Indian River Flood Shoal Dredging and Beneficial Use Project

Analysis of Chemical Contaminants in Sediments

Prepared by

Karen A. Taylor, Coastal Environmental Scientist IV
John G. Cargill, Hydrologist VI

Delaware Department of Natural Resources and Environmental Control
Shoreline and Waterway Management Section

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APPENDIX

1. Introduction

The Delaware Department of Natural Resources and Environmental Control (DNREC) Shoreline and Waterway Management Section (SWMS) is seeking emergency authorization to restore the beach and dune system at the northside Indian River Inlet beach (North Beach), Delaware Seashore State Park, Sussex County, Delaware, using dredged material to enhance resiliency and protect critical infrastructure from the effects of coastal erosion. Conditions at North Beach have been severely deteriorating overtime and adding sand via truck haul can no longer overcome the current rate of erosion. Presently, conditions are such that a minor storm surge or swell event is very likely to breach the dune and potentially flood Delaware State Route-1 (DSR-1), which is an evacuation route. North Beach needs to be rebuilt with a large volume of sand that is delivered rapidly.

The Project aims to hydraulically dredge up to 550,000 cubic yards (cy) of material from the Indian River Flood Shoal for placement onto North Beach. Restoration would occur from the north jetty and extend northward for approximately 5,200 linear feet. A similar project was performed in 2013 by the US Army Corps of Engineers following Hurricane Sandy.

Dredging and disposal activities raise several environmental concerns including risks from the disruption of sediment that can mobilize contaminants and impact the surrounding water quality. Dredged material intended for beneficial use also raises the concern of mobilizing contaminants to nearshore environments, and the potential toxic risk to aquatic life and human health.

As part of the permit application procedure, DNREC SWMS collected sediment samples from the proposed Indian River Flood Shoal for geotechnical analysis and bulk contaminant evaluation. Chemical testing and risk assessment methods, results, and conclusions are described below.

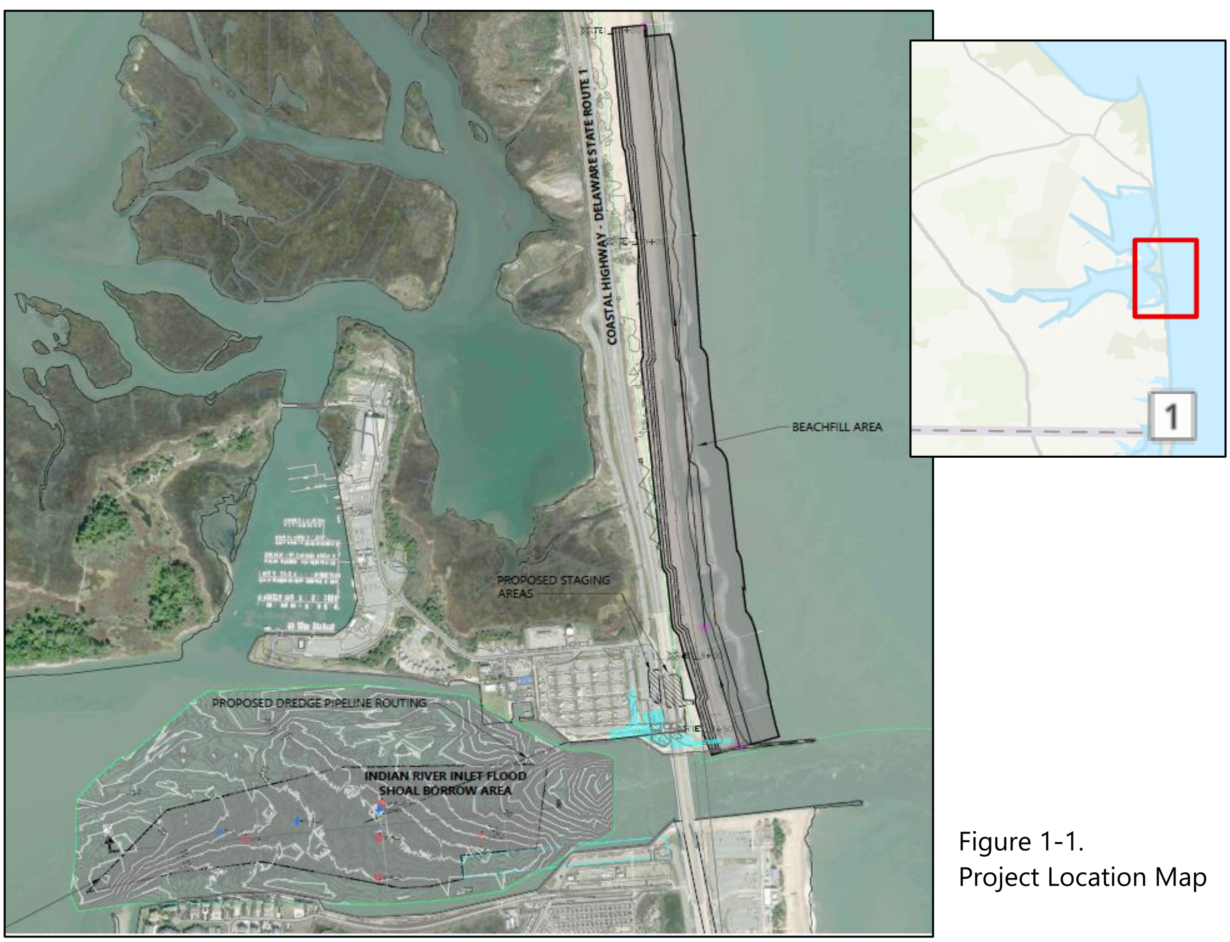

Figure 1-1.
Project Location Map

2. Methods

Chemical testing and analysis of Indian River Flood Shoal samples was performed to characterize toxic contaminant levels in sediments from the proposed dredging site, and subsequently determine if concentrations are acceptable for aquatic organisms and human exposure based on risk standards developed by the United States Environmental Protection Agency (US EPA) and the State of Delaware.

2.1. Field Methods

To evaluate contaminants in sediments from the proposed dredge site, Anchor QEA, Inc., Aqua Survey Inc., and Athena Technologies, Inc. (Athena) were contracted by DNREC SWMS to collect and process sediment core and grab samples within the Indian River Flood Shoal. Figure 2-1 shows a map of the sampling sites within the proposed dredge boundary.

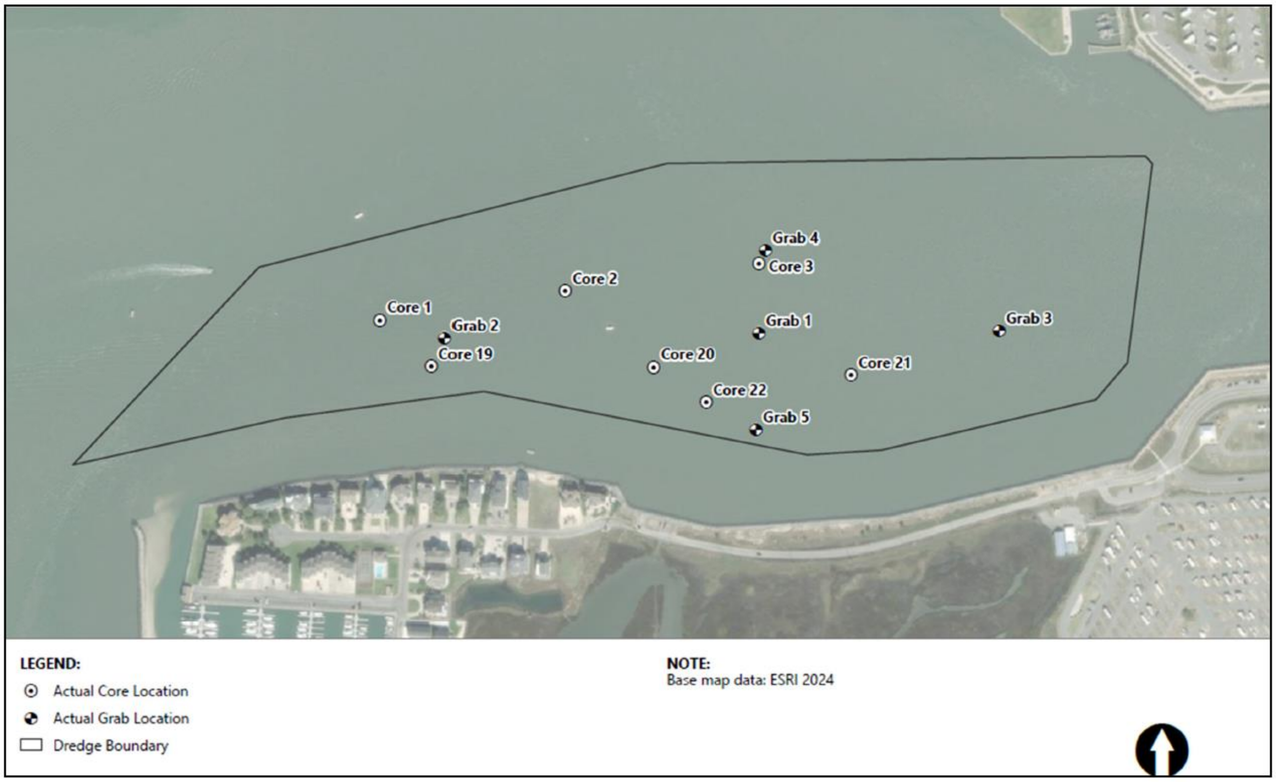

Figure 2-1. Sediment sampling locations

Core locations were selected to characterize the material throughout the flood shoal with a targeted elevation of -24 feet NAVD88. Six (6) sediment cores were collected on October 3-4, 2024, by Athena using a 35-foot research vessel, *Artemis*, as a vibracore sampling platform. The vibracore system consisted of a generator with a mechanical vibrator attached via cable to a 3-inch diameter, stainless-steel sample barrel. A core liner was not used to promote greater recovery of the high-sand content material. Standard sampling protocols were utilized to minimize any potential for cross-contamination. Once samples were collected, field descriptions and photographs were recorded. Entire sediment cores (less the bottom 2-inches) were homogenized into two (2) composite samples: IRI-1-Top and IRI-3-Top. Similarly, the bottom 2-inches from each core were homogenized into two composite samples: IRI-2-Bottom and IRI-4-Bottom. See Table 2-1 for details on the compositing scheme. For grain size analysis, the top portion of Cores 1, 2,19, and 22 were retained and homogenized individually.

Five (5) surface grab samples were also collected on September 12, 2024, using a Ponar grab sampler. Surface sediments were combined into one composite sample (IRI-5) as described in Table 2-2. All samples were stored cold, in laboratory-provided bottles prior to analysis.

Table 2-1. Indian River Flood Shoal Sediment Core Samples

Core Sample ID	Northing DE State Plane NAD83 (US feet)	Easting DE State Plane NAD83 (US feet)	Composite Sample ID
Core_1	221310.53	753622.13	IRI-1-Top IRI-2-Bottom
Core_2	2221403.00	754199.03	
Core_19	221166.77	753782.24	
Core_3	221488.12	754804.28	IRI-3-Top IRI-4-Bottom
Core_20	221164.10	754475.88	
Core_21	221137.95	755093.17	
Core_22[1]	221052.99	754639.37	N/A

1. *Core_22 added in the field for additional grain size information.*

Table 2-2. Indian River Flood Shoal Surface Sediment Grab Samples

Sample ID	Northing DE State Plane NAD83 (US ft)	Easting DE State Plane NAD83 (US ft)	Composite Sample ID
Grab_1	221270.95	754804.84	IRI-5
Grab_2	221256.66	753824.39	
Grab_3	221277.54	755555.90	
Grab_4	221527.54	754825.19	
Grab_5	220969.21	754795.83	

2.2. Laboratory Testing

Five (5) composite samples from the Indian River Flood Shoal were analyzed for inorganics (metals), polychlorinated biphenyl (PCB) homologs, polycyclic aromatic hydrocarbons (PAHs), pesticides, dioxins/furans, grain size, and total organic carbon. Table 2-3 lists the standard test methods used for bulk chemical analysis by Eurofins Lancaster Laboratories Environment Testing, LLC in Lancaster, Pennsylvania. Results were provided on a dry weight basis, and method detection limits were less than or equal to DNREC guidelines.

Table 2-3. Laboratory methods for bulk chemical analysis of sediments

Chemical Analysis	Test Method
Target Analyte List (TAL) Metals	USEPA 6020B

Mercury (Hg)	USEPA 7471B
Polycyclic Aromatic Hydrocarbons (PAHs)	USEPA 8270E SIM
Polychlorinated Biphenyls (PCB)	USEPA 680
Organochloride (OC) Pesticides	USEPA 8081A
Dioxins/Furans	USEPA 1613B
Total Organic Carbon (TOC)	Lloyd Kahn
Grain Size Analysis	ASTM D422

2.3. Risk-Based Assessment Methods

Laboratory results were used to assess toxic risk to aquatic life and human health associated with dredging the Indian River Flood Shoal and beneficially placing all material onto North Beach.

Contaminant levels detected in sediments were used to estimate dissolved concentrations in the sediment interstitial (pore) and overlying surface water to assess toxic risk to benthic aquatic life. Equilibrium partitioning calculations were conducted and resulting porewater concentrations were then compared to established water quality criteria to predict toxic effects to benthic organisms. There are several methods for evaluating risk, depending upon the contaminant, that are described in more detail below (Section 3.2).

Calculated porewater concentrations were also used, when applicable, to evaluate potential bioaccumulation risk for the protection of human health from adverse effects through consumption of fish that have been exposed to contaminants in surface water. Risk to human health was also evaluated for toxicity due to incidental (direct) exposure to a contaminant. The Hazardous Substance Cleanup Act (HSCA) Screening Level Table for soil (DNREC, 2013) was used to identify potential contaminants of concern for additional assessment with "acceptable risk" defined as the probability of one additional lifetime incidence of cancer in 100,000 ($1x10^{-5}$) or less for carcinogens, and a hazard index (HI) of one (1) or less for non-carcinogens, as applicable.

Summarization of the methodologies and results of the Indian River Flood Shoal sediment toxicity evaluations are described in Section 3.

3. Results and Discussion

Laboratory results of sediment samples collected and analyzed during this assessment were compared to the appropriate guideline concentrations to determine the potential aquatic life and/or human health impacts of dredging and beneficially using dredged material to rebuild the dune/beach system at North Beach. DNREC Surface Water Quality Standards (DNREC, 2011) and DNREC-HSCA Screening Level Values for soil (DNREC, 2013) were used for data and modeled concentration estimate comparisons.

3.1. Sediment Grain Size Distribution and Total Organic Carbon

The grain size distribution results of the Indian River Flood Shoal sediments are shown in Table 3-1. On average, the flood shoal consists of 96.3% sand. While Core_19 has a lower overall % sand content compared to other cores, the core log indicated a silt/clay layer in the bottom of the core. Since the complete core was homogenized to represent the Core_19 sample, the results from that individual core are slightly skewed. A composite sample for Cores 1, 2 and 19 was also collected, but that did not include the silty material at the bottom of the core (which will be avoided). The composite sample contains over 99% sand and is a more realistic representation of the material that will be dredged and placed onto North Beach. Laboratory results of the complete sieve-hydrometer analysis are included in Appendix A.

Table 3-1. Laboratory methods for bulk chemical analysis of sediments

Core Sample ID	Core_1	Core_2	Core_19	Core_22	Composite Cores_1,2,19	Composite Cores_3,20,21
Gravel	3.2	0.4	0.2	0.7	0.7	0.6
Sand	96.8	99.6	83.1	99.3	99.3	99.4
Silt	0.0	0.0	16.7	0.0	0.0	0.0

The total organic carbon (TOC) content among the four composite sediment cores averaged 0.075% and ranged from < 0.012% to 0.13%. Given the amount and distribution of TOC between top and bottom composite samples, combined with mixing that will occur during dredging activities, the average TOC value was applied throughout this evaluation.

3.2. Laboratory Results for Contaminants in Sediments

Results of the bulk chemical analyses of composite sediments and risk assessment methods are summarized and discussed below. All field and laboratory data are included in Appendix A. Additional information regarding the methods used for calculating risk assessment and results are included in Appendix B.

3.2.1. Inorganic (Metals) Assessment

Despite the presence of metals in sediments, toxicity to aquatic life due to metals is not expected from dredging activities and beneficial placement of material onto North Beach. To evaluate the toxicity of metals to benthic organisms, bulk concentrations measured in composite sediments (mg/kg dry wt) were converted to dissolved porewater concentrations (ug/L) by dividing laboratory results by the appropriate sediment-to-porewater partition coefficient published by the US EPA (2005a). Resulting concentrations were further partitioned into dissolved organic carbon (DOC)-bound and freely dissolved metals in porewater (ug/L) by performing calculations using an estimated porewater DOC concentration and the appropriate mean partition coefficient published by the US EPA (2005a). Porewater DOC was assumed to be five (5) times greater than water column DOC, which is expected to average 3.5 mg/L (Thurman 1985; Caron and Suffet 1989). Non-detected results were assigned a value of one-half (1/2) the method detection limit (MDL).

The resulting metal concentrations in porewater were compared to the applicable water quality criterion for the protection of aquatic life (DNREC 2023b). The ratio of the estimated metal concentration in porewater to the applicable water quality criterion was expressed as toxic units ($T.U._a$, $T.U._c$), where ratios greater than one (1) suggest exposure concentrations exceed the toxic criterion. Lastly, to evaluate the acute and chronic additive effects of specific divalent metals on benthic organisms, Interstitial Water Benchmark Units (IWBU) were calculated by summing the individual toxic unit values for cadmium, copper, lead, nickel, silver, and zinc for each sample as fully described by the US EPA (2005b). IWBU values greater than one (1) indicate a greater potential for toxic risk to benthic organisms. Sediments with IWBU values less than one (1) are not likely to be toxic to benthic aquatic life due to the presence of divalent metals.

The average acute (IWBU = 0.07) and chronic (IWBU = 0.04) IWBU values determined for composite samples are far less than one (1) and suggest no risk to aquatic life due to metal toxicity.

Several metals detected in composite sediments were not included in the IWBU calculation; therefore, separate comparisons were made for dissolved arsenic, antimony, barium, beryllium, and chromium in the porewater. While porewater concentrations were predicted for antimony, barium, and beryllium for each sample, no aquatic life criteria exist for these metals and thus no conclusions can be drawn about potential toxicity. Arsenic and chromium concentrations do not appear to have an associated risk to aquatic life. Selenium, thallium, and mercury were not detected in composite samples.

Lastly, metals concentrations in composite samples were compared to DNREC Hazardous Substance Cleanup Act (HSCA) Screening Level values (DNREC, 2023b) to ensure that concentrations would not pose unacceptable risk once sediment is dredged and deposited onto the beach. Metals detected in Indian River Flood Shoal sediments did not exceed the HSCA screening levels, and therefore are not likely to pose risk to human health.

Additional information regarding the calculations applied for risk assessment and results are included in Appendix B.

3.2.2. Polycyclic Aromatic Hydrocarbon (PAH) Assessment

Polycyclic aromatic hydrocarbons (PAHs) were detected in composite sediment samples from the Indian River Flood Shoal with total concentrations ranging from 6.6-173 ug/kg dry wt (or parts per billion, ppb). The method used to evaluate toxicity of PAHs was to compare carbon normalized concentrations to literature derived equilibrium partitioning (EqP) based mechanistic sediment quality guidelines called Equilibrium Partitioning Sediment Benchmarks (ESBs) (Burgess et. al. 2013). Results are expressed as a ratio of the organic carbon normalized concentration to the ESB. Individual ratios are summed for each sample and expressed as toxic units. Toxicity units greater than 1 indicate an increased likelihood of risk to ecological receptors. Results indicate that toxic unit values are far less than one (average = 0.083), and thus toxicity to aquatic life due to PAHs in Indian River Flood Shoal sediments is not expected.

Lastly, to evaluate the potential risk to human health if sediment were dredged and deposited onto North Beach, concentrations of PAHs in composite samples were compared to the DNREC HSCA Soil Screening Level values (DNREC, 2023b). PAHs detected in Indian River Flood Shoal sediments did not exceed the HSCA screening levels, and therefore are not expected to pose risk to human health.

Additional information regarding the calculations applied for risk assessment and results are included in Appendix B.

3.2.3. Dioxins and Furans Assessment

Dioxins and Furans were detected in all composite core samples from the Indian River Flood Shoal at concentrations exceeding method detection limits. Of the dioxin and furan compounds present, OCDD (1,2,3,4,6,7,8,9-octachlorodibenzodioxin) dominates on a weight percentage basis, contributing between 90-100% of the dioxin and furan mass. The second most abundant compound present was 1,2,3,4,6,7,8-HpCDD (1,2,3,4,6,7,8-heptachlorodibenzodioxin), contributing 8-9% of the dioxin and furan mass. Air deposition is the likely source of dioxins and furans in composite samples, although overall emissions appear to be declining over time in the United States (US EPA, 2006).

To assess potential toxicity to benthic aquatic life in composite samples, dioxin-like (2,3,7,8-TCDD) Toxicity Equivalency Quotients (TEQs) were calculated by multiplying the concentration of each dioxin and furan compound detected by its associated toxicity equivalence factor, or TEF, and the then summing the products for each sample (Van den Berg, et.al., 2006, US EPA, 2010). The resulting TEQ is compared to a screening value to assess potential toxicity and determine if further evaluation is needed. Calculated TEQ concentrations in composite core samples ranged from 0.004 – 0.108 ng/kg and are far below the marine/estuarine sediment screening value for 2,3,7,8-TCDD (0.5 ng/kg); therefore no impact to benthic aquatic life is expected (US EPA, 2018).

While OCDD is the most abundant dioxin and furan compound in composite samples, OCDD is the least toxic among the class. Consequently, the contribution of OCDD to dioxin-like TEQ concentrations is much less than its mass contribution to the total dioxins and furans. This was determined by calculating the fractional contribution of each compound relative to the total TEQ in each sample. For example, the contribution of OCDD in sample 241004-IRI-1-TOP was 90% based on mass, while OCDD accounts for only 23% of the same sample based on the TEQ.

The potential for dioxin and furans in the sediments to bioaccumulate in the aquatic food chain and contribute to human health impacts related to fish consumption near Indian River Inlet was evaluated. Organic carbon normalized dioxin/furan concentrations in sediments were compared to a bioaccumulation-based sediment quality criterion (BBSQC) that was back-calculated from an acceptable fish tissue concentration (Greene, 1997). Results are expressed as a ratio of the measured concentration to the established criterion with ratios greater than 1 indicating an increased likelihood of bioaccumulation in fish along with an increased risk to consumers of those fish. The ratios determined for Indian River Flood Shoal sediments are far less than 1, suggesting no bioaccumulation risk due to dioxins/furans.

Another method to evaluate potential human health impacts was to compare the estimated sediment porewater concentrations to criteria published in the State of Delaware Surface Water Quality Standards (DNREC, 2023b) associated with eating fish. Results are expressed as a ratio, with values greater than 1 indicating the increased likelihood of human health impacts from eating fish near Indian River Inlet. Results showed that for two of the composite samples, predicted porewater concentrations exceed the surface water quality criterion of 5.1 E^{-9} μg/L (ppb) for 2,3,7,8- TCDD (as TEQs). Toxic units ranged from 12.3 to 14.9. It should be noted that this method is a very conservative screening technique and assumes that concentrations of contaminants in the sediment porewater are in equilibrium with the surface water. This is not always the case, especially within a turbulent area like Indian River Inlet, and therefore does not account for the potential for dilution from overlying surface water. In support of this idea, there are no fish consumption advisories established in Indian River Bay for dioxins/furans; as such, it is concluded that dioxins and furans measured in the sediments are not likely to impact human health through consumption of fish.

Finally, laboratory analytical results were used to evaluate whether the sediment contains dioxin/furans at concentrations that would pose an unacceptable risk to human health. Comparison of laboratory results to the DNREC HSCA Screening Level values for soil confirm that dioxins/furans do not pose a risk to human health if sediments were dredged from the Indian River Flood Shoal for beneficial placement at North Beach (DNREC, 2023b). Additional information regarding the calculations applied for risk assessment and results are included the Appendix B.

3.2.4. Polychlorinated Biphenyl (PCB) Assessment

PCBs were not detected in composite sediment samples from the Indian River Flood Shoal at concentrations above analytical method detection limits. Therefore, there is no predicted aquatic life or human health impacts from PCBs at this site.

3.2.5. Pesticides

Pesticides were not detected in composite sediment samples from the Indian River Flood Shoal at concentrations above analytical method detection limits. Therefore, there is no predicted aquatic life or human health impacts from pesticides at this site.

4. Summary

Sediments from Indian River Flood Shoal were evaluated for the presence of contaminants and associated potential toxicity to benthic aquatic life and human health using risk-based assessment methods and appropriate guideline concentrations. While laboratory results detected a few contaminants in composite samples, none were found at concentrations that would impact aquatic life or human health if sediments were dredged and beneficially placed on North Beach.

Overall, the potential dredge material at the Indian River Flood Shoal is mostly sand (avg. 96%). Metals were detected in composite sediment samples, but acute and chronic toxicity to aquatic life due to individual metals or from the additive effect of divalent metals is not likely based on this evaluation. In addition, no human health risks due to metals, including mercury, are expected based upon the evaluation.

Despite the presence of PAHs detected in composite sediments from the Indian River Flood Shoal, little to no risk of adverse effects to benthic aquatic life is expected. In addition, human health impacts due incidental exposure to PAHs in sediments is not expected.

Dioxin/furan concentrations detected in composite samples are not expected to cause adverse impacts to aquatic life or human health. OCDD dominates 90-100% of the total mass and is the least toxic. Finally, there is also minimal risk for bioaccumulation and no fish consumption advisories exist in the Indian River Bay for dioxins/furans.

PCBs and pesticides were not detected in composite sediments from the Indian River Flood Shoal; therefore the potential for toxic risk to benthic aquatic life is unlikely.

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