Chapter 4

An Initial Assessment of the Potential for Biological Effects of Sediment-Associated Contaminants in Florida Coastal Waters

4.0 Introduction

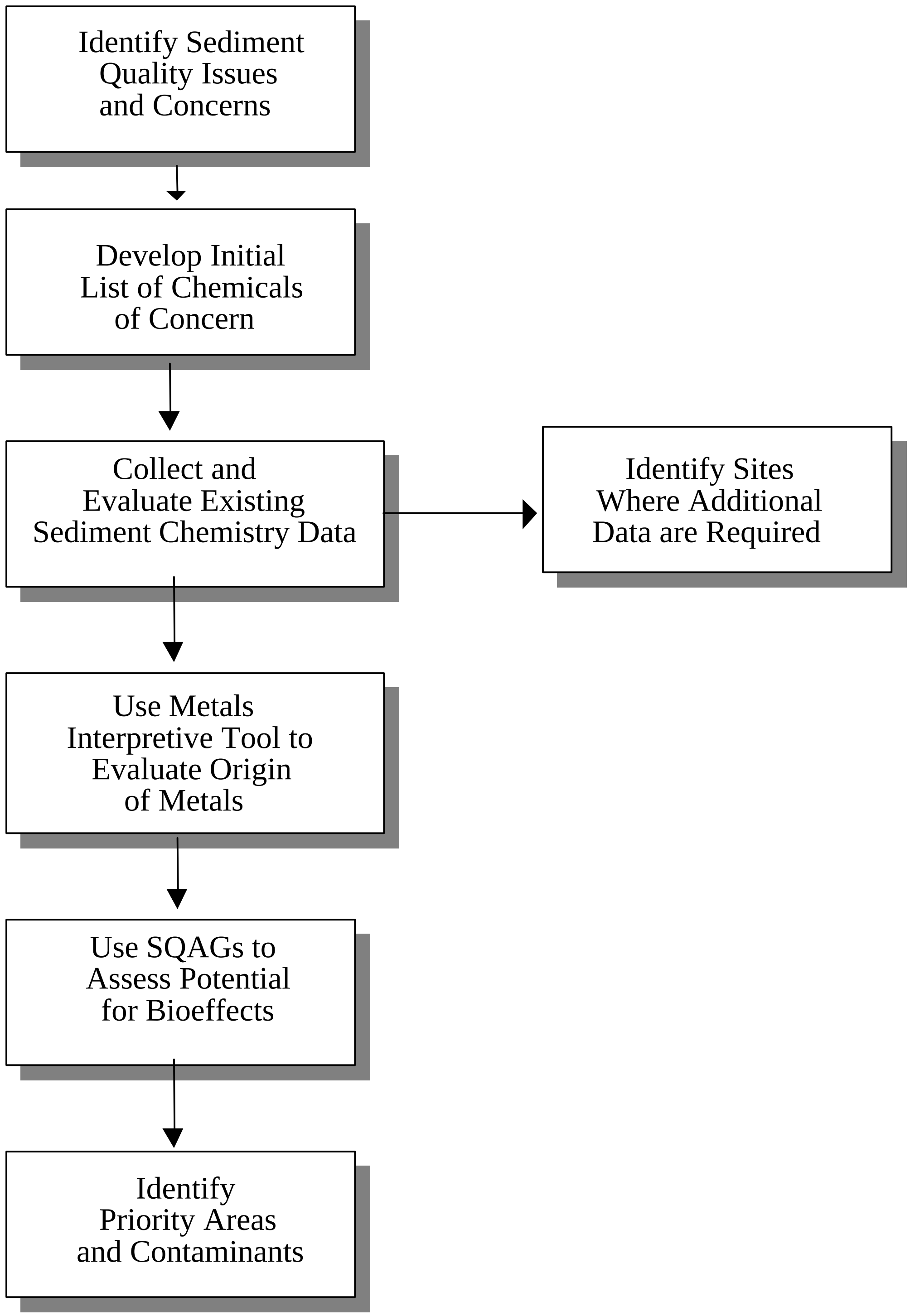
This Chapter presents an initial assessment of the potential for biological effects of sediment-associated contaminants, using Florida Department of Environmental Protection (FDEP) coastal sediment chemistry data and the sediment quality assessment guidelines (SQAGs) recommended in Volume 1 (MacDonald 1994). Although preliminary, this assessment helps focus sediment management efforts by identifying priority contaminants and priority sites with respect to the potential for adverse biological effects. The exercise also illustrates how an identification of sediment quality concerns conducted on a regional scale would help direct limited resources to yield the greatest environmental benefits.

This initial regional assessment of sediment quality consists of several parts. In Volume 1, regional sediment quality issues and concerns were identified by reviewing potential sources of contaminants in the state. Priority substances with respect to sediment contamination were subsequently identified by compiling relevant data from several sources. Next, numerical SQAGs were derived preferentially for preliminary substances of concern in Florida sediments. This chapter carries the derivation of SQAGs forward by compiling a database containing sediment chemistry data for Florida coastal waters, and comparing sediment chemistry data with the metals interpretive tool (Schropp and Windom 1988) and the SQAGs (Figure 6).

4.1 Identification of Regional Sediment Quality Issues and Concerns

In Florida, sediment quality issues and concerns are primarily associated with direct and non-point (diffuse) source discharges of contaminants from urban and suburban areas into coastal waters. These inputs include effluent discharges from wastewater treatment plants, stormwater runoff, and a variety of related sources. In addition, industrial facilities have the potential to release significant quantities of contaminants into estuarine and marine systems.

Figure 6. Framework for conducting preliminary regional sediment quality assessment of Florida coastal waters.



Furthermore, intensive agricultural operations have the potential to contribute pesticides and fertilizers to aquatic ecosystems. Other possible sources of contaminants into Florida coastal waters include leachates from landfills, dredging operations, and the operation of boat repair and moorage facilities. Each of these potential sources of contaminants was considered in identifying substances for this preliminary evaluation. A discussion of sediment quality issues and concerns, and anthropogenic influences in Florida is provided in MacDonald (1994), while a list of substances likely to be associated with coastal sediments is provided in Table 1.

4.2 Development of a Database on Sediment Chemistry in Florida

Over the past 10 years, the FDEP has conducted coastal sediment contaminant surveys in various regions throughout the state. This information has now been assembled into a database (the Florida coastal sediment contaminants database; FDEP 1994) in dBase IV™ format. This database contains information on approximately 700 stations located in estuarine and nearshore marine areas throughout Florida. While most of these stations are located in the vicinity of cities and their satellite communities, roughly 17% of the stations are located in pristine areas for the purpose of identifying natural background conditions.

There are over 11,000 miles of tidal shoreline in Florida, and the database is not representative of the full extent of the state's coastal conditions. The Florida coastal sediment contaminants database has focused on metals due to the prevalence of anthropogenic activities that generate metals-enriched wastes. The metals most commonly measured in the survey include aluminum, cadmium, chromium, copper, nickel, lead, mercury, and zinc. Typically, two samples have been collected and analyzed at each station. Organic substances are also represented in the database at a limited number of stations. In general, sampling for organic substances was conducted when land use activities suggested that there would be a high probability of detecting these substances in sediments.

4.3 Evaluate the Probable Origin of Sediment-Associated Metals

The metals interpretive tool (Schropp and Windom 1988; Schropp *et al.* 1989; Schropp *et al.* 1990) provides a reliable basis for evaluating the probable origin of sediment-associated metals. To identify the areas in which the concentrations of sediment-associated metals have been enriched anthropogenically, the metals interpretive tool was applied to the existing sediment chemistry data. In this evaluation, the preliminary areas of greatest concern were identified as those with the greatest frequency of metals concentrations that exceeded the 95% prediction limits. Similarly, the highest priority metals, with respect to anthropogenic enrichment were identified as those that frequently exceeded their respective 95% prediction limits. Pooled data for a number of sampling stations and sampling dates were used to

Table 1. Preliminary identification of chemicals of concern in Florida coastal waters.

Substance	Reference/Rationale
Metals	
Arsenic	Long et al. (1991); FDEP (1994).
Cadmium	Long et al. (1991); FDEP (1994).
Chromium	Long and Morgan (1990); Long et al. (1991); FDEP (1994).
Copper	Used in aquatic herbicides/found in fish; Long et al. (1991); Trefry et al. (1983); Leslie (1990); FDEP (1994).
Lead	Long and Morgan (1990); Long et al. (1991); FDEP (1994).
Mercury	Long and Morgan (1990); Long et al. (1991); FDEP (1994).
Nickel	Long et al. (1991); FDEP (1994).
Silver	Long and Morgan (1990); FDEP (1994).
Tributyltin	Used as an antifoulant on ships.
Zinc	Long and Morgan (1990); Long et al. (1991); FDEP (1994).
Polycyclic Aromatic Hydrocarbons (PAHs)	
Acenaphthene	Delfino et al. (1991); FDEP (1994).
Acenaphthylene	Delfino et al. (1991); FDEP (1994).
Anthracene	Long and Morgan (1990); Delfino et al. (1991); FDEP (1994).
Benz(a)anthracene	Long and Morgan (1990); Delfino et al. (1991); FDEP (1994).
Benzo(a)pyrene	Long and Morgan (1990); Delfino et al. (1991); FDEP (1994).
Chrysene	Long and Morgan (1990); Delfino et al. (1991); FDEP (1994).
Dibenzo(a,h)anthracene	Long and Morgan (1990); Delfino et al. (1991); FDEP (1994).
Fluorene	Long and Morgan (1990); Delfino et al. (1991); FDEP (1994).
Fluoranthene	FDEP (1994).
Napthalene	Long and Morgan (1990); Delfino et al. (1991); FDEP (1994).
2-methylnapthalene	Long and Morgan (1990).
Phenanthrene	Long and Morgan (1990); Delfino et al. (1991); FDEP (1994).
Pyrene	Long and Morgan (1990); Delfino et al. (1991); FDEP (1994).
Total PAHs	Long and Morgan (1990); Long et al. (1991); FDEP (1994).
Polychlorinated Biphenyls (PCBs)	
Total PCBs	Long and Morgan (1990); Long et al. (1991); Delfino et al. (1991); FDEP (1994).

Table 1. Preliminary identification of chemicals of concern in Florida coastal waters (continued).

Substance	Reference/Rationale
Pesticides	
Aldrin/Dieldrin	Long and Morgan (1990); Long et al. (1991); FDEP (1994).
Azinphos-methyl (guthio	Organophosphorous insecticide (Kow > 10,000?)
Chlordane	Long and Morgan (1990); Long et al. (1991); FDEP (1994).
Chlorothalonil	Chlorophenyl fungicide (Kow = 20,000)
Chlorpyrifos	Organophosphorous insecticide (Kow > 50,000)
DDT and metabolites	Long and Morgan (1990); Long et al. (1991); FDEP (1994); Delfino et al. (1991).
Disulfoton	Organophosphorous insecticide (Kow > 10,000)
Endosulfan	Delfino et al. (1991); FDEP (1994).
Endrin	Organochlorine insecticide (Kow > 10,000?); FDEP (1994).
Heptachlor	Organochlorine insecticide (Kow > 10,000?); FDEP (1994).
Heptachlor epoxide	Organochlorine insecticide (Kow > 10,000?); FDEP (1994).
Lindane (gamma-BHC)	Organochlorine insecticide (Kow > 10,000?); FDEP (1994).
Mirex	Organochlorine insecticide (Kow > 10,000?); FDEP (1994).
Phorate	Organophosphorous insecticide (Kow > 10,000?).
Quintozene (PCNB)	Chlorophenyl fungicide (Kow = 10,000).
Toxaphene (alpha-BHC)	Organochlorine insecticide; FDEP (1994).
Trifluralin	Dinitroanaline herbicide (Kow > 200,000); FDEP (1994).

* Kow = Octanol-water partition coefficient which provides an indication of the hydrophobicity of a substance; Criteria for selection of pesticides: Kow > 5,000.

Substance	Reference/Rationale
Chlorinated Organic Compounds	
2,3,7,8-T4CDD	Pulp and paper industry.
2,3,7,8-T4CDF	Pulp and paper industry
Pentachlorophenol	Delfino et al. (1991); FDEP (1994).
Phthalates	
Bis(2-ethylhexyl)phthala	Delfino et al. (1991).
Dimethyl phthalate	Delfino et al. (1991).
Di-n-butylphthalate	Delfino et al. (1991).

evaluate the extent of anthropogenic metals enrichment within each geographic area. It was not possible to evaluate enrichment of any of the organic contaminants measured in Florida coastal waters.

4.4 Derivation of Numerical Sediment Quality Assessment Guidelines

Effects-based SQAGs provide a basis for assessing the potential for biological effects associated with various concentrations of contaminants. In Florida, threshold (TELs) and probable effects levels (PELs) have been recommended for 34 substances or groups of substances (MacDonald 1994). These guidelines define three ranges of contaminant concentrations: a probable effects range; a possible effects range; and, a minimal effects range. The procedure used to derive these guidelines is presented in MacDonald (1994), while the uses of the SQAGs are described in Chapters 2 and 3 of this document.

4.4.1 Preliminary Areas of Concern

In the FDEP coastal contaminants database, measurements of metals levels were organized into 20 general geographic areas to facilitate this evaluation (Figure 7). While this database provides important information for evaluating sediment quality in Florida coastal waters, its broad applicability is limited by the number of samples that have been collected in certain areas. For example, fewer than ten sites have been sampled in the Jupiter, Ft. Lauderdale, and Florida Keys areas. Nonetheless, it is apparent that metals concentrations have been significantly enriched in many areas of the state.

On the Atlantic coast (Table 2), the highest frequency of exceedances of the 95% prediction limits for metals occurred in the vicinity of Miami. Cadmium, chromium, copper, lead, mercury and zinc were all anthropogenically-enriched at a large proportion of the sites sampled. Almost three-quarters of the sites had lead to aluminum enrichment ratios of greater than one, with ratios of greater than 100 observed at certain sites. Significant anthropogenic enrichment of metals was also apparent in the Jacksonville and West Palm Beach areas.

In the Gulf of Mexico (Table 3), coastal sediments in the vicinity of Tampa and Pensacola had the highest frequency of exceedances of the 95% prediction limits of the eight metals considered. The concentrations of cadmium, copper, chromium, lead, mercury, and zinc were all enriched in these areas. In Tampa Bay, more than a third of the sites had cadmium to aluminum enrichment ratios of greater than one. In Pensacola Bay, more than 20% of the sites sampled had zinc to aluminum enrichment ratios of greater than one, which indicates that a relatively high proportion of the sites have anthropogenically-enriched levels of zinc.

Figure 7. Florida Department of Environmental Protection coastal survey area map.

Table 2. Evaluation of anthropogenic-enrichment of metals levels for each Atlantic coast sampling area.

Substance	Number of Exceedances of the 95% Prediction Limits									
	JAX	STA	DAY	IRS	JPT	WPB	FTL	MIA	KEY	Total
Metals										
Arsenic	0	0	0	0	0	0	0	**4**	0	**4**
Cadmium	**15**	0	**4**	**8**	0	**2**	0	**48**	**1**	**78**
Chromium	**2**	0	0	**2**	0	**2**	0	**51**	0	**57**
Copper	**10**	**3**	**6**	**8**	0	**8**	**4**	**48**	0	**87**
Lead	**27**	0	**2**	**6**	0	**26**	**5**	**78**	**1**	**145**
Mercury	**25**	**1**	0	**9**	0	**6**	**2**	**55**	**2**	**100**
Nickel	**2**	0	0	0	0	**1**	0	**1**	0	**4**
Silver	-	-	-	-	-	-	-	-	-	**0**
Zinc	**27**	0	0	**6**	0	**23**	**5**	**20**	**2**	**83**
Number of Samples	68	37	31	86	7	27	5	110	4	558

Place names indicate the general coastal vicinity of sampling station locations.
JAX = Jacksonville; STA = St. Augustine; DAY = Daytona Beach; IRS = Indian River; JPT = Jupiter; WPB = West Palm Beach; FTL = Ft. Lauderdale; MIA = Miami; KEY = Florida Keys.

Table 3. Evaluation of anthropogenic-enrichment of metals levels for each Gulf coast sampling area.

Substance	Number of Exceedances of the 95% Prediction Limit											
	EVG	FTM	TPA	WCF	APL	APA	SJB	PCY	DES	PEN	PER	Total
Metals												
Arsenic	0	0	**1**	**1**	0	0	0	0	0	**1**	0	**3**
Cadmium	0	**4**	**51**	**8**	0	**1**	**2**	**2**	**1**	**7**	**1**	**77**
Chromium	0	**1**	**17**	**6**	0	0	0	0	0	**7**	**2**	**33**
Copper	0	**3**	**14**	**11**	0	0	**1**	**1**	**1**	**4**	0	**35**
Lead	**3**	**2**	**38**	**7**	0	0	**1**	**1**	**1**	**11**	**1**	**65**
Mercury	0	**4**	**32**	**1**	0	0	**7**	**2**	0	**12**	**2**	**60**
Nickel	0	0	**4**	**1**	0	0	0	0	0	0	0	**5**
Silver	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Zinc	0	**3**	**31**	**6**	0	**1**	**1**	**1**	**1**	**18**	**3**	**65**
Number of Samples	96	67	141	30	56	30	22	39	20	79	17	597

Place names indicate the general coastal vicinity of sampling station locations.
EVG = Everglades; FTM = Ft. Mayers; TPA = Tampa Bay; WCF = West Central Florida; APL = Apalachee Bay; APA = Apalachichola Bay; STJ = St. Josephs Bay; PCY = Panama City; DES = Destin; PEN = Pensacola Bay; PER = Perido Bay.

4.4.2 Preliminary Metals of Concern

The results of this evaluation indicate that anthropogenic-enrichment of metals levels occurs relatively frequently in Florida coastal sediments. Of the substances considered, lead was identified as the metal of greatest concern. Mercury to aluminum ratios of greater than one were observed at a total of 210 sites, with the majority of these sites located in the Atlantic coast (145 of 210). Somewhat lower frequencies of exceedance of the 95% prediction limits were observed for cadmium (155), mercury (160), and zinc (148). Once again, the highest frequency of metals enrichment was observed on the Atlantic coast. In contrast, the metals to aluminum ratios for arsenic and nickel rarely exceeded one, indicating that these metals represent minor concerns with respect to sediment contamination. Chromium and copper were enriched at 90 and 122 sites, respectively. For these two metals, the highest frequency of enrichment was observed on the Atlantic coast.

4.5 Assessment of the Potential for Biological Effects of Sediment-Associated Contaminants

The existing sediment chemistry data were used in conjunction with the recommended SQAGs to conduct an initial assessment of the potential for adverse biological effects in Florida coastal sediments. This assessment was conducted by screening the FDEP coastal sediment chemistry database (FDEP 1994) using the SQAGs. In this way, the sites with contaminant concentrations that exceeded the probable effects level and the threshold effects level, respectively, could be readily identified. The highest priority areas with respect to sediment contamination were identified as those with the greatest frequency of contaminant concentrations within the probable effects ranges. The highest priority substances with respect to sediment contamination were identified as those that frequently occurred at concentrations within the probable effects ranges. For metals, the areas and contaminants of greatest concern were those that had concentrations that were known to be anthropogenically enriched and that were likely to be associated with biological effects. Pooled data for a number of sampling stations and sampling dates were used to assess sediment quality within each geographic area.

4.5.1 Areas of Concern in Florida Coastal Waters

Chemical measurements in the FDEP database were organized into 20 general geographic areas in this initial assessment of sediment quality (Figure 7). Although evaluation of the database provides insight into sediment quality conditions at sites within these areas, this initial assessment is constrained by data limitations for some areas. For example, data on levels of metals were available for less than ten sites in the Jupiter, Ft. Lauderdale and Florida Keys areas. Even more severe limitations on the data were apparent when PAHs, PCBs, pesticides and other organic contaminants were considered (see Tables 4-7). In spite of these limitations, it is apparent that sediment quality represents a significant environmental concern in a number of locations within the state.

On the Atlantic coast (Table 4), coastal sediments in the vicinity of Miami had the highest frequency of contaminant concentrations within the **probable** effects ranges. Copper, lead, mercury, silver zinc, phenanthrene, chrysene, pyrene and total PCBs were all present at concentrations that are considered to represent significant hazards to aquatic organisms. In addition, several PAHs were present at levels in excess of their respective PELs in the Jacksonville and Daytona Beach areas; these included benz(a)anthracene, fluoranthene, phenanthrene, and pyrene. Concentrations of several metals also fell within the probable effects range in the Jacksonville and Indian River areas.

All of the Atlantic coastal areas surveyed, with the exception of the Jupiter area, had concentrations of one or more contaminants that fell within the **possible** effects range (Table 5). The greatest number of exceedances were observed in the Miami area, reflecting both the degree of contamination and the total number of samples collected within the area. Metals appear to represent the greatest hazard to aquatic organisms on the Atlantic coast of Florida; however, PAHs and PCBs have also been detected at levels of concern in many areas. Elevated levels of two DDT degradation products (i.e., DDD and DDE) were recorded in the Ft. Lauderdale area. The total number of samples and the number of exceedances of the SQAGs for each area on the Atlantic coast are presented in Tables 4 and 5.

Coastal sediments in the Gulf of Mexico appeared to be somewhat less contaminated than sediments on the Atlantic coast of Florida (Table 6). The greatest frequency of exceedance within the **probable** effects range occurred in Tampa Bay, with arsenic, cadmium, copper, chromium, lead, and zinc being the principal contaminants of concern in this area. Several other sampling programs have indicated that PAHs and pesticides are present at levels of concern in Tampa Bay, however (Long and Morgan 1990; E. Long. NOAA. Seattle, Washington. Personal communication). Elevated levels of several metals (i.e., ≥ PEL) have also been observed in Pensacola Bay and the Panama City area. Pensacola Bay also had multiple exceedances of the SQAGs for several PAHs, including benz(a)anthracene, fluoranthene, and pyrene. While concentrations of organic contaminants rarely fell within the probable effects ranges along the Gulf coast, this region has been only infrequently sampled for this class of analytes.

All of the areas surveyed along the Gulf coast had concentrations of four or more contaminants that fell within the **possible** effects ranges (Table 7). The greatest number of observations within the possible effects ranges occurred in Tampa Bay; this reflects the level of sampling effort that has been directed at this area, as well as the level of contamination. The other main areas of concern in terms of metals contamination are Pensacola Bay, Panama

Table 4. Number of samples that fall within the probable effects range (i.e., >= PEL) of contaminant concentrations for each Atlantic coast sampling area.

Substance	Number of Observations Within the Probable Effects Range									
	JAX	STA	DAY	IRS	JPT	WPB	FTL	MIA	KEY	Total
Metals										
Arsenic	**2**	**1**	0	0	0	0	0	0	0	**3**
Cadmium	0	0	0	0	0	0	0	**2**	0	**2**
Chromium	**1**	0	0	**1**	0	0	0	**2**	0	**4**
Copper	0	0	0	0	0	0	0	**14**	0	**14**
Lead	0	0	0	0	0	0	0	**21**	0	**21**
Mercury	**1**	0	0	**4**	0	**1**	**1**	**29**	0	**36**
Nickel	**1**	0	0	0	0	0	0	0	0	**1**
Silver	**3**	0	0	**3**	0	0	0	**11**	0	**17**
Zinc	0	0	0	0	0	0	0	**9**	0	**9**
Number of Samples	68	37	31	86	7	27	5	110	4	375
Polycyclic Aromatic Hydrocarbons (PAHs)										
Acenaphthene	**9**	0	0	0	0	0	0	**1**	0	**10**
Acenaphthylene	**1**	0	0	0	0	0	0	**1**	0	**2**
Anthracene	**1**	0	0	0	0	0	0	**3**	0	**4**
Benz(a)anthracene	0	0	0	0	0	0	**1**	**7**	0	**8**
Benzo(a)pyrene	**4**	0	0	0	0	0	0	**5**	0	**9**
Chrysene	0	0	0	0	0	0	0	**15**	0	**15**
Dibenzo(a,h)anthracene	**1**	0	0	0	0	**1**	0	0	0	**2**
Fluoranthene	**3**	0	**3**	0	0	0	0	**9**	0	**15**
Fluorene	**2**	0	0	0	0	0	0	0	0	**2**
2-methylnaphthalene	0	0	0	0	0	0	0	0	0	**0**
Naphthalene	0	0	0	0	0	0	0	**2**	0	**2**
Phenanthrene	**2**	0	**4**	0	0	0	0	**10**	0	**16**
Pyrene	**4**	0	**1**	0	0	0	0	**10**	0	**15**
Number of Samples	34	2	6	7	0	6	4	66	0	125

Table 4. Number of samples that fall within the probable effects range (i.e., >= PEL) of contaminant concentrations for each Atlantic coast sampling area (continued).

Substance	Number of Observations Within the Probable Effects Range									
	JAX	STA	DAY	IRS	JPT	WPB	FTL	MIA	KEY	Total
Pesticides										
Aldrin	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Azinophosmethyl (Guthion)	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Chlordane	**2**	0	0	0	0	0	0	**3**	0	**5**
Chlorthalonil	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Chlorpyrifos	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
p,p'-DDD	0	0	0	0	0	0	**1**	0	0	**1**
p,p'-DDE	0	0	0	0	0	0	0	0	0	**0**
p,p'-DDT	0	0	0	0	0	0	**1**	**3**	0	**4**
Dieldrin	0	0	0	0	0	0	0	0	0	**0**
Disulfoton	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Endosulfan	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Heptachlor	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Heptachlor epoxide	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Lindane (gamma-BHC)	0	0	0	0	0	0	0	0	0	**0**
Phorate	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Quintozene (PCNB)	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Toxaphene (alpha-BHC)	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Trifluralin	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Number of Samples	47	3	6	21	0	11	5	78	0	171
Polychlorinated Biphenyls (PCBs)										
Total PCBs	0	0	0	0	0	0	0	**7**	0	**7**
Number of Samples	47	3	6	21	0	11	5	78	0	171

NG = no guideline; insufficient data to derive sediment assessment quality guidelines.
Place names indicate the general coastal vicinity of sampling station locations.
JAX = Jacksonville; STA = St. Augustine; DAY = Daytona Beach; IRS = Indian River; JPT = Jupiter; WPB = West Palm Beach; FTL = Ft. Lauderdale; MIA = Miami; KEY = Florida Keys.

Table 5. Number of samples that fall within the possible effects range (i.e., > TEL and < PEL) of contaminant concentrations for each Atlantic coast sampling area.

	Number of Observations Within the Possible Effects Range									
Substance	JAX	STA	DAY	IRS	JPT	WPB	FTL	MIA	KEY	Total
Metals										
Arsenic	**17**	**14**	**9**	**8**	0	**2**	0	**16**	0	**66**
Cadmium	**15**	0	**2**	**13**	0	**1**	0	**26**	0	**57**
Chromium	**7**	**8**	**1**	**14**	0	0	0	**31**	0	**61**
Copper	**27**	**9**	**12**	**23**	0	**1**	**2**	**23**	0	**97**
Lead	**22**	0	**1**	**12**	0	**2**	**2**	**19**	0	**58**
Mercury	**33**	**1**	**6**	**15**	0	**6**	**1**	**32**	**4**	**98**
Nickel	**7**	**5**	0	**7**	0	**1**	0	**1**	0	**21**
Silver	**2**	0	0	**2**	0	0	0	**6**	0	**10**
Zinc	**9**	0	**1**	**8**	0	0	0	**10**	0	**28**
Number of Samples	68	37	31	86	7	27	5	110	4	375
Polycyclic Aromatic Hydrocarbons (PAHs)										
Acenaphthene	**3**	0	0	0	0	0	0	0	0	**3**
Acenaphthylene	**1**	0	0	0	0	0	0	0	0	**1**
Anthracene	**6**	0	0	0	0	**1**	**2**	**4**	0	**13**
Benz(a)anthracene	0	0	0	0	0	0	0	0	0	**0**
Benzo(a)pyrene	**4**	0	0	0	0	**3**	**1**	**9**	0	**17**
Chrysene	**7**	0	0	0	0	0	**1**	**6**	0	**14**
Dibenzo(a,h)anthracene	0	0	0	0	0	0	0	0	0	**0**
Fluoranthene	**16**	**2**	**3**	0	0	**6**	**1**	**25**	0	**53**
Fluorene	**2**	0	0	0	0	0	**1**	0	0	**3**
2-methylnaphthalene	0	0	0	0	0	**1**	0	0	0	**1**
Naphthalene	**6**	0	0	0	0	**1**	0	0	0	**7**
Phenanthrene	**1**	**2**	**2**	0	0	0	0	**5**	0	**10**
Pyrene	**12**	0	**2**	0	0	**3**	**2**	**19**	0	**38**
Number of Samples	34	2	6	7	0	6	4	66	0	125

Table 5. Number of samples that fall within the possible effects range (i.e., > TEL and < PEL) of contaminant concentrations for each Atlantic coast sampling area (continued).

	Number of Observations Within the Possible Effects Range									
Substance	JAX	STA	DAY	IRS	JPT	WPB	FTL	MIA	KEY	Total
Pesticides										
Aldrin	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Azinophosmethyl (Guthion)	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Chlordane	0	0	0	0	0	0	0	0	0	**0**
Chlorthalonil	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Chlorpyrifos	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
p,p'-DDD	0	0	0	0	0	0	**2**	0	0	**2**
p,p'-DDE	0	0	0	0	0	0	**3**	0	0	**3**
p,p'-DDT	0	0	0	0	0	0	0	0	0	**0**
Dieldrin	0	0	0	0	0	0	0	0	0	**0**
Disulfoton	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Endosulfan	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Heptachlor	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Heptachlor epoxide	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Lindane (gamma-BHC)	0	0	0	0	0	0	0	0	0	**0**
Phorate	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Quintozene (PCNB)	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Toxaphene (alpha-BHC)	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Trifluralin	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Number of Samples	47	3	6	21	0	11	5	78	0	171
Polychlorinated Biphenyls (PCBs)										
Total PCBs	**2**	0	**4**	0	0	0	0	**6**	0	**12**
Number of Samples	47	3	6	21	0	11	5	78	0	171

NG = no guideline; insufficient data to derive sediment quality assessment guidelines.
Place names indicate the general coastal vicinity of sampling station locations.
JAX = Jacksonville; STA = St. Augustine; DAY = Daytona Beach; IRS = Indian River; JPT = Jupiter; WPB = West Palm Beach; FTL = Ft. Lauderdale; MIA = Miami; KEY = Florida Keys.

Table 6. Number of samples that fall within the probable effects range (i.e., >= PEL) of contaminant concentrations for each Gulf coast sampling area.

	Number of Observations Within the Probable Effects Range											
Substance	EVG	FTM	TPA	WCF	APL	APA	SJB	PCY	DES	PEN	PER	Total
Metals												
Arsenic	0	0	**9**	**1**	0	**1**	0	0	0	**1**	0	**12**
Cadmium	0	0	**2**	0	0	0	0	0	0	**1**	0	**3**
Chromium	0	**1**	**13**	**1**	0	0	0	0	0	**8**	**2**	**25**
Copper	0	0	**3**	**1**	0	0	0	**2**	0	**1**	0	**7**
Lead	0	0	**7**	0	0	0	0	0	0	**2**	0	**9**
Mercury	0	0	**6**	**1**	0	0	**1**	**1**	0	**4**	0	**13**
Nickel	0	0	**1**	0	0	0	0	0	0	0	0	**1**
Silver	0	0	0	0	**1**	0	0	0	**1**	0	0	**2**
Zinc	0	0	**4**	0	0	0	0	0	0	**4**	0	**8**
Number of Samples	96	67	141	30	56	30	22	39	20	79	17	597
Polycyclic Aromatic Hydrocarbons (PAHs)												
Acenaphthene	0	0	0	0	0	0	0	0	0	**1**	**1**	**2**
Acenaphthylene	0	0	0	0	0	0	0	0	0	0	0	**0**
Anthracene	0	0	0	0	0	0	0	0	0	**1**	0	**1**
Benz(a)anthracene	0	0	0	0	0	0	0	0	0	**5**	0	**5**
Benzo(a)pyrene	0	0	0	0	0	0	0	0	0	**2**	**1**	**3**
Chrysene	0	0	0	0	0	0	0	0	0	0	0	**0**
Dibenzo(a,h)anthracene	0	0	0	0	0	0	0	0	0	0	0	**0**
Fluoranthene	0	0	0	0	0	0	0	0	0	**3**	0	**3**
Fluorene	0	0	0	0	0	0	0	0	0	0	0	**0**
2-methylnaphthalene	0	0	0	0	0	0	0	0	0	0	0	**0**
Naphthalene	0	0	0	0	0	0	0	0	0	0	0	**0**
Phenanthrene	0	0	0	0	0	0	0	0	0	**2**	0	**2**
Pyrene	0	0	0	0	0	0	0	0	**1**	**7**	**2**	**10**
Number of Samples	3	12	11	0	0	0	0	0	3	29	9	67

Table 6. Number of samples that fall within the probable effects range (i.e., >= PEL) of contaminant concentrations for each Gulf coast sampling area (continued).

Substance	Number of Observations Within the Probable Effects Range											
	EVG	FTM	TPA	WCF	APL	APA	SJB	PCY	DES	PEN	PER	Total
Pesticides												
Aldrin	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Azinophosmethyl (Guthion)	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Chlordane	0	0	0	0	0	0	0	0	0	**1**	0	**1**
Chlorthalonil	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Chlorpyrifos	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
p,p'-DDD	0	0	0	0	0	0	0	0	0	0	0	**0**
p,p'-DDE	0	0	0	0	0	0	0	0	0	0	0	**0**
p,p'-DDT	0	0	0	0	0	0	0	0	0	0	0	**0**
Dieldrin	0	0	0	0	0	0	0	0	0	0	0	**0**
Disulfoton	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Endosulfan	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Heptachlor	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Heptachlor epoxide	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Lindane (gamma-BHC)	0	0	0	0	0	0	0	0	0	0	0	**0**
Phorate	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Quintozene (PCNB)	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Toxaphene (alpha-BHC)	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Trifluralin	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Number of Samples	3	8	24	0	0	0	5	3	3	29	7	82
Polychlorinated Biphenyls (PCBs)												
Total PCBs	0	0	0	0	0	0	0	0	0	0	0	**0**
Number of Samples	3	8	24	0	0	0	5	3	3	29	7	82

NG = no guideline; insufficient data to derive sediment quality assesment guidelines.
Place names indicate the general coastal vicinity of sampling station locations.
EVG = Everglades; FTM = Ft. Mayers; TPA = Tampa Bay; WCF = West Central Florida; APL = Apalachee Bay; APA = Apalachichola Bay; STJ = St. Josephs Bay;
PCY = Panama City; DES = Destin; PEN = Pensacola Bay; PER = Perido Bay.

Table 7. Number of samples that fall within the possible effects range (i.e., > TEL and < PEL) of contaminant concentrations for each Gulf coast sampling area.

Substance	Number of Observations Within the Possible Effects Range											
	EVG	FTM	TPA	WCF	APL	APA	SJB	PCY	DES	PEN	PER	Total
Metals												
Arsenic	**7**	**1**	**16**	**3**	**6**	**7**	**5**	**11**	**4**	**20**	**8**	**88**
Cadmium	0	**3**	**51**	**4**	**2**	0	**3**	**3**	**1**	**6**	**2**	**75**
Chromium	**1**	**1**	**35**	**8**	**2**	**5**	**7**	**10**	**4**	**20**	**2**	**95**
Copper	**1**	**3**	**33**	**10**	0	**5**	**5**	**4**	**3**	**16**	**3**	**83**
Lead	0	**2**	**26**	**1**	0	**4**	**3**	**5**	**3**	**9**	**2**	**55**
Mercury	**2**	**6**	**43**	**5**	**3**	0	**6**	**5**	**1**	**15**	**3**	**89**
Nickel	**1**	0	**20**	**2**	0	**6**	**5**	**7**	**2**	**4**	**2**	**49**
Silver	0	0	**14**	0	0	0	0	**6**	**1**	0	0	**21**
Zinc	0	**1**	**18**	**1**	0	0	0	**1**	**1**	**14**	**1**	**37**
Total Number of Samples	96	67	141	30	56	30	22	39	20	79	17	597
Polycyclic Aromatic Hydrocarbons (PAHs)												
Acenaphthene	0	0	0	0	0	0	0	0	0	0	0	**0**
Acenaphthylene	0	0	0	0	0	0	0	0	0	0	0	**0**
Anthracene	0	0	0	0	0	0	0	0	0	**4**	0	**4**
Benz(a)anthracene	0	0	0	0	0	0	0	0	0	0	0	**0**
Benzo(a)pyrene	0	0	0	0	0	0	0	0	0	**12**	**2**	**14**
Chrysene	0	0	0	0	0	0	0	0	0	**1**	**5**	**6**
Dibenzo(a,h)anthracene	0	0	0	0	0	0	0	0	0	0	0	**0**
Fluoranthene	0	0	0	0	0	0	0	0	0	**10**	**4**	**14**
Fluorene	0	0	0	0	0	0	0	0	0	0	0	**0**
2-methylnaphthalene	0	0	0	0	0	0	0	0	0	0	0	**0**
Naphthalene	0	0	0	0	0	0	0	0	0	**1**	**1**	**2**
Phenanthrene	0	0	0	0	0	0	0	0	0	**8**	**2**	**10**
Pyrene	0	0	0	0	0	0	0	0	0	**10**	**4**	**14**
Total Number of Samples	3	12	11	0	0	0	0	0	3	29	9	67

Table 7. Number of samples that fall within the possible effects range (i.e., > TEL and < PEL) of contaminant concentrations for each Gulf coast sampling area (continued).

Substance	Number of Observations Within the Possible Effects Range											
	EVG	FTM	TPA	WCF	APL	APA	SJB	PCY	DES	PEN	PER	Total
Pesticides												
Aldrin	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Azinophosmethyl (Guthion)	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Chlordane	0	0	0	0	0	0	0	0	0	0	0	**0**
Chlorthalonil	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Chlorpyrifos	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
p,p'-DDD	0	0	0	0	0	0	0	0	0	0	0	**0**
p,p'-DDE	0	0	0	0	0	0	0	0	0	0	0	**0**
p,p'-DDT	0	0	0	0	0	0	0	0	0	**2**	0	**2**
Dieldrin	0	0	0	0	0	0	0	0	0	0	0	**0**
Disulfoton	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Endosulfan	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Heptachlor	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Heptachlor epoxide	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Lindane (gamma-BHC)	0	0	0	0	0	0	0	0	0	0	0	**0**
Phorate	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Quintozene (PCNB)	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Toxaphene (alpha-BHC)	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Trifluralin	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Total Number of Samples	3	8	24	0	0	0	5	3	3	29	7	82
Polychlorinated Biphenyls (PCBs)												
Total PCBs	0	**2**	0	0	0	0	0	0	0	**6**	0	**8**
Total Number of Samples	3	8	24	0	0	0	5	3	3	29	7	82

NG = no guideline; insufficient data to derive sediment quality assessment guidelines.
Place names indicate the general coastal vicinity of sampling station locations.
EVG = Everglades; FTM = Ft. Mayers; TPA = Tampa Bay; WCF = West Central Florida; APL = Apalachee Bay; APA = Apalachichola Bay; STJ = St. Josephs Bay; PCY = Panama City; DES = Destin; PEN = Pensacola Bay; PER = Perido Bay.

City, Perdido Bay, and West Central Florida. Elevated levels of PAHs and PCBs were also observed in Pensacola Bay and Perdido Bay. Significantly more sampling effort is required to fully evaluate contamination of coastal sediments by organic substances in the Gulf of Mexico region of Florida. The total number of samples and the number of exceedances of the SQAGs for each area on the Gulf coast are presented in Tables 6 and 7.

4.5.2 Contaminants of Concern in Florida Coastal Waters

The contaminants of greatest concern in Florida coastal waters were identified by screening the data in the FDEP (1994) coastal sediment chemistry database with the SQAGs recommended by MacDonald (1994). For each substance, the percent of the total number of samples that had concentrations that fell within the probable (i.e., ≥ PEL) and possible (i.e., ≥ TEL and < PEL) effects ranges was calculated. Contaminants with concentrations that equalled or exceeded the PEL in many samples (i.e., 5%) were considered to be of greatest concern. The contaminants which had a high incidence (i.e., ≥ 10%) of concentrations within the possible effects range and one or more exceedance of the PEL were considered to be of somewhat lower priority (Table 8).

On the Atlantic coast, lead, mercury, acenaphthene, benz(a)anthracene, benzo(a)pyrene, chrysene, fluoranthene, phenanthrene, and pyrene were considered to be the highest priority contaminants. In general, the PAHs had the highest percent incidence of concentrations within the probable effects range. Arsenic, cadmium, chromium, copper, and anthracene were also considered to be contaminants of concern, albeit of lower priority than the substances listed above.

Elevated levels of toxic substances were somewhat less common on the Gulf coast of Florida than on the Atlantic coast. Only two substances had a high incidence of concentrations within the probable effects range, benz(a)anthracene and pyrene. The lower priority contaminants of concern included arsenic, cadmium, chromium, copper, mercury, chrysene, fluoranthene, phenanthrene, and total PCBs. It was not possible to evaluate the relative importance of the 17 preliminary contaminants of concern (see MacDonald 1994) for which SQAGs were not available.

4.6 Summary

The initial assessment of the potential for observing adverse biological effects has been conducted to identify areas and contaminants of concern in Florida coastal sediments. The results of this evaluation suggest that the areas in the vicinity of Miami, Jacksonville, Tampa, and Pensacola should be considered to be the highest priority for conducting further

Table 8. Percent of sediment quality samples with contaminant concentrations that exceed the sediment quality assessment guidelines.

Substance	Atlantic Coast		Gulf Coast	
	>= PEL (%)	>=TEL; <PEL (%)	>= PEL (%)	>=TEL; <PEL (%)
Metals				
Arsenic	0.8	17.6	2	14.7
Cadmium	0.5	15.2	0.5	12.6
Chromium	1	16.3	4.2	15.9
Copper	3.7	25.9	1.1	13.9
Lead	5.6	15.5	1.5	9.2
Mercury	9.6	26.1	2.2	14.9
Nickel	0.3	5.6	0.2	8.2
Silver	4.5	2.7	0.3	3.5
Zinc	2.4	7.5	1.3	6.2
Polycyclic Aromatic Hydrocarbons (PAHs)				
Acenaphthene	8	2.4	3	0
Acenaphthylene	1.6	0.8	0	0
Anthracene	3.2	10.4	1.5	6
Benz(a)anthracene	6.4	0	8.9	0
Benzo(a)pyrene	7.2	13.6	4.5	20.9
Chrysene	12	11.2	0	23.9
Dibenzo(a,h)anthracene	1.6	0	0	0
Fluoranthene	12	42.4	4.5	20.9
Fluorene	1.6	2.4	0	0
2-methylnaphthalene	0	0.8	0	0
Naphthalene	1.6	5.6	0	3
Phenanthrene	12.8	8	3	14.9
Pyrene	12	30.4	14.9	20.9

Table 8. Percent of sediment quality samples with contaminant concentrations that exceed the sediment quality assessment guidelines (continued).

Substance	Atlantic Coast		Gulf Coast	
	>= PEL (%)	>=TEL; <PEL (%)	>= PEL (%)	>=TEL; <PEL (%)
Pesticides				
Chlordane	2.9	0	1.3	0
p,p'-DDD	0.6	1.2	0	0
p,p'-DDE	0	1.8	0	0
p,p'-DDT	2.3	0	0	2.5
Total DDE	0	0	0	0
Lindane (gamma-BHC)				
Polychlorinated Biphenyls (PCBs)				
Total PCBs	4.1	8.2	0	10

PEL = Probable Effect Level; TEL = Threshold Effect Level investigations, including bioassessments. As surveys have recently been completed in Tampa Bay and Pensacola Bay, the highest priority areas for new studies are Biscayne Bay and the St. Johns River. Overall, benzo(a)pyrene and pyrene are considered to be the highest priority contaminants; however, lead, mercury, acenaphthene, benz(a)anthracene, chrysene, fluoranthene, and phenanthrene are important on the Atlantic coast. Interestingly, the levels of arsenic at several sites exceed the PELs, yet are not anthropogenically-enriched.

While this initial assessment of sediment quality provides an indication of the potential for biological effects of sediment-associated contaminants, these results should not be used, by themselves, to make management decisions regarding sediment quality. Several limitations of this assessment are identified to emphasize this point. The sediment chemistry database used in this assessment has broad coverage; however, the data on many analytes are limited. As such, several of the constituents that are likely to be found in Florida sediments were not measured in the FDEP surveys. Much of the data on levels of organic contaminants is relatively old (greater than 5 years old) and, therefore, of questionable value with respect to reflecting present conditions. In addition, the extent to which the available data accurately reflect the spatial variability in sediment quality conditions is largely unknown. For these reasons, comparable data collected by others such as the EPA Environmental Monitoring and Assessment Program (EMAP), Delfino *et al.* (1991), and by NOAA (NSTP) should be evaluated to provide a more comprehensive assessment of sediment quality.

For metals, the results of the assessment of the potential for biological effects must be considered in light of the evaluation of the probable origin of these substances. In general, there was a high degree of agreement between the evaluations conducted using the SQAGs and the metals interpretive tool. Significant anthropogenic-enrichment was observed in association with exceedance of the PELs for most chemicals and at most sites. Therefore, the results of the evaluation of areas of concern and contaminants of concern conducted using the PELs can be considered to be reliable. However, poor concordance between the two evaluations was observed for arsenic. Only two of the 15 sites with arsenic concentrations greater than the PEL were anthropogenically enriched. Therefore, arsenic should not be considered as a contaminant of high concern in Florida. In addition, high background levels of several metals in West Central Florida and nearby Panama City are indicated by the exceedances of PELs, but not the 95% prediction limits. Therefore, these areas should not be considered to be high priority areas of concern, based on metal concentrations alone.