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Post-Katrina Interagency Performance Evaluation Task Force (IPET)

Effects of Hurricane Katrina-Related Levee Failures on Wetland Sediments

Burton Suedel, Jeffery Steevens, Alan Kennedy, and Sandra Brasfield

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Final report

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Abstract: The U.S. Army Engineer Research and Development Center (ERDC) Environmental Laboratory, Vicksburg, MS, conducted a study to determine the extent to which Katrina floodwaters in the New Orleans area may have had impacts on wildlife habitat and other biological resources in surrounding areas. These experiments were conducted as part of the Interagency Performance Evaluation Task Force (IPET), which is investigating environmental impacts originating from the failure of the hurricane protection system to perform as designed around New Orleans, Louisiana during Hurricane Katrina. This report presents data regarding the effects of pumped floodwaters on sediment chemistry and benthic invertebrate toxicity near pumping stations that discharged floodwaters into marshes near Chalmette and Violet, Louisiana. Spatial trends were observed for concentrations of chemicals in sediment. Chemical contamination of sediments was visible and appeared to have trends among sample location groups (e.g., outfall locations, wastewater treatment plant, canals, and wetlands); however, these trends were not always consistent with the bioassay results. A comparison of the sediment chemistry data from this study with two other studies reporting concentrations of chemicals in sediments within the city of New Orleans suggested that sediments and associated contaminants present within the levees were not pumped into the marsh in appreciable quantities.

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Preface

This report is a deliverable product under the Interagency Performance Evaluation Task Force (IPET), which is investigating environmental impacts originating from the failure of the hurricane protection system to perform as designed around New Orleans, Louisiana during Hurricane Katrina. The study was conducted in collaboration with the Institute of Water Resources (IWR) during the period February through March 2006.

This publication was prepared by personnel from the U.S. Army Engineer Research and Development Center (ERDC), Environmental Laboratory (EL), Vicksburg, MS. The findings and recommendations presented in this report are based upon experiments and analyses conducted at the Waterways Experiment Station. The research team consisted of Dr. Burton C. Suedel, Dr. Jeffery Steevens, and Alan Kennedy, Environmental Processes - Risk Branch (EP-R); and Dr. Sandra Brasfield, SpecPro, Inc.

Dr. Suedel and associates prepared this publication under the supervision of Dr. Robert R. Jones, Chief, EP-R, Dr. Richard E. Price, Chief, EPED, and Dr. Beth Fleming, Director, EL.

COL Gary E. Johnston was Commander and Executive Director of ERDC. Dr. James R. Houston was Director.

Summary

Introduction

Hurricane Katrina came ashore along the Alabama, Mississippi, and Louisiana coasts on 29 August 2005, resulting in significant physical damage to infrastructure. As a result of the storm, levees were breached or overtopped, resulting in flooding of New Orleans and surrounding areas, including many areas in St. Bernard Parish. Within St. Bernard Parish, floodwaters in Chalmette and Violet, Louisiana, were pumped into the adjacent Violet Marsh. One of the primary undesirable environmental impacts on the marsh ecosystem resulting from levee breaches and pumping activities is chemical and biological contamination. A study was conducted after the storm to compare chemistry and toxicity in sediment samples at sites in the immediate vicinity of active and inoperable pumping stations that discharge into Violet Marsh. One aspect of Task 9 of the Interagency Performance Evaluation Task Force (IPET) is investigating environmental impacts originating from the failure of the hurricane protection system to perform as designed around New Orleans, Louisiana during Hurricane Katrina. This study is needed to determine the extent to which Katrina floodwaters in the New Orleans area may have had impacts on biological resources in surrounding marsh land.

To assess the potential impacts of pumping water and suspended sediment from urban areas to adjacent ecosystems, sediment samples were collected from Violet Marsh (due to its proximity to urban areas, receipt of floodwaters pumped from the adjacent city of Chalmette, and potential importance as a buffer from hurricane-induced storm surges). Sediment samples were collected at four pump stations: two that were rendered inoperable by floodwaters and two that pumped water post-Katrina and could have transported contaminants from urban areas into the marsh. Sediment samples were collected at various distances from these pumps in Violet Marsh to determine the range of transport of these contaminants into the marsh. Sediments were also collected from a ditch that ran through portions of the Murphy Oil property and the outfall of a wastewater treatment plant (WWTP) to investigate these two potential contaminant sources. This document presents data regarding the effects of pumped floodwaters on sediment chemistry and benthic invertebrate toxicity near pump stations in Chalmette and Violet, Louisiana.

Materials and methods

Sampling occurred on 14-15 February 2006. Sediment samples were collected using a grab sampler and deployed from the shore or boat. Sediments were thoroughly homogenized and aliquots of the homogenized sediments were partitioned for chemical analyses. Whole sediment acute (10-day) toxicity tests were conducted using the estuarine amphipod, *Leptocheirus plumulosus*. Samples were analyzed for volatile and semivolatile organic compounds, polychlorinated biphenyls (PCBs, as Aroclors), metals (including mercury), pesticides, diesel range organics (DRO), oil range organics (ORO), and total organic carbon (TOC) analyses using USEPA methods, as appropriate.

Results and discussion

Sediment chemistry data from this study were compared with two other studies that focused on sediment concentrations within the city of New Orleans and surrounding suburbs. The comparison showed that the relative concentrations for four representative chemicals (arsenic, benzo[a]pyrene, DDD [a breakdown product of DDT, a banned pesticide], and lead) with the exception of sediments collected near the WWTP, were lower than the concentrations reported within New Orleans by other investigators. This suggests that sediments and the associated contaminants present within the levees may not have been pumped into the marsh in appreciable quantities (see Dortch et al. (2006) appendix). Furthermore, data do not show any differences in chemical concentrations in sediments at functioning pump stations 4 and 6 versus inoperable pump stations 2 and 3.

A comparison of the bioassay and chemical analysis results suggests a relationship between the concentrations of several chemicals in the sediment (e.g., Cd, Cu, Pb, Zn, Ag, polycyclic aromatic hydrocarbons, DDD, and dieldrin) and significant mortality of *L. plumulosus* for several sampling stations. Canal stations having a larger percentage of sand and gravel generally had lower chemical concentrations and produced less mortality to *L. plumulosus*.

Spatially, there were trends that suggested that sediments close to the WWTP and pump stations had elevated chemical concentrations and significant mortality to *L. plumulosus*. Generally, sediments further from the levees into Violet Marsh had lower contaminant concentrations and resulted in less *L. plumulosus* mortality relative to other samples. Some inconsistencies between sediment chemistry and bioassay results were observed for sample locations BB-3 and BB-4, where significant mortality was observed in the bioassay but very few chemicals exceeded sediment screening values. The observed mortality is likely due to chemicals that were not measured or test species' sensitivity to confounding factors other than chemical contamination (e.g., salinity, sediment grain size, and predation).

There were no observable trends in sediment chemistry and toxicity results to suggest that pump stations functioning after the flood event resulted in transport and deposition of contaminated sediments as compared to inoperable pump stations (see also appendix by Dortch et al. (2006) for related discussion).

Uncertainty

Several potential sources of uncertainty exist regarding the conclusions that can be drawn from the data collected in this study and what can be concluded regarding the ecological impacts of the dewatering of New Orleans following Hurricane Katrina. For example, the sediment chemistry and bioassay results are limited due to the scope of the study, limited number of samples, and current tools available to assess toxicity and risk to ecological receptors. These results provide information regarding a single sampling event, with limited spatial coverage, and biological effects using a single test organism. The study was limited to a single wetland (Violet Marsh), so it is difficult to predict whether similar impacts would be expected for other wetlands. Other risk pathways (bioaccumulation and biomagnification) were not assessed as part of this study. Food web analysis should be conducted to determine the potential ecological risks posed by the elevated levels of pesticides, polycyclic aromatic hydrocarbons, and metals found in sediments. Additional information on the New Orleans Hurricane Protection Projects can be found at: *https://ipet.wes.army.mil/*.

1 Introduction

Hurricane Katrina came ashore along the Alabama, Mississippi, and Louisiana coasts on 29 August 2005, resulting in significant physical damage to infrastructure. As a result of the storm, levees were breached or overtopped, leading to flooding of New Orleans and surrounding areas, including many areas in St. Bernard Parish. Within St. Bernard Parish, floodwaters in Chalmette and Violet, Louisiana were pumped into the adjacent Violet Marsh (Figures 1 and 2). Potential undesirable environmental impacts on the marsh ecosystem result from levee breaches and pumping activities. The primary environmental concerns are elevated salinity and chemical and biological contaminants. This section focuses on chemical contamination; salinity and biological contamination issues are discussed elsewhere in this report. To address chemical concerns, a study was conducted after the storm to compare chemistry and toxicity in sediment samples at sites in the immediate vicinity of active and inactive (flooded during Katrina) pumping stations that discharge into Violet Marsh (Figure 1). This baseline investigation builds on a pilot study that was conducted in December 2005, which consisted of sampling sediments for chemical analysis, toxicity testing, and benthic invertebrates, and recording salinity measurements throughout Violet Marsh. Pilot study benthic invertebrate results are addressed in Ray (2006) and salinity results in Lin and Kleiss (2006), respectively; the baseline investigation of benthic invertebrates is presented elsewhere in this report. The pilot study by Suedel et al. (2006) describes the results of the collection of sediment samples for chemical and toxicological analysis. This report describes a baseline study to discern patterns in chemical contamination and toxicity of sediments at select pumping stations and other locations within Violet Marsh.

Objective

The Interagency Performance Evaluation Task Force (IPET) is investigating the environmental impacts of the failure of the hurricane protection system to perform as designed around New Orleans, Louisiana during Hurricane Katrina. This study is needed to determine the extent to which Katrina floodwaters in the New Orleans area may have had impacts on wetlands habitat and other biological resources in surrounding areas. This report presents data regarding the effects of pumped floodwaters on sediment chemistry and benthic invertebrate toxicity near pumping stations that pumped floodwaters into marshes near Chalmette and Violet, Louisiana.

Background and approach

To assess the potential impacts of pumping water and suspended sediment from urban areas to adjacent ecosystems, sediment samples were collected from Violet Marsh. Violet Marsh was selected for study because of its 1) proximity to urban areas, 2) receipt of floodwaters pumped from the adjacent city of Chalmette, and 3) potential importance as a buffer from hurricane-induced storm surges.

Figure 1. Regional view of Violet Marsh and surrounding areas.

Violet Marsh covers an area of approximately 81.6 hectares (31.5 mi[2]) between Chalmette, Louisiana and Lake Borgne in St. Bernard Parish, Louisiana (Figure 1). Violet Marsh is bordered to the east by the Mississippi River Gulf Outlet (MRGO), to the north by the Intercoastal Waterway and to the south by the back protection levee. Thus, the marsh is connected directly to both the Mississippi River and the MRGO. Bayou Bienvenue winds through the marsh from the west near the municipal wastewater treatment plant (WWTP) to the MRGO to the east. The pumps used to remove floodwaters from Chalmette and the surrounding suburbs are located along the back protection levee.

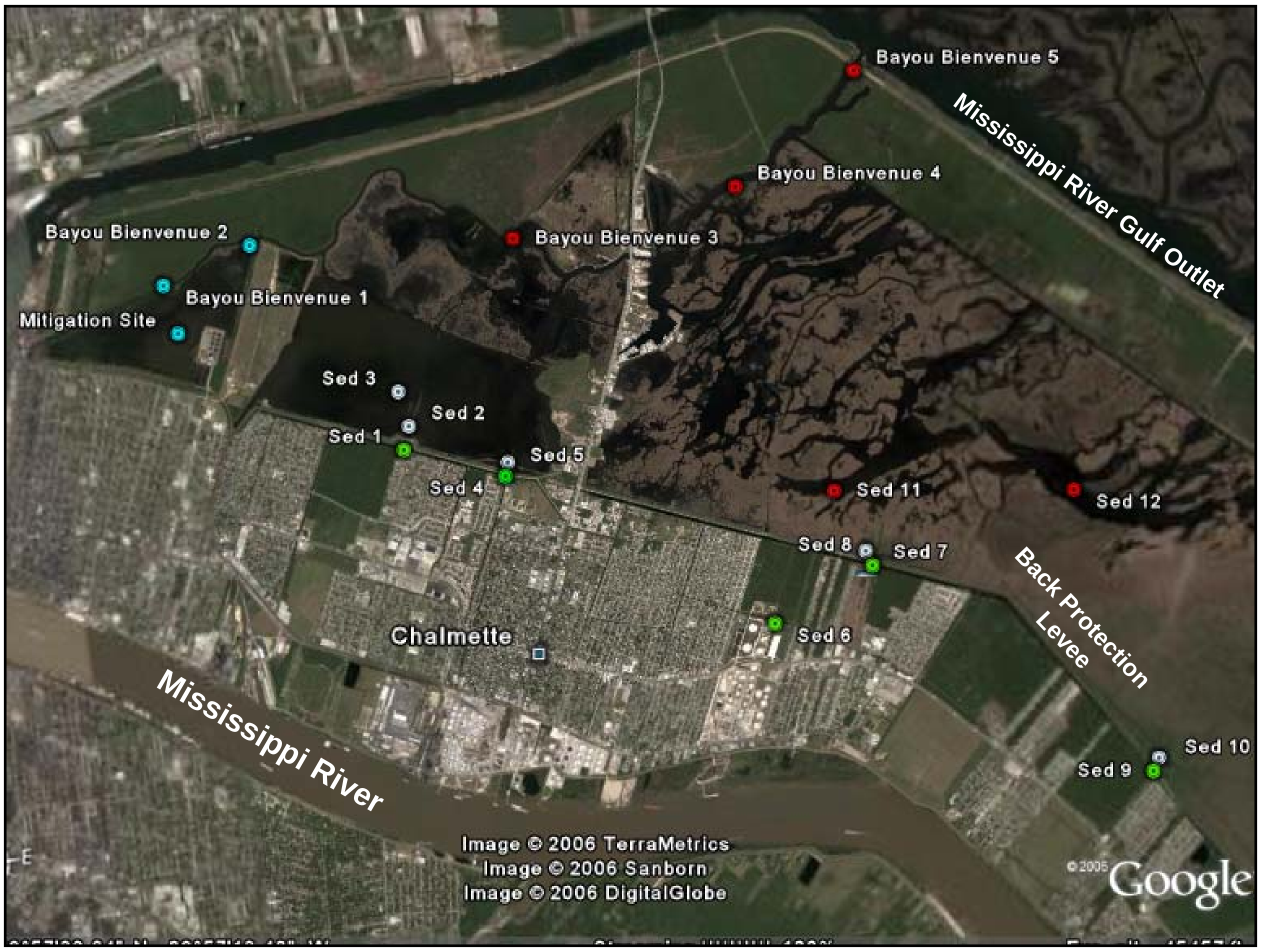

Figure 2. Overview of Violet Marsh and sampling locations. Solid circles represent sample groupings as follows: WWTP vicinity (blue); pump station outfalls (white); canals (green); and outer marsh and bayou (red).

To assist interpretation of the analytical and toxicological data, the 18 sediment sampling locations were divided into four groups depending on their proximity to potential sources of chemical contamination (Table 1).

The groups were: (1) Outer Marsh and Bayou, located in Violet Marsh furthest from the back protection levee; (2) Canals, located within the canals parallel to the back protection levee (these canals drain Chalmette and adjacent urban areas); (3) Pump Station Outfalls, located in the receiving water basins in the marsh; and (4) Waste Water Treatment Plant (WWTP) Vicinity, located in the vicinity of the WWTP. Of the pumps sampled, only Pump Stations Meraux 4 and Jean Lafitte 6 operated in the aftermath of the storm to drain floodwaters from the Chalmette area, pumping water over the back protection levee into Violet Marsh. Pump Stations Guichard 2 and Villere 3 were flooded by Katrina and were rendered inoperable.

Table 1. Sediment samples and associated groupings and proximity to potential chemical contamination sources.

Group	Station	Associated Pump Stations/ Pump Station Activity
WWTP Vicinity	Mitigation Site (MS)	NA/NA
WWTP Vicinity	BB1	NA/NA
WWTP Vicinity	BB2	NA/NA
Pump Station Outfalls	Sed 2	#6/Active
Pump Station Outfalls	Sed 3	#6/Active
Pump Station Outfalls	Sed 5	#2/Inactive
Pump Station Outfalls	Sed 8	#3/Inactive
Pump Station Outfalls	Sed 10	#4/Active
Canals	Sed 1	#6/Active
Canals	Sed 4	#2/Inactive
Canals	Sed 7	#3/Inactive
Canals	Sed 9	#4/Active
Canals	Sed 6	NA/NA
Outer Marsh and Bayou	BB3	NA/NA
Outer Marsh and Bayou	BB4	NA/NA
Outer Marsh and Bayou	BB5	NA/NA
Outer Marsh and Bayou	Sed 11	#3/Inactive
Outer Marsh and Bayou	Sed 12	#4/Active

Note: WWTP = waste water treatment plant; NA/NA = No association/Not applicable; BB = Bayou Bienvenue.

Sediment samples were collected both immediately upstream and downstream of these four pump stations (for example, see Figures 3 and 4). Sediments were also collected from a ditch that ran through portions of the Murphy Oil property (Sed 6) and the outfall of the WWTP to investigate these two potential contaminant sources. Sediment samples were also collected at various distances from these pumps in Violet Marsh to determine the range of transport of these contaminants into the marsh.

Figure 3. Station Sed 10 at Pump Station Meraux 4

Figure 4. Station Sed 9 at Pump Station Meraux 4 on 40 Arpent Canal

2 Materials and Methods

Sampling procedures

Sampling occurred on 14-15 February 2006. Sediment samples were collected with a standard Ekman grab according to standard guidance (U.S. Environmental Protection Agency (USEPA) 2001) and attached to a 6-ft aluminum pole deployed from shore or boat. Sediments were placed in an HDPE 5-gallon bucket and thoroughly homogenized using a stainless steel spoon in the field to achieve consistent texture and water content. Aliquots of the homogenized sediments were partitioned for chemical analyses. Remaining sediment was archived in plastic bags and placed on ice. Several sediments were compromised during shipment, so those samples were not used in this study.

Toxicity testing

Whole sediment acute (10-day) toxicity tests using the estuarine amphipod, *Leptocheirus plumulosus*, were conducted at the Engineer Research and Development Center (ERDC), Vicksburg, MS according to standard guidance (USEPA/USACE 1994). Experimental conditions are outlined in Table 2. Test sediments were stored in the dark at 4 ± 1 °C and used in testing within eight weeks of collection, as recommended (USEPA/USACE 1998). Sediments were homogenized using a motorized impeller mixer (Lightnin, Rochester, NY) prior to use and approximately 100 mL (1.5-cm depth) of each test sediment was added to each of five replicate test chambers (1-L beakers). Sediment was then overlain with 20 parts per thousand synthetic seawater (Crystal Sea® Marine Mix; Marine Enterprises International, Inc., Baltimore, MD, USA) and allowed to equilibrate in test chambers overnight. The test chambers were supplied trickle-flow aeration in a temperature- (25.0 ± 1.0 °C) and photoperiod- (continuous light) regulated water bath. At test initiation, *L. plumulosus* (500 – 750 µm) were obtained from ERDC in-house cultures and 20 amphipods were gently transferred into each test chamber. Water quality measurements (temperature, dissolved oxygen, pH, salinity, and overlying water ammonia) were determined at test initiation and termination. Water quality was measured using a model ABMTC handheld refractometer (Aquafauna Bio-Marine, Hawthorne, CA, USA) for salinity, a model 315i meter (WTW; Weilheim, Germany) for pH, and a model Oxi

330 meter (WTW; Weilheim, Germany) for dissolved oxygen (D.O.) Environmental chamber temperature (min/max) was monitored and recorded daily. Animals were not fed during the test.

The test assessment endpoint was survival. Test sediments were assessed using performance control sediment (Sequim, WA, USA) and reference sediment (Lake Pontchartrain, LA, USA). For tests to be considered valid, at least 90 percent survival had to be observed in the performance control and overlying water quality (pH, temperature, dissolved oxygen) within the ranges specified by guidance (USEPA/USACE 1994). For test sediment to be considered "toxic," two decision criteria must be met; the survival in the test sediment must be statistically reduced relative to the reference sediment and the reduction must be greater than 20 percent of the reference survival value (USEPA/USACE 1998).

Chemical analyses

Chemical analyses were performed by Severn Trent Laboratories, Inc., Pittsburgh, PA. Samples were prepared and analyzed for volatile and semivolatile organic compounds, polychlorinated biphenyls (PCBs, as Aroclors), metals (including mercury) using USEPA methods found in SW-846, *Test Methods for Evaluating Solid Waste, Physical/Chemical* Methods (1994) and updates. Samples were analyzed for volatile organic compounds (VOCs) using method 8260B (gas chromatography/mass spectrometry (GC/MS)) and for semi-volatile organic compounds (SVOCs) using method 8270C (GC/MS). Metals were analyzed using method 6020B (Inductively Coupled Plasma (ICP) -Atomic Absorption (AA) Spectrometry) and mercury was analyzed using Method 7471A (Cold-Vapor AA). Pesticides and PCBs were analyzed using Method 8081A (GC) and 8082 (GC), respectively. Samples were analyzed for diesel range organics (DRO) and oil range organics (ORO) following method 8015 (GC/flame ionization detector (FID)). Total organic carbon (TOC) analyses were quantified using the Lloyd Kahn method.

Statistical analyses

Data normality (Kolmogorov-Smirnov test), homogeneity (Levene's Test) and treatment differences ($\alpha = 0.05$) compared to the reference sediment were determined using SigmaStat statistical software (SPSS, Chicago, IL). Survival data were arcsine-square root transformed and a one-way ANOVA (Dunnett's post-hoc comparison) was used to determine if statistical differences existed between individual test sediments and the reference sediment.

Table 2. Conditions for conducting 10-day sediment toxicity tests with the estuarine amphipod, *Leptocheirus plumulosus*.

Test Type	Static Non-Renewal
Test duration	10 days
Temperature	25.0 ± 1.0°C
Salinity	20 ± 2 ppt
pH	7.8 ± 0.5
Light quality	Ambient Laboratory
Light intensity	500 – 1000 lux
Photoperiod	24:0 hr (light:dark)
Test chamber size	1 liter
Sediment volume (depth)	100 mL (1.5 cm)
Overlying water volume	Fill to 950 mL
Sediment settling time	Overnight
Water renewal	None
Age of test organisms	Neonates (500 – 750 μm)
Organisms/chamber	20
Replicates/treatment	5
Organisms/treatment	100
Feeding regime	None
Test chamber cleaning	None
Test solution aeration	> 40% O_2 saturation
Dilution water	20 ppt
Dilution series	None
Endpoint(s)	Survival

3 Results and Discussion

Chemical analyses

A total of 163 chemicals were analyzed for this project; 102 of these chemicals were not detected in any sediment sample (see Tables A1 and A2). Results qualified with a "J" value (estimated) were considered detected. Of the chemicals detected in at least one sample, only two of the 44 VOCs analyzed were detected (acetone and toluene). Twenty-six (26) SVOCs, 7 pesticides, 3 PCBs (as Aroclors) and all 21 metals were also detected. Most of the SVOCs detected were polycyclic aromatic hydrocarbons. Oil range organics (motor oil) and diesel range organics (diesel fuel) were also detected in some samples.

To evaluate potential adverse effects on benthic organisms residing in Violet Marsh sediments, sediment concentrations were compared to numerical sediment quality guidelines (SQGs) (see figures in Appendix A). The SQGs used were the threshold effect levels (TELs) and probable effects levels (PELs), which are the most recently published SQGs for marine and estuarine sediments (MacDonald et al. 2000, Buchman 1999). The TELs are intended to identify chemical concentrations below which harmful effects on sediment-dwelling organisms only rarely occur. The PELs are intended to identify chemical concentrations above which adverse effects frequently occur. Values for TELs and PELs have been developed for 9 metals, 13 PAHs, total PCBs, and 7 pesticides (MacDonald et al. 2000).

The PEL values were exceeded in several samples; most exceedances were in samples collected in the vicinity of the WWTP (see figures in Appendix A). Station MS had exceedances of Pb, Hg, Ag, and dieldrin PELs, while station BB1 had PEL exceedances for Pb, Hg, Zn, acenapthalene, benzo[a]anthracene, fluoranthene, phenanthrene, DDD, and dieldrin. Station BB2 exceeded the PEL for Pb. For samples collected at pump stations, Sed 2 exceeded PELs for Zn and DDD, Sed 8 exceeded the Pb PEL, and Sed 5 exceeded the DDD PEL. For canal stations, the only exceedances observed were at Sed 4, where PELs were exceeded for Cu and dieldrin. Sediments collected in the outer marsh and bayou had no chemicals exceeding PEL values.

Exceeding a TEL or PEL is not indicative of adverse effects; rather, it signifies that further evaluation of sediments may be necessary. Sediment quality guidelines can be used as a simple first screen of potential hazards to benthos using the chemical analysis of sediments (Wenning et al. 2005). SQG values can be used to:

- Identify the needs for additional benthic evaluations.Determine that a sediment is not likely to cause effects to benthos.
- Focus the scope of additional study (e.g., reduce number of contaminants of concern or pathways to be considered in baseline assessment).
- SQG values may be used in a weight-of-evidence approach with other data (benthic toxicity, biological indices, tissue residues, effects data).

Sediment quality guidelines have several limitations (USACE 1998). The SQG values do not provide estimates of risk because:

- Some pathways are not considered (bioaccumulation and trophic transfer).
- SQG values do not address more than one chemical or their interactions.
- Screening with SQG values does not address or quantify exposure.
- SQG values are not site-specific.
- Biological availability is not taken into account.

Furthermore, high rates of false positives and false negatives have been demonstrated in the application of SQG values. A study by O'Connor et al. (1998) reported that of 239 samples that exceeded at least one SQG, the effects range median (ERM), only 38 percent were toxic to amphipods. In an additional study by Long and MacDonald (1998), the probability of toxicity below the effects range low (ERL) was as high as 10 percent. Because of these limitations, SQG values should not be used as a remediation goal, to predict biological effects, or to estimate human or ecological risk. The USEPA Superfund Office has the same technical position with regard to the use of SQG values for remediation goals.

Following Hurricane Katrina, three studies described chemical concentrations in environmental media around the New Orleans area.

Most of these data focused on the concentration of chemicals in the floodwaters or sediment associated with settling of suspended material in floodwaters. The USEPA has compiled information regarding the concentration of chemicals in floodwater and sediments in the city (USEPA 2006). Pardue et al. (2005) reported concentrations of chemicals in floodwater samples and Presley et al. (2006) assessed chemical and pathogen concentrations in sediment samples. These three studies all focused on urban areas within the city. To date, there are no studies that have reported chemical concentrations of sediments in the wetlands outside levees and the city of New Orleans that received pumped floodwaters.

Sediment chemistry data from the current study were compared to the USEPA (2006) and Presley et al. (2006) studies in Table 3. While the other two studies focused on sediment concentrations within the city, the comparison illustrates the relative concentrations for arsenic, benzo[a]pyrene, DDD (dichlorodiphenyldichloroethane), and lead. These chemicals were selected for comparison based on their frequency of detection and their wide-ranging physicochemical, toxicological, and environmental fate characteristics. With the exception of the sediments collected near the outfall of the East Bank WWTP, concentrations of the four representative chemicals were lower than the concentrations reported within New Orleans by USEPA (2006) and Presley et al. (2006). This suggests that sediments and associated contaminants present within levees may not have been transported by the pump stations into the marsh in appreciable quantities. Furthermore, there do not appear to be any differences in chemical concentrations in sediments at functioning pump stations 4 and 6 that pumped water following Katrina (Sed 1, Sed 2, Sed 9, Sed 10) versus pump stations 2 and 3 that were non-functioning and did not pump water following the flood event (Sed 4, Sed 5, Sed 7, Sed 8).

Table 3. Summary of chemical analysis of sediments following Hurricane Katrina. The table summarizes results from the current IPET study, Presley et al. (2006), and USEPA (2006).

Analyte	IPET Study, Suedel et al. 2006[1]				Presley et al. 2006[2]	USEPA 2006		
	Outer Marsh Bayou	Canals	Pump Station Outfalls	WWTP Vacinity	East of Industrial Canal	New Orleans West of Industrial Canal	New Orleans East, North of MRGO	New Orleans South of MRGO
Arsenic (mg/kg)	4.2 (4.2-11.1)	6.3 (3.6-8.8)	8.7 (3.9-10.9)	7.6 (6.7-8.4)	24.2 (5.7-24.2)	8.65 (0.3-78)	9.97 (0.82-45.5)	4.66 (0.54-29.5)
Benzo[a]pyrene (µg/kg)	ND (<0.59)	35 (<7.5-46)	79 (<6.5-200)	260 (93-670)	810 (0.00-1260)	1745 (59-31,350)	1762 (103-37,600)	845 (33-50,100)
DDD (µg/kg)	0.261[3] (<0.1-4.4)	5.4[3] (<1.1-5.7)	27[3] (<0.2-61)	52[4] (<2.2-52)	NA	110 (10-785)	114 (20-3,015)	21 (<2-540)
Lead (mg/kg)	14.6 (12.1-29.2)	54.3 (15.4-83.9)	84.7 (32.2-129)	202 (105-285)	642 (341.5-642.0)	87.5 (1.17-1,160)	43.7 (9.21-295)	25.4 (14.4-689)
Simple number	5	5	5	3	3 metals, 5 organics	149-153	80-84	209

[1] Non-detects in IPET study and synthesis of USEPA data were handled by taking ½ reporting limit.

[2] Presley et al. (2006) report geometric mean values of two samples per site. Reported value is geometric mean at Industrial Canal. Range of values is from values reported in the study.

[3] The DDD values were calculated by taking the geometric mean of detected values.

[4] Single detected value.

Sediment bioassay

Bioassay results satisfied test acceptability criteria according to the performance control (survival >90 percent) and water quality parameters (Tables 2 and 4). Several of the sediments collected in Violet Marsh and Bayou Bienvenue caused reduced survival in the 10-d toxicity test ($p=0.003$), but when compared to the Lake Pontchartrain reference sediment (Control LP), none demonstrated a statistically significant reduction in survival based on Dunnett's Method (Table 5). However, the laboratory control sediment (Control SC) survival was much higher (97.4 percent) and when used as a reference in this test, several of the sites (Sed 2, Sed 8, MS, BB3, BB4) had statistically significant reductions in growth ($p<0.001$). Among the sediments that were statistically reduced relative to the control, PEL values were exceeded for Sed 2 (Zn, DDD), Sed 8 (Pb), MS (Pb, Hg, Ag, and, dieldrin) and BB1 (Pb, Hg, Zn, acenapthalene, benzo[a]anthracene, fluoranthene, phenanthrene, DDD, and dieldrin). Sediments BB3 and BB4 did not have analytes that exceeded PEL values and were not particularly high in petroleum hydrocarbons. No sediments that were statistically similar to the control had analytes that exceeded PEL values.

Table 4. Mean ± 1 standard deviation of parameters (ranges in parentheses) measured on Days 0 and 10 of the 10-day sediment toxicity test with *L. plumulosus*.

Sample ID	Temperature (°C)	Salinity (‰)	pH (SU)	D.O. (mg/L)
Control (SC)	24.3 ± 1.9 (24.1 – 24.5)	22 ± 2 (20 – 25)	7.9 ± 0.1 (7.7 – 8.1)	7.3 ± 0.7 (6.3 – 8.0)
Reference (LP)	24.4 ± 0.0 (24.0 – 24.5)	20 ± 0 (20 – 20)	7.7 ± 0.2 (7.5 – 7.9)	7.7 ± 0.4 (7.0 – 8.0)
Sed 2	24.2 ± 2.2 (22.8 – 24.5)	21 ± 2 (20 – 27)	8.0 ± 0.1 (7.8 – 8.1)	7.9 ± 0.3 (7.5 – 8.2)
Sed 3	24.2 ± 1.6 (23.1 – 24.5)	21 ± 2 (20 – 25)	7.9 ± 0.2 (7.5 – 8.1)	7.8 ± 0.3 (7.1 – 8.2)
Sed 8	24.1 ± 1.4 (23.1 – 24.5)	21 ± 1 (20 – 24)	7.9 ± 0.1 (7.6 – 8.1)	7.9 ± 0.2 (7.5 – 8.2)
Sed 7	24.3 ± 1.0 (23.9 – 24.5)	21 ± 1 (20 – 23)	7.9 ± 0.2 (7.5 – 8.1)	7.9 ± 0.3 (7.5 – 8.1)
IHNC MS	24.3 ± 0.7 (24.0 – 24.5)	21 ± 1 (20 – 22)	8.0 ± 0.1 (7.9 – 8.1)	8.0 ± 0.2 (7.8 – 8.2)
BB 1	24.2 ± 1.3 (23.4 – 24.5)	21 ± 1 (20 – 24)	7.8 ± 0.3 (7.1 – 8.1)	7.8 ± 0.2 (7.4 – 8.0)
BB2	24.1 ± 1.8 (23.2 – 24.5)	22 ± 2 (21 – 25)	8.0 ± 0.1 (7.9 – 8.2)	7.4 ± 1.3 (3.8 – 8.2)
BB3	24.1 ± 1.5 (23.1 – 24.5)	24 ± 2 (21 – 25)	8.0 ± 0.1 (7.7 – 8.1)	7.8 ± 0.4 (6.7 – 8.3)
BB4	24.1 ± 1.3 (23.7 – 24.5)	22 ± 1 (21 – 24)	7.9 ± 0.1 (7.7 – 8.1)	7.9 ± 0.3 (7.5 – 8.2)

Table 5. Percent survival (mean ± standard deviation) at termination of the 10-day sediment toxicity test with *L. plumulosus*.

Sample ID	Percent Survival	Min / Max
Control (SC)	97 ± 7	85 – 100
Reference (LP)	81 ± 9	70 – 90
Sed 2	58 ± 37[1]	0 – 95
Sed 3	78 ± 10	65 – 90
Sed 7	89 ± 11	75 – 100
Sed 8	64 ± 17	35 – 80
IHNC MS	52 ± 18	30 – 75
BB 1	48 ± 13	30 – 65
BB2	88 ± 12	75 – 100
BB3	57 ± 27	15 – 85
BB4	53 ± 16	35 – 70

[1] Indicates treatment survival is statistically different ($p<0.05$) from SC sediment survival when analyzed using one way ANOVA and Dunnett's post-hoc test.

Comparison of the bioassay and chemical analysis results suggests a relationship between chemical concentrations in sediment (PEL exceedances for Cd, Cu, Pb, Zn, Ag, polycyclic aromatic hydrocarbons, DDD, and dieldrin) and significant mortality of *L. plumulosus* (BB-1, 3, 4, Sed 2, Sed 8). Sediment quality guidelines can be used to gain a better understanding of the toxicity observed in the bioassay. However, there are several other factors that should be considered when interpreting these results as outlined above (e.g., salinity, total organic carbon, sediment grain size). Canal sites having a larger percentage of sand and gravel (Sed 4, Sed 7, Sed 9) generally had lower levels of chemicals and did not result in significant toxicity to *L. plumulosus*.

Spatially, trends suggest that sediments close to the East Bank WWTP, and pump stations had elevated levels of chemicals and significant *L. plumulosus* mortality. Generally, sediments further from the levees in Violet Marsh had lower chemical concentrations and less toxicity relative to other stations. Some inconsistencies between sediment chemistry and bioassay results were observed for sample locations BB-3 and BB-4, where significant mortality was observed in the bioassay but very few chemicals exceeded SQGs. The observed mortality is likely due to chemicals that were not measured or test species' sensitivity to confounding factors other than chemical contamination (e.g., salinity, sediment grain size, and predation).

There were no observable trends in sediment chemistry results to suggest that pump stations that were functioning following Katrina resulted in deposition of contaminated sediments in Violet Marsh as compared to non-functioning pump stations. This conclusion is further reinforced by the bioassay results for sites Sed 2 and 8, where toxicity was observed for a functioning pump station and non-functioning pump station, respectively.

Uncertainty of study results

Uncertainty is related to either the natural variability of a measurement or from unknown information that cannot be derived from the study. There are several sources of uncertainty regarding the conclusions that can be drawn from the data collected in this study and what can be concluded regarding the ecological impacts of the dewatering of New Orleans following Hurricane Katrina. First, sediment chemistry and bioassay data generated are limited due to the scope of the study, limited number of samples collected, and current tools available to assess toxicity and risk to ecological receptors. For example, only nine sediments from the Violet Marsh were assessed using the amphipod bioassay to determine the potential ecological impacts. These results provide information regarding a single sampling event, with limited spatial coverage, and biological effects using a single test organism. The study was limited to a single wetland (Violet Marsh) so it is difficult to predict whether similar impacts would be expected in other wetlands. Risk pathways such as bioaccumulation and biomagnification of contaminants were not assessed as part of this study. A food web analysis should be conducted to determine the potential ecological risks to upper trophic level ecological receptors posed by the pesticides, polycyclic aromatic hydrocarbons, and metals found in sediments.

4 Conclusions

On the basis of this study, the following observations can be made:

1. Spatial trends were observed for concentrations of chemicals in sediment. The highest to lowest concentrations were reported in sediments within the city of New Orleans, wetlands receiving outfalls from pumps or WWTP, canals transporting urban runoff, and wetland areas distant from pump stations.

2. Visible trends of chemical concentrations in sediment were observed among sample location groups (e.g., outfall locations, WWTP, canals, wetlands); however, these trends were not always consistent with bioassay results.

3. A comparison of the sediment chemistry data from this study with two other studies reporting sediment concentrations within the city of New Orleans indicates that chemical concentrations in sediments within the levees were greater than concentrations in Violet Marsh, with one exception.

4. There are several sources of uncertainty in this study. These results may not be representative of other wetland areas subjected to dewatering activities, and ecological effects resulting from food web biomagnification of chemicals, especially pesticides and metals, were not assessed.

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Appendix A
Sediment Chemistry Data

Table A1. Analytes not detected in any samples.

Petroleum Hydrocarbons	Gasoline		
Volatile Organics	1,1,1-Trichloroethane	2-Hexanone	Dibromochloromethane
	1,1,2,2-Tetrachloroethane	4-Methyl-2-pentanone	Dichlorodifluoromethane
	1,1,2-Trichloro-1,2,2-trifluoroethane	Benzene	Isopropylbenzene
	1,1,2-Trichloroethane	Bromodichloromethane	Methyl acetate
	1,1-Dichloroethane	Bromoform	Methyl tert-butyl ether
	1,1-Dichloroethene	Bromomethane	Methylcyclohexane
	1,2,4-Trichlorobenzene	Caprolactam	Methylene chloride
	1,2-Dibromo-3-chloropropane	Carbon tetrachloride	Styrene
	1,2-Dibromoethane	Chlorobenzene	Tetrachloroethene
	1,2-Dichlorobenzene	Chloroethane	trans-1,2-Dichloroethene
	1,2-Dichlorobenzene	Chloroform	trans-1,3-Dichloropropene
	1,2-Dichloroethane	Chloromethane	Trichloroethene
	1,2-Dichloropropane	cis-1,2-Dichloroethene	Trichlorofluoromethane
	1,3-Dichlorobenzene	cis-1,3-Dichloropropene	Vinyl chloride
	2-Butanone	Cyclohexane	
Semivolatile Organics (BNA)	1,1'-Biphenyl	3,3'-Dichlorobenzidine	Dimethyl phthalate
	1,4-Dichlorobenzene	3-Nitroaniline	Di-n-butyl phthalate
	2,2'-oxybis(1-Chloropropane)	4,6-Dinitro-2-methylphenol	Hexachlorobenzene
	2,4,6-Trichlorophenol	4-Bromophenyl phenyl ether	Hexachlorobutadiene
	2,4-Dichlorophenol	4-Chloro-3-methylphenol	Hexachlorocyclopentadiene
	2,4-Dimethylphenol	4-Chloroaniline	Hexachloroethane
	2,4-Dinitrophenol	4-Chlorophenyl phenyl ether	Isophorone
	2,4-Dinitrotoluene	4-Nitroaniline	Nitrobenzene
	2,6-Dinitrotoluene	4-Nitrophenol	N-Nitrosodi-n-propylamine

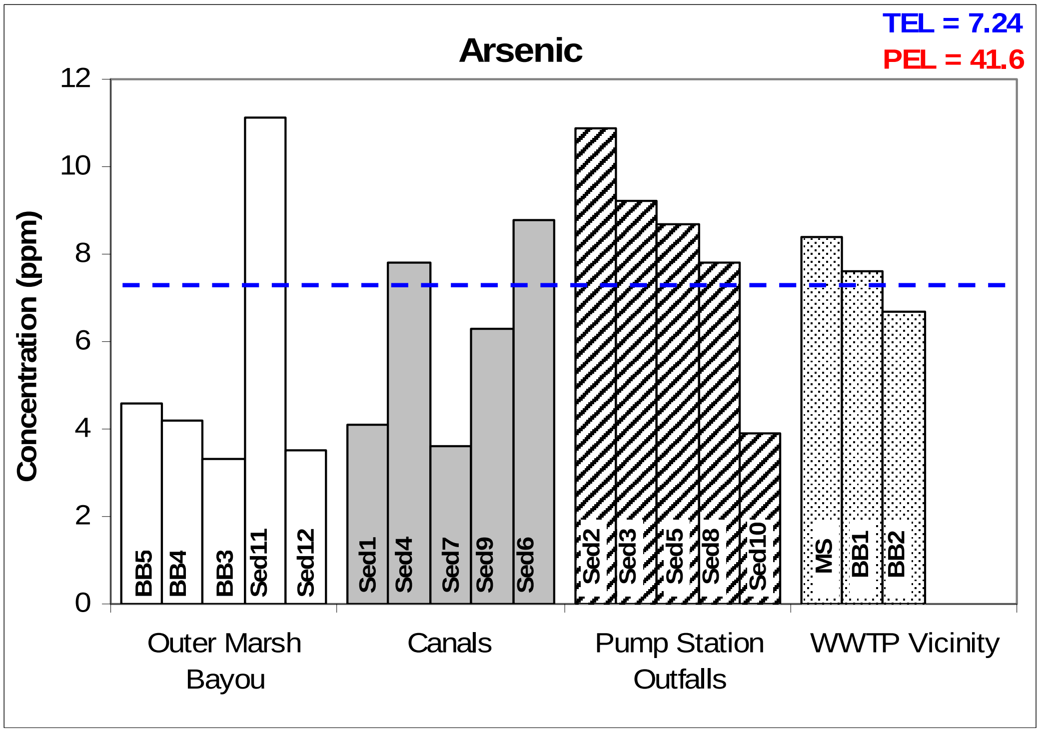
	2-Chloronaphthalene	Acetophenone	N-Nitrosodiphenylamine
	2-Chlorophenol	Benzaldehyde	Pentachlorophenol
	2-Nitroaniline	bis(2-Chloroethoxy)methane	Phenol
	2-Nitrophenol	bis(2-Chloroethyl) ether	
Pesticides	4,4'-DDE	Atrazine	gamma-BHC (Lindane)
	4,4'-DDT	beta-BHC	Heptachlor
	Aldrin	delta-BHC	Heptachlor epoxide
	alpha-BHC	Endosulfan I	Methoxychlor
	alpha-Chlordane	Endosulfan sulfate	Toxaphene
PCBs	Aroclor 1221	Aroclor 1242	
	Aroclor 1232	Aroclor 1248	

Table A2. Analytes detected in at least one sample.

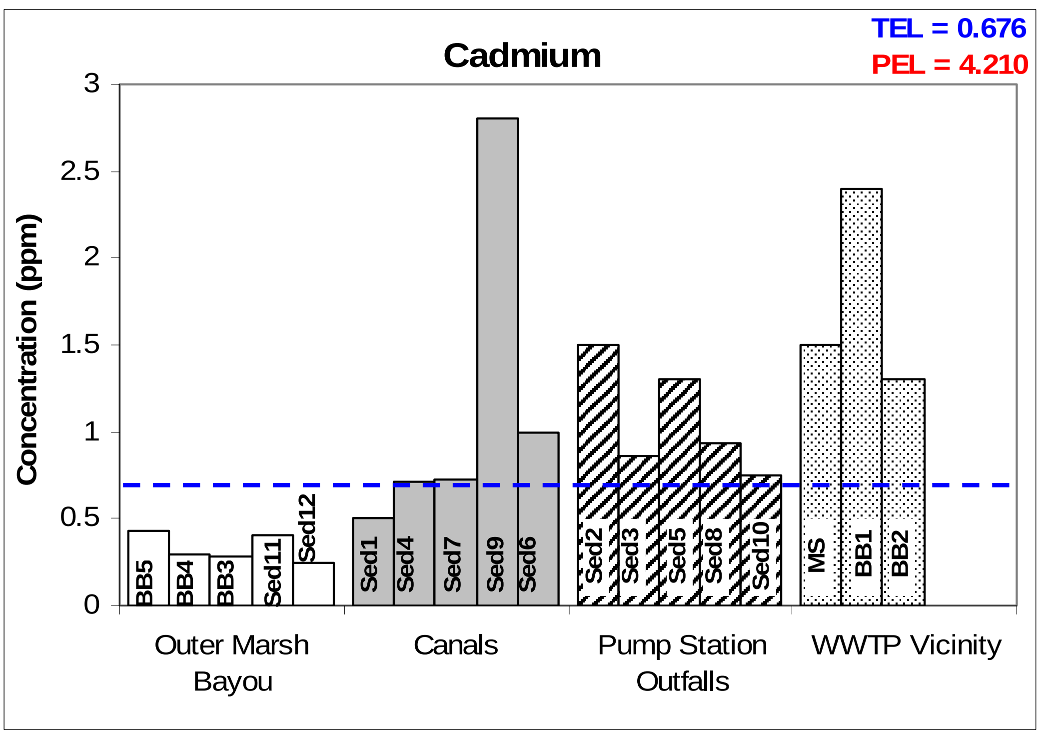
Petroleum Hydrocarbons	Motor Oil	Diesel Fuel
Volatile Organics	Acetone	Toluene
Semivolatile Organics (BNA)	2-Methylnaphthalene	Carbazole
	2-Methylphenol	Carbon disulfide
	4-Methylphenol	Chrysene
	Acenaphthene	Dibenz(a,h)anthracene
	Acenaphthylene	Dibenzofuran
	Anthracene	Diethyl phthalate
	Benzo(a)anthracene	Di-n-octyl phthalate
	Benzo(a)pyrene	Fluoranthene
	Benzo(b)fluoranthene	Fluorene
	Benzo(ghi)perylene	Indeno(1,2,3-cd)pyrene
	Benzo(k)fluoranthene	Naphthalene
	bis(2-Ethylhexyl) phthalate	Phenanthrene
	Butyl benzyl phthalate	Pyrene
Pesticides	4,4'-DDD	Endrin aldehyde
	Dieldrin	Endrin ketone
	Endosulfan II	gamma-Chlordane
	Endrin	

PCBs	Aroclor 1016	Aroclor 1260
	Aroclor 1254	
Metals	Aluminum	Lead
	Arsenic	Magnesium
	Barium	Manganese
	Antimony	Mercury
	Beryllium	Nickel
	Cadmium	Potassium
	Calcium	Selenium
	Chromium	Silver
	Cobalt	Sodium
	Copper	Thallium
	Iron	

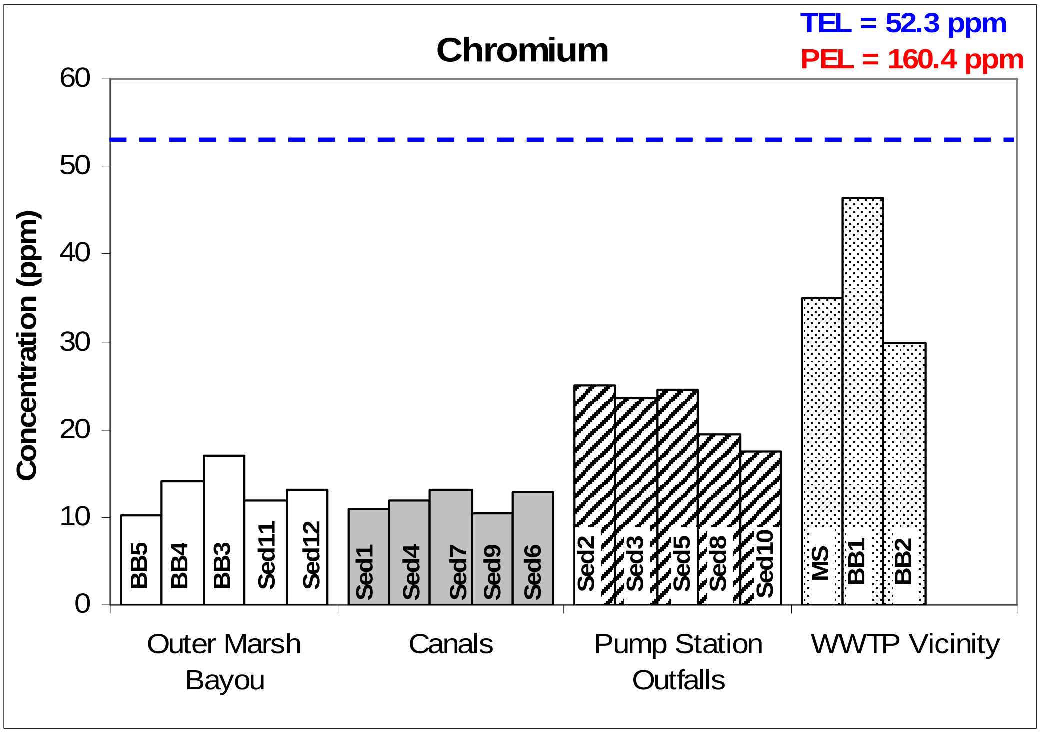
Note for Appendix A figures: Sediment quality benchmarks for individual chemicals are expressed in the following figures as threshold effects levels (TEL; dashed blue line) and probable effects levels (PEL; solid red line). Bars representing non-detected values have dashed borders and are marked with an asterisk.

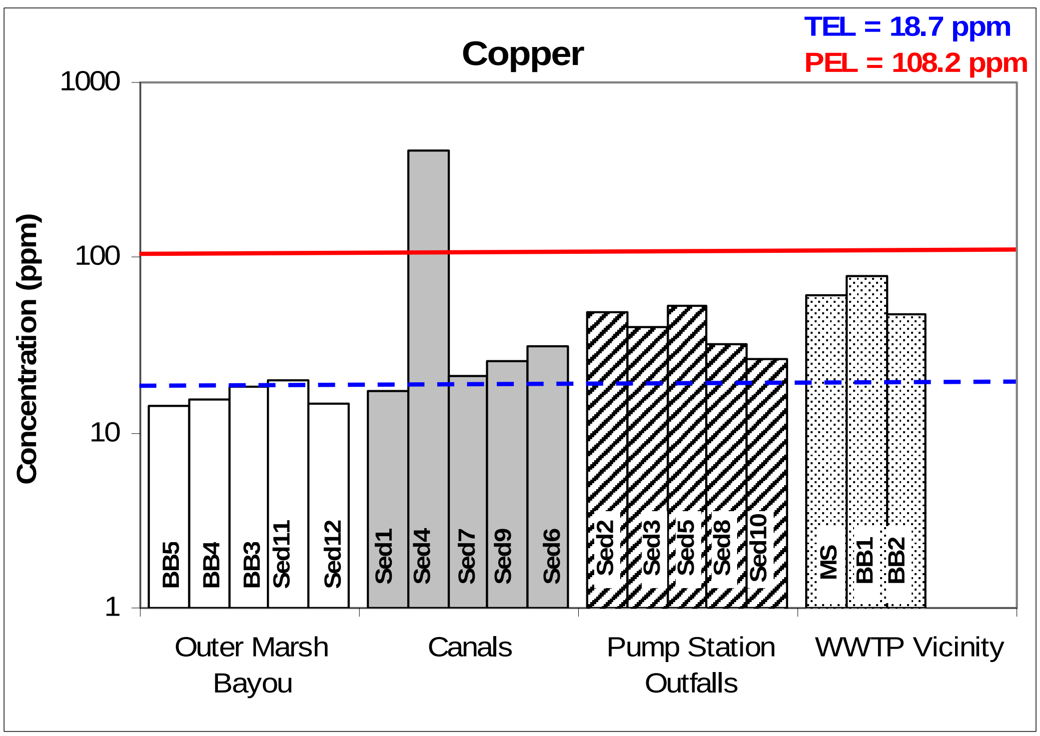


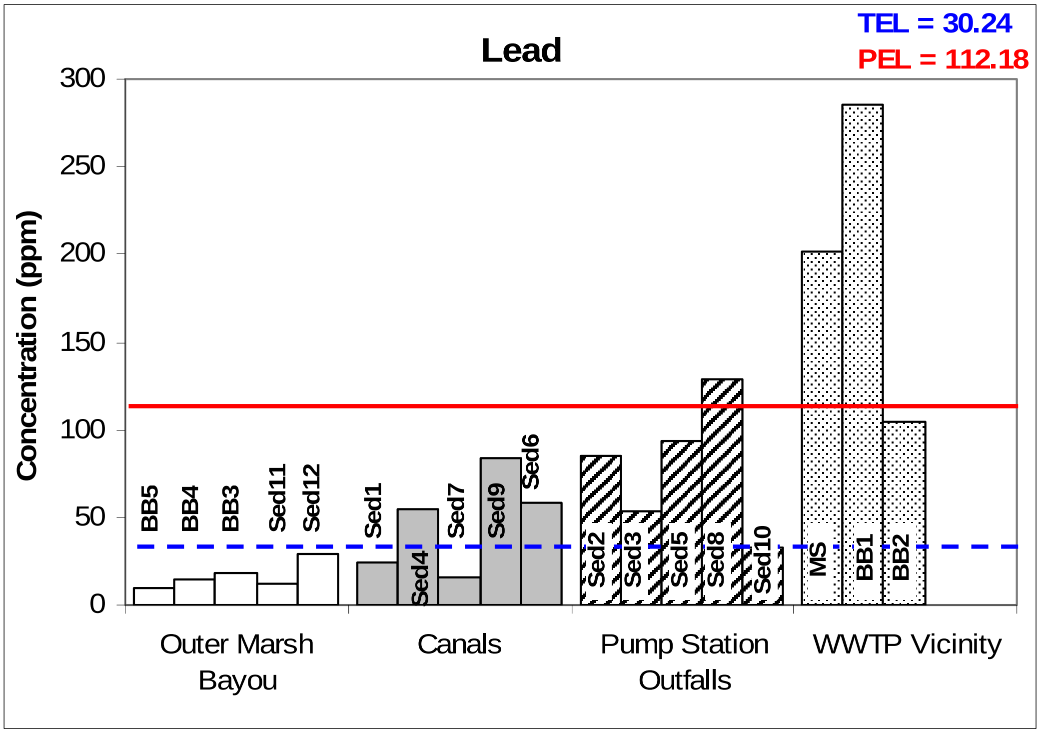
Arsenic
TEL = 7.24
PEL = 41.6
Concentration (ppm)
0
2
4
6
8
10
12
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity

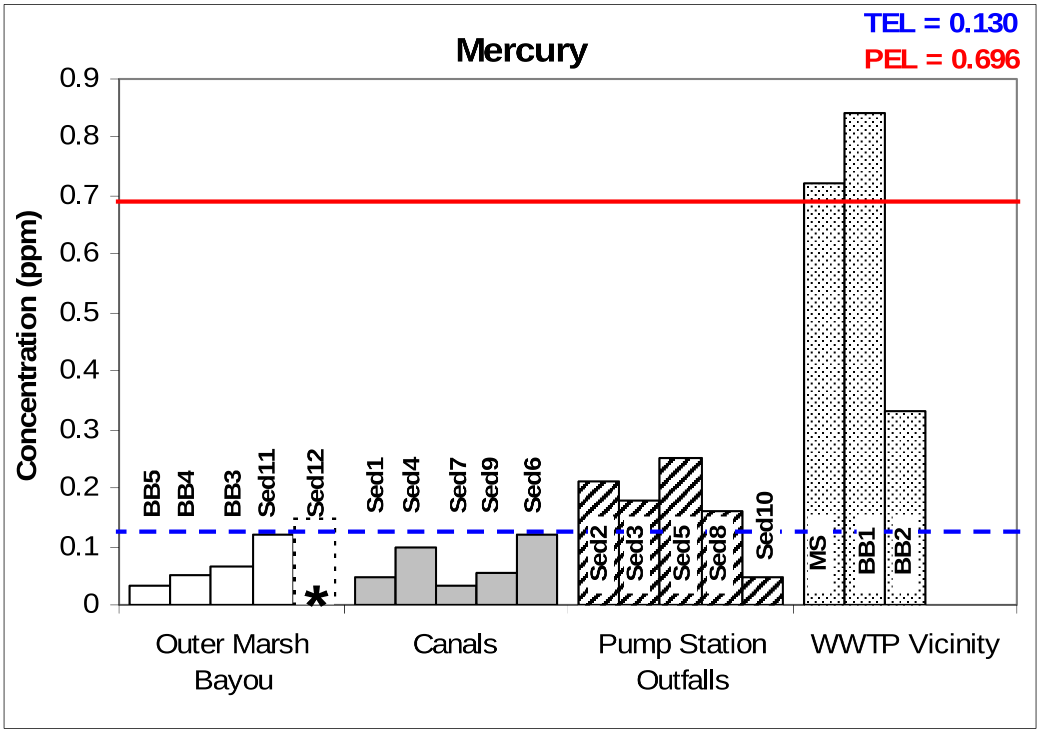


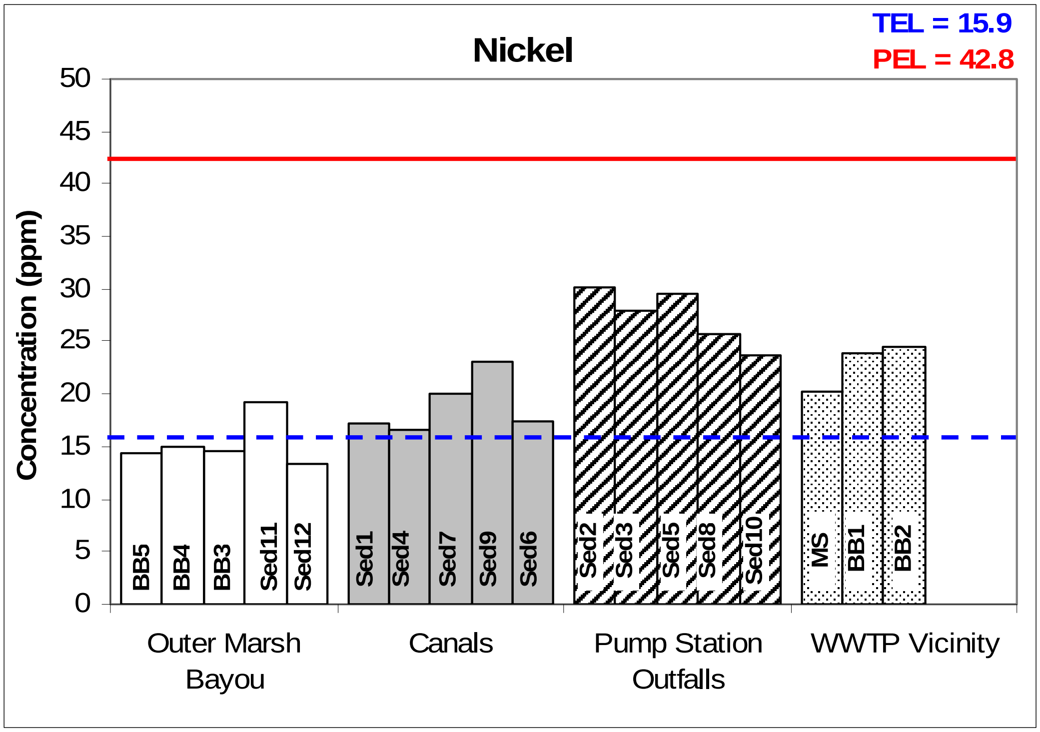
Cadmium
TEL = 0.676
PEL = 4.210
Concentration (ppm)
0
0.5
1
1.5
2
2.5
3
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity


Chromium
TEL = 52.3 ppm
PEL = 160.4 ppm
Concentration (ppm)
60
50
40
30
20
10
0
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity


Copper
TEL = 18.7 ppm
PEL = 108.2 ppm
Concentration (ppm)
1000
100
10
1
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity


Lead
TEL = 30.24
PEL = 112.18
Concentration (ppm)
300
250
200
150
100
50
0
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity


Mercury
TEL = 0.130
PEL = 0.696
Concentration (ppm)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
BB5
BB4
BB3
Sed11
Sed12
*
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity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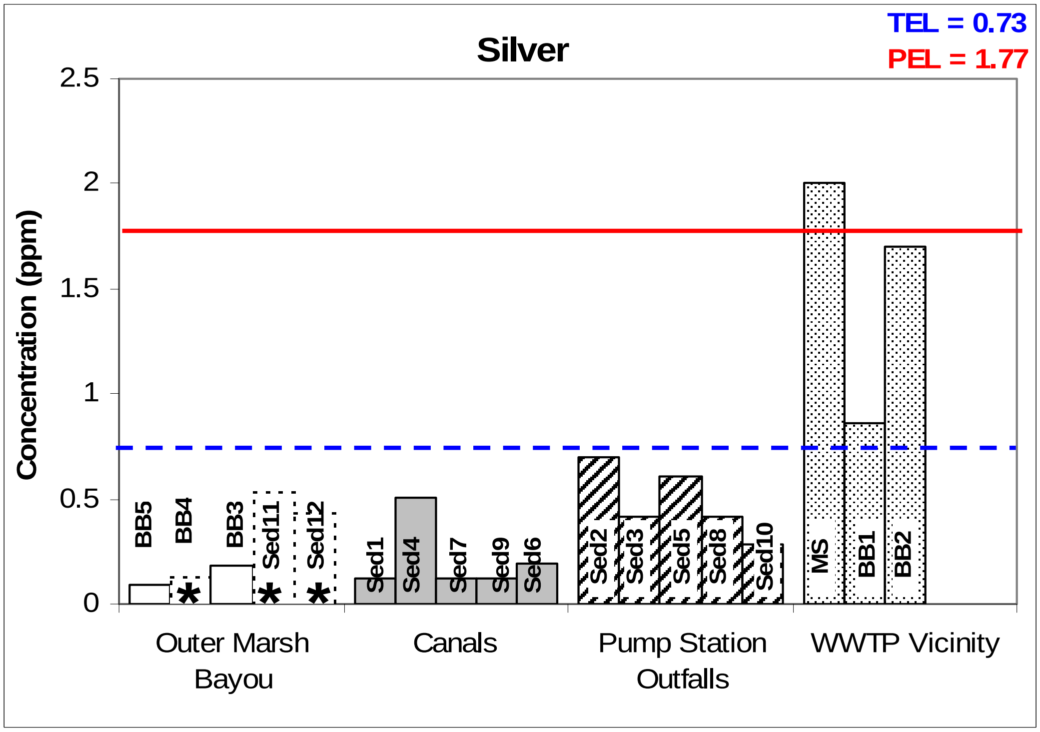
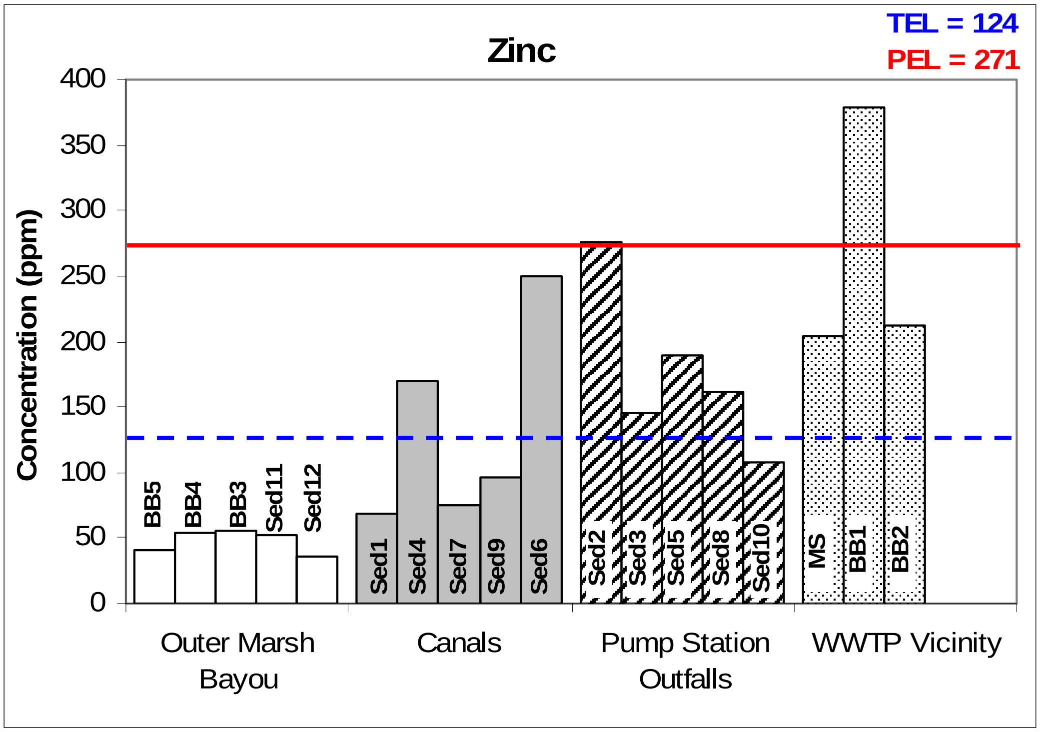
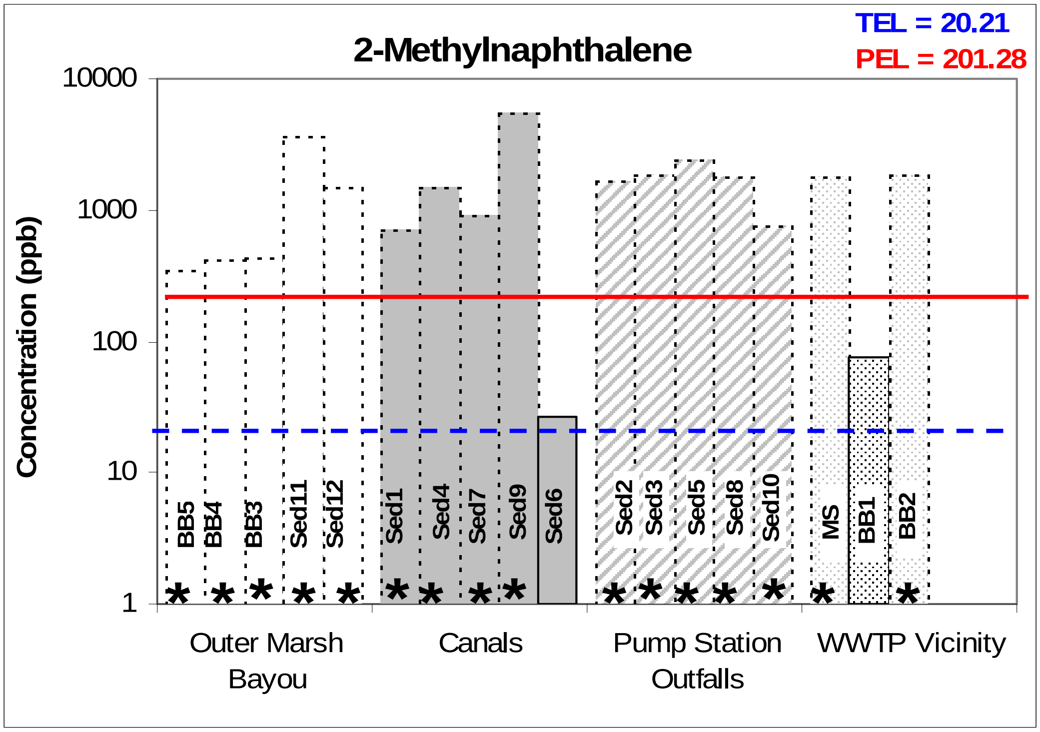
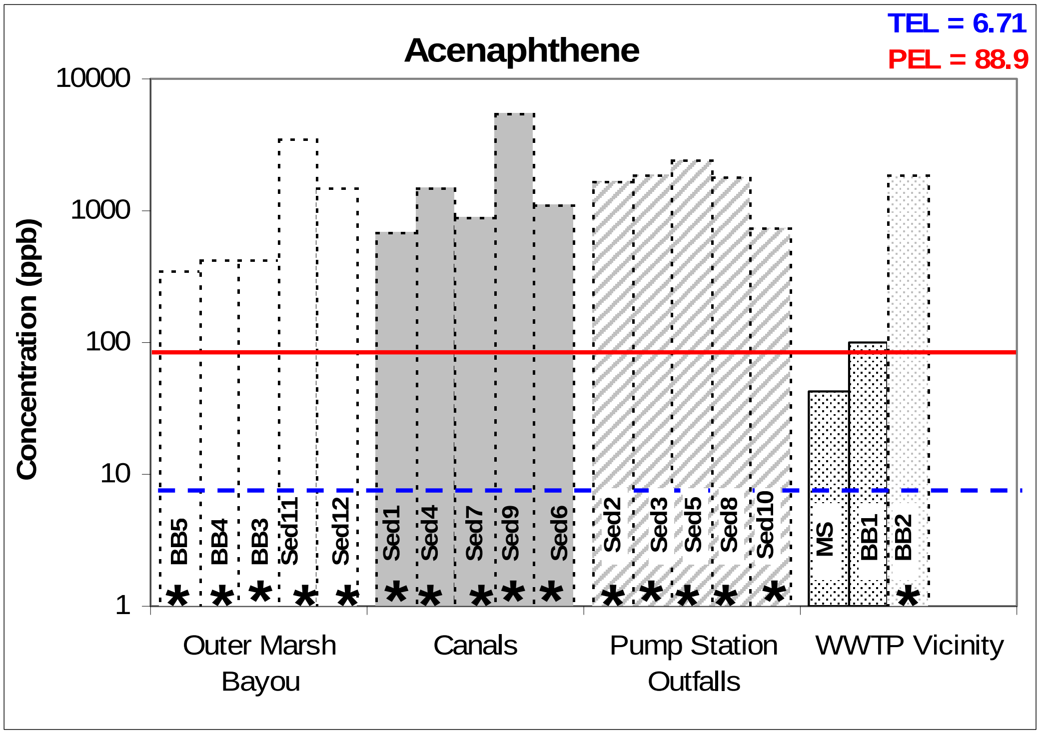
PEL = 42.8
Concentration (ppm)
50
45
40
35
30
25
20
15
10
5
0
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity

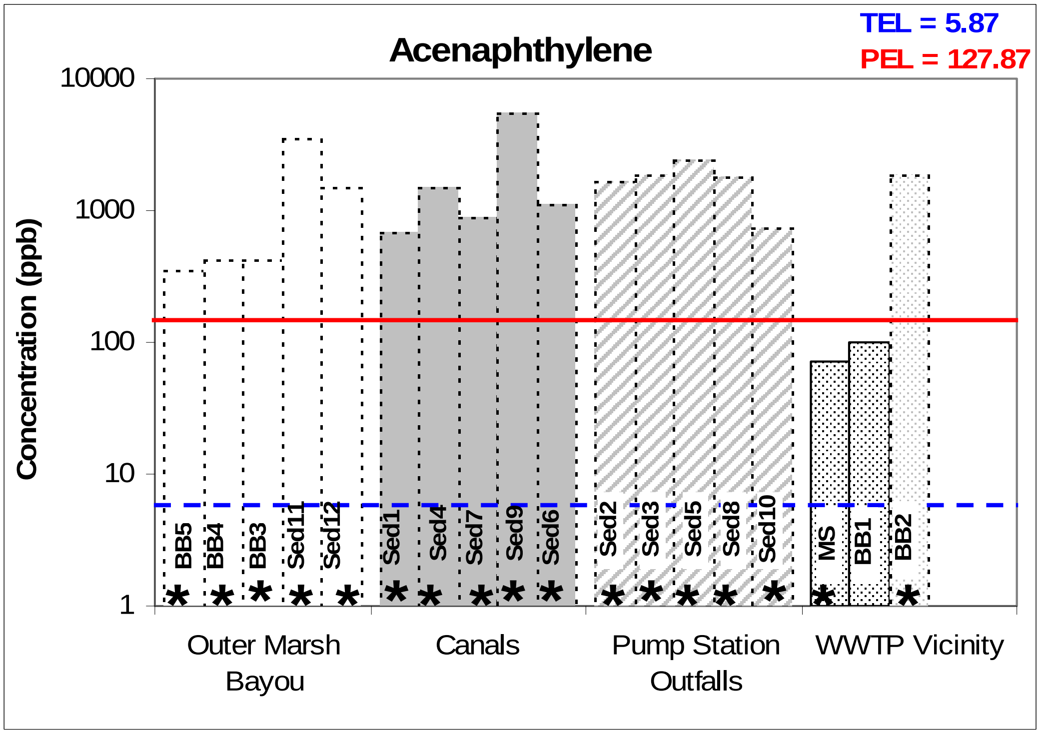

Silver
TEL = 0.73
PEL = 1.77
Concentration (ppm)
2.5
2
1.5
1
0.5
0
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity


Zinc
TEL = 124
PEL = 271
Concentration (ppm)
400
350
300
250
200
150
100
50
0
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity

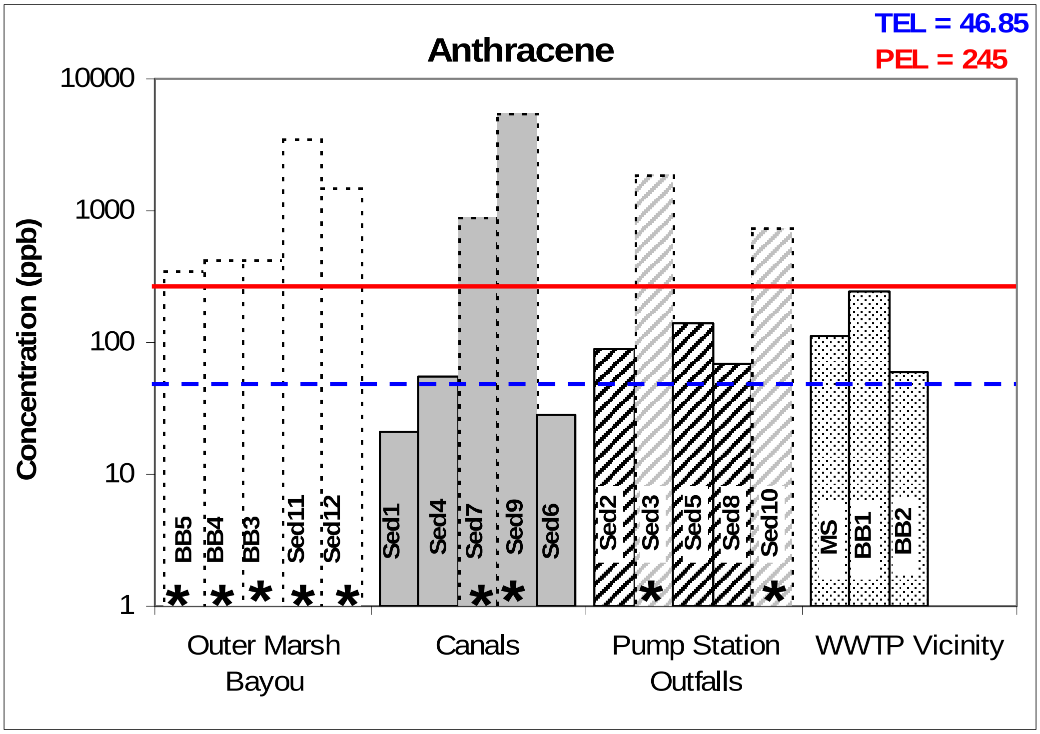

2-Methylnaphthalene
TEL = 20.21
PEL = 201.28
Concentration (ppb)
10000
1000
100
10
1
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity

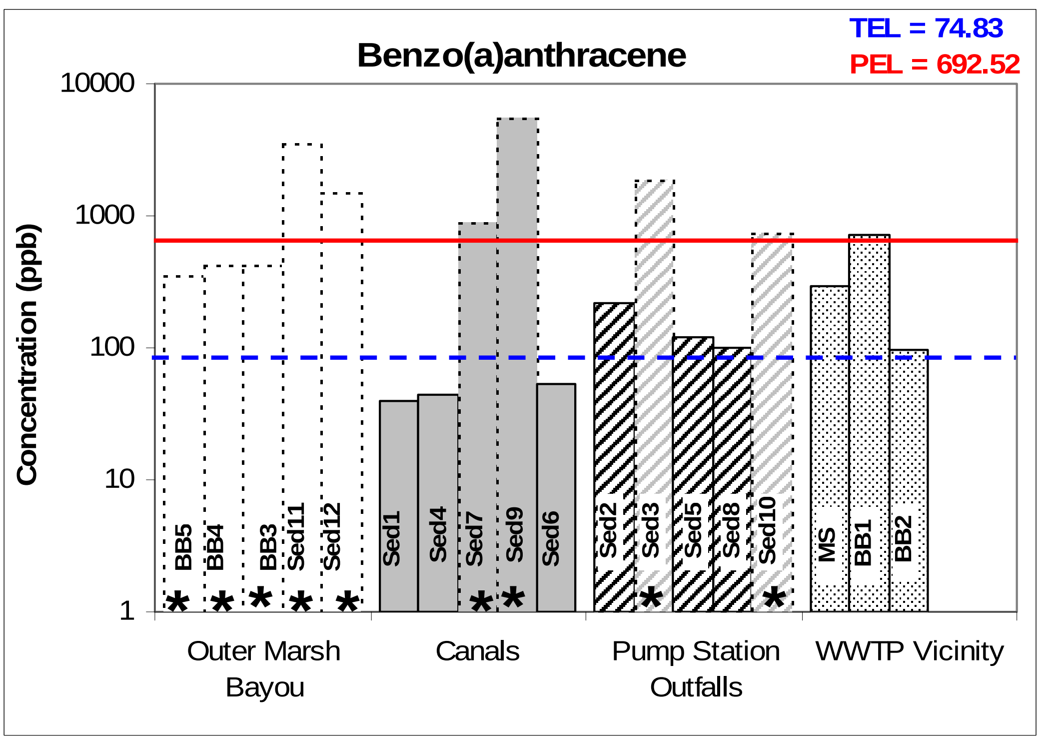


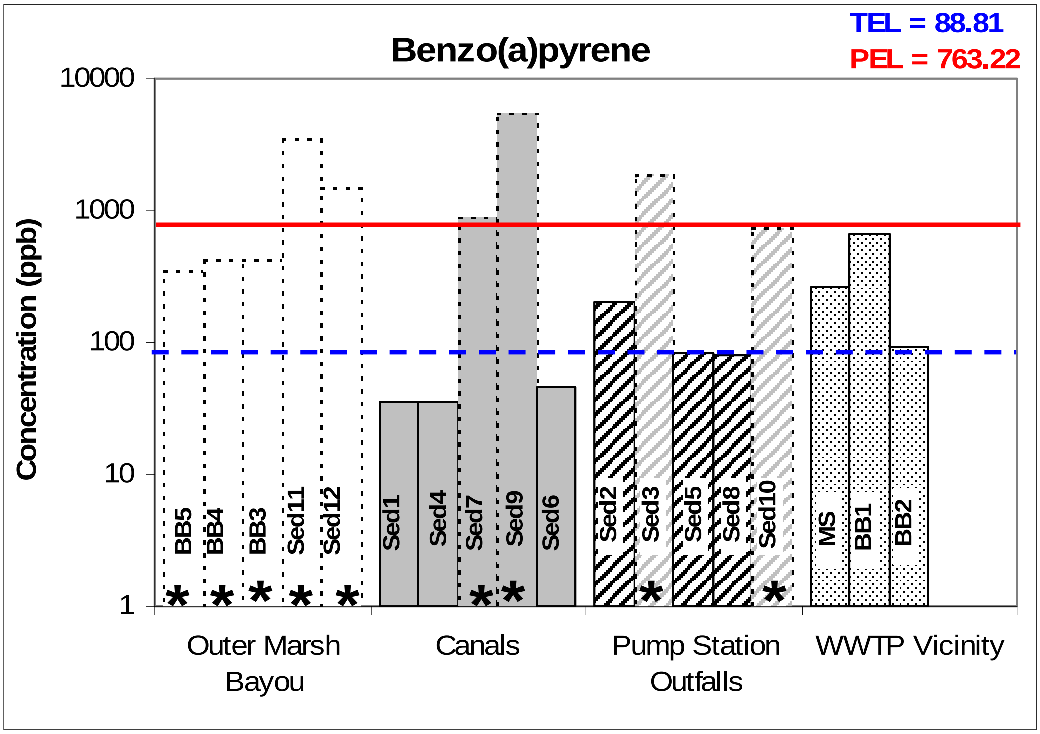
Acenaphthene
TEL = 6.71
PEL = 88.9
Concentration (ppb)
10000
1000
100
10
1
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity

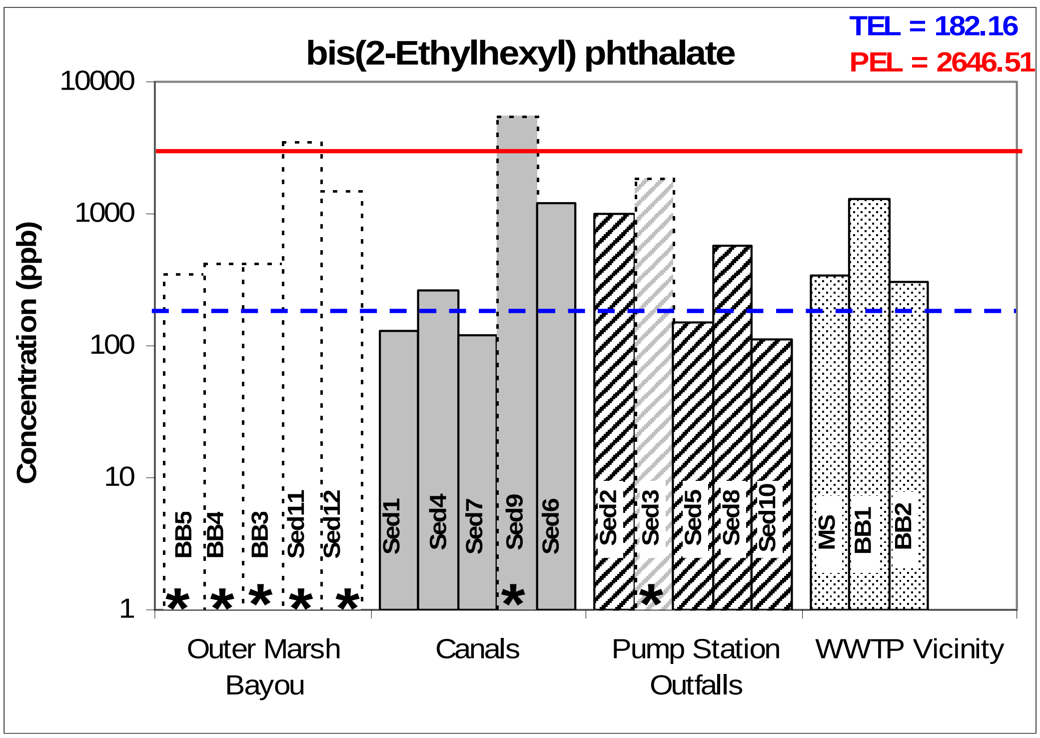


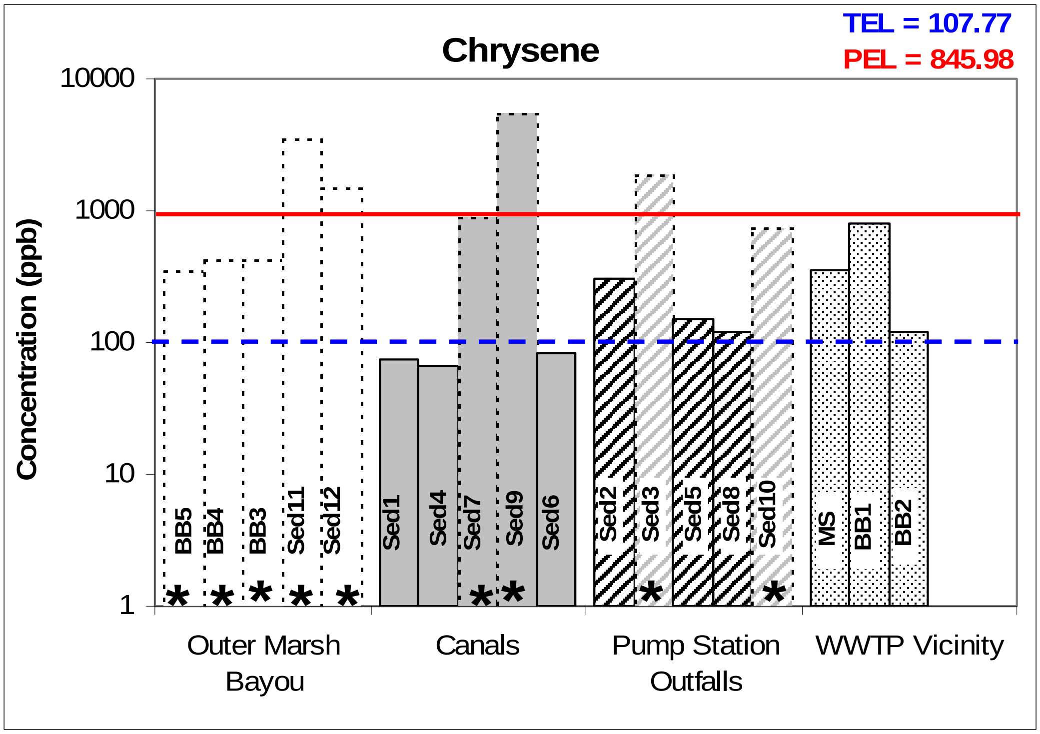
Acenaphthylene
TEL = 5.87
PEL = 127.87
Concentration (ppb)
10000
1000
100
10
1
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity

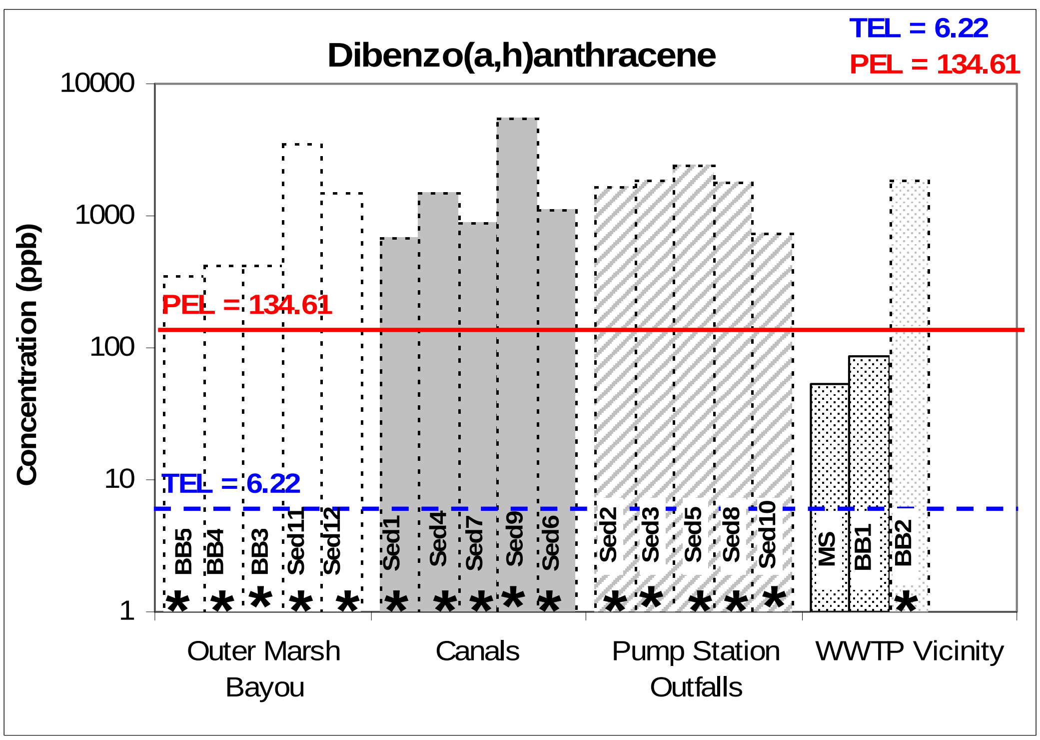

Anthracene
TEL = 46.85
PEL = 245
Concentration (ppb)
10000
1000
100
10
1
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity

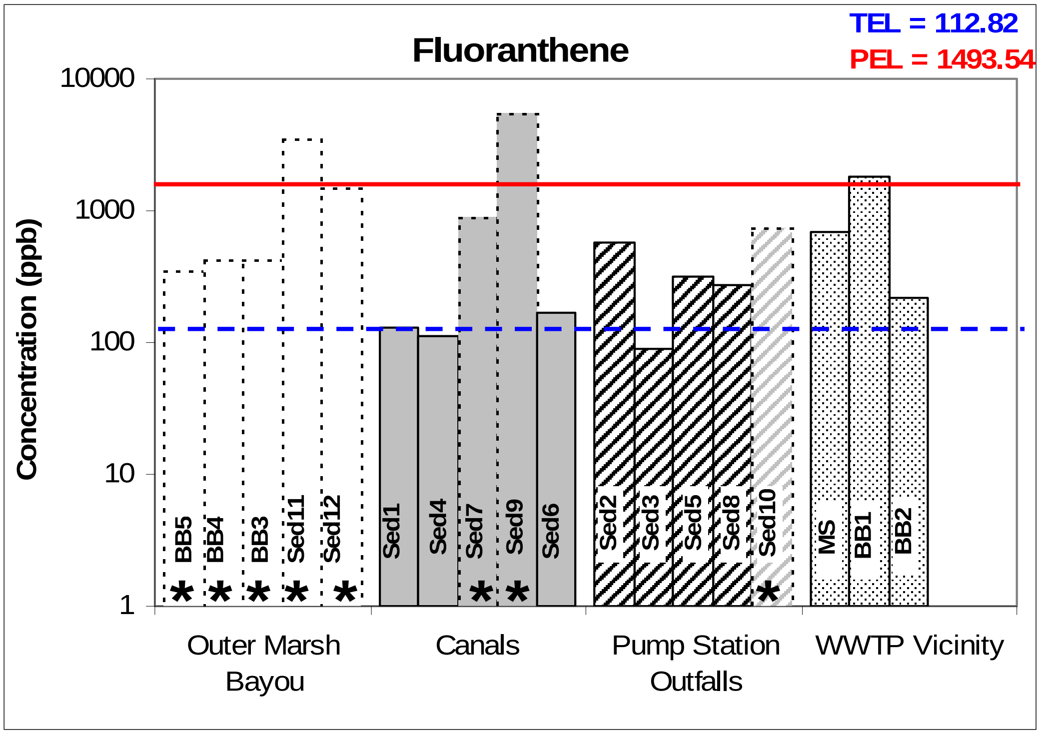

Benzo(a)anthracene
TEL = 74.83
PEL = 692.52
Concentration (ppb)
10000
1000
100
10
1
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity

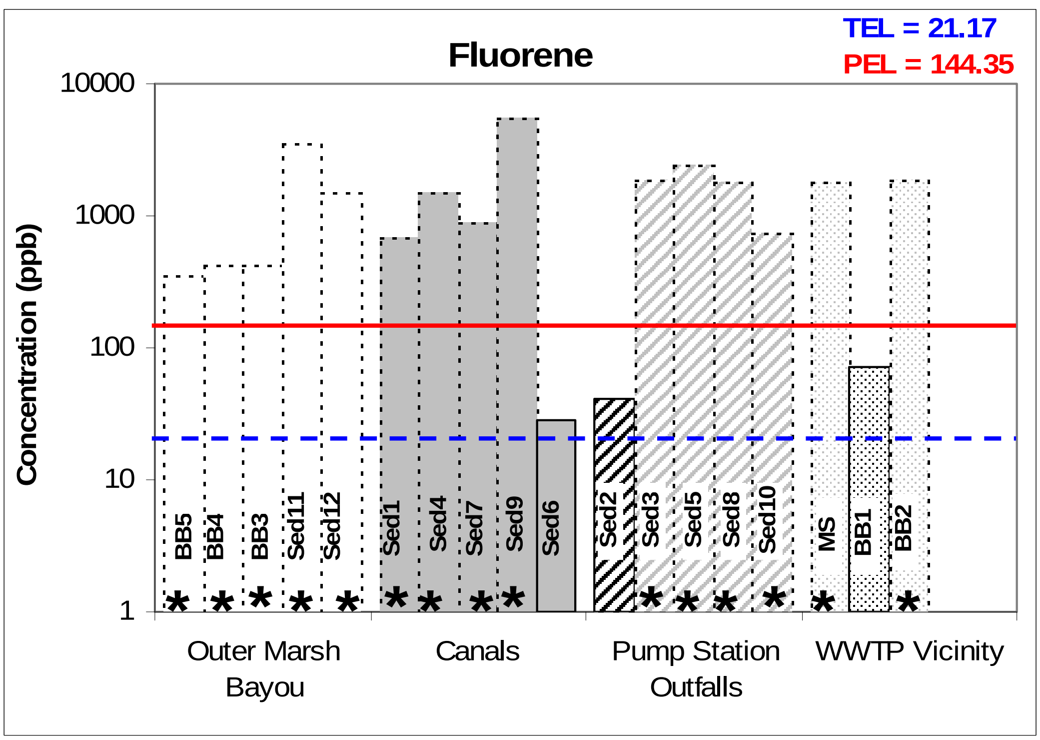

Benzo(a)pyrene
TEL = 88.81
PEL = 763.22
Concentration (ppb)
10000
1000
100
10
1
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity

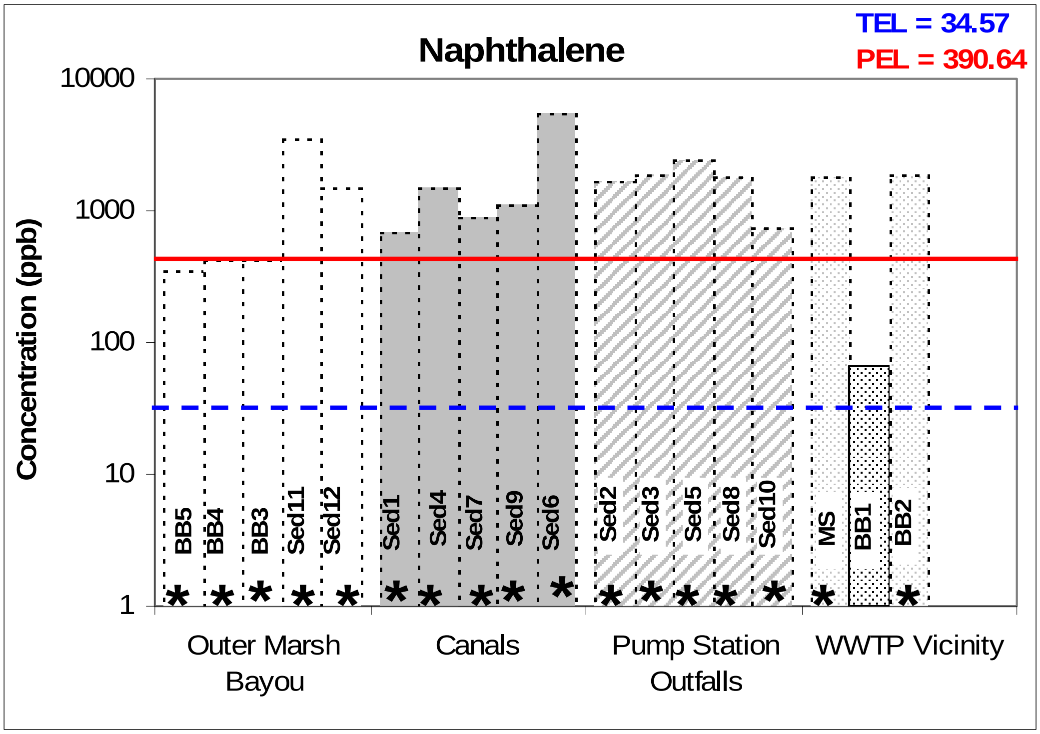

bis(2-Ethylhexyl) phthalate
TEL = 182.16
PEL = 2646.51
Concentration (ppb)
10000
1000
100
10
1
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity

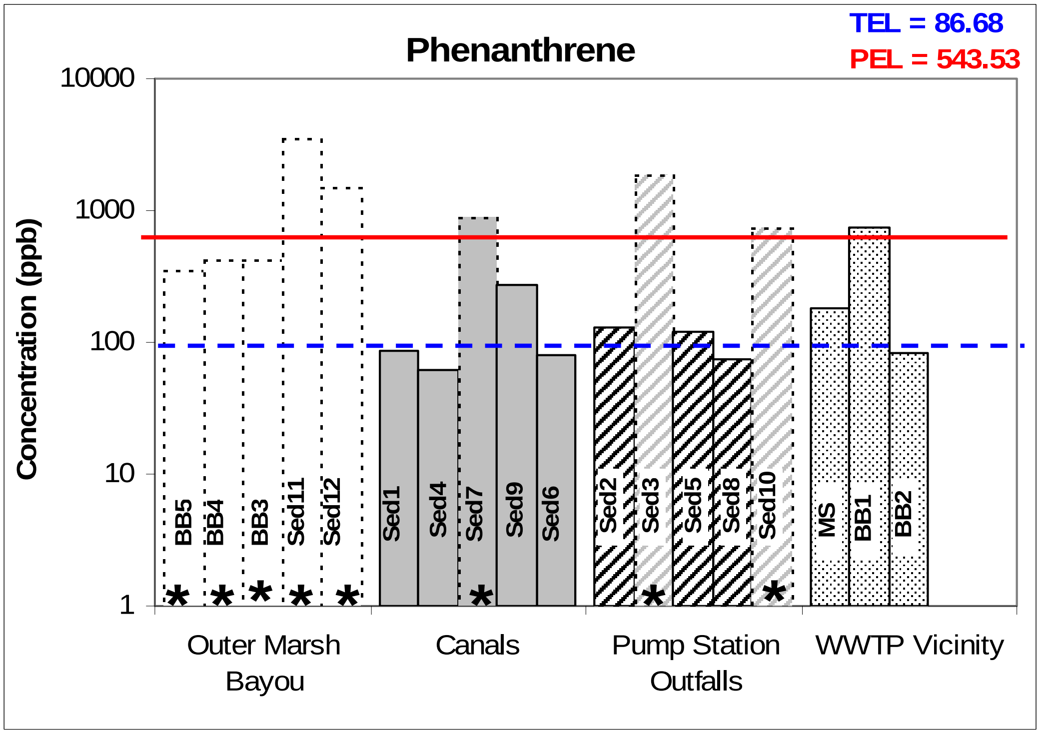

Chrysene
TEL = 107.77
PEL = 845.98
Concentration (ppb)
10000
1000
100
10
1
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity

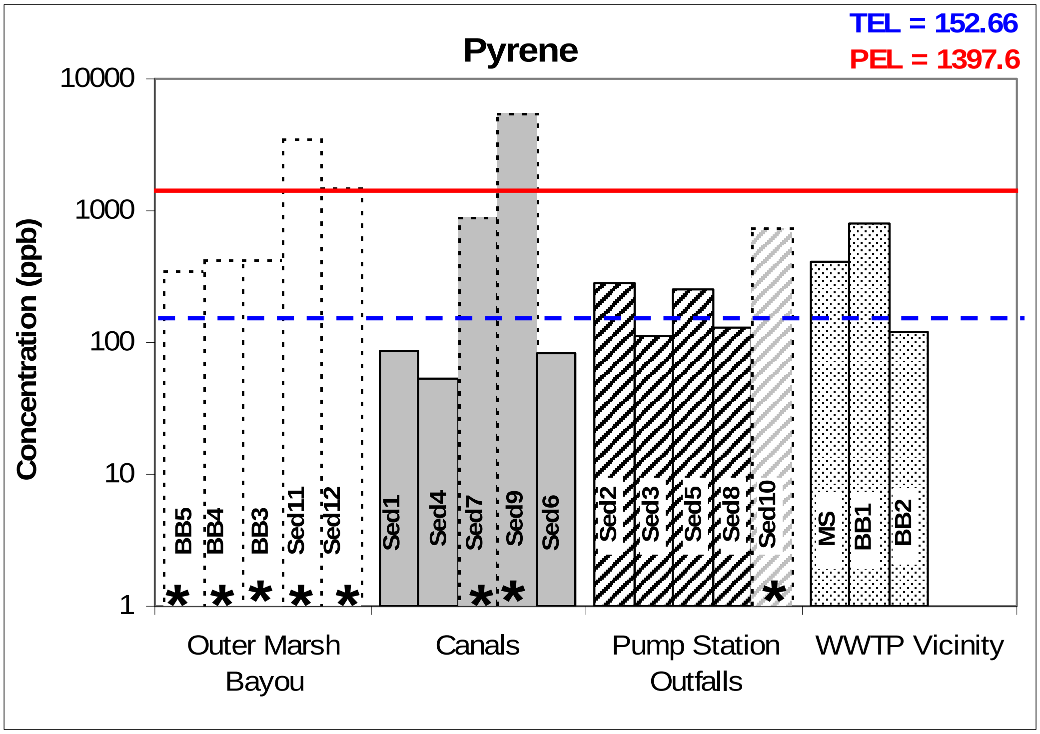

Dibenzo(a,h)anthracene
TEL = 6.22
PEL = 134.61
Concentration (ppb)
10000
1000
100
10
1
PEL = 134.61
TEL = 6.22
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity

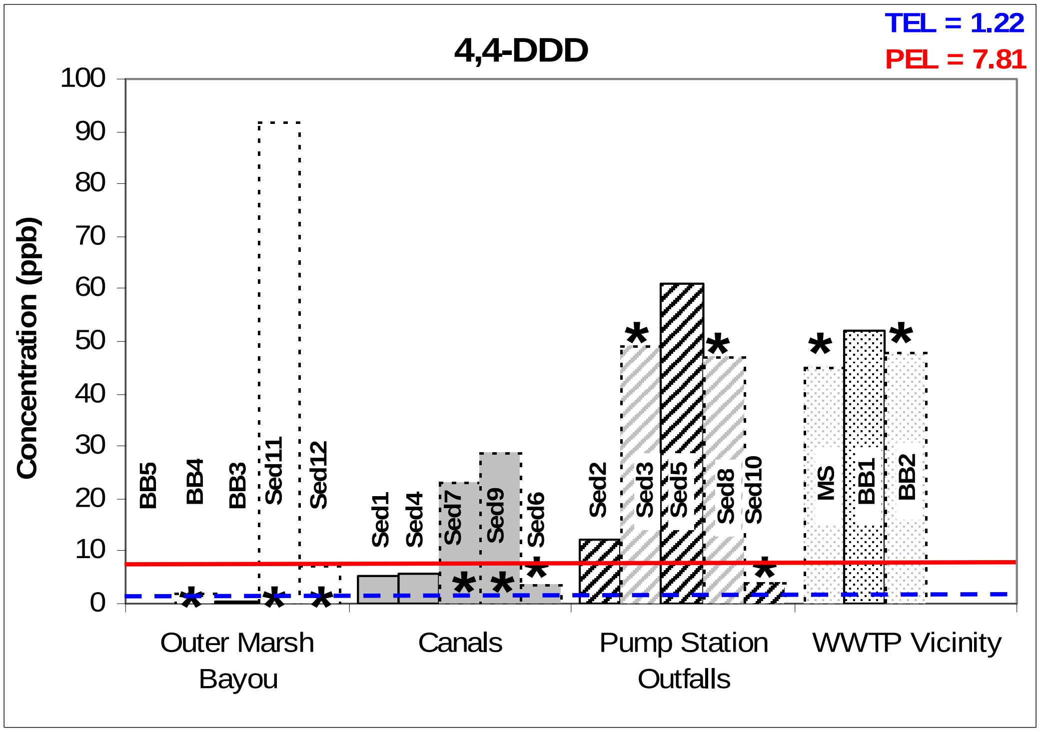

Fluoranthene
TEL = 112.82
PEL = 1493.54
Concentration (ppb)
10000
1000
100
10
1
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity

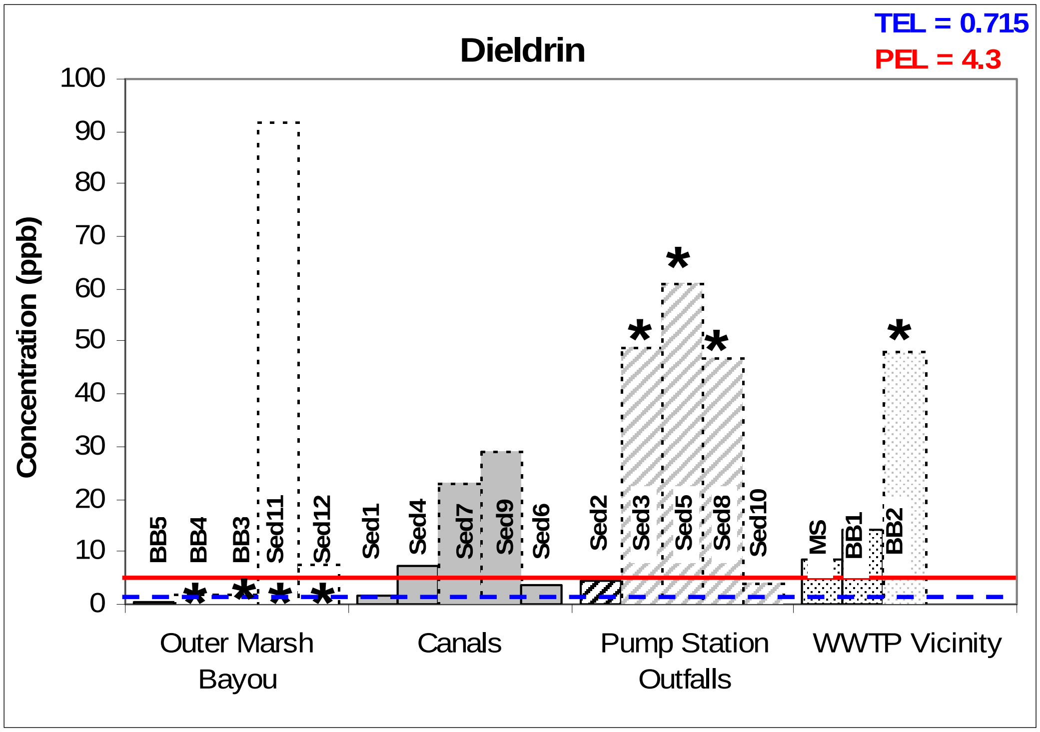

Fluorene
TEL = 21.17
PEL = 144.35
Concentration (ppb)
10000
1000
100
10
1
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity

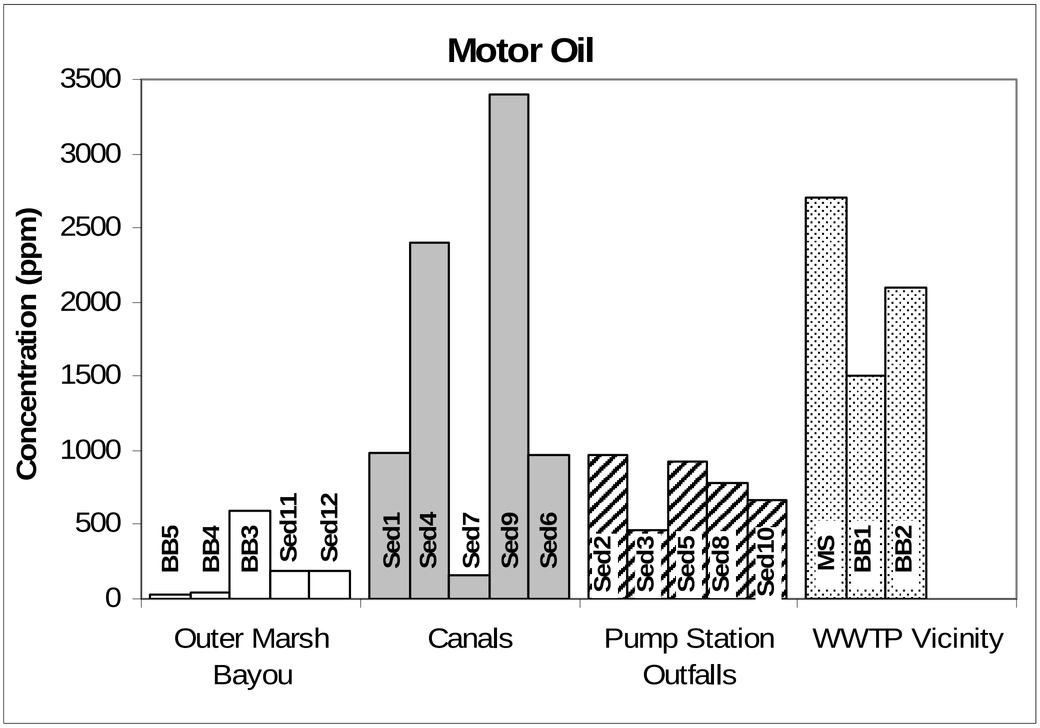

Naphthalene
TEL = 34.57
PEL = 390.64
Concentration (ppb)
10000
1000
100
10
1
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity

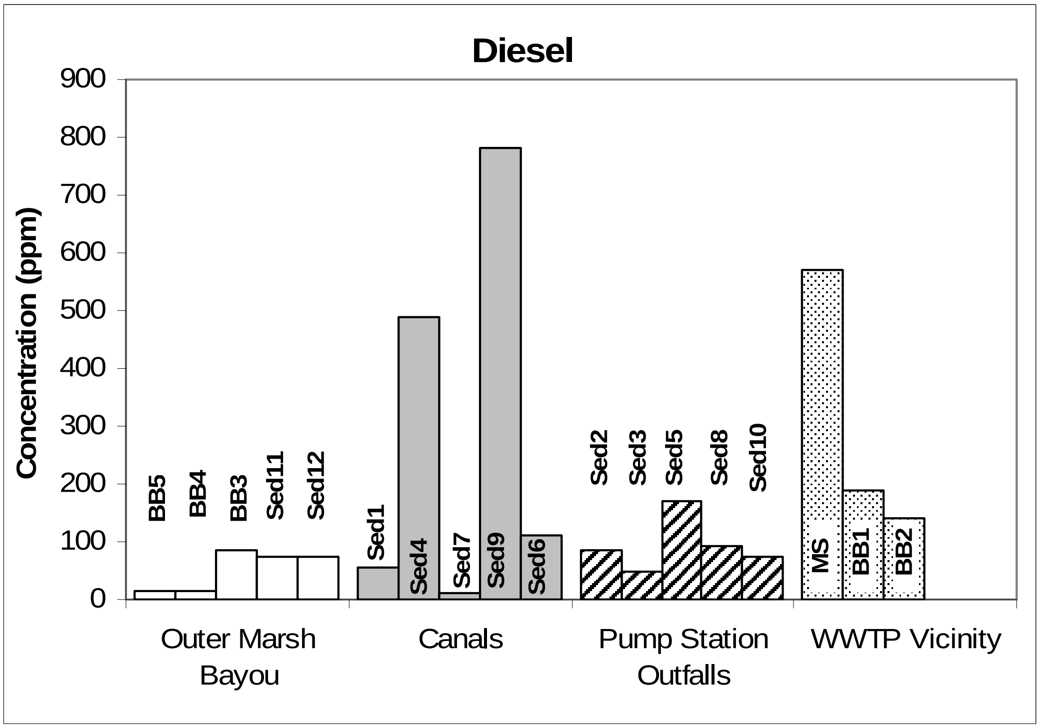

Phenanthrene
TEL = 86.68
PEL = 543.53
Concentration (ppb)
10000
1000
100
10
1
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity

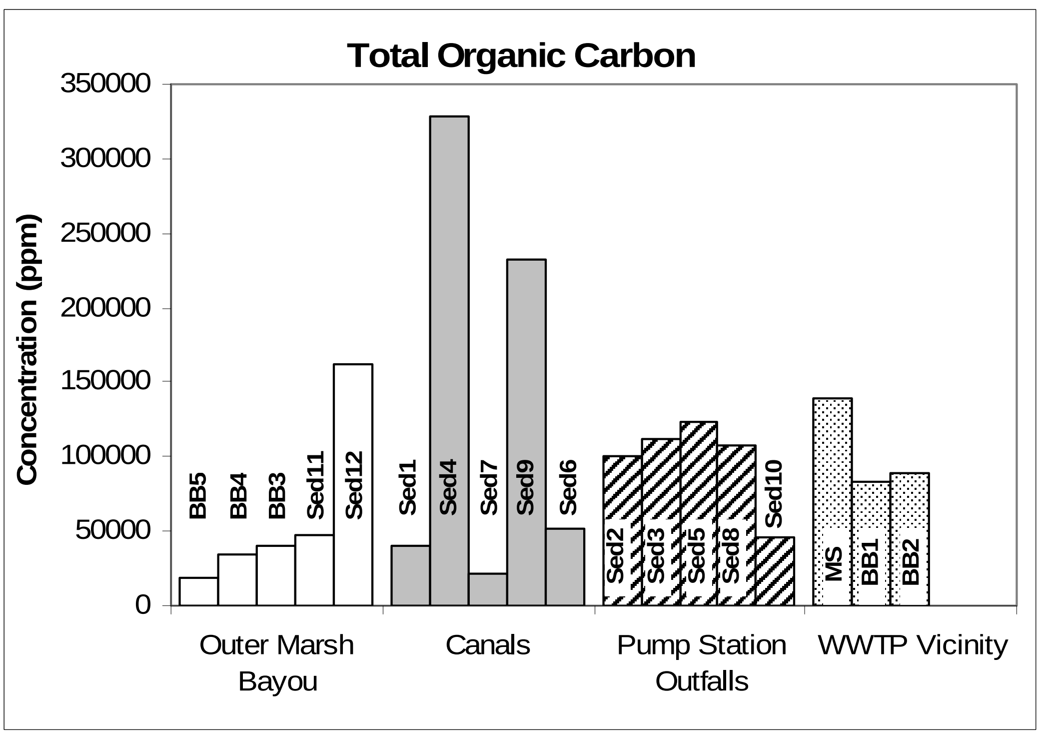

Pyrene
TEL = 152.66
PEL = 1397.6
Concentration (ppb)
10000
1000
100
10
1
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity

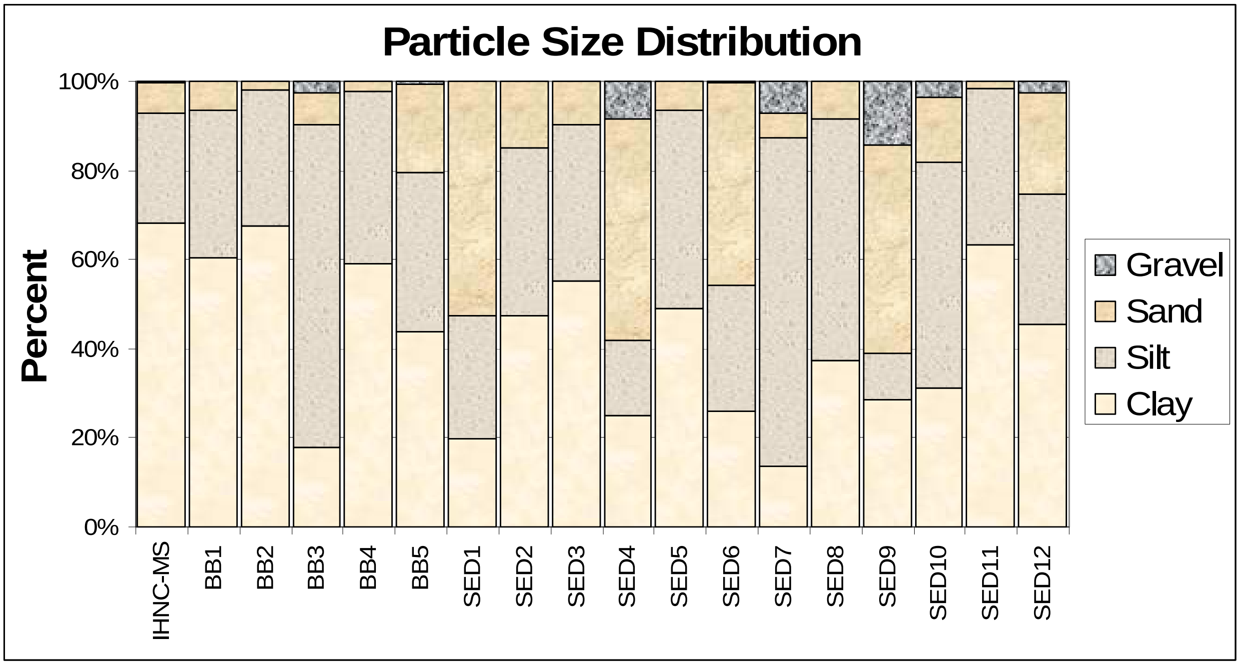

4,4-DDD
TEL = 1.22
PEL = 7.81
Concentration (ppb)
100
90
80
70
60
50
40
30
20
10
0
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity


Dieldrin
TEL = 0.715
PEL = 4.3
Concentration (ppb)
100
90
80
70
60
50
40
30
20
10
0
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity


Motor Oil
Concentration (ppm)
3500
3000
2500
2000
1500
1000
500
0
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity


Diesel
900
800
700
600
500
400
300
200
100
0
Concentration (ppm)
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity


Total Organic Carbon
350000
300000
250000
200000
150000
100000
50000
0
Concentration (ppm)
BB5
BB4
BB3
Sed11
Sed12
Sed1
Sed4
Sed7
Sed9
Sed6
Sed2
Sed3
Sed5
Sed8
Sed10
MS
BB1
BB2
Outer Marsh Bayou
Canals
Pump Station Outfalls
WWTP Vicinity


Particle Size Distribution
Percent
100%
80%
60%
40%
20%
0%
IHNC-MS
BB1
BB2
BB3
BB4
BB5
SED1
SED2
SED3
SED4
SED5
SED6
SED7
SED8
SED9
SED10
SED11
SED12
Gravel
Sand
Silt
Clay

REPORT DOCUMENTATION PAGE

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Burton Suedel, Jeffery Steevens, Alan Kennedy, and Sandra Brasfield

5d. PROJECT NUMBER

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

The U.S. Army Engineer Research and Development Center (ERDC) Environmental Laboratory, Vicksburg, MS, conducted a study to determine the extent to which Katrina floodwaters in the New Orleans area may have had impacts on wildlife habitat and other biological resources in surrounding areas. These experiments were conducted as part of the Interagency Performance Evaluation Task Force (IPET), which is investigating environmental impacts originating from the failure of the hurricane protection system to perform as designed around New Orleans, Louisiana during Hurricane Katrina. This report presents data regarding the effects of pumped floodwaters on sediment chemistry and benthic invertebrate toxicity near pumping stations that discharged floodwaters into marshes near Chalmette and Violet, Louisiana. Spatial trends were observed for concentrations of chemicals in sediment. Chemical contamination of sediments was visible and appeared to have trends among sample location groups (e.g., outfall locations, wastewater treatment plant, canals, and wetlands); however, these trends were not always consistent with the bioassay results. A comparison of the sediment chemistry data from this study with two other studies reporting concentrations of chemicals in sediments within the city of New Orleans suggested that sediments and associated contaminants present within the levees were not pumped into the marsh in appreciable quantities.

15. SUBJECT TERMS

Benthic invertebrate toxicity	Interagency Performance Evaluation Task Force (IPET)	Sediment chemistry
Hurricane Katrina	New Orleans, LA	Violet, LA

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
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