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U.S. Environmental Protection Agency, National Oceanic and Atmospheric Administration, New Jersey Department of Environmental Protection, New York State Department of Environmental Conservation, New York City Department of Environmental Protection, Suffolk County Department of Health Services, and Town of Hempstead

Estuarine Bed-Sediment-Quality Data Collected in New Jersey and New York after Hurricane Sandy, 2013

Data Series 905

U.S. Department of the Interior
U.S. Geological Survey

Cover. Photographs showing U.S. Geological Survey personnel collecting sediment samples off the coast of New Jersey and New York. Photographs by Irene Fisher (left) and Vicki Blazer (right), U.S. Geological Survey. Background: Natural-color image of Hurricane Sandy Geostationary Operational Environmental Satellite 13 captured at 1:45 p.m. Eastern Daylight Time on October 28, 2012. (Courtesy of National Aeronautics and Space Administration)

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U.S. Department of the Interior
SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

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Figures

Tables

Data tables referenced in this report are available in Microsoft® Excel format (.xlsx) and may be downloaded from *http://dx.doi.org/10.3133/ds905*. Selected tables are also available for download in PDF.

Conversion Factors

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square kilometer (km^2)	247.1	acre
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
cubic meter (m^3)	6.290	barrel (petroleum, 1 barrel = 42 gal)
liter (L)	33.82	ounce, fluid (fl. oz)
liter (L)	2.113	pint (pt)
liter (L)	1.057	quart (qt)
liter (L)	0.2642	gallon (gal)
cubic meter (m^3)	264.2	gallon (gal)
cubic decimeter (dm^3)	0.2642	gallon (gal)
cubic meter (m^3)	0.0002642	million gallons (Mgal)
cubic centimeter (cm^3)	0.06102	cubic inch (in^3)
cubic decimeter (dm^3)	61.02	cubic inch (in^3)
liter (L)	61.02	cubic inch (in^3)
cubic decimeter (dm^3)	0.03531	cubic foot (ft^3)
cubic meter (m^3)	35.31	cubic foot (ft^3)
	Flow rate	
cubic meter per second (m^3/s)	70.07	acre-foot per day (acre-ft/d)
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
cubic meter per second (m^3/s)	22.83	million gallons per day (Mgal/d)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)
	Pressure	
kilopascal (kPa)	0.009869	atmosphere, standard (atm)
megapascal (mPa)	9.869233	atmosphere, standard (atm)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$°F=(1.8\times°C)+32$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

Concentrations of chemical constituents in water are given in either milligrams per liter (mg/L) or micrograms per liter (µg/L).

Concentrations of chemical constituents in sediment are given in either milligrams per kilogram (mg/kg) or micrograms per kilogram (µg/kg).

Abbreviations

µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µg	micrograms
µL	microliters
µ	microns
1SD	one standard deviation
AR	androgen receptor
ASE	accelerated solvent extraction
ATR–FTIR	attenuated total reflectance–Fourier transform infrared spectroscopy
BLYES	bioluminescent yeast estrogen screen
BLYR	bioluminescent yeast reporter
BSF	bulk storage facility
CBS	chemical bulk storage
CSO	combined sewer outfall
DI	deionized
EC_{50}	effective concentration that produces a response in biota halfway between a baseline and the maximum effect
EPA	U.S. Environmental Protection Agency
ER	estrogen receptor
FEMA	Federal Emergency Management Agency
FTIR	Fourier transform infrared spectroscopy
G	gravitational force
g	grams
GR	glucocorticoid receptor
HLB	hydrophilic lipophilic balance
HUC	hydrologic unit code
km	kilometers
kPa	kilopascals

LOD	limit of detection
LRB	laboratory reagent blank
LRS	laboratory reagent spike
mg	milligrams
mg/kg	milligrams per kilogram
mL	milliliters
mm	millimeters
MOSF	major oil storage facility
MOTF	modeling task force
mPa	megapascals
MRL	minimum reporting level
NAICS	North American Industry Classification System codes
NCCA	National Coastal Conditions Assessment
ng/L	nanograms per liter
ng	nanograms
NIST	National Institute of Standards and Technology
NJDEP	New Jersey Department of Environmental Protection
NLCD	National Land Cover Dataset
nM	nanomolar
nm	nanometers
NOAA	National Oceanic and Atmospheric Administration
NR	nuclear receptor
NS&T	National Status and Trends
NWIS	National Water Information System
NWQL	National Water Quality Laboratory
NYC	New York City
NY/NJ	New York/New Jersey
NYS RISE	New York State Resiliency Institute for Storms and Emergencies
NYSDEC	New York State Department of Environmental Conservation

OCP	organochlorine pesticide
OD	optical density. Subscript refers to wavelength of measurement.
OGRL	U.S. Geological Survey Organic Geochemistry Research Laboratory
PAH	polycyclic aromatic hydrocarbon
PBS	petroleum bulk storage
PCB	polychlorinated biphenyl
pM	picomolar
PP2A	protein phosphatase 2A
ppm	parts per million
pXRF	portable hand-held X-ray fluorescence
QAPP	quality assurance performance plan
QA/QC	quality assurance / quality control
REMAP	Regional Environmental Monitoring and Assessment Program
RL	reporting limit
RPD	relative percent difference
RSD	relative standard deviation
SPE	solid-phase extraction
SRM	standard reference material
SSO	storm-sewer outfall
STORET	storage and retrieval data warehouse
STP	sewage-treatment plant
USACE ERDC	U.S. Army Corp of Engineers Engineer Research and Development Center
USDA NRCS	U.S. Department of Agriculture National Resources Conservation Service
USGS	U.S. Geological Survey
v/v	volume to volume
WBD	watershed boundary dataset
WQDP	Water-Quality Data Portal
XRD	X-ray diffraction
XRF	X-ray fluorescence

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Abstract

This report describes a reconnaissance study of estuarine bed-sediment quality conducted June–October 2013 in New Jersey and New York after Hurricane Sandy in October 2012 to assess the extent of contamination and the potential long-term human and ecological impacts of the storm. The study, funded through the Disaster Relief Appropriations Act of 2013 (PL 113-2), was conducted by the U.S. Geological Survey in cooperation with the U.S. Environmental Protection Agency and the National Oceanographic and Atmospheric Administration. In addition to presenting the bed-sediment-quality data, the report describes the study design, documents the methods of sample collection and analysis, and discusses the steps taken to assure the quality of the data.

Bed-sediment samples were collected from June to October 2013 from 167 estuarine sites extending from Cape May, New Jersey, to the New York Harbor and the eastern end of Long Island. Each sampling location and study region was characterized by using geographic information to identify potential contaminant sources. Characterizations included land cover, locations and types of businesses (industrial, financial, and others), spills (sewage, chemical, and others), bulk storage facilities, effluent discharges within 2 kilometers of the sampling point, and discharges within inundated and non-inundated regions near the sampling location. Samples were analyzed for particle size, total organic carbon, metals and trace elements, semivolatile organic compounds, wastewater compounds, hormones, and sediment toxicity. Samples were also screened using x-ray fluorescence, Fourier transform infrared spectroscopy, and x-ray diffraction. In addition, bioassays for endocrine disruptors and protein phosphatase 2A inhibition were conducted. The study was designed to provide the data needed to understand the extent and sources of contamination resulting from Hurricane Sandy, to compare the chemistry and toxicity of estuarine bed sediments before and after the storm, and to evaluate the usefulness of rapid screening and bioassay approaches in disaster settings.

Introduction

Low-elevation coastal areas throughout New Jersey and New York were inundated by tidal surge when Hurricane Sandy struck the northeastern United States in late October 2012. Remote imagery and inundation mapping indicate that most, if not all, bays and estuaries along the New Jersey shore, New York/New Jersey (NY/NJ) Harbor, and the southern shore of Long Island were impacted by tidal surge and (or) river flood waters (fig. 1). Many elements of the built and natural environment, including residential structures, industrial manufacturing and storage facilities, wastewater-treatment facilities, and known contaminated sediment sites, were compromised. Storm-related damage to buildings and infrastructure had the potential to release a variety of contaminants that could subsequently be transported to local rivers and bays.

As flood waters flowed and receded, contaminants from compromised facilities and disturbed sediments were mobilized. Weeks after the storm, billions of gallons of untreated or partially treated wastewater continued to be released from wastewater-treatment facilities that failed as a result of disruptions in electrical service and flooding of treatment works. Treatment plants, pumping stations, and pipelines that were overwhelmed by the storm surge released billions of gallons of raw and partially treated sewage into the rivers, bays, and estuaries of New Jersey and New York. According to Kenward and others (2013), approximately 93 percent of the sewage overflows along the East Coast resulting from Hurricane Sandy occurred in New York (47 percent) and New Jersey (46 percent). Public-health agencies responded to address acute effects (such as damaged homes and spills) of Hurricane Sandy, but the potential long-term human and ecological effects caused by the introduction of contaminants from compromised infrastructure, weathering debris, and redistribution of previously contaminated sediments are unknown.

Immediately following Hurricane Sandy, the U.S. Geological Survey (USGS) developed a science plan (Buxton and others, 2013) to coordinate USGS activities with those of

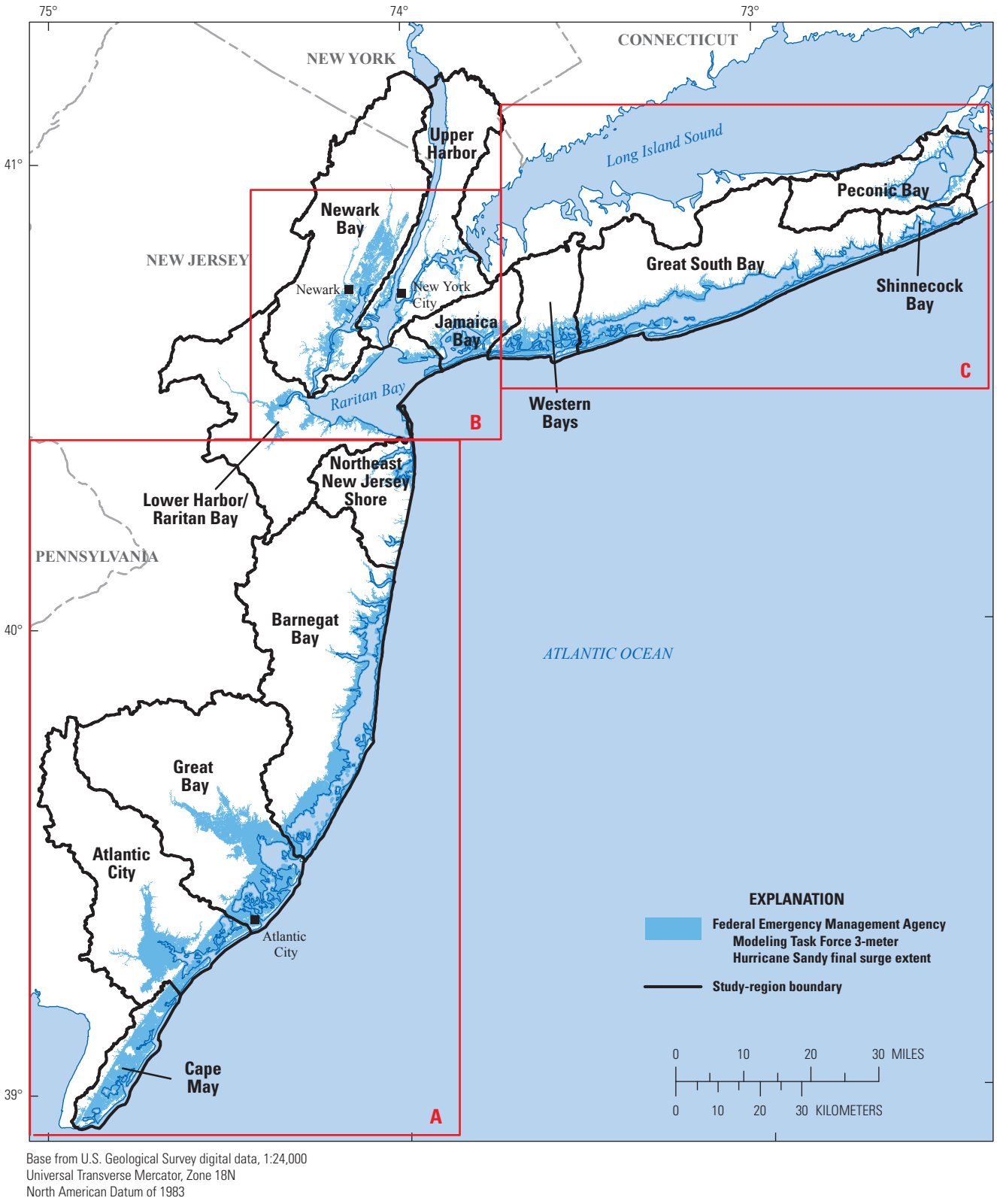


Figure 1. Extent of study area, areas inundated by Hurricane Sandy, study regions, and locations of maps for sampling locations in the southern New Jersey coast (A), the Lower Harbor/Raritan Bay (B), and Long Island, New York (C).

other Federal agencies and to guide continued data collection and analysis to ensure support for recovery and restoration efforts. Activities outlined in the plan were organized into five themes based on impact types and information needs. These themes are (1) coastal topography and bathymetry; (2) impacts to coastal beaches and barriers; (3) impacts of storm surge and estuarine and bay hydrology; (4) impacts on environmental quality and persisting contaminant exposures; and (5) impacts to coastal ecosystems, habitats, and fish and wildlife.

The data described in this report were compiled to address selected objectives of theme 4. In particular, regional reconnaissance sampling of estuarine bed sediments was conducted to assess potential long-term human and ecological impacts of contaminant mobilization caused by Hurricane Sandy. This study was funded through the Disaster Relief Appropriations Act of 2013 (PL 113-2).

Study Objectives and Purpose and Scope of Report

The objective of the regional reconnaissance sampling of bed sediments was to assess the extent of sediment contamination in the estuary resulting from Hurricane Sandy and its associated human and ecological impacts. The data presented in this report will be used in interpretive studies conducted to define the extent and sources of contamination, and to compare the chemistry and toxicity of estuarine bed sediments before and after the storm. The specific objectives of this theme 4 reconnaissance study were to—

1. determine changes in concentrations of selected organic compounds, trace elements, and metals in bed sediments collected before and after Hurricane Sandy;

2. determine chronic (28-day) sediment toxicity to invertebrates exposed to sediments collected after Hurricane Sandy;

3. quantify concentrations of wastewater indicator compounds and selected steroid hormones in sediments collected after Hurricane Sandy to determine the extent of raw-sewage contamination; and

4. evaluate screening approaches for determining inorganic compound concentrations, the presence of organic functional groups, and the potential for sediment to inhibit biological activity.

This report describes the study design, documents the methods of sediment collection and analysis, presents the quality-assurance data and analyses, and provides the chemical and toxicological data for the reconnaissance study of the impacts of Hurricane Sandy on human and ecological exposure to sediment-bound contaminants.

Study Area

The study area (fig. 1) consists of bays and near-shore areas adjacent to lands in New Jersey and New York that were inundated by Hurricane Sandy. Centered on the harbor and bay area between New Jersey and New York, it extends about 150 miles (mi) (241 kilometers [km]) south from New York City (NYC) along the New Jersey shore to Cape May, and about 100 mi (161 km) east of NYC along the southern shore of Long Island to Peconic Bay. The study area was divided into 13 study regions (fig. 1) on the basis of hydrologic divides and similar patterns of land use and contaminant exposure to facilitate data comparison and interpretation in order to evaluate differential impacts associated with Hurricane Sandy.

Previous Studies

Information about previous sediment contamination in the NY/NJ coastal area was reviewed and compiled to examine the sediment contamination effects of Hurricane Sandy in historical context. Federal, State, local, and institutional sources of data were consulted, an extensive literature search was conducted, and data were retrieved. These data together with previously published interpretations can be used to evaluate changes in contaminant levels over time and may also provide a basis for evaluating the presence of contaminants that have not been measured in sediment until recently (for example, steroid hormones or pharmaceuticals).

The most temporally and spatially extensive and readily available regional estuarine sediment monitoring in the study area is conducted by the U.S. Environmental Protection Agency (EPA) Regional Environmental Monitoring and Assessment Program (REMAP; *http://www.epa.gov/emap2/remap/*) and National Coastal Conditions Assessment (NCCA; *http://water.epa.gov/type/oceb/assessmonitor/ncca.cfm*). The National Oceanic and Atmospheric Administration (NOAA) Mussel Watch Program (*http://ccma.nos.noaa.gov/about/coast/nsandt/musselwatch.aspx*) also conducts studies in the area. Sediment monitoring conducted as part of these programs focuses primarily on metals and chlorinated organic contaminants. These programs have been assessing the occurrence of sediment-borne contaminants since the 1990s. Data are readily available at the indicated Web sites, and periodic reports describe the extent of contamination and trends over time (for example, see Adams and others, 2003).

A few interstate, State, local, and institutional programs also have collected sediment-quality data related to a wide range of chemical contamination in the urbanized/industrialized bays and harbors of the study area. For example, the Contaminant Assessment and Reduction Project (CARP; *http://www.carpweb.org/main.html*), a consortium of industries and regulatory agencies, studied metals and organic contaminants

entering the NY/NJ Harbor and Raritan Bay. Other, localized studies of particular bays (for example, Bonnevie and others, 1994; Bopp and others, 1993), some of which focused on a limited number of contaminants, also have been conducted.

Literature Search

Peer-reviewed scientific articles containing chemical and biological data collected prior to Hurricane Sandy (October 2012) were identified by using the Google Scholar Internet search engine. Each search included three classes of search terms: (1) location, (2) medium, and (3) class of contaminant (table 1). Locations included many of the major bays along the Atlantic Shore in New Jersey and New York. The medium was sediment. Contaminants of concern included several classes of organic compounds, inorganic compounds, trace elements, metals, and several emerging contaminants.

Each search used a unique set of search terms to identify references. The search date and number of references retrieved were recorded. The results of each retrieval were reviewed and articles pertinent to this study were downloaded for inclusion in the literature database. The number, location, and types of articles retrieved are shown in table 2.

Data Retrieval

In an effort to better understand the effects of Hurricane Sandy on contaminants in bed sediments, sediment-quality data from throughout the area were retrieved. These data are stored in a Microsoft® Access database. The data that were retrieved were quality assured and will be used to evaluate changes in contaminant concentrations by comparing them to results of reconnaissance sampling conducted after the storm.

Sediment contaminant data were retrieved from many sources, including EPA's REMAP and NCCA programs, and the NOAA Mussel Watch Program. In addition, the National Water Quality Monitoring Council Water-Quality Data Portal (WQDP) at *http://www.waterqualitydata.us/portal.jsp* was used in conjunction with the EPA Storage and Retrieval (STORET) Data Warehouse at *http://www.epa.gov/storet/dbtop.html* and the NOAA Center for Coastal Monitoring and Assessment National Status and Trends (NS&T) Data Portal at *http://ccma.nos.noaa.gov/about/coast/nsandt/download.aspx* to determine the number and type of bed-sediment-quality samples collected prior to the post-Hurricane Sandy sampling effort in the NY/NJ Harbor and surrounding bay areas. The WQDP can be queried for USGS National Water Information System (NWIS) and STORET (post-1999) data. Additional historical data (excluding USGS data) can be obtained through the STORET Legacy Data Center, which contains data provided to the EPA prior to 1999. The NS&T Data Portal provides access to NOAA data from the Mussel Watch Program as well as other NS&T biological studies (Benthic Surveillance and Bioeffects). The query parameters for each database and the results returned are provided in this report. All of the data were organized and archived in a Microsoft® Access database at the USGS office in Lawrenceville, New Jersey.

The WQDP was queried for subsurface, estuarine, and ocean samples collected in Atlantic, Bergen, Cape May, Essex, Hudson, Middlesex, Monmouth, Ocean Passaic, and Union, Counties in New Jersey, and Bronx, Kings, Nassau, New York, Richmond, Suffolk, and Queens Counties in New York. The sampling parameter selected for the query was "sediment."

The WQDP retrieval was conducted on July 8, 2014, and a total of 613 stations were returned. Of those stations, 339 in New Jersey and 267 in New York were designated as estuary stations, and 7 (all in New York) were designated as ocean stations. A total of 68,932 organic-compound, trace-element, metals, nutrient, and (or) field parameters measured in sediment samples were returned for the time period 1970–2012. Samples were collected by the New Jersey Department of Environmental Protection (NJDEP), New York State Department of Environmental Conservation (NYSDEC), USGS, and EPA.

The STORET Legacy water-quality database was also used to obtain data (excluding USGS data) collected prior to 1999. The STORET Legacy database was queried individually by state and county to include all the counties in the WQDP

Table 1. Terms used in the sediment contamination literature search conducted in May and June 2014.

Term	Definition
Locations	Barnegat Bay-Little Egg Harbor, Raritan Bay, Newark Bay, New York Harbor, Passiac River Estuary, Jamaica Bay, South Oyster Bay, Great South Bay, and Peconic Bay
Media	Sediments
Contaminants and contaminant indicators	Trace metals, pesticides, polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs) and flame retardants, polycyclic aromatic hydrocarbons (PAHs), sediment toxicity, hormones, fragrances, detergents, antibiotics, pharmaceuticals, personal-care products, and wastewater indicators

Table 2. Results of sediment contamination literature searches conducted from May 15 to June 6, 2014, for listed contaminants in Barnegat Bay-Little Egg Harbor, Newark Bay-New York Harbor-Raritan Bay-Passaic River Estuary, Jamaica Bay, Great South Bay, South Oyster Bay, and Peconic Bay, New Jersey and New York.

[Refer to table 1 for terms used in literature searches. PAHs, polycyclic aromatic hydrocarbons; PBDEs, polybrominated diphenyl ethers; PCBs, polychlorinated biphenyls]

Contaminants and contaminant indicators	Barnegat Bay–Little Egg Harbor		Newark Bay–New York Harbor–Raritan Bay–Passaic River Estuary		Jamaica Bay		Great South Bay		South Oyster Bay		Peconic Bay	
	Search results	Relevant articles	Search results	Relevant articles	Search results	Relevant articles	Search results	Relevant articles	Search results	Relevant articles	Search results	Relevant articles
Antibiotics	31	0	32	2	149	17	39	1	0	0	61	0
Detergents	53	1	105	1	149	21	85	0	2	0	18	0
Fragrances	6	0	13	0	40	0	18	0	0	0	11	0
Hormones	58	0	153	7	134	19	57	0	2	0	17	0
PAHs	60	6	478	19	155	17	31	0	0	0	15	0
PBDEs/flame retardants	14	1	66	3	18	1	3	0	1	0	0	0
PCBs	171	8	826	42	273	26	94	0	6	0	44	0
Personal-care products	112	1	127	2	65	13	88	0	0	0	45	0
Pesticides	213	4	580	69	308	26	214	0	9	0	74	0
Pharmaceuticals	42	1	120	0	60	7	67	0	3	0	39	0
Sediment toxicity	449	5	900	34	559	25	438	3	23	1	164	0
Trace metals	329	6	610	34	412	21	365	8	29	1	128	3
Wastewater compounds	266	1	385	18	2	0	295	0	16	0	105	0

retrieval. Retrieved data were loaded into Microsoft® Access to identify sediment samples collected in estuary or ocean settings. The station type code and the units of measurement commonly used for sediment (milligrams per kilogram, micrograms per kilogram, and dry weight) were used to differentiate sediment samples from water samples.

Of the total of 105 stations returned with associated bed-sediment data, 55 were in New Jersey and 50 in New York. Of those, 28 were designated as estuary bed-sediment stations (19 in New Jersey and 9 in New York), and 77 were designated as ocean bed-sediment stations (36 in New Jersey and 41 in New York). All New Jersey estuary bed-sediment stations were located in Bergen (4), Hudson (8), Middlesex (5), and Union (2) Counties, whereas the ocean bed-sediment stations were located in Middlesex (1), Monmouth (34), and Ocean (1) Counties. All New York estuary bed-sediment stations were located in Nassau (5) and Richmond (4) Counties, whereas the ocean bed-sediment stations were located in Bronx (4), Nassau (19), Queens (7), and Richmond (11) Counties. A total of 129 estuary bed-sediment results (1966–82) and 579 ocean bed-sediment results (1972–88), including organic compounds and (or) metals and trace-element parameters, were retrieved for New York. A total of 453 estuary bed-sediment results (1981–89) and 413 ocean bed-sediment results (1973–88), including organic compounds and (or) metals and trace-element parameters, were retrieved for New Jersey. All data retrieved from STORET were originally collected by the NYSDEC, NJDEP, and EPA.

The NS&T Data Portal was used to obtain sediment-quality data by state. This data portal allows the user to specify a dataset—in this case, "chemical" and "physical." In each dataset, the user is then asked to choose from a list of parameters—in this case, all parameters under "chemical" were chosen, and grain size was chosen under "physical." Once the selections are made, the program "Fetches" and "Downloads" the data into text files, which can then be uploaded into Microsoft® Access for additional querying.

A total of 190 stations with associated sediment-quality chemical analyses were returned—57 in New Jersey and 133 in New York, with a total of 7,030 associated organic-compound, metals, or carbon results for New Jersey and 14,825 for New York. Samples were collected in many bays and harbors surrounding New York City and Long Island as part of the Benthic Surveillance (909), Hudson/Raritan Estuary (2,041), Long Island Sound (2,656), Mussel Watch (6,452), Newark Bay (1,120), and World Trade Center Special Studies (1,647)

programs in New York from 1984 to 2009. In New Jersey, many samples were collected along the East Coast and within and north of the Delaware Bay as part of the Benthic Surveillance (921), Delaware Bay (3,186), Hudson/Raritan Estuary (820), Mussel Watch (1,980), and World Trade Center Special Studies (123) programs from 1984 to 2007.

A total of 165 stations with associated grain-size analyses were returned—55 in New Jersey and 110 in New York—with a total of 1,002 grain-size analyses results—284 for New Jersey and 718 for New York. Many samples were collected from the bays and harbors surrounding New York City and Long Island as part of the Benthic Surveillance (5), Hudson/Raritan Estuary (135), Long Island Sound (270), Mussel Watch (273), and World Trade Center Special Studies (35) programs. Samples from New Jersey were collected along the East Coast and within and north of the Delaware Bay as part of the Benthic Surveillance (9), Hudson/Raritan Estuary (55), Mussel Watch (95), Delaware Bay (120), and World Trade Center Special Studies (5) programs.

Methods

A total of 167 sites were identified for inclusion in the reconnaissance study (figs. 2 and 3). These sites are distributed throughout the 13 regions in New Jersey and New York delineated for this study. Estuarine sediments collected at each site were analyzed and screened for more than 150 organic and inorganic chemical constituents, as well as sediment toxicity to selected invertebrates. Site-selection, sample-collection, and analytical methods are described below.

Site Selection

The USGS consulted with other Federal agencies (EPA and NOAA), State agencies (NJDEP and NYSDEC), and municipal agencies (New York City Department of Environmental Protection, Suffolk County Department of Health Services, and Town of Hempstead) to evaluate potential sampling locations and obtain information on spills and land cover that would assist in site selection. Many potential sampling sites in the bays and estuaries were identified on the basis of the presence of pertinent historical sediment-quality information in order to facilitate comparison of pre- and post-Hurricane Sandy sediment-quality data. Other potential sampling sites were identified on the basis of the need to characterize regional differences in contaminant patterns (for example, sewage spills). From this list of potential sites, 167 were selected for sampling (figs. 2 and 3). Sites were selected to reflect a broad range of affected land-cover types and their associated contaminant sources, and most had been sampled previously (table 3, at end of report). They provide a representative distribution for assessment of regional storm impacts.

About 25 percent of the sampling sites are located in the relatively open estuarine waters of the NY/NJ Harbor, with the remainder located in back bays along the coast of New Jersey and Long Island. Samples were collected before the storm at 89 percent of the sites. Archived sediment samples collected before the storm were available for some of the selected sites. Some of these archived samples were submitted for analysis for constituents with limited historical data (for example, waste-indicator compounds and hormones) that were not previously measured. Sediment-sampling locations and the availability of historical data are listed in table 3 by region.

Site Characterization from Geographic Information

A variety of State databases were queried to identify the locations and types of contaminant sources that may have impacted sites that were sampled during this study. Queried databases include the 2011 National Land Cover Dataset (NLCD), the NYSDEC Spill database, New Jersey and New York businesses flooded during Hurricane Sandy, New Jersey and New York combined sewer outfall (CSO) locations, and New Jersey and New York bulk storage facility (BSF) locations. Each dataset was overlain with FEMA Modeling Task Force (MOTF) 3-meter (m) Hurricane Sandy Final Storm Surge Extent polygons (Federal Emergency Management Agency, 2013—hereafter called the "surge-extent boundary") to distinguish between flooded and non-flooded infrastructure (Federal Emergency Management Agency, 2013). These data were then attributed to sediment-sampling locations and study regions (figs. 2 and 3).

Study regions were defined on the basis of the hydrology and geography of the bays and similar patterns of land use and potential contaminant exposure. Study-region boundaries were defined from 12-digit hydrologic unit code (HUC-12) boundaries, which were obtained from the publicly available Watershed Boundary Dataset (WBD) compiled by the U.S. Department of Agriculture National Resources Conservation Service (USDA NRCS), the USGS, and the EPA (U.S. Department of Agriculture, Natural Resources Conservation Service, 2014). HUC-12 subwatershed areas were used to account for any upland areas that may have contributed contaminants to each bay or estuary.

Each sampling location was represented by a buffer area with a 2-km radius (fig. 4). This buffer area was used to characterize potential contaminant sources near the sampling location.

Tabular summaries of contaminant sources were compiled for each sampling location and region for comparison to sediment–quality data. Summaries specified the numbers and types of spills, damaged businesses, BSFs, and wastewater discharges. Geospatial analyses were conducted in a geographic information system (ArcMap™ 10.1; Esri®, Redlands,

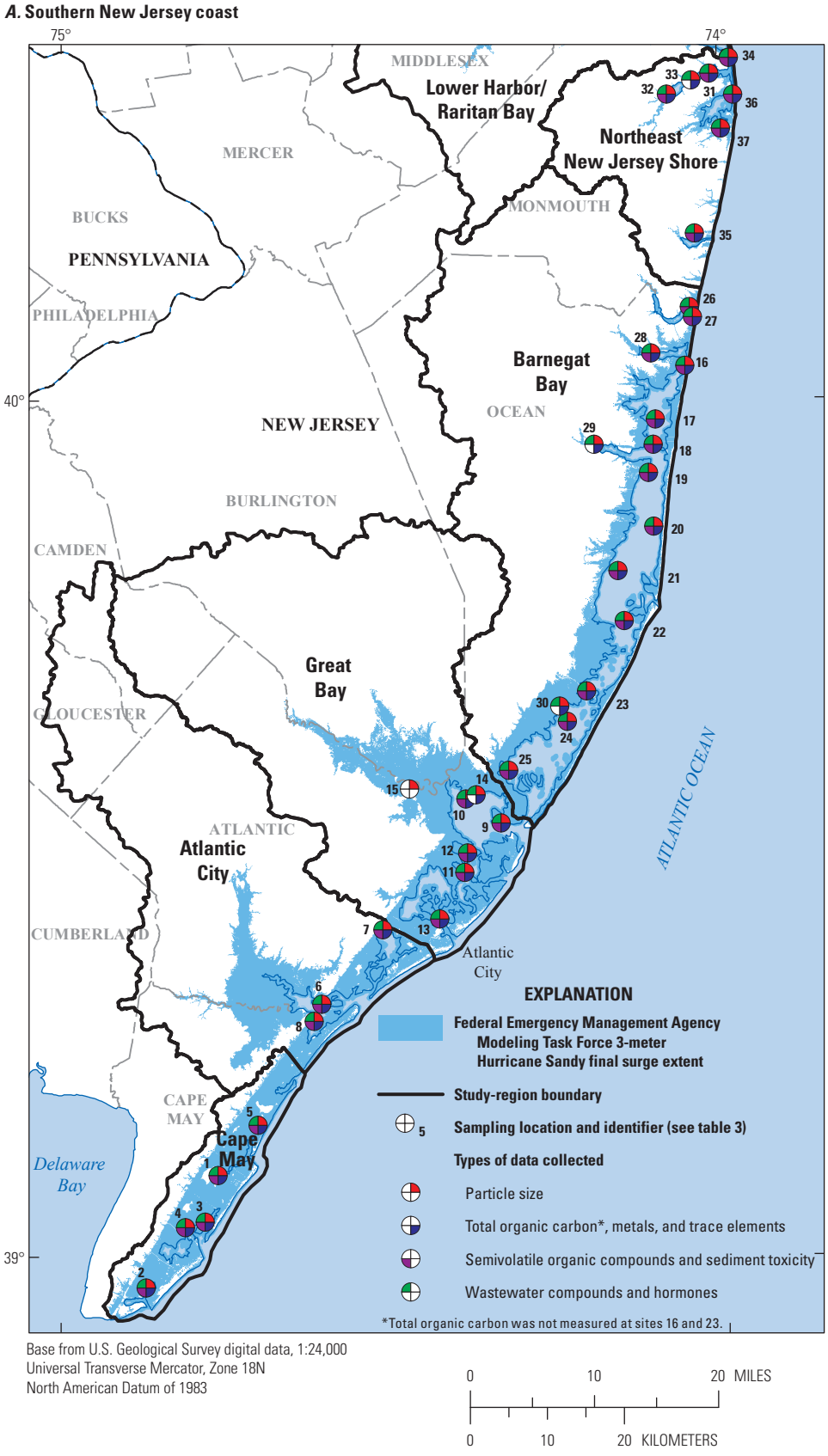


Figure 2. Sampling locations and types of analytical data collected for *A*, the southern New Jersey coast, *B*, the Lower Harbor / Raritan Bay, and *C*, Long Island.

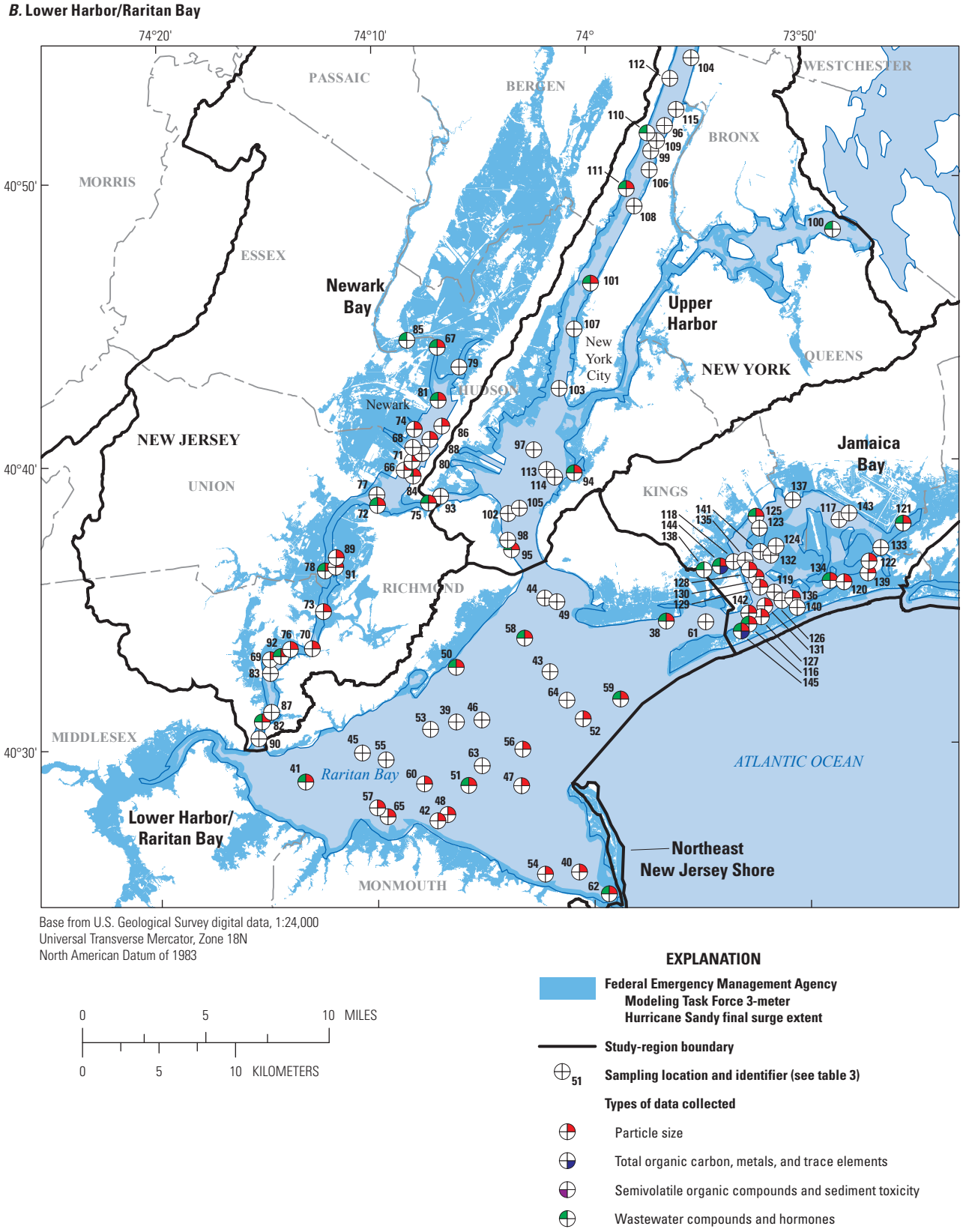
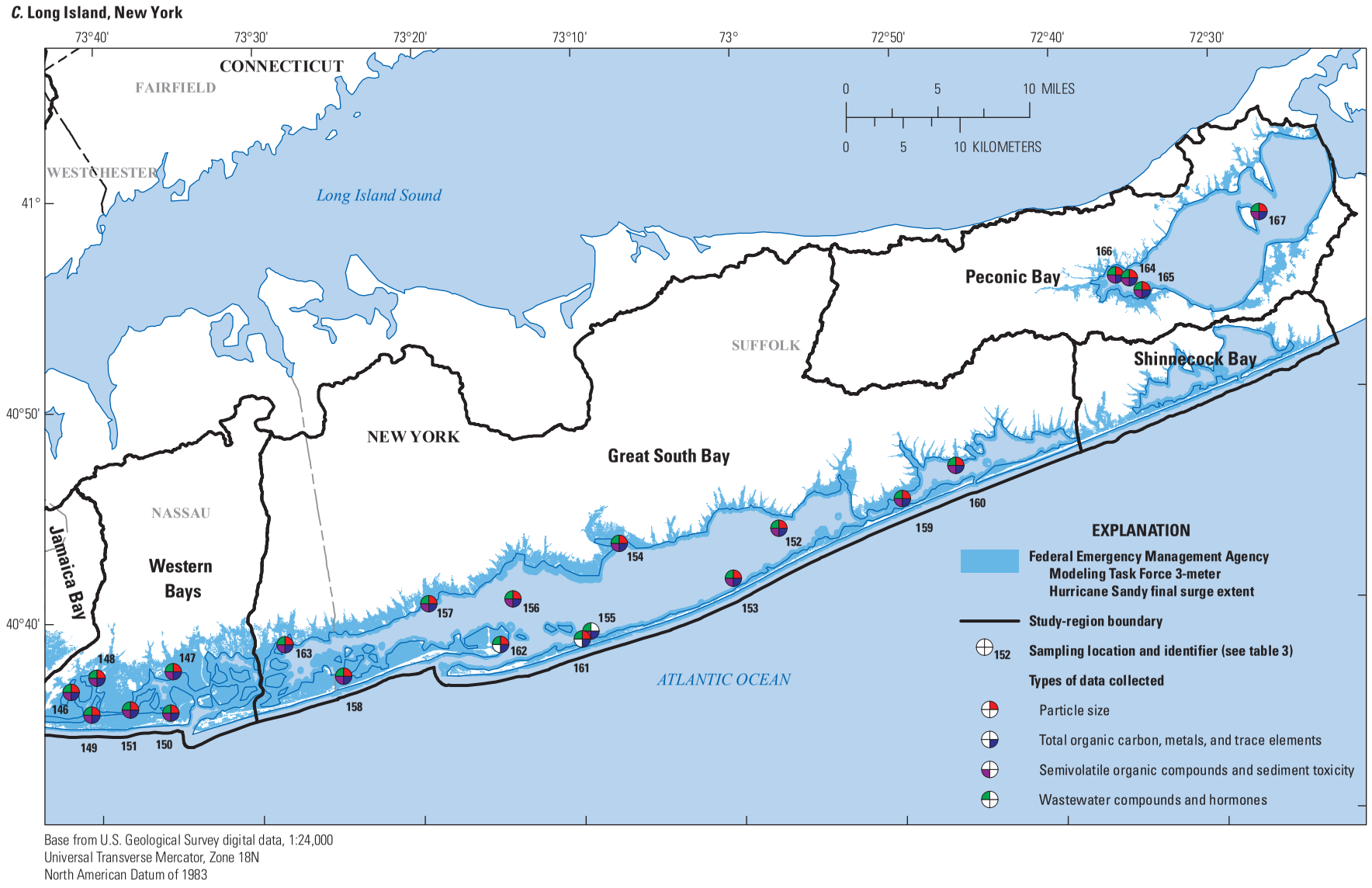


Figure 2. Sampling locations and types of analytical data collected for *A*, the southern New Jersey coast, *B*, the Lower Harbor / Raritan Bay, and *C*, Long Island.—Continued



Base from U.S. Geological Survey digital data, 1:24,000
Universal Transverse Mercator, Zone 18N
North American Datum of 1983

Figure 2. Sampling locations and types of analytical data collected for *A*, the southern New Jersey coast, *B*, the Lower Harbor / Raritan Bay, and *C*, Long Island.—Continued

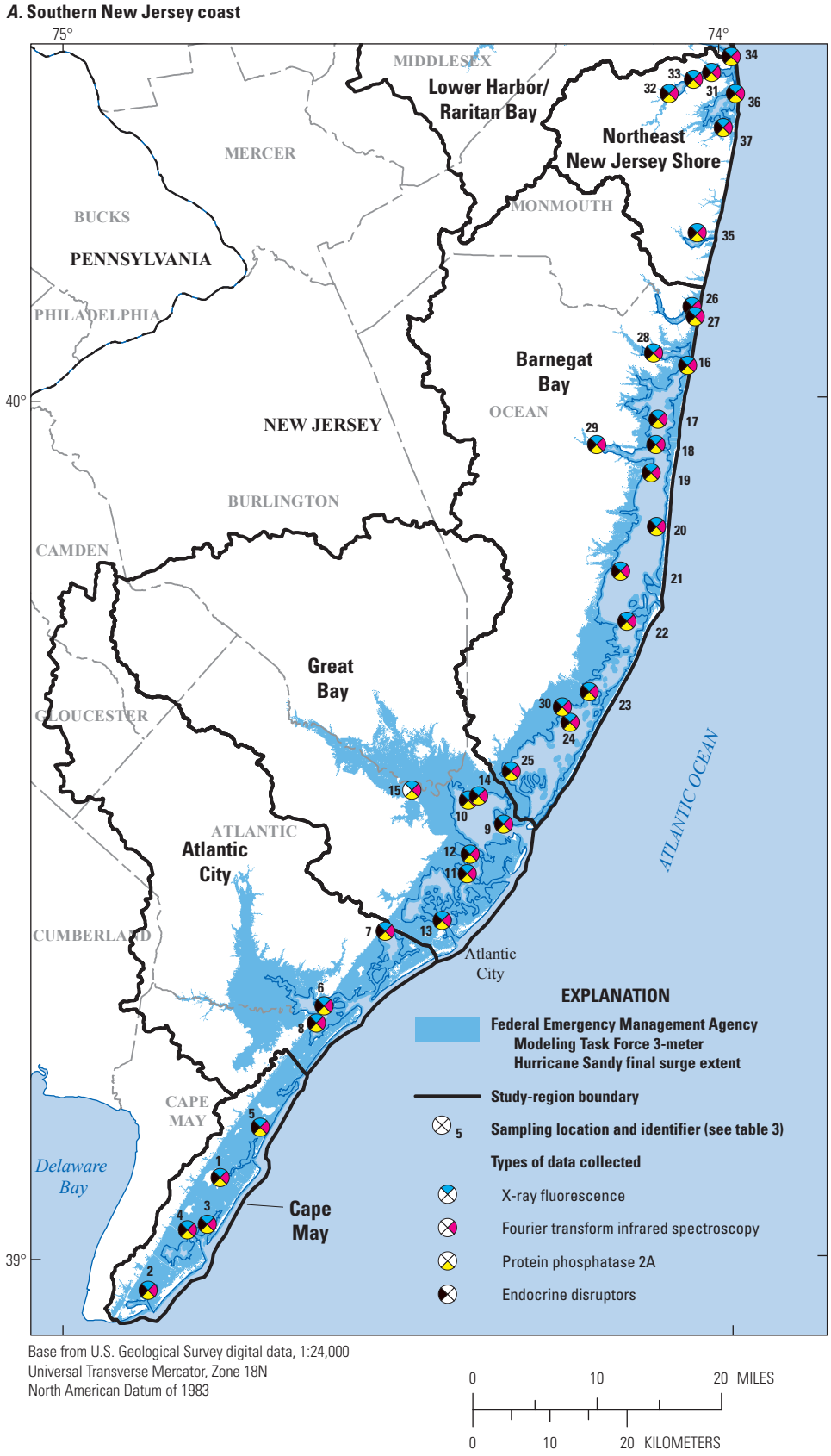


Figure 3. Sampling locations and types of screening data collected for *A*, the southern New Jersey coast, *B*, the Lower Harbor / Raritan Bay, and *C*, Long Island.

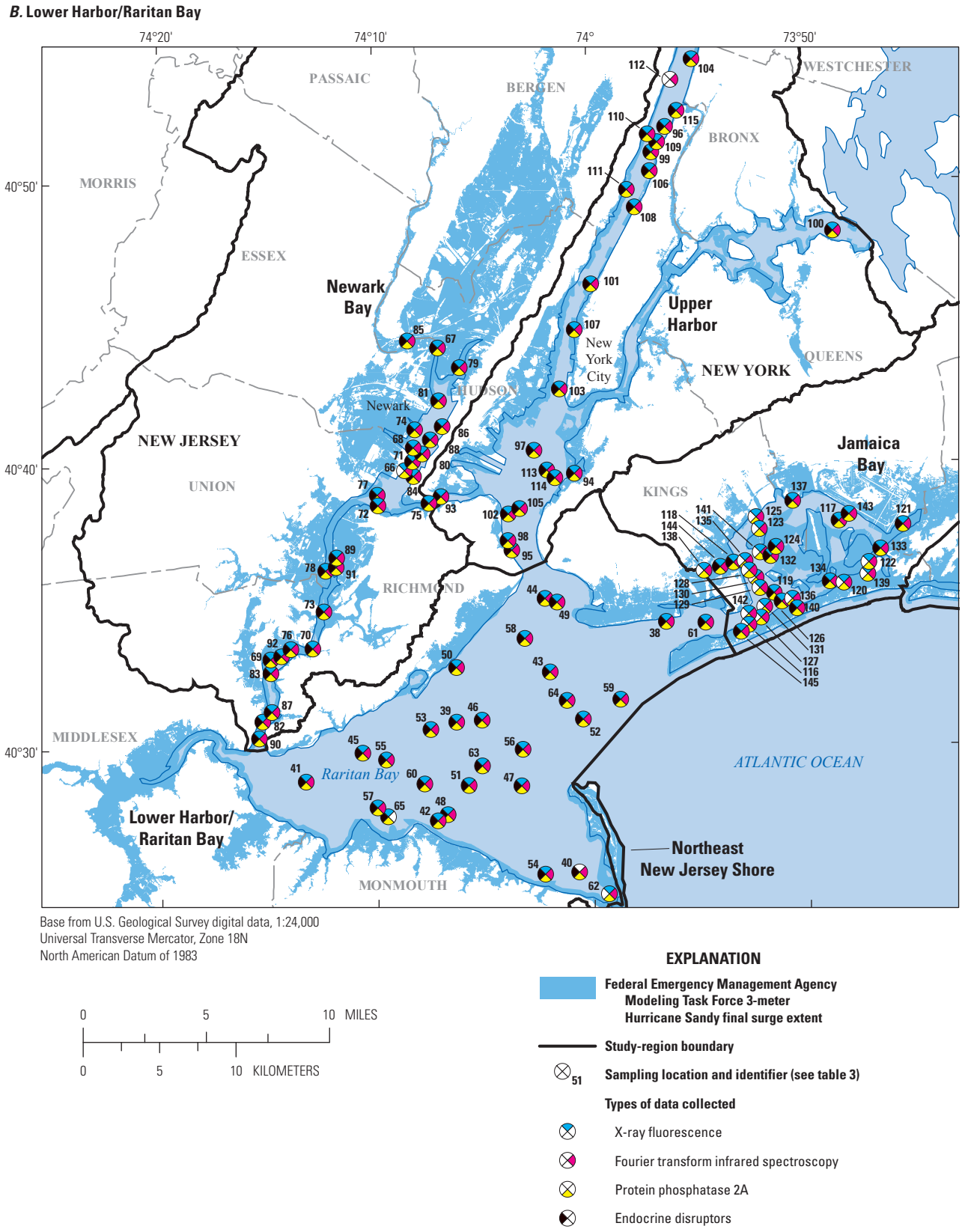


Figure 3. Sampling locations and types of screening data collected for *A*, the southern New Jersey coast, *B*, the Lower Harbor / Raritan Bay, and *C*, Long Island.—Continued

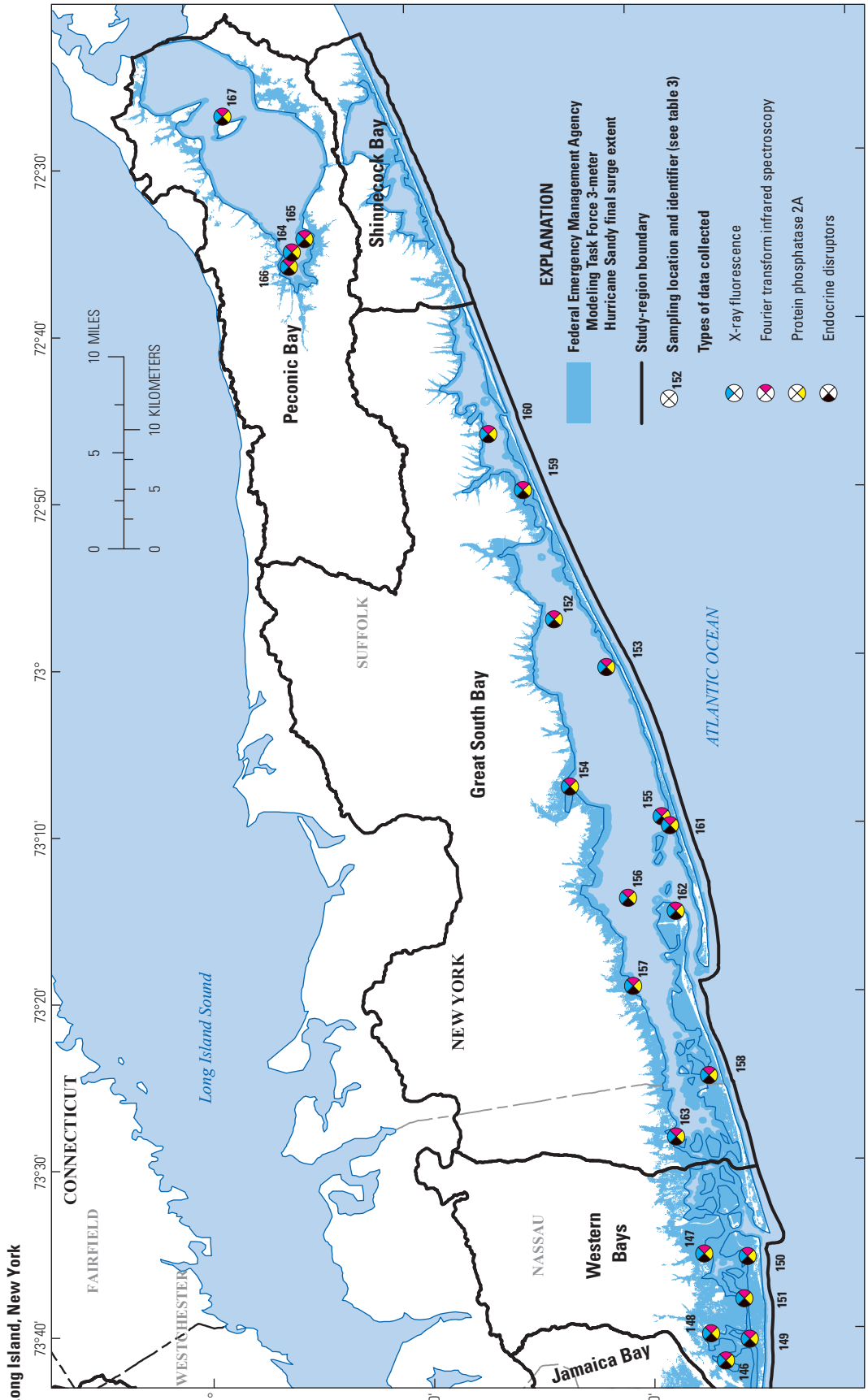


Figure 3. Sampling locations and types of screening data collected for *A*, the southern New Jersey coast, *B*, the Lower Harbor / Raritan Bay, and *C*, Long Island.—Continued

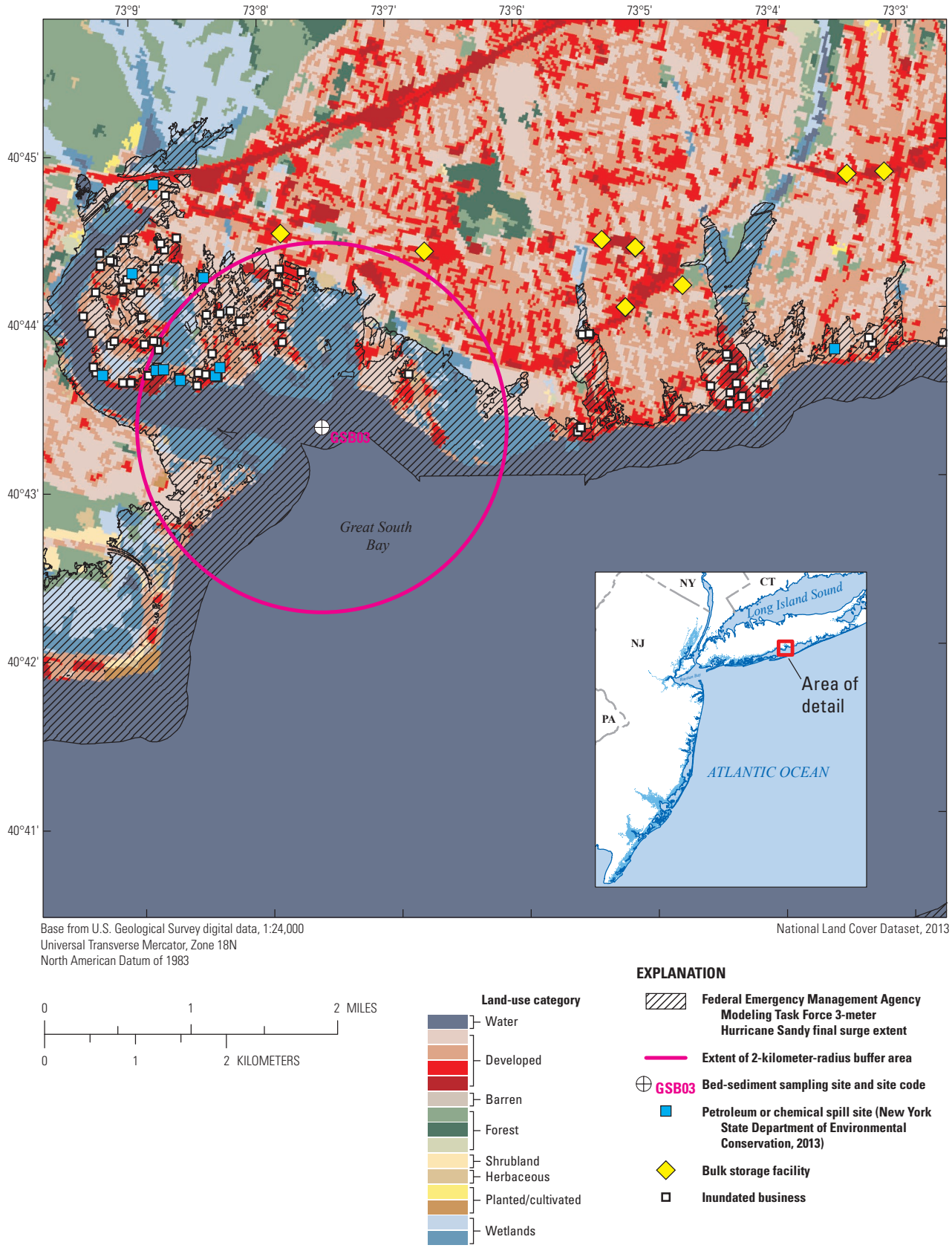


Figure 4. How land use, landscape attributes, and potential contaminant sources within and outside the Hurricane Sandy inundation zone were attributed within a 2-kilometer-radius buffer area of each sampling location in the Hurricane Sandy study area.

California). Contaminant source data were matched with regional and sampling areas using the ArcMap™ intersect tool to attribute potential contaminant sources to those locations. Regional summaries were generated by assigning regional identifiers to all potential contaminant data that fell within each region, with a distinction between flooded and non-flooded areas that were distinguished using the surge-extent boundaries (Federal Emergency Management Agency, 2013). Sampling location summaries represent data on potential contaminants that were within the 2-km-radius buffer area of each sampling location. Regions and sampling locations were excluded from summary tables if no potential contaminant sources were located within the region boundaries or within the 2-km-radius buffer area.

Data Sources used for Site Characterization

Multiple datasets were downloaded and cataloged to identify potential contaminant sources for each sediment sampling location and region. Where appropriate, datasets were merged with the surge-extent boundary to identify areas that were inundated during the storm surge (Federal Emergency Management Agency, 2013). The spatial join tool in ArcMap™ was used to assign region identifiers to each contaminant characterization dataset. Similarly, a spatial join was performed for all contaminant characterization data for locations within a 2-km-radius buffer area of each sampling location. All zonal and proximity analyses were performed in ArcMap™. Joined datasets were exported from ArcMap™ as tables and summarized using the R statistical software (R Development Core Team, 2010).

National Land Cover Dataset

The 2011 NLCD for New Jersey and New York was obtained from the USDA NRCS Geospatial Data Gateway (*http://datagateway.nrcs.usda.gov/*), and mosaicked to provide continuous coverage of the regions. The 2011 dataset is the most recent national land-cover product, and utilizes the 16-class Anderson classification system to distinguish between land-cover types (Anderson and others, 1976; Jin and others, 2013). Level II land-cover classes were summarized for each region in units of square kilometers and as percentages of each region's total area. Land-cover classes in the inundated portion of each region as defined by the surge-extent boundary were summarized separately to highlight land uses inundated during Hurricane Sandy. To simplify later data interpretation, summaries were also aggregated to Level I Anderson classes.

Inundated Businesses

A dataset of New Jersey and New York business locations that were inundated during Hurricane Sandy was obtained from Nathan Wood (U.S. Geological Survey, written commun., 2013). This dataset was compiled from New Jersey and New York State Government listings that existed 3 to 4 months before Hurricane Sandy. Summarized business attributes include address match codes (for example, 0 = location is verified at business, x = unknown accuracy), North American Industry Classification System (NAICS) codes, and employee counts for each business location. Business data were first filtered to only those with an address match code of 0 to exclude addresses listed as U.S. Post Office boxes. Spatial joins were then performed between the filtered business dataset, region polygons, and 2-km-radius sampling-location buffer areas. Resulting business data were aggregated to economic sectors on the basis of two-digit NAICS codes (see *https://www.census.gov/eos/www/naics/*) and then summarized by region and sampling location. Counts of businesses within each economic sector were tabulated for each region and sampling location. Regions and sampling locations with no inundated businesses were excluded from summary tables.

New York State Department of Environmental Conservation Spill Database

The NYSDEC maintains and updates a petroleum and chemical spill database to comply with Federal and State laws that require notification and remediation of unauthorized spills and discharges. More than 4,800 spills were reported during Hurricane Sandy, and others may have occurred that were not reported (New York State Department of Environmental Conservation, 2013). Reported contaminant spill data for New York were obtained from the NYSDEC and information on spills associated with Hurricane Sandy was extracted. As part of the New York State Resiliency Institute for Storms and Emergencies consortium (NYS RISE), addresses of spill locations were georeferenced and mapped as points for geospatial analyses by Park Ng and Bruce Bronawell at Stony Brook University (written commun., 2014). Spill data were summarized by region and sampling location, and sites inside and outside the surge-extent boundary were differentiated. Tabular summaries of the spill data were generated and grouped by the source (for example, commercial vehicle, private dwelling, transformer) and cause (for example, equipment failure, human error, storm) of each reported spill. The number of each spill source and cause combination was tabulated for each sampling location and region.

Bulk Storage Facilities

BSF locations for New York, generated as part of its Bulk Storage Program, were obtained from the NYSDEC. Locations of New Jersey BSFs were obtained from the NJDEP. Facilities included in the New York database are petroleum bulk storage (PBS), major oil storage facilities (MOSF), and chemical bulk

storage (CBS) facilities (see *http://www.dec.ny.gov/chemical/2650.html*). The PBS designation applies to any facility with an underground storage tank larger than 110 gallons (416 liters), or a cumulative storage capacity (above and below ground) of more than 1,100 gallons (4,160 liters) but less than 400,000 gallons (1,514 cubic meters). The MOSF designation applies to all facilities with a cumulative storage capacity of 400,000 gallons (1,514 cubic meters) or more. Finally, the CBS designation applies to any storage of hazardous substances in above-ground tanks with a capacity of 185 gallons (700 liters) or more, any underground storage tanks regardless of capacity, and non-stationary tanks used to store 2,200 pounds (998 kilograms) or more for at least 90 consecutive days. New Jersey records were not classified according to PBS, MOSF, or CBS designations; therefore, all New Jersey facilities were labeled "unclassified bulk storage" in summary tables. Counts of BSF locations in New Jersey and New York were tabulated for each region and sampling location, and facilities inside and outside the surge-extent boundary were differentiated.

Combined and Storm-Sewer Outfalls and Sewage-Treatment Plants

Combined sewer-outfall (CSO) and sewage-treatment-plant (STP) locations for New Jersey and New York were obtained from the NJDEP and the NYSDEC, respectively. Counts of CSO and STP locations were tabulated for each sampling location and region, and sites inside and outside the surge-extent boundary were differentiated.

Sample Collection

Bed-sediment samples were collected by USGS or EPA staff at 167 sites using standard methods outlined by the USGS (Hladik and others, 2009; Radtke, 2005) and EPA (U.S. Environmental Protection Agency, 2001a). Bed-sediment samples were collected from boats using grab samplers during June-October 2013. The location of each sampling site was determined using a global positioning system. Field conditions, such as air and water temperature, specific conductance, pH, salinity, and weather conditions, were recorded. USGS personnel collected bed sediment using either an Ekman or Petite Ponar sampler depending on sampling conditions (for example, sediment texture, or presence of shells or vegetation) using standard methods (Radtke, 2005; U.S. Environmental Protection Agency, 2001a; Lauenstein and Cantillo, 1993). EPA personnel collected bed sediment using a modified Van Veen type sampler using standard methods (U.S. Environmental Protection Agency, 2001a). Regardless of the sampling device used, only the upper 2 centimeters (cm) of sediment was retained for analysis to standardize sample collection among sites in an attempt to obtain samples representative of sediment-quality conditions after the hurricane.

All bed-sediment samples were processed in a similar manner. Sediment particles in overlying water on the grab sample were allowed to settle, and then water was gently drawn off with a suction pump and tubing. A clean, methanol-rinsed stainless steel or Teflon® spoon was used to remove the upper 2 cm of sediment (or the entire sample if 2 cm or less was collected) from the sampler. Sediment was placed in a clean, methanol-rinsed glass or stainless steel mixing bowl until at least 1 gallon (3.8 liters) of sediment was obtained. If 1 gallon of sediment could not be collected from a single grab, or if an excessive amount of large debris (greater than 2 cm) or particles was present, a second grab sample was collected and processed. In all cases, the amount of sample collected was estimated by measuring the thickness of sediment removed and multiplying by the cross-sectional area of the sampler. Before the unused sample was discarded at each site, one unsieved subsample was collected from the bottom of the grab sampler for diatom analysis to determine whether the top and bottom of the sample were different. Between sampling sites, the grab samplers were rinsed with seawater, and sampling spoons, bowls, and other equipment were washed with deionized water and rinsed with methanol. All equipment was field rinsed with site water before it was used at each sampling location.

The total sample collected from one or more grabs was homogenized prior to filling individual sampling containers for analysis. Subsamples were analyzed for a suite of physical, chemical, biological, and toxicological constituents and properties (table 4) to determine the type, concentration, potential sources, and biological activity or inhibition of contaminants present. The analyses conducted are described in detail in the "Analytical Methods" section below.

Samples were processed either on the boat or in a laboratory. Whereas most subsamples were unsieved, subsamples to be analyzed for hormones and wastewater indicator compounds were sieved (2-millimeter (mm) screen) to remove plant debris and gravel before they were transferred to a separate container. Subsamples were collected using clean stainless steel or Teflon® spoons and placed in appropriate containers (table 4). All samples were stored in an ice-filled cooler while on the boat and during transport back to the office. Samples were stored and preserved as specified in table 4 prior to processing and shipment to laboratories for analysis. Chilled or frozen samples were packed with ice and shipped overnight to the appropriate laboratory.

Table 4. Summary of container types, sample processing, amount of sediment needed, and preservation required for methods used during the Hurricane Sandy reconnaissance study, June–October 2013.

[PAHs, polycyclic aromatic hydrocarbons; PCBs, polychlorinated biphenyls; cm, centimeters; HDPE, high density polyethylene; mL, milliliters; g, grams; L, liters]

Type of analysis	Type of container	Processing	Amount	Preservation
Trace metals	125-mL, HDPE, jar	Unsieved	50 g	Freeze at -20 degrees Celsius
PAHs, PCBs, and legacy pesticides	250-mL, baked, amber glass jar	Unsieved	¾ full jar	Freeze at -20 degrees Celsius
Total organic carbon	250-mL, baked, amber glass jar	Unsieved	50 g	Freeze at -20 degrees Celsius
Screening methods	30-mL, sealed plastic bag	Unsieved	20 g	Room temperature
Particle-size analysis	30-mL, sealed plastic bag	Unsieved	10 g	Room temperature
Diatoms (upper 2 cm)	30-mL, sealed plastic bag	Unsieved	10 g	Room temperature
Diatoms (base of sample)	30-mL, sealed plastic bag	Unsieved	10 g	Room temperature
Bioassays	125-mL, amber glass jar	Unsieved	20 g	Chill
Sediment toxicity	4-L, screw-top, poly bucket	Unsieved	2.5 L	Chill
Wastewater compounds and hormones	500-mL, baked, amber glass jar	Sieved	120 g	Freeze
Archive sample	500-mL, baked, amber glass jar	Sieved	¾ full jar	Freeze

Analytical Methods

The broad range of organic and inorganic contaminants that were introduced into the study area as a result of current and historical industrial and agricultural activities were likely mobilized and redistributed by Hurricane Sandy. Many of these contaminants are regulated and have been monitored at various locations as part of a remedial activity (such as a Superfund cleanup), or regionally as part of monitoring programs (such as EPA REMAP). For this reason, all bed-sediment samples were analyzed for a suite of EPA priority pollutants to match those that were previously analyzed for, including selected metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and legacy (no longer sold or applied) pesticides. Analyses for priority pollutants in bed sediment were conducted by EPA and U.S. Army Corp of Engineers (USACE) contract laboratories in accordance with standard methodologies and an EPA Quality Assurance Project Plan. The results of USACE analyses were provided to the USGS for this study; the results of EPA analyses of sediment from locations that are not part of their routine monitoring sites are also provided. Results generated by EPA and its contractors for routine monitoring sites will be made available to the public on the EPA REMAP Web site (*http://www.epa.gov/emap2/remap/html/data.html*), and through STORET. Other physical and chemical characterizations conducted on sampled bed sediments included particle-size analysis and determination of the amount of organic carbon present. In addition, the USGS conducted two portable screening tests, x-ray fluorescence (XRF) and Fourier transform infrared spectroscopy (FTIR), as well as x-ray diffraction (XRD) and bioassays on almost all of the samples. These techniques are described in the "Screening Methods" section below.

Particle-Size Analysis

Particle-size distributions in the bed-sediment samples were characterized by optical diffraction (Gee and Or, 2002) using a Coulter LS-230 Particle Size Analyzer. The range of measurement is 0.04 to 2,000 microns (μ) divided into 116 equal bins. Prior to analysis, particles larger than 2,000 μ were sieved out and weighed. These data were integrated into the size-distribution results after optical analyses were completed. The fraction composed of particles smaller than 2,000 μ was carefully disaggregated when necessary using a mortar and rubber-tipped pestle, and then sonicated before analysis. Samples were split with a riffle splitter to obtain appropriate random subsamples for analysis. The particle analyzer suspends the sediment subsample in filtered water within a fluid module attached to a device containing a light source and detectors. A pump within the fluid module circulates the suspended sample through a cell in the optical bench. A laser beam then passes through the cell and light is deflected off particles of various sizes. The pattern of scattered light intensity was used to deduce the distribution of particle sizes using a mathematical model based on Fraunhoffer diffraction theory. Samples were run through the device for 90 seconds, and each sample was analyzed twice. Results were determined by averaging the results of the two sample runs.

Total Organic Carbon

Total organic carbon in estuarine bed-sediment samples was measured at the EPA–Region 2 laboratory in Edison, New Jersey, using EPA Method 415.1 modified for sediment by using a boat sampling module (U.S. Environmental Protection Agency, 1983). The reporting limit (RL) for total organic carbon was 1,000 milligrams per kilogram (mg/kg) dry weight.

Metals and Trace Elements

Twenty-two metals and trace elements were measured in estuarine bed-sediment samples under EPA contract at the Institute for Integrated Research in Materials, Environments, and Society (IIRMES) facility in Long Beach, California, by inductively coupled plasma–mass spectrometry using EPA Method 6020A (U.S. Environmental Protection Agency, 2007). Total mercury was also measured under EPA contract at IIRMES by cold vapor atomic fluorescence spectrometry using EPA Method 245.7 (U.S. Environmental Protection Agency, 2005). RLs for aluminum and lead and for mercury were 5 mg/kg and 0.02 mg/kg dry weight, respectively. All other metals had a RL of 0.1 mg/kg dry weight.

Semivolatile Organic Compounds

Semivolatile organic compounds were measured in estuarine bed-sediment samples under EPA contract at the IIRMES facility by gas chromatography/mass spectrometry using EPA Method 8270C (U.S. Environmental Protection Agency, 1998). The method included analysis for 25 priority and alkylated PAHs, 53 PCB congeners, and 29 legacy organochlorine pesticides (OCPs). RLs for PAHs, PCBs, and OCPs were 5 micrograms per kilogram (µg/kg) dry weight.

Wastewater Compounds

The wastewater method (Burkhardt and others, 2006) focuses on the determination of 61 compounds indicative of wastewater, which were chosen on the basis of potential toxicity or endocrine disruption potential. Wastewater compounds include surfactants, fragrances, antioxidants, disinfectants, food additives, plastic components, industrial solvents, PAHs, fecal and plant sterols, phosphate flame retardants, and high-use domestic pesticides.

The compounds of interest in bed-sediment samples were extracted from interfering matrix components with isopropyl alcohol in a pressurized solvent extraction system. Compounds were then isolated using disposable solid-phase extraction (SPE) cartridges containing chemically modified polystyrene–divinylbenzene resin. The cartridges were dried with nitrogen gas, and then the sorbed compounds were eluted with a methylene chloride–diethyl ether mixture (80:20 volume/volume (v/v)) through a Florisil®/sodium sulfate SPE cartridge. The compounds of interest were determined by capillary-column gas chromatography/mass spectrometry.

Recoveries in reagent sand samples fortified at 4 to 72 µg (micrograms) averaged 76 percent ±13 percent relative standard deviation and RLs ranged from 50 to 500 µg/kg for all wastewater compounds (Burkhardt and others, 2006). However, RLs for this method are scaled on the basis of the mass used for analysis, and therefore vary substantially among samples analyzed during this study. Concentrations of some compounds were reported as estimated with an "E" remark code for one of three reasons: (1) recovery was biased unacceptably low (less than 60 percent) or was highly variable (greater than 25 percent relative standard deviation), (2) the reference standards used were prepared from technical mixtures, or (3) the blank samples potentially could be contaminated.

Steroid Hormones

The steroid hormone analytical method (Foreman and others, 2012) focuses on the determination of steroid hormone compounds, sterols (cholesterol, 3-beta coprostanol), and a plastic component (bisphenol A). Steroid hormones measured include estrogens, androgens, and progestins. These compounds have natural and manmade sources and result from industrial, pharmaceutical, human-waste, and agricultural applications. They are also excreted by animals and plants in the aquatic environment. Hormones affect most major physiological functions in mammals and other vertebrates (Casals-Casas and Desvergne, 2011). They control gene transcription and therefore substantially modulate physiology. Environmental exposure to steroid hormones may impair reproductive and immunological functions; modulate the timing of reproductive cycles; and (or) affect growth, development, and general metabolism in vertebrates.

Extraction of bed-sediment samples for hormone analysis was similar to that described by Burkhardt and others (2006). The extraction typically used up to 10 grams (g) of material (dry weight), with lesser amounts used for matrices anticipated to have high organic-matter or analyte concentrations. Samples were stored frozen (≤ –15 degrees Celsius [°C]) if they were not extracted after 4 days following receipt; otherwise, they were refrigerated. Thawed samples were homogenized prior to subsampling for extraction or for separate dry-weight determination. Dry weight was obtained by weighing a sample aliquot contained in a tared aluminum pan before and after heating at 130 °C for at least 16 hours. Sample aliquots for extraction were placed in a tared Accelerated Solvent Extraction (ASE-200; Thermo Scientific, Sunnyvale, CA) cell and reweighed to determine the wet weight of the extracted sample aliquot. Reagent sand was added to the cell as needed as determined from cell and sample size. The sample was fortified with 100 nanograms (ng) (1,000 ng for cholesterol-d_7) of deuterium or carbon-13-labeled isotopic dilution standards (IDSs) . Other IDSs fortified in these samples were fortified at the same concentrations used for the hormones in water method (Foreman

and others, 2012). The sample was extracted by pressure-solvent extraction using the ASE instrument with a water–isopropyl alcohol mixture (50:50 v/v) at 165 °C using three static cycles (10 minutes per cycle) at 13.8 megapascals (mPa). The resultant ASE extract portions were fortified with 50 milligrams (mg) of sodium chloride (NaCl) and diluted with 50 milliliters (mL) of phosphate buffer solution and sequentially passed through an Oasis® hydrophilic lipophilic balance (HLB, Waters Corporation, Milford, Massachusetts) SPE column to isolate the steroid hormone compounds on the column using a procedure similar to that given in Burkhardt and others (2006), except that the sample reservoir was Teflon® instead of polypropylene, the HLB column was precleaned with a dichloromethane–methanol elution solvent mixture (90:10 v/v), and only one (165 °C) instead of two (120 and 180 °C) ASE extracts was passed through the column. The column was dried with nitrogen gas at a flow rate of about 2 liters per minute (L/min) for 15 minutes. Steroid hormone compounds were eluted from the Oasis® HLB column and passed through a 2-g Florisil® cleanup column (containing about 2.5 g sodium sulfate above the Florisil®) by using 25 mL of a dichloromethane–methanol mixture (90:10 v/v). The resultant extract was concentrated to 1 to 2 mL by using nitrogen gas evaporation, then transferred to a silanized 5-mL reaction vial by using a 1.5-mL rinse with the dichloromethane–methanol mixture (90:10 v/v). The extract was evaporated until dry using nitrogen gas. The steroid hormone compounds were derivatized using 500 microliters (µL) of activated MSTFA (N-Methyl-N-trimethylsilyltrifluoroacetamide) derivatization reagent and analyzed by gas chromatography/tandem mass spectrometry as described for the "hormones-in-water" method (Foreman and others, 2012). Steroid hormone analytes were quantified by using an isotope dilution quantification procedure that includes using multilevel calibration curves.

Laboratory quality assurance and quality control (QA/QC) was monitored in part by evaluating IDS and surrogate compound recoveries in each sample matrix, which represent absolute recoveries for the steroid hormone method. QA/QC sample types include one laboratory reagent blank (LRB) sample and one laboratory reagent spike (LRS) sample that are included with each sample preparation set and processed along with the associated environmental samples. The LRB and LRS samples were prepared using baked (450 °C for 2 hours) reagent sand. The LRB sample was used to monitor for interferences and the possible introduction of steroid hormone analytes during sample preparation. The LRS sample was used to assess recovery performance for steroid hormone analytes. Additional laboratory-optional QA/QC sample types sometimes included (1) a randomly selected duplicate field sample to assess reproducibility of determined concentrations in a specific matrix, and (or) (2) a randomly selected laboratory matrix spike (LMS) sample used to assess analyte recoveries in a specific matrix. Additional field-based QA/QC sample types included blanks, replicate samples, and laboratory matrix spike samples, which were processed and analyzed along with the environmental samples.

Sediment Toxicity

A 28-day toxicity evaluation was conducted at the U.S. Army Corp of Engineers Engineer Research and Development Center (USACE–ERDC) on estuarine bed-sediment samples. Samples were analyzed for survival, growth (weight and total biomass), and reproductive effects (ratio of neonates to survivors) as the determining endpoints. The amphipod *Leptocheirus plumulosus* was used to evaluate the estuarine bed sediments using EPA Method 600/R-01/020 (U.S. Environmental Protection Agency, 2001b). Statistical methods were used to identify significant differences between field samples and laboratory control samples. The Kolmogorov-D test was used to determine whether the data distribution was normal or non-normal, and the Bartlett's test was used to test the variance. If the variance of the data was determined to be unequal, a Wilcoxon rank sum test was used to determine whether sediment samples from the field and laboratory control samples differed significantly. If the variance of the data was determined to be equal, a Bonferroni t-test was used to identify significant differences.

Screening Methods

A screening approach including spectroscopy and laboratory-based biomarker assays (bioassays) was used to evaluate estuarine bed sediments for contaminant occurrence and potential adverse biological effects. Such methods have been used increasingly in complex matrices, including estuarine sediments, to investigate potentially hazardous conditions for humans and aquatic and terrestrial biota because they provide a rapid screening approach that has a higher throughput than more traditional contaminant- or effect-specific analytical techniques (Karuppiah and Gupta, 1998; Escher and others, 2014). Screening approaches can be used to guide the more traditional contaminant- and effect-specific work by identifying the presence and concentrations of contaminants in the environment as well as provide a rapid assessment of potential undesired human-health or ecological effects.

Screening tools used in this study include field-portable spectroscopic techniques that provide qualitative and semi-quantitative measurements of mineralogy and contaminants, as well as biological assays that assess potential biological effects of contaminants. Specific screening analyses conducted include field-portable x-ray fluorescence (pXRF), attenuated total reflectance–Fourier transform infrared spectroscopy

(ATR–FTIR), x-ray diffraction (XRD), and multiple bioassays to measure environmentally relevant activities such as estrogenicity, androgenicity, genotoxicity, and protein phosphatase 2A inhibition. An overview of each technique and the associated sample-preparation methods used in this study are described below.

Field-Portable Spectroscopy

Spectroscopic analyses conducted during this study include handheld XRF and ATR–FTIR. XRF provides a rapid assay of elements in a sample, and ATR-FTIR provides a rapid assessment of various organic and inorganic functional groups in a sample.

X-Ray Fluorescence

XRF measures the emission characteristics of secondary x-rays, or fluorescence, from a material that has been bombarded with high-energy x-rays. It is widely used for elemental analysis of solids and liquids. A field-portable XRF analytical instrument (pXRF) was used in the current study. It can rapidly identify and quantify elements heavier than magnesium, and commonly provides limits of detection (LODs) in the 10- to 50-mg/kg range for a given element. This nondestructive method allows for real-time elemental analysis, which is ideal for environmental screening for metals and other inorganic contaminants in geologic and manufactured materials.

All samples for pXRF analysis were analyzed in the laboratory at the USGS Central Energy Resources Science Center in Denver, Colorado. Samples were dried in the collection container at 30 °C prior to analysis. This low-temperature drying was chosen to preserve any volatile metal species, such as mercury, in the sample. The samples were then placed in XRF cups and covered with 7-µ-thick Mylar® film. All samples were analyzed on a Niton XL3t GOLDD+ XRF Analyzer (Thermo Scientific, 2010, Pittsburgh, Pennsylvania) for 120 seconds in the "Test All Geo" mode.

The pXRF Analyzer was calibrated by the manufacturer for 40 elements on the basis of National Institute of Standards and Technology (NIST) traceable standards (NIST 2709, 2710, and 2711) that span a range of concentrations from 100 to 60,000 parts per million (ppm) for a sediment-type matrix. The instrument reports concentrations for a suite of elements and calculates a "balance" value based on Compton scattering, which represents a concentration for elements not measured by the instrument (Hall and others, 2012). Test All Geo mode was used for all analyses. NIST standard 2710 was run at the start and at the end of each batch of samples analyzed for quality control and to monitor any drift of the instrument. This standard was used because it has certified and nominal elemental values for many more elements than NIST 1944.

Fourier Transform Infrared Spectroscopy

Mid-range (400–3,600 cm^{-1}) FTIR is a nondestructive analysis for identifying dominant and minor organic and inorganic functional groups (for example, C–C and C–H bonds present in aliphatic and aromatic organic moieties; Si–O and C–O bonds present in silicates and carbonates; –OH bonds representative of hydroxyl groups associated with clays) on the surface of sediment particles. It also provides complementary information for chemical structural identification. Attenuated total reflectance (ATR) is a technique used with FTIR that facilitates analysis with minimal sample preparation, and therefore allows for a more rapid analysis. Functional groups are identified on the basis of unique vibration frequencies, which are related to stretching or deformation of chemical bonds. Identification of individual compounds is relatively straightforward, but sediments are complex mixtures and contain multiple mineral phases and organic matter. For screening purposes, qualitative assessment of the spectra is the first step and involves identification of major mineral phases (for example, clays, carbonates, and silica) and organic content (for example, compounds containing aliphatic, aromatic and carbonyl groups). Mineral identifications are confirmed by comparing the sample spectra to mineral standards, much as minerals are identified in x-ray diffraction. The contribution of each phase to the sample can be estimated on the basis of major peak intensities. Whereas the frequencies of many functional group peaks are stable, others are affected by sample chemistry, preparation techniques, and nearby functional groups (Oudghiri and others, 2014). For example, peaks like the carbon-hydrogen stretches of methyl and methylene groups are very stable in terms of their positions, whereas the distribution of peaks for silicon-oxide stretches varies substantially between quartz (silicate) and aluminosilicates such as illite or kaolinite, and the position of the minor carbonate peak at about 700 cm^{-1} is different for different carbonate minerals—for example, calcite (713 cm^{-1}) and dolomite (730 cm^{-1}). With respect to sediment characterization and environmental health, FTIR can identify specific mineral phases, such as clay types and how they are modified (for example, hydrated, ammoniated), and organic matter alteration (for example, deamination) (Pironon and others, 2003). FTIR can also provide insight into biological activity (for example, protein I and II amide bands, or polysaccharides), petroleum products (for example, aromatic hydrocarbons), and contamination from agricultural, industrial, and domestic sources if contamination is sufficiently great (Sivakumar and others, 2012; Abdel-Gawad and others, 2012).

All samples to be analyzed by FTIR were dried in the collection container at 30 °C prior to analysis. Aliquots (about 100 mg) of dried material were disaggregated, using either an agate mortar and pestle or a steel-plated jaw crusher

(ASC Model JC-300), to achieve a particle size of less than 1 mm. Measurements were made using a Bruker ALPHA spectrometer (model A250/D, Bruker Optics, Inc., Billerica, MA) equipped with an ATR sampling module (model A220/D-01) and a diamond internal-reflection element. Measurements were made and processed to remove background effects and for baseline correction using the OPUS 7 software package (Bruker Optics, Inc., Billerica, MA). Spectra were acquired and converted to absorbance mode from 16 scans between 4,000 and 400 cm^{-1} at a resolution of 4 cm^{-1}. Replicate spectra were measured on every 10th sample to confirm consistent peak positions and absorbance intensities. Commercially available standard sediments (NIST Standard Reference Materials (SRMs) 1944, 2710, and 2711) were analyzed under the same conditions as the environmental samples for consistency with the analytical protocols used in this study.

X-Ray Diffraction

Quantitative whole-rock XRD mineralogic analysis was conducted following the methods described by Eberl (2003). The particle size of the sample was reduced to less than 5 μ and an internal standard was added. XRD data were collected on randomly oriented, homogenized, powdered bed-sediment samples. The instrument setup parameters were as follows: Copper Kα x-ray line radiation source with a scan range from 5 to 65 degrees two-theta using a step size of 0.02 degrees two-theta and a 2-second count time per step. Mineral phases were identified using Jade 9 XRD Pattern Processing, Identification, and Quantification Software (Materials Data, Inc. (MDI), Livermore, CA) referencing the International Centre for Diffraction Data's 2012 PDF-4 and NIST Inorganic Crystal Structure Database. Semi-quantitative mineral concentrations were calculated using MDI Whole Pattern Fit software, which simultaneously calculates a whole pattern fit and a Rietveld refinement (Young, 1995) of the minerals. Reference minerals are selected from the database containing a full crystallographic description of the mineral. A calculated model of the observed pattern is produced by nonlinear least-squares optimization. The calculations, performed by the software, involve the application of various parameters to improve the fit of the model to the observed data. Modeling parameters include background reduction, profile fitting, and lattice constants. The software iterates and minimizes a residual error between the calculated x-ray diffraction patterns from the selected references and the measured scan of the sample. All data were normalized to 100 percent on the basis of the identified minerals within a 1-percent error.

Bioassays

Enzyme inhibition and whole-cell-based bioassays add relevance to chemical data by providing a context for toxicity and other possible contaminant effects. Bioassays used in this study were selected on the basis of a need to assess perturbations in important mammalian and vertebrate biological pathways and (or) as indicators of chemical accumulation from natural and manmade sources. Bioassays selected for this study include those to measure perturbations in steroid hormones (estrogens and androgens), glucocorticoid hormones, and protein phosphatases because they govern major physiological functions in mammals and other vertebrates (Melmed and others, 2011).

Normal endocrine system function includes binding of endogenous steroid hormones to nuclear receptors (NRs) that control gene transcription and therefore modulate physiological processes (Melmed and others, 2011). Synthetic chemicals produced for industrial, pharmaceutical, and agricultural applications also have the potential to bind to NRs and lead to unintended (not instructed by the physiology of the organism) activation or deactivation of processes such as reproduction, growth, and metabolism (endocrine disruption) (Casals-Casas and Desvergne, 2011).

Endocrine disruptors that bind to the estrogen receptor are the most studied, but it is clear that other endocrine-disrupting compounds that disrupt other NR pathways are present in the environment (Stavreva and others, 2012; Zhang and others, 2014). Endocrine-disrupting compounds may impair reproductive and immunological health; modulate the timing of reproductive cycles; and (or) affect growth, development, and general metabolism (Casals-Casas and Desvergne, 2011; Melmed and others, 2011). These effects can occur following exposure to nanogram-per-liter or lower concentrations, which have been measured in wastewater effluent, treated waste, soils, manures, biosolids, surface and groundwater, and, in some cases, even finished drinking water (Westerhoff and others, 2005; Schenck and others, 2012; Kolpin and others, 2002).

Estrogenicity is a measure of estrogen receptor (ER) activation. Endogenous estrogens bind and activate estrogen receptors, a class of NR. They are typically associated with the maintenance and promotion of the female phenotype, but they are also present in males. They are critical to regulation of the reproductive cycle, maintenance of bone growth, modulation of immune function, and control of blood-vessel dilation and general metabolism (Melmed and others, 2011). Estrogens also affect behavior, fluid balance, and adipocyte function and modulate immune function (Casals-Casas and Desvergne, 2011). They are also associated with a number of ER-positive cancers including, but not limited to, breast, uterine, and cervical cancers (Birnbaum and Fenton, 2003).

Androgenicity is a measure of androgen receptor (AR) activation (agonism). Endogenous androgens are anabolic steroids that affect the development and maintenance of the male phenotype as well as other physiological functions. They are not unique to males, however, as both males and females utilize testosterone as a substrate for estrogen synthesis (Melmed and others, 2011). In addition to their biological regulatory role in normal male physiology, they affect skeletal muscle anabolism and adipocyte function and behavior (O'Connor and others, 2004; Singh and others, 2006). They

are associated with the induction of pathologies such as AR-associated cancers (prostate), adult acne, immune dysfunction, and hair loss (alopecia) (Price, 2003; Gilver, 2010; Karantanos and others, 2013).

Glucocorticoids are steroid hormones that are endogenous agonists of the glucocorticoid receptor (GR). They are commonly referred to as stress hormones. They are potent modulators of immune function and are best recognized for down-regulating inflammation (Franchimont, 2004). They are also critical regulators of fetal lung development, glucose metabolism, water balance, behavior, and memory (Munk and others, 1984).

Protein phosphatase 2A (PP2A) is one of many protein serine/threonine phosphatases present in eukaryotic cells that are known to have an important role in cellular processes. PP2A proteins in combination with protein phosphatase 1 make up more than 90 percent of mammalian serine/threonine phosphatase activity, according to Oliver and Shenolikar (1998), who report that more than 50 known environmental toxins are capable of inhibiting protein serine/threonine phosphatases. The list has since grown to include more than 80 microcystin variants (Graham and others, 2010), nodularins, okadaic acid, and dinophysistoxins (Valdiglesias and others, 2013) produced from freshwater and marine phytoplankton, calyculin A purified from marine sponges, fostriecin produced by *Streptomyces pulveraceus*, tautomycin produced by several *Streptomyces* species, and cantharidin produced by blister beetles. Most of these are being researched not only regarding their toxicity, but also as therapeutic pharmaceutical leads (Swingle and Honkanen, 2007). Acute exposures to PP2A inhibitors such as known algal toxins like microcystins, nodularins, and okadaic acids can lead to jaundice, internal bleeding (liver), liver failure, tumors, and even death (Chen and others, 2006; Oliver and Shenolikar, 1998).

Bioassay Sample Preparation

Wet bed-sediment split samples of at least 5 g dry weight were received by the USGS Organic Geochemistry Research Laboratory (OGRL) in Lawrence, Kansas, for bioassay analyses. The entire wet sample was centrifuged (Thermo-Forma 1LP bench top centrifuge, Pittsburgh, Pennsylvania) for 20 minutes at 5,000 G (5,000 times the acceleration of gravity) and 4 °C to remove bulk seawater from the sample. Bulk seawater isolated by centrifuge from a subset of sediment samples was retained for further analysis. Pelletized wet sediment samples were oven dried at 30 °C for 1 to 3 weeks (sandy sediments dry faster than finer sediments). A temperature of 30 °C was selected to minimize degradation of organic chemicals where possible. Dried sediment samples were sieved through a #10 sieve (nominal mesh size 2 µ) to remove intact seashells and other debris. Sieved samples were ground in a porcelain mortar, resieved, and weighed to determine dry weight.

Polar extractions were conducted prior to evaluation by bioassay for androgenicity, estrogenicity, glucocorticoid activity, and protein phosphatase 2A inhibition with minimal sample clean-up steps to facilitate rapid, cost-effective screening and to prevent loss of potentially biologically active compounds. One gram of each dried and sieved sediment sample was combined by porcelain mortar and pestle with 1 g of diatomaceous earth (Hydromatrix, Varian, Inc., Palo Alto, CA) to improve extraction efficiency. Sediment/Hydromatrix samples were loaded into 40-mL amber volumetric glass vials for extraction. Samples were extracted with a 10-mL aliquot of acidified acetonitrile (0.1-percent formic acid), rotated for 24 hours at 30 °C, and centrifuged at 3,000 G for 10 minutes, and solvent was decanted. Samples were re-extracted with an additional 10-mL aliquot of acidified acetonitrile (0.1-percent formic acid) for 2 hours, then centrifuged, and solvent was decanted for a total of 20 mL of extraction solvent. Fine particulates were removed by filtration with 0.7-µ glass-fiber syringe filtration prior to analysis. Sample extracts were evaporated to near dryness at 30 °C under a nitrogen blanket (103-172 kilopascals (kPa); Turbovap, Zymark Corp., Hopkinton, Massachusetts) and solvent was exchanged with 4 mL of methanol/deionized (DI) water (50:50 v/v). Two milliliters of 50:50 methanol/DI water extracts were shipped overnight to the USGS Leetown Science Center (Kearneysville, West Virginia) for analysis for estrogen, androgen, and glucocorticoid activity using yeast bioreporter assays.

The remaining 2-mL extracts were split in half. The 1-mL aliquots of the 50:50 methanol/DI water extracts were evaporated to remove methanol and replaced with DI water at a final volume of 1 mL for use with the PP2A inhibition assay. All samples were filtered at their final stage by 0.45-µ glass-fiber syringe filtration to remove particulates that formed during solvent exchanges and storage prior to analysis. Samples for the estrogenicity, androgenicity, and glucocorticoid activity assays were further clarified by centrifugation at 8,000 G for 5 minutes in an Eppendorf 5415D centrifuge (Eppendorf, Hauppauge, New York).

Bioassay Analytical Methods

Extraction effectiveness for each bioassay was evaluated through extracted, unamended and amended Ottawa Sand and bed-sediment samples, replicate analyses of amended samples, and replicate extractions of sediment subsamples. Ottawa Sand and bed-sediment samples were amended at the middle to upper range of inhibition or concentration by either an individual standard matched to the given assay or a standard mixture of 17-beta-estradiol (for estrogen), dihydrotestosterone (for androgen), desoxycorticosterone (for glucocorticoid), and microcystin lysine-arginine (LR) amino acid side chain substitutions (for PP2A).

Inhibition of the bioreporter by extracts was determined using bioluminescent yeast reporter (BLYR; Sanseverino and others, 2009). Strain BLYR was grown to an optical sample density measured at 600 nanometer (nm) (OD_{600}) of 0.5 absorption units. Doubling dilution series of extracts of 0 to 50 percent were prepared for 20 percent of all extracts. All samples were run in duplicate wells. This prescreening

indicated that a 1:80 dilution of extract was necessary to achieve approximately 50-percent inhibition or less of the reporter. All samples were screened for toxicity at a dilution of 2.5 percent. Strain BLYR was added to samples and incubated for 4 hours at 30 ºC. Toxicity was expressed as the percent reduction in bioluminescence of samples relative to yeast cultured in growth media containing 2.5 percent methanol (negative control) alone. Positive controls for inhibition included yeast incubated in 10 percent sodium azide and 2.5 percent methanol. Luminescence was read using a SpectraMax® M4 (Molecular Devices, Sunnyvale, CA) in luminescence mode. Duplicate plates were run on separate days to demonstrate reproducibility for all endocrine assays.

Total estrogenicity was determined using the bioluminescent yeast estrogen screen (BLYES) as described by Ciparis and others (2012), with slight modification. Strain BLYES was purchased from 490 Biotech (Knoxville, Tennessee). Estrogen equivalents were determined by interpolation to a standard curve of 17-beta-estradiol. Yeast were grown to an OD_{600} of 0.5 absorption units. Methanol in all wells was at a final concentration of 2.5 percent as determined from the inhibition and toxicity tests. Strain BLYES was added to samples and incubated for 4 hours at 30 ºC. All samples and standards were run in duplicate wells. Luminescence was read using a SpectraMax® M4 in luminescence mode. ER activity was determined by interpolation to the standard curve using a four-parameter regression model generated in SoftMax® Pro 6.2.2. Given the observed toxicity in greater than 90 percent of bed-sediment extracts, data are reported only as detected or not detected. Estrogenic activity was reported as a detection when assay response was 1 standard deviation (1SD) or greater above the negative control. Results greater than or equal to 1SD above the result obtained for the negative control were reported as positive (+) and values less than 1SD below the result for the negative control were reported as negative (-). All plates included negative controls (growth media containing 2.5 percent methanol). An additional control including 200 picomolar (pM) of 17-beta-estradiol was included on all plates to assess interassay plate variation. If the relative standard deviation (RSD) of 17-beta-estradiol between plates exceeded 20 percent, the results were rejected and the assay was repeated.

Androgenicity was determined using yeast strain DSY-1555. Yeast were grown in synthetic complete media without leucine, uracil, or tryptophan (SC-LUW) growth media to an OD_{600} of 0.5 absorption units. A standard curve was generated using dihydrotestosterone. All sample extracts were diluted with SC-LUW media to a final methanol concentration of 2.5 percent, resulting in a 1:80 dilution of the extract. Strain DSY-1555 was added to samples and incubated for 4 hours at 30 ºC, according to the method of Balsiger and others (2010). All samples and standards were run in duplicate wells. Beta-galactosidase (β-gal) was developed using the Tropix Gal Screen Kit (Applied Biosystems, Foster City, CA) with buffer B, according to manufacturer protocols. Luminescence was read using a SpectraMax® M4 in luminescence mode. AR activity was determined by interpolation to the standard curve using a four-parameter regression model generated in SoftMax® Pro 6.2.2. Given the observed toxicity in greater than 90 percent of bed-sediment extracts, data are reported only as detected or not detected. Interpolated values greater than 1SD above the lowest standard value were considered a detection. Androgen activity was reported as a detection when assay response was 1SD or greater above the results obtained for the negative control. Results greater than or equal to 1SD above background were reported as positive (+) and values less than 1SD were reported as negative (-). Standard curves were run on all plates. All plates included negative controls (growth media containing 2.5 percent methanol). An additional control including 20 nanomolar (nM) of dihydrotestosterone was included on all plates to assess interassay plate variation. If the RSD exceeded 20 percent, the results were rejected and the assay was repeated.

Activation of the human glucocorticoid receptor (GR) was determined using yeast strain MCY-098. Culture conditions were identical to those used for strain DSY-1555. The growth medium was SC-LUW. Yeast were grown to an OD_{600} of 0.5 absorption units. A standard curve was generated using deoxycortisone. All sample extracts were diluted with SC-LUW growth media to a final methanol concentration of 2.5 percent, resulting in a 1:80 dilution of the extract. Strain MCY-098 was added to samples and incubated for 4 hours at 30 ºC, according to Balsiger and others (2010). All samples and standards were run in duplicate wells. β-gal was developed using the Tropix Gal Screen Kit (Applied Biosystems, Foster City, CA) with buffer B according to manufacturer protocols. Luminescence was read using a SpectraMax® M4 in luminescence mode. GR activity was determined by interpolation to the standard curve using a four-parameter regression model generated in SoftMax® Pro 6.2.2. Given the observed toxicity in greater than 90 percent of bed-sediment extracts, data are reported as detected or not detected. Interpolated values greater than 1SD above the lowest standard were considered a detection. Glucocorticoid activity was reported as a detection when assay response was 1SD or greater above the negative control. Results greater than or equal to 1SD above background were reported as positive (+) and values less than 1SD above background were reported as negative (-). Standard curves were run on all plates. All plates included negative controls (growth media containing 2.5 percent methanol). An additional control including 20 nM of deoxycortisone was included on all plates to assess interassay plate variation. If the RSD exceeded 20 percent, the results were rejected and the assay was repeated.

Protein phosphatase 2A inhibition in undiluted aqueous bed-sediment extracts was measured using the quantitative, colorimetric assay distributed by Abraxis, LLC (Warminster, PA, PN: 520032) (An and Carmichael, 1994; Bouaicha and others, 2002). Filtered, reconstituted sediment extracts (100 percent DI water) were analyzed by the dissolved-phase procedure as described in the assay instructions (Abraxis,

2014). Semilogarithmic expressions were used to generate calibration curves for each assay run. Plates were analyzed at 405 nm on a MeterTech® AccuReader 96 well plate reader using M965 Mate software (v. 1.0.27, MeterTech, Inc., Nan-Gang, Taipei, Taiwan). Positive PP2A inhibition was noted when assay response was 0.25 micrograms per liter (µg/L) as microcystin-LR equivalents or greater. Responses greater than 2.5 µg/L as microcystin-LR equivalents were diluted back into calibration range, with the final reported concentration corrected for dilution. Positive (microcystin-LR) controls provided by the manufacturer were used to evaluate intra-assay performance with the requirement that positive controls be within 28.3 percent RSD of 1.0 µg/L as microcystin-LR equivalents. Unspiked 100-percent DI water utilized as the extract reconstitution solution was used as a negative control, and both the DI water and Ottawa Sand blank responses were required to be less than 0.25 µg/L as microcystin-LR.

In an attempt to determine the effect of sample matrix on bioreporter response kinetics, standards curves for all hormones were generated in instant ocean®, an Ottawa Sand blank, sample UH401 (81-percent inhibitory), or sample NB459 (5-percent inhibitory). Samples were spiked to a 1:80 dilution and all samples contained 2.5 percent methanol. The growth medium containing 2.5 percent methanol was used as a control. The concentration of a compound at which 50 percent of its maximal effect is observed (EC_{50}) was determined for each sample using SigmaPlot® for Windows v.11.0 (Systat Software, Inc., San Jose, CA).

Site Characteristics, Quality-Assurance Results, and Bed-Sediment-Quality Data

This section of the report presents results of the site characterizations, quality-assurance data, and estuarine bed-sediment-quality data. Data and quality-assurance results are presented for analytical and screening methods for determining chemical and biological characteristics of bed sediment.

Sampling-Site and Study-Region Characteristics

Sampling sites and study regions were characterized to determine land-cover characteristics that might be useful in interpreting bed-sediment data. Two regional summaries were produced for each region—one for the entire region and one for the inundated portion of each region (as defined by the FEMA MOTF surge-extent boundary). The 2011 NLCD Anderson Level II land-cover classes (in square kilometers) were summarized for each region and for inundated parts of the region (table 5, on CD-ROM). Anderson Level I and II land-cover classes also were summarized as percentages for each region and for inundated parts of the region (table 6, on CD-ROM). Counts of businesses in New Jersey and New York within each economic sector were tabulated for each sampling location and region (table 7, on CD-ROM). The number of each spill source and cause combination in New York was tabulated for each sampling location and region (table 8, on CD-ROM). Counts of BSF locations in New Jersey and New York were tabulated for each sampling location and region and identified as being inundated, or not, based on the surge-extent boundary (table 9, on CD-ROM). Counts of combined sewer-outfall and sewage-treatment-plant locations in New Jersey and New York were tabulated for each sampling location and region and identified as being within the surge zone, or not, based on the surge-extent boundary (table 10, on CD-ROM). Counts of flooded businesses and infrastructure in tables 7–10 should be used with caution. The method only accounts for flooding of surface infrastructure, and cannot discern flooding of subsurface structures. For instance, the method indicates that only one sewage-treatment plant was flooded; however, it is known that many more failed as a result of loss of power, flooding below the surface, and other Hurricane Sandy-related damage.

Particle Size

Particle-size analyses of 114 estuarine bed-sediment samples and 5 field replicate samples are reported in table 11 (on CD-ROM). The samples were composed predominantly of sand and silt. Sixty-five percent of the samples were more than 50 percent sand, and 22 percent of the samples were more than 50 percent silt. Thirty-two percent of the samples contained 10 to 30 percent clay particles, and less than 10 percent of the samples had any measurable coarse grains. The five replicate samples differed from each other in average particle size by 1 to 8 percent.

Total Organic Carbon

Concentrations of total organic carbon were measured in samples from 58 estuarine bed-sediment sites (table 12, on CD-ROM). Measured concentrations ranged from 1,100 to 110,000 mg/kg, with a median of 7,100 mg/kg. The 10th- and 90th-percentile concentrations were 1,700 and 30,000 mg/kg, respectively. The table also includes results for four field replicate samples, which were analyzed to assess the variability of the field sample-collection method, and two laboratory split samples, which were analyzed to assess analytical variability. The relative percent difference (RPD) for the field replicates ranged from 27 to 70 percent and the RPD for the laboratory split samples ranged from 0 to 18 percent. The higher variability in the field replicate samples was likely caused by the heterogeneity of the bed sediment in the field. The analytical results for the replicate and split samples were of acceptable quality according to the established EPA Quality Assurance Performance Plan (QAPP) except for samples from NOAA2, where the total organic carbon concentration was less than the RL (1,000 mg/kg) in the environmental sample and 1,700 mg/kg in the corresponding replicate sample.

Metals and Trace Elements

Concentrations of metals and trace elements in samples from 60 estuarine bed-sediment sites, 6 field replicate samples, and 5 laboratory split samples are reported in table 13 (on CD-ROM). The field replicate samples were analyzed to assess the variability of the field sample-collection method and the laboratory split samples were analyzed to assess analytical variability. Other QA/QC data available include the analyses of laboratory blanks, laboratory spikes, laboratory spiked duplicates, field replicates, and SRM 1944 (New Jersey/New York waterway sediment), which were analyzed along with each batch of environmental samples.

Laboratory Blanks and Spike Samples

No metals or trace elements were detected in any of the four laboratory blanks analyzed along with their corresponding environmental samples. Percent recoveries for laboratory trace-element spikes ranged from 80 to 125 percent, with a median of 95 percent; percent recoveries for laboratory mercury spikes ranged from 84 to 100 percent, with a median of 93 percent. RPDs for laboratory trace-element spike duplicates ranged from 0 to 34 percent, with a median of 1 percent; RPDs for laboratory mercury spike duplicates ranged from 1 to 4 percent, with a median of 2 percent.

Standard Reference Materials

Concentrations of metals and trace elements in SRM 1944 are reported in table 14 (on CD-ROM). The percent recoveries based on the NIST-certified values for metals and trace elements ranged from 57 to 133 percent with a median of 99 percent. All reported concentrations were within the 95-percent confidence intervals compared to the NIST-certified value (table 14).

Replicate Samples

Laboratory split and field replicate samples were analyzed as part of the metals and trace-elements bed-sediment analysis. Six field replicates were analyzed to assess the variability of the field sample-collection and laboratory analyses. Laboratory replicates were used to assess variability within the lab as well as possible sample heterogeneity. Subsamples of the bed-sediment sample were removed in the laboratory and subjected to separate extraction and analysis. The analysis of the six field replicates yielded 23 paired concentration comparisons (detections in both samples) and 3 unpaired comparisons (detections in one of the two samples), and all results were considered to be acceptable. For those metals and trace elements that were detected in only one of the two samples, measured concentrations were censored and assigned a "nondetect" value. The median RPD for the six field replicates was 12 percent, with more than 90 percent of the replicates having RPDs less than 50 percent. Analysis of three laboratory replicates yielded 23 paired comparisons and no unpaired comparisons, and all results were considered to be acceptable. The median RPD for the laboratory replicates was 11 percent, with all but one of the replicates having differences less than 33 percent. A set of four homogenized and unhomogenized replicate samples was analyzed to evaluate potential variability introduced during field processing. The paired samples were compared by using a nonparametric t-test, and no significant difference between concentrations was observed (p-value less than 0.05).

Semivolatile Organic Compounds

Concentrations of semivolatile organic compounds including selected PAHs, PCBs, and legacy pesticides in estuarine bed sediment from 52 sampling sites are reported in tables 15, 16, and 17, respectively (on CD-ROM). Five field replicate samples also were analyzed to assess the variability of the field sample-collection method. QA/QC data include analysis results for laboratory surrogates, laboratory blanks, laboratory spikes, laboratory matrix spikes, laboratory matrix spike duplicates, field and laboratory replicates, and SRM 1944 (New Jersey/New York waterway sediment) with each batch of environmental samples. Recovery surrogates were added to each sample to measure method performance. For PAHs, mean percent recoveries and standard deviations of the surrogates acenapthene-d_{10}, phenanthrene-d_{10}, chrysene-d_{12}, perylene-d_{12}, and naphthalene-d_8 were 81 ± 15 percent, 92 ± 12 percent, 102 ± 12 percent, 83 ± 14 percent, and 59 ± 18 percent, respectively. For PCBs and OCPs, mean percent recoveries and standard deviations of the surrogates PCB30, PCB112, PCB198, and 2,4,5,6-tetrachloro-m-xylene (TCMX) were 90 ± 12 percent, 99 ± 7 percent, 100 ± 6 percent, and 90 ± 12 percent, respectively.

Laboratory Blanks and Spike Samples

No compounds were detected in any of the laboratory blanks analyzed along with their corresponding environmental samples. QA/QC results for laboratory spikes consisting of all compounds spiked into DI water were of acceptable quality. Percent recoveries for laboratory spike samples for the PAHs ranged from 67 to 117 percent, with a median of 98 percent. RPDs for spike duplicates ranged from 0 to 51 percent, with a median of 3 percent. Percent recoveries for the PCB congeners ranged from 78 to 116 percent, with a median of 101 percent. RPDs for spike duplicates ranged from 0 to 12 percent, with a median of 2 percent. Percent recoveries for the OCPs ranged from 14 to 130 percent, with a median of 97 percent. RPDs for spike duplicates ranged from 0 to 63 percent, with a median of 2 percent. Recoveries for endrin aldehyde were lowest and most variable, but were considered acceptable on the basis of the EPA QA/QC reporting standards (U.S. Environmental Protection Agency, 2008) and the established EPA QAPP.

Standard Reference Materials

Concentrations of semivolatile organic compounds in SRM 1944 are reported in table 18 (on CD-ROM). The percent recoveries based on NIST-certified values for PAHs, PCBs, and OCPs ranged from 53 to 128 percent with a median of 97 percent, from 70 to 128 percent with a median of 87 percent, and from 72 to 130 percent with a median of 109 percent, respectively. All reported concentrations fell into the acceptable concentration range based on the 95-percent confidence intervals of the NIST-certified value (table 18).

Matrix Spike Samples

A total of six matrix spike samples were also analyzed for PAHs, PCBs and OCPs. The percent recoveries of PAHs, PCBs, and OCPs ranged from 71 to 168 percent (median of 106 percent), from 73 to 130 percent (median of 103 percent), and from 8 to 128 percent (median of 99 percent), respectively. Again, recoveries for endrin aldehyde were lowest but were considered acceptable on the basis of EPA QA/QC reporting standards (U.S. Environmental Protection Agency, 2008) and the established EPA QAPP. Recoveries for the several PAHs were high as a result of the presence of high concentrations of fluoranthene and pyrene in the environmental sample. All matrix spikes were also analyzed as matrix spike duplicates in the laboratory to monitor variability between the spiked samples as part of the established EPA QAPP. The RPDs of the matrix spike/matrix spike duplicate pairs for PAHs, PCBs, and OCPs ranged from 0 to 31 percent with a median of 2 percent, from 0 to 17 percent with a median of 3 percent, and from 0.1 to 28 percent with a median of 3 percent, respectively.

Replicate Samples

Laboratory and field replicates were analyzed as part of the determination of semivolatile organic compounds in bed sediment. Four field replicates were analyzed to assess the variability of the field sample collection and laboratory analysis. Laboratory replicates were used to assess variability within the lab as well as possible sample heterogeneity. Subsamples were removed from the bed-sediment sample in the laboratory and were subjected to separate extraction and analysis. Analysis of the four field replicates yielded 25 paired concentration comparisons (detections in both samples) and 6 unpaired comparisons (detections in one of the two samples). For those compounds that were detected in only one of the two samples, measured concentrations were near the RL and some were reported as estimates. The median RPD for the field replicates was 42 percent, with more than 90 percent of the replicates having differences less than 100 percent. Analysis of three laboratory replicates yielded 26 paired comparisons with no unpaired comparisons, and all data were considered to be of acceptable quality on the basis of the established EPA QAPP. The median RPD for the laboratory replicates was 9 percent, with more than 99 percent of the replicates having differences less than 100 percent.

Wastewater Compounds

Concentrations of wastewater compounds in estuarine bed-sediment samples from 87 sampling sites are reported in table 19 (on CD-ROM). Six field replicate samples also were analyzed to assess the variability of the field sample-collection method. QA/QC data available for the wastewater method include analysis results for blank, spike, and field replicate samples.

Set Blank Samples

On the basis of detections in laboratory set blank samples (clean sediment), samples were censored by using the approach outlined in the USGS Office of Water Quality Technical Memorandum 2012.01 (U.S. Geological Survey, 2011). The approach used to censor data relies on a comparison between the detection in the set blank within the sample preparation set and the environmental data associated with that sample preparation set (U.S. Geological Survey, 2011, approach 1). Concentrations in set blanks generally were low—typically 30 µg/kg or less (table 20, on CD-ROM).

Spike Samples

Set spikes were included with each set of bed-sediment samples to determine percent recoveries for target analytes in reagent-grade water spikes that were analyzed by the laboratory for each set. The percent-recovery data available for the 13 set spikes that correspond to the bed-sediment samples analyzed in this study are summarized in figure 5 and table 21 (on CD-ROM). Mean percent recoveries for the set spikes for these compounds ranged from 0 to 104 percent, with RSDs ranging from 8 to 97 percent. More than half (31 compounds) of the compounds in the wastewater method had low bias (mean recoveries between 60 and 110 percent) and low variability (RSDs less than 30 percent) (fig. 5, table 21). Most of the compounds in the combustion, petroleum, or gasoline compounds group; the other compounds group; and the personal-care or domestic-use compounds group had low bias and low variability. In contrast, few compounds (less than 20 percent) in the plant and animal biochemical compounds group and the plasticizer compounds group had low bias and low variability for the set spike samples.

Replicate Samples

Field replicate samples for the wastewater method included two independent samples collected at the same location in the field but analyzed separately. These replicate

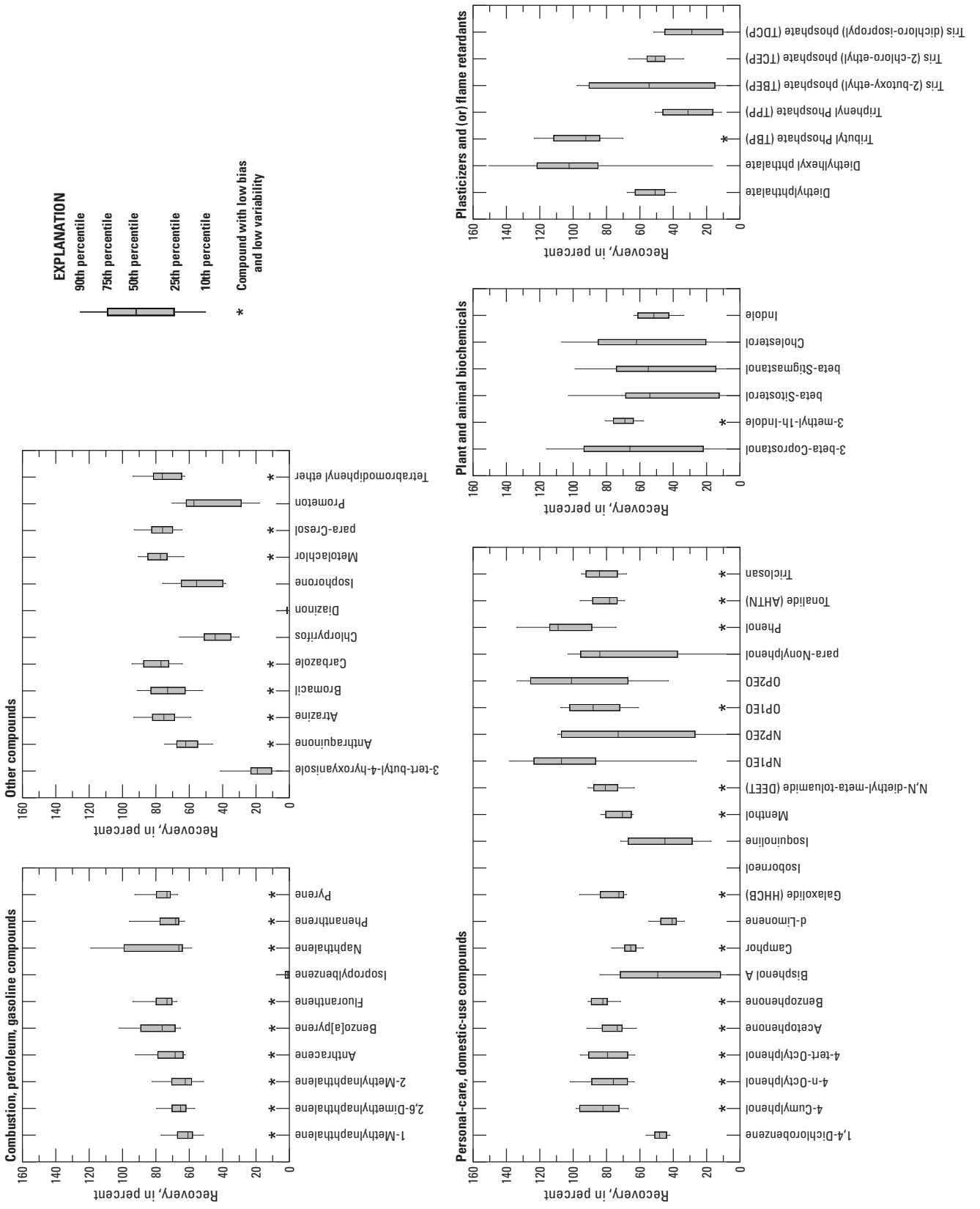


Figure 5. Set spike and matrix spike recoveries for estuarine bed-sediment samples analyzed for wastewater compounds during the Hurricane Sandy reconnaissance study, June–October 2013.

samples were used to assess the combined variability of the field sample collection and laboratory analysis.

Six field replicate samples were analyzed using the wastewater method during the study. This analysis yielded 77 paired concentration comparisons (with detections in both samples), and 22 unpaired comparisons (with a detection in only one of the two samples). The median replicate RPD for these replicates was 27 percent, with most (90 percent) of the replicates having RPDs of 100 percent or less (fig. 6).

Steroid Hormones and Other Compounds

Concentrations of steroid hormones and other compounds for samples from 87 estuarine bed-sediment sampling sites are reported in table 22 (on CD-ROM). Six field replicate samples also were analyzed to assess the variability of the field sample-collection method. QA/QC data available for the steroid hormone method included results for laboratory set blank and spike samples prepared using reagent sand, and laboratory and field replicate samples.

Set Blank Samples

Five compounds were detected in one of the 16 laboratory set blanks associated with the samples analyzed for steroid hormones (table 23, on CD-ROM). With the exception of *trans*-diethylstilbestrol, these blank detections were low (less than 0.07 µg/kg). Concentrations of compounds that were apparent detections in the environmental samples were compared with concentrations measured in the corresponding laboratory blank for the sample preparation set using approach number 1 outlined in USGS Office of Water Quality Technical Memorandum 2012.01 (U.S. Geological Survey, 2011). With this approach, three detections for 17-beta-estradiol, two detections for 17-alpha-estradiol, and two detections for 4-androstene-3,17-dione were censored. The censored concentrations ranged from less than 0.1 to less than 0.4 µg/kg.

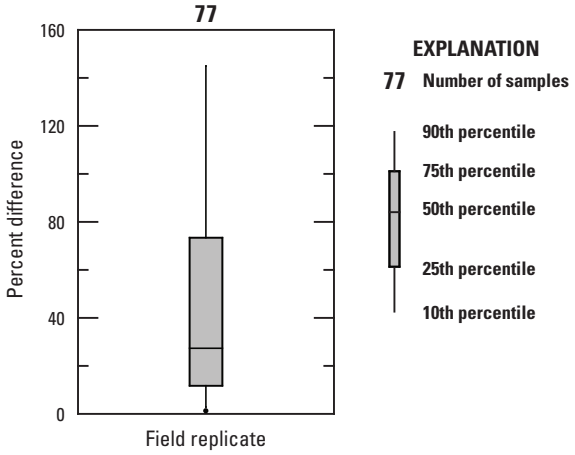


Figure 6. Relative percent difference for field replicates of estuarine bed-sediment samples analyzed for wastewater compounds during the Hurricane Sandy reconnaissance study, June–October 2013.

Spike Samples

Each set of environmental samples has an associated laboratory set spike sample that was prepared by fortifying the method analytes onto reagent-grade sand. Analyte recovery data from 16 set spikes corresponding to the environmental samples are summarized in figure 7 and table 24 (on CD-ROM). Mean analyte recoveries for the set spikes ranged from 90 to 110 percent. RSDs for these recoveries ranged from 4.0 to 8.3 percent except for bisphenol A, which had an RSD of 23 percent.

Eleven matrix spike samples were prepared using splits of bed-sediment samples from the study. Recovery results were similar to those for laboratory set spikes, although recoveries for some of the compounds were lower or more variable. Average matrix spike recoveries ranged from 65 to 126 percent, with the exception of equilenin, which had an average recovery of 20 percent. RSDs for the matrix spikes were generally less than or equal to 25 percent for all of the compounds except dihydrotestosterone (37 percent), testosterone (34 percent), and equilenin (65 percent). Only two matrix spike results were available for cholesterol because concentrations of this compound in the environmental (unspiked) sample were elevated. Hence, it was not possible to compute statistics for method performance for this compound, as such matrix performance for this compound was not well characterized. Recoveries for several compounds (17-alpha-ethynylestradiol, 17-beta-estradiol, 3-beta-coprostanol, 4-androstene-3,17-dione, bisphenol-A, epitestosterone, equilenin, estriol, estrone, mestranol, progesterone, and *trans*-diethylstilbesterol) were similar to those for the set spikes; however, recoveries for many of the compounds were lower for the matrix spikes than for the set spikes. In addition, method performance was more variable for the matrix spikes than for the set spikes, as RSDs for only three compounds (17-alpha-estradiol, estriol, and estrone) were less than 10 percent. The poorer method performance for the matrix spikes may reflect the greater complexity of the matrix associated with the estuarine bed-sediment samples than of the simple reagent-sand matrix used for the set spikes; alternatively, it could result from the comparatively high concentrations of target analytes in the corresponding environmental (unspiked) samples.

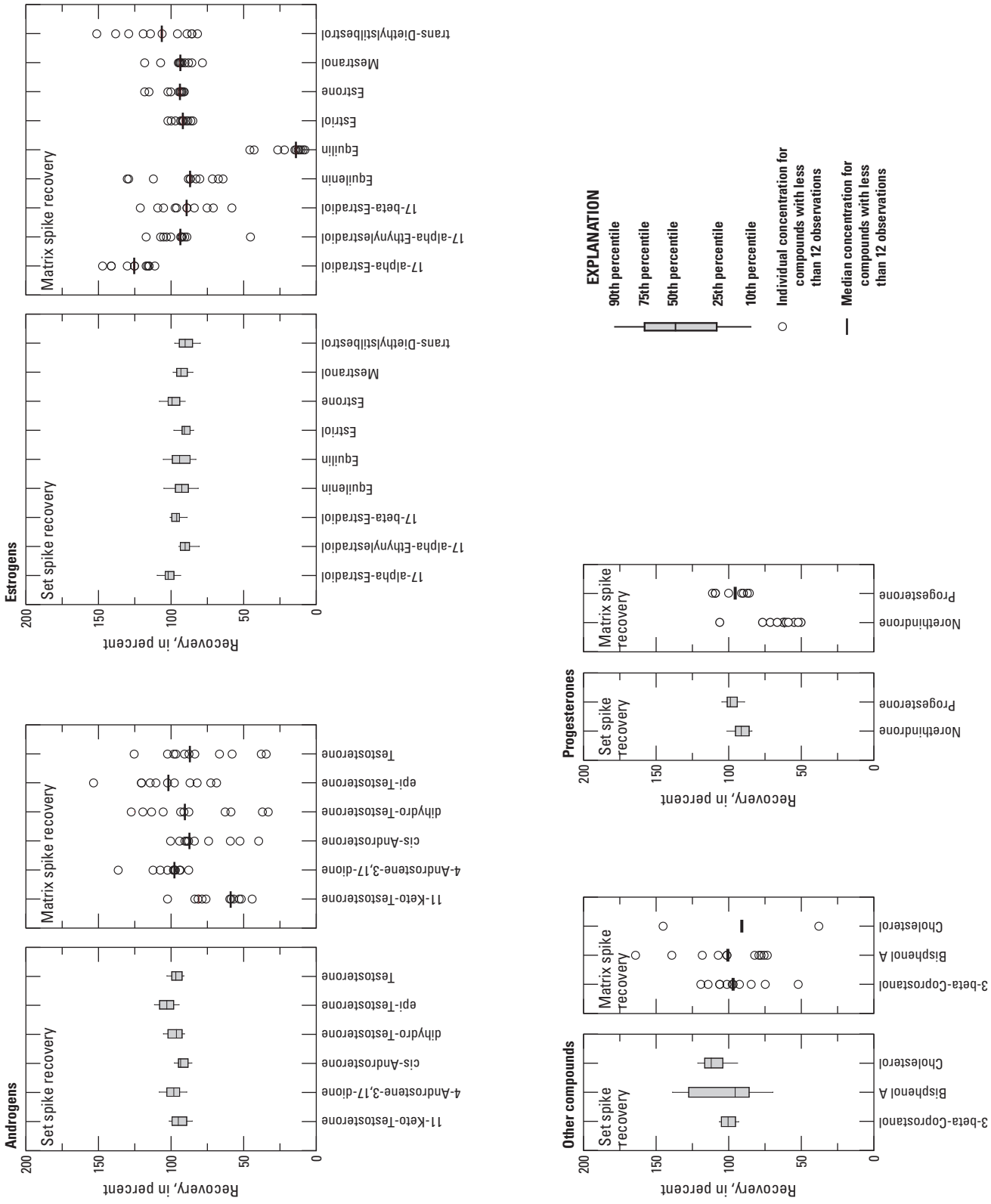


Figure 7. Set spike and matrix spike recoveries for estuarine bed-sediment samples analyzed for steroid hormones during the Hurricane Sandy reconnaissance study, June–October 2013.

Replicate Samples

Laboratory and field replicates were analyzed as part of the determination of steroid hormones in bed sediment. Six field replicates, each consisting of a second sample collected independently at the same location as an environmental sample, were analyzed to assess the combined variability of the field sample-collection methods and laboratory techniques. Laboratory replicates, which consist of splits of the same sample that were extracted separately, were analyzed to assess variability of laboratory techniques as well heterogeneity in the sample.

Analysis of the six field replicates yielded 23 paired concentration comparisons (with detections in both samples) and seven unpaired comparisons (with a detection in only one of the two samples). The median RPD for these analyses was 31 percent, with most (90 percent) of the differences being 80 percent or less (fig. 8). Analysis of the 11 laboratory replicates yielded 51 paired concentration comparisons and 16 unpaired comparisons. The median RPD for the laboratory duplicates was 30 percent, with most (90 percent) of the differences being less than 130 percent. A nonparametric comparison of the median differences for the field and laboratory replicates showed no significant difference at the 0.05 level (fig. 8). Overall, these data indicate that the variability in analytical results due to differences in field collection of samples at the sites where replicates were collected was indistinguishable from the laboratory replicate variability.

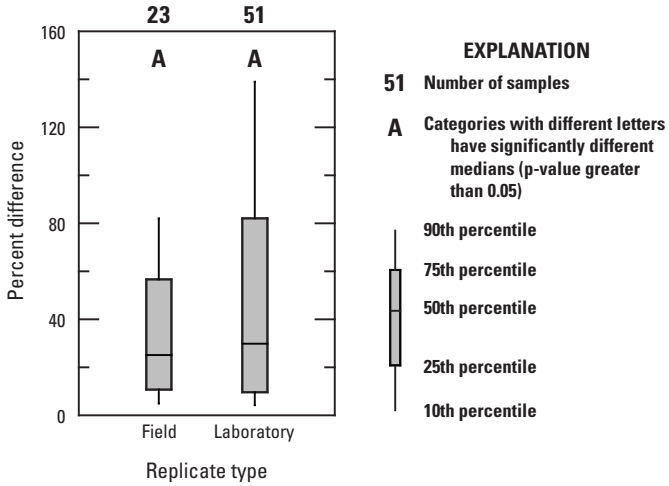


Figure 8. Relative percent difference for field and laboratory replicates of estuarine bed-sediment samples analyzed for steroid hormones during the Hurricane Sandy reconnaissance study, June–October 2013.

Sediment Toxicity

Sediment toxicity for samples from 52 estuarine bed-sediment sites was determined at the USACE–ERDC laboratory (tables 25–30, on CD-ROM). Five field replicate samples also were analyzed to assess the variability of the field sample-collection method. The estuarine amphipod *Leptocheirus plumulosus* was used to determine percent survival, difference in biomass, individual dry weight following a 28-day exposure to bed-sediment samples, and reproductive effects. Reproductive effects were determined by calculating the amphipod survivor:neonate ratio. A laboratory control sample was analyzed with each sample batch. Three sample batches were analyzed along with three control samples. Summary results are reported in tables 25, 26, and 27, and endpoint and initial weight results for all three batches are reported in tables 28, 29, and 30.

Results of the bed-sediment toxicity analyses on amphipods for the 28-day exposure to sediment samples in batch 1 indicate a significant difference in the means for survival between the laboratory control sample and sample BB01 (table 25). Mean biomass weight, individual dry weight, and reproductive effects were also significantly different between BB01 and the corresponding laboratory control sample.

Results of the bed-sediment toxicity analyses on amphipods for the 28-day exposure to sediment samples in batch 2 indicate a significant difference in the means for survival between the laboratory control sample and sample NOAA2, but this result was not duplicated in the replicate sample (table 26). Lack of duplication in replicate samples is most likely related to the method of replicate sample collection and (or) sediment heterogeneity (Daniel Farrar, U.S. Army Corps of Engineers, written commun., 2014). Additionally, significant differences in mean biomass weight, individual dry weight, and reproductive effects were observed between NOAA2 and the corresponding laboratory control sample for this site.

Results of the bed-sediment toxicity analyses on amphipods for the 28-day exposure to sediment samples in batch 3 indicate a significant difference in the means for survival between the laboratory control sample and samples BHB01 and HHB01. These results were not duplicated in the replicate sample, likely as a result of the sampling method and (or) sediment heterogeneity (table 27). Significant differences were determined in mean biomass weight between the laboratory control sample and GSB06, HHB01, and BHB01 (result not duplicated in replicate sample, likely as a result of the sampling method). Additionally, GSB06 and the laboratory control sample were significantly different with respect to the means for individual dry weight and reproductive effects.

X-Ray Fluorescence

XRF results for major and trace elements in samples from 166 estuarine bed-sediment sampling sites are reported in tables 31 and 32 (on CD-ROM), respectively. Eleven field

replicate samples also were analyzed to assess the variability of the field sample-collection method. XRF results for major and trace elements with an atomic number greater than 12 (magnesium) are shown. These data represent heterogeneous material and may be biased as a result of the presence of large shells or pebbles, which can increase the concentration of calcium and silica, respectively.

The errors in XRF measurements are reported in tables 31 and 32 as twice the standard deviation (two sigma). Measurement errors are limited to the error associated with instrument performance and do not reflect the variability of the sample resulting from its heterogeneity. The LOD for any particular element is equivalent to three sigma, is matrix dependent, and therefore is calculated for each element in each sample.

Almost all the "balance" values reported in tables 31 and 32 exceed 600,000 ppm (equivalent to greater than 60 percent by weight). These high balance values show that the combined concentrations of hydrogen, carbon, nitrogen, oxygen, fluorine, and sodium are large in all the samples. Most likely the sodium concentration is substantial in all the samples given that any seawater present was evaporated and the resultant brine solidified. This hypothesis is supported by the high chloride values observed throughout the dataset.

Bed sediment analyzed in this screening effort was dominated by silica, aluminum, and, in some cases, iron. The following correlations were noted in the data: (1) Silica and aluminum concentrations have a strong inverse correlation, which indicates that samples high in aluminum are clay-rich whereas samples high in silica are dominated by quartz; (2) potassium and aluminum concentrations are strongly correlated, indicating that most of the potassium is occupying sites in clay and feldspar minerals; (3) iron has a positive correlation with aluminum, chromium, arsenic, sulfur, and zinc; (4) aluminum correlates positively with potassium, chromium, vanadium, titanium, and thallium; and (5) titanium and vanadium display a strong positive correlation with each other. In addition to the correlations noted above, manganese and iron concentrations are elevated in some samples, and elevated concentrations of calcium are likely derived from the abundant shell material in the samples.

Standard performance was monitored with NIST SRM 2710 of highly elevated trace-element concentrations in Montana soil. This standard was chosen because it was deemed most similar to sediments in the study area. Performance for major and trace elements was variable (tables 33 and 34, respectively; on CD-ROM). Concentrations of most major elements had percent differences (offsets) of 5 to 10 percent from the standard. The differences for aluminum and titanium were more than 20 percent, and those for phosphorus and sulfur exceeded 100 percent. For trace-element concentrations, the percent differences from the standard for half the elements were in the range of 5 to 25 percent. Differences for copper, lead, and zinc were all less than 5 percent. Errors for other elements, such as chromium and nickel, ranged from 50 to more than 400 percent (table 34).

Attenuated Total Reflectance–Fourier Transform Infrared Spectroscopy

Baseline-corrected ATR–FTIR spectra for samples collected from 167 estuarine bed-sediment sampling sites are reported in table 35 (on CD-ROM). Twenty-one field replicate samples also were analyzed to assess the variability of the field sample-collection method. The mineral content of all samples was dominated by large silicon-oxygen bands indicative of quartz and aluminosilicates, and some carbonates; these observations corroborate the mineralogy determined by XRF and XRD analysis. Organic functional group identification was largely masked by large absorbances caused by an abundance of inorganic compounds and a smaller representation of organic functional groups. The lack of evidence supporting the presence of organic amines, proteins, and aromatic and unsaturated hydrocarbons may result from a combination of compound volatility, sample drying at 30 °C, the unextracted nature of the samples, or the absence of compounds bearing these functional groups. However, two separate weak aliphatic carbon-hydrogen stretching bands were frequently observed between 2,800 and 3,000 cm^{-1}. It is not clear whether low-concentration unsaturated and (or) aromatic functionality existed given (1) the weak absorptions that occur at wavenumbers greater than 3,000 to 3,100 cm^{-1} and (2) the interference of carbonate and silica bands in the fingerprint and aromatic regions (for example, 400–1,600 cm^{-1}), which would overlap where stronger unsaturated/aromatic bands typically occur.

Additional sample treatment is needed to fully resolve identification of bands at approximately 1,430 and 1,640 cm^{-1} and to determine whether they represent organic, inorganic, or mixed functional groups. Absorptions at about 1,640 cm^{-1}, when they occurred, were weak and broad, and did not strongly support the presence of carbonyl groups such as protein I and II amide bands (Abdel-Gawad and others, 2012), but this peak has been identified as a metal carboxylate (Oudghiri and others, 2014). However, the presence of weak-to-moderate absorption bands in the 1,430 and 1,640 cm^{-1} range in combination with silicon-oxygen bands and SiO–H stretching (approximately 3,600 cm^{-1}) is also consistent with hydrated interlayer ammoniated aluminosilicate clays such as illites and smectites (Pironon and others, 2003). The presence of absorption bands at 712, 874, and 1,430 cm^{-1} has also been described as indicative of calcite (Moros and others, 2010).

X-Ray Diffraction

The quantitative mineralogy for 13 bed-sediment samples is given in table 36 (on CD-ROM). All the samples contain abundant quartz, feldspar, and calcite with minor amounts of pyrite, halite, aragonite (formed by biological and physical processes in marine and freshwater environments), and clay minerals (chlorite, illite, illite-smectite, and kaolinite). The sample mineralogy ranges from silica-rich (high quartz

content—for example, 89 percent for the sample collected at site JB701) to clay-rich (for example, 32 percent for the sample collected at site NOAA1).

Estrogenicity, Androgenicity, Glucocorticoids, and Protein Phosphatase 2A Inhibition

Bioassays conducted for this study measure perturbations in steroid hormones (estrogens and androgens), glucocorticoid hormones, and protein phosphatase 2A. These hormones govern major physiological functions in mammals and other vertebrates. Bioassay data can be used along with chemical data for evaluating toxicity and other contaminant effects.

Inhibition of Yeast Bioreporter Assays

Inhibition of the bioreporter by the bed-sediment extracts was evaluated by screening 1:80 dilutions of extract with strain BLYR. This strain constitutively expresses the bioluminescent reporter. Although a reduction in bioluminescence may indicate overt toxicity, it may also indicate alterations in the bioreporter cellular biochemistry. In either case, such a reduction indicates the presence of analytes in an extract that will affect the relation of the bioreporter to control samples. Here, inhibition of the bioreporter was observed in all samples. The range of inhibition was 5 to 89 percent. Average inhibition of the sediment samples screened at this dilution was 61 percent. Average inhibition by the Ottawa Sand blank and the spiked Ottawa Sand blanks was 25 and 33 percent, respectively.

Nuclear Receptor Reporter Quality Control

Hormone standards were spiked into 1:80 dilutions of Ottawa Sand blank, Instant Ocean®, and samples collected at sites UH401 (81 percent inhibitory) and NB459 (5 percent inhibitory) to evaluate the effects of these matrices of EC_{50} and general kinetics of the bioreporter (table 37, on CD-ROM; fig. 9). Variability was observed in the LOD, EC_{50}, and kinetics of the bioreporter response to standards. This relation differed among the assays as well. Inhibition of the bioreporter was observed in samples spiked with all bioactive compound standards. A dose response was observed and is likely associated with the presence of diazinon in the standard.

Nuclear Receptor Activation

A total of 145 bed-sediment samples were screened for estrogen, androgen, or glucocorticoid activity (table 38, on CD-ROM). Table 38 also shows results for 13 field replicate samples, which were analyzed to assess the variability of the field sample-collection method. On the basis of unknown interferences with bioreporter kinetics and indicated by the quality-control measures, nuclear receptor activation is reported here as detected or not detected. The LOD varied with the individual sample matrix, but determination of the LOD on a per sample basis was beyond the scope of this screening. Of the 158 samples screened, 9.5, 17.1, and 4.4 percent were positive for estrogenic, androgenic, and glucocorticoid activity, respectively. By design, false positives are exceptionally rare in these yeast reporter assays. The positives identified here are highly unlikely to be artifacts; rather, it is more likely that this dataset included a number of false negatives. These samples were diluted 1:80 to reduce the effect of bioreporter inhibition. The EC_{50} values for the estrogen, androgen, and glucocorticoid assays were 233 pM, 15 nM, and 29 nM, respectively—that is, the sensitivity of the estrogen assay was greater than that of the androgen or glucocorticoid assay. Although these data are useful for guiding further investigation, additional optimization of sample preparation is needed for these bioassays to be reliable screening tools in which estimated equivalency concentrations can be assigned.

Inhibition of Protein Phosphatase 2A

The PP2A assay used in this study is available as a quantitative assay for PP2A inhibitors such as microcystins, nodularins, and okadaic acids in surface water; however, to our knowledge this is the first use of this assay in extracts of estuarine bed sediments. Unamended Ottawa Sand was extracted in each set of samples where no inhibition was measured above the minimum reporting level (MRL) of the assay (MRL 0.25 µg/L as microcystin-LR). Unamended extracts of NIST 1944 sediment were used as a pre-Hurricane Sandy NY/NJ Harbor certified reference material in each extraction run; all results were positive for PP2A inhibition, with a mean concentration of 1.52 µg/L as microcystin-LR (RPD 3.5 percent, n=10). Unamended blank water with up to 10 percent methanol and 36 grams per liter (g/L) of Instant Ocean® were examined to ensure that residual solvent from exchange and extracted salinity would not cause false positives in the PP2A assay. Microcystin-LR positive controls (1 µg/L) were analyzed with each run to evaluate assay performance and had a mean microcystin-LR concentration of 1.03 µg/L (RPD 4.9 percent, n=52). Microcystin-LR-amended Ottawa Sand extracts tested positive for PP2A inhibition. No false positives were observed as a result of the addition of up to 10 percent methanol or the increase in salinity resulting from the addition of up to 36 g/L of Instant Ocean®.

Samples from 164 bed-sediment sampling sites were analyzed for PP2A inhibition (table 38). Fifteen field replicate samples also were analyzed to assess the variability of the field sample-collection method. Binary PP2A inhibition results were positive (+) for 96 percent (n=180) of samples (MRL 0.25 µg/L as microcystin-LR). After serial dilution of up to 1:40 of a subset of positive extracts, some samples still showed positive PP2A inhibition, indicating that the initial detections were not false positives. Additional work is needed to confirm the detections, however, and to understand how matrix effects and the extraction process might influence the future presentation of quantitative sample extract results. Microcystin-LR recovery/quantitation appeared to be sample dependent as a result of matrix effects.

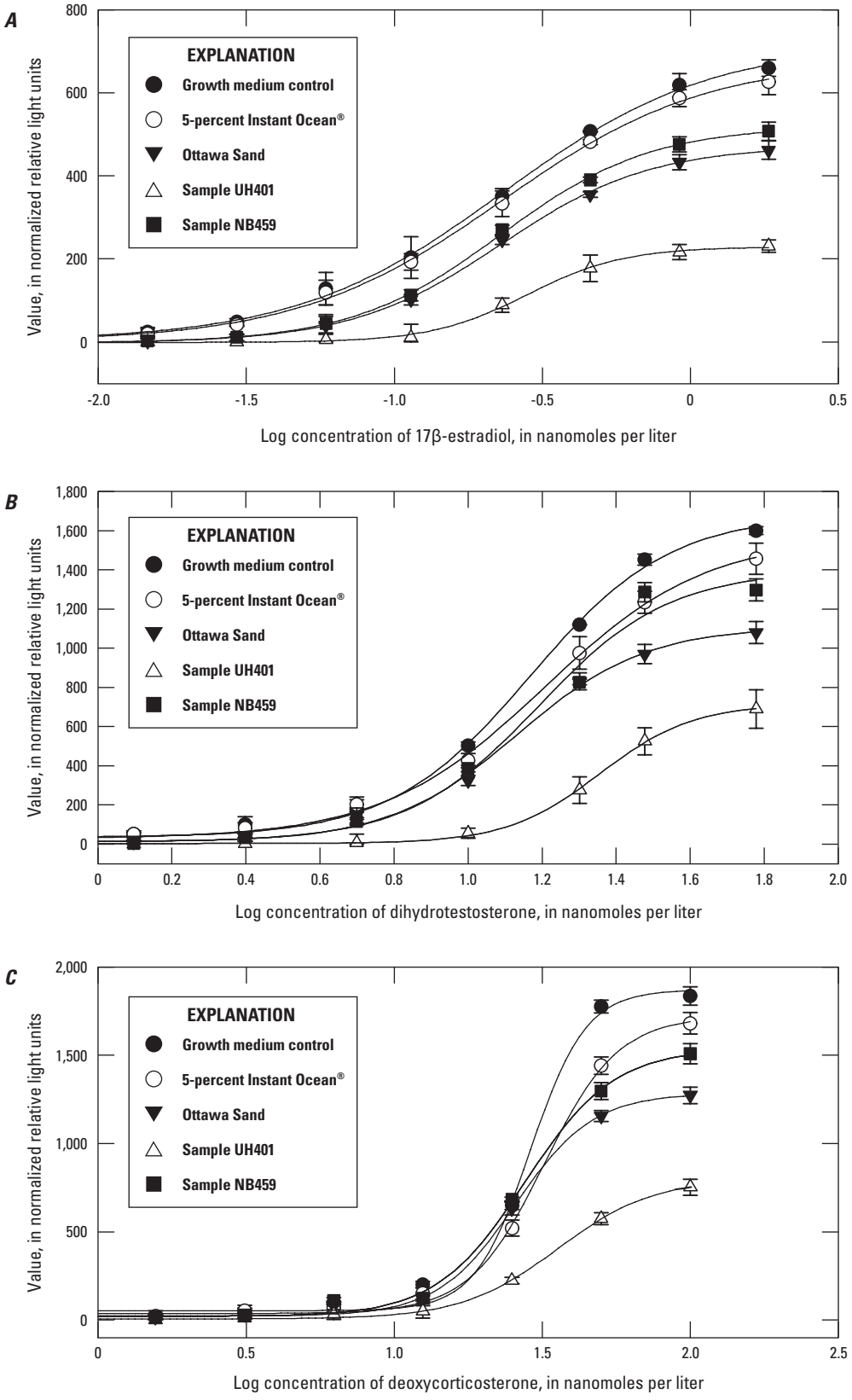


Figure 9. Kinetics of *A*, the strain BLYES (estrogen receptor activation); *B*, the strain DST-1555 (androgen receptor activation); and *C*, the strain MCY-098 (glucocorticoid receptor activation) in the presence of 1:80 dilutions of different matrices.

References Cited

Abdel-Gawad, F.K., Ibrahim, H.S., Ammar, N.S., and Ibrahim, M., 2012, Spectroscopic analysis of pollutants in water, sediment and fish. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, v. 97, p. 771–777.

Abraxis, LLC, Microcystins/Nodularins PP2A, Microtiter Plate, test for the detection of microcystins and nodularins in water, accessed May 26, 2014, at *http://www.abraxiskits.com/uploads/products/docfiles/371_APP2A%20PL%20Users%20Guide.pdf*.

Adams, D.A., and Benyi, Sandra, 2003, Sediment quality of the NY/NJ Harbor system: A 5-year revisit—An investigation under the Regional Environmental Monitoring and Assessment Program (REMAP): Edison, N.J., U.S. Environmental Protection Agency—Region 2, EPA/902-R-03-002.

An, J., and Carmichael, W.W., 1994, Use of a colorimetric protein phosphatase inhibition assay and enzyme linked immunosorbent assay for the study of microcystins and nodularins: Toxicon, v. 32, p. 1495–1507.

Anderson, J.R., Hardy, E.E., Roach, J.T., and Witmer, R.E., 1976, A land use and land cover classification system for use with remote sensor data: U.S. Geological Survey Professional Paper 964, 28 p., *http://landcover.usgs.gov/pdf/anderson.pdf*.

Balsiger, H.A., de la Torre, R., Lee, W.-Y., and Cox, M.B., 2010, A four-hour yeast bioassay for the direct measure of estrogenic activity in wastewater without sample extraction, concentration, or sterilization: Science of the Total Environment, v. 408, no. 6, p. 1422–1429.

Birnbaum, L.S., and Fenton, S.E., 2003, Cancer and developmental exposure to endocrine disruptors: Environmental Health Perspectives, v. 111, no. 4, p. 389–394.

Bonnevie, N.L., Huntley, S.L., Found, B.W., and Wenning, R.J., 1994, Trace metal contamination in surficial sediments from Newark Bay, New Jersey: Science of The Total Environment, v. 144, iss. 1–3, p. 1–16, DOI: 10.1016/0048-9697(94)90423-5.

Bopp, R.F., Simpson, H.J., Chillrud, S.N., and Robinson, D.W., 1993, Sediment-derived chronologies of persistent contaminants in Jamaica Bay, New York: Estuaries, v. 16, iss. 3, p. 608–616.

Bouaïcha, N., Maatouk, I., Vincent, G., and Levi, Y., 2002, A colorimetric and fluorometric microplate assay for the detection of microcystin-LR in drinking water without preconcentration: Food and Chemical Toxicology, v. 40, p. 1677–1683.

Burkhardt, M.R., Zaugg, S.D., Smith, S.G., and ReVello, R.C., 2006, Determination of wastewater compounds in sediment and soil by pressurized solvent extraction, solid-phase extraction, and capillary-column gas chromatography/mass spectrometry: U.S. Geological Survey Techniques and Methods, book 5, chap. B2, 40 p., *http://pubs.usgs.gov/tm/2006/tm5b2/*.

Buxton, H.T., Andersen, M.E., Focazio, M.J., Haines, J.W., Hainly, R.A., Hippe, D.J., and Sugarbaker, L.J., 2013, Meeting the science needs of the Nation in the wake of Hurricane Sandy—A U.S. Geological Survey science plan for support of restoration and recovery: U.S. Geological Survey Circular 1390, 26 p., *http://pubs.usgs.gov/circ/1390/*.

Casals-Casas, Cristina, and Desvergne, Béatrice, 2011, Endocrine disruptors: from endocrine to metabolic disruption: Annual Review of Physiology, v. 73, p. 135–162, DOI: 10.1146/annurev-physiol-012110-142200.

Chen, Y.-M., Lee, T.-H., Lee, S.-J., Huang, H.-B., Huang, R., and Chou, H.-N., 2006, Comparison of protein phosphatase inhibition activities and mouse toxicities of microcystins: Toxicon, v. 47, p. 742–746.

Ciparis, S., Iwanowicz, L.R., and Voshell, J.R., 2012, Effects of watershed densities of animal feeding operations on nutrient concentrations and estrogenic activity in agricultural streams: Science of Total Environment, v. 414, p. 268–276.

Eberl, D.D., 2003, User's guide to RockJock—a program for determining quantitative mineralogy from powder X-ray diffraction data: U.S. Geological Survey Open-File Report 2003–78, 47 p.

Escher, B.I., Allinson, M., Altenburger, R., Bain, P.A., Balaguer, P., Busch, W., Crago, J., Denslow, N.D., Dopp, E., Hilscherova, K., Humpage, A.R., Kumar, A., Grimaldi, M., Jayasinghe, B.S., Jarosova, B., Jia, A., Makarov, S., Maruya, K.A., Medvedev, A., Mehinto, A.C., Mendez, J.E., Poulsen, A., Prochazka, E., Richard, J., Schifferlie, A., Schlenk, D., Scholz, S., Shiraishi, F., Snyder, S., Su, G., Tang, J.T.M., van der Burg, B., van der Linden, S.C., Werner, I., Westerheide, S.D., Wong, C.K.C., Yang, M., Yeung, B.H.Y., Zhang, X., and Leusch, F.D.L., 2014, Benchmarking organic micropollutants in wastewater, recycled water and drinking water in vitro bioassays: Environmental Science and Technology, v. 48, p. 1940–1956.

Federal Emergency Management Agency—Modeling Task Force, 2013, Final high resolution–field-verified Hurricane Sandy storm surge data for New York and New Jersey, accessed December 2, 2013, at *http://184.72.33.183/GISData/MOTF/Hurricane%20Sandy/*.

Foreman, W.T., Gray, J.L., ReVello, R.C., Lindley, C.E., Losche, S.A., and Barber, L.B., 2012, Determination of steroid hormones and related compounds in filtered and unfiltered water by solid-phase extraction, derivatization, and gas chromatography with tandem mass spectrometry: U.S. Geological Survey Techniques and Methods, book 5, sec. B, chap. 9, 118 p., *http://pubs.usgs.gov/tm/5b9/*.

Franchimont, D., 2004, Overview of the actions of glucocorticoids on the immune response: a good model to characterize new pathways of immunosuppression for new treatment strategies: Annual, N.Y. Academy of Sciences, v. 1024, p. 124–137.

Gee, G.W., and Or, D., 2002, Particle-size analysis, *in* Dane, J.H., and Topp, G.C., eds., Methods of soil analysis, Part 4—physical methods: Madison, Wisc., Soil Science Society of America, Soil Science Society of America Book Series no. 5, p. 255–293.

Gilver, S.C., 2010, Sex steroids as inflammatory regulators: The Journal of Steroid Biochemistry and Molecular Biology, v. 120, no. 2–3, p. 105–115. doi: 10.1016/j.jsbmb.2009.12.015.

Graham, J.L., Loftin, K.A., Meyer, M.T., and Ziegler, A.C., 2010, Cyanotoxin mixtures and taste-and-odor compounds in cyanobacterial blooms from the midwestern United States: Environmental Science and Technology, v. 44, p. 7361–7368.

Hall, G., Buchar, A., and Bonham-Carter, G., 2012, Quality Control Assessment of Portable XRF Analyzers: development of standard operating procedures, performance on variable media and recommended uses: Sudbury, Canada, Canadian Mining Industry Research Organization (CAMIRO) Exploration Division, CAMIRO Project 10E01 Phase 1.

Hladik, M.L., Orlando J.L., and Kuivila, K.M., 2009, Collection of pyrethroids in water and sediment matrices: development and validation of a standard operating procedure: U.S. Geological Survey Scientific Investigations Report 2009–5012, 22 p., accessed September 3, 2013, at *http://pubs.usgs.gov/sir/2009/5012/*.

Jin, S., Yang, L., Danielson, P., Homer, C., Fry, J., and Xian, G., 2013, A comprehensive change detection method for updating the National Land Cover Database to circa 2011: Remote Sensing of Environment, v. 132, p. 159–175.

Karantanos, T., Corn, P.G., and Thompson, T.C., 2013, Prostate cancer progression after androgen deprivation therapy: mechanisms of castrate resistance and novel therapeutic approaches: Oncogene, v. 32, p. 5501–5511.

Karuppiah, M., and Gupta, G., 1998, Chronological changes in toxicity of and heavy metals in sediments of two Chesapeake Bay tributaries. Journal of Hazardous Materials., v. 59, p. 159–166.

Kenward, A., Yawitz, D., and Raja, U., 2013, Sewage overflows from Hurricane Sandy: Princeton, N.J., Climate Central, accessed December 2, 2013, at *http://www.climatecentral.org/pdfs/Sewage.pdf*.

Kolpin, D.W., Furlong, E.T., Meyer, M.T., Thurman, E.M., Zaugg, S.D., Barber, L.B., and Buxton, H.T., 2002, Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999-2000: a national reconnaissance: Environmental Science and Technology, v. 36, no. 6, p. 1202–1211. DOI: 10.1021/es011055j.

Lauenstein, G.G., and Cantillo, A.Y.,1993, Sampling and analytical methods of the National Status and Trends Program National Benthic Surveillance and Mussel Watch projects, 1984–1992 (v. 71): U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of Ocean Resources Conservation and Assessment, Coastal Monitoring and Bioeffects Assessment Division, 157 p.

Melmed, S., Polonsky, K.S., Reed Larsen, P., and Kronenberg, H.M., 2011, Williams textbook of endocrinology (12th ed.): Cambridge, Mass., Elsevier Health Sciences, 1904 p.

Moros, J., Cassella, R.J., Barciela-Alonso, M.C., Moreda-Pińeiro, A., Herbello-Hermelo, P., Bermejo-Barrera, P., Garrigues, S., and de la Guardia, M., 2010, Estuarine sediment quality assessment by Fourier-transform infrared spectroscopy: Vibrational Spectroscopy, v. 53, p. 204–213.

Munk, A., Guvre, P.M., and Holbrook, N.J., 1984, Physiological functions of glucocorticoids in stress and their relation to pharmacological actions: Endocrine Reviews. v. 5, no. 1, p. 25–44.

New York State Department of Environmental Conservation, 2013, Division of Environmental Remediation 2012/2013 annual report, accessed December 2, 2013, at *http://www.dec.ny.gov/docs/remediation_hudson_pdf/derannualreport.pdf*.

O'Connor, D.B. , Archer, John, and Wu, F.C.W., 2004, Effects of testosterone on mood, aggression, and sexual behavior in young men: a double-blind, placebo-controlled, crossover study: Journal of Clinical Endocrinology and Metabolism, v. 89, no. 6, p. 2837–2845.

Oliver, C.J., and Shenolikar, S., 1998, Physiologic importance of protein phosphatase inhibitors: Frontiers in Biosciences, v. 3, p. 961–972.

Oudghiri, F., García-Morales, J.L., Rodríguez-Barroso, M.R., 2014, Rapid screening of estuarine sediments properties using thermogravimetric analysis and attenuated total reflectance (ATR) by Fourier transform infrared (FTIR) spectrometry: Water Air Soil Pollution, v. 225, no. 1853, p. 1–10.

Pironon, J., Pelletier, M., de Donato, P., and Mosser-Ruck, R., 2003, Characterization of smectite and illite by FTIR spectroscopy of interlayer NH4+ cations: Clay Minerals, v. 38, p. 201–211.

Price, V.H., 2003, Androgenic alopecia in women: Journal of Investigative Dermatology Symposium Proceedings, v. 8, p. 24–27, doi:10.1046/j.1523-1747.2003.12168.x.

R Development Core Team, 2010, R—A language and environment for statistical computing:Vienna, Austria, R Foundation for Statistical Computing, accessed December 2, 2013, at *http://www.R-project.org*.

Radtke, D.B., revised June 2005, Bottom-material samples: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A8, accessed September 3, 2013, at *http://pubs.water.usgs.gov/twri9A*.

Romanok, K.M., Reilly, T.J., Lopez, A.R., Trainor, J.J., Hladik, M.L., Stanley, J.K., and Farrar, Daniel, 2014, Characterization of selected bed-sediment-bound organic and inorganic contaminants and toxicity, Barnegat Bay and major tributaries, New Jersey, 2012: U.S. Geological Survey Data Series 867, 51 p., *http://dx.doi.org/10.3133/ds867*.

Sanseverino, J., Eldridge, M.L., Layton, A.C., Easter, J.P., Yarbrough, J., Schultz, T.W., Sayler, G.S., 2009, Screening potentially hormonally active chemicals using bioluminescent yeast bioreporters: Toxicological Sciences, v. 107, no. 1, p. 122–134.

Schenck, K., Rosenblum, L., Wiese, T.E., Wymer, L., Dugan, N., Williams, D., Mash, H., Merriman, B., Speth, T., 2012, Removal of estrogens and estrogenicity through drinking water treatment: Journal of Water and Health, v. 10, p. 43–55.

Singh, Rajan, Artaza, J.N., Taylor, W.E., Braga, Melissa, Yuan, Xin, Gonzalez-Cadavid, N.F., and Bhasin, Shalender, 2006, Testosterone inhibits adipogenic differentiation in 3T3-L1 cells: nuclear translocation of androgen receptor complex with β-catenin and T-cell factor 4 may bypass canonical Wnt signaling to down-regulate adipogenic transcription factors: Endocrinology, v. 147, no. 1, p. 141–154.

Sivakumar, S., Ravisankar, R., Raghu, Y., Chandrasekaran, A., and Chandramohan, J., 2012, FTIR spectroscopic studies on coastal sediment samples from Cuddalore district, Tamilnadu, India: Indian Journal of Advances in Chemical Science, v. 1, p. 40–46.

Stavreva, D.A., George, A.A., Klausmeyer, P., Varticovski, L., Sack, D., Voss, T.C., Schiltz, R.L., Blazer, V.S., Iwanowicz, L.R., and Hager, G.L., 2012, Prevalent glucocorticoid and androgen activity in U.S. water sources: Scientific Reports, v. 2, no. 937, p. 1–8.

Swingle, M., Ni, L., and Honkanen, R.E., 2007, Small molecule inhibitors of Ser/thr protein phosphatases: specificity, use and common forms of abuse: Methods of Molecular Biology, v. 365, p. 23–28.

U.S. Department of Agriculture, Natural Resources Conservation Service, 2014, Watershed Boundary Dataset for New Jersey and New York, accessed January 23, 2014, at *http://datagateway.nrcs.usda.gov*.

U.S. Census Bureau, 2014a, North American Industrial Classification System, accessed July 7, 2014, at *http://www.census.gov/eos/www/naics*.

U.S. Census Bureau, 2014b, Standard Industrial Classification System, accessed July 7, 2014, at *http://www.census.gov/epcd/www/sic.html*.

U.S. Environmental Protection Agency, 2008, Office of Super Fund Remediation and Technology Innovation, USEPA Contract Laboratory Program, National functional guidelines for Superfund organic methods data review: Washington, D.C., U.S. Environmental Protection Agency, 540-R-08-01.

U.S. Environmental Protection Agency, 2007, Method 6020A, Inductively coupled plasma-mass spectrometry: Washington, D.C., U.S. Environmental Protection Agency, accessed June 12, 2014, at *http://www.epa.gov/osw/hazard/testmethods/sw846/pdfs/6020a.pdf*.

U.S. Environmental Protection Agency, 2005, Method 245.7, Mercury in water by cold vapor atomic fluorescence spectrometry: Washington, D.C., U.S. Environmental Protection Agency accessed June 12, 2014, at *http://water.epa.gov/scitech/methods/cwa/bioindicators/upload/2007_07_10_methods_method_245_7.pdf*.

U.S. Environmental Protection Agency, 2001a, Methods for collection, storage and manipulation of sediments for chemical and toxicological analyses: Technical manual: Washington, D.C., U.S. Environmental Protection Agency, Office of Water, EPA 823-B-01-002, accessed June 13, 2014, at *http://water.epa.gov/polwaste/sediments/cs/upload/collectionmanual.pdf*.

U.S. Environmental Protection Agency, 2001b, Methods for assessing the chronic toxicity of marine and estuarine sediment-associated contaminants with the amphipod *Leptocheirus plumulosus*: Washington, D.C., U.S. Environmental Protection Agency, EPA/600/R-01/020, accessed September 13, 2013, at *http://water.epa.gov/polwaste/sediments/cs/upload/guidancemanual.pdf*.

U.S. Environmental Protection Agency, 1998, Method 8270C, Semi-volatile organic compounds by gas chromatograph/mass spectrometry (GS/MS): Washington, D.C., U.S. Environmental Protection Agency, accessed June 13, 2014, at *http://www.caslab.com/EPA-Methods/PDF/8270c.pdf*.

U.S. Environmental Protection Agency, 1983, Methods for chemical analysis of water and wastes: Cincinnati, Ohio, U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory EPA-600/4-79-020, accessed June 13, 2014, at *http://www.epa.gov/nscep/index.html.*

U.S. Geological Survey, 2011, U.S. Geological Survey Office of Water Quality Technical Memorandum 2012.01, accessed October 28, 2014, at *http://water.usgs.gov/admin/memo/QW/qw12.01.pdf.*

Valdiglesias, V., Prego-Faraldo, M.V., Pásaro, E., Méndez, J., and Laffon, B., 2013, Review: okadaic acid: more than a diarrheic toxin: Marine Drugs, v. 11, p. 4328–4349.

Westerhoff, P., Yoon, Y., Snyder, S., and Wert, E., 2005, Fate of endocrine-disruptor, pharmaceutical, and personal care product chemicals during simulated drinking water treatment processes: Environmental Science & Technology, v. 39, p. 6649–6663.

Young, R.A., ed., 1995, The Rietveld Method: International Union of Crystallography Monographs #5: New York, Oxford University Press, 298 p.

Zhang, Q.Q., Zhao, J.L., Ying, G.G., Liu, Y.S., and Pan, C.G., 2014, Emission estimation and multimedia fate modeling of seven steroids at the river basin scale in China: accessed July 2, 2014, at *http://www.ncbi.nlm.nih.gov/pubmed/24964360*.

Table 3. Station identification information for bed-sediment sites sampled in the harbors and bays in New Jersey and New York during the Hurricane Sandy reconnaissance study, June–October 2013.

[Map location number refers to figures 2 and 3. USGS, U.S. Geological Survey; EPA, U.S. Environmental Protection Agency; REMAP, Regional Environmental Monitoring and Assessment Program; NCCA, National Coastal Condition Assessment; NOAA, National Oceanic and Atmospheric Administration; NJ, New Jersey; NY, New York; NA, not applicable]

Site code	Map location number	USGS station number	State code	USGS site name	Latitude (decimal degrees)	Longitude (decimal degrees)	Method[1]	Sampling agency	Associated historical data
				Cape May region					
NCA10-1625/BBC/SJ10	1	390551074455201	NJ	Great Sound near Avalon, NJ	39.0975	-74.7645	A,B,C,D,E,F,G,H,I	USGS/EPA Region 2	[2]EPA NCCA 2006/2010
BBE/SJ13	2	385758074522301	NJ	Jarvis Sound near Flower Mound, NJ	38.9660	-74.8730	A,B,C,D,E,F,G,H,I	USGS	[2]EPA NCCA 2006
BBG/SJ11	3	390235074470201	NJ	Dung Thorofare near Nummy Island, NJ	39.0430	-74.7840	A,B,C,D,E,F,G,H,I	USGS	[2]EPA NCCA 2006
BBH/SJ12	4	390213074484701	NJ	Turtle Gut near Grassy Sound, NJ	39.0370	-74.8130	A,B,C,D,E,F,G,H,I	USGS	[2]EPA NCCA 2006
BBM/SJ9	5	390920074421401	NJ	Ludlum Thorofare near 47th Place at Sea Isle City, NJ	39.1557	-74.7040	A,B,C,D,E,F,G,H,I	USGS	None. Added to inform regional impact
				Atlantic City region					
NCA10-1616/BBA/SJ7	6	391750074363001	NJ	Great Egg Harbor Bay near Drag Island, NJ	39.2973	-74.6084	A,B,C,D,E,F,G,H,I	USGS/EPA Region 2	[2]EPA NCCA 2010
NCA10-1623/BBB/SJ6	7	392302074305701	NJ	Lakes Bay near Pleasantville, NJ	39.3839	-74.5159	A,B,C,D,E,F,G,H,I	USGS/EPA Region 2	[2]EPA NCCA 2010
BBL/SJ8	8	391637074371201	NJ	Peck Bay at Beesley's Point, NJ	39.2770	-74.6200	A,B,C,D,E,F,G,H,I	USGS	[2]EPA NCCA 2006
				Great Bay region					
NCA10-2622/BBD/SJ2	9	393027074201101	NJ	Great Bay Shooting Thorofare near Fish Island, NJ	39.5076	-74.3365	A,B,C,D,E,F,G,H,I	USGS	[2]EPA NCCA 2010
BBF/SJ1	10	393210074231701	NJ	Great Bay near Graveling Point, NJ	39.5360	-74.3880	A,B,C,D,E,F,G,H,I	USGS	[2]EPA NCCA 2006
BBI/SJ4	11	392700074233101	NJ	Little Bay near Pearch Cove, NJ	39.4500	-74.3920	A,B,C,D,E,F,G,H,I	USGS	[2]EPA NCCA 2006
BBJ/SJ3	12	392823074231301	NJ	Main Marsh Thorofare near Hammock Cove at EBFNWR, NJ	39.4730	-74.3870	A,B,C,D,E,F,G,H,I	USGS	[2]EPA NCCA 2006
BBK/SJ5	13	392346074254801	NJ	Absecon Channel at Mankiller Bay near Atlantic City, NJ	39.3960	-74.4300	A,B,C,D,E,F,G,H,I	USGS	[2]EPA NCCA 2006
NOAA9	14	393215074231001	NJ	Great Bay near Bogans Cove, NJ	39.5375	-74.3861	A,B,C,E,F,G,H,I	USGS	[3]NOAA, Mussel Watch
NCA10-1615	15	393253074283001	NJ	Great Bay EPA NCCA site NCA10-1615	39.5481	-74.4751	A,F,G,H	EPA Region 2	[2]EPA NCCA 2010
				Barnegat Bay region					
BB01	16	01408168	NJ	Barnegat Bay at Mantoloking, NJ	40.0400	-74.0522	A,C,D,E,F,G,H,I	USGS	Romanok and others, 2014
BB02	17	395839074055401	NJ	Barnegat Bay near Lavallette, NJ	39.9776	-74.0985	A,B,C,D,E,F,G,H,I	USGS	Romanok and others, 2014
BB03	18	395653074060501	NJ	Barnegat Bay 700 feet north of Route 37 Bridge, NJ	39.9482	-74.1015	A,B,C,D,E,F,G,H,I	USGS	Romanok and others, 2014
BB05A	19	395458074063401	NJ	Barnegat Bay between Ocean Gate & South Seaside Park, NJ	39.9158	-74.1094	A,B,C,D,E,F,G,H,I	USGS	Romanok and others, 2014
BB06	20	395109074060701	NJ	Barnegat Bay 1.2 miles south of Cedar Creek mouth, NJ	39.8526	-74.1021	A,B,C,D,E,F,G,H,I	USGS	Romanok and others, 2014
BB07A	21	394805074092601	NJ	Barnegat Bay 0.5 miles south of Oyster Creek mouth, NJ	39.8013	-74.1571	A,B,C,D,E,F,G,H,I	USGS	Romanok and others, 2014
BB09	22	394433074085201	NJ	Barnegat Bay 2 miles south of Barnegat Inlet, NJ	39.7426	-74.1479	A,B,C,D,E,F,G,H,I	USGS	Romanok and others, 2014
BB10	23	393939074122301	NJ	Manakawkin Bay 800 feet south of Route 72 Bridge, NJ	39.6610	-74.2065	A,C,D,E,F,G,H,I	USGS	Romanok and others, 2014
BB11	24	393731074140801	NJ	Little Egg Harbor 0.8 miles north of Westecunk Creek mouth, NJ	39.6254	-74.2357	A,B,C,D,E,F,G,H,I	USGS	Romanok and others, 2014
BB13	25	393408074192801	NJ	Little Egg Harbor near mouth of Tuckerton Creek, NJ	39.5690	-74.3246	A,B,C,D,E,F,G,H,I	USGS	Romanok and others, 2014
MANA1	26	0140804850	NJ	Watson Creek at mouth at Manasquan, NJ	40.1086	-74.0447	A,B,C,D,E,F,G,H,I	USGS	None. Added to inform regional impact
MANA2	27	01408049	NJ	Lake Louise at Point Pleasant Beach, NJ	40.0970	-74.0398	A,B,C,D,E,F,G,H,I	USGS	None. Added to inform regional impact
NOAA3	28	01408161	NJ	Metedeconk River near Island Drive near Metedeconk, NJ	40.0549	-74.1038	A,B,C,D,E,F,G,H,I	USGS	[3]NOAA, Mussel Watch
NOAA4	29	01408718	NJ	Toms River near Kilpatrick Point near Toms River, NJ	39.9490	-74.1911	A,B,C,E,F,G,H,I	USGS	[3]NOAA, Mussel Watch
NOAA10	30	393837074144901	NJ	Little Egg Harbor near Drum Point, NJ	39.6436	-74.2469	A,B,C,E,F,G,H,I	USGS	[3]NOAA, Mussel Watch

Table 3. Station identification information for bed-sediment sites sampled in the harbors and bays in New Jersey and New York during the Hurricane Sandy reconnaissance study, June–October 2013.—Continued

[Map location number refers to figures 2 and 3. USGS, U.S. Geological Survey; EPA, U.S. Environmental Protection Agency; REMAP, Regional Environmental Monitoring and Assessment Program; NCCA, National Coastal Condition Assessment; NOAA, National Oceanic and Atmospheric Administration; NJ, New Jersey; NY, New York; NA, not applicable]

Site code	Map location number	USGS station number	State code	USGS site name	Latitude (decimal degrees)	Longitude (decimal degrees)	Method[1]	Sampling agency	Associated historical data
Northeast New Jersey shore region									
NAV1	31	01407540	NJ	Navesink River near Oceanic Bridge at Rumson, NJ	40.3810	-74.0110	A,B,C,D,E,F,G,H,I	USGS	[2]EPA NCCA 2006
NAV2	32	01407533	NJ	Navesink River at Coopers Bridge near Red Bank, NJ	40.3572	-74.0766	A,B,C,D,E,F,G,H,I	USGS	[2]EPA NCCA 2010
NOAA1	33	01407539	NJ	Navesink River below McClees Creek near Fairview, NJ	40.3737	-74.0392	A,B,C,E,F,G,H,I	USGS	[3]NOAA, Mussel Watch
NOAA2	34	01407605	NJ	Shrewsbury River at Highlands, NJ	40.3990	-73.9811	A,B,C,D,E,F,G,H,I	USGS	[3]NOAA, Mussel Watch
SHARK1	35	01407768	NJ	Musquash Brook at Neptune City, NJ	40.1944	-74.0357	A,B,C,D,E,F,G,H,I	USGS	None. Added to inform regional impact
SHREW1	36	01407598	NJ	Shrewsbury River near Gunning Island at Sea Bright, NJ	40.3559	-73.9752	A,B,C,D,E,F,G,H,I	USGS	[2]EPA NCCA 2010
SHREW2	37	01407588	NJ	Troutmans Creek at mouth at Branchport, NJ	40.3170	-73.9950	A,B,C,D,E,F,G,H,I	USGS	[2]EPA NCCA 2005
Lower Harbor/Raritan Bay region									
RB401	38	403424073563301	NY	Rockaway Inlet near Manhattan Beach, NY	40.5733	-73.9425	A,E,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB402	39	403056074062001	NY	Raritan Bay EPA REMAP site RB402	40.5155	-74.1055	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB403	40	402534074004301	NJ	Sandy Hook Bay EPA REMAP site RB403	40.4260	-74.0120	A,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB404	41	402851074132001	NY	Raritan Bay near Tottenville, NY	40.4808	-74.2222	A,E,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB405	42	402726074071401	NJ	Raritan Bay EPA REMAP site RB405	40.4572	-74.1206	A,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB406	43	403240074015901	NY	Lower NY Harbor EPA REMAP site RB406	40.5445	-74.0331	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB407	44	403516074021101	NY	Lower NY Harbor EPA REMAP site RB407	40.5877	-74.0365	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB408	45	402952074104201	NY	Raritan Bay EPA REMAP site RB408	40.4977	-74.1784	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB409	46	403059074050901	NY	Raritan Bay EPA REMAP site RB409	40.5163	-74.0858	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB410	47	402839074032101	NJ	Raritan Bay EPA REMAP site RB410	40.4775	-74.0559	A,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB411	48	402739074064701	NJ	Raritan Bay EPA REMAP site RB411	40.4608	-74.1131	A,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB413	49	403508074013801	NY	Lower NY Harbor EPA REMAP site RB413	40.5855	-74.0271	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB414	50	403251074061901	NY	Lower New York Bay near Oakwood Beach, NY	40.5475	-74.1053	A,E,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB416	51	402841074054801	NJ	Sandy Hook Bay near Keansburg, NJ	40.4780	-74.0965	A,E,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB450	52	403059074002801	NY	Lower NY Harbor EPA REMAP site RB450	40.5164	-74.0078	A,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB451	53	403040074073301	NY	Raritan Bay EPA REMAP site RB451	40.5111	-74.1258	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB453	54	402530074021701	NJ	Sandy Hook Bay EPA REMAP site RB453	40.4250	-74.0381	A,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB454	55	402936074093701	NY	Raritan Bay EPA REMAP site RB454	40.4934	-74.1603	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB455	56	402956074031701	NJ	Raritan Bay EPA REMAP site RB455	40.4990	-74.0548	A,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB456	57	402755074100201	NJ	Raritan Bay EPA REMAP site RB456	40.4653	-74.1671	A,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB457	58	403352074030901	NY	Lower New York Bay near Swinburne Island, NY	40.5644	-74.0525	A,E,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB458	59	403140073584401	NY	Lower New York Bay near Rockaway Point, NY	40.5278	-73.9789	A,E,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB460	60	402845074075101	NJ	Raritan Bay EPA REMAP site RB460	40.4792	-74.1308	A,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB461	61	403422073544401	NY	Lower NY Harbor EPA REMAP site RB461	40.5728	-73.9121	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB462	62	402447073592201	NJ	Shrewsbury River near Highlands, NJ	40.4132	-73.9894	A,E,F,G,H	EPA Region 2	[4]EPA REMAP 2008/2013
RB463	63	402922074050901	NJ	Raritan Bay EPA REMAP site RB463	40.4894	-74.0859	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB464	64	403139074011301	NY	Lower NY Harbor EPA REMAP site RB464	40.5276	-74.0203	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
RB465	65	402736074093201	NJ	Raritan Bay EPA REMAP site RB465	40.4599	-74.1589	A,F,H,I	EPA Region 2	[4]EPA REMAP 2008/2013

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Site code	Map location number	USGS station number	State code	USGS site name	Latitude (decimal degrees)	Longitude (decimal degrees)	Method[1]	Sampling agency	Associated historical data
Newark Bay region									
NB401	66	403954074082701	NJ	Newark Bay EPA REMAP site NB401	40.6650	-74.1408	A,F,G,H,	EPA Region 2	[4]EPA REMAP 2008/2013
NB405	67	01392630	NJ	Passaic River near Kearny Point, NJ	40.735900	-74.1173	A,E,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB406	68	404038074081401	NJ	Newark Bay EPA REMAP site NB406	40.6771	-74.1371	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB409	69	403310074144701	NJ	Arthur Kill EPA REMAP site NB409	40.5529	-74.2464	A,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB410	70	403333074125801	NY	Arthur Kill EPA REMAP site NB410	40.5592	-74.2161	A,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB412	71	404009074081601	NJ	Newark Bay EPA REMAP site NB412	40.6692	-74.1377	A,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB413	72	403836074095301	NY	Newark Bay near Shooters Island, NY	40.6433	-74.1647	A,E,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB414	73	403451074122601	NY	Arthur Kill EPA REMAP site NB414	40.5808	-74.2073	A,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB416	74	404116074080701	NJ	Newark Bay at Port Newark, NJ	40.6879	-74.1354	A,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB418	75	403840074073001	NJ	Kill van Kull at Bergen Point, NJ	40.644567	-74.1251	A,E,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB419	76	403331074140101	NJ	Arthur Kill EPA REMAP site NB419	40.5587	-74.2336	A,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB423	77	403859074095401	NJ	Newark Bay EPA REMAP site NB423	40.6496	-74.1651	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB424	78	403621074121501	NY	Arthur Kill near Pralls Island, NY	40.6058	-74.2042	A,E,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB425	79	404328074060301	NJ	Newark Bay EPA REMAP site NB425	40.7244	-74.1008	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB426	80	404026074075001	NJ	Newark Bay EPA REMAP site NB426	40.6738	-74.1305	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB427	81	404218074070201	NJ	Newark Bay near Oak Island Yards, NJ	40.7050	-74.1172	A,E,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB429	82	403100074151901	NJ	Arthur Kill near Perth Amboy, NJ	40.5165	-74.2553	A,E,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB430	83	403242074145601	NY	Arthur Kill EPA REMAP site NB430	40.5450	-74.2488	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB431	84	403938074081301	NJ	Newark Bay at Bayone, NJ	40.6604	-74.1370	A,E,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB450	85	01392610	NJ	Passaic River near Kearny, NJ	40.7402	-74.1409	E,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB452	86	404123074065301	NJ	Newark Bay EPA REMAP site NB452	40.6896	-74.1146	A,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB453	87	403119074145301	NJ	Arthur Kill EPA REMAP site NB453	40.5220	-74.2481	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB454	88	404055074072601	NJ	Newark Bay EPA REMAP site NB454	40.6819	-74.1238	A,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB455	89	403643074115101	NY	Arthur Kill EPA REMAP site NB455	40.6118	-74.1974	A,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB457	90	403024074152901	NY	Arthur Kill EPA REMAP site NB457	40.5066	-74.2581	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB459	91	403629074115801	NY	Arthur Kill EPA REMAP site NB459	40.6081	-74.1994	A,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NB461	92	403318074142501	NJ	Arthur Kill near Woodbridge, NJ	40.5549	-74.2404	A,E,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
Upper Harbor region									
NB407	93	403854074065701	NJ	Kill van Kull EPA REMAP site NB407	40.6483	-74.1159	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
UH401	94	403941074004501	NY	Upper New York Bay at Gowanus Bay, NY	40.6614	-74.0125	A,E,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
UH402	95	403659074034101	NY	The Narrows near Rosebank, NY	40.6164	-74.0614	A,E,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
UH404	96	405155073562101	NY	Upper NY Harbor EPA REMAP site UH404	40.8652	-73.9392	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
UH408	97	404031074023601	NJ	Upper NY Harbor EPA REMAP site UH408	40.6752	-74.0435	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
UH409	98	403719074035201	NY	Upper NY Harbor EPA REMAP site UH409	40.6220	-74.0645	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
UH411	99	405101073570201	NY	Upper NY Harbor EPA REMAP site UH411	40.8503	-73.9505	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
UH412	100	404810073483601	NY	East River at Whitestone, NY	40.8028	-73.8100	E,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013

Table 3. Station identification information for bed-sediment sites sampled in the harbors and bays in New Jersey and New York during the Hurricane Sandy reconnaissance study, June–October 2013.—Continued

[Map location number refers to figures 2 and 3. USGS, U.S. Geological Survey; EPA, U.S. Environmental Protection Agency; REMAP, Regional Environmental Monitoring and Assessment Program; NCCA, National Coastal Condition Assessment; NOAA, National Oceanic and Atmospheric Administration; NJ, New Jersey; NY, New York; NA, not applicable]

Site code	Map location number	USGS station number	State code	USGS site name	Latitude (decimal degrees)	Longitude (decimal degrees)	Method[1]	Sampling agency	Associated historical data
				Upper Harbor region—Continued					
UH413	101	404622073595301	NY	Hudson River at West 57th Street at Manhattan, NY	40.7728	-73.9981	A,E,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
UH415	102	403816074035001	NY	Upper NY Harbor EPA REMAP site UH415	40.6377	-74.0639	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
UH416	103	404240074012401	NY	Upper NY Harbor EPA REMAP site UH416	40.7111	-74.0234	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
UH451	104	405417073550601	NY	Upper NY Harbor EPA REMAP site UH451	40.9048	-73.9184	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
UH452	105	403828074031901	NY	Upper NY Harbor EPA REMAP site UH452	40.6410	-74.0553	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
UH455	106	405021073570601	NY	Upper NY Harbor EPA REMAP site UH455	40.8392	-73.9518	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
UH456	107	404445074004101	NY	Upper NY Harbor EPA REMAP site UH456	40.7460	-74.0113	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
UH457	108	404905073575001	NY	Upper NY Harbor EPA REMAP site UH457	40.8181	-73.9638	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
UH459	109	405124073565001	NY	Upper NY Harbor EPA REMAP site UH459	40.8567	-73.9473	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
UH461	110	405135073570401	NJ	Hudson River at Englewood Cliffs, NJ	40.8598	-73.9512	E,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
UH463	111	404942073581101	NJ	Hudson River at Edgewater, NJ	40.8283	-73.9697	A,E,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
UH465	112	405335073560401	NJ	Upper NY Harbor EPA REMAP site UH465	40.8931	-73.9344	G	EPA Region 2	[4]EPA REMAP 2008/2013
UH466	113	403945074015701	NY	Upper NY Harbor EPA REMAP site UH466	40.6624	-74.0326	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
UH468	114	403935074014201	NY	Upper NY Harbor EPA REMAP site UH468	40.6597	-74.0283	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
UH469	115	405229073554901	NY	Upper NY Harbor EPA REMAP site UH469	40.8747	-73.9304	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
				Jamaica Bay region					
JB401	116	403419073524501	NY	Rockaway Inlet near Neponsit, NY	40.5719	-73.8792	A,E,F,G,H	EPA Region 2	[4]EPA REMAP 2008/2013
JB403	117	403759073482301	NY	Jamaica Bay EPA REMAP site JB403	40.6330	-73.8064	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
JB404	118	403628073532501	NY	Jamaica Bay EPA REMAP site JB404	40.6079	-73.8902	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
JB405	119	403523073513201	NY	Jamaica Bay EPA REMAP site JB405	40.5898	-73.8589	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
JB406	120	403543073481801	NY	Jamaica Bay EPA REMAP site JB406	40.5952	-73.8050	A,F,G,H	EPA Region 2	[4]EPA REMAP 2008/2013
JB407	121	403745073453101	NY	Jamaica Bay Head of Bay near John F. Kennedy Airport, NY	40.6292	-73.7586	A,E,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
JB409	122	403621073470901	NY	Jamaica Bay EPA REMAP site JB409	40.6057	-73.7857	A,F,G,H	EPA Region 2	[4]EPA REMAP 2008/2013
JB410	123	403738073521201	NY	Jamaica Bay EPA REMAP site JB410	40.6273	-73.8700	F,G,H	EPA Region 2	[4]EPA REMAP 2008/2013
JB415	124	403653073513401	NY	Jamaica Bay EPA REMAP site JB415	40.6148	-73.8594	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
JB416	125	403804073522101	NY	Jamaica Bay near Canarsie, NY	40.6344	-73.8725	A,E,F,G,H	EPA Region 2	[4]EPA REMAP 2008/2013
JB417	126	403504073510901	NY	Jamaica Bay EPA REMAP site JB417	40.5846	-73.8526	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
JB419	127	403430073520901	NY	Jamaica Bay EPA REMAP site JB419	40.5751	-73.8692	A,F,G,H	EPA Region 2	[4]EPA REMAP 2008/2013
JB422	128	403608073523701	NY	Jamaica Bay EPA REMAP site JB422	40.6022	-73.8769	A,F,G,H	EPA Region 2	[4]EPA REMAP 2008/2013
JB423	129	403534073521101	NY	Jamaica Bay EPA REMAP site JB423	40.5927	-73.8698	A,F,G,H	EPA Region 2	[4]EPA REMAP 2008/2013
JB454	130	403560073522601	NY	Jamaica Bay EPA REMAP site JB454	40.5999	-73.8739	A,F,G,H	EPA Region 2	[4]EPA REMAP 2008/2013
JB458	131	403453073515801	NY	Jamaica Bay EPA REMAP site JB458	40.5815	-73.8662	A,F,G,H	EPA Region 2	[4]EPA REMAP 2008/2013
JB459	132	403649073513901	NY	Jamaica Bay EPA REMAP site JB459	40.6136	-73.8608	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
JB464	133	403654073463501	NY	Jamaica Bay EPA REMAP site JB464	40.6150	-73.7764	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
JB466	134	403546073485701	NY	Jamaica Bay near Broad Channel, NY	40.5961	-73.8158	A,E,F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
JB467	135	403631073525201	NY	Jamaica Bay EPA REMAP site JB467	40.6087	-73.8812	F,G,H	EPA Region 2	[4]EPA REMAP 2008/2013

Table 3. Station identification information for bed-sediment sites sampled in the harbors and bays in New Jersey and New York during the Hurricane Sandy reconnaissance study, June–October 2013.—Continued

[Map location number refers to figures 2 and 3. USGS, U.S. Geological Survey; EPA, U.S. Environmental Protection Agency; REMAP, Regional Environmental Monitoring and Assessment Program; NCCA, National Coastal Condition Assessment; NOAA, National Oceanic and Atmospheric Administration; NJ, New Jersey; NY, New York; NA, not applicable]

Site code	Map location number	USGS station number	State code	USGS site name	Latitude (decimal degrees)	Longitude (decimal degrees)	Method[1]	Sampling agency	Associated historical data
Jamaica Bay region—Continued									
JB468	136	403505073505201	NY	Jamaica Bay EPA REMAP site JB468	40.5847	-73.8478	A,F,G,H	EPA Region 2	[4]EPA REMAP 2008/2013
JB471	137	403837073503801	NY	Jamaica Bay EPA REMAP site JB471	40.6437	-73.8439	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
JB472	138	403611073544701	NY	Jamaica Bay Mill Basin near Flatlands, NY	40.6031	-73.9131	E,F,G,H	EPA Region 2	[4]EPA REMAP 2008/2013
JB474	139	403604073471101	NY	Jamaica Bay EPA REMAP site JB474	40.6011	-73.7865	A,F,G,H	EPA Region 2	[4]EPA REMAP 2008/2013
JB480	140	403457073504801	NY	Jamaica Bay EPA REMAP site JB480	40.5824	-73.8467	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
JB481	141	403649073520901	NY	Jamaica Bay EPA REMAP site JB481	40.6135	-73.8692	F,G,H	EPA Region 2	[4]EPA REMAP 2008/2013
JB486	142	403429073524801	NY	Jamaica Bay EPA REMAP site JB486	40.5738	-73.8790	A,F,G,H	EPA Region 2	[4]EPA REMAP 2008/2013
JB487	143	403805073480901	NY	Jamaica Bay EPA REMAP site JB487	40.6348	-73.8026	F,G,H,I	EPA Region 2	[4]EPA REMAP 2008/2013
NOAA5	144	403620073540101	NY	Jamaica Bay near Mill Basin, NY	40.6053	-73.9003	A,B,C,E,F,G,H,I	USGS	[3]NOAA, Mussel Watch
NOAA6	145	403408073525901	NY	Jamaica Bay near Riis Landing, NY	40.5689	-73.8830	A,B,C,E,F,G,H,I	USGS	[3]NOAA, Mussel Watch
Western Bays region									
BHB01	146	403645073415901	NY	Brosewere Bay in Hempstead Bay, NY	40.6126	-73.6986	A,B,C,D,E,F,G,H,I	USGS	None. Added to inform regional impact
BMB01	147	403723073351801	NY	Baldwin Bay near Middle Bay, NY	40.6276	-73.5922	A,B,C,D,E,F,G,H,I	USGS	None. Added to inform regional impact
HHB01	148	403729073401501	NY	Hewlett Bay in Hempstead Bay, NY	40.6237	-73.6714	A,B,C,D,E,F,G,H,I	USGS	None. Added to inform regional impact
RC01	149	403541073403401	NY	Reynolds Channel north of Long Beach, NY	40.5943	-73.6772	A,B,C,D,E,F,G,H,I	USGS	None. Added to inform regional impact
RC02	150	403547073353001	NY	Reynolds Channel near Long Meadow Island, NY	40.5948	-73.5956	A,B,C,D,E,F,G,H,I	USGS	[3]NOAA, Mussel Watch
RC03	151	403550073381501	NY	Reynolds Channel south of Garrett Marsh, NY	40.5977	-73.6373	A,B,C,D,E,F,G,H,I	USGS	None. Added to inform regional impact
Great South Bay region									
GSB01	152	404357072573701	NY	Greast South Bay near Howells Creek, NY	40.7320	-72.9598	A,B,C,D,E,F,G,H,I	USGS	None. Added to inform regional impact
GSB02	153	404139073004901	NY	Great South Bay north of Davis Park, NY	40.6933	-73.0074	A,B,C,D,E,F,G,H,I	USGS	[2]EPA NCCA 2010
GSB03	154	404322073073301	NY	Great South Bay near Connetquot River, NY	40.7227	-73.1260	A,B,C,D,E,F,G,H,I	USGS	None. Added to inform regional impact
GSB04	155	403908073092401	NY	Great South Bay at Ocean Beach, NY	40.6540	-73.1571	B,C,D,E,F,G,H,I	USGS	None. Added to inform regional impact
GSB05	156	404052073141601	NY	Great South Bay east of Robert Moses Causeway, NY	40.6808	-73.2377	A,B,C,D,E,F,G,H,I	USGS	[2]EPA NCCA 2010
GSB06	157	404031073192901	NY	Great South Bay south of Carlls River, NY	40.6781	-73.3261	A,B,C,D,E,F,G,H,I	USGS	None. Added to inform regional impact
GSB07	158	403715073245701	NY	Great South Bay near West Gilgo Beach, NY	40.6220	-73.4150	A,B,C,D,E,F,G,H,I	USGS	None. Added to inform regional impact
MB01	159	402710072494601	NY	Moriches Bay south of Mastic Beach, NY	40.7530	-72.8303	A,B,C,D,E,F,G,H,I	USGS	None. Added to inform regional impact
MB02	160	404637072462301	NY	Moriches Bay south of Terrell River, NY	40.7785	-72.7734	A,B,C,D,E,F,G,H,I	USGS	[3]NOAA, Mussel Watch
NOAA7	161	403851073100101	NY	Great South Bay near Ocean Beach, NY	40.6474	-73.1669	A,B,C,E,F,G,H,I	USGS	[3]NOAA, Mussel Watch
NOAA8	162	403841073150401	NY	Great South Bay near Captree Marina, NY	40.6448	-73.2510	A,B,C,E,F,G,H,I	USGS	[3]NOAA, Mussel Watch
SOB01	163	403860073282401	NY	South Oyster Bay near Massapequa Creek, NY	40.6478	-73.4754	A,B,C,D,E,F,G,H,I	USGS	None. Added to inform regional impact

Table 3. Station identification information for bed-sediment sites sampled in the harbors and bays in New Jersey and New York during the Hurricane Sandy reconnaissance study, June–October 2013.—Continued

[Map location number refers to figures 2 and 3. USGS, U.S. Geological Survey; EPA, U.S. Environmental Protection Agency; REMAP, Regional Environmental Monitoring and Assessment Program; NCCA, National Coastal Condition Assessment; NOAA, National Oceanic and Atmospheric Administration; NJ, New Jersey; NY, New York; NA, not applicable]

Site code	Map location number	USGS station number	State code	USGS site name	Latitude (decimal degrees)	Longitude (decimal degrees)	Method[1]	Sampling agency	Associated historical data
				Peconic Bay region					
FB01	164	405022072351401	NY	Flanders Bay near Goose Creek Point, NY	40.9231	-72.5878	A,B,C,D,E,F,G,H,I	USGS	None. Added to inform regional impact
FB02	165	405448072343101	NY	Flanders Bay near Red Cedar Point, NY	40.9134	-72.5752	A,B,C,D,E,F,G,H,I	USGS	None. Added to inform regional impact
FB03	166	405531072360701	NY	Flanders Bay southeast of Reeves Creek, NY	40.9254	-72.6021	A,B,C,D,E,F,G,H,I	USGS	None. Added to inform regional impact
PB01	167	405822072270001	NY	Peconic Bay east of Robins Island, NY	40.9728	-72.4501	A,B,C,D,E,F,G,H,I	USGS	[2]EPA NCCA, 2010

[1]Type of analysis performed:

A, Particle grain-size analysis by optical diffraction using Coulter LS-230 Particle Size Analyzer (Gee and Or, 2002); U.S. Geological Survey, Menlo Park, California;

B, Total organic carbon by EPA Method 415.1 (U.S. Environmental Protection Agency, 1983); EPA Laboratory, Edison, New Jersey;

C, Trace metals by EPA Method 6020 (U.S. Environmental Protection Agency, 2007); total mercury by U.S. Environmental Protection Agency Method 245.7 (2005); Institute for Integrated Research in Materials, Environments and Society (IIRMES) Laboratory, Long Beach, California;

D, Semivolatile organic compounds, polychlorinated biphenyl congeners, and legacy organochlorine pesticides by EPA Method 8270C (U.S. Environmental Protection Agency, 1998); IIRMES; sediment toxicity analysis by EPA Method 600/R-01/020 (U.S. Environmental Protection Agency, 2001b); U.S. Army Corps of Engineers Engineer Research Laboratory, Long Beach, California;

E, Hormone analysis by solid-phase extraction, derivatization, and gas chromatography with tandem mass spectrometry (Foreman and others, 2012); wastewater-compound analysis by pressurized solvent extraction, solid-phase extraction, and capillary-column gas chromatography/mass spectrometry (Burkhardt and others, 2007); U.S. Geological Survey National Water Quality Laboratory, Denver, Colorado;

F, Portable x-ray fluorescence (pXRF) by Niton XL3t GOLDD+XRF Analyzer (Hall and others, 2012); U.S. Geological Survey Central Energy Science Center, Denver, Colorado;

G, Attenuated total reflectance-Fourier transform infared spectroscopy (ATR-FTIR) screening analysis (Oudghiri and others, 2014); U.S. Geological Survey Organic Geochemistry Research Laboratory, Lawrence, Kansas;

H, Protein phosphatase 2A (PP2A) by colorometric assay (An and Carmichael, 1994); U.S. Geological Survey Organic Geochemistry Research Laboratory, Lawrence, Kansas;

I, Bioassay endocrine disruptors by bioluminescent yeast estrogen screen (Ciparis and others, 2012); U.S. Geological Survey Leetown Science Center, Kearneysville, West Virginia.

[2]*http://water.epa.gov/type/oceb/assessmonitor/ncca.cfm*.

[3]*http://ccma.nos.noaa.gov/about/coast/nsandt/musselwatch.aspx*.

[4]*http://www.epa.gov/emap2/remap/*.

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