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June, 2012

Cumberland Bay Sludge Bed – Wilcox Dock
Site # 5-10-017
Removal and Disposal Project
Pre-to Post-Dredging Monitoring
(Volume I of II)
Ten Year Review

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Executive Summary

This Pre- to Post-Dredging Monitoring Report - Ten Year Review presents the baseline sampling and eleven years of data collected at the Cumberland Bay PCB New York State Superfund site (New York State Registry of Inactive Hazardous Waste Sites # 510017) since the sludge bed was remediated 1999/2000. Cumberland Bay is a small (1.9 mi by 2.5 mi), somewhat rectangular part of the West Side of Lake Champlain. The city of Plattsburgh is located on the west side of the Bay, where the Saranac River and Scomotion Creek flow into the Bay. The north shoreline of Cumberland Bay is occupied by the Plattsburgh Municipal Beach, a New York State (NYS) Office of Parks and Recreation campground, and numerous motels and restaurants. On the east side, Cumberland Head, a large peninsula forms the northern part of the east shore of the bay. The Cumberland Bay sludge bed was located between the Saranac River and Scomotion Creek.

The Cumberland Bay sludge bed was composed of wood pulp, wood chip debris, fine organic matter, and other processing wastes that were discharged from local wood product industries (sawmills, wood chip producing industries, and paper manufacturing and processing industries). The concentrations of polychlorinated biphenyls (PCBs) in the sludge, pulp and fine wood debris was the major contaminant of concern at the site. Concentrations of PCBs as great as 13,000 mg/kg were detected in sludge samples. New York State Department of Health (NYSDOH) sampling in 1994 detected PCB concentrations in the wood chip debris washing up on shore and nearby bathing beaches as high as 210 mg/kg.

Remediation of the Wilcox Dock Site was conducted between July 19, 1999 and October 19, 2000. This remediation consisted of the use of hydraulic dredging to remove 230,000 cubic yards (CY) of contaminated sludge containing 20,000 pounds of PCBs. The operational criterion for the dredging was the removal of sludge down to the native sand bottom. The confirmatory sampling in 2000 indicated an average concentration of 1.5 mg/kg PCB in the dredged area, which was a significant reduction from the pre-remediation average concentrations of 33 mg/kg in the mudflats and breakwater areas, and 431 mg/kg in the dock area itself.

The objective of the monitoring program was to measure changes in PCB concentrations and congener patterns in fish, sediment, and water at selected sites in Cumberland Bay and adjacent Lake Champlain in response to remediation. The baseline sampling occurred in April 1999 prior to commencement of remediation.

Sampling was conducted at nine Long Term Monitoring (LTM) sites.

- Site 1 is at the Wilcox Dock;
- Site 2 has been split into two separate locations. The “Mouth of Saranac” site 2M is in Cumberland Bay just south of the mouth of the Saranac River. The “Jetty” site 2J is in the Bay approximately 0.5 kilometers southeast of the “Mouth of Saranac” site;
- Site 3 is south of the dredge site near the oil terminals;
- Site 4 is within the westernmost bay of Valcour Island, north of the island’s western peninsula;

- Site 5 is located at the south end of Valcour Island;
- Site 6 is on the Vermont shore near Sawyer Bay;
- Site 7 is on the northeast side of Cumberland Head;
- Site 8 is just west of the southern tip of Cumberland Head; and
- Site 9 is east of Cumberland Bay State Park.

LTM Sites 4 and 5 are located in close vicinity to one another near Valcour Island. Since both of these locations were chosen to represent the regional background, data for these two locations were grouped together for this assessment and are referred to as LTM Site 4/5.

Assessing these data sets revealed patterns of PCBs that illustrate the response of the system to the remediation with location and over time.

Concentrations of PCBs in Passive In-Situ Chemical Extracting Samplers (PISCES), fish, and water were always highest at the site itself and decreased outward from the site. To some degree in the PISCES data, but very noticeably in the fish data, the homolog distribution (i.e., composition of PCB mixtures) of the PCBs tended to change with the distance from the sludge bed site. These observations of the gradient support the hypothesis that the Wilcox Dock served as the source of PCBs to the surrounding area.

All of the data indicate that PCB concentrations in water and fish dropped after the remediation. The concentrations of the Tri+ PCBs (which tend to be more important in terms of biota uptake) were very clearly declining in the PISCES data. The lipid normalized fish data typically show a drop by more than 80 to 90 percent, although the wet weight fish data were somewhat more variable due to changes in the lipid content of the fish. Also of interest is the fact that the concentrations at the outlying stations meant to serve as controls (LTM Site 4/5) also showed indications of dropping, suggesting that the remediation, as well as a more global decline in environmental PCBs may have influenced those stations as well.

The post remediation monitoring program has provided strong evidence that PCB concentrations have declined throughout the area sampled since the remediation. These declines followed a first order exponential pattern and are now approaching the laboratory detection limits for PCBs in many of the fish and the PISCES. These results demonstrate that the remediation has mitigated the release of PCBs from the site.

The NYSDOH health advisory first issued in 1984 and in 1995 applied to three species: yellow perch, brown bullhead, and American eel. The 10 year post-remediation monitoring program has demonstrated a consistent first order decline in PCB concentrations in these species to levels consistent with other waters with only the state wide health advisory applied to them. Due to these declines in PCB concentration, the NYS DOH has removed the site specific advisories for yellow perch and brown bullhead as of this year (2012).

The monitoring program has shown that the PCB concentrations in the media monitored have declined exponentially approaching undetectable levels. This shows that the remediation conducted in 1999 to 2000 has achieved its goals.

1.0 Introduction

1.1 Introduction

This Pre- to Post-Dredging Monitoring Report - Ten Year Review presents the baseline sampling and eleven years of data collected at the Cumberland Bay PCB New York State Superfund site (New York State Registry of Inactive Hazardous Waste Sites # 510017) following remediation of PCB contaminated sediments. The Cumberland Bay site was remediated in 1999-2000 under the auspices of the New York State Environmental Conservation Law (ECL) and Title 6 New York Code of Rules and Regulations (NYCRR) Part 375. A long term monitoring plan was implemented to monitor the effectiveness of the remedial action. This report provides a review of the eleven years of post-remedial monitoring. The monitoring at the site and the preparation of this report were conducted under a New York State Department of Environmental Conservation (NYSDEC) Superfund Contract. Monitoring of the site was conducted by the NYSDEC and coordinated by AECOM Technical Services Northeast, Inc. (AECOM) in the years 1999 to 2011. This report was prepared by AECOM for the NYSDEC.

This report is divided into the following Sections: Section 1(Introduction), Section 2 (Monitoring Methods), Section 3 (Data Interpretation and Evaluation), Section 4 (Conclusions), and Section 5 (References).

1.2 Site Description

As described in more detail under Site History (Section 1.3), the sludge bed was composed of wood pulp, wood chip debris, fine organic matter, and other processing wastes that were discharged from local wood product industries (sawmills, wood chip producing industries, and paper manufacturing and processing industries). Concentrations of PCBs in the sludge, pulp, and fine wood debris were the major concern at the site. Concentrations of PCBs as great as 13,000 mg/kg were detected in sludge samples. New York State Department of Health (NYSDOH) sampling in 1994 detected PCB concentrations in the wood chip debris washing up on shore and nearby bathing beaches as high as 210 mg/kg.

In 1984, a fish consumption advisory was issued for brown bullhead in the Plattsburgh area due to PCBs. Since 1995, a health advisory had been in effect for brown bullhead, American eel, and yellow perch in Cumberland Bay within Lake Champlain due to elevated PCB concentrations in the fish. In addition, the commercial sale of yellow perch from Cumberland Bay was prohibited due to PCB concentrations in the fish, which exceed the US Food and Drug Administration (FDA) marketplace standard of 2 mg/kg. The site specific fish advisory for yellow perch and brown bullhead was lifted in 2012.

Cumberland Bay is a small (1.9 mi by 2.5 mi), somewhat rectangular part of the West Side of Lake Champlain (Figure 2-1). Depths in the Bay can exceed 50 feet, but average water depths in the vicinity of the Site do not exceed 20 feet and are generally less than 10 feet. The city of Plattsburgh is located on the west side of the Bay, where the Saranac River and Scomotion Creek flow into the Bay. The north shoreline of Cumberland Bay is occupied by the Plattsburgh Municipal Beach, a NYS Office of Parks and Recreation campground, and numerous motels and restaurants. On the east side, Cumberland Head, a large peninsula, extends into the Bay.

The Wilcox Dock is an engineered structure, 200 feet wide by 400 feet long, and is presently controlled by the New York State Canal Corporation under the jurisdiction of the New York State Thruway Authority (NYSTA). The south and east sides of the dock and a short portion of the north side of the dock are reinforced with sheet piling. Wilcox Dock itself is open to the public. A small boat launch was recently constructed at the site to allow increased public access to the lake in Cumberland Bay. The Georgia Pacific Corporation controls access to a second entry to the dock area where it maintains a pump house for plant operations.

Data collected in prior investigations (Callinan et al, 1998; Rowell, 1996) showed that near Wilcox Dock and across Cumberland Bay, PCB congener patterns in fish, sediment, suspended sediment, and water/ PISCES showed a strong Aroclor 1242 signature. This pattern differed from the PCB pattern found in the Saranac River and main lake and clearly connected contamination of the Cumberland Bay to the sludge bed. Those previous studies suggest that bottom currents may have been carrying sludge bed PCBs out of the Bay into Lake Champlain. PCB concentrations found in sediment cores from the lake just outside the Bay may have been the result of this hydrodynamic transport.

Remediation of the Wilcox Dock Site was conducted between July 19, 1999 and October 19, 2000 (Earth Tech, 2002). This remediation consisted of the use of hydraulic dredging to remove 230,000 cubic yards (CY) of contaminated sludge containing 20,000 pounds of PCBs. The operational criterion for the dredging was the removal of sludge down to the native sand bottom. The confirmatory sampling in 2000 indicated an average concentration of 1.5 mg/kg PCBs in the dredged area, which was a significant reduction from the pre-remediation average concentrations of 33 mg/kg in the mudflats and breakwater areas and 431 mg/kg in the dock area itself.

1.3 Site History

Historically, land adjacent to Cumberland Bay, deeded to Willard G. Wilcox by the State of New York in the late 1800s was reappropriated back to the State of New York Department of Public Works in 1914. By 1920, a barge canal terminal was envisioned, planned, designed, and constructed, allowing the beginning of commercial traffic to the dock facility.

Industries in the area at the turn of the century and early 1900s included the Lozier Automobile Company, Saranac Pulp and Paper Company, Standard Pulp and Products Company, and Borst-Forest-Dixfiel. Several oil companies, including Colonial Beacon, Standard, Shell, and Sucony Vacuum Oil Company maintained pipelines from Wilcox Dock to storage facilities inland from the bay. In 1935 and in 1951, the NYS Division of Canals and Waterways dredged the canal access along the dock to accommodate larger fuel bearing vessels. The Diamond Match Company (1944), Vanity Fair (1955), and ultimately the Georgia Pacific Company (1963-present), occupied property adjacent to the Site (Callinan et al, 1998).

Records indicate that for several decades wastes from some local industries were discharged to local streams that ultimately discharge into Cumberland Bay or were directly discharged into the bay forming extensive sludge beds. Sawmills on the Saranac River discharged wastes into Cumberland Bay, where prevailing winds and currents in the summer dispersed the solids against the beach areas at the north end of the bay. Also, pulp and paper mills on the shore of the bay near Dead Creek disposed of solids and organic materials in the bay (Frederic R. Harris, Inc., 1979). Untreated waste disposal ended in the early 1970s when the Plattsburgh Sewage Treatment Plant began treating wastes from the local industries. Over the years, wave action and water currents eroded the sludge bed and transported wood chips and organic debris along the shorelines and beaches to the north as well as to other areas within Cumberland Bay. For many years, the Site was considered a public nuisance, emitting unpleasant odors and hampering boating and swimming activities in the area. Environmental sampling from 1992 through 1994 confirmed the presence of PCBs within the sludge and along the shoreline and beach areas.

Remediation of the Cumberland Bay Sludge Bed commenced April 1999, with clearing of areas on shore to allow installation of staging areas, water treatment facilities, and offices. One thousand feet of temporary sheet piling was installed in the bay in June and early July of 1999. This sheet piling, along with silt curtains, was used to contain any resuspended sediment. Dredging began on June 12 and continued until late December of 1999. Shoreline excavation began on July 28 and continued until November 9, 1999. Dredging was resumed on April 27 of 2000 and continued until late October of 2000.

The intent of the remedial dredging was to remove the contaminated sludge, which was distinguishable from the underlying native sand, to the extent practicable. Post remediation sediment sampling was conducted in summer and fall of 2000 to confirm the effectiveness of the dredging operation. The final post-dredge sampling program involved sampling a grid pattern with over 100 locations within the Wilcox Dock area. Previous sampling showed that the native sand did not have detectable concentrations of PCBs at a detection limit of 0.01 mg/kg; therefore, if a location had silty sediment, a sample of the silt was analyzed for PCBs, and underlying sand was occasionally analyzed to confirm the previous assumptions regarding the lack of PCBs in this material. For those locations which contained only native sand, no chemical analysis was conducted, and it was assumed that the concentrations were less than 1 mg/kg for the purpose of assessing the PCB concentrations in these locations. Only a few samples exceeded 10 mg/kg, and the overall average concentration (both silty and sand locations) was about 1.5 mg/kg total PCBs.

1.4 Goals and Objectives of the Post-Remediation Monitoring Program

The primary goals of the post-remediation monitoring program (Earth Tech, 1999) were to:

- Clearly document the effectiveness of the sludge bed PCB remediation activities in multiple media;
- support revision/removal of the Cumberland Bay site specific fish advisory; and
- support reclassification in and/or removal of the site from the NYS Registry of Inactive Hazardous Waste Sites.

The immediate objective was to measure PCB concentrations and congener patterns in fish and water at selected sites in Cumberland Bay and adjacent Lake Champlain for comparison to pre-remediation conditions. This objective was met through the following activities:

- Review of historical PCB data including fish tissue and water;
- Fish tissue and water samples were collected prior to, during, and post-remediation in Cumberland Bay for assessment of changes in PCB concentrations;
- Trends in PCB concentrations were assessed; and
- Comparisons were made in PCB homolog profiles (i.e., composition of PCB mixtures) between different monitoring locations.

2.0 Monitoring Methods

The investigation of PCB contamination in the Cumberland Bay area included sampling at numerous locations in Lake Champlain. Figure 2-1 provides the location of Cumberland Bay in Lake Champlain, and also provides the locations of historical collections of fish samples for the analysis of PCBs in the lake. Figure 2-2 provides the locations of the Long Term Monitoring (LTM) Sites discussed throughout the rest of this report. These LTM sites were selected to coincide with historical sample locations, and cover a general area, since the historical sampling programs for different media (i.e., fish, water, PISCES) were located in slightly different locations as shown in the figure.

The sampling for the long term monitoring program began in April 1999 prior to commencement of remediation. All sample locations were located with a Global Positioning System (+/- 10 m) during the April 1999 sampling event so that the same sites could be re-occupied during subsequent sampling events.

Primary LTM sample sites (Figure 2-2) are numbered 1 through 9. These sites are:

- Site 1 is at the Wilcox Dock and is considered the source area;
- Site 2 is a location which is considered to be within the affected area within Cumberland Bay although it may also be influenced by any sources of PCBs in the Saranac River. It has been split into two separate locations in order to include appropriate habitats for different species, since few rock bass were evident at the original mouth of the Saranac River location; an alternate site with better habitat for rock bass was located at a nearby jetty. The “Mouth of Saranac” site 2M is just south of the mouth of the Saranac River. The “Jetty” site 2J is approximately 0.5 kilometers southeast of the “Mouth of Saranac” site;
- Site 3 is a location which is considered to be within the affected area in Cumberland Bay and is south of the dredge site near the former oil terminals located near Cliff Haven;
- Site 4 is considered to be a regional background location and is located within the westernmost bay of Valcour Island, north of the island’s western peninsula;
- Site 5 is considered to be a regional background location and is located at the south end of Valcour Island;
- Site 6 is considered to be a regional background location and is on the Vermont shore near Sawyer Bay;
- Site 7 is considered to be a regional background location and is on the northeast side of Cumberland Head at Gravelly Bay;
- Site 8 is considered to be a regional background location and is just west of the southern tip of Cumberland Head; and
- Site 9 is a location which is considered to be within the affected area in Cumberland Bay and is east of Cumberland Bay State Park.

LTM Sites 4 and 5 are located in close vicinity to one another near Valcour Island. Since both of these locations were chosen to represent the regional background, data for these two locations were grouped together for this assessment and are referred to as LTM Site 4/5.

A summary of fish samples collected prior to completion of this eleven year monitoring review is provided on Table 2-1. Sampling methods and locations, and analytical methods for PCBs in fish, PISCES, water, and sediment are described in the following sections.

2.1 Fish Sampling

2.1.1 Collection Methods

Electrofishing was the primary means of obtaining fish samples. The primary target species were yellow perch (*Perca flavescens*) and rock bass (*Ambloplites rupestris*). Yellow perch was selected as a target species because it is one of the most common species in the area, and was a primary target for both recreational and commercial fisheries. High concentrations of PCBs in yellow perch caused the state to issue an advisory for consumption of this species and close the commercial fishery in 1995. Rock bass was selected because it was also common, was often caught in recreational fishing, and its more localized habits provided more consistent results for trend analysis. Up to 20 fish for each of these two species at each site were collected and analyzed. Secondary species of brown bullhead (*Ameiurus nebulosus*), American eel (*Anguilla rostrata*), largemouth bass (*Micropterus salmoides salmoides*), smallmouth bass (*Micropterus dolomieu*), and pumpkinseed sunfish (*Lepomis gibbosus*) were analyzed when they were collected. Sample populations of these secondary species ranging from 1 to 12 fish per location were collected and analyzed if available. (One reason that bass were not selected as a primary target species was the concern that bass caught during tournaments from other areas were being released near the site.) Additional details on the collection and preparation of fish samples is provided in Appendix I.

2.1.2 Collection Locations

LTM Sites 1 to 9 were selected as fish monitoring locations prior to and during site remediation to represent gradients away from the dredge site as well as control sites (Figure 2-2). The number of monitoring locations was modified during the monitoring period for various reasons. LTM Site 8 was dropped because of poor recovery of fish and for safety concerns. LTM Site 6 was dropped for similar concerns after the 2001 collections. LTM Site 5 was dropped after 2001 leaving LTM Site 4 in the cove on the northwest shore of Valcour Island to be used to represent this area of the lake. LTM Sites 3 and 7 were only sampled up to 2003. Thus, after dropping the sites described above, only the four sites LTM Sites 1, 2, 4, and 9 were sampled (see Table 2-1) from 2004 onward.

2.1.3 Sample Analysis Methods

For the majority of the samples, each fish was analyzed for PCB Aroclors by EPA Method 8280 and lipids by PACE Analytical Services in Green Bay, WI. In 2007 and 2010 congener analyses (EPA Method 1668) were also run on a subset of the fish samples.

2.1.4 Sample Preparation

Starting with the long term monitoring program in 2000, analysis was usually performed on a whole fish preparation rather than a fillet for the primary species of yellow perch and rock bass in the fall collection. In 2010 and 2011, in order to provide appropriate data for assessing human health risks as they relate to the NYSDOH fish consumption advisories, additional fish were collected to allow a subset of the larger fish to be run as fillet samples (see Appendix I).

Prior to 2000 (e.g., 1994 and 1997), many of the yellow perch were prepared as standard fillets. During the spring collections from 1999 to 2006 for yellow perch and rock bass, the head and viscera were removed for many of the samples. These were discussed with the whole fish in this report.

American eel and brown bullhead were always processed as modified fillets (see Appendix I) in which the head, viscera, and skin were removed. This preparation technique is typically used for these species since the skin causes difficulties in the extraction process, and because these species are typically skinned prior to human consumption.

2.1.5 Task Responsibilities

Responsibilities for sample collection and analysis were split between AECOM and the NYSDEC. AECOM contracted analytical laboratories to perform the PCB Aroclor and lipid analyses.

The NYSDEC provided the boat, electrofishing equipment, staffed the sample collection effort, prepared the fish, and submitted them to the lab sub-contracted by AECOM. Results of the analyses were reported to AECOM, whose subcontractor, YEC, incorporated the data into a database. AECOM evaluated the data and prepared this monitoring report.

2.2 Zebra Mussel Sampling

Although sampling of zebra mussels was part of the original work plan, this aspect of the monitoring program was not carried out due to contractual and technical difficulties.

2.3 PISCES Sampling

2.3.1 Collection Methods

The Passive In-Situ Chemical Extracting Sampler (PISCES) surface water sampler is a device that passively extracts PCBs from the surrounding water continuously for a period of several weeks. It is essentially a hexane filled tube with a permeable membrane at one end. The tube is suspended several feet below the water surface from an anchored buoy. While the PISCES is deployed, the PCBs dissolved in the water preferentially diffuse into the hexane, building up concentrations in the hexane much greater than those in the water. Upon retrieval, the hexane is removed from the device and shipped to the laboratory for congener analysis. The fact that the PISCES is allowed to accumulate PCBs for an extended period of time not only allows for a more sensitive analysis, but also integrates the water concentrations over time, averaging out any fluctuations in PCB concentrations. Based on Litten et al (1993), the total PCB values from the hexane can be converted to an estimated PCB concentration in water, adjusting for temperature and time.

At each station, two PISCES units were deployed for two to four weeks during each annual monitoring event.

2.3.2 Collection Locations

The PISCES were deployed at the nine LTM sites also being sampled for fish during the pre-remediation and post-remediation sampling events. During remediation, samples were collected at all LTM sites. During the post-remediation sampling events, a variable number of locations were sampled (Table 2-2), and for the last five years samples were collected at LTM sites 1, 2, 3, and 9.

2.3.3 Sample Analysis Methods

After two to four weeks of deployment, the PISCES samplers were retrieved and brought to the analytical lab. Samples from each site were analyzed for PCBs on a congener basis by the Green Bay Mass Balance Method (NEA013_04.DOC) at Northeast Analytical Inc (now Pace) in Schenectady, NY. Duplicates, spikes, and blanks were analyzed at each sampling event.

2.3.4 Task Responsibilities

AECOM had responsibility for purchasing and providing 20 PISCES samplers and subcontracting the analytical laboratories. In addition, AECOM purchased and provided additional field supplies associated with the deployment of the PISCES samplers, including, but not limited to anchor weights, rope, and buoys.

The NYSDEC provided staff and a boat necessary to access the sample locations for deploying and retrieving the samplers. The NYSDEC submitted samples to the laboratory under contract with AECOM. AECOM received the analytical results, coordinated the subcontractor, YEC to update the project database, and evaluated the data for this monitoring report.

2.4 Water Sampling

2.4.1 Collection Methods

Water samples were collected to assess the level of concern for human health due to direct contact and/or incidental ingestion. Water samples were generally collected near the top of the water column at each location (a few samples were collected at depth). Samples were collected using a Van Dorn sampler placed over the side of a boat to 1 meter water depth repeatedly until 4 liters of water was collected. Samples were generally collected 2 to 4 times a year for each location until 2004 although this varied during baseline. Following the 2004 collections, sampling was discontinued since the PCB concentrations (when detected) were consistently well below the point of comparison; the NYSDOH drinking water standard. (Table 2-3).

2.4.2 Collection Location

Over the course of the study water samples were collected at all LTM sites and two monitoring point locations (MP4S and MP4D) in the middle of Cumberland Bay.

2.4.3 Sample Analysis Methods

The water samples were analyzed for PCB concentrations based on Aroclors (EPA Method 8082).

2.4.4 Task Responsibilities

NYSDEC collected and analyzed the water samples.

2.5 Sediment Sampling

2.5.1 Collection Methods

Three sediment samples were collected using a Ponar grab sampler in both 2002 and 2004 to allow comparison for PCBs between the Wilcox Dock confirmation data and post-remediation conditions. In addition, in 2002 three samples of suspended material were collected using a zooplankton sampling net towed behind the boat.

2.5.2 Collection Location

The sediment samples were collected at the Wilcox Dock site (LTM Site1), while the suspended sediment samples were collected at LTM Site 1, LTM Site 2, and LTM Site 9.

2.5.3 Sample Analysis Methods

NYSDEC performed the Aroclor analyses using EPA method 8082.

2.5.4 Task Responsibilities

NYSDEC had responsibility to collect the sediment and suspended sediment samples in the bay and to perform the PCB Aroclor analysis.

2.6 Analytical Quality Control

The fish tissue laboratory data were subject to third party validation by Mary Enard, IYER Environmental Group, and Nancy Potak under subcontract with AECOM. Data Usability Summary Reports are available on CD in Appendix IV. The data tables in this report reflect any qualifier changes based on the data quality review.

3.0 Data Interpretation and Evaluation

3.1 Characteristics of PCBs

PCBs are a class of chemical compounds which consist of two connected rings of six carbons each (bi phenyls), to which one or more (up to ten) chlorines are attached (polychlorinated) (Figure 3-1). Due to the different arrangements of the chlorine atoms, a large number of different chemical structures (209) are possible within this class. These 209 different chemicals are referred to as congeners. PCB congeners are often grouped in two ways, based on chemistry or based on commercial products.

Congeners can be grouped by the number of chlorines on the biphenyl structures. There are ten such groupings, which are referred to as homologs. As shown in Figure 3-1, the number of congeners in each group varies with the number of potential combination of locations for the chlorines with only a single congener possible for decachlorobiphenyl (ten chlorines) and 46 congeners for pentachlorobiphenyls. The chemical and physical characteristics of each congener tend to be most similar to other congeners in the same homolog group, and these characteristics tend to vary with the degree of chlorination. The fewer chlorines on the molecule, the more soluble, more volatile, and more prone to bacterial or physical degradation is the PCB congener. The more chlorines, the more the molecule will tend to adsorb to particles or fat, and the longer they tend to last in the environment since they do not tend to break down or volatilize into the atmosphere.

One very important characteristic in PCB chemistry is the concept of partitioning. Partitioning refers to the fact that a chemical, when exposed to two different types of media (e.g. oil and water), will be found in each of the two media in a ratio that is predictable. The ratio is referred to as the partition coefficient. Two partition coefficients commonly used are the K_{ow} and the K_{oc}. The K_{ow} is the ratio of PCB concentrations in octanol to the PCB concentrations in water. As discussed in Barron (1990) and Ewald and Larsson (1994) the K_{ow} is often used as a surrogate for the partitioning between fatty tissue (i.e., the lipid in fish) and water. K_{oc} is the ratio of PCB concentrations found in organic carbon and the concentrations in water. The K_{oc} is often used to describe the partitioning between the organic material in sediments and water. As discussed in the Technical Guidance for Screening Contaminated Sediments (NYSDEC, 1999), the K_{oc} very nearly equals the K_{ow}, and the guidance uses the two coefficients interchangeably. The K_{oc} values for PCBs range from about 25,000 for monochlorobiphenyl (1 chlorine) to 20,000,000 for nonochlorobiphenyl (nine chlorines) (Mackay, 1992). Thus, very low concentrations of PCBs may be found in water, yet be in equilibrium with high concentrations in fish or sediment.

PCBs are also often grouped by commercial mixture. The largest manufacturer of PCBs in the United States (Monsanto) typically sold PCBs in commercial mixtures called Aroclors. Each of these mixtures may contain close to one hundred congeners, but vary in the types of homologs that they contained. In the U.S. each Aroclor product marketed was given a four digit numbering code: the first two digits (12) indicated the number of carbon atoms and the last two digits represent the approximate percent chlorine by weight in the mixture. Aroclor 1242 for example, is a US produced PCB mixture of varying amounts of mono- through heptachlorinated homologs with an average chlorine content of 42 percent by weight (See Table 3-1). Similar to the characteristics of the homolog groups, the Aroclor mixtures as a whole will exhibit characteristics which will change with the level of chlorination; with the highly chlorinated Aroclors being more persistent in the environment, more tightly adsorbed to particles or fat tissue, and less soluble in water. At the same time, because they are mixtures with many compounds with various physico-chemical characteristics, when they are released to the environment, the composition of the Aroclor mixtures will change.

The makeup of the mixture will typically be different in different media (e.g., water may contain more of the more water soluble congeners, while fatty tissue in fish may accumulate more of the less water soluble congeners). Typically the less chlorinated homologs will tend to volatilize to the atmosphere or be degraded, while the heavier homologs will stay in the aquatic environment. Because of these losses, the PCB mixtures that are in the aquatic system (whether in sediment, water, or fish) will tend to shift to the remaining heavily chlorinated homologs, and thus Aroclor 1242 mixture may start to look like a 1248 or 1254 after being in the system for a number of years.

At the same time, other processes may change the mixture to lighter homologs. It has been demonstrated that certain bacteria under special conditions (certain concentrations of PCBs and a lack of oxygen) will remove chlorines from the heavier PCB congeners in a process called dechlorination (TAMS, 1997). This results in the heavier homologs being converted to more lightly chlorinated homologs (e.g. a 1254 mixture may start to look like a 1248 Aroclor). Of particular note are the congeners detected in peak 5 on the DB-1 column analysis which includes 2, 2 and 2, 6 dichlorobiphenyls. These congeners are prominent dechlorination products, and appeared prominently in the 2004 PISCES data.

3.2 Site History

Paper mills in the area of Plattsburgh began reprocessing carbonless paper which contained PCBs in the early 1960s (Callinan et al, 1998). Discharges of waste from these mills entered Lake Champlain/Cumberland Bay near Wilcox Dock. These wastes included paper sludge solids, which were typically soft, light, mushy, organic rich material which were very odoriferous when they decomposed. This sludge settled into a large delta next to Wilcox Dock, which was roughly 100 acres in area and up to 16 feet thick. Because the sludge was relatively light it was easily resuspended by wave action during rough weather, and was carried around the bay and into the lake. This was evident when the local government and citizens had to clean large piles of foul smelling sludge off of lake front areas around the bay. Much of this sludge was also distributed throughout Cumberland Bay, and settled out on the bottom.

As noted above, this sludge contained PCBs. In the sludge bed itself, concentrations as high as 13,000 mg/kg were found. The highest concentration of PCBs found in the material washed up on the beach was 210 mg/kg. Sampling of the bottom sediments in the deeper parts of Cumberland Bay typically had low concentrations of PCBs (less than 0.1 mg/kg).

Remediation of the Cumberland Bay Sludge Bed commenced April 1999 (Earth Tech, 2002), with clearing of areas on shore to allow installation of staging areas, water treatment facilities, and offices. One thousand feet of temporary sheet piling was installed in the bay in June and early July of 1999. This sheet piling, along with silt curtains, was used to contain any sediment resuspended during remediation. Dredging began on June 12 and continued until late December of 1999. Shoreline excavation began on July 28 and continued until November 9, 1999. Dredging was resumed on April 27, 2000 and continued until late October of 2000. Post remediation sediment sampling was conducted in summer and fall of 2000 to confirm the effectiveness of the dredging operation. The final post-dredge sample program involved sampling on a grid pattern with more than 100 locations. Only a few samples exceeded 10 mg/kg, and the overall average concentration was about 1.5 mg/kg total PCB.

The sludge bed itself represented a source of highly concentrated PCBs to the Lake Champlain ecosystem. Based on analyses completed during the initial investigation and in the Site Characterization report (Rust, 1995) the PCBs in the sludge bed resembled unaltered Aroclor 1242. Some of these PCBs were distributed out into the Bay. Fish and other aquatic organisms could have been exposed to the PCBs in the area of the sludge bed, or to the sludge that had been transported to other areas. The removal of the sludge bed in 1999 and 2000 eliminated this source of PCBs to the system.

3.3 Interaction between PCBs and Biota

The PCB Aroclor 1242 is the contaminant of concern at the Cumberland Bay site. This PCB Aroclor also is the primary contaminate at other sediment sites. Therefore, the PCB studies and other research done for other sites are applicable to Cumberland Bay. Based on a long and extensive database, certain patterns can be seen in the behavior of PCBs in the environment in regards to uptake in biota (Sloan et al, 2002, 2005; TAMS, 1997). As discussed earlier, PCBs tend to partition strongly to organic matter, in particular fat (more formally referred to as lipid) in fish. In regards to PCBs, fish can be thought of as being made up of two types of tissues; lipid and aqueous tissue such as muscle, bone, etc. The PCBs within the fish will still partition according to K_{oc} based ratios; therefore, the PCBs will partition strongly into the lipid with only very small amounts of PCBs in the aqueous tissues. This partitioning will result in nearly all of the PCBs in fish being found in the lipid and at a concentration that is in equilibrium with the surrounding water.

This presents a complication in interpreting PCB concentrations in fish. Health advisories and risk assessments are based on a concentration of PCBs in the entire edible portions of the fish (total mass of PCBs/total mass of fish tissue referred to as wet weight), since this represents the portion of the fish that people eat. However, since nearly all of the PCBs are found in the lipid tissue, and the concentrations of the PCBs in the lipid will be in equilibrium with the environment, to a large degree, the wet weight PCB concentration will depend on how much lipid the fish has in its body. For example, it is possible that two fish caught in the same location (and therefore the same exposure) can have the same PCB concentration in their lipid tissue, but if one fish has twice as much fat as the other, it will have twice the wet weight concentration of PCBs. Thus, while a wet weight PCB concentration is useful for evaluating potential risks to consumers of fish, the variability in lipid content in individual fish makes it difficult to assess the PCB exposure that the fish are subject to (e.g., assessing the effectiveness of a remediation in reducing exposures) on a wet weight concentration basis. For this reason, it is useful to use a lipid normalized PCB concentrations to assess changes and trends in PCB concentrations in fish. Therefore, dividing the wet weight PCB concentration for each fish by its lipid content, the PCB concentration in the fish=s lipid tissue is expressed (i.e., lipid normalized PCB concentration). This value is much higher than the wet weight concentration; however, the results will provide a better basis to compare fish within each sampling round and year to year and provides a better measure of the fish exposure to PCBs in the environment. Thus, this report will generally discuss PCBs in fish in terms of total wet weight PCBs (abbreviated to wwPCB) and total lipid normalized PCBs (abbreviated to LPCB).

Because lipid is not uniformly distributed throughout the fish, the partitioning of PCBs into lipid tissue presents another factor which must be considered when assessing data. Those portions of the fish which have less lipid would have a smaller total amount of PCBs. This is an issue for those species which are analyzed either as a whole fish (as this implies) or as a fillet. The standard fillet as described by the NYSDEC is a skin-on fillet in which the meat is separated from the ribs with the skin left on. Most people would normally eat only the fillet portion of a fish; therefore, much of the time the NYSDEC prepares fish using a standard fillet as the sample used for the PCB analysis. The percentage of fat contained in the fillet is different than in the whole fish (TAMS 1999, TAMS 1997, TAMS 2002) with the lipid content (and PCB content) significantly less in the fillet. Therefore, the wet weight PCB concentrations of a fillet cannot be directly compared to concentrations in a whole fish; although conceptually it is likely that lipid normalized data should be comparable.

By using LPCB concentration some additional patterns were seen in the data base. Very often the wet weight concentrations in different species of fish can vary greatly. However, by lipid normalizing the data, it has been demonstrated that there was little to no significant differences in the PCB concentrations between species that have the same environmental exposure to PCBs (Sloan et al, 2002). That is, any difference between species is mainly due to differences in their lipid content. This lack of a significant difference extended not just to different species of fish but even to other classes of organisms such as insect larvae and mollusks. There are however differences in species' behavior which could result in species having different concentrations. This could occur when a species migrates or has a very large home range and would therefore not have the same exposure as a localized species.

Furthermore, some minor differences would be expected between species based on habitat/behavior if the environment is not well mixed and homogeneous. If the PCB contamination is very localized or spotty in the sediments, those species which are not very mobile (benthic macroinvertebrates) may have more varied tissue concentrations depending on which sediments they are found. A fish species (e.g., rock bass) which tends to remain near very coarse grained sediments (which tend to have low concentrations of PCBs) may have slightly lower tissue concentrations, while a species that tends to be in close contact with fine grained sediments (e.g., bullhead) may have slightly higher tissue concentrations.

Having reviewed the behavior of PCBs between different media, the overall site conceptual model can be described and the relationships of monitoring data further discussed.

3.4 Conceptual Site Model

The monitoring of the Cumberland Bay site following the remediation included sampling of fish and water (both directly and by using PISCES). The monitoring was designed around the following conceptual site model.

The sludge bed represented a source of highly concentrated unaltered PCBs (Aroclor 1242). Some of these PCBs were transported to other areas of the bay, but because this transported material was in smaller quantities and was spread out and mixed with cleaner material it tended to be less concentrated. Thus, PCB concentrations would be expected to be high at the sludge bed itself and to grade out into lower (and more sporadic) concentrations in the sediments further from the site. During this transport process, certain other processes would act upon the PCB containing material. Some of the more soluble PCBs would enter the water column, and from there would volatilize into the atmosphere and thus leave the system. It is possible that some of the lighter PCBs were degraded and destroyed by aerobic bacteria, and at the same time some of the heavier congeners have been dechlorinated by anaerobic bacteria to become more lightly chlorinated PCBs. That is, it would be expected that the PCBs in areas other than the sludge bed itself would change in character as well as in concentration.

The PCBs in the sludge material and in the sediments would partition into the water. Since some of the PCBs in the water column would leave the system, be destroyed, or be transported very far into the lake, the concentrations in the lake water would slowly decline. In order for the equilibrium with the sediments to be maintained, additional PCBs would dissolve into the water. However, due to the high concentrations of PCBs in the sludge and the very high K_{oc} (which would imply that it would take only small amounts of PCBs in the sediments to maintain the PCB concentrations in the water), the sludge bed and the surrounding sediments would serve as an almost infinite source of PCBs to the system. At the same time it would be expected that the water column directly over the sludge bed would have higher PCB concentrations than water overlying the sediments which contained lower concentration of PCBs. However, the distribution of the concentrations in the water column will change quickly over time depending on the current and wave conditions. For example, it is likely that PCB concentrations in the water will increase temporarily when wave action resuspends the high concentration sludge during rough weather events (Callinan, 1998).

Fish and other biota living in the water of Cumberland Bay are exposed to the dissolved PCBs in the water column, and the PCBs in lipid tissue will come into equilibrium with the PCBs in the water. Because the sludge bed represents a relatively localized source of high concentration PCBs, it is likely that there would be variations in the exposures to the dissolved PCBs that the biota experience. A fish that spends most or all of its time directly over the sludge beds will have higher exposures (and therefore higher LPCB concentrations) than fish that spend more time over less contaminated sediments, or fish that migrate over a large area and therefore are only exposed to the sludge bed for a relatively small fraction of the time.

The remediation that took place in 1999-2000 removed 230,000 cubic yards of sludge with extremely high concentrations of PCBs. This removal would be expected to cause a number of changes in the PCB regime of Cumberland Bay.

The remediation removed the sediment/sludge with the highest PCB concentrations from the system. This would be expected to greatly reduce the PCB concentrations in the water directly above the sludge bed. In turn that would be expected to reduce the lipid normalized concentrations in the biota (fish) living directly above the bed. This would be reflected in a reduction in the average LPCB concentration in fish collected from the area of Wilcox Dock. In particular, the maximum PCB concentrations found in fish lipid tissue, representing the smaller number of fish that spend most or all of their time over the beds, would be expected to be reduced.

The sludge bed would no longer act as a source of fresh high concentration PCBs to the surrounding area. The concentrations of PCBs in the surrounding sediment would be expected to slowly decline, and perhaps more rapidly to change in character, becoming either more lightly or more heavily chlorinated depending on the conditions. These changes would be reflected in the overlying water, and in turn in the lipid of the biota living in that water.

3.5 Assessment of Post Remedial Monitoring Data

3.5.1 Data Treatment

As discussed above, PCBs actually consist of 209 possible congeners and were sold as different mixtures of these congeners called Aroclors. In the chemical analysis of the samples, PCBs were reported as either congeners or as Aroclors.

For the congener analysis conducted on the PISCES and certain fish samples, individual congeners were measured and reported. The laboratory method used accounts for all 209 congeners, however the laboratory instruments cannot separate many closely related congeners (i.e., co-eluting) and these pairs/groups are reported as several congeners combined as a single concentration, resulting in 118 separate concentrations being reported. After the laboratory analysis, these results were sometimes added together to provide total PCBs, homolog totals, or partial totals (e.g., all of the congeners containing three or more chlorines). Note that these totals are based on all of the individual concentrations being added together.

For most of the fish samples, the concentrations were reported as Aroclors. In this case, the laboratory, using the concentrations of certain key congeners and a computer algorithm, determines which Aroclors the data most closely resembles and calculates a total concentration for all of the congeners in that Aroclor. Thus the laboratory does not simply add together all of the congeners detected, but instead bases the Aroclor concentration on a combination of specific concentrations and assumptions about the makeup of various Aroclors. The laboratory may report concentrations for multiple Aroclors. When total PCBs are reported based on Aroclor analysis, the Aroclor results are added together.

The detection limit of a chemical analysis is the minimum concentration of an analyte that can be detected at a known confidence level. That is, the detection limit is the lowest concentration that is clearly above any noise in the instrument output and can be given a numerical concentration that is statistically defensible. This is an important concept since it defines the lowest concentration that is detectable. A sample in which no PCBs were detected is not described has having 0 mg/kg PCBs, but rather is described as not having PCBs at concentrations above the detection limit. Potentially, PCBs may be present but at a concentration less than the detection limit. For the fish tissue samples, the detection limit for Aroclors is about 0.02 mg/kg (although this can vary sample to sample), and a non-detect result is reported as <0.02 mg/kg. Since all of the fish analyzed in this study were exposed to PCBs in the environment it is reasonable to assume that there are very likely some PCBs in the fish tissue analyzed.

When no PCBs are detected in a sample from an area with known contamination, it is more likely that there are some PCBs still present in the samples than that there are absolutely no PCBs since the fish were exposed to PCBs. To account for these PCBs that may be present but are below the detection limit, when calculating PCB concentrations, the following procedure is followed to address the reporting of non-detect results for use in this assessment.

- Scenario 1 - Two or more Aroclors detected. Total PCBs are equal to the sum of all detected Aroclors.
- Scenario 2 - Exactly one Aroclor detected. Total PCBs are equal to the sum of the detected Aroclor concentration, plus one-half the detection limit of one other Aroclor.
- Scenario 3 - No Aroclors detected. Total PCBs are equal to one half the detection limit of each of two Aroclors (nominally, one “low molecular weight” Aroclor, such as 1016 or 1242, and one “high molecular weight” Aroclor, such as 1260). This value is used as the “quantitation limit.”

3.5.2 PISCES

Because of the difficulty in detecting PCBs in water, other methods of assessing the PCBs dissolved in the water column were utilized. PISCES are samplers that are deployed for weeks at a time and extract hydrophobic compounds (e.g., PCBs) from the dissolved phase of the surrounding water by allowing the PCBs to passively diffuse across a membrane into hexane contained within the sampler. These samplers thus concentrate the PCBs into the hexane at concentrations that are easily detectable. These PCBs are analyzed using a method to quantify the individual congeners, allowing a more detailed assessment of the make-up of the PCB mixture either as Aroclor mixtures or as the ten

PCB homolog groups. In addition, since PISCES are left in the field for several weeks, they integrate over time, catching one-time events and averaging out any fluctuations in PCB concentrations. Based on Litten et al (1993), the raw PCB content of the hexane extract (expressed as a PCB content in nanograms [ng]) can be normalized based on empirical relationships with length of deployment, temperature, and other factors, and an estimated dissolved phase water concentration can be expressed in ng/L. These estimates are derived from individual congener results, and where used, any concentration of homolog groups or total PCBs was based on the sum of individual congeners. The patterns of the relative amounts of each congener can be used to assess the type of PCBs detected, although to simplify this assessment the distribution of the ten homolog grouping is used in this report. These calculated PCB in water concentrations are provided in the appendices and discussed below for Cumberland Bay. Because chemical equilibrium between total water and dissolved phase PCBs is reached relatively rapidly, the PISCES results successfully provide a semi-quantitative view of PCB distribution in the host water, but are biased somewhat towards the lighter dissolved congeners and away from the heavier, particle-bound congeners.

In general, a PISCES total PCB recovery below 100 ng does not provide enough detectable PCB to be reliably converted to a concentration, especially when the homolog patterns of the replicate samples look different, and/or the congener patterns do not resemble Aroclors. For this dataset, after 2004 all sites except the Wilcox Dock sludge bed location itself are below this reliable detection level, which translates to 5 to 10 ng/L PCB dissolved in the water column.

The PISCES data from LTM Site 1 (Wilcox Dock) show that the estimated PCB Aconcentrations@ in 1999 (first year of construction/remediation) were about 190 ng/L, with the majority of the PCBs consisting of di-, tri- , and tetra-chlorobiphenyls (Figure 3-2). The total PCB concentrations declined each year following remediation, with a total estimated PCB concentration in 2011 of about 6.7 ng/L. Accompanying the drop in 2004 was a shift to an altered composition with a much larger portion of the composition made up of mono and dichlorobiphenyl (with a large portion of this as congeners 2,2 or 2,6 dichlorobiphenyl, a distinctive dechlorination product of PCBs). This shift was followed by a return to the distribution seen in the earlier data. These PISCES data show that at the Wilcox Dock site, total concentrations have fallen by more than 95 percent, indicating that the original source of concentrated Aroclor 1242 has been substantially reduced. The homolog distribution has remained relatively consistent, with an exception in 2004. Because of the tendency for fish to preferentially accumulate the more heavily chlorinated PCBs, a measure of these homologs is to sum the tri- chlorinated and higher homologs (referred to as the Tri+ homologs). In terms of the Tri + homologs, the concentrations seen at this station dropped from 114 ng/L to 4 ng/L (a drop of more than 95 percent).

Two areas were sampled which represent areas that are distant from the Wilcox Dock, and would therefore exhibit values that represent the more widespread conditions in Lake Champlain and would be expected to be relatively uninfluenced by the Wilcox Dock site. These are LTM Sites 4 and 5, which are stations around Valcour Island (sampled in 1999 and 2004), and LTM Site 7 on the far side of Cumberland Head (sampled in 1999 and 2002). The average total concentration for these sites in 1999 was less than 2 ng/L, with the homolog distribution containing primarily di-, tri-, and tetra-chlorobiphenyls.

The station that is closest to the Wilcox Dock site, LTM Site 2 near the Jetty at the mouth of the Saranac River, shows a decline but with a much more variable pattern (Figure 3-3). The baseline sample in April/May of 1999 contained a total estimated concentration of 18 ng/L with most of the content being comprised of di, tri, and tetra-chlorinated biphenyls. During the remediation period (2000) the total estimated concentration of PCBs was 92 ng/L with a somewhat heavier homolog pattern with more penta-and hexa-chlorobiphenyl. Total PCB concentrations dropped to 0.5 ng/L in

2011 (a 99 percent reduction), with the last three years containing an estimated concentration below a reliable limit of about 5 to 10 ng/L. The data showed a very distinct shift in homolog pattern in 2004 to a highly dechlorinated PCB mixture dominated by dichlorobiphenyl, then a return to the previous pattern. It is likely that the higher variability in both concentration and composition is due to the distance from the Wilcox Dock source and its proximity to the Saranac River, which may dilute the concentrations and may contain a different source (Callinan et al, 1998). The Tri + PCBs have declined from a high concentration of 84.6 ng/L in 2000 to a concentration of 0.3 ng/L in 2011.

LTM Site 3 (near Cliff Haven) and LTM Site 9 (at the public beach) are two stations that are within Cumberland Bay but are somewhat distant from the Wilcox Dock and have PISCES results spanning from 1999 to 2011. These stations show two distinct regimes in terms of estimated concentrations; up to 2004 and after 2004 (Figures 3-4 and 3-5). The earlier concentrations (1999 to 2004) tended to be between about 10 and 66 ng/L and decreased to between about <1 to 2 ng/L by 2011. Both stations show the distinct homolog shift in 2004 to lightly chlorinated homologs seen at LTM Site 2, which included a distinct drop in heavily chlorinated homologs and a large increase in the dichlorobiphenyls, followed by the return to the heavier pattern. The Tri+ PCB concentrations dropped from 7 ng/L to 0.4 ng/L to 2 ng/L (LTM Site 3), and 25 ng/L to <1 ng/L (LTM Site 9) between 2000 and 2011 (greater than 90 percent declines). For last four years, the estimated total PCB concentrations were below the reliable limits.

These data are consistent with the conceptual site model, which indicated that the Wilcox Dock site (LTM Site 1) contained high concentrations of Aroclor 1242 which had not been altered over time while in the environment, and acted as an ongoing source of PCB contaminated solids to the other sites within Cumberland Bay. The greatest influence was observed at those sites closest to the dock (LTM Site 2), and lesser influence was observed on those farther away (LTM Site 3 and LTM Site 9). The model predicted that the sediments in these areas would act as a PCB source to the water column (which was sampled by the PISCES), but the homolog profile would be expected to have shifted during transport. Once the source condition at the Wilcox Dock had been removed, the PCB concentrations would have declined most steeply at the site and more slowly as the sampling moved further from the source. Little influence would be expected at those stations expected to be representative of widespread conditions in the lake (LTM Sites 4, 5, and 7). This change in congener makeup in the water column would be expected produce changes in PCB in fish, but not necessarily the exact same changes.

These PISCES data do show a pronounced drop in total PCBs and Tri+ PCB concentrations at the Wilcox Dock site. The station close to the site (LTM Site 2) shows a distinct drop in both total and Tri+ PCB concentration. The stations farther from the site but still within the Bay (LTM Site 3 and LTM Site 9) also show a clear drop in total PCBs, and a drop in the Tri+ PCB concentration, although with more variability in the data. The overall impact of the remediation is the elimination of the major ongoing source of PCBs to the area. This has caused a reduction in total PCB concentrations in the areas close to the Wilcox Dock.

3.5.3 Fish

Fish were collected somewhat sporadically prior to the remediation in 1999 and 2000, in terms of time, place, and species. While these data provide a larger database for the assessment of the fish PCB concentrations, the sensitivity of PCB concentration trends to differences in location restricts the discussion of trends to those locations with a longer term sampling program (LTM Sites 1 through 9). Even within these stations, only LTM Site 1 and LTM Site 9 have data from before the remediation was conducted (see Table 2-1).

3.5.3.1 Lipid Content

As discussed above, a major factor in the amount of PCBs that a fish will take up from the environment is the amount of lipid (i.e., fat) the fish has in its body. Therefore, the amount of lipid in each fish was measured during the laboratory analyses, and the patterns in the data are assessed here based on species, location, and year.

Yellow perch was one of the species most intensively sampled during post remediation monitoring. As seen in Figure 3-6, the whole fish yellow perch throughout the area have average lipid contents ranging from 1.1 to 2.4 percent from fish collected in the fall (the full range for individual fish is from 0.41 to 6.3 percent). Note that some of the fish prior to 2000 and in 2010 were prepared as fillets and therefore have lower lipid contents. Some of the spring samples were prepared with head and viscera removed which, along with the different season, would explain the lower lipid content.

Rock bass was the second most sampled species and had higher lipid content than the yellow perch, with average lipid content ranging from about 2.4 to 4.7 percent in the fall (Figure 3-7). Although not sampled as consistently for a trend analysis, American eel tend to have higher lipid content, with individuals having 10 percent to greater than 30 percent lipid content (see Appendix III).

3.5.3.2 Lipid Normalized PCBs

As discussed above, lipid normalization provides the best way to view the data for the purpose of assessing the impact that the remediation has had on the environment and in particular the fish in Cumberland Bay.

Yellow Perch

The yellow perch LPCB concentrations for Wilcox Dock (LTM Site 1) are presented in Figures 3-8a and b. It is apparent that there are two populations of data that are distinct from each other, spring and fall, with spring collected fish consistently being lower in LPCB concentrations. It appears that the yellow perch in the spring include primarily fish that migrate into this area from other areas, thereby lowering the mean PCB concentrations.[1] Because of this, spring fish were not collected beyond 2003. Therefore, for the yellow perch, comparisons will only be made with fish collected in the fall. Note that

[1] Cumberland Bay is a yellow perch spawning area with large incursions of perch into this area during the spring breeding season. The lower LPCB concentrations for yellow perch at LTM Sites 1 and 2 in the spring is consistent with an influx of fish from other areas. The changes in PCB concentration do not appear to be caused by changes in lipid. A change in lipid content of type might be expected over the winter. However, lipid normalization is meant to eliminate the variations caused by lipid content. Furthermore, the changes in lipid content between spring and fall fish were relatively small, and were not consistently significant. The differences in LPCB concentration were somewhat unique to LTM 1 and 2, and were not observed at the other locations. Therefore it is unlikely that a change in lipid type or some other change in yellow perch would only occur in a limited area. Furthermore these differences were not seen in the other main target species, even at these two locations. It is unlikely that localized changes in PCB exposure caused the differences. Therefore the most likely explanation for the sharp difference between spring and fall LPCB concentration in yellow perch is that two different populations were being sampled: a fall resident population and a spring population that includes a substantial number of fish from elsewhere in the lake.

the data from 1994, 1997, and some from 2010 and 2011 are from fillet samples. Whole fish samples, with their higher lipid content, tend to have several times higher total PCB content. Theoretically, if expressed on a lipid normalized basis, the fillet samples should be similar to whole fish samples, but the inconsistent preparation method may be a source of uncertainty in the trend assessment.

As seen in Figure 3-8a, the highest concentrations of lipid normalized PCBs clearly decline after remediation, with the maximum concentrations declining from over 1,200 mg/kg lipid normalized PCBs prior to remediation to 173 mg/kg LPCBs in 2011. These maximum values represent a relatively smaller percentage of the fish population that would spend most or all of their time on the site itself. Prior to remediation, these fish would have been exposed to extremely high concentrations of PCBs, and therefore would have been expected to have exceptionally high LPCB concentrations. The remediation dramatically reduced the sediment PCB concentrations, and as seen in the PISCES samples, greatly reduced the water column concentrations. Thus, it is reasonable to expect this reduction in the maximum total PCB concentrations seen in the fish after remediation.

The mean LPCB concentrations with 95 percent confidence limits for LTM Site 1 are presented in Figure 3-8b. Two general trends are seen in these data. The mean LPCB concentrations are lower in the years following remediation (from 460 mg/kg lipid normalized total PCBs in 1997 to a 83 mg/kg lipid normalized total PCBs in 2011, a decline of about 80 percent), and the confidence limits around those means are smaller. This is again a reflection of the lower concentrations of PCBs in the surrounding media. The tighter confidence limits suggest that the PCB concentrations in those media are becoming more uniform as well as lower, with fewer occurrences of higher concentrations. This decline appears to be most pronounced between the years 2005 and 2007 (five to seven years after remediation).

These significant decreases in lipid normalized total PCB concentration in yellow perch at the Wilcox Dock site were not as clearly reflected in perch at other locations. Of those locations that are within Cumberland Bay (LTM Sites 2, 3, and 9), only LTM Sites 2 and 9 have data up to 2011(Figures 3-9 and 3-10). LTM Site 3 has only a few years of data from immediately after the remediation. Neither LTM Sites 2 nor 9 show a clear decline or a tightening of the confidence intervals as was seen at LTM Site 1. However, there may also be complicating factors at both of these locations, as discussed below.

LTM 2M is located at the mouth of the Saranac River, where it is exposed to both the Wilcox Dock site and possible sources in the Saranac River (Callinan et al, 1998). Thus, there may be resistance to reductions in PCB concentrations due to other sources. It should however be noted that PCB lipid normalized concentrations from the last five years (18 to 57 mg/kg lipid normalized PCBs) are all lower than in 2001 (65 mg/kg lipid normalized PCBs), with the average concentration in 2011 of 42 mg/kg .

LTM 9 may also reflect some ambiguities in the data. In reviewing Figure 3-10a, it can be seen that the data at this location often contain a few fish with exceptionally high LPCB concentrations (particularly in 2006 and 2008). It is possible that these are fish moving from the Wilcox Dock area and cause additional noise in the trend for this location (keep in mind the influx of fish to Wilcox Dock during spawning season). The average LPCB concentration in 2011 was 16 mg/kg.

The locations around Valcour Island (LTM Site 4-5) represent PCB exposures found further out in the lake in a generally upstream position (i.e., the lake flows from south to north) and are more indicative of the background PCB concentration for this region of Lake Champlain, although it is possible that the Wilcox Dock source area could be affecting this location to some degree. The average concentrations (Figures 3-11b) seen here range from about 1 to about 6 mg/kg lipid normalized PCBs but interestingly suggest a clearer trend than some of the closer stations. It should be noted that by 2011, all of five fish collected at this location had no detectable PCBs, and for those fish the values shown on the plots are based on one-half of the detection limit. The concentrations here are similar to those of location LTM Site 7, which is also removed from the Wilcox Dock source but in a different direction and supports the concentrations of 1 to 5 mg/kg LPCB as the background concentration in this portion of the lake.

The locations within the Bay (LTM Sites 2 and 9) were already relatively low in LPCB concentration in 2001 or earlier (10 to 75 mg/kg) compared with the Wilcox Dock area, although not as low as those sites distant from the source (i.e., LTM Site 4). Thus even before the remediation, there was a gradient of PCB concentrations with high concentrations at the source, with concentrations dropping with distance from the site. This gradient is still evident in the years after remediation from 2001 on-ward (Figure 3-12 through 3-12g). This is not necessarily inconsistent with the conceptual site model. As discussed above, the source at Wilcox Dock would be expected to provide a supply of fresh PCBs to replenish the surrounding areas. Therefore, lower concentrations would be expected in the outlying areas. The remediation would not be expected to have an immediate, nor as large an impact on the surrounding areas. Rather, with the removal of this source, the PCB concentration in the sediments (and thus in the surrounding water and biota) would slowly decline as any remaining PCBs are degraded, transported to the atmosphere, distributed further out into the lake, or buried.

LTM Site 3 is located between LTM Site 2 and LTM Site 4/5 and would be expected to have LPCB concentrations intermediate between those two sites. During the few years that data were collected from LTM Site 3, the LPCB concentrations for yellow perch were indeed mid-range between the other two sites with average concentrations of between 5 and 12 mg/kg LPCB, helping to confirm the decreasing concentration gradient outward from Wilcox Dock.

Rock Bass

The rock bass differ from the yellow perch in an important aspect; rock bass tend to be much more localized in their habits, with a smaller home range than the yellow perch. One reflection of this is seen in Figures 3-13a and b, is that there are no apparent differences in LPCB concentrations between the spring and fall fish collections. This allows certain advantages in assessing the rock bass data over those of the yellow perch. The spring and the fall data can be assessed together, which allows the inclusion of some years where only spring data were collected (i.e. 1999 at some locations). Also the combined spring and fall data provide larger numbers, which provide added confidence in the conclusions drawn from the data. Finally, since the rock bass tend to be more localized, there is not as much mixing of different populations of fish from different areas. This lack of movement between areas and lack of population mixing means that there should be much less variability in the PCB concentrations in the rock bass collected and therefore much less noise in the data. These advantages combine to make the rock bass a potentially better indicator of the trends in PCB exposures at a particular location. The following text concentrates on the fall collections.

The lipid normalized total PCBs for rock bass at Wilcox Dock (LTM Site 1) in Figure 3-13 show many of the same trends and have concentrations in a similar range (generally 25 to 400 mg/kg) as that of the yellow perch from this location, consistent with the partitioning concepts discussed earlier. The concentrations in the rock bass from 2002 to 2011 indicate a clear decline with the maximum concentrations for each year decreasing from greater than 300 to 45 mg/kg lipid normalized total PCBs, although the maximum concentration in 2011 was 103 mg/kg LPCB. The mean LPCB concentrations show a steady decline from 2001 to 2009 dropping from about an average of 280 mg/kg to 27 mg/kg LPCB (a 90 percent decline), although the mean in 2011 was slightly higher (41 mg/kg) with the one high result.

Those locations that are within Cumberland Bay (LTM Sites 2 and 9) show a decline in LPCBs. Average concentrations at LTM Site 2, by the Jetty, (Figure 3-14a and b) dropped from 38 mg/kg LPCBs in 1999 to 5.6 mg/kg LPCBs in 2011 (a drop of 85 percent). At LTM Site 9 (Figures 3-15a and b) the mean LPCB concentration in rock bass dropped from 17 mg/kg LPCBs in 1999 to 4 mg/kg LPCBs in 2010 (a drop of about 75 percent).

The location around Valcour Island (LTM Site 4-5) represents PCB exposures found further out in the lake and is more indicative of the background PCB concentration for Lake Champlain. The concentrations (Figures 3-16a and b) detected at this location range from less than 1 to 12 mg/kg LPCBs. Also suggesting declining PCB concentrations, the average detected concentrations dropped from a mean of 8.8 mg/kg lipid normalized PCBs in 2000 to 0.6 mg/kg LPCBs in 2011 (a drop of about 95 percent). It should be noted that by 2011, the five rock bass collected at this location did not have detectable PCB concentrations, and for those fish, the values shown on Figures 3-16a and b are based on one-half of the detection limit. The concentrations here are similar to those of LTM Site 7, which is also removed from the Wilcox Dock source and confirms the concentrations of <1 to 5 mg/kg LPCB as the background concentration in this portion of the lake.

LTM Site 3 is located between LTM Site 2 and LTM Site 4-5 and would be expected to have LPCB concentrations intermediate between those two sites for rock bass as well as for yellow perch. During the few years that data were collected from LTM Site 3 (means of 2 to 7 mg/kg), the LPCB concentrations were indeed mid-range between the other two sites, helping to confirm the decreasing concentration gradient outward from Wilcox Dock.

As discussed above, because of the more restricted habits of the rock bass, less noise might be expected in the data than in the yellow perch, and patterns may be discernible in this species not seen in the yellow perch. Indeed, declines are seen in the rock bass that are not seen in the yellow perch. These declines are seen in all of the stations sampled, and while not as dramatic in terms of absolute values as at LTM Site 1 (a drop of 253 mg/kg lipid normalized PCBs), all of the stations drop by approximately half or more.

Brown Bullhead

Brown bullhead were collected in, 1999, 2001, and 2007 to 2011 at two stations; LTM Site 1 and LTM Site 2, and prepared as head, viscera and skin removed (a modified fillet). Brown bullhead are opportunistic feeders, which consume a variety of prey in the water column; therefore their exposure to PCBs through their diet is similar to that of many other species. However, their habit of resting on or swimming very close to the sediment-water interface, combined with a small home range, can expose them to higher concentration of PCBs. Thus, it would be expected that brown bullhead may have higher PCB concentrations than some other species. This would also tend to make brown bullhead more sensitive to changes in the PCB concentrations in the sediments. However, if the home range of the bullhead is exceptionally small, the concentrations seen in a local population may be highly variable, due to the variable nature of PCBs in the sediments.

The mean LPCB concentrations in brown bullhead at LTM Site 1 was 584 mg/kg LPCBs in the spring of 1999 (Figures 3-17a and b). This concentration dropped to 37 mg/kg LPCBs by the fall of 2009 and 18 mg/kg LPCBs in the fall of 2011.

At the mouth of the Saranac River (LTM Site 2) (Figures 3-18a and b) the brown bullhead had a mean LPCB concentration of 9.8 mg/kg in the fall of 2011. Prior to remediation, in the spring of 1999, this concentration was 118 mg/kg LPCBs.

3.5.3.3 Weight Wet PCB Concentrations

The use of lipid normalized data provides the best means of assessing the trends and effectiveness of the remediation; however, there are other uses of data which require the use of wwPCB concentrations. Wet weight concentrations allow for the estimation of the ingestion rate of total amount of PCBs consumed by those higher levels of consumer (e.g., humans, piscivorous wildlife) feeding on the fish being analyzed. These consumption rates are used in the assessment of risks to humans and to piscivorous wildlife. Because of this, the NYSDOH issues their fish consumption advisories for people consuming wild caught fish based on wwPCB concentrations (with fillet PCB data preferred).

Year to year changes in the lipid content will mask changes in PCB concentrations in the lipid tissue of fish when the data are assessed on a wet weight basis. For some species, the fish collected in different years varied on what portions (and hence lipid content) were analyzed. This added an artificial variability on top of the natural variability in the data. Therefore, care was taken to compare only fish that were prepared in the same manner (e.g., fillet or whole fish).

Yellow Perch

The wwPCB concentrations for yellow perch at Wilcox Dock (LTM Site 1) are presented in Figures 3-19a and b. Note that since this long term monitoring program started in 2000, most yellow perch collected in the fall were prepared as whole fish, while in 1994, 1997, and selected fish from 2010, and 2011 were prepared as fillets. Some of the spring collections were prepared as head and viscera removed. The discussion below concentrates on the fall whole fish collections.

As shown in Figure 3-19a, the maximum wwPCB concentrations at the site have declined since the remediation, with a decline from about 16 mg/kg in 2000 to 1.6 mg/kg in 2009 and 3.5 in 2011. Note that there were fillet samples collected in 1992 that were measured as having wwPCB concentrations of 18 mg/kg, and whose concentrations in the whole fish would have been much higher. The mean wwPCB concentrations (Figure 3-19b) have declined from 11 mg/kg in 2000 to 1.04 mg/kg in 2009 (a drop of 90 percent) and 1.7 mg/kg in 2011. From within Cumberland Bay, LTM Site 9 shows little consistent decline in the mean concentration from 0.34 mg/kg in 2001 to 0.19 mg/kg in 2010, and 0.31 mg/kg in 2011, with some variability in 2007 and 2008 (Figures 3-20a and b). Also within the bay, LTM Site 2 (Figures 3-21a and b) also shows a declining trend since fall sampling began in 2001, with an average wwPCB concentration of 1.3 mg/kg that dropped to 0.48 mg/kg in 2011.

The fact that these drops in wwPCB concentrations are more definitive than with the lipid normalized data is in part explained by the change in lipid concentrations during these years. The yellow perch exhibited lower lipid concentrations in 2005 and later years than in the years 2000 to 2004 (Figure 3-6). Thus, the decreases in lipid normalized PCBs in addition to distinct drops in lipid content provide very clear decreases in the wet weight concentrations. Also note that the increase from 2009 to 2010 is due primarily to an increase in lipid content from 1.36 to 1.87 percent.

There are no fall data available from before the remediation at the station outside the Bay proper (LTM Site 4-5), which is reflective of lake wide conditions. From the available data, this station shows a decline in wwPCB concentrations between 2001 (0.13 mg/kg) and 2011 (0.027 mg/kg, all of which were non-detect) (Figures 3-22a and b). As previously discussed, these declines have as much to do with changes in the lipid content as with the PCB exposure.

Rock Bass

Since the long term monitoring program started, most rock bass sampled were prepared as whole fish, while limited samples in the spring were prepared with head and viscera removed. The wwPCB concentrations from these fall samples data are discussed below.

At Wilcox Dock (LTM Site 1) rock bass data are available from 2001. The wet weight data for the rock bass at this station (Figures 3-23a and b) indicate a drop in the maximum concentrations and a clear downward trend in the mean wwPCB concentration from about 9 mg/kg in 2001 to 0.71 mg/kg in 2010, and 1.1 mg/kg in 2011 (reflecting an increase in lipid content). These results are similar to the lipid normalized data but enhanced by the lower lipid content in the last five years compared to the lipid contents of 2001 to 2005.

Declining trends in wwPCBs have been observed at the stations that are within Cumberland Bay (LTM Sites 2 and 9). At LTM Site 2, near the Jetty (Figures 3-24a and b), a slight trend is seen in fall samples with 0.6 mg/kg in 2001 and 0.31 mg/kg in 2011. This decline is more significant between 2005 and 2007. The fall samples at LTM Site 9 also show a clear declining trend with an average wwPCB concentration of 0.54 mg/kg in 2002, 0.10 mg/kg in 2009, and 0.14 mg/kg in 2011 (Figure 3-25b).

The stations chosen to represent broader lake-wide conditions also suggested decreasing wwPCB concentrations, with concentration at LTM Site 4-5 (Valcour Island) (Figure 3-26b) decreasing from 0.4 mg/kg in 2001 to 0.032 mg/kg in 2009 and 0.02 mg/kg (all non-detects) in 2011.

3.5.3.4 Wet Weight PCBs in Fillet Samples

Yellow Perch

Samples for yellow perch were collected as fillets in the fall of 1994, 1997, 2010, and in 2011. The wwPCB concentrations for those samples from LTM Sites 1, 2, 4, and 9 are shown in Figure 3-27. In the later collections (2010 and 2011) the larger fish were selected for fillets to allow for ease of preparation. This would tend to bias the wet weight PCB analysis to fish that tend to have higher lipid content, and would thus tend to bias the wwPCB results higher.

The concentrations at LTM Site 1 from prior to the remediation averaged about 5 mg/kg wet weight with a maximum concentration of 18 mg/kg. Those levels contributed to the NYSDOH issuing an advisory limit or the consumption of yellow perch from Cumberland Bay. These concentrations dropped to an average of 0.12 mg/kg with a high of 0.2 mg/kg in 2011. It should be noted that for four fish out of the ten collected in 2010, and one of the fish in 2011, the results were non-detect, and the concentrations are based on one half of the detection limit of 0.02 mg/kg. This represents a decline of at least 95 percent and is approaching the limits of the laboratory analysis to detect PCBs in the fillets at this location.

At LTM Site 9, fillet samples were collected in 1997. These samples had an average wwPCB concentration of 0.14 mg/kg and a maximum concentration of 0.23 mg/kg. In 2011, the wwPCB concentrations in the fillet samples from LTM Site 9 averaged 0.05 mg/kg with eight out of ten fish being reported as non-detect for PCBs. At location LTM Site 2 (at the mouth of the Saranac River) the fillet samples from 2011 had an average concentration of 0.05 mg/kg with three out of ten fish being reported as non-detect.

Fillets were also collected for yellow perch at Valcour Island (LTM Site 4-5) in 2011. This site represents the background for this portion of the lake. Wet weight PCB concentrations for fillets here averaged 0.02 mg/kg; however, none of these samples had detectable PCBs, and the average concentration was based on the detection limit of 0.02 mg/kg.

Brown Bullhead

The brown bullhead was consistently analyzed as a modified standard fillet with head, viscera, and skin removed. This preparation method is consistent with human consumption of this species. Because the skin of the bullhead tends to cause problems with the grinder used to homogenize the sample, this species is normally prepared in this manner in NYSDEC collections. Therefore, the data discussed here is the same as for the wet weight PCBs.

The mean wwPCB concentrations in brown bullheads collected from LTM Site 1 (Figures 3-28a and b) 3.5 mg/kg in 1994 with a maximum of 7.8 mg/kg. In the spring of 1999 prior to remediation, the mean concentration was about 12.7 mg/kg. These levels contributed to the NYSDOH issuing an advisory to limit consumption of bullhead from Cumberland Bay. In 2011, the average wwPCB concentration for bullhead modified fillet at this location was 0.46 mg/kg (all samples had detectable concentrations) with a maximum of 1.45 mg/kg, representing an average decline of 95 percent.

At the mouth of the Saranac River (LTM Site 2M), the brown bullhead collected in 1999 had an average wwPCB concentration of 8.5 mg/kg (Figures 3-29a and b). In 2011, the wwPCB concentration for bullhead modified fillet at the mouth of the Saranac River was about 0.26 mg/kg (based on three fish), representing a decline of greater than 95 percent.

American Eel

Prior to the initiation of the sampling program directly associated with the site, American eel were collected in 1985. Those eels were collected near the current LTM Site 9 and LTM Site 4-5. As with brown bullhead, eels are normally prepared with head, viscera, and skin removed due to processing issues, and this is considered the edible modified fillet portion. It should be noted that eel typically have very high lipid content, and tend to have higher wet weight concentrations of PCBs.

Twenty-four American eel were collected in 1985; at Valcour Island (LTM Site 4-5) and another regional background location the eels averaged wwPCB concentrations of 1.8 mg/kg, and at a location between LTM 2 and LTM3, 3.7 mg/kg. These eels had lipid concentrations of greater than 20 percent. These results were considered in the NYSDOH issuing a consumption advisory for American eel in Cumberland Bay not to eat more than one meal of eel per month. In 2011, the wwPCB concentrations were 0.02 mg/kg (n=1) at LTM Site 4-5, 0.72 mg/kg (n=1) at LTM Site 1, 0.25 mg/kg (n=2) at LTM 2J, and 0.2 mg/kg (n=4) at LTM Site 9. These changes represent declines of over 95 percent, although some of the decline is attributable to lower lipid concentrations. However, the low number of American eel collected in recent years (which reflect the severely depressed populations along the Atlantic coast during this time) are not sufficient to make strong statistical conclusions. This is the reason that the NYS DOH has not altered the advisory for American eel.

3.5.3.5 Congener Analysis Homolog Distribution Comparison

In order to provide adequate data for assessing the makeup of the PCBs, congener analyses were conducted on fish collected in 2007 and 2010 in addition to the Aroclor analysis. Due to the way in which the PCB data are detected and reported as individual congeners, the results from the congener analysis provides lower detection limits and more detailed information on the makeup of the PCBs present. These data collected during the post-remediation monitoring program can be compared to congener analysis conducted on fish collected in 1992 and 1994.

As discussed in the Introduction (Section 3.1), there are 209 different PCB congeners (individual compounds). These congeners can be divided into ten grouping (homologs) based on the number of chlorines present. In order to simplify the assessment somewhat and to make apparent the degree of chlorination of the PCBs present, the congener results are presented here as homolog concentrations (similar to that of the PISCES data).

The following text will present some examples of homolog distributions in the fish discussed in this monitoring report, and some examples of graphical correlations for homolog distributions between pairs of sites are provided. These correlations allow for a simple, quantitative method of comparing the homolog distributions between sites. Following these examples, the discussion will focus on correlations between the other monitoring sites discussed in this report.

Homolog Profiles

The homolog profile for yellow perch at LTM Site 1 from 2007 is presented in Figure 3-30. The PCBs at this location are primarily tri- and tetra- biphenyls with decreasing concentrations of higher homologs.

The homolog profile for yellow perch from 2007 at LTM Site 4-5, Valcour Island, representing a regional background concentration, is presented in Figure 3-31. The PCBs at this location are primarily penta- and hexa- biphenyls with lower levels of tetra- and hepta-chlorobiphenyl. Thus, the background has a distinctly higher proportion of heavily chlorinated homologs than the fish exposed to the source PCB material at the Wilcox Dock.

The homolog profile for yellow perch from 2007 at LTM Sites 2, 3, and 9 are similar; and to represent these sites the profile for LTM Site 9 is presented in Figure 3-32. The profiles are intermediate between the profile at the source (LTM Site 1) and the background (LTM Site 4-5), suggesting a decreasing influence from the source as the fish are collected further from the Wilcox Dock.

As an additional example, the homolog distribution for pure Aroclor 1242 (which was the type of Aroclor disposed of at the site) is shown in Figure3-33.

<u>Homolog Correlations</u>

The above analysis indicates a clear distinction between the PCB homolog distribution at the Wilcox Dock site and regional background (LTM Site 4-5), with the Wilcox Dock area having a higher proportion of less chlorinated homologs than the regional background. LTM Sites 2J, 2M, and 9, located between the source and background, all showed intermediate patterns. In order to provide a more quantitative comparison between homolog profiles, a simple correlation approach is presented below.

In this approach the concentrations of each homolog for a particular data set (e.g., species, location, and year) is matched with the concentration of the same homolog for the data set to which it is being compared. A linear trend line is applied to the data, and the correlation coefficient (r^2) for the trend is calculated. The correlation coefficient is a measure of how well the values on the x-axis will predict the values on the y-axis. In a perfect correlation the data would line up in a straight line and the coefficient would be equal to 1, signifying that the two data sets are very similar/closely related. If there was no relation between the two data sets, the points would plot randomly, and the correlation coefficient would be near 0. The stronger (closer to 1.0) the correlation coefficient for a linear trend line is, the closer the match. As examples, the homolog concentrations from yellow perch at LTM Sites 1 and 9 in 2007 are plotted against one another (Figure 3-34). Figure 3-35 shows the correlation for those data from LTM Site 1and LTM Site 4-5.

As shown in Figure 3-34, the correlation coefficient is somewhat weak (r^2 = 0.456) showing that there is some relationship between the two sites but not a strong one with LTM Site 9 having relatively higher proportions of penta-, hexa-, and hepta- chlorobiphenyls than the source at LTM Site 1. In Figure 3-35, the correlation coefficient is very low (r^2 = 0.145) indicating that the PCB at the two sites have very little in common, and background location LTM Site 4-5 contains even higher proportions of the highly chlorinated (hexa- and hepta- chlorobiphenyls) than the source at LTM Site 1. It is possible that the PCBs at LTM 4/5 are at least partially derived from the Wilcox Dock source, but have been heavily altered in the environment.

The table below presents a summary of the correlation coefficients between the various sites for yellow perch in 2007. The very low correlation factor 0.145 indicates a distinct difference between the source at LTM Site 1 and the regional background at LTM Site 4-5. The other three sites (LTM Sites 2J, 2M, and 9), located intermediate between the source and the background, show some correlation with LTM Site 1 (r^2 of approximately 0.5). These have a stronger correlation (r^2 of about 0.8) with LTM Site 4-5, indicating that the influence of the Wilcox Dock source is now limited throughout Cumberland Bay, with the exception of the Dock itself.

2007 Yellow Perch Correlation Coefficients					
LTM Sites	1	9	2J	2M	4-5
1	1	0.456	0.548	0.398	0.145
9		1	**0.986**	**0.969**	**0.855**
2j			1	**0.976**	**0.75**
2m				1	**0.82**
4-5					1

Bold indicates a statistically significant relationship at $p<0.05$.

The table below provides a summary of the correlations between yellow perch and rock bass for each location in 2007 (2010 had similar results). The correlation coefficients are all very high (r^2 of about 0.99), showing the similarity between the two species. These correlations indicate a similar exposure to PCBs for the two species. The limited samples from other species (brown bullhead and American eel) also have similarly high correlations.

2007 Correlations Between Rock Bass and Yellow Perch				
LTM Site 1	LTM Site 9	LTM Site 2J	LTM Site 2M	LTM Site 4-5
0.990	**0.991**	**0.924**	**0.961**	**0.991**

Bold indicates a statistically significant relationship at $p<0.05$.

Comparisons Between Years

In 1992 and 1994 the NYSDEC collected five species of fish (largemouth bass, brown bullhead, yellow perch, rock bass, and lake trout) for congener analysis. The largemouth bass, brown bullhead, and yellow perch were collected at the Wilcox Dock site (LTM Site 1) in 1994. Rock bass were collected at the jetty at the mouth of the Saranac River (LTM Site 2J) in 1994. Lake trout were collected from remote locations (equivalent to the LTM Site 4-5 in terms of exposure) in 1992. Since the homolog profiles for a particular site showed very strong correlations between species, varied species could be used for comparison of homolog profiles for the three sites sampled in 1994. Because the 1994 collections did not have consistent species across the sites sampled, different species have to be used at each site; yellow perch at LTM 1, rock bass at LTM 2J, and lake trout at regional background.

The table below presents a summary of the correlation coefficients between the various sites in 1992/1994. The very low correlation factor (r^2 =0.111) indicates a very distinct difference between the source at LTM Site 1 and the regional background at LTM Site 4-5. The other site (LTM Site 2J), located intermediate between the source and the background, shows some correlation with the LTM Site 1 source with a correlation coefficient (r^2) of 0.563. There is a stronger correlation (r^2 of 0.656) with LTM Site 4-5.

1994 Yellow Perch Correlation Coefficients					
LTM sites	1	9	2J	2M	4-5
1	1		0.563		0.111
2j			1		**0.656**
4-5					1

Bold indicates a statistically significant relationship at $p<0.05$.

The table below presents a summary of the correlation coefficients between the various sites in 2010. The very low correlation factor (r^2 of 0.127) again indicates a very distinct difference between the source at LTM Site 1 and the regional background at LTM Site 4-5. The other three sites (LTM Sites 2J, 2M, and 9), which are located intermediate between the source and the background, show some correlation with the LTM Site 1 source (r^2 of approximately 0.6 to 0.8) and similar stronger correlations (r^2 of approximately 0.5 to 0.79) with LTM Site 4-5.

2010 Yellow Perch Correlation Coefficients					
LTM sites	1	9	2J	2M	4-5
1	1	**0.799**	**0.681**	0.621	0.127
9		1	**0.963**	**0.953**	0.526
2j			1	**0.99**	0.599
2m				1	**0.665**
4-5					1

Bold indicates a statistically significant relationship at $p<0.05$.

Overall Results of Fish Homolog Comparisons

By comparing the correlations of the homolog distributions between sites, the data indicate that:

- Fish collected at the same locations have very similar homolog profiles reflecting the similar exposure to the same source conditions;
- There is a distinct difference in the homolog makeup of fish exposed to the Wilcox Dock source area and the regional background PCB exposure;
- The fish that are collected within Cumberland Bay show evidence of exposure to both the Wilcox Dock source and the regional background PCB conditions; and
- There is no clear change over the years in the homolog makeup for those fish within the bay (i.e., they continue to show homolog profiles intermediate between the source and the background conditions).

3.5.4 Water

Water samples were collected at the Cumberland Bay site from 1996 to 2004 in order to assess concerns about direct contact exposure by the public to surface water. Since the remediation the total PCB concentration in the water at the Wilcox site (LTM Site 1) were below detection limits (0.013 to 0.024 µg/L) in 11 out of twenty samples, and of those with detectable concentrations the average concentration was 0.040 µg/L with a maximum of 0.200 µg/L. There appeared to be an increase in PCB concentration associated with increased turbidity/suspended solids in the water column due to wind driven resuspension. Concentrations of PCBs in water at the public beach (LTM Site 9) had a single positive result of 0.009 µg/L. The PCBs were not detected at the other stations. The concentrations detected were below levels of concern in terms of human health due to recreational exposure (for example, the New York State standard for PCBs in public drinking water supplies is 0.5 µg/L, NYS DOH 2007), although, many of those results were above the US EPA aquatic life water quality criteria for chronic exposure of 0.014 µg/L (USEPA 2009).

This was expected since, based on the partitioning coefficients of PCBs, the vast majority of PCBs in an aquatic system will be associated with solids (either sediment or biota). The partitioning theory indicates that if there are concentrations in fish or sediments on the order of 1 mg/kg (as at this site), then concentrations in the water would be on the order of 0.05 to 40 ng/L depending on the homolog. The laboratory methods used in this study (which are among the more sensitive available) typically had detection limits of 6 to 25 ng/L depending on conditions and the Aroclor being quantified. Thus, depending on the homolog distribution in the water, it would be expected that many of the samples would not have detectable concentrations of PCBs.

3.5.5 Sediment

Six sediment samples were collected in the Wilcox Dock area (LTM Site 1) in 2002 and 2004. The mean of the samples was 1.7 mg/kg, with the results ranging from 0.9 to 2.4 mg/kg. These values are consistent with the confirmatory sampling conducted immediately after the remediation which averaged 1.5 mg/kg.

In addition, in 2002 suspended sediment in the water column was collected at LTM Site 1, LTM Site 2, and LTM Site 9, with total PCB values of 0.0243 mg/kg, 0.213 mg/kg, and 0.0615 mg/kg, respectively. In 1995 suspended sediment samples at LTM 1 contained PCB at a concentration of 78 mg/kg. Suspended sediments could represent a number of materials including zooplankton, resuspended sediments, and material transported from outside of the lake by tributaries and the variability expected from a grab sample from the water column would be high. However these data show that the PCB concentrations in suspended sediments have declined by orders of magnitude since the remediation of the site.

4.0 Conclusions

4.1 Risk and Advisories

The New York State Department of Health advisory on consumption of fish from Cumberland has been as follows:

- first year - 1984 - advisory was 1 meal/month of brown bullhead, area specified as "at Plattsburgh" - stayed in effect until 1985
- 1985 - changed to EAT NONE for American eel, 1 meal/month for brown bullhead, area specified as "vicinity of Plattsburgh" - stayed in effect through 1987
- 1988 changed to 1 meal/month of American eel & brown bullhead, area specified as "Bay within Cumberland Head to Valcour Island"- stayed in effect through 1994
- 1995 changed to 1 meal/month of American eel, brown bullhead & yellow perch, area specified as "Bay within Cumberland Head to Crab Island"- stayed in effect through 1999
- 2000 changed to EAT NONE for brown bullhead and 1 meal/month of American eel & yellow perch, area still specified as "Bay within Cumberland Head to Crab Island"- stayed in effect through 2010
- 2011 changed to 1 meal/month of American eel, brown bullhead & yellow perch, area still specified as "Bay within Cumberland Head to Crab Island"- stayed in effect until 2012
- 2012 changed to 1 meal/month of American eel, area still specified as "Bay within Cumberland Head to Crab Island. " Specific advisories for brown bullhead & yellow perch were dropped, so general advisory (4 meals/month) now apply as it does to all unlisted species.

As discussed in Section 3.5.2, yellow perch (prepared as fillets) were collected in Cumberland Bay in 1994, 1997, 2010, and 2011. The fillet data from all of the LTM sites for Cumberland Bay (LTM Sites 1, 2, 4-5, and 9) are presented in Figure 3-27. The average concentrations have dropped from 5.4 mg/kg to 0.14 mg/kg (with about one third of those results being non-detect). This 97 percent drop in concentrations in the yellow perch fillet samples mirrors the trends seen in the whole fish samples (both lipid normalized and wet weight). Thus, while the fillet data are not as extensive as the whole fish data or the PISCES data, the trends are consistent, and the multiple lines of evidence support the conclusion that the wet weight fillet PCB concentrations reflect a long term stable trend of decreasing PCB concentrations and are presently approaching undetectable levels.

Modified fillets (head viscera and skin removed) were collected for American eel (1985, 2009 and 2010) and brown bullhead (1992, 1994, 1999, and 2007 to 2010) at varied locations. These species also experienced large decreases in PCB concentrations similar to the yellow perch. Bullhead modified fillet samples declined from means of 2.0 to 12.7 mg/kg to a mean of 0.5 mg/kg in 2010. American eel modified fillet samples declined from a mean of 3.7 mg/kg in 1985 to mean of 0.02 to 0.8 mg/kg.

Overall, the PCB concentrations seen in fillets (yellow perch) or modified fillets (American eel and brown bullhead) are consistent with concentrations detected in waters with only the state wide advisory of "*Eat no more than one meal (one-half pound) per week of fish from the state's freshwaters*" applied to them. However insufficient eels were collected to provide strong statistical analysis on PCB trends. In 2012 NYS DOH revised the advisory for yellow perch and brown bullhead to the state-wide advisory.

4.2 Ten Year Review Conclusions

The objective of the monitoring program was to measure total PCB concentrations and patterns of Aroclors/homologs/congeners in fish, sediment, and water at selected sites in Cumberland Bay and adjacent Lake Champlain. Assessing these data sets revealed patterns of PCBs that illustrate the response of the system to the remediation on a geographic and a temporal basis. The PISCES and fish data showed large declines in total PCB concentrations. These changes were greatest in the source area of the Wilcox Dock site.

Two intensive sampling programs were completed during this post remediation monitoring program: PISCES, and fish. Each of these data sets demonstrates different strengths and weaknesses. The PISCES data provide congener specific data on the water column PCB content and is time integrated to reduce variability, although the number of samples collected is somewhat limited. The fish data provide a direct PCB measurement for use in risk assessment, integrates over a full year, and integrates all possible routes of exposure to biota. However, fish data tend to be variable due to changes in lipid content, changes in behavior and movement of the fish, and the fish data were often analyzed on an Aroclor basis limiting some types of assessment.

Sampling was conducted at the Wilcox Dock site, at stations expected to be under the influence of the site within Cumberland Bay, and at stations expected to be representative of conditions on a wider lake basis. Assessing these data sets revealed patterns of PCBs that illustrate the response of the system to the remediation on a geographic and a temporal basis.

4.2.1 Geographic

Concentrations of PCBs in PISCES and fish were always highest at the site itself and decreased outward from the site. As seen in Figure 3-12, the fish from the source area at Wilcox Dock were about 50 times higher in LPCB concentration than the regional background concentrations, and 5 to 20 times greater than the intermediate monitoring locations. The PISCES concentrations exhibited a similar pattern.

To some degree in the PISCES data, but very noticeably in the fish data, the homolog distribution of the PCBs in the fish tended to change with the distance from the sludge bed site. The source area at Wilcox Dock had more lightly chlorinated PCBs than at the regional background conditions, with the monitoring sites within the bay showing an intermediate distribution.

These observations of a strong gradient for both concentration and homolog distribution support the hypothesis that the Wilcox Dock served as the source of PCBs to the surrounding area in the bay, with very high concentrations of unaltered PCBs at the dock itself, and rapidly dropping off, but still apparent at sites within Cumberland Bay.

4.2.2 Temporal

All of the data indicate that PCB concentrations in water and fish dropped dramatically after the remediation was completed.

The concentrations of the total and Tri+ PCBs (which tend to be more important in terms of biota uptake) were very clearly declining in the PISCES data. At the source, both total PCBs and Tri+ PCBS declined by over 95 percent, with the other monitoring sites also showing comparable decline. As shown in Figures 4-1 and 4-2, these declines at LTM Site 1 fits an classic exponential decay trend line with correlation coefficients of total PCBs of 0.97 and tri+ PCBs of 0.95 ($p<0.05$). The calculated half-lives for these declines are about 2.5 years.

The lipid normalized fish data typically show a drop close to 90 percent. The results vary slightly by species, but lipid normalized data at the source (LTM Site 1) showed a 80 percent drop in the yellow perch, and over 90 percent in brown bullhead and rock bass. The declines tend to be slightly less in the outlying locations which already had much lower PCB concentrations. Interestingly enough, even LTM Site 4-5 at Valcour Island, which is thought to represent areas unaffected by the site at Wilcox Dock, showed a 70 percent decline in its already low concentrations. This likely reflects a long term trend in declining PCBs in the environment after they were banned in the 1970s (as illustrated in the Great Lakes Integrated Atmospheric Deposition Network [IADN]), as well as reflecting elimination of sources in the watershed including Wilcox Dock.

Using the species with the least amount of variability in the data set (rock bass), a plot of the decline at LTM Site 1 with an exponential trend line fitted to it is shown in Figure 4-3. The rate of decline is very similar to that of the decline on Tri+ PCBs in the water column as measured by the PISCES, with a half-life of about 2.7 years. As shown in Figure 4-4, there is very high correlation between the Tri+ PCBs in the water as measured by PISCES and the lipid normalized PCBs in rock bass (r^2 of 0.95, $p<0.05$). Yellow perch show similar results, although the data are somewhat more variable.

This strongly suggests that the fish PCB concentrations reflect the exposure from the water column. It is likely that these water column concentrations are due to residuals that would be expected following a dredging event, as a small layer of resuspended material settles back onto the dredged area as discussed in USACE (2008) and confirmed in the post construction sediment sampling. As these residuals are depleted of PCBs, the PCBs detected in other media will also decline.

Although the wet weight fish data were somewhat more variable due to changes in the lipid content of the fish, they tend to follow these same trends. Of key interest in terms of human exposure to PCBs, the wwPCB concentrations in fillets and modified fillets in yellow perch, brown bullhead, and American eel have dropped from high concentrations (e.g. 5 to 18 mg/kg) to concentrations of less than 0.2 to 0.8 mg/kg. These declines are approaching the point where many of the fish have PCB concentrations below the laboratory detection limits.

The post remediation monitoring program has shown strong evidence throughout the area sampled that PCB concentrations have declined since the remediation. These declines followed a first order exponential decline and are now approaching the laboratory detection limits for many of the fish and the PISCES. These results demonstrate that the remediation has accomplished its goal to eliminate/mitigate the release or exposure pathway resulting from the site contamination.

4.3 Resulting Actions

The NYSDOH health advisory applied to three species: yellow perch, brown bullhead, and American eel. The 10 year post-remediation monitoring program has demonstrated a consistent first order decline in PCB concentrations in these species. The NYSDOH has removed the site specific fish consumption advisory applied to Cumberland Bay for the species primarily targeted by fishermen (i.e., yellow perch and brown bullhead) in light of the data presented here and sampling will be discontinued.

The monitoring program has shown that the PCB concentrations in the media monitored are now at the far end of an exponential decline approaching undetectable levels and has demonstrated that the remediation has achieved its goal.

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