Illinois Lake Michigan (nearshore) Toxics TMDL Scoping Report

Prepared for:
USEPA
Contract No. EP-C-12-052,
Task Order No. 0003
Public Notice Version
May 8, 2015

Michael Baker INTERNATIONAL
LimnoTech
Water | Scientists
Environment | Engineers

Blank Page

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

List of Acronyms

AOC	Area of Concern
BAF	Bioaccumulation Factor
CAIR	Clean Air Interstate Rule
CAMR	Clean Air Mercury Rule
CAWS	Chicago Area Waterway System
CMAP	Chicago Metropolitan Agency for Planning
CWA	Clean Water Act
FCMP `	Fish Contaminant Monitoring Program
GEM	Gaseous Elemental Mercury
GIS	Geographic Information System
GLCFS	Great Lakes Coastal Forecasting System
GLENDA	Great Lakes Environmental Database
GLI	Great Lakes Water Quality Initiative
GLNPO	Great Lakes National Program Office
GLRI	Great Lakes Restoration Initiative
HPV	Health Protection Value
IDNR	Illinois Department of Natural Resources
IEPA	Illinois Environmental Protection Agency
LMMBS	Lake Michigan Mass Balance Study
MGD	Million Gallons per Day
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System
MWRD	Metropolitan Water Reclamation District
NCCA	National Coastal Condition Assessment
NOAA	National Oceanic and Atmospheric Administration
ORD	Office of Research and Development
PCB	Polychlorinated Biphenyl
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
REMSAD	Regional Modeling System for Aerosols and Deposition

SOP	Standard Operating Procedure
TMDL	Total Maximum Daily Load
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

1 Introduction

Within the Illinois Lake Michigan Basin, the Illinois Environmental Protection Agency (IEPA) has identified a total of 56 nearshore beach/shoreline, harbor and open water segments that are impaired due to concentrations of polychlorinated biphenyls (PCBs) and mercury in fish tissue and the water column (IEPA, 2014). The fish consumption use is impaired for all of these waterbody segments, and one segment (Waukegan Harbor North) is also impaired for aquatic life use. These impaired waters are included on Illinois' Clean Water Act (CWA) Section 303(d) list. This project will develop mercury and PCB Total Maximum Daily Loads (TMDLs) for these impaired waterbodies to quantify pollutant load reductions needed to reduce mercury and PCB levels in fish tissue and the water column so that the waterbodies can meet water quality standards.

This memorandum includes the following information:

- Section 2. A description of the study area and impaired waterbodies
- Section 3. A summary of data sources and review of data for inclusion in the final database
- Section 4. A description of applicable standards and targets
- Section 5. A discussion of the selection of target fish species
- Section 6. An introduction to TMDL development approaches
- Section 7: A discussion of model selection considerations
- Section 8: A discussion of a range of applicable frameworks
- Section 9: A description of conceptual model development and data gap assessment
- Section 10: A discussion of candidate approaches
- Section 11: A recommendation for a preferred approach

This information will ultimately form the basis for development of TMDLs for mercury and PCBs for the impaired waterbodies.

Blank Page

2
Study Area and Impaired Waterbodies

The project study area is shown in Figure 2-1, and includes one nearshore open water segment, fifty-one beach/shoreline segments and four harbors that are identified by IEPA (IEPA, 2014) as being impaired due to both mercury and polychlorinated biphenyls. All fifty-six impaired waters are located in Lake and Cook Counties, Illinois. The fish consumption use is *Not Supporting* for all segments, and the aquatic life use is also *Not Supporting* for Waukegan Harbor North. Appendix A contains a full listing of the impaired segments and causes[1].

As described later in this document, IEPA assesses use support for both the nearshore open water segment and the shoreline segments based on samples collected in the nearshore open water segment. For discussions regarding sampling data, the nearshore open water segment and all 51 shoreline segments are combined into a single 'TMDL zone' referred to as the "nearshore open water/shoreline" zone. The pairing of the impaired waterbodies and TMDL zones is shown in Appendix A.

[1] As part of the Quality Assurance (QA) of the project database, the GIS shapefiles for the impaired waterbody segments were reviewed (See Appendix B). Based on discussions with IEPA and U.S. Environmental Protection Agency (USEPA), the shapefiles were refined as part of this project, and the resulting waterbody sizes presented in Appendix B differ from those in the 2014 303(d) report. Figure 2-1 and Appendix A waterbody lengths and areas reflect those refinements and are the waterbody sizes that will be used in the TMDL.

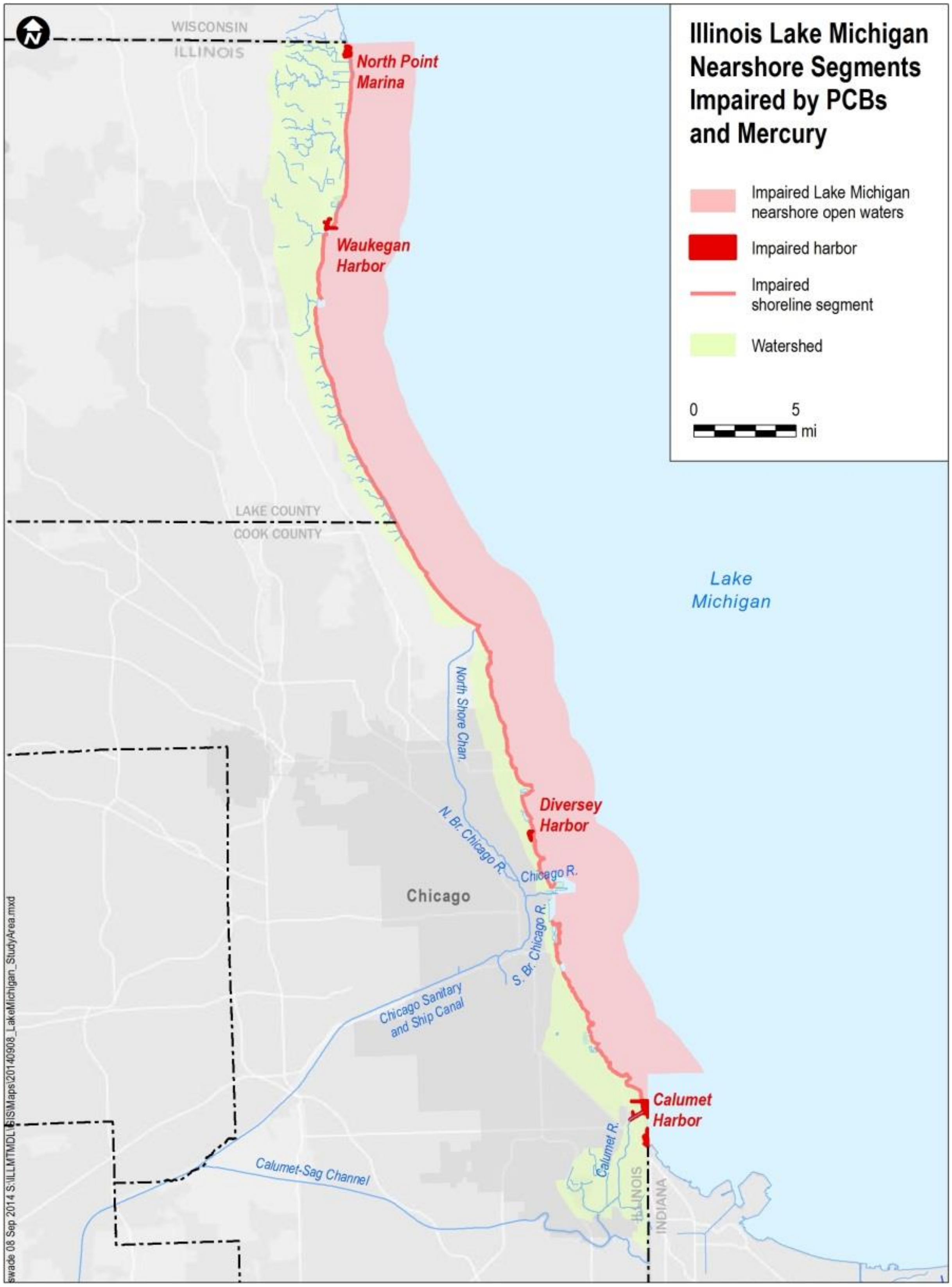

Figure 2-1. Project Study Area and Impaired Segments

2.1 Watershed description

The study area watershed is long and narrow and encompasses roughly 100 square miles within Lake and Cook Counties, Illinois that drain to Lake Michigan. With the exception of the lower Calumet River and occasional flow reversals from the Chicago Area Waterways System (CAWS), the waterbodies within the watershed are generally small streams and ravines that carry intermittent stormwater and surface drainage to Lake Michigan.

Within Lake County, the watershed boundary generally follows the crest of the glacial Highland Park moraine, and extends much farther inland than it does to the south (Illinois Department of Natural Resources [IDNR], 2015). The watershed narrows near the southern end of Lake County and northern end of Cook County, due to diversion of flows into the CAWS. As discussed below, the CAWS is excluded from the study area watershed because it flows away from Lake Michigan, except during extreme wet weather conditions. At the southern end of the study area, the watershed again extends inland further to the O'Brien Lock and Dam and includes those waterbodies such as Lake Calumet, that have a hydrologic connection to Lake Michigan.

The study area watershed is highly developed and land use is roughly distributed as: residential (73%), industrial (4%), commercial (4%) and open space (19%). The watershed includes portions of the following municipalities: Wilmette, Winnetka, Kenilworth, Winthrop Harbor, Chicago, Burnham, Highland Park, Lake Bluff, Beach Park, Highwood, Waukegan, North Chicago, Zion, Evanston, Glencoe and Lake Forest. All but one of the municipalities (Burnham) listed above have Municipal Separate Storm Sewer System (MS4) permits that discharge to Lake Michigan, and together with the MS4 permits for the Cook County Highway Department, Lake County, Shields Township and Waukegan Township, cover roughly 100% of this drainage. Although there are a number of permitted point sources located in the watershed, only one was identified that has the potential to discharge PCBs to the impaired waters (Figure 2-2).

The CAWS is comprised of man-made and natural waterways, which provide navigation, receive water reclamation plant effluents, combined sewer overflows and stormwater runoff and convey flows from the Chicago Metropolitan Area to the Des Plaines River watershed and away from the study area waterbodies. This system is heavily altered from its natural state, including diversion of the Chicago River (in 1900), and the Little and Grand Calumet River (in 1922) away from Lake Michigan. There are three locations where the flows from the CAWS can reverse and discharge to Lake Michigan: the Wilmette Pumping Station, the Chicago River Lock and Controlling Works and O'Brien Lock and Controlling Works, on the Calumet River (Figure 2-2).

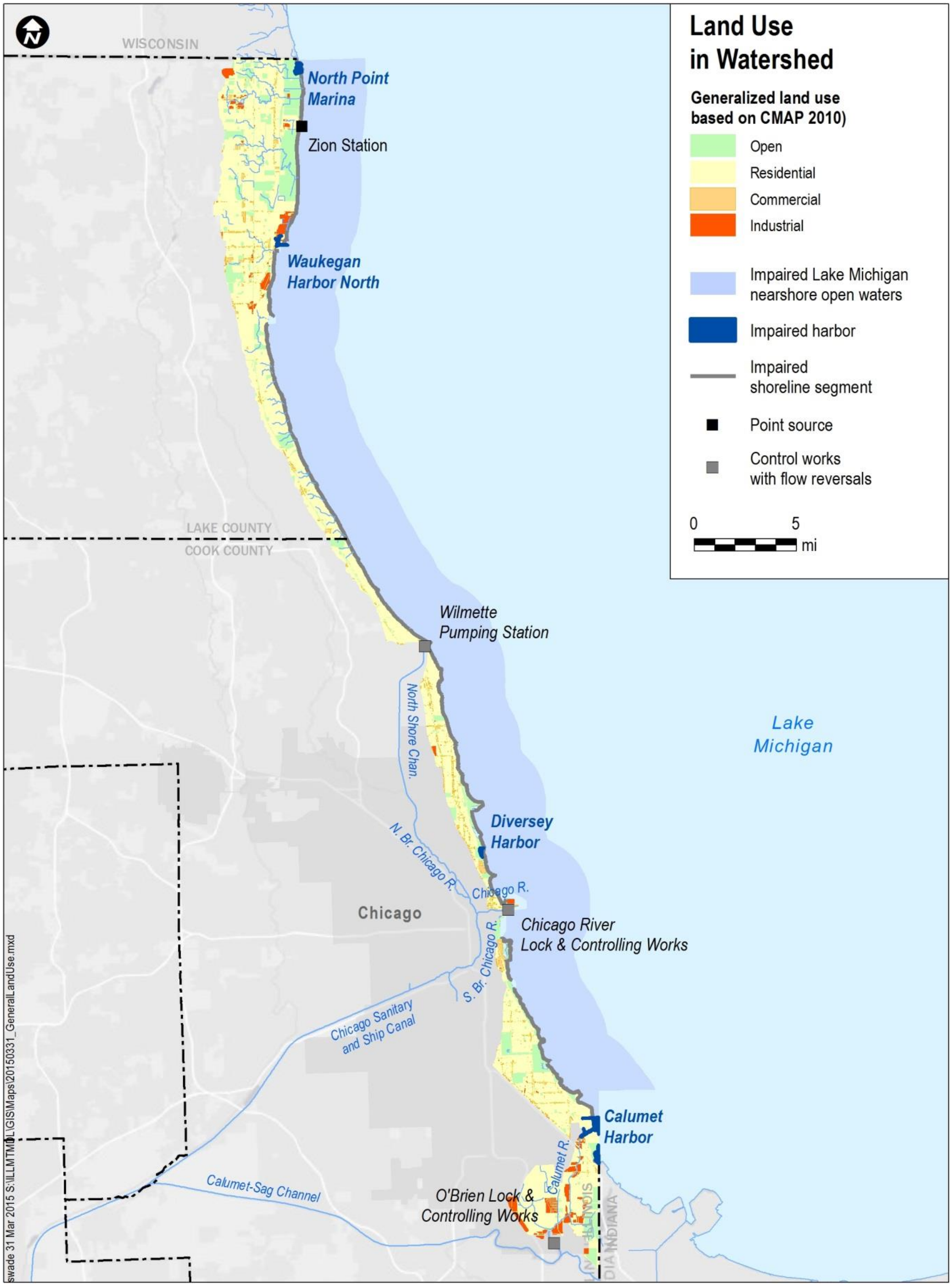

Figure 2-2. Study Area Land Use

2.2 Impaired waterbody description

There are a total of fifty-six segments impaired due to PCBs and mercury. The impaired nearshore open water segment is 180 square miles in size, extending 5 km into Lake Michigan from the Illinois Lake Michigan shoreline, with Lake Michigan serving as its eastern boundary. Additionally, there are fifty-one shoreline (beach) segments identified as impaired due to mercury and PCBs. The term shoreline segment is used in this document because not all of the segments have beaches. The total length of these shoreline segments is approximately 63.5 miles, with segment lengths ranging from 0.07 to 5.5 miles. Finally, interspersed with the shoreline segments, are four harbors that are impaired due to mercury and PCBs. These are shown in Figure 2-3 and are described briefly below. The four harbors are: Waukegan Harbor North (~0.07 square miles), North Point Marina (~0.12 square miles), Diversey Harbor (~0.05 square miles) and Calumet Harbor (~2.4 square miles).

Waukegan Harbor is a Federally-authorized navigation project located in Waukegan, Illinois and is used for both industrial and recreational activities. The United States Army Corps of Engineers (USACE) has been involved with dredging operations at this harbor since 1889. With the exception of some intermittent harbor deepening projects, the vast majority of dredging operations have focused on maintaining navigable conditions, primarily within the Approach Channel (Department of the Army Chicago District Corps of Engineers, 2013), which is beyond the extent of the impaired area shown in Figure 2-3. In 1975, PCBs were discovered in Waukegan Harbor sediments. The site was added to the National Priorities List in the early 1980s and in 1981, the US and Canadian governments identified Waukegan Harbor as an Area of Concern (AOC). In 1992 and 1993, roughly one million pounds of PCBs were removed during remediation activities at the Outboard Marine Corporation site and Waukegan Harbor, including the removal of 32,000 cubic yards of contaminated sediments from the Waukegan Harbor AOC. In 2012 and 2013, 124,000 cubic yards of contaminated sediment were removed from Waukegan Harbor (USEPA, 2015).

North Point Marina is located in Winthrop Harbor, Illinois and is the largest marina on the Great Lakes (IDNR, 2015a). **Diversey Harbor** is located in Lincoln Park, within Lake Shore Drive. Due to bridge restrictions, Diversey Harbor can only accommodate power boaters (Chicago Harbors, 2015). **Calumet Harbor** is located on the southwest shore of Lake Michigan in Chicago, Cook County, Illinois and the approach channel and outer harbor are located Lake County, Indiana. Calumet Harbor is a deep draft commercial harbor that is protected by 12,153 linear feet of steel sheetpile and timber crib breakwater structures (United States Army Corps of Engineers Detroit District, 2015). This is the largest of the four impaired harbors located within the study area.

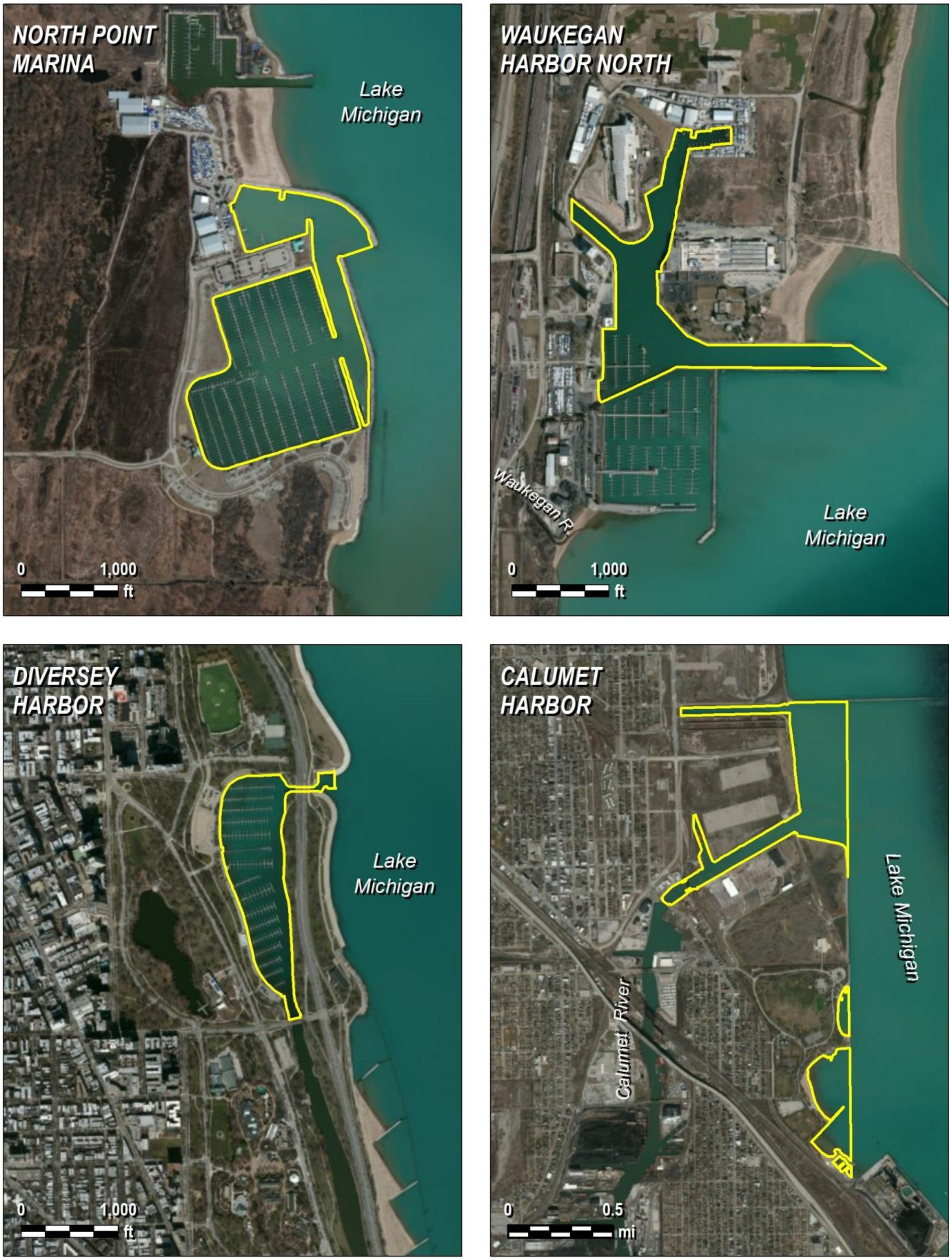

Figure 2-3. Impaired Harbor Segments

3 Sources of Technical Data and Data Inventory

Technical data were inventoried, obtained and reviewed in order to develop a database to support waterbody characterization, confirmation of waterbody listing, and TMDL development. This section describes the sources that were researched to develop the project database, and summarizes the data available to support subsequent analyses.

3.1 Researched data sources

All potentially useful sources of data were identified based on project team knowledge, including much input from IEPA and USEPA staff, internet queries, and communication with agencies and Great Lakes researchers familiar with the project study area. In addition, the project team led a webcast on September 17, 2014 to present the objectives of the study to a much broader audience and to solicit input on additional studies or datasets that may be relevant for this project. The project team followed up on all leads identified as a result of the webcast.

Agencies contacted for data included: USEPA Great Lakes National Program Office (GLNPO), USEPA Office of Research and Development (ORD) Grosse Isle, MI, USEPA Superfund Division, USEPA Water Division, Illinois EPA Toxicity Assessment, Illinois EPA Bureau of Water, Illinois EPA Fish Contaminant Monitoring Program, Illinois Department of Natural Resources, Wisconsin Water Science Center of the US Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), Environment Canada, Area of Concern project managers, USACE, US Navy, Waukegan Citizens Advisory Group, North Shore Sanitary District, Illinois Lake Michigan Fisheries Program, and researchers at Loyola University and the University of Iowa.

3.2 Data review

Identified datasets were reviewed first to ensure they were relevant to the project, and second to ensure they met the quality objectives and criteria outlined in the project Quality Assurance Project Plan (QAPP).

To ensure the data compilation was focused on data relevant to this project, the following data conditions were established:

- Media: Fish tissue, water column and sediment samples
- Location: Data were collected within the impaired waterbody segments. Water column data collected within the Southern Lake Michigan open waters were also compiled.
- Vintage: Data were collected after 1999

Consistent with the project QAPP, the following criteria were applied when reviewing the available data: data are from a known and reliable source; data are of known quality; and data are appropriate for the intended use.

3.2.1 Data are from a known and reliable source

Data included in the project database were obtained from reliable state, federal and peer-reviewed sources. The sources of the data retained for the project database include those from IEPA (fish and water column data), USEPA (fish and water column data) and USGS (water column and sediment data).

3.2.2 Data are of known quality

Data were evaluated for adequacy in terms of the applicable common data quality indicators, such as precision, accuracy, representativeness, comparability, completeness and sensitivity, depending on what data were available in the compiled datasets. Data obtained from government databases and peer-reviewed publications were assessed to determine if known quality requirements were applied during the sampling and analysis of data. These data and all other data were reviewed for usability, general quality and consistency with other available data sources using the following data evaluation criteria:

- The data were generated under an approved QAPP or other sampling document;
- The data include quality assurance statements, descriptions, qualifiers and/or associated QC data that allows evaluation for precision, bias, representativeness, completeness, comparability and/or sensitivity, as appropriate;
- The data come from peer-reviewed publications;
- The data quality is limited or unknown, but come from a reliable source.

Fish data were available from IEPA's fish contaminant database (12 sample locations), USEPA's Great Lakes Environmental Database (USEPA GLENDA, 1 station), and USEPA's National Coastal Condition Assessment (USEPA-NCCA, 4 stations). These data came from reliable sources but information about data quality had to be researched more thoroughly through agency contacts. For example:

- Units were not specified in the database for the mercury, PCB and lipid content measurements obtained from IEPA. This was resolved through communication with Dr. Tom Hornshaw (IEPA fish contaminant monitoring program), who confirmed that the units for mercury and PCBs in fish were mg/kg wet weight. Additionally, it was determined that fish lipid content from 2000-2001 was entered both in percent format (i.e., 40%) and decimal format (i.e., 0.40). Dr. Hornshaw reported that lipid content for "bass, walleye, and yellow perch and other panfish species [is] almost always in the range of 0.3-1.5%, catfish [is] in the range of 1-4%, and carp [is] in the range of 2-6%" (personal communication). Using this as guidance, fish lipid result values from 2000-2001 were converted from decimal to percent when it seemed reasonable.
- Fish data obtained from USEPA-NCCA have not been published but were collected using rigorous QA/QC protocols. The USEPA-NCCA QAPP was provided for this project (National Coastal Condition Assessment, Quality Assurance Project Plan, USEPA, July 2010).

Water column data were available from IEPA (21 stations), the 2010-2014 Great Lakes Restoration Initiative (GLRI) Mercury Cycling and Bioaccumulation in the Great Lakes study headed by David Krabbenhoft of USGS (2 stations), and 2010 sampling work from Environment Canada (1 station). The IEPA mercury data (only available through 2002), were excluded due to high detection limits that resulted in all samples being non-detect, IEPA has suspended water column mercury sampling across all Surface Water programs due to collection methodology; the proper collection requires at least two staff performing "clean hands/dirty hands" technique. The PCB and mercury data from Environment Canada were excluded because they were available as a lake-wide average only.

The IEPA PCB data and 2010-2014 GLRI data were retained in the project database. These data also came from reliable sources but information about data quality had to be researched more thoroughly through agency contacts. The recently collected GLRI water column mercury data were collected outside the TMDL study area, but were retained in the database because they may be valuable for later stages of the project. These data have not been published yet, but were collected and analyzed using rigorous QA/QC protocols (personal communication with David Krabbenhoft, Wisconsin Water Science Center – USGS). The collection and analysis of low-level mercury samples used ultra trace level clean collection and analytical methods. The water collection device consists of a 12 position sampling rosette with

Teflon- coated 8L Niskin bottles that was purchased especially for Great Lakes work.[2] The USGS Standard Operating Procedure (SOP) for ultra-trace level mercury analysis is available at http://wi.water.usgs.gov/mercury-lab/index.html. The IEPA PCB water column data were also retained in the database, but were flagged as follows:

- IEPA PCB data from pre-2003 did not have units, so the units were assumed to be "ug/L" which was consistent with the PCB units used in later sampling efforts.
- IEPA PCB data pre-2010 did not have a specified sampling depth. In these cases, the sampling depth was assumed to be 0.9144 m (3 ft.) which was based on the known depth of the pump used to collect samples aboard the research vessel.

Sediment data contained within the project database are from the 2010-2014 GLRI Mercury- Cycling and Bioaccumulation in the Great Lakes study headed by Dave Krabbenhoft, Wisconsin Water Science Center – USGS. These data were collected near the TMDL study area, and are paired with water column data described above. Additional potential sources of sediment data were identified (e.g., USEPA GLENDA, USEPA STORET (STOrage and RETrieval), MercNet (mercury monitoring network), NOAA, Environment Canada, University of Minnesota Calumet Harbor Sediment Study, USACE, and USGS) but will not be investigated in detail unless and until a need for additional sediment data is determined.

An additional 162 document files were received from USACE for Waukegan Harbor and Calumet Harbor, after the database was finalized. These documents were reviewed and files containing water column or sediment PCB and mercury data were identified and summarized for consideration in TMDL development. The files did not include any fish sampling data.

3.2.3 Data are appropriate for intended use

Datasets included in the project database were documented based on their usability. From the QAPP, usability is defined as:

- The data satisfy the project objectives;
- The data satisfy the evaluation and modeling requirements;
- The data exhibit appropriate characteristics (e.g., quality, quantity, temporal, spatial); and
- The data were generated using appropriate methods.

Judgments on the usability of the data were checked when feasible by comparing the data trends and by comparing data with other comparable datasets. However, the number of available data sources was limited, especially for water column data. The available mercury water column data are consistent with overall declining mercury concentrations that have been observed throughout the Great Lakes region (personal communication with David Krabbenhoft, Wisconsin Water Science Center – USGS). The average PCB fish concentration data obtained from IEPA and USEPA GLENDA databases are consistent for coho salmon, which is the only species represented in the USEPA GLENDA database. Mercury data are not available for coho salmon in the IEPA database for comparison to the USEPA GLENDA data.

3.3 Database development

Table 3- 1 summarizes the data included in the project database. All data entered manually or electronically were confirmed by checking the source data. Limitations in the datasets will be

[2] USGS sampling protocols are explained in the following references: Low-Level Collection Techniques and Species- Specific Analytical Methods for Mercury in Water, Sediment, and Biota (Mark L. Olson and John F. DeWild, 1999); and Mercury sources, distribution, and bioavailability in the North Pacific Ocean: Insights from data and models (Sunderland, Krabbenhoft, Moreau, Strode and Landing, May 2009).

acknowledged and included in discussions of their use. Data qualification codes and/or descriptions are in the final database so as to readily describe any data limitations, and will be described in communications about the data and work results and/or in the final report, as applicable. Qualified datasets are being examined on a case by case basis to determine if they should be used. The decision to include qualified data will depend on a sensitivity analysis of the effect of uncertainty in the data on the result outcome.

Table 3-1. Summary of Data Included in Project Database by Source, Sample Media and Parameter

SOURCE FOR FINAL DATABASE	WATER COLUMN DATA			FISH DATA[a]			SEDIMENT DATA[2]		REMARKS
	Mercury	PCB	General Water Quality	Mercury	PCB	Lipids	Mercury	PCB	
IEPA				✓	✓	✓			All water column PCB data were non-detect; Fish mercury data are from 6 stations; Fish PCB and lipids data are from 12 stations
USEPA Great Lakes Environmental Database (GLENDA)				✓	✓	✓			Data collected from 1 station
USEPA National Coastal Condition Assessment (NCCA)				✓	✓	✓			Data collected from 4 stations
USGS 2010-2014 Great Lakes Restoration Initiative (GLRI) Hg Cycling	✓		✓				✓		All data collected on 9/24/13 from 2 stations located offshore

[a] 127 IEPA fish PCB samples collected at Station Q-02 were initially excluded from the database on recommendation from IEPA, because they were collected from 'multiple harbors' and the exact sample location was unknown. Seven composite coho salmon samples collected by USEPA at Station P233-Cook County Illinois were excluded for the same reason. Because the Level One approach currently being considered for TMDL development does not require the exact harbor location be known for these data (i.e., it is sufficient to know the samples were collected from within the project study area), these data were subsequently analyzed to determine if they would add value to the TMDL. They do not, because the species in these harbor datasets have much lower concentrations of PCBs than the target species recommended in Section 5.2. These data have been added to the project database, but are not used in analyses described in this scoping report and are not expected to be used for TMDL development.

Subsequent to finalizing the project database, additional USACE harbor assessment datafiles were provided in pdf format for Calumet and Waukegan Harbors. Relevant data will be added to the project database, if needed, to support TMDL development.

3.3.1 Summary of data by TMDL Zone

Sampling locations for all water column, fish, and sediment data in the database were paired with impaired segment(s), with input from IEPA, reflecting which sampling stations are located within the impaired segments. Per IEPA, the nearshore open water segment is assessed based on samples collected in the nearshore open water segment. The 51 shoreline segments are similarly assessed based on samples collected in the nearshore open water segment. Because the data collected in the nearshore open water are used to assess the nearshore as well as the 51 shoreline segments, these segments are collectively referred to as being within the 'nearshore open water/shoreline' TMDL Zone. Samples collected within each of the four impaired harbors (Calumet, Diversey, North Point Marina and Waukegan North) were assigned to the respective harbor. Based on input from Dr. David Bunnell, a USGS research fisheries biologist, and concurrence by IEPA, fish samples collected just outside the nearshore open water segment were also categorized as "nearshore open water/shoreline" due to fish mobility. Samples collected from Lake Michigan well outside the nearshore open water segment were classified as "offshore." Additional designations were included in the database for Wolf Lake (located in the Calumet Harbor watershed, upstream of Calumet Harbor), and Jackson Harbor. Data collected from Wolf Lake were excluded from the Calumet Harbor assessment because the fish collected from Wolf Lake are not likely to reflect conditions in Calumet Harbor. Jackson Harbor was excluded because it is not included on the 303(d) list as impaired by PCBs or mercury.

To summarize, sampling data are classified into TMDL Zones to reflect which sampling locations are reflective of the impaired waterbody segments. The TMDL Zones are: nearshore open water/shoreline, Calumet Harbor, Diversey Harbor, North Point Marina, Waukegan Harbor North and offshore. The impaired segments associated with the TMDL zones are shown in Table 3-2 and the number of sampling locations associated with each TMDL zone is also reported. Appendix C presents a count of fillet samples by TMDL zone, which are the fish data used in the subsequent data analysis. Table 3-3 provides a summary of fish and water column samples by TMDL zone.

Table 3-2. TMDL Zones and Impaired Segments

TMDL Zone	Associated Impaired Segment(s)	Number of Sampling Locations in Project Database			
		Fish[a]		Water column	
		Mercury	PCB	Mercury	PCB
Nearshore open water/shoreline	1 nearshore open water segment 51 shoreline segments	4	4	0	21 (all ND)
Calumet Harbor	Calumet Harbor	2	2	0	0
Diversey Harbor	Diversey Harbor	0	1	0	0
North Point Marina	North Point Marina	1	1	0	0
Waukegan Harbor North	Waukegan Harbor North	1	1	0	0
Offshore	Lake Michigan open waters outside of and distant from the study area	0	0	2	0

[a]Fish sampling locations include whole and fillet fish samples

Table 3-3. Count of Fish and Water Column Samples by TMDL Zone

TMDL Zone	Mercury (fish)	PCB (fish)[a]	Mercury (water)	PCB (water)
Nearshore open water/shorelinea	7f,w	76f,w	0	110 (all non-detect)b
Calumet Harbor	6f	7f	0	0
Diversey Harbor	0	1f	0	0
North Point Marina	14f	29f	0	0
Waukegan Harbor North	13f,w	72f,w	0	0
Offshore			6	

[a]Samples collected in the nearshore open water segment are described as "Nearshore open water/shoreline" because data collected in the nearshore open water segment are also used to assess use support for the 51 shoreline segments.

[b] Detection levels range from 0.04 ug/L to 0.55 ug/L, with sample distribution as follows: 70 samples at 0.04 ug/L; 39 samples at 0.1 ug/L; and 1 sample at 0.55 ug/L.

[f]Includes fillet samples.

[w]Includes whole fish samples

4
TMDL Targets

This section describes relevant water quality standards, designated use support and numeric TMDL targets for PCBs and mercury.

4.1 Water quality standards

The Clean Water Act Section 303(c)(2)(A) requires states to designate appropriate water uses for all waterbodies, and adopt, water quality standards for the protection and propagation of fish, shellfish, and wildlife, and recreation in and on the water. Designated uses describe the various uses of waters that are considered desirable, and identify those waters that should be protected. Surface waters in Illinois fall into one of four categories: General Use, Public and Food Processing Water Supplies, Chicago Area Waterways, and Lake Michigan Basin. Each category has its own set of water quality standards. The standards for the Lake Michigan Basin are found at 35 IAC 302.501-595 (Subpart E). Some of the Lake Michigan Basin water quality standards apply to all waters within the basin while others apply only to the open waters of the Lake or only to tributary waters of the Lake. Water quality standards for the Lake Michigan Basin protect aquatic life, human health, wildlife and recreational uses. Waters of the Lake Michigan Basin must be free from any substance or any combination of substances in concentrations toxic or harmful to human health, or to animal, plant or aquatic life (35 IAC 302.540). Lake Michigan Basin waters include all tributaries of Lake Michigan, harbors and open waters of the Illinois portion of the lake. Numeric water quality criteria are developed to protect the designated uses of surface waters, and are described for PCBs and mercury, below.

4.1.1 PCBs

Water quality standards for PCBs in surface waters of the Lake Michigan basin are 120 pg/L for the protection of wildlife, and 26 pg/L for the protection of human health [35 IAC 302.504(e)]. The PCB standard applies to all waters of the Lake Michigan Basin. These standards were adopted as part of the Great Lakes Water Quality Initiative (GLI). These criteria are interpreted as the arithmetic average of at least four consecutive samples collected over a period of at least four days.

4.1.2 Mercury

Water quality standards for mercury in surface waters of the Lake Michigan basin are 0.0013 µg/L (or 1.3 ng/L) for the protection of wildlife, 0.0031 µg/L (or 3.1 ng/L) for the protection of human health, and 1,700 ng/L (1.7) µg/L and 910 ng/L (0.91 µg/L) for the protection of aquatic life from adverse effects due to acute and chronic toxicity, respectively [35 IAC 302.504(e)]. These standards also originated with the GLI and apply to all waters of the Lake Michigan Basin. The acute standard must not be exceeded at any time and the chronic human health and wildlife standards must not be exceeded by the arithmetic average of at least four consecutive samples.

4.2 Designated use support

Every two years, the State of Illinois evaluates the extent to which waters of the state are attaining their designated uses. The degree of support of a designated use in a particular area (assessment unit) is determined by an analysis of various types of information, including biological, physicochemical, physical habitat, and toxicity data. When sufficient data are available, each applicable designated use in each assessment unit is assessed as *Fully Supporting* (good), *Not Supporting* (fair), or *Not Supporting* (poor). Waters in which at least one applicable use is not fully supported are considered impaired.

Fish consumption use is associated with all waterbodies in the state. The assessment of fish consumption use is based on (1) waterbody-specific fish-tissue data and also on (2) fish-consumption advisories issued by the Illinois Fish Contaminant Monitoring Program (FCMP). The FCMP uses a risk-based process developed in the Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory (Anderson et al. 1993). The Protocol requires the determination of a Health Protection Value (HPV) for a contaminant, which is then used to calculate the level of contaminant in fish tissue that will be protective of human health at several meal consumption frequencies (ranging from unlimited consumption to "do not eat"). The level of contaminant in fish is then calculated that will not result in exceeding the HPV at each meal consumption frequency.

4.2.1 PCBs

For PCBs, the Health Protection Value (HPV) for fish consumption is 0.05 µg/kg/day. Based on this HPV, the lowest fish tissue concentration that results in a fish consumption advisory is 0.06 mg/kg; this is, therefore, the concentration used to assess support of the fish consumption use. There is no relationship between the fish tissue assessment concentration and numeric water column criteria.

Except in extraordinary circumstances, two or more recent sampling events in a waterbody in two different sampling years finding fish exceeding the fish tissue level of concern are necessary for issuing an advisory (based on data collected since 1985). The issuance of a fish-consumption advisory for a specific waterbody provides the basis for a determination that fish consumption use is impaired, with the contaminant of concern listed as a cause of impairment.

Aquatic life uses are assessed using the most recent three years of available data. For Lake Michigan open waters and harbors, if two or more samples exceed the acute aquatic life criterion, the waters are considered impaired. If more than 10% of the samples exceed the chronic aquatic life criterion, the waters are considered impaired.

4.2.2 Mercury

For mercury, the Health Protection Value (HPV) for fish consumption for sensitive populations is 0.10 µg/kg/day. Based on this HPV, the most stringent fish tissue concentration that would result in a fish consumption advisory is 0.06 mg/kg; this is, therefore, the concentration used to assess support of the fish consumption use. The 0.06 mg/kg fish tissue concentration is used by the Fish Contaminant Monitoring Program as the starting point for issuing a 1 meal/week advisory is a risk-based advisory concentration developed from an extensive database of studies of the health effects of methyl mercury. This concentration was derived by the Great Lakes Fish Advisory Task Force and accepted by the Great Lakes states for use in their sport fish advisory programs. There is no relationship between the fish tissue assessment concentrations and numeric water column criteria.

While there is a statewide fish consumption advisory for mercury because of widespread contamination above criteria levels throughout the state, not all waterbodies have been sampled, and not all samples exceeded criteria levels. For mercury, fish consumption use is assessed as *Not Supporting* only for those specific waters where at least one fish-tissue sample is available and where at least one fish species exceeds the 0.06 mg/kg criterion for mercury. Also, because the statewide advisory is for predator species, fish consumption use is only assessed as *Fully Supporting* in those waters where predator fish-tissue data from the most recent two years do not show mercury contamination above criteria levels. Waters where sufficient fish-tissue data are unavailable are considered Not Assessed.

Aquatic life uses are assessed using the most recent three years of available data. For Lake Michigan open waters and harbors, if two or more samples exceed the acute aquatic life criterion, the waters are considered impaired. If more than 10% of the samples exceed the chronic aquatic life criterion, the waters are considered impaired.

4.3 Numeric TMDL Targets

TMDL targets are established at a level that attains and maintains the applicable WQS, including designated uses, numeric and narrative criteria, and antidegradation policy [40 CFR §130.7(c)(1)]. TMDL submittals must include a description of any applicable water quality standard, and must also identify numeric water quality targets, which are quantitative values used to measure whether or not applicable WQS are being attained. Depending on the designated use being addressed, a TMDL target may be based on human health, aquatic life, or wildlife criteria (U.S. EPA, 2008a). Where possible, the water quality criterion for the pollutant causing impairment is used as the numeric water quality target when developing the TMDL. Because all of the assessment units addressed in this TMDL are impaired for the fish consumption use, the Health Protection Value (HPV) for fish consumption for sensitive populations was used to derive the TMDL target of 0.06 mg/kg for PCB and 0.06 mg/kg for mercury. This TMDL will also need to demonstrate that compliance with the fish tissue TMDL target will also meet the water quality targets including the human health and wildlife criteria described above (for all waters) and additionally for Waukegan Harbor, the aquatic life criteria. This will be accomplished via the application of published bioaccumulation factors (BAFs) for the Great Lakes, which provide a translator between pollutant concentration in water column and resulting fish tissue contamination (USEPA, 1995). TMDL loads will be set to ensure compliance with the lower of the two concentrations (water column or fish tissue) used to protect the designated use.

Blank Page

5
Target Fish Selection

Fish tissue PCB and mercury concentrations have been sampled in a wide range of species across the study area, and show varying degrees of bioaccumulation. The use of fish tissue samples from multiple species to form the basis for compliance with the fish consumption advisories incorporates these varying degrees of bioaccumulation across the study area into the assessment for impairment of the fish consumption designated use. However, one fish species must be selected to establish how much pollutant loads must be reduced to meet the fish tissue target value and obtain the designated use. The species selected to represent the achievement of the target fish tissue concentration level in most (but not all) fish should be protective of concentrations in other fish species, such that load reductions set to attain the target level in the selected species will result in fish tissue concentrations at or below the target level in other species. The fish species used for comparison with the TMDL fish tissue target concentration would ideally possess the following characteristics:

- They should possess concentrations near the upper bound of the range of all species, such that TMDL reductions designed to achieve attainment in the target species will be protective of other species.
- They should be consumable by humans and therefore appropriate to represent the linkage between the fish tissue concentration that is the basis for the fish consumption advisory that is the assessment measure for the standard.
- They should allow for the application of a TMDL approach that considers geographic, chemical, loading and temporal variability.
- They should be sampled abundantly enough to allow calculation of a reduction factor that is not overly influenced by potential sampling variability.

5.1 Data review

5.1.1 PCBs

LimnoTech reviewed the fish tissue data (i.e., IEPA's fish contaminant database, USEPA's Great Lakes Environmental Database, and USEPA's National Coastal Condition Assessment) to make an assessment of which fish species would be suitable to serve as a TMDL target for PCBs. Only data from the edible portion monitoring were considered since these are the data that support the fish consumption designated use assessment. Table 5-1 summarizes the available data across the entire study area. The highest observed fish tissue concentrations are observed both in North Point Marina and Waukegan Harbor. The data present both mean and 90th percentile tissue concentrations, as other fish tissue-based PCB TMDL have been based on protection of an upper-bound percentile of the range of population data. Results for the 90^{th} percentile values should be evaluated only in a qualitative manner, however, because:

1. The large majority of fish data represent the composite of multiple fish; with up to 25 fish composited per analysis.
2. Results for the majority of fish species were based on fewer than ten measurements, making the estimate of the 90^{th} percentile value highly uncertain.

Table 5-1. Mean and 90th Percentile Fish Fillet PCB Concentration (mg/kg) across Entire Study Area

Species	Count	Mean	90th percentile*
Carp	52	4.329	7.6500
Lake trout	30	0.811	2.0200
Black bullhead	3	1.027	1.3600
Rock Bass	10	0.276	0.7660
Sunfish	7	0.189	0.4180
Largemouth Bass	4	0.225	0.3960
Bloater	7	0.270	0.3660
White sucker	6	0.237	0.3550
Smallmouth bass	7	0.172	0.2620
Pumpkinseed sunfish	3	0.183	0.2400
Alewife	6	0.187	0.2300
Round goby	3	0.137	0.1580
Yellow perch	22	0.092	0.1000
Brown Trout	1	0.659	Can't Calculate
Rainbow trout	2	0.152	Can't Calculate
Rainbow smelt	1	0.100	Can't Calculate

90th percentile concentration calculated when there are at least three samples

PCB tissue levels in carp (Trophic Level 3) are the highest observed for all species of fish, and carp are also the most widely sampled species. Despite being the most widely sampled species, carp tissue PCB data are not available for every impaired segment. As shown in Table 5-2, the number of carp tissue samples available ranges from zero (Diversey Harbor, Calumet Harbor and the nearshore open water/shoreline) to 40 (Waukegan Harbor). While the majority of the carp measurements come from Waukegan Harbor, the conclusion that carp are the most contaminated species is not driven solely by results from Waukegan Harbor. PCB concentrations in carp from North Point Marina are similar to, and slightly higher on average than, PCB concentrations in carp from Waukegan Harbor.

Table 5-2. Number of Carp PCB Fillet Samples Available by TMDL Zone

TMDL Zone	Count
Nearshore open water/shoreline	0
Calumet Harbor	0
North Point Marina	12
Waukegan Harbor	40
Diversey Harbor North	0

As will be discussed subsequently in the Assessment section, the fact that carp obtain much of their PCB body burden from contaminated sediments causes some limitation in their suitability to serve as target species due to the fact that sediment concentrations may be more reflective of legacy pollutant sources than active sources. For that reason, the fish tissue database was further examined to identify additional candidates to serve as target species for PCBs. As seen in Table 5-1, lake trout (Trophic Level 4), black bullhead (Trophic Level 3), and rock bass (Trophic Level 3) have some of the highest PCB concentrations among all sport fish. Lake trout had the second highest 90th percentile concentration, but were not sampled from any of the harbors. All lake trout samples came from nearshore open water/shoreline zone. The third and fourth highest 90th percentile concentrations were found for black bullhead followed by rock bass. Black bullhead were only sampled a total of three times at one location in one TMDL Zone (Waukegan Harbor). Rock bass are among the most sampled species. A review of the distribution of sampling locations (Table 5-3) by TMDL zone shows that all of the rock bass samples came from harbors. If TMDLs are developed separately for harbors and the nearshore zone, rock bass will be a suitable candidate to represent harbors. Rock bass will not be a suitable target species for to represent the open water/shoreline zone, as there are no rock bass samples for this portion of the study area.

Table 5-3. Number of Rock Bass PCB Fillet Samples Available by TMDL Zone

TMDL Zone[a]	Count
Nearshore open water/shoreline	0
Calumet Harbor	1
North Point Marina	4
Waukegan Harbor North	5
Diversey Harbor	0

The database was further reviewed to find a potential target species to represent the nearshore open water/shoreline TMDL zone. Lake trout were determined to be the best candidate, because: 1) they possess high tissue levels, 2) they are a sport fish that serve as the subject of fish consumption advisories, and 3) they are the most widely sampled species in the nearshore open water/shoreline zone, with all 30 lake trout PCB fillet samples coming from this zone (Appendix C).

5.1.2 Mercury

LimnoTech reviewed the fish tissue data to make an assessment of which fish species would be suitable to serve as a TMDL target for mercury. Similar to PCBs, only data from the edible portion monitoring were considered. For the same reasons described above for PCBs, results for the 90th percentile values should be evaluated only in a qualitative manner. Table 5-4 summarizes the available data across the entire study area.

Table 5-4. Mean and 90th Percentile Fish Fillet Mercury Concentration (mg/kg) across Entire Study Area

Species	Count	Mean	90th percentile
Largemouth Bass	3	0.2800	0.4120
Smallmouth bass	7	0.1096	0.1660
Rock Bass	9	0.1023	0.1580
White sucker	4	0.0528	0.0666
sunfish	5	0.0328	0.0510
Black bullhead	2	0.0550	Can't Calculate
Rainbow trout	2	0.0638	Can't Calculate
Brown Trout	1	0.1030	Can't Calculate

90th percentile concentration calculated when there are at least three samples

Mercury tissue levels in largemouth bass are the highest observed for all species of fish, although only three tissue concentration samples exist. As shown in Table 5-5, all three largemouth bass tissue samples were collected in North Point Marina.

Table 5-5. Number of Largemouth Bass Mercury Fillet Samples Available by TMDL Zone

TMDL Zone	Count
Nearshore open water/shoreline	0
Calumet Harbor	0
North Point Marina	3
Waukegan Harbor North	0
Diversey Harbor	0

As shown in Table 5-5, no largemouth bass samples are present from the nearshore open water/shoreline zone. Review of the database indicates that that there are no more than two samples available for any species describing mercury concentration in the nearshore zone.

5.2 Recommendations

5.2.1 PCBs

The current fish tissue dataset is not capable of providing a single target species that can support segment-specific TMDL reduction calculations for PCBs, due to the lack of samples completely covering TMDL zones. Carp are the most highly contaminated and widely sampled species, but there are no carp data for Diversey Harbor, Calumet Harbor or the nearshore open water/shoreline zone. Rock bass and lake trout are also candidate target species, although no harbor data exist for lake trout, and no data exist for rock bass in Diversey Harbor or the nearshore open water/shoreline, and only a single rock bass data point exists for Calumet Harbor.

The use of carp as a target species poses some issues in terms of TMDL development. Carp, being benthic feeders, obtain much of their PCBs from bottom sediments. Sediment PCB concentrations respond much more slowly to changes in loading than do water column concentrations. The Level One TMDL approach described below is based upon the assumption that fish tissue PCB levels are dictated by the current PCB loading rate to the system. Observed carp PCB data reflect some degree of historical loading rates and do not accurately reflect current loading. As a result, TMDL reductions required by the Level One approach for carp may be greater than what are necessary to ultimately achieve fish tissue targets, by ignoring the fact that fish tissue levels reflect historical loading rates.

Considering the above factors, the following recommendations are made in terms of target fish species selection for the PCB TMDL:

- Carp should be used as one of the target species for the PCB TMDL. To the extent that the available data allow, the TMDL approach should differentiate the percentage of current carp body burden that is attributable to current PCB sources versus that attributable to legacy PCB sources. This will be accomplished by comparing estimated historical water column PCB loading rates to current loading rates, and considering the response time of surficial sediments to changes in water column loading rates.
- TMDL calculations should also consider rock bass and lake trout, to verify that reductions in current sources necessary to protect carp are also protective of these species. Lake trout are migratory open water species, such that their use as a target species will require consideration of the amount of exposure they receive in nearshore areas versus what they receive from their time in the main body of the lake.
- TMDL calculations will require the pooling of fish data across sites to account for the absence/limited number of fish samples in certain TMDL zones. One potential grouping scheme would be to pool all fish data from harbors, and all fish data from nearshore open water/shoreline areas.

5.2.2 Mercury

The current fish tissue dataset is not capable of providing a target species that can support segment-specific TMDL reduction calculations for mercury, due to the lack of samples completely covering TMDL zones. Largemouth bass are the most highly contaminated species, but only three tissue samples exist, all from North Point Marina. Should the desire exist to base the TMDL on more than three tissue samples, tissue data from largemouth bass could be pooled with tissue data from smallmouth bass to generate a larger data set. Smallmouth bass are from the same genus (Micropterus) as largemouth bass, and have the second-highest concentration of all fish sampled. Seven tissue samples exist for smallmouth bass, taken from Calumet Harbor and North Point Marina.

Considering the above factors, the following recommendations are made in terms of target fish species selection for the PCB TMDL:

- Largemouth bass should be used as the target species for the mercury TMDL, possibly supplemented with data from smallmouth bass.
- TMDL calculations will require the extrapolation of fish data across sites to account for the absence/limited number of fish samples in certain TMDL zones, given the lack of data from several harbors and the nearshore open water/shoreline zone.

Blank Page

6
TMDL Development Approaches

TMDLs are required to define the maximum pollutant loading rate that will result in compliance with water quality standards. Development of TMDLs therefore requires the use of a mechanism to translate a pollutant loading rate into units that can be compared to the water quality standard, e.g. water column or fish tissue concentration. This translation is typically done with some type of mathematical modeling framework, either empirical (i.e. based on observed data correlations) or mechanistic (i.e. based on a description of the specific mechanisms that affect pollutant concentrations.)

A wide range of modeling frameworks exist that could potentially be used to support development of the Illinois Lake Michigan Nearshore PCB and Mercury TMDLs. This section summarizes the range of potential approaches for developing PCB and mercury TMDLs for Illinois nearshore waters, and is intended to assist USEPA and IEPA to evaluate the best option(s) for completing these TMDLs. It is divided into subsections describing:

- Model selection considerations
- Range of applicable frameworks
- Conceptual model and data gap assessment
- Candidate approaches
- Recommendation for preferred approach

Blank Page

7
Modeling Selection Considerations

Available model frameworks for conducting PCB and mercury TMDLs vary in terms of:

- Temporal Scale
- Spatial Scale
- Loading Sources Considered
- Pollutant Forms
- Environmental Compartments Considered
- Fate and Transport Processes Considered
- Assessment of Bioaccumulation

Each of these factors impacts the data needed to support the model development and application. It is important to assure that adequate data are available to support the selected model framework, as a model is only as good as the data available to support it. The relevant aspects of each of these factors relative to PCB and mercury TMDLs are described below.

7.1 Temporal Scale

Temporal scale relates to a model's ability to describe how concentrations change over time. Temporal scale can be divided into two broad categories: 1) steady state, and 2) time-variable. Steady state models predict the concentration that will (eventually) occur in response to constant loading and constant environmental conditions. They are not capable of predicting the response time of concentrations to changes in loading rates. Time-variable models predict how concentrations change in response to changes in loading and/or environmental conditions. Gradations of temporal resolution exist within the category of time-variable models, as some models are designed to predict changes on an hour by hour basis while other models may predict with much coarser temporal resolution such as year to year.

The primary consideration of temporal scale for TMDLs is whether the TMDLs need to define the response time between load reduction and attainment of water quality standards. This is relevant for these TMDLs because PCBs and mercury do not degrade rapidly and therefore have longer response times than most other pollutants. Secondary considerations for requiring a time-variable model include the desire to simulate inputs that fluctuate widely over time, and/or water quality standards that are expressed in terms of allowable percent of time that standards may be exceeded. Time-variable models will be able to address these considerations, while steady state models will not. Time-variable models are generally more complex and have greater data needs than steady state models. The ability of a model to make predictions at a fine scale temporal resolution is - may not be appropriate for PCB and mercury TMDLs that consider the relationship between pollutant sources and the measured contaminant concentration in fish tissue. The impairment of the designated use for the waterbodies in this TMDL are due to fish consumption advisories which are determined by excessive contaminant concentration in fish tissue. Tissue levels in target fish species respond slowly to changes in pollutant concentrations, so that simulating short-term changes in pollutant concentration in the waterbodies are of less importance than the bioaccumulation of the contaminants in the tissue of predatory fish over years. A temporal resolution of years will adequately capture the resulting concentration in fish tissue which is the focus of the addressing the impairment.

7.2 Spatial Scale

Spatial scale relates to a model's ability to describe how concentrations vary over space within the model domain. Spatial scale can be divided into broad categories corresponding to the number of different spatial dimensions considered by a model. Zero-dimensional models do not consider how changes vary within the model domain, and treat the entire system as a single well-mixed entity. One dimensional models predict changes over a single spatial dimension (e.g., longitudinally). Two dimensional models predict changes over two spatial dimensions (e.g., longitudinally and laterally, or longitudinally and vertically). Three dimensional models predict changes over all spatial dimensions - longitudinally, laterally, and vertically. Gradations of spatial resolution also exist, as different model frameworks can describe changes on a meter-by-meter or mile-by-mile basis. Again, increasing spatial resolution/dimensionality increases a model's complexity and the data needs for the model development and application.

The primary consideration of spatial scale for PCB and mercury TMDLs is that the model needs to have sufficient spatial resolution to capture gradients in pollutant concentrations that are important with respect to the management decisions being made. For example, if the management objective is to have separate TMDLs for harbors and nearshore shoreline and open water areas, the model must contain sufficient spatial resolution to differentiate the load-response relationship between these areas. Similarly, if the requirement is for water quality standards to be met at "any place, any time" (as opposed to being averaged over an entire segment), the model must have sufficient spatial resolution to capture the variability in concentrations within a given segment. It should be noted that increases in spatial scale require a large increase in the amount of data required to support model application.

7.3 Loading Sources Considered

A specific TMDL model framework can also vary in terms of the range of loading sources that it considers. Potentially important loading sources of PCBs and mercury to the Illinois nearshore waters of Lake Michigan include:

- Atmospheric load, either via direct deposition or (for PCBs) gas-phase exchange
- Transport of pollutants originating in the main Lake Michigan basin into the nearshore and harbors
- Stormwater loading from the contributing watershed
- Flow reversals from the Chicago Area Waterways (CAWS)
- Direct point sources other than stormwater
- Legacy sediment contamination

To the extent that any of these loading sources contribute a significant amount of pollutant to any of the impaired waterbodies of concern, they will need to be considered in the TMDL model. Conversely, if it can be demonstrated using site-specific data or the scientific literature that any of these loading sources do not contribute a significant amount of pollutant to any of the waterbodies of concern, they can be excluded from the TMDL analysis. Other TMDLs (e.g. Connecticut Department of Environmental Protection et al., 2007; MPCA, 2007) have used a cut-off of 1-2% of the total in terms of defining what constitutes a "significant" load. Based on this precedent, the Illinois Lake Michigan Nearshore PCB and Mercury TMDLs will define any loading source estimated to be greater than 1% of the total load to be defined as significant.

7.4 Pollutant Forms

PCBs and mercury can exist in different forms in the environment. PCBs are comprised of 209 different congener forms, and can exist either in a dissolved state or adsorbed onto particulate matter. Mercury can exist in a range of inorganic forms which can be dissolved or adsorbed onto particulate matter, as well as in organic forms of methyl-mercury. Some model frameworks are capable of simulating individual forms of pollutants, while others consider all pollutant forms lumped together as total pollutant.

There are two potential reasons for selecting a model framework capable of simulating multiple pollutant forms. The first is in cases where the fate and transport of the pollutant strongly depends on the form that the pollutant is in, and future management controls will significantly alter the distribution between pollutant forms. For example, only sorbed forms of a pollutant settle from the water column and only certain dissolved forms of a pollutant can exchange with the gas phase in the atmosphere. The second is cases where the water quality endpoint strongly depends on the pollutant form, and future management controls will significantly alter the distribution between forms. For example, only the methylated form of mercury is bioaccumulated through the food chain to fish.

7.5 Environmental Compartments Considered

Mathematical models for PCB and mercury TMDLs can explicitly simulate pollutant concentrations in up to three different environmental compartments: water column, bed sediments, and biota (see Figures 9-2 and 9-3 below for examples). The most rigorous models simulate the processes that affect pollutant concentrations in each compartment. It is not necessary, however, to explicitly simulate all compartments in order to estimate load reductions necessary to meet target pollutant levels in biota. For example, some modeling approaches allow the pollutant concentrations of PCBs and mercury in biota to be estimated directly from the predicted water column concentrations through the use of bioaccumulation factors.

7.6 Fate and Transport Processes Considered

Fate and transport describes those processes related to transformation and/or movement of chemicals once discharged into the environment. These processes are potentially important to simulate because they control the rate at which pollutant loading sources are diluted. The processes include hydrodynamic transport (i.e. movement by water), settling of particulate-bound pollutants from the water column to bed sediments, volatilization of pollutants from the water column to atmosphere, and resuspension or diffusion of pollutants from bed sediments to the water column. Even though fate and transport processes both affect the pollutant load-response relationship, it not necessarily required to explicitly simulate them in a TMDL. If controls required by the TMDL do not affect the relative impact of fate and transport processes, the TMDL can be based upon the assumption of proportional relationship between pollutant loading rate and resulting concentration.

7.7 Assessment of Bioaccumulation

The final consideration in model selection pertains to a description of how fish tissue obtains chemicals from the receiving water, lower levels of the food chain and/or bed sediments. The simplest bioaccumulation models assume a directly proportional relationship between pollutant loading rate and fish tissue concentrations. Intermediate level models predict pollutant concentrations in the water column and sediment, and use bioaccumulation factors that are derived from observed measurements to predict fish tissue concentrations. The most complex models explicitly simulate how pollutants are transferred through the food web, including the rate at which they are absorbed (and released) by fish as part of their diet.

Blank Page

8
Range of Applicable Frameworks

With at least two options available for each of the seven categories of factors described above, there are theoretically hundreds of potential permutations of model frameworks that could be developed. In reality, there are much fewer realistic options, as selection of one factor often dictates the nature of selection of other factors (e.g. selection of a "proportional relationship" in place of explicit modeling of fate and transport processes requires selection of a steady state temporal approach). This section presents three candidate frameworks, divided into categories corresponding to different levels of TMDL approaches described in the USEPA (2011) PCB TMDL Handbook (which are equally relevant for mercury TMDL development as well.)

8.1 Level One: Simple Proportionality Approaches

Level One modeling approaches for TMDLs described in USEPA (2011) include assuming a directly proportional relationship between PCB loadings and environmental concentrations, and/or back-calculating the loading capacity from the fish tissue targets and fish tissue data.

The Level One approach corresponds to the model selection factors described above as:

- Steady state: Level One approaches are unable to describe how pollutant concentrations will change over time in response to source reductions.
- Zero dimensional: Level One approaches are unable to describe how pollutant concentrations will vary spatially within a study area, beyond assuming that the existing spatial distribution of pollutants remains identical in response to load reductions (i.e. concentrations in all locations are reduced proportionally).
- Loading sources: Level One approaches generally assume the existence of a single loading source. They can be applied to multiple loading sources for cases where it can be assumed that the load-response relationship for each source is identical (e.g. a one pound per day reduction in loading results in the exact same system response regardless of which source is reduced).
- Pollutant forms: Level One approaches are designed to only address total pollutant concentrations.
- Environmental compartments considered: Level One approaches can consider all environmental compartments: water column, sediments, and biota.
- Fate and transport processes considered: Level One approaches do not explicitly describe fate and transport processes. These processes are generally implicitly considered, by assuming that whatever fate and transport processes control the existing load-response relationship will remain unchanged in response to future load reductions.
- Bioaccumulation: Bioaccumulation is implicitly predicted, via the assumption of a proportional relationship between load and fish tissue concentration.

Level One approaches were recently used in the Michigan Statewide PCB TMDL (LimnoTech, 2012) and Michigan Statewide Mercury TMDL (LimnoTech, 2013), and have previously been used in the Minnesota statewide mercury TMDL (MPCA, 2007). This approach is largely empirical and requires a minimal amount of data, limited to measurements of pollutant load and system response (e.g. fish tissue pollutant concentration).

8.2 Level Two: Steady State Mass Balance Approaches

Level Two approaches for TMDL development described in USEPA (2011) PCB TMDL Handbook consist of simpler mass balance models. The Level Two approach corresponds to the model selection factors described above as:

- Steady state: Level Two approaches are unable to describe how pollutant concentrations will change over time in response to source reductions.
- Multi-dimensional: Level Two approaches are capable of simulating multiple spatial dimensions, but are generally applied in zero or one dimension due to the fact that two- and three-dimensional steady state descriptions of transport processes are rarely available. As a rule, if sufficient resources are available to develop a two- or three-dimensional hydrodynamic model, sufficient resources are also available to support a Level Three modeling approach.
- Loading sources: Level Two approaches are capable of simulating multiple loading sources. The primary constraint of these approaches with loading sources is that they are not suited for assessing the response of the system to sources that change over time, due to its steady state nature.
- Pollutant forms: Level Two approaches can simulate a range of pollutant forms.
- Environmental compartments considered: Level Two approaches explicitly simulate concentrations in the water column and sediments.
- Fate and transport processes considered: Level Two approaches can simulate a wide range of fate and transport processes, with primary constraints being that the processes can be assumed to be relatively constant over time, given the steady state nature of the framework.
- Bioaccumulation: Level Two approaches rely on an assumed relationship between concentrations in these compartments and biota to predict fish tissue concentrations.

A Level Two approach was used in the Shenandoah River PCB TMDL (USEPA and VADEQ, 2001).

8.3 Level Three: Time-variable Model of Pollutant Forms in Water Column and Sediments

The most rigorous model framework suitable for the PCB and mercury TMDLs is a time-variable, spatially detailed model of pollutant forms in water column and sediments.

- Time-variable: Level Three approaches are capable of describing how pollutant concentrations will change over time in response to source reductions. Level Three approaches can also be used to provide steady state results, by holding loads and environmental conditions constant and simulating a sufficiently long period of time such that environmental concentrations eventually remain constant. While this type of approach provides identical results as a steady state framework, it provides the additional benefit of defining how much time will be required for steady state conditions to occur.
- Multi-dimensional: Level Three approaches are capable of simulating multiple spatial dimensions, at fine levels of spatial detail.
- Loading sources: Level Three approaches are capable of simulating the entire range of loading sources, including those that change over time.
- Pollutant forms: Level Three approaches can simulate a range of pollutant forms.
- Environmental compartments considered: Level Three approaches are capable of explicitly simulating concentrations in the water column, sediments, and biota.

- Fate and transport processes considered: Level Three approaches can simulate the entire range of fate and transport processes.
- Bioaccumulation: Level Three approaches are capable of explicitly simulating bioaccumulation throughout the food web. Similar to Level Two approaches, they often rely on an assumed relationship between concentrations in the water column/sediments and biota to predict fish tissue concentrations.

The primary limitation of Level Three approaches is that they require significantly more resources (i.e. data, time, and staff) than Level One or Level Two approaches. Level Three approaches have been used in the Delaware River Estuary PCB TMDLs (DRBC, 2003), the Tidal Portions of the Potomac and Anacostia Rivers TMDLs (ICPRB, 2007), the Lake Ontario PCB TMDL, and the Savannah River mercury TMDL (USEPA, 2001).

Blank Page

9 Conceptual Model and Data Gap Assessment

DePinto et al (2004) summarize the basic principles for TMDL model selection and conclude that there is no one best model for all TMDLs; model selection should be driven by an explicit consideration of management objectives, site-specific characteristics, and resource/data constraints. Consideration of site-specific characteristics requires defining the constituents and processes of concern for the site of interest. This is done by: 1) Defining all of the potential processes composing the site-specific linkages between causes and effects, either in the form of a simple list or a more formal box and arrow process diagram; 2) Estimating the magnitude of each of the component processes using available data, and 3) Eliminating those processes that play an insignificant role in the site-specific cause-effect linkage.

Development of this conceptual model is also useful for identifying data gaps. The process of estimating the magnitude of each of the component processes in the conceptual model requires the same type of information necessary to support development of the TMDL model itself. Any gaps in available data that are identified during the development of the conceptual model will also be data gaps for the development of the TMDL itself.

This section describes the conceptual model development and data gap assessment for PCBs and mercury. It begins with a conceptual model of all potentially relevant processes applicable to both pollutants, then presents separate refined conceptual models and data gap assessments for PCBs and mercury.

9.1 Conceptual Model of All Potentially Relevant Processes

A conceptual model of all potentially relevant processes applicable to PCBs and mercury is shown in the form of box and arrow diagrams in Figures 9-1, 9-2 and 9-3. Figure 9-1 depicts processes related to hydrodynamic transport and spatial resolution. Figure 9-2 depicts all other loading, fate and transport processes potentially applicable to water column and bed sediment pollutant concentrations in a given spatial segment. Figure 9-3 depicts bioaccumulation pathways between pollutants in the water column/sediment and various locations in the food web.

Figure 9-1 represents a separate model segment for each impaired waterbody, which is the minimum spatial resolution capable of providing TMDLs unique to each impaired segment. Note that options exist to lump multiple impaired segments together for TMDL purposes, or to further divide individual impaired segments into smaller sub-segments. Key transport processes that would need to be defined at this level of resolution include:

- Hydrodynamic transport between each harbor and its adjacent shoreline segment.
- Hydrodynamic transport between Calumet Harbor and the main body of Lake Michigan
- Hydrodynamic transport between each adjacent shoreline segment
- Hydrodynamic transport between each shoreline segment and the adjacent nearshore open water segment
- Hydrodynamic transport between the nearshore open water segment and Lake Michigan
- Hydrodynamic transport between each adjacent nearshore open water segment, if multiple nearshore open water segments are used in the model

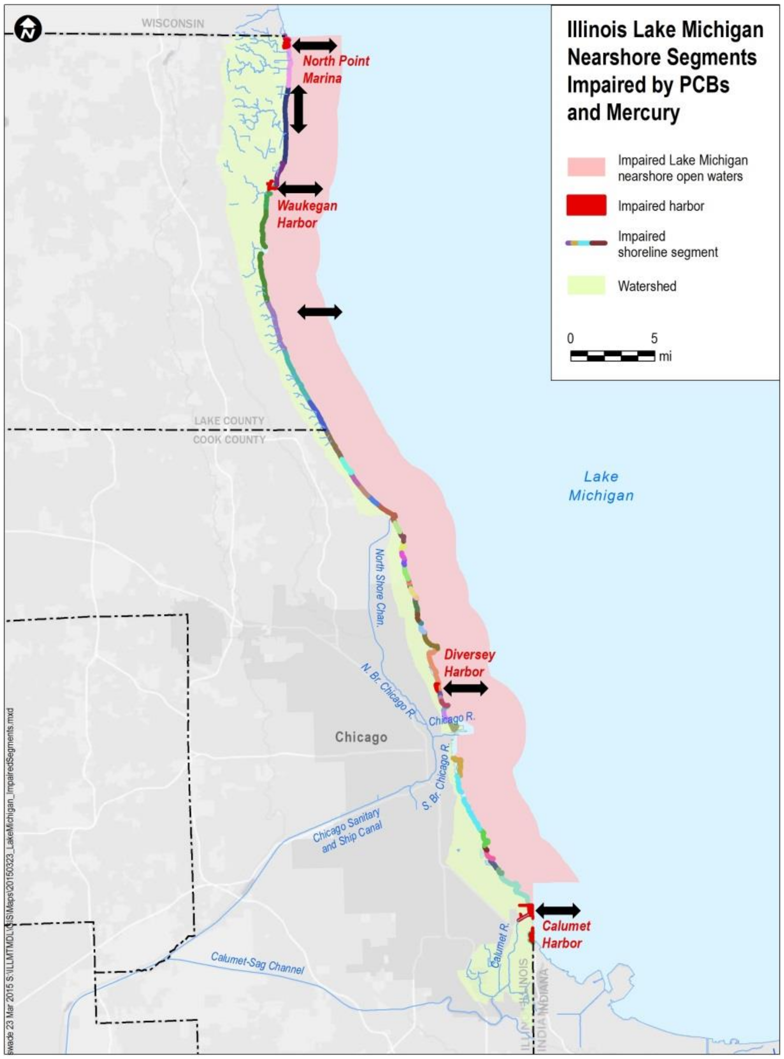

Figure 9-1. Conceptual Model with Arrows Depicting All Potentially Relevant Processes Related to Hydrodynamic Transport and Spatial Resolution.

Figure 9-2 depicts all other loading, fate and transport processes potentially applicable to a given spatial segment, in addition to transport of pollutants from Lake Michigan into the study area. With respect to external loads, potential loading sources of PCBs and mercury consist of:

- Atmospheric loading, including wet deposition, dry deposition, and gas-phase exchange
- Stormwater loading to harbors and shoreline segments
- Flow reversals from the Chicago Area Waterways
- Point source discharges to harbors and shoreline segments
- Resuspension and/or pore water diffusion from contaminated sediments

The remaining potentially applicable fate and transport processes consist of:

- Phase partitioning between the adsorbed and dissolved forms of pollutant in the water column
- Phase partitioning between the adsorbed and dissolved forms of pollutant in bed sediments
- Settling of the adsorbed pollutant
- Volatilization of the dissolved form of the pollutant
- Pollutant decay processes (e.g. biodegradation)

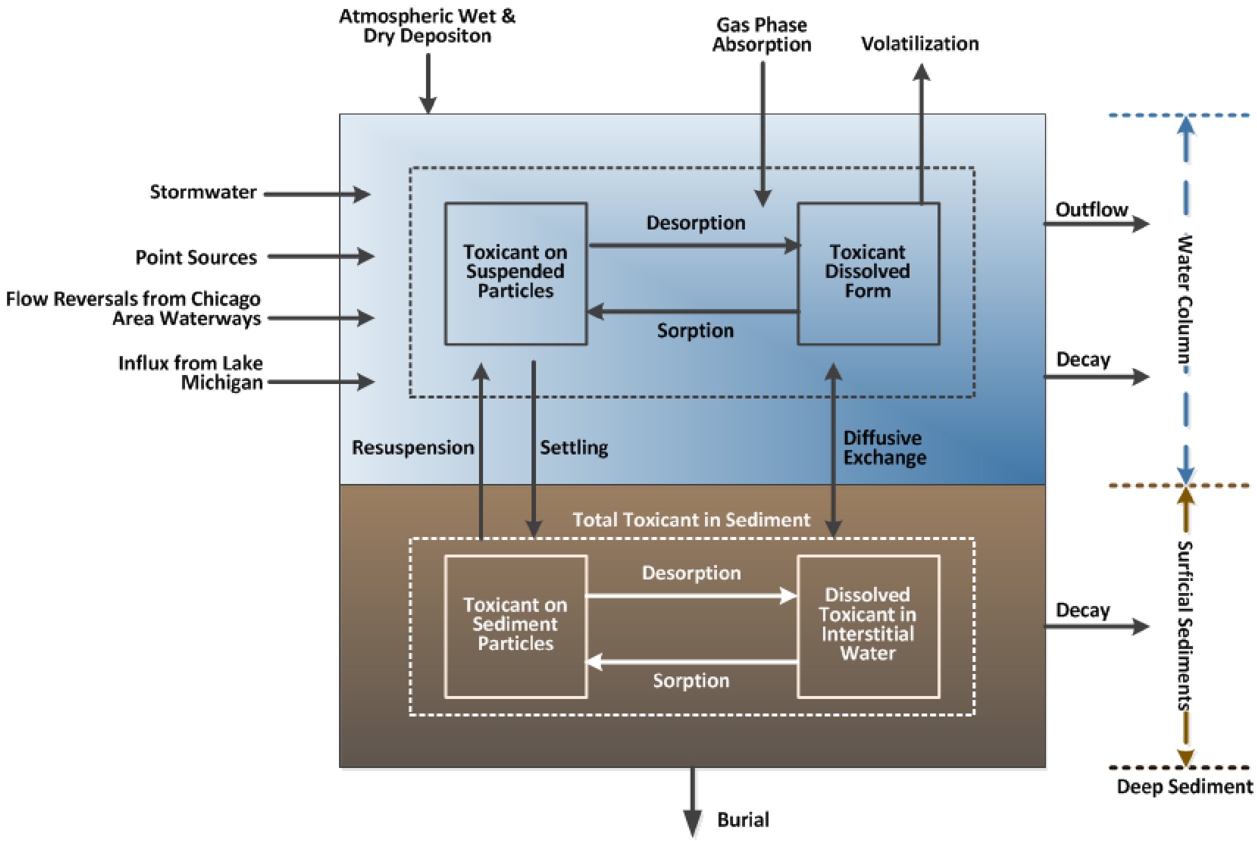

Figure 9-2. Conceptual Model of Relevant Loading, Fate and Transport Processes for PCBs and Mercury (adapted from LimnoTech, 2004)

Figure 9-3 depicts the transfer of chemicals through the food web and the relevant uptake and loss mechanisms in fish. Food web icons represent the order of different trophic levels, and arrows represent the interactions of each trophic level with lower trophic levels and surrounding medium. The base of the food chain can either be based on bed bottom sediment (i.e., benthic invertebrates) or water column (i.e., phytoplankton). A food web bioaccumulation model can either be a stand-alone model, which requires inputs for exposure concentrations in water and sediment, or it can be linked to the results of a water quality model through the use of empirical bioaccumulation factors. Modeling bioaccumulation in fish found in the Illinois nearshore Lake Michigan area is complex, due to the presence of migratory fish species (e.g., lake trout) that spend only a portion of their life cycle in the study area and the remainder in the main body of Lake Michigan.

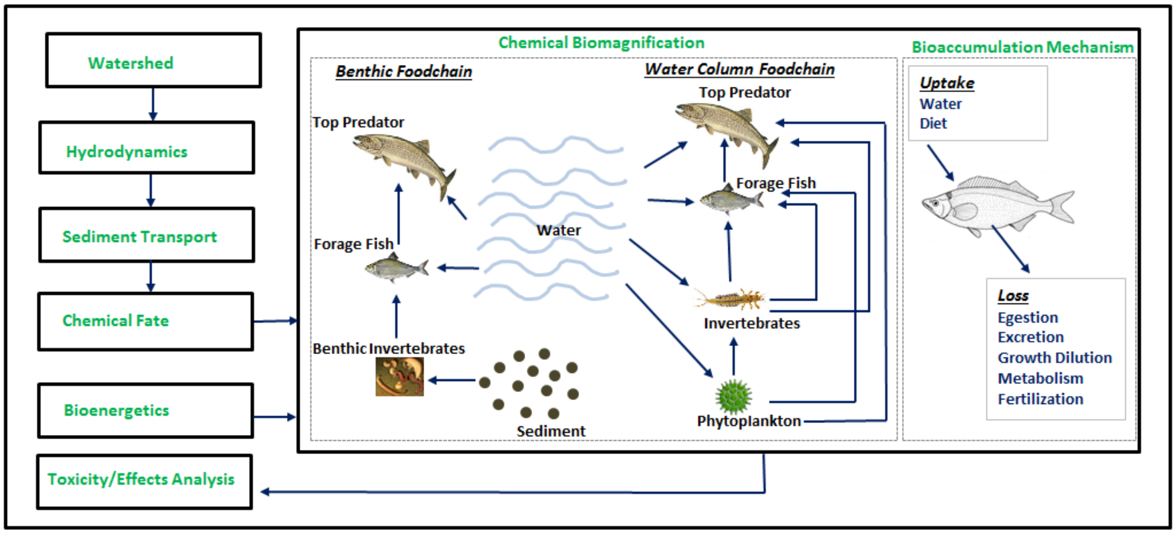

Figure 9-3. Conceptual Model of Aquatic Food Web Bioaccumulation (from EPRI, 2013)

9.2 Refined Conceptual Model and Data Gap Assessment for Hydrodynamic Transport

Development of a refined conceptual model consists of estimating the magnitude of each of the component processes in the full conceptual model, and eliminating those processes that play an insignificant role in the site-specific cause-effect linkage. The process of estimating the magnitude of each of the component processes also identifies potential data gaps for the development of the TMDL.

The NOAA Great Lakes Coastal Forecasting System (GLCFS) is the one tool capable of describing the transport of pollutants in the study area. The GLCFS is a set of models that simulate and predict the 2-D and 3-D structure of currents, temperatures, winds, waves, ice in the Great Lakes. The GLCFS uses a modified Princeton Ocean Model, developed by NOAA's Great Lakes Environmental Research Laboratory and Ohio State University, and is supported by the National Weather Service (NOAA, 2015). The model is sufficient to provide an estimate of the hydrodynamic transport between the nearshore open water segment and Lake Michigan; however, because of its 4 km^2 (2 km x 2 km) grid size, it lacks the spatial resolution necessary to predict hydrodynamic exchange between adjacent shoreline segments or hydrodynamic exchange between harbors and their adjacent nearshore open water segments. For example, the average surface area of the impaired harbors is 0.37 km^2, which is much smaller than a single grid cell in the model.

Given this limitation of spatial detail on hydrodynamic transport, any TMDL developed based on available information will require a lumping of all segments for assessment purposes (or development of a hydrodynamic model capable of describing the exchange between harbors and their adjacent nearshore open water segments). For this reason, the refinement of conceptual models in the subsequent section will focus more on the relative importance of various components to the system as a whole, as opposed to evaluating processes on a segment-by-segment basis.

Results from the GLCFS can be used to estimate the gross transfer of PCBs and mercury into the study area. This is first accomplished by estimating the annual average flow of Lake Michigan water into the study area. Results were extracted for the GLCFS model located on the northern edge of the study area as the predominant lake current is in this direction (Beletsky and Schwab, 2001; Beletsky et al. 1999). Figure 9-4 shows the mean circulation adapted from Beletsky and Schwab (2001). The mean current speed from the north was 3.35 cm/s for 2014. The area of conveyance for this velocity is 54,000 m^2, which was calculated by multiplying the average depth of the first two model grid cells from the GLCFS (10 m and 17 m) by the width of each cell (2 km each). Multiplying the average speed by the area equals an average flow into the study area of 1,810 m^3/s. Results from the USEPA Great Lakes Aquatic Contamination Survey data estimate the open lake PCB concentration in Lake Michigan of approximately 0.14 ng/L in 2004. Venier et al. (2014) report Lake Michigan PCB concentrations near Chicago of 0.233 ng/L. Multiplying these concentrations by the flow equals 8-13 kg/yr of PCB's entering the system. The Lake Michigan Mass Balance Study estimated that by 2014, the average lake-wide PCB concentration could be as low as 0.08 ng/L if the "continued slow recovery" scenario is followed as shown in Figure 9-5. This could reduce the annual PCB load entering the study area from 8-13 kg/yr to 4.5 kg/yr. Mercury concentrations from Lake Michigan (USGS, undated) measured near the study area averaged 0.18 ng/L, which would equal approximately 10 kg/yr of mercury transported into the study area using the flow information from above. Hydrodynamic transport out of the study area for PCBs and mercury should be of similar magnitude as transport into the study area.

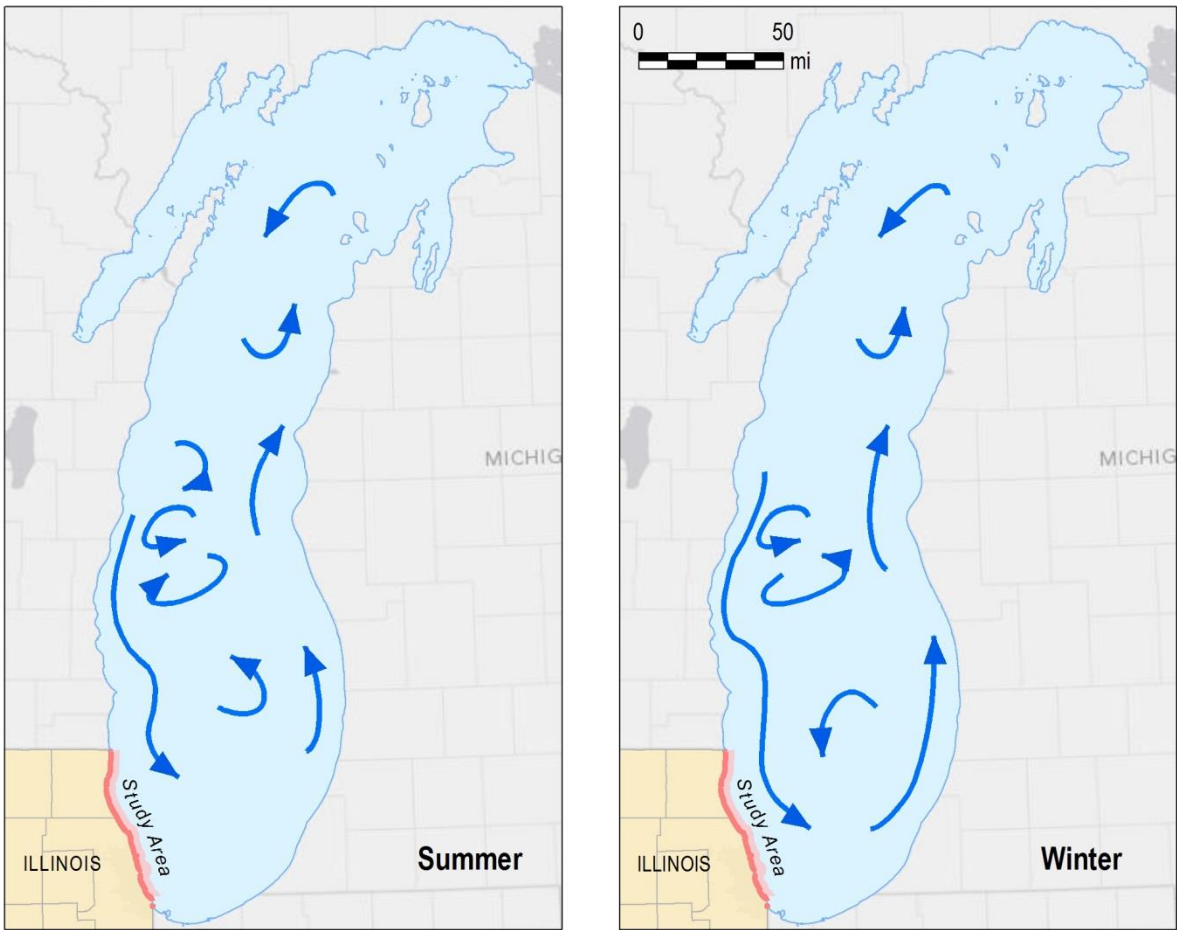

Figure 9-4. Observed Mean Circulation in Lake Michigan (Adapted from Beletsky et al., 1999 cited in Beletsky and Schwab, 2001).

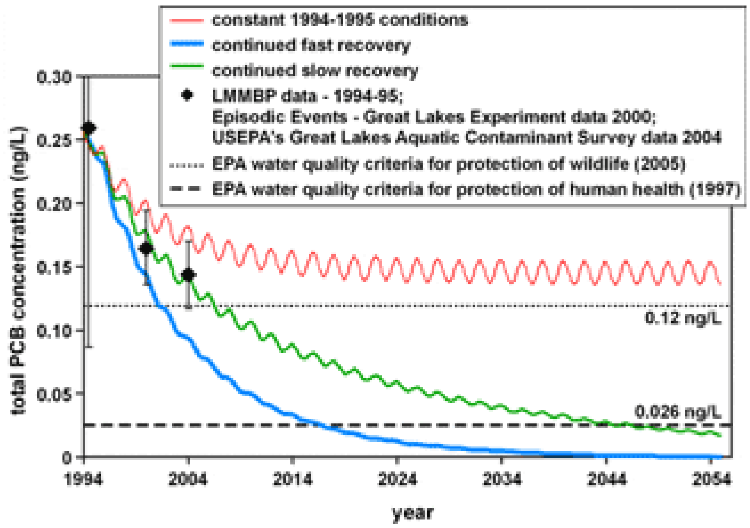

Figure 9-5. Lake Michigan Mass Balance Monitoring Data and Model Results
http://www.epa.gov/med/grosseile_site/LMMBP/pcbs.html

9.3 Refined Conceptual Model and Data Gap Assessment for PCBs

This section identifies the magnitude of all other potentially applicable loading, fate and transport processes for PCBs beyond hydrodynamic transport. Those sources are:

- Atmospheric loading to the harbors and nearshore open water segments, including wet deposition, dry deposition, and gas-phase exchange
- MS4 stormwater loading to harbors and nearshore open water segments
- Flow reversals from the Chicago Area Waterways
- Point source discharges to the study area
- Resuspension and/or pore water diffusion from contaminated bed sediments
- Phase partitioning between adsorbed and dissolved form of the pollutant in the water column and bed sediments
- Settling of the particle-bound pollutant
- Volatilization of the dissolved form of the pollutant
- Pollutant decay processes
- Bioaccumulation

A data gap assessment and refined conceptual model for PCBs are presented at the end of this section.

9.3.1 Atmospheric PCB Loading

Potentially important atmospheric loading sources include wet deposition, dry deposition, and gas-phase exchange. The magnitude of these processes is estimated as follows. Wet deposition calculations were based on annual average rainfall, observed average PCB concentration in rainfall, and the surface area of the study domain. Average PCB concentrations in rainwater ranged from 4.1 ng/L to 189 ng/L during four events in 1994 and 1995 near Chicago with an average of 54 ng/L (Offenberg and Baker, 1997). With an average rainfall of 36.1 inches (0.94 m) per year and a surface area of the nearshore waters of 473 km^2 (surface area of the impaired nearshore open water segment and four impaired harbors, based on a GIS analysis) the mass of PCB deposited by rainfall is 23.4 kg/yr.

Franz et al (1998) estimated PCB dry deposition near Chicago to range from 0.02 to 2.1 $ug/m^2/d$. Assuming an approximate rate of 0.1$ug/m^2/d$ the annual dry deposition across the study area could approach 17 kg/yr.

Gross PCB gas phase absorption from the atmosphere to the water column was estimated by downscaling estimates from the Lake Michigan Mass Balance Study (LMMBS) (USEPA, 2004). The LMMBS estimated a lake-wide absorption of 1507 kg for 1994 and 1995 (753.5 kg/yr). The nearshore open water segment of the Illinois waters of Lake Michigan and four impaired harbors comprise approximately 0.82% of the total surface area of Lake Michigan (473km^2/58,000km^2). So the downscaled absorption of PCBs in the study area would be approximately 6.1 kg/yr. However it has been documented that gas phase concentrations of PCBs in southwest Lake Michigan are up to four times higher than the average Lake Michigan concentration (USEPA 2004), therefore atmospheric absorption would be about four times higher as well because Henry's Law states that the solubility of a gas in a liquid is directly proportional to the partial pressure of the gas above the liquid. This would increase the estimate of gas phase absorption to 24.6 kg/yr for the study area. The total atmospheric load is determined as the sum of wet deposition (23.4 kg/yr), dry deposition (17 kg/yr), and gas phase absorption (24.6 kg/yr), and is equal to 65 kg/yr.

9.3.2 MS4 Stormwater PCB Loading to Harbors and Nearshore Open Water Segments

93.5% of the study area watershed lies within an MS4 city or village, and in addition, the County of Lake, Shields Township, Waukegan Township, and the Cook County Highway Department have MS4 permits. As a result, close to 100% of the study area is within an MS4 area. No site-specific data were available to quantify stormwater PCB loads for the study area watershed (MWRDGC, 2015). Another nearby state, Michigan, also reported that they do not collect, or have plans to collect stormwater PCB data (MDEQ, 2015). The magnitude of stormwater PCB loads was therefore estimated as the product of runoff quantity, the study area drainage area, and an assumed stormwater PCB concentration. The development of these inputs is described below.

Runoff quantity was calculated using the method developed by the Metropolitan Washington Council of Governments (Schueler, 1987) as: **R = P * Pj * Rv**

Where:

R = Annual runoff (inches),

P = Annual rainfall (inches) estimated as 36.1 inches, based on the average annual rainfall reported for Chicago Midway Airport 3 SW for the 1929-2013 period (http://www.crh.noaa.gov/lot/?n=111577_Midway)

Pj = Fraction of annual rainfall events that produce runoff (set to the default of 0.9)

Rv = Runoff coefficient. Rv is a function of impervious cover in the study area watershed, and was calculated using GIS analysis to determine impervious cover for commercial (0.71), industrial (0.54) and residential (0.37) land uses. The resulting runoff coefficients were: commercial (0.69), industrial (0.54) and residential (0.38).

The area of the contributing watershed was calculated as 99.6 square miles, broken down as: 3.82 square miles (commercial), 4.05 square miles (industrial) and 91.73 square miles (residential). The PCB concentration was based on measurements from the City of Spokane (2014) representing 'typical' urban stormwater, and was set to 7.27 ng/L. The estimated stormwater PCB load equals 1.36 lbs/year (0.62 kg/yr).

9.3.3 PCB Loading from Flow Reversals from the Chicago Area Waterways

Limited site-specific data were available to quantify the magnitude of bypass PCB loads from the Chicago Area Waterways. The magnitude of loads entering the study area waters from periodic flow reversals of the Chicago Area Waterways is estimated based on measured flow and concentration data. Flow reversals from the Chicago Area Waterways to Lake Michigan occur periodically through O'Brien Lock, the Chicago River Lock, and Wilmette Lock. The volume of flow is reported by the Metropolitan Water Reclamation District (MWRD) on their website for 1985 through 2014. http://www.mwrd.org/irj/go/km/docs/documents/MWRD/internet/protecting_the_environment/Combined_Sewer_Overflows/pdfs/Reversals.pdf

Until recently, MWRD conducted sampling during flow reversals, including measurements of PCBs. PCB loads were estimated based on concentration data collected twice at each sampling station during the 2013 flow reversals (Table 9-1), and the average 2010-2014 annual volume (4,021.4 million gallons) of water entering Lake Michigan through the three locks.

Table 9-1. Measured CAWS PCB Concentrations during Times of Flow Reversals

Location	Location of PCB sampling	Total PCB results (4/18/13)
O'Brien Lock	Calumet Harbor, 95th St. Bridge: Calumet Harbor, Ewing Ave. Bridge	All 4 samples < 0.3 ug/L
Chicago River Lock	Chicago River Locks, Inner Harbor Sluice Gate; Chicago River Locks, Sluice Gate, DuSable Harbor	Both samples < 0.3 ug/L
Wilmette Lock	Wilmette Harbor, Wilmette Pump Station	Both samples < 0.3 ug/L

Because all PCB concentration measurements are less than detection, loads for this source cannot be accurately quantified. However, total PCBs from this source can be estimated to be less than 100.7 lbs/yr (45.68 kg/yr), using the detection limit as the basis for an upper-bound estimate of PCB concentration. It is recognized that the PCB detection limit of 0.3 ug/L could be orders of magnitude higher than actual concentrations, such that this may be a high upper bound estimate. For the purposes of estimating a potential pollutant load in the absence of data, PCB loads from the CAWS were calculated using data from another urban area which had lower detection limits. Observed PCB concentration data in combined sewer overflows collected by the City of Spokane (2014) using low detection limits provide a more realistic upper bound PCB concentration. Using their observed average PCB concentration of 0.01242 ug/L results in an upper-bound PCB loading estimate of less than 4.2 lbs/yr (1.9 kg/yr). Note that CSO measurements of PCBs are not available for the study area (MWRDGC, 2015a).

9.3.4 Other Point Source PCB Discharges to the Study Area

Other point source PCB loads were calculated based on permitted flow and measured concentration data, for facilities determined to have the potential to contribute PCB loads to the study area. These facilities were identified based on input and data provided by Illinois EPA.

One facility (IL0002763, Zion Station) was determined to have the potential to contribute PCB loads to the study area waterbodies, based on permit monitoring requirements. All 23 effluent PCB measurements (2009-2014) were less than the 0.001 mg/L detection limit. Because all samples are less than the detection limit, point source loads cannot be accurately quantified. However, based on the average measured flow (3.6 MGD) and a concentration of 0.001 mg/L (set at the detection limit), the load is estimated to be less than 11 lbs/yr (5 kg/yr).

9.3.5 Resuspension and/or Pore Water Diffusion of PCBs from Contaminated Bed Sediments

No site-specific data are available defining the magnitude of pore water diffusion and/or resuspension from bed sediments. The magnitude of pore water diffusion from bed sediments is estimated based on a combination of physical-chemical properties taken from the Lake Ontario PCB model (LimnoTech, 2004), combined with site-specific sediment PCB concentrations. The properties taken from the Lake Ontario PCB model were bed porosity by volume (0.92), fraction organic carbon of bed sediment solids (0.02), bed sediment particle density (2.45 g/cm^3), and organic carbon partition coefficient for PCBs (106.1 m^3/kg).

Results from the Lake Michigan Mass Balance Study (USEPA, 2006) indicate that sediment PCB concentrations over the study domain are on the order of 20 ng/g, resulting in a gross sediment flux of 0.012 kg/year across the entire study area. Lacking site-specific data on the magnitude of sediment resuspension bed sediment PCBs, it can be reasonably assumed that this process is much smaller than sediment diffusion, given that this is a lake (rather than river) environment and that much of the sediment PCB re-deposits shortly after resuspension events.

9.3.6 Phase Partitioning Between the Adsorbed and Dissolved Form of PCB in the Water Column and Bed Sediments

While this process does not directly cause transfer of PCBs into or out of the system (and therefore is not represented with a magnitude in Table 9-2), it can be important in determining the magnitude of other phase-dependent processes such as settling and volatilization. No site-specific data are available defining the phase partitioning between adsorbed and dissolved form of PCBs, either in the water column or bed sediments. However, the degree of partitioning between dissolved and adsorbed forms and be roughly estimated from existing total suspended solids and particulate organic carbon data.

9.3.7 Settling of Particle-Bound PCB

No site-specific data are available defining the settling of particle-bound PCBs from the water column to bed sediments. Screening-level estimates of the magnitude of this process, suitable for determining its potential significance for inclusion can be obtained using inputs from the Lake Ontario PCB model (LimnoTech, 2004). Assuming a suspended solids settling velocity of 1.37 m/day as used for Lake Ontario, gross settling loss of PCBs in nearshore Lake Michigan is estimated at 4.2 kg/yr.

9.3.8 Volatilization of Dissolved Form PCB

No site-specific data are available defining the volatilization of PCBs from the water column to the atmosphere, although screening-level estimates of the magnitude of this process can be obtained using inputs from the Lake Ontario PCB model (LimnoTech, 2004). Volatilization losses of PCB from nearshore Lake Michigan is estimated at 8.4 kg/yr.

9.3.9 PCB Decay Processes

No site-specific data are available defining the PCB decay processes. PCBs are known to decay very slowly in the water column, with the only potentially significant loss component being biodegradation in bed sediments (due to very long sediment resident times).

9.3.10 Bioaccumulation

Section 5.1.1 of this report reviewed the available fish tissue PCB data. This review showed that carp were the most widely sampled fish species, with a total of 52 measurements available from Waukegan Harbor and North Point Marina. . Lake trout were the next most widely sampled species, with 30 measurements available from the nearshore open water/shoreline zone. Only two other fish species have ten measurements or more: rock bass and yellow perch.

9.3.11 Data Gap Assessment for PCBs

Table 9-2 summarizes the result of the data gap assessment for PCBs. Site-specific data sufficiency is characterized as poor (indicating the use of literature values and/or measurements less than the detection level) for the majority of the processes of concern, with hydrodynamic transport and atmospheric loading being the only sources that can be acceptably defined with existing data. Fewer than ten fish tissue samples are available on a study area-wide basis, making characterization of 90th percentile values difficult. Insufficient data are available to characterize fish tissue concentrations specific to each impaired segment.

Table 9-2. Summary of Data Gap Assessment for PCBs.

Process	Data Sufficiency	Estimated Magnitude
Hydrodynamic transport from main body of Lake Michigan	Acceptable	4.5 to 13 kg/yr
Hydrodynamic transport to main body of Lake Michigan	Acceptable	4.5 to 13 kg/yr
Atmospheric Loading	Acceptable	65 kg/yr
MS4 Stormwater Loading	Poor. Rough estimate made using literature-based concentrations	0.62 kg/yr
Flow Reversals from the Chicago Area Waterways	Poor. Estimate of upper bound; all available data are non-detect	<1.9 kg/yr
Other Point Source Discharges	Poor. Estimate of upper bound; all available data are non-detect	< 5 kg/yr
Diffusion and/or Resuspension from Bed Sediments	Poor. Rough estimate made using literature-based values	0.012 kg/yr
Phase Partitioning Between Adsorbed and Dissolved Form	Moderate. Can be estimated from available data.	n/a
Settling	Poor. Rough estimate made using literature-based values.	4.2 kg/yr
Volatilization	Moderate. Reasonable estimate made using literature-based values.	8.2 kg/yr
Decay Processes	Poor, but process believed to be small.	n/a
Bioaccumulation	Moderate. Tissue PCB data are available for most impaired segments, but are generally insufficient to calculate 90th percentiles on a segment-specific basis.	n/a

9.3.12 Refined Conceptual Model for PCBs

The results in Table 9-2 also allow an assessment of which fate and transport processes are potentially significant enough to merit inclusion in the TMDL model framework. Hydrodynamic transport of PCBs from the main body of Lake Michigan and atmospheric loading are clearly important loading sources. A definitive determination cannot be made for stormwater loading, other point source discharges, or flow reversals from the Chicago Area Waterways, because site-specific PCB concentration data is either below detection limits or not available. While literature-based estimates for these sources indicate that they are likely a minor contributor to the study area as a whole, the potential exists for them to be significant contributors to individual harbors. Hydrodynamic transport, settling and volatilization appear to be important loss processes.

9.4 Refined Conceptual Model and Data Gap Assessment for Mercury

This section identifies the magnitude of all other potentially applicable loading, fate and transport processes for mercury beyond hydrodynamic transport. Those sources are:

- Atmospheric loading to the harbors and the nearshore open water segment, including wet deposition, dry deposition
- MS4 stormwater loading to harbors and nearshore open water segments
- Flow reversals from the Chicago Area Waterways
- Point source discharges to the study area
- Resuspension and/or pore water diffusion from contaminated bed sediments
- Phase partitioning between adsorbed and dissolved form of pollutant in the water column and bed sediments
- Settling of the particle-bound pollutant
- Volatilization of the dissolved form of the pollutant
- Pollutant decay processes (e.g. photolysis)

A data gap assessment and refined conceptual model for mercury are presented at the end of this section.

9.4.1 Atmospheric Mercury Loading

An initial estimate of the total atmospheric mercury deposition across the nearshore open waters and harbors of the study area was obtained from USEPA's Regional Modeling System for Aerosols and Deposition (REMSAD; USEPA, 2008). REMSAD results were provided previously for use in the Statewide Michigan Mercury TMDL by USEPA (USEPA, 2012), and were used to make an initial estimate of atmospheric mercury deposition for this project. REMSAD is a "three-dimensional grid model designed to calculate the concentrations of both inert and chemically reactive pollutants by simulating the physical and chemical processes in the atmosphere that affect pollutant concentrations" (USEPA, 2008). REMSAD simulates both wet and dry deposition of mercury. Wet deposition occurs as a result of precipitation scavenging, in which mercury is removed from the air by attaching to water vapors or rain/snow. Dry deposition occurs when gas phase and particulate-bound mercury are deposited on terrestrial and aquatic surfaces. Atmospheric mercury loading to terrestrial and aquatic water surface occur via wet and dry deposition. Unlike PCBs, the atmospheric loading via air-water exchange is not significant for mercury. The Particle and Precursor Tagging Methodology feature of REMSAD allows the user to tag or track emissions from selected sources or groups of sources, and quantify their contribution to mercury deposition throughout the modeling domain and simulation period.

The REMSAD model was applied at a national scale. The year 2001 was chosen as the annual simulation year because REMSAD model inputs (emissions and meteorology) were primarily derived from the 2001 Clean Air Interstate Rule (CAIR) database, which USEPA used in the evaluation of the CAIR and the Clean Air Mercury Rule (CAMR).

The mass of mercury deposited on the nearshore open waters and harbors was calculated based on the total surface area of these waterbodies (473 square kilometers) and the model-predicted areal mercury deposition rate (ranges from 27.6 to 54.3 grams/square kilometer/yr). The annual mercury load deposited on the nearshore open water segment and four harbors is estimated to be between 28.7 and 56.7 lbs/yr (13 – 25.7 kg/yr).

9.4.2 MS4 Stormwater Mercury Loading to Harbors and Nearshore Open Water Segments

93.5% of the study area watershed lies within an MS4 city or village, and in addition, the County of Lake, Shields Township, Waukegan Township, and the Cook County Highway Department have MS4 permits. As a result, close to 100% of the study area is within an MS4 area. No site-specific data were available to quantify stormwater mercury loads for the study area watershed. The magnitude of stormwater mercury loads was therefore estimated as the product of runoff, the study area drainage area, and an assumed mercury concentration. The development of these inputs is described below.

Runoff quantity was calculated using the method developed by the Metropolitan Washington Council of Governments (Schueler, 1987) as: **R = P * Pj * Rv**

Where:

R = Annual runoff (inches),

P = Annual rainfall (inches) estimated as 36.1 inches, based on the average annual rainfall reported for Chicago Midway Airport 3 SW for the 1929-2013 period (http://www.crh.noaa.gov/lot/?n=111577_Midway)

Pj = Fraction of annual rainfall events that produce runoff (set to the default of 0.9)

Rv = Runoff coefficient. Rv is a function of impervious cover in the study area watershed, and was calculated using GIS analysis to determine impervious cover for commercial (0.71), industrial (0.54) and residential (0.37) land uses. The resulting runoff coefficients were: commercial (0.69), industrial (0.54) and residential (0.38).

The area of the contributing watershed was calculated as 99.6 square miles, broken down as: 3.82 square miles (commercial), 4.05 square miles (industrial) and 91.73 square miles (residential).

The mercury concentration was based on stormwater measurements from the USGS for the Columbia River Basin, Washington and Oregon (2009-2010) (Morace, 2012). The value used for load calculation was based on the average of reported values for total mercury, which equals 37.17 ng/L. The estimated stormwater mercury load equals 6.96 lbs/year (3.16 kg/yr).

9.4.3 Mercury Loading from Flow Reversals from the Chicago Area Waterways

The magnitude of loads from the Chicago Area Waterways is estimated based on flow and concentration measurements. Flow reversals from the Chicago Area Waterways to Lake Michigan occur periodically through O'Brien Lock, the Chicago River Lock, and Wilmette Lock. The volume of flow is reported by MWRD on their website for 1985 through 2014.
http://www.mwrd.org/irj/go/km/docs/documents/MWRD/internet/protecting_the_environment/Combined_Sewer_Overflows/pdfs/Reversals.pdf

Until recently, MWRD conducted sampling during flow reversals, including measurements of mercury. Mercury loads to the study area from flow reversals were calculated based on mercury concentration data collected at approximately 30 minute intervals during the 2013 flow reversals at each of these three locations (Table 9-3), and the average 2010-2014 annual volume (4,021.4 million gallons).

Table 9-3. Measured CAWS Mercury Concentrations during Times of Flow Reversals

Location	Location of mercury sampling	Mercury results (4/18/13)
O'Brien Lock	Calumet Harbor, 95th St. Bridge: Calumet Harbor, Ewing Ave. Bridge	All 68 samples < 0.2 ug/L
Chicago River Lock	Chicago River Locks, Inner Harbor Sluice Gate; Chicago River Locks, Sluice Gate, DuSable Harbor	All 28 samples < 0.2 ug/L
Wilmette Lock	Wilmette Harbor, Wilmette Pump Station	All 12 samples < 0.2 ug/L

Because all concentration measurements are less than detection, loads from this source cannot be accurately characterized. However, mercury loads from this source can be estimated to be less than 67 lbs/yr (30.4 kg/yr), using the detection limit as the basis for an upper-bound estimate of mercury concentration. Similar to PCBs, the availability of mercury measurements for CSOs was investigated. CSO measurements for CSOs in the study area are not available (MWRDGC, 2015a).

9.4.4 Other Point Source Mercury Discharges to the Study Area

Point source mercury loads were calculated based on permitted flow and measured concentration data, for facilities determined to have the potential to contribute mercury loads to the study area. These facilities were identified based on input and data provided by Illinois EPA. There are no facilities with mercury permit limits or mercury effluent monitoring requirements within the study area. Therefore, the mercury load from permitted point source dischargers was assumed to equal zero.

9.4.5 Pore Water Diffusion and/or Resuspension of Mercury from Contaminated Bed Sediments

No site-specific data are available defining the magnitude of pore water diffusion and/or resuspension from bed sediments. Pore water diffusion of mercury is typically an insignificant component of the total mercury budget to the lake, and can be assumed unimportant for the Illinois Lake Michigan nearshore area. Based on a mercury mass balance for Lake Michigan, Zhang et al. (2014) reported that the mass flux of mercury settling from water column is roughly four-times greater compared to mercury resuspension from sediments. Therefore, similar to PCBs, it can also be reasonably assumed that resuspension flux of mercury is relatively small, given that this is a lake (rather than river) environment and that much of the sediment-bound mercury re-deposits shortly after resuspension events.

9.4.6 Phase Partitioning Between Adsorbed and Dissolved Form of Mercury in the Water Column and Bed Sediments

While this process does not directly cause transfer of mercury into or out of the system, it is important in determine the magnitude of other phase-dependent processes such as settling and volatilization. No site-specific data are available defining the phase partitioning between adsorbed and dissolved form of mercury, either in the water column or bed sediments. However, the degree of partitioning between dissolved and adsorbed forms and be roughly estimated from existing total suspended solids and particulate organic carbon data.

9.4.7 Settling of Particle-Bound Mercury

No site-specific data are available defining the settling of particle-bound mercury from the water column to bed sediments. Screening-level estimates of the magnitude of this process can be obtained using inputs from the Lake Ontario PCB model (LimnoTech, 2004). Assuming a suspended solids settling velocity of

1.37 m/day as used for Lake Ontario, the gross settling loss of mercury in nearshore Lake Michigan is estimated at 15.6 kg/yr.

9.4.8 Volatilization of Mercury

Volatilization is an important loss pathway for mercury from aquatic systems (Denkenberger et al., 2012). The water-air exchange of mercury is driven by reduction of dissolved mercury species in the water column to gaseous elemental mercury (GEM) and its subsequent loss to the atmosphere. Denkenberger et al. (2012) reported an annual average volatilization rate of 0.75 $ng/m^2/hr$ for Lake Michigan. Applying this value to the study area, the mercury volatilization loss is estimated at 3.1 kg/yr.

9.4.9 Mercury Biological Decay Processes

Mercury being an elemental compound, can undergo redox or sorption reactions to change speciation, but it does not undergo biological decay. This process can also be assumed to be zero.

9.4.10 Bioaccumulation

Section 5.1.2 of this report reviewed the available fish tissue mercury data. This review showed that largemouth bass was the species with the highest concentration, but that only a total of three measurements were available, all from North Point Marina. Smallmouth bass were the next most contaminated species, with seven measurements available from Waukegan Harbor and North Point Marina.

9.4.11 Data Gap Assessment for Mercury

Table 9-4 summarizes the result of the data gap assessment for mercury. Site-specific data sufficiency is characterized as poor (indicating the use of literature values and/or measurements less than the detection level) for the majority of the processes of concern, with hydrodynamic transport and atmospheric loading being the only sources that can be acceptably defined with existing data. Sufficient fish tissue data are available to estimate 90^{th} percentile values for two species on a study area-wide basis. Insufficient data are available to characterize fish tissue concentrations specific to each impaired segment.

Table 9-4. Summary of Data Gap Assessment for Mercury.

Process	Data Sufficiency	Estimated Magnitude
Hydrodynamic transport from main body of Lake Michigan	Acceptable	10 kg/yr
Hydrodynamic transport from main body of Lake Michigan	Acceptable	10 kg/yr
Atmospheric Loading	Acceptable	13 – 25.7 kg/yr
MS4 Stormwater Loading	Poor. Rough estimate made using literature-based values	3.16 kg/yr
Flow Reversals from the Chicago Area Waterways	Poor. Estimate of upper bound; available data are all below detection.	<30.4 kg/yr
Other Point Source Discharges	Acceptable. No known point sources.	0
Diffusion and/or Resuspension from Bed Sediments	Acceptable. Process can be considered insignificant.	n/a
Phase Partitioning Between Adsorbed and Dissolved Form	Moderate. Can be estimated from available data.	n/a
Settling	Poor. Rough estimate made using literature-based values.	15.6 kg/yr
Volatilization	Poor. Rough estimate made using literature-based values.	3.1 kg/yr
Decay Processes	Acceptable. Process can be considered insignificant.	0
Bioaccumulation	Moderate. Tissue mercury data are available for most impaired segments, but are generally insufficient to calculate 90th percentiles on a segment-specific basis.	n/a

9.4.12 Refined Conceptual Model for Mercury

The results in Table 9-4 also allow an assessment of which fate and transport processes are potentially significant enough to merit inclusion in the TMDL model framework. Hydrodynamic transport of mercury from the main body of Lake Michigan and atmospheric loading are clearly important loading sources. A definitive determination cannot be made for stormwater loading, other point source discharges, or flow reversals from the Chicago Area Waterways, because site-specific mercury concentration data is either below detection limits or not available. While literature-based estimates for these sources indicate that they are likely a minor contributor to the study area as a whole, the potential exists for them to be significant contributors to individual harbors. Hydrodynamic transport and settling appear to be important loss processes.

10
Candidate Approaches

Three different candidate approaches are provided for the Illinois Lake Michigan Nearshore PCB and Mercury TMDLs, based upon the refined conceptual models and data gap assessments described above. Three different approaches are provided, corresponding to:

- Level One: Proportionality Approach
- Level Two: Steady State Mass Balance Approach
- Level Three: Time-Variable Approach

10.1 Level One: Proportionality Approach

The simplest option for the Illinois Lake Michigan Nearshore PCB and Mercury TMDLs corresponds to the Level One Proportionality Approach. This approach is based on the assumption that fish tissue pollutant concentrations are directly proportional to the pollutant load delivered to the waterbody of interest, i.e.

$$\text{Fish Tissue Pollutant Concentration} = a \times \text{Pollutant Load} \qquad (1)$$

where a = proportionality constant

With this approach, Equation 1 can be rearranged to calculate the proportionality constant based on current fish tissue concentration and pollutant load:

$$a = \text{Current Fish Tissue Pollutant Concentration} \div \text{Current Pollutant Load} \qquad (2)$$

This proportionality constant can either be a single coefficient based on average values of terms on right hand side, or it can be calculated as the slope of a straight line formed by fitting to multiple values (i.e., different loads and associated fish tissue concentrations).

The proportionality constant can then be used to determine the maximum amount of pollutant load that will meet desired fish tissue concentrations:

$$\text{Maximum Allowable Pollutant Load} = \text{Target Fish Tissue Pollutant Concentration} \div a \qquad (3)$$

This proportionality approach requires the following assumptions:

- All loading sources to the system have the same relative effect on fish tissue concentrations, i.e. the proportionality constant calculated in Equation 2 is equally applicable to all pollutant loading sources. Because this approach does not consider spatial variability, it also assumes that a given load has the same effect on fish tissue regardless of location in the study area.
- The system is currently at steady state, i.e. current fish tissue pollutant concentrations are caused solely by the current pollutant load.

These assumptions, combined with the data gaps defined above, pose some potential limitations with respect to the Illinois Lake Michigan Nearshore PCB and Mercury TMDLs. First, this approach cannot currently be used to define the amount of pollutant loading to individual harbors that will exactly result in compliance with fish targets in those harbors. This is because insufficient information is available to accurately define the existing pollutant load to harbors, as well as to define the amount of dilution that pollutant loads to harbors receive as a result of exchange with Lake Michigan. Second, this approach poses problems for the use of carp as a target fish species for PCBs. This is because carp obtain much of their PCB contamination from bed sediments, and bed sediments are less amenable to the assumption that the system is currently at steady state with respect to loading than is the water column.

The violation of these key assumptions does not necessarily prohibit the use of the Level One Proportionality Approach for the Illinois Lake Michigan Nearshore PCB and Mercury TMDLs, as modifications can be made to this approach to minimize the issues caused by the violation of the key assumptions. The first necessary modification is to require that both the mercury and PCB TMDLs limit direct loading to harbors to concentrations that would be protective of fish tissue concentrations. This modification would ensure that the TMDL was protective of harbors, even though the amount of dilution that harbors receive is unknown. The second required modification is that the level of PCB load reduction necessary to attain compliance in Lake Michigan would need to be based on a species other than carp. The loading target would need to be based on a species, such as lake trout, where it could be reasonably assumed that tissue concentrations current are caused primarily by the current pollutant load as opposed to legacy sediment concentrations. Separate calculations would need to be provided as part of the TMDL demonstrating that PCB loads that are protective of lake trout would ultimately be protective of carp as well.

Consideration of seasonal variation, margin of safety (MOS) and daily loads would be addressed in a manner similar to the statewide Michigan PCB and mercury TMDLs (LimnoTech, 2012 and LimnoTech, 2013). TMDLs are required to consider seasonal variations and critical environmental conditions [40 CFR§130.7(c)(1)]. Atmospheric PCB concentrations are known to vary seasonally due to changes in air temperature. Seasonal variation will be considered in the PCB TMDLs through the use of expected daily maximum concentration associated with expected daily maximum temperature. Mercury concentrations in the atmosphere and water column can fluctuate seasonally. However, accumulation of mercury in fish tissue over time masks any seasonal variations. Due to the extremely slow response time of water and fish concentrations to changes in atmospheric loads, essentially no seasonal variation occurs in fish mercury concentrations due to seasonal variations in atmospheric concentrations. The mercury concentration in the fish represents an integration of all temporal variation up to the time of sample collection. Variability among fish because of differences in size, diet, habitat, and other undefined factors are expected to be greater in sum than seasonal variability (MPCA, 2007).

The MOS is a required part of the TMDL to account for any uncertainty in the relationship between pollutant loading and receiving water quality (40 CFR, Part 130.7(c)(1)). The MOS can be either explicit (e.g., stated as an additional percentage load reduction) or implicit (i.e., conservative assumptions in the TMDL calculations or overall approach) in the calculations of the TMDL, or a combination of the two. An implicit MOS is planned for these TMDLs, supported by the use of the following conservative assumptions that will be used to calculate the TMDL:

- Fish tissue reduction targets will be based on fish species showing the highest pollutant concentration. A TMDL that obtains compliance for these species will ensure compliance for all other fish species.
- The 90th percentile fish tissue concentration will be used as a basis for these TMDLs.

Calculating the TMDL based on these relatively high tissue concentrations will incorporates a MOS into determining the percent reduction required of fish tissue to meet the target goal.

USEPA encourages that TMDLs be expressed on a daily basis, so these annual average concentrations will also be expressed as daily maximum values in this TMDL. An annual load is the most technically appropriate way to express these TMDLs because the goal is to address long term bioaccumulation, rather than track short term effects. Consistent with the Northeast U.S. and Minnesota mercury TMDLs, a daily load will be estimated for these TMDLs by dividing the annual load by 365 (MPCA, 2007, NEIWPCC, 2007).

10.2 Level Two: Steady State Mass Balance Approach

Level Two provides an intermediate complexity option towards development of the Illinois Lake Michigan Nearshore PCB and Mercury TMDLs, and consists of a steady state mass balance approach. The mass balance equation for any given segment can be written as:

$$V_i d[C_i]/dt = W_i + Q_{in,i}[C_{in,i}] - Q_{out,i}[C_i] - V_i k_i[C_i] \qquad (4)$$

where V_i = volume of segment i (L^3)

$[C_i]$	=	pollutant concentration in segment i (M/L^3)
W_i	=	pollutant load to segment i (M/T)
$Q_{in,I}$	=	flow into segment i from adjacent "upstream" segment ($M/L^3/T$)
$[C_{in,i}]$	=	pollutant concentration in adjacent "upstream" segment (M/L^3)
$Q_{out,i}$	=	flow out of segment i ($M/L^3/T$)
$[k_i]$	=	pollutant loss rate coefficient in segment i (1/T)

A separate mass balance equation could be written for the pollutant concentrations in bed sediments, if predictions of bed sediment concentrations are of interest. Because Level 2 represents a steady state condition, Equation 4 can be rearranged to solve for the steady state pollutant concentration (i.e. $d[C^i]/dt = 0$) that is expected to occur in response to steady loads and steady environmental conditions:

$$[C_i] = (W_i + Q_{in,i}[C_{in,i}] - V_i k_i[C_i]) / Q_{out,i} \qquad (5)$$

Pollutant concentrations estimated using Equation 5 could then be linked to a steady state bioaccumulation model that computes fish tissue concentration as a function of direct uptake from the water plus bioaccumulation via the food chain.

This approach improves upon the capabilities of the Level One approach, by not requiring the assumption that all loading sources to the system have the same relative effect on fish tissue concentrations. It therefore provides the capability of generating unique results for each impaired segment, and would allow the loading capacity of individual harbors to be assessed separately from the loading capacity of the lumped nearshore harbor/shoreline/open water system. Consideration of seasonal variation, margin of safety (MOS) and daily loads would be addressed in the same manner as described above for the Level One approach.

The disadvantage to the Level Two approach is that site-specific data do not exist to define the values of many of the required inputs to Equations 4 and 5. For example, the Great Lakes Coastal Forecasting System has the capability of defining hydrodynamic exchange between the nearshore open water segments and shoreline segments, but it does not have the spatial resolution to define hydrodynamic exchange between harbors and the nearshore open water segment. Similarly, insufficient data are available to rigorously define the pollutant loss rate coefficient by segment.

The lack of data to rigorously define many Level Two model inputs does not necessarily prohibit the use of this approach for the Illinois Lake Michigan Nearshore PCB and Mercury TMDLs, as sufficient information exists to allow the missing input values to be roughly estimated. For example, the Great Lakes Coastal Forecasting System predicts time-variable changes in water surface elevation near the entrances to the harbors of interest. The water level information could be used to estimate the amount of hydraulic exchange between each harbor and the nearshore waters. Existing pollutant fate and transport models developed for the Great Lakes would provide rough estimates of the pollutant loss rate coefficient. While these missing inputs could only be roughly estimated, model sensitivity analyses could be conducted to determine the extent to which uncertainty in these inputs affects TMDL model results.

10.3 Level Three: Time-Variable Approach

The Level Three approach provides the greatest level of temporal detail, spatial detail, and process complexity. The mass balance equation for any given water column segment is similar to Equation 4, differing in the partitioning of total pollutant concentration in dissolved and particle-bound phases and the explicit consideration of interaction with the bed sediments. In addition, a mass balance equation is also solved for the bed sediments

$$V_i d[C_i]/dt = W_i + Q_{in,i}[C_{in,i}] - Q_{out,i}[C_i] - V_i kd_i[Cd_i] - V_i kp_i[Cp_i] + v_{rs,i}/A_i[CS_i] \quad (6)$$

$$VSid[CSi]/dt = VSikpi[Cpi] - vrs,i/Ai[CSi] - vb,i/Ai[CSi] \quad (7)$$

where Vi = volume of segment i (L^3)

[Ci]	=	total pollutant concentration in segment i (M/L^3)
Wi	=	total pollutant load to segment i (M/T)
$Q_{in,i}$	=	flow into segment i from adjacent "upstream" segment ($M/L^3/T$)
$[C_{in,i}]$	=	total pollutant concentration in adjacent "upstream" segment (M/L^3)
$Q_{out,I}$	=	flow out of segment i ($M/L^3/T$)
$[kd_i]$	=	pollutant loss rate coefficient for dissolved phase pollutant in segment i (1/T)
$[kp_i]$	=	pollutant loss rate coefficient for particle-bound pollutant in segment i (1/T)
$v_{rs,i}$	=	flux velocity of pollutants out of bed sediments in segment i (M/T)
A_i	=	Surface area of sediment-water interface in segment i (L^2)
$[VS_i]$	=	volume of active bed sediment layer in segment i (L^3)
$[CS_i]$	=	pollutant concentration of bed sediments in segment i (M/L^3)
$V_{b,i}$	=	burial velocity of pollutants in bed sediments of segment i (M/T)

Results from Equations 6 and 7 can be used to define fish tissue concentrations either via linkage to a food web bioaccumulation model through the use of empirical bioaccumulation factors.

The primary difference between Level Three and the other candidate approaches is that the Level Three approach is capable of simulating how pollutant concentrations change over time. This allows accurate consideration of time-variable loading sources, as well as consideration of the response time that the system will require to attain water quality standards after the TMDL is implemented. This capability is especially useful in terms of assessing existing carp tissue contamination data, as carp contamination may be driven by exposure to legacy sediment contamination which is not readily considered by steady state approaches.

Seasonal variation and expression of the TMDL as daily loads would be explicitly considered in the Level Three approach, as it would simulate the day-to-day variability in pollutant loads and receiving water concentrations. The margin of safety would be handled in the same implicit manner as for Levels One and Two, through the use of conservative assumptions.

The overwhelming limitation of the Level Three approach is the absence of data available to support its application. Level Three models require not only information for each of the inputs to Equations 6 and 7, but they also require an understanding of how each of these inputs has varied over time. This information is not available for the Illinois Lake Michigan Nearshore area, for either mercury or PCBs.

Blank Page

11
Recommendation for Preferred Approach

None of the candidate model frameworks are ideally suited for the Illinois Lake Michigan Nearshore PCB and Mercury TMDLs. Selection of the Level One approach brings an *a priori* requirement that all loads to impaired harbors must be demonstrated to be insignificant, or be restricted to concentrations that will comply with water quality standards. Selection of the Level Two approach will require several model input parameters to be roughly estimated. Both the Level One and Level Two approaches are incapable of directly addressing the potential that carp tissue PCB concentration are influenced by legacy contamination. The Level Three approach, while theoretically free of the limitations of the Level One and Level Two approaches, requires significantly more data than are currently available.

Of the above limitations, only the severe lack of data to support a Level Three approach can be considered insurmountable. Indirect methods can be used in the Level One and Level Two approaches to assess whether a given TMDL will be protective of carp tissue PCB levels. Values for missing Level Two inputs can be estimated, and the uncertainty associated with these inputs can be evaluated.

Selection between the Level One and Level Two approaches requires a policy decision. If it is acceptable to require *a priori* that all loads to impaired harbors must be at concentrations that will comply with water quality standards, the Level One approach is capable of defining the necessary reduction in local and regional atmospheric sources necessary to attain fish tissue targets. If regulatory flexibility is desired to allow sources to impaired harbors to be at concentrations above water quality standards (and therefore make use of the assimilative capacity of the harbors), the Level Two approach is recommended. Based upon consultation with Illinois EPA and USEPA, the Level One approach is recommended.

Blank Page

12 References

Beletsky, D. and D. J. Schwab, 2001. Modeling circulation and thermal structure in Lake Michigan: Annual cycle and interannual variability. *Journal Geophysical Research,* 106 (C9): 19,745-19,771.

Beletsky, D., J. H. Saylor, and D. J. Schwab, 1999. Mean circulation in the Great Lakes. *Journal of Great Lakes Res*earch, 25, 78-93.

Chicago Harbors, 2015. Diversey Harbor. Accessed online on March 31, 2015 http://www.chicagoharbors.info/harbors/diversey/

City of Spokane, 2014. Draft Integrated Clean Water Plan. https://static.spokanecity.org/documents/publicworks/wastewater/integratedplan/integrated-clean-water-plan-draft.pdf

Connecticut Department of Environmental Protection, Maine Department of Environmental Protection, Massachusetts Department of Environmental Protection, New Hampshire Department of Environmental Services, New York State Department of Environmental Conservation, Rhode Island Department of Environmental Management, Vermont Department of Environmental Conservation, and New England Interstate Water Pollution Control Commission. 2007. Northeast Regional Mercury Total Maximum Daily Load. http://www.dec.ny.gov/docs/water_pdf/tmdlnehg.pdf

Delaware River Basin Commission (DRBC), 2003. Total Maximum Daily Loads for Polychlorinated Biphenyls (PCBs) for Zones 2-5 of the Tidal Delaware River, December 15, 2003, http://www.epa.gov/reg3wapd/tmdl/pa_tmdl/DelawareRiver/TMDLreport.pdf

Denkenberger, J.S., C.T. Driscoll, B.A. Branfireun, C.S. Eckley, M. Cohen, and P. Selvendiran. 2012. A synthesis of rates and controls on elemental mercury evasion in the Great Lakes Basin. *Environmental Pollution*. 161: 291 – 298.

DePinto, J.V.; Freedman, P.L.; Dilks, D.W.; Larson, W.M., 2004. Models Quantify the Total Maximum Daily Load Process. *J. of Environ. Eng*. 130(6), 703-713.

Electric Power Research Institute (EPRI), 2013. Review of Bioaccumulation Models of Mercury and PCBs in Aquatic Systems. Electric Power Research Institute, Palo Alto, CA: 2013. 3002001198.

Franz, T.P., S.J. Eisenreich, and T.M. Holson. 1998. Dry Deposition of Particulate Polychlorinated Biphenyls and Polycyclic Aromatic Hydrocarbons to Lake Michigan. *Environ. Sci. Technol.* 32 (23) 3691-3688.

Illinois Department of Natural Resources (IDNR), 2015. Illinois Coastal Management Program Boundaries, accessed on 03/31/15 http://www.dnr.illinois.gov/cmp/Pages/boundaries.aspx

IDNR, 2015a. North Point Marina. A Accessed online on March 31, 2015 https://dnr.state.il.us/lands/landmgt/parks/north_po/INDEX.htm

Interstate Commission on the Potomac River Basin (ICPRB), 2007. Total Maximum Daily Loads of Polychlorinated Biphenyls (PCBs) for Tidal Portions of the Potomac and Anacostia Rivers in the District of Columbia, Maryland, and Virginia. Prepared for District of Columbia Department of the Environment, Maryland Department of the Environment, and Virginia Department of Environmental Quality. October 31, 2007. http://www.potomacriver.org/cms/index.php?option=com_content&view=article&id=136:tidal-pcb-tmdl&catid=41:pollution&Itemid=1

Landis, M.S. and G.J. Keeler, 2002. Atmospheric Mercury Deposition to Lake Michigan during the Lake Michigan Mass Balance Study. *Environ. Sci. Technol.* 36, 4518-4524.

LimnoTech, 2015. Technical Data Inventory and Target Fish Selection. Prepared for USEPA, under subcontract to Michael Baker International. February 2, 2015.

LimnoTech, 2013. Statewide Michigan Mercury TMDL. Public Review Draft. January 2013. Prepared for Michigan Department of Environmental Quality and USEPA Region 5 under subcontract to Battelle.

LimnoTech, 2012. Statewide Michigan PCB TMDL. Public Review Draft. November 2012. Prepared for Michigan Department of Environmental Quality and USEPA Region 5 under subcontract to Battelle.

LimnoTech, 2004. LOTOX2 Model Documentation: In Support of Development of Load Reduction Strategies and a TMDL for PCBs in Lake Ontario. Prepared for USEPA Region 2, New York, New York.

Minnesota Pollution Control Agency (MPCA). 2007. Minnesota Statewide Mercury Total Maximum Daily Load. Minnesota Pollution Control Agency. March 27, 2007. http://www.pca.state.mn.us/index.php/view-document.html?gid=8507

Metropolitan Water Reclamation District of Greater Chicago (MWRDGC), 2015. Personal communication February 5, 2015.

MWRDGC, 2015a. Personal communication, March 19, 2015.

Michigan Department of Environmental Quality (MDEQ), 2015. Personal communication, March 23, 2015.

Morace, J.L., 2012, Reconnaissance of contaminants in selected wastewater-treatment-plant effluent and stormwater runoff entering the Columbia River, Columbia River Basin, Washington and Oregon, 2008–10: U.S. Geological Survey Scientific Investigations Report 2012–5068, 68 p. http://pubs.usgs.gov/sir/2012/5068/table15.html

National Oceanic and Atmospheric Administration (NOAA), 2015. Great Lakes Coastal Forecasting System Fact Sheet. http://www.glerl.noaa.gov/pubs/brochures/glcfs.pdf

Offenberg, J.H. and J.E. Baker. 1997. Polychlorinated Biphenyls in Chicago Precipitation: Enhanced Wet Deposition to Near-Shore Lake Michigan. Environ. Sci. Technol. Vol 31. Pp 1534-1538

Schueler, T. 1987. Controlling Urban Runoff: A Manual for Planning and Designing Urban Stormwater Best Management Practices. Metropolitan Washington Council of Governments. Washington, DC.

United States Army Corps of Engineers (USACE) Detroit District, 2015. Harbor Infrastructure Inventories: Calumet Harbor, Illinois and Indiana. Accessed online on March 31, 2015 at: http://www.lre.usace.army.mil/Portals/69/docs/Navigation/RiskCommunication/Calumet%20Harbor.pdf

United States Environmental Protection Agency (USEPA), 2015. Great Lakes Areas of Concern: Waukegan River Harbor. Accessed online on March 31, 2015 at: http://www.epa.gov/greatlakes/aoc/waukegan/index.html

USEPA. 2012. Personal communication with D. Atkinson, U.S. EPA. April, 2012.

USEPA, 2011. PCB TMDL Handbook. EPA Report #841-R-11-006. http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/upload/pcb_tmdl_handbook.pdf

USEPA. 2008. Model-Based Analysis and Tracking of Airborne Mercury Emissions to Assist in Watershed Planning. Watershed Branch, Office of Wetlands, Oceans, and Watersheds. Washington, D.C. http://www.epa.gov/owow/tmdl/pdf/final300report_10072008.pdf

USEPA. 2006. Results of the Lake Michigan Mass Balance Project: Polychlorinated Biphenyls Modeling Report. Large Lakes Research Station. EPA-600/R-04/167

USEPA. 2004. Results of the Lake Michigan Mass Balance Study: Biphenyls and trans-Nonachlor Data Report. Report. April 2004. EPA 905 R-01-011. Chicago, IL. Accessed online http://www.epa.gov/glnpo/lmmb/results/pcb/lmmbpcb.pdf and summarized online http://www.epa.gov/med/grosseile_site/LMMBP/pcbs.html

USEPA, 2001. Total Maximum Daily Load for Total Mercury in the Middle/Lower Savannah River, GA. February 28, 2001. http://www.epa.gov/owow/tmdl/examples/mercury/ga_savfinal.pdf

USEPA, 1995. Great Lakes Water Quality Initiative Technical Support Document for the Procedure to Determine Bioaccumulation Factors. Office of Water. EPA-820-B-95-005.

USEPA and Virginia Department of Environmental Quality (VADEQ), 2001. "Development of Shenandoah River PCB TMDL," available at http://www.epa.gov/reg3wapd/pdf/pdf_tmdl/ShennandoahRiver_DR_Report_Appendices.pdf

United States Geological Survey (USGS), undated. USGS, 2010-2014 Great Lakes Restoration Initiative, Hg Cycling Study, unpublished data for Lake Michigan station MI102-GS.

Venier, M., A. Dove, K. Romanak. S. Backus, and R. Hites. 2014. Flame Retardants and Legacy Chemicals in Great Lakes' Water. Environ. Sci. Technol., 2014, 48 (16), pp 9563–9572.

Zhang, X., K. Rygwelski, R. Kreis, Jr., R. Rossmann. 2014. A Mercury Transport and Fate Model (LM2-Mercury) for Mass Budget Assessment of Mercury Cycling in Lake Michigan. Journal of Great Lakes Research 40 (2014) 347-359.

Blank Page

Appendix A: 303(d) List of Impaired Segments and Causes

Table A-1. Impaired segments in the project study area

TMDL Zone	HUC 10	Waterbody Name	Segment ID	Size	Size Units	Designated Use Impairment	Cause(s)
Nearshore open water/shoreline	Lake Michigan Shoreline	North Point Beach	IL_QH-01	0.42	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	IL Beach State Park North	IL_QH-03	2.72	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Waukegan North Beach	IL_QH-04	1.51	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Waukegan South Beach	IL_QH-05	1.55	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	IL Beach State Park South	IL_QH-09	4.67	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Lake Bluff Beach	IL_QI-06	5.5	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Lake Forest Beach	IL_QI-10	3.79	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Rosewood Beach	IL_QJ	2.19	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Park Ave. Beach	IL_QJ-05	4.08	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Glencoe Beach	IL_QK-04	2.15	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Tower Beach	IL_QK-06	1.17	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Lloyd Beach	IL_QK-07	0.32	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Maple Beach	IL_QK-08	0.57	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Elder Beach	IL_QK-09	0.92	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Kenilworth Beach	IL_QL-03	0.76	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Gilson Beach	IL_QL-06	2	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Greenwood Beach	IL_QM-03	0.38	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Lee Beach	IL_QM-04	0.43	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Lighthouse Beach	IL_QM-05	0.64	Miles	Fish consumption	Mercury, PCBs

TMDL Zone	HUC 10	Waterbody Name	Segment ID	Size	Size Units	Designated Use Impairment	Cause(s)
Nearshore open water/shoreline	Lake Michigan Shoreline	Northwestern University Beach	IL_QM-06	0.73	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Clark Beach	IL_QM-07	0.94	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	South Boulevard Beach	IL_QM-08	0.98	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Touhy (Leone) Beach	IL_QN-01	0.41	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Loyola (Greenleaf) Beach	IL_QN-02	0.29	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Hollywood/ Ostermann Beach	IL_QN-03	0.27	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Foster Beach	IL_QN-04	0.65	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Montrose Beach	IL_QN-05	1.45	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Juneway Terrace	IL_QN-06	0.07	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Rogers Beach	IL_QN-07	0.16	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Howard Beach	IL_QN-08	0.16	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Jarvis Beach	IL_QN-09	0.26	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Pratt Beach	IL_QN-10	0.19	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	North Shore/Columbia	IL_QN-11	0.16	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Albion Beach	IL_QN-12	0.53	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Thorndale Beach	IL_QN-13	0.69	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	North Ave. Beach	IL_QO-01	0.55	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Fullerton Beach	IL_QO-02	3.07	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Webster Beach	IL_QO-03	0.29	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Armitage Beach	IL_QO-04	0.27	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Schiller Beach	IL_QO-05	0.57	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Oak St. Beach	IL_QP-02	0.64	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Ohio St. Beach	IL_QP-03	0.93	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	12th St. Beach	IL_QQ-01	1.93	Miles	Fish consumption	Mercury, PCBs

TMDL Zone	HUC 10	Waterbody Name	Segment ID	Size	Size Units	Designated Use Impairment	Cause(s)
Nearshore open water/shoreline	Lake Michigan Shoreline	31st St. Beach	IL_QQ-02	3.32	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	49th St. Beach	IL_QR-01	1.43	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Jackson Park/63rd Beach	IL_QS-02	0.73	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Rainbow	IL_QS-03	3.34	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	57th St. Beach	IL_QS-04	0.33	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	67th St. Beach	IL_QS-05	0.71	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	South Shore Beach	IL_QS-06	0.43	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Shoreline	Calumet Beach	IL_QT-03	1.29	Miles	Fish consumption	Mercury, PCBs
Nearshore open water/shoreline	Lake Michigan Open Water	Open waters Lake Michigan Nearshore	IL_QLM-01	180	Square miles	Fish consumption	Mercury, PCBs
North Point Marina Harbor	North Point Marina Harbor	North Point Marina Harbor	IL_QH	0.121	Square miles	Fish consumption	Mercury, PCBs
Waukegan Harbor	Waukegan Harbor	Waukegan Harbor North	IL_QZO	0.0652	Square miles	Fish consumption, Aquatic life	Mercury, PCBs
Calumet Harbor	Calumet Harbor	Calumet Harbor	IL_3S	2.4	Square miles	Fish consumption	Mercury, PCBs
Diversey Harbor	Diversey Harbor	Diversey Harbor	IL_QZI	0.04563	Square miles	Fish consumption	Mercury, PCBs

Blank Page

Appendix B: GIS Data Compilation and QA Review

GIS data layers were compiled in an ArcGIS file geodatabase. All data in the geodatabase have a consistent projection/coordinate system and horizontal units:

Illinois State Plane Coordinate System (SPCS)
East Zone (FIPS Zone 1201)
NAD 1983
U.S. survey feet

Spatial data layers are grouped within feature datasets: Hydrography, Political, Sources, and Stations (Table B-1). Source information will be used to support development of the TMDL approach and the TMDLs.

Table B-1. Data types and sources

Data type	Spatial data layer	Source
Hydrography	Lake Michigan shoreline segments	Illinois EPA
	Lake Michigan open water segment	Illinois EPA
	Lake Michigan harbors	Illinois EPA
	Streams and lakes	National Hydrography Dataset (NHD)
	Hydrologic units (watersheds)	Watershed Boundary Dataset (WBD)
	Control structures on Chicago Area Waterway System	Metropolitan Water Reclamation District of Greater Chicago
Political	City boundaries	U.S. Census Bureau
	County and state boundaries	U.S. Census Bureau
	County and state boundaries	National Map (U.S. Geological Survey)
Sources	Permitted dischargers	Illinois EPA
	Regulated facilities	U.S. EPA
Stations	Sampling station location	U.S. EPA, Illinois EPA, USGS

For all acquired spatial data, location accuracy was assessed using GIS. If discrepancies were found, further checks or data revisions were pursued. For example, Illinois EPA provided a draft version of the Lake Michigan 5-km open waters segment. Its total area did not match an IEPA documented area, so further checks were made. The shoreline side of the segment was found to not match the IEPA-assessed shoreline segments. As a result, LimnoTech established a standard shoreline shared by the open water and shoreline segments, eliminated harbors that were not open waters, and constructed a GIS data layer for a consistent 5-km buffer truncated at established state boundaries.

Similarly, coordinates of sample stations were first checked to see if they placed a station at the place in its description. If not, LimnoTech used the description and other available information to determine an approximate location for the station. Then locations were compared to the study area boundary (defined by the impaired segments and the contributing watershed), including the open waters buffer and the Lake Michigan watershed on the land side in Illinois, which includes small tributaries directly to Lake Michigan.

Blank Page

Appendix C: Count of Fish Fillet Samples by TMDL Zone

Table C-1 presents a count of fish mercury fillet samples by species and TMDL zone. Table C-2 presents the same information for PCB fillet samples.

Table C-1. Count of fish mercury fillet samples by species and TMDL zone

Fish Species	TMDL Zone				Grand Total
	Nearshore open water/ shoreline	Calumet Harbor	North Point Marina	Waukegan Harbor	
Black bullhead				2	2
Brown trout	1				1
Largemouth bass			3		3
Rainbow trout	2				2
Rock bass		1	4	4	9
Smallmouth bass		5	2		7
Sunfish			3	2	5
White sucker			2	2	4
Grand Total	**3**	**6**	**14**	**10**	**33**

Table C-2. Count of fish PCB fillet samples by fish species and TMDL zone.

Fish Species	TMDL Zone					Grand Total
	Nearshore open water/ shoreline	Calumet Harbor	Diversey Harbor	North Point Marina	Waukegan Harbor	
Alewife	6					6
Black bullhead					3	3
Bloater chub	7					7
Brown trout	1					1
Carp				12	40	52
Lake trout	30					30
Largemouth bass				3	1	4
Pumpkinseed sunfish			1		2	3
Rainbow smelt	1					1
Rainbow trout	2					2
Rock bass		1		4	5	10
Round goby		1		2		3
Smallmouth bass		5		2		7
Sunfish				4	3	7
White sucker				2	4	6
Yellow perch	21				1	22
Grand Total	**68**	**7**	**1**	**29**	**59**	**164**