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Cleveland Harbor (Upper Cuyahoga River Channel) Dredged Material Evaluation—2013

EVALUATION OF CLEVELAND HARBOR FEDERAL NAVIGATION CHANNEL (UPPER CUYAHOGA RIVER) DREDGED MATERIAL WITH RESPECT TO SUITABILITY FOR OPEN-LAKE PLACEMENT

EXECUTIVE SUMMARY

Cleveland Harbor, Ohio sediments within the upper reach of the Cuyahoga River Channel were evaluated to determine their suitability for open-lake placement. In 2012, sediments from this reach of the harbor were sampled as management units DMMU-1, DMMU-2a and DMMU-2b, and subjected to a suite of tests. In addition, bottom sediments from two separate, two-square mile deep-water areas in Lake Erie (open-lake placement areas CLA-1 and CLA-4) being investigated for the placement of this dredged material were sampled and subjected to a similar suite of tests. Testing generally included bulk sediment physical and chemical analyses, cationic metal simultaneously extracted metals/acid volatile sulfide (SEM/AVS) analysis, elutriate testing, standard sediment and elutriate bioassays, and sediment bioaccumulation testing for polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), dichlorodiphenyldichloroethane (DDD) and dichlorodiphenyldichloroethylene (DDE). Data generated from this effort were used to evaluate whether this material meets Federal (U.S. Environmental Protection Agency [USEPA]/U.S. Army Corps of Engineers [USACE]) guidelines for open-lake placement, which includes compliance with applicable water quality standards (WQs) or criteria (WQC).

To determine whether this dredged material meets Federal guidelines for open-lake placement with respect to contaminant-related impacts, relevant contaminant pathways were examined to evaluate fate, exposure and risks. Primary contaminant exposure pathways in the water column include the uptake of contaminants by plankton and fish as they are released from the dredged material during discharge. Water column bioassays using a water flea (48-hour survival of *Ceriodaphnia dubia*) and minnow (96-hour survival of *Pimephales promelas*) were used as measurement endpoints to assess these risks. Contaminant exposure pathways from the dredged material on the lake bottom include uptake (bioaccumulation) and/or trophic transfer through bioaccumulation. Standard whole sediment bioassays using an amphipod (10-day survival of *Hyalella azteca*) and midge (10-day survival and growth of *Chironomus dilutus*), and bioaccumulation experiments using worm (28-day *Lumbriculus variegatus* bioaccumulation) were used as measurement endpoints to assess these risks. With respect to whole sediment, the bioassay data demonstrated that the dredged material would not be acutely toxic when placed on the lake bottom. Nickel, ammonia-nitrogen (Ammonia-N), toluene, PCBs and sum DDT (Σ DDT) were determined to be contaminants of concern (COCs) in the sediments. Nickel was identified



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as a COC due to one higher bulk concentration but was eliminated because its bioavailability was low as shown through SEM/AVS analysis. Ammonia is most appropriately addressed through the water column pathway. Toluene was identified as a COC due to bulk concentrations (maximum 14.5 mg/kg [DMMU-2a]) exceeding open-lake placement area concentrations. However, it was determined to not be toxic because the maximum total potential hydrocarbon toxicity (including contribution from toluene) of the sediments relative to *H. azteca* and *C. dilutus* were 0.5 toxic units (TU) and 0.2 TU (DMMU-2a), respectively. These values were less than 1.0 TU, indicating that the dredged material would not be a significant source of narcotic toxicity to benthic organisms. PCBs (tPCBs) and ΣDDT were determined to be COCs in sediments due to their potential to bioaccumulate in benthic invertebrates and organisms higher in the food web. The quantification of bioaccumulation of these COCs in *L. variegatus* was used to predict potential exposure to yellow perch (*Perca flavescens*) and walleye (*Sander vitreus*) as receptor species. While *L. variegatus* bioaccumulation of these COCs from most of the dredged material was found to be statistically higher (ΣPCB range 33.2±4.20 µg/kg-tissue to 55.6±4.30 µg/kg-tissue; ΣDDT range 3.41±0.38 µg/kg-tissue to 5.64±0.66 µg/kg-tissue) relative to sediments at one or both open-lake areas (ΣPCB range 12.9±1.22 µg/kg-tissue to 32.2±4.70 µg/kg-tissue; ΣDDT range 2.7±2.2 µg/kg-tissue to 5.4±0.5 µg/kg-tissue), the differences were determined to not be biologically significant because of the low level of exposure to yellow perch and walleye. In fact, the predicted increased exposure of receptor species via the bioaccumulation pathway to PCB and DDT residues in invertebrates associated with the dredged material was found to be within the generally accepted range of analytical variability alone.

With respect to the release of contaminants from the dredged material during discharge and associated toxicity in the water column, elutriate testing, water column bioassays and sediment pore water predictions identified ammonia-N (maximum measured elutriate concentration 16.8 mg/L [DMMU-2a]) and toluene (maximum predicted pore water concentration 2485 µg/L [DMMU-2a]) as COCs in the water column. However, ammonia is transient and not environmentally persistent, and rapidly dilutes in water and would not be toxic to fish or water column organisms at the concentrations observed. Further, toluene is not bioaccumulative, readily partitions to water and air, and volatilizes such that much would be liberated during the dredging process, and it would not be toxic to fish and other water column organisms at the concentrations observed. Finally, evaluation of total phosphorus (TP) releases during placement of the dredged material indicated no potential to contribute toward nuisance algae proliferation, including harmful algal blooms (HABs). Elutriate data and modeling indicated that discharge of the dredged material at the two open-lake areas would comply with relevant WQSS/WQC for the protection



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of aquatic life after consideration of mixing and dilution.

Subject to specific conservative limitations, this evaluation indicates that the discharge of material dredged from DMMU-1, DMMU-2a and DMMU-2b at open-lake areas CLA-1 and CLA-4 would not culminate in contaminant-related, unacceptable adverse impacts to the aquatic ecosystem. Therefore, it is concluded that this dredged material meets Federal guidelines for open-lake placement. Open-lake placement controls include: (1) use of mechanical equipment to dredge and discharge the dredged material; (2) spatially limiting the placement of material dredged from DMMU-2a and DMMU-2b to a one-square mile area within CLA-4 and CLA-1; and (3) spatially limiting the placement of material dredged from DMMU-1 to a one-square mile area within CLA-1 and two-third square mile area within CLA-4.

Sediment data from 2007, 2010 and 2012 sampling events were examined in an attempt to decipher trends in the quality of DMMU-1, DMMU-2a and DMMU-2b sediments over the last five years. This assessment indicated a net decline or no ecologically meaningful increase in sediment contaminant-based concentrations and/or toxicity over time.



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1.0 INTRODUCTION AND BACKGROUND

Cleveland Harbor, Ohio is located on south shore of Lake Erie at the mouth and lower reach of the Cuyahoga River at Cleveland, Ohio. Federal navigation channels in the harbor are deep-draft and designed to accommodate commercial navigation, and include a River Channel, Turning Basin, Old River Channel and Outer Harbor channels. These channels have authorized depths ranging from -23 to -29 feet low water datum (LWD)¹. Cleveland Harbor is situated within the designated Cuyahoga River Great Lakes Area of Concern (AOC) (U.S. Environmental Protection Agency [USEPA] 2013a). The AOC includes the lower 45 miles of the river from the Ohio Edison Dam to the mouth, and approximately 10 miles of Lake Erie shoreline from Edgewater Park to Wildwood Park on the west and east sides of Cleveland, respectively.

Cleveland Harbor requires maintenance dredging on an annual basis to facilitate commercial, deep-draft navigation. About 80 percent of the harbor's annual dredging needs are typically in the upper reach of the River Channel between the upstream limit (Station 799+00) and downstream upper Turning Basin (Station 736+00). The quantity of material annually dredged from this reach is on the order of 200,000 cubic yards, the vast majority of which has been placed in Federal and non-Federal confined disposal facilities (CDFs) since about 1968. Cleveland Harbor is typically dredged in two phases; in the Spring between May and June, and Fall in between October and November. The vast majority of material is dredged during the Spring phase.

The objective of this report is to evaluate and determine whether material dredged from Cleveland Harbor's Federal navigation channels in the upper Cuyahoga River Channel (between Station 799+00 and Station 736+00) meets Federal guidelines for open-lake placement. This evaluation is in accordance with the protocols and guidelines prescribed in the Great Lakes Dredged Material Testing and Evaluation Manual (USEPA/U.S. Army Corps of Engineers [USACE] 1998a) and Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S.—Testing Manual (USEPA/USACE 1998b), and is specific to 40 CFR 230.11(d) ("contaminant determination") (USEPA 2013b). Further, it is consistent with 33 CFR 336 toward establishment of the Federal standard relating to the least costly dredged material management alternative, consistent with sound engineering practices and selected through

¹ Low Water Datum for Lake Erie is elevation 569.2 feet above mean water level at Rimouski, Quebec, Canada (International Great Lakes Datum [IGLD] 1985).



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Section 404(b)(1) Guidelines (USACE 2013a).

2.0 SEDIMENT SAMPLING AND TESTING

This evaluation emphasizes 2012 analyses performed on sediment samples collected from Cleveland Harbor Federal navigation channels and two deep water open-lake areas in Lake Erie (USACE 2013b). It also considers relevant sediment data from 2007 (USACE 2007) and 2010 (Kreitinger *et al.* 2011).

2.1 2012 Investigation

2.1.1 Objective

The overall objective of the 2012 sediment sampling and analysis effort was to determine whether material dredged from Cleveland Harbor Federal navigation channels meets Federal guidelines (which includes compliance with applicable State water quality standards [WQSS]) for open-lake placement.

2.1.2 Sediment sampling

This investigation entailed the collection of bulk surface sediment grab samples from the Federal navigation channels, which were represented by discrete sites CH-1 through CH-37 (Figures 1, 2 and 3). In addition, surface sediment grab discrete samples were collected from two proposed, two square mile deep-water open-lake placement areas in Lake Erie; open-lake area CLA-1 (discrete sites CLA1-1 through CLA1-4) and open-lake area CLA-4 (discrete sites CLA4-1 through CLA4-4) (Figure 4). Discrete sediment samples were also composited into a dredged material management unit (DMMU)/composite, or open-water placement area samples as follows (see Figures 1 through 4): Federal navigation channel management units – composite DMMU-1 (discrete sites CH-1 through CH-5), composite DMMU-2a (discrete sites CH-6 through CH-10), composite DMMU-2b (discrete sites CH-11 through CH-15), composite MRR (discrete sites CH-16 through CH-20) and composite LRR (discrete sites CH-21 through CH-26) in the Cuyahoga River Channel; composite ORR (discrete sites CH-27 through CH-29) for the Old River Channel; and composite OHR (discrete sites CH-30 through 37) for the Outer Harbor channels; proposed open-water placement areas—composite CLA-1 (discrete sites CLA1-1 through CLA1-4) and composite CLA-4 (discrete sites CLA4-1 through CLA4-4). Finally, a single composite sample of sandy material



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was collected from the dredged material contained in confined disposal facility (CDF) 10B in the Cleveland Outer Harbor (CDF comp).

2.1.3 Sediment analyses

The sediment samples were analyzed as follows:

a. Bulk sediment analyses

(1) *Discrete samples*—Discrete sediment samples from the harbor and lake were analyzed for bulk grain size (sieve and hydrometer) and percent moisture, target analyte list (TAL) metals (aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, potassium, selenium, silver, sodium, thallium, vanadium and zinc), total cyanide (CN), ammonia-nitrogen (ammonia-N or NH_3), total phosphorus (TP), total Kjeldahl nitrogen (TKN), total organic carbon (TOC), polychlorinated biphenyls (PCBs) (as Aroclors), pesticides and polycyclic aromatic hydrocarbons (PAHs) (16 USEPA priority pollutants and methylnaphthalenes). In addition, discrete samples representing only DMMU-1, DMMU-2a, DMMU-2b, CLA-1 and CLA-4 were analyzed for percent organic matter, simultaneously extracted metals/acid volatile sulfide (SEM/AVS), benzene-toluene-ethylbenzene-xylenes (BTEX), solid-phase microextraction (SPME) fiber burdens and total extractable hydrocarbons.

The primary purpose of this bulk sediment testing was to identify any preliminary contaminants of concern (PCOCs) or contaminants of concern (COCs) in the dredged material and, should any toxicity be observed via biological testing, provide information concerning the potential cause of that toxicity at the benthic level.

(2) *Composite samples*—Composite sediment samples from the harbor (DMMU-1, DMMU-2a and DMMU-2b only) and lake (CLA-1 and CLA-4) were also analyzed for bulk grain size (sieve and hydrometer) and percent moisture, TAL metals, CN, NH_3 , TP, TKN, TOC, PCBs (as Aroclors and congeners [PCBs 1, 3, 5, 6, 7, 8, 9, 12/13, 14, 15/16, 17, 18, 19, 20, 22, 24, 25, 26, 27, 28/31, 29, 32, 33, 34, 35, 37, 40, 41, 42, 44, 45, 46, 47, 48, 49, 51, 52, 53, 54, 56, 59, 60, 63, 64, 66, 67, 69, 70, 71, 73, 74, 75, 77, 81, 82, 83, 84, 85, 87, 90/101, 91, 92, 93, 95, 97, 99, 100, 103, 104, 105, 107, 110/115, 114, 117, 118, 119, 122, 123, 124, 128, 129, 130, 131, 132, 134, 135, 136, 137, 138/163, 141, 144, 146,



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147, 149, 151, 153, 154, 156, 157, 158, 164, 165, 167, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 183, 185, 187, 189, 190, 191, 193, 194, 195, 196, 197, 199, 200, 201, 202, 203, 205, 206, 207 and 208]), pesticides and PAHs (16 USEPA priority pollutants and methylnaphthalenes). The composite samples were analyzed for percent organic matter, SEM/AVS, SPME fiber burdens and total extractible hydrocarbons. In addition, sediment pore water was analyzed for 34 PAHs (USEPA 2003), a list including many of the most common parent PAH compounds and many alkylated PAH compounds frequently found in PAH mixtures.

b. Biological testing

(1) *10-day Hyalella azteca and Chironomus dilutus toxicity tests*

(bioassays) (solid phase)—10-day solid phase bioassays employing the test species *H. azteca* (amphipod) and *C. dilutus* (midge fly) were applied to harbor composite samples DMMU-1, DMMU-2a and DMMU-2b, and lake composite samples CLA-1 and CLA-4. The biological measurement endpoints for these tests were survival, and survival and growth, respectively. The primary purpose of these bioassays was to assess the potential toxicity of the dredged material to benthic organisms relative to lake bottom sediments.

(2) *28-day Lumbriculus variegatus bioaccumulation (from sediment)*

—28-day *L. variegatus* bioaccumulation tests for PCBs (analysis of the primary PCB congeners PCBs 1, 3, 5, 6, 7, 8, 9, 12/13, 14, 15/16, 17, 18, 19, 20, 22, 24, 25, 26, 27, 28/31, 29, 32, 33, 34, 35, 37, 40, 41, 42, 44, 45, 46, 47, 48, 49, 51, 52, 53, 54, 56, 59, 60, 63, 64, 66, 67, 69, 70, 71, 73, 74, 75, 77, 81/87, 82, 83, 84, 85, 90/101, 91, 92, 93, 95, 97, 99, 100, 103, 104, 105, 107, 110, 114, 115, 117, 118, 119, 122, 123, 124, 128, 129, 130, 131, 132, 134, 135, 136, 137, 138, 141, 144, 146, 147, 149, 151, 153, 154, 156, 157, 158, 163/164, 165, 167/185, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180/193, 183, 187, 189, 190, 191, 194, 195, 196, 197, 199, 200, 201, 202, 203, 205, 206, 207 and 208) were applied to harbor composite samples DMMU-1, DMMU-2a and DMMU-2b and lake composite samples CLA-1 and CLA-4. *L. variegatus* tissues from these experiments were also analyzed for residues of the pesticides dichlorodiphenyltrichloroethane (DDT), dichlorodiphenyldichloroethylene (DDE) and dichlorodiphenyldichloroethane (DDD). Lipid content in *L. variegatus* tissue was determined. The primary purpose of these experiments was to assess the PCB and ΣDDT bioaccumulation risks of placing material



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dredged from these management units in the open-lake.

(3) 48-hour *Ceriodaphnia dubia* and 96-hour *Pimephales promelas* bioassays (water column)—48-hour *C. dubia* (water flea) and 96-hour *P. promelas* (fathead minnow) bioassays were performed on 100% elutriate from harbor composite sample DMMU-1, DMMU-2a and DMMU-2b. Survival was the biological measurement endpoint for both tests. If required, toxicity reduction evaluations (TRE) were performed for these water column bioassays (USEPA 1991). The primary purpose of these bioassays was to assess the toxicity of contaminants potentially released to the water column during dredged material placement in the lake/bay environs.

c. Elutriate testing

(1) Standard elutriate test (SET)—SET on harbor (DMMU-1, DMMU-2a and DMMU-2b) and lake (CLA-1 and CLA-4) composite samples were run for TAL metals, CN, NH₃, TP, TKN, TOC, water hardness, total suspended solids (TSS) and turbidity. In addition, SET elutriates from harbor composite samples DMMU-1, DMMU-2a and DMMU-2b were analyzed for PCBs (as Aroclors), pesticides and PAHs (16 USEPA priority pollutants and methyl-naphthalenes).

(2) Modified elutriate test (MET)—MET on harbor composite samples DMMU-1, DMMU-2a, DMMU-2b, MRR, LRR, ORR and OHR were run for TAL metals, CN, NH₃, TP, TKN, TOC, water hardness, total suspended solids (TSS) and turbidity (Note: water hardness was not run on MRR, LRR, ORR and OHR composite samples). In addition, MET elutriates from harbor composite samples DMMU-1, DMMU-2a, DMMU-2b, MRR, LRR, ORR and OHR were analyzed for PCBs (as Aroclors), pesticides and PAHs (16 USEPA priority pollutants and methyl-naphthalenes).

A lake water sample was analyzed for TAL metals, CN, NH₃, TP, ortho-phosphate, TKN, TOC, TSS, water hardness, turbidity, PCBs (as Aroclors), pesticides and PAHs (16 USEPA priority pollutants and methyl-naphthalenes).

The primary purpose of the SET and MET was to quantify the potential release of contaminants from the dredged material during placement and ascertain compliance with applicable water quality standards (WQSs).



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3.0 DREDGED MATERIAL EVALUATION

This evaluation focuses on material dredged from the upper Cuyahoga River Channel as represented by DMMU-1, DMMU-2a and DMMU-2b, and its placement at open-lake areas CLA-1 and CLA-4 in Lake Erie.

3.1 Site conceptual model

The site conceptual model for this activity focuses on potential contaminant-related adverse impacts to the aquatic ecosystem that would occur as a result of the discharge of the dredged material at the two deep-water open-lake areas designated as CLA-1 and CLA-4. Both areas are two square miles in area and are in water depths of between 50 and 60 feet. Aquatic habitats at these open-lake placement areas are similar and consist primarily of warmwater, mud-bottom (mainly silt/clay), benthic substrate with overlying water column. Open-lake area CLA-1 has been impacted as it was previously used for the placement of material dredged from Cleveland Harbor over 40 years ago. Bottom sediments at these areas are colonized by a community of benthic invertebrates that are relatively low in species diversity and dominated by oligochaetes and chironomids. The water column at these areas is used by most fish, nekton and plankton on a transient basis as required for foraging and migration. Aquatic birds use the water surface and water column on a transient basis for resting and foraging. Examples of key biological receptors at these open-lake areas include pelagic and/or demersal fish species such as walleye, yellow perch and rainbow smelt.

Under this dredged material management alternative, material from Cleveland Harbor would typically be mechanically dredged from the channel using a clamshell bucket, then placed in a scow for transport and discharged at a designated open-lake placement area. The dredged material is composed of sands, silts, clays and water with residual bulk concentrations of contaminants and organic matter. During discharge, dredged material is released from the scow and descends through the water column until it hits the bottom substrate, then collapses and spreads out before coming to rest on the lake bottom. Contaminant-related impacts can occur in both the water column and benthic environs, and are assessed mainly through toxicity and bioaccumulation endpoints relative to biological receptors. Typical exposure pathways between the dredged material and receptors would include uptake through absorption (bioconcentration) and absorption/ingestion (bioaccumulation), and trophic transfer through



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bioaccumulation. With respect to contaminant-related impacts in the water column, effects require exposure to biota and include the release of dissolved contaminants from the dredged material and turbidity, both of which are short-term events. These effects are evaluated via comparison of sediment elutriate data with water quality standards after considering the effects of mixing, and by elutriate bioassays using a minnow and water flea as representative test species, and modeling. With respect to contaminant-related benthic impacts associated with the placed dredged material, effects require exposure to biota and include toxicity and bioaccumulation. These effects are evaluated through bulk sediment chemistry, solid phase bioassays using an amphipod and midge as representative test species, bioaccumulation experiments using an aquatic worm, and modeling. Regarding dredged material movement on the lake bottom, the placed sediment would behave in a manner similar to the adjacent and surrounding lake bottom sediments; deeper depths of the open-lake placement areas would serve to allay the potential for sediment erosion, resuspension and movement. However, some of the dredged material could migrate from the areas under severe storm conditions.

3.2 2012 Investigation

The initial step toward evaluating the toxicological effects of placing the dredged material in the open-lake is to compare bulk contaminant concentrations in the management unit samples to those from the open-lake placement areas. If any management unit contaminant concentration significantly exceeded open-water placement area sediment concentrations such that they would present a potential toxicological risk, it was identified as preliminary contaminant of concern (PCOC) or COC, and then subjected to further testing and/or evaluation.

3.2.1 Bulk sediment analyses

a. Physical testing

Table 1 presents the results of these analyses. The particle size data across the DMMU-1, DMMU-2a and DMMU-2b sediment samples show that the sediments are comprised of between about 4% (Site CH-2) to 96.9% (Site CH-13) silts and clays, with the remainder sands and gravels (average 63.7% sand/gravels; DMMU-1 composite 77% sands/gravels). Sediments within DMMU-1 and the immediately downstream Site CH-6 were more coarse-grain in nature, ranging from 37.3% (Site CH-5) to 95.5% (Site



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CH-6) sands and gravels. Bottom sediments across the two open-lake placement areas were consistently fine-grain in nature, and composed of 87.8% (CLA1-comp) to 97.9% silts and clays (Site CLA1-2), with the remainder sands and gravels. Note that most of the sand present in the management units sediments was fine and was not much different in size than silt particles.

b. Chemical testing

(1) Inorganic analyses

(a) Metals—Table 2 presents the results of these analyses. The bulk concentration of most metals in sediment samples from DMMU-1, DMMU-2a and DMMU-2b were comparable or lower than those at one or both open-lake placement areas. With respect to open-lake placement areas CLA-1 and CLA-4, copper (76.7 mg/kg at Site CH-2) and nickel (139 mg/kg at Site CH-2) were the only notable exceptions. The copper concentration was not of significant toxicological concern. The concentration of nickel was about twice that of both open-lake placement area sediment concentrations and could potentially be of toxicological concern. Therefore, nickel was identified as a sediment COC at Site CH-2.

•**SEM/AVS**—AVS is regarded as a key sediment partitioning phase that binds cationic metals (cadmium, copper, lead, nickel, silver and zinc) to form insoluble sulfide complexes, thereby reducing their presence in sediment interstitial water and bioavailability (Di Toro *et al.* 1992).

SEM/AVS data on the DMMU-1, DMMU-2s and DMMU-2b sediment samples are summarized in Table 3. Methodology from USEPA (2005) was applied to determine whether an excess of SEM relative to AVS (on a molar basis) existed in these samples. Based on that methodology, the Σ SEM/AVS model holds that when the molar concentrations of metals exceeds that of AVS (i.e., the Σ SEM-AVS difference is greater than 0 μ mol), the solid phase concentrations of metals may not be protective of benthic organisms.

Across the discrete samples in the management units, Σ SEM-AVS values ranged from being less than 0 (almost all) (excess AVS 20.5 μ mol/g; Site CH-9) to 1.6 μ mol/g (Site CH-2). For the discrete open-lake placement area samples, Σ SEM-AVS values ranged from less than 0 (most) (excess AVS 7.16 μ mol/g; Site CLA1-4) to 0.58 μ mol/g (Site CLA4-2).



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Site CH-2 was the only management unit sample that showed an excess of SEM, and zinc ($3.55 \mu\text{mol/g}$) was the major contributor among the six metals (remaining $\Sigma\text{SEM}=0.37 \mu\text{mol/g}$). The sediment concentrations of nickel of $6.78 \mu\text{g/g}$ and $0.12 \mu\text{mol/g}$ were within the range of the other sites (range $4.5 \mu\text{g/g}$ and $0.08 \mu\text{mol/g}$ [Site CH-15] to $11.5 \mu\text{g/g}$ and $0.20 \mu\text{mol/g}$ [Site CH-1]), and about half of that measured in the sediment composite ($9.95 \mu\text{g/g}$ and $0.17 \mu\text{mol/g}$) which showed no significant toxicity (see paragraph 3.2.2). Based on this information, nickel at Site CH-2 was concluded to be insufficiently bioavailable to exert significant toxicity and was therefore eliminated as a sediment COC.

Further evaluation of the excess SEM and bioavailable zinc at Site CH-2 was necessary to decipher whether it had the potential to exert significant benthic toxicity at the open-lake placement areas. This is explained as follows:

◇ $\Sigma\text{SEM}/\text{AVS}$ model and zinc toxicity—This model predicts that no toxicity in sediment will occur if $\Sigma\text{SEM}/\text{AVS} \leq 1.0$, although it is not intended to predict whether a sediment is toxic if $\Sigma\text{SEM}/\text{AVS} > 1.0$. While the AVS/SEM ratio of 1.68 at Site CH-2 exceeds 1.0, experiments using zinc-spiked freshwater field sediments found that $\Sigma\text{SEM}/\text{AVS}$ ratios less than 2.0 will not be toxic (Burton *et al.* 2005). This suggests that zinc at Site CH-2 is not sufficiently bioavailable to induce significant toxicity to benthic organisms.

◇ $\Sigma\text{SEM}-\text{AVS}$ model normalized to organic carbon (OC)—Normalizing $\Sigma\text{SEM}-\text{AVS}$ to OC content reduces variability associated with the prediction of sediment toxicity. The excess SEM through OC normalization yielded an $\Sigma\text{SEM}-\text{AVS}/f_{oc}$ of $726 \mu\text{mol/g}_{oc}$. This value falls within the OC-normalized excess SEM range of $130 \mu\text{mol/g}_{oc}$ to $3000 \mu\text{mol/g}_{oc}$ in which toxicity to benthic organisms is considered uncertain (toxicity associated with values below $130 \mu\text{mol/g}_{oc}$ is not likely) (USEPA 2005). However, the TOC concentration of 0.22% at Site CH-2 site was determined to be an outlier and estimated to be 1% (see paragraph 3.1.1[b][1][b]). Use of this corrected TOC content in this model then yields $160 \mu\text{mol}$ excess SEM/ g_{oc} . This value falls within the extreme lower (almost 1%) $130 \mu\text{mol/g}_{oc}$ to $3000 \mu\text{mol/g}_{oc}$ range, suggesting low or insignificant toxicity. Further, this excess SEM also approaches $147.5 \mu\text{mol/g}_{oc}$ below which sediments were found to not be chronically toxic, although sediments with an excess of between 148 and $154 \mu\text{mol/g}_{oc}$ were shown to be variably toxic to benthic macroinvertebrates (Burton *et al.* 2005).



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◇Spatial considerations—Site CH-2 shows isolated excess SEM. It was the only site within DMMU-1, DMMU-2a and DMMU-2b to yield excess SEM under the 2012 sampling event, and is flanked by Sites CH-1 and CH-3 with surplus AVS ($\Sigma\text{SEM-AVS} = -3.88 \mu\text{mol/g}$ and $-3.89 \mu\text{mol/g}$, respectively). Further, no excess SEM was observed across this same harbor reach under the 2010 sampling event (i.e., $\Sigma\text{SEM-AVS}$ range $-0.66 \mu\text{mol/g}$ to $-0.42 \mu\text{mol/g}$) (Kreitinger *et al.* 2011). In reality, Sites CH-1, CH-2 and CH-3 are much more representative of a scow load of dredged material (e.g., 1500 cubic yards) than a single site. The surplus $6.17 \mu\text{mol/g}$ AVS across these sites exceeded the averages (but not composites) of sediments at both open-lake areas (CLA-1 average $3.58 \mu\text{mol/g}$, composite $10.2 \mu\text{mol/g}$; CLA-4 average $2.24 \mu\text{mol/g}$, composite $24.5 \mu\text{mol/g}$). Allowing for this spatial factor and when conservatively setting $\Sigma\text{SEM-AVS}$ at Sites CH-1 and CH-3 to 0, an average $\Sigma\text{SEM-AVS}/f_{oc}$ of $55 \mu\text{mol/g}_{oc}$ is yielded, which, while greater than the calculated excess SEM for the two discrete open-lake area placement sites, is well below the $130 \mu\text{mol/g}_{oc}$ (USEPA 2005) and $148 \mu\text{mol/g}_{oc}$ (Burton *et al.* 2005) values, indicating that chronic (and acute) toxicity is unlikely. Moreover, the considerable spatial difference between the CH-1 to CH-3 dredging reach (estimated 3.5 acres) and just one eighth of the open-lake placement areas (160 acres) assumed to offer excess SEM make this difference inconsequential.

Based on this information, zinc was not identified as a PCOC at Site CH-2.

(b) Other inorganics—Table 4 presents the results of these analyses.

●TOC—TOC content in the sediment samples from DMMU-1, DMMU-2a and DMMU-2b ranged from 0.22% (Site CH-2) to 2.4% (Site CH-12). The abnormally low TOC content at Site CH-2 was concluded to be an outlier because the POM to percent TOC ratio of 13.2 was clearly different than the ratios for the remaining sites analyzed (range 1.6 to 4.2) (Figure 5). Without the Site CH-2 value, POM to percent TOC ratios for all of the other sites were not statistically different (analysis of variance [ANOVA] least significant difference [LSD] test; $\alpha=0.05$). Use of the average ratio of 2.9 without the TOC outlier yielded an estimated TOC content of 1% at Site CH-2. TOC content in the open-lake placement area sediment samples was very consistent and ranged from 1.9% (Site CLA4-4) to 2.6% (Site CLA1-1).



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●*TP*—Concentrations of TP in the sediment samples from DMMU-1, DMMU-2a and DMMU-2b ranged from 400 µg/kg (Site CH-2) to 824 µg/kg (Site CH-11). In the open-lake placement area sediments, TP concentrations ranged from 683 µg/kg (Site CLA4-2) to 925 µg/kg (Site CLA1-1). TP concentrations in both harbor and open-lake placement area sediments were on the high end. However, none of the TP concentrations in the management unit sediments exceeded the maximum concentrations in the open-lake placement area sediments.

It should be noted that when evaluating TP in dredged material proposed for open-water placement, comparisons of bulk sediment concentrations to those at open-lake reference areas are relatively unimportant. The most important and relevant measurement endpoint for TP in the sediment is how much soluble reactive phosphorus (SRP) would be released to the water column during placement. SRP is the form of P that is most bioavailable to algae, including nuisance algae and cyanobacterium species such as *Microcystis aeruginosa* (planktonic algae) and *Lyngbya wollei* (filamentous, benthic, mat-forming algae) that are known to be involved in Lake Erie harmful algal blooms (HABs). SRP is usually not analyzed for, but within a given sample, it is a fraction of dissolved TP measured in a SET. A conservative assumption is 100% of the dissolved TP is SRP. Note that there is no functional relationship between TP in sediment and what is predicted to be released in the dissolved form to the water column during open-lake placement. However, typically, dissolved TP is less than 1% (usually orders of magnitude less than 1%) of the measured bulk TP. See paragraph 3.2.5 (a)(1)(b) for an evaluation of the TP SET data with respect to water quality and potential to influence HABs.

●*Ammonia*—Ammonia levels in the sediment samples from DMMU-1, DMMU-2a and DMMU-2b ranged from 25 µg/kg (Site CH-2) to 211 µg/kg (Site CH-13). Ammonia levels in the open-lake placement area sediments ranged from 60.4 µg/kg (Site CLA4-1) to 152 µg/kg (Site CLA1-2). Ammonia was identified as a COC at Site CH-5, and Sites CH-7 through CH-15 because concentrations significantly exceeded those in the open-lake placement area sediments. Ammonia is an atypical COC because it is not persistent. While it may be toxic to some benthic organisms in sediments at very high concentrations, ammonia can leach from dredged material during open-lake placement and temporarily reach high enough concentrations in the water column to become acutely toxic to fish (invertebrates are typically not as sensitive as fish to ammonia levels [USEPA 1999]). Therefore, ammonia toxicity is most appropriately characterized through the water column pathway and is addressed in



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paragraph 3.2.5 (a)(1)(a).

- TKN—Concentrations of TKN in the sediment samples from DMMU-1, DMMU-2a and DMMU-2b ranged from 287 µg/kg (Site CH-2) to 2000 µg/kg (Site CH-8). In the open-lake placement area sediments, TKN concentrations ranged from 1850 µg/kg (Site CLA1-3) to 3900 µg/kg (Site CLA1-2). None of the TKN concentrations in the management unit sediments exceeded the maximum concentrations in the open-lake placement area sediments.

(2) Organic analyses

(a) PAHs—Table 5 presents the results of these analyses. Total PAH concentrations in the sediments samples from DMMU-1, DMMU-2a and DMMU-2b ranged from 0.84 mg/kg (Site CH-2) to 16.4 mg/kg (Site CH-8). At open-lake placement areas CLA-1 and CLA-4, total PAH concentrations in the sediment samples ranged from 2.07 mg/kg to 8.10 mg/kg and 1.64 mg/kg to 33.4 mg/kg, respectively. Total PAH concentrations at Sites CH-3 through CH-15 exceeded those relative to open-lake placement area CLA-1. Total PAH concentrations in all of the management unit samples were less than those at open-lake placement area CLA-4.

With respect to placement of the dredged material at open-lake placement area CLA-1, total PAHs at Sites CH-3 through CH-15 were further examined to determine if they should be of potential toxicological concern. The potential risk of PAH mixtures in these sediment samples to the freshwater amphipod *H. azteca* was estimated using hydrocarbon narcosis and equilibrium partitioning (EqP) models (USEPA 2003). Note that sediments typically contain a mixture of PAHs from both petrogenic and pyrogenic sources. In comparison to petrogenic PAHs, pyrogenic PAH compounds are often more persistent and less mobile and bioavailable in the environment, often resulting in lower toxicities (Gustaffsson *et al.* 1997). PAH mixtures that arise from pyrogenic sources often include forms of black carbon that exhibit strong partitioning behavior. Such mixtures strongly adsorb to this black carbon, thus limiting their concentration in interstitial water, and reducing mobility, bioavailability and toxicity (on a bulk sediment concentration basis) (e.g., Pastorok *et al.* 1994).

To decipher the predominant origin of PAH mixtures, PAH compound diagnostic ratios were calculated for the sediment samples collected at Sites CH-3, CH-5 and CH-7. These sites were used as a worst-case scenario in this case because they offered among the highest bulk total PAH concentrations coupled with the lowest TOC content. Neff *et al.*



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(2005) recommends that fluoranthene/pyrene (FL/PY) and phenanthrene/anthracene (PH/AN) ratios both be used to aid in differentiating between sediment-associated pyrogenic and petrogenic PAHs. The FL/PY ratios for these sediment samples (range 2.15 [Site CH-5] to 3.25 [Site CH-7]) were all greater than 1.0, indicating that they were of pyrogenic origin. While the PH/AN ratios approach or exceeded 5 (range 4.78 [Site CH-3] to 7.03 [Site CH-5]) (Neff *et al.* 2005), a PAH profile showing a PH/AN ratio less than 10 are indicative of pyrogenic sources and PH/AN ratio greater than 15 are predominantly petrogenic in origin (Brown *et al.* 2008). Based on this information, it was concluded that the PAH assemblages were predominantly of pyrogenic origin.

The hydrocarbon narcosis and EqP models (USEPA 2003) assume that the risk of PAH mixtures to benthic organisms is attributable to the number of PAH toxic units that are freely dissolved in sediment pore water, and is used to calculate EqP Sediment Benchmark Toxic Units, Final Acute Value ($\sum \text{ESBTU}_{\text{FAV}}$) (USEPA 2003). The presence of TOC is an important partitioning parameter as it acts to sequester PAHs in the sediment phase, thus lowering the amount of PAHs available in the water phase. $\text{ESBTU}_{\text{FAV}}$ s are calculated as follows:

(1)

$$\text{ESBTU}_{\text{FAV}} = \frac{C/f_{\text{OC}}}{C_{\text{OC, PAH}_i, \text{FAV}_i}}$$

Where:

$C_{\text{OC, PAH}_i, \text{FAV}_i}$ = Final acute (FAV) concentration in sediment ($\mu\text{g}/\text{g}_{\text{OC}}$) (see USEPA 2003)

C = Concentration of PAH compound in sediment ($\mu\text{g}/\text{g}$ dry weight)

f_{OC} = Decimal fraction of TOC in sediment (TOC) ($\mu\text{g}/\text{g}_{\text{OC}}$ dry weight)

Freshwater sediments containing $\sum \text{ESBTU}_{\text{FAV}} < 1.0$ for a mixture of 34 or more PAH compounds are predicted to be acceptable for the protection of benthic organisms. Conversely, $\sum \text{ESBTU}_{\text{FAV}} \geq 1.0$ suggest that sensitive benthic organisms may be affected by the PAH mixture. USACE guidelines (USEPA/USACE 1998) emphasize acute toxicity tests for dredged material evaluations. This model employed $C_{\text{OC, PAH}_i, \text{FAV}_i}$ specific to *H. azteca* (Kreitinger, personal communication; USEPA 2003), which is one of two recommended test species used for standard acute toxicity tests in



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dredged material toxicity evaluations (USEPA/USACE 1998a), and is anticipated to be more sensitive to PAHs than most other freshwater organisms (including *C. dilutus*). The $C_{OC\ PAH_i, FAV_i}$ values for *H. azteca* are based on an acute toxicity critical body burden of 13.9 $\mu\text{mol/g}$ lipid, which is the geometric mean of the acute value for fluoranthene within the genus (GMAV) based on data originally published by Spehar *et al.* (1999) (see Appendix C of USEPA 2003). Use of this single critical body burden in the model is assumed to be valid because hydrophobicity-normalized toxicity is considered to be equivalent among Type I narcotic chemicals. The 13.9 $\mu\text{mol/g}$ octanol GMAV for *H. azteca* has been confirmed in the literature. Hawthorne *et al.* (2007) predicted a critical body burden of 15 $\mu\text{mol/g}$ lipid (lower 95% confidence interval) for 85% or greater survival when 97 field collected sediments were evaluated in 28-day laboratory tests and the dissolved PAH concentration in sediment porewater was determined by ASTM D7363 (Hawthorne *et al.* 2007). In addition, the lethal residue (LR_{50}) value of 33.0 $\mu\text{mol/g}$ lipid determined by Hawthorne *et al.* (2007) using these 97 field samples was in very good agreement with the LR_{50} value of 32 $\mu\text{mol/g}$ lipid determined in water only laboratory exposures using radio-labeled fluoranthene (Schuler *et al.* 2006).

The calculation of $C_{OC\ PAH_i, FAV_i}$ for individual PAH compounds was based on the following equation:

(2)

$$C_{OC\ PAH_i, FAV_i} = K_{OC} * MW * [10^{-0.945 * \log(K_{OW}) + \log(GMAV)}]$$

Where:

K_{OC} = Organic carbon-water partition coefficient for PAH compound

K_{OW} = Octanol-water partition coefficient for PAH compound

MW = Molecular weight of PAH compound, g/mol

GMAV = Geometric mean of acute toxicity (critical body burden) values for fluoranthene within the genus, 13.9 $\mu\text{mol/g}$ lipid

For PAH mixtures at Sites CH-3, CH-5 and CH-7, an uncertainty factor of 3.6 with a confidence level of 95% (Hawthorne *et al.* 2006) was applied to the ΣESBTU_{FAV} because the analyses covered only the 16 USEPA priority pollutant PAH compounds, and because the PAHs were assumed to be predominantly of pyrogenic origin based on the diagnostic ratios. Calculated ΣESBTU_{FAV} across these sites were all less than 1 (range 0.63 [Site CH-7] to 0.77 [Site CH-5]), suggesting no unacceptable PAH-associated acute toxicity to *H. azteca* in these sediments. The



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predicted low acute toxicity resulting from the total PAH concentration in these sediment samples is consistent with a no observed effect concentration (NOEC) of 17 mg/kg determined for Buffalo River Area of Concern (AOC) sediments (Kreitinger, personal communication) based on standard 10-day solid phase bioassay data using *H. azteca* and *C. dilutus*, with survival, and survival and growth, as the biological measurement endpoints, respectively (USEPA/USACE 1998a).

Table 6 summarizes sediment pore water concentrations of 34 PAH structures (18 non-alkylated parent compounds and 16 groups of generic alkylated forms) which have been identified as being generally most abundant in the environment and commonly measured (USEPA 2003). Sediment pore water concentrations of these compounds were measured as it is the phase that is bioavailable and has the potential to cause toxicity. Across the management units, calculated Σ ESBTU_{FAV} (the chronic endpoint) ranged from <1 (DMMU-1) to 0.1 (DMMU-2a and DMMU-2b), indicating that PAH contamination in the sediments is sufficiently protective of benthic organisms.

Based on this information, total PAHs were not identified as a PCOC at Sites CH-3 through CH-15.

(b) PCBs

●**Aroclors**—Table 7 summarizes the results of these analyses. Aroclors 1248 and 1254 were usually detected in sediment samples from DMMU-1, DMMU2a and DMMU-2b, as well as from the two open-lake placement areas. Total PCBs (tPCBs) were determined by summing Aroclor 1248 and 1254 with non-detectable concentrations valued at the method detection limit (MDL). Across sites within the three management units, tPCB concentrations ranged from 33.3 µg/kg (Site CH-1) to 343 µg/kg (Site CH-3). Total PCB concentrations at Sites CLA-1 and CLA-4 were similar, ranging from 107 µg/kg to 150 µg/kg and 104 µg/kg to 157 µg/kg, respectively. Except for Site CH-3, all tPCB concentrations in the management unit sediments were below the maximum open-lake placement area sediment concentrations. On a TOC-normalized basis, concentrations at several sites across the three management units (range 8100 ng/g-TOC to 26385 ng/g-TOC) exceeded those of the maximum open-lake placement areas (6000 ng/g-TOC [CLA-1] and 7957 ng/g-TOC [CLA-4]). Based on this information, tPCBs were identified as a sediment COC.

●**Congeners**—Table 8 presents the results of these analyses on the



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management unit and open-lake placement area composite samples. The majority of PCB congeners were non-detectable. Sum PCB (Σ PCB) concentrations were determined by summing all detected congeners and non-detectable congeners valued at one-half the MDL. In the management unit sediments, Σ PCB concentrations ranged from 147 $\mu\text{g}/\text{kg}$ (DMMU-2a and DMMU-2b) to 149 $\mu\text{g}/\text{kg}$ (DMMU-1). In the open-lake placement area sediments, Σ PCB concentrations ranged from 135 $\mu\text{g}/\text{kg}$ (CLA-4) to 148 $\mu\text{g}/\text{kg}$ (CLA-1).

Table 9 summarizes estimated tPCB concentrations using the congener data. Total PCB concentrations in the sediment samples were determined based on an assumption that the total of 209 congeners can be reliably estimated as follows (e.g., see Committee on Remediation of PCB-Contaminated Sediments *et al.* 2001; USEPA 2002a):

(3)

$$\text{tPCBs} = 2 \times (\Sigma\text{PCB } 8, 18, 28, 44, 49, 52, 66, 87, 101, 105, 118, \\ 128, 138, 153, 170, 180, 183, 184, 187, 195, 206, 209)$$

Note that PCBs 184 and 209 were not included in the analysis and therefore could not be included in the estimates. These two congeners are not typically found in minnows, oligochaetes or carp (McFarland and Clarke 1989), suggesting low environmental concentrations and bioavailability. Recent analyses of Duluth-Superior Harbor sediments in which PCB 184 and PCB 209 were non-detectable in all harbor samples ($<0.10 \mu\text{g}/\text{kg}$ to $<0.16 \mu\text{g}/\text{kg}$ and $<0.09 \mu\text{g}/\text{kg}$ to $<0.13 \mu\text{g}/\text{kg}$, respectively) are consistent with low environmental concentrations of these congeners (Futurenet Group 2012). Therefore, it was concluded that the absence of these congeners in the estimates had minimal effect on the results. In the tPCB estimations, non-detectable congener concentrations were assigned a value of one-half the MDL. Estimated tPCB concentrations in the Federal navigation channel DMMU sediments ranged from 112 $\mu\text{g}/\text{kg}$ to 126 $\mu\text{g}/\text{kg}$. In the open-lake placement area sediments, estimated tPCB concentrations ranged from 122 $\mu\text{g}/\text{kg}$ to 124 $\mu\text{g}/\text{kg}$. On a TOC-normalized basis, concentrations in all three management unit composite samples (range 8407 ng/g-TOC to 12625 ng/g-TOC) exceeded those of the maximum open-lake placement areas (4962 ng/g-TOC [CLA-1] and 5114 ng/g-TOC [CLA-4]). This result supported the identification of tPCBs as a COC.

(c) **Pesticides**—Table 10 summarizes the results of these analyses.



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DDT, DDD and DDE were detected in the majority of the sediment samples from DMMU-1, DMMu2a and DMMU-2b, and DDD and DDE were detected in samples from the two open-lake placement areas. Sum DDT (Σ DDT) was determined by summing DDD, DDE and DDT with non-detectable concentrations valued at the MDL. Across sites within the three management units, Σ DDT concentrations ranged from 3.36 $\mu\text{g}/\text{kg}$ (Site CH-1) to 26.3 $\mu\text{g}/\text{kg}$ (Site CH-7). Σ DDT concentrations at CLA-1 and CLA-4 ranged from 7.89 $\mu\text{g}/\text{kg}$ to 8.21 $\mu\text{g}/\text{kg}$ and 8.88 $\mu\text{g}/\text{kg}$ to 17.9 $\mu\text{g}/\text{kg}$, respectively. Except for Sites CH-1 and CH-2, and Sites CH-15 through CH-37 (except for CH-25), all Σ DDT concentrations in management unit sediments exceeded the maximum sediment concentrations at open-lake placement area CLA-1 and/or CLA-4. Based on this information, Σ DDT was identified as a sediment COC. Most other pesticides in the management unit sediments were undetectable at MDLs ranging from 0.003 $\mu\text{g}/\text{kg}$ to 1.40 $\mu\text{g}/\text{kg}$. Dieldrin was measured at 8.96 $\mu\text{g}/\text{kg}$ at Site CH-3. At Site CH-4, aldrin was measured at 42.9 $\mu\text{g}/\text{kg}$ and gamma-chlordane was measured at 2.62 $\mu\text{g}/\text{kg}$ at Site CH-6. Note that aldrin is often rapidly metabolized by many species to dieldrin (USEPA 1980), indicating that its ecological risk is better assessed as the more toxic metabolite. At Site CH-7, alpha-chlordane and beta-BHC were measured at 5.74 $\mu\text{g}/\text{kg}$ and 4.18 $\mu\text{g}/\text{kg}$, respectively. None of these bulk concentrations are of significant toxicological concern.

(d) BETEX—Table 11 summarizes the results of these analyses. Except for toluene, none of the volatile organic compounds (VOCs) were detected at any of the sediment samples from DMMU-1, DMMu2a and DMMU-2b, or from the two open-lake placement areas, at MDLs ranging from 0.092 $\mu\text{g}/\text{kg}$ to 92.7 $\mu\text{g}/\text{kg}$. Toluene was measured at concentrations ranging from 0.231 $\mu\text{g}/\text{kg}$ (CH-1) to 14,500 $\mu\text{g}/\text{kg}$ (CH-8), and well over those at the open-lake placement areas. Therefore, toluene was identified as a COC. Concentrations across the management units were very variable; geometric mean concentrations were 141 $\mu\text{g}/\text{kg}$ (DMMU-1), 2225 $\mu\text{g}/\text{kg}$ (DMMU-2a) and 221 $\mu\text{g}/\text{kg}$ (DMMU-2b). Toluene is not bioaccumulative and tends to not be environmentally persistent, partitions to water and air, and volatilizes. There are several lines of evidence as to why such toluene concentrations would not be toxic in the aquatic environs:

- *Bioassays*

- ◊ Solid-phase bioassays. The results of the two solid phase tests are discussed in paragraph 3.2.2 and did not evidence any significant sediment-associated acute toxicity. However, water in the bioassays



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was periodically exchanged due to high ammonia levels, which also likely served to remove a portion of the toluene contamination. This process in the laboratory, however, can be regarded as having an effect similar to that which a field dredging operation would have on sediment-associated toluene contamination. Dredging with a clamshell bucket entrains water from the water column with the excavated material which would dilute released toluene. This material is then placed in a scow where a portion of the toluene would volatilize.

Water column bioassays. The results of the two water column bioassays are discussed in paragraph 3.2.5(b). One of the water column bioassays indicated some acute toxicity relative to elutriate associated with the DMMU-2a and DMMU-2b samples. However, the subsequent TRE and a review of the literature strongly suggest that the observed toxicity was attributable to ammonia, and therefore not associated with toluene.

•*Prediction of toxicity via narcotic modes of action—USEPA (2008)* derives Tier 2 equilibrium partitioning sediment benchmarks (ESBs) for nonionic organic compounds (including toluene) that are protective of freshwater benthic organisms. The EqP approach is used because it addresses compound bioavailability across different sediments and associates a concentration with biological effects at the benthic level. The calculated narcosis ESB is 810 $\mu\text{g}/\text{g}_{\text{oc}}$ and three orders of magnitude greater than the conventional freshwater/marine ESB of 5 $\mu\text{g}/\text{g}_{\text{oc}}$. The conventional approach uses secondary chronic values (SCVs) that incorporate higher uncertainties and the use of protective adjustments due to the absence of additional toxicity data (USEPA 2008), and as such, can yield very conservative values with a degree of uncertainty. First, generic secondary acute factors (SAFs) used to compute the conventional SCVs (range 2 to 242) are inappropriate and too high for narcotic chemicals (range >1.7 to 3.1), which directly translates into significant discrepancies among the two ESBs. Second, acute-chronic ratios (ACRs) used to convert secondary acute values (SAVs) to SCVs were higher for the conventional ESBs. For example, a default ACR of 18 (based on a variety of chemicals) was often applied for the conventional ESBs, and Di Toro *et al.* (2000a and 2000b) calculated an ACR of 5.09 specific to narcotic chemicals. Finally, the SVC for toluene also did not conform to the minimum requirement of using toxicity data from a single taxonomic family (e.g., daphnids). Using this information in combination with the strong agreement among narcosis ESBs and observed toxicity demonstrates that the toxicity of toluene is explained through the narcosis mode of action. Moreover,



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toluene fell directly on the one-to-one line comparing observed vs. predicted LC_{50} (concentration causing 50% mortality) values (USEPA 2008). Therefore, it is concluded that the narcosis ESB is the most relevant ESB to gauge toluene toxicity.

Table 12 summarizes the calculated toluene narcosis ESBs in comparison to bulk sediment concentrations across the sediment samples from DMMU-1, DMMU-2a and DMMU-2b. With the exception of two discrete samples, none of the bulk sediment concentrations exceed the respective ESB. The two exceedances were at Site CH-5 at 10.8 $\mu\text{g/g}$ (ESB 8.91 $\mu\text{g/g}$) and at Site CH-10 at 13.4 $\mu\text{g/g}$ (12.2 $\mu\text{g/g}$). These excursions ranged from 10% to 21% and were concluded to be of minor consequence. First, these ESBs were a result of relatively higher toluene concentrations coupled with lower TOC content. Regardless of the toluene concentration, a modest 10% increase in f_{oc} would be required to generate ESBs that are comparable or lower to the bulk sediment concentration. Not only is this well within the range of generally accepted analytical variability, but TOC and toluene concentrations across the management units varied considerably. In fact, if just sites flanking CH-5 and CH-10 are considered, the average ESBs of 11.6 $\mu\text{g/g}$ across Sites CH-4, CH-5 and CH-6 and 12.4 $\mu\text{g/g}$ across Sites CH-9, CH-10 and CH-11 are well above the respective average bulk sediment toluene concentrations of 6.86 $\mu\text{g/g}$ and 8.41 $\mu\text{g/g}$. Second, the geometric mean ESBs of 12.2 $\mu\text{g/g}$, 7.21 $\mu\text{g/g}$ and 10.5 $\mu\text{g/g}$ for DMMU-1, DMMU-2a and DMMU-2b, respectfully, all fall well below the corresponding bulk sediment concentrations of 0.25 $\mu\text{g/g}$, 4.9 $\mu\text{g/g}$ and 0.76 $\mu\text{g/g}$. These geometric mean ESBs are 1.5 to 49 times higher than the bulk sediment toluene concentrations and given the dredging process, are the most representative of the dredged material that would be discharged.

It should be noted that ESBs do not consider the potential antagonistic, additive or synergistic toxicity resulting from the presence of other co-occurring chemicals in the sediments, particularly those with a narcotic mode of action due in part to their additive toxicity (USEPA 2003). Nevertheless, the bulk concentrations of other neutral organic compounds (NOCs) in the sediments were quite low, suggesting minimal contributions to overall narcotic potency. The results of both solid phase and water column bioassays support insignificant toxicity including via the narcotic mode of action. The hydrocarbon toxicity potential (HTP) discussion below more directly addresses this question.

- HTP—Solid-phase microextraction (SPME) is a sample preparation



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technique involving the use of fiber coated with a liquid or sorbent (in this case, polydimethylsiloxane [PDMS]) to extract hydrophobic organic compounds (HOCs) from sediments in the laboratory. This technique measures the freely dissolved interstitial concentration (or chemical activity) of the HOC. SPME was utilized to extract the bioavailable fraction of HOCs from DMMU-1, DMMU-2a and DMMU-2b composite samples, and used to estimate the total narcotic toxicity potential of the sediment samples. The HOC analysis using SPME includes analysis of the unresolved complex mixtures (UCM) of hydrocarbons that may be bioavailable; the UCM component represents weathered petroleum hydrocarbons, the aqueous aromatic fraction of which has been identified as a potentially significant source of narcotic toxicity to aquatic organisms (Scarlett *et al.* 2007). In addition to UCM of aromatic hydrocarbons, analysis of SPME fibers using the gas chromatography/flame ionization detection (GS/FID) method permits the quantification of other HOCs (such as toluene) that may also contribute to narcotic toxicity.

SPME fiber concentrations can be correlated to organism body residues, allowing for the derivation of critical body burdens to assess the narcotic toxicity of petroleum hydrocarbon mixtures (and other HOCs) to a number of aquatic organisms (Pakerton *et al.* 2007 and 2009). SPME fiber burden concentrations relative to the DMMU-1, DMMU-2a and DMMU-2b sediment samples were expressed in millimoles of hydrocarbon per fiber (mM PDMS). HTP was then converted into toxic units (TUs) for *H. azteca* and *C. dilutus* where one TU is equivalent to 20 mM PDMS (Pakerton *et al.* 2007) and 66 mM PDMS (Pakerton *et al.* 2009), respectively. TUs ≤ 1.0 are acceptable for the protection of the benthic organism, while TUs > 1.0 signify that the benthic organisms may be unacceptably affected. Table 13 summarizes the SPME fiber burden and TU results with corresponding bulk sediment toluene concentrations. Although there are no fiber burden/TU data for the maximum toluene concentration of 14.4 mg/kg measured at Site CH-8, the TUs for the DMMU-2a sample and remaining sites with the highest bulk concentrations (CH-10, CH-5 and CH-3; range 10.5 to 13.4 mg/kg) ranged from 0 to 0.5 and 0 to 0.2 for *H. azteca* and *C. dilutus*, respectively.

Toluene was determined to not be toxic because the maximum total HTP (including contribution from toluene) of the sediment samples relative to *H. azteca* and *C. dilutus* were 0.5 TU and 0.2 TU (DMMU-2a), respectively. These values are < 1.0 and indicate that the dredged material would not be a significant source of narcotic toxicity to these sensitive benthic organisms.



Based on this information, toluene was eliminated as a COC.

3.2.2 Solid phase bioassays

The results of these tests are summarized in Table 14.

a. **H. azteca**—The mean survival of this test species exposed to the management unit samples ranged from 82±25% (DMMU-2b) to 94±6% (DMMU-1 and DMMU-2a), and were not statistically different than that associated with the open-lake placement areas (CLA-1 mean survival 84±15% [Dunnett's test; $\alpha=0.05$]; CLA-4 mean survival 92±11% [Steel's many-one rank test; $\alpha=0.05$]).

b. **C. dilutus**—The mean survival of this test species exposed to the management unit samples ranged from 80±7% (DMMU-1) to 90±10% (DMMU-2b), and was not reduced by more than 20 percent and not statistically different than that associated with the open-water placement areas (CLA-1 mean survival 90±10% [Steel's many-one rank test; $\alpha=0.05$]; CLA-4 mean survival 88±5% [Dunnett's Test; $\alpha=0.05$]). With respect to *C. dilutus* growth, mean biomass expressed as mean dry weight (MDW) exposed to the management unit ranged from 2.17±0.299 mg (DMMU-2b) to 3.51±0.116 mg (DMMU-1). All values exceeded those associated with the open-lake placement area MDWs as well as a MDW of 0.6 mg (USEPA/USACE 1998b).

These solid phase bioassay data did not show any significant acute or sublethal toxicity associated with the management unit sediments. These results indicate that placement of material dredged from DMMU-1, DMMU-2a and DMMU-2b at open-lake placement areas CLA-1 and CLA-4 would not result in any contaminant-related, unacceptable adverse impacts.

3.2.3 PCB bioaccumulation testing

Bioaccumulation was the most appropriate biological measurement endpoint for sediment-associated PCBs in this case. The results of this testing in terms of Σ PCB tissue residues are summarized in Table 15. Note that the summation of PCB congener concentrations for the statistical comparison of sum PCB tissue residues in management unit vs. open-lake reference area treatments was determined by first screening out congeners that were not detected across all of the treatment replicate samples. Of the remaining congeners, those



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detected in less than five harbor management unit replicate samples were screened out. Congeners detected in only the open-lake reference area replicate samples, or congeners measured in the open-lake reference area replicate samples at higher concentrations relative to harbor management unit replicate samples, were also screened out. The purpose of this screening was an attempt to minimize the number of NDs for statistical comparison purposes. Based on this approach, the following 22 congeners were included in the PCB summation (note that this list is not the same as the list of 22 congeners utilized to predict tPCB concentrations [see below]): PCB 44, 52, 64, 66, 70, 75, 81/87, 90/101, 95, 97, 105, 107, 110, 118, 122, 138, 149, 151, 153, 163/164, 170 and 187. Mean Σ PCB residues in *L. variegatus* tissues exposed to the management unit samples ranged from 33.2 ± 4.20 $\mu\text{g}/\text{kg}$ (DMMU-2a) to 55.6 ± 4.30 $\mu\text{g}/\text{kg}$ (DMMU-1). For the open-lake placement area sediments, associated Σ PCB tissue residues ranged from 12.9 ± 1.22 $\mu\text{g}/\text{kg}$ (CLA-4) to 32.2 ± 4.70 $\mu\text{g}/\text{kg}$ (CLA-1).

Table 16 summarizes the predicted mean tPCB residues in *L. variegatus* tissues for all management unit samples and open-lake placement area sediments using the methodology contained in Committee on Remediation of PCB-Contaminated Sediments *et al.* (2001) and USEPA (2002a) and as shown in Equation 1. As with the tPCB concentrations predicted for the composite sediment samples (see Table 9), PCBs 184 and 209 were not included in the analysis and therefore could not be included in the estimates. For the management unit samples, predicted mean tPCB residues in *L. variegatus* tissues ranged from 50.6 ± 6.0 $\mu\text{g}/\text{kg}$ (DMMU-2a) to 72 ± 8.2 $\mu\text{g}/\text{kg}$ (DMMU-1). Predicted open-lake placement area mean tPCB residues in *L. variegatus* tissues ranged from 19.3 ± 2.8 $\mu\text{g}/\text{kg}$ (CLA-4) to 48.2 ± 7.2 $\mu\text{g}/\text{kg}$ (CLA-1). PCB bioaccumulation data relative to DMMU-1, DMMU-2a and DMMU-2b were interpreted as follows:

a. Comparisons to open-lake placement areas

Mean Σ PCB residues in *L. variegatus* tissues exposed to DMMU-1 (55.6 ± 4.3 $\mu\text{g}/\text{kg}$), DMMU-2a (33.2 ± 4.2 $\mu\text{g}/\text{kg}$) and DMMU-2b (36.6 ± 2.7 $\mu\text{g}/\text{kg}$) samples were significantly greater relative to sediments at open-lake placement area CLA-4 (one-tailed LSD test; $\alpha=0.1$). Further, mean Σ PCB residues in *L. variegatus* tissues exposed to the DMMU-1 sample was significantly greater relative to sediments at open-lake placement area CLA-1 (one-tailed LSD test; $\alpha=0.1$). This indicates that material dredged from these management units requires additional evaluation for placement at the respective open-lake areas. For this



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reason, tPCBs was retained as a COC in these management unit sediments relative to the respective open-lake placement area(s). Mean Σ PCB residues in *L. variegatus* tissues exposed to the DMMU-2a and DMMU-2b samples were not significantly greater relative to sediments at open-lake placement area CLA-1 (one-tailed LSD test; $\alpha=0.1$).

b. Additional evaluation

USEPA/USACE (1998b) provides that when the bioaccumulation of contaminants from dredged material is statistically greater in comparison to that associated with open-water reference area sediments, several other factors should be assessed (Section 6.3) to determine the acceptability of open-lake placement. These factors define the biological significance of the exceedance, and include such things as the toxicological importance of the contaminants, potential for effects at the observed concentrations, magnitude of increase observed, and concentrations found in species living in the vicinity of the proposed dredged material placement area.

(1) Tissue levels, toxicological significance and potential to biomagnify—It is useful to place these benthic bioaccumulation data within the perspective of other Great Lakes dredging projects or open-lake reference/placement areas that have quantified and assessed sediment-associated PCB bioaccumulation. Table 17 summarizes predicted or measured PCB bioaccumulation data on oligochaetes associated with open-lake reference and placement areas in the Central Basin of Lake Erie, showing the variation and range of PCB bioaccumulation at the benthic level. Tissue residue predictions were based on Equation 1 or the theoretical bioaccumulation potential (TBP) model. TBP is an equilibrium theory-based algorithm used to predict the potential bioaccumulation of neutral, organic compounds, such as PCBs, in sediments (McFarland 1984) at the benthic level. This model is expressed as:

(4)

$$TBP = BSAF \times L \times (C_s/TOC)$$

Where:

TBP = Predicted whole body tissue concentration of tPCBs ($\mu\text{g}/\text{kg}$ -wet weight)

BSAF = Biota-sediment accumulation factor



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L = Concentration of lipid in target animal (decimal fraction of wet weight)

C_s = Concentration of tPCBs in sediment ($\mu\text{g}/\text{kg}$ -dry weight)

TOC = Total organic carbon concentration in sediment (decimal fraction of dry weight)

The target animal used in this case is an oligochaete worm. In this model, a 1% lipid content, an average that is characteristically representative of oligochaete worms (e.g., Ankley *et al.* 1992, Pickard *et al.* 2001, USAERDC 2013a), a BSAF of 1.48 (USACE 2010), and PCB and TOC data from various sources were used.

Several conclusions can be drawn from the lake sediment-related tPCB oligochaete residue data contained in Table 17. First, the range of 50.6 $\mu\text{g}/\text{kg}$ to 72 $\mu\text{g}/\text{kg}$ and mean of 58.2 $\mu\text{g}/\text{kg}$ predicted tPCB residues in *L. variegatus* exposed to the DMMU-1, DMMU-2a and DMMU-2b samples are quite comparable to the 57.8 $\mu\text{g}/\text{kg}$ mean concentration measured in *L. variegatus* exposed to sediments at the actively used Ashtabula Harbor open-lake placement area (USACE 2010). Second, this range and mean are comparable to those for predicted and measured tissue residues associated with other open-lake reference areas in the Lake Erie Central Basin (range 19.1 $\mu\text{g}/\text{kg}$ to 168 $\mu\text{g}/\text{kg}$; mean 59.1 $\mu\text{g}/\text{kg}$). Further, this range and mean are also comparable to those for only measured tissue residues associated with other open-lake reference areas in the basin (range 20 $\mu\text{g}/\text{kg}$ to 168 $\mu\text{g}/\text{kg}$; mean 63.9 $\mu\text{g}/\text{kg}$). Collectively, this information shows that while the bioaccumulation of PCBs from the dredged material in oligochaetes (and other benthic invertebrates) may be statistically higher relative to Cleveland Harbor open-lake areas, it is still very comparable to or well within the range of background bioaccumulation of PCBs by oligochaetes across the basin.

Biomagnification is the process whereby the tissue concentration of a contaminant increases as it passes up the food web through two or more trophic levels. The biomagnification of PCBs varies among congeners. Table 15 shows that the tissue concentrations of almost all of the congeners in *L. variegatus* exposed to the management unit sediments were at higher concentrations relative to those exposed to open-lake placement area CLA-4 sediments. Nevertheless, few of these congeners (i.e., PCBs 81/87, 118, 105 and 138) were among the "dioxin-like" aryl hydrocarbon hydroxylase (AHH)-inducing PCBs. While PCB 126 is a potent AHH-inducer (pure 3-methylcholanthrene (MC)-type inducer), it was not analyzed for under the 2012 investigation but is also rarely detected



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in biological tissues including oligochaetes (McFarland and Clarke 1989) in the parts per billion (ppb) range. AHH-inducing PCBs are structurally-similar to 2378-tetrachlorodibenzo-p-dioxin (TCDD), and include no ortho, two para and two or more meta chlorines, their mono-ortho analogs, and some di-ortho congeners. These congeners elicit similar toxic responses by promoting induction of AHH enzyme system in invertebrates which can result in weight loss, immunotoxicity, and adverse effects in reproduction and development. Trowbridge and Swackhamer (2002) found that 14 dioxin-like PCB congeners preferentially biomagnified in a lower-trophic-level food web relative to the remaining congeners. These AHH-inducing PCBs include congeners 81, 77, 123, 118, 114, 105, 138, 158, 128, 167, 156, 157, 169 and 189. Of these congeners (except for PCB 189 which was not analyzed for), only PCBs 81/87, 105, 118 and 138 were detected in *L. variegatus* tissues among the DMMU-1, DMMU-2a and DMMU-2b samples (assuming the co-eluting 87/81 congener was PCB 81). PCBs 81/87, 118 and 138 were also detected in *L. variegatus* tissues associated with one or both of the open-lake placement area sediments, but usually at lower concentrations. Similarly, PCBs 81, 105, 118 and 138 were also detected at lower concentrations in *L. variegatus* exposed to sediments from open-lake reference areas offshore of Ashtabula Harbor, Ohio (PCB 81 [up to 0.016 µg/kg], 105 [average 0.21 µg/kg], 118 [average 0.53 µg/kg] and 138 [average 1.8 µg/kg]) (USACE 2010). From this information, it can be inferred that PCBs 81, 105, 118 and 138 have the potential to biomagnify from benthic invertebrates associated with the management unit sediments. However, despite the potential to biomagnify, it is also noted that congeners 105, 118 and 138 should be of low toxicological concern. Van den Berg *et al.* (1998) does not include the di-ortho-substituted PCB 138 in its listing of congeners with assigned toxic equivalence factors (TEFs) because of insufficient evidence toward AHH receptor activity. Van den Berg *et al.* also concluded that fish are extremely insensitive to the mono-ortho-substituted PCBs 105 and 118 and, consequently assigned them the lowest TEFs for fish (0.000005). These data on relative toxicity of the congeners measured in *L. variegatus* tissue indicate that with the exception of the detection of PCB 87 (the concentration of which is ambiguous due to co-elution with PCB 87), the magnitude of total PCBs that have toxicological significance is low.

(2) Magnitude by which bioaccumulation from the dredged material exceeds that associated with open-lake reference area sediments—Analytical variability, along with all other sources of uncertainty in predicting PCB bioaccumulation into higher trophic level species, are important



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considerations for the interpretation of laboratory test results. A statistically significant difference between mean bioaccumulation from dredged material and reference area sediments from laboratory tests may not be biologically or ecologically significant because it may simply fall within the range of natural variation. Therefore, the absolute difference in measured bioaccumulation should be considered in addition to a statistically significant difference. The magnitude of difference (MOD) between mean Σ PCB residues in *L. variegatus* tissues exposed to DMMU-1, DMMU-2a and DMMU-2b samples vs. sediments at open-lake placement area CLA-4 was 4.3, 2.6 and 2.8, respectively. Further, the MOD between Σ PCB residues in *L. variegatus* tissues exposed to the DMMU-1 sample and sediments at open-lake placement area CLA-1 was 1.7 (worst-case relative to CLA-1).

Standard guidance in American Society of Testing and Materials (ASTM) (2010) indicates that a two-fold difference between tissue residues in test and reference sediments should in most cases provide a sufficient signal for potential ecological and human health concerns. This implies that tissue concentrations less than twice those of reference tissue concentrations should not be considered a *biologically* significant difference within the context of bioaccumulation evaluation of dredged material. Based on this, the placement of material dredged from DMMU-1 at CLA-1 (MOD=1.7) would not result in biologically significant accumulation of tPCBs.

(3) Spatially explicit screening-level exposure evaluation of bioaccumulation test data on dredged material—Predictions of potential exposure to PCBs, and the associated risk to ecological receptors and human health, require explicit consideration of both spatial and temporal factors within food web models. For example, receptors may utilize habitat and consume organisms originating from the dredged material open-lake placement area will often utilize habitat and forage in other areas well outside of the placement area. Further, their diet is usually not comprised of 100% benthic organisms associated with dredged material placed at the open-lake placement area, either within or outside the placement area.

A spatially explicit screening-level exposure procedure has been developed to address the relatively small spatial area for dredged material placement compared to the overall area utilized by receptors to obtain food. This area is referred to as the receptor's home range. Fish with a home range larger than the open-lake placement area will obtain only a fraction of their diet from the area influenced by the



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placement of dredged material, thus resulting in a reduction in net bioaccumulation compared to what is reflected in laboratory bioaccumulation experiments alone. The following equation provides a simple way to mathematically express this concept by using an area-weighted average concentration for prey species:

(5)

$$C_o = \frac{[(HR - \{PA+FPA\})(C_r)] + [(PA)(C_{dm})] + [(FPA)(C_{dmfpa})]}{HR}$$

Where:

C_o = Estimated PCB tissue residue in oligochaete populations across fish species' home range ($\mu\text{g}/\text{kg}$ -wet weight)

HR = Assumed home range of fish species of interest (in same units as area of open-water placement site)

PA = Assumed area of dredged material placement site (in same units as receptor's home range)

FPA = Assumed area of formerly used dredged material placement site (in same units as receptor's home range)

C_r = Measured PCB tissue residue in *L. variegatus* exposed to open-water reference/placement area sediments ($\mu\text{g}/\text{kg}$ -wet weight)

C_{dm} = Measured PCB tissue residue in *L. variegatus* exposed to dredged material ($\mu\text{g}/\text{kg}$ -wet weight)

C_{dmfpa} = Measured PCB tissue residue in *L. variegatus* exposed to dredged material at former placement area ($\mu\text{g}/\text{kg}$ -wet weight)

The use of this equation requires a receptor species and an estimate of its home range. In this case, yellow perch (*Perca flavescens*) and walleye (*Sander vitreus*) were used as receptor species'. *P. flavescens* was selected as a receptor species for several reasons: (1) it utilizes and forages in the water column and benthic habitat at the open-lake placement area (e.g., Smith 1985); (2) it is a top sport and commercial species in Lake Erie; (3) it is native and ecologically integral to the lake; (4) it a favorite for human consumption; and (5) its diet has a direct benthic link (e.g., Smith 1985). *S. vitreus* was selected as a second receptor species because: (1) it utilizes water column at the open-lake placement area); (2) it is a top sport and commercial species in the lake; (3) it is native and ecologically integral to the lake; (4) it a favorite for human consumption; and (5) it is a top predator species (e.g., Smith 1985).



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A minimum and conservative home range for *P. flavescens* in Lake Erie was estimated based on Lake Michigan *P. flavescens* mark-recapture data contained in Glover *et al.* (2008). A conservative estimate for the home range of *P. flavescens* was developed by assuming an elliptical-shaped area based on minimum observed mark-recapture distances. The home range estimate for individuals recaptured from various locations was determined to be:

(6)

$$HR_{cs} = \pi \left[\left(\{N_s \times 0.5\} + \{N_{ns} \times 0.5\} \right) / 2 + \left(\{S_s \times 0.5\} + \{S_{ns} \times 0.5\} \right) / 2 \right] \times \left[\left(\{E_s \times 0.5\} + \{E_{ns} \times 0.5\} \right) / 2 + \left(\{W_s \times 0.5\} + \{W_{ns} \times 0.5\} \right) / 2 \right]$$

Where:

HR_{cs} = Estimated cross-season home range (km²)

π = 3.14

N_s = Average north distance traveled from tagging site in summer (km)

N_{ns} = Average north distance traveled from tagging site in non-summer (km)

S_s = Average south distance traveled from tagging site in summer (km)

S_{ns} = Average south distance traveled from tagging site in non-summer (km)

E_s = Average east distance traveled from tagging site in summer (km)

E_{ns} = Average east distance traveled from tagging site in non-summer (km)

W_s = Average west distance traveled from tagging site in summer (km)

W_{ns} = Average west distance traveled from tagging site in non-summer (km)

Table 18 presents the home range calculations. Note that Glover *et al.* (2008) showed some lacking recaptures in the north and south directions, and few recaptures in the east and west directions. If any directional distance value was lacking, the single remaining distance traveled was used in lieu of a mean toward determining a cross-seasonal directional distance traveled. Further, if a mean X- or Y-distance was lacking for the purposes of computing an estimated site-specific home range, an arbitrary distance of 3.2 km (2 miles) was utilized. The minimum estimated home range was at the Indiana 1 (IN-1) tagging site at 46.5 km² or 18 mi². This minimum home range was used as the basis



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for developing area-weighted exposure estimates for *P. flavescens*. While this estimation of home range should not be assumed to be accurate, it is nevertheless conservative in the intended application based on the following: (1) it uses the minimum cross-season home range value generated (range 18 mi² to 69.4 mi²); (2) it assumes that the home range is simply elliptical based on mark-recapture data when it is likely that the home range is much wider and longer, and irregularly shaped, and therefore significantly greater in spatial extent; (3) as a default value, it assumes a minimal width of two miles; and (4) it is less than other conservative home range estimates for this species of 25.1 mi² and 50.2 mi² mi to 60.8 mi² based on mark-recapture distance data from Lake Michigan at Port Washington, Wisconsin (Smith and Van Oosten 1940) and Green Bay, Wisconsin (Mraz 1950; Glover *et al.* 2008), respectively, using an assumed width (semi-minor axis) of one mile for the elliptical home range.

For Equation 5, 18 mi² and 51.8 mi² home range estimates were used for *P. flavescens* and *S. vitreus*, respectively. The home range for *S. vitreus* was conservatively based on data from Wang *et al.* (2007) by applying Equation 6 using a calculated 33 mi mean minimum linear distance moved by males in Lake Erie and an assumed semi-minor axis of one mile for the elliptical home range. If it is assumed that the “footprint” of dredged material placement is one square mile resulting in oligochaete ΣPCB bioaccumulation equal to 55.6 µg/kg (using sediments from DMMU-1 as the worst-case scenario) and the remaining area of the fish home range offers oligochaete populations with ΣPCB tissue residues of 12.9 µg/kg (conservatively using open-lake area CLA-4), including within it a one square mile area with oligochaete populations with ΣPCB tissue residues of 32.2 µg/kg (i.e., at CLA-1), this results in an average oligochaete tissue exposure level of 16.3 and 14.1 µg/kg for *P. flavescens* and *S. vitreus*, respectively (Table 19). These values are comparable to the mean ΣPCB tissue concentration of 12.9 µg/kg in *L. variegatus* exposed to the open-lake area sediments and approach or are within the generally accepted range of analytical variability alone (e.g., ±20%).

A spatially-explicit screening-level exposure comparison (SESLEC) approach has been developed that can be applied to conservatively identify the need for more extensive, complicated and costly dredged material evaluations. This approach generates a value referred to as a bioaccumulation exposure factor (BEF), which is a spatially weighted average concentration in prey benthic invertebrate tissues (oligochaetes in this case) after dredged material placement, divided



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by the spatially weighted average concentration in oligochaete tissues prior to placement. This model is essentially a simplification of the dietary exposure portion of the TrophicTrace bioaccumulation model (USAERDC 2013a). The BEF is expressed as follows:

(7)

$$\text{BEF} = \frac{C_o}{\frac{([\text{PA}/\text{HR}] \times C_{dm}) + ([\text{FPA}/\text{HR}] \times C_{dmfpa}) + ([\text{HR} - \{\text{PA}+\text{FPA}\}]/\text{HR}) \times C_r}{C_r}} =$$

Where:

C_o = Estimated PCB tissue residue in oligochaete populations across fish species' home range ($\mu\text{g}/\text{kg}$ -wet weight)

PA = Assumed area of dredged material placement site (in same units as receptor's home range)

C_{dm} = Measured mean PCB tissue residue in *L. variegatus* exposed to dredged material ($\mu\text{g}/\text{kg}$ -wet weight)

FPA = Assumed area of former dredged material placement site (in same units as receptor's home range)

C_{dmfpa} = Measured mean PCB tissue residue in *L. variegatus* exposed to dredged material at former placement area ($\mu\text{g}/\text{kg}$ -wet weight)

C_r = Measured mean PCB tissue residue in *L. variegatus* exposed to open-water reference/placement area sediments ($\mu\text{g}/\text{kg}$ -wet weight)

HR = Assumed home range of receptor species (in same units as area of open-lake placement site)

This equation was applied using *P. flavescens* and *S. vitreus* as the receptor species'. Assumptions included that a one square mile placement area results in oligochaete tPCB bioaccumulation equal to 55.6 $\mu\text{g}/\text{kg}$ (again using sediments from DMMU-1 as the worst-case scenario), a one square mile area of dredged material lake bottom from the former open-lake placement area CLA-1 with oligochaete populations with tissue residues of 32.2 $\mu\text{g}/\text{kg}$, and the remaining area of the fish home range offers oligochaete populations with tPCB tissue residues of 12.9 $\mu\text{g}/\text{kg}$ (open-lake area sediments CLA-4 sediments). This yields tPCB BEFs of 1.27 and 1.10 for *P. flavescens* and *S. vitreus*, respectively (Table 20). Such BEFs, which are based on a worst-case



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scenario, are not substantially greater than 1 and either approach or are within the generally accepted range of analytical variability. This indicates that the placement of material dredged from DMMU-1, DMMU-2a and DMMU-2b at open-lake area CLA-4 would result in negligible PCB exposure risk with respect to fish, wildlife and human health. If the placement of material dredged from DMMU-1 was spatially limited within open-lake placement area CLA-4 to a two-third square mile area (this assumes no dispersal of the dredged material after placement), the resulting BEF would be reduced to 1.20 and fall within the generally accepted range of analytical variability. This would be a conservative measure.

3.2.4 DDT/DDD/DDE bioaccumulation testing

Bioaccumulation was the most appropriate biological measurement endpoint for sediment-associated DDT/DDD/DDE in this case. The results of this testing in terms of Σ DDT tissue residues are summarized in Table 21. With one exception, DDT metabolites 4,4'-DDE and 4,4'-DDD, were the only isomers detected in *L. variegatus* tissues. Therefore, a summation of only these isomers was used as Σ DDT tissue residues. Mean Σ DDT residues in *L. variegatus* tissues exposed to the DMMU samples ranged from 3.41 ± 0.38 $\mu\text{g}/\text{kg}$ (DMMU-2a) to 5.64 ± 0.66 $\mu\text{g}/\text{kg}$ (DMMU-2b). For the open-lake placement area sediments, associated Σ DDT tissue residues ranged from 2.65 ± 2.2 $\mu\text{g}/\text{kg}$ (CLA-4) to 5.40 ± 0.55 $\mu\text{g}/\text{kg}$ (CLA-1).

a. Comparisons to open-lake placement areas

Mean Σ DDT residues in *L. variegatus* tissues exposed to DMMU-1 (5.3 ± 0.36 $\mu\text{g}/\text{kg}$) and DMMU-2b (5.64 ± 0.66 $\mu\text{g}/\text{kg}$) samples were significantly greater relative to sediments at open-lake placement area CLA-4 (one-tailed LSD test; $\alpha=0.1$). This indicates that material dredged from these two DMMUs requires additional evaluation for placement at open-lake area CLA-4. For this reason, Σ DDT was retained as a COC in these management unit sediments. Mean Σ DDT residues in *L. variegatus* tissues exposed to the DMMU-1, DMMU-2a and DMMU-2b samples were not significantly greater relative to sediments at open-lake placement area CLA-1 (one-tailed LSD test; $\alpha=0.1$). In addition, mean Σ DDT tissue residues exposed to the DMMU-2a sample were not significantly greater relative to sediments at open-lake placement area CLA-4 (one-tailed LSD test; $\alpha=0.1$).

b. Additional evaluation



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In addition to PCBs, Σ DDT was the second contaminant found to bioaccumulate in *L. variegatus* from the dredged material to levels that were statistically greater relative to one or both of the open-lake placement area sediments. PCBs and Σ DDT were both identified as bioaccumulative PCOCs in the dredged material (except for the Σ DDT for the DMMU-2a sample). PCBs were subsequently eliminated as a COC.

As with PCBs, several factors were used to assess the biological significance of the exceedance of Σ DDT bioaccumulation relative to open-lake placement area CLA-4 (USEPA/USACE 1998b). These include toxicological importance of the contaminants, potential for effects at the observed concentrations, magnitude of increase observed, and concentrations found in species living in the vicinity of the proposed dredged material placement area.

(1) Tissue levels, toxicological significance and potential to biomagnify—DDT and its metabolites biomagnify. However, Σ DDT tissue residues observed in *L. variegatus* associated with the DMMU-1 and DMMU-2b samples (range 5.3 $\mu\text{g}/\text{kg}$ to 5.6 $\mu\text{g}/\text{kg}$) were low. Total DDT in Lake Erie walleye are declining and are below a Great Lakes Water Quality Agreement (GLWQA) tissue criterion of 1 mg/kg for top predator fish (USEPA 2013b). According to Rowan and Rasmussen (1992), DDT was found to range in mid to higher trophic level fish from 90 $\mu\text{g}/\text{kg}$ (e.g., emerald shiner [*Notropis atherinoides*], rainbow smelt [*Osmerus mordax*]) to 1220 $\mu\text{g}/\text{kg}$ (e.g., *P. flavescens*, *S. vitreus*, coho salmon [*Oncorhynchus kisutch*]).

(2) Magnitude by which bioaccumulation from the dredged material exceeds that associated with open-lake reference area sediments—A statistically significant difference between mean bioaccumulation from dredged material and reference area sediments from laboratory tests may not be biologically or ecologically significant because it may simply fall within the range of natural variation. Therefore, the absolute difference in measured bioaccumulation should be considered in addition to a statistically significant difference. The MOD in reference to CLA-4 for the DMMU-1 and DMMU-2b samples was 2 and 2.1, respectively. These differences approach the less than two-fold difference between tissue residues in test and reference sediments that is a sufficient signal for potential ecological and human health concerns (ASTM 2010).

(3) Spatially explicit screening-level exposure evaluation of bioaccumulation test data on dredged material—Predictions of potential exposure to DDT and its metabolites, and risk to ecological receptors and human health, require explicit consideration of both spatial and temporal factors



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within food web models. Therefore, the SESLEC was employed to evaluate the potential exposure of receptors to Σ DDT residues in oligochaetes residing in dredged material discharged from DMMU-1 and DMMU-2b. As with tPCBs, *P. flavescens* and *S. vitreus* were evaluated as the receptors. *P. flavescens* and *S. vitreus* in and around the open-lake placement areas are expected to have minimum home ranges of 18 mi² (based on data from Glover *et al.* 2008) and 51.8 mi² (based on data from Wang *et al.* 2007). Equation 5 was first applied to demonstrate that only a fraction of these receptors' diet could potentially be exposed to dredged material placed at open-lake area CLA-4. If it is assumed that the "footprint" of dredged material placement is one square mile, the presence of the dredged material from DMMU-2b (as a worst-case scenario) at CLA-4 resulting in oligochaete Σ DDT bioaccumulation equal to 5.64 $\mu\text{g}/\text{kg}$ and the remaining area of the fish home range offers oligochaete populations with tissue residues of 2.65 $\mu\text{g}/\text{kg}$ (including dredged material from the former open-lake placement area [CLA-1] with oligochaete populations with tissue residues of 5.40 $\mu\text{g}/\text{kg}$), this results in average oligochaete tissue exposure levels of 2.95 $\mu\text{g}/\text{kg}$ and 2.75 $\mu\text{g}/\text{kg}$ for *P. flavescens* and *S. vitreus*, respectively (Table 22). These values are comparable to the mean Σ DDT tissue concentration in *L. variegatus* of 2.65 $\mu\text{g}/\text{kg}$ exposed to the open-lake area sediments and the difference between them is well within the generally accepted range of analytical variability.

Application of the BEF model (Equation 7) with the assumptions that a one square mile placement area results in oligochaete Σ DDT bioaccumulation equal to 5.64 $\mu\text{g}/\text{kg}$ (using dredged sediments from DMMU-2b as the worst-case scenario) and the remaining area of the fish home ranges offer oligochaete populations with Σ DDT tissue residues of 2.65 $\mu\text{g}/\text{kg}$ (within which a one square mile area at CLA-1 offers oligochaete populations with Σ DDT tissue residues of 5.40 $\mu\text{g}/\text{kg}$) yields BEFs of 1.12 and 1.04 for *P. flavescens* and *S. vitreus*, respectively (Table 23). Such BEFs, which are based on a worst-case scenario, are not substantially greater than 1 and well within the generally accepted range of analytical variability. This indicates that the placement of material dredged from DMMU-1 and DMMU-2b at open-lake area CLA-4 would result in negligible Σ DDT exposure risk with respect to fish, wildlife and human health.

3.2.5 Elutriate testing

a. SET/MET



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(1) **Metals and other inorganics**—Tables 24 and 25 summarize the results of this testing for metals and other inorganics, respectively. The elutriate data show low to moderate releases of metals and other inorganics. Dissolved (i.e., SET-F) ammonia-N concentrations in the management unit elutriates ranged from 7.1 mg/L (DMMU-1) to 16.8 mg/L (DMMU-2a). Therefore, ammonia was identified as a water column PCOC and would require dilution during dredged material discharge operations.

(a) **Ammonia-N**—The average dissolved ammonia level in sediment elutriate across management unit samples was 11.5 mg/L (Table 25). Fairchild *et al.* (2005) exposed several fish species to ammonia in the laboratory over a chronic 28-day duration. The most sensitive fish species was *P. promelas* exposed as 4-day olds. For this species, they reported a no observed effect concentration (NOEC), lowest observed effect concentration (LOEC) and chronic value (ChV; the geometric mean of the NOEC and LOEC) of 0.31, 0.60 and 0.43 mg/L unionized ammonia (NH₃), respectively. At 25°C and the reported pH of 8.34, this ChV equates to a total ammonia concentration of approximately 6.3 mg/L. The ChV is considered a protective value (Adams and Rowland 2002) and is very conservative in terms of evaluating acute exposures associated with the discharge of dredged material from a scow. Fairchild *et al.* (2005) also reported no *P. promelas* mortality after a shorter seven day exposure period to 0.31 mg/L NH₃ which translates to 3.7 mg/L total ammonia at 25°C. Therefore, after immediate mixing in the water column (see next paragraph), ammonia released from these sediments would not be of any significant concern with respect to fish toxicity.

The Short-Term (ST)-Fate simulation model was employed to predict and evaluate the release of contaminants to the water column during discharge of dredged material in the open-water. Modeling assumptions include (1) clamshell bucket (mechanical) dredging with discharge of the dredged material via scow; (2) mechanically dredged material with a solids content of 45% (about 10% less than *in-situ* material due to water entrained during dredging); (3) use of a 1500 cubic yard (CY) scow with a bin that is 120 ft x 30 ft x 12 ft; (4) dredged material is a single dump from a slowly moving vessel over a one-minute period; (5) use of a single rectangular two-square mile open-lake placement area in a west-to-east direction with minimum depths of 50 ft; (6) a uniform water column density of 0.999; (7) five depth-averaged current velocities (0.33, 0.66, 0.98, 1.31 and 1.64 feet per second [fps]); (8) the dredged material was free of clumps in DMMU-1, but was predicted to have 37% clumps by volume in DMMU-2a and 41% clumps by volume in DMMU-



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2b; and (9) volumetrically, the dredged material in DMMU-1 was 57% water, 0% clumps, 33% sand, 9% silt and 1% clay, the dredged material in DMMU-2a was 47% water, 37% clumps, 4% sand, 11% silt and 2% clay, and the dredged material in DMMU-2b was 44% water, 41% clumps, 1% sand, 13% silt and 1% clay; and (10) all fractions except clumps are stripped in the water column with the silt/clay fractions being cohesive. The results of the ST-Fate model runs are presented in USAERDC (2013b).

Assuming a maximum ammonia-N release of 16.8 mg/L (worst-case) from the dredged material discharge and lake water background ammonia concentration of 0.03 µg/L, the ST-Fate model run indicated that the effluent would achieve an OMZM WQS of 2.9 µg/L for the Protection of Aquatic Life (OEPA 2013) during the first two minutes after discharge within the actual discharge footprint and well within the boundaries of the placement areas.

In summary, ample water column mixing for ammonia is available at both open-lake placement areas CLA-1 and CLA-4. Based on this information, ammonia was eliminated as a water column COC.

(b) TP—Dissolved TP in sediment elutriate across management unit samples ranged from 0.07 mg/L (DMMU-1) to 0.12 mg/L (DMMU-2b). However, the measured concentrations in Table 25 were adjusted to estimated dissolved values because measureable levels of TSS were detected in the elutriates, indicating that a fraction of the measured filtered TP was not truly dissolved and bioavailable. ST-Fate modeling of both filtered and dissolved TP releases showed that all water quality standards for filtered/dissolved TP (as low as 0.007 mg/L) would be met within 5 minutes and 400 feet of the discharge, even when considering a background filtered TP concentration of 0.005 mg/L. Also note that a portion of the measured dissolved TP includes that associated with dissolved organic carbon (DOC), which is not truly bioavailable.

•*Potential of sediment TP release during dredged material placement to influence HABs*—A detailed evaluation of the potential of TP releases from open-lake placement of material dredged from DMMU-1, DMMU-2a and DMMU-2b to influence HABs is presented in USAERDC (2013c). Several water column TP criteria (both dissolved [filtered] and total [unfiltered]) for surface waters were developed to address this question when considering the range, data and uncertainty in dissolved TP values examined: (1) 7 µg/L of dissolved TP, which is considered a conservative value below which little chance for cyanobacteria



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dominance in algal biomass; (2) 10 µg/L of dissolved TP, which is considered a more realistic value above which the frequency of cyanobacteria dominance over algal biomass increases (this is a mean annual TP concentration goal for the Central Basin established under the Great Lakes Water Quality Agreement [GLWQA]); (3) 20 µg/L of total TP based on an increasing trend of cyanobacteria dominance above 20 µg/L dissolved TP; (4) 35 µg/L of total TP based on a probability of cyanobacteria dominance increasing sharply above 35 µg/L dissolved TP; and (5) 50 µg/L of total TP based on a conservative total TP concentration estimate required to yield 26 µg/L concentration of Chlorophyll a (Chl-*a*) at which most people would tend to recognize a surface water algal bloom. This last criterion assumes that the Chl-*a* yield from TP is less than 0.52 g Chl-*a*/g TP, which is a highly conservative estimate for potential chlorophyll yield in pre-*Dreissena* invaded Lake Erie water. The yield of Chl-*a* yield in the presence of dreissenids can be almost an order of magnitude lower at 0.069 g Chl-*a*/g TP (Nicholls *et al.* 1999).

ST-Fate modeling of filtered/dissolved TP elutriate showed that a dissolved water column TP concentration of 7 µg/L would be achieved after five minutes within a maximum area of 354 x 148 ft, and that plume concentrations would rapidly dissipate below this concentration over time. Although it is clear that the dissolved TP plume decays rapidly to the criteria of 10 µg/L and 7 µg/L, note that a SRP concentration (SRP is a fraction of dissolved TP) of 30 µg/L has been shown to be a critical value to avoid the development of *Microcystis* blooms (Wetzel 2001). With respect to unfiltered TP elutriate, the modeling showed that a total TP water column concentration of 50 µg/L would be achieved after five minutes within an area of 320 x 125 ft, and that plume concentrations would rapidly dissipate below this concentration over time. Within 32 minutes, unfiltered TP concentrations between the 20 µg/L to 35 µg/L range would be readily achieved in the plume within areas of 1107 x 206 ft and 391 x 141 ft, respectively.

In summary, ample water column mixing for TP is available at both open-lake placement areas CLA-1 and CLA-4. The extent and duration of the predicted TP plumes within the boundaries of open-lake placement areas CLA-1 and CLA-4 are very short-lived and small. Modeled TP plumes at concentrations sufficient to stimulate a HAB (based on conservative criteria for both filtered and unfiltered concentrations) would be inadequate to trigger or pose an effect on the occurrence of HABs, or



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to significantly impact water quality in the Central Basin of Lake Erie.

(2) **PAHs**—Table 26 summarizes the results of this testing. Various dissolved PAH compounds were detected in the elutriates at very low concentrations.

(3) **PCBs**—Table 27 summarizes the results of this testing. Dissolved Aroclors were not detected in any of the elutriates at an MDL of 0.03 µg/L.

(4) **Pesticides**—Table 28 summarizes the results of this testing. Dissolved pesticides were not detected in any of the elutriates at an MDL of 0.001 µg/L.

(5) **Toluene**—Toluene was not measured in any of the elutriate tests. In lieu of elutriate data for toluene, conservatively predicted sediment elutriate concentrations were used to estimate concentrations that would be released from the dredged material to the water column during discharge. This approach can also be used to gauge the bioavailability of toluene because of its relatively low hydrophobicity ($\log K_{ow} = 2.7$) and chemical potential of toluene to be more in the dissolved phase. Since a significant amount of the residual toluene measured in the sediments would be lost during the dredging process and storage of the dredged material in the scow, such estimates should be considered to be conservative. A conservative sediment organic carbon/water partition coefficient (K_{oc}) for toluene was selected from the literature; specifically, the geometric mean of 140 L/kg across 12 measured values reported in USEPA (2002b). A DMMU-specific dissolved concentration of toluene (K_d) was then calculated for each management unit using a sediment-specific K_d computed using the K_{oc} and composited TOC. Next, the total toluene concentration in the simulated elutriate slurry was calculated from a 1:4 dilution of the composited sediment using a volume based compositing of the dry bulk densities and bulk sediment concentrations. The dissolved fraction of the total toluene concentration was calculated for equilibrium conditions based on the simulated solids concentration and the K_d of each DMMU. The fraction dissolved was about 97% for all three management units.

Bulk sediment toluene data from Table 11 and TOC data from Table 4, along with the K_{oc} of 140 L/kg were used in the predictions. Across DMMU-1, DMMU-2a and DMMU-2b, predicted dissolved concentrations at discrete sites ranged from 0.075 µg/L (CH-1) to 2485 µg/L (CH-8).



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Calculated composite sediment dissolved elutriate concentrations were 1097 µg/L (DMMU-1), 1752 µg/L (DMMU-2a) and 268 µg/L (DMMU-2b). Toluene was identified as a water column PCOC and would require dilution during dredged material discharge operations.

Assuming a maximum sediment toluene release of 2485 µg/L (Site CH-8 within DMMU-2b) (worst-case) from the dredged material discharge, application of the ST-Fate model indicated that the effluent would achieve an outside mixing zone maximum (OMZM) WQS of 560 µg/L for the Protection of Aquatic Life (OEPA 2013) during the first two minutes after discharge. The maximum concentration in the plume prior to migrating outside of the placement area when discharging in the middle of the placement area under the highest velocity conditions was about 5 µg/L and well below even the OMZA of 62 µg/L. Since this OMZA WQS is a chronic criterion value and intended to apply to fixed and continuous discharges, it is a very conservative value toward the evaluation of the intermittent, discontinuous discharges characteristic of mechanical dredged material discharges via scow.

In summary, ample water column mixing for toluene is available at both open-lake placement areas CLA-1 and CLA-4.

b. Water column bioassays

The results of these tests are summarized in Table 29.

(1) *C. dubia*—Mean survival associated with the lake site water (80±28%) was not statistically different than the laboratory control (100%). The mean survival of this test species exposed to the undiluted (100%) elutriate ranged from 76±17% (DMMU-2b) to 100% (DMMU-1). Relative to the site water, the undiluted elutriates showed no statistically significant differences in mean survival. These bioassay data indicate no significant acute toxicity and show that the release of contaminants from the dredged material to the water column during open-water placement would not result in any contaminant-related unacceptable, adverse impacts.

(2) *P. promelas*—Mean survival associated with both the lake site water and laboratory control were 100%. The mean survival of this test species exposed to the undiluted elutriate ranged from 0 (DMMU-2a and DMMU-2b) to 98±4% (DMMU-1). Other than the undiluted elutriates of DMMU-2a and DMMU-2b, no other elutriate concentration showed statistically significant differences in mean survival relative to lake



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site water. The DMMU-2a and DMMU-2b bioassay data both yielded a no observed effect concentration (NOEC), lowest observed effect concentration (LOEC) and LC₅₀ of 50%, 100% and 67%, respectively. These bioassay data indicated acute toxicity associated with the undiluted DMMU-2a and DMMU-2b elutriates. Bioassay data on the remaining elutriates across the management unit samples showed insignificant acute toxicity.

In the DMMU-2a and DMMU-2b 25%, 50% and 100% elutriate treatments, dissolved oxygen (DO) fell below the 40% saturation guidance value (USEPA/USACE 1998b) at one point during the test. It is unlikely that the 100% mortality observed in the undiluted elutriates was attributable solely to low DO because no significant toxicity was evidenced in the 25% and 50% elutriates. Further, subsequent toxicity reduction evaluation (TRE) testing of the DMMU-2a and DMMU-2b undiluted elutriates with aeration exceeding 40% also yielded complete mortality, confirming that DO was not the cause of the mortality in the original bioassay.

The collective results of these water column bioassays suggest that the toxicity observed in the *P. promelas* tests on the DMMU-2a and DMMU-2b elutriate was related to ammonia. First, the toxicity occurred in the *P. promelas* bioassay and not in the *C. dubia* bioassay; *C. dubia* (and other invertebrates) is generally less sensitive to ammonia relative to fish. Further, ammonia levels measured in the DMMU-2a and DMMU-2b elutriates were sufficient to cause the observed toxicity to *P. promelas*. Unionized ammonia (usually the form most responsible for causing toxicity) was 1.0 mg/L and 0.9 mg/L for the DMMU-2a and DMMU-2b elutriates, respectively, and was much lower at <0.1 mg/L for the DMMU-1 elutriate. The unionized ammonia concentrations in the undiluted DMMU-2a and DMMU-2b elutriates were equal to or exceeded *P. promelas* LC50 values reported in the literature (e.g., Nimmo *et al.* 1989; Buhl *et al.* 2002).

In an attempt to decipher the cause of the observed toxicity to *P. promelas*, a TRE was performed on the DMMU-2a and DMMU-2b samples. In order to accomplish this, the undiluted elutriates, and undiluted elutriate treatments slightly modified for pH, zeolite ammonia stripping and ethylenediaminetetraacetic acid (EDTA) metal chelating were performed. As with the first round of tests, 100% mortality resulted in the undiluted DMMU-2a and DMMU-2b elutriates. For both elutriates, the zeolite stripping treatment completely reduced toxicity and the EDTA treatment did not reduce toxicity. While zeolite can also



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bind some metals, SET data indicate that all dissolved metal concentrations in the DMMU-2a and DMMU-2b sediment elutriates (Table 24) were protective of aquatic life. These TRE results strongly indicate that ammonia was the cause of toxicity in the DMMU-2a and DMMU-2b undiluted elutriates. Therefore, an application factor of 10 was used to compute a limited permissible concentration (LPC) of 6.7%, as opposed to using an application factor of 100 to compute a LPC of 0.67% if the toxicity were a result of toxicants of other than ammonia.

Assuming a LPC of 6.7% for the dredged material discharge from DMMU-2a and DMMU-2b, application of the ST-Fate model indicated that the effluent would achieve the LPC during the first five minutes after discharge and within 140 ft of the discharge. If the toxicity were not caused by ammonia and an LPC of 0.67% were used (as a worst-case), application of the ST-Fate model indicated that the effluent would achieve the LPC during the first forty minutes after discharge under the lowest velocity conditions and within 2300 ft of the discharge under the highest velocity conditions.

Collectively, these SET and water column bioassay data show that the release of contaminants from the dredged material to the water column during open-water placement would not result in any contaminant-related unacceptable, adverse impacts to the aquatic ecosystem.

3.2.6 COCs

Toluene was identified as a sediment COC in most of the management unit sediments. PCBs and ΣDDT were identified as sediment COCs in some or all of the management unit sediments. Nickel was identified as a sediment COC at Site CH-2 within DMMU-1. Ammonia-N and toluene were identified as PCOCs in the water column. Further evaluation eliminated all PCOCs and COCs.

3.3 Sediment quality assessment with trends over time

This section assesses the 2012 management unit data in concert with other harbor sediment data generated under USACE (2007) and Kreitinger *et al.* (2011) in order to decipher trends in sediment quality over the last five years. To facilitate comparisons among the three sampling events, Table 30 summarizes the 2007 and 2010 sampling sites relative to those used in 2012, and also groups the sites into management units that were either explicit (as in 2010 and 2012) or combined afterward



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(DMMU-2 in 2007) for the purposes of data interpretation. Note that there were fewer observations undertaken in the 2007 and 2010 events.

3.3.1 Bulk sediment analyses

a. Physical testing

The particle size data on the management unit sediments across the 2007, 2010 and 2012 investigations showed both variation and similarities in physical composition over time. In 2012, sediments within the general area of DMMU-1 were more coarse-grain in nature (average 69.1% [Sites CH-1 through CH-6]), then mostly fine-grain at all of the downstream sites in DMMU-2a and DMMU-2b. In 2010, sediments within the general area of DMMU-1 were comparably much less coarse-grain being comprised of less than 33.3% (Site CH-1) sands and gravels. Similar to the 2012 investigation, downstream sediments were mostly fine-grain. In 2007, sediments within the general area of DMMU-1 were about one-half coarse-grain (average 55.2% sands and gravels [Sites CH-1 through Ch-5]) and, as in the 2007 and 2012 investigations, downstream sediments were mostly fine-grain.

b. Chemical testing

(1) *Inorganic analyses*

(a) **Metals**—Copper, lead and zinc were used as metal indicators because they have been shown to be closely correlated with nine metals including cadmium, cobalt, chromium, copper, iron, manganese, nickel, lead and zinc (Birch and Olmos 2008). These metals, and nickel (due to its higher concentration at Site CH-2), were closely examined to decipher contamination and/or bioavailability trends over time. Where appropriate, bulk concentrations were normalized to clay or TOC to better gauge metal bioavailability. Since AVS (or SEM) data were either not available or not available on discrete sediment samples, AVS binding was not included as a factor in the reduction of cationic metal bioavailability.

•**Copper**—Except for discrete site CH-2, there was a decline across all discrete sites between 2007 and/or 2010, and 2012 (Figure 6). For DMMU-1, there was a net decline between 2007 (geometric mean 50.4 mg/kg) and 2012 (geometric mean 41.7 mg/kg). Data on DMMU-2 indicate a net decline in bulk concentrations between 2007 (geometric mean 47



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mg/kg) and/or 2010 (geometric mean 49.2 mg/kg), and 2012 (geometric mean 36.4 mg/kg).

Simple linear regression showed an inverse relationship of bulk concentration to both clay and TOC. Therefore, it was assumed that neither variable had a significant influence on sediment partitioning (and bioavailability) of copper.

•*Lead*—There was an increase across almost all discrete sites between 2007 and 2010. However, there was a decline across all discrete sites between 2007 and/or 2010, and 2012. For DMMU-1, there was a net decline between 2007 (geometric mean 35.3 mg/kg) and 2012 (geometric mean 26.3 mg/kg). Data on DMMU-2 indicate a small decline in bulk concentrations between 2007 (geometric mean 39.4 mg/kg) and/or 2010 (geometric mean 43.9 mg/kg), and 2012 (geometric mean 36.7 mg/kg).

Simple linear regression showed a positive relationship of bulk concentration to both clay ($R^2=0.52$) and TOC ($R^2=0.56$). Therefore, it was assumed that both variables had a measureable influence on sediment partitioning of lead. Clay-normalized values declined across all discrete sites between 2007 and/or 2010, and 2012 (Figure 7). For DMMU-1, there was a substantial decline between 2007 (geometric mean 337 mg/kg-clay) and 2012 (geometric mean 18.6 mg/kg-clay). Data on DMMU-2 indicate a substantial decline in clay-normalized lead concentrations between 2007 (geometric mean 320 mg/kg-clay) and 2010 (geometric mean 12.8 mg/kg-clay), and 2012 (geometric mean 5.43 mg/kg-clay). TOC-normalized concentrations increased across all discrete sites between 2007/2010, and 2012 (Figure 8). For DMMU-1, there was a substantial increase between 2007 (geometric mean 1842 mg/kg-TOC) and 2012 (geometric mean 3324 mg/kg-TOC). Data on DMMU-2 indicate an increase in TOC-normalized lead concentrations between 2007 (geometric mean 320 mg/kg-TOC) and 2010 (geometric mean 1583 mg/kg-TOC), and 2012 (geometric mean 2324 mg/kg-TOC). Nevertheless and despite this overall increase in lead concentrations with respect to TOC, none of the bulk concentrations measured in 2012 would appear to be of toxicological significance.

•*Nickel*—There was a small increase across almost all discrete sites between 2007 and 2010. However, except for Site CH-2, there was a decrease across all discrete sites between 2007 and/or 2010, and 2012 (Figure 9). For DMMU-1, there was a small decrease between 2007 (geometric mean 29.6 mg/kg) and 2012 (geometric mean 35.1 mg/kg). Data on DMMU-2 indicate generally uniform bulk concentrations between 2007



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(geometric mean 30.0 mg/kg) and/or 2010 (geometric mean 35.1 mg/kg), and 2012 (geometric mean 30.8 mg/kg).

Simple linear regression showed an inverse relationship of bulk concentration to both clay and TOC. Therefore, it was assumed that neither variable had a significant influence on sediment partitioning of nickel.

•**Zinc**—There was an increase across almost all discrete sites between 2007 and 2010. However, there was a decline across all discrete sites between 2007 and/or 2010, and 2012. For DMMU-1, there was a small decline between 2007 (geometric mean 152 mg/kg) and 2012 (geometric mean 143 mg/kg). Data on DMMU-2 indicate a net decline or general uniformity in bulk concentrations between 2007 (geometric mean 194 mg/kg) and/or 2010 (geometric mean 206 mg/kg), and 2012 (geometric mean 165 mg/kg).

Simple linear regression showed a positive relationship of bulk concentration to both clay ($R^2=0.36$) and TOC ($R^2=0.05$). However, the straight line relationship between bulk concentration and TOC was extremely weak. Therefore, it was assumed that only clay had a measureable influence on sediment partitioning of zinc. Except for Site CH-2, clay-normalized values declined across all discrete sites between 2007 and/or 2010, and 2012 (Figure 10). For DMMU-1, there was a substantial decline between 2007 (geometric mean 1450 mg/kg-clay) and 2012 (geometric mean 101 mg/kg-clay). Data on DMMU-2 suggest a substantial decline in clay-normalized zinc concentrations between 2007 (geometric mean 1652 mg/kg-clay) and 2010 (geometric mean 60.2 mg/kg-clay), and 2012 (geometric mean 24.3 mg/kg-clay).

(b) Other inorganics

•**TOC**—TOC data on the management unit sediments across the 2007, 2010 and 2012 investigations showed both variation and similarities. In 2012, sediments within the upstream end of DMMU-1 showed low TOC content (average 0.42% [Sites CH-1 and CH-2]), then relatively higher levels at downstream sites in the lower part of DMMU-1, and DMMU-2a and DMMU-2b, ranging from 0.9% to 2.4% (average 1.56% [Sites CH-3 through CH-15]) (Table 4). TOC content in 2010 was substantially higher and more consistent across the management unit sediments, ranging from 2.4% to 3.9% (average 3.1% [Sites CH-1 through CH-8]). In 2007, TOC content was moderate, fairly consistent and more comparable to the 2012 investigation, ranging from 1.4% to 2.5% (average 2.1% [Sites CH-1



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through CH-8]).

- TP**—Simple linear regression showed a positive relationship of bulk concentration to percent silts/clays ($R^2=0.73$). Silt/clay-normalized TP values increased across all discrete sites between 2010 and 2012 (Figure 11). For DMMU-1, there was a substantial increase (geometric means 523 mg/kg to 2524 mg/kg) and data on DMMU-2 suggest less but still substantial increase (geometric means 456 mg/kg to 994 mg/kg).

As previously discussed, the most meaningful endpoint with respect to sediment-associated TP is the dissolved concentration predicted to be released to the water column during open-lake placement (i.e., elutriate test result). Although releases from sediments are typically less than 1% of bulk concentration, bulk concentration-based values are typically not indicative of (e.g., proportional to) dissolved TP releases. Both filtered and unfiltered SET data are available on the management unit sediment composites from 2010 (Kreitinger *et al.* 2011) and 2012 (Table 25). Because filtered TP values (e.g., water concentrations of TP in general) inherently vary to some degree, another comparison of TP SET data across the two sampling events in this case is through the use of TSS-normalized unfiltered elutriate concentrations. Figure 12 graphs these values and shows an order of magnitude decline in TSS-normalized TP concentrations in elutriates for both DMMU-1 (2.58 mg/g-TSS to 0.69 mg/g-TSS) and DMMU-2 (4.05 mg/g-TSS to 0.71 mg/g-TSS) between the two sampling events. This demonstrates that the bioavailability of TP in the elutriate, as it is associated with TSS, was substantially lower in 2012 than 2010. Figure 13 shows the dissolved TP in elutriates between 2010 and 2012. The inordinately high dissolved TP of 6 mg/L in the DMMU-2 elutriate sample from 2010 appeared to be an anomaly because of the much lower dissolved TP concentrations for DMMU-1 (<0.02 mg/L) coupled with similar TSS concentrations in the unfiltered elutriates. Figure 14 also indicates an increase in dissolved TP for both management units between the two sampling events but assumes that the measured 6 mg/L measurement for DMMU-2 in 2010 was an anomaly. Across DMMU-1 and DMMU-2, the increase in dissolved TP releases between 2010 and 2012 was less than 0.03 mg/L.

- Ammonia**—Simple linear regression showed a positive relationship of bulk concentration to percent silts/clays ($R^2=0.80$). Silt/clay-normalized TP values increased across all discrete sites between 2010 and 2012 (Figure 15). For DMMU-1, there was a substantial increase (geometric means 7.02 mg/kg to 260 mg/kg) and data on DMMU-2 also suggest a substantial increase (geometric means 5.93 mg/kg to 254



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mg/kg).

•**TKN**—Simple linear regression showed a positive relationship of bulk concentration to percent silts/clays ($R^2=0.58$). Silt/clay-normalized TKN values increased across all discrete sites between 2010 and 2012 (Figure 16). For DMMU-1, there was a substantial increase (geometric means 2177 mg/kg to 4095 mg/kg) and data on DMMU-2 also suggest a substantial increase (geometric means 1690 mg/kg to 2386 mg/kg). However, like TP and ammonia-N, the most relevant way to characterize sediment-associated TKN is through dissolved elutriate measurements. Since TKN elutriate data are not available under the 2007 and 2010 sampling events, dissolved releases could not be assessed among the three sampling events.

(2) *Organic analyses*

(a) **Total PCBs**—Bulk tPCB concentrations were normalized to TOC because PCBs are typically assumed to predominantly partition to the OC carbon compartment in sediment. Although there was an increase in TOC-normalized PCBs at two discrete sites (CH-2 and CH-3), there was an overall uniformity of PCB residues between 2007 (geometric mean 10665 ug/kg-TOC) and 2012 (geometric mean 10776 ug/kg-TOC) in DMMU-1 (Figure 17). Data on DMMU-2 suggest a decline in sediment-associated PCB residues between 2007 (geometric mean 7242 ug/kg-TOC) and 2012 (geometric mean 5719 ug/kg-TOC). Bulk tPCB concentrations were very low in 2010 relative to both 2007 and 2012.

(b) **ΣDDT**—Like PCBs, bulk ΣDDT concentrations were normalized to TOC because DDT and its metabolites are typically assumed to predominantly partition to the OC carbon compartment in sediment. Although there was an increase in TOC-normalized ΣDDT concentrations at several discrete sites between 2007 and 2012 (CH-2, CH-3, CH-6 and CH-14 in both management units), there was an overall decline between 2007 (geometric mean 1450 ug/kg-TOC) and 2012 (geometric mean 1151 ug/kg-TOC) in DMMU-1 (Figure 18). Data on DMMU-2 also suggest a decline in sediment-associated ΣDDT residues between 2007 (geometric mean 1569 ug/kg-TOC) and 2012 (geometric mean 1209 ug/kg-TOC). Bulk ΣDDT concentrations were low in 2010 relative to both 2007 and 2012.

3.3.2 Solid phase bioassays

Solid phase bioassay data were examined across the 2007 (USACE 2007),



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2010 (Kreitinger *et al.* 2011) and 2012 (USAERDC 2012) sampling events. The relevant biological measurement endpoints used to assess toxicity in these tests included *H. azteca* survival, and *C. dilutus* survival and growth. Delineated management units (when present) for the bioassay data corresponded generally well across the three events: DMMU-1 used in 2012 was similar to DMMU-1 in both 2010 and 2007, and the combined DMMU-2a and DMMU-2b were spatially equivalent to DMMU-2 from 2010. In 2007, no management unit downstream of DMMU-1 (i.e., DMMU-2, DMMU-2a or DMMU-2b) was used. Trends for these bioassay data were grouped into DMMU-1 and DMMU-2, and assessed as follows:

a. DMMU-1—Bioassay survival data for *H. azteca* and *C. dilutus* are graphed as control-corrected values in Figure 19 (bioassay data were control-corrected to eliminate variation due to testing laboratory). Mean survival of *H. azteca* showed a steady increase in control-corrected values across the three sampling events (59.1% in 2007, 93.6% in 2010 and 104% in 2012). For *C. dilutus*, a trend toward increased survival is evidenced across the three sampling events (76.6% in 2007 to 85.1% in 2012), although there was a reduction between 2010 (106%) and 2012. Note that USEPA (2004) indicates that control-corrected survival rates for *C. dilutus* greater than or equal to an arbitrary 75% is an acceptable measurement endpoint for acute toxicity. Furthermore, the measured mean survivals were not statistically different than those for the open-lake placement area sediments (see paragraph 3.2.2). Mean control-corrected *C. dilutus* growth increased between 2010 (1.23 g) and 2012 (1.70 g) (Figure 20).

b. DMMU-2—Bioassay survival data for *H. azteca* and *C. dilutus* are graphed as control-corrected values in Figure 21. Mean survival of *H. azteca* increased between the 2010 (61.7%) and 2012 (97.8%) sampling events. A reduction of *C. dilutus* control-corrected survival is evidenced between 2010 (112%) and 2012 (93.6%) which was not biologically significant. Mean control-corrected *C. dilutus* growth increased between 2010 (0.83 g) and 2012 (1.08 g) (Figure 21).

3.3.3 Summary

Evaluation of sediment quality data across the 2002, 2007 and 2012 sampling events indicated either an overall net decline in contamination or contaminant availability, and/or no ecologically meaningful increase in sediment contaminant-based concentrations and/or toxicity over time. This is based on the following findings:



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a. Metals—The only evidenced increase in indicator metals between 2007 and 2012, on average across both management units, was TOC-normalized lead. This would not appear to be of toxicological significance given the low measured bulk concentrations (maximum discrete concentrations 52.9 mg/kg and 44 mg/kg in 2010 and 2012, respectively), which themselves showed a net decline between 2010 and 2012. While bulk nickel concentrations substantially increased at discrete Site CH-2 between 2010 (33.6 mg/kg) and 2012 (138 mg/kg), average management unit concentrations showed general uniformity across 2007, 2010 and 2012.

b. TP—The overall bioavailability of TP (unfiltered elutriate normalized to TSS) in dredged material elutriates was lower in 2012 than in 2010. However, if it is assumed that one high TP SET measurement from the 2010 sampling event is an anomaly, predicted releases of dissolved TP between the two sampling events showed a minor increase between 2010 and 2012. This higher release is attributable to measureable TSS in the filtered elutriate samples.

c. PCBs and DDT—The data indicate a decline or overall uniformity in sediment-associated PCBs and DDT (normalized to TOC) residues across the management units between 2007 and 2012.

d. Solid phase bioassays—With respect to the three biological measurement endpoints, the bioassay data show that the toxicity of the sediments in DMMU-1 and DMMU-2 has either declined and/or has been at an acceptable level over the last five years. A steady increase in control-corrected survival was observed for *H. azteca* between 2007 (for DMMU-1 sediments only because DMMU-2 was not yet designated a management unit), 2010 and 2007. While there was an observed increase in control-corrected *C. dilutus* survival between 2007 and 2012 for DMMU-1 sediments, there was also a decrease in control-corrected survival between 2010 and 2012 for both DMMU-1 and DMMU-2 sediments. Nevertheless, the survivals observed in 2012 were acceptable. Finally, control-corrected *C. dilutus* growth in both DMMU-1 and DMMU-2 increased between 2010 and 2012.

4.0 CONCLUSION

Based on the data contained in USAERDC (2012) and other relevant information, contamination and toxicity associated with Cleveland Harbor Federal navigation channel sediments, as represented by management units DMMU-1, DMMU-2a and DMMU-2b, has been shown to be comparable relative to open-lake placement area sediments and/or would



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not represent any appreciable increased toxicological risk to the affected aquatic ecosystems if placed at open-lake areas CLA-1 or CLA-4. Therefore, subject to three conservative limitations, all material dredged from DMMU-1, DMMU-2a and DMMU-2b meets Federal guidelines for open-lake placement. These controls are based on water quality modeling, and the PCB and DDT/DDD/DDE bioaccumulation measurement endpoints in receptor species', and include: (1) use of mechanical equipment to dredge and discharge the dredged material; (2) spatially limiting the placement of material dredged from DMMU-2a and DMMU-2b to a one-square mile area within CLA-4 and CLA-1; and (3) spatially limiting the placement of material dredged from DMMU-1 to a one-square mile area within CLA-1 and two-third square mile area within CLA-4.

A detailed examination of sediment quality data across the 2007, 2010 and 2012 sampling events indicated a net decline or no ecologically meaningful increase in sediment contaminant-based concentrations and/or toxicity over time.

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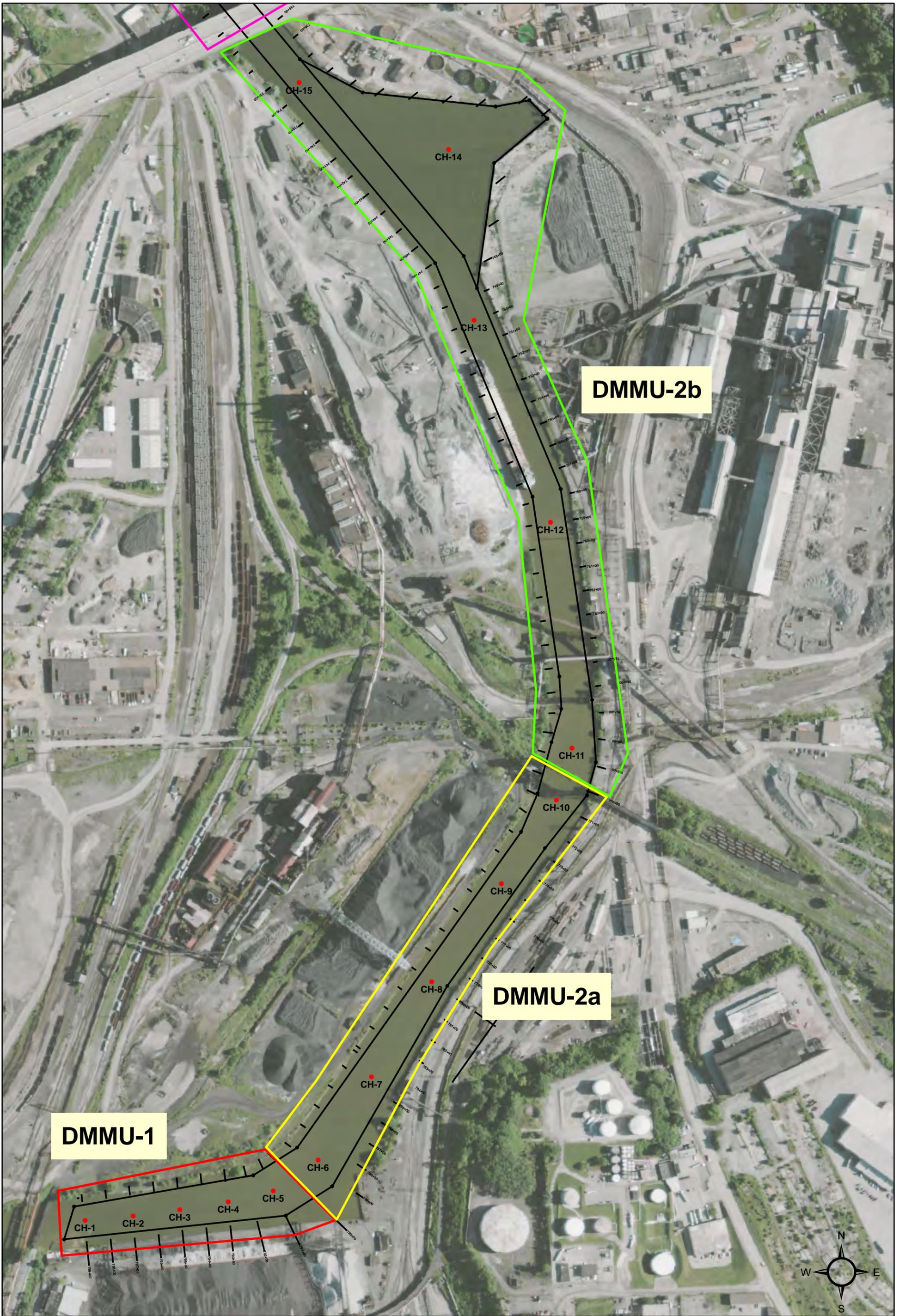


FIGURE 1. Cleveland Harbor sediment sampling sites and management units in Upper Cuyahoga River Channel.

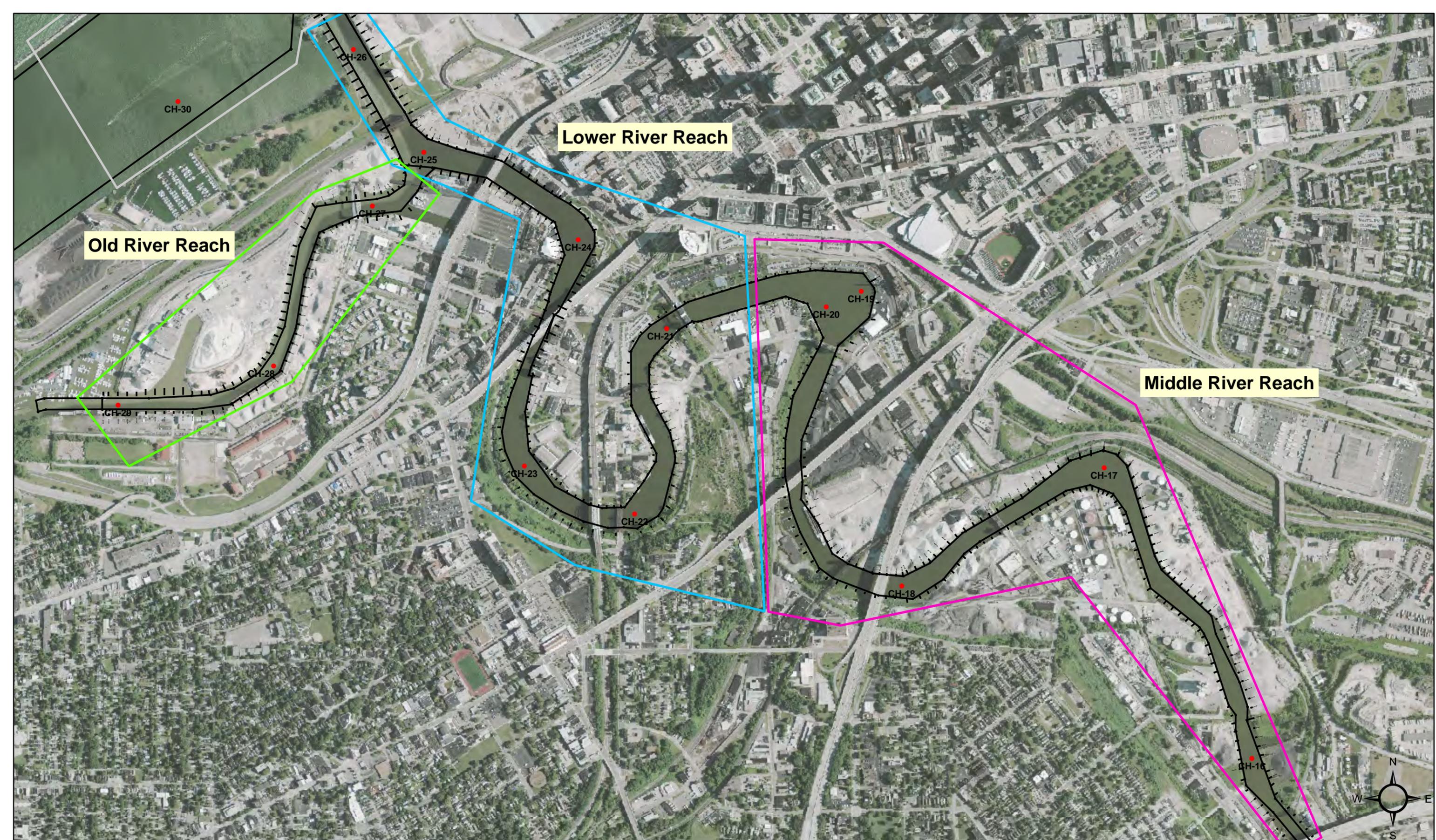


FIGURE 2. Cleveland Harbor sediment sampling sites and composite sample boundaries for the Middle and Lower Cuyahoga River Channel and Old River Channel reaches.



FIGURE 3. Cleveland Harbor Sediment sampling sites and composite sample boundaries for the Outer Harbor Channel reach.

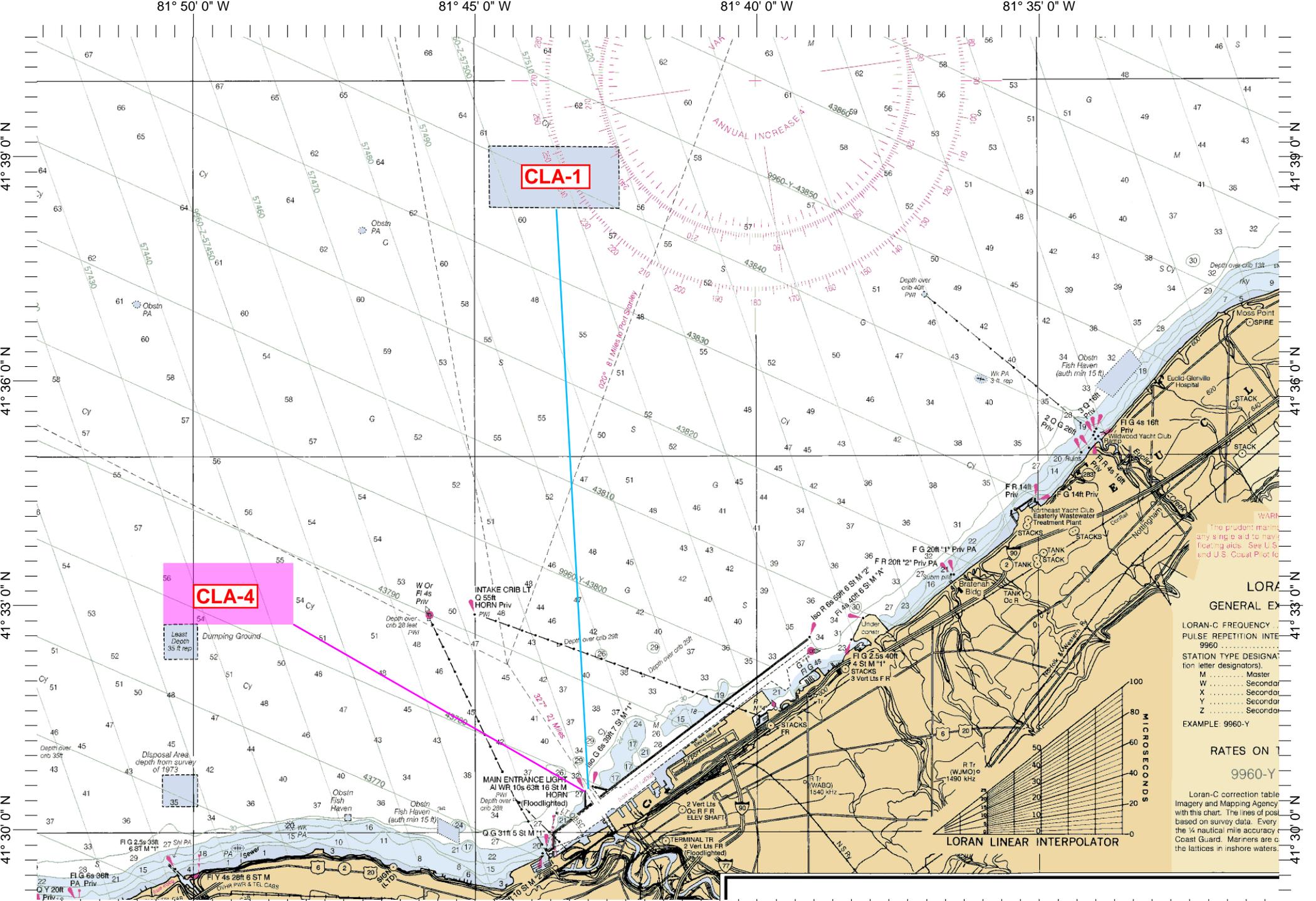


FIGURE 4. Proposed open-lake placement areas CLA-1 and CLA-4 for material dredged from Cleveland Harbor Upper Cuyahoga River Channel.

FIGURE 5. Graph of organic matter:total organic carbon ratios for upper Cuyahoga River Channel sediments.

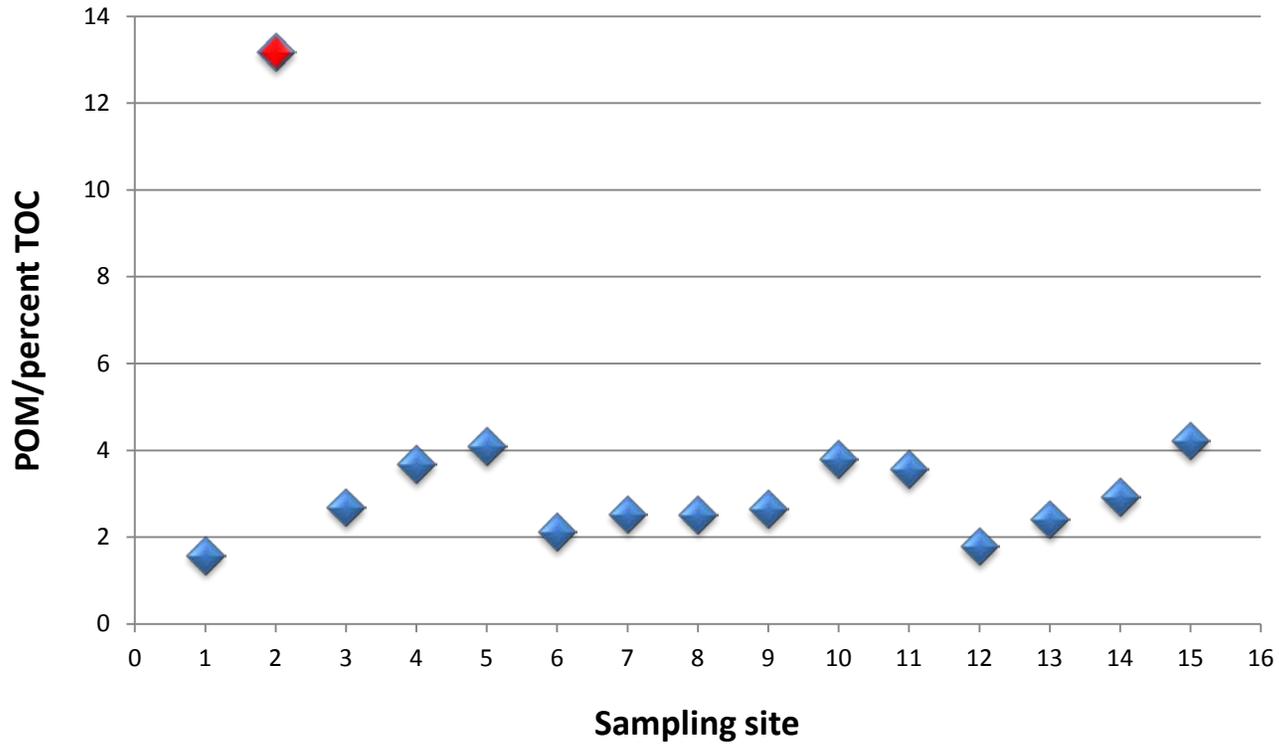


FIGURE 6. Bulk sediment concentrations of copper in upper Cuyahoga River Channel sediments in 2007, 2010 and 2012.

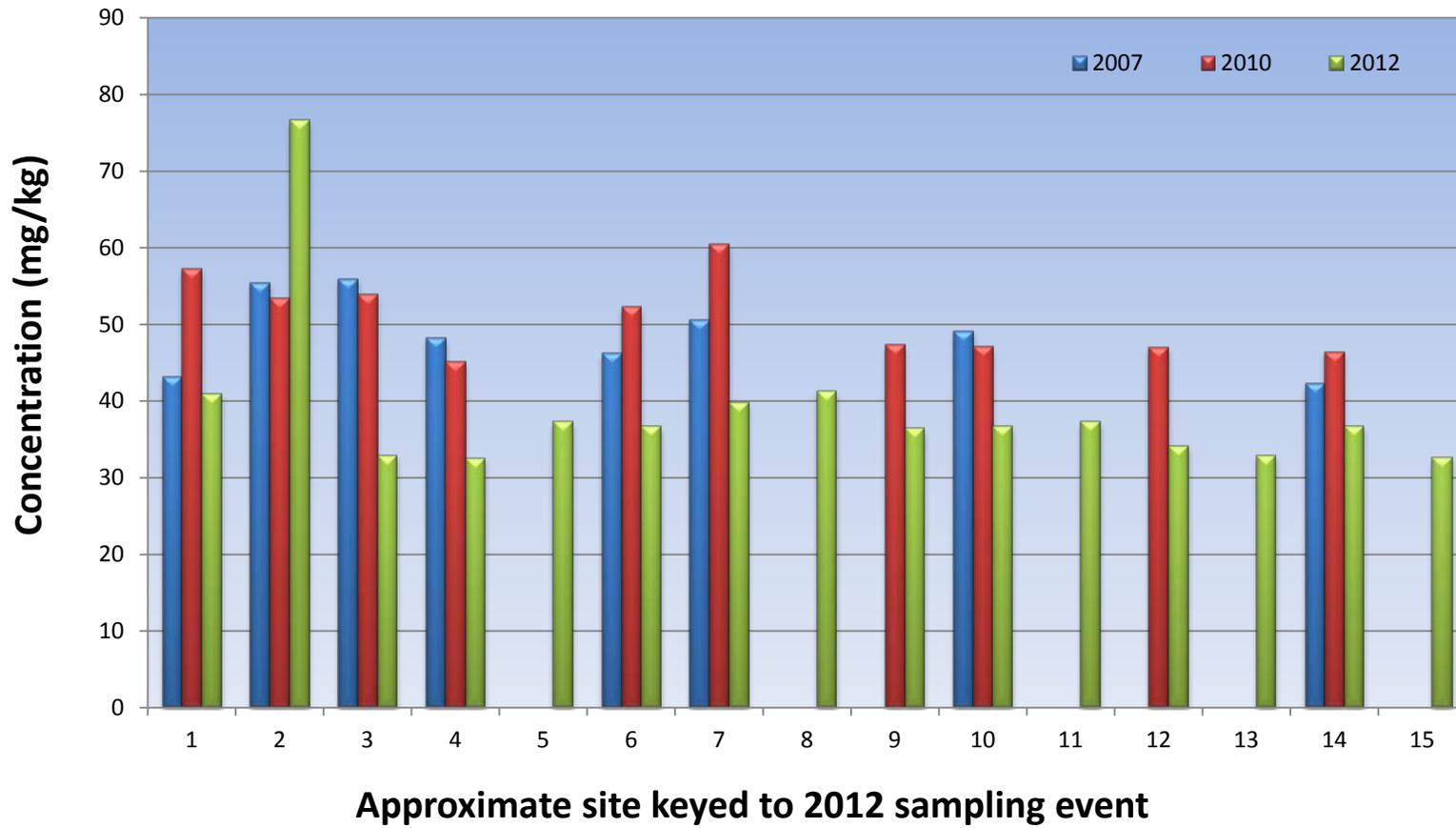


FIGURE 7. Clay-normalized sediment concentrations of lead in upper Cuyahoga River Channel sediments in 2007, 2010 and 2012.

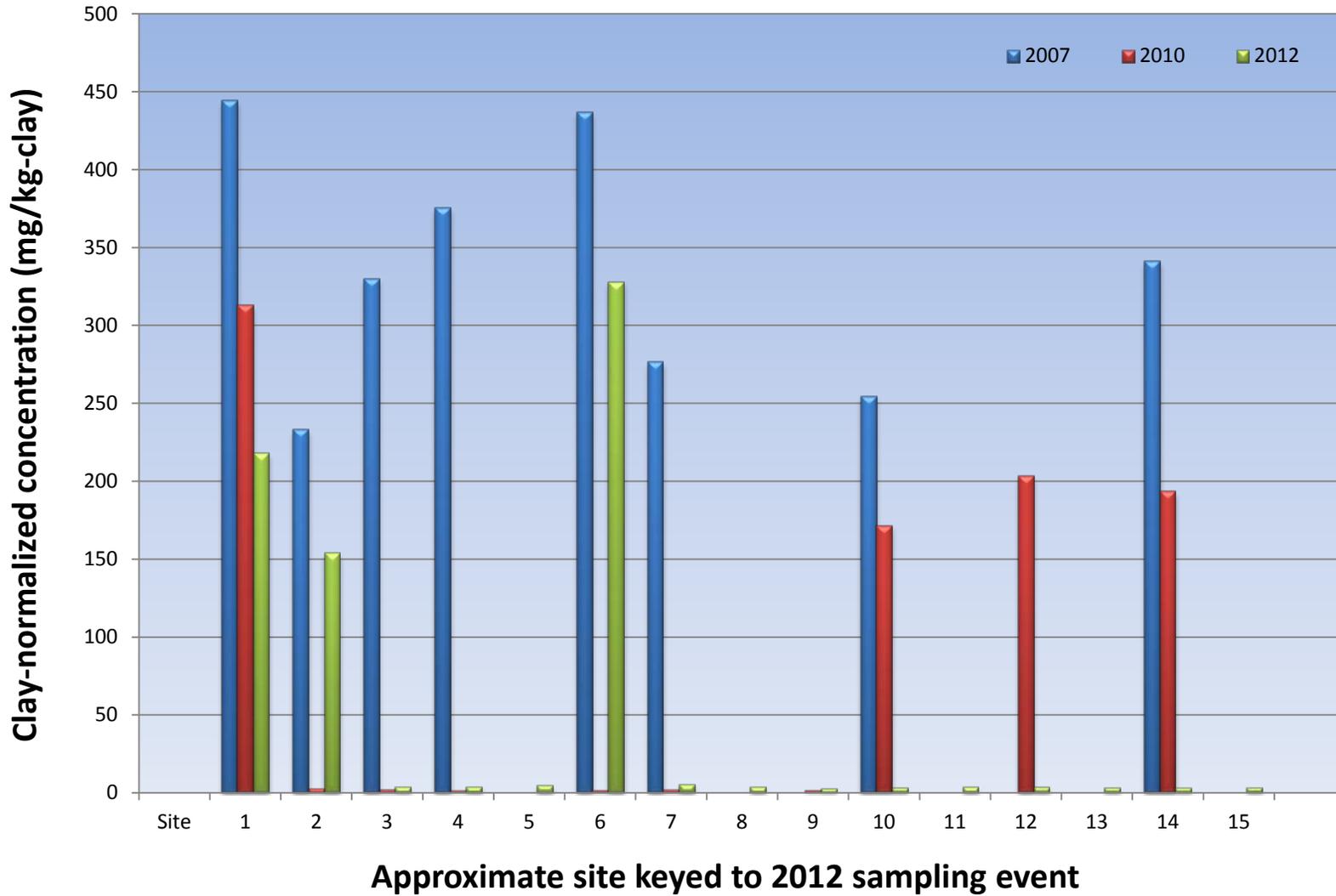


FIGURE 8. TOC-normalized sediment concentrations of lead in upper Cuyahoga River Channel sediments in 2007, 2010 and 2012.

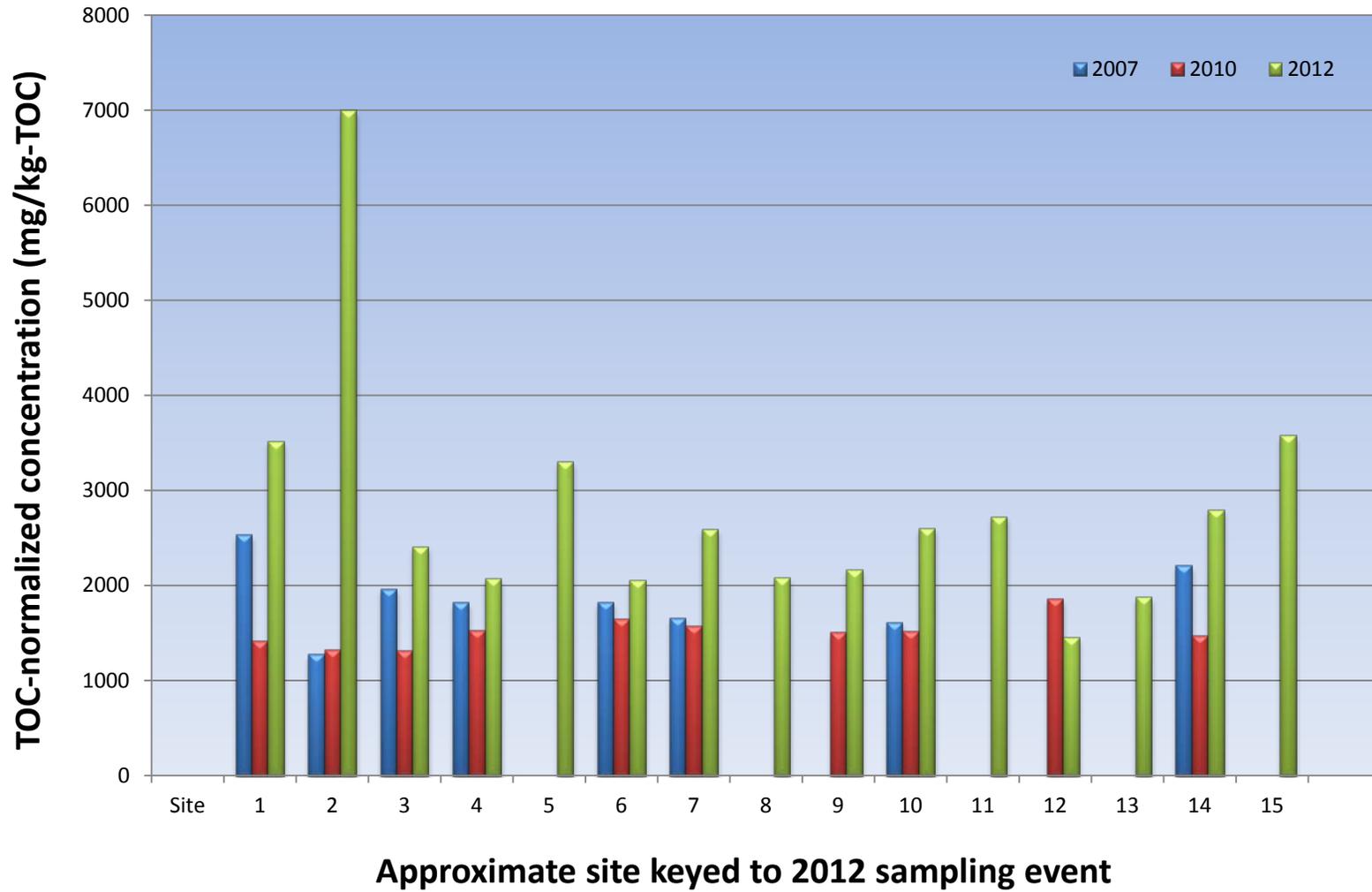


FIGURE 9. Bulk sediment concentrations of nickel in upper Cuyahoga River Channel sediments in 2007, 2010 and 2012.

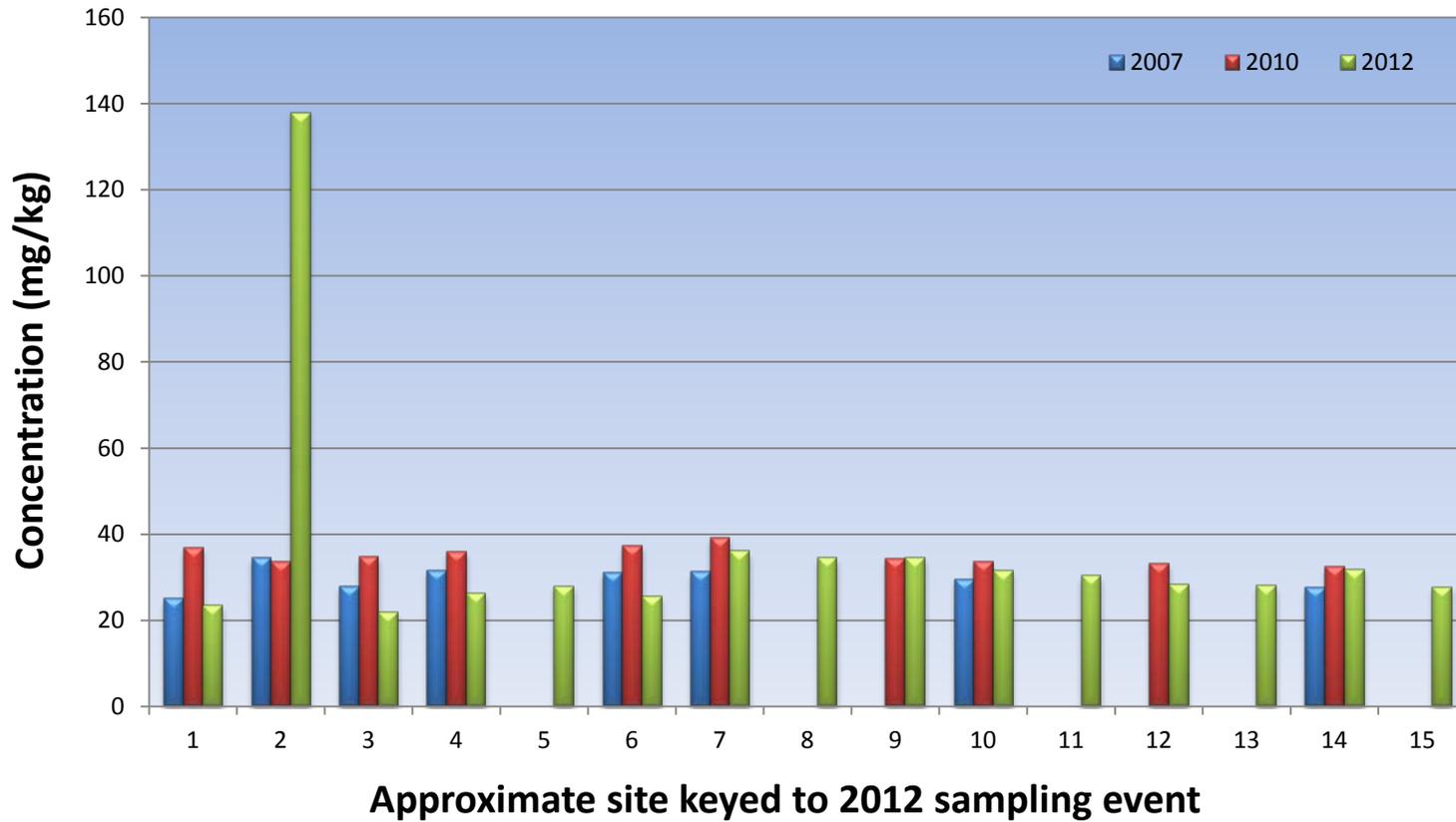


FIGURE 10. Clay-normalized sediment concentrations of zinc in upper Cuyahoga River Channel sediments in 2007, 2010 and 2012.

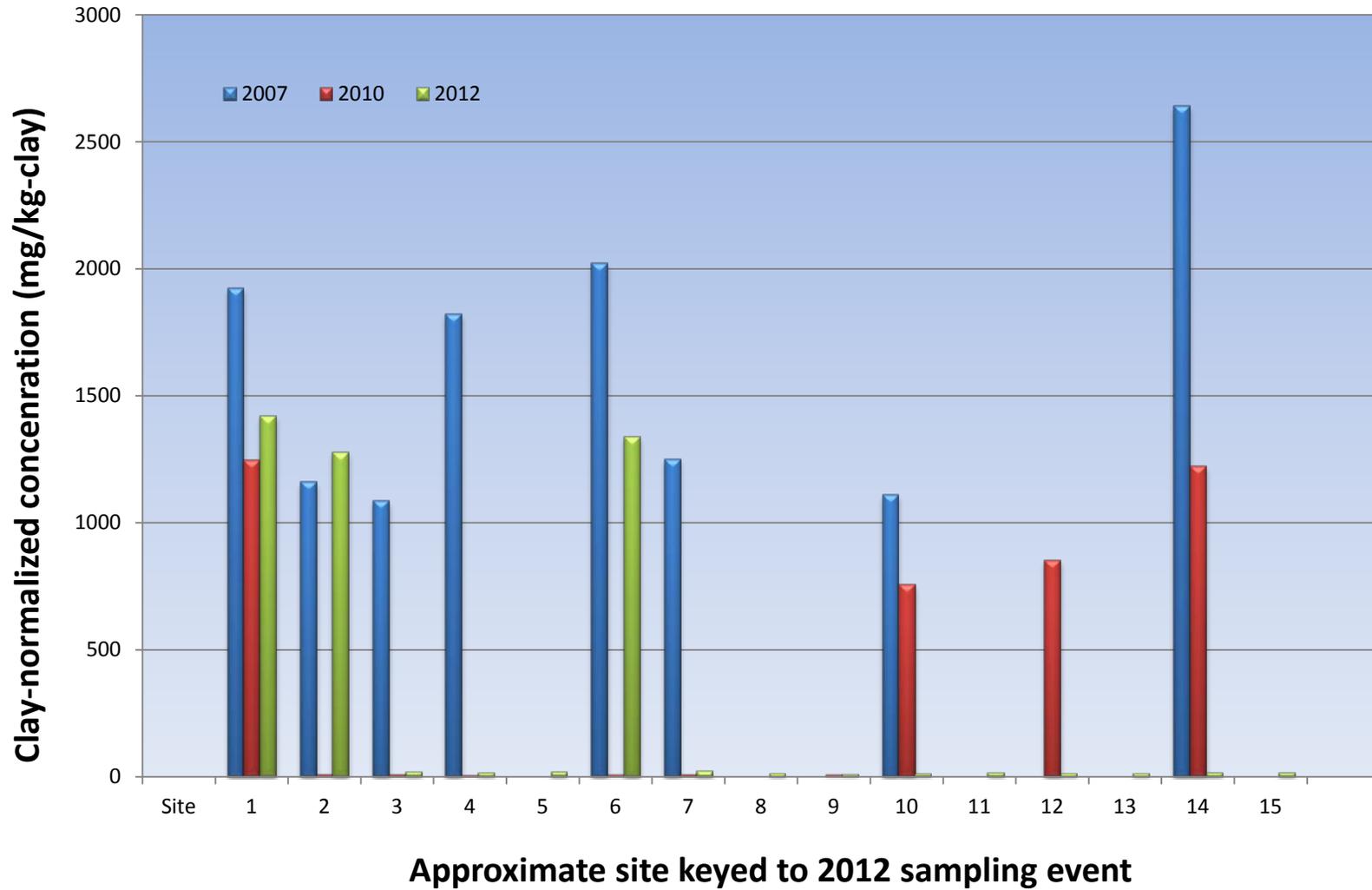


FIGURE 11. Silt/clay-normalized sediment concentrations of TP in upper Cuyahoga River Channel sediments in 2010 and 2012.

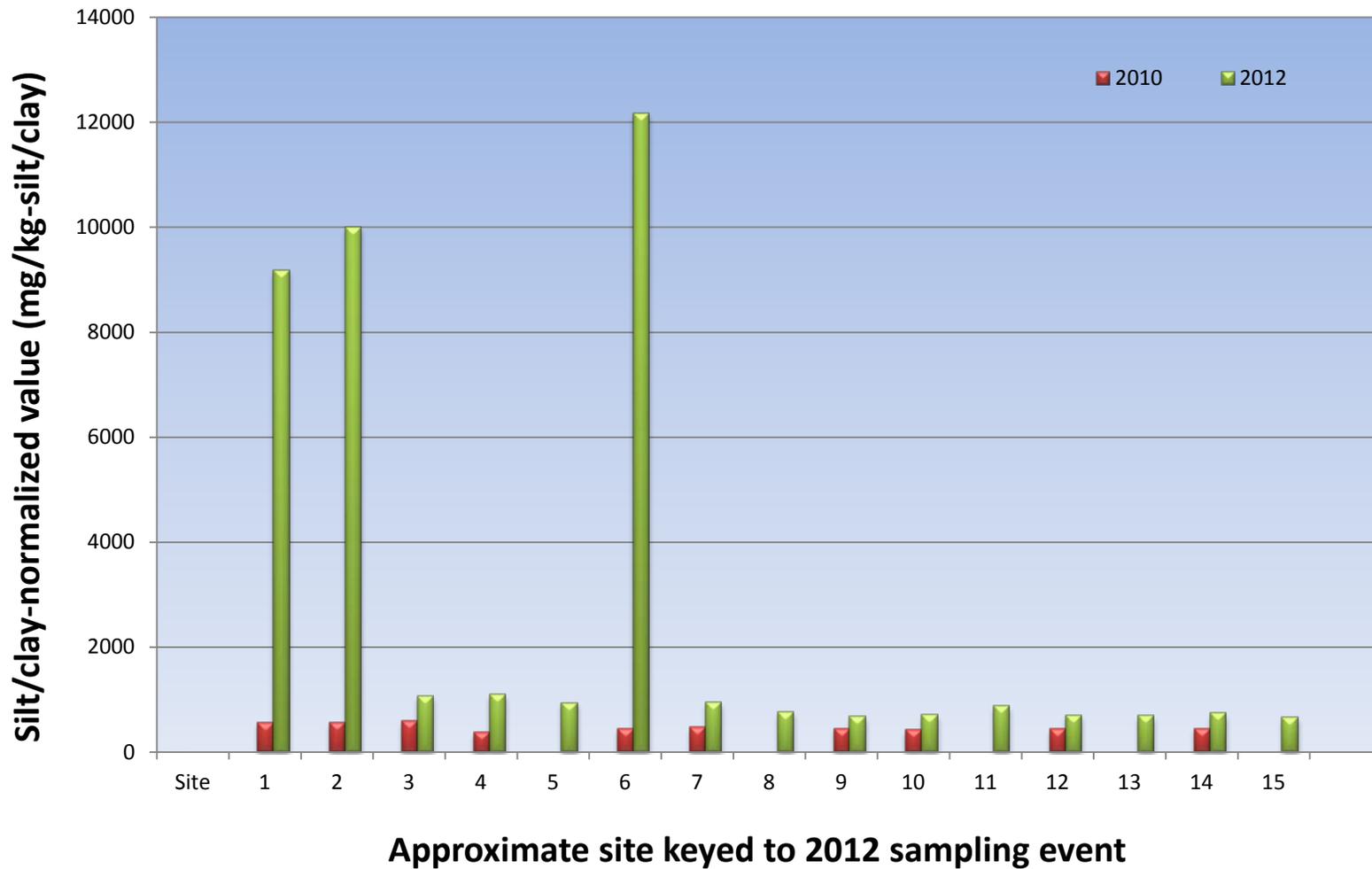


FIGURE 12. Unfiltered elutriate TP normalized to TSS, 2010 and 2012.

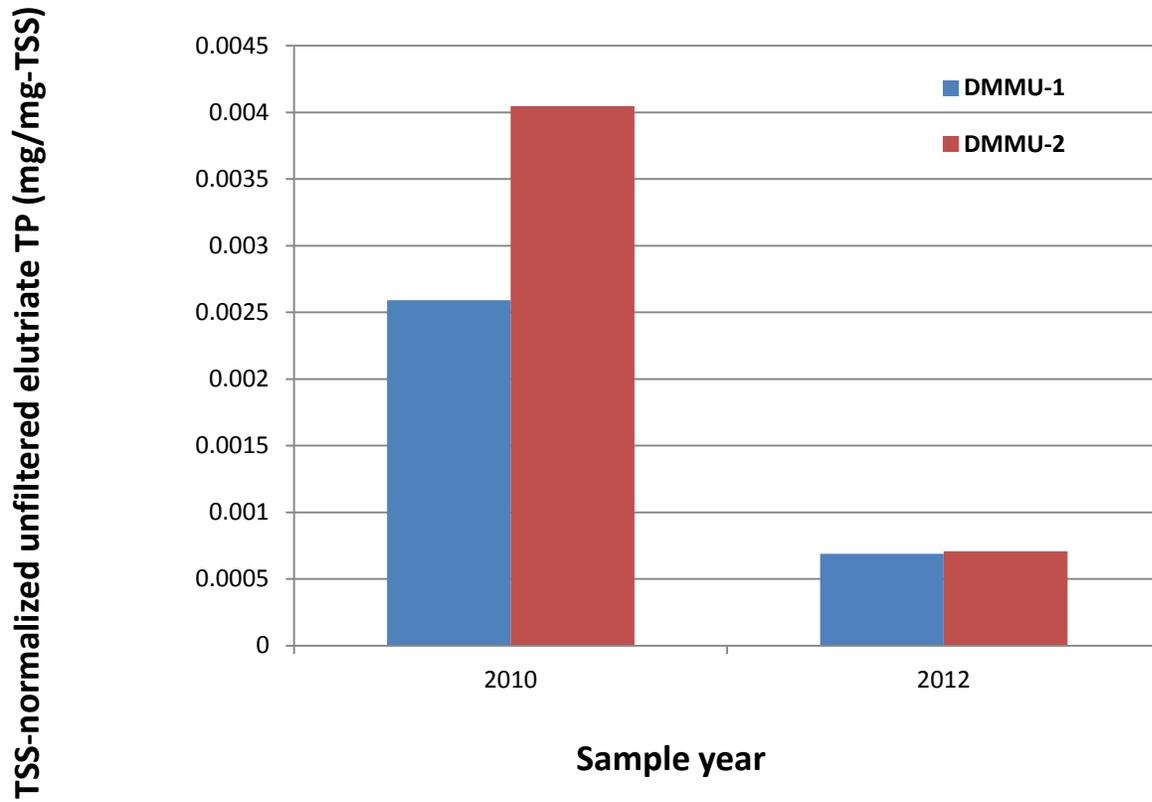


FIGURE 13. Dissolved TP in elutriate, 2010 and 2012.

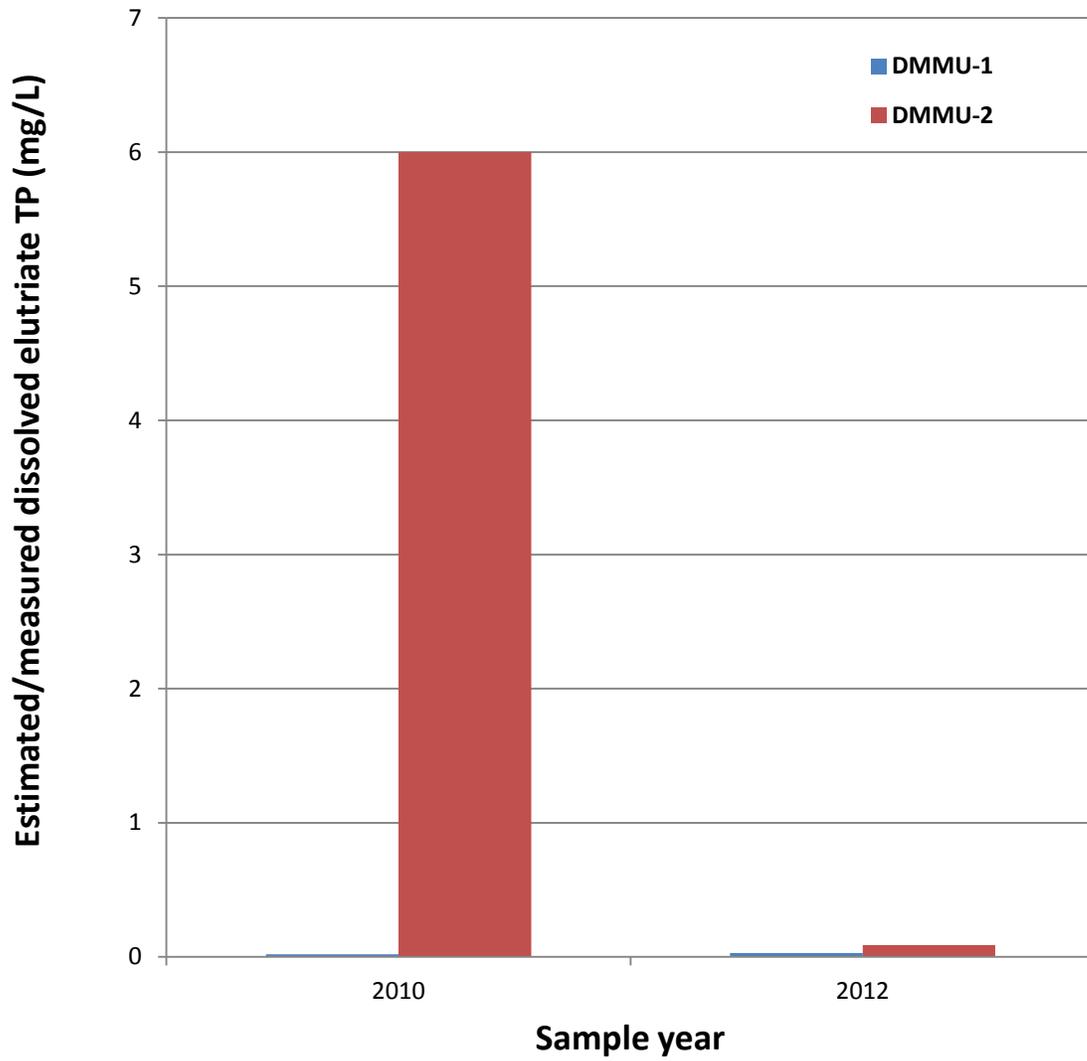


FIGURE 14. Dissolved TP in elutriate (without assumed DMMU-2 anomaly in 2010), 2010 and 2012.

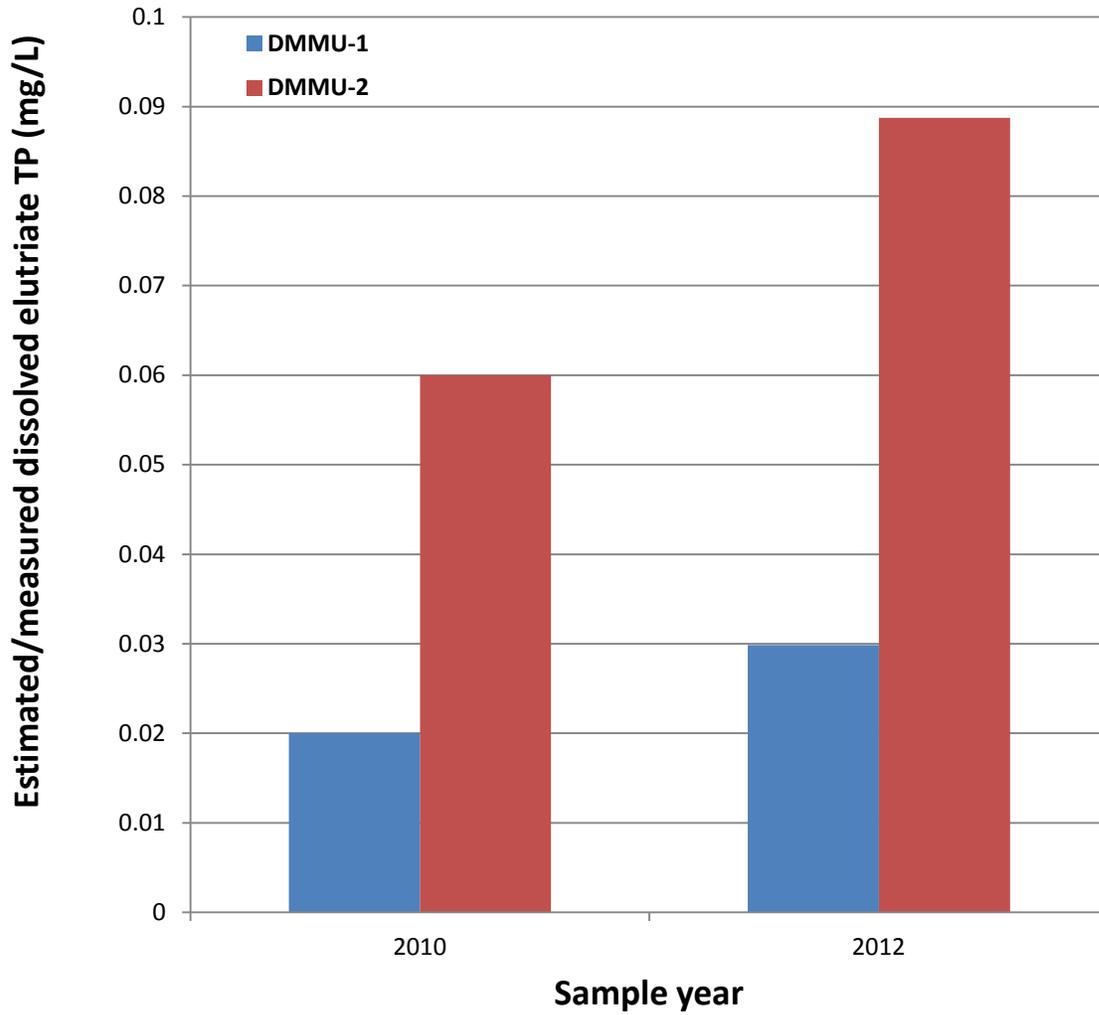


FIGURE 15. Silt/clay-normalized sediment concentrations of ammonia-nitrogen in upper Cuyahoga River Channel sediments in 2010 and 2012.

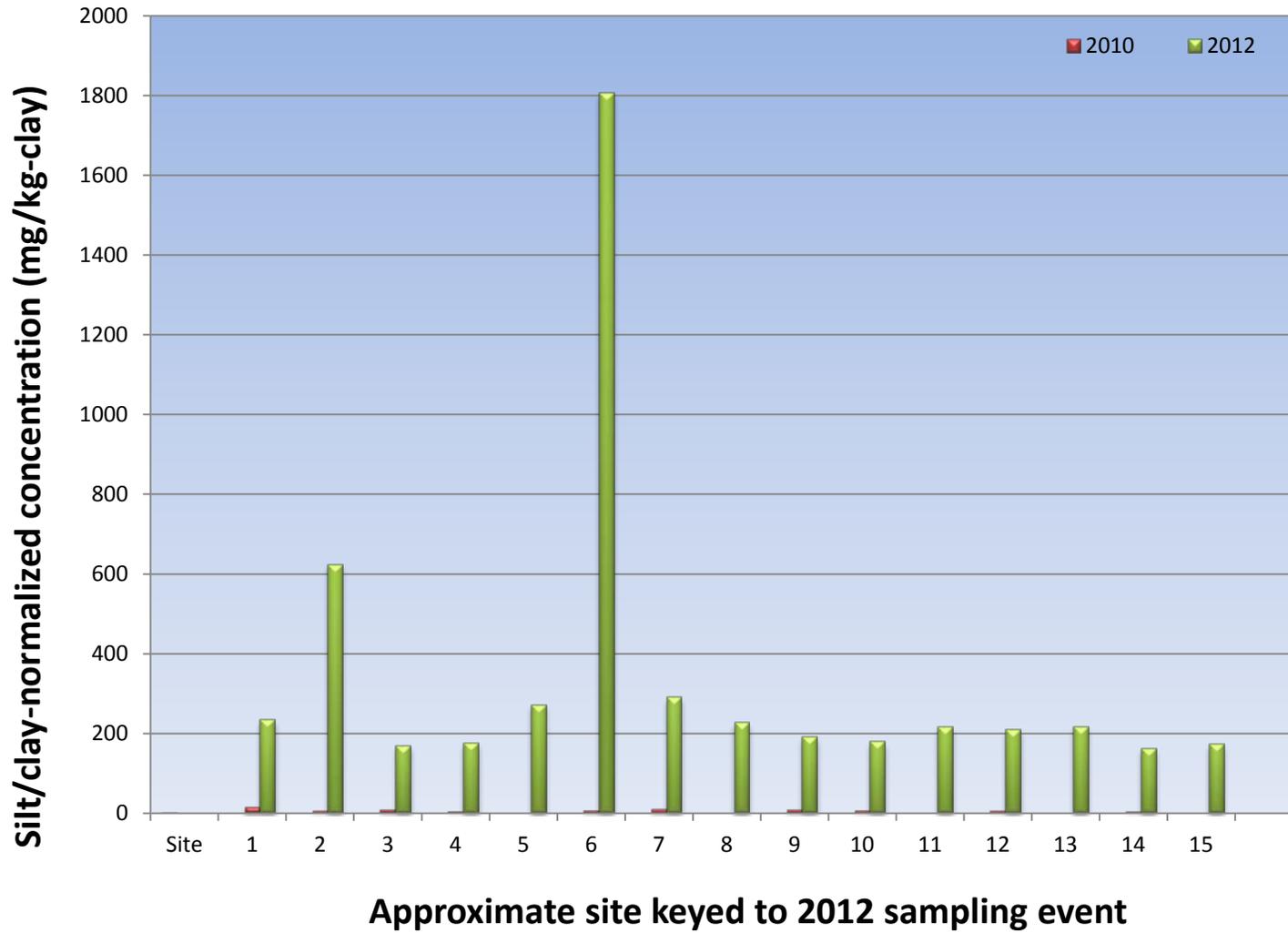


FIGURE 16. Silt/clay-normalized sediment concentrations of TKN in upper Cuyahoga River Channel sediments in 2010 and 2012.

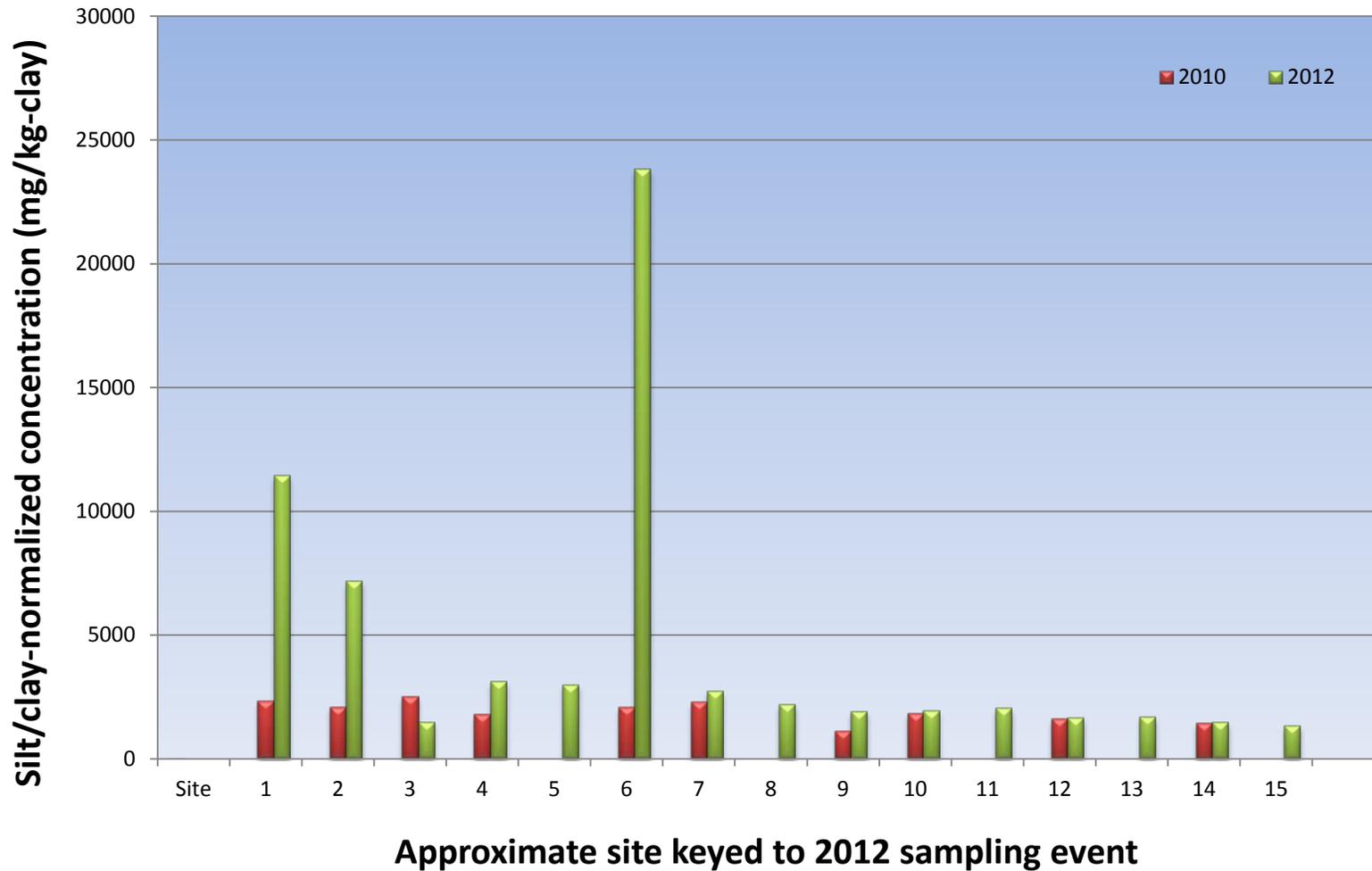


FIGURE 17. Total organic carbon (TOC)-normalized concentrations of tPCBs in upper Cuyahoga River Channel sediments in 2007, 2010 and 2012.

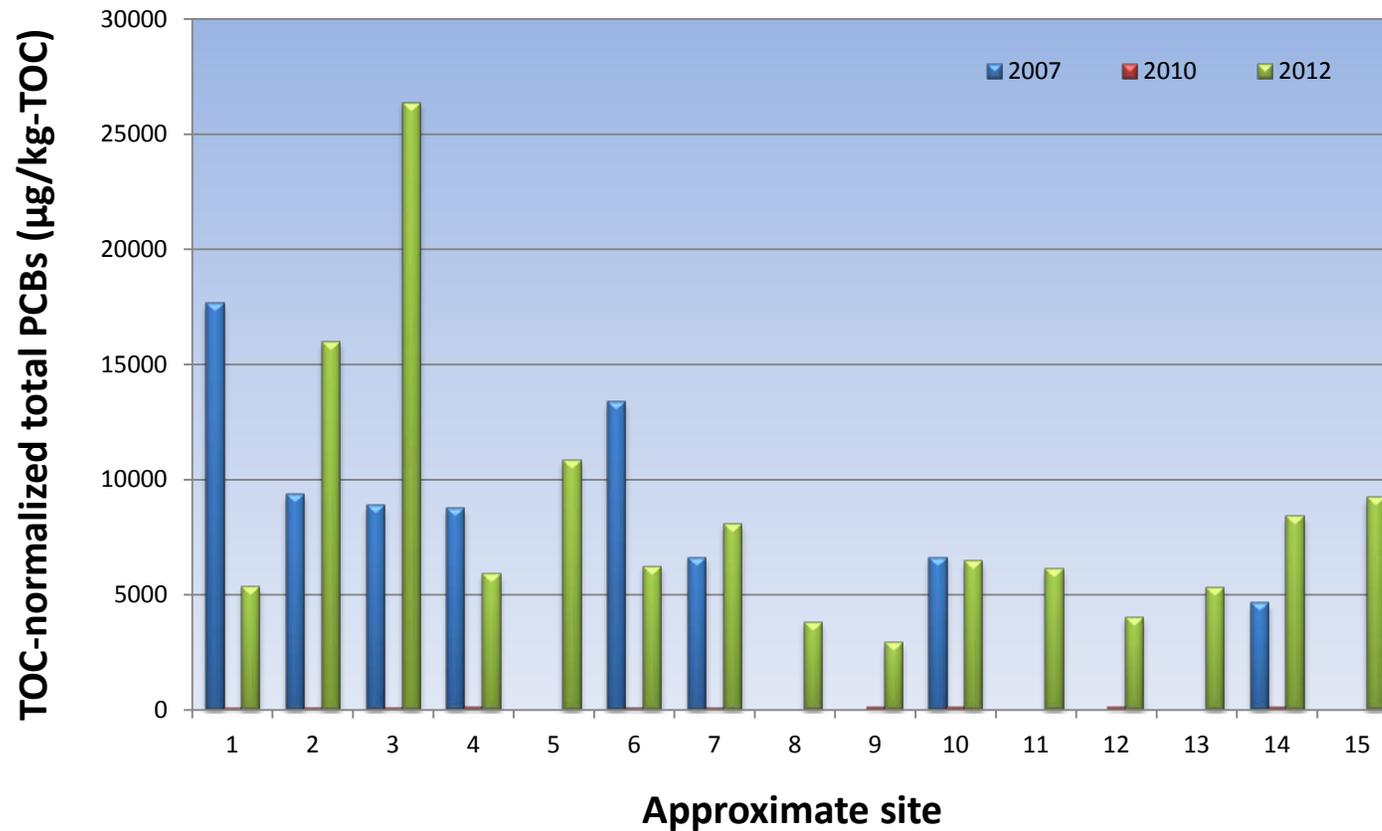


FIGURE 18. Total organic carbon (TOC)-normalized concentrations of Σ DDT in upper Cuyahoga River Channel sediments in 2007, 2010 and 2012.

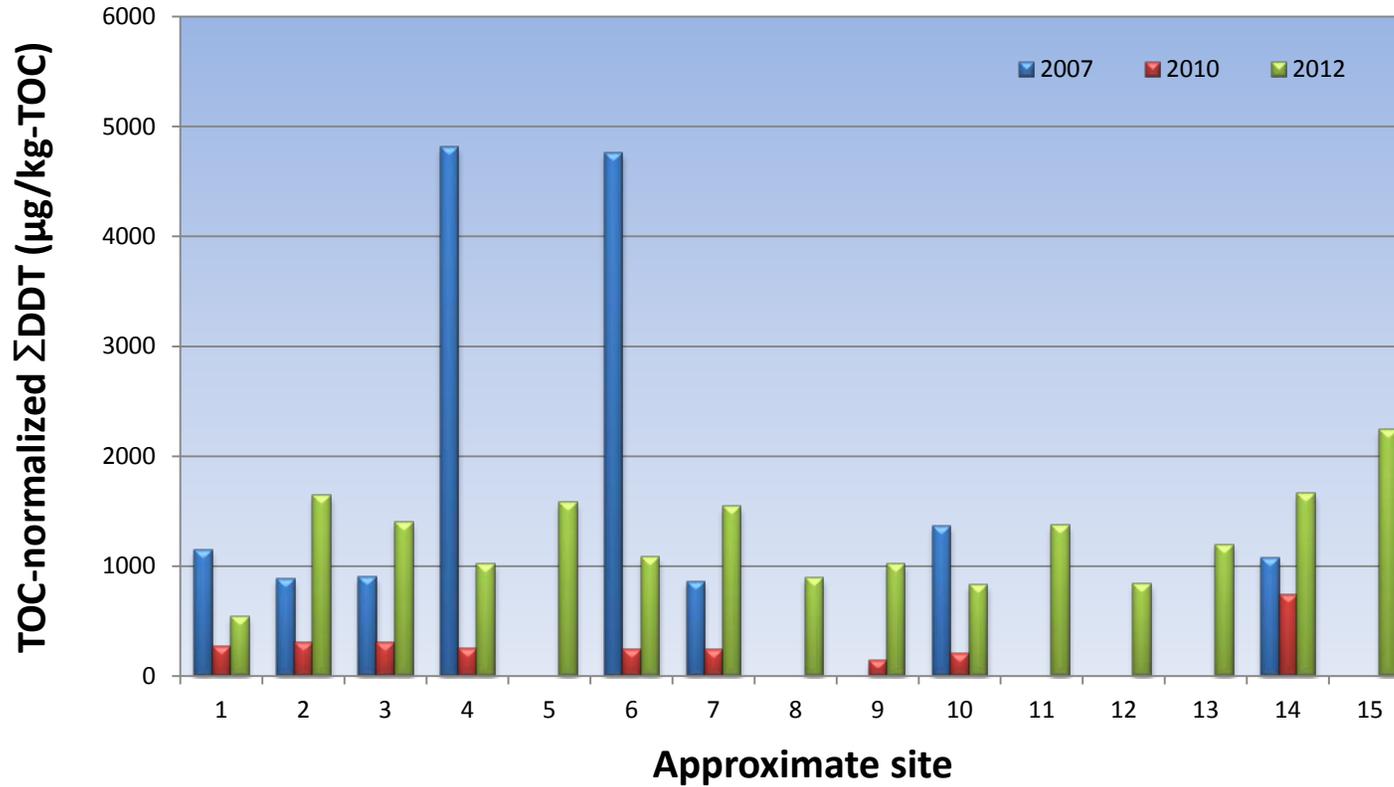


FIGURE 19. Control-corrected survival of test species relative to upper River Channel DMMU-1 sediments in 2007, 2010 and 2012.

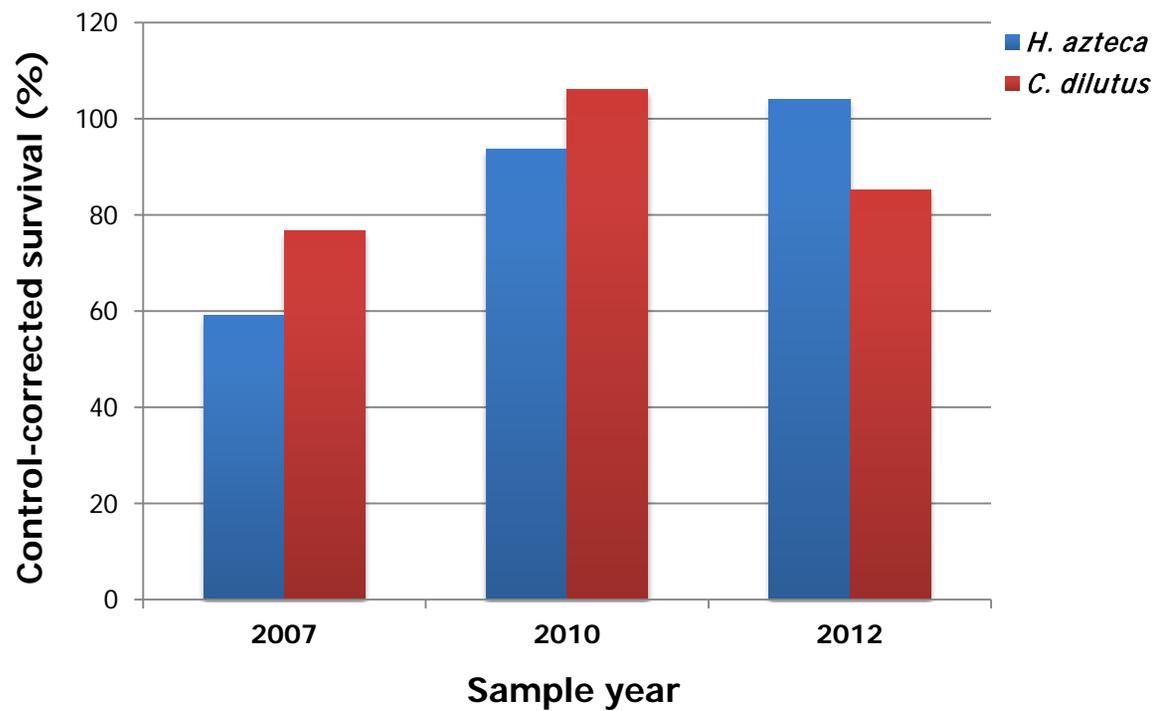


FIGURE 20. Control-corrected growth of *C. dilutus* relative to upper River Channel DMMU-1 sediments in 2010 and 2012.

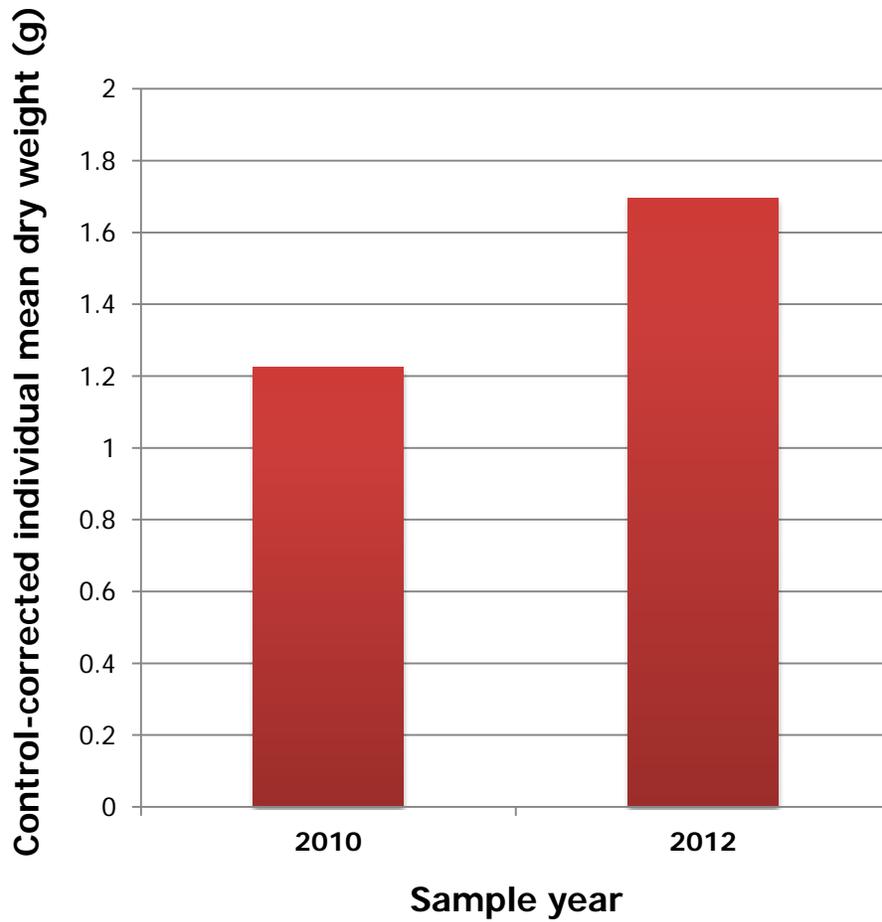


FIGURE 21. Control-corrected survival of test species relative to upper River Channel DMMU-2 (for 2012, averages across DMMU-2a and 2b) sediments in 2010 and 2012.

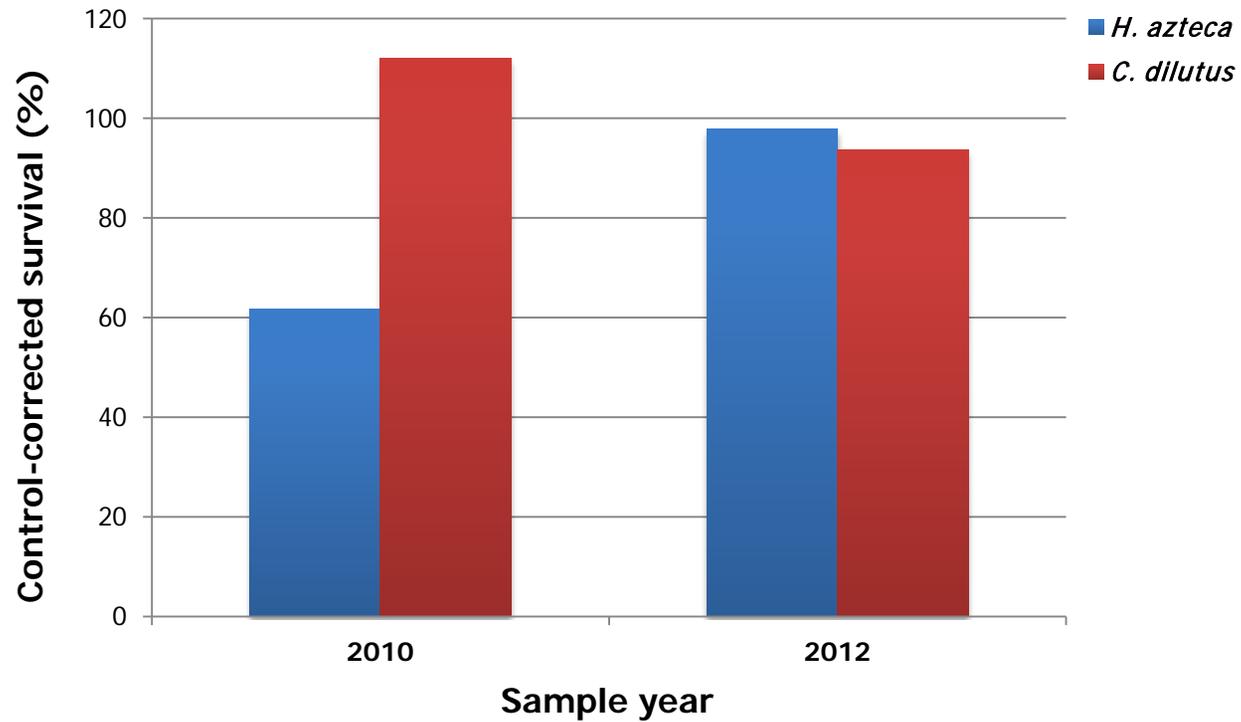


FIGURE 22. Control-corrected growth of *C. dilutus* relative to upper River Channel DMMU-2 (for 2012, average across DMMU-2a and 2b) sediments in 2010 and 2012.

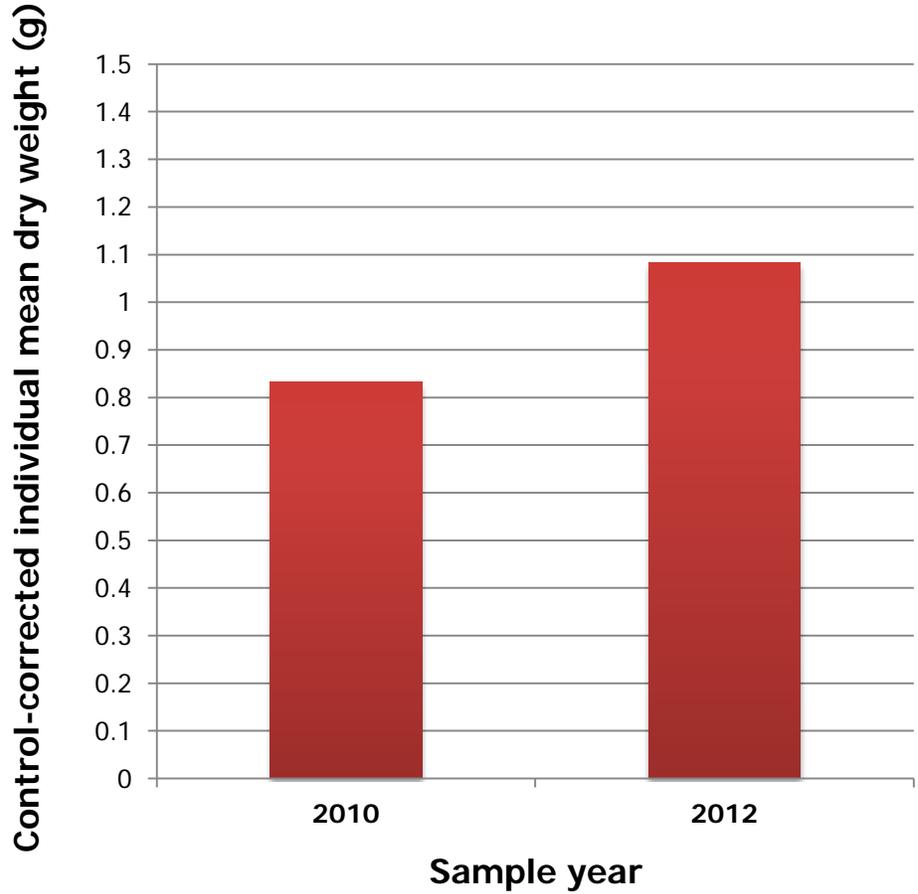


TABLE 1. Particle size data on Cleveland Harbor Federal navigation channel, CDF and Lake Erie vicinity sediments (USACE 2013b).

Particle Size (%)	Lake Area #1					Lake Area #4					DMMU 1						DMMU 2a						DMMU 2b						CDF 10B	
	CLA1-1	CLA1-2	CLA1-3	CLA1-4	CLA1 Comp	CLA4-1	CLA4-2	CLA4-3	CLA4-4	CLA4 Comp	CH-1	CH-2	CH-3	CH-4	CH-5	DMMU1	CH-6	CH-7	CH-8	CH-9	CH-10	DMMU2a	CH-11	CH-12	CH-13	CH-14	CH-15	DMMU2b	CDF Comp	
GRAVEL	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	2.5	0.3	0.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	5.7
SAND	4.0	2.0	10.6	2.3	12.2	1.8	0.5	0.7	1.5	1.2	94.9	93.7	42.6	46.0	37.1	77.0	95.5	33.2	8.6	3.9	6.6	23.5	6.4	4.2	3.1	2.8	4.6	4.9	89.9	
SILT	66.8	67.7	63.7	72.5	55.5	68.6	65.0	66.9	68.3	63.4	4.4	4.0	48.7	44.9	54.6	21.1	4.7	58.9	79.6	82.1	80.9	66.0	83.5	85.7	86.7	85.2	85.4	85.1	4.5	
CLAY	29.2	30.2	25.7	25.2	32.3	29.6	34.5	32.4	30.2	35.4	-0.2	-0.2	8.4	8.3	8.1	1.9	-0.2	7.9	11.8	14.0	12.5	10.4	10.0	10.1	10.2	12.0	10.0	10.0	-0.1	

Particle Size (%)	Middle River Reach (MRR)					Lower River Reach (LRR)						Old River Reach (ORR)			Outer Harbor Reach (OHR)							
	CH-16	CH-17	CH-18	CH-19	CH-20	CH-21	CH-22	CH-23	CH-24	CH-25	CH-26	CH-27	CH-28	CH-29	CH-30	CH-31	CH-32	CH-33	CH-34	CH-35	CH-36	CH-37
GRAVEL	4.8	2.2	2.6	3.5	4.9	4.3	3.8	1.2	0.7	0.6	4.5	14.3	1.8	6.2	13.4	4	3.2	6.9	9.7	15.5	3.1	6.2
SAND	23.8	21	21.3	19.2	20.7	22.3	29.9	23.5	24.3	25.5	32.1	43.1	60.3	56.5	37.5	34.5	36.8	27.1	31	38.5	28.4	26.2
SILT	63	66.6	66.8	63.1	62.4	63.8	58	65	61.7	62.5	53.4	36.9	26.7	31.2	42.2	47.6	52.7	54.3	46.8	38.2	54.6	53.2
CLAY	8.4	10.2	9.3	14.2	12	9.6	8.3	10.3	13.3	11.4	10	5.7	11.2	6.1	6.9	13.9	7.3	11.7	12.5	7.8	13.9	14.4

TABLE 4. Inorganic chemistry data on Cleveland Harbor Federal navigation channel, CDF and Lake Erie vicinity sediments (USACE 2013b).

Inorganic Parameter (mg/kg)	Lake Area #1					Lake Area #4					DMMU 1					DMMU 2a					DMMU 2b					CDF 10B																																																											
	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ																																																				
Ammonia-N	120			152			104			144			140			106			60.4			83.9			77.7			73.9			10.3			25			96.3			93.6			171			66.2			84.9			195			208			183			167			189			202			201			211			158			165			146			5.6
Phosphorus, Total (As P)	925			814			804			763			775			742			683			734			690			851			404			400			611			587			592			462			572			632			708			654			670			637			824			678			677			722			636			684			334
Cyanide, Total	0.95			1			0.8			0.93			0.94			0.89			0.9			0.91			0.89			0.87			0.55			1.8			1.3			0.43			0.41			0.32			0.36			0.75			0.63			0.39			0.65			0.51			0.43			0.43			0.41			0.35			0.39			0.44			0.26
Nitrogen, Total Kjeldahl	2,380			3,900			1,850			3,100			2,460			2,770			2,360			3,450			2,480			1,980			504			287			850			1,670			1,880			1,570			1,120			1,830			2,000			1,850			1,800			1,910			1,680			1,570			1,640			1,430			1,290			1,920			230
Total Organic Carbon	26,000			25,000			25,000			25,000			25,000			25,000			25,000			19,000			24,000			6,200			2,200			13,000			16,000			11,000			15,000			16,000			17,000			21,000			17,000			15,000			8,900			14,000			24,000			13,000			9,000			13,000			1,800						
Organic Matter (%)	4.8			5.3			4.1			4			5.2			3.8			3.5			4.2			4			5.2			0.98			2.9			3.5			5.9			4.5			2.8			3.4			4.3			5.3			4.5			5.7			4.4			5			4.3			4.1			3.8			3.8			3.7			0.81

Inorganic Parameter (mg/kg)	Middle River Reach (MRR)					Lower River Reach (LRR)					Old River Reach (ORR)			Outer Harbor Reach (OHR)																																																					
	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ																												
Ammonia-N	240			160			140			170			140			180			160			140			120			190			93			120			130			160			190			200			220			160			220			160									
Phosphorus, Total (As P)	300			240			230			290			320			300			330			270			310			320			300			300			420			530			300			540			310			300			410			400			360			450			J
Cyanide, Total	0.63	J		1.6	U		0.62	J		0.59	J		1.7	U		0.83	J		0.73	J		0.65	J		1.8	U		1.7	U		1.6	U		2.5			2.0	U		1.1	J		1.7	U		2.0	U		2.2	U		2.5	U		2.4	U		2.3	U								
Nitrogen, Total Kjeldahl	1,200			800			790			1,300			590			1,400			1,100			1,200			1,100			1,300			950			1,400			1,300			1,700			1,600			1,900			1,800			2,100			2,100			3,000									
Total Organic Carbon (AVG)	32,100			26,800			25,200			25,300			23,600			27,500			22,500			24,900			22,600			21,100			25,000			21,200			24,900			26,100			23,900			24,600			26,400			24,700			22,900			25,200			24,500			31,500			
Percent Moisture (%)	44			39			35			44			43			46			43			42			43			40			37			37			41			51			45			40			49			55			60			58			57						

LQ - Laboratory qualifiers:
 U = Indicates the compound was analyzed for but not detected at or above the method detection limit (MDL).
 J = Indicates values below the RL but greater than the MDL.
 VQ - Data validation qualifiers:
 J = Phosphorus parent samples CH-20 and CH-37 flagged with "J" as a result of MS/MSD recovery problems in the phosphorus batches (SDG: 1204A28).

TABLE 6. PAH pore water data on Cleveland Harbor Federal navigation channel, CDF and Lake Erie vicinity sediments (USACE 2013b).

PAH Compounds (ug/L)	Lake Area						Harbor Management Unit									CDF 10B		
	CLA1 Comp			CLA4 Comp			DMMU 1			DMMU 2a			DMMU 2b			CDF Comp		
	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ
Naphthalene	0.802	U		0.802	U		0.802	U		0.802	U		0.854			0.802	U	
2-methylnaphthalene	0.4	U		0.4	U		0.4	U		0.4	U		0.4	U		0.4	U	
1-methylnaphthalene	0.4	U		0.4	U		0.4	U		0.4	U		0.4	U		0.4	U	
C2-Naphthalenes	0.59			0.557	U		0.557	U		0.557	U		0.557	U		0.557	U	
C3-Naphthalenes	4.78			0.911	U		0.911	U		0.911	U		0.911	U		0.911	U	
C4-Naphthalenes	6.14	B		1.13	B	U	1.13	BU		1.13	BU		1.13	BU		1.13	BU	
Acenaphthylene	0.2	U		0.2	U		0.2	U		0.2	U		0.2	U		0.2	U	
Acenaphthene	0.459			0.2	U		0.2	U		0.2	U		0.2	U		0.2	U	
Fluorenes	0.12	U		0.12	U		0.12	U		0.12	U		0.12	U		0.12	U	
C1-Fluorenes	1.46			0.164	U		0.164	BU		0.164	BU		0.164	U		0.164		U
C2-Fluorenes	3.12			0.203		U	0.203	BU		0.203	BU		0.203	B	U	0.203		BU
C3-Fluorenes	0.343	B	U	0.343		U	0.343	BU		0.343	BU		0.343	B	U	0.343		BU
Phenanthrene	0.407			0.12	U		0.142	B		0.272			0.314			0.12		U
Anthracene	0.12	U		0.12	U		0.12	U		0.12	U		0.12	U		0.12		U
C1-Phenanthracenes/Anthracenes	0.952			0.21	U		0.21	BU		0.21	BU		0.21	U		0.21		U
C2-Phenanthracenes/Anthracenes	1.6	B		0.375	U		0.375	BU		0.375	U		0.375	U		0.375		U
C3-Phenanthracenes/Anthracenes	0.635	B		0.414	U		0.414	U		0.414	U		0.414	U		0.414		U
C4-Phenanthracenes/Anthracenes	1	U		1	U		1	U		1	U		1	U		1		U
Fluoranthene	0.291			0.04	U		0.114	B		0.188			0.198			0.04		U
Pyrene	0.255			0.04	U		0.074	B		0.128			0.139			0.04		U
C1-Fluoranthenes/pyrenes	0.184			0.078	U		0.078	U		0.078	U		0.078		U	0.078		U
Benz[a]anthracene	0.019			0.004	U		0.007			0.011			0.014			0.004		U
Chrysene	0.027			0.004	U		0.016			0.03			0.027			0.004		U
C1-Benzo(a)anthracenes/Chrysenes	0.006	U		0.006	U		0.006	U		0.006		U	0.006	U		0.006		U
C2-Benzo(a)anthracenes/Chrysenes	0.014	U		0.014	U		0.014	BU		0.014	BU		0.014	U		0.014	B	U
C3-Benzo(a)anthracenes/Chrysenes	0.017	U		0.017	U		0.017	BU		0.017	B	U	0.017	U		0.017		U
C4-Benzo(a)anthracenes/Chrysenes	0.024	BU		0.024	BU		0.024	B	U	0.024	B	U	0.024	B	U	0.024	B	U
Benzo(b)fluoranthene	0.024	U		0.024	U		0.024	U		0.024	U		0.024	U		0.024		U
Benzo(k)fluoranthene	0.024	U		0.024	U		0.024	U		0.024	U		0.024	U		0.024		U
Benzo(e)pyrene	0.024	U		0.024	U		0.024	U		0.024	U		0.024	U		0.024		U
Benzo(a)pyrene	0.024	U		0.024	U		0.024	U		0.024	U		0.024	U		0.024		U
Perylene	0.024	U		0.024	U		0.024	U		0.024	U		0.024	U		0.024		U
Indeno(1,2,3-cd)pyrene	0.024	U		0.024	U		0.024	U		0.024	U		0.024	U		0.024		U
Dibenz(a,h)anthracene	0.024	U		0.024	U		0.024	U		0.024	U		0.024	U		0.024		U
Benzo(ghi)perylene	0.024	U		0.024	U		0.024	U		0.024	U		0.024	U		0.024		U
Total Toxic Units	2.8			<0.1			<0.1			0.1			0.1			<0.1		

LQ - Laboratory qualifiers:

U = Indicates the compound was analyzed for but not detected at or above the method detection limit (MDL).

B = Analyte detected in the Method Blank

BU = Concentration less than Reporting Limit (RL) due to Method Blank subtraction.

VQ - Data validation qualifiers:

U - Sample concentration corrected (subtracted) for blank concentration, indicates analyte was not detected in chromatogram.

All toxic units calculated using porewater concentrations corrected for blanks

Chronic Value obtained from U.S. EPA. 2003. Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: PAH Mixtures. EPA-600-R-02-013. Office of Research and Development. Washington, DC 20460

TABLE 8. PCB congener data on Cleveland Harbor Federal navigation channel, CDF and Lake Erie vicinity sediments (USACE 2013b).

PCB Congener (ug/kg)	Lake Area						Harbor Management Unit						CDF 10B				
	CLA1 Comp			CLA4 Comp			DMMU 1		DMMU 2a		DMMU 2b		CDF Comp				
	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ		
1	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
3	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
5	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
6	0.31	U		0.31	U		3.29			0.14	U		0.14	U		0.09	U
7	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
8	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
9	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
12/13	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
14	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
15/16	0.31	U		1.22			6.76			12.60			9.96			11.40	
17	0.31	U		0.31	U		1.89			1.52			0.80			0.09	U
18	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
19	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
20	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
22	0.31	U		0.31	U		2.74			0.14	U		0.14	U		0.09	U
24	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
25	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		1.84	
26	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
27	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
28/31	4.60			8.12			9.49			4.10			7.72			20.80	
29	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
32	0.31	U		0.31	U		3.75			2.81			0.14	U		0.09	U
33	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
34	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
35	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
37																	
40	0.62			0.31	U		1.39			1.67			1.72			1.22	
41	2.61			0.31	U		0.77			0.14	U		0.14	U		1.62	
42	1.34			0.71			0.11	U		0.14	U		0.14	U		0.09	U
44	2.60			0.94			5.14			9.08			13.40			9.49	
45	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
46	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
47																	
48	0.31	U		1.08			1.25			1.23			1.52			0.09	U
49	2.08			1.54			2.95			2.26			2.32			7.36	
51	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
52	3.51			6.52			8.73			7.64			6.23			10.50	
53	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.87	
54	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
56	3.36			3.54			7.94			11.60			9.80			12.20	
59	0.31	U		0.31	U		0.73			0.79			0.51			0.09	U
60	0.31	U		1.09			1.35			0.71			0.70			0.73	
63	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
64																	
66	3.33			3.22			3.42			2.43			2.39			5.14	
67	0.31	U		0.31	U		0.61			0.14	U		0.14	U		0.09	U
69	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
70	4.40			3.88			4.16			5.73			3.86			7.61	
71																	
73	0.31	U		0.31	U		0.48			0.62			0.90			2.65	
74	1.98			2.24			1.34			4.60			4.62			2.99	
75	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
77	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
81	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
82	2.92			2.13			0.11	U		0.14	U		0.14	U		0.09	U
83	0.31	U		0.31	U		0.79			1.07			1.07			0.09	U
84	3.42			0.31	U		1.94			0.14	U		1.52			5.84	
85	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
87	2.83			2.36			2.88			1.60			1.47			8.07	
90/101	6.16			5.34			5.98			4.96			5.14			7.76	
91	1.08			0.70			1.19			1.14			1.44			2.94	
92	1.27			1.93			0.11	U		0.14	U		0.14	U		3.29	
93	0.31	U		0.31	U		1.55			1.59			1.32			0.09	U
95	4.95			4.12			5.54			4.88			4.54			6.95	
97	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
99	2.71			0.31	U		2.25			2.72			1.73			2.68	
100	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
103	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
104	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
105	5.44			6.26			3.64			3.03			3.44			5.38	
107	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
110/115	7.78			6.61			6.15			4.59			4.78			9.16	
114	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
117	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
118	8.04			7.20			6.05			5.43			5.68			10.99	
119	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
122	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
123																	
124	0.31	U		0.31	U		1.14			0.14	U		0.14	U		0.09	U
128	1.73			1.29			1.08			0.95			0.95			0.09	U
129	0.75			0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
130	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
131	0.31	U		0.31	U		0.80			0.63			0.86			0.09	U
132	3.07			2.25			1.75			1.12			1.57			3.04	
134	0.31	U		0.31	U		1.26			1.14			0.67			0.09	U
135	1.94			0.31	U		0.86			1.23			1.18			2.31	
136	0.31	U		0.31	U		0.82			0.14	U		2.35			0.09	U
137	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
138/163	8.29			7.07			5.62			4.63			5.12			6.37	
141	1.07			1.09			1.04			0.80			0.76			0.09	U
144	0.31	U		0.31	U		1.35			0.14	U		0.14	U		0.09	U
146	0.63			0.85			0.54			0.72			0.70			0.09	U
147	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
149	5.43			4.58			5.05			5.44			5.21			9.63	
151	1.62			0.87			1.11			1.07			0.74			4.26	
153	5.48			5.32			4.07			3.76			4.01			3.88	
154	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
156	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
157	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
158	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
164	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
165	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
167	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U
170	0.31</																

TABLE 9. Estimated total PCB concentrations in Cleveland Harbor Federal navigation channel, CDF and Lake Erie vicinity sediments (USACE 2013b).

PCB Congener (ug/kg)	Lake Area						Harbor Management Unit									CDF 10B		
	CLA1 Comp			CLA4 Comp			DMMU 1			DMMU 2a			DMMU 2b			CDF Comp		
	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ
8	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U	
18	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U	
28/31	4.60			8.12			9.49			4.10			7.72			20.80		
44	2.60			0.94			5.14			9.08			13.40			9.49		
49	2.08			1.54			2.95			2.26			2.32			7.36		
52	3.51			6.52			8.73			7.64			6.23			10.50		
66	3.33			3.22			3.42			2.43			2.39			5.14		
87	2.83			2.36			2.88			1.60			1.47			8.07		
90/101	6.16			5.34			5.98			4.96			5.14			7.76		
105	5.44			6.26			3.64			3.03			3.44			5.38		
118	8.04			7.20			6.05			5.43			5.68			10.99		
128	1.73			1.29			1.08			0.95			0.95			0.09	U	
138/163	8.29			7.07			5.62			4.63			5.12			6.37		
153	5.48			5.32			4.07			3.76			4.01			3.88		
170	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U	
180	3.17			3.11			1.99			3.05			3.10			3.84		
183	0.65			0.58	J		0.54			0.71			0.14	U		0.09	U	
184																		
187	2.06			1.73			1.20			2.20			1.81			0.09	U	
195	0.31	U		0.31	U		0.11	U		0.14	U		0.14	U		0.09	U	
206	1.45			0.31	U		0.11	U		0.14	U		0.14	U		0.09	U	
209																		
Total PCBs*	124.1			122.7			126.1			112.4			126.4			199.9		
Total organic carbon (TOC) (decimal %)	0.025			0.024			0.015			0.0089			0.013			0.0018		
TOC-normalized total PCBs (ug/kg-TOC)	4962			5114			8407			12625			9723			111073		

LQ - Laboratory qualifiers:

U = Indicates the compound was analyzed for but not detected at or above the method detection limit (MDL).

J = Indicates values below the RL but greater than the MDL.

Blue shaded cells indicated congener can't be resolved due to multiple co-elutions.

* Total PCBs estimated using methodology consistent with USEPA (2002) and assigning any non-detectable congeners a value of one-half the MDL.

TABLE 12. Comparison of Cleveland Harbor DMMU-1, DMMU-2a and DMMU-2b bulk sediment toluene concentrations to equilibrium partitioning sediment benchmarks (ESBs) relating to the narcotic mode of action (based on data from USACE 2013b).

Site	Narcosis ESB (µg/g _{oc})	f _{oc}	ESB (µg/g)	Toluene (µg/g)
CH-1	810	0.0062	5.022	0.0002
CH-2	810	0.0022	1.782	0.007
CH-3	810	0.013	10.53	10.5
CH-4	810	0.016	12.96	5.99
CH-5	810	0.011	8.91	10.8
Composite Value/Geometric Mean*	810	0.015	12.15	0.248675834
CH-6	810	0.016	12.96	3.81
CH-7	810	0.017	13.77	8.75
CH-8	810	0.021	17.01	14.5
CH-9	810	0.017	13.77	8.6
CH-10	810	0.015	12.15	13.4
Composite Value/Geometric Mean*	810	0.0089	7.209	4.900679608
CH-11	810	0.014	11.34	3.22
CH-12	810	0.024	19.44	1.8
CH-13	810	0.017	13.77	0.337
CH-14	810	0.013	10.53	2.15
CH-15	810	0.009	7.29	0.059
Composite value/Geometric Mean*	810	0.013	10.53	0.756501424

*Excepting the narcosis ESB; f_{oc} is a composite measurement and toluene is a geometric mean due to the absence of a composite measurement.

TABLE 13. Hydrocarbon toxicity potential (HTP) analyses and associated *Hyalella azteca* and *Chironomus dilutus* toxic units (TUs) for Cleveland Harbor Federal navigation channel, CDF and Lake Erie vicinity sediments (based on data from USACE 2013b).

Site	SPME Fiber Burden (mM PDMS)	Total Extractable Hydrocarbons (mM/kg)	<i>H. azteca</i> TUs*	<i>C. dilutus</i> TUs**
CH-1	0	0.063	0	0
CH-2	0	-	-	-
CH-3	0	-	0	0
CH-4	0	1.03	0	0
CH-5	1	0.43	0.1	0
DMMU-1	6	0.27±0.23***	0.3	0.1
CH-6	0	-	0	0
CH-7	0	0.094	0	0
CH-8	-	-	-	-
CH-9	0	0.11	0	0
CH-10	0	-	0	0
DMMU-2a	10	-	0.5	0.2
CH-11	0	-	0	0
CH-12	0	-	0	0
CH-13	3	-	0.2	0
CH-14	7	0	0.4	0.1
CH-15	-	0.28	-	-
DMMU-2b	9	-	0.5	0.1
CLA1-1	-	0.64	-	-
CLA1-2	-	ND	-	-
CLA1-3	-	6.27	-	-
CLA1-4	-	-	-	-
CLA1-comp	26	ND	-	-
CLA4-1	5	ND	0.3	0.1
CLA4-2	5	ND	0.3	0.1
CLA4-3	5	ND	0.3	0.1
CLA4-4	6	ND	0.3	0.1
CLA4-comp	-	-	1.3	0.4
CDF	6	-	0.3	0.1

- No data

*1 TU=20 mM PDMS (Parkerton *et al.* 2007)

**1 TU=66 mM PDMS (Parkerton *et al.* 2009)

***Two replicate analysis performed

TABLE 14. Results of standard 10-day *Hyalella azteca* and *Chironomus dilutus* solid phase bioassays (± 1 standard deviation [SD] from the mean) on Cleveland Harbor Federal navigation channel sediments (*Management Units 1, 2a and 2b only*; Sites CH-1 through CH-15) and open-lake placement areas sediments (CLA-1 and CLA-4) (USAERDC 2012).

Test Species	Measurement Endpoint	Harbor			Lake		Control
		DMMU-1	DMMU-2a	DMMU-2b	CLA-1	CLA-4	
<i>H. azteca</i>	Survival (%)	94 \pm 6	94 \pm 6	82 \pm 25	84 \pm 15	92 \pm 11	90 \pm 7
<i>C. dilutus</i>	Survival (%)	80 \pm 7	86 \pm 13	90 \pm 10	90 \pm 10	88 \pm 5	94 \pm 6
	Growth (mass, mg DW)	3.513 \pm 0.116	2.311 \pm 0.282	2.171 \pm 0.299	1.699 \pm 0.142	1.720 \pm 0.156	2.069 \pm 0.237

TABLE 15. Results of 28-day *L. variegatus* PCB bioaccumulation experiments on Cleveland Harbor Federal navigation channel, CDF and Lake Erie vicinity sediments (highlighted values are non-detectable concentrations valued at one-half the MDL) (USAERDC 2012). For statistical comparison purposes, tissue residues are presented as Σ PCBs (see text).

PCB Congener (ug/kg)	Lake Area										Harbor Management Unit															CDF 10B								
	CLA 1 Comp replicate					CLA 4 Comp replicate					DMMU 1 replicate					DMMU 2a replicate					DMMU 2b replicate					CDF Comp replicate								
	1	2	3	4	5	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5					
44	0.64	0.69	0.82	0.74	1.00	0.16	0.15	0.16	0.15	2.81	2.21	2.05	2.02	2.90	0.17	0.16	0.16	0.14	0.15	0.17	0.16	0.16	0.14	0.15	0.17	0.16	0.16	0.14	0.15	1.70	1.39	2.00	2.70	2.17
52	1.76	1.65	1.72	1.55	1.99	0.16	0.15	0.16	0.15	4.05	4.66	3.20	2.41	3.74	1.38	0.95	1.34	2.14	1.20	1.36	1.33	1.71	1.24	1.21	3.66	3.01	3.87	5.83	4.22					
64	0.14	0.13	0.16	0.15	0.16	0.16	0.15	0.16	0.15	1.29	1.05	0.94	0.92	1.14	0.17	0.16	0.16	0.14	0.15	0.17	0.16	0.90	0.14	0.15	0.14	0.16	1.04	0.15	1.08					
66	0.72	0.62	0.91	0.71	1.08	1.00	1.63	1.03	0.76	1.66	1.82	2.26	1.96	1.72	2.19	3.12	3.63	2.96	2.31	3.27	2.36	2.06	2.70	0.83	1.27	0.84	1.37	1.83	1.76					
70	1.36	1.05	1.38	1.61	1.82	0.16	0.15	0.16	0.15	3.26	3.48	3.20	3.01	3.52	1.15	1.39	1.36	1.55	1.34	1.23	1.05	1.10	1.23	0.94	2.60	1.82	2.58	3.88	2.82					
75	0.14	0.13	0.16	0.15	0.16	0.16	0.15	0.16	0.15	2.13	2.29	2.09	2.24	2.41	0.17	0.16	0.16	0.14	0.15	0.17	0.16	0.16	0.14	0.15	0.17	0.16	0.16	0.14	0.15	0.14	0.16	0.16	0.15	0.16
81/87	3.09	2.71	3.22	3.22	3.78	0.16	0.15	0.16	0.53	9.16	4.79	4.78	4.53	8.68	3.76	4.51	4.83	6.18	5.02	5.92	4.80	5.77	5.82	4.77	7.97	6.06	8.53	12.79	9.85					
90/101	3.52	3.91	4.23	3.71	4.36	2.83	1.90	2.31	1.33	4.88	4.76	5.45	5.12	5.36	0.17	0.16	0.16	0.14	0.15	0.17	0.16	0.16	0.14	0.15	9.97	7.59	10.22	15.40	12.78					
95	5.56	5.18	6.12	4.83	5.69	1.70	1.41	1.21	1.01	5.00	5.03	5.13	5.02	5.65	1.59	2.14	2.43	3.71	2.69	2.39	1.98	2.07	2.15	1.71	5.60	4.20	5.49	8.75	6.98					
97	1.06	0.98	1.10	1.40	1.61	0.16	0.15	0.16	0.15	1.78	2.11	3.53	2.18	2.29	0.60	0.76	0.85	1.00	1.01	0.77	0.76	0.82	0.81	0.94	2.34	1.78	2.71	3.99	3.09					
105	0.14	0.13	0.16	0.15	0.16	0.16	0.15	0.16	0.15	0.72	0.71	0.77	0.73	0.78	0.17	0.16	0.16	0.14	0.15	0.17	0.16	0.16	0.14	0.15	1.16	0.92	1.42	2.15	1.53					
107	0.14	0.13	0.16	0.15	0.16	0.16	0.15	0.16	0.15	1.11	0.75	0.61	0.64	0.54	0.63	2.04	0.63	0.70	0.88	2.70	1.10	0.95	0.65	0.48	1.65	0.89	1.06	1.08	1.17					
110	0.14	0.13	0.16	0.15	0.16	0.16	0.15	0.16	0.15	0.17	0.17	0.17	0.16	0.15	0.17	0.16	0.16	0.14	0.15	1.61	2.80	3.19	4.11	3.14	9.52	7.18	10.21	15.15	11.71					
118	2.26	2.12	2.57	2.45	3.01	0.16	0.15	0.16	0.15	3.45	3.37	3.51	3.37	3.67	1.16	1.30	1.41	1.73	1.50	1.25	1.32	1.27	1.29	1.17	5.81	4.46	6.69	10.17	7.71					
122	0.14	0.13	0.16	0.15	0.16	0.16	0.15	0.16	0.15	0.17	0.99	0.17	0.17	1.15	0.61	0.72	0.78	1.13	0.89	0.94	0.85	1.02	0.96	0.82	0.14	0.16	0.16	0.15	0.16					
138	3.20	3.61	3.94	3.22	3.88	1.80	2.33	1.97	1.73	3.95	4.00	5.83	4.60	4.93	1.56	1.85	1.93	2.45	2.08	2.20	2.00	2.18	2.70	1.90	7.69	6.21	8.80	13.38	10.48					
149	0.14	0.13	0.16	0.15	0.16	1.52	2.28	1.94	1.62	2.65	2.35	2.86	2.73	2.70	1.00	1.33	1.40	1.55	1.46	1.50	1.49	1.56	1.65	1.45	3.90	2.95	4.13	6.57	5.35					
151	1.18	1.22	1.75	1.52	1.60	0.16	0.15	0.16	0.15	1.18	1.07	1.70	1.55	0.15	0.50	0.16	0.16	0.71	0.15	0.17	0.65	0.16	0.14	0.15	1.77	1.48	1.82	1.88	1.89					
153	2.39	2.35	2.78	2.41	2.96	1.41	1.20	1.20	1.05	2.26	1.99	2.50	2.33	2.30	0.80	0.95	1.07	1.36	1.14	1.20	1.20	1.28	1.30	1.08	4.40	3.17	4.82	6.83	5.60					
163/164	0.14	0.13	2.13	0.15	2.14	0.16	0.15	0.16	0.59	1.68	1.39	1.90	1.76	1.67	0.84	0.65	0.89	0.85	0.87	0.92	0.90	0.95	1.04	0.88	2.47	1.89	2.67	4.24	2.97					
170	0.14	0.13	3.85	2.83	0.16	0.16	0.15	0.16	0.15	0.17	0.17	0.17	4.78	5.15	7.00	7.28	9.51	8.08	8.05	4.64	9.86	8.38	8.81	8.59	0.91	0.76	1.03	1.25	1.13					
187	0.14	0.13	0.16	0.15	0.16	0.79	1.13	0.99	0.75	2.17	1.74	2.04	1.78	2.00	1.52	1.62	1.90	1.73	1.95	2.14	2.13	2.18	2.31	2.09	1.90	1.30	1.98	3.12	2.84					
Σ PCBs	28.14	27.39	37.76	31.51	36.36	13.38	14.13	12.98	11.26	55.69	50.89	54.85	54.00	62.60	27.28	31.70	35.05	38.67	33.44	35.03	37.36	38.17	39.61	32.90	76.71	58.37	82.75	121	97.45					
Mean Σ PCBs	32.2					12.9					55.6					33.2					36.6					87.3								
Mean lipid	1.6					1.3					1.2					1.2					1.2					1.3								

TABLE 16. Estimated total PCB residues in *L. variegatus* tissues following 28-day exposure to Cleveland Harbor Federal navigation channel, CDF and Lake Erie vicinity sediments (highlighted values are non-detectable concentrations valued at one-half the MDL) (USAERDC 2012).

PCB Congener (ug/kg)	Lake Area										Harbor Management Unit															CDF 10B										
	CLA 1 Comp replicate					CLA 4 Comp replicate					DMMU 1 replicate					DMMU 2a replicate					DMMU 2b replicate					CDF Comp replicate										
	1	2	3	4	5	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5							
8	0.14	0.13	0.16	0.15	0.16	0.16	0.15	0.16	0.15	0.17	0.17	0.17	0.16	0.15	0.17	0.16	0.16	0.14	0.15	0.17	0.16	0.16	0.14	0.15	0.14	0.16	0.16	0.15	0.16	0.15	0.16	0.16	0.15	0.16	0.15	0.16
18	0.14	0.13	0.16	0.15	0.16	0.16	0.15	0.16	0.15	0.17	0.17	0.17	0.16	0.15	0.17	0.16	0.16	0.14	0.15	0.17	0.16	0.16	0.14	0.15	0.14	0.16	0.16	0.16	0.15	0.16	0.16	0.15	0.16	0.15	0.16	
28/31	0.14	0.13	0.16	0.15	0.16	0.16	0.15	0.16	0.15	0.17	0.17	0.17	0.16	0.15	0.17	0.16	0.16	0.14	0.15	0.17	0.16	0.16	0.14	0.15	0.14	0.16	0.16	0.16	0.15	0.16	0.16	0.15	0.16	0.15	0.16	
44	0.64	0.69	0.82	0.74	1.00	0.16	0.15	0.16	0.15	2.81	2.21	2.05	2.02	2.90	0.17	0.16	0.16	0.14	0.15	0.17	0.16	0.16	0.14	0.15	1.70	1.39	2.00	2.70	2.17							
49	0.14	1.81	2.33	0.15	1.38	0.16	0.15	0.16	0.15	0.17	0.17	0.17	0.16	0.15	0.17	0.16	0.16	0.14	0.15	0.17	0.16	0.16	0.14	0.15	0.14	0.16	0.16	0.15	0.16	0.15	0.16	0.15	0.16	0.15	0.16	
52	1.76	1.65	1.72	1.55	1.99	0.16	0.15	0.16	0.15	4.05	4.66	3.20	2.41	3.74	1.38	0.95	1.34	2.14	1.20	1.36	1.33	1.71	1.24	1.21	3.66	3.01	3.87	5.83	4.22							
66	0.72	0.62	0.91	0.71	1.08	1.00	1.63	1.03	0.76	1.66	1.82	2.26	1.96	1.72	2.19	3.12	3.63	2.96	2.31	3.27	2.36	2.06	2.70	0.83	1.27	0.84	1.37	1.83	1.76							
87	3.09	2.71	3.22	3.22	3.78	0.16	0.15	0.16	0.53	9.16	4.79	4.78	4.53	8.68	3.76	4.51	4.83	6.18	5.02	5.92	4.80	5.77	5.82	4.77	7.97	6.06	8.53	12.79	9.85							
90/101	3.52	3.91	4.23	3.71	4.36	2.83	1.90	2.31	1.33	4.88	4.76	5.45	5.12	5.36	0.17	0.16	0.16	0.14	0.15	0.17	0.16	0.16	0.14	0.15	9.97	7.59	10.22	15.40	12.78							
105	0.14	0.13	0.16	0.15	0.16	0.16	0.15	0.16	0.15	0.72	0.71	0.77	0.73	0.78	0.17	0.16	0.16	0.14	0.15	0.17	0.16	0.16	0.14	0.15	1.16	0.92	1.42	2.15	1.53							
118	2.26	2.12	2.57	2.45	3.01	0.16	0.15	0.16	0.15	3.45	3.37	3.51	3.37	3.67	1.16	1.30	1.41	1.73	1.50	1.25	1.32	1.27	1.29	1.17	5.81	4.46	6.69	10.17	7.71							
128	0.14	0.86	0.16	0.15	0.16	0.16	0.15	0.16	0.15	0.17	0.17	0.17	0.16	0.15	0.17	0.16	0.16	0.14	0.15	0.17	0.16	0.16	0.14	0.15	0.14	0.16	0.16	0.15	0.16	0.15	0.16	0.15	0.16	0.15	0.16	
138	3.20	3.61	3.94	3.22	3.88	1.80	2.88	1.97	1.73	3.95	4.00	5.83	4.60	4.93	1.56	1.85	1.93	2.45	2.08	2.20	2.00	2.18	2.70	1.90	7.69	6.21	8.80	13.38	10.48							
153	2.39	2.35	2.78	2.41	2.96	1.41	1.20	1.20	1.05	2.26	1.99	2.50	2.33	2.30	0.80	0.95	1.07	1.36	1.14	1.20	1.20	1.28	1.30	1.08	4.40	3.17	4.82	6.83	5.60							
170	0.14	0.13	3.85	2.83	0.16	0.16	0.15	0.16	0.15	0.17	0.17	0.17	4.78	5.15	7.00	7.28	9.51	8.08	8.05	4.64	9.86	8.38	8.81	8.59	0.91	0.76	1.03	1.25	1.13							
180	0.14	0.13	0.16	0.15	0.16	0.16	0.15	0.16	0.15	0.17	0.17	0.17	0.16	0.15	0.17	0.16	0.16	0.14	0.43	0.17	0.16	0.16	0.58	0.15	0.14	0.16	0.16	0.15	0.16	0.15	0.16	0.15	0.16	0.15	0.16	
183	0.14	0.74	1.21	0.15	0.16	0.16	0.15	0.16	0.15	0.17	0.17	0.17	0.16	0.15	0.17	0.16	0.16	0.45	0.54	0.17	0.86	0.16	0.14	0.15	0.14	0.16	0.16	0.70	0.54							
184																																				
187	0.14	0.13	0.16	0.15	0.16	0.79	1.13	0.99	0.17	2.17	1.74	2.04	1.78	2.00	1.52	1.62	1.90	1.73	1.95	2.14	2.13	2.18	2.31	2.09	1.90	1.30	1.98	3.12	2.84							
195	0.14	0.13	0.16	0.15	0.16	0.16	0.15	0.16	0.15	0.17	0.17	0.17	0.16	0.15	0.17	0.16	0.16	0.14	0.15	0.17	0.16	0.16	0.14	0.15	0.14	0.16	0.16	0.15	0.16	0.15	0.16	0.15	0.16	0.15	0.16	
206	0.14	2.56	0.16	0.15	0.16	0.16	0.15	0.16	0.15	0.17	0.17	0.17	0.16	0.15	0.17	0.16	0.16	0.14	0.15	0.17	0.16	0.16	0.14	0.15	0.14	0.16	0.16	0.15	0.16	0.15	0.16	0.15	0.16	0.15	0.16	
209																																				
Subtotal PCBs	19.26	24.67	28.98	22.44	25.20	10.16	10.99	9.83	7.60	36.76	31.70	34.04	35.03	42.57	21.35	23.44	27.48	28.62	25.72	23.96	27.57	26.69	28.29	23.44	47.28	36.64	51.66	76.90	61.41							
Mean subtotal PCBs	24.1					9.6					36.0					25.3					26.0					54.8										
Estimated mean total PCBs*	48.2					19.3					72.0					50.6					52.0					109.6										

* Total PCBs estimated using methodology consistent with USEPA (2002).

TABLE 17. Measured and modeled tissue residues of tPCBs in oligochaetes associated with open-lake reference and placement area sediments in the Central Basin of Lake Erie (based on data from various sources).

Lake area	Mean tPCB tissue concentration (µg/kg)	Measured/predicted	Description	Data source
Cleveland Harbor proposed open-lake placement area	19.3	Predicted	Extrapolation based on subset of 22 congeners measured in tissue	USAERDC (2012)
Cleveland Harbor old open-lake placement area	48.2	Predicted	Extrapolation based on subset of 22 congeners measured in tissue	USAERDC (2012)
Cleveland Harbor open-lake reference area	19.1	Predicted	TBP prediction based on detected Aroclor 1254 measured in sediment	EI (2007)
Ashtabula Harbor open-lake reference area	20	Measured	Sum of 209 congeners measured in tissue	USACE (2010)
Ashtabula Harbor open-lake reference area	29.5	Measured	Sum of 209 congeners measured in tissue	USACE (2010)
Ashtabula Harbor open-lake reference area	28.1	Measured	Sum of 209 congeners measured in tissue	USACE (2009)
Ashtabula Harbor open-lake placement area	57.8	Measured	Sum of 209 congeners measured in tissue	USACE (2009)
Ashtabula Harbor open-lake reference areas (two)	110	Predicted	TBP prediction based on sum of Aroclors 1248 and 1260 measured in sediment	USACE (2010)
Ashtabula Harbor open-lake reference area 1	43.4	Measured	Sum of Aroclors 1248 and 1260 measured in tissue	(ESE 1993)
Ashtabula Harbor open-lake reference area 2	94.6	Measured	Sum of Aroclors 1248 and 1260 measured in tissue	(ESE 1993)
Ashtabula Harbor open-lake reference area 3	168	Measured	Sum of Aroclors 1248 and 1260 measured in tissue	(ESE 1993)
Range (all areas)	19.1 to 168			
Average (all areas)	58.0			
Range (reference areas only)*	19.1 to 168			
Average (reference areas only)*	59.1			
Range (placement areas only)	48.2 to 57.8			
Average (placement areas only)	53.0			

*Also includes proposed ("unimpacted") Cleveland Harbor open-lake placement area.

TABLE 18. Home range estimates for *Perca flavescens* based on data from Glover *et al.* (2008).

Season	Tagging site	Distance moved in direction (degree range) relative to tagging location (km)				Distance (km)		Estimated home range	
		North	South	East	West	Average Y-distance for fish recapture from tagging site	Average X-distance for fish recapture from tagging site	Area (km ²) representing mean distance traveled	Area (mi ²) representing mean distance traveled
		315°-45°	135°-225°	45°-135°	225°-315°				
Summer	WI1	20.5	31.3			51.8	3.2	130.12	50.18
	IL1	10.7	11.1			22.1	3.2	55.52	21.41
	IL2	10.9	29.7			40.6	3.2	101.99	39.33
	IL3	19.1	39.6			58.7	3.2	147.45	56.86
	IL4	22.7	44.2			66.9	3.2	168.05	64.81
	IL5	24.4	35.1			59.5	3.2	149.46	57.64
	IN1		1.1	9.1	40.5	1.1	49.6	42.83	16.52
	MI1	38.8	1			39.8	3.2	99.98	38.56
	MI2	18.3	19.1			37.4	3.2	93.95	36.23
						Minimum	42.83	16.52	
Non-summer	WI1	6	0			6	3.2	15.07	5.81
	IL1	23.2	64.1			87.3	3.2	219.30	84.57
	IL2	11.6	55.2			66.8	3.2	167.80	64.71
	IL3	33.9	50.6			84.5	3.2	212.26	81.86
	IL4	12.5	51.2			63.7	3.2	160.01	61.71
	IL5	27.1	50			77.1	3.2	193.68	74.69
	IN1				49	3.2	49	123.09	47.47
	MI1	62.1				62.1	3.2	156.00	60.16
	MI2	43.3				43.3	3.2	108.77	41.95
						Minimum	15.07	5.81	
Cross-season	WI1	13.25	31.3			44.55	3.2	111.91	43.16
	IL1	16.95	38			54.95	3.2	138.03	53.23
	IL2	11.25	41.95			53.2	3.2	133.64	51.54
	IL3	26.5	45.1			71.6	3.2	179.86	69.36
	IL4	17.6	47.7			65.3	3.2	164.03	63.26
	IL5	25.75	42.55			68.3	3.2	171.57	66.16
	IN1		1.1	9.1	44.75	1.1	53.9	46.54	17.95
	MI1	50.45	1			51.45	3.2	129.24	49.84
	MI2	30.8	19.1			49.9	3.2	125.35	48.34
						Minimum	46.54	17.95	

TABLE 19. Estimated PCB oligochaete tissue residues (C_o) to which receptor species would be exposed to within a home range that overlaps both open-lake placement areas CLA-1 and CLA-4.

Receptor species	Management unit	Home range (mi ²) *	Area of placement area (CLA-1) (mi ²)	Area of former placement area (CLA-4) (mi ²)	C_{HREF} (µg/kg) **	C_{HDM} (µg/kg) **	$C_{\Sigma HDMFPA}$ (µg/kg) **	C_o (µg/kg)
Walleye	DMMU-1	51.8	1	1	12.9	55.6	32.2	14.0969112
	DMMU-2a	51.8	1	1	12.9	33.2	32.2	13.66447876
	DMMU-2b	51.8	1	1	12.9	36.6	32.2	13.73011583

*Home range estimate based on Wang *et al.* (2007) (minimum, male, 28.6 mi distance with assumed two mi width, yielding a HR of 28.6 mi² [conservative]).

**Sum of PCB congeners 44, 52, 64, 66, 70, 75, 81/87, 90/101, 95, 97, 105, 107, 110, 118, 122, 138, 149, 151, 153, 163/164, 170 and 187.

Receptor species	Management unit	Home range (mi ²) *	Area of placement area (CLA-1) (mi ²)	Area of former placement area (CLA-4) (mi ²)	C_{HREF} (µg/kg) **	C_{HDM} (µg/kg) **	$C_{\Sigma HDMFPA}$ (µg/kg) **	C_o (µg/kg)
Yellow perch	DMMU-1	18	1	1	12.9	55.6	32.2	16.34444444
	DMMU-2a	18	1	1	12.9	33.2	32.2	15.1
	DMMU-2b	18	1	1	12.9	36.6	32.2	15.28888889

*Home range estimate based on data from Glover *et al.* (2008).

**Sum of PCB congeners 44, 52, 64, 66, 70, 75, 81/87, 90/101, 95, 97, 105, 107, 110, 118, 122, 138, 149, 151, 153, 163/164, 170 and 187.

TABLE 20. Receptor species' PCB bioaccumulation exposure factors (BEFs) for upper Cuyahoga River Channel dredged material placed at open-lake placement areas CLA-1 and CLA-4 (BEF > 1.2 signals excursion beyond 20% analytical variability alone).

Receptor species	Management unit	Area of placement area (CLA-4) (mi ²)	C _{ΣHDM} (µg/kg)*	C _{ΣHDMFPA} (µg/kg)*	Area of former placement area (CLA-1) (mi ²)	C _{ΣHREF} (µg/kg)*	HR (mi ²)**	BEF
Walleye	DMMU-1	1	55.6	32.2	1	12.9	51.8	1.092783814
	DMMU-2a	1	33.2	32.2	1	12.9	51.8	1.05926192
	DMMU-2b	1	36.6	32.2	1	12.9	51.8	1.064350064

*Sum of PCB congeners 44, 52, 64, 66, 70, 75, 81/87, 90/101, 95, 97, 105, 107, 110, 118, 122, 138, 149, 151, 153, 163/164, 170 and 187.

**Home range estimate based on Wang *et al.* (2007) (minimum, male, 28.6 mi distance with assumed two mi width, yielding a HR of 28.6 mi² [conservative]).

Receptor species	Management unit	Area of placement area (CLA-4) (mi ²)	C _{ΣHDM} (µg/kg)*	C _{ΣHDMFPA} (µg/kg)*	Area of former placement area (CLA-1) (mi ²)	C _{ΣHREF} (µg/kg)*	HR (mi ²)**	BEF
Yellow perch	DMMU-1	1	55.6	32.2	1	12.9	18	1.267011197
	DMMU-1	0.663	55.6	32.2	1	12.9	18	1.20503919
	DMMU-2a	1	33.2	32.2	1	12.9	18	1.170542636
	DMMU-2b	1	36.6	32.2	1	12.9	18	1.185185185

*Sum of PCB congeners 44, 52, 64, 66, 70, 75, 81/87, 90/101, 95, 97, 105, 107, 110, 118, 122, 138, 149, 151, 153, 163/164, 170 and 187.

***Home range estimate based on data from Glover *et al.* (2008).

TABLE 21. Results of 28-day *L. variegatus* ΣDDT bioaccumulation experiments on Cleveland Harbor Federal navigation channel, CDF and Lake Erie vicinity sediments (highlighted values are non-detectable concentrations valued at one-half the MDL) (USAERDC 2012). For statistical comparison purposes, tissue residues are presented as ΣPCBs (see text).

DDT Isomer (ug/kg)	Lake Area										Harbor Management Unit															CDF 10B				
	CLA 1 Comp replicate					CLA 4 Comp replicate					DMMU 1 replicate					DMMU 2a replicate					DMMU 2b replicate					CDF Comp replicate				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
4,4'-DDD	1.990	2.300	2.500	3.090	2.540	0.748	0.679	2.420	0.587	0.693	1.390	1.810	1.200	1.200	1.330	0.894	0.873	0.934	0.993	0.950	1.340	1.580	1.380	1.560	1.390	0.936	0.604	0.829	1.460	1.070
4,4'-DDE	2.580	2.790	3.312	2.670	3.210	1.190	0.934	4.190	0.994	0.824	4.290	3.850	3.870	4.010	3.530	2.170	2.210	2.680	2.340	3.020	4.290	3.430	3.880	5.180	4.170	1.950	1.330	2.040	3.390	2.830
4,4'-DDT	0.048	0.051	0.053	0.051	0.055	0.054	0.052	0.051	0.053	0.051	0.057	0.056	0.057	0.052	0.051	0.056	0.053	0.054	0.047	0.051	0.056	0.051	0.056	0.049	0.051	0.048	0.053	0.053	0.052	0.055
2,4'-DDD	0.085	0.089	0.093	0.089	0.50*	0.094	0.092	0.090	0.092	0.089	0.100	0.099	0.099	0.092	0.089	0.098	0.093	0.094	0.083	0.090	0.097	0.089	0.097	0.086	0.089	0.085	0.092	0.093	0.091	0.096
2,4'-DDE	0.085	0.089	0.093	0.089	0.097	0.094	0.092	0.090	0.092	0.089	0.100	0.099	0.099	0.092	0.089	0.098	0.093	0.094	0.083	0.090	0.097	0.089	0.097	0.086	0.089	0.085	0.092	0.093	0.091	0.096
2,4'-DDT	0.085	0.089	0.093	0.089	0.097	0.094	0.092	0.090	0.092	0.089	0.100	0.099	0.099	0.092	0.089	0.098	0.093	0.094	0.083	0.090	0.097	0.089	0.097	0.086	0.089	0.085	0.092	0.093	0.091	0.096
ΣDDT	4.570	5.090	5.812	5.760	5.750	1.938	1.613	6.610	1.581	1.517	5.680	5.660	5.070	5.210	4.860	3.064	3.083	3.614	3.333	3.970	5.630	5.010	5.260	6.740	5.560	2.886	1.934	2.869	4.850	4.243
Mean ΣDDT	5.396					2.652					5.296					3.413					5.640					3.356				
Mean lipid	1.6					1.3					1.2					1.2					1.2					1.3				

TABLE 22. Estimated Σ DDT oligochaete tissue residues (C_o) to which receptor species would be exposed to within a home range that overlaps both open-lake placement areas CLA-1 and CLA-4.

Receptor species	Management unit	Home range (mi ²)*	Area of placement area (CLA-1) (mi ²)	Area of former placement area (CLA-4) (mi ²)	C_{HREF} (μg/kg)**	C_{HDM} (μg/kg)**	$C_{\Sigma HDMFPA}$ (μg/kg)**	C_o (μg/kg)
Walleye	DMMU-1	51.8	1	1	2.65	5.3	5.4	2.754247104
	DMMU-2a	51.8	1	1	2.65	3.41	5.4	2.717760618
	DMMU-2b	51.8	1	1	2.65	5.64	5.4	2.760810811

*Home range estimate based on Wang *et al.* (2007) (minimum, male, 28.6 mi distance with assumed two mi width, yielding a HR of 28.6 mi² [conservative]).

**Sum of DDD and DDE.

Receptor species	Management unit	Home range (mi ²)*	Area of placement area (CLA-1) (mi ²)	Area of former placement area (CLA-4) (mi ²)	C_{HREF} (μg/kg)**	C_{HDM} (μg/kg)**	$C_{\Sigma HDMFPA}$ (μg/kg)**	C_o (μg/kg)
Yellow perch	DMMU-1	18	1	1	2.65	5.3	5.4	2.95
	DMMU-2a	18	1	1	2.65	3.41	5.4	2.845
	DMMU-2b	18	1	1	2.65	5.64	5.4	2.968888889

*Home range estimate based on data from Glover *et al.* (2008).

**Sum of DDD and DDE.

TABLE 23. Receptor species' ΣDDT bioaccumulation exposure factors (BEFs) for upper Cuyahoga River Channel dredged material placed at open-lake placement areas CLA-1 and CLA-4 (BEF > 1.2 signals excursion beyond 20% analytical variability alone).

Receptor species	Management unit	Area of placement area (CLA-4) (mi ²)	C _{ΣHDM} (μg/kg)*	C _{ΣHDMFPA} (μg/kg)*	Area of former placement area (CLA-1) (mi ²)	C _{ΣHREF} (μg/kg)*	HR (mi ²)**	BEF
Walleye	DMMU-1	1	5.3	5.4	1	2.65	51.8	1.03933853
	DMMU-2a	1	3.41	5.4	1	2.65	51.8	1.025570044
	DMMU-2b	1	5.64	5.4	1	2.65	51.8	1.0418154

*Sum of DDD and DDE.

**Home range estimate based on Wang *et al.* (2007) (minimum, male, 28.6 mi distance with assumed two mi width, yielding a HR of 28.6 mi² [conservative]).

Receptor species	Management unit	Area of placement area (CLA-4) (mi ²)	C _{ΣHDM} (μg/kg)*	C _{ΣHDMFPA} (μg/kg)*	Area of former placement area (CLA-1) (mi ²)	C _{ΣHREF} (μg/kg)*	HR (mi ²)**	BEF
Yellow perch	DMMU-1	1	5.3	5.4	1	2.65	18	1.113207547
	DMMU-2a	1	3.41	5.4	1	2.65	18	1.073584906
	DMMU-2b	1	5.64	5.4	1	2.65	18	1.12033543

*Sum of DDD and DDE.

***Home range estimate based on data from Glover *et al.* (2008).

TABLE 25. Inorganic standard and modified elutriate test (SET/MET) data on Cleveland Harbor Federal navigation channel, CDF and Lake Erie vicinity sediments (USACE 2013b).

Inorganic Parameter (mg/L)	Cleveland Lake Water (CL)			Lake Area #1 (CLA1)						Lake Area #4 (CLA4)						DMMU 1						DMMU 2a						DMMU 2b						CDF 10B								
				SET-UF*			SET-F**			SET-UF			SET-F			SET-UF			SET-F			MET-UF			MET-F			SET-UF			SET-F			MET-UF			MET-F			SET-F		
	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ			
Ammonia-N	0.03											7.2	7.1					3.7			15.8	16.8			11.7	11.4	10.6				10.5	0.078										
Cyanide, Total	0.01											0.01	0.01					0.01	0.01		0.011	0.012			0.012	0.01	0.01				0.01	0.01										
Hardness (mg equil CaCO3)	120											226	175					145			216	215			185	319	239				202	207										
Phosphorus, Total (As P)	0.0313 J			0.453			0.0319 J			0.225	0.0316 J			0.997	0.0653	0.637		0.0602			0.503	0.11	0.458	0.105	1.51	0.124	0.464			0.464	0.1170	0.0569										
Total Organic Carbon	2.0											10.9	12.6	6.9	5.9	47.7	53.2	40.7	40.4	75.4	74.3	64.6	64.6	64.6	64.6	64.6	64.6	64.6	64.6	64.6	64.6	64.6	64.6	64.6	64.6	64.6	64.6	64.6				
Total Suspended Solids	3.0 J			640			3.0 J			458	2.0 J			1,450	53.3	725		10			760	52.8	217	17.5	2,080	40	265			22.7	500											
Turbidity (NTU)	6.1			2,900			76			74	950			1,300	66	775		28			825	40	500	16.4	1,850	34	400			21	400											

Inorganic Parameter (mg/L)	Middle River Reach (MRR)			Lower River Reach (LRR)			Old River Reach (ORR)			Outer Harbor Reach (OHR)												
	MET-UF			MET-F			MET-UF			MET-F												
	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ							
Cyanide, Total	0.0088 J			0.0072 J			0.0073 J			0.0230			0.0058 J			0.0080 J			0.0063 J			0.0100 U
Phosphorus, Total (As P)	0.71			0.15			0.66			0.1			0.15			0.024			0.052			0.0058 J
Turbidity (NTU)	40			12			96			14			77			6.3			15			1.4
Total Suspended Solids	140 J			2.0 J			54 J			3.0 J			41			1.0 U J			42 J			1.0 U J
Ammonia-N	7.1			5.7			4.8			4.6			2.2			1.9			3.1			2.9
Total Organic Carbon	19			14			6.6			7.0			2.9			2.7			2.5			2.5

*Unfiltered water.
 **Filtered water.
 LQ - Laboratory qualifiers:
 U = Indicates the compound was analyzed for but not detected at or above the method detection limit (MDL).
 J = Indicates values below the RL but greater than the MDL.
 VQ - Data validation qualifiers:
 RTI (samples MRR, LRR, ORR, and OHR) TSS analysis (SM 2540D) exceeded the analysis holding time. The samples were flagged with a J.

TABLE 26. PAH SET/MET data on Cleveland Harbor Federal navigation channel, CDF and Lake Erie vicinity sediments (USACE 2013b).

PAH (ug/L)	Cleveland Lake Water (CL)	Lake Area #1 (CLA1)				Lake Area #4 (CLA4)				DMMU 1				DMMU 2a				DMMU 2b				CDF 10B											
	Result LQ VQ	SET-UF		SET-F		SET-UF		SET-F		SET-UF		SET-F		MET-UF		MET-F		SET-UF		SET-F		MET-UF		MET-F		SET-F							
		Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ		
1-Methylnaphthalene	1.6 U						1.6 U			1.6 U			1.6 U			1.6 U			1.6 U			1.6 U			1.6 U			1.6 U			1.6 U		
2-Methylnaphthalene	1.6 U						1.6 U			1.6 U			1.6 U			1.6 U			1.6 U			1.6 U			1.6 U			1.6 U			1.6 U		
Acenaphthene	0.04 U						0.08 J			0.04 U			0.04 U			0.04 U			0.04 U			0.04 U			0.04 U			0.04 U			0.04 U		
Acenaphthylene	0.04 U						0.08 J			0.04 U			0.04 U			0.04 U			0.04 U			0.04 U			0.04 U			0.04 U			0.04 U		
Anthracene	0.04 U						0.32			0.04 U			0.04 J			0.04 J			0.16 J			0.04 U			0.04 J			0.04 U			0.04 U		
Benzo(a)anthracene	0.04 U						2.0			0.04 J			0.24			0.28			0.04 J			0.16 J			0.72			0.04 J			0.2		
Benzo(a)pyrene	0.04 U						2.4			0.08 J			0.44			0.44			0.04 J			0.28			0.88			0.04 J			0.32		
Benzo(b)fluoranthene	0.04 U						2.8			0.12 J			0.64 J			0.76 J			0.08 J			0.44 J			1.24 J			0.04 J			0.48 J		
Benzo(g,h,i)perylene	0.04 U R						2.68			0.08 J			0.48			0.56			0.08 J			0.32			1.04			0.04 J			0.36		
Benzo(k)fluoranthene	0.04 U						2.56 J			0.08 J			0.6 J			0.6 J			0.08 J			0.4 J			1.12 J			0.04 J			0.4 J		
Chrysene	0.04 U						3.36			0.08 J			0.52			0.52			0.08 J			0.32			1.12			0.04 J			0.36		
Dibenz(a,h)anthracene	0.04 U R						0.36			0.04 U			0.08 J			0.08 J			0.04 U			0.04 J			0.12 J			0.04 U			0.04 J		
Fluoranthene	0.04 U						6.76			0.16 J			0.64			1.12			0.16 J			0.68			3.0			0.08 J			0.8		
Fluorene	0.04 U						0.16 J			0.04 U			0.04 J			0.04 J			0.04 U			0.04 U			0.08 J			0.04 U			0.04 J		
Indeno(1,2,3-cd)pyrene	0.04 U						2.72			0.08 J			0.44			0.48			0.08 J			0.32			1.04			0.04 J			0.32		
Naphthalene	0.04 U						0.12 J			0.04 U			0.04 J			0.04 J			0.04 J			0.04 J			0.04 J			0.04 J			0.08 J		
Phenanthrene	0.04 U						1.48			0.04 J			0.2			0.28			0.04 J			0.16 J			0.72			0.04 J			0.24		
Pyrene	0.04 U						2.44			0.12 J			0.8			0.6			0.08 J			0.36			1.04			0.08 J			0.44		
Total PAHs*	0.64						30.32			1.12			5.28			5.92			1.00			3.68			12.4			0.72			4.20		

PAH (ug/L)	Middle River Reach (MRR)			Lower River Reach (LRR)			Old River Reach (ORR)			Outer Harbor Reach (OHR)							
	MET-UF*		MET-F**	MET-UF		MET-F	MET-UF		MET-F	MET-UF		MET-F					
	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ
2-Methylnaphthalene	0.27 U J	0.25 U J	0.26 U J	0.26 U J	0.27 U J	0.27 U J	0.25 U J	0.26 U J	0.25 U J	0.27 U J	0.25 U J	0.25 U J					
Acenaphthene	0.21 U J	0.19 U J	0.20 U J	0.20 U J	0.20 U J	0.20 U J	0.19 U J	0.20 U J	0.19 U J	0.20 U J	0.19 U J	0.19 U J					
Acenaphthylene	0.20 U J	0.18 U J	0.19 U J	0.19 U J	0.19 U J	0.19 U J	0.18 U J	0.19 U J	0.18 U J	0.19 U J	0.18 U J	0.18 U J					
Anthracene	0.20 U J	0.18 U J	0.19 U J	0.19 U J	0.19 U J	0.19 U J	0.18 U J	0.19 U J	0.18 U J	0.19 U J	0.18 U J	0.18 U J					
Benzo(a)anthracene	0.20 U J	0.19 U J	0.19 U J	0.19 U J	0.19 U J	0.20 U J	0.18 U J	0.19 U J	0.19 U J	0.19 U J	0.19 U J	0.19 U J					
Benzo(a)pyrene	0.18 U J	0.17 U J	0.17 U J	0.17 U J	0.17 U J	0.18 U J	0.16 U J	0.17 U J	0.17 U J	0.17 U J	0.17 U J	0.17 U J					
Benzo(b)fluoranthene	0.25 U J	0.23 U J	0.24 U J	0.23 U J	0.23 U J	0.24 U J	0.23 U J	0.24 U J	0.23 U J	0.24 U J	0.23 U J	0.23 U J					
Benzo(g,h,i)perylene	0.27 U J	0.25 U J	0.26 U J	0.25 U J	0.26 U J	0.26 U J	0.24 U J	0.26 U J	0.25 U J	0.26 U J	0.25 U J	0.25 U J					
Benzo(k)fluoranthene	0.22 U J	0.20 U J	0.21 U J	0.21 U J	0.20 U J	0.21 U J	0.2 U J	0.21 U J	0.20 U J	0.21 U J	0.20 U J	0.20 U J					
Chrysene	0.21 U J	0.19 U J	0.20 U J	0.20 U J	0.20 U J	0.20 U J	0.19 U J	0.20 U J	0.19 U J	0.20 U J	0.19 U J	0.19 U J					
Dibenz(a,h)anthracene	0.29 U J	0.26 U J	0.27 U J	0.27 U J	0.27 U J	0.28 U J	0.26 U J	0.28 U J	0.26 U J	0.28 U J	0.26 U J	0.26 U J					
Fluoranthene	0.40 J	0.19 U J	0.36 J	0.36 J	0.19 U J	0.20 U J	0.18 U J	0.19 U J	0.19 U J	0.19 U J	0.19 U J	0.19 U J					
Fluorene	0.18 U J	0.17 U J	0.18 U J	0.17 U J	0.17 U J	0.18 U J	0.17 U J	0.18 U J	0.17 U J	0.18 U J	0.17 U J	0.17 U J					
Indeno(1,2,3-cd)pyrene	0.28 U J	0.26 U J	0.27 U J	0.27 U J	0.27 U J	0.27 U J	0.26 U J	0.27 U J	0.26 U J	0.27 U J	0.26 U J	0.26 U J					
Naphthalene	0.25 U J	0.23 U J	0.24 U J	0.23 U J	0.23 U J	0.24 U J	0.23 U J	0.24 U J	0.23 U J	0.24 U J	0.23 U J	0.23 U J					
Phenanthrene	0.15 U J	0.20 J	0.22 J	0.14 U J	0.15 U J	0.15 U J	0.14 U J	0.15 U J	0.14 U J	0.15 U J	0.14 U J	0.14 U J					
Pyrene	0.23 U J	0.21 U J	0.22 J	0.22 U J	0.23 U J	0.23 U J	0.21 U J	0.22 U J	0.21 U J	0.22 U J	0.21 U J	0.21 U J					
Total PAHs*	3.72	3.30	3.67	3.31	3.42	3.20	3.38	3.24									

*Unfiltered water.
 **Filtered water.
 LQ - Laboratory qualifiers:
 U = Indicates the compound was analyzed for but not detected at or above the method detection limit (MDL).
 J = Indicates values below the RL but greater than the MDL.
 VQ - Data validation qualifiers:
 PAH analysis (8270) in batch B205032 (CL-Site Water) had recoveries of dibenz(a,h)anthracene and benzo(g,h,i)perylene that were below criteria. Non-detect results were rejected (R flagged).
 PAH analysis (8270) in batch B205068 for all elutriate samples (except CL-Site Water) had recoveries of benzo(b)fluoranthene and benzo(k)fluoranthene that were above criteria. Associated sample results that were detected were flagged with a J. Non-detect results did not require further qualification.
 RTI (MRR, LRR, ORR, AND OHR samples) PAH analysis (8082) exceeded the extraction to analysis holding time. The samples were flagged with a J.
 *Total PAHs represents the sum of the 16 priority pollutant PAHs (excluding 1- and 2-Methylnaphthalene). MDL used as value for undetected analytes.

TABLE 28. Pesticides SET/MET data on Cleveland Harbor Federal navigation channel, CDF and Lake Erie vicinity sediments (USACE 2013b).

Pesticide (ug/kg)	Cleveland Lake Water (CL)			Lake Area #1 (CLA1)			Lake Area #4 (CLA4)			DMMU 1				DMMU 2a				DMMU 2b				CDF 10B										
	SET-UF*			SET-F**			SET-UF		SET-F		SET-UF		SET-F		MET-UF		MET-F		SET-UF		SET-F		MET-UF		MET-F		SET-F					
	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ		
4,4'-DDD	0.001	U	J									0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U	
4,4'-DDE	0.001	U	J									0.001	U		0.001	U		0.003	J		0.003	J		0.001	U		0.001	U		0.003	J	
4,4'-DDT	0.001	U	R									0.001	U		0.001	U		0.003	J		0.001	U		0.001	U		0.001	U		0.001	U	
Aldrin	0.001	U	J									0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U	
alpha-BHC	0.001	U	J									0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U	
alpha-Chlordane	0.001	U	J									0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U	
beta-BHC	0.001	U	J									0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U	
delta-BHC	0.001	U	R									0.001	U	R	0.001	U	R	0.001	U	R	0.001	U	R	0.001	U	R	0.001	U	R	0.001	U	R
Dieldrin	0.001	U	J									0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U	
Endosulfan-I	0.001	U	J									0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U	
Endosulfan-II	0.001	U	J									0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U	
Endosulfan-Sulfate	0.001	U	J									0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U	
Endrin	0.001	U	J									0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U	
Endrin Aldehyde	0.001	U	J									0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U	
Endrin Ketone	0.001	U	R									0.001	U	R	0.001	U	R	0.001	U	R	0.001	U	R	0.001	U	R	0.001	U	R	0.001	U	R
gamma-BHC	0.001	U	J									0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U	
gamma-Chlordane	0.001	U	J									0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U	
Heptachlor	0.001	U	J									0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U	
Heptachlor Epoxide	0.001	U	J									0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U	
Methoxychlor	0.001	U	J									0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U	
Toxaphene	0.001	U	J									0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U		0.001	U	

Pesticide (ug/kg)	Middle River Reach (MRR)			Lower River Reach (LRR)			Old River Reach (ORR)			Outer Harbor Reach (OHR)					
	MET-UF			MET-F			MET-UF			MET-F					
	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ	Result	LQ	VQ
4,4'-DDD	0.0031	U	J	0.0030	U	J	0.0031	U	J	0.0030	U	J	0.0030	U	J
4,4'-DDE	0.0260	J		0.0180	J		0.0210	J		0.0150	J		0.0140	J	
4,4'-DDT	0.0032	U	J	0.0031	U	J	0.0032	U	J	0.0031	U	J	0.0031	U	J
Aldrin	0.0031	U	J	0.0030	U	J	0.0031	U	J	0.0030	U	J	0.0030	U	J
alpha-BHC	0.0020	U	J	0.0020	U	J	0.0020	U	J	0.0020	U	J	0.0020	U	J
alpha-Chlordane	0.0032	U	J	0.0031	U	J	0.0032	U	J	0.0031	U	J	0.0031	U	J
beta-BHC	0.0031	U	J	0.0030	U	J	0.0031	U	J	0.0030	U	J	0.0030	U	J
delta-BHC	0.0020	U	J	0.0020	U	J	0.0020	U	J	0.0020	U	J	0.0020	U	J
Dieldrin	0.0031	U	J	0.0030	U	J	0.0031	U	J	0.0030	U	J	0.0030	U	J
Endosulfan I	0.0032	U	J	0.0031	U	J	0.0032	U	J	0.0031	U	J	0.0031	U	J
Endosulfan II	0.0031	U	J	0.0030	U	J	0.0031	U	J	0.0030	U	J	0.0030	U	J
Endosulfan sulfate	0.0031	U	J	0.0030	U	J	0.0031	U	J	0.0030	U	J	0.0030	U	J
Endrin	0.0028	U	J	0.0027	U	J	0.0028	U	J	0.0110	J		0.0090	J	
Endrin aldehyde	0.0036	U	J	0.0035	U	J	0.0036	U	J	0.0035	U	J	0.0035	U	J
Endrin ketone	0.0032	U	J	0.0120	J		0.0032	U	J	0.0031	U	J	0.0074	J	
gamma-BHC	0.0020	U	J	0.0020	U	J	0.0020	U	J	0.0020	U	J	0.0020	U	J
gamma-Chlordane	0.0032	U	J	0.0031	U	J	0.0032	U	J	0.0031	U	J	0.0031	U	J
Heptachlor	0.0029	U	J	0.0028	U	J	0.0029	U	J	0.0028	U	J	0.0028	U	J
Heptachlor epoxide	0.0033	U	J	0.0032	U	J	0.0033	U	J	0.0032	U	J	0.0032	U	J
Methoxychlor	0.0031	U	J	0.0030	U	J	0.0031	U	J	0.0030	U	J	0.0030	U	J

*Unfiltered water.

**Filtered water.

LQ - Laboratory qualifiers:

U = Indicates the compound was analyzed for but not detected at or above the method detection limit (MDL).

J = Indicates values below the RL but greater than the MDL.

VQ - Data validation qualifiers:

Pesticide analysis (8081) in batches B205032 and B205068 for elutriate samples and CLSite Water had recoveries of delta BHC that were below criteria. Non-detect results were rejected (R flagged).

Pesticide analysis (8081) in batch B205032 for sample CL-Site Water exceeded the extraction to analysis holding time. The results have been qualified with a UJ value.

Pesticide analysis (8081) in batch B205032 for sample CL-Site Water had recoveries of 4,4'-DDT that were below criteria. Non-detect results were rejected (R flagged).

RTI (MRR, LRR, ORR, AND OHR samples) pesticides analysis (8081) exceeded the extraction to analysis holding time. The samples were flagged with a J.

TABLE 29. Results of 48-hour *Ceriodaphnia dubia* and 96-hour *Pimephales promelas* elutriate bioassays on Cleveland Harbor Federal navigation channel, CDF and Lake Erie vicinity sediments (USAERDC 2012).

Sample	Elutriate concentration (%)	Species							
		<i>C. dubia</i>				<i>P. promelas</i>			
		Measurement Endpoint				Measurement Endpoint			
		Survival (%)	NOEC (%)	LOEC (%)	LC50 (%)	Survival (%)	NOEC (%)	LOEC (%)	LC50 (%)
DMMU-1	6	100	100	N/A	N/A	98±4	100	N/A	N/A
	13	96±9				98±4			
	25	92±18				100			
	50	100				96±9			
	100	100				98±4			
DMMU-2a	6	100	100	N/A	NC	100	50	100	67 (63-71)
	13	96±9				96±5			
	25	92±18				100			
	50	84±17				96±5			
	100	84±17				0			
DMMU-2b	6	92±18	100	N/A	NC	100	50	100	67 (63-71)
	13	100				100			
	25	100				96±5			
	50	92±11				96±5			
	100	76±17				0			
CDF	6	84±17	100	N/A	N/A	100	100	N/A	N/A
	13	96±9				100			
	25	92±11				100			
	50	92±11				100			
	100	88±18				100			
Control	N/A	92±18	N/A	N/A	N/A	100	N/A	N/A	N/A
Lake Site Water	0	80±28	N/A	N/A	N/A	100	N/A	N/A	N/A

TABLE 30. Cleveland Harbor upper Cuyahoga River Channel sediment management units and sampling sites among 2007, 2010 and 2012 investigations, as keyed to 2012 sampling event.

Management unit		Year/sampling site		
		2007	2010	2012
		Site	Site	Site
DMMU-1		1	1	1
		2	2	2
		3	3	3
		4	4*	4
				5
DMMU-2**	a	5	5	6
		6	6a	7
				8
			6b	9
		7	7a	10
	b			11
			7b	12
				13
		8	8	14
				15

*This site is captured under DMMU-2 because DMMU-1 in this investigation was somewhat smaller in comparison to the 2012 sampling event.

**Under the 2012 investigation, this management unit was subdivided into a and b; also, this management unit (including 2a and 2b) was not explicit in 2007.