INDIANA HARBOR AND CANAL

2014 AIR MONITORING DATA ANALYSIS

Prepared by U.S. Army Corps of Engineers – Chicago District

August 20, 2015

This Page Left Intentionally Blank

INDIANA HARBOR AND CANAL – AIR MONITORING DATA ANALYSIS

Introduction

In November 2001, the U.S. Army Corps of Engineers (USACE) implemented an air monitoring program at the property known as the Energy Cooperative, Inc. (ECI) site, located in East Chicago, Indiana. The ECI site is the location of a confined disposal facility (CDF), which was constructed to hold sediment dredged from the Indiana Harbor and Canal (IHC). In July 2003, CDF construction was initiated and the construction phase of the air monitoring program was implemented. CDF construction activities were substantially complete in 2011, and dredging of the IHC started in October 2012. Air monitoring continued during the post-construction, pre-dredging period. The air monitoring program results, including the background phase, construction phase, and post-construction/pre-dredging phase monitoring through 2012 are presented in several reports (USACE 2003b, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013). Post-dredging period (late 2012 through 2013) air monitoring results are first reported in USACE (2014). Table A presents a summary of the air monitoring program at the IHC CDF.

Table A: IHC CDF Air Monitoring Program

Phase	Dates	Activities during Phase	Monitor Locations	Sampling Frequency
Background	Nov 2001 – July 2003	No major construction activities on site or canal	HS and 4 CDF on-site points	6 day monitoring frequency
CDF Construction	July 2003 – May 2004 (SW) May – Sep 2005 (D) July – Nov 2006 (D, SW) April – Sep 2007 (D, TP) March – Dec 2008 (TP, GCS, CW) Jan – Nov 2009 (GCS, CW) July – Nov 2010 (D, TP) May – Sep 2011 (D, TP, SEF)	Slurry wall (SW) construction CDF dike (D) construction Interim wastewater treatment plant (TP) operation Gradient control system (GCS) construction South cutoff wall (CW) construction South end facility (SEF) construction	HS and 4 CDF on-site points through April 2004; HS and CDF South Parcel afterwards	6 day monitoring frequency through October 2008; 12 day frequency afterwards
Idle Periods during Construction Phase	June 2004 – April 2005 Oct 2005 – June 2006 Dec 2006 – Mar 2007 Oct 2007 – Feb 2008 Dec 2009 – June 2010 Dec 2010 – Apr 2011	No major construction activities on site or canal	HS and CDF South Parcel	6 day monitoring frequency through October 2008; 12 day frequency afterwards
Post Construction/ Pre-Dredging	Oct 2011 – Oct 2012	No major construction activities on site or canal	HS and CDF South Parcel	12 day monitoring frequency
Active Dredging	Oct – Dec 2012 April – Aug 2013 May – July 2014	Dredging and discharge of dredged material to CDF	HS and 4 CDF on-site points	6 day monitoring frequency
No Dredging/ Material in CDF	Jan – Mar 2013 Sep 2013 – April 2014 Aug – Dec 2014	Idle periods between dredging events; CDF is a quiescent pond	HS and 4 CDF on-site points	12 day monitoring frequency

Annual air monitoring reports include detailed information on the selection of the monitoring sites, an evaluation of meteorological data, and statistical analyses of the air monitoring data collected through the pre-dredging period. These reports serve as a compilation of all data collected prior to the start of dredging in the IHC and therefore document conditions prior to dredging start. Interested readers are referred to the above referenced documents for details.

The purpose of this annual report is to follow up the last annual report that presents statistical analysis of air monitoring data collected from the start of dredging of the IHC and disposal of dredged material into the CDF cells starting in October 2012 through December 2014. By comparing post-dredging data with pre-dredging data from 2010 through October 2012, this report aim to evaluate potential impacts of dredging and sediment disposal activities and dredged material storage at the CDF site on ambient air conditions at the study area.

2012 – 2014 Dredging and Dredged Material Disposal

Post-dredging air monitoring data presented in this report span three dredging events at the IHC corresponding to fall 2012, spring/summer 2013, and late spring/early summer 2014.

The fall 2012 IHC dredging commenced on October 23, 2012 with a limited amount of material removed for equipment placement. Dredging includes mechanical removal of sediment from the canal using a closed clamshell (environmental) bucket. The initially dredged quantity was a few hundred cubic yards, which was stored in a barge adjacent to the CDF site until the continuous operation started in November 2012. The continuous dredging operation and hydraulic off-loading operation started on November 14, 2012, with sediment removal in the Lake George Branch of the canal. Continuous dredging in the Lake George Branch occurred from November 14, 2012 through November 26, 2012. The dredging operation then moved to the harbor, and occurred from December 1, 2012 to December 19, 2012.

The hydraulic off-loading operation was conducted from barges set up in the Lake George Branch. Sediment and water were slurried from a barge and pumped into the CDF through double walled piping. Sediment was distributed within the CDF by a manifold of discharge pipes. Sediment was placed in the east cell of the CDF during the 2012 dredging. Sediment disposal continued until seasonal shut-down of the dredging operation on December 21, 2012. The total volume of dredged material removed from the canal in 2012 is 93,937 cubic yards, which includes 23,806 from the Lake George Branch and 70,131 from the harbor area.

No dredging or sediment disposal occurred between December 21, 2012 and April 1, 2013. The spring/summer 2013 dredging commenced on April 2, 2013 and continued through August 2, 2013. Dredging occurred in the harbor and entrance channel areas. Dredging and sediment disposal were mostly continuous during this dredging event, with some interruption of work due to bridge construction and/or bridge malfunctioning preventing movement at IHC. Annual shut-down of the spring/summer 2013 dredging operation started on August 2, 2013.

The total volume of dredged material removed from the canal in 2013 is 305,947 cubic yards. Of that quantity, the majority, 237,379 cubic yards was dredged from the federal channel and non-federal areas outside the channel in Reach 2. The remaining volume, 68,568 cubic yards, came from Reaches 3, 4 and 5 of the IHC. Dredged material was disposed to the east and west cells of the CDF.

The 2014 dredging began on May 23, 2014 and continued through July 10, 2014. The total volume of dredged material removed from the IHC in 2014 is 210,099 cubic yards. Of that quantity, the majority, 165,760 cubic yards was dredged from the federal channel in Reach 4. The remaining volume, 44,339 cubic yards, came from Reaches 1, 5, 7, and 13. Sediment was disposed of continuously into the CDF except for one interruption between June 4th and June 10th. All 2014 dredged material was disposed in the CDF west cell. Shut down of the 2014 dredging operation started July 10, 2014 and no additional dredging was performed the rest of the year.

In summary, approximately 200,000 cubic yards of dredged material was placed into each cell of the CDF during the 2012 and 2013 dredging events. Approximately 210,000 cubic yards was placed into the CDF west cell during the 2014 dredging event. The material is allowed to settle and consolidate with a layer of water on top during the non-dredging period. Groundwater pumped from the site is continuously added to the east cell pond; water is added to the west cell during sediment off-loading or as needed to maintain the water over the sediment.

Air Monitoring Data

Locations, Schedule, and Parameters

The air monitoring data used for the statistical analysis for the pre-dredging period were collected at two locations, referred to as the “south” site and as the “high school” site. During the first part of the pre-dredging period (2001 to mid 2004), data were collected from five monitors, four onsite and one offsite at the high school. However, the four onsite monitors were scaled back to one after statistical analysis indicated no significant difference between the 4 onsite monitors during this period. The pre-dredging south site is located adjacent to the Lake George Branch of the Indiana Harbor Canal on the south parcel of the ECI site and represents the CDF site conditions. The high school site is located approximately 1700 feet south of the south sampler, on the East Chicago High School property, and represents an off-site receptor location. The rationale for these monitoring locations is discussed in previous reports.

Immediately prior to the start of dredging, the two air sampling stations were operating in tandem, on a 12-day rotational schedule. Sampling had been conducted every 6 days from 2001 through September 2008. The sampling schedule was changed to every twelve days in October 2008 until the start of the dredging /disposal phase to continue establishing the trends database, but on a less frequent schedule.

In October 2012, the ambient air monitoring program was changed back to five sampling sites to monitor the dredging and sediment disposal activities which started on October 23, 2012. The five monitors include 4 new monitors in the four cardinal directions on top of the earthen dikes that form CDF disposal cells (South, East, North, and West) and the existing monitor at East Chicago High School. The monitoring frequency was changed to a six-day rotational schedule at the same time. The rationale for the additional monitors and higher sampling frequency is to observe the effects (if any) of the dredging and dredged material disposal activities on the ambient air.

The six-day sampling schedule was employed during the fall 2012, spring/summer 2013, and late spring/early summer 2014 dredging events and through approximately one month after sediment disposal ended for the events. Outside of these periods, air monitoring samples were collected on a 12-day schedule.

Each air monitoring sample is a 24 hour sample. Parameters measured include polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), volatile organic compounds (VOCs), metals, and Total Suspended Particulates (TSP). Selection of the "chemicals of concern" for measurement and analysis is discussed in previous reports. Parameters used in the statistical analysis are listed in Table B. Metals data are currently under review and will be presented along with the 2015 data in next year's annual report.

Table B: Air Monitoring Analytes Included in 2014 Annual Report

PCBs	**PAHs**
Congener 8 (PCB 8) Congener 15 (PCB 15) Congener 18 (PCB 18) Congener 28 (PCB 28) Congener 31 (PCB 31)	Acenaphthene (Ace) Acenaphthylene (Acy) Fluoranthene (Fla) Fluorene (Flo) Naphthalene (Nap) Phenanthrene (Phe) Pyrene (Pyr)
VOCs	**Total Suspended Particulates** (TSP)
Benzene (Benz) Toluene (Tol)	

The PAH and PCB samples are obtained using a high-volume vacuum pump air sampler, with a glass fiber filter, a polyurethane foam (PUF) and adsorbent resin (XAD-2) media. Total suspended particulates are collected using a separate high-volume vacuum pump air sampler, with a glass fiber filter medium. VOCs are collected using specially treated stainless steel canisters, which utilize a bellows-type pump to draw in air. More detailed description of the sampling methodologies including sampling media, analytical methods, and quality assurance methods can be found in the *Indiana Harbor and Canal Dredging and Disposal Project, Ambient Air Monitoring Plan: Volume 1* (USACE, 2003a). The sampling methodology and analytes remained consistent after the post dredging air monitoring phase was initiated in October 2012. The analytical laboratory was changed in September 2013, and there were some minor changes in reporting methods and limits at that time.

Data Organization and Preparation

Pre-dredging data

The ambient air monitoring data can be subdivided into two main groups: Pre-dredging and post-dredging. Pre-dredging refers to all data collected prior to sediment disposal to the CDF in October 2012 back to the start of 2010, when most of the construction activities at the CDF were substantially complete. The entire monitoring data set collected from 2001 to October 2012 was initially considered as the pre-dredging data set. However, trend analyses performed over this extended period of time indicate statistically significant evidence of decreasing or increasing trends for several parameters. The changing trends in ambient air levels of these parameters in the project area over the pre-dredging period may potentially be attributed to industry/source changes, regulation changes, climate change, etc., over the extended sampling period between 2001 and 2012. Identification of the exact cause(s) is beyond the scope of this analysis. However, recognizing these trends, the pre-dredging data set was reduced to data collected between January 2010 and October 2012 to be more representative of a "background" period. This period coincides with the period after most of the CDF construction activities were substantially complete and prior to the start of sediment disposal to the CDF. Thus the data collected earlier are not used as the main basis for this evaluation.

As discussed previously, the pre-dredging south monitoring station was located on the south side of the Lake George Branch of the Indiana Harbor Canal. For practical reasons, the pre-dredging south monitor was not located on the CDF site because the area was an active construction site from 2004 to 2010 with various activities such as dike building, grading, slurry wall installation, which would have been physically obstructed by the monitor. On-site monitors were installed in 2012 including a new south station monitor that was located on the north or 'CDF' side of the canal. Therefore, it is worthy to note that pre- and post-dredging "on-site" conditions are represented by monitors that are in different locations relative to the canal and other potential sources, albeit with the same naming convention (south station) and within relatively close proximity (the new south monitor is less than 1000 feet away from the old south monitor site).

Post-dredging data

Post-dredging data collected after sediment disposal to the CDF started in November 2012 through December 2014 were further divided into active Discharge and idle Quiescent Pond periods, with Active Discharge signifying periods when dredging and dredged material disposal are occurring, and Quiescent Pond signifying shutdown periods with no dredging or disposal but the presence of the CDF. This is the first report in which the post-dredging dataset is subdivided into Discharge and Quiescent Pond because of sufficient amounts of data available to represent the populations. See Table A for active dredging and quiescent pond dates. In this report Active and Idle refers to the sediment disposal activities during the post-dredging period, not the construction activities that occurred prior to 2010 and were reported on in previous reports.

Temperature correction

Atmospheric concentrations of semi-volatile and volatile compounds (i.e. PAHs, PCBs, and VOCs) depend on temperature because volatilization from sources like soil, sediment, and water bodies is a temperature-controlled process. The Clausius-Clapeyron equation was used to model temperature-dependence of the measured data. When a significant negative trend was observed for PAH, PCB, and VOC partial pressures with the inverse of ambient temperature, regression parameters were used to ‘temperature-correct’ the data to a reference temperature of 15 deg C. Removing this temperature-dependence allows greater discernment of underlying trends in the data. PAH and PCB data were temperature-corrected for the entire study period (January 2010 through December 2014) however VOCs were only temperature-corrected from February 2012 through December 2014 due to a lack of temperature information prepared for the earlier sampling times, which can be obtained for a future report (see Future Considerations section below). Data analyses were performed mainly using temperature-corrected data sets.

Non-detect data

Non-detects were replaced with the median values of the reporting limit (the same value for each constituent) as determined for the 2013 report. Future reports should be updated to include all current data (benzene and toluene detection limits have changed since September 2013 due to the laboratory change discussed above). Replacement values of half the detection limit can be considered to estimate censored data more accurately. While most compounds are less than 15% non-detect, more highly censored data like Fluoranthene (17%), Pyrene (28%), Toluene (34%), PCB 15 (39%), Nickel (41%), Benzene (55%), Arsenic (56%), Selenium (58%), Acenaphthylene (76%), and Cobalt (76%) may require other methods to handle non-detects . Results for these parameters, especially Benzene, Arsenic, Selenium, Acenaphthylene, and Cobalt should be regarded as having high uncertainty.

Data transformation

Like most environmental data sets, the air quality data were not normally distributed but rather log-normally distributed. Prior to regression and hypothesis testing the data were transformed using the natural logarithm to better approximate a normal distribution.

Additional data groups

Data from the five (high school and on-site) sampling locations were analyzed as one data set as well as by individual monitor to assess potential effect of localized CDF activities on the on-site air monitors plus the high school location. Analyses were performed to evaluate whether data collected at the high school and four CDF stations are statistically similar or whether localized work activities at the site may affect samples collected from the different locations.

Data were also broken down by season: Spring/fall (March, April, May, October, November), summer (June, July, August, September), and winter (December, January, February) corresponding to mean monthly temperatures of <40^{o}F (winter), 40 – 60^{o}F (spring/fall), and >60^{o}F (summer) in order to investigate seasonal effects on air quality.

In summary, based on monitor station location (All, High School, South CDF, East CDF, North CDF, West CDF), sampling period (Entire/2001-2014, Recent/2010-2014), season (all, spring/fall, summer, winter), dredging status (all, background/pre-dredging, active/discharge, idle/quiescent pond), and temperature-correction (measured, temp-corrected), a total of 27 sub-groups were analyzed for each parameter:

- All monitoring stations, Entire sampling period, all data, measured
- All monitoring stations, Recent sampling period, all data, measured
- All monitoring stations, Entire sampling period, all data, temp-corrected
- All monitoring stations, Recent sampling period, all data, temp-corrected
- High School station, Recent sampling period, all data, temp-corrected
- South CDF station, Recent sampling period, all data, temp-corrected
- East CDF station, Recent sampling period, all data, temp-corrected
- North CDF station, Recent sampling period, all data, temp-corrected
- West CDF station, Recent sampling period, all data, temp-corrected
- All monitoring stations, Recent sampling period, spring/fall data, temp-corrected
- All monitoring stations, Recent sampling period, summer data, temp-corrected
- All monitoring stations, Recent sampling period, winter data, temp-corrected
- All monitoring stations, Recent sampling period, background data, temp-corrected
- All monitoring stations, Recent sampling period, discharge data, temp-corrected
- All monitoring stations, Recent sampling period, quiescent pond data, temp-corrected
- High School station, Recent sampling period, background data, temp-corrected
- High School station, Recent sampling period, discharge data, temp-corrected
- High School station, Recent sampling period, quiescent pond data, temp-corrected
- South CDF station, Recent sampling period, background data, temp-corrected
- South CDF station, Recent sampling period, discharge data, temp-corrected
- South CDF station, Recent sampling period, quiescent pond data, temp-corrected
- East CDF station, Recent sampling period, discharge data, temp-corrected
- East CDF station, Recent sampling period, quiescent pond data, temp-corrected
- North CDF station, Recent sampling period, discharge data, temp-corrected
- North CDF station, Recent sampling period, quiescent pond data, temp-corrected
- West CDF station, Recent sampling period, discharge data, temp-corrected
- West CDF station, Recent sampling period, quiescent pond data, temp-corrected

Statistical Analysis

All statistical analyses presented in this report were performed with Microsoft Excel and the integrated Analyse-it statistical software (version 3.9) developed by Analyse-it for use in environmental data analysis and application.

Air quality data were plotted over time and descriptive statistics were tabulated to summarize the measured data. The Shapiro-Wilk test (90% confidence level) was used to identify non-normal populations prior to testing. Long term trends in concentrations with time were analyzed by linear regression analysis. Statistical comparison between sub-groups (monitoring stations, sampling periods, season, and dredging status or activity) were made using two-sample and paired Student *t*-tests (for normally distributed data or data with sample numbers >100) and two-sample Wilcoxon-Mann-Whitney and paired Wilcoxon tests (for non-normally distributed data). Levene's test was used to determine homogeneity of variance (95% confidence level) prior to statistical two-sample comparisons. All comparisons were two-sample except for monitoring stations which were paired-sample tests. Statistical tests were performed at the 95% confidence level. Note that tests were performed on temperature-corrected data to identify trends unrelated to temperature (i.e., dredging activities).

Spearman rank correlations were also performed using actual data to determine relationships between compounds.

For PCBs, plots and descriptive statistics are shown for congeners 8, 15, 18, 28, 31, and the sum of the 18 congeners originally reported when the ambient air monitoring program started in 2001 (presented as Total PCBs in this report). Statistical tests for Total PCBs were performed using the sum of 5 congeners rather than 18 however because temperature-corrected values were not available for the additional congeners. Congeners 8, 15, 18, 28, 31 were originally selected for statistical analysis because they have lower molecular weight and therefore are relatively more volatile than other congeners reported, because they are detected most frequently of the congeners reported, and because they are generally detected at higher concentrations than other congeners that were reported. Note that the analytical laboratory for the ambient air monitoring program began reporting 13 additional congeners in late 2011, however for consistency subsequent analysis and presentation were still performed using the sum of the originally reported PCB congeners even after additional congeners were added (analysis of the additional congeners shall be performed in future reports).

Summary of Pre-Dredging and Post-Dredging Data Analysis

A summary of the pre-dredging data analysis collected from 2001 to November 2012 is available in USACE 2014. The air monitoring data used for the statistical analysis for the pre-dredging period were collected the south site (representing the CDF) and the high school site, and analyzed by site, season, and period of construction activities at the CDF to understanding background ambient air conditions prior to dredging start.

The primary purpose of post-dredging air data analysis is to assess the effect of dredging and dredged material disposal activities and dredged material storage at the CDF site on the atmospheric conditions at the CDF site and off site at the selected potential receptor location at the high school. To this end, pre-dredging background data are compared to post-dredging data to identify significant differences and identify temporal trends at all CDF stations and the HS station. 'Recent' pre-dredging data from 2010 to 2012 were utilized as representative of background for most statistical analyses rather than the entire pre-dredging monitoring period starting 2001. The post-dredging period is broken down into "active" periods of discharge / sediment placement and "idle" periods with quiescent pond only / no sediment placement to explore the potential effects of CDF operations and whether pre-dredging background trends have changed at the CDF stations or high school. This report analysis focuses on the subdivided post-dredging data sets (active discharge and idle quiescent pond) and individual monitoring station data (south, east, north, west, and high school) rather than aggregate post-dredging and CDF data sets for detailed results.

It is important to recognize that except for dredging in the Lake George Branch (which occurred in October and November 2012), dredging activities in the IHC are not expected to impact the air at the High School or the CDF site primarily due to the distance between the dredge sites outside the Lake George Branch and the project air monitors. The impact of this project on the air quality at the High School and CDF would be likely more from the placement of dredged material into the CDF cells and the presence of the dredged material stored in the cells (in the future the designation of pre-dredging and post-dredging periods may be more appropriately re-designated pre- and post-sediment placement periods).

PCB Analysis

Atmospheric concentrations of PCBs vary by well over an order of magnitude over the entire monitoring period (Figures 1-6). All PCBs exhibit a clear oscillatory pattern with levels increasing in the warmer months and decreasing in the cooler month, signifying PCBs are heavily dependent on temperature. As previously described, this temperature-dependence is removed for most statistical tests. Higher concentrations are observed in the post-dredging period (October 2012 - December 2014) compared to the pre-dredging period which will be explored in further statistical detail. While PCB 8 dominated total PCB levels in the past, Table 1 shows median concentrations of PCB 18 (22.44 pg/m^3), PCB 28 (19.44 pg/m^3), and PCB 31 (16.88 pg/m^3) exceed PCB 8 (16.56 pg/m^3) in recent years. All PCBs are highly positively correlated with one another (Table 2). Spearman correlation coefficients (significant at the 95% level) range from 0.855 to 0.981.

Trend analysis

Table 3 presents results from a linear regression analysis of PCB concentrations over different monitoring periods and combinations of monitoring stations. For all stations combined over the entire sampling period (2001-2014), PCB 8, PCB 15, and Total PCBs decrease statistically with time while PCB 18, PCB 28, and PCB 31 exhibit no significant trend. Over the recent monitoring period however (2010-2014), only PCB 15 decreases, PCB 8 and Total PCBs exhibit no trend, and PCB 18, PCB 28, and PCB 31 statistically increase. Table 3 also shows that PCB trends vary by site. PCB 8 decreases at the high school and east station, and displays no trend at the south, north, and west stations. PCB 15 decreases only at the east station and maintains no trend at the other stations. PCB 18, PCB 28, and PCB 31 decrease at the east station, show no trend at the high school, north station, and west station, and increase at the south station. Total PCBs decrease at the high school and east station, exhibit no trend at the north and west stations, and increase at the south station.

In summary, there are no PCB increases over time at the high school, indicating dredging and sediment placement activities are not significantly impacting PCB concentrations at the high school. The only PCB increases occur at the south station for congeners 18, 28, and 31. Because the south station is nearest the canal and offloading activities, sediment disposal may influence concentrations of PCB 18, PCB 28, and PCB 31 in the localized area. Other sources of PCBs, particularly affecting the high school and east station, appear to be decreasing. The trend differences between the east station (decreasing) and the other CDF stations (no change or increasing) may also be due to more disposal in the west cell compared to the east cell through 2014. The effect of active disposal cell has not been tested in this report and may be analyzed in the future. These results support the finding that sediment discharge at the CDF impacts PCB levels at the disposal site (south station) but not at the high school or all CDF stations.

Season

Table 4 compares PCB concentrations between summer, winter, and spring/fall seasons. With temperature effects removed from the dataset, Total PCBs and most PCBs show no significant differences between seasons. PCB 8 is higher in winter than spring/fall, and PCB 15 is higher in both summer and winter than spring/fall. In future reports, spring/fall can potentially be separated to further examine seasonality in terms of seasonal wind direction or source emission effects.

Monitoring stations

Table 5 compares PCB concentrations between monitoring stations. All PCBs are statistically less at the high school than any of the CDF stations. Among the CDF stations, PCBs are generally highest at the south and north stations and lower at the east and west stations. Differences are explored further in Table 6 considering active dredging data (three events between October 2012 and December 2014), idle quiescent pond data (inactive periods between October 2012 and December 2014), and pre-dredging background data (January 2010 through October 2012). Note that smaller number of samples (n = 25, 60, and 80 for active discharge, idle quiescent pond, and pre-dredging background respectively) may limit the power of the test. Because the east, north and west stations began operating once dredging commenced in October 2012, only high school and south stations are compared for the pre-dredging background phase.

Active/Discharge

During sediment discharge into the CDF, all PCB levels are similar among CDF monitoring stations, and levels at the CDF stations are statistically higher than levels at the high school (Table 6). This finding supports the hypothesis that dredging and disposal affects atmospheric concentrations near the CDF more than near the high school.

Idle/Quiescent pond

During idle quiescent pond conditions, all PCBS are also statistically higher at CDF stations than at the high school (Table 6). Among CDF stations, higher levels are generally found at the south and north stations than the east and west stations. Currently there is no explanation for this finding, but it may be investigated further with wind and source information in the future.

Pre-dredging/Background

Most pre-dredging background PCB concentrations are statistically higher at the south station than the high school station. The only exception is PCB 8 with levels that are similar. Thus the newly observed trend of higher PCB 8 concentrations at the CDF than the high school during post-dredging (discharge and quiescent pond) may be due to dredged material disposal activities and/or sediment storage at the CDF site. The trend for other PCBs (higher levels at the CDF than the high school) remains consistent between pre-dredging and post-dredging periods.

In conclusion, PCB levels at the high school are statistically less than levels at the CDF during post-dredging and pre-dredging periods. There is no evidence to suggest CDF activities are significantly impacting the high school. Higher concentrations of PCBs at the CDF site are attributed to known concentrations of PCBs in the adjacent canal sediment and water column, as well as sediment placement and storage in the CDF.

Dredging activity

Table 7 compares PCB levels between pre-dredging background, active discharge, and idle quiescent pond data. All PCBs are statistically greater during active discharge than during background phase. All PCBs are also statistically greater during quiescent pond periods than background phase, except for PCB 8 which is no different. Finally, all PCBs are statistically higher during active discharge than quiescent pond period. PCB concentrations increase post-dredging and as CDF activities intensify. These results confirm that dredging activities have an effect on PCB concentrations. Differences between activity are examined further in Table 7 considering monitoring station. Note that only discharge and quiescent pond periods are compared at the east, north, and west stations due to background data size limitations.

High school

PCB 8 levels are statistically lower during the quiescent pond period than during the background phase at the high school, consistent with the decreasing trend of PCB 8 with time (Table 3). This trend over time is independent of the CDF and dredging activities. Other PCB levels are similar between background, discharge, and quiescent pond periods at the high school. Thus dredging activities have no significant effect on concentrations at the high school.

South

Similar to the site-combined results, PCB levels at the south station are higher during active discharge than quiescent pond periods, and greater during quiescent pond periods than the background phase (except for PCB 8 which is no different). Thus PCB concentrations increase at the south station as CDF activities intensify.

East, north, and west

PCBs at the east station (similar to the south) are statistically higher during active discharge than quiescent ponding (except for 15 which is no different). PCB levels are no different at north and west stations, except for PCB 8, PCB 15 (north) and PCB 18 (west) which are statistically higher during discharge periods than quiescent pond periods. The effect on PCBs from active discharge and quiescent pond conditions differs among monitoring stations.

In conclusion, PCB levels at the south station and CDF overall increase with intensity of sediment disposal and storage activities (active discharge > idle quiescent pond > pre-dredging background). In contrast, post-dredging activities show no effect on PCB levels at the high school (active discharge = idle quiescent pond = pre-dredging background). This lack of significant differences between pre- and post-dredging concentrations at the high school coupled with higher PCB post-dredging concentrations at the south station suggest that CDF activities have not impacted the atmospheric PCB conditions off-site at the high school, though sediment disposal and sediment storage have distinct effects on the local CDF air-shed.

PAH Analysis

Atmospheric PAH concentrations vary over an order of magnitude over the entire monitoring period (Figures 7-13). Table 1 shows naphthalene (Nap) composes over half the PAH load (median concentration of 50.15 ng/m^3) followed in decreasing order by phenanthrene (Phe), acenaphthene (Ace), fluorene (Flo), fluoranthene (Fla), pyrene (Pyr), and acenaphthylene (Acy). All PAHs exhibit a cyclical pattern similar to PCBs, except for Acy which exhibits a negative relationship with temperature (higher in cooler temperatures and lower in warmer temperatures) and Nap which exhibits no temperature relationship (Figures 7-13). Thus only Ace, Fla, Flo, Phe, and Pyr are temperature-corrected. Table 2 shows that measured Ace, Fla, Flo, Phe, and Pyr concentrations are positively correlated (Spearman correlation coefficients ranging from 0.720 to 0.955) while Acy and Nap do not correlate highly with any PAHs. These results suggest Acy and Nap are emitted from different sources (without the same temperature-dependence) than other PAHs.

Trend Analysis

Table 3 presents results from a linear regression analysis of PAH concentrations over time. Over the entire sampling period, Acy, Flo, Nap and Phe levels decrease statistically with time while Ace, Fla and Pyr levels show no significant trend. In contrast, no PAHs exhibit a decreasing trend and Fla, Nap, and Pyr levels increase statistically from 2010 through 2014. These trends are broken down further by site. Ace and Flo increase statistically at the south station but exhibit no trend at any other station. Acy exhibits no trend at any station. Fla and Pyr increase at all stations except for the high school. Nap exhibits no trend at the high school, south and west stations but increases at the east and north station. Phe decreases at the high school station, exhibits no trend at east and north stations, and increases at south and west station.

In summary, Ace, Flo, Fla, Phe, and Pyr levels increase over time (2010-2014) at the south station and some CDF stations, however no PAH levels increase (and Phe levels decreases) at the high school. This supports the finding that sediment discharge and storage activities impact PAH concentrations at the disposal site but have minor effect beyond the CDF. Because Acy and Nap levels do not increase at the south station or exhibit temperature-dependent behavior typical of volatile emissions, these PAHs are thought to be driven by sources outside the canal and CDF.

Season

Table 4 compares PAH concentrations between summer, winter, and spring/fall. Temperature-corrected PAHs generally do not show differences between seasons, however Fla, Phe, and Pyr exhibit statistically lower concentrations during spring/fall than winter or summer. Acy levels are higher in winter than spring/fall, and higher in spring/fall than summer. Future analysis with wind and/or source data may elucidate what seasonal or temporal events explain these patterns.

Monitoring stations

Table 5 compares PAH concentrations between monitoring stations. Ace is statistically higher at the south station than east, north, and west stations, and statistically higher at east station than north. Acy is only statistically different between the east and west station. Fla is higher at the high school than CDF stations, and higher at the south than the north station. Flo is higher at the south station than all other stations, higher at the high school and east stations than north and west stations, and higher at the north than west station. Nap is higher at the high school than south, north, and west stations, higher at the south station than the west station, and higher at the east station than the north and west stations. Phe is higher at the south station than all other stations, higher at the east station than the high school, north and west stations, and higher at the high school than north and west stations. Pyr is statistically higher at the south and east stations than the north, west, and high school stations, and north station is higher than west and high school stations.

In summary, PAH levels vary considerably by site. The lack of clear trends indicates PAHs are impacted by multiple sources unrelated to the CDF, or other confounding factors not identified in this report.

Active/Discharge

During sediment discharge into the CDF, Ace levels are higher at south stations than all other stations including the high school, and higher at the east than the north station (Table 6). Fla exhibits no difference between any monitoring stations including the high school. Flo and Phe are higher at the south station, are higher at the east station than high school, and show no different between the high school, north, and west stations, or between the east and north station. Nap levels are higher at the south than the north station and also higher at the east than west station, but are not statistically different among any other stations. Pyr levels are higher at all south, east, and north stations than the high school and exhibit no difference between the east and north stations and the south, north, and west stations.

In summary, during sediment discharge PAH concentrations are often higher at the south station than other stations and never higher at the high school or west station than other stations. These results indicate dredging activities may impact local atmospheric conditions at the disposal site more than at the high school.

Idle/Quiescent pond

During quiescent pond conditions, Ace levels are higher at the south station than all stations, but higher at the high school than the north and west stations (Table 6). Acy levels are higher at the south station compared to the west station. Fla levels are higher at the high school than all other stations, and higher at the south station than the east and north stations. Flo and Phe levels are higher at south stations than all others, higher at high school than the north and west stations, and higher at east station than the north station (as well as the west station for Phe). Nap levels are higher at the high school than the south and west stations, and higher at the east and north stations than the west station. Pyr levels are higher at south and east stations than all other stations, higher at the north station than the high school and west stations, and higher at the west station than the high school station.

In summary, a number of PAHs are higher at the south station than other stations during idle quiescent pond conditions, however Fla and Nap are higher at the high school than the south station, suggesting the quiescent pond may have less effect than active discharge on atmospheric concentrations.

Pre-dredging/Background

Prior to sediment dredging, disposal, and storage, all PAHs (except Acy which is no different) are statistically higher at the high school than the south station. This is in contrast to statistically higher Ace, Flo, Phe and Pyr levels post-dredging and similar Fla and Nap levels during active dredging. Thus sediment disposal activities and dredged material storage at the CDF have likely elevated the levels of these parameters near the CDF to levels comparable or higher than those at the high school. These findings further support that sediment disposal activities and/or sediment storage at the CDF site may have impacted the local atmospheric conditions of some PAHs at the site, but have not impacted atmospheric PAH concentrations at the high school. Unlike PCBs however, higher pre-dredging levels at the high school suggest additional significant sources of PAHs impact the high school more than the CDF.

Dredging activity

Table 7 compares PAH levels between pre-dredging background, active discharge, and idle quiescent pond data. Ace, Fla, Flo, and Pyr levels are greater during discharge periods than background phase, Fla and Pyr levels are greater during quiescent pond periods than background phase, and Ace and Flo levels are greater during discharge periods than quiescent pond periods. These results confirm that dredging activities have a localized effect on PAH concentrations near the CDF. Differences between activities are examined further in Table 7 considering monitoring station.

High school

All PAHs are similar between background, discharge, and quiescent pond periods at the high school. The lack of significant differences between the pre-dredging and post-dredging PAH concentrations at the high school suggest that sediment disposal and storage at the CDF have minimal impact on atmospheric PAH conditions off-site.

South

Ace, Fla, Flo, Phe, and Pyr levels are greater during active discharge and quiescent pond post-dredging periods than background phase at the south station. Ace and Flo levels are greater during discharge periods than quiescent pond periods as well (Table 7). These results indicate dredging activities affect concentrations at the south station significantly.

East, north, west

PAHs are statistically similar between active discharge and quiescent pond periods for east, north, and west monitoring stations (Table 7).

In summary, all PAHs (except Acy and Nap) are statistically higher during post-dredging than pre-dredging at the south station, while no PAHs are statistically different at the high school based on dredging activity. This is consistent with the finding that sediment placement and storage impacts CDF atmospheric conditions and not high school atmospheric conditions, and that Acy and Nap have different sources than the other PAHs.

VOC Analysis

Atmospheric concentrations of VOCs vary about an order of magnitude over the entire monitoring period (Figures 14-15). Benzene in particular appears higher during the early years of monitoring than later years, and has a higher proportion of non-detects from 2007 – 2014 than other periods (Figures 14-15). Values observed below non-detect replacement values for benzene and toluene from 2013 through 2014 indicate a change in the way VOC detection limits were reported due to a change in analytical laboratory in Fall 2013. Although the Clausius-Clapeyron analysis showed the VOCs exhibit some temperature dependence, a strong seasonal pattern is not as clear as with PCBs and many PAHs. Temperature-dependence was removed for subsequent analyses for data from February 2012 - 2014 when temperature data corresponding to VOC sampling times were generated. Thus analyses were run on two datasets for VOCs: non-temperature corrected data from January 2010 through 2014 and temperature-corrected data from February 2012 through 2014 (which includes less than a year of pre-dredging background data).

Table 1 shows toluene concentrations (median concentration of 1.19 ug/m^3) are about twice that of benzene (median concentrations of 0.66 ug/m^3). The VOC data are highly right-skewed due to numerous non-detects and long tails with outliers. Table 2 shows measured benzene and toluene concentrations are statistically correlated with a spearman correlation coefficient of 0.702. A correlation analysis by site (high school, south, east, north, and west) indicated only 19 out of 45 correlations (including benzene-toluene, benzene-benzene, and toluene-toluene comparisons) have coefficients over 0.7 (results not shown). Correlations including benzene at the high school, west, and south stations and toluene at the north and west stations were not always significant. These results indicate VOCs often behave differently at different stations and possibly come from different sources.

Trend Analysis

Table 3 presents results from a linear regression analysis of measured as well as temperature-corrected VOC concentrations over time. Over the entire sampling period, both benzene and toluene levels decrease statistically with time (actual data). Toluene continues this trend in recent years (2010-2014) however benzene shows no significant trend. With temperature-corrected data, both benzene and toluene show no trend from 2012-2014. At the high school, both VOCs decrease statistically with measured data but show no trend with temperature-corrected data. CDF stations exhibit no significant trend for benzene or toluene with both sets of data. Note that decreases observed with measured data may be due to numerous additional (pre-dredging) sample points or to a temperature effect which may mask the true long term trend, and imply that a temperature-sensitive source may be impacting the high school station only.

In summary, benzene and toluene do not increase over any time period at any station, and the high school is the only site with potentially decreasing VOC levels. There is no evidence to indicate that sediment disposal activities or the presence of dredged material at the CDF have impacted the atmospheric benzene and toluene concentrations at the CDF or the high school.

Season

Table 4 compares VOC concentrations between summer, winter, and spring/fall. A temperature-driven seasonal effect is clear with measured VOC concentrations that are higher in the summer than the spring/fall and higher in the spring/fall than the winter. Temperature-corrected toluene shows no difference between seasons, however benzene shows statistically lower levels in summer than in winter and spring/fall, perhaps related to a seasonal emission source.

Monitoring stations

Table 5 compares VOC concentrations between monitoring stations. Measured benzene levels are higher at the east station than the high school and west station but otherwise similar between all sites Temperature-corrected benzene levels are higher at the east station than all other stations, and levels at all CDF stations are higher than the high school. Relatively higher levels at the east station may be related to year-round groundwater discharge into the east cell, an activity that was not investigated in the current report but may be analyzed in the future. Measured toluene levels are higher at the high school than the south, north, and west stations, while temperature-corrected levels are higher at the east station than the high school. Levels are higher at the east station than the south, north, and west for both datasets. Because only comparisons with the high school change by dataset, it appears that toluene levels near the high school are temperature-dependant, while levels near CDF are temperature-independent (unrelated to temperature). Note that during active discharge and quiescent pond conditions the same data points are compared, thus only temperature-corrected results are discussed in the following two sections.

Active/Discharge

During sediment discharge to the CDF, Table 6 shows benzene levels are similar at all monitoring stations. Toluene levels are similar between the CDF stations and the high school while levels remain higher at the east station than other CDF stations.

In summary, benzene and toluene concentrations are not statistically different between the high school and CDF stations for the active discharge period.

Idle/Quiescent pond

During quiescent pond periods, benzene levels are higher at the east station than the high school and the north station, and higher at the south and west stations than at the high school (Table 6). Because these results indicate the quiescent pond impacts the CDF air-shed more than active discharge, it is thought sources other than sediment disposal may be responsible for these differences. Ongoing groundwater discharge to the east cell may also influence higher levels at the east station. Toluene levels at the east station remain higher than other CDF stations and are similar between CDF and high school sites.

In summary, benzene levels are statistically higher at the south station than the high school (in contrast to active discharge) and toluene levels are no different between the high school and south station (similar to active discharge).

Pre-dredging/Background

Pre-dredging temperature-corrected levels of benzene and toluene are statistically similar between the high school and south stations (note this is one year of data; 2012). Measured benzene levels are also not different, however measured toluene levels are higher at the high school than the south station.

In summary, the benzene pre-dredging trend (no difference between high school and south station) is similar to the active discharge trend, however an increase at the south station compared to the high school appears during quiescent pond phase that may be explained by additional urban or industrial sources of benzene or onsite disposal of groundwater into the south side of the east cell. The temperature-corrected toluene pre-dredging trend (no difference between high school and south station) is similar to the post-dredging trends, while the measured toluene pre-dredging trend (levels greater at the high school than the south station) is similar to the quiescent pond trend but disappears during active discharge, possibly due to CDF activity during that period.

Dredging Activity

Table 7 compares VOC levels between pre-dredging background, active discharge, and idle quiescent pond data. Temperature-corrected benzene and toluene levels are higher during sediment discharge and quiescent pond periods than background, while measured benzene and toluene levels show no difference between pre- and post-dredging. Temperature-corrected benzene and toluene levels are not different between active sediment discharge and idle quiescent pond periods, however measured toluene levels are higher during active discharge (note that dredging activities occur in warmer weather).

High school

At the high school, there are no significant differences in benzene levels and toluene levels between background, discharge, and quiescent pond periods. Thus dredging activities show no effect on VOC concentrations at the high school.

South

At the south station, there are also no significant differences in VOC levels between background, discharge, and quiescent pond periods. Thus sediment disposal and storage activities show no impact on benzene or toluene concentrations at the CDF station.

East, north, west

VOCs are statistically similar between active discharge and quiescent pond periods for east, north, and west monitoring stations (Table 7).

In summary, benzene and toluene levels are not statistically different at any site between background, discharge, and quiescent pond periods. This lack of difference at all sites suggests that sediment disposal activities and dredged material storage at the CDF have not impacted the atmospheric benzene and toluene conditions at the CDF or at the high school. This result is consistent with monitoring station results that suggest the CDF has less influence on VOC levels than other background sources. However, results considering all sites together indicate higher post-dredging levels than pre-dredging levels, indicating that there may be an effect revealed by improved statistical power. This trend will be revisited in future reports with additional data and by combining active discharge and quiescent pond into a larger post-dredging analysis.

TSP Analysis

Atmospheric concentrations of Total Suspended Particulates (TSP) vary in level and pattern (Figure 16). Total Suspended Particulates exhibit slightly cyclical behavior. While not dependent on temperature-controlled volatilization and thus not temperature corrected, TSP may still follow a seasonal trend likely due to drying and wind conditions. The median TSP value is 4.03 g/m^3 (Table 1).

Trend Analysis

Table 3 presents results from a linear regression analysis of TSP concentrations over time. Over the entire sampling period as well as the recent sampling period, TSP decrease statistically with time. When broken down further by site, TSP decreases at the high school and south station but exhibits no trend at the north, east and west stations. Unlike PAHs and PCBs, TSP behaves similarly at the south station and the high school, indicating influence by the same regional sources. Because TSP concentrations decrease at the south station, its long term behavior is not likely related to the canal and post-dredging activities.

Season

Table 4 compares TSP concentrations between summer, winter, and spring/fall. Although not subject to temperature-controlled volatilization, TSP exhibits seasonal atmospheric behavior and is statistically higher in the summer than in the spring/fall and higher in the spring/fall than in the winter. This seasonality may be related to precipitation, drying, freezing, or wind conditions that have not been examined in this report.

Monitoring stations

Table 5 compares TSP concentrations between monitoring stations. TSP concentrations are higher at the east and north stations than at the high school, and higher at the north station than at the west station.

Active/Discharge

During sediment offloading and placement into the CDF, TSP concentrations at the south station are higher than at the high school and west station (Table 6). The relationship of TSP to sediment discharge is investigated further in the Dredging Activity section below. Because offloading mostly occurs during summer months, the higher levels during offloading may also be related to seasonal effects discussed above.

Idle/Quiescent pond

During sediment storage quiescent pond periods, TSP is no longer different between the south and high school and west stations (Table 6). Sediment storage does not affect TSP levels at the monitoring sites differently.

Pre-dredging/Background

TSP levels are statistically higher at the high school station than south station during pre-dredging (Table 6). This result reverses during post-dredging, with lower levels of TSP at the high school. Thus there may be a dredging effect on TSP levels because levels at the south station become elevated compared to the high school from pre-dredging to post-dredging periods (high school is higher during background, high school and south station are the same during quiescent pond, and south station is higher during dredging).

Dredging activity

Table 7 compares TSP concentrations between pre-dredging background, active discharge, and idle quiescent pond periods. TSP levels are lower under quiescent pond conditions than pre-dredging and active discharge conditions. Because levels are statistically no different between the discharge and pre-dredging period (and statistically less during quiescent pond period than pre-dredging period), it appears that TSP is not significantly impacted by sediment disposal. These results are in contrast to PCBs, PAHs, and VOCs.

High school

At the high school, TSP is always greater pre-dredging than post-dredging, suggesting no effects from dredging activities on TSP levels at the high school.

South

At the south station, TSP levels are less under quiescent pond conditions than active discharge or pre-dredging conditions. Because TSP levels during post-dredging activities are statistically less than or similar to pre-dredging period, sediment disposal does not significantly impact concentrations at the south station.

East, north, west

TSP concentrations between post-dredging activities (quiescent pond and active discharge periods) are not significantly different at the east, north, and west stations.

Conclusions

The air monitoring data presented were statistically analyzed based on location and by pre-dredging (background) and quiescent pond and active discharge post-dredging periods. Tables present the data and statistical significance. The following conclusions summarize the main findings from the analysis.

PCBs

- All PCB congener concentrations during post-dredging are statistically lower at the high school than the CDF (south, east, north, and west) stations. This is consistent with pre-dredging results where the high school concentrations are also statistically lower than the south station concentrations (except for PCB 8 which was no different between the two locations during the background period). During active discharge, concentrations at the CDF stations are similar, however during quiescent pond periods concentrations at the south and north station are generally greater than at the east and west stations.
- Post-dredging PCB congeners 15, 18, 28, 31, and Total PCB concentration (all but PCB 8 which was no different) were statistically higher than pre-dredging concentrations at the CDF. Concentrations during active discharge were also higher than concentrations during quiescent pond for all PCBs. Active discharge is related to higher levels compared to quiescent pond for the east station as well, but most PCBs do not show a difference for north and west station.
- Pre-dredging and post-dredging PCB data are not statistically different at the high school, except for PCB congener 8 which was statistically lower for the quiescent pond period than the pre-dredging/background period. There are also no differences between active discharge and quiescent pond periods.
- Temporal analysis of Total PCBs at the high school (2010-2014, including pre-dredging and post-dredging data) identifies a statistically significant decreasing over time driven by PCB 8. All PCBs decrease statistically at the east station. Total PCBs at the south station statistically increase over this time period driven by PCB 18 28, and 31.
- These findings suggest that dredged material disposal activities and the presence of dredged material at the CDF may have impacted (increased) the atmospheric PCB conditions at the CDF site, but have not impacted the atmospheric PCB conditions at the high school. A source affecting the east station may be decreasing over time, including sediment disposal into the east cell.

PAHs

- Many PAHs (Ace, Flo, Phe, and Pyr) are statistically higher at the south station than the high school during active sediment discharge in contrast to pre-dredging data, where all PAHs except Acy are statistically higher at the high school than the south station. Ace, Flo, Phe, and Pyr remain higher at the south station during quiescent pond periods, but Fla and Nap become higher at the high school consistent with pre-dredging trends. Thus Ace, Flo, Phe, and Pyr post-dredging trends and Fla and Nap discharge trends are attributed to sediment disposal activities and/or sediment storage at the CDF.
- South station post-dredging Ace, Fla, Flo, Phe, and Pyr concentrations are statistically higher than pre-dredging concentrations (Acy and Nap are no different). Ace and Flo are also statistically higher during active discharge than quiescent pond periods at the south station, however no PAHs differed at the east, north, and west stations between discharge and quiescent pond periods.
- PAHs are not statistically different between the pre- and post-dredging periods, or between the discharge and quiescent pond periods, at the high school.
- Temporal analysis shows no PAHs statistically increase at the high school (in fact Phe decreases), however all PAHs except Nap and Acy increase statistically at the south station from 2010-2014. Fla and Pyr increase statistically at all CDF stations; Nap increases only at the east and north.
- These findings suggest that dredged material disposal activities and the presence of dredged material at the CDF impact (increase) the localized atmospheric conditions of some PAHs at the CDF site (Ace, Fla, Flo, Phe and Pyr) but do not impact the atmospheric PAH conditions at the high school. The data suggest that Acy and Nap (though increasing) are not influenced heavily by the CDF, and that Fla may also have a significant external source.

VOCs

- Temperature-corrected benzene and toluene data are statistically similar between the south station and the high school during the active discharge, consistent with pre-dredging trends. Benzene concentrations do not differ between any locations during active discharge, while toluene is higher only at the east station than the other CDF stations. During the quiescent pond period, benzene is higher at the south station (as well as the east and north) than the high school, while toluene is again higher at the east than other CDF stations.
- Temperature-corrected benzene and toluene data are not statistically different between the pre-dredging and post-dredging (discharge or quiescent pond) periods at the south station. VOC concentrations are also no different between active discharge and quiescent pond periods at any stations. Additional data are needed to confirm these trends in the future.
- Temperature-corrected benzene and toluene data are not statistically different between the pre-dredging and discharge or quiescent pond periods at the high school.
- Temperature-corrected benzene and toluene concentrations do not exhibit an increasing or decreasing long term trend from 2012-2014 at any station.

- These findings suggest that sediment disposal and storage at the CDF do not significantly impact atmospheric benzene and toluene concentrations at the CDF or at the high school.

Total Suspended Particulates (TSP)

- TSP concentrations at the south station are higher than the high school during discharge, similar to the high school during quiescent pond, and lower than the high school during pre-dredging.
- South station TSP concentrations are higher during the pre-dredging phase than quiescent pond period, and higher during active discharge than quiescent pond period.
- At the high school, TSP concentrations are statistically higher during pre-dredging period than active discharge, and higher during pre-dredging than quiescent pond period.
- TSP decreases over time at the high school and at the south station.
- These findings suggest that dredging activities do not drive atmospheric TSP concentrations at the high school or south station, mainly because TSP levels do not increase during sediment placement or storage compared to pre-dredging.

Future Analysis

The air monitoring program is continuing at the four CDF monitors and the high school monitor at a rate of one sample per monitor every 12 days during the non-dredging period, and one sample per monitor every 6 days during the dredging/dredged material disposal period. The data will be re-evaluated on an annual basis to re-assess the currently observed trends.

As additional post-dredging data are generated, future reporting can potentially include the following to improve the quality of the data and analysis:

- Metals 2014 data are currently under review and will be presented along with the 2015 data in next year's annual report.
- Reevaluate the handling of non-detects and account for the most current detection limit information. Replacement values of half the detection limit should be considered to estimate censored data more accurately. While most compounds are less than 15% non-detect and can be handled using a non-detect replacement method, more highly censored data (Fluoranthene (17%), Pyrene (28%), Toluene (34%), PCB 15 (39%), Nickel (41%), Benzene (55%), Arsenic (56%), Selenium (58%), Acenaphthylene (76%), and Cobalt (76%)) may require other methods. A high percentage of non-detects reduces data quality and certainty in results.
- Outliers can be identified and removed in future analyses.
- Temperature-corrected VOC concentrations from January 2010 through February 2012 can be calculated by obtaining temperature data concurrent with VOC sampling times.
- Additional 13 PCB congeners (analyzed since 2011) can be evaluated in future reports.
- Correlation analyses can be performed by individual site in addition to all sites combined.
- The linear regression long-term temporal analysis can be improved by including slope parameters and coefficients of determination to calculate half-lives and further describe

increasing or decreasing trends; also consider using different models and statistical tests for temporal analysis.

- Spring can be separated from fall to identify seasonal variation more precisely.
- Active discharge and quiescent pond data can be analyzed together as a larger post-dredging dataset to improve the power of statistical tests. Similarly, south, east, north and west stations can be combined and analyzed as a larger CDF dataset.
- Assess the effect of wind on individual site pre-dredging and post-dredging data by modeling the effect of wind direction on concentrations (also by performing correlations between concentration and wind data) to investigate potential emissions from the CDF (and outside sources).
- A source apportionment analysis (Principal Component Analysis, etc) performed with post-dredging data (or possibly site-specific data) could be used to identify and quantify sources of contaminants from the region and further determine the role of sediment discharge and storage on atmospheric contaminant concentrations.
- Assess the effect of specific sediment discharge location: east versus west pond, as well as specific discharge pipe along the dredge discharge pipe manifold.
- Assess the effect of groundwater discharge in the east cell, specifically on parameters that are more associated with groundwater than with the sediment (i.e., benzene).

References

USACE 2003a. Indiana Harbor and Canal Dredging and Disposal Project. Ambient Air Monitoring Plan, Volume 1. USACE Chicago District, October 2003.

USACE 2003b. Indiana Harbor and Canal Air Monitoring: Background Phase Ambient Summary & Construction Phase Ambient Air Monitoring Program, USACE Chicago District, November 2003.

USACE 2005. Indiana Harbor and Canal Ambient Air Monitoring Program: Construction Phase Annual Report 2004, USACE Chicago District, June 2005.

USACE 2006. Indiana Harbor and Canal Ambient Air Monitoring Program: Construction Phase Annual Report 2005, USACE Chicago District, June 2006.

USACE 2007. Indiana Harbor and Canal Ambient Air Monitoring Program: Construction Phase Annual Report 2006, USACE Chicago District, July 2007.

USACE 2008. Indiana Harbor and Canal Ambient Air Monitoring Program: Construction Phase Annual Report 2007, USACE Chicago District, July 2008.

USACE 2009. Indiana Harbor and Canal Ambient Air Monitoring Program: Construction Phase Annual Report 2008, USACE Chicago District, September 2009.

USACE 2010. Indiana Harbor and Canal Ambient Air Monitoring Program: Construction Phase Annual Report 2009, USACE Chicago District, June 2010.

USACE 2011. Indiana Harbor and Canal Ambient Air Monitoring Program: Construction Phase Annual Report 2010, USACE Chicago District, July 2011.

USACE 2012. Indiana Harbor and Canal Ambient Air Monitoring Program: Construction Phase Annual Report 2011, USACE Chicago District, July 2012.

USACE 2013. Indiana Harbor and Canal Ambient Air Monitoring Program: Construction Phase Annual Report 2012, USACE Chicago District, April 2013.

USACE 2014. Indiana Harbor and Canal Ambient Air Monitoring Program: Construction Phase Annual Report 2013, USACE Chicago District, July 2014.

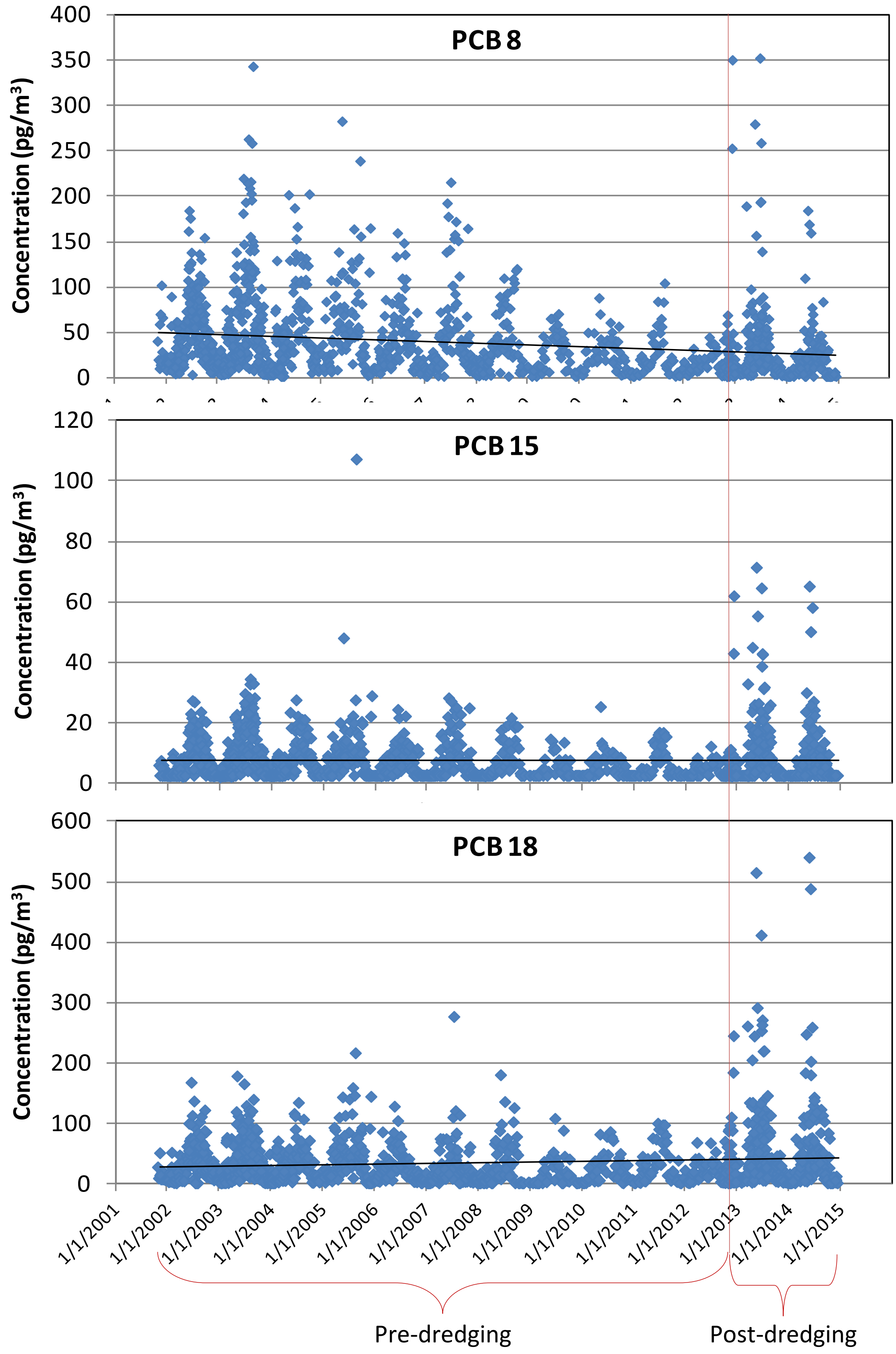

Figure 1 - 3. Atmospheric concentrations of PCB 8, PCB 15, and PCB 18 (pg/m^3) from all stations over the entire monitoring period.

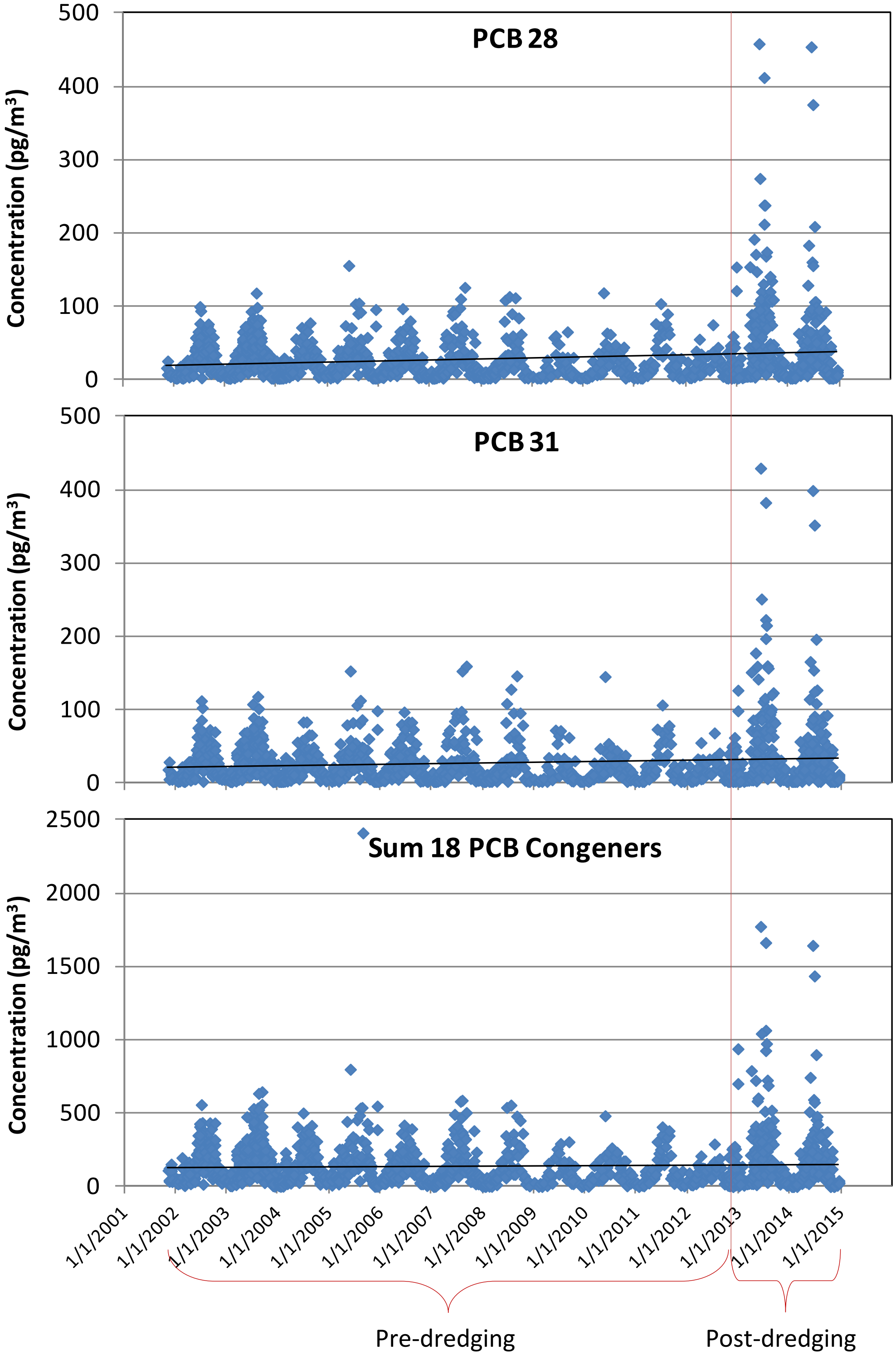

Figure 4 - 6. Atmospheric concentrations of PCB 28, PCB 31, and Σ_{18} PCB congeners (pg/m^3) from all stations over the entire monitoring period. One outlier is not shown for PCB 28 (928.75 pg/m^3) and one for PCB 31 (551.44 pg/m^3) on 9/1/05 at the south station.

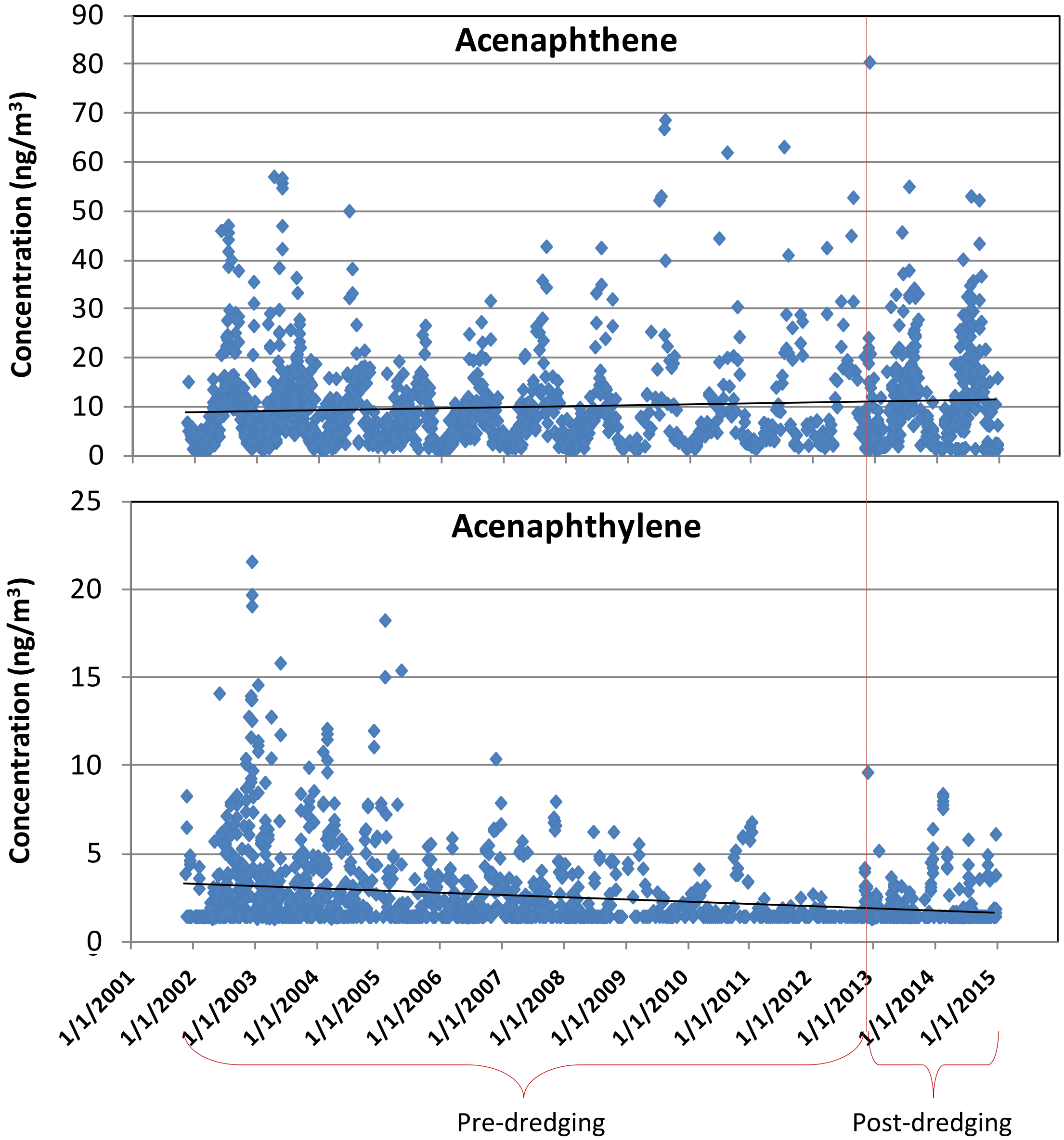

Figure 7 - 8. Atmospheric concentrations of acenaphthene and acenaphthylene (ng/m^3) from all stations over the entire monitoring period.

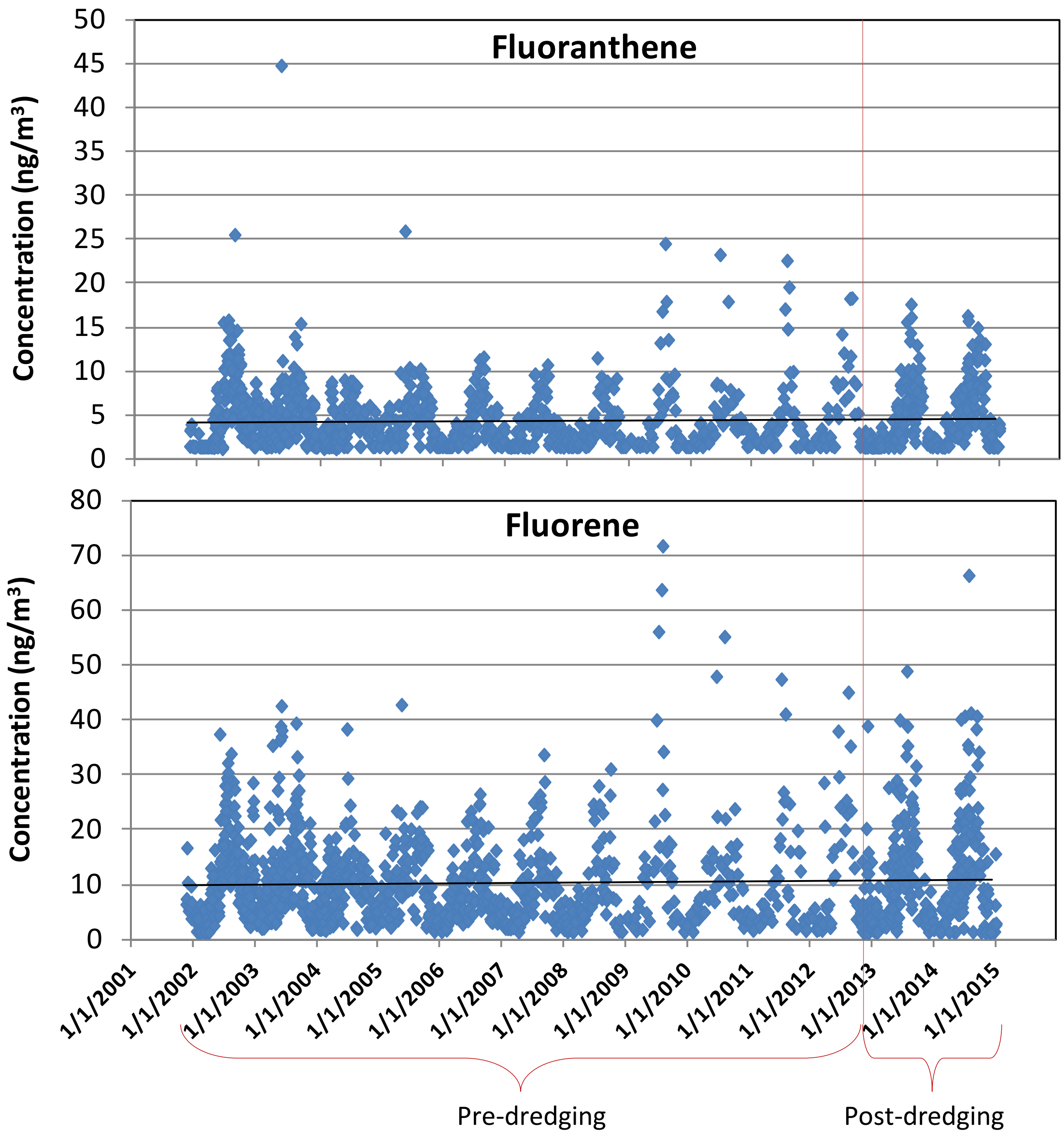

Figure 9 - 10. Atmospheric concentrations of fluoranthene and fluorene (ng/m^3) from all stations over the entire monitoring period.

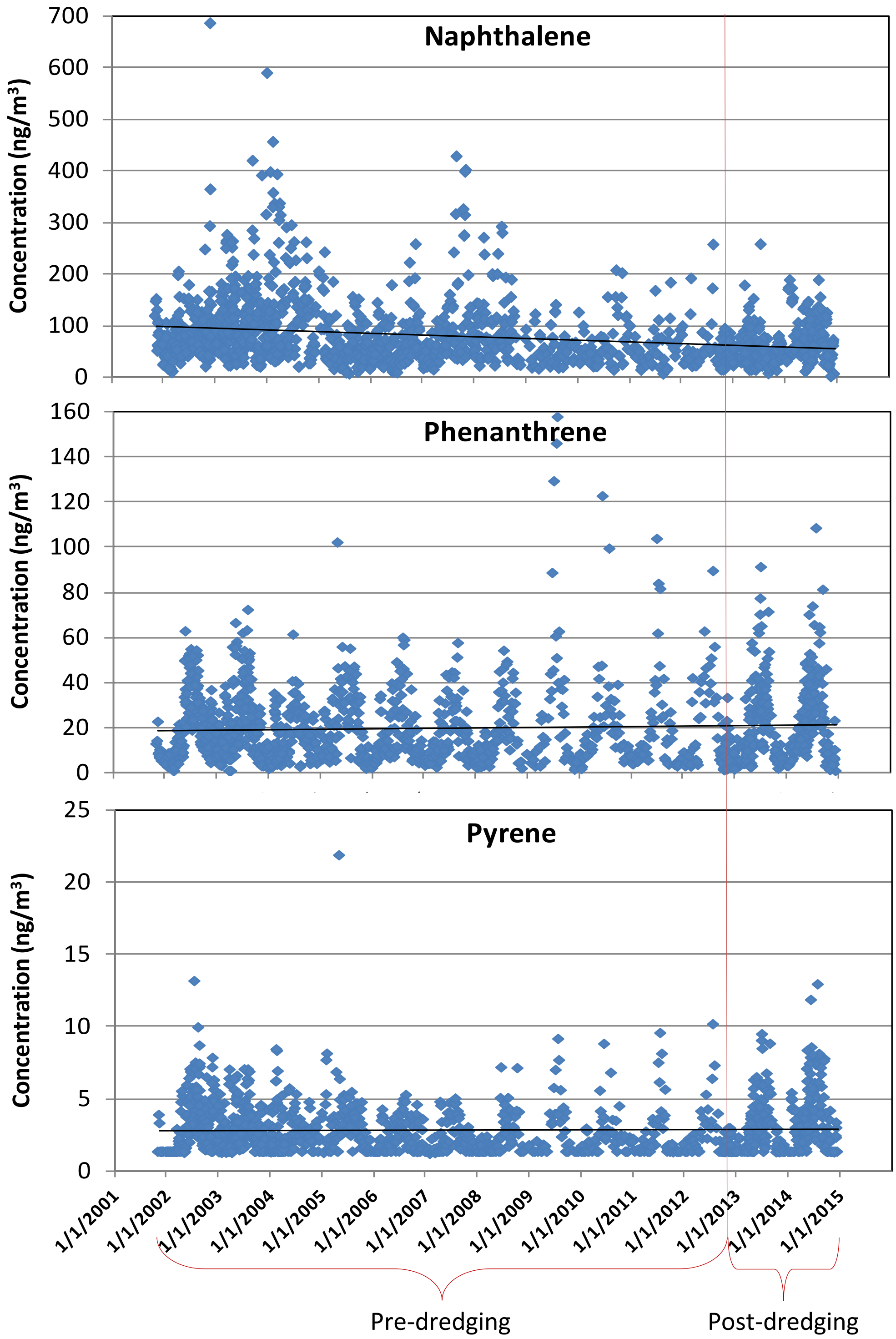

Figure 11 - 13. Atmospheric concentrations of naphthalene, phenanthrene, and pyrene (ng/m^3) from all stations over the entire monitoring period.

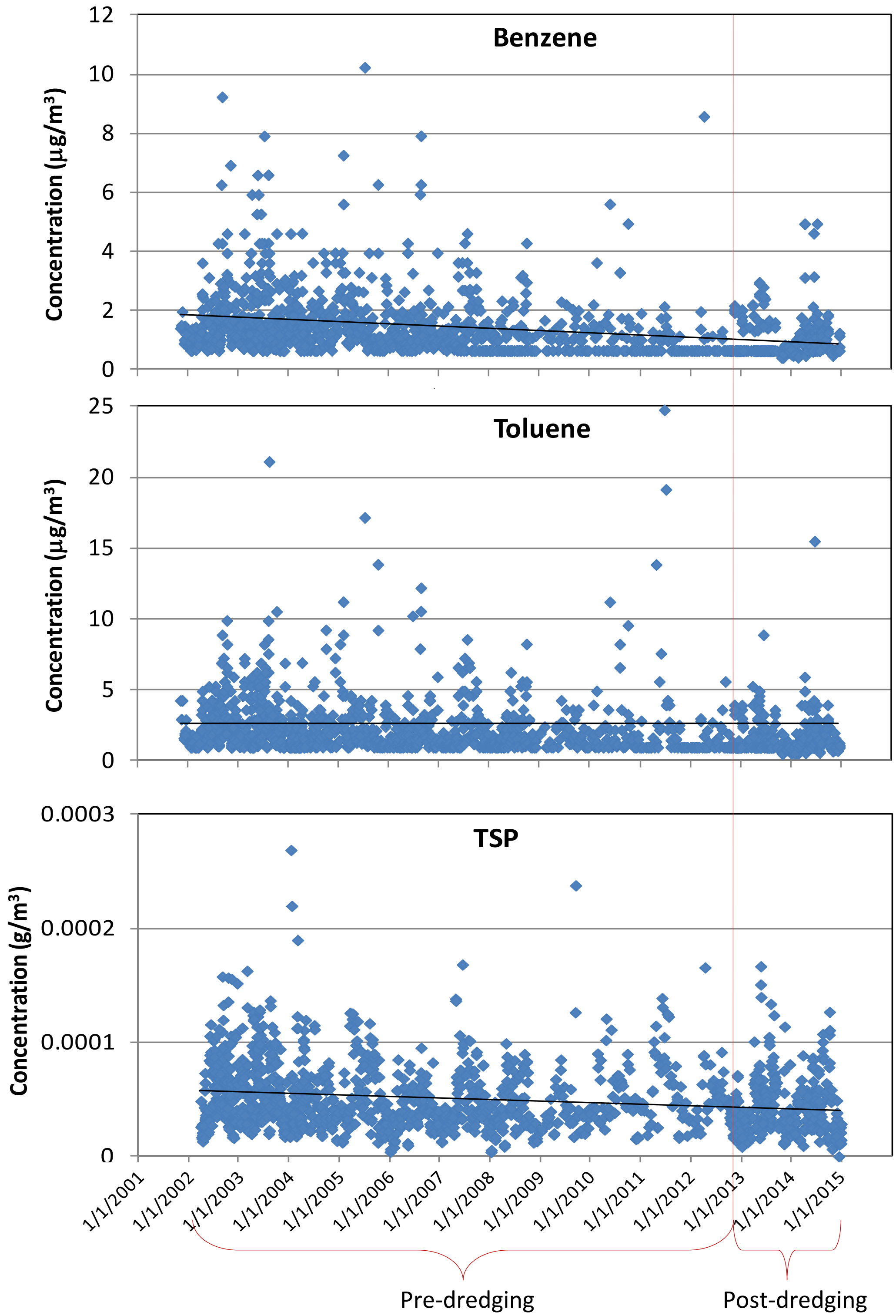

Figure 14 - 16. Atmospheric concentrations of benzene (µg/m³), toluene (µg/m³), and Total Suspended Particulates (g/m³) from all stations over the entire monitoring period. Two outliers are not shown for benzene on 8/13/03 at the north station and 4/27/11 at the south station, and for toluene on 6/14/11 and 6/26/11 at the high school.

Table 1. Statistical description of measured PCB (pg/m^3), PAH (ng/m^3), VOC (ug/m3), and TSP (g/m3) concentrations[a] at all sites from 2010 - 2014.

	No. of Cases	Minimum	Maximum	Interquartile Range	Median	Arithmetic Mean	SEM	SD	Skewness
PCB 8	551	2.56	353.37	22.94	16.56	26.44	1.60	37.54	4.9
PCB 15	552	2.58	71.60	5.88	4.19	7.70	0.38	8.95	3.7
PCB 18	552	2.85	540.87	42.13	22.44	42.28	2.58	60.59	4.1
PCB 28	552	2.76	458.26	34.75	19.44	35.51	2.18	51.23	4.3
PCB 31	552	2.62	429.61	32.15	16.88	32.26	2.01	47.28	4.3
Σ_{18}PCB	552	2.56	1774.01	153.23	80.86	146.43	8.68	203.97	4.0
Ace	553	1.30	80.48	11.89	7.87	11.35	0.45	10.66	2.0
Acy	553	1.29	9.61	0.24	1.43	1.89	0.05	1.14	3.5
Fla	553	1.37	23.26	4.33	3.19	4.48	0.15	3.58	1.8
Flo	551	1.28	66.34	11.42	7.41	10.70	0.41	9.67	1.8
Nap	553	1.43	257.66	41.93	50.15	59.43	1.65	38.69	1.6
Phe	553	1.43	123.16	21.44	13.55	20.37	0.77	18.15	1.9
Pyr	553	1.39	13.02	2.29	2.23	2.91	0.08	1.87	1.8
Benz	539	0.43	20.15	0.40	0.66	1.02	0.05	1.10	11.0
Tol	539	0.53	429.49	1.02	1.19	3.05	0.88	20.34	18.7
TSP	529	2.4E7	1.67E4	3.08E5	4.03E5	4.52E5	1.13E6	2.60E5	1.4

[a] Data are original (have not been corrected or transformed).

Table 2. Spearman correlation coefficients[a] between PCB (upper right), PAH (bottom left), and VOC (below) concentrations[b] at all sites from 2010 - 2014.

	8	**15**	**18**	**28**	**31**	**Σ_{18} PCBs**	
		0.855	0.862	0.884	0.891	0.922	**8**
Ace			0.871	0.905	0.904	0.916	**15**
Acy	0.081			0.971	0.959	0.979	**18**
Fla	0.769	0.015			0.981	0.990	**28**
Flo	0.955	0.074	0.825			0.985	**31**
Nap	0.447	0.447	0.343	0.433			**Σ_{18} PCBs**
Phe	0.875	0.005	0.923	0.926	0.368		
Pyr	0.720	0.106	0.908	0.779	0.376	0.867	
	Ace	**Acy**	**Fla**	**Flo**	**Nap**	**Phe**	

	Toluene
Benzene	0.702

[a] All correlations are significant at the 95% confidence level except for Acy with Ace, Fla, Flo, and Phe. [b] All data are measured (not corrected) and all data are ln-transformed.

Table 3. Statistically significant trends[a] of atmospheric PCB, PAH, VOC, and TSP[b] concentrations over time and by site. 'I' indicates a significant increase, 'D' indicates a significant decrease, and '-' indicates no significant trend.

	All sites 2001-2014	**All sites 2010-2014**	**H 2010-2014**	**S 2010-2014**	**E 2010-2014**	**N 2010-2014**	**W 2010-2014**
PCB 8	D	-	D	-	D	-	-
PCB 15	D	D	-	-	D	-	-
PCB 18	-	I	-	I	D	-	-
PCB 28	-	I	-	I	D	-	-
PCB 31	-	I	-	I	D	-	-
Σ_5PCBs	D	-	D	I	D	-	-
Ace	-	-	-	I	-	-	-
Acy[b]	D	-	-	-	-	-	-
Fla	-	I	-	I	I	I	I
Flo	D	-	-	I	-	-	-
Nap[b]	D	I	-	-	I	I	-
Phe	D	-	D	I	-	-	I
Pyr	-	I	-	I	I	I	I
Benz[c]	D	- -	D -	- -	- -	- -	- -
Tol[c]	D	D -	D -	- -	- -	- -	- -
TSP[b]	D	D	D	D	-	-	-

[a] Linear regression analysis with t-test performed at the 5% significance level to determine if slope parameter is equal to zero (no trend) versus increasing (significant positive slope) or decreasing (significant negative slope). [b]All data except Acy, Nap, and TSP are temperature-corrected and all data are ln-transformed. When two results are shown for Benzene and Toluene, the first is from non-temperature-corrected data, the second is from temperature-corrected data dated February 2012 – December 2014.

Table 4. Two-sample two-tailed *t*-test for significant differences[a] in PCBs, PAHs, VOCs, and TSP[b] concentrations between seasons from 2010-2014.

	Sum-Win	**Sum-Sp/F**	**Win-Sp/F**
PCB 8	-	-	>
PCB 15	-	>	>
PCB 18	-	-	-
PCB 28	-	-	-
PCB 31	-	-	-
Σ_5PCBs	-	-	-
Ace	-	-	-
Acy	<	<	>
Fla	-	>	>
Flo	-	-	-
Nap	-	-	-
Phe	-	>	>
Pyr	-	>	>
Benz	> <	> <	> -
Tol	> -	> -	> -
TSP	>	>	<

[a] > indicates greater than, < indicates less than, and - indicates no significant difference using a significance level of 5%. [b] All data except Acy, Nap, and TSP are temperature-corrected and all data have been ln-transformed. Two results are shown for Benzene and Toluene: the first is from non-temperature-corrected data, the second is from temperature corrected data dated February 2012 – December 2014.

Table 5. Paired two-tailed *t*-test for significant differences[a] in PCBs, PAHs, VOCs, and TSP[b] concentrations between monitoring stations from 2010-2014.

	H-S	H-E	H-N	H-W	S-E	S-N	S-W	E-N	E-W	N-W
PCB 8	<	<	<	<	>	>	>	-	-	-
PCB 15	<	<	<	<	>	-	-	<	-	>
PCB 18	<	<	<	<	>	-	>	<	-	>
PCB 28	<	<	<	<	>	-	>	-	-	-
PCB 31	<	<	<	<	>	-	>	-	-	-
Σ_5PCBs	<	<	<	<	>	-	>	<	-	-
Ace	-	-	-	-	>	>	>	>	-	-
Acy	-	-	-	-	-	-	-	-	>	-
Fla	>	>	>	>	-	>	-	-	-	-
Flo	<	-	>	>	>	>	>	>	>	>
Nap	>	-	>	>	-	-	>	>	>	-
Phe	<	<	>	>	>	>	>	>	>	-
Pyr	<	<	<	-	-	>	>	>	>	>
Benz	- <	< <	- <	- <	- <	- -	- -	- >	> >	- -
Tol	> -	- <	> -	> -	< <	- -	- -	> >	> >	- -
TSP	-	<	<	-	-	-	-	-	-	>

[a] > indicates greater than, < indicates less than, and - indicates no significant difference using a significance level of 5%. [b] All data except Acy, Nap, and TSP are temperature-corrected and all data have been ln-transformed. Two results are shown for Benzene and Toluene: the first is from non-temperature-corrected data, the second is from temperature corrected data dated February 2012 – December 2014.

Table 6. Paired *t*-test or Wilcoxon test for significant differences[a] in PCBs, PAHs, VOCs, and TSP[b] concentrations among monitoring stations for Discharge, Quiescent Pond, and Background data between 2010-2014.

	Discharge										Quiescent Pond										Background
	H-S	**H-E**	**H-N**	**H-W**	**S-E**	**S-N**	**S-W**	**E-N**	**E-W**	**N-W**	**H-S**	**H-E**	**H-N**	**H-W**	**S-E**	**S-N**	**S-W**	**E-N**	**E-W**	**N-W**	**H-S**
PCB 8	<	<	<	<	-	-	-	-	-	-	<	<	<	<	>	-	>	-	-	-	-
PCB 15	<	<	<	<	-	-	-	-	-	-	<	<	<	<	>	-	-	<	-	>	<
PCB 18	<	<	<	<	-	-	-	-	-	-	<	<	<	<	>	-	>	<	-	>	<
PCB 28	<	<	<	<	-	-	-	-	-	-	<	<	<	<	>	-	>	<	-	-	<
PCB 31	<	<	<	<	-	-	-	-	-	-	<	<	<	<	>	-	>	<	-	-	<
Σ_5PCBs	<	<	<	<	-	-	-	-	-	-	<	<	<	<	>	-	>	<	-	>	<
Ace	<	-	-	-	>	>	>	-	-	-	<	-	>	>	>	>	>	>	-	-	>
Acy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	>	-	-	-	-
Fla	-	-	-	-	-	-	-	-	-	-	>	>	>	>	>	>	-	-	-	<	>
Flo	<	<	-	-	>	>	>	-	>	-	<	-	>	>	>	>	>	>	-	-	>
Nap	-	-	-	-	-	>	-	-	>	-	>	-	-	>	-	-	-	-	>	>	>
Phe	<	<	-	-	>	>	>	-	>	-	<	-	>	>	>	>	>	>	>	-	>
Pyr	<	<	<	-	-	-	-	-	>	>	<	<	<	>	-	>	>	>	>	>	>
Benz	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- <	< <	- <	- -	- -	- -	- -	- >	> -	- -	- -
Tol	- -	- -	- -	- -	- <	- -	- -	> >	> >	- -	> -	- -	- -	- -	- <	- -	- -	> >	> >	- -	> -
TSP	<	<	<	-	-	-	>	-	-	>	-	<	<	-	-	-	-	-	-	-	>

[a] > indicates greater than, < indicates less than, and - indicates no significant difference using a significance level of 5%. [b] All data except Acy, Nap, and TSP are temperature-corrected and all data have been ln-transformed. Two results are shown for Benzene and Toluene: the first is from non-temperature-corrected data, the second is from temperature corrected data dated February 2012 – December 2014.

Table 7. Two-sample *t*-test for significant differences[a] in PCBs, PAHs, VOCs, TSP[b] concentrations between dredging activities (Background BG, Discharge D, Quiescent Pond QP) for all sites and by each monitoring station.

	All sites			High School			South			East	North	West
	D-BG	**QP-BG**	**D-QP**	**D-BG**	**QP-BG**	**D-QP**	**D-BG**	**QP-BG**	**D-QP**	**D-QP**	**D-QP**	**D-QP**
PCB 8	>	-	>	-	<	-	>	-	>	>	>	>
PCB 15	>	>	>	-	-	-	>	>	>	-	>	-
PCB 18	>	>	>	-	-	-	>	>	>	>	-	>
PCB 28	>	>	>	-	-	-	>	>	>	>	-	-
PCB 31	>	>	>	-	-	-	>	>	>	>	-	-
Σ_5PCBs	>	>	>	-	-	-	>	>	>	>	-	-
Ace	>	-	>	-	-	-	>	>	>	-	-	-
Acy	-	-	-	-	-	-	-	-	-	-	-	-
Fla	>	>	-	-	-	-	>	>	-	-	-	-
Flo	>	-	>	-	-	-	>	>	>	-	-	-
Nap	-	-	-	-	-	-	-	-	-	-	-	-
Phe	-	-	-	-	-	-	>	>	-	-	-	-
Pyr	>	>	-	-	-	-	>	>	-	-	-	-
Benz	- >	- >	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Tol	- >	- >	> -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TSP	-	<	>	<	<	-	-	<	>	-	-	-

[a] > indicates greater than, < indicates less than, and - indicates no significant difference using a significance level of 5%. [b] All data except Acy, Nap, and TSP are temperature-corrected and all data have been ln-transformed. Two results are shown for Benzene and Toluene: the first is from non-temperature-corrected data, the second is from temperature corrected data dated February 2012 – December 2014.