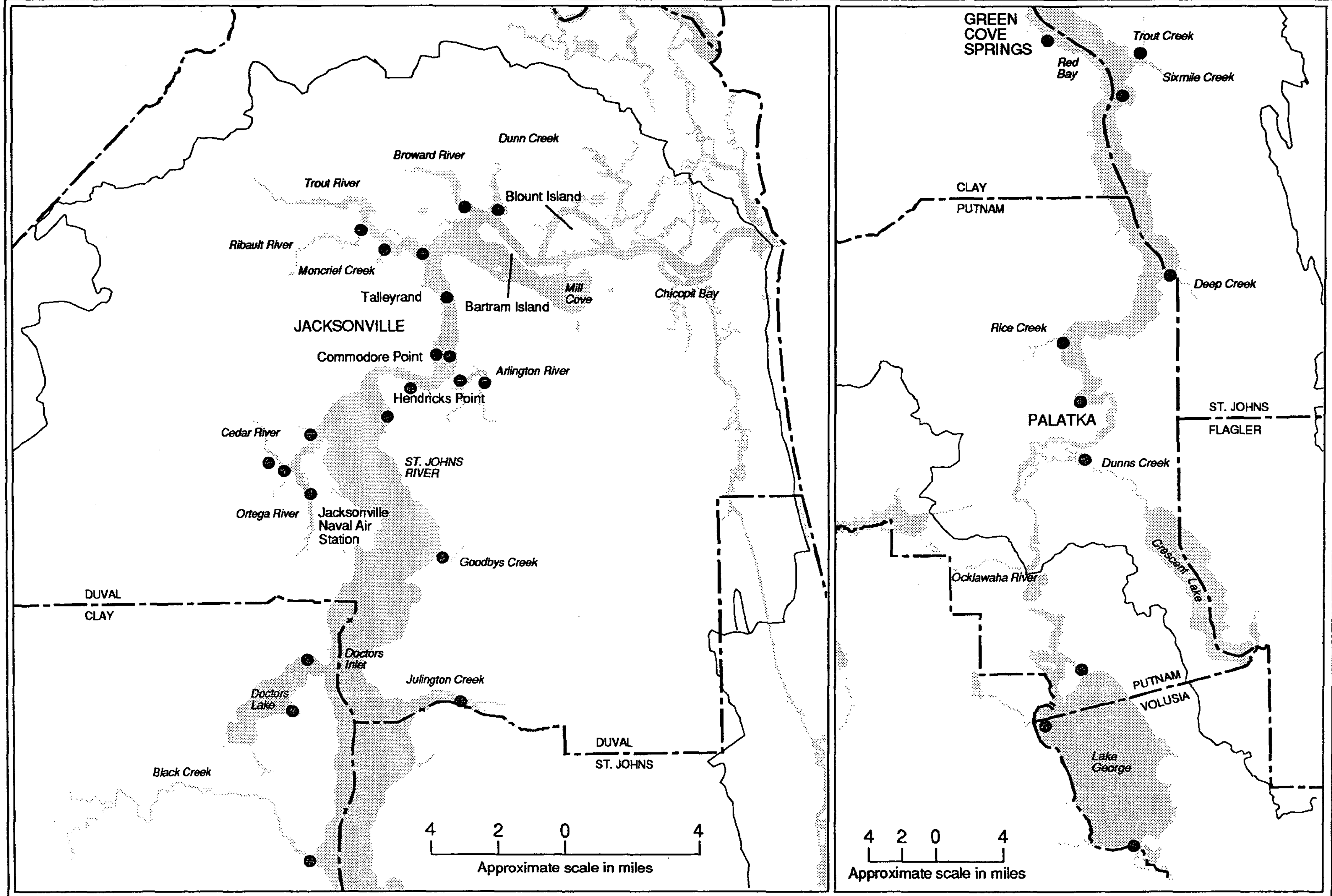


Figure 5.4 **Sediment sampling stations used by Mote Marine Laboratory in 1988**

Source: Pierce et al. 1988

transported downstream with normal flow. As metal-laden fresh water mixes with more saline water of marine origin, a complex set of chemical changes results in the precipitation of suspended solids and the associated metals. In particular, the solubility of a metal depends on various conditions such as salinity, changes in pH, and temperature (Cross and Sunda 1978). Cationic metals precipitate from the water column and concentrate in estuarine sediments (Schropp and Windom 1987). Metals in sediments, therefore, can come from the nearby areas or from industrial and residential communities many miles upstream.

Results from investigations by Mote (Pierce et al. 1988), FDER (1988), NOAA's NMFS (Hanson and Evans 1991), and current SJRWMD studies indicate that the area from the Arlington River upstream to Julington Creek is contaminated with a variety of heavy metals. Lead, mercury, and zinc were common contaminants in samples collected by Mote personnel (Pierce et al. 1988). The NMFS study of fish and sediments (Hanson and Evans 1991) concluded that of the three estuaries sampled intensively (Galveston Bay, Sapelo Island, and LSJRB), LSJRB had the highest concentrations of heavy metals and the most stations with values above the 95 percent upper confidence limit. Unpublished data (FDER 1988; SJRWMD 1993) indicate that several tributaries of LSJRB may have elevated metal concentrations.

Most of the 16 locations sampled by Dames and Moore (1983) were found to have measurable metal concentrations. Sedimentation from five sites near the Talleyrand area contained three or four metals, including mercury, chromium, copper, cadmium, lead, and/or zinc.

FDER (Shropp and Windom 1987) evaluated the level of metal contamination in the sediments, based on the ratio between the metal of concern and aluminum. Aluminum was chosen as the reference element to normalize sediment metal concentrations because it is the most abundant naturally occurring metal and it is highly refractory. Levels of aluminum are unusually high in unimpacted sediments because aluminum absolute concentrations normally are not influenced by anthropogenic sources. Aluminum concentrations, therefore, remain constant (Schropp and Windom 1987) even though concentrations of other metals increase with human activity. The ratio between the metal of concern and aluminum will increase with increased human activity. By comparing this ratio for areas impacted by human activities to the ratios for areas in which human impacts are minimal, the sediments from many locations in LSJRB were found to be *enriched* with mercury, copper, cadmium, lead, and zinc. That is, these metals were found at levels higher than would be found in areas unimpacted by human activities.

The part of the river with the greatest metal enrichment (Figure 5.5), Arlington River to Julington Creek, is in the zone where fresh and salt water meet and mix. This portion of the river is the area with the greatest amount of residential and industrial development. Activities and land use in these areas (pesticide use on lawns and gardens, metal release from fossil fuels, metal stripping, etc.) can result in the deposition of significant amounts of heavy metals.

ORGANIC CONTAMINANTS

As previously mentioned (see p. 12), sediments in some areas of LSJRB, particularly the tributaries, contain a high TOC concentration, making these sediments a reservoir for organic contaminants such as PAHs, PCBs, and chlorinated pesticides. PAHs are derived mainly from combustion of fossil fuels or fires. Prior to 1974, PCBs were used in dielectric fluid, as lubricants, as plasticizers, and as solvents. After 1974, these compounds were used mainly in dielectric fluids (EPA 1992). PCB production in the United States was halted as of 1979. In 1985, uses of PCBs that were manufactured prior to 1979 were restricted to electrical transformers in low traffic areas (EPA 1992). PAHs, PCBs, and chlorinated pesticides adsorb to organic sediments.

Pierce et al. (1988) reported organic contaminants in the lower St. Johns River. Sediments in the area from Dunn Creek to Julington Creek (Figure 5.6) were contaminated by PAHs. The

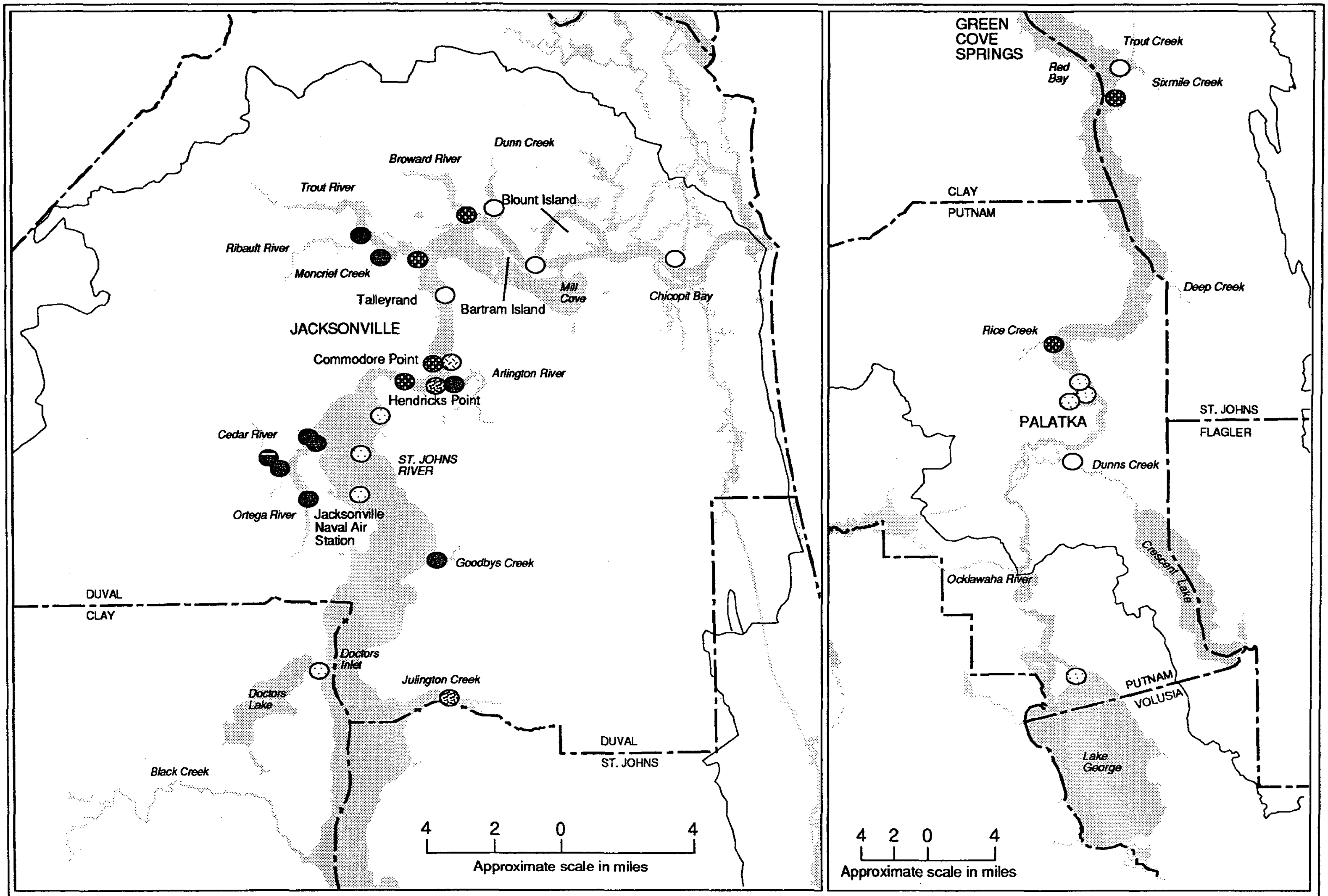


Figure 5.5 **Mote Marine Laboratory 1987-88 sediment stations "enriched" with metals.** *The metals measured were cadmium, copper, lead, zinc, and mercury.*

Source: Pierce et al. 1988

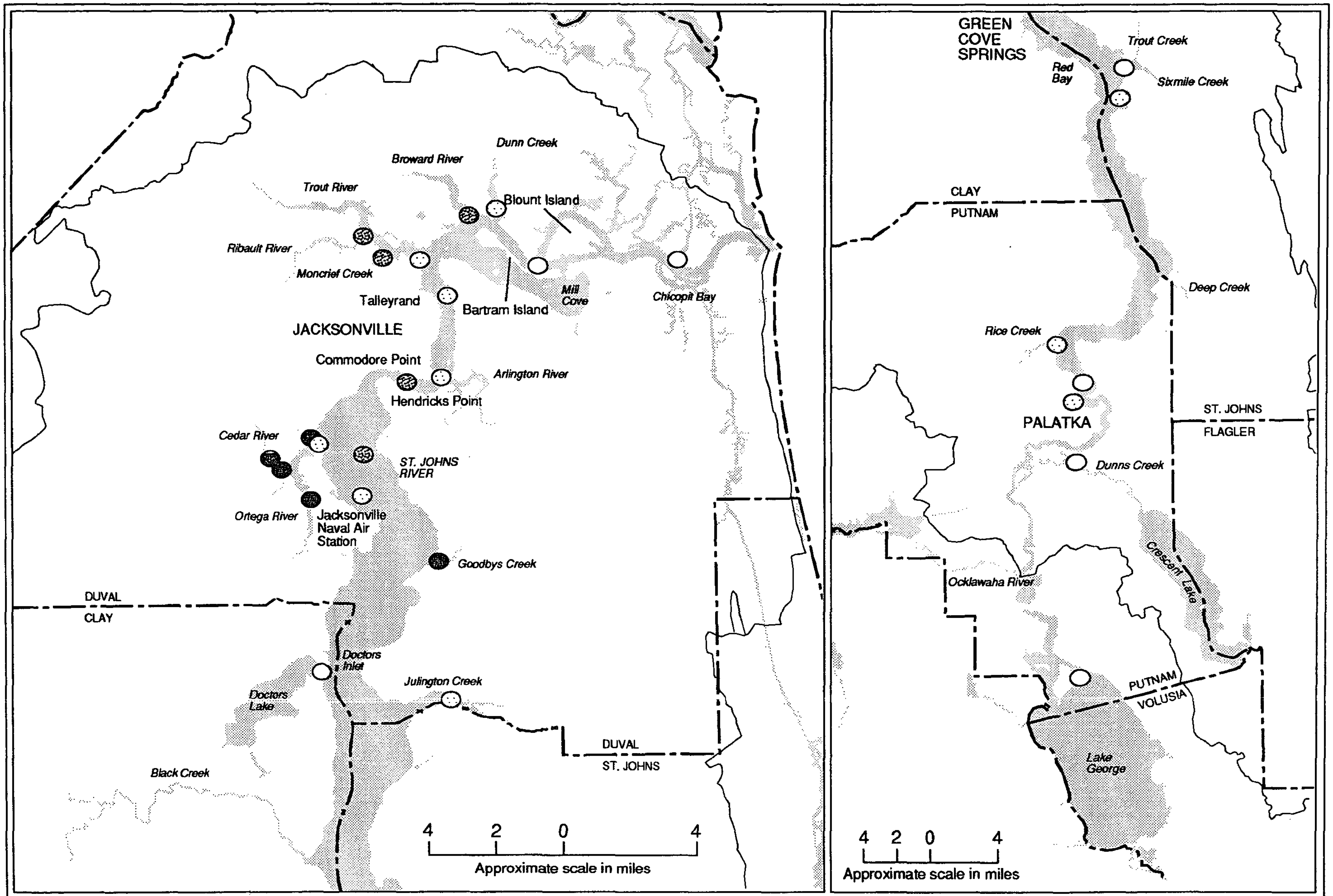
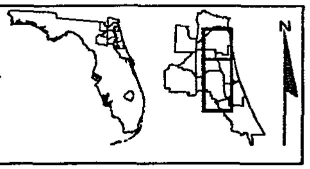


Figure 5.6 **Concentrations of total polycyclic aromatic hydrocarbons (PAHs) detected in Mote Marine Laboratory 1987-88 sediment stations**

Source: Pierce et al. 1988

- ○ <1 mg/kg dry sediment
- ◌ 1-9 mg/kg dry sediment
- ▨ 10-15 mg/kg dry sediment
- ● 16-35 mg/kg dry sediment
- — - — County boundary
- —— Lower St. Johns River Basin boundary



area from Dunn Creek to Goodbys Creek was contaminated by chlorinated pesticides, for example, DDT, chlordane, and nanochlor (Figure 5.7). The area from Dunn Creek to Julington Creek was contaminated with PCBs (Figure 5.8). Since these areas are not major agricultural areas, the most likely sources of the pesticides would be buried DDT and chlordane used in residential and commercial buildings. Concentrations of PCBs exceeding 1.0 mg/kg of sediment (dry weight) were reported, particularly in the Ortega River tributary basin. Other specific areas of significant contamination identified were the Arlington River, the Talleyrand area of Jacksonville, and the river adjacent to the Jacksonville Naval Air Station (NAS). These areas showed very high levels of a number of contaminants, but not all contaminants were found at each station. Boehnke et al. (1983) also found elevated levels of PAHs in this same region of the river.

The National Status and Trends Program (NOAA 1988) conducted a less extensive study of LSJRB sediments that included samples collected from two sites in Chicopit Bay near the mouth of the St. Johns River. Compared to 212 other coastal sites sampled nationally, the lower St. Johns River had the 17th highest level of PCB contamination (384 micrograms per kilogram [µg/kg] dry sediment). Elevated levels of DDT, DDT-derivatives, and chlordane also were reported. In 1982, the U.S. Environmental Protection Agency (EPA) found concentrations of PCBs as high as 7.3 mg/kg in Cedar River sediment (City of Jacksonville 1982). In 1985, the City of Jacksonville's Bio-Environmental Services Division found 3.3 mg/kg of PCBs per kilogram of sediment in samples taken in the Cedar River (City of Jacksonville 1985). Sediment samples collected by SJRWMD in the Cedar River, Moncrief Creek, Goodbys Creek, and the Ribault River during 1990-92 contained substantial concentrations of several PAHs (approaching the individual "no observed effects level" [NOEL]). PCBs also were found in significant concentrations in these samples (exceeding NOEL).

Dames and Moore (1983) reported the results of chemical analyses for PCBs, chlorinated pesticides, and nine metals at 15

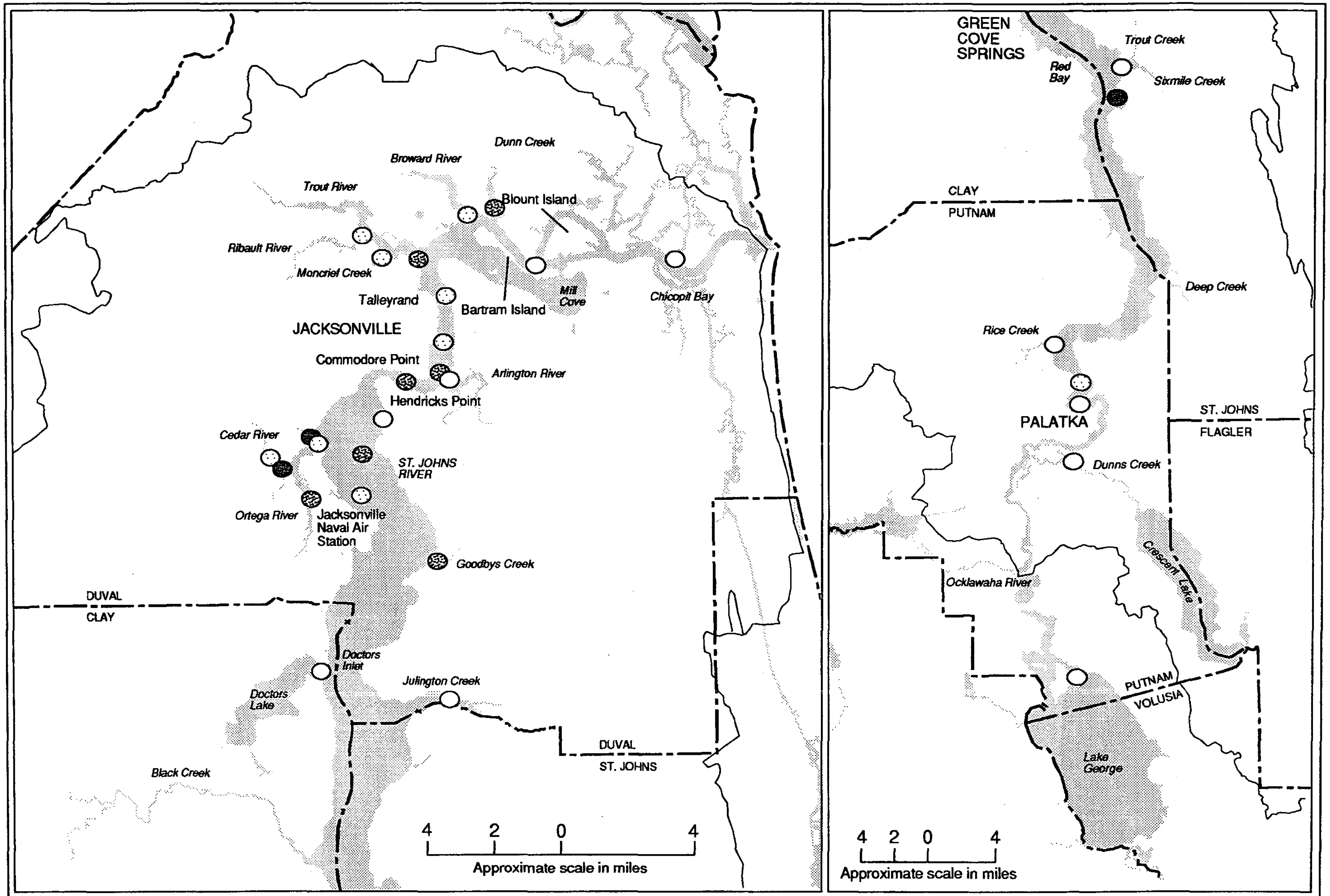


Figure 5.7 **Concentrations of chlorinated pesticides detected in Mote Marine Laboratory 1987-88 sediment stations**

Source: Pierce et al. 1988

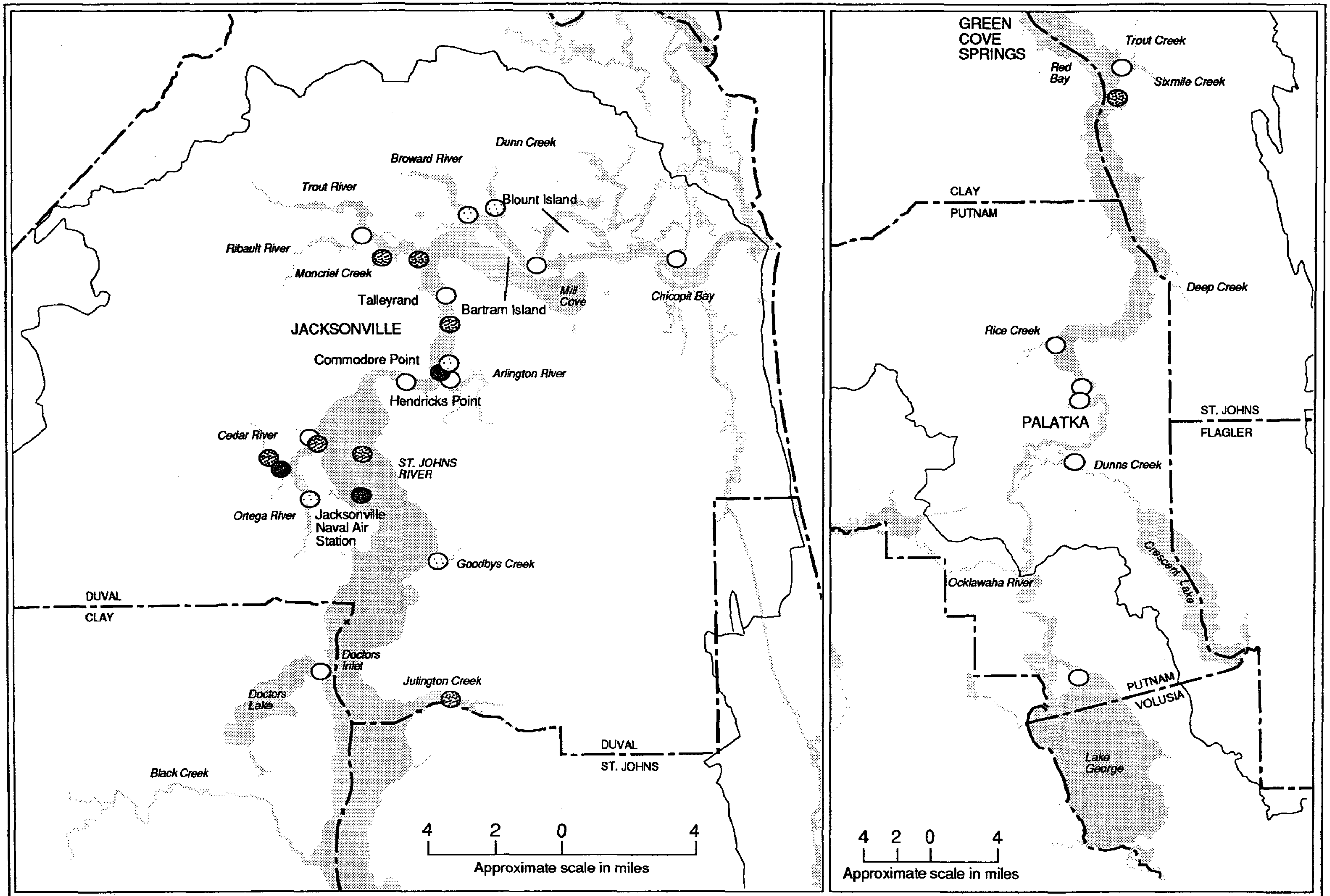


Figure 5.8 **Concentrations of polychlorinated biphenyls (PCBs) detected in Mote Marine Laboratory 1987-88 sediment stations**

Source: Pierce et al. 1988

main channel sediment sample sites. PCB and chlorinated pesticide levels in the sediment were either low and approaching the limit of detection, or actually below the detection limit (1.0 nanogram per kilogram [ng/kg]) for all the samples except one, which was collected near the Buckman Street Sewage Treatment Plant discharge pipe at the Talleyrand terminal. The lower contaminant levels reported by Dames and Moore (1983), as compared to the other studies, may be due to the selection of sample sites. The Dames and Moore (1983) sample sites were restricted to the main channel of the river, while Mote, EPA, and the City of Jacksonville included the tributaries of LSJRB in their sampling program.

SEDIMENT TOXICITY

A recent NOAA report (Long and Morgan 1990) attempted to correlate published laboratory toxicity data with the results obtained from the ongoing National Status and Trends Program (NOAA 1988). The report assessed the relative likelihood or potential for adverse biological effects due to exposure of biota to toxicants in sediments. Following extensive evaluation of the scientific literature, Long and Morgan determined two values from the data for each chemical: an effects range-low or ER-L, a concentration at the low end of the range in which effects had been observed, and an effects range-median or ER-M, a concentration approximately midway in the range of reported values associated with biological effects.

FDER (MacDonald 1993) developed a set of sediment quality guidelines for use in Florida coastal waters, based on the Long and Morgan (1990) analysis. Two critical concentrations were established for each contaminant: "no observed effects level" (NOEL) and a "probable effects level" (PEL) (Figure 5.9). NOEL is the highest concentration at which no detrimental impact on biota is expected. PEL represents the concentration at which a contaminant is likely to exert a negative impact on the biota. NOEL and PEL, which vary from one substance to another (Tables 5.2-5.4), are more conservative than similar categories established by Long and Morgan (1990) because a safety factor was used to reflect the potential effects of chronic long-term exposure. Since actual toxicity depends on many conditions that can vary from site to site, between organisms, or by method of evaluation (equilibrium partitioning, sediment quality triad, etc.), NOEL and PEL values determined from the literature are approximate values. MacDonald did not determine NOEL and PEL concentrations for many contaminants due to lack of sufficient data.

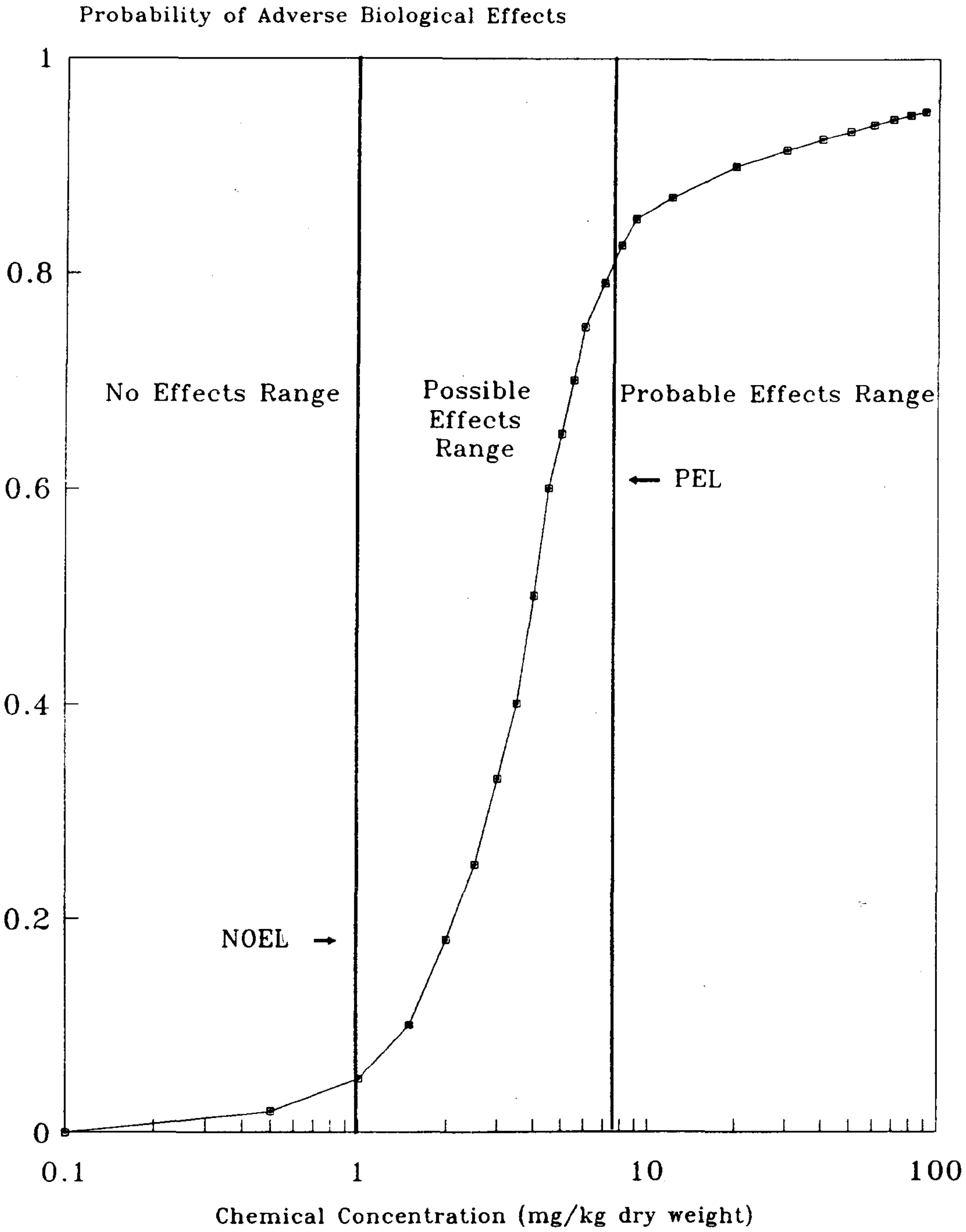


Figure 5.9 **Conceptual example of sediment quality assessment guidelines**

Source: MacDonald 1993 (modified)

Table 5.2 Sediment quality guidelines for metals in Florida coastal areas

Contaminant	NOEL[1] (mg/kg)	PEL[2] (mg/kg)
Arsenic	8.0	64.0
Cadmium	1.0	7.5
Chromium	33.0	240.0
Copper	28.0	170.0
Lead	21.0	160.0
Mercury	0.1	1.4
Silver	0.5	2.5
Zinc	68.0	300.0

[1] No observed effects level
[2] Probable effects level

Source: MacDonald 1993

Table 5.3 Sediment quality guidelines for polychlorinated biphenyls (PCBs) pesticides, and phthalates in Florida coastal areas

Contaminant	NOEL[1] (µg/kg)	PEL[3] (µg/kg)	ER-L[2] (µg/kg)	AET[4] (µg/kg)	EqPA[5] (µg/kg)
Aldrin/Dieldrin				1.9-6.2	
Bis(2-ethylhexyl) phthalate				1,300-5,100	
DDD					2-20
DDE	1.7	130	2		
DDT			1		
Di-n-butyl phthalate				1,400-5,100	
Dimethyl phthalate				71-490	
Endosulfan		50-340			
Endrin			0.02		0.5-3.2
Heptachlor					5
Lindane				0.7 to > 1.3	
PCBs	24.0	260	50		
PCP				360-690	
tChlordane			0.5		>6
tDDT	4.5	270	3		

[1] No observed effects level in micrograms per kilogram
[2] Probable effects level in micrograms per kilogram
[3] Effects range-low in micrograms per kilogram
[4] Apparent effects threshold in micrograms per kilogram
[5] Equilibrium partitioning in micrograms per kilogram

Sources: MacDonald 1993
Long and Morgan 1990

Table 5.4 Sediment quality guidelines for polycyclic aromatic hydrocarbons (PAHs) in Florida coastal areas

Contaminant	NOEL[1] (µg/kg)	PEL[2] (µg/kg)
Acenaphthene	22	450
Anthracene	85	740
Benzo(a)anthracene	160	1,300
Benzo(a)pyrene	230	1,700
Chrysene	220	1,700
Dibenzo(a,h)anthracene	31	320
Fluoranthene	380	3200
Fluorene	18	460
Naphthalene	130	1,100
Phenanthrene	140	1,200
Pyrene	290	1,900
Total PAH Content	2,900	28,000

[1] No observed effects level in micrograms per kilogram
[2] Probable effects level in micrograms per kilogram

Source: MacDonald 1993

HEAVY METALS

Heavy metal concentrations were measurable at the majority of sites sampled in LSJRB since the mid-1980s. Sediment metal concentrations in 29 of 36 samples collected by SJRWMD (1993) were found to equal or exceed NOEL, as defined by FDER (MacDonald 1993). Mercury, lead, chromium, and zinc concentrations exceeded NOEL more often than did other metals (Table 5.5). PEL was exceeded at 15 locations (Table 5.6), most often by lead, zinc, and copper.

Sediments collected at some stations by Pierce et al. (1988) contained four or more heavy metals in concentrations exceeding NOEL. Some of these metals exceeded PEL. Sediments in the Cedar and Ortega rivers were among those with the highest concentrations. In these rivers, lead and zinc were found at levels above PEL; cadmium, copper, and mercury were present in excess of NOEL. In Moncrief Creek, sediment concentrations of lead, mercury, and zinc exceeded NOEL. The copper concentration in Moncrief Creek sediments surpassed PEL. Cadmium, copper, lead, and zinc were also high in Big Fishweir Creek.

A survey of 29 sediment stations in the St. Johns River conducted in 1988 by the FDER Coastal Management Section (FDER 1988) found chromium, copper, arsenic, lead, and mercury contamination to be widespread. Sediments from ten stations contained concentrations of four or more heavy metals that were higher than NOEL. Once again, the Ortega River area ranked among the worst, along with a station off Jacksonville NAS, a site off of McCoy Creek, and two sites in the vicinity of the docks north of the Main St. Bridge at Hendricks Point.

The two sample sites used in the National Status and Trends Program (NOAA 1988) were located near the mouth of the St. Johns River at Chicopit Bay and reflect conditions in the estuary. NOAA detected arsenic, chromium, lead, and zinc in the sediments at these two sites at concentrations above NOEL.

Table 5.5 Sediment sites sampled by the St. Johns River Water Management District and by the City of Jacksonville where metal contamination approached or exceeded the "no observed effects level" (NOEL)

Site	Contaminant	Measured Concentration (mg/kg)	NOEL (mg/kg)
Red Bay 1A	Mercury	0.323	0.1
Red Bay 1B	Mercury	0.383	0.1
	Lead	37.1	21.0
Red Bay 2A	Mercury	0.167	0.1
	Lead	41.1	21.0
Red Bay 2B	Mercury	0.156	0.1
Jacksonville Naval Air Station 1A	Mercury	0.312	0.1
	Lead	45.7	21.0
Jacksonville Naval Air Station 1B	Chromium	81.7	33.0
	Mercury	0.355	0.1
	Lead	59.0	21.0
	Zinc	145	68.0
Jacksonville Naval Air Station 2A	Chromium	89.1	33.0
	Mercury	0.280	0.1
	Lead	85.3	21.0
	Zinc	160	68.0
Jacksonville Naval Air Station 2B	Chromium	95.8	33.0
	Mercury	0.331	0.1
	Lead	80	21.0
	Zinc	160	68.0
Jacksonville Naval Air Station 3A	Chromium	88.2	33.0
	Mercury	0.399	0.1
	Lead	60	21.0
	Zinc	123	68.0

Table 5.5—*Continued*

Site	Contaminant	Measured Concentration (mg/kg)	NOEL (mg/kg)
Jacksonville Naval Air Station 3B	Chromium	99.8	33.0
	Mercury	0.425	0.1
	Lead	59.2	21.0
	Zinc	130	68.0
Goodbys Creek 1A	Mercury	0.30	0.1
	Lead	60.5	21.0
Goodbys Creek 1B	Mercury	0.36	0.1
	Lead	100	21.0
	Zinc	188	68.0
Goodbys Creek 2A	Mercury	0.36	0.1
	Lead	98.4	21.0
	Zinc	120	68.0
Goodbys Creek 2B	Mercury	0.42	0.1
	Lead	121	21.0
	Zinc	184	68.0
Moncrief Creek 1A	Mercury	0.47	0.1
Moncrief Creek 1B	Chromium	106	33.0
	Mercury	0.45	0.1
	Lead	140	21.0
Moncrief Creek 2A	Chromium	128	33.0
	Mercury	0.52	0.1
	Lead	156	21.0
	Zinc	256	68.0
Moncrief Creek 2B	Chromium	140	33.0
	Mercury	0.52	0.1
	Lead	178	21.0
Julington Creek 5A	Lead	47.3	21.0
	Zinc	131	68.0

Table 5.5—*Continued*

Site	Contaminant	Measured Concentration (mg/kg)	NOEL (mg/kg)
Julington Creek 5B	Mercury	0.32	0.1
	Lead	51.1	21.0
	Zinc	150	68.0
Julington Creek 10A	Mercury	0.15	0.1
	Lead	43	21.0
Julington Creek 1A Regulatory Environmental Services Division (RESD), City of Jacksonville	Copper	73	28.0
	Mercury	0.49	0.1
	Lead	150	21.0
Julington Creek 1B (RESD)	Mercury	0.40	0.1
Julington Creek 2A (RESD)	Mercury	0.49	0.1
	Lead	114	21.0
Julington Creek 2B	Mercury	0.29	0.1
	Lead	124	21.0
Julington Creek 3A (RESD)	Mercury	0.41	0.1
	Lead	93.8	21.0
	Zinc	206	68.0
Julington Creek 3C (RESD)	Chromium	82.6	33.0
	Mercury	0.43	0.1
	Lead	122	21.0
	Zinc	224	68.0
Ribault River 1A	Copper	73	28.0
	Mercury	.049	0.1
	Lead	150	21.0
Ribault River 1B	Mercury	.40	0.1
Ribault River 2A	Mercury	0.49	0.1
	Lead	114.0	21.0
Ribault River 2B	Mercury	.29	0.1
	Lead	124	21.0

Table 5.5—*Continued*

Site	Contaminant	Measured Concentration (mg/kg)	NOEL (mg/kg)
Ribault River 3A	Mercury	0.41.	0.1
	Lead	93.8	21.0
	Zinc	206.	38.0
Ribault River 3C	Chromium	82.6	33.0
	Mercury	0.43	0.1
	Lead	122	21.0
	Zinc	224	68.0
River Run 11A	Mercury	0.46	0.1
	Lead	50.7	21.0
	Zinc	136	68.0
River Run 11B	Mercury	0.56	0.1
	Lead	43.3	21.0
Rice Creek 1	Mercury	0.59	0.1
	Zinc	166	68.0
Rice Creek 2	Mercury	0.70	0.1
	Zinc	177	68.0
Rice Creek 3	Copper	91.4	28.0
	Mercury	0.90	0.1
	Zinc	192	68.0

Table 5.6 **Sediment sites sampled by the St. Johns River Water Management District where metal concentrations exceeded the "probable effects level" (PEL)**

Site	Contaminant	Measured Concentration (mg/kg)	PEL (mg/kg)
Cedar River 1A	Lead	329	160
	Zinc	862	300
Cedar River 1B	Lead	373	160
	Zinc	989	300
Cedar River 2A	Zinc	347	300
Cedar River 2B	Zinc	338	300
Ribault River 1B	Lead	166	160
	Zinc	400	300
Ribault River 2A	Zinc	383	300
Ribault River 2B	Zinc	312	300
Moncrief Creek 1A	Copper	258	170
	Lead	178	160
	Zinc	398	300
Moncrief Creek 1B	Copper	196	170
	Zinc	309	300
Moncrief Creek 2A	Copper	292	170
Moncrief Creek 2B	Copper	278	170
	Zinc	304	300

NMFS (Hanson and Evans 1991) sampled five stations in the St. Johns River between 1984 and 1987. Four stations were sampled in 1987, and one was sampled each year from 1984 to 1987. Seven heavy metals were measured in Ortega River sediments at concentrations above NOEL. These included silver, cadmium, copper, mercury, chromium, lead, and zinc. The Trout River had potentially harmful levels of copper, mercury, chromium, lead, and zinc.

The 1983 maintenance dredging study performed for FDER by Dames and Moore (1983) included analyses of sediments from 16 locations in the shipping channel seaward of NAS Jacksonville. Mercury was detected at levels exceeding NOEL of 0.1 mg/kg sediment in all samples. None had mercury concentrations above PEL. The five samples collected in the Talleyrand area near the channel contained cadmium, chromium, copper, zinc, and/or lead at levels surpassing NOEL.

Taken together, data from all of these studies demonstrate the widespread nature of metal contamination in LSJRB, particularly in the industrialized areas (e.g., the Ortega River-Cedar River system, Moncrief Creek) and in locations where the interaction between fresh water and salt water is greatest. While sediments from many locations in LSJRB are contaminated with heavy metals, impacts on resident biota have not been determined. The fact that a number of metals are present at concentrations found to be toxic to biota elsewhere suggests that faunal communities of LSJRB are being adversely affected by these contaminants. Toxicity tests and surveys of biological communities are the only ways to assess actual impacts because significant portions of sediment metals may be bound to sulfides, hydroxides, or oxides and, therefore, may be biologically inert. A standard method of determining the biologically significant fraction of metals in sediments is now being developed by EPA. The method compares the amount of metal released from a sediment following an acid wash to the total amount of metal that is biologically available. The toxicity of copper, chromium, zinc, and lead to benthic organisms has been accounted for using this method and is currently being reviewed by EPA (Di Toro et al. 1990).

ORGANIC CONTAMINANTS

Mote personnel (Pierce et al. 1988) found PCB concentrations exceeding NOEL (24 µg/kg, Table 5.3) at 14 of 61 sites (Figure 5.10). The highest total PCB concentration was at the confluence of the Cedar and Ortega rivers, 1,776 µg/kg, over six times higher than the recommended PEL. This site likely was affected by a PCB spill that occurred in the early 1980s during a fire at the American Electric Company, near the Cedar River. Although sampling locations were distributed about equally between the mainstream of the river and tributary locations, PCB distribution showed no preference for tributaries over the mainstream. The highest concentrations, however, were observed along the mid-St. Johns River (Pierce et al. 1988). Thirteen locations sampled by Pierce et al. (1988) had total PAH concentrations higher than NOEL (2,900 µg/kg, Table 5.4), and the Cedar River station exceeded PEL (28,000 µg/kg). Tributary sites comprised all but three of the stations that had elevated levels of PAHs (Figure 5.11). Total DDT derivatives (tDDTs) were found at concentrations above NOEL (4.5 µg/kg, Table 5.3) in 50 of the 61 samples collected at the thirty sites used in the Mote study (Figure 5.12).

A study of sediments conducted by NOAA (1988) detected organic contaminants at both of its St. Johns river estuary sample sites. At the Chicopit Bay site, total PCBs (67.9 µg/kg) and tDDTs (8.56 µg/kg) exceeded NOEL established by FDER (Table 5.3). The St. Johns River site near the mouth of the river had a total PCB concentration of 180 µg/kg, which is seven times NOEL. Neither individual PCBs nor tDDTs were reported. PAHs did not exceed NOEL.

Dames and Moore (1983) reported the results of chemical analyses (PCBs, chlorinated pesticides, and nine metals) of 16 main channel sediment samples. None of the sediment samples collected in 1982 contained organic contaminants at levels

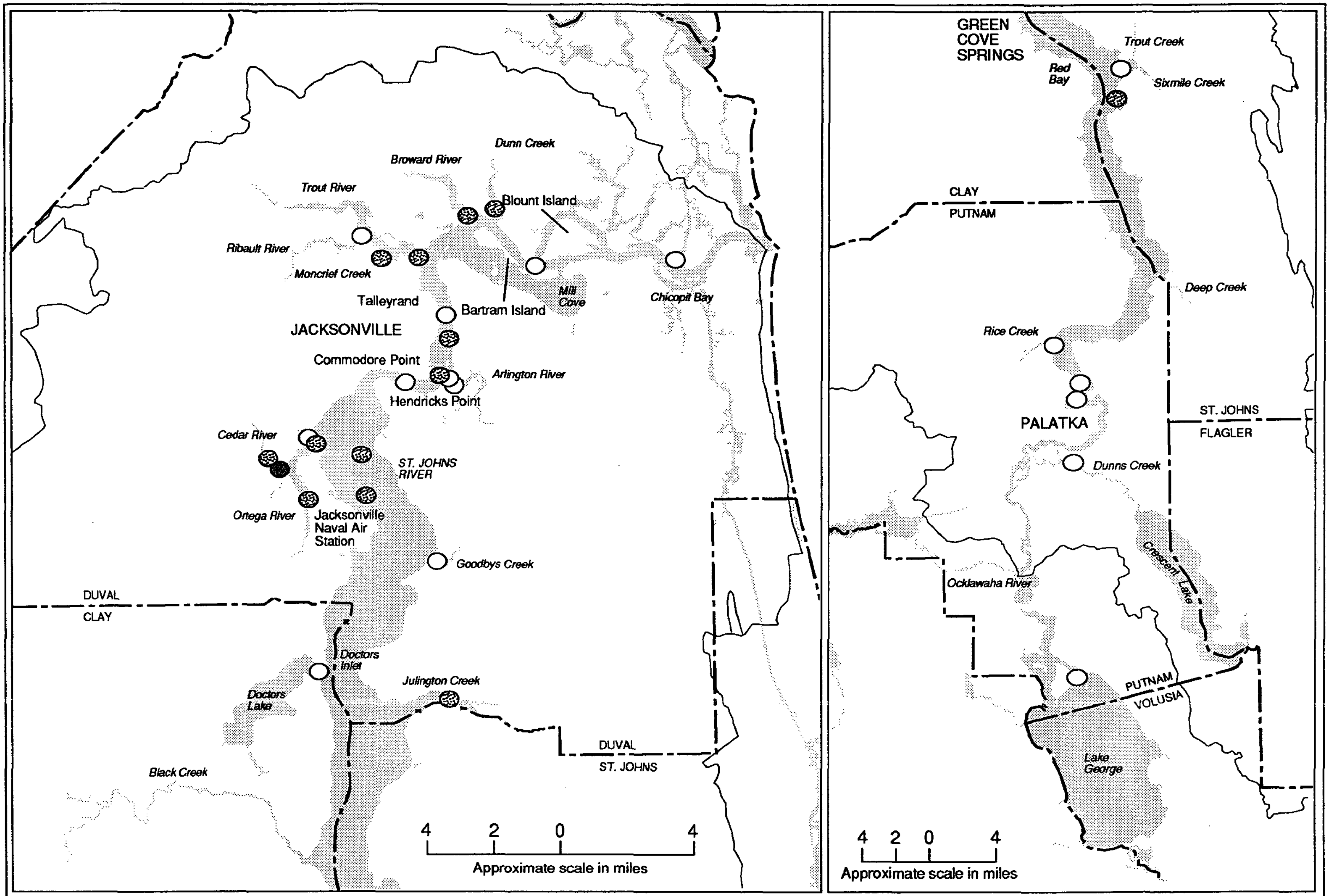


Figure 5.10 **Toxicity ratings for concentrations of polychlorinated biphenyls (PCBs) detected in the Mote Marine Laboratory 1987-88 study.** *The sites are rated by potential for biological effects—no observed effects level (NOEL) and probable effects level (PEL).*

Source: Pierce et al. 1988

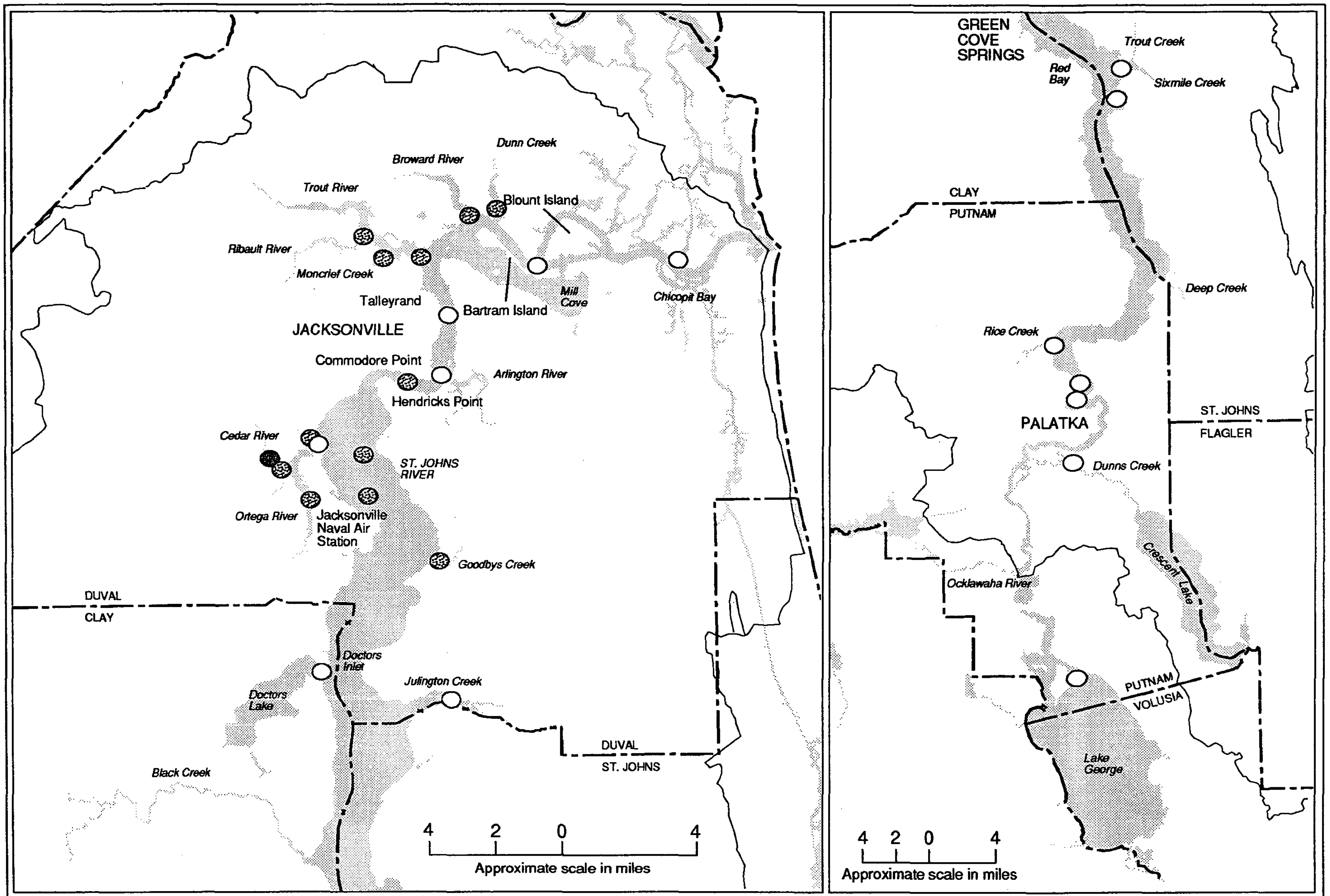


Figure 5.11 **Toxicity ratings for concentrations of total polycyclic aromatic hydrocarbons (PAHs) detected in the Mote Marine Laboratory 1987-88 study.** *The sites are rated by potential for biological effects—no observed effects level (NOEL) and probable effects level (PEL).*

Source: Pierce et al. 1988

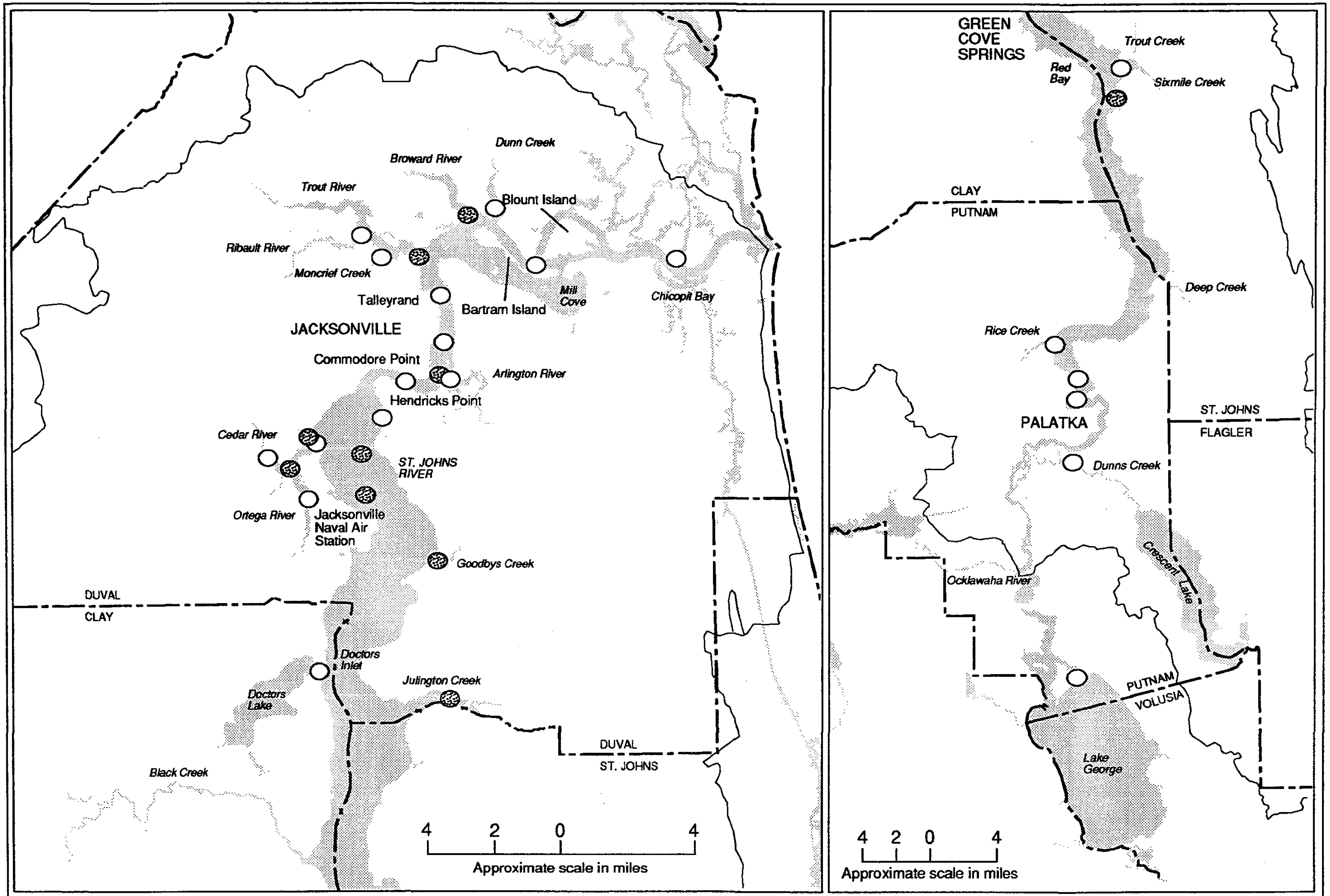


Figure 5.12 **Toxicity ratings for concentrations of tDDT detected in the Mote Marine Laboratory 1987-88 study.** *Of the chlorinated pesticides, only DDT has a toxicity rating. The sites are rated by potential for biological effects—no observed effects level (NOEL) and probable effects level (PEL).*

Source: Pierce et al. 1988

○ below NOEL (4.5 µg/kg)

▨ between NOEL and PEL (4.5 - 270 µg/kg)

● above PEL (270 µg/kg)

— — County boundary

—— Lower St. Johns River Basin boundary

N

approaching NOEL. Most of the 29 sampling sites included in the 1987-88 FDER study (FDER 1988) had concentrations of PCBs, PAHs, and chlorinated pesticides below detection limits. However, one or more PAHs exceeded the NOEL at the Mill Cove, Cedar River, Julington Creek, Popo Point, Green Cove Springs, and Bluff Branch sites. The PCB concentrations of sediments from Green Cove Springs (21 µg/kg) and Popo Point (32 µg/kg) were near NOEL (24 µg/kg).

A 1989 statewide survey of priority organic pollutants included four sites in LSJRB (Delfino et al. 1991). Three of these had PAH concentrations higher than PEL—Deer Creek, Rice Creek, and Little Sixmile Creek. The samples collected in Deer Creek and in the St. Johns River near Deer Creek (Talleyrand) reflected impacts from creosote stored in waste pits and tanks. The sample contained elevated concentrations of fluoranthene, phenanthrene, pyrene, anthracene, and benzo(a)anthracene, which could be attributed to the stored cresote. Another set of samples was taken near the Georgia-Pacific paper mill on Rice Creek and near its confluence with the St. Johns River. Acenaphthene, anthracene, and benzo(a)pyrene were measured at concentrations above PEL and, therefore, pose a potential threat to biota. Analyses of dioxins were not performed on the samples from Rice Creek. Little Sixmile Creek receives leachate from the Picketville Road landfill. In the Delfino et al. (1991) study, no sites in LSJRB had detectable levels of PCBs or other chlorinated compounds.

Analyses of sediments in LSJRB collected by SJRWMD reinforced previous studies. Samples from Cedar River, Moncrief Creek, Goodbys Creek, and Ribault River were all found to contain organic pollutants in concentrations between suggested NOEL and PEL values for Florida coastal waters (MacDonald 1993). These results indicate that, although the LSJRB sediments are not as contaminated as those evaluated from other areas of the country (Long and Morgan 1990), the levels present in St. Johns River sediments may pose a significant environmental risk to the resident biota.

NOEL for individual PAH values varies considerably (Table 5.4). Eleven sites sampled by SJRWMD had PAH concentrations in the sediments exceeding NOEL (Table 5.7). Some impairment of the biological community is possible at these sites. Six other sites had concentrations of one or more of the PAHs that exceeded PEL (Table 5.8). The biological community would be expected to exhibit negative effects as a result of the high PAH levels at these six sites. SJRWMD did not find DDT or PCBs in sediments at levels likely to cause impairment to biota.

Dioxin concentrations were measured by SJRWMD on three samples of sediments collected in Rice Creek, near Palatka. Dioxin is a byproduct of the bleach-kraft process. The targeted area has received effluents from a paper mill for many years. Dioxin levels were between 6.8 and 52.8 ng/kg sediment (dry weight). These dioxin levels in sediments are high relative to those in other United States streams that receive effluent from paper mills (EPA 1992). Dioxins have a significant tendency to bioconcentrate as compared to other toxic compounds (e.g., chloropyrifos; EPA 1992). Selected fish collected from Rice Creek by SJRWMD contained levels as high as 46.1 parts per trillion of dioxin; therefore, these high sediment dioxin levels could have an impact on other aquatic organisms and animals that consume them.

Table 5.7 **Sediment sites sampled by the St. Johns River Water Management District where polycyclic aromatic hydrocarbon (PAH) concentrations equalled or exceeded the "no observed effects level" (NOEL)**

Site	Contaminant	Measured Concentration (µg/kg)	NOEL (µg/kg)
Moncrief Creek 1A	Benzo(a)anthracene	720	160
	Benzo(a)pyrene	880	230
	Chrysene	1,500	220
	Fluoranthene	1,700	380
	Phenanthrene	630	140
	Pyrene	1,300	290
Moncrief Creek 1B	Benzo(a)anthracene	530	160
	Benzo(a)pyrene	400	230
	Chrysene	830	220
	Fluoranthene	1,200	380
	Phenanthrene	330	140
	Pyrene	810	290
Moncrief Creek 2B	Benzo(a)anthracene	300	160
	Chrysene	400	220
	Pyrene	630	290
Ribault River 1A	Benzo(a)anthracene	650	160
	Benzo(a)pyrene	800	230
	Chrysene	1,100	220
	Fluoranthene	1,200	380
	Phenanthrene	360	140
	Pyrene	1,300	290

Table 5.7—*Continued*

Site	Contaminant	Measured Concentration (µg/kg)	NOEL (µg/kg)
Ribault River 1B	Benzo(a)anthracene	320	160
	Benzo(a)pyrene	420	230
	Chrysene	1,000	220
	Fluoranthene	1,300	380
	Phenanthrene	440	140
	Pyrene	1,200	290
Ribault River 2B	Benzo(a)anthracene	740	160
	Benzo(a)pyrene	1,000	230
	Fluoranthene	1,600	380
	Phenanthrene	500	140
	Pyrene	1,600	290
Ribault River 2C	Phenanthrene	890	140
Ribault River 3A	Benzo(a)anthracene	380	160
	Benzo(a)pyrene	400	230
	Chrysene	640	220
	Pyrene	670	290
Goodbys Creek 1A	Benzo(a)anthracene	700	160
	Benzo(a)pyrene	690	230
	Chrysene	1,200	220
	Fluoranthene	3,000	380
	Phenanthrene	590	140
Goodbys Creek 2A	Benzo(a)anthracene	700	160
	Benzo(a)pyrene	830	230
	Fluoranthene	2,700	380
	Phenanthrene	530	140

Table 5.7—*Continued*

Site	Contaminant	Measured Concentration (µg/kg)	NOEL (µg/kg)
Goodbys Creek 2B	Benzo(a)anthracene	470	160
	Benzo(a)pyrene	570	230
	Chrysene	760	220
	Fluoranthene	1,900	380
	Phenanthrene	1,000	140

Table 5.8 Sediment sites sampled by the St. Johns River Water Management District where polycyclic aromatic hydrocarbon (PAH) concentrations approached or exceeded the "probable effects level" (PEL)

Site	Contaminant Level	Measured Concentration (µg/kg)	PEL (µg/kg)
Cedar River 1A	Benzo(a)anthracene	1,170	1,300
	Benzo(a)pyrene	1,460	1,700
	Dibenzo(a,h)anthracene	2,080	320
	Fluoranthene	3,500	3,200
	Pyrene	2,960	1,900
Ribault River 2B	Chrysene	1,300	1,700
Ribault River 2C	Benzo(a)anthracene	1,800	1,300
	Benzo(a)pyrene	2,300	1,700
	Chrysene	2,900	1,700
	Fluoranthene	3,400	3,200
	Pyrene	3,000	1,900
Goodbys Creek 1A	Benzo(a)anthracene	1,400	1,300
	Benzo(a)pyrene	1,700	1,700
	Chrysene	2,400	1,700
	Fluoranthene	3,400	3,200
	Pyrene	3,200	1,900
Goodbys Creek 2A	Benzo(a)anthracene	1,800	1,300
	Benzo(a)pyrene	2,200	1,700
	Chrysene	3,600	1,700
Goodbys Creek 2A	Fluoranthene	3,800	3,200
	Phenanthrene	1,100	1,200
	Pyrene	3,600	1,900
	Chrysene	2,500	1,700

SUMMARY

During the past 10 years, nine studies have evaluated the degree of contamination of LSJRB sediments. These studies were limited in scope. Sources of sediments within the river are poorly understood, and information concerning the complex flow patterns and water chemistry that affect sediment deposition and distribution is virtually non-existent. The limited information that is available relies heavily on general knowledge of sediment characteristics and transport mechanisms, and very little upon empirical data gathered within the estuary. Nonetheless, several points are clear.

The primary physical and chemical properties affecting sediment formation and transport result from the unique characteristics of the basin. The sediments of LSJRB are composed of very fine material (silts and clays) and are poorly sorted. The low gradient of the river basin results in the absence of strong downstream flow and in extended tidal effects. This combination allows more upstream transport of suspended load, as well as allowing a broad area to be affected by the mixing of salt and fresh water. The chemical differences between fresh and salt water cause flocculent material to form from the suspended silt and clays and heavy metals to precipitate into the sediment at the interface between fresh and salt water.

The sediments of LSJRB are high in total organic carbon content, particularly in the tributaries, making the sediments perfect sinks for hydrophobic chemicals. Data published in several reports on sediment quality (Dames and Moore 1983; Pierce et al. 1988; Hanson and Evans 1991; NOAA 1988; Savannah Laboratory and Environmental Services 1988; Delfino et al. 1991) and unpublished information obtained from FDER (1988), the City of Jacksonville (1990), and SJRWMD (1993) indicate that river sediments are contaminated significantly (concentrations above NOEL) by a number of different classes of compounds including heavy metals, PCBs, PAHs, and chlorinated pesticides. Not surprisingly, the most severe contamination (values may exceed

PEL) in LSJRB appears to be localized between Julington Creek and the Arlington River, in tributary and mainstream areas with industrial or residential development.

RECOMMENDATIONS

A review of the available literature indicates that sediments in LSJRB have been characterized inadequately, both physically and chemically. Therefore, the following activities are recommended.

- Conduct studies of basic sedimentation and sediment transport processes (wind-driven currents, tidal currents, boat traffic, runoff, etc.) affecting LSJRB to determine how these processes may contribute to contaminant storage and distribution in sediments.

- Model the sediment dynamics of LSJRB. This information is vital to predict areas of probable deposition and accumulation of sediments and associated toxic contaminants.

- Increase sediment sampling activities in the tributaries to determine the extent to which sediments are contaminated. Because many of the tributary sediments have a high organic content and this organic-rich environment is a sink for the hydrophobic organic pollutants, the tributaries may be the areas of greatest environmental concern.

- Identify the temporal and spatial distribution of sediment types and toxic contaminants, especially heavy metals. This information should be incorporated into a geographic information system.

- Research the relative toxicity of sediment-bound contaminants to resident species. Although there is a great deal of information on the effects of various toxic chemicals on aquatic species that are not necessarily found in LSJRB, species resident to LSJRB may have different sensitivities. Therefore, toxicological research needs to be focused on native fish and invertebrate populations.

- Research the bioavailability of heavy metals found in the sediments of LSJRB. Although a number of reports indicate that the sediments of LSJRB contain enriched metal concentrations, available information does not address the relative toxicity of these metal concentrations.

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