Water Quality Analyses for Zinc in the Middle Harbor and Curtis Bay/Creek Portions of Patapsco River Mesohaline Chesapeake Bay Tidal Segment in Baltimore City, Baltimore County, and Anne Arundel County, Maryland

FINAL

Department of the Environment
1800 Washington Boulevard, Suite 540
Baltimore, MD 21230-1718

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Watershed Protection Division
U.S. Environmental Protection Agency, Region III
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Philadelphia, PA 19103-2029

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AVS-SEM	Acid Volatile Sulfides – Simultaneously Extracted Metals
BDL	Below Detection Limit
BIBI	Benthic Index of Biotic Integrity
BOD	Biochemical Oxygen Demand
BSM	Baltimore Harbor Sediment Mapping Study
CBL	Chesapeake Biological Laboratory
CFR	Code of Federal Regulation
Cm	Centimeter
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
DC	Deep Channel
DO	Dissolved Oxygen
DW	Dry Weight
EPA	Environmental Protection Agency
ERL	Effects Range Low
ERM	Effects Range Median
MDE	Maryland Department of the Environment
NOAA	National Oceanic and Atmospheric Administration
PATMH	Patapsco River Mesohaline
PCB	Polychlorinated Biphenyl
PEL	Probable Effects Level
SERC	Smithsonian Environmental Research Center
SQG	Sediment Quality Guideline
TEL	Threshold Effects Level
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
UMCES	University of Maryland Center for Environmental Science
µg/g DW	Micrograms per gram Dry Weight
µg/L	Micrograms per Liter
µmole/g	Micromoles per gram
WREC	Wye Research and Education Center
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment
Zn	Zinc

EXECUTIVE SUMMARY

Section 303(d) of the federal Clean Water Act (CWA) and the EPA's implementing regulations direct each State to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS listed in the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report), the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a Water Quality Analysis (WQA) that water quality standards are being met (CFR 2020). This document presents a WQA of zinc (Zn) in the Middle Harbor and Curtis Bay/Creek (Maryland 8-Digit basin number: 02130903) portions of the Patapsco River Mesohaline (PATMH) Chesapeake Bay Tidal Segment (2018 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-PATMH-Middle Harbor and MD-PATMH-Curtis_Bay_Creek).

Maryland's Surface Water Use Designations in the Code of Maryland Regulations (COMAR) state that all surface waters of Maryland shall be protected for water contact recreation, fishing, and the protection of aquatic life and wildlife (COMAR 2020a). In addition, the specific designated use class of the Middle Harbor and Curtis Bay/Creek portions of the PATMH Chesapeake Bay Tidal Segment is Use Class II (*Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting*) (COMAR 2020b,c).

The Maryland Department of the Environment (MDE) has identified the entire PATMH Chesapeake Bay Tidal Segment (Integrated Report Assessment Unit ID: PATMH) on the State's 2018 Integrated Report as impaired by nutrients (nitrogen & phosphorus) (1996), total suspended solids (TSS) (1996), and impacts to biological communities (2004). The Curtis Bay/Creek portion of the PATMH Chesapeake Bay Tidal Segment has been identified as impaired by polychlorinated biphenyls (PCBs) (1998) and Zn in sediment (1998). The Middle Harbor portion of the PATMH Chesapeake Bay Tidal Segment has been identified as impaired by Zn in sediment (1998) (MDE 2018). A PCB TMDL for the Curtis Bay/Creek portion of the PATMH Chesapeake Bay Tidal Segment was approved by EPA on October 1, 2012. The Chesapeake Bay TMDL, which was established by the EPA on December 29, 2010, addressed the nutrient and TSS listings for the PATMH Chesapeake Bay Tidal Segment. The listing for impacts to biological communities in the PATMH Chesapeake Bay Tidal Segment will be addressed separately at a future date.

The 2018 Integrated Report specifies that the Zn impairment in sediment for the Middle Harbor and Curtis Bay/Creek portions of the PATMH Chesapeake Bay Tidal Segment does not support the protection of the aquatic life designated use of the waterbody. Zn in sediments is toxic to aquatic life causing lethal (i.e., mortality) and sub-lethal effects (e.g., impacts on reproduction and growth). Aquatic organisms can be exposed to Zn through multiple pathways (e.g., respiration, skin absorption, and eating).

The WQA presented herein by MDE will address the 1998 Zn impairment listings in sediment for Middle Harbor and Curtis Bay/Creek, for which a data solicitation was conducted, and all readily available data have been considered. From this point on in the Executive Summary of this report, the Middle Harbor and Curtis Bay/Creek portions of the PATMH Chesapeake Bay Tidal Segment will simply be referred to as Middle Harbor and Curtis Bay/Creek, respectively.

An analysis of recent sediment quality data from Middle Harbor and Curtis Bay/Creek used the sediment quality triad approach, incorporating an evaluation of sediment chemistry, sediment toxicity, and benthic community health data to demonstrate that aquatic life in sediments are not adversely impacted by Zn. The sediment quality evaluation established that Zn contamination within the sediments of the Middle Harbor and Curtis Bay/Creek is either not bioavailable to aquatic life or at levels that will not cause adverse impacts. In addition, an analysis of water quality data demonstrates that aquatic life in the overlying water column are not adversely impacted by Zn that may leach out of the sediment. These results indicate that while these portions of the PATMH Chesapeake Bay Tidal Segment are in poor health, they are not impaired by Zn.

As stated above, the analysis presented in this report supports the conclusion that a TMDL for Zn is not necessary to achieve water quality standards in Middle Harbor or Curtis Bay/Creek. Although the tidal waters of Middle Harbor and Curtis Bay/Creek do not display signs of a Zn impairment in sediment, the State reserves the right to require future controls if evidence suggests that Zn from the watershed is contributing to downstream water quality problems.

Barring the receipt of contradictory data, this report will be used to support a revision of the 2018 Integrated Report impairment listings for Zn in sediment for Middle Harbor and Curtis Bay/Creek from Category 5 (“waterbody is impaired, does not attain the water quality standard, and a TMDL is required”) to Category 2 (“waterbodies meeting some [in this case Zn related] water quality standards, but with insufficient data to assess all impairment”) when MDE proposes revision of the Integrated Report.

1.0 INTRODUCTION

Section 303(d) of the federal Clean Water Act (CWA) and the EPA's implementing regulations direct each State to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS listed in the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report), the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a Water Quality Analysis (WQA) that water quality standards are being met (CFR 2020). This document presents a WQA of zinc (Zn) in the Middle Harbor and Curtis Bay/Creek (Maryland 8-Digit basin number: 02130903) portions of the Patapsco River Mesohaline (PATMH) Chesapeake Bay Tidal Segment (2018 Integrated Report of Surface Water Quality in Maryland Assessment Unit ID: MD-PATMH-Middle_Harbor and MD-PATMH-Curtis_Bay_Creek).

A segment identified as a WQLS may not require the development and implementation of a TMDL if more recent information invalidates previous findings. The most common scenarios that would eliminate the need for a TMDL are:

1. An analysis of more recent data indicating that the impairment no longer exists (i.e., water quality standards are being met)
2. Results of a more recent and updated water quality model demonstrate that the segment is now attaining water quality standards
3. Refinements to water quality standards or to the interpretation of those standards accompanied by the analysis demonstrating that standards are being met
4. Identification and correction of errors made in the initial listing.

This document presents a WQA that eliminates the need for a TMDL for Zn in the Middle Harbor and Curtis Bay/Creek portions of the PATMH Chesapeake Bay Tidal Segment by incorporating the first and third scenarios described above.

Maryland's Surface Water Use Designations in the Code of Maryland Regulations (COMAR) state that all surface waters of Maryland shall be protected for water contact recreation, fishing, and the protection of aquatic life and wildlife (COMAR 2020a). The specific designated use class of the Middle Harbor and Curtis Bay/Creek portions of the PATMH Chesapeake Bay Tidal Segment is Use Class II (*Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting*) (COMAR 2020b,c).

The Maryland Department of the Environment (MDE) has identified the PATMH Chesapeake Bay Tidal Segment (Integrated Report Assessment Unit ID: PATMH) on the State's 2018 Integrated Report as impaired by nutrients (nitrogen & phosphorus) (1996), total suspended solids (TSS) (1996), and impacts to biological communities (2004). The Curtis Bay/Creek portion of the PATMH Chesapeake Bay Tidal Segment has been identified as impaired by polychlorinated biphenyls (PCBs) (1998) and Zn in sediment (1998). The Middle Harbor portion of the PATMH Chesapeake Bay Tidal Segment is identified as impaired by Zn in sediment (1998) (MDE 2018). A PCB TMDL for the Curtis Bay/Creek portion of the PATMH Chesapeake Bay Tidal Segment was approved by EPA on October 1, 2012. The Chesapeake Bay TMDL, which was approved by the EPA on December 29, 2010, addressed the nutrient and TSS listings for the PATMH Chesapeake Bay Tidal Segment. The listing for impacts to biological communities in the PATMH Chesapeake Bay Tidal Segment will be addressed separately at a future date.

The 2018 Integrated Report specifies that the Middle Harbor and Curtis Bay/Creek portions of the PATMH Tidal Chesapeake Bay Segment do not support the protection of the aquatic life designated use of the waterbody due to the Zn impairment in sediment. From this point on in this report, the Middle Harbor and Curtis Bay/Creek portions of the PATMH Tidal Chesapeake Bay Segment will simply be referred to as Middle Harbor and Curtis Bay/Creek, respectively.

The original 1998 Zn impairment listings in sediment for Middle Harbor and Curtis Bay/Creek were determined based on a comprehensive weight-of-evidence approach, referred to as the Sediment Quality Triad, using data from the Baltimore Harbor Sediment Mapping Study (BSM) conducted in 1996 (MDE 2019; UMCES CBL 1997). The sediment quality triad approach incorporates an evaluation of sediment chemistry, sediment toxicity, and benthic community health data to assess sediment quality. While the 1998 Benthic Index of Biological Integrity (BIBI) data, an indicator of benthic community health, demonstrated that the community was not degraded, the study showed high Zn concentrations and toxicity to aquatic life in the sediments. Based on these findings, MDE determined at the time that Zn was a biological impairing substance in the sediments of the Middle Harbor and Curtis Bay/Creek.

The WQA presented herein by MDE will address the 1998 impairment listings for Zn in sediment for Middle Harbor and Curtis Bay/Creek, for which a data solicitation was conducted, and all readily available data have been considered. The analysis was conducted using more recent:

1. Sediment chemistry data
2. Sediment toxicity data
3. Benthic community health data
4. Water column chemistry data

2.0 GENERAL SETTING

The PATMH Chesapeake Bay Tidal Segment, also known as the Baltimore Harbor, is an estuary located on the western shore of the Chesapeake Bay with a waterbody surface area of 23,137 acres (36.2 square miles). The Middle Harbor and Curtis Bay/Creek are subsegments of the PATMH Chesapeake Bay Tidal Segment. Curtis Bay/Creek has a waterbody surface area of 1,746 acres (2.7 square miles) and is located within both Baltimore City and Anne Arundel County, while Middle Harbor has a waterbody surface area of 7,437 acres (11.6 square miles) and is located within Baltimore City, Anne Arundel, and Baltimore Counties. The locations of the Middle Harbor, Curtis Bay/Creek, and PATMH Chesapeake Bay Tidal Segment are displayed in Figure 1.

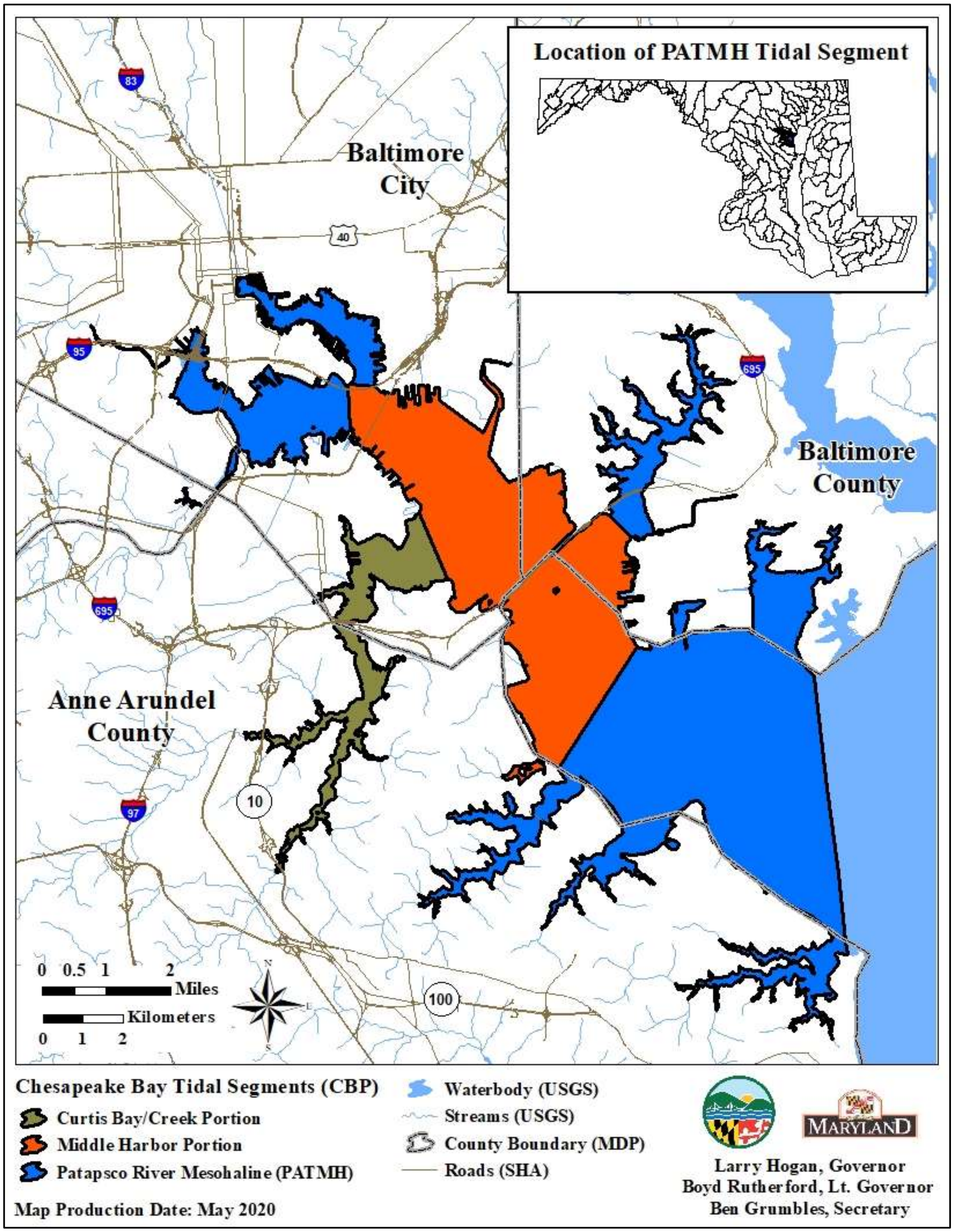

Figure 1: Map of the PATMH Tidal Segment (also known as Baltimore Harbor)

3.0 SEDIMENT & WATER QUALITY CHARACTERIZATION

A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include support of aquatic life, primary or secondary contact recreation, drinking water supply, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

Maryland's Surface Water Use Designations in the COMAR state that all surface waters of Maryland shall be protected for water contact recreation, fishing, and the protection of aquatic life and wildlife (COMAR 2020a). In addition, the specific designated use class of Middle Harbor and Curtis Bay/Creek is Use Class II (*Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting*) (COMAR 2020b,c).

Maryland's current water quality standards include numeric criteria for metals and other toxic substances in the water column, which establish threshold concentrations that are protective of aquatic life and human health. Maryland's current water quality standards, however, do not include numeric criteria for metals and other toxic substance concentrations in sediments.

The 2018 Integrated Report specifies that the designated use for protection of aquatic life is not supported in the Middle Harbor and Curtis Bay/Creek due to a Zn impairment in the sediments. Zn is toxic to aquatic life) in sediments (e.g., benthic organisms such as bivalves and amphipods) and aquatic life in the overlying water (e.g., bottom feeding organisms such as catfish and American eel) causing lethal (i.e., mortality) and sub-lethal effects (e.g., impacts on reproduction and growth). Aquatic organisms can be exposed to Zn through multiple pathways (e.g., respiration, skin absorption, and eating). In order to address these impairment listings, this WQA demonstrates through an assessment of sediment quality data that aquatic life in the sediments are not adversely impacted by Zn, thus indicating the designated use for protection of aquatic life in sediments is not impaired by Zn.

MDE uses a comprehensive weight-of-evidence approach, referred to as the sediment quality triad, to assess sediment quality and make sediment impairment determinations (MDE 2019). The WQA applies this approach to demonstrate that the benthic organisms are not impaired by Zn. The approach incorporates the evaluation of sediment chemistry, sediment toxicity, and benthic community health, which is presented in Sections 3.3.1, 3.3.2, and 3.3.3, respectively. The sediment quality triad uses all three sets of measurements to assess sediment quality.

Zn contamination within the sediment can also leach out into the overlying water column potentially impacting aquatic life outside the benthic zone. This WQA also demonstrates through an assessment of water quality data that aquatic life in the overlying water column is not adversely impacted by Zn. The sediment and water column evaluations indicate that the designated use for protection of aquatic life in the overlying water column is not impaired by Zn. The water chemistry evaluation is presented in Section 3.4.

3.1 WATER QUALITY CRITERIA

MDE's numeric water column Zn criteria are shown in Table 1 (COMAR 2020d). Maryland's water quality standards contain acute and chronic freshwater and saltwater aquatic life Zn criteria and a human health Zn criterion. The exposure periods for aquatic life being in contact with the water column are defined as one-hour for acute exposure and 96 hours (4 days) for a chronic exposure (US EPA 2002). For the purposes of this analysis the chronic criteria were applied in order to assess whether or not Zn concentrations in the overlying water column are impairing the Middle Harbor and Curtis Bay/Creek designated use, since they are the most conservative and thus protective of all conditions. Maryland's Surface Water Use Designations in COMAR indicate that Middle Harbor and Curtis Bay/Creek are saltwater waterbodies (COMAR 2020b). Therefore, the saltwater aquatic life chronic Zn criterion were applied within this analysis.

Table 1: Numeric Water Column Zn Criteria

Metal	Aquatic Life (µg/L)				Human Health (µg/L)
	Freshwater		Saltwater		Water + Organism
	Acute	Chronic	Acute	Chronic	
Zn	120	120	90	81	7,400

3.2 SEDIMENT & WATER QUALITY SAMPLING

Sediment and water column surveys were conducted at 23 monitoring stations, 14 within Middle Harbor and 9 within Curtis Bay/Creek (see Figure 2 and Tables 2 & 3). Four of the stations, two in Middle Harbor and two in Curtis Bay/Creek, are located in the deep channel to ensure water quality is fully characterized establishing a holistic view of the entire waterbody. Two surficial sediment and overlying water column samples were collected at each monitoring station in July and September 2014.

The bulk surficial (top 2 centimeters (cm)) sediment samples were collected by MDE's Intensive Studies Section in the Middle Harbor and Curtis Bay/Creek.

The University of Maryland Center for Environmental Science (UMCES) Chesapeake Biological Laboratory (CBL) analyzed:

- All sediment samples for total Zn concentrations (µg/g dry weight) in bulk sediment
- All water samples for dissolved and total Zn concentration (µg/L)

The Smithsonian Environmental Research Center (SERC) analyzed all sediment samples for AVS-SEM concentrations (µmole/g) in bulk sediment.

The University of Maryland Wye Research Center (WREC) conducted 10-day acute whole sediment toxicity tests on sediment samples collected at 10 stations, 6 in Middle Harbor and 4 in Curtis

Bay/Creek in July 2014. Additionally, sediment samples were also recollected at these same 10 stations in September 2016 and used in 28-day chronic whole sediment and porewater toxicity tests.

Sediment toxicity tests were only conducted at monitoring stations originally tested in support of the 1998 Zn impairment listings in sediment for Middle Harbor and Curtis Bay/Creek. Tables 2 & 3 identify the monitoring stations and what combination of samples were measured: water chemistry, sediment chemistry and sediment toxicity.

Table 2: Middle Harbor Monitoring Stations

Station ID	Latitude	Longitude	Sample Analysis		
			Water Chemistry	Sediment Chemistry	Sediment Toxicity
BH-23	39.1915	-76.5195	X	X	X
BH-24	39.2026	-76.5021	X	X	
BH-25	39.2069	-76.5270	X	X	
BH-27	39.2236	-76.5147	X	X	X
BH-36	39.2278	-76.5208	X	X	X
BH-37	39.2362	-76.5430	X	X	
BH-38	39.2564	-76.5361	X	X	X
BH-39	39.2497	-76.5515	X	X	
BH-41	39.2272	-76.5476	X	X	X
BH-43	39.2179	-76.5427	X	X	
BH-53	39.2449	-76.5668	X	X	
BH-54	39.2583	-76.5683	X	X	X
BH-DC3	39.2471	-76.5598	X	X	
BH-DC4	39.2082	-76.5157	X	X	

Table 3: Curtis Bay/Creek Monitoring Stations

Station ID	Latitude	Longitude	Sample Analysis		
			Water Chemistry	Sediment Chemistry	Sediment Toxicity
BH-44	39.1915	-76.5195	X	X	X
BH-45	39.2026	-76.5021	X	X	X
BH-47	39.2069	-76.5270	X	X	X
BH-49	39.2236	-76.5147	X	X	X
BH-50	39.2278	-76.5208	X	X	
BH-51	39.2362	-76.5430	X	X	
BH-52	39.2564	-76.5361	X	X	
BH-DC5	39.2497	-76.5515	X	X	
BH-DC6	39.2272	-76.5476	X	X	

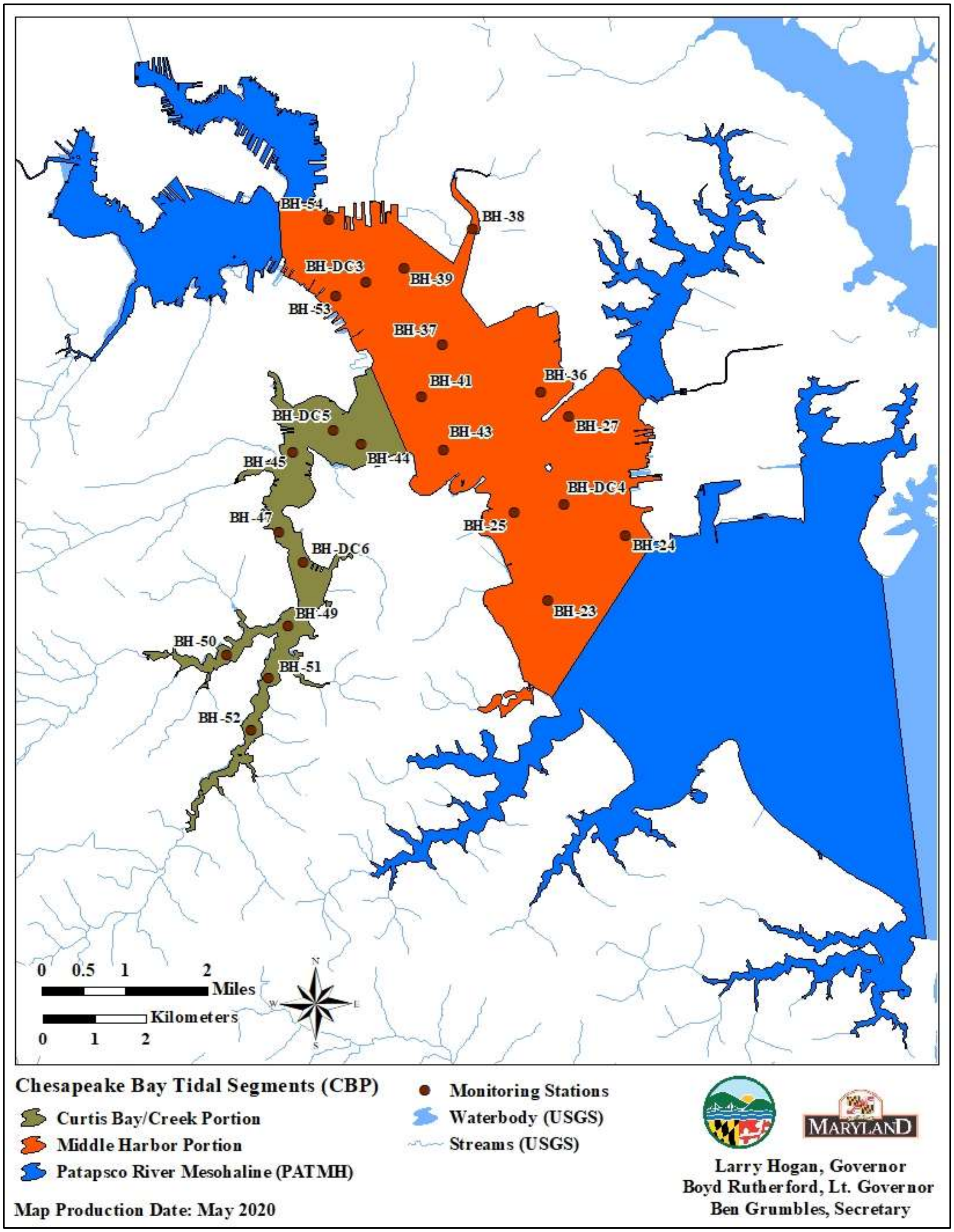

Figure 2: Middle Harbor and Curtis Bay/Creek Sampling Locations

3.3 SEDIMENT QUALITY TRIAD APPROACH

MDE applies the sediment quality triad approach in order to assess sediment quality and make sediment impairment determinations. This WQA applies this approach to demonstrate that aquatic life in the sediments is not impaired by Zn. The approach incorporates the evaluation of sediment chemistry, sediment toxicity, and benthic community health.

3.3.1 Sediment Chemistry Evaluation

The sediment chemistry evaluation component of the sediment quality triad includes an assessment of:

1. Zn concentrations in bulk sediment
2. AVS-SEM concentrations

Sediment Zn concentrations were compared to National Oceanic and Atmospheric Administration (NOAA) Sediment Quality Guidelines (SQGs), which include four benchmarks listed in order of increasing probability of toxicity: Threshold Effects Level (TEL), Effects Range – Low (ERL), Probable Effects Level (PEL), and Effects Range – Median (ERM) (Buchman 2008). Sediment concentrations below threshold effects levels (i.e. TEL, ERL) indicate a low probability of toxicity to aquatic life in sediment whereas sediment concentrations above probable effects levels (i.e. PEL, ERM) indicate a high probability of toxicity. The results of the analysis are presented in Tables 4 and 5.

Sediment Zn concentrations for four samples collected at only 2 out of the 14 stations in Middle Harbor, BH-27 and BH-36 did not exceed the TEL, the most stringent threshold of the SQGs. Concentrations below the TEL denoted by a single asterisk (*) in Table 4. All remaining sediment Zn concentrations exceed the PEL except for two samples at stations BH-54 and BH-DC3. Concentrations below the PEL are denoted by two asterisks (**) in Table 4. Figure 3 shows sediment Zn sample concentrations in relation to the SQGs for Middle Harbor.

Table 4: Middle Harbor Total Zn Sediment Data

Station	Total Zn (µg/g DW)	
	July 2014	Sept 2014
BH-23	852	1,497
BH-24	758	1,403
BH-25	476	1,026
BH-27	40*	67*
BH-36	20*	29*
BH-37	316	522
BH-38	651	1,209
BH-39	423	719
BH-41	632	1,786
BH-43	731	1,262
BH-53	271	643
BH-54	259**	685
BH-DC3	155**	868
BH-DC4	509	560
*Sample concentration below the TEL (94) **Sample concentration below the PEL (271)		

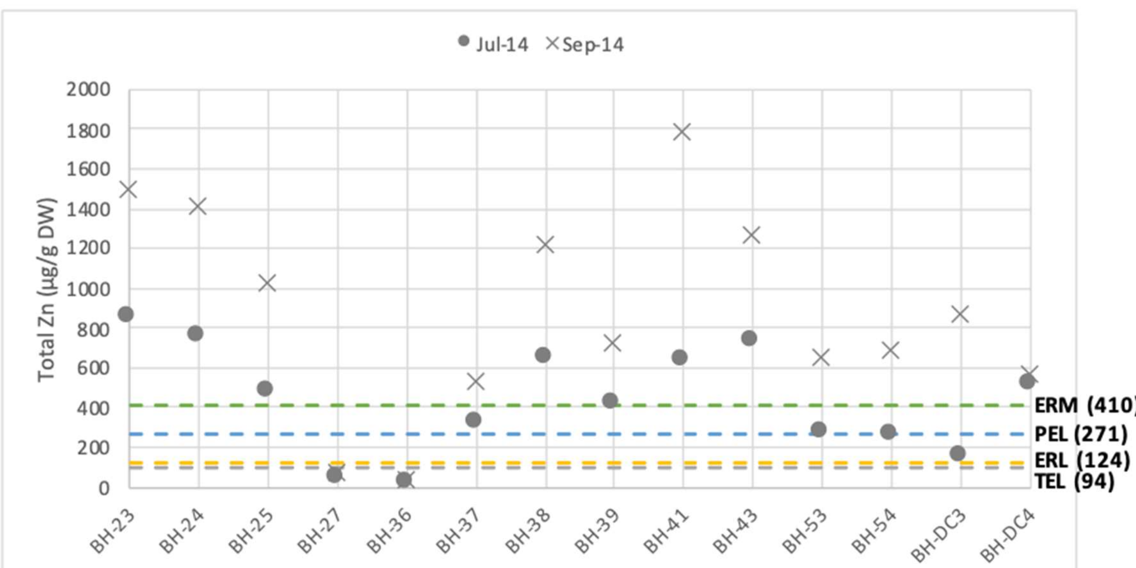

Figure 3: Middle Harbor Zn Sediment Data Quality Guideline Comparison

All sediment Zn concentrations for samples collected in Curtis Bay/Creek exceed the TEL. Only two samples collected at BH-47 have sediment Zn concentrations that do not exceed the PEL. Concentrations below the PEL are denoted by two asterisks (**) in Table 5. Figure 4 shows sediment Zn sample concentrations in relation to the SQGs for Curtis Bay/Creek.

Table 5: Curtis Bay/Creek Total Zn Sediment Data

Station	Total Zn (µg/g DW)	
	July 2014	Sept 2014
BH-44	639	1,070
BH-45	590	1,263
BH-47	175**	122 **
BH-49	519	980
BH-50	594	1,176
BH-51	531	1,314
BH-52	455	762
BH-DC5	357	535
BH-DC6	848	1,300
** Sample concentration below the PEL (271)		

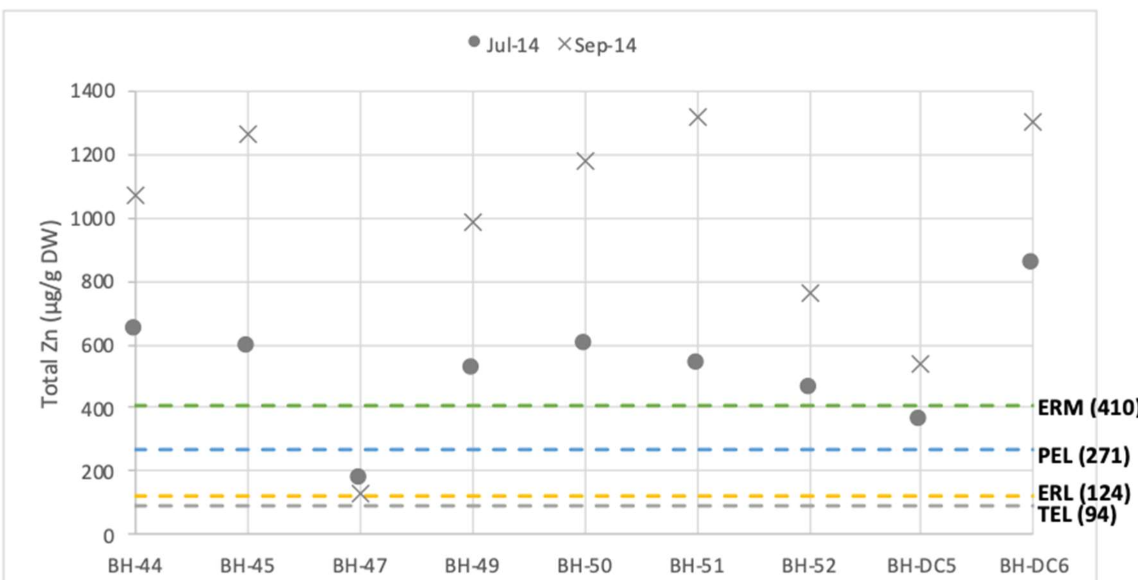

Figure 4: Curtis Bay/Creek Zn Sediment Data Quality Guidelines Comparison

While sediment Zn concentrations that exceed PELs indicate a high probability of toxicity, this does not take into consideration various environmental conditions (e.g., sulfides) that may mitigate the bioavailability of Zn resulting in no adverse impacts to aquatic life in sediments.
Sediments in the Middle Harbor and Curtis Bay/Creek are generally anoxic, having low levels of dissolved oxygen (DO), which results in the production and accumulation of sulfides in sediments due to anaerobic bacterial processes. Sulfides react with divalent metals including Zn to form complexes which precipitate out reducing bioavailability to aquatic life in the sediments. If sufficient concentrations of sulfides are present to bind all divalent metals, the bioavailability of these substances will be fully mitigated resulting in no adverse impact to aquatic life in sediments.

An AVS-SEM analysis was conducted in order to measure the sulfide and divalent metals concentrations in the sediment. The AVS-SEM data is presented in Tables 6 and 7. AVS-SEM concentrations are presented on a molar basis to determine the molecular balance of sulfides and divalent metals in the sediment. An AVS/SEM ratio of greater than one indicates that sulfide molar concentrations are sufficient to bind all divalent metals thus mitigating their bioavailability.

The Middle Harbor data presented below in Table 6 shows that samples taken at Stations BH-23, BH-27, and BH-36 have AVS/SEM ratios below 1 indicating the sediments did not contain enough sulfides to complex all divalent metals; however, the Zn sediment concentrations at BH-27 and BH-36 were well below the TEL, the most stringent threshold of the SQGs, presented in Table 4. AVS/SEM ratios below 1 are noted by a double asterisk (**). While Zn sediment concentrations for the two samples collected at Station BH-23 were above the TEL, one sample had an AVS/SEM ratio slightly below 1.

Table 6: Middle Harbor AVS/SEM Sediment Data*

Station	Date Sampled	AVS/SEM Zn	AVS/SEM Divalent Metals Cu, Cd, Zn, Pb	AVS	AVS/SEM Ratio	Total Zn below TEL
		(µmol/g)	(µmol/g)	(µmol/g)	(µmol/g)	(µg/g DW)
BH-23	7/24/14	6.47	8.47	23.76	2.81	
	9/23/14	10.88	14.30	11.71	0.82**	
BH-24	7/24/14	4.50	5.09	133.28	26.20	
	9/23/14	8.78	10.18	94.62	9.30	
BH-25	7/24/14	3.81	4.81	20.31	4.23	
	9/23/14	5.27	7.30	8.26	1.13	
BH-27	7/24/14	0.22	0.28	0.02	0.07**	X
	9/22/14	0.31	0.41	0.01	0.01**	X
BH-36	7/23/14	0.11	0.18	0.13	0.75**	X
	9/23/14	0.11	0.21	0.11	0.54**	X
BH-37	7/23/14	3.70	4.66	22.46	4.82	

Station	Date Sampled	AVS/SEM Zn	AVS/SEM Divalent Metals Cu, Cd, Zn, Pb	AVS	AVS/SEM Ratio	Total Zn below TEL
		(µmol/g)	(µmol/g)	(µmol/g)	(µmol/g)	(µg/g DW)
	9/23/14	4.59	5.54	160.74	29.03	
BH-38	7/22/14	6.96	8.14	133.63	16.43	
	9/23/14	9.05	11.00	146.20	13.29	
BH-39	7/22/14	4.09	4.69	58.58	12.49	
	9/23/14	4.92	5.79	96.59	16.68	
BH-41	7/23/14	5.43	6.97	515.62	73.92	
	9/23/14	8.12	9.58	185.59	19.38	
BH-43	7/28/14	5.18	6.21	463.52	74.65	
	9/22/14	6.55	8.59	18.00	2.10	
BH-53	7/22/14	2.70	3.81	35.09	9.21	
	9/23/14	4.96	5.50	142.15	25.85	
BH-54	7/22/14	2.15	2.98	127.93	42.92	
	9/23/14	2.61	3.73	61.11	16.37	
BH-DC3	7/22/14	0.59	0.68	2.32	3.42	
	9/23/14	5.31	6.69	82.58	12.35	
BH-DC4	7/24/14	3.71	4.54	163.57	36.06	
	9/23/14	3.54	4.45	77.07	17.31	

*The analysis is presented on a molar basis to account for the various molecular weights of the analytes.
**Sample AVS/SEM ratio below 1

The Curtis Bay/Creek data presented below in Table 7 shows that all the samples had AVS/SEM ratios above 1 indicating the sediments contain enough sulfides to complex all divalent metals. Based on the analysis of the sediment Zn and AVS/SEM concentrations for Middle Harbor and Curtis Bay/Creek, only one sample at Station BH-23 had a sediment Zn concentration above the TEL and an AVS/SEM ratio below 1. All remaining samples either have an AVS/SEM ratio above 1 or a sediment Zn concentration below the TEL demonstrating that Zn contamination within the sediment is either not bioavailable or at levels that would not cause adverse impacts to aquatic life in the sediments.

Table 7: Curtis Bay/Creek AVS/SEM Sediment Data*

Station	Date Sampled	AVS/SEM Zn	AVS/SEM Divalent Metals Cu, Cd, Zn, Pb	AVS	AVS/SEM Ratio
		(µmol/g)	(µmol/g)	(µmol/g)	(µmol/g)
BH-44	7/23/14	5.23	6.15	804.86	130.77
	9/24/14	5.98	7.17	167.87	23.41
BH-45	7/23/14	4.46	5.38	615.25	114.38
	9/24/14	7.74	9.20	155.63	16.91
BH-47	7/23/14	2.48	3.92	133.64	34.09
	9/24/14	0.66	0.95	1.54	1.63
BH-49	7/23/14	4.43	5.11	619.52	121.17
	9/24/14	8.07	9.27	238.15	25.68
BH-50	7/23/14	4.07	4.57	859.42	187.95
	9/24/14	5.77	6.42	141.73	22.06
BH-51	7/23/14	4.06	4.67	591.40	126.74
	9/24/14	5.81	6.62	91.93	13.88
BH-52	7/23/14	5.95	6.55	308.69	47.11
	9/24/14	3.91	4.37	131.64	30.13
BH-DC5	7/23/14	3.12	4.44	106.18	23.89
	9/24/14	3.51	4.52	203.85	45.10
BH-DC6	7/23/14	8.15	9.33	485.48	52.02
	9/24/14	6.55	7.75	433.10	55.90
*The analysis is presented on a molar basis to account for the various molecular weights of the analytes.					

Figure 5 shows the relationship between AVS/SEM ratios and sediment Zn concentrations, highlighting the potential Zn desorption and toxicity zone in which samples have an AVS/SEM ratio below 1 and sediment Zn concentrations greater than the ERL sediment quality guideline.

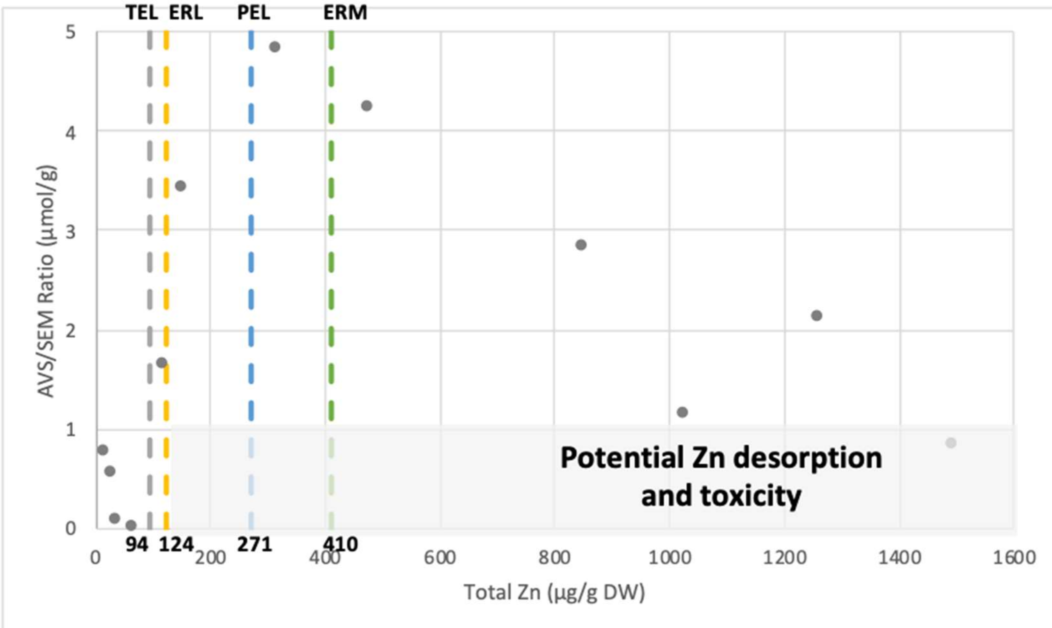

Figure 5: AVS/SEM Ratio vs Total Zn

3.3.2 Sediment Toxicity Evaluation

The sediment toxicity evaluation component of the sediment quality triad includes an assessment of:

1. 10-day acute whole sediment toxicity
2. 28-day chronic whole sediment toxicity
3. Porewater toxicity

Sediment toxicity tests assess whether or not toxic contaminants including metals in Middle Harbor and Curtis Bay/Creek sediments adversely impact aquatic life.

Three sediment toxicity tests were conducted by WREC using sediment samples collected from select stations within Middle Harbor and Curtis Bay/Creek. Only stations that were originally tested in 1996 that supported the 1998 Zn impairment listings were tested for toxicity. The tests include a 10-day acute whole sediment toxicity test, a 28-day chronic whole sediment toxicity test, and a 96-hour porewater toxicity test (WREC 2015, 2017). The marine amphipod *L. plumulosus* was selected as the test organism for each test. This species was chosen because of its ecological relevance to the waterbodies of concern. *L. plumulosus* is an EPA-recommended test species for assessing the toxicity of estuarine or marine sediments (US EPA 2001).

The 10-day acute sediment toxicity test sediment samples were collected in 2014 and the 28-day chronic sediment toxicity and 96-hr porewater toxicity test sediment samples were collected in 2016. Surficial (top 2 cm) sediment samples were collected using a petite ponar dredge sampling device. Control site sediment samples for the acute sediment toxicity tests were collected from the Wye River, in a depositional area with low levels of toxic contaminants/metals. Sediment from station BH-27 was used as a site control for the chronic sediment toxicity tests because sediment from this location has shown good survival and growth in past toxicity testing at WREC covering a period of approximately 25 years.

For each toxicity test, a certain number of test organisms were exposed to field sediments from the 6 stations sampled in Middle Harbor and 4 stations sampled in Curtis Bay/Creek and a control sediment for the designated time period (10-day, 28-day, 96-hr). Individual tests for each field and control sediment sample are referred to as treatments. For the 10-day acute sediment toxicity and 28-day chronic sediment toxicity tests, each field and control sample were replicated five times. For the 96-hour porewater toxicity test, each field and control sample were replicated three times. Each control and field treatment for the 10-day acute sediment toxicity, 28-day chronic sediment toxicity, and 96-hour porewater toxicity tests contained 20, 20, and 5 amphipod organisms, respectively.

Summary results for lethal/sub-lethal effects on test organisms (average survival, growth rate, and average reproduction) are presented for Middle Harbor and Curtis Bay/Creek for each of the three toxicity tests, when applicable, in Tables 8 and 9. Refer to Tables 2 and 3 for station locations. Detailed results from each sediment toxicity test are presented in Appendix A.

Table 8: Middle Harbor Sediment Toxicity Test Results Summary

Station	Sediment Toxicity Test (L. plumulosus Lethal/Sub-lethal Effects)				
	10-day Acute	28-day Chronic			96-hr Porewater
	Survival (%)	Survival (%)	Growth Rate (mg/day)	Reproduction (offspring/survivor)	Survival (%)
Control 1*	99	91	0.019	0.41	100
Control 2	96	-	-	-	-
BH-23[1]	94	72	0.021	0.45	100
BH-27[1]	99	91	0.019	0.41	100
BH-36[1]	100	81	0.020	0.85	100
BH-38[1]	96	84	0.024	2.30	0**
BH-41[1]	95	68	0.016	0.54	100
BH-54[2]	92	74	0.013	0.22	100
Average	96	78	0.019	0.80	83

Superscript corresponds to respective Control for 10-day acute sediment toxicity test
*Only one control for 28-day chronic sediment toxicity and 96-hr porewater toxicity tests
** Station observed to contain the highest total ammonia concentration at Day 0 and test end (see Table 10)

Table 9: Curtis Bay/Creek Sediment Toxicity Test Results Summary

Station	Sediment Toxicity Test (L. plumulosus Lethal/Sub-lethal Effects)				
	10-day Acute	28-day Chronic			96-hr Porewater
	Survival (%)	Survival (%)	Growth Rate (mg/day)	Reproduction (offspring/survivor)	Survival (%)
Control 1*	97	91	0.019	0.41	100
Control 2	99	-	-	-	-
BH-44[1]	95	85	0.026	1.77	100
BH-45[1]	97	82	0.021	0.57	100
BH-47[2]	95	89	0.030	1.86	100
BH-49[2]	98	72	0.021	1.50	100
Average	96	82	0.025	1.43	100
Superscript corresponds to respective Control for 10-day acute sediment toxicity test *Only one control for 28-day chronic sediment toxicity and 96-hr porewater toxicity tests					

Sediment toxicity test performance criteria require a survival rate of at least 80% in the control treatment for 28-day chronic toxicity tests and at least 90% in the control treatment for 10-day acute toxicity tests, as well as measurable growth and reproduction of neonates (amphipod offspring) in order to validate field treatment results. This performance criteria determines if test results are valid and is not an indication of whether field treatments are toxic, which is dependent on significant difference. The average survival of amphipods ranged between 92 and 100%, with an average of 96%, for the 10-day acute sediment toxicity test, 68 and 91%, with an average of 80%, for the 28-day chronic sediment toxicity test, and 100% survival for the 96-hour porewater toxicity test for all stations except BH-38. This station was observed to contain the highest total ammonia concentration at Day 0 and test end shown in the Table 10 below, which may have contributed to the observed porewater toxicity in conjunction with exposure to other contaminant(s).

Table 10: Ammonia Concentration at Day 0

Station	Ammonia (mg/L)
Control 1	0.38
Control 2	0.38
Control 3	0.63
BH-23[2]	0.21
BH-27[2]	0.20
BH-36[2]	0.19
BH-38[2]	6.40
BH-41[2]	0.23
BH-54[3]	1.24
BH-44[1]	0.36
BH-45[1]	0.48
BH-47[2]	0.26
BH-49[2]	0.50
Superscript corresponds to respective Control	

Amphipod survival percentages were assessed for normality and homogeneity of variance, which found that the average survival for field treatments in all three sediment toxicity tests were not statistically different from those of the control treatments.

For the 28-day chronic sediment toxicity test, the average growth rate (mg/day) of amphipods ranged between 0.013 and 0.030 mg/day and the average amphipod reproduction ranged between 0.22 and 2.30 neonates per amphipod. Average growth rate in control treatments was 0.019 mg/day and average reproduction was 0.41 neonates per amphipod. Amphipod growth rate and reproduction was also assessed for normality and homogeneity of variance, which found that the average growth rate and reproduction for field treatments in the bioassay were not statistically different from the control treatments. Based on these results, Middle Harbor and Curtis Bay/Creek sediments do not exhibit toxicity and toxic contaminants/metals in the sediments are not contributing to mortality or reductions in growth rate or reproduction of the test organisms.

3.3.3 Benthic Community Evaluation

The benthic community health evaluation component of the sediment quality triad includes an assessment of BIBI data. The Chesapeake Bay Long-Term Benthic Monitoring and Assessment Program collects BIBI data annually at two stations within the Middle Harbor and Curtis Bay/Creek (Llansó and Zaveta 2019). The data is presented in Table 11. The program measures water quality, sediment quality, and the abundance and richness of benthic invertebrates in calculating BIBI values for each station. Samples with BIBI values of 3.0 or more are considered to have good benthic condition indicative of good habitat quality. A comprehensive BIBI assessment was not conducted recently by MDE in the Middle Harbor or Curtis Bay/Creek as the original benthic evaluation for the 1998 Zn impairment listings demonstrated that the benthic community was not impaired at the time.

Table 11: Benthic Community Health Evaluation

Waterbody	Station	Avg	BIBI (2018)	BIBI (2017)	BIBI (2016)	BIBI (2015)	BIBI (2014)	BIBI (2013)	BIBI (2012)	BIBI (2011)	BIBI (2010)
Middle Harbor	23	2.4	3.9	1.1	3.5	2.9	1.9	1.3	1.3	3.4	2.6
Curtis Bay	202	1.4	1.9	1.3	1.4	2.3	1.0	1.0	1.1	1.3	1.0

While most BIBI scores from 2010-2018 in the Middle Harbor and Curtis Bay/Creek are indicative of poor biological health of the benthic community except for Middle Harbor in years 2016 and 2018, the BIBI values alone do not specify whether community degradation is due to toxic contaminants/metals and may be impacted by low DO, ammonia, or other underlying factors.

3.4 WATER CHEMISTRY EVALUATION

Zn contamination within the sediment can also leach out into the overlying water column potentially impacting aquatic life. The WQA demonstrates through an assessment of water chemistry data that aquatic life in the overlying water column is not impaired by Zn.

The dissolved water column Zn concentrations in Middle Harbor and Curtis Bay/Creek were compared to the saltwater aquatic life chronic Zn criterion to determine whether water quality standards are being met (i.e., whether or not Zn is impairing the aquatic life designated use of the segment). Based on MDE's Integrated Report Toxics Assessment Methodology, a waterbody is impaired if there is more than one exceedance of the chronic aquatic life criterion in a three-year period with a minimum of 10 samples (MDE 2019). Therefore, a waterbody is not impaired for Zn as long as there is no more than one sample exceedance of the applicable water quality criteria.

Water column samples were collected in July and September 2014 by MDE personnel and analyzed by CBL. The detection limit for the Zn water column analysis is 0.08 µg/L.
Dissolved water column Zn concentrations (µg/L) for Middle Harbor and Curtis Bay/Creek are displayed in Tables 12 and 13, respectively, and are compared to the applicable saltwater aquatic life chronic Zn criterion listed in Table 1 (81 µg/L). Greater than half of the dissolved water column Zn concentrations in Middle Harbor were Below Detection Limit (BDL) while the rest were 8.4 (µg/L) and under, which is an order of magnitude below the criterion. Dissolved water column Zn concentrations in Curtis Bay/Creek ranged between BDL and 13 (µg/L). Dissolved water column Zn concentrations in both Middle Harbor and Curtis Bay/Creek were less than the saltwater aquatic life chronic Zn criterion in all samples. Thus, none of the samples exceed the criterion and consequently, based on MDE's Integrated Report toxics assessment methodology, dissolved Zn concentrations in the water column are not impairing the aquatic life designated use of Middle Harbor or Curtis Bay/Creek.

Table 12: Middle Harbor Dissolved Zn Water Column Data

Station	Water Column (µg/L)	
	July 2014	Sept 2014
BH-23	BDL	3.5
BH-24	BDL	BDL
BH-25	BDL	BDL
BH-27	BDL	BDL
BH-36	BDL	BDL
BH-37	4.6	3.8
BH-38	4.6	BDL
BH-39	6.2	BDL
BH-41	8.4	6.0
BH-43	BDL	BDL
BH-53	6.7	BDL
BH-54	4.8	BDL
BH-DC3	5.6	3.9
BH-DC4	BDL	BDL

Table 13: Curtis Bay/Creek Dissolved Zn Water Column Data

Station	Water Column (µg/L)	
	July 2014	Sept 2014
BH-44	BDL	BDL
BH-45	13	5.1
BH-47	6.7	BDL
BH-49	3.4	BDL
BH-50	3.3	5.6
BH-51	4.8	4.3
BH-52	5.6	BDL
BH-DC5	4.0	BDL
BH-DC6	5.3	5.3

4.0 DISCUSSION

MDE identified the Middle Harbor and Curtis Bay/Creek in Maryland's 2018 Integrated Report as impaired for Zn in sediment in 1998. Maryland's Integrated Report specifies that the designated use for protection of aquatic life is not supported in Middle Harbor and Curtis Bay due to the Zn impairment in sediment. MDE applied the sediment quality triad approach in order to assess sediment quality and make sediment impairment determinations. The approach includes an evaluation of sediment chemistry, sediment toxicity, and benthic community health to assess sediment quality.

The sediment chemistry evaluation established that Zn contamination within the sediments of the Middle Harbor and Curtis Bay/Creek is either not bioavailable to aquatic life or at levels that will not cause adverse impacts. AVS/SEM analyses in Middle Harbor and Curtis Bay/Creek show sulfide levels that are well in excess of what is needed to sequester Zn into metallic sulfide compounds that render them unavailable to partition into the porewater in dissolved phase at quantities that would cause adverse impacts to aquatic life except for five sediment samples at three stations in Middle Harbor. In these sediment samples where sulfide levels are not in excess, Zn sediment concentrations fall below the most stringent SQGs except for a single sediment sample at Station BH-23. The other sample at Station BH-23 has sulfide levels in excess of metals. The remaining 27 sediment samples in Middle Harbor including the second sample at Station BH-23 either have Zn sediment concentration below the most stringent SQG or sulfides that are in excess of metals.

Zn contamination within the sediment can also leach out into the overlying water column potentially impacting aquatic life. The WQA demonstrated through an assessment of water chemistry data that aquatic life in the overlying water column is not adversely impacted by Zn. The water chemistry evaluation found that Zn concentrations in all overlying water samples were well below Zn water quality criterion. Therefore, Zn in the overlying water column of the Middle Harbor and Curtis Bay/Creek does not impact the designated use for protection of aquatic life in the overlying water column and is thus not an impairing substance.

Sediment toxicity tests were conducted for this analysis to assess whether or not toxic contaminant/metals concentrations in Middle Harbor and Curtis Bay/Creek sediments adversely impact aquatic life. Results of the acute sediment toxicity, chronic sediment toxicity, and porewater toxicity tests found that neither Middle Harbor nor Curtis Bay/Creek exhibited signs of toxicity, with the exception of Station BH-38 where porewater toxicity was present. This station was observed to contain the highest total ammonia concentration at Day 0 and test end, which may have contributed to the observed porewater toxicity in conjunction with other contaminant(s). Therefore, toxic contaminant/metal concentrations in the sediments are not contributing to a reduction in the survival, growth, or reproduction of test organisms.

The benthic community health evaluation established that BIBI data from the Chesapeake Bay Long-Term Benthic Monitoring and Assessment Program indicated poor benthic conditions in Middle Harbor and Curtis Bay/Creek; however, the BIBI values alone do not specify whether community degradation is due to toxic contaminants and may be impacted by low DO, ammonia, or other underlying factors.

Using all three sets of measurements to assess sediment contamination, the sediment quality triad decision matrix shown in Table 14 indicates that the results of this WQA support the conclusion that without evidence of toxicity or elevated chemical concentrations, it is most likely that the degraded biological community is not due to this chemical contaminant (MDE 2019).

Table 14: Sediment Quality Triad Decision Matrix

Toxicity	Chemistry	Community Alteration	Listing Decision
-	-	+	Do not list for toxics
"+" Indicates measured difference between test and control or reference conditions. "-" Indicates no measurable difference between test and control or reference conditions.			

5.0 CONCLUSION

The sediment chemistry evaluation indicated that Zn contamination within the sediments of Middle Harbor and Curtis Bay/Creek is not bioavailable or at levels that would not cause adverse impacts to aquatic life; and the sediment toxicity evaluation indicated that the sediments do not exhibit toxicity contributing to a reduction in the survival, growth, or reproduction of test organisms. In addition, the water chemistry evaluation showed dissolved Zn concentrations in the overlying water column above the sediments are also well below the Zn water quality criterion. However, the benthic community health evaluation indicated that the community is degraded in Middle Harbor and Curtis Bay/Creek.

Under the sediment quality triad approach as defined in MDE's Assessment Methodology for Toxic Contaminants, when a benthic community is degraded, but sediment toxicity is not exhibited and chemical contaminant concentrations in sediments are not at levels that cause adverse impacts to aquatic life, the biological degradation is not likely due to chemical contaminants. Therefore, based on this approach, Zn present in the sediments of Middle Harbor and Curtis Creek/Bay does not impact the designated use for protection of aquatic life in sediments and is thus not an impairing substance.

Barring the receipt of contradictory data, this report will be used as supporting material to revise the Zn in sediment impairment listings for Middle Harbor and Curtis Bay/Creek from Category 5 ("waterbody is impaired, does not attain the water quality standard, and a TMDL is required") to Category 2 ("waterbody is meeting some [in this case Zn related] water quality standards, but with insufficient data to assess all impairment") when MDE proposes the revision of Maryland's Integrated Report for public review. The waterbodies will remain listed for biological impairments and the Chesapeake Bay Long-Term Benthic Monitoring and Assessment Program will continue monitoring to determine if the community is improving due to Chesapeake Bay TMDL implementation. If improvement does not occur, toxic contamination will be reevaluated in the future. Although the tidal water of Middle Harbor and Curtis Bay/Creek do not display signs of a Zn impairment to aquatic life in the sediment or overlying water column, the State reserves the right to require future controls if evidence suggests that Zn from the watershed is contributing to downstream sediment and water quality problems.

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APPENDIX A

Table A1: Middle Harbor 10-day Acute Sediment Toxicity Data

Station	Treatment	Amphipod Survival (#)	Average Survival (%)
Control 1	A	20	99
	B	20	
	C	19	
	D	20	
	E	20	
Control 2	A	19	96
	B	19	
	C	19	
	D	20	
	E	19	
BH-23[1]	A	19	94
	B	19	
	C	18	
	D	18	
	E	20	
BH-27[1]	A	20	99
	B	19	
	C	20	
	D	20	
	E	20	
BH-36[1]	A	20	100
	B	20	
	C	20	
	D	20	
	E	20	
BH-38[1]	A	19	96
	B	20	
	C	18	
	D	20	
	E	19	
BH-41[1]	A	18	95
	B	19	
	C	19	
	D	19	
	E	20	
BH-54[2]	A	19	92
	B	16	
	C	20	
	D	19	
	E	18	
Superscript corresponds to respective Control			

Table A2: Curtis Bay/Creek 10-day Acute Sediment Toxicity Data

Station	Treatment	Amphipod Survival (#)	Average Survival (%)
Control 1	A	20	97
	B	20	
	C	20	
	D	20	
	E	17	
Control 2	A	20	99
	B	20	
	C	19	
	D	20	
	E	20	
BH-44[1]	A	19	95
	B	17	
	C	20	
	D	19	
	E	20	
BH-45[1]	A	20	97
	B	18	
	C	19	
	D	20	
	E	20	
BH-47[2]	A	19	95
	B	18	
	C	20	
	D	20	
	E	18	
BH-49[2]	A	20	98
	B	19	
	C	19	
	D	20	
	E	20	
Superscript corresponds to respective Control			

Table A3: Middle Harbor 28-day Chronic Sediment Toxicity Data

Station	Treatment	Survival (#)	Growth Rate (mg/d)	Neonates (#)	Average Survival (%)	Average Growth Rate (mg/d)	Average Reproduction (offspring/survivor)
Control	A	20	0.022	15	91	0.019	0.41
	B	20	0.026	16			
	C	20	0.014	8			
	D	20	0.019	2			
	E	17	0.016	0			
BH-23	A	11	0.022	7	72	0.021	0.45
	B	13	0.022	4			
	C	14	0.017	7			
	D	14	0.019	9			
	E	20	0.025	3			
BH-27	A	20	0.022	15	91	0.019	0.41
	B	20	0.026	16			
	C	20	0.014	8			
	D	20	0.019	2			
	E	17	0.016	0			
BH-36	A	16	0.017	10	81	0.020	0.85
	B	16	0.016	8			
	C	14	0.021	21			
	D	19	0.022	30			
	E	16	0.023	1			
BH-38	A	19	0.034	45	84	0.024	2.30
	B	12	0.029	60			
	C	20	0.018	27			
	D	16	0.022	30			
	E	17	0.019	15			
BH-41	A	12	0.022	15	68	0.016	0.54
	B	15	0.012	2			
	C	15	0.018	6			
	D	15	0.015	3			
	E	11	0.015	8			
BH-54	A	20	0.013	0	74	0.013	0.22
	B	9	0.009	0			
	C	16	0.021	8			
	D	5	0.013	3			
	E	14	0.010	0			

Table A4: Curtis Bay/Creek 28-day Chronic Sediment Toxicity Data

Station	Treatment	Survival (#)	Growth Rate (mg/d)	Neonates (#)	Average Survival (%)	Average Growth Rate (mg/d)	Average Reproduction (offspring/survivor)
Control	A	20	0.022	15	91	0.019	0.41
	B	20	0.026	16			
	C	20	0.014	8			
	D	20	0.019	2			
	E	17	0.016	0			
BH-44	A	20	0.035	49	85	0.026	1.77
	B	18	0.029	31			
	C	18	0.025	11			
	D	14	0.022	22			
	E	15	0.021	36			
BH-45	A	19	0.013	2	82	0.021	0.57
	B	14	0.019	2			
	C	16	0.017	3			
	D	13	0.031	12			
	E	20	0.023	30			
BH-47	A	20	0.026	29	89	0.030	1.86
	B	20	0.031	59			
	C	10	0.028	22			
	D	19	0.031	22			
	E	20	0.032	31			
BH-49	A	17	0.022	49	72	0.021	1.50
	B	7	0.018	0			
	C	20	0.031	45			
	D	13	0.016	24			
	E	15	0.017	8			