EXECUTIVE SUMMARY

Sediment quality is a useful indicator of aquatic environmental conditions. Sediments are the major repository of contaminants in surface water systems, and play a significant part in influencing the fate and effects of potentially toxic substances. The purpose of the Florida Coastal Sediment Contaminants Atlas is to describe the spatial extent of chemical contamination in Florida's coastal waterbodies, and to assist in comparing contaminant levels and distributions between waterbodies. Most of the highest concentrations for any particular contaminant are found at sites near Tampa, Pensacola, Miami, and Jacksonville. However, high contaminant concentrations are occasionally found near other cities, and low to moderate levels of contaminants are common adjacent to many less developed coastal areas. Sediment chemistry data indicate the most common metal contaminants are lead, zinc, cadmium, and mercury, and the most common class of organic contaminant is the polynuclear aromatic hydrocarbons. Stormwater runoff appears to be the major cause of contamination of sites identified in the Atlas. Regional monitoring of contaminants in living resources and sediments, augmented by other assessments, is strongly recommended to keep a finger on the pulse of Florida's coastal ecosystems.

Sediment information is used by local, state, and federal regulatory agencies for many purposes, including trend monitoring, permitting, and restoration. To improve the use of this information, the FDEP initiated a series of coastal sediment contaminants surveys in 1982. The Atlas provides the results of the surveys through 1991. In addition to FDEP data, the Atlas has been strengthened by inclusion of statewide sediment data from the National Oceanic and Atmospheric Administration's (NOAA) National Status and Trends Program, as well as sediment data produced by the Mote Marine Laboratory, an independent marine research facility located in Sarasota, Florida.

Sediment chemical data, presented on Atlas maps as barcharts, allow comparison of sediment contaminants levels within coastal areas, and between estuarine systems. The Atlas includes information on eight trace metals (arsenic, cadmium, chromium, copper, mercury, lead, nickel, and zinc), and five classes of organic compounds - chlorinated hydrocarbons, polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), phenolic hydrocarbons, and aliphatic hydrocarbons. To interpret metals contamination, individual metal concentrations are reported using an interpretive statistical approach developed by the Department. The total concentration of each class of organic compound is normalized to total organic carbon to help account for differences in the tendency of sediments to accumulate organic contaminants. A Technical Volume accompanies this Atlas and provides ancillary information for users of this document. The Atlas qualitatively presents the extent of contamination of estuarine and marine habitats; however, it should not be used without additional information to predict biological effects of contaminants.
1.0 Introduction

The purpose of this atlas is to describe the spatial extent of chemical contamination in sediments of Florida's coastal environments and to assist in comparing contaminant levels and distributions between these waterbodies. Sediments are the major repository of contaminants in aquatic environments, and sediment quality data, as a direct indicator of the health of coastal aquatic habitats, are increasingly relied on by federal, state, and local agencies to support resource management programs. The Florida Coastal Sediment Contaminants Atlas summarizes results of coastal sediment contaminant surveys conducted from 1982 to 1991 by the Florida Department of Environmental Protection (FDEP). The Atlas also includes sediment chemistry data from surveys conducted by the National Oceanic and Atmospheric Administration (NOAA) and other agencies. A survey in the Lower St. Johns River estuary was conducted by the Mote Marine Laboratory. The Atlas provides a broader use of data gathered by these surveys in environmental management programs. It also offers a way for the public to interpret map and graphical information, form an understanding of the data presented, and find this document useful in assessing impacts of development in coastal areas.

1.1 How to Use the Florida Coastal Sediment Contaminants Atlas

The Atlas contains sediment contaminants data placed in a spatial reference framework. An attempt has been made to present map areas that display complete hydrographic regions defined by coastal waters. The national waters are subdivided into nine geographic regions: 1) the panhandle, which includes Pensacola Bay, Choctawhatchee Bay, St. Andrews Bay, St. Joseph Bay, and Apalachicola Bay; 2) the Big Bend region, which covers the area between Apalachicola Bay and Tarpon Springs; 3) Tampa Bay; 4) Charlotte Harbor and Caloosahatchee River; 5) the Everglades; 6) the Florida Keys; 7) the southeast region (Biscayne Bay to Jupiter); 8) the east-central region (Indian River Lagoon); and 9) the northeast region (Daytona Beach to Fernandina Beach). In intensively sampled areas, such as Tampa Bay or the Lower St. Johns River, inset maps provide more detail on individual sediment sampling locations.

Different site symbols are employed to indicate which group of researchers (FDEP, red triangle; NOAA, green star; Mote Marine Laboratory, blue flag) produced the sediment chemistry data. The bar chart format allows for quick discernment of trace metal enrichment or the presence of toxic contaminants at individual sites. A color-coded legend for the bar charts is included on the first map of each region. Trace metal bar charts present the concentration enrichment value (VAR), which is the ratio of the expected background value. If the concentration of a trace metal in sediment at a site falls within the expected natural range, no bar is plotted. A bar is plotted if the measured value is 10 times greater than the expected background value. If a sediment sample is enriched by a factor of 10 times above expected natural levels, a "×10" sign above the bar indicates this enrichment factor.

As with the metals data, organic contaminants data are normalized; however, the organic concentration is normalized to total organic carbon (TOC) to account for possible biological effects. The enrichment factor (VAR) is calculated using a logarithmic scale. The larger the bar representing a class of organic contaminants, the more likely the impact on benthic organisms at the site.

If a particular trace metal or class of organic contaminants was not analyzed, an open circle is placed under the bar chart in the appropriate column. For explanations of the trace metal enrichment factors and organic contaminants normalization procedure, please see Sections 4.1 and 5.1, as well as the Technical Volume that accompanies this publication.

2.0 Sediment Quality Issues

2.1 Sediment Quality: An Indicator of Ecosystem Health

Coastal monitoring programs based solely on water column measurements do not effectively indicate coastal contamination. Sediment quality information is useful as an indicator of ecosystem health, as sediments play a significant role in influencing the fate and effects of many toxic contaminants. Many toxic organic compounds rapidly adsorb (attach) to suspended particles. The particles settle in estuarine and marine ecosystems and become incorporated in sediments. Measurements of contaminants in the water column often show that contaminant concentrations are within state water quality standards, but concurrent measurements of sediments may show the site to be highly contaminated. As such, sediments integrate contaminant inputs over time and may become sources of contamination long after the event that resulted in widespread sediment contamination.

Sediments link chemical and biological processes in benthic (sediment-dwelling) communities. Sediments provide essential habitat for spawning, incubation, and other biological processes. Direct contact with or ingestion of contaminated sediments may affect the health and behavior (feeding/burrowing) of benthic organisms. As contaminants accumulate in these organisms, subsequent bioaccumulation may occur and the contaminants are transferred to consumer organisms such as fish, birds, and humans. Elevated levels of toxic contaminants have been observed in fish and wildlife in many locations in the United States and concern over the risk of consuming contaminated seafood and fish has increased public awareness of the issues of sediment contamination and coastal pollution.

The protection of unimpacted sediments and management of contaminated sediments is critical to maintaining marine and estuarine ecosystem health. The presentation of sediment quality in this document not only provides a statewide perspective on contaminants levels, but also provides a context for local assessment of sediment quality conditions.

3.0 Introduction

This section describes the objectives of the Florida coastal sediment contaminant surveys and summarizes computer mapping procedures, sampling procedures, laboratory analyses, and the sediment chemistry database. Detailed information on these topics is included in a separate Technical Volume. In addition to the FDEP coastal sediment contaminant surveys, other agencies and research groups have collected Florida sediment chemistry data (Section One, Technical Volume). In evaluating and comparing such databases, a principle concern is to ensure that sampling and analytical methods are comparable (Section Two, Technical Volume). The Atlas includes data from two additional sediment chemistry databases, including the National Status and Trends Programs and the Mote Marine Laboratory FDEP database. Insufficient funds were available to evaluate and include additional sediment data sets.

3.1 FDEP Coastal Sediment Contaminants Surveys

Results presented in the Atlas do not represent a spatially unbiased view of sediment contamination. The majority of the sampling locations in the Atlas represent areas adjacent to developed coastal areas. However, the Atlas also includes sediment information on areas likely to experience growth and areas likely to remain isolated from development.

The FDEP surveys conducted data for the Atlas were conducted under different projects (Section One, Technical Volume). For the Deepwater Ports Project (1983-1984), most sites were located to assess the impacts of coastal development and off-shore facilities. These sites are near densely developed areas and are located in areas likely to accumulate contami-
nants. A second type of survey (1985-1991) focused on parts of estuaries likely to be contami-
nated due to tributary inflow and land use pat-
terns or likely to receive contaminants due to future
development. In a third type of survey conducted to
devlop data on unperturbed sediments, sites were
located in remote areas removed from known or
suspected contaminant sources. These reference or "clean" sites represent the wide variety of coastal
sediments in Florida. Given the above site
selection objectives, the results presented in the
Atlas do not represent a spatially unbiased view of
sediment contamination. Thus, the proportion of
coastal contamination cannot be estimated. Rather,
the database represents a statewide overview of
sediment conditions in areas ranging from pristine
to highly contaminated.

3.2 The FDEP Coastal Sediment Contaminants
Database
The FDEP sediment contaminants database used in the
Atlas includes information on nearly 700 sites
visited between 1983 and 1992. Some sites were
resampled. Sediment samples were analyzed using
comparable techniques (Section Two, Technical
Volume). Although the Atlas reports data for
total phosphorous, and total organic carbon), and
visited between 1983 and 1992. Some sites were
resampled. Sediment samples were analyzed using
corresponding water, and biological data for
arsenic, cadmium, chromium, copper, mercury,
nickel, lead and zinc, the FDEP sediment database
and nonmetallic elements (beryllium, iron, lithium,
manganese, silver, titanium, and vanadium). The
FDEP sediment database also includes measure-
ments of grain size, nutrients (total Kjeldahl nitrogen,
total phosphorous, and total organic carbon), and
toxic organic contaminants, such as polychlorinated
biphenyls (PCBs), chlorinated aromatic hydrocar-
bons (PAHs), phthalic acid, and aliphatic hydrocarbons;
and chlorinated pesticides (e.g. DDT).

Measurement of trace metal concentrations is stan-
dard in sediment surveys because of the prevalence
of processes which can result in metals conta-
mination. Section Four of the Technical Volume lists
common uses of sources of metals contaminants
examined in the Atlas. Most metals examined in the
FDEP sediment surveys are present in the micro-
gram per gram (parts per million, ppm) range. However,
very low level of metals (parts per billion, ppb) range in
virtually all pristine estuarine sediments. State-of-the-art analytical tech-
niques are therefore required for mercury measure-
ments of these metals to detect trace amounts and
accurate concentration values. Near urban centers,
the presence of high levels of metals often signals
the presence of organic contaminants but, due to
high analytical costs, not every site measured for
metals was analyzed for organic contaminants. Virtually all of the organic contaminants occur in the
ppb concentration range.

All sediment chemistry data are stored in the FDEP
sediment database in DBASE IV format. Station
coordinates, water column parameters (conductivity,
temperature, salinity), dissolved oxygen, and metals in
sediment types in Florida. Given the above site
selection objectives, the results presented in the
Atlas do not represent a spatially unbiased view of
sediment contamination. Thus, the proportion of
coastal contamination cannot be estimated. Rather,
the database represents a statewide overview of
sediment conditions in areas ranging from pristine
to highly contaminated.

3.3 NOAA and MOTE Marine Laboratory Sediment
Contaminants Surveys
Data from two sediment chemistry databases besides FDEP have been incorporated into the Florida Coastal Sediment Contaminants Atlas. Since
1984, the National Status and Trends Program of the
NOAA has monitored the concentrations of metals and toxic organic contaminants in bottom-feeding
fish, shellfish and sediments at United States coastal
sites. Forty-two NOAA sites are located in Florida
coastal sediments, and 53 sites analyzed a suitable suite of metals and toxic organic compounds similar to those in the
FDEP surveys and employed comparable analytical

The Mote Marine Laboratory (MML), based in
Sarasota, Florida, conducted a sediment quality
study of southern Florida between 1987 and 1988. The project, entitled Characterization of
Baseline Conditions of the Physical, Chemical, and
Microbiological Environments in the St. Johns River Estuary, produced sediment metals and toxic organ-
ic contaminants data for 33 sites, as well as other environmental data. The MML sampling and analyti-
cal methods were consistent with FDEP methods.

3.4 Spatial Analysis of Site Locations
Atlas maps were prepared by the Center for Spatial
and Environmental Analysis in the University of
South Florida Department of Geography. The sedi-
mant data and station notation information
were plotted with the ARC/INFO program on base maps taken from a Geographical Information
Systems (GIS) database. Station notation informa-
tion and metal and organic contaminants data of the
FDEP, NOAA, and MML were graphically expressed
through the use of ARC/INFO software. Coordinates
sampling locations were rectified with original chart
station locations to ensure accurate identification.

SECTION 4: FLORIDA SEDIMENT TRACE
METALS DATA
4.0 Mineralogy and Trace Metals of Florida
Coastal Sediments
Florida coastal sediments are composed of sand,
silt, clay, carbonates minerals, and organic debris.
Metals are natural components of these diverse sed-
iments, and their concentration varies significantly.
Therefore, interpretation of sediment trace metals
data is not straightforward. To identify metal conta-
nimation, anthropogenic trace metal enrichment
must be distinguished from a variable natural back-
ground.

Florida estuarine sediments are produced primarily
by three sedimentation processes: 1) erosion and
redistribution of coastal and upland sediments
flood plains in Alabama, Georgia, and South Carolina. These sediments, south Florida estuarine sediments usual-
ly contain low levels of metals.

4.1 The Metal to Aluminum Normalization
Method for Identifying Metal Enrichment in
Florida Sediments
Interpretation of sediment metal data is complicated by the fact that natural metal concentrations in sedi-
ments vary by orders of magnitude depending on
geologic setting and distance from a source of input.
In the Florida coastal sedimentary province, it is impossible to quantify the amount of anthropogenic contamination based solely on absolute metal concentrations. This observation is important because the lack of accounting for natural metals burdens often has led to incorrect interpretation of contamination. In the past, large variations in metal concentrations were incorrectly interpreted as reflecting anthropogenic inputs.

To distinguish natural variability from variability induced by contamination and to compare Florida's
diverse coastal areas described above, the FDEP
developed an interpretive statistical tool based on
normalization of metal concentrations to the concen-
trations of aluminum (Schropp et al. 1987; Windom and
1988; Windom et al. 1989; Schropp et
1990). The interpretive tool corrects for natural metal background levels in sediments. The barchart
presentation method in the Atlas identifying metal
northern Florida than in the southern part of the state.
contamination is based on the metal to aluminum normalization method. The bars indicate the amount of metal present above expected natural concentrations for each location.

At present the FDEP does not have confidence that mercury enrichment can be identified through a relationship with aluminum. To present mercury enrichment information, a maximum mercury concentration associated with uncontaminated estuarine areas is assumed typical of natural sediments.

Interpretation of the barcharts was discussed in Section One of the Atlas. Section 2.3 of the Technical Volume contains a detailed explanation of the aluminum normalization method and trace metal barchart presentations.

SECTION 5: FLORIDA SEDIMENT TOXIC ORGANIC CONTAMINANTS DATA

5.0 Introduction

Toxic organic contaminants can be classified based on their chemical structure and presence or absence of certain elements (e.g., chlorine). The FDEP database contains five separate classes of toxic organic contaminants: pesticides (e.g., DDT, dieldrin), polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), phenolic compounds, and aliphatic petroleum hydrocarbons. Section Five of the Technical Volume summarizes potential sources of the five toxic organic compound classes. Chlorinated organic and phenolic compounds are man-made, therefore detection of these compounds indicates anthropogenic input or contamination. Certain PAHs and aliphatic petroleum hydrocarbons are produced by natural processes such as forest fires and underwater petroleum seeps. However, the presence of these compounds in Florida coastal sediments can be attributed almost entirely to human activities such as the use of petroleum derivatives in asphalt road construction or crude oil and fuel spills (Eisler 1987; NOAA 1991). Careful consideration is needed concerning laboratory preparation of sediment samples. Since some organic contaminants are toxic in the parts per billion range (MacDonald 1993), laboratory methods must have adequate detection limits to produce useful sediment data.

5.1 Interpretation of Organic Contaminants Data

As with the sediment metal data, organic contaminants data also are normalized, in this case to the concentration of total organic carbon (TOC) in the sample (see Section 2.4, Technical Volume). Naturally occurring organic molecules on sediment particle surfaces enhance adsorption of organic contaminants, thus sediments with elevated TOC levels have a greater capacity to chemically bond with organic contaminants. Thus, high TOC concentrations tend to reduce the bioavailability of organic contaminants. The concentration of organic contaminants is normalized to account for the influence of organic carbon upon bioavailability, and, therefore, the potential for toxicity. High concentrations of organic contaminants may not pose toxicity problems if they are effectively sequestered by the TOC of the sample.
sediment. On the other hand, relatively sandy sediments with moderate to low concentrations of TOC may be toxic.

The concentrations of all analyzed compounds in an organic contaminants class are summed together for plotting purposes. For example, individual chlorinated pesticides are first measured as separate compounds. Then the individual pesticides are summed into a single category, which is normalized to the TOC concentration in the sample. Similar procedures are performed for the other organic contaminants classes. In the Atlas, the larger the bar representing a certain category of organic contaminants the greater the potential impact on the benthic organisms at that site. An important point to realize is that even extremely low concentrations of organic contaminants therefore plot on these barcharts.

SECTION 6: STATEWIDE COASTAL CONTAMINANTS OVERVIEW AND DISCUSSION OF ESTUARIES

6.0 Introduction

This section provides a statewide summary of coastal sediment quality, as well as a synopsis of sediment quality at many estuarine systems. The discussions, based on information shown in the trace metals and organic contaminants maps, do not provide detailed analysis of estuarine water quality, watershed features, or land use practices. However, general physical characteristics such as mean water depth, estuarine surface area, and estuarine drainage area (EDA) are listed for each estuarine system. The EDA is the land and water component of the watershed that directly affects an estuary (NOAA 1985).

6.1 Statewide Summary of Coastal Sediment Contaminants

The coastal contaminants surveys primarily established to help identify contaminated sites. For this reason, the sample survey strategies were biased, with the majority of samples collected from sites adjacent to or near developed areas. Therefore, the sites do not represent a spatially unbiased view, and we cannot make estimates of the proportion of the coast as a whole that may be contaminated. Nevertheless, in our opinion, the surveyed sites provide a useful picture of estuaries affected by development, and in that vein, allow a qualitative statewide coastal summary.

With respect to the eight metals measured (arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc), enrichment above expected natural levels of these elements was most frequently observed for cadmium, mercury, lead and zinc (Figure 1, page 6). At least one of the five classes of organic contaminants is present in measurable concentrations in almost 75 percent of the sites evaluated for organic contaminants (Figure 2). As might be expected, there is a positive correlation between the concentrations of metals and for both metals and organic contaminants, stormwater runoff appears to be the major cause of contamination of sites identified in the Atlas. However, organic contaminants occasionally are detected at locations far from urban areas, and this type of contamination may be due to agricultural and atmospheric inputs.

6.2 Estuaries of the Florida Panhandle Region

In the Atlas, the Panhandle of Florida consists of the area that extends west from the Ochlockonee River drainage basin to the Florida-Alabama boundary (Map 1). Sediments of Florida Panhandle estuaries consist mostly of quartz sand and silt, clay minerals, and organic debris. The rivers which form these estuaries are in drainage basins in southern Alabama and southern Georgia, as well as west Florida counties.

6.2.1 Perdido Bay

Located at the boundary of Florida and Alabama, Perdido Bay has an estuarine surface area of 86 mi² and an average depth of just over seven feet. The Perdido Bay estuarine drainage area (EDA) encompasses 1205 mi² in the Coastal Plain in parts of Baldwin and Escambia Counties in Alabama, and western Escambia County in Florida (NOAA 1985). Streams in the upper basin feed the Perdido River and its two major tributaries, the Syx and Blackwater Rivers. Lower in the watershed, Elevenmile Creek and numerous small streams enter the bay. Local residents associated with the Pensacola Bay area, located in the Perdido Bay watershed.

Slight lead and zinc enrichment has been observed in sediments of Bayou Marcus, with slight zinc enrichment in sediments of Elevenmile Creek and Bayou Grande. Although there may be some source of lead and zinc contamination in Bayou Marcus (Schropp et al., 1991), PAHs are present at every DEP site within the Perdido Bay system. PCBs are present at three sites, and aliphatic hydrocarbon compounds are present at four sites (Map 66).

6.2.2 Pensacola Bay

The four major subdivisions of the Pensacola Bay estuarine system are Escambia Bay, Pensacola Bay, Blackwater Bay, and Bayou Marcus. Together, they form one of the largest estuarine systems of Florida, encompassing over 152 mi² of estuarine surface water area. The EDA of these four bays covers 3480 mi² of Escambia, Santa Rosa, Okaloosa and Walton Counties, and parts of some southern Alabama counties. Average water depth in the estuary is 19 feet (NOAA 1985). Major tributaries of the estuary include the Yellow, Blackwater and Escambia Rivers as well as several smaller streams. Santa Rosa Sound, located north of Santa Rosa barrier island, provides a hydrologic connection between the Pensacola Bay and the Choctawhatchee Bay estuaries.

The Pensacola Bay System is one of the more heavily impacted estuarine systems of Florida. Escambia Bay and East Bay have experienced extreme submerged vegetation losses, and there have been widespread fluctuations in fish and shellfish harvests (Pensacola Bay SWIM Plan 1990). Land uses within the system's watershed include urban development, recreational, conservation, and agriculture. The western part of the Pensacola Bay system is predominantly urban whereas the eastern portion is mostly undeveloped. The urban center of Pensacola contains extensive industrial, commercial, and residential development. Industrial facilities entering the Pensacola Bay area are located along Bayou Chico, the Escambia River, and near Escambia Bay.

Slight trace metal contamination is present at many sites throughout the Pensacola Bay area (Maps 2-5). However, high levels of metal contamination have been observed in certain parts of the bay system. Sediments in Bayou Grande show moderate to high enrichment factors in several metals, particularly cadmium, lead, and zinc (Map 3). The highest metal...
enrichment factors in the Pensacola Bay system are at sites in Bayou Chico (Map 4), where two sites have chrome and zinc enrichment greater than ten times the expected background value. Bayou Chico sediments also are contaminated with PAHs and PCBs (Maps 66 and 67). These FDEP observations in Bayou Chico are supported by sediment data of other research groups (Stone and Morgan 1991). In Pensacola Bay, PAHs and PCBs were detected close to shore and in the central part of the bay, probably due to commercial and agricultural activities. Some of the FDEP sites in Pensacola Bay are associated with paper mill operations, and significant metal enrichment is separated from the Gulf of Mexico by the barrier islands.

6.2.4 St. Andrew Bay and St. Joseph Bay

St. Andrew Bay is an estuarine surface area of 123 mi², and an EDA of 2259 mi² located west of St. Andrew Bay, Franklin, Washington and Bay county, and parts of southern Alabama. The St. Andrew Bay is the major tributary, but several creeks also empty into the estuary. Average water depth is about 22 feet (NOAA 1985). With the exception of a site near Destin, and a lead enriched site near Valparaiso, no metal enrichment has been observed in this bay system (Map 6). PAHs were detected at the site near Destin, and PAHs, PCBs and pesticides were detected at NOAA sites near Valparaiso and in eastern St. Andrew Bay (Map 68).

6.4 Tampa Bay

The Tampa Bay estuarine system, with an estuarine surface area of 129 mi², and an EDA of 1130 mi² located east of St. Andrew Bay, Franklin, Washington, Jackson, Calhoun, and Gulf counties. The average depth of the bay is 27 feet (NOAA 1985). The main source of elevated trace metals appears to be stormwater runoff from urbanized areas and around Panama City. Mercury, cadmium, copper and chromium enrichment was detected (Map 7). Sediments in Watson Bayou, Massalina Bayou, and near Sulphur Point exhibit slight to moderate enrichment of PAHs, PCBs, and pesticides at three sites (Map 70). A recent estuarine sediment study (Livingston 1983) indicated that PAHs in sediments are not supported by a marine algae component but rather are supported by runoff from agricultural practices. In the middle bay, metal enrichment is also evident in the central areas, with sites exhibiting slight to moderate enrichment in copper, cadmium, lead and zinc concentrations.

6.5 Apalachicola Bay

For purposes of the Atlas, the Big Bend Region extends from Apalachicola Bay south along the coastal area near the Anclote River (Map 10). The estuaries of the Big Bend region appear to be the least impacted systems in the state. With the exception of the Suwannee River, riverine systems in the Big Bend may be classified as spring-fed rivers and even the Suwannee River discharge is greatly increased by contributions from springs. The Big Bend estuaries have developed over an ancient shallow-water carbonate platform (the Floridan shelf system). Geologically the Big Bend coastline is described as a sand-starved, low wave energy system dominated by coastal dunes (Hine et al. 1998). Compared to other Floridian coastal areas, there is little urban development in this region.

No metal contamination was detected in the FDEP or NOAA sites in Apalachicola Bay (Map 11), Steinhatchee River estuary (Map 12), or Suwannee River estuary (Map 13). Very slight cadmium enrichment to the Apalachicola River system (Map 14). The NOAA surveys detected PAHs, PCBs, and pesticides at sites in Apalachicola Bay, the West Pass of the Suwannee River, and near Cedar Key (Map 71). The Apalachicola estuarine system covers an area of about 210 mi² and has an average depth of over 27 feet. The EDA of the estuary in Florida is 2970 mi² and occupies parts of Gulf, Franklin, Liberty, Jackson and Calhoun counties (NOAA 1985). The estuary is bounded by four barrier islands: St. Vincent Island, Cape (or Little) St. George Island, St. George Island, and Dog Island. Apalachicola Bay sediments have the highest average aluminum concentrations observed in Florida estuarine systems and also have the highest trace metals background concentrations in Florida.

6.3 Estuaries of the Big Bend Region

For purposes of the Atlas, the Big Bend Region extends from Apalachicola Bay south along the coast to the area near the Anclote River (Map 10). The estuaries of the Big Bend region appear to be the least impacted systems in the state. With the exception of the Suwannee River, riverine systems in the Big Bend may be classified as spring-fed rivers and even the Suwannee River discharge is greatly increased by contributions from springs. The Big Bend estuaries have developed over an ancient shallow-water carbonate platform (the Floridan shelf system). Geologically the Big Bend coastline is described as a sand-starved, low wave energy system dominated by coastal dunes (Hine et al. 1998). Compared to other Floridian coastal areas, there is little urban development in this region.

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6.4 Tampa Bay

The Tampa Bay estuarine system, with an estuarine surface area of just over 400 mi², is the largest estuary in Florida. The Y-shaped estuary has an EDA of 1860 mi² which covers parts of Pasco, Pinellas, Hillsborough, Hardee, Manatee, and Sarasota counties. The bay, with an average depth of just over 16 feet, receives runoff from nine rivers, the largest of which include the Hillsborough, Alafia, Little Manatee, and Manatee Rivers. Hillsborough Bay is itself subdivided into five sections (Map 17). In the organic contaminants maps, the Tampa Bay region is subdivided into three sections (Map 72). Stormwater runoff from urban and residential areas around the bay is an important non-point source of contaminants. Significant metal contamination is common in areas adjacent to major urban centers (Tampa, Clearwater, St. Petersburg, and Bradenton) which include the Hillsborough, Alafia, Little Manatee, and Manatee Rivers discharges. Even the Suwannee River discharge is greatly increased by contributions from springs. The Big Bend estuaries have developed over an ancient shallow-water carbonate platform (the Floridan shelf system). Geologically the Big Bend coastline is described as a sand-starved, low wave energy system dominated by coastal dunes (Hine et al. 1998). Compared to other Floridian coastal areas, there is little urban development in this region.
In southern Old Tampa Bay, metal enrichment factors for several elements, particularly Pb, Cd, and Cd, are 10 times higher than their background values (Map 29). Cadmium is a common metal contaminant at these sites. Sites in Bayboro Harbor near downtown St. Petersburg exhibit enrichment in many metals. The FDEP sediment survey detected PAHs, PCBs, and pesticides at sites close to shore, as well as in the center of Old Tampa Bay (Maps 71 and 74). Slight levels of metal enrichment, as well as PAHs, PCBs, and pesticides, were detected at NOAA sites in Boca Ciega Bay (Maps 24 and 72). Slight metal enrichment was detected in southeastern Tampa Bay and in the Little Manatee River sediments (Map 25). PAHs, PCBs, and pesticides were detected in Cockroach Bay (Map 75). Agricultural areas adjacent to Cockroach Bay likely provided the source of pesticides. Biscayne Bay is dominated by the New River estuary area, lead and zinc enrichment is present at several sites near Bradenton (Map 26).

6.5 Charlotte Harbor and Caloosahatchee River

The southwest Florida coast has one of the highest population growth rates in the state. The Charlotte Harbor/Caloosahatchee River estuarine system is the second largest estuary in the state and supports highly productive and commercial fisheries. Charlotte Harbor, moderated by the marine inundation of the Myakka and Peace Rivers, has an EDA of 5030 m² which contains all or parts of Sarasota, De Soto, Hardee, Charlotte, and Lee counties. This part of the system has an average depth of over eight feet. The EDA for the Caloosahatchee River estuary, at just over 1400 m², is located in parts of Charlotte, Glades, Lee and Hendry counties. Average depth is just over six feet (NOAA 1985). Two cities, Port Charlotte and Punta Gorda, are located in the Charlotte Harbor drainage basin, while the cities of Fort Myers and Cape Coral are located in the Caloosahatchee River drainage basin (Maps 27 and 76).

Sites in the Charlotte Harbor and Caloosahatchee River estuaries exhibit slight metal enrichment (Maps 28, 29, and 30). Slight lead and zinc enrichment is present in the Caloosahatchee River near Fort Myers. However, FDEP and NOAA surveys detected PAHs, PCBs, and pesticides in Charlotte Harbor and the Caloosahatchee River (Maps 77 and 78). PCBs were detected at six out of seven sites in San Carlos Bay and the Caloosahatchee River (Map 78).

6.6 Everglades Region

In the Atlas, the Everglades region is defined as the geographic area between Naples and Cape Sable (Map 31). Numerous small rivers drain the extensive marshlands of the western Everglades and flow into the Ten Thousand Islands area. Average water depth in the Ten Thousand Islands estuary is extremely shallow, at just over four feet (NOAA 1985). Although limited metal enrichment was detected (Maps 32 and 33), this area was one of the few estuaries with high sediment PAHs, PCBs, and pesticides at four of five sites (Map 79). Estuarine and freshwater sediment quality studies by the Collier County Pollution Control Department identified cadmium enrichment at certain sites. Organic contaminants such as pesticides were also identified. These data are not plotted in the Atlas but are available from the Collier County Pollution Control Department (Grabe 1991a; 1991b).

6.7 Florida Bay and the Florida Keys

As noted earlier, sediments of Florida Bay and the Florida Keys are mineralogically different from sediments in other parts of Florida. Carbonate minerals such as calcite and aragonite (both CaCO₃) constitute a larger percentage of sediment in this part of Florida. However, clay minerals and fine-grained detrital material may still cause significant metal enrichment problems. The natural metals burden (background) in these sediments is much lower than sediments in the rest of the state, the metal-to-aluminum geochemical relationship still allows for determination of the degree of anthropogenic contamination. Metal enrichment is present near urbanized areas in the Keys (Map 34), but no metal enrichment was detected in the open areas of Florida Bay. No organic contaminants were detected at FDEP sites evaluated in this region, therefore no map for these substances was generated.

6.8 Southeast Region

In the Atlas, the southeast region encompasses the area from the Loxahatchee River estuary near Jupiter south through Biscayne Bay to Baham Sound (Maps 35 and 80). The Biscayne Bay estuarine drainage area of 1850 m² is located in Dade and Broward counties. The bay has an average depth of 7.5 feet (NOAA 1985). Numerous sediment types have been identified in Biscayne Bay, indicating the highly variable nature of this bay system. The bay represents the area where predominantly carbonate sedimentary environments of the Florida Keys and Biscayne Bay meet the predominantly clastic sedimentary environments of eastern Florida. Adjacent to the largest population center in Florida, Biscayne Bay has experienced significant degradation.

The FDEP conducted intensive sediment sampling in the vicinity of Miami, as well as sampling near Fort Lauderdale and in the Card Sound area of southern Biscayne Bay (Maps 36, 38, 81 and 83). Metal enrichment was identified in a marina in Card Sound near the mouth of the New River, which drains into Card Sound. The FDEP survey did not detect organic contaminants in sediments of Snapper Creek, which drains a large residential area of central and southern Dade County. The NOAA survey detected from 1 to 5.5 times enrichment in sediments in the vicinity of Miami, as well as sampling near Fort Lauderdale, with particularly high levels of lead and zinc enrichment (Map 37). PAHs and PCBs were present at every Little River site and virtually every site in Biscayne Bay near the mouth of the river. Pesticides were detected at one site in the Little River (Map 82). Similar to the Miami River, but to a lesser extent, the Little River appears to be contributing significant contaminants to adjacent areas of Biscayne Bay.

Extensive residential and urban development has resulted in significant metal enrichment at most locations, as well as expenditure of the coastal and estuarine habitats. Metal contamination is present in the New River sediments near Fort Lauderdale, with particularly high levels of lead and zinc enrichment (chromium, copper, mercury, and nickel also was detected (Map 36). Some of the highest levels of PAHs and PCBs in the FDEP database are found in the vicinity of Miami. These pollutants were also detected in these sediments (Map 81).

Both metal and organic contaminants are ubiquitous north of Fort Lauderdale, but are usually present in much lower levels than at sites near Miami and Fort Lauderdale. Lead and zinc enrichment is present at most sites, and mercury enrichment also occurs at many sites. A few sites in the Lake Worth Lagoon north of the city of Lake Worth have significant enrichment in metals, particularly at a site just north of the mouth of the New River, in the north part of Lake Worth Lagoon (Maps 42 and 43). PAHs and PCBs also were detected slightly south of West Palm Beach (Map 87).

6.9 East Central Region

The east central region represented in the Atlas consists of the Indian River Lagoon (IRL) system, which is composed of three interconnected estuarine lagoons - Mosquito Lagoon, Indian River Lagoon, and Banana River Lagoon - all protected by a series of barrier islands. The lagoonal system extends for a distance of over 150 miles through six counties, from Volusia County in the north to Palm Beach County in the south. It varies in width between 0.5 to 5.5 miles (Maps 44 and 88), and contains both true estuarine subsystems (e.g. St. Lucie estuary) and lagoonal systems (e.g. Mosquito Lagoon). The IRL estuarine drainage area is nearly 1250 m² and the average depth is just under six feet (NOAA 1985).

Significant alteration of the original water circulation patterns of the IRL system has occurred from construction of bridges, causeways, navigation channels, and upland drainage facilities. Wide fluctua-
tions in freshwater entering the estuarine system produce biologically undesirable salinity variations and increases in sedimentation. Habitat and species diversity in the IRL system has been adversely affected by declining water and sediment quality, and loss of seagrass habitat. Numerous manmade and boat yards contribute to locally elevated levels of metals and organic contaminants (Indian River SWIM Plan, 1989).

Little metal enrichment has been detected in the northern region of the IRL system (Map 45). In the central part of the lagoon system, near the southern part of Merritt Island, slight to moderate metal enrichment is present (Map 48). Pesticides were detected at two sites near Cocoa (Map 89). Enrichment in cadmium, copper, and zinc was detected in the United States Navy turning basin in the Port Canaveral area (Maps 47 and 90). Pesticides were also detected in the turning basin. Cadmium, copper, mercury, lead, and zinc enrichment was detected at a site near Eau Gallie, and lead and zinc enrichment was detected near Sebastian (Map 48). Slight metal enrichment, usually lead, was detected near Fort Pierce (Map 49). PAHs, PCBs, and pesticides were detected by NOAA in the IRL system north of the city of Sebastian (Map 91).

6.10 Northeast Region

The largest estuarine waterbody in the northeast part of Florida is the St. Johns River system, which extends over a distance of 300 miles from St. Lucie County northward to Duval County. The EDA is over 6500 mi² and the average depth of the estuary is 14 feet. Tidal influence is observed slightly upstream of Lake George, a distance of over 120 miles from the Atlantic Ocean (NOAA 1985). As is the case with Florida estuaries adjacent to urban centers, the St. Johns River estuary is affected by point and non-point source pollution. Deteriorating water and sediment quality are problems which have approached a critical state in certain areas of the estuary (Lower St. Johns River SWIM Plan 1992).

The sampling programs of the FDEP, NOAA, and Mote Marine Laboratory (MML) were located in the portion of the river system referred to as the Lower St. Johns River (LSJR). Site locations of the FDEP and MML extended well into the freshwater zone, with the most inland site located in the northern end of Lake George in Putnam County (Maps 50 and 92). The high number of sampling sites in the LSJR system in Duval County required separate index maps for metal and organic contaminants (Maps 52 and 93).

Slight metal enrichment was detected in five of twelve sites in the Blount Island/Mill Cove area downstream of Jacksonville, but PAHs, PCBs, pesticides, and chlorinated hydrocarbon compounds were detected at five FDEP sites (Maps 53 and 94). Slight to moderate trace metal enrichment was detected in the LSJR near the City of Jacksonville at the confluence of St. Johns and Trout Rivers, but PAHs, PCBs, and pesticides are present at virtually every site (Maps 54 and 95). The MML site located in the Trout River has elevated levels of cadmium, copper, mercury, lead, and zinc. This tributary to the St. Johns River receives stormwater runoff from parts of northern Jacksonville.

Metal enrichment is present in most sites near downtown Jacksonville (Map 55). Organic contaminants also are present at numerous sites in this area (Map 96). Upstream of downtown Jacksonville, slight metal enrichment was detected in the open river sections of the LSJR, but high levels of metals enrichment were detected in the MML sites in the Ortega River. One or more classes of organic contaminants were detected at every site in this map area (Maps 56 and 97). Slight metal enrichment, usually lead and zinc, was detected in the central part of the LSJR system in Clay and Putnam Counties (Maps 57 and 58), but two or more classes of organic contaminants were detected at every site in this area (Maps 58 and 98). Alliopbatic hydrocarbons were detected at five FDEP sites in southern Clay and northern Putnam counties.

Low levels of metal contamination were detected at sites located near the river mouth (Map 59). Slight copper enrichment was detected at sites in Pablo Creek and lead enrichment was detected at a site west of Mayport. PAHs, PCBs, and pesticides were detected at sites near the river mouth by both NOAA and MML. PAHs and PCBs were detected in Pablo Creek, and PAHs were detected in the Tomatomo River north of South Ponte Vedra Beach (Map 100).

Metal enrichment was detected occasionally at sites along the Atlantic coastline from the mouth of the SJR in Duval County south to Mosquito Lagoon in northern Brevard County (Maps 60, 61, 62, and 63). Enrichment in copper, lead, and zinc occurs frequently in coastal waters. PAHs and PCBs were detected at every site in the Matanzas or Halifax Rivers in St. Johns, Flagler, and Volusia Counties. PCBs are also present at many of these sites, and pesticides were detected at one site in St. Johns County (Map 101).

Generally other sites sampled in the northeast region exhibit lower levels of contamination. Virtually no metal contamination was detected at the three sites in the St. Marys River estuary in Nassau County, indicative of the relatively unimpacted nature of this estuarine system (Map 51). An initial evaluation of the potential for biological effects associated with contaminants levels at sites represented in the Atlas is provided in the document Development of an Approach to the Assessment of Sediment Quality in Florida Coastal Waters (MacDonald 1993). This report can be obtained from the authors of the Atlas.

SECTION 7: CONCLUSION

Most of the highest concentrations for any particular contaminant are found at sites near Tampa, Pensacola, Miami, and Jacksonville. However, high contaminant concentrations are occasionally found near some of the highest organic contaminants levels occur in the New River in Fort Lauderdale. Perhaps surprisingly, contaminants are common in less developed areas. For example, PAHs, PCBs and pesticides have been detected in the Charlotte Harbor-Calosasahatchee River area, and elevated levels of copper occur in sediments of the Crystal River National Wildlife Refuge.

Analysis of the FDEP sediment chemistry database indicates that statewide the most common metal contaminants are (listed in decreasing degree of contamination) lead, zinc, mercury, cadmium, copper, nickel, and aluminum. Most commonly encountered class of organic contaminant is the polynuclear aromatic hydrocarbons, followed by polychlorinated biphenyls.

Stormwater runoff appears to be the major cause of contamination of sites identified in the Atlas. As a result of pollution control efforts by local, county, state, and federal agencies, the practices resulting in coastal contamination may be abating, but they have not stopped. Major accomplishments have been made in controlling point sources of pollution and, more recently, environmental protection programs have increased efforts to control urban stormwater discharges and agricultural land runoff. Monitoring the effectiveness of these controls is a challenge that will face the state for many years. As this document illustrates, sediment monitoring efforts in combination with other assessment activities are essential in keeping a finger on the pulse of coastal ecosystems of Florida.
REFERENCES


Livingston, R.J., 1983. Identification and analysis of sources of pollution in the Apalachicola River and Bay system. As cited in the Apalachicola River and Bay Management Plan, Northwest Florida Water Management District.


Metal Contaminants

Parcharts represent the enrichment factor, which is the ratio of the measured metal concentration in the sediment to the maximum expected natural concentration.

NOTE: Where no bar is shown, metal concentration is within the expected natural range. A circle below a bar indicates that metal concentration is above the expected natural range. A cross above a bar indicates that metal concentration exceeded the maximum expected natural value.
Suwannee River
and Cedar Keys
Metal Contaminants

Big Bend Region
Inset C
Suwannee River and Cedar Keys
Barcharts represent the enrichment factor, which is the ratio of the measured metal concentration in the sediments to the concentration range within the expected natural range. A circle below a bar indicates that no data were available. A cross above a bar indicates that metal concentration exceeded the maximum expected natural value.

Map 16: Tampa Bay Region Index to Insets

Tampa Bay Region
Index to Insets
Metal Contaminants
Charts represent the enrichment factor, which is the ratio of the measured metal concentration in the sediment to the maximum expected natural concentration. 

NOTE: When no bar is shown, metal concentration is within the expected natural range. A circle below a bar indicates no data were available. A cross above a bar indicates the metal concentration exceeded the maximum expected natural value.

Map 31 - Everglades Region Index to Insets
Barcharts represent the enrichment factor, which is the ratio of the measured metal concentration in the sediment to the maximum expected natural concentration.

NOTE: When no bar is shown, metal concentration is within the expected natural range. A circle below a bar indicates that no data were available. A cross above a bar indicates that metal concentration exceeded the maximum expected natural value.
Southeast Region Index to Inset Series A-2
Miami/Biscayne Bay Metal Contaminants
Map 50 - Northeast Region Index to Insets
Northeast Region
Inset A
Amelia Island Area
Metal Contaminants

Georgia
Florida
Nassau Co.
Duval Co.

Atlantic Ocean

Map 51 Northeast Region Inset A
Amelia Island Area
Northeast Region
Inset B-3
Jacksonville Area
Metal Contaminants

Jacksonville

St Johns River

Floral Bluff

Arlington

McCoy Cr

Map 55 - Northeast Region Inset B-3 - Jacksonville Area
GULF OF MEXICO

Panhandle Region
Inset D

Apalachicola Bay
Organic Contaminants

Map 70 - Panhandle Region Inset D - Apalachicola Bay
Everglades Region
Organic Contaminants

Bar charts represent the ratio of measured organic contaminant concentration to the measured concentration of total organic carbon (TOC).

NOTE: When no bar is shown, no organic contaminant was detected. A circle below the bar indicates the normalized value of the measured organic contaminant concentration exceeded a value of 25 above zero.
Northeast Region
Inset A-2
Trout River Area
Organic Contaminants

Map 95 - Northeast Region Inset A-2 - Trout River Area