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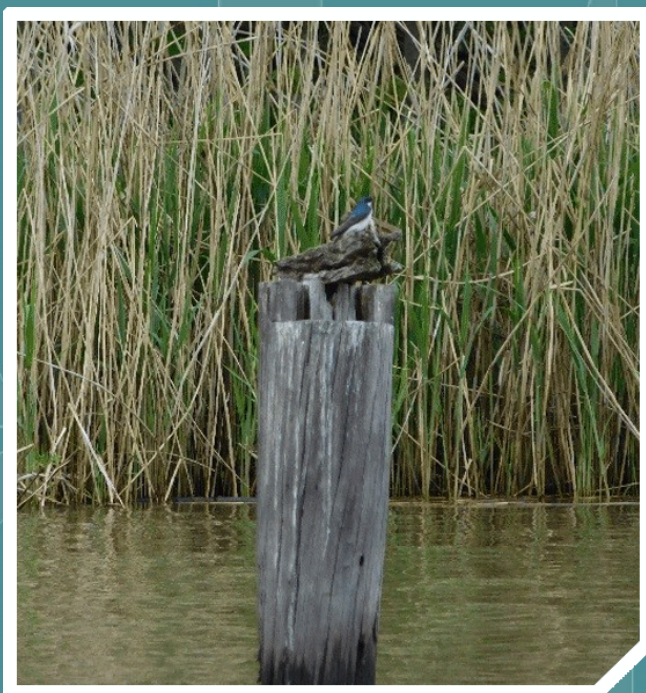
2012 Annual Report to Characterize the Ottawa River Using Physical, Biological, and Chemical Lines of Evidence



Office of Research and Development
National Risk Management Research Laboratory
Land and Materials Management Division

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2012 Annual Report to Characterize the Ottawa River Using Physical, Biological, and Chemical Lines of Evidence

by

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Cincinnati, OH 45268

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Disclaimer

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Foreword

The U.S. Environmental Protection Agency (U.S. EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, U.S. EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments, and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment, advancing scientific and engineering information to support regulatory and policy decisions, and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

Contaminated sediments continue to be a concern nationally and internationally. Sediments serve as long-term sinks for compounds such as polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), metals, and other contaminants of concern (COCs). Large areas of contaminated sediment accumulation are known to pose a threat to benthic, aquatic and terrestrial ecosystems, as well as human health. Sediment contamination exists in every region and state of the Nation, negatively impacting overlying surface waters and surrounding ecosystems. To date, three primary technologies have been applied to the remediation of contaminated sediment sites: 1) engineered capping with clean materials such as sand, 2) monitored natural recovery (MNR) wherein the contaminant source has been removed and natural capping with sediment is allowed to cover or bury the contaminated sediment over a long period of time while natural chemical, physical, and microbial processes break down contaminants in the buried sediment, and 3) environmental dredging that relies on rapid mechanical removal of the contaminated sediment layer and subsequent off-site confined disposal.

The Great Lakes National Program Office (GLNPO) selected environmental dredging as the remedy of choice for remediation and cleanup of the Ottawa River. The Ottawa River, located in northwestern Ohio on the west side of Toledo, is a part of the Maumee River Area of Concern (AOC). PCBs, PAHs, and lead constituted the COCs for this site. Dredging was carried out on selected segments of Reaches 2, 3, and 4 of the Ottawa River during the summer and fall of 2010.

In 2008, U.S. EPA's Office of Research and Development (ORD) partnered with GLNPO to conduct an extensive evaluation of the remedial project scheduled to take place on the lower Ottawa River site over the next 7 years (through 2015) to:

- Develop methods and metrics designed to monitor the progress of the remediation project and provide sufficient information to permit a remedy effectiveness assessment (REA) to be performed, and
- Carry out an REA at the conclusion of this GLNPO-sponsored environmental dredging project.

A Phase 1 baseline assessment of the site (U.S. EPA, 2017) was conducted in the summer and fall of 2009 and the spring of 2010 prior to the onset of dredging. A comprehensive evaluation and monitoring program conducted by U.S. EPA ensued that utilized established methods and metrics and developed and evaluated innovative methods and approaches. In addition to the Phase 1 pre-remedy baseline assessment, monitoring was conducted: 1) during the dredging period in the summer and fall of 2010 (Phase 2), 2) immediately following dredging (near-term evaluation) in the late fall of 2010 and the summer and fall of 2011 (Phase 3), and 3) over three of the next four summers in 2012 (Phase 4-1; this report), 2013 (Phase 4-2), and 2015 (Phase 4-3) to assess long-term recovery of the river and surrounding ecosystem. Tasks for Phases 2, 3, and 4 will be documented and summarized in future data reports. A final comprehensive interpretive report (along with an REA) will conclude documentation of this project.

Monitoring and evaluation activities were carried out along multiple lines of evidence (LOEs – physical, biological, and chemical) to assess COC fate and transport and ecosystem response and recovery. These activities included sampling and analysis of sediment, water, indigenous fish, macroinvertebrates, riparian spiders, basal resources, and worm tissues. Data were also generated from deployment, retrieval, and analysis of passive samplers and analysis of macroinvertebrate community data as a measure of biotic integrity.

Cynthia Sonich-Mullin, Director
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Abstract

International concern about contaminated sediments is increasing as sustainable practices are needed to maintain water resources and waterways as important economic, commercial, recreational, and community resources. Sediments often serve as long-term sinks for legacy pollutants, such as polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), inorganics, and other emerging and known contaminants of concern (COCs). Large areas of contaminated sediment accumulation are known to pose a threat to benthic, aquatic, and terrestrial ecosystems, as well as human health. Sediment contamination exists in every United States Environmental Protection Agency (U.S. EPA) Region and state of the Nation, negatively impacting overlying surface waters and surrounding ecosystems, and ultimately the health and quality of life for surrounding communities.

U.S. EPA's Office of Research and Development (ORD) conducts interdisciplinary contaminated sediment research projects within the Agency's Sustainable and Healthy Communities (SHC) Research Program to evaluate the effectiveness of risk management strategies and develop innovative treatment technologies. These projects have investigated and documented methods and approaches to assess remediation projects in the short term (project driven goals) and over longer-term restoration and recovery periods (programmatic goals). Research described in this report focuses on the development of methods and approaches to conduct a remedy effectiveness assessment (REA) on environmental remediation projects. In this research effort, several monitoring and sampling approaches were utilized and evaluated during the remediation of contaminated sediments in the Ottawa River within the Maumee River Area of Concern (AOC). These approaches have been developed on contaminated sediment sites by ORD in cooperation with U.S. EPA's Great Lakes National Program Office (GLNPO) and U.S. EPA's Superfund (SF) Program. Environmental dredging was designated as the remedy of choice for the Ottawa River project (located in northwestern Ohio on the west side of Toledo). The Ottawa River is part of the Maumee River AOC, which drains into Lake Erie at Toledo. Environmental dredging was employed on the most contaminated areas or units within Reaches 2, 3, and 4 of the Lower Ottawa River stretching upstream (generally south and west) from River Mile (RM) 3.5 to RM 8.4. A total of 18 sampling stations was established between RM 3.2 and RM 8.8; in Reach 2 and 3, three of the six stations were located in remediated zones and three stations were located in un-remediated zones for comparison. In Reach 4, four stations were located in the remediated zone and two stations were located in the un-remediated zone. The total for the three reaches is 10 stations in the remediated zone and eight stations in the un-remediated zone.

PCBs constituted the primary COC for this site, with PAHs and lead comprising secondary COCs. Hydraulic dredging was carried out from May 2010 through December 2010 on this Great Lakes Legacy Act (GLLA) remediation project. Extensive site characterization was conducted by GLNPO, ORD, and their partners at Federal and State agencies in the fall of 2009 and the early spring of 2010 prior to the onset of remediation (referred to as Phase 1). Phase 2 consisted of monitoring and sampling activities conducted during dredging operations from late spring to early winter of 2010. Phase 3 details near-term or immediate post-remedy monitoring that was performed in November 2010 and from March to September 2011. Long-term monitoring commenced in Phase 4 of the study in 2012 and continued during three of the ensuing four years

through 2015. Phase 4 monitoring was conducted in the summers of 2012 (Phase 4-1; this report), 2013 (Phase 4-2), and 2015 (Phase 4-3).

In partnership with GLNPO and other Federal and State agencies, a comprehensive sustained research program (2009-2015) was implemented by ORD for the Ottawa River remediation project to evaluate and optimize the assessment and monitoring methods first developed and evaluated as part of the larger ORD Research Program. These methods were conceived and developed along physical, biological, and chemical lines of evidence (LOEs) that can be used in a weight of evidence (WOE) framework to assess sediment remedies. Utilization, monitoring, and evaluation of these methods and LOE approach on the Ottawa River project began with site characterization and baseline assessment prior to the onset of environmental dredging in 2009 (U.S. EPA, 2017) and continued during and following dredging through 2015.

The LOE approach is especially well suited and adaptable to monitoring contaminant fate and transport and ecosystem recovery through the use of physical, biological, and chemical assessment methodologies such as: 1) comprehensive sampling and chemical analysis of contaminants in surface, suspended, and historic sediments; 2) sampling, chemical analysis, and development of alternative toxicity endpoints for indigenous fish; 3) bathymetry-based approaches; 4) multi-purpose macroinvertebrate collection techniques for determining benthic conditions and contaminant exposure; and 5) passive sampler technologies and deployment techniques. Using multiple LOE-based metrics and a WOE framework, specific mechanisms and processes can be characterized to quantify and inform a project manager on the short- and long-term effectiveness of a selected remedy on the surrounding ecosystem.

This report summarizes the site characterization and data collection tasks carried out in 2012 (Phase 4-1; see Section 3.8), the first year of long-term post remediation operations. Additional data reports will follow that document the subsequent phases of the Ottawa River project, long-term post-dredging monitoring in 2013 (Phase 4-2), and long-term post-dredging monitoring in 2015 (Phase 4-3). The Phase 1 baseline report (U.S. EPA, 2017) was prepared to document the project objectives and designs as well as report the baseline condition prior to remediation. The baseline report constitutes an expanded overview of the project and documents details, methods, appendices, etc. that will not be repeated in the subsequent reports except as needed for clarification. Companion data analysis and monitoring reports are also available for during dredging operations in 2010 (Phase 2) and immediately or near-term post dredging characterization in 2010-2011 (Phase 3). Methods, appendices, etc. that are introduced in previous reports or will be introduced in subsequent report are or will be respectively, documented and described therein; otherwise, they will be referenced back to the Phase 1 baseline report.

The objective of the Phase 4-1 study was to provide a characterization of sediment, water column, and food web characteristics in the long-term post dredging operations, and ecosystem conditions in selected zones of the Ottawa River. Specifically, the tasks carried out in Phase 4-1 over two field events and reported herein consisted of the following:

- Collection and analysis of surficial sediment samples,
- Characterization of the physical habitat,
- Collection and analysis of water column samples,

- Deployment, retrieval, and analysis of Hester-Dendy (H-D) macroinvertebrate samplers to assess both tissue chemistry and biotic condition,
- Deployment, retrieval, and analysis of passive samplers,
- Collection and analysis of fish, basal resources, and invertebrate samples,
- Collection and analysis of Brown Bullhead fish samples,
- Sediment toxicity evaluation, and
- Collection and analysis of riparian spiders.

Acknowledgements

A project of this scope and magnitude requires the support and active participation of a large group of committed staff including managers, researchers, administrators, field support personnel, and analytical chemists and microbiologists. The dedication and competency of this staff encompassing both government employees and contractors demonstrated over the past 8 years of this multi-phase project are appreciated and commended. The partnership established between the National Risk Management Research Laboratory (NRMRL) and the National Environmental Exposure Laboratory (NERL) of the U.S. Environmental Protection Agency's (U.S. EPA's) Office of Research and Development (ORD) and the U.S. EPA's Great Lakes National Program Office (GLNPO) over the course of this long project is a testimony to mutual sustained interdepartmental cooperation and trust. Funding provided by GLNPO and ORD throughout this project is gratefully acknowledged. The results of this project along with those from a sister project carried out on the Ashtabula (OH) River Area of Concern (AOC) during roughly the same time period have laid the groundwork for conducting remedy effectiveness assessments (REAs) on future contaminated sediment remediation projects.

The primary contractor for this project, Battelle Memorial Institute (Columbus, Ohio), has provided many of the field deployment and sampling duties and most of the chemical analyses associated with this project. Its attention to detail in performing the complex field and laboratory phases of this project coupled with proficient synthesizing of the large database generated into numerous interpretable data reports were key factors in the success of this undertaking. The cooperation of J.F. Brennan Company, Inc. in providing dredge location and inventory data and working with field crews during the dredging operations was essential to matching dredging inventories and residuals with environmental measurements and is much appreciated.

The principal authors of this report, Eric Foote^, Heather Thurston, Stacy Pala, and Paul Sokoloff^ from Battelle, along with EPA Co-Principal Investigators Marc Mills*, Ken Fritz, James Lazorchak, Joseph Schubauer-Berigan, and John Meier♦ and EPA Task Order Manager Richard Brenner♦ wish to express their appreciation to the following individuals for their substantial and valuable contributions to this research project:

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Appendices (Published as a Separate Report)

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List of Acronyms and Abbreviations

AOC	Area of Concern
AVS/SEM	Acid Volatile Sulfide/Simultaneously Extracted Metals
AWBERC	Andrew W. Breidenbach Environmental Research Center
BB	bioaccumulation or body burden
BUI	beneficial use impairment
COC	contaminant of concern
CPOM	coarse particulate organic matter
DNA	deoxyribonucleic acid
DO	dissolved oxygen
DQO	data quality objective
ft	foot/feet
g	grams
GLLA	Great Lakes Legacy Act
GLNPO	Great Lakes National Program Office
HASP	Health and Safety Plan
H-D	Hester-Dendy multi-plate artificial samplers
IBI	Index of Biotic Integrity
ID	identification
LICI	Lacustuary Invertebrate Community Index
LOC	level of chlorination
LOEs	lines of evidence
MDL	method detection limit
mg/L	milligrams per liter
MIwB	Modified Index of well-being
NERL	National Environmental Exposure Laboratory
NRMRL	National Risk Management Research Laboratory
Ohio EPA	Ohio Environmental Protection Agency
ORD	Office of Research and Development
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PED	polyethylene devices
PPAH	priority pollutant PAH
PRC	performance reference compound
PSD	particle size distribution

QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
QHEI	Qualitative Habitat Evaluation Index
R2R2R	Remediation to Restoration to Revitalization
REA	Remedy Effectiveness Assessment
RL	reporting limit
RM	River Mile
RMHRW	reformulated moderately hard reconstituted water
S.D.	standard deviation
SE	standard error
SF	Superfund
SHC	Sustainable and Healthy Communities
SOP	standard operating procedure
SPMD	semipermeable membrane device
SWAC	surface weighted average concentration
TOC	total organic carbon
tPCB	total PCBs calculated as the sum of 117 PCB congeners
TSS	total suspended solids
µg/L	micrograms per liter
U.S. EPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WOE	weight of evidence
yd^3	cubic yard

1 Introduction

1.1 Contaminated Sediments Research

Research on the effectiveness of remediation of contaminated sediment sites is being conducted under the Sustainable and Healthy Communities (SHC) Research Program in the United States Environmental Protection Agency's (U.S. EPA's) Office of Research and Development (ORD). This research effort responds to needs within U.S. EPA's Great Lakes National Program Office (GLNPO), EPA's Superfund (SF) Program, EPA Regions, and State Environmental Agencies to define comprehensive assessment approaches for characterizing the efficacy of contaminated sediment remediation projects. The research carried out under the SHC Program is focused on developing and evaluating physical, biological, and chemical methods and metrics to measure environmental changes resulting from remedial activities and applying these multiple lines of evidence (LOEs) in a weight of evidence (WOE) assessment. These assessments are project specific and an important part of a larger goal to remediate, restore, and revitalize selected water bodies and their associated communities. Through the paradigm of Remediation to Restoration to Revitalization (R2R2R), a systems approach of prioritizing remediation and restoration projects can be targeted to more expeditiously benefit wildlife, human health, and the surrounding communities.

The research project described in this report was focused on the development and evaluation of methods and metrics along physical, biological, and chemical LOEs to measure the effectiveness in remediating contaminated sediments within selected segments of the Ottawa River. A long-term objective was to utilize the data generated to support the preparation of a remedy effectiveness assessment (REA) of the remediation project at its conclusion. ORD, through its research mission, assumed the lead role in methods and metrics development and will be responsible for conducting the aforementioned REA in conjunction with its partners. The Ottawa Baseline Report (U.S. EPA, 2017) described the goals and objectives of the entire project while focusing on the pre-remedy data produced from a baseline characterization of environmental conditions within the project area. This report and subsequent reports will provide results and summaries of post-remedy monitoring conducted by ORD and its partners. Finally, at the conclusion of the project, a synthesis report will be prepared that considers the project as a whole (i.e., pre-remedy, during-remedy, and post-remedy data), evaluates and compares methods and metrics, and presents an REA for the remediation activities carried out on the Ottawa River by GLNPO. Details of the collaborations with GLNPO and other Federal and State partners are described in Section 1.2 of the Baseline Report (U.S. EPA, 2017).

1.2 Site Description

The Ottawa River lies in the extreme northwest part of Ohio, flowing into Lake Erie's western basin at the City of Toledo. The Ottawa River is a component of the Maumee River Area of Concern (AOC) (https://www.epa.gov/maumee-river-aoc).

This section of the river has four reaches based on longitudinal changes in geomorphology and hydrology. Reach 1 starts at River Mile (RM) 0.0 and proceeds southerly to RM 3.2, Reach 2 from RM 3.2 to RM 4.9, Reach 3 from RM 4.9 to RM 6.5, and Reach 4 from RM 6.5 to RM 8.8.

Figure 1-1 shows Reaches 2, 3, and 4 and the 18 ORD stations that were sampled within these reaches.

1.3 Remedy Design

Approximately 260,000 cubic yards (yd^3) of contaminated sediments were targeted for removal between RM 8 and RM 3.2. The contaminants of concern (COCs) include polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), metals (principally lead), and oil and grease. Remediation was accomplished through environmental dredging in targeted management units to established cut lines (Westcott et al., 2011) based on contaminant concentration profiles. These cut lines were established to reach specific post-cleanup and final goals for the remedial project area. Hydraulic dredging along with dewatering and containment of contaminated sediment using geomembranes and treatment of water draining through the geomembranes constituted the sediment removal and disposal system utilized on this project. Details of the remedial design and operations of the remediation project are available in Conestoga Rovers and Associates (2009).

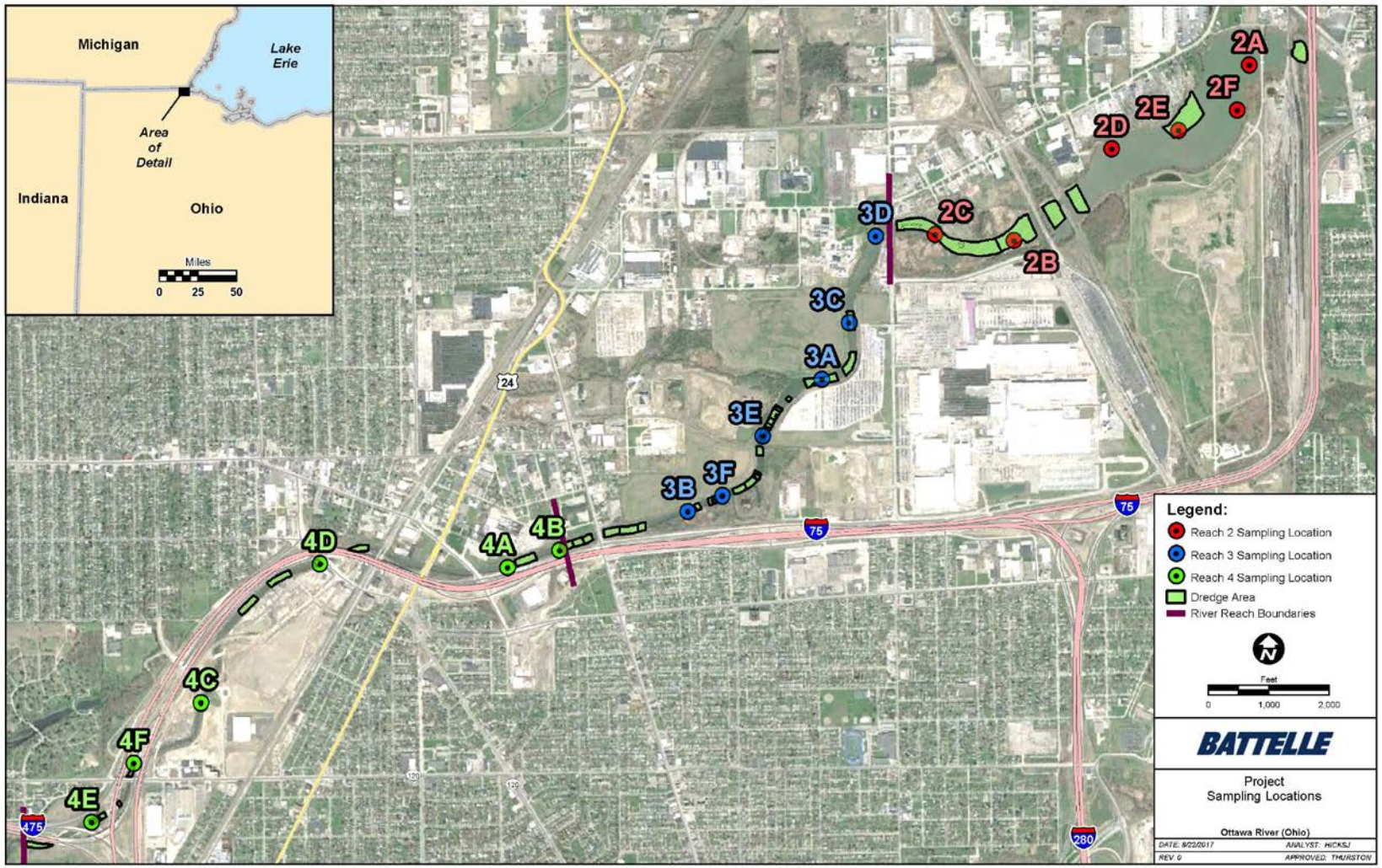


Figure 1-1. Ottawa River Reaches 2, 3, and 4 and ORD Sampling Stations.

2 Research Project Objectives – Evaluation of Methods and an Approach for Conducting REAs

The overall objectives of this research effort were to:

1. Develop methods and metrics along physical, biological, and chemical LOEs to evaluate remedy effectiveness following contaminated sediment remediation operations.
2. Develop an approach to quantify and locate the sources of post-dredge residuals.

These objectives, jointly shared by GLNPO and ORD, are complementary and will be described further in the final comprehensive report that evaluates the four phases of the project: pre-remedy baseline assessment, during-remedy monitoring, immediate post-remedy monitoring, and long-term post-remedy monitoring. This report will focus on the first year of long-term monitoring (2012) phase of the project.

Objective 1

Objective 1 focused on evaluating specific methods and metrics to support an approach to quantify remedy effectiveness following an environmental remediation project. This approach follows three LOEs: physical, biological, and chemical. Using these LOEs, a WOE assessment evaluates remedy effectiveness, specifically: 1) the recovery of surface sediment concentrations immediately following remedial actions and over time, and 2) the response and recovery of biological indicators during and following remedial activities. This approach was developed on a site-specific basis and was limited to environmental dredging and specific COCs, but with considerations toward developing an approach to be applied on sediment remediation projects in general.

Objective 2

Methods used to achieve Objective 2 included sediment core profiling and sediment chemistry analysis, field analysis to characterize metals, and bathymetric surveys to characterize dredge residuals. Two primary sources of residual contamination are left behind following an environmental dredging project. These sources are divided into dredge residuals and undredged residuals. The undredged residuals are generally considered contaminated sediments that have been missed during dredge operations either due to not dredging to the targeted sediment removal elevations (cut lines) or inadequate dredge pass overlaps. The second category of residuals, dredge residuals, are generally accepted as materials that have been resuspended during dredge operations and have either settled back or flowed back into the dredge cut. This research was more focused toward dredge residuals that will be described and evaluated in a future final comprehensive report. A final comprehensive report will evaluate the four phases of the project to determine if the two objectives were met.

The Phase 1 baseline report describes the details of the project and the environmental baseline assessment conducted in 2009-2010 by ORD and its partners. Ultimately, an REA will be reported for the Great Lakes Legacy Act (GLLA) remediation of the Ottawa River that occurred between 2009 and 2015. The goal of the REA will be to provide pre- and post-remedy comparisons using a combination of quantitative and qualitative metrics to assess environmental changes. Environmental impact data along three LOEs (physical, biological, and chemical) are detailed herein. Table 2-1 presents the matrices evaluated in each phase of the project.

Table 2-1. Matrices Evaluated for each Line of Evidence in each Phase of the Project.

Phases of the Project	1	2	3	4-1	4-2	4-3
Study Periods	**2009-May 2010**	**May-Oct 2010**	**Nov 2010/ March-Sept 2011**	**June-Sept 2012**	**June-Sept 2013**	**June-Sept 2015**
Physical LOEs						
Bathymetry and Remediated Sediment Volume	X		X			
Ecological Assessment	X	X	X	X	X	X
Qualitative Habitat Evaluation Index (QHEI)	X[1]					X
Biological LOEs						
Lacustuary Invertebrate Community Index (LICI) for Macroinvertebrates	X[2]	X	X	X	X	X
Toxicity Testing – *Chironomus tentans* and *Hyalella azteca*	X	X	X	X	X	X
Index of Biotic Integrity (IBI) and Modified Index of well-being (MIwB)	X[3]					X
Fish Tumors and Anomalies	X[3]					X
Sport Fish Tissue Consumption Advisory						X
Chemical LOEs						
Contaminants in Surface Sediment	X	X	X	X	X	X
Sediment Characteristics – Bulk Density and Moisture	X	X	X	X	X	X
Particle Size Distribution (PSD) Data	X	X	X	X	X	X
Surface Sediment Metals and Acid Volatile Sulfides/Simultaneously Extractable Metals (AVS/SEM)	X					X
Passive Samplers - Sediment[4]	X		X			
Surface Weighted Average Concentration (SWAC)	X					X
Subsurface PAH and PCB Mass Estimates	X		X			
Contaminants in Water	X	X	X	X	X	X
Water Characteristics – TOC, TSS, and Turbidity						
Direct Water Concentrations	X	X	X	X	X	X
Passive Samplers in Water Column[4]	X		X	X	X	X
Porewater Concentrations	X					X
Contaminants in Tissue	X	X	X	X	X	X
Contaminants in Macroinvertebrates	X	X	X	X	X	X
Contaminants in Fish Tissue	X	X	X	X	X	X
Contaminants in Tetragnathidae Spiders	X	X	X	X	X	X
Contaminants in Araneidae Spiders			X			
Contaminants in Adult Terrestrial Insects		X				
Contaminants in Basal Resources, Periphyton, and Coarse Particulate Organic Matter (CPOM)	X					
Bioaccumulation assessment - *Lumbriculus*	X					X

[1] QHEI data actually collected in 2007.
[2] Data collected in 2007 and 2009 were presented in the Baseline Report.
[3] Data collected in 2007.
[4] Semipermeable membrane devices (SPMDs) in 2009 and 2011; polyethylene devices (PEDs) in 2012, 2013, and 2015.

3 Experimental Approach

3.1 Project Organization by Phases

The conceptual design of this project was developed to address the two overall project objectives described in Section 2. The approach to addressing these objectives and associated issues are described in detail below as a series of overall sub-objectives related to the entire project.

- Phase 1 was the baseline characterization conducted pre-remediation (2009-spring 2010).
- Phase 2 was conducted during remediation (May-December 2010).
- Phase 3 was conducted immediately post-remediation (November 2010, and March-September 2011).
- Phase 4 was the longer-term monitoring conducted post-remediation (August-September 2012, July-September 2013, and July-September 2015).

3.2 Sampling Design

Field sampling activities across the four phases of this project consisted of a multiple LOEs approach that characterized physical, biological, and chemical metrics within the project area. By design, the sampling was targeted to cover the entire project area, specifically areas that underwent active remediation (dredging) and areas that were not actively remediated. Phase 4-1 field sampling was conducted following preparation of the Phase 2 and 3 Quality Assurance Project Plan (QAPP; U.S. EPA, 2010a) and the Phase 1 Health and Safety Plan (HASP; U.S. EPA, 2010b) as provided in Appendix A.

3.2.1 Sampling Stations

A total of 18 sampling stations, six each in Reaches 2, 3, and 4, were selected for this study (see *Pre-Remedy Baseline Characterization of the Ottawa River Using Physical, Biological, and Chemical Lines of Evidence* for more information on these stations [U.S. EPA, 2017]). During Phase 4-1 (long-term post-dredging monitoring), 18 stations were sampled (10 remediated and 8 non-remediated stations across three reaches of the Lower Ottawa River). In August of 2012, water column passive samplers (polyethylene devices [PEDs]) and Hester-Dendy (H-D) multi-plate artificial substrate samplers were deployed in duplicate (Figure 3-1 [U.S. EPA, 2017]). Concurrent surface sediment (6-in. deep cores) and mid-water column samples were collected during deployment (Figure 3-2 [U.S. EPA, 2017]). Duplicate samples are field duplicates that are collected in the same manner as the original sample and processed and analyzed as a separate sample. Macroinvertebrate samples were harvested from the artificial substrates following retrieval of the H-D samplers after a 42-day deployment. Benthic macroinvertebrates were collected to assess biological integrity (Lacustuary Invertebrate Community Index [LICI]) at three remediated stations (2B, 3A, and 4D) and three non-remediated stations (2A, 3B, and 4A), and to measure body burden (BB) H-D tissue COCs (also referred to as bioaccumulation H-Ds) at the 18 stations. Sediment, water, macroinvertebrates, spiders, and fish tissue were analyzed for PCBs and PAHs as well as biological assessments of health (e.g., toxicity and bioavailability assays). The sampling conducted during Phase 4-1 of this study deviated from the baseline site characterization in that the following LOEs were not assessed in this phase: bathymetry, Qualitative Habitat Evaluation Index (QHEI), Ohio EPA's Index of Biotic Integrity (IBI) and

Modified Index of Well-Being (MIwB), surface weighted average concentrations (SWACs) of contaminants, and subsurface PCB mass estimates. These LOEs are described in detail in U.S. EPA (2017). In addition, the passive samplers deployed in the 2009 baseline study were semi-permeable membrane device (SPMD) samplers. In 2012, PEDs were deployed in the water column and were used moving forward throughout Phase 4 of this study. For this 2012 study, no performance reference compounds (PRCs) were added to the PEDs as were done with the SPMDs in 2011.

3.2.2 Water Depth

Average water depth in the Ottawa River ranged from 0.95 feet (ft) at Station 2D to 11.0 ft at Station 3E (Table 3-1). Water depth in Reach 2 ranged from 0.5 ft to 9.02 ft, in Reach 3 ranged from 3.8 ft to 11.32 ft, and in Reach 4 ranged from 2.0 ft to 10.9 ft.

Table 3-1. Reach Information for the 18 ORD Stations and River Mile and Minimum, Maximum, and Average Water Depths When Available.

REACH	Station ID	River Mile	Minimum Water Depth (ft)	Maximum Water Depth (ft)	Average Water Depth (ft)
REACH 2	2A	3.5	3.1	4.2	3.7
REACH 2	2B	4.6	8.1	9.0	8.6
REACH 2	2C	4.9	3.4	4.1	3.7
REACH 2	2D	4	0.5	1.4	1.0
REACH 2	2E	3.9	3.9	4.5	4.2
REACH 2	2F	3.7	1.0	2.3	1.7
REACH 3	3A	5.5	8.5	9.1	8.8
REACH 3	3B	6.2	5.1	6.2	5.7
REACH 3	3C	5.3	4.7	4.8	4.8
REACH 3	3D	5	3.8	4.4	4.1
REACH 3	3E	5.8	10.7	11.3	11.0
REACH 3	3F	6.1	7.1	7.4	7.3
REACH 4	4A	6.8	4.2	4.2	4.2
REACH 4	4B	6.5	8.6	8.6	8.6
REACH 4	4C	8	9.8	10.9	10.4
REACH 4	4D	7.3	4.3	4.3	4.3
REACH 4	4E	8.6	2.0	2.5	2.3
REACH 4	4F	8.4	2.0	5.5	3.7

NA = Not available
* Approximate RM based on visual observation in comparison to known RM for 18 ORD stations.

3.3 Field Sampling Methods

The following sections describe the general field sampling methods employed for collection of field samples in Phase 4-1 of the Ottawa River study. The Phase 4-1 results are presented in this

report in Section 4; field sampling information such as chain-of-custody logs, field logs photos, and field notes are provided in Appendix B. Figures 3-1 through 3-3 show the locations for the ORD Phase 4-1 samples. Table 3-2 provides the station coordinates for the 2009 Baseline Study and the 2012 Phase 4-1 Sampling and the offset for each station. To sample designated study locations, a 24-ft boat was positioned on station so that the center of the boat was as close to the target as possible given the GPS equipment, water level and flow, weather conditions, and access. Water grab samples and sediment composite samples were collected from these stations. For composite sediment samples, four to eight 6-in. shallow cores were collected from each side of the boat including front and back. The boat was then repositioned approximately 4 ft downstream to deploy the H-D samplers. Significant offsets were required at times due to access to study locations due to weather, water levels, on-site construction activities, etc. Offsets were noted in the field notes and calculated and reported in Table 3-2.

3.4 Physical Lines of Evidence

Remediation of contaminated sediments often results in large-scale physical changes to the sediment, hydrodynamics, and geomorphology of the system. These changes impact the overall water depth (bathymetry), water flow, and sediment composition.

Physical habitat was recorded using Ohio EPA's Ecological Assessment field form. Physical habitat data from the Ecological Assessment field form (see Figure 3-12 in U.S. EPA, 2017) were collected at six stations where benthic macroinvertebrates were sampled for the LICI.

A more detailed description of the physical LOEs used on the Ottawa River to determine remedy effectiveness can be found in U.S. EPA (2017).

3.5 Biological Lines of Evidence

Data collected along biological LOEs assist in evaluating biological community response to a remedial action and in evaluating biologically focused clean-up goals. Biological surveys and metrics that measure the presence, condition, and population distributions of specific types of fish, insects, algae, plants, and aquatic life assess the overall health of the community and quality of the associated habitat in the GLLA project area. The biological metrics used to assess ecosystem health in the pre-remedy baseline site characterization were: the LICI for macroinvertebrates; toxicity testing; the IBI; the MIwB; and fish tumors and anomalies, and DNA damage in Brown Bullhead catfish (U.S. EPA, 2017). In this Phase 4-1 report, only the LICI for macroinvertebrate and toxicity testing were measured. This information informs the status of a beneficial use impairment (BUI) #6: Degradation of Benthos (Ohio EPA, 2016).

3.5.1 Lacustuary Invertebrate Community Index (LICI) for Macroinvertebrates

Ohio EPA's LICI is a multi-metric index used to evaluate the biological condition of Ohio's lacustuaries for the Clean Water Act and the BUI status associated with degradation of benthos (Ohio EPA, 2016). The Ottawa River has an aquatic life use designation of warm-water habitat. Ohio EPA considers aquatic community data to be useful as response indicators for assessing changes in the true environment of water bodies (Ohio EPA, 2007a). Further details on the LICI, including the specific metrics and their scoring, are provided in the 2009 Baseline Report (U.S.

Table 3-2. Station Coordinates for the 2009 Baseline Study and 2012 Phase 4-1 Sampling Event and Offsets for each Location

Station ID	2009				2012				Offset between 2009 and 2012 (ft)
	Northing[1]	Easting[1]	Latitude[2]	Longitude[2]	Northing[1]	Easting[1]	Latitude[2]	Longitude[2]	
2A	746403.945	1693885.173	41.710998	83.505766	746399.247	1693891.031	41.710985	83.505744	7.5
2F	745676.221	1693706.707	41.708995	83.506389	745673.572	1693700.811	41.708988	83.506410	6.5
2E	745347.736	1692735.554	41.708063	83.509931	745346.463	1692738.847	41.708059	83.509919	3.5
2D	745040.677	1691628.905	41.707185	83.513971	745040.331	1691632.744	41.707184	83.513956	3.9
2B	743413.851	1689912.295	41.702666	83.520187	743412.745	1689914.971	41.702663	83.520177	2.9
2C	743611.076	1688630.1	41.703166	83.524890	743610.854	1688632.214	41.703165	83.524883	2.1
3D	743590.206	1687708.98	41.703079	83.528262	743588.463	1687706.97	41.703074	83.528270	2.7
3C	742154.952	1687260.537	41.699126	83.529842	742158.196	1687262.296	41.699135	83.529836	3.7
3A	741222.28	1686808.589	41.696552	83.531457	741224.839	1686810.627	41.696559	83.531449	3.3
3E	740305.281	1685854.004	41.694004	83.534912	740304.485	1685856.301	41.694002	83.534903	2.4
3F	739301.25	1685164.929	41.691227	83.537391	739319.614	1685171.454	41.691277	83.537368	19.5
3B	739050.784	1684596.043	41.690521	83.539463	739045.765	1684607.084	41.690508	83.539422	12.1
4B	738420.262	1682491.934	41.688722	83.547138	738408.306	1682520.906	41.688690	83.547032	31.3
4A	738095.556	1681619.445	41.687802	83.550318	738095.806	1681616.163	41.687802	83.550330	3.3

Table 3-2 (continued). Station Coordinates for the 2009 Baseline Study and 2012 Phase 4-1 Sampling Event and Offsets for each Location

Station ID	2009				2012				Offset between 2009 and 2012 (ft)
	Northing[1]	Easting[1]	Latitude[2]	Longitude[2]	Northing[1]	Easting[1]	Latitude[2]	Longitude[2]	
4D	738123.391	1678508.019	41.687775	83.561709	738174.99	1678500.324	41.687916	83.561740	52.2
4C	736026.508	1676689.315	41.681960	83.568273	736034.016	1676614.831	41.681978	83.568546	74.9
4F	734984.009	1675528.999	41.679060	83.572474	734977.27	1675527.948	41.679042	83.572477	6.8
4E	733916.009	1674738	41.676103	83.575321	733915.57	1674740.599	41.676102	83.575311	2.6

[1] State Plane Datum - Ohio State Plane, NAD83, North Zone 3401, U.S. Survey Feet
[2] Latitude/Longitude Datum - GCS_North_American_1983
NA – Not applicable; no samples collected during remedy activities

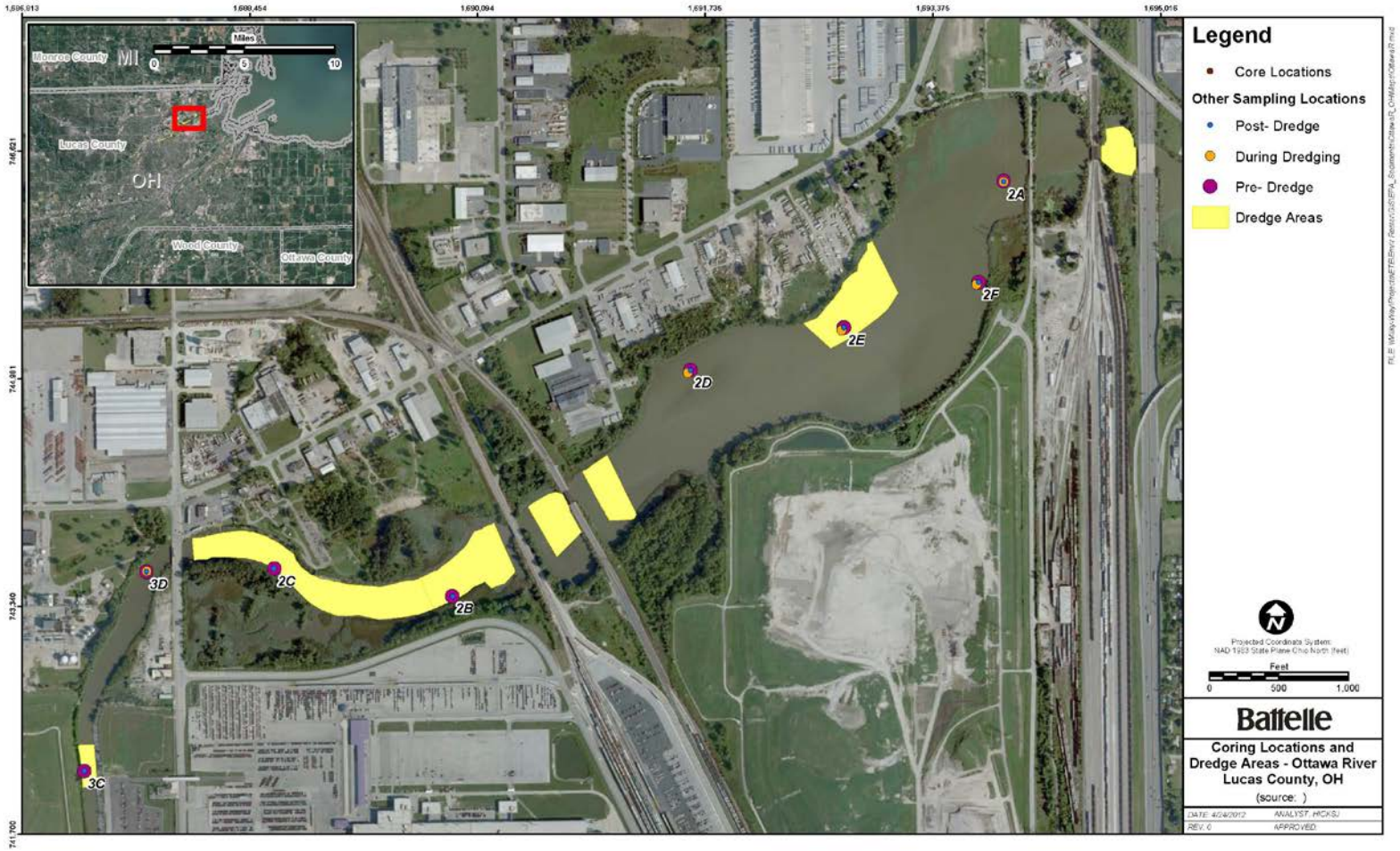


Figure 3-1. ORD Sampling Stations in Reach 2.

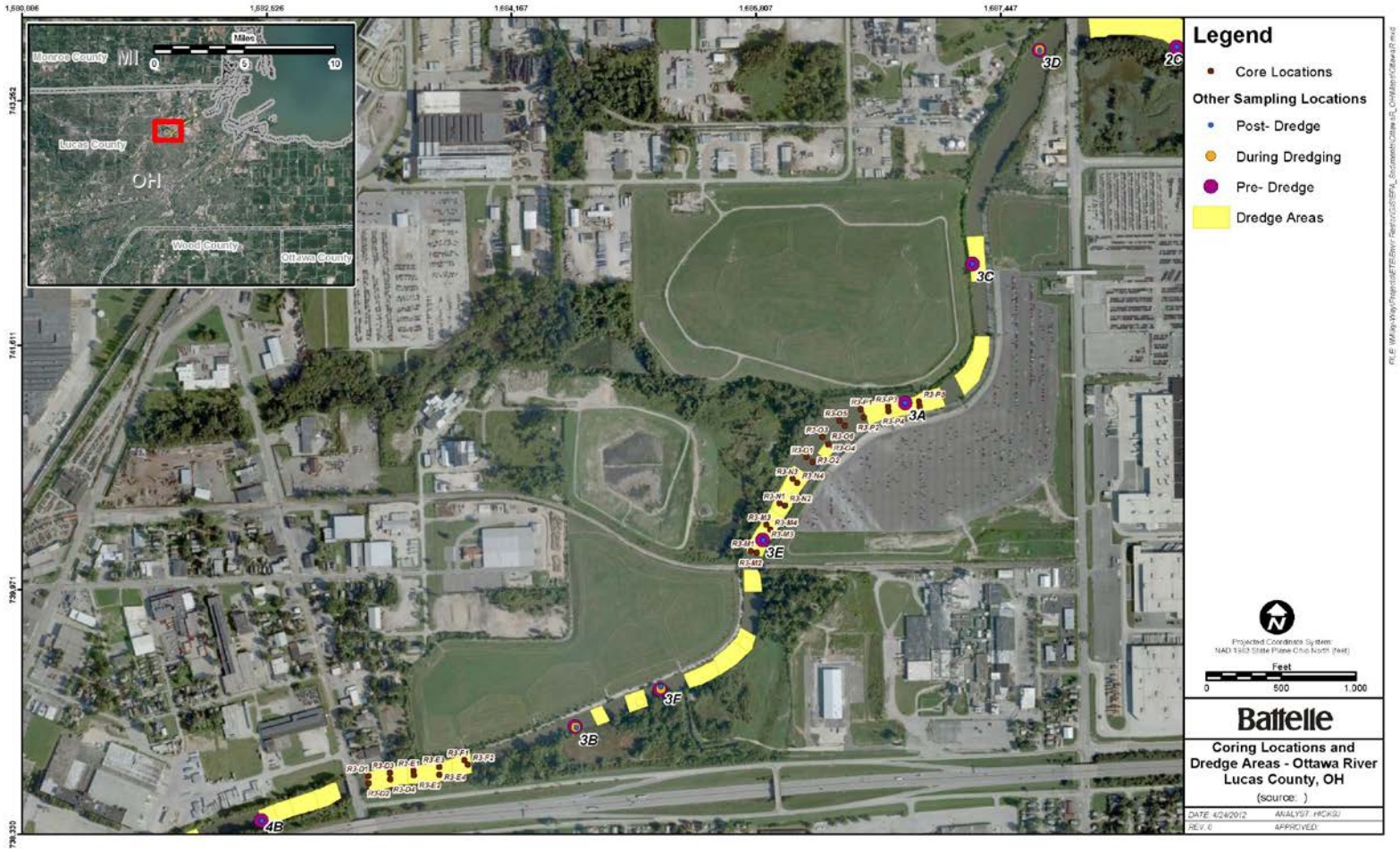


Figure 3-2. ORD Sampling Stations in Reach 3.

Figure 3-3. ORD Sampling Stations in Reach 4.

EPA, 2017). Macroinvertebrate assemblage data for the LICI were collected at three remediated (2B, 3A, and 4D) and three non-remediated stations (2A, 3B, and 4A).

From composited surface sediment samples (top 6- in. core composites), 2 liters (L) of sediment were collected at each station at the times of deployment (Round 1) and retrieval (Round 2) of the macroinvertebrate samplers. These samples were returned to NERL-Cincinnati, and 10-day static-renewal bulk sediment toxicity tests using *Chironomus tentans* and *Hyalella azteca* were conducted for each round. The toxicity endpoints measured were percent survival and growth with physical/chemical parameters (i.e., ammonia, pH, dissolved oxygen, conductivity, and temperature). Further details on the toxicity testing method are described in U. S. EPA (2017).

3.5.2 Whole-Sediment Toxicity Assays

Bioassays were performed with the benthic invertebrates *Hyalella azteca* and *Chrironomus tentans* to ascertain any adverse effects on survival and/or growth via sediment contamination. Sediment samples were collected from 18 sites along the Ottawa River in August 2012. Testing in the Andrew W. Breidenbach Environmental Research Center (AWBERC), Cincinnati, Ohio Cincinnati Aquatic Research Facility occurred in September and October 2012. Organisms were exposed to 100 mL of homogenized sediment with 175 mL of overlying laboratory produced synthetic water (reformulated moderately hard reconstituted water [R-MHRW]) for a 10-day duration in replicates of six per site sample. Water was changed daily by a 2X water volume additions of R-MHRW in a flow-through apparatus then fed. Upon exposure completion, organisms were sieved to enumerate live organisms then dried and weighed to obtain mass. The survival and growth effect endpoints are determined via one-tailed t-tests comparing each treatments response (% survival and mass) to that of a control sample. A sample p-value < 0.05 with <80% survival for *H. azteca* and <70% survival for *C. tentans* (U.S. EPA, 2000) classifies the sample as toxic via statistically significant adverse mortality, while a p-value < 0.05 and mass less than that of the control treatment reveals the sample has an adverse effect on organism growth.

3.6 Chemical Lines of Evidence

Typical metrics for chemical LOEs include concentration of contaminants in surface sediments and biological tissues and the mass of chemical contaminants removed. LOEs for 2012 sampling are provided in Table 2-1. Sediment concentration measurements can be used to determine human and aquatic life exposure assessments, sediment remediation goals, and potential causes and sources of biological impairment and to assist in determining appropriate disposal strategies for dredged sediment. Detailed methods for the analysis of contaminants in the Ottawa River can be in found U.S. EPA (2017). During the baseline study, PCB congeners, homologs, and Aroclors were measured; however, in Phase 4-1, only PCB congeners and homologs were analyzed.

3.7 Data Management

Total PCBs were determined by summing the concentrations of 117 PCB congeners (Table 3-3). These congeners were consistently analyzed across the project period (2009 through 2015), and their sum is henceforth referred to as tPCB. Additional PCB congeners were analyzed but not consistently across the project period and the data are available in Appendix C. Non-detected values were included at one-half the method detection limit (MDL) for summing. Similarly, PCB homologs for the 10 levels of chlorination (LOCs) were determined by summing the individual congeners within each LOC.

Total PAHs were presented separately as the sum of the 16 Priority Pollutant PAHs (PPAHs) and as the sum of 18 alkylated PAHs (Table 3-4). Additional PAHs were analyzed and the data are available in Appendix C. All non-detects were considered as one-half the MDL for summing purposes. Total Priority PAHs calculated as a sum of the 16 PAHs are henceforth referred to as total PPAH.

An Ottawa relational database was created in Oracle to store all years of data collected from 2009 to 2015, with exports into Microsoft® Access and Excel. Sample collection metadata and analytical results from all laboratories were submitted for inclusion in this data repository so that the data could be standardized (i.e., parameter codes) and reviewed for consistency (i.e., station identifiers), completeness (i.e., field collection information available for all fields), and accuracy by quality assurance (QA) staff. For this 2012 report, exports from the database were created for each analytical group (i.e., PAHs, PCBs, lipids, total organic carbon [TOC], etc.) and then for each matrix (i.e., sediment, water, and tissues). Totals were also calculated for PCBs and PAHs, and, where appropriate, results were normalized for lipids and TOC.

3.8 Quality Assurance/Quality Control

This multidisciplinary research project was a collaborative effort of the U.S. EPA ORD's National Risk Management Research Laboratory (NRMRL) and National Environmental Exposure Laboratory (NERL) in coordination with their U.S. EPA program office partner GLNPO. Each organization had project objectives specific to their mission. Organizing this research effort required the coordination of the multiple U.S. EPA entities over a multi-year period.

The U.S. EPA quality system is integral to this effort, providing policy and procedures that are implemented in all aspects of the project to ensure that the data generated from each discipline would be of a type and quality necessary and sufficient to achieve project objectives. The U.S. EPA's quality system encompasses management and technical activities related to the planning, implementation, assessment, and improvement of environmental programs that involve:

- the collection, evaluation, and use of environmental data, and
- the design, construction, and operation of environmental technology.

Consistent with the requirements of the U.S. EPA quality system, the participating U.S. EPA organizations have implemented Quality Management Plans to define the specific processes and procedures that each U.S. EPA organization uses to ensure implementation of the U.S. EPA quality system. The following QA tools were implemented during the project:

- A systematic planning approach was implemented to develop acceptance or performance criteria for all work covered by the U.S. EPA quality system as defined in the QAPPs for the project (see Appendix A to this report). Several QAPPs (U.S. EPA, 2010a, 2010b, 2010c, 2012) were developed and approved for use by Battelle and the U.S. EPA quality staff for each project effort before any data collection activities were initiated in the field or laboratory. The field sampling and laboratory analysis for Phases 4-1, 4-2, and 4-3 were conducted following the Phase 2 and 3 QAPP (U.S. EPA, 2012) and the Addendum #02 QAPP (U.S. EPA, 2012) and provided in Appendix A of this report. QAPPs that were developed and implemented for this project are identified in the relevant sections of this report and in the references section.

Table 3-3. List of 117 Individual PCB Congeners that were Consistently Analyzed for all Ottawa River Project Studies (2009-2015).

PCB Congener	Description	PCB Congener	Description
PCB 1	2-chlorobiphenyl	PCB 54	2,2',6,6'-tetrachlorobiphenyl
PCB 3	4-chlorobiphenyl	PCB 56	2,3,3',4'-tetrachlorobiphenyl
PCB 4	2,2'-dichlorobiphenyl	PCB 60	2,3,4,4'-tetrachlorobiphenyl
PCB 5	2,3-dichlorobiphenyl	PCB 64	2,3,4',6-tetrachlorobiphenyl
PCB 6	2,3'-dichlorobiphenyl	PCB 66	2,3',4,4'-tetrachlorobiphenyl
PCB 7	2,4-dichlorobiphenyl	PCB 70	2,3',4',5-tetrachlorobiphenyl
PCB 8	2,4'-dichlorobiphenyl	PCB 71	2,3',4',6-tetrachlorobiphenyl
PCB 9	2,5-dichlorobiphenyl	PCB 74	2,4,4',5-tetrachlorobiphenyl
PCB 11	3,3'-dichlorobiphenyl	PCB 77	3,3',4,4'-tetrachlorobiphenyl
PCB 13	3,4'-dichlorobiphenyl	PCB 81	3,4,4',5-tetrachlorobiphenyl
PCB 15	4,4'-dichlorobiphenyl	PCB 82	2,2',3,3',4-pentachlorobiphenyl
PCB 16	2,2',3-trichlorobiphenyl	PCB 83	2,2',3,3',5-pentachlorobiphenyl
PCB 17	2,2',4-trichlorobiphenyl	PCB 84	2,2',3,3',6-pentachlorobiphenyl
PCB 18	2,2',5-trichlorobiphenyl	PCB 85	2,2',3,4,4'-pentachlorobiphenyl
PCB 19	2,2',6-trichlorobiphenyl	PCB 87	2,2',3,4,5'-pentachlorobiphenyl
PCB 22	2,3,4'-trichlorobiphenyl	PCB 91	2,2',3,4',6-pentachlorobiphenyl
PCB 24	2,3,6-trichlorobiphenyl	PCB 92	2,2',3,5,5'-pentachlorobiphenyl
PCB 25	2,3',4-trichlorobiphenyl	PCB 95	2,2',3,5',6-pentachlorobiphenyl
PCB 26	2,3',5-trichlorobiphenyl	PCB 97	2,2',3',4,5-pentachlorobiphenyl
PCB 27	2,3',6-trichlorobiphenyl	PCB 99	2,2',4,4',5-pentachlorobiphenyl
PCB 28	2,4,4'-trichlorobiphenyl	PCB 100	2,2',4,4',6-pentachlorobiphenyl
PCB 30	2,4,6-trichlorobiphenyl	PCB 101	2,2',4,5,5'-pentachlorobiphenyl
PCB 31	2,4',5-trichlorobiphenyl	PCB 105	2,3,3',4,4'-pentachlorobiphenyl
PCB 32	2,4',6-trichlorobiphenyl	PCB 110	2,3,3',4',6-pentachlorobiphenyl
PCB 33	2',3,4-trichlorobiphenyl	PCB 114	2,3,4,4',5-pentachlorobiphenyl
PCB 37	3,4,4'-trichlorobiphenyl	PCB 115	2,3,4,4',6-pentachlorobiphenyl
PCB 40	2,2',3,3'-tetrachlorobiphenyl	PCB 118	2,3',4,4',5-pentachlorobiphenyl
PCB 41	2,2',3,4-tetrachlorobiphenyl	PCB 123	2',3,4,4',5-pentachlorobiphenyl
PCB 42	2,2',3,4'-tetrachlorobiphenyl	PCB 124	2',3,4,5,5'-pentachlorobiphenyl
PCB 43	2,2',3,5-tetrachlorobiphenyl	PCB 126	3,3',4,4',5-pentachlorobiphenyl
PCB 44	2,2',3,5'-tetrachlorobiphenyl	PCB 128	2,2',3,3',4,4'-hexachlorobiphenyl
PCB 45	2,2',3,6-tetrachlorobiphenyl	PCB 130	2,2',3,3',4,5'-hexachlorobiphenyl
PCB 46	2,2',3,6'-tetrachlorobiphenyl	PCB 134	2,2',3,3',5,6-hexachlorobiphenyl
PCB 47	2,2',4,4'-tetrachlorobiphenyl	PCB 135	2,2',3,3',5,6'-hexachlorobiphenyl
PCB 48	2,2',4,5-tetrachlorobiphenyl	PCB 136	2,2',3,3',6,6'-hexachlorobiphenyl
PCB 49	2,2',4,5'-tetrachlorobiphenyl	PCB 137	2,2',3,4,4',5-hexachlorobiphenyl
PCB 51	2,2',4,6'-tetrachlorobiphenyl	PCB 138	2,2',3,4,4',5'-hexachlorobiphenyl
PCB 52	2,2',5,5'-tetrachlorobiphenyl	PCB 141	2,2',3,4,5,5'-hexachlorobiphenyl
PCB 53	2,2',5,6'-tetrachlorobiphenyl	PCB 144	2,2',3,4,5',6-hexachlorobiphenyl

Table 3-3 (continued). List of 117 Individual PCB Congeners that were Consistently Analyzed for all Ottawa River Project Studies (2009-2015).

PCB Congener	Description
PCB 146	2,2',3,4',5,5'-hexachlorobiphenyl
PCB 149	2,2',3,4',5',6-hexachlorobiphenyl
PCB 151	2,2',3,5,5',6-hexachlorobiphenyl
PCB 153	2,2',4,4',5,5'-hexachlorobiphenyl
PCB 156	2,3,3',4,4',5-hexachlorobiphenyl
PCB 157	2,3,3',4,4',5'-hexachlorobiphenyl
PCB 158	2,3,3',4,4',6-hexachlorobiphenyl
PCB 163	2,3,3',4',5,6-hexachlorobiphenyl
PCB 164	2,3,3',4',5',6-hexachlorobiphenyl
PCB 167	2,3',4,4',5,5'-hexachlorobiphenyl
PCB 169	3,3',4,4',5,5'-hexachlorobiphenyl
PCB 170	2,2',3,3',4,4',5-heptachlorobiphenyl
PCB 171	2,2',3,3',4,4',6-heptachlorobiphenyl
PCB 172	2,2',3,3',4,5,5'-heptachlorobiphenyl
PCB 174	2,2',3,3',4,5,6'-heptachlorobiphenyl
PCB 176	2,2',3,3',4,6,6'-heptachlorobiphenyl
PCB 177	2,2',3,3',4',5,6-heptachlorobiphenyl
PCB 178	2,2',3,3',5,5',6-heptachlorobiphenyl
PCB 179	2,2',3,3',5,6,6'-heptachlorobiphenyl
PCB 180	2,2',3,4,4',5,5'-heptachlorobiphenyl
PCB 183	2,2',3,4,4',5',6-heptachlorobiphenyl
PCB 184	2,2',3,4,4',6,6'-heptachlorobiphenyl
PCB 185	2,2',3,4,5,5',6-heptachlorobiphenyl
PCB 187	2,2',3,4',5,5',6-heptachlorobiphenyl
PCB 189	2,3,3',4,4',5,5'-heptachlorobiphenyl
PCB 190	2,3,3',4,4',5,6-heptachlorobiphenyl
PCB 193	2,3,3',4',5,5',6-heptachlorobiphenyl
PCB 194	2,2',3,3',4,4',5,5'-octachlorobiphenyl
PCB 195	2,2',3,3',4,4',5,6-octachlorobiphenyl
PCB 201 (BZ)/ 199 (IUPAC)	2,2',3,3',4,5,5',6'-octachlorobiphenyl
PCB 199 (BZ)/ 200 (IUPAC)	2,2',3,3',4,5,6,6'-octachlorobiphenyl
PCB 200 (BZ)/ 201 (IUPAC)	2,2',3,3',4,5',6,6'-octachlorobiphenyl
PCB 202	2,2',3,3',5,5',6,6'-octachlorobiphenyl
PCB 203	2,2',3,4,4',5,5',6-octachlorobiphenyl
PCB 205	2,3,3',4,4',5,5',6-octachlorobiphenyl
PCB 206	2,2',3,3',4,4',5,5',6-nonachlorobiphenyl
PCB 207	2,2',3,3',4,4',5,6,6'-nonachlorobiphenyl
PCB 208	2,2',3,3',4,5,5',6,6'-nonachlorobiphenyl
PCB 209	decachlorobiphenyl

Table 3-4. List of PAHs that Comprise the 16 PPAHs and 18 Alkylated PAHs.

16 Priority PAHs	18 Alkylated PAHs
Naphthalene	C1-Naphthalenes
Acenaphthylene	C2-Naphthalenes
Acenaphthene	C3-Naphthalenes
Fluorene	C4-Naphthalenes
Anthracene	C1-Fluorenes
Phenanthrene	C2-Fluorenes
Fluoranthene	C3-Fluorenes
Pyrene	C1-Phenanthrenes/Anthracenes
Benzo(a)anthracene	C2-Phenanthrenes/Anthracenes
Chrysene	C3-Phenanthrenes/Anthracenes
Benzo(b)fluoranthene	C4-Phenanthrenes/Anthracenes
Benzo(k)fluoranthene	C1-Fluoranthenes/Pyrenes
Benzo(a)pyrene	C2-Fluoranthenes/Pyrenes
Indeno(1,2,3-cd)pyrene	C3-Fluoranthenes/Pyrenes
Dibenz(a,h)anthracene	C1-Chrysenes
Benzo(g,h,i)perylene	C2-Chrysenes
	C3-Chrysenes
	C4-Chrysenes

- Standard operating procedures (SOPs) were implemented for all applicable field and laboratory activities to ensure consistency in the collection of samples, operation of environmental technologies, and generation of environmental data in the field and in the laboratory.
- Appropriate training was provided for staff to ensure that quality-related responsibilities and requirements as defined in the QAPPs were understood, and that SOPs were implemented for all applicable activities. This practice ensured that research activities are conducted in a consistent and reproducible manner, with the intent that the research data produced would meet project data quality objectives and/or acceptance criteria for usability to achieve project objectives.
- Data were reviewed and verified by research staff after collection and audited by the Battelle QA staff to ensure that the type, quantity, and quality were sufficient to reach conclusions stated in this report and ultimately to achieve project objectives.

The data review process identified exceedances of acceptance criteria and applied appropriate qualifiers to the data to indicate limitations to the data that could affect data usability and the ability to reach conclusions with respect to project objectives. The laboratory data qualifiers used for the Ottawa River project are defined below. Limitations to the data are identified in the relevant subsections of this report.

Qualifier	Definition
B	Denotes blank contamination: the analyte was detected at greater than five times the MDL in the procedural blank or was detected in a field sample at a concentration that was less than five times the concentration measured in the procedural blank.
D	Denotes that the initial analytical run was outside the linear range of the instrument, and the flagged value is the analytical result of a subsequent analysis of a diluted sample.
E	Denotes that the value is an estimate, and that the result is greater than the highest concentration level in the calibration.
J	Denotes that the analyte was positively identified above the MDL but was less than the sample-specific Reporting Limit (RL). The RL is the minimum concentration of an analyte that can be reliably identified, measured, and reported with complete confidence that the analyte concentration is greater than zero.
ME	Denotes significant matrix interference with detection of the analyte, resulting in an estimated value.
n	Denotes that the quality control (QC) value is outside the accuracy or precision data quality objective (DQO), but meets the contingency criteria.
N	Denotes that the QC value is outside the accuracy or precision DQO.
NA	Not applicable.
T	Denotes that the holding time of the sample was exceeded. The QAPP lists the holding times for each of the analyses.
U	Denotes that the analyte was undetected at the MDL, which is the minimum concentration of a substance measurable with 99% confidence that the analyte concentration is greater than zero. For non-detected analytes, the sample-specific MDL (adjusted for sample size and dilutions) was inserted into the value field. When calculating sums (tPCBs and total PAHs), one-half the MDL was used for non-detected analytes.

Furthermore, it is a requirement that all U.S. EPA quality system elements “flow down” to the contractor support entities. U.S. EPA quality system specifications are incorporated into all applicable U.S. EPA-funded agreements and are defined in 48 CFR 46. An important element of this system for contracted analytical services is certification by an independent accrediting organization, such as the National Environmental Laboratory Accreditation Conference. This certification ensures that data are collected according to SOPs and methodologies under a quality system that is equivalent to American National Standards Institute/American Society of Quality Control E4, which is the basis of the U.S. EPA quality system.

4 Data Results

A summary of the analytical results for the 2012 post-remedy study is presented in this section. Tables and figures in this section summarize results by LOEs. Appendix C includes the laboratory analytical data and the QA/QC summaries for analysis of sediment samples, tissue samples, surrogate biological samples, and water samples.

4.1 Physical Lines of Evidence

4.1.1 Ecological Assessment

Physical habitat information collected using the Ohio EPA Ecological Assessment field form are summarized in Table 4-1. A hydrological component of the physical habitat where aquatic invertebrate samples were collected was deep and slow turbid flow. Two sites (RM 5.5 and 7.3) had notable amounts of rip rap rubble along the wetted margins, but bed sediments were predominantly fines (silt and muck). Narrow strips of woody riparian vegetation were noted along both backs at most sites and the downstream sites also had emergent wetland grasses (mainly *Typha*, *Phragmites*, and *Phalaris*) (Table 4-1).

Table 4-1. 2012 Physical Habitat Data from the Ecological Assessment Field Form Collected at the Planned Remediated (R) and Non-remediated (N) Stations along the Lower Ottawa River that were Sampled for the Lacustuary Invertebrate Community Index (LICI).

Station	2A	2B	3A	3B	4A	4D
River mile	3.5	4.6	5.5	6.2	6.8	7.3
Reach	2	2	3	3	4	4
R/N[1]	N	R	R	N	N	R
Date	8/22	8/22	8/23	8/23	8/22	8/22
Width (m)	140	100	30	30	30	30
Depth (m)	0.65	2.00	1.25	2.50	0.60	1.05
Velocity (m/s)	0	0	0	0.01	0	0
Channel morphology	Natural	Natural	Channelized	Channelized	Channelized	Channelized
Bank erosion	None	None	None	Moderate	Moderate	Moderate
Riffle development	Absent	Absent	Absent	Absent	Absent	Absent
Clarity	Turbid	Turbid	Turbid	Turbid	Turbid	Turbid
Color	Brown	Brown	Brown	Brown	Brown	Brown
Riparian canopy	Open (0%)	Open (0%)	Open (0%)	Open (6.25 %)	Open (6.25%)	75% (ND)
% Bedrock	0	0	0	0	0	0
% Boulder	0	0	0	0	0	0
% Rubble	0	0	60	0	0	33
% Coarse gravel	0	0	0	0	0	33
% Fine gravel	0	0	0	0	0	33
% Sand	0	0	0	0	0	0
% Silt	100	100	40	50	90	0
% Clay	0	0	0	0	0	0
% Detritus	0	0	0	0	10	0
% Peat	0	0	0	0	0	0
% Muck	0	0	0	50	0	0
% Other	0	0	0	0	0	0
% Macrophyte	0	0	0	0	0	0
% Algae	0	0	0	0	0	0
% Artifacts	0	0	0	0	0	0
Compaction	Soft	Moderate	Soft	Soft	Soft	Firm
Land use*	I(B), W(B)	I(B), W(B)	I (B)	I (B)	I (B)	I (B)
Left bank large trees (m)	0	0	0	10	5	10
Left bank small trees (m)	10	10	5	10	5	10
Left bank shrubs (m)	0	0	0	0	0	10
Left bank grass (m)	35	20	0	0	5	0
Left bank none (m)	0	0	0	0	0	0
Right bank large trees (m)	0	0	10	10	5	10
Right bank small trees (m)	0	0	10	10	5	10
Right bank shrubs (m)	0	0	0	0	0	10
Right bank grass (m)	20	30	10	5	0	0
Right bank none (m)	0	0	20	0	0	0
Margin habitats	Grass, RR	Grass	RR, BH	Grass, silt, muck	RR, root mats	RR
Margin quality	Fair	Fair	Poor	Poor	Poor	Poor

* I = Industrial, W = Wetland, (B) = Both Banks, (L) = Left Bank, (R) = Right Bank; RR = Rip Rap; HP = Hardpan

[1] R/N = Remediated/Non-remediated

4.2 Biological Lines of Evidence

4.2.1 LICI Macroinvertebrate Data

The overall 2012 mean LICI score across the six study sites was 18 (±1.79 standard error [SE]), 16 LICI units below the restoration target for the degraded benthos BUI and falling within the Poor narrative class as used by Ohio EPA. The LICI scores from remediated and non-remediated sites did not differ significantly (Figure 4-1, t-test, p = 0.34). All six sites scored individually within the Poor narrative class (Figure 4-2; Table 4-2). Dipterans represented more than half of the taxa present at all the sites (Table 4-2). The numerically dominant taxa included the tolerant chironomids *Glyptotendipes* (*G.*) sp. and *Dicrotendipes* spp. and oligochaete segmented worms, collectively representing between 82.4% and 96.2% of the taxa collected at a site. Out of a total of 38 taxa and 33,455 individuals collected from the multi-plate samples across six sites in 2012, only two taxa are considered by Ohio EPA to be sensitive to stressors. These taxa included *Caenis* (Ephemeroptera: Caenidae) and earlier instar mayflies (Ephemeroptera). The mayfly *Caenis* had not been collected from Ottawa River since 2002.

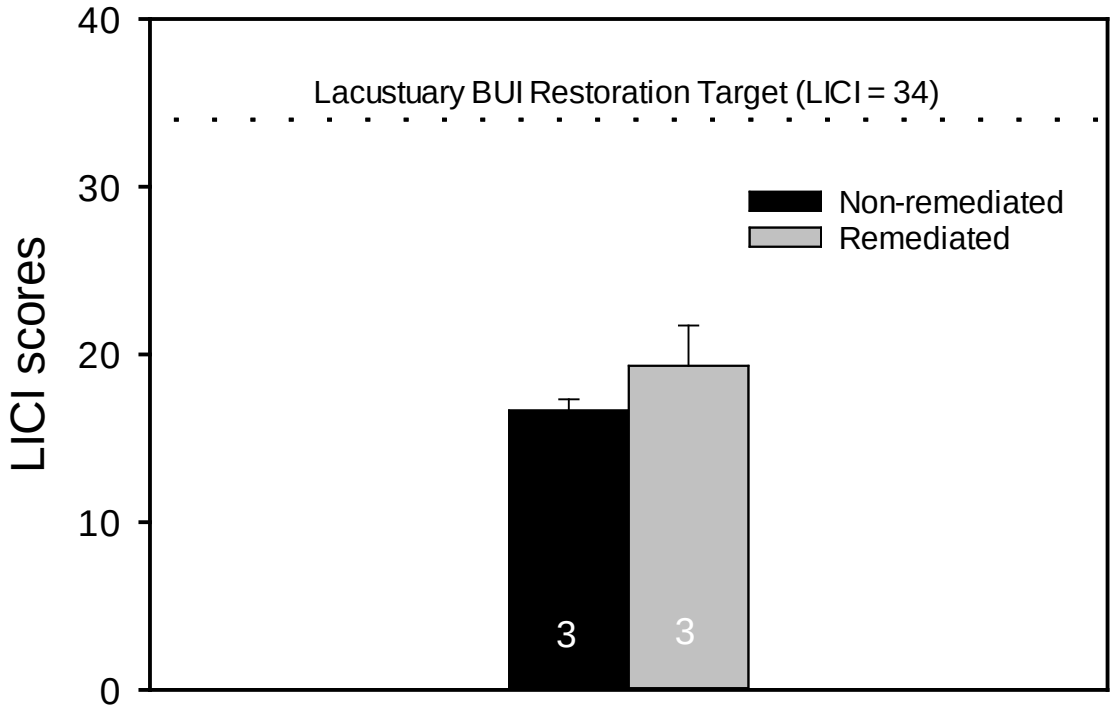


Figure 4-1. Mean Lacustuary Invertebrate Community Index (LICI) Scores (±1 SE) at Remediated and Non-remediated Sites in 2012. The Number of Sites within each Treatment is Shown in the Bars. The Dashed Line Identifies the Lacustuary Restoration Target for the Degraded Benthos Beneficial Use Impairment (BUI).

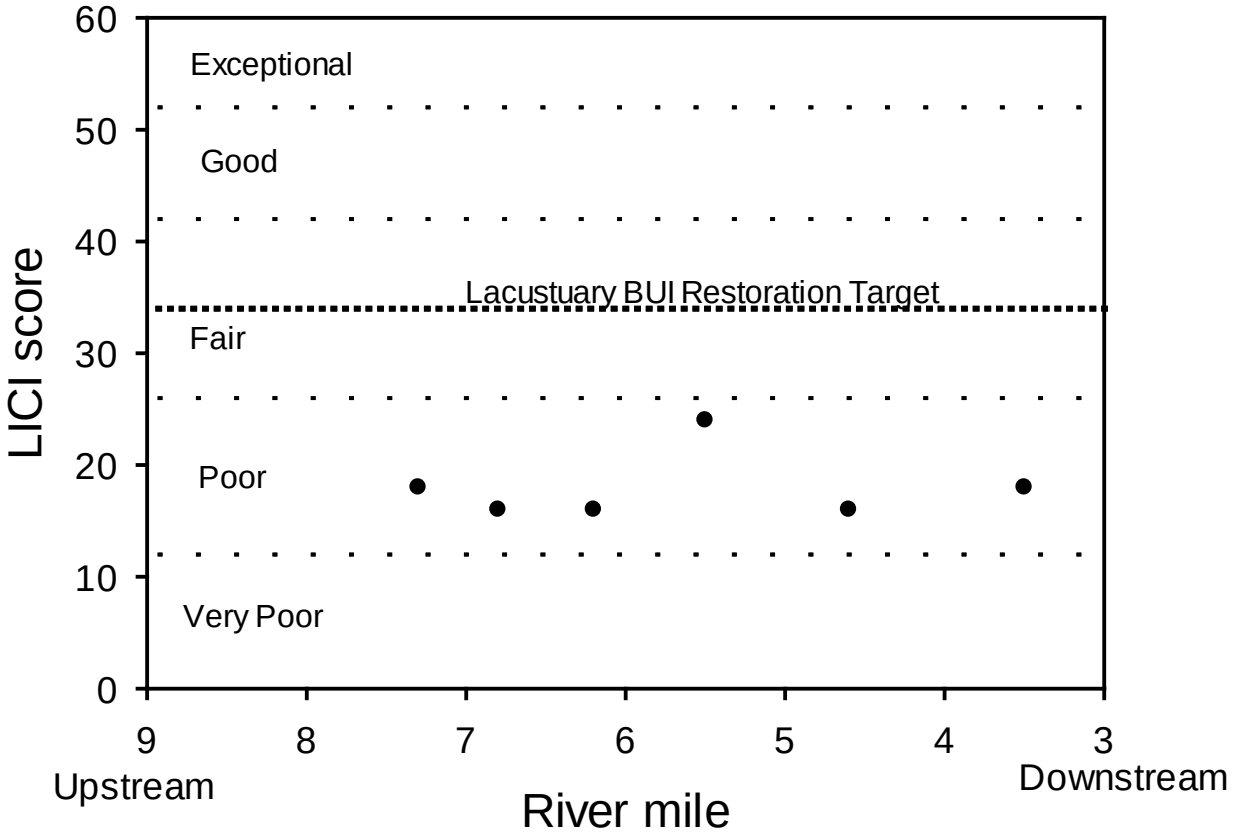


Figure 4-2. Lacustuary Invertebrate Community Index (LICI) Scores from 2012 along the Lower Ottawa River. Dashed Horizontal Lines Delineate the Ohio EPA Narrative Classes, and the Dotted Horizontal Line Delineates the Degraded Benthos Beneficial Use Impairment (BUI) Restoration Target LICI Score.

Table 4-2. Lacustuary Invertebrate Community Index (LICI) Metrics and Scores from 2012 Across the Remediated (R) and Non-remediated (N) Sites along the Lower Ottawa River.

	2012					
Station	2A	2B	3A	3B	4A	4D
River mile	3.5	4.6	5.5	6.2	6.8	7.3
Reach	2	2	3	3	4	4
R/N	N	R	R	N	N	R
% Lacustuary	42.2	68.9	68.9	75.6.	81.1	81.1
Deployment date	7/10	7/10	7/11	7/9	7/9	7/10
Retrieval date	8/21	8/22	8/21	8/20	8/20	8/22
Total taxa	14	18	17	12	18	22
Diptera taxa	9	10	10	7	10	14
Sensitive taxa	1	0	1	0	0	1
% predominant taxon	27.7	35.1	40.5	41.9	42.8	55.5
% other Diptera	100	100	100	100	100	99.6
% mayfly & caddisfly taxa	7.90	1.14	12.31	0.10	0.04	0.02
% sensitive taxa	1.94	0	12.22	0	0	0.02
% collector-gatherers	93.6	95.5	94.9	97.5	97.9	96.7
Diptera density	993.8	732.6	498.5	648.8	784.9	411.4
Qualitative EPT	0	0	0	0	0	0
LICI score	18	16	24	16	16	18
Narrative class	Poor	Poor	Poor	Poor	Poor	Poor
Total density (#/ft^2)	1464.3	1010.0	1062.0	1122.1	1018.1	940.9
Total biomass (mg AFDM)	812.2	723.2	193.4	557.4	609.1	237.8

4.2.2 Toxicity Testing

Sediments were obtained by compositing surface sediment samples (top 6- in. core composites). Two liters of sediment were collected at each station at the times of deployment (Round 1) and retrieval (Round 2) of the body-burden macroinvertebrate samplers. These samples were returned to NERL-Cincinnati, and 10-day static-renewal bulk-sediment toxicity tests using *Chironomus tentans* and *Hyalella azteca* were conducted for each round. The toxicity endpoints measured were percent survival and growth, with physical/chemical parameters (i.e., ammonia, pH, dissolved

oxygen, conductivity, and temperature). Further details on the toxicity testing method is described in U.S. EPA (2017).

Chironomus tentans

Table 4-3 contains the results from the *C. tentans* 10-day sediment toxicity tests conducted in October 2012 using Ottawa River sediment samples. The October 2012 toxicity test passed with survival of the control organisms at 73.33%, which met the minimum established survival criteria of 70% (U.S. EPA, 2000). The bioassay determined no samples were toxic based on midge survival data, while growth data yielded two (11.1%) adverse growth effects.

During the *C. tentans* bioassay, none of the samples were characterized as toxic based on t-test results versus control survival (Table 4-3). The survival rate in any one sample ranged from 60.00 to 93.33%. The growth endpoint reveals two (Stations 3A and 3F) of the 18 samples had an adverse effect on *C. tentans* development.

Bench-top chemistries for Round 1 suggest the water quality of the associated samples was within expected ranges. Day 0 conductivity ranges were between 543 to 653 µS, while Day 10 ranged from 436 to 483 µS. Day 0 pH values ranged from 7.24 to 7.45, while Day 10 ranges were between 7.00 and 7.33. Daily temperatures overwhelmingly were 23.0º C +/- 1º C, with the exception of Days 1 through 4 (15.1 º C to 18.8 º C) due to incubator failure. The dissolved oxygen (DO) of Day 0 samples varied from 6.7 to 8.5 mg/L, while Day 10 DO values were between 5.9 and 6.9 mg/L.

Ammonia sediment values for each sample were derived from a 1:1(v/v) ratio of sediment to reformulated moderately hard reconstituted water (RMHRW) slurry as depicted in Table 4-4, while ammonia water column values are based from measurements taken on water overlying sediment. Un-ionized sediment ammonia concentrations ranged from 0.7 to 14.5 mg/L, while un-ionized water column ammonia concentrations ranged from 0.00 to 0.58 mg/L.

None of the toxicity values noted are thought to be attributed to the common water quality parameters associated with sediment samples (pH, conductivity, temperature, and DO). However, all observed growth toxicity (Stations 3A and 3F) *may* be attributable to un-ionized sediment ammonia concentrations since all affected samples exhibited levels above the assumed toxic threshold of 0.4 mg/L. Un-ionized ammonia slurry concentrations were derived via normalization, assuming a pH of 8.0 at a temperature of 25ºC from total ammonia measurements. Un-ionized ammonia concentrations in the water column were generally below the toxic threshold. The 2012 Ottawa River sediment samples exhibited two samples (Stations 3C and 3F) exceeding the threshold, of which only Station 3F exhibited any adverse (growth) affects in the bioassay. Un-ionized ammonia water column concentrations were derived via normalization, assuming a pH of 8.0 at a temperature of 23ºC from total ammonia measurements.

Table 4-3. Results from the C. tentans 10-day Sediment Toxicity Tests using Sediment Collected from the Ottawa River.

Year/Round	Sample ID	Site ID	Col. Date	Test Date	Percent Survival	S.D.	CV	P-value	Wt (mg)	S.D.	CV	P-value
2012 / 1	100% sand	n/a	n/a	10/5/2012	73.3	20.7	28.2	n/a	0.730	0.16	22.3	n/a
2012 / 1	MAH-201	2A	8/21/12	10/5/12	73.3	20.7	28.2	0.50	0.708	0.25	35.4	0.43
2012 / 1	MAH-202	2B	8/22/12	10/5/12	60.0	21.9	36.5	0.15	0.670	0.30	44.5	0.34
2012 / 1	MAH-203	2C	8/21/12	10/5/12	70.0	16.7	23.9	0.38	0.668	0.12	18.3	0.24
2012 / 1	MAH-204	2D	8/22/12	10/5/12	73.3	20.7	28.2	0.50	0.873	0.13	15.0	0.06
2012 / 1	MAH-205	2E	8/21/12	10/5/12	83.3	19.7	23.6	0.21	0.887	0.26	29.8	0.12
2012 / 1	MAH-206	2F	8/22/12	10/5/12	66.7	32.7	49.0	0.34	0.686	0.49	72.2	0.42
2012 / 1	MAH-301	3A	8/21/12	10/5/12	93.3	10.3	11.1	0.03	0.403	0.13	32.3	0.00
2012 / 1	MAH-302	3B	8/20/12	10/5/12	86.7	10.3	11.9	0.10	0.687	0.12	17.7	0.31
2012 / 1	MAH-303	3C	8/21/12	10/5/12	69.4	21.3	30.7	0.38	0.693	0.24	35.1	0.38
2012 / 1	MAH-304	3D	8/21/12	10/5/12	93.3	10.3	11.1	0.03	0.648	0.10	15.3	0.16
2012 / 1	MAH-305	3E	8/21/12	10/5/12	93.3	10.3	11.1	0.03	0.918	0.26	27.8	0.08
2012 / 1	MAH-306	3F	8/20/12	10/5/12	73.3	27.3	37.3	0.50	0.094	0.06	61.7	0.00
2012 / 1	MAH-401	4A	8/20/12	10/5/12	86.7	16.3	18.8	0.12	0.712	0.33	45.9	0.45
2012 / 1	MAH-402	4B	8/20/12	10/5/12	80.0	12.7	15.8	0.26	1.06	0.25	24.0	0.01
2012 / 1	MAH-403	4C	8/22/12	10/5/12	90.0	11.0	12.2	0.06	1.06	0.17	16.3	0.00
2012 / 1	MAH-404	4D	8/22/12	10/5/12	80.0	17.9	22.4	0.28	0.743	0.16	21.7	0.45
2012 / 1	MAH-405	4E	8/22/12	10/5/12	76.7	19.7	25.7	0.39	0.939	0.21	22.0	0.04
2012 / 1	MAH-406	4F	8/22/12	10/5/12	76.7	8.2	10.7	0.36	1.02	0.19	18.3	0.01

Note: Orange shading indicates the control sample run for each batch of toxicity tests. Percent survival for a valid test is 70%.
Red shading indicates which samples were acutely toxic based on t-test results compared to the control sample.

Table 4-4. *C. tentans* Ammonia Sediment Values for Each Sample Derived from the 1:1 (Volume/Volume) Ratio of Sediment to RMHRW Slurry.

Year/ Round	Sample ID	Site ID	Collection Date	Test Date	Total Ammonia Sediment (mg/L)	Un-ionized Ammonia Sediment (mg/L)	Total Ammonia in Water Column (mg/L)	Un-ionized Ammonia in Water Column (mg/L)
2012 / 1	100% sand	n/a	n/a	10/5/2012	0.027	0.00	0.104	0.00
2012 / 1	MAH-201	2A	8/21/12	10/5/12	220	11.84	3.42	0.16
2012 / 1	MAH-202	2B	8/22/12	10/5/12	184	9.88	2.40	0.11
2012 / 1	MAH-203	2C	8/21/12	10/5/12	270	14.53	5.76	0.27
2012 / 1	MAH-204	2D	8/22/12	10/5/12	92.4	4.97	0.942	0.04
2012 / 1	MAH-205	2E	8/21/12	10/5/12	170.	9.16	2.10	0.10
2012 / 1	MAH-206	2F	8/22/12	10/5/12	139	7.46	2.11	0.10
2012 / 1	MAH-301	3A	8/21/12	10/5/12	69.0	3.71	0.816	0.04
2012 / 1	MAH-302	3B	8/20/12	10/5/12	36.6	1.97	0.608	0.03
2012 / 1	MAH-303	3C	8/21/12	10/5/12	196	10.56	12.3	0.58
2012 / 1	MAH-304	3D	8/21/12	10/5/12	27.4	1.47	0.987	0.05
2012 / 1	MAH-305	3E	8/21/12	10/5/12	234	12.59	5.67	0.27
2012 / 1	MAH-306	3F	8/20/12	10/5/12	261	14.03	10.9	0.51
2012 / 1	MAH-401	4A	8/20/12	10/5/12	51.8	2.79	0.706	0.03
2012 / 1	MAH-402	4B	8/20/12	10/5/12	82.2	4.42	1.53	0.07
2012 / 1	MAH-403	4C	8/22/12	10/5/12	24.6	1.32	0.130	0.00
2012 / 1	MAH-404	4D	8/22/12	10/5/12	74.8	4.03	1.03	0.05
2012 / 1	MAH-405	4E	8/22/12	10/5/12	13.6	0.73	0.278	0.01
2012 / 1	MAH-406	4F	8/22/12	10/5/12	63.4	3.41	1.37	0.06

Note: Orange shading indicates the control sample run for each batch of toxicity tests.
Red shading indicates samples at or above toxic un-ionized ammonia threshold of 0.4 mg/L.
Blue shading indicates samples below toxic un-ionized ammonia threshold of 0.4 mg/L.
Yellow shading indicates samples determined toxic for at least one endpoint.

Hyalella azteca

Table 4-5 contains results from the *H. azteca* 10-day sediment toxicity tests conducted in September 2012 using sediment samples received from the Ottawa River. The September 2012 toxicity tests exceeded minimum control survival criteria (80%) with survival rates of 100%.

During this bioassay, none of the 18 samples (Table 4-5) were characterized as toxic based on t-test results versus control survival. The survival rate in any one sample ranged from 81.67 to 98.33%. The growth endpoint revealed 10 of the 18 samples had an adverse effect on *Hyalella azteca* development when compared to control growth.

Bench-top water chemistries were within the expected ranges. Day 0 conductivity ranges were between 434 and 536 µS, while Day 10 ranged from 407 to 504 µS. Day 0 pH values ranged from 6.67 to 7.42, while Day 10 ranges were between 6.98 and 8.73. Daily temperatures consistently were at 23.0º C +/- 1º C. The DO of Day 0 samples varied from 6.9 to 7.9 mg/L, while Day 10 DO values were between 5.2 and 6.8 mg/L.

Ammonia sediment values were derived from a 1:1(v/v) ratio of sediment to RMHRW (slurry), while ammonia water column values are based from measurements taken on water overlying sediment as depicted in Table 4-6. Un-ionized sediment ammonia concentrations ranged from 0.73 to 14.53 mg/L. Water column un-ionized ammonia concentrations ranged from 0.01 to 0.56 mg/L.

The 2012 *H. azteca* bioassay indicates none of the Ottawa River samples were toxic based on mortality endpoints specifically used to characterize toxicity since all samples met minimum survival criteria of ≥80%. Conversely, adverse growth effects were recorded in 10 of the 18 samples (55.6%).

None of the toxicity values noted are thought to be attributed to the common water quality parameters associated with sediment samples (pH, conductivity, temperature, and DO). However, all observed growth toxicity *may* be attributable to un-ionized sediment ammonia concentrations since all affected samples exhibited levels above the assumed toxic threshold of 0.4 mg/L. Un-ionized ammonia slurry concentrations were derived via normalization, assuming a pH of 8.0 at a temperature of 25ºC from total ammonia measurements. Un-ionized ammonia concentrations in the water column were generally below the toxic threshold. *H. azteca* overlying water had two samples (Stations 3C and 3F) exceeding the threshold, during which both exhibited growth endpoint toxicity. Un-ionized ammonia water column concentrations were derived via normalization, assuming a pH of 8.0 at a temperature of 23ºC from total ammonia measurements.

Table 4-5. Results from the *Hyalella azteca* 10-Day Sediment Toxicity Tests from Sediment Collected from the Ottawa River.

Year/Round	Sample ID	Site ID	Collection Date	Test Date	Percent Survival	S.D.	CV	P-value	Wt (mg)	S.D.	CV	P-value
2012 / 1	100% sand	n/a	n/a	09/07/12	100	0.00	0.00	n/a	0.205	0.02	11.86	n/a
2012 / 1	MAH-201	2A	8/21/12	9/7/12	98.3	4.08	4.15	0.18	0.161	0.01	5.75	<0.01
2012 / 1	MAH-202	2B	8/22/12	9/7/12	90.0	11.0	12.2	0.04	0.187	0.01	3.06	0.07
2012 / 1	MAH-203	2C	8/21/12	9/7/12	90.0	12.7	14.1	0.06	0.168	0.02	11.0	<0.01
2012 / 1	MAH-204	2D	8/22/12	9/7/12	90.0	15.5	17.2	0.09	0.184	0.02	8.79	0.06
2012 / 1	MAH-205	2E	8/21/12	9/7/12	88.3	7.53	8.52	0.01	0.197	0.02	9.51	0.28
2012 / 1	MAH-206	2F	8/22/12	9/7/12	96.7	5.16	5.34	0.09	0.171	0.03	15.7	0.03
2012 / 1	MAH-301	3A	8/21/12	9/7/12	96.7	5.16	5.34	0.09	0.132	0.01	9.49	<0.01
2012 / 1	MAH-302	3B	8/20/12	9/7/12	81.7	27.9	34.1	0.08	0.186	0.03	13.7	0.11
2012 / 1	MAH-303	3C	8/21/12	9/7/12	98.3	4.08	4.15	0.18	0.167	0.02	13.8	0.01
2012 / 1	MAH-304	3D	8/21/12	9/7/12	93.3	8.16	8.75	0.05	0.160	0.02	10.6	<0.01
2012 / 1	MAH-305	3E	8/21/12	9/7/12	91.7	7.53	8.21	0.02	0.190	0.02	8.75	0.13
2012 / 1	MAH-306	3F	8/20/12	9/7/12	83.3	13.7	16.4	0.02	0.138	0.02	12.6	<0.01
2012 / 1	MAH-401	4A	8/20/12	9/7/12	93.3	8.16	8.75	0.05	0.160	0.02	15.1	<0.01
2012 / 1	MAH-402	4B	8/20/12	9/7/12	90.0	12.7	14.1	0.06	0.196	0.05	23.3	0.34
2012 / 1	MAH-403	4C	8/22/12	9/7/12	91.7	7.53	8.21	0.02	0.210	0.02	7.85	0.33
2012 / 1	MAH-404	4D	8/22/12	9/7/12	90.0	10.95	12.2	0.04	0.144	0.04	24.5	<0.01
2009 / 1	MAH-405	4E	8/22/12	9/7/12	95.0	8.37	8.81	0.10	0.231	0.02	8.45	0.03
2009 / 1	MAH-406	4F	8/22/12	9/7/12	96.7	5.16	5.34	0.09	0.176	0.01	7.27	0.02

Note: Orange shading indicates the control sample run for each batch of toxicity tests. Percent survival for a valid test is 70%.
Red shading indicates which samples were acutely toxic based on t-test results comparing to the control sample.

Table 4-6. *H. azteca* Ammonia Sediment Values for Each Sample Derived from the 1:1 (Volume/Volume) Ratio of Sediment to RMHRW Slurry.

Year/Round	Sample ID	Site ID	Collection Date	Test Date	Total Ammonia Sediment (mg/L)	Un-ionized Ammonia Sediment (mg/L)	Total Ammonia Water Column (mg/L)	Un-ionized Ammonia Water Column (mg/L)
2012 / 1	100% sand	n/a	n/a	09/07/12	0.027	0.00	0.048	0.00
2012 / 1	MAH-201	2A	8/21/12	9/7/12	220	11.8	3.95	0.19
2012 / 1	MAH-202	2B	8/22/12	9/7/12	184	9.88	2.81	0.13
2012 / 1	MAH-203	2C	8/21/12	9/7/12	270	14.5	4.65	0.22
2012 / 1	MAH-204	2D	8/22/12	9/7/12	92.4	4.97	2.29	0.11
2012 / 1	MAH-205	2E	8/21/12	9/7/12	170	9.16	3.27	0.15
2012 / 1	MAH-206	2F	8/22/12	9/7/12	139	7.46	3.05	0.14
2012 / 1	MAH-301	3A	8/21/12	9/7/12	69.0	3.71	1.04	0.05
2012 / 1	MAH-302	3B	8/20/12	9/7/12	36.6	1.97	0.610	0.03
2012 / 1	MAH-303	3C	8/21/12	9/7/12	196	10.6	12.0	0.56
2012 / 1	MAH-304	3D	8/21/12	9/7/12	27.4	1.47	0.768	0.04
2012 / 1	MAH-305	3E	8/21/12	9/7/12	234	12.6	5.95	0.28
2012 / 1	MAH-306	3F	8/20/12	9/7/12	261	14.0	10.7	0.50
2012 / 1	MAH-401	4A	8/20/12	9/7/12	51.8	2.79	0.775	0.04
2012 / 1	MAH-402	4B	8/20/12	9/7/12	82.2	4.42	1.73	0.08
2012 / 1	MAH-403	4C	8/22/12	9/7/12	24.6	1.32	0.521	0.02
2012 / 1	MAH-404	4D	8/22/12	9/7/12	74.8	4.03	0.977	0.05
2012 / 1	MAH-405	4E	8/22/12	9/7/12	13.6	0.73	0.281	0.01

Note: Orange shading indicates the control sample run for each batch of toxicity tests.
Red shading indicates samples at or above toxic un-ionized ammonia threshold of 0.4 mg/L.
Blue shading indicates samples below toxic un-ionized ammonia threshold of 0.4 mg/L.
Yellow shading indicates samples determined toxic for at least one endpoint.

4.3 Chemical Lines of Evidence

This section presents the contaminant concentrations (PAHs and PCBs) in sediment, whole water, and tissue samples; sediment characteristics (i.e., bulk density, TOC, total solids); and PSD values for the 11 ORD sampling stations. Appendix C contains the analytical data packages and QA/QC summaries for all data. Stations located within the remediation footprint are identified with an asterisk (*) on the graphs.

4.3.1 Contaminant Concentrations in Surface Sediment

Total PPAH and total alkylated PAH concentrations (both standard and TOC-normalized) for the composite surficial sediment samples collected for the 18 ORD stations during the Phase 4-1 August 2012 deployment are shown in Figure 4-3. Figure 4-4 presents the tPCB data for the August 2012 deployment. The concentration data are shown in the top figures, and the concentration data normalized to organic carbon are shown in the bottom figures. Homolog data are presented in Figure 4-5.

Appendix C contains the analytical data packages and QA/QC summaries for PCB and PAH analyses of all sediment samples.

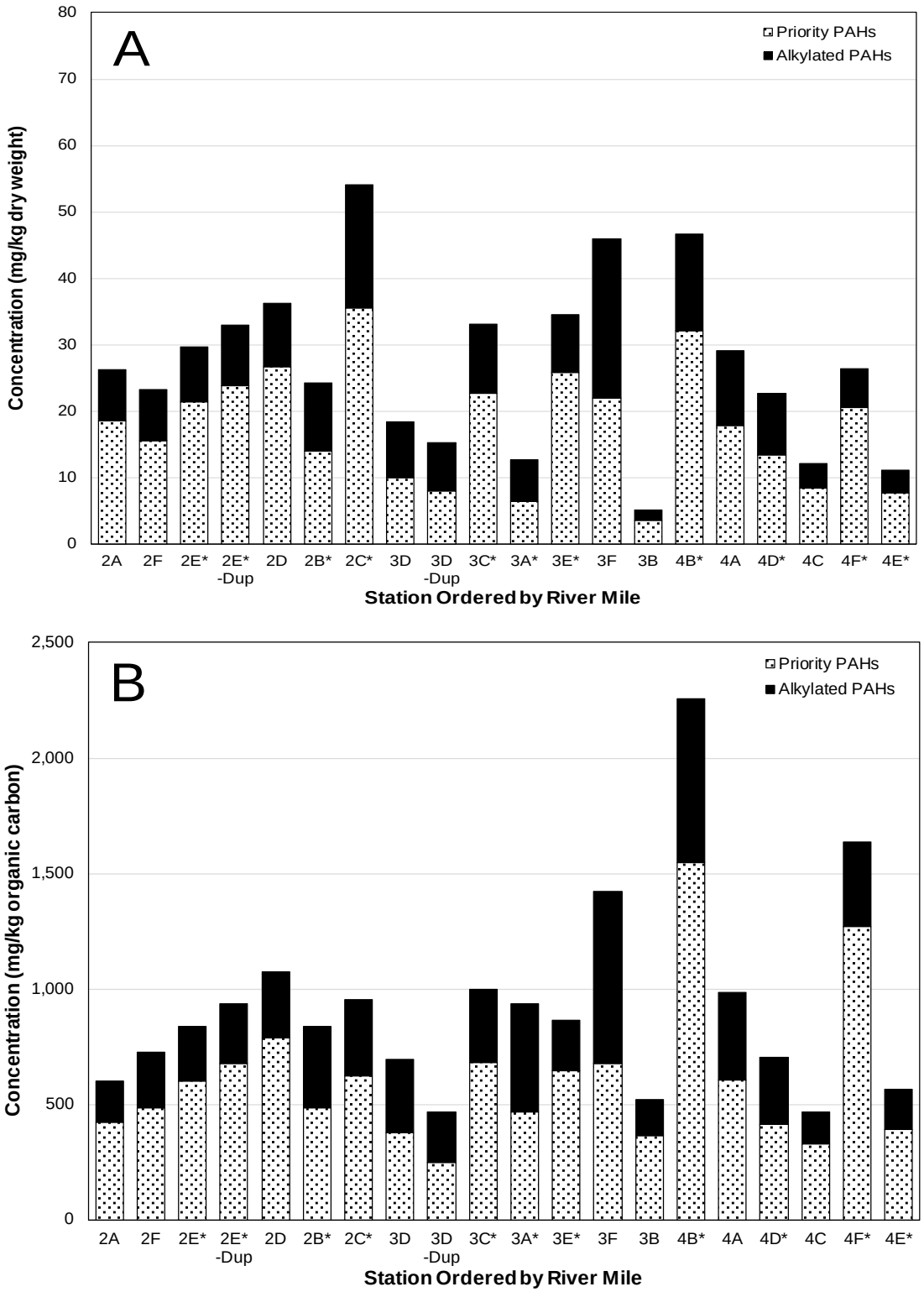


Figure 4-3. Total PAH Concentrations (A – Dry Weight and B – Organic Carbon Normalized) in Surface Sediments (August 2012 – Deployment). Stations with an * are within the Remediation Footprint.

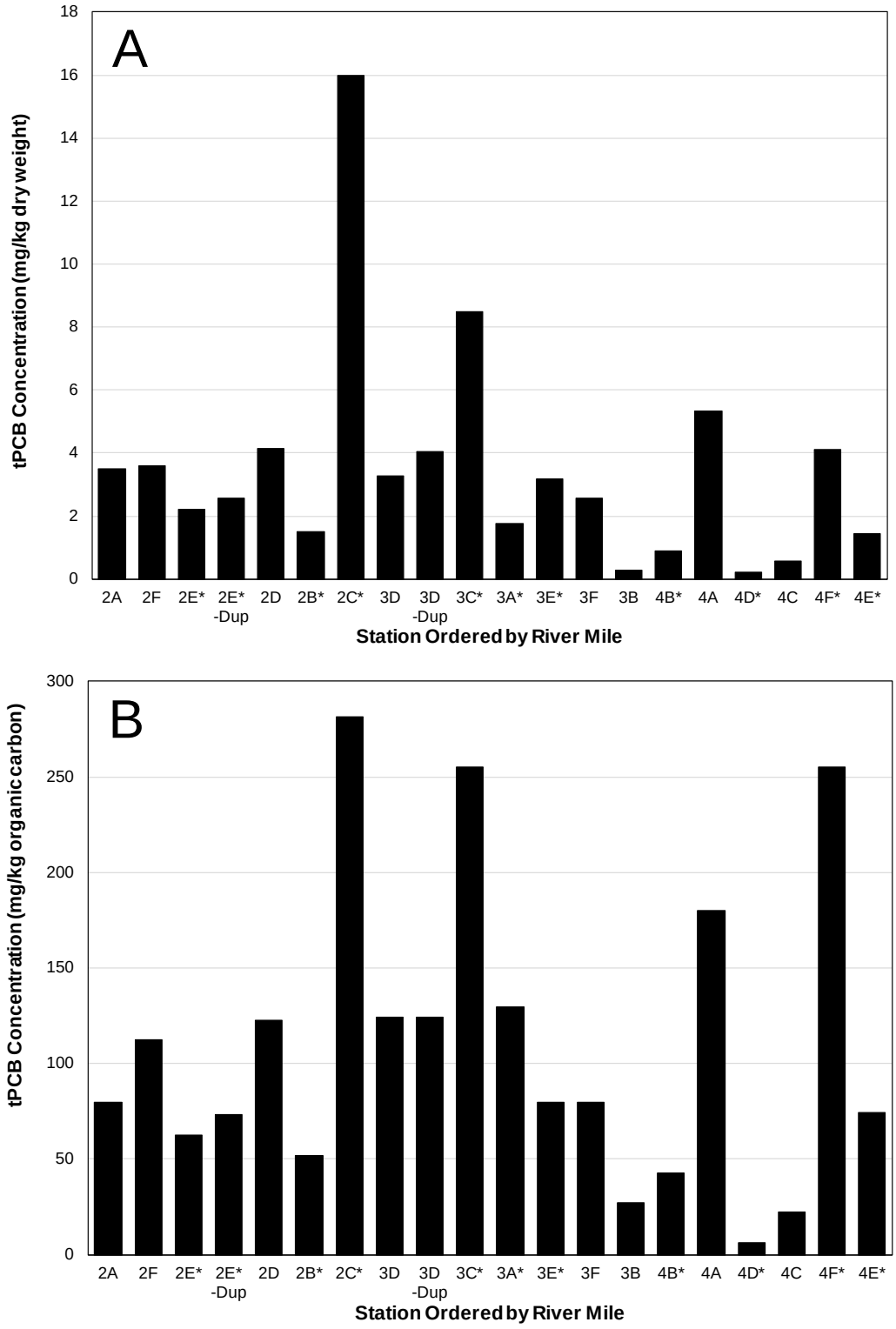


Figure 4-4. tPCB Concentrations (A – Dry Weight and B – Organic Carbon Normalized) in Surface Sediment (August 2012 – Deployment). Stations with an * are within the Remediation Footprint.

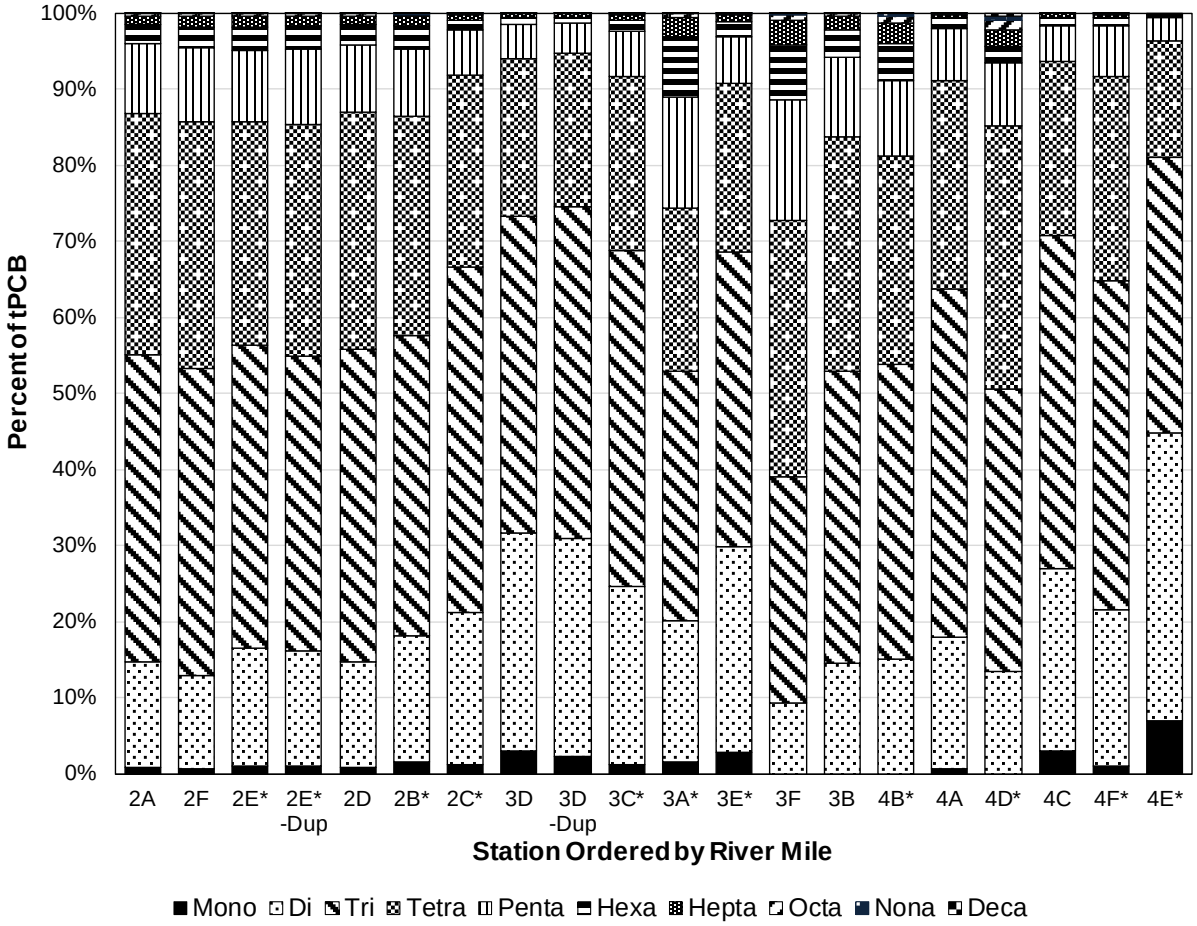


Figure 4-51. Contribution of PCB Homologs in Percent tPCB in Surface Sediment (August 2012 – Deployment). Stations with an * are within the Remediation Footprint.

4.3.1.1 Sediment Characteristics

Surface sediment characteristics (percent moisture and TOC) in the 18 ORD stations (0 to 0.5 ft deep) for the August 2012 deployment period (plus duplicate samples) sampled following remediation activities are presented in Table 4-7.

Table 4-7. Surface Sediment Characteristics of 18 ORD Station Sediments Collected in August 2012.

Sample ID	Percent Moisture (%)	TOC (%)
2A	45.5	4.38
2F	46.8	3.2
2E	45.8	3.55
2E-Dup	48.7	3.52
2D	42.3	3.37
2B	43.9	2.89
2C	44.4	5.68
3D	25.9	2.63
3D-Dup	24.3	3.24
3C	36.3	3.32
3A	28.5	1.36
3E	47.3	3.99
3F	37.7	3.23
3B	28.2	0.972
4B	28.5	2.07
4A	25.9	2.96
4F	28.0	3.22
4C	18.5	2.58
4F	29.5	1.61
4E	14.0	1.95

4.3.1.2 Particle Size Distribution (PSD) Data

PSD data from the 18 ORD stations collected following remediation activities in 2012 are presented graphically in Figure 4-6.

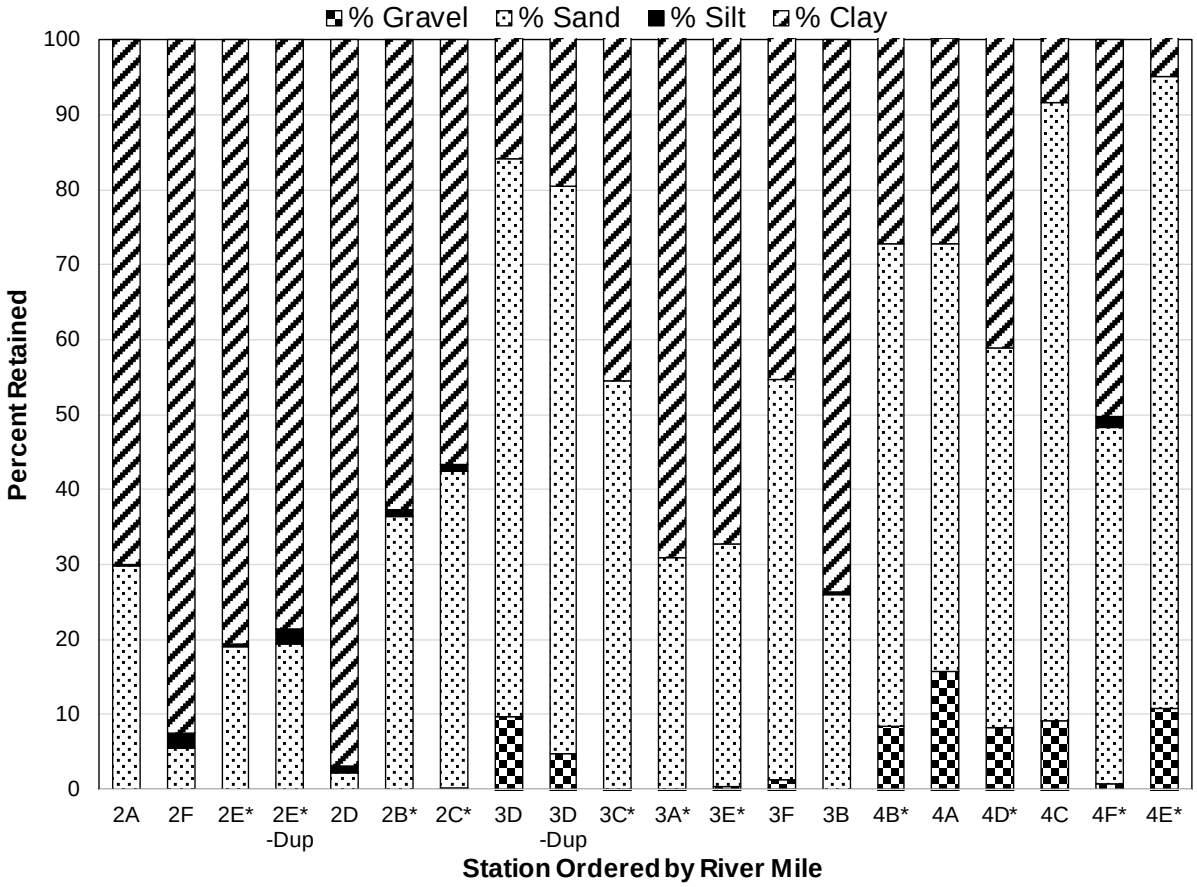


Figure 4-6. PSD Data from Surface Sediments (August 2012 – Deployment). Stations with an * are within the Remediation Footprint.

4.3.2 Water Samples

Whole water samples were collected and analyzed in 2012. Appendix C contains the complete laboratory data sets for analyses performed on all water samples plus the analytical data packages and QA/QC summaries for PCB and PAH analyses carried out on all water samples.

Table 4-8 presents the TOC (micrograms per liter [µg/L]) and total suspended solids (TSS) (µg/L) results for water samples collected from the 18 ORD stations. The PAH, tPCB, and PCB homolog results for the water samples are shown in Figures 4-7 through 4-9, respectively.

Table 4-8. Characteristics of Whole Water Samples (August 2012).

Station ID	Total Organic Carbon (µg/L)	Total Suspended Solids (µg/L)
2A	5800	102000
2F	5270	193000
2E	4960	64000
2E-Dup	4860	59000
2D	5210	30500
2B	5090	33500
2C	5070	28500
3D	4660	44000
3D-Dup	4590	65000
3C	4660	61000
3A	4800	34500
3E	4840	45500
3F	4420	32500
3B	4620	30500
4B	4780	35000
4A	4860	17000
4D	6210	21000
4C	5640	65500
4F	5390	31000
4E	5340	22500

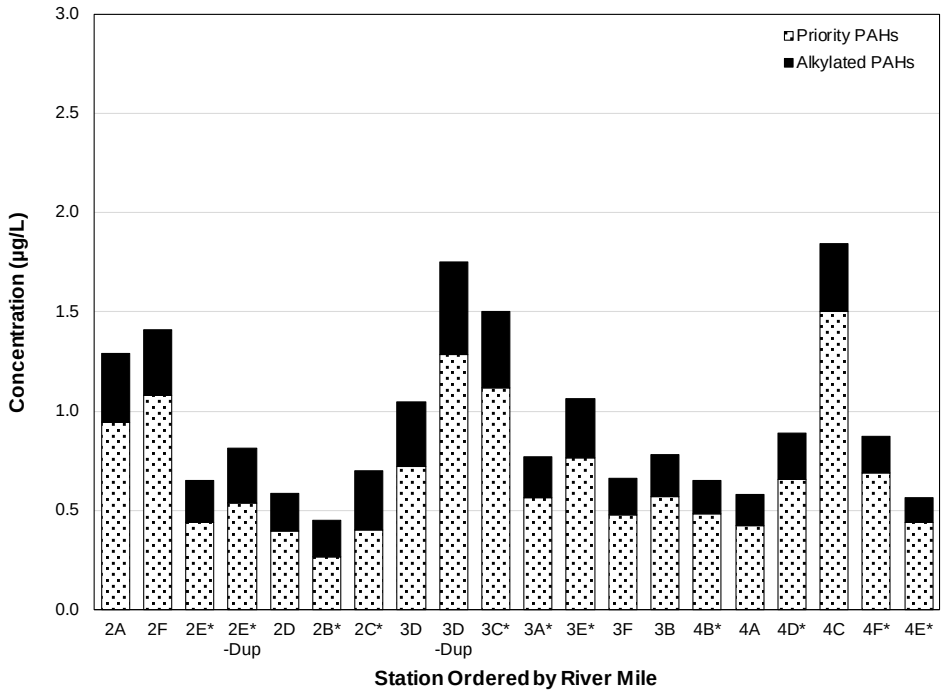


Figure 4-7. Total PAH Concentrations in Whole Water Samples (August 2012). Stations with an * are within the Remediation Footprint.

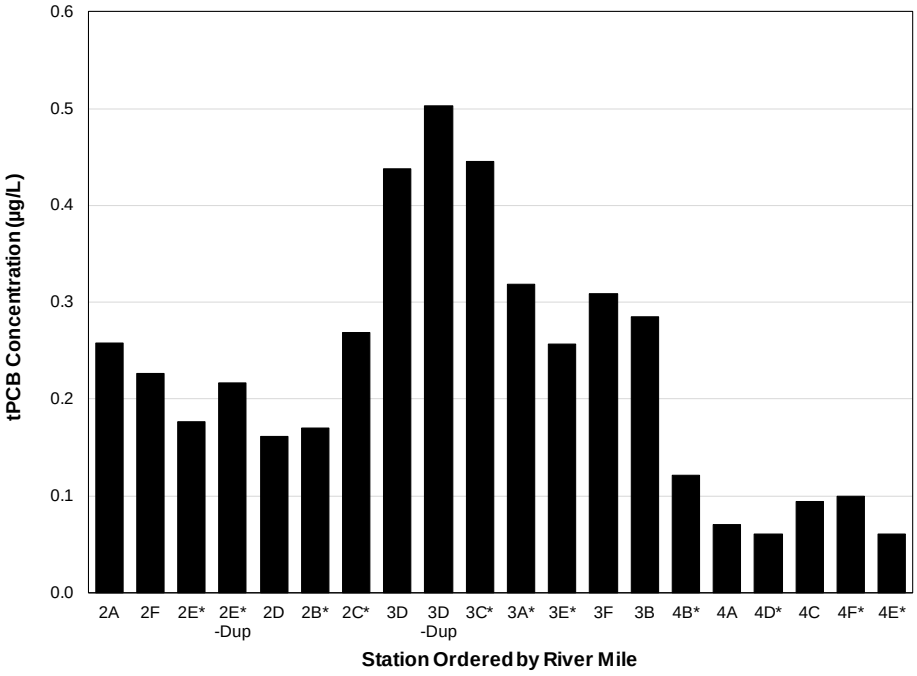


Figure 4-8. tPCB Concentrations in Whole Water Samples (August 2012). Stations with an * are within the Remediation Footprint.

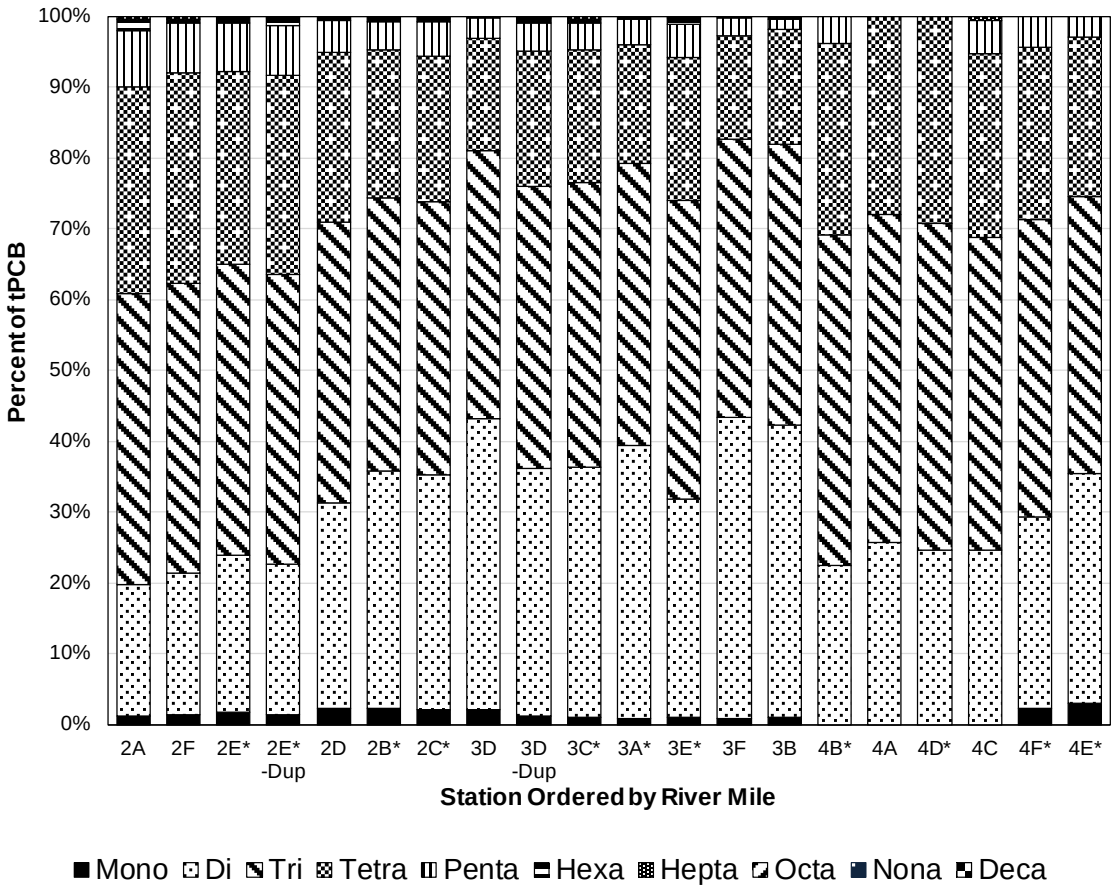


Figure 4-9. Percent of tPCB as Homolog Contributions in Whole Water Samples (August 2012). Stations with an * are within the Remediation Footprint.

4.3.2.1 Passive Sampler Concentration Data for PEDs Suspended in the Water Column

The total PAH, tPCB, and PCB homolog results for PEDs suspended in the water column are summarized in Figures 4-10 through 4-12, respectively.

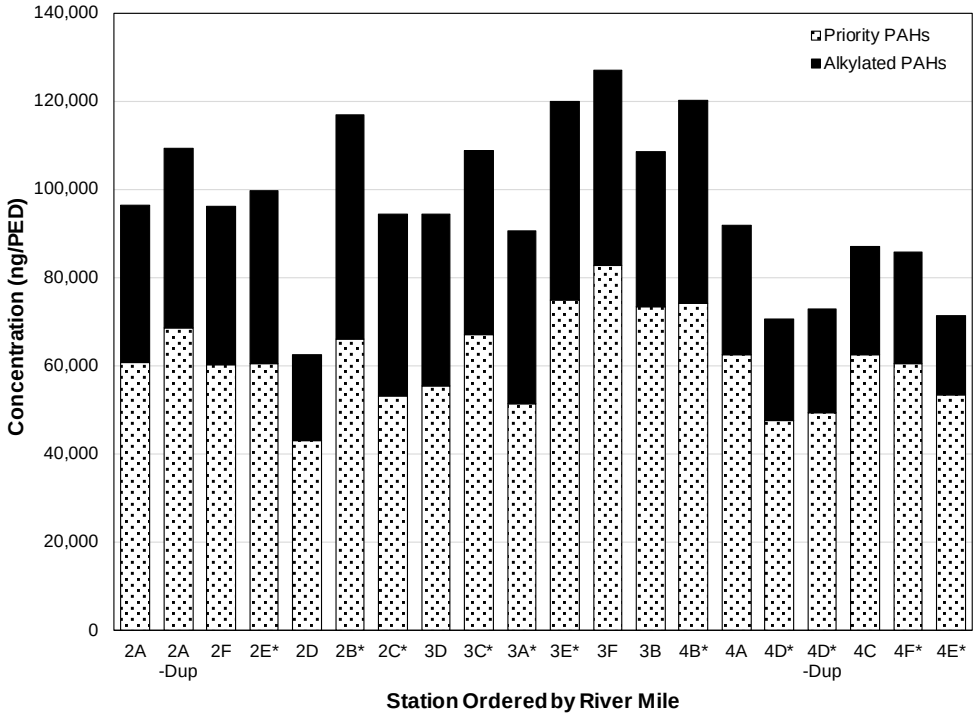


Figure 4-10. Total PAH Concentrations per PED Suspended in the Water Column (August 2012). Stations with an * are within the Remediation Footprint.

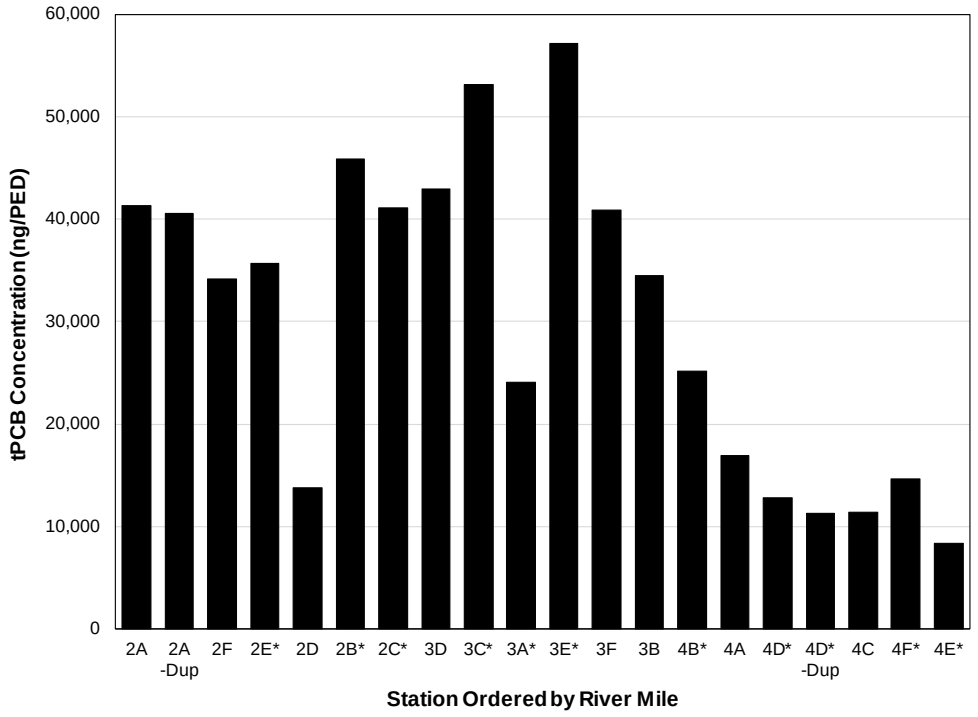


Figure 4-11. tPCB Concentration per PED Suspended in the Water Column (August 2012). Stations with an * are within the Remediation Footprint.

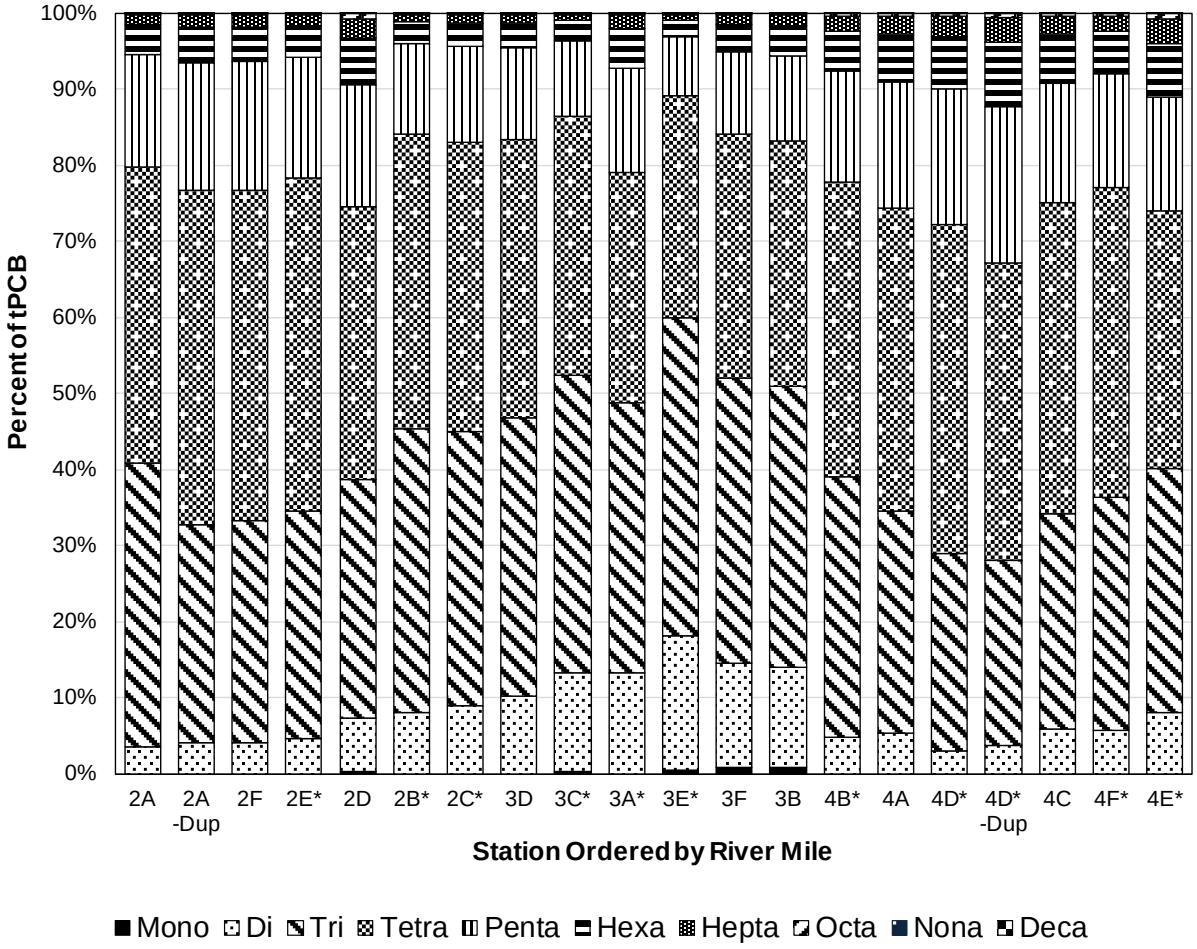
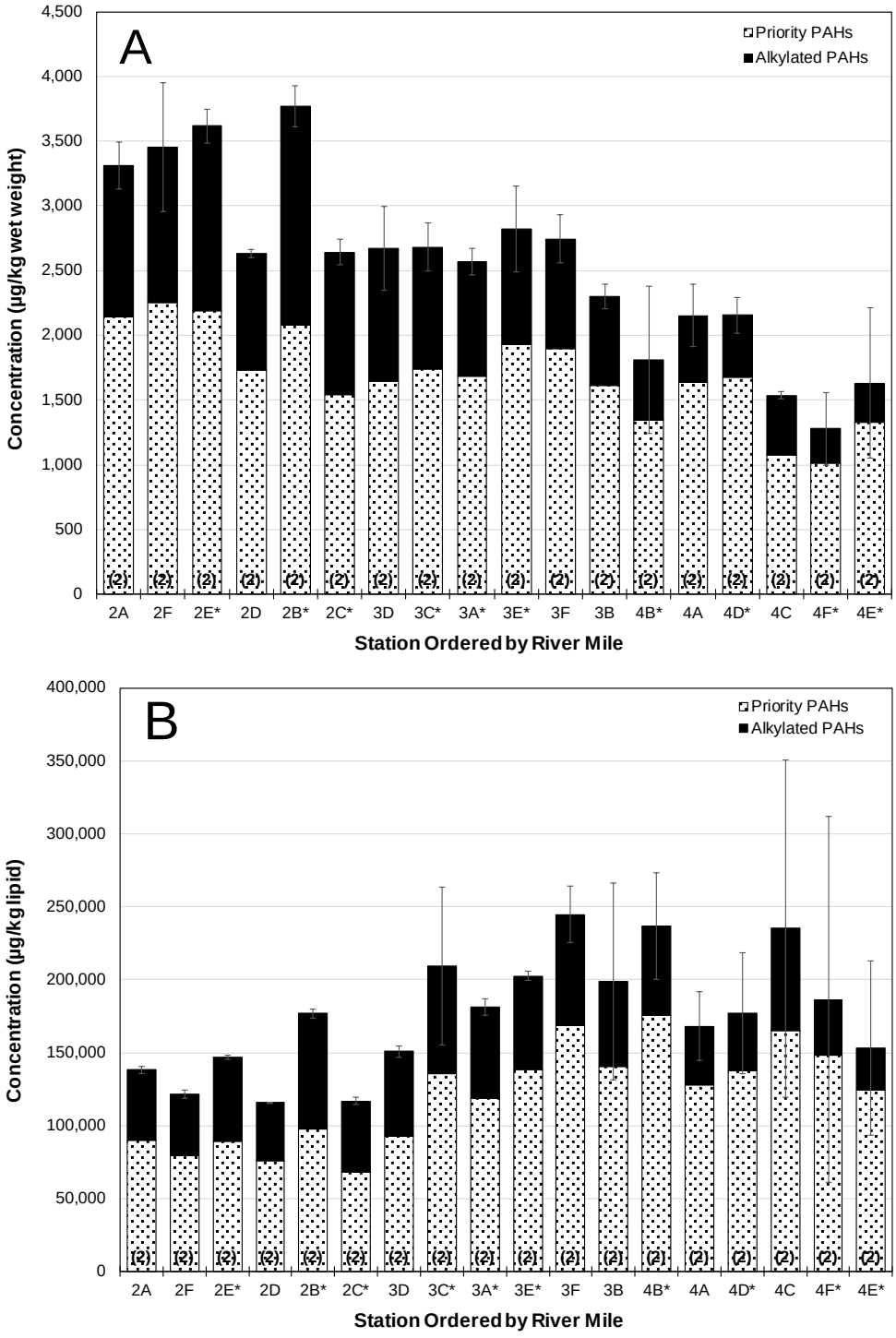


Figure 4-12. Percent of tPCB as Homolog Contribution for Water Column PED Samples (August 2012). Stations with an * are within the Remediation Footprint.

4.3.3 Contaminant Concentrations in Tissue Samples

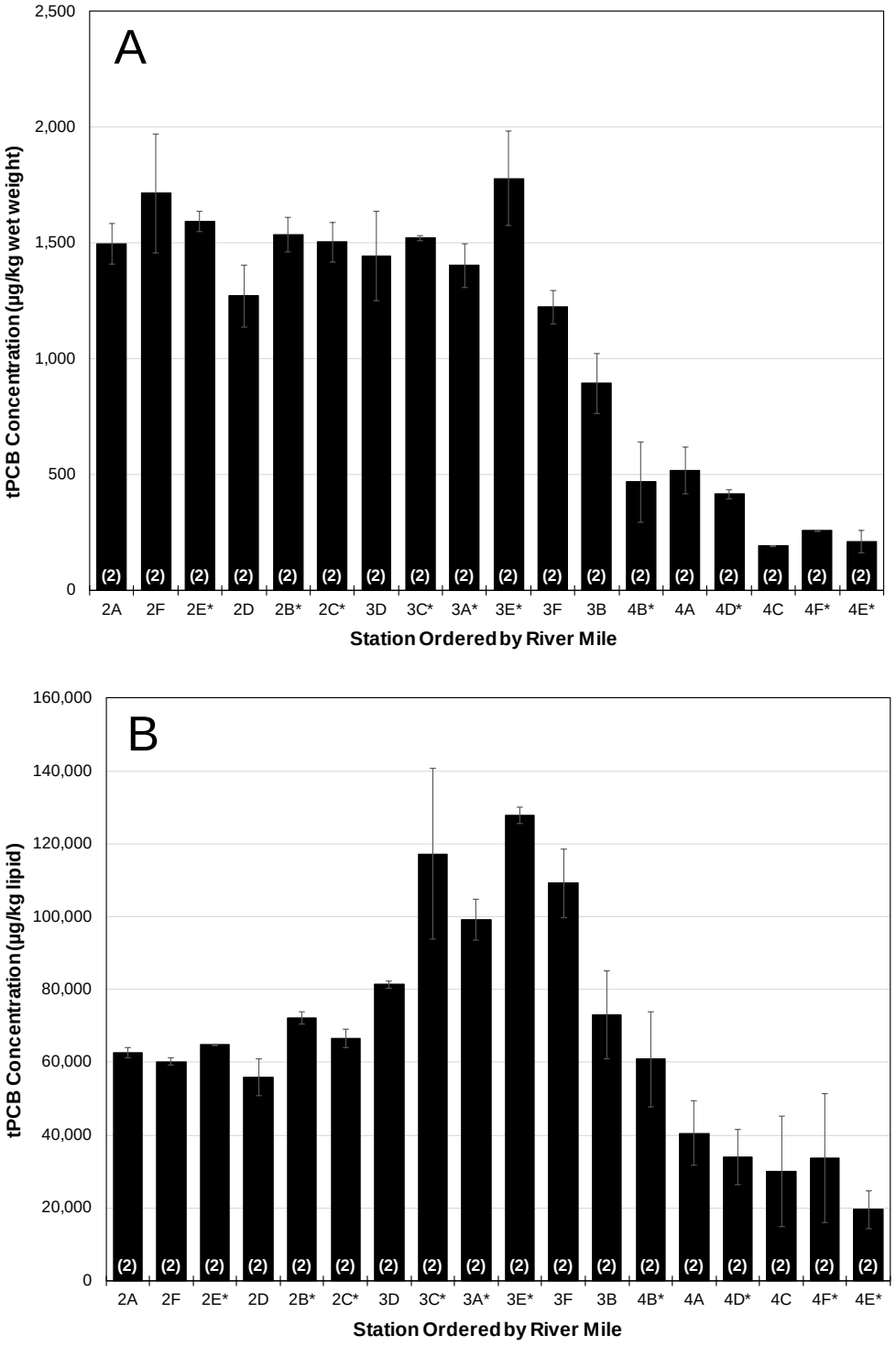
4.3.3.1 Contaminant Concentrations in Macroinvertebrates

Figures 4-13 through 4-15 summarize total PAHs, tPCBs, and PCB homologs for the BB macroinvertebrates harvested from each H-D sampler deployed at each station. The concentration data are shown in the top figures, and the concentration data normalized to lipid tissue concentrations are shown in the bottom figures. Duplicate samples were collected at each station. Appendix C contains the complete analytical data packages and QA/QC summaries for all tissue samples.



Note: The numbers of samples analyzed per station are shown within the data bar of the graph in parentheses

Figure 4-13. Total Priority Pollutant PAHs and Total Alkylated PAH Concentrations (A – Wet Weight and B – Lipid-Normalized) with Error Estimates (±1 SE) in Macroinvertebrates Samples from the Ottawa River (August 2012). Stations with an * are within the Remediation Footprint.



Note: The numbers of samples analyzed per station are shown within the data bar of the graph in parentheses

Figure 4-14. Mean tPCB Concentrations (A – Wet Weight and B – Lipid-Normalized) with Error Estimates (±1 SE) in Macroinvertebrates Samples from the Ottawa River (August 2012). Stations with an * are within the Remediation Footprint.

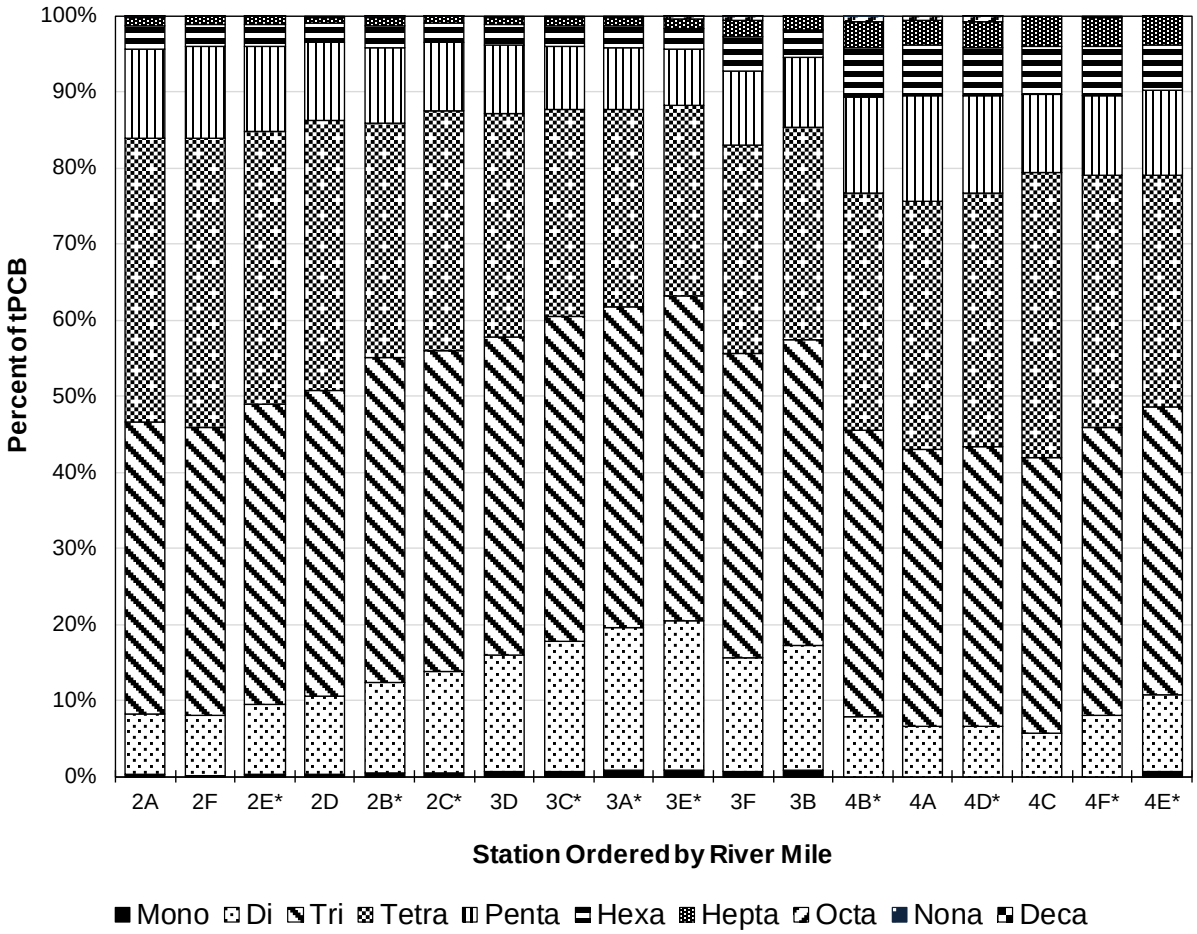
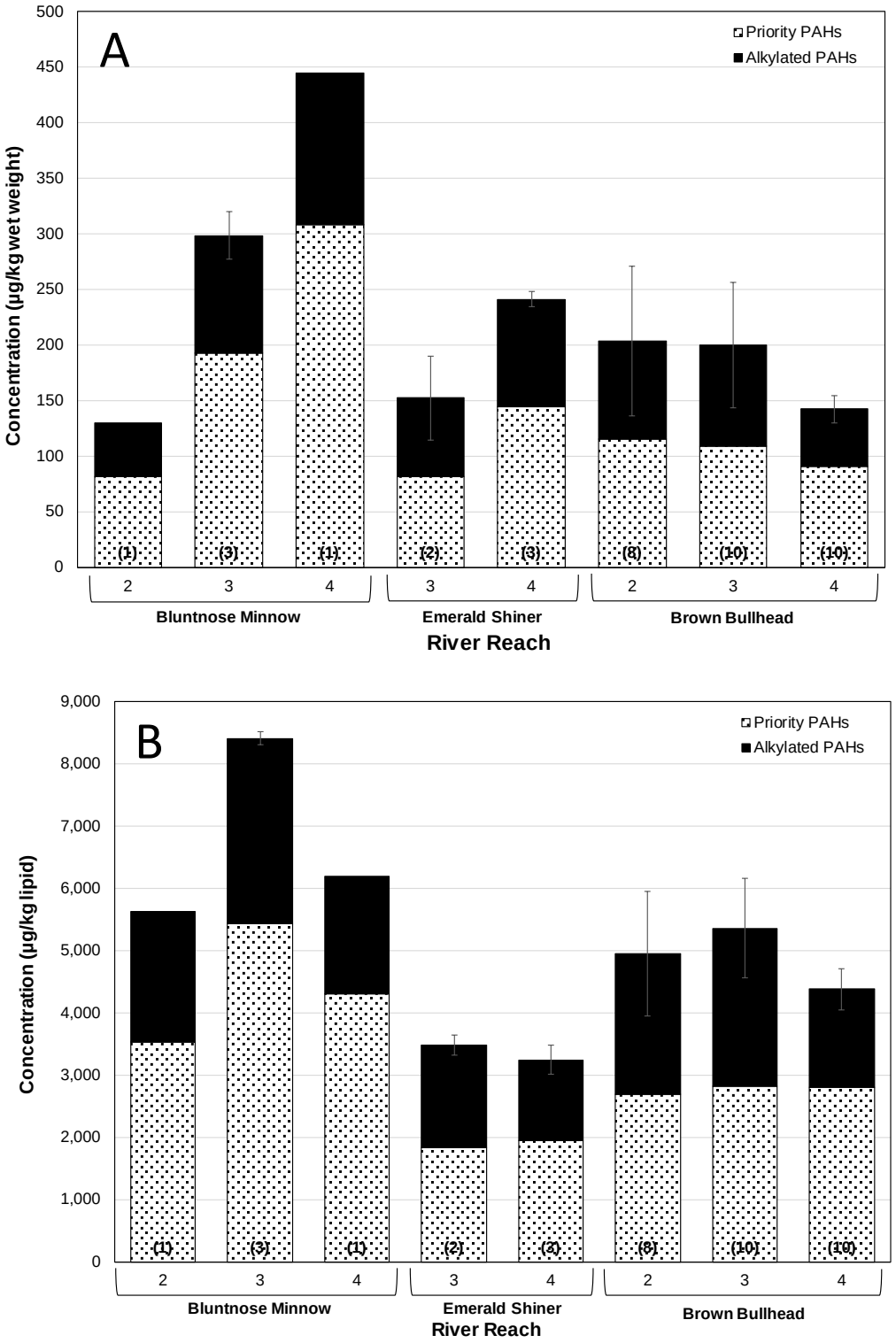


Figure 4-15. Contributions of PCB Homologs in Percent tPCB in Macroinvertebrates (August 2012). Stations with an * are within the Remediation Footprint.

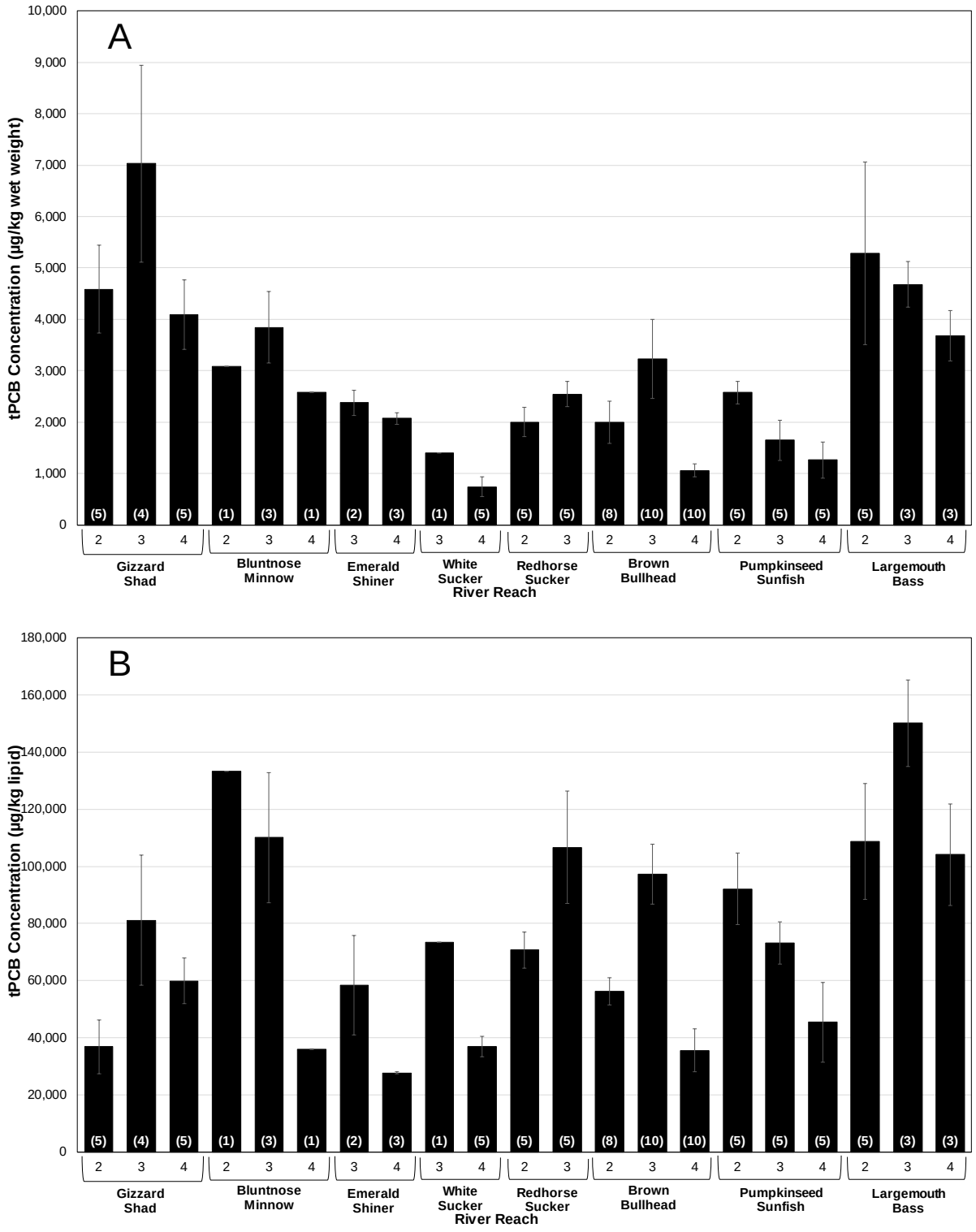
4.3.3.2 Contaminant Concentrations in Fish Tissue Samples

Figures 4-16 and 4-17 present the total PPAH, total alkylated PAH, and tPCB concentrations in fish collected in July and August 2012. The concentration data are shown in the top figures, and the concentration data normalized to lipid tissue concentrations are shown in the bottom figures. Figure 4-18 depicts the contribution of PCB homologs to the tPCB concentrations. Appendix C contains the complete analytical data packages and QA/QC summaries for all tissue samples.



Note: Number of fish analyzed within each reach is shown within the data bar of the graph.

Figure 4-16. Mean Total PAH Concentrations (A – Wet Weight and B – Lipid Normalized) with Error Estimates (±1 SE) in Fish Collected from Each of the Reaches of the Ottawa River.



Note: Number of fish analyzed within each reach is shown within the data bar of the graph

Figure 4-17. Mean tPCB Concentrations (A – Wet Weight and B – Lipid Normalized) with Error Estimates (±1 SE) in Fish Collected from the Ottawa River.

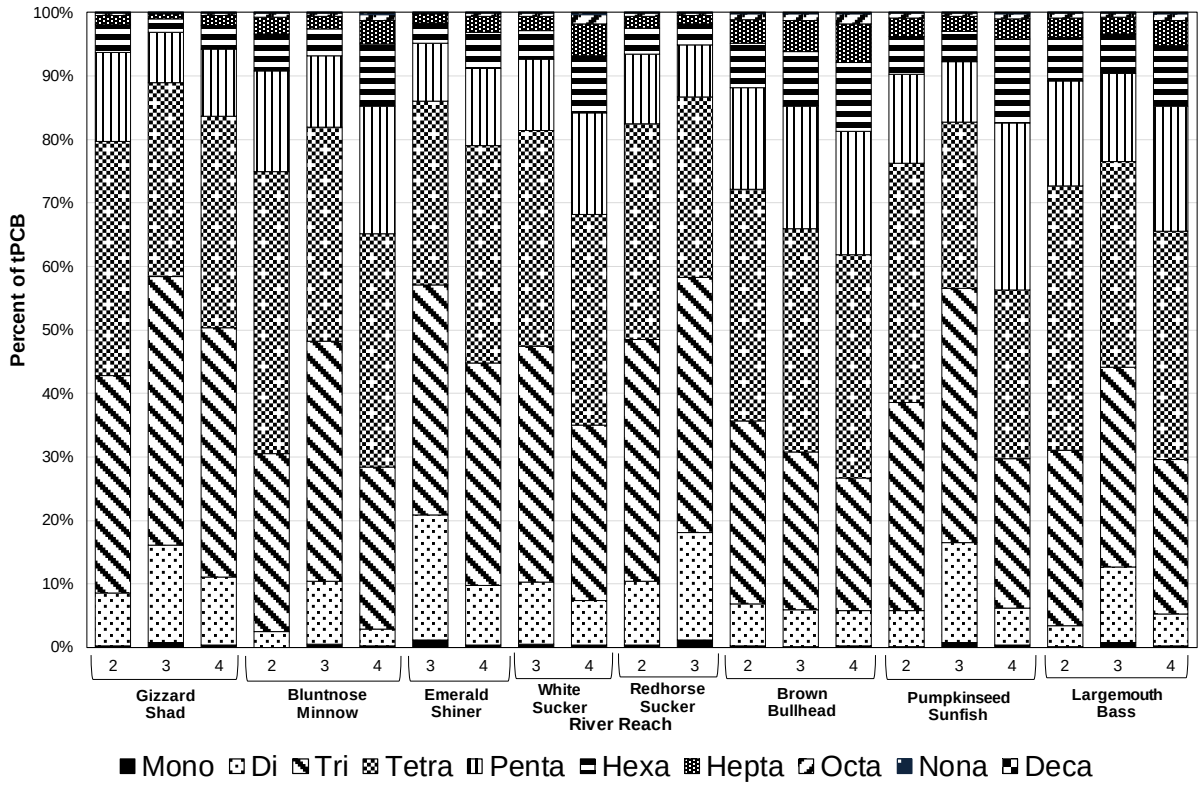
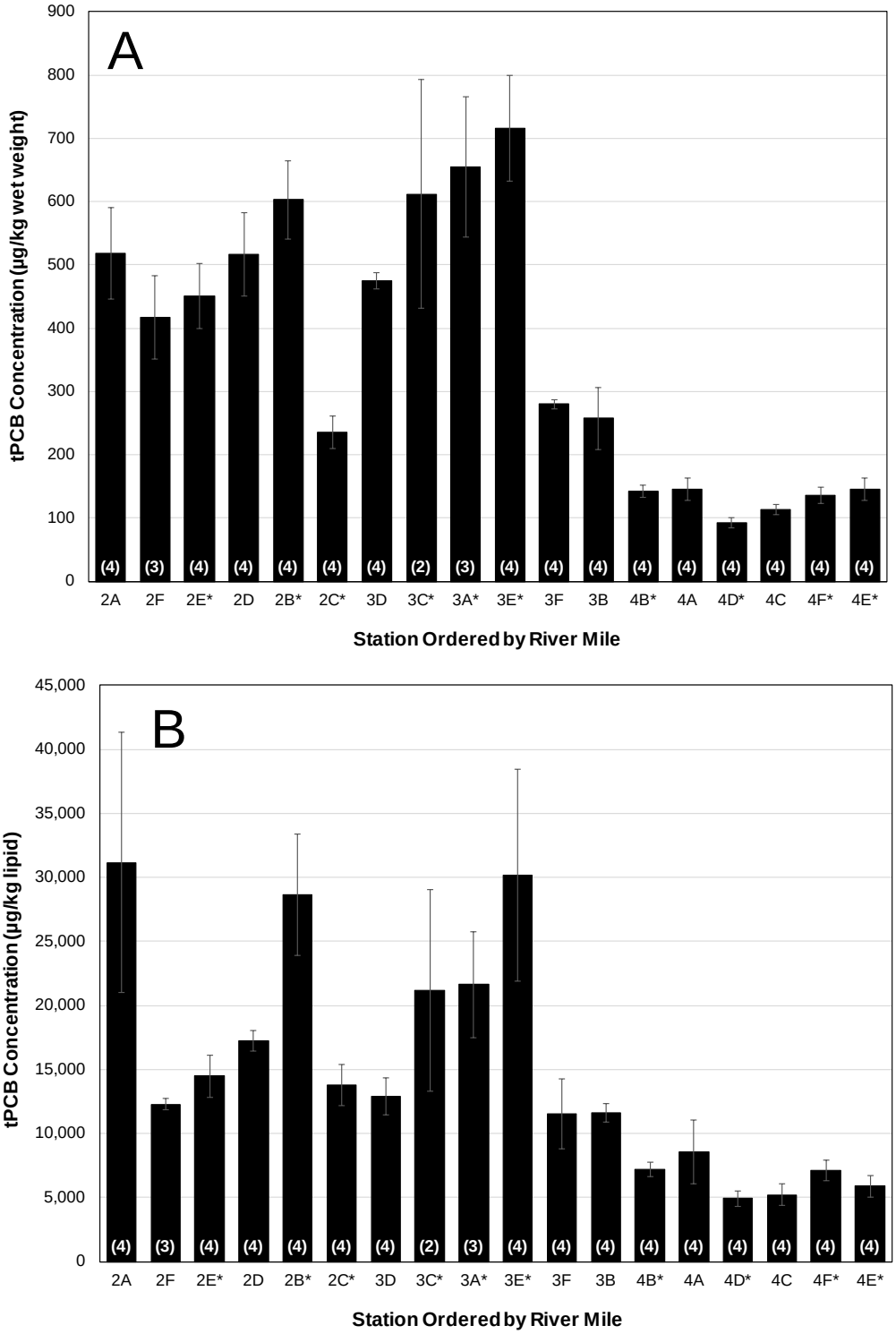


Figure 4-18. Contribution of PCB Homologs in Percent tPCB from Fish Collected from the Ottawa River.

4.3.3.3 Contaminant Concentrations in Tetragnathidae Spiders

Figures 4-19 and 4-20 summarize tPCB and tPCB by homolog concentrations in spiders of the family Tetragnathidae from 18 stations along the lower Ottawa River. The concentration data are shown in the top figures, and the concentration data normalized to lipid tissue concentrations are shown in the bottom figures.



Note: The numbers of samples analyzed per station are shown in the bars of the graph.

Figure 4-19. Mean (± 1 SE) tPCB Concentrations (A – Wet Weight and B – Lipid-Normalized) in Tetragnathid Spiders Collected along Three Reaches of the Lower Ottawa River (August/September 2012). Stations with an * are within the Remediation Footprint.

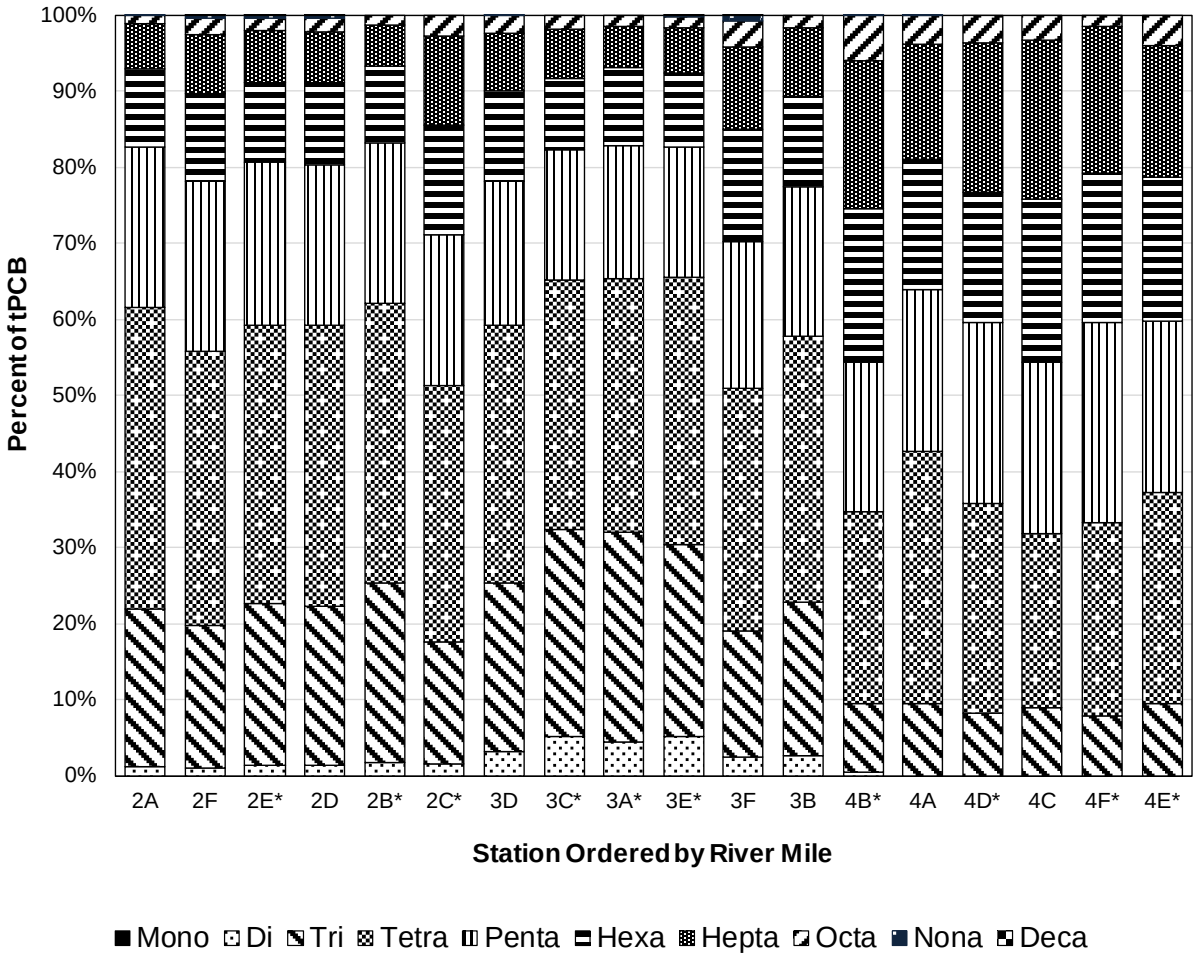


Figure 4-20. Contribution of PCB Homologs in Percent tPCB in Tetragnathid Spiders from the Ottawa River (August/September 2012). Stations with an * are within the Remediation Footprint.

The research project described in this report was focused on the development and evaluation of methods and metrics along physical, biological, and chemical LOEs to measure the effectiveness in remediating contaminated sediments within selected segments of the Ottawa River. This report detailed the first phase of long-term post-remedy monitoring conducted by ORD and its partners. Subsequent reports will detail the results of the remaining two phases of long-term post-remediation monitoring (Phases 4-2 and 4-3).

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