From:	Wortman, Santina
To:	Carpenter, Thomas
Subject:	WLEEM reports
Date:	Friday, December 05, 2014 3:38:35 PM

Tom,

In response to Dr. Connolly's request for Limnotech's WLEEM reports, Dr. Joseph DePinto provided two reports, which comprise the most current documentation of this model:

Development of an Integrated Modeling Approach for Quantifying the GLRI Deposition Metric
Pilot Application to Toledo Harbor
Final Report
Prepared for:
U.S. Army Corps of Engineers – Buffalo District

and -

Final Study Report
Influence of Open-Lake Placement of Dredged Material on Western Lake Erie Basin Harmful Algal Blooms
Contract No. W912P4-10-D-0002
August 2014
Prepared for:
UNITED STATES ARMY CORPS OF ENGINEERS
Buffalo District
Prepared by:
ECOLOGY AND ENVIRONMENT INC.
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Note that the model has since been updated for application to the Lake Erie Phosphorus Objectives effort. We intend to include the most current description of the model calibration and application for this effort in our final report for peer review. Furthermore, Dr. DePinto asked that I relay the following to the Panel: "It is important to recognize that this model has evolved over the past five years through a series of projects funded by multiple agencies. The two reports being shared are the two latest applications of the model to issues in the Western Basin of Lake Erie, but they do not fully represent the latest state or application of the WLEEM for the Annex 4 Lake Erie Ensemble Modeling effort."

I hope these reports are helpful to the reviewers. Let us know if any further information or clarification is needed with regards to the WLEEM, or other models.

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Final Study Report

Influence of Open-Lake Placement of Dredged Material on Western Lake Erie Basin Harmful Algal Blooms

Contract No. W912P4-10-D-0002

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BUILDING STRONG

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List of Abbreviations and Acronyms

°C	degrees Celsius
A2EM	Advanced Aquatic Ecosystem Model
ADCP	Acoustic Doppler Current Profiler
Al-P	aluminum-bound phosphorus
Ca-P	calcium-bound phosphorus
cm/yr	centimeters per year
CSM	conceptual site model
DMR	discharge monitoring report
DPO_4	dissolved orthophosphate
DP	dissolved phosphorus
E & E	Ecology and Environment Engineering, P.C.
EFDC	Environmental Fluid Dynamics Code
EPA	(United States) Environmental Protection Agency
Fe-P	iron-bound phosphorus
g/cm^3	grams per cubic centimeter
GLCFS	Great Lakes Coastal Forecasting System
GLENDA	Great Lakes Environmental Database
GLERL	Great Lakes Environmental Research Laboratory
GLNPO	Great Lakes National Program Office
GLOS	Great Lakes Observing System
GLRI	Great Lakes Restoration Initiative
GPS	Global Positioning System
HAB	harmful algal bloom
HQI	HydroQual, Inc.
IFYLE	International Field Year in Lake Erie
kg	kilograms

List of Abbreviations and Acronyms (cont.)

LISST	laser in situ scattering and transmissometry
LOI	loss on ignition
LWD	low water datum
µg/L	micrograms per liter
$mg/m^2/d$	milligrams per square meter per day
mg/g	milligrams per gram
mg/L	milligrams per liter
mg P/L	milligrams of phosphorus per liter
NCWQR	National Center for Water Quality Research
NH_3	ammonia nitrogen
NO_2	nitrite
NO_3	nitrate
NOAA	National Oceanic and Atmospheric Administration
NTU	Nephelometric turbidity unit
PA	placement area
PAR	photo synthetically active radiation
PP	particulate phosphorus
RA	reference area
RCA	Row-Column AESOP
SAP	Sampling and Analysis Plan
SiO_2	silicon dioxide
SNL	*Sandia National Laboratory*
SOW	Statement of Work
SRP	soluble reactive phosphorus
SWAN	Simulating Waves Nearshore
TKN	total Kjeldahl nitrogen
TP	total phosphorus
TSP	total soluble phosphorus
TSS	total suspended solids
USACE	United States Army Corps of Engineers - Buffalo District
USGS	United States Geological Survey
VSS	volatile suspended solids
WLEB	Western Lake Erie Basin

List of Abbreviations and Acronyms (cont.)

WLEEM	Western Lake Erie Ecosystem Model
WWTP	Wastewater Treatment Plant

1 Introduction

1.1 Purpose and Scope

This draft Study Report was prepared in response to the work described in the Statement of Work (SOW) entitled *Influence of Open-Lake Placement of Dredged Material on Western Lake Erie Basin Harmful Algal Blooms (HABs) Toledo Harbor Lucas County, Ohio* (USACE 2012). The purpose of this study was to assess the potential of phosphorus release from open-lake placement of dredged material from Toledo Harbor and its potential influence on the phosphorus budget that may promote HAB development in the Western Lake Erie Basin (WLEB; see Figure 1-1). In recent years, the problem of harmful and nuisance algal blooms in the WLEB has become widespread and has been linked to the increased loading of soluble reactive phosphorus (SRP). HABs are cyanobacteria (blue-green algae) blooms which occur in nutrient enriched environments when other factors, such as elevated temperature and calm water, are also present. Some cyanobacteria produce toxins, called cyanotoxins, which can be harmful to human and animal health. The HABs in the WLEB tend to be largely composed of *Microcystis sp.,* which can produce a toxin known as microcystin.

The federal standard for the management of most material dredged from Toledo Harbor federal navigation channels is open lake placement in the WLEB, as it is the least costly, environmentally acceptable alternative that is consistent with sound engineering practices. In 2003, a large HAB event occurred in the same year in which the quantity of Toledo Harbor dredged material placed in the WLEB was significantly increased by the USACE. Since then, there have been recurring concerns about the amount and intensity of annual HABs, and the potential exacerbating influence over external nutrient loads posed by dredged material placement in the WLEB. The major factors of concern with regard to dredged material placement are: phosphorus release from the dredged sediment (exacerbating HAB development); changes in turbidity; and the horizontal transport of the material potentially leading to the transport of suspended solids and nutrients to other vulnerable parts of the WLEB, such as the City of Toledo and City of Oregon potable water intakes. Generally, the purpose of this study was to address concerns by assessing the relative contribution of open-lake placement of Toledo Harbor dredged material to turbidity and HABs in the WLEB through a field sampling/laboratory testing and modeling program. Results from the study were input into an existing model (Western Lake Erie Ecosystem Model [WLEEM]) in an effort to determine whether the open-lake placement of Toledo Harbor dredged material significantly contributes to WLEB HABs or if long-range transport of open-lake placed dredged material takes place.

Ecology and Environment, Inc. (E & E), their subcontractor LimnoTech, and its subcontractors assisted the United States Army Corps of Engineers - Buffalo District (USACE) in completing the technical analyses associated with this project. The second-tier subcontractors supporting this project include:

- Heidelberg University;
- University of Toledo; and
- University of Wisconsin–Stout.

1.2 Objectives and Approach

The main objective of this study was to conduct a coordinated field sampling/laboratory testing and modeling program designed to assess the relative contribution of open-lake placement of Toledo Harbor dredged material to bioavailable phosphorus, water clarity/turbidity, and HABs production in the WLEB. The objectives of the field/experimental portion of this project were to monitor the response of the WLEB to the open-lake placement operations and to provide input and calibration/corroboration data for an existing linked hydrodynamic-sediment transport-eutrophication model (WLEEM) that LimnoTech has developed for assessments of the type proposed for this study (LimnoTech 2010). The *Final Sampling and Analysis Plan (SAP) for the Influence of Open-Lake Placement of Dredged Material on Western Lake Erie Basin Harmful Algal Blooms* was prepared that detailed the field sampling program designed to meet the study objectives (E & E/LimnoTech 2013). A description of the experimental approach and model input data is provided in Section 2 of the SAP. Section 5 of this report provides a detailed list of project objectives and a discussion of how the study findings related to these objectives.

1.3 Study Area - Site Description

Toledo Harbor is located near the southwest shore of Lake Erie at the mouth of the Maumee River at the city of Toledo, Lucas County, Ohio. Federal navigation channels in the project area include the 18-mile Lake Approach Channel in Maumee Bay and the WLEB and the 7-mile River Channel in Maumee River (see Figure 1-1). These harbor channels are regularly maintenance-dredged by the USACE to accommodate efficient and safe deep-draft commercial navigation. Dredged material determined to meet federal guidelines for open-lake placement is placed at the existing 2-square-mile (1,280-acre) open-lake placement area in the WLEB, located just north of the Lake Approach Channel near Lake Mile 11 (see Figure 1-1). The center of this area is on an azimuth of 33º at a distance of 3.5 miles from the Toledo Harbor Light. Dredged material placement has typically been restricted to the square mile section located in the northeast portion of this area (640 acres). However, as of 2014 placement is being performed in the southwest half of the site. This site has depths that range from 20 to 23 feet below low water datum (LWD) and is within a warm-water aquatic ecosystem that consists mainly of soft unstructured bottom and water column habitat. Bottom sediments at the open-lake placement area consist primarily of silts and clays. Typical annual dredging requirements are approximately 850,000 cubic yards. The vast majority of this volume is derived from the Lake Approach Channel, which is also located in the WLEB, and placed in the open-lake placement area.

Lake Erie's long, narrow orientation parallels the direction of the prevailing southwest winds. Strong southwest winds and strong northeast winds set up seiches, causing a difference in water depth as much as 14 feet between Toledo and Buffalo (Hamblin 1987). The effect is most prevalent in the WLEB where large areas of the lake bottom are exposed when water is blown to the northeast, or large areas of shoreline are flooded as water is blown to the southwest. Overall current and wave patterns in Lake Erie are complex, highly changeable, and often related to wind direction (USEPA 2008).

1.4 Scope of Report

Section 2 of this report provides a brief overview of the literature review and conceptual site model that serves as the basis for the study design. Section 3 describes the field and laboratory data collection activities and methods. Section 4 presents the summary of the results from the data collection activities and a description of the WLEEM model that has been used to synthesize the data from this project with other forcing functions and conditions during the 2013 open-lake placement period. Section 5 presents a discussion of the results of both the field sampling program and the incorporation of the open-lake placement for the whole season into a simulation of HABs in the full 2013 summer and the relative contribution of the open-lake placement to the HABs. Section 6 presents the conclusions of the study.

02:EE-004054-0001-04TTO-B3752\Figure 1-1 Project Vicinity Map.ai-3/26/13-GRA

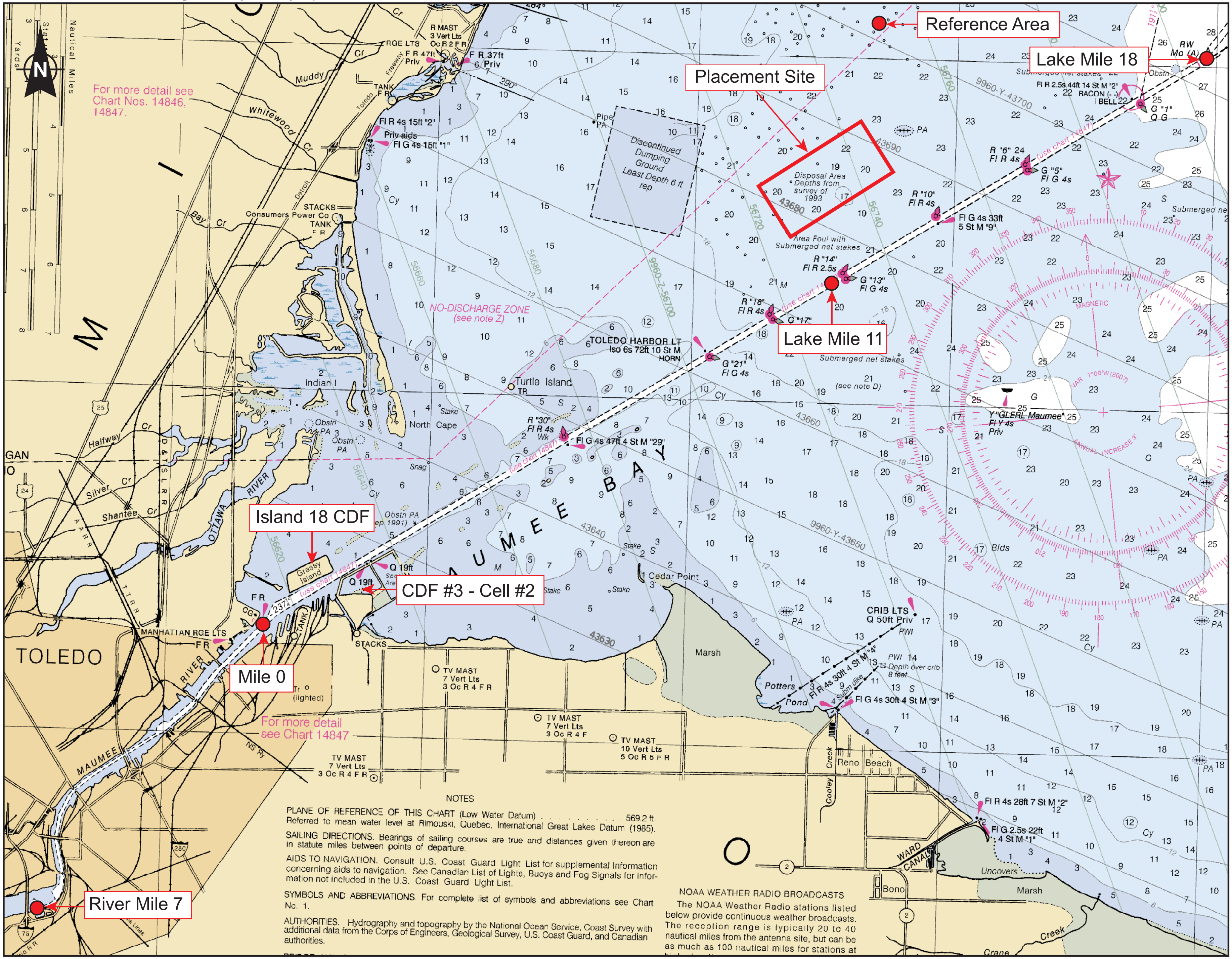

Figure 1-1 Project Vicinity Map

2 Background and General Approach

This section provides a summary of background data collected as part of this project and a conceptual site model developed based on this data. The section also provides a summary of the SAP.

2.1 Literature Review

As part of this study, the project team performed an examination of current literature (academic journal articles and other reports) related to HAB development and the impact of dredged material placement activities. The Literature Review Summary Report (see Appendix A) compiles, synthesizes, and interprets existing information building a comprehensive picture of HAB development in the WLEB and addresses potential links to the open-lake placement of dredged material.

2.1.1 HAB Development Dynamics

Phytoplankton, the drifting algae found in the open water of lakes, is a diverse assemblage of nearly all major taxonomic groups, including cyanobacteria. Phytoplankton requires sunlight and inorganic nutrients, such as nitrogen, phosphorus, and sulfur compounds in order to live and grow. Some cyanobacteria produce toxins, called cyanotoxins, which can be harmful to human and animal health. Blooms occur when nutrient levels spike in aquatic environments or nutrient levels are selective toward *Microcystis aeruginosa*, which is the common variety but not the only toxic HAB.

Excess nutrients, in particular phosphorus, have been linked to the increasing appearance of HABs in Lake Erie (OEPA 2010). In the 1960s and early 1970s Lake Erie's HABs were one of the major water quality issues in the United States. As a result of the of the Great Lakes Water Quality Agreement in 1972, nutrient effluent limits were enforced for point sources, and the water quality of Lake Erie improved drastically, which resulted in HABs being diminished for several years (DePinto et al. 1986a). However by the mid-1990s, phytoplankton biomass began to increase across Lake Erie in the summer months. By the late 1990s and early 2000s, cyanobacteria biomass began increasing in the summer months across Lake Erie and large HAB occurred in 2003 and in the 2008 to 2011 period (OEPA 2010; Stumpf et al. 2012).

Cyanobacteria blooms are usually confined to the western basin of Lake Erie, however, in some summers these have extended into the central basin (Stumpf et al. 2012). Satellite images of the progression of the blooms consistently point toward the Maumee Bay and areas near the bay as having the highest concentrations of cyanobacteria (Wynne et al. 2010; Binding et al. 2012).

The extent of HABs within a given year has been correlated strongly with spring phosphorus loads that are discharged from the Maumee River (Stumpf et al. 2012). In the WLEB it has been demonstrated that most of the phosphorus load is discharged by the early spring (March through June), but the blooms do not begin to form until months later (Stumpf et al. 2012). Nutrients are available for HAB formation earlier in the year, but formation of algal blooms requires: the correct environmental conditions (i.e., temperature, light availability, low mixing), and the correct concentration and ratio of nutrients (nitrogen:phosphorus [N:P]) (Elser 1999; Sullivan 1987).

A study by Bridgeman et al. (2012) considered the algal composition along a gradient from the Maumee River out into the western basin during the growing season of 2009. The study showed that in June, green algae dominate in the Maumee River and Lake Erie (46% and 60%, respectively), with a smaller percentage of cyanobacteria in the Maumee River (17%). By August, the cyanobacteria percentage of total biomass increased to 32% in Lake Erie and dropped to 3% in Maumee River. In the open lake water during August, *Microcystis aeruginosa* is the dominant cyanobacteria, and in the nearshore area of Maumee Bay (at a depth of 1.5 to 3.5 meters [m]). *Lyngbya wollei* has emerged as a nuisance, attached, filamentous, cyanobacterial algae that can either wash up on shore or be swept out into the lake (Bridgeman et al. 2012; Bridgeman and Penamon 2010).

Phosphorus entering Lake Erie occurs in two basic forms, dissolved phosphorus (DP) and particulate phosphorus. Together, DP and particulate phosphorus comprise total phosphorus (TP). DP can be further subdivided into dissolved reactive phosphorus (DRP) and dissolved organic phosphorus (DOP). The DRP is considered to be 100% bioavailable to support algal growth and DOP bioavailability varies, but up to 74% of it could be ultimately bioavailable to support algal growth (OEPA 2010; Lambert 2012). The DRP fraction of TP discharged from the Maumee River has been increasing since 1995 (Baker 2011a).

Other nutrients, such as nitrogen, have been steadily increasing over the years and may be limiting to certain algae (Paerl and Scott 2010; OEPA 2010). However a nutrient limitation study suggests that cyanobacteria had sufficient nitrogen and micronutrients to meet their maximum growth potential (Chaffin et al. 2011). Ecosystem changes such as the spread of Dreissenid mussels and climate change could also be playing a role in the expansion of HABs (Zhang et al. 2011; Paerl and Paul 2012; Hartig et al. 2009).

2.1.2 Sediment Loading and Dredged Material Placement

Point source loadings (e.g., wastewater treatment plants, combined sewer overflows, and industrial discharges) have remained fairly consistent since 1981 and are not considered to be a significant contributor to the recent increases in DRP loads measured in Ohio's Lake Erie tributaries (Baker 2011b). Atmospheric deposition of phosphorus into Lake Erie has remained relatively constant for the last 20 years, and is approximately 5% of the total load to the lake (Dolan and Chapra 2012). Non-point source loadings (e.g., urban, residential and agricultural runoff) contribute nutrients from surface water runoff of farm fields and the urban environment. However, urban land accounts for only a small percentage of land area in the Maumee River watershed (7 %).

The loading data indicates that Lake Erie (on average) receives 20 times more nitrogen than is required to satisfy the generally accepted N:P ratio of 16:1, the "Redfield ratio" (Stumpf et al. 2012), which suggests that Lake Erie is a phosphorus limited system (Chaffin et al. 2011).

Internal loading (e.g., phosphorus released from sediments) greatly influences the trophic status of a lake. The release of phosphorus from sediments has been extensively studied and is well understood (James 2007). In comparison with the water column, sediments in Lake Erie store much more phosphorus (Chaffin and Kane 2010) and in most cases they serve as a phosphorus source to the lake.

Reine et al. (2007) found that the total suspended solids (TSS) plumes produced by bucket dredging (15-cubic-yard dredge bucket) of the Toledo Harbor Lake Approach Channel were relatively narrow bands of elevated concentrations of resuspended sediments, that decayed rapidly over short distances from the source. The spatial extent of the plume measured no more than approximately 600 feet (200 meters) up or down channel from the source with a maximum width of approximately 300 feet (100 meters). The maximum TSS concentration in the immediate vicinity of the excavation exceeded the ambient conditions. Detectable plumes decayed to ambient conditions within 600 feet (200 meters) of the source.

The Ohio Lake Erie Phosphorus Task Force (OEPA 2010) observed that the phosphorus concentrations in western basin sediments are similar to concentrations in agricultural soils. Aluminum concentrations in the sediment may be high enough to effectively tie up most of the phosphorus, keeping its bioavailability low. However, they found that the constant mixing of the extremely fine clay sediment particles by wind and waves in the shallow western basin may increase the opportunity for phosphorus to dissolve in the water column. The sediments have a fairly high iron concentration and much of the phosphorus on the surface sediments is bound with ferric iron. When the bottom water oxygen concentration drops below 2 ppm, iron reduction occurs and phosphorus is released into the water column.

2.2 Conceptual Site Model

As part of the initial steps of the study, a conceptual site model (CSM) (see Figure 2-1) was developed and presented in a technical memorandum to describe the influence of open-lake placement of dredged material on WLEB HABs (see Appendix B). To accomplish this, the CSM was designed to address how this system behaves and what processes need to be considered to address the management questions. The CSM also evaluates all of the sources believed to contribute to cyanobacteria blooms, including open-lake placement. The goal, through a combination of data collection and model application derived from this conceptual model, was to make an evaluation of the relative contribution of each driver. The CSM was based on previous work by LimnoTech (2010) as well as a review of relevant literature sources in Appendix A.

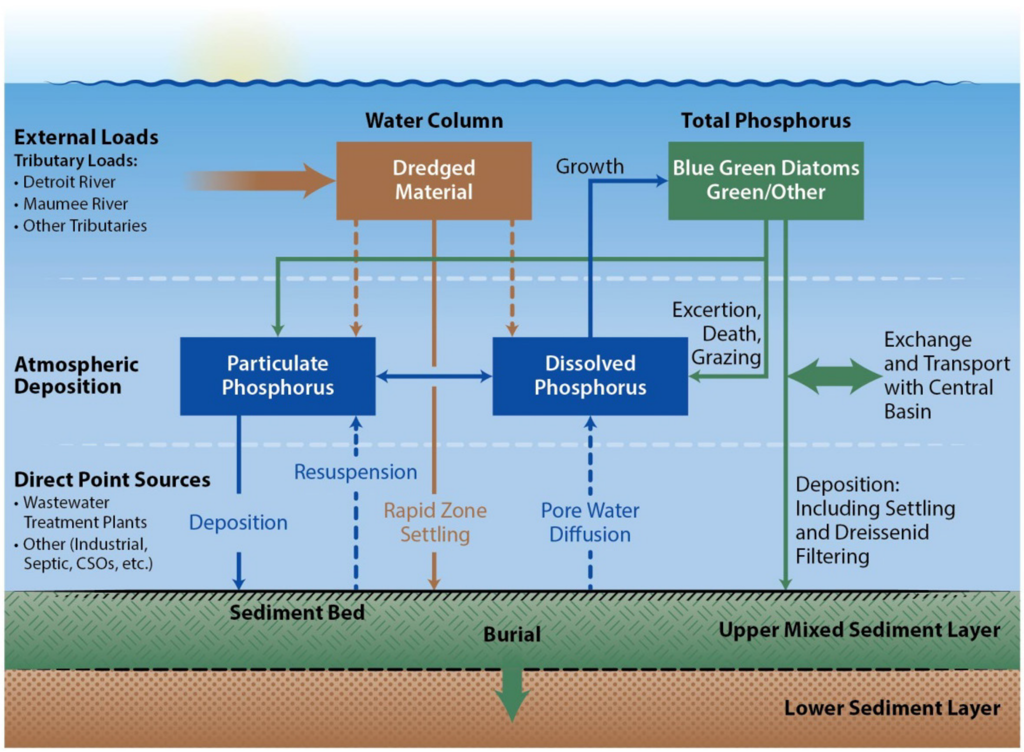

Figure 2-1 Conceptual Diagram of Linking Phosphorus Loads to Algal Blooms

Figure 2-1 presents a visual representation of the fate and transport of phosphorus and its connection to algal growth in the WBLE. It includes all of the external and internal sources of algal-available phosphorus that contribute to the development of blue-green algal blooms, including how open-lake placement of dredged material can contribute to bloom development. The dashed lines represent internal loads. Green arrows trace the movement of nutrients to and from algae and brown arrows trace the fate of dredged material in the water column. The blue arrows show the nutrient interaction within the water column and the sediment bed. The loading of DP and particulate phosphorus from external sources was combined into TP for simplicity. Additional detail on the on different sources of

TP and their associated forms represent different levels of algal availability is shown on Figure 2-2.

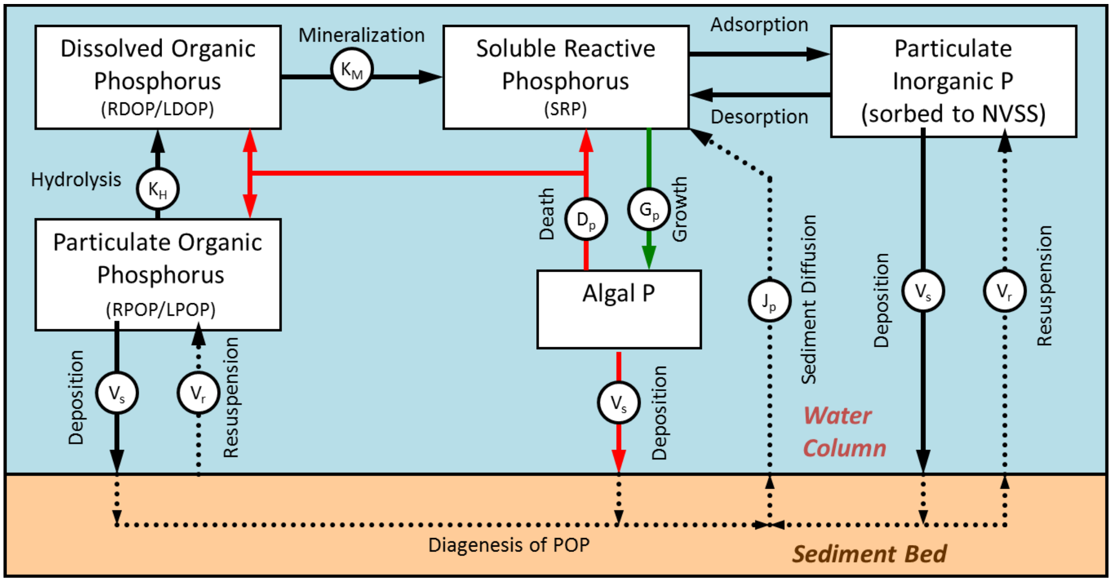

Figure 2-2 Conceptual Diagram of Phosphorus Forms

2.2.1 External Phosphorus Loads

The total external phosphorus load to the WBLE was estimated at 7,108 metric tons per year between 1998 and 2005 (OEPA 2010). This includes contributions from the connecting channels via the Detroit River, Maumee River, other smaller tributaries and direct point sources, and atmospheric deposition. Each major load category is discussed below.

- Atmospheric Deposition - Particulate phosphorus settles on the water surface throughout the year and is included here for completeness. Between 1998 and 2005 this accounted for 80 metric tons or approximately 1% of the total load delivered to the basin (OEPA 2010)
- Detroit River - The Detroit River load of phosphorus is comprised of tributary loads delivered to the Huron-Erie Corridor (HEC) (Lake Huron to Lake Erie, including Lake St. Clair), the inflow to the HEC from Lake Huron, direct point sources to the HEC including the Detroit Wastewater Treatment Plant, and CSOs associated with the cities along the HEC. The Detroit River TP load accounts for 37% of the total external load to the western basin (Dolan and Chapra 2012; OEPA 2010), even though the flow from the Detroit River represents approximately 95% of the total external flow into the western basin (Baker 2010) .
- Maumee River - Even though the annual inflow from the Maumee is only approximately 4% of the total inflow to the western basin, it also accounts for approximately 42% of the total external TP load (OEPA 2010). This means that the flow-weighted concentration of TP in the Maumee River discharge to Lake Erie is close to 400 µg/L, almost 40 times higher than the Detroit River (Baker 2011a; Burniston et al. 2012).

- Other tributaries - The Raisin, Huron, Ottawa, Portage, Cedar, and Stony tributaries, and other direct point sources comprise the remainder of the external TP load to the western basin. These sources contribute approximately 10% of the total load to the western basin (OEPA 2010).

2.2.2 Internal Loads to the Water Column

The bottom sediments of the western basin contain a very large reservoir of phosphorus that can enter the water column by a number of processes, and a certain fraction of that phosphorus either is, or can become, algal-available.

- Resuspension - The resuspension of bottom sediments by wind/wave induced bottom sheer stresses increases the water column concentration of particulate phosphorus. Particulate phosphorus concentrations remain elevated until the resuspended material settles back down to the sediment bed, which can be on the order of hours to days depending on particle sizes and turbulent mixing (DePinto et al. 1986b).
- Sediment Diffusion - The bottom sediments of the WBLE can release DP back into the water column by diffusion across the sediment-water interface (Chaffin and Kane 2010; Smith and Matisoff 2008). The flux of phosphorus from the sediments is primarily governed by the pore-water concentration of DP, which can increase significantly under anoxic conditions (James 2007; James 2010).
- Dredged Material - The net effect of open-lake placement is similar to the natural process of sediment resuspension, but on a smaller local scale, whereby particulate phosphorus is reintroduced into the water column and allowed to settle to the bottom. Previous work suggests that dredged material settles to the bottom relatively quickly allowing for very limited contact time with the water column (DePinto et al. 1986a).

2.2.3 Phosphorus Forms

Figure 2-2 represents the interactions among the phosphorus forms in the western basin. This figure provides additional detail on dissolved and particulate forms of phosphorus. The white boxes also correspond to the state variables (i.e., dynamically simulated and tracked through time and space) that are included in the WLEEM.

- Dissolved Phosphorus – This pool of phosphorus passes through a 0.45 µm filter. Within this fraction there is further division into inorganic (SRP) and organic (DOP) forms. The SRP fraction is the form that is immediately available for uptake by algae. DOP phosphorus can be converted into SRP through biologically-mediated mineralization processes that ultimately make it available for uptake by algae. However, only a given fraction of DOP can be easily converted into SRP, this form is considered the labile portion (LDOP) or sometimes referred to as the algal-bioavailable form (Baker 2010). The remaining fraction of DOP is considered refractory (RDOP) because the conversion to SRP is much slower and can take years to mineralize.

- Particulate Phosphorus – This is the pool of phosphorus that is retained on a 0.45 µm filter. On the particulate phosphorus side there is a division between particulate inorganic phosphorus (PIP) and particulate organic phosphorus (POP). The PIP is sorbed to non-volatile suspended sediments (NVSS) or sometimes called inorganic suspended solids (ISS). Some PIP can desorb and be transformed into SRP. The reverse process (adsorption) can also take place depending on concentrations of each form in the water column. The POP forms can be converted to DOP through a process called hydrolysis.
- Algal Phosphorus – The last remaining form of phosphorus in the water column is bound up in the algae itself. This form of phosphorus is considered part of the total particulate phosphorus described in the previous bullet because it is retained on a filter.
- Sediment Phosphorus – Once any of the particulate forms of phosphorus reaches the sediment bed it becomes a part of the sediment bed. Here it is available for reincorporation into the water column by either resuspension processes or conversion to dissolved forms within the sediment bed.

2.2.4 Algal Growth and Other Biological Processes

Figure 2-3 illustrates how zooplankton, Dreissenids, and benthic algae interact with water column algae and particulate and DP on the water column. In addition to the nutrients described previously, algal growth requires appropriate light and temperature. The nutrient, light, and temperature ranges for optimum growth rates of algae are species-specific. Processes that lead to loss of algal biomass include: settling and deposition, grazing by zooplankton, filtering by Dreissenids, endogenous respiration, and bacterial-mediated decomposition.

Zooplankton graze on algae in the water column and lock a portion of the phosphorus in their biomass and release the remainder as fecal material. Additionally zooplankton die and settle to the bottom sediments. Dreissenid mussels can significantly reduce the water column particulate phosphorus concentration through physical filtration. However, once filtered, mussels release phosphorus back into the water column in a dissolved form that is readily available for uptake by algae. Therefore Dreissenid mussels can enhance the ratio of DP to particulate phosphorus in the water column without having to undergo a much slower transformation process in the sediment bed that depends on anoxic conditions to see significant release into the water column. Additional detail on the interaction of Dreissenid mussels with TP is provided in Bierman et al. (2005).

2.3 Sampling and Analysis Plan Summary

Based on the literature review and CSM, a sampling and analysis program was finalized and presented in the SAP. The SAP describes the activities in support of the project performed directly by or under oversight by E & E or LimnoTech. Section 2 of the SAP summarizes the approach to meeting the sampling objectives and Section 3 presents a summary of the activities and methodologies that were performed during the field effort. A Quality Assurance Project Plan and site-specific Accident Prevention Plans are provided as appendices to the SAP. Project Team standard operating procedures outlining the procedures for implementing field activities described in the SAP are included in an appendix to the SAP. Instrument manuals and field data collection forms also are included in appendices to the SAP. Any deviations from the SAP are presented in Section 3.2 of this report. The objectives and approach to meet the objectives are briefly described below.

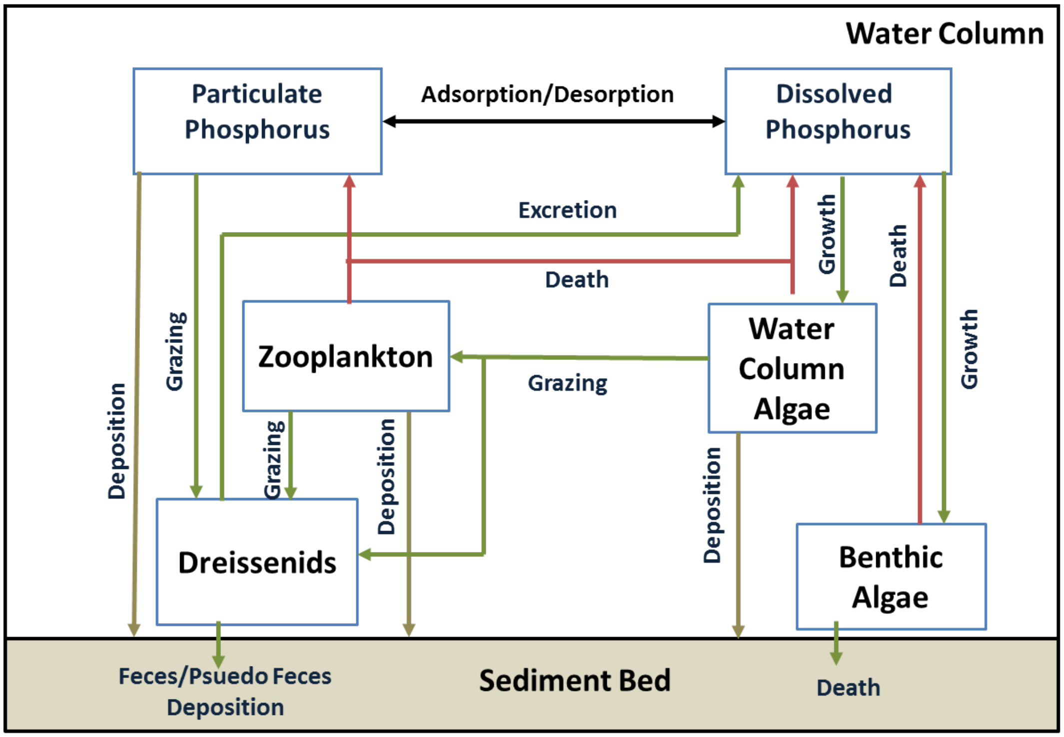

Figure 2-3 Interaction of Zooplankton, Dreissenids, and Benthic Algae with Particulate and Dissolved Phosphorus

- Objective 1 – Assess phosphorus flux during the open-lake placement of Toledo Harbor dredged material. Quantify the flux of phosphorus from dredged material as a function of equilibrium phosphorus characteristics. Compare dredged material with natural lake sediment to better assess the potential impact of settling material on soluble phosphorus concentrations in the water column. Measure the actual concentrations of TSS, particle size distributions and concentrations of phosphorus in the water column before, during, and after a selected subset of dredged material placement events, adequate to characterize the dynamics.
  - Approach – To meet this objective the study approach was designed to follow the transport and fate of dredged material, including the solids and associated phosphorus forms, as it is released from the barge at the placement site.

  - Both long-term and short-term monitoring events were performed to monitor both settling and dispersion SRP pathways during the dredging material placement process. Long-term monitoring included measuring water quality parameters over the period of June through October 2013. Short-term monitoring was conducted over the course of each individual sampling event. The first and last events monitored baseline and post dredging conditions. The two middle sampling events captured short-term variability in dredged material transport and deposition at both the active placement site and a reference area location. In addition, composited grab samples of the dredged material were collected from several barges to determine the phosphorus and sediment characteristics of dredged material.

- Objective 2 – Measure the net release of phosphorus per unit of lake bottom area in the placement site and from resuspended material transported from the placement area via natural circulation. Net releases from reference area of lake bed (representative of background) were also measured.
  - Approach – To meet this objective the study approach was designed to gain a quantitative understanding of the longer-term bioavailable phosphorus release from the material that has initially deposited in the placement site.
  - There are two mechanisms for bioavailable phosphorus to be released from this bottom sediment area: pore diffusion of DP from the sediments into the water column; and resuspension of these bottom sediments followed by desorption of DP while those resuspended sediments are still in the water column. The former mechanism was assessed by collecting intact sediment cores from the placement site and reference area and processing in a controlled laboratory environment as described in Appendix E. Sediment cores were collected at the beginning of the study prior to dredging operations and after most of the dredged material had been placed to characterize sediment flux before and after dredged material placement. The second part of this objective (measure net release/export of resuspended material from natural circulation) was met through collection of long term datasets and the application of the WLEEM model.
  - One final piece of field data that was collected to meet this objective was deployment of a set of sediment traps at the placement site and reference area. The sediment traps served to integrate the gross amount of material that is resuspended from the sediment bed and deposited at each site.

- Objective 3 – Assess long-term diffusive phosphorus flux from the deposited dredged material at the placement site and reference area sediments. Assess horizontal transport of phosphorus and re-suspended sediments from the placement site and reference area with in-lake measurements.
  - Approach - The first part of this objective was answered by the data collected to meet the previous objective (e.g., flux rates of phosphorus from intact cores) and the model, which integrates the flux rates over time and across a range of environmental conditions. The second part of this objective (assess horizontal transport) was met with some of the data collected

in the previous section (continuous monitoring of turbidity at both sites and sediment traps), but relied mostly on the application of the model as it can quantify material transported from the placement area in comparison with material transported from the reference area.

- Objective 4 – Assess vertical variations within the sediment phosphorus pools at the placement site and reference area to evaluate the long-term accumulation of dredged material, the size of the mobile phosphorus pool, and the probable, long-term pattern of phosphorus release into the overlying water.
  - Approach - As part of the sediment coring mentioned above to quantify phosphorus release, a second set of intact sediment cores were collected from the placement site and reference area. These cores were vertically sectioned to obtain a vertical profile of a suite of physical (e.g., bulk density, loss-on-ignition) and chemical (TP) parameters. In the surface of each core, P fractionation was measured as described in Appendix E.
- Objective 5 – Assess fractionation of sediment phosphorus and classify the phosphorus species classified into groups (pools) that reflect the ecological function of differing phosphorus species in the aquatic environment.
  - Approach - This objective was met by measuring phosphorus fractionation in the surface of sediment cores as described in Section 2.2.4.
- Objective 6 – Characterize water and sediment chemistry before, during and after dredged material placement operations to support detailed numeric modeling of water and phosphorus movements in relation to placement of the dredged material in the WLEB.
  - Approach - This objective was met by all of the short-term and continuous monitoring data collected as well as the sediment sampling program presented in Appendix E.

3 Data Collection Activities

This section provides a summary of the activities and methodologies that were performed during the field effort to collect the data identified in the SAP. In general, the field work included: long-term continuous monitoring, short-term continuous monitoring, water column sampling, and sediment sampling. Sampling activities occurred during four field events:

- Event 1a: May 9 and May 17, 2013: Deployed long-term monitoring buoys and equipment;
- Event 1b: June 18, 19, 20, and 24, 2013: Collected sediment grabs, sediment cores, water column samples, and deployed sediment traps;
- Event 2: July 22, 23, 24, 25, and 30, 2013: Collected surface water, dredged sediments, and sediment trap samples;
- Event 3: August 19, 20, and 21, 2013: Collected water column samples; and
- Event 4: October 1 and 2, 2013: Collected sediment grabs, sediment cores, water column, and sediment trap samples. Buoys and equipment were decommissioned at a later date.

3.1 Field Activities

The first sampling event took place prior to dredging operations at the location within the open-lake placement area where the USACE and their dredging contractor had determined that material would be placed in 2013. Events 2 and 3 took place during dredging operations. The Event 4 was planned to take place after dredging was completed for the season; however, due to rapidly declining weather conditions, Event 4 actually took place after most of material had been disposed of at the placement area. Just prior to the last event, the contractor moved the placement area to a different section within the placement area so that the "before" and "after" dredging conditions could be properly assessed. All notable deviations to the SAP were documented in field adjustment forms (see Appendix C) and are summarized in Section 3.2.

A detailed summary of the sampling efforts by event is provided on Table 3-1.

Table 3-1 Summary of Sampling Events

Activity	Event 1a May 9 and 17, 2013	Event 1b June 18 – 20, 24, 2013	Event 2 July 22 – 25, 30, 2013	Event 3 Aug 19-21,2013	Event 4 Oct 1 and 2, 2013
Long-term Monitoring Buoy/Instrument Deploy-ment	PA Station 26 RA-0 MR Station 28	RA-1 Station 25 RA-2 Station 27			
Short-term Monitoring Buoy/Instrument			PA Stations N, S, E, W	PA Stations N, S, E, W	
Buoy Maintenance		PA Station 26 RA-1Station 25 RA-2 Station 27 MR Station 28	PA Station 26 RA-1Station 25 MR Station 28	PA Station 26 RA 1Station 25 MR Station 28	
Surface Sediment Grab Sampling	PA Stations 1, 2, 3 RA-0 (original RA)	PA Stations 1 through 20 RA-1 Stations 21, 23, 25 RA-2 Stations 22, 24, 27			PA Stations 5, 6, 8-20, 26 RA-1 Stations 21, 23, 25, 30 RA-2 Stations 22, 24, 27
Sediment Cores Sampling		PA Stations 1, 19, and 20 RA-1 Stations 21, 23, 25 RA-2 Stations 22, 24, 27			PA Station 19, 20 RA-1 Station 21, 23, 25 RA-2 Stations 22, 24, 27
Sediment Traps		RA-1 Station 25 RA-2 Station 27	PA Station 26 RA-1 Station 25 RA-2 Station 27 (7/22, 7/30)		PA Station 26 RA-1 Station 25 RA-2 Station 27
Barge Sediment Sampling			3 samples (7/23) 6 samples (7/30)		
Water Column Profiling		PA Stations 1, 19, 26 RA-1 Station 25 MR Station 28	PA Station 26 (7/22, 7/23, 7/30) RA-1 Station 25 (7/22, 7/23, 7/30) RA-2 Station 27 (7/22, 7/23, 7/30) MR Station 28 (7/22, 7/23, 7/30)	PA Station 26 (8/19, 8/20, 8/21) RA-1 Station 25 (8/19, 8/20, 8/21) RA-2 Station 27 (8/19, 8/20, 8/21) MR Station 28 (8/19, 8/20, 8/21)	

Table 3-1 Summary of Sampling Events

Activity	Event 1a May 9 and 17, 2013	Event 1b June 18 – 20, 24, 2013	Event 2 July 22 – 25, 30, 2013	Event 3 Aug 19-21,2013	Event 4 Oct 1 and 2, 2013
Integrated Water Column Sampling		PA Stations 1, 19, 26 RA-1 Station 25 MR Station 28	PA Station 26 (7/22, 7/23, 7/30) RA-1 Station 25 (7/22, 7/23, 7/30) RA-2 Station 27 (7/22, 7/23, 7/30) MR Station 28 (7/22, 7/23, 7/30)	PA Station 26 (8/19, 8/20, 8/21) RA-1 Station 25 (8/19, 8/20, 8/21) RA-2 Station 27 (8/19, 8/20, 8/21) MR Station 28 (8/19, 8/20, 8/21)	PA Station 19, 26 (10/1) RA-1 Station 25 (10/1) RA-2 Station 27 (10/1) MR Station 28 (10/1)
Laser In Situ scattering Transmissometry (LISST)		RA-1 Station 25	PA Station 26 (7/22, 7/23, 7/30) RA-1 Station 25 (7/22, 7/23, 7/30) RA-2 Station 27 (7/22, 7/23, 7/30) MR Station 28 (7/22, 7/23, 7/30) PA Stations E, W (7/22) and W (7/30)	PA Station 26 (8/19, 8/20, 8/21) RA-1 Station 25 (8/19, 8/20, 8/21) RA-2 Station 27 (8/19, 8/20, 8/21) MR Station 28 (8/19, 8/20, 8/21)	
Biomass Sampling		PA Stations 1, 19, 26 RA-1 Station 25 MR Station 28	PA Station 26 (7/22, 7/23, 7/30) RA-1 Station 25 (7/22, 7/23, 7/30) RA-2 Station 27 (7/22, 7/23, 7/30) MR Station 28 (7/22, 7/23, 7/30)	PA Station 26 (8/19, 8/20, 8/21) RA-1 Station 25 (8/19, 8/20, 8/21) RA-2 Station 27 (8/19, 8/20, 8/21) MR Station 28 (8/19, 8/20, 8/21)	
Plume Monitoring			5 Stations on 7/22 8 Stations on 7/23 (samples at 5 Stations) 5 Stations 7/30 5 Stations 8/19 5 Stations 8/20	5 Stations and monitored turbidity in a concentric pattern (8/19) 5 Stations and monitored turbidity at fixed location in center of initial plume	

Key:
PA = Placement Area; RA = reference area; MR = Maumee River

3.1.1 Long-term Continuous Monitoring

Long-term continuous monitoring buoys equipped with multi-parameter sondes (i.e., turbidity, conductivity, and temperature) were deployed at three locations in the placement area (PA [26]), RA-(RA-1 [25]), and the mouth of the Maumee River (MR [28]). Data from the project sondes are complemented by data from multi-parameter sondes deployed by other agencies as described in Section 3.3. The long-term continuous monitoring stations are shown in Figure 3-1 and listed in Table 3-2. Data from the long-term continuous monitoring buoys deployed by the study team are included in Appendix C-1. Data from the long-term continuous monitoring buoys deployed by University of Toledo is included in Appendix D.

Additional instrumentation (an Acoustic Doppler Current Profiler [ADCP] and weather station) were deployed at the placement area buoy (PA [26]) to measure ambient lake currents through wind speed, gust speed, direction, air temperature, humidity, pressure, solar radiation, wave height, and wave period. This ancillary data were used to verify hydrodynamic model calibration (wave height and water currents) and to collect high quality local input data for the model (wind speed and direction, air temperature, and solar radiation). All of these data served to calibrate and corroborate the model's ability to simulate sediment resuspension and transport as a function of hydrometeorological forcing functions (i.e., wind velocity, temperature, tributary flows) in the system.

The original RA-0 was selected to be up-current from the placement area based on circulation modeling and comparable water depth to the placement area (see Figure 3-2). However, as described in the field adjustment form dated July 11, 2013 (see Appendix C), this location was abandoned due to the presence of abundant dreissenid mussel shells and harder than expected substrate, which prevented in-tact cores and surface sediment samples from being collected. The reference area was then relocated approximately 4 miles southwest of the placement area noted as RA-1 on Figure 3-1. Following analysis of sediment cores collected from RA-1, it was determined that sediment at RA-1 had much higher phosphorus releases than sediments in the placement area. There was concern that the RA-1 location was not solely representative of the sediments of open waters of the WLEB and that the dreissenids in this area may cause a higher phosphorus release due to biological activity. Therefore, a second reference area (RA-2) was selected and sediment cores were collected from this area. RA-2 was located approximately 5 miles northeast of the placement area, near an established National Oceanic and Atmospheric Administration (NOAA) Great Lakes Environmental Research Laboratory (GLERL) Real-Time Meteorological Observation Network monitoring station (Toledo Light #2) and the NOAA GLERL western Lake Erie master monitoring station WE4, as shown in Figure 3-1. Data from NOAA GLERL were integrated with the rest of the study data from RA-2, therefore a separate water quality sonde was not deployed at RA-2. Samples were collected from both reference areas (RA-1 and RA-2) throughout the study. The data collected are summarized in Section 4.1.1.

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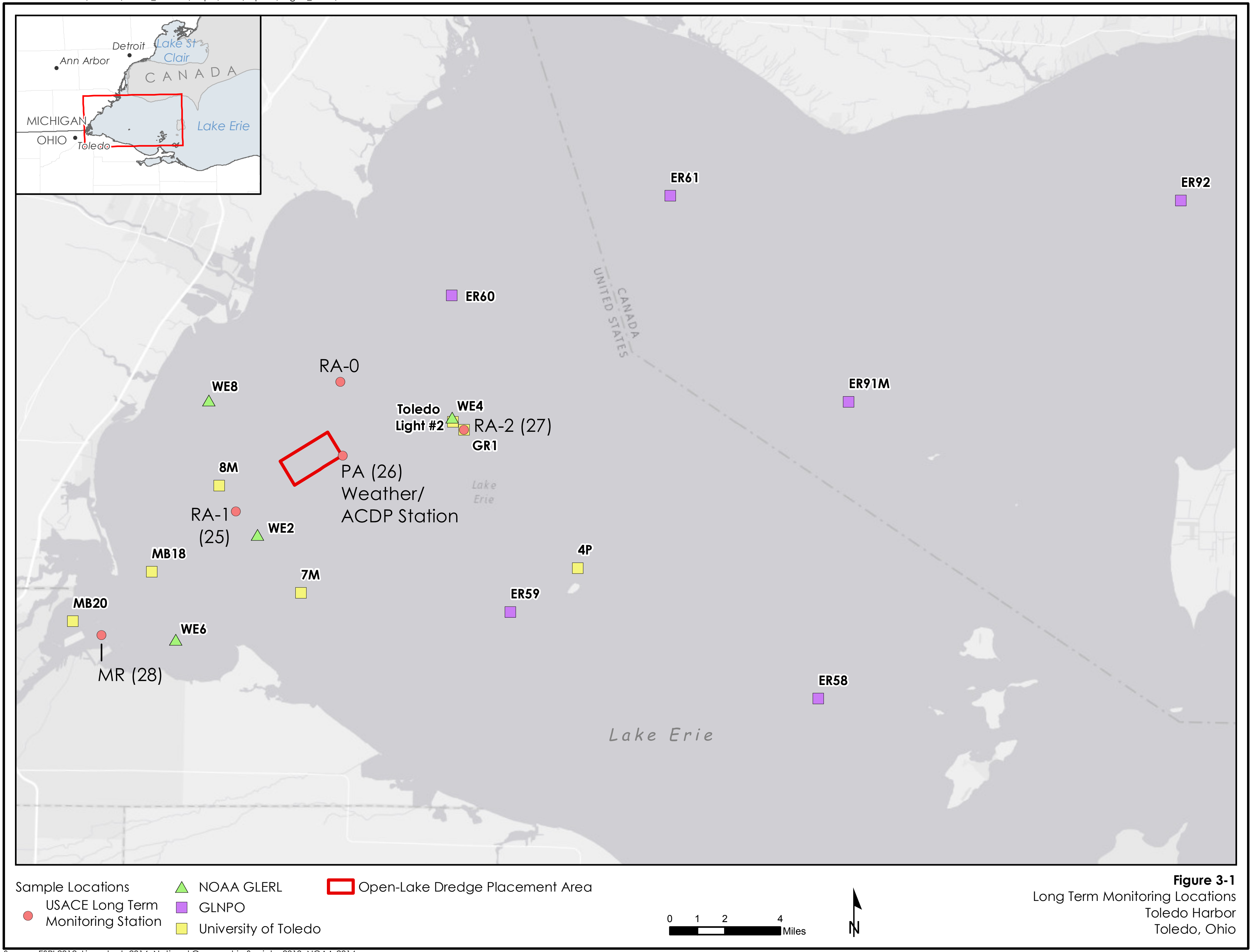

Figure 3-1
Long Term Monitoring Locations
Toledo Harbor
Toledo, Ohio

Source- ESRI 2012; Limnotech 2014; National Geographic Society, 2010; NOAA 2014.

Table 3-2 Monitoring Locations

Location	Station No.	Latitude	Longitude	Location Type
Placement Area	PA (26)	41.80625	-83.26998	Long-term Monitoring, Continuous and Event Sampling
Original Reference Area	RA-0	41.84479	-83.27313	
RA-1	RA-1 (25)	41.77539	-83.34378	
RA-2	RA-2 (27)	41.8214	-83.1855	Long-term Monitoring, Event Sampling
Mouth of Maumee River Site	MR (28)	41.70883	-83.43523	Long-term Monitoring, Continuous and Event Sampling
Toledo Light #2	THLO1	41.76187	-83.329	Long-term Monitoring, Continuous (via NOAA-GLERL – Real time meteorological)
Placement Area –Just outside of Barge Dumping Area	North	41.81705	-83.28211	Short Term Monitoring Buoy
	South	41.81001	-83.28211	
	East	41.81312	83.27759	
	West	41.81291	83.28689	
Placement Area	1	41.8049	-83.2868	Sediment Sampling
	2	41.80216	-83.2867	
	3	41.8049	-83.2831	
	4	41.80768	-83.2794	
	5	41.80759	-83.2868	
	6	41.80764	-83.2905	
	7	41.80485	-83.2904	
	8	41.80774	-83.2831	
	9	41.81036	-83.2868	
	10	41.81031	-83.2904	
	11	41.81544	-83.2851	
	12	41.81371	-83.2858	
	13	41.81502	-83.283	
	14	41.81338	-83.2834	
	15	41.81291	-83.2814	
	16	41.81463	-83.2813	
	17	41.81417	-83.2795	
	18	41.81255	-83.2795	
	19	41.81409	-83.2825	
	20	41.81437	-83.2846	
RA-1	21	41.77481	-83.3457	Sediment Sampling
	23	41.77602	-83.3419	
	25	41.7754	-83.3438	
RA-2	22	41.8225	-83.1868	
	24	41.8203	-83.1842	
	27	41.8214	-83.1855	

Key:
RA = reference area

3.1.2 Water Quality Sampling

Water column sampling involved collecting a series of water column profiles and surface water grab samples each sampling day. The station locations are summarized in Table 3-2 for monitoring locations and Table 3-3 for water quality samples. The results for all water quality samples are discussed in Section 4.1.2. Water quality sample locations are shown on Figures 3-2 and 3-3.

Water Column Vertical Profiles

Vertical profiles were logged for pH; turbidity, conductivity, dissolved oxygen, and temperature at each of the long-term monitoring stations (see Table 3-2). The field data are included in Appendix C-3. In addition, particle size distribution (laser in situ scattering and transmissometry [LISST]) was performed in conjunction with the water column vertical profiling and the field data are presented in Appendix C-4a to C-4d. Although particle size data were collected, the data was not analyzed as part of this study. These data can be utilized in the future if desired to further characterize particle sizes of ambient and dredged material in the water column.

Based on the SAP, in addition to the long-term continuous monitoring stations, vertical profiles were to be collected at 16 water quality stations in the placement area each day. Two additional stations (i.e., Stations 1 and 19) in the placement area were monitored during Event 1. In Events 2 and 3, the vertical profile plan was changed to track the plume in different ways (see Section 3.1.3 for additional details).

Water Column Integrated Sampling

During the four sampling events, water column grab samples were collected using a depth integrated sampler at select stations in the placement area and at the other long-term monitoring locations. The locations within the placement area are shown on Figure 3-3. Water sampling during sampling Events 1 and 4 were performed on one sampling day to establish pre- and post-dredge water quality conditions. Water column samples were collected with a depth-integrated sampling tube from the surface to 3 feet above the lake bottom as described in the SAP. The depth of the samples was noted in the sample ID. Samples for cyanobacteria biomass were collected using a 0.5-meter diameter, 112-micron mesh plankton net towed from within 1 meter of the lake bottom to the surface. The water column integrated samples were analyzed for the parameters listed on Table 3-5.

During Events 2 and 3, samples were collected over multiple days. The samples are noted on Table 3-3 and the data are presented in Appendix D-1. Samples were collected at the long-term monitoring stations and at five additional locations based on the visual sediment plume. These locations were also recorded using a Global Positioning System (GPS) and the locations are noted on Table 3-4 and Figure 3-4. Results of the surface water grab samples are presented in Section 4.1.2.

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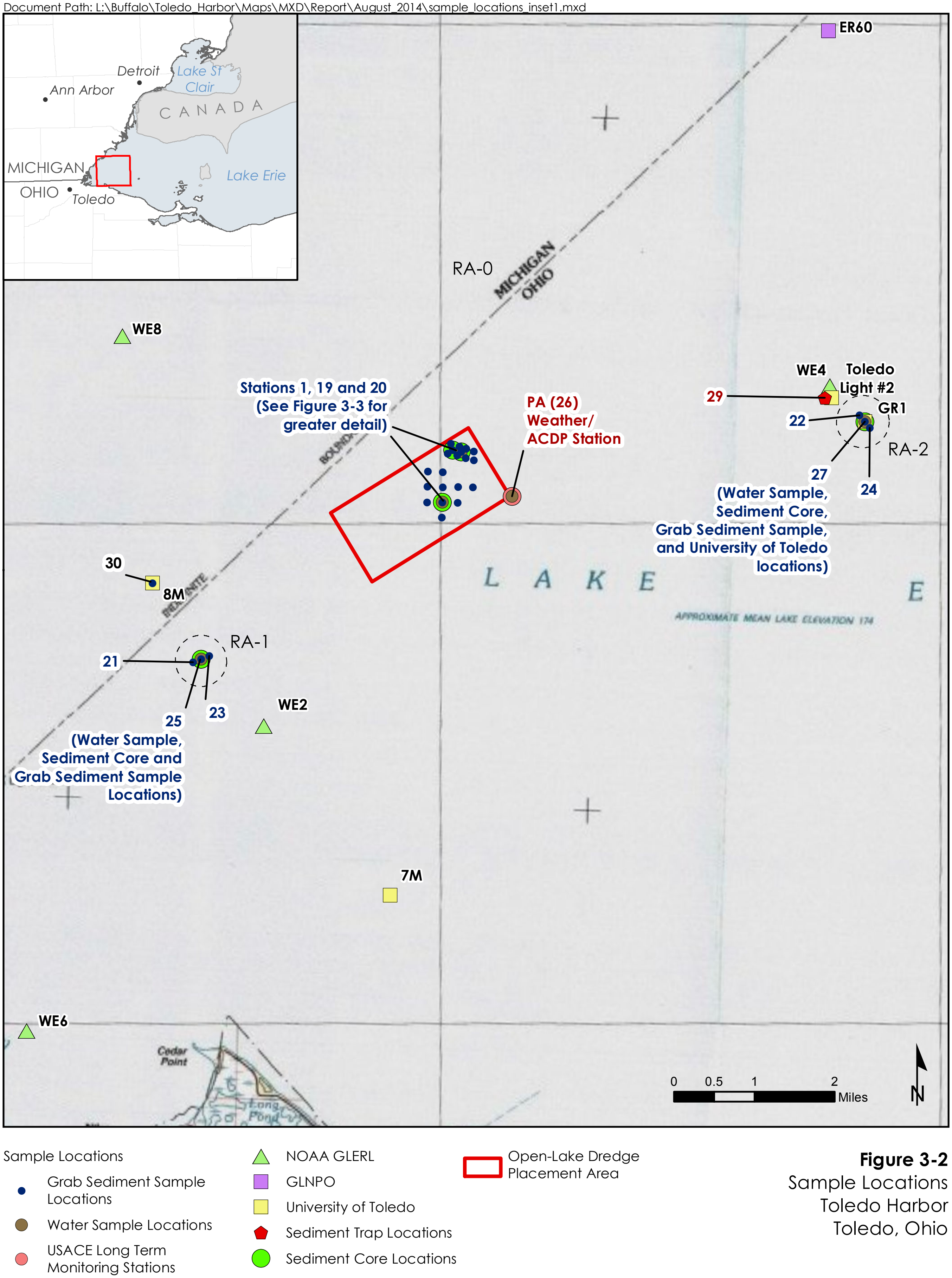

Figure 3-2
Sample Locations
Toledo Harbor
Toledo, Ohio

Source- ESRI 2012; Limnotech 2014; National Geographic Society, 2010; NOAA 2014; 100K Topo Quad- Toledo.

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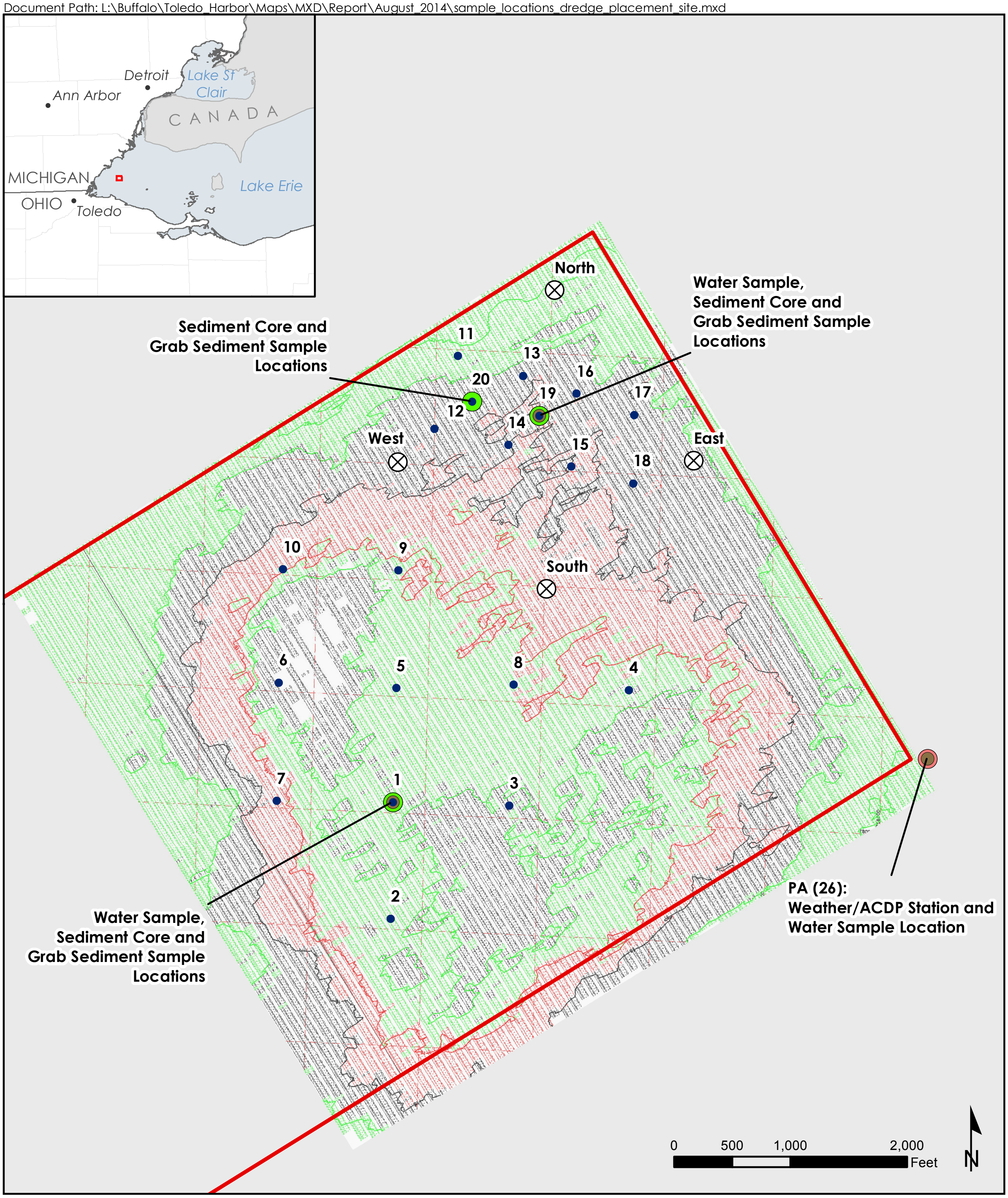

Sample Locations

- Grab Sediment Sample Locations
- Water Sample Locations
- USACE Long Term Monitoring Stations
- Short Term Monitoring Buoy
- Sediment Core Locations

Open-Lake Dredge Placement Area

Depth Soundings
Black (central portion): <14 ft
Green (central portion): 14-16 ft
Red: 16-18 ft
Black (outer portion): 18-20 ft
Green (outer portion): >20 ft

Note- Contours and soundings are U.S. survey feet referred to Low Water Datum of 569.2 feet International Great Lakes Datum 1985 (IGLD85). Contour Interval = 2 feet. The topographic information depicted on the map represents the results of surveys made on April 23, 2013 and can only be considered as indicating the general condition at that time.

Figure 3-3
Dredge Placement Site Locations
Toledo Harbor
Toledo, Ohio

Source- ESRI 2012; Limnotech 2014; National Geographic Society, 2010; NOAA 2014; 100K Topo Quad- Toledo.

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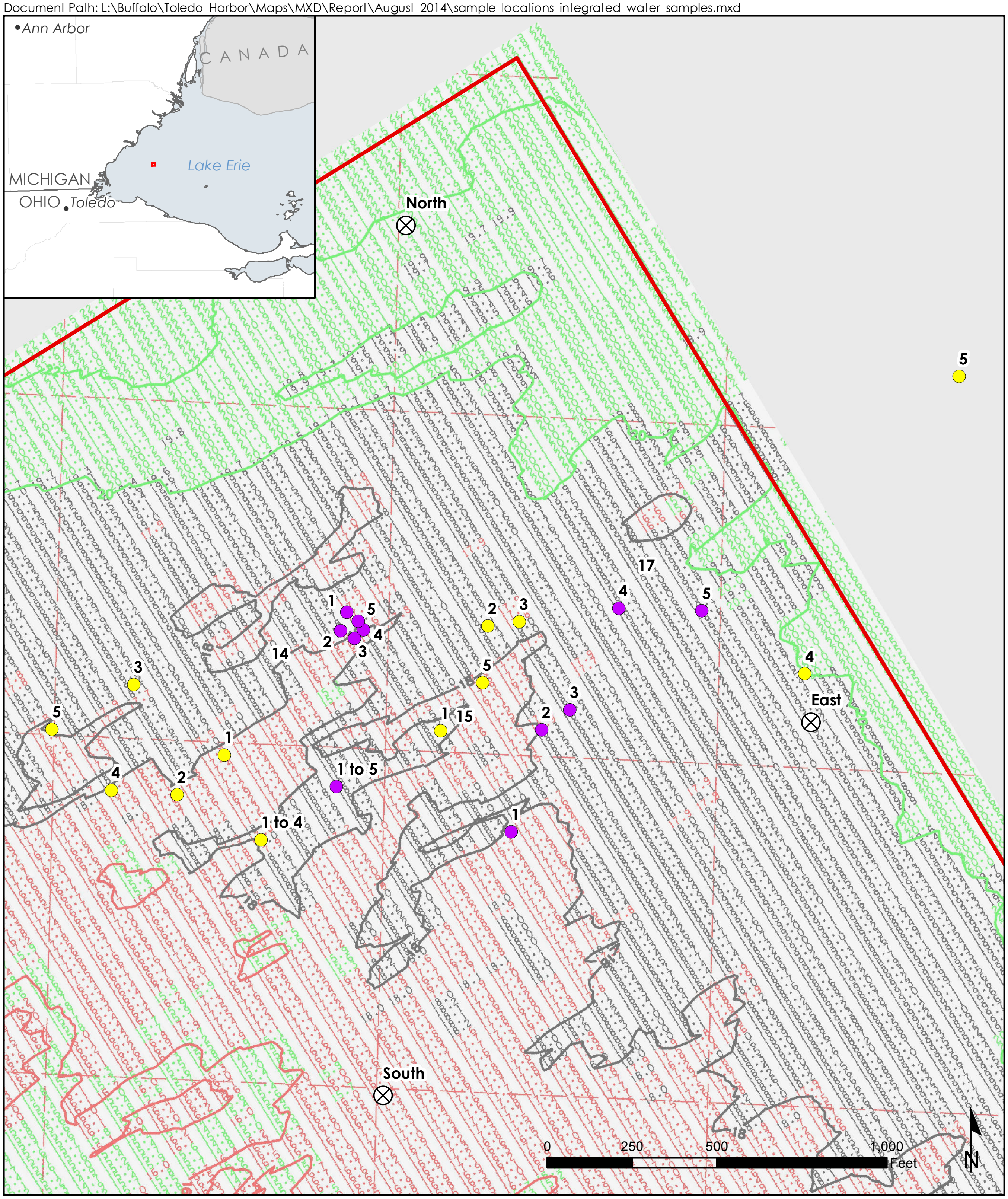


Sample Locations

Short Term Monitoring Buoy

Open-Lake Dredge Placement Area

Integrated Water/Plume Event Sample Locations

Event 2

Event 3

Depth Soundings
Black (central portion): <14 ft
Green (central portion): 14-16 ft
Red: 16-18 ft
Black (outer portion): 18-20 ft
Green (outer portion): >20 ft

Note- Contours and soundings are U.S. survey feet referred to Low Water Datum of 569.2 feet International Great Lakes Datum 1985 (IGLD85). Contour Interval = 2 feet. The topographic information depicted on the map represents the results of surveys made on April 23, 2013 and can only be considered as indicating the general condition at that time.

Figure 3-4
Integrated Water, Plume Monitoring Events
Toledo Harbor
Toledo, Ohio

Source- ESRI 2012; Limnotech 2014; National Geographic Society, 2010; NOAA 2014; 100K Topo Quad- Toledo.

Table 3-3 Surface Water Quality Samples

EVENT 1		EVENT 2						EVENT 3						EVENT 4	
June 24, 2013		July 22, 2013		July 23, 2013		July 30, 2013		August 19, 2013		August 20, 2013		August 21, 2013		October 1, 2013	
Location	Station	Location	Station	Location	Station	Location	Station	Location	Station	Location	Station	Location	Station	Location	Station
RA-1	25	RA-1	25	RA-1	25	RA-1	25	RA-1	25	RA-1	25	RA-1	25	RA-1	25
RA-2	27	RA-2	27	RA-2	27	RA-2	27	RA-2	27	RA-2	27	RA-2	27	RA-2	27
PA	1	PA	26	PA	26	PA	26	PA	26	PA	26	PA	26	PA	26
PA	19	MR	28	MR	28	MR	28	MR	28	MR	28	MR	28	PA	29
PA	26	Plume	1	Plume	1	Plume	1	Plume	1	Plume	1	Plume	1	MR	28
MR	28	Plume	2	Plume	2	Plume	2	Plume	2	Plume	2	Plume	2		
		Plume	3	Plume	3	Plume	3	Plume	3	Plume	3	Plume	3		
		Plume	4	Plume	4	Plume	4	Plume	4	Plume	4	Plume	4		
		Plume	5	Plume	5	Plume	5	Plume	5	Plume	5	Plume	5		
Total	**6**	**Total**	**9**	**Total**	**9**	**Total**	**9**	**Total**	**9**	**Total**	**9**	**Total**	**9**	**Total**	**5**

University of Toledo Sampling						
Maintenance July 3, 2013		Maintenance July 30, 2013		Weekly Sampling Various		
Location	Station	Location	Station	Location	Station	Date
RA-1	8M	RA-1	8M	PA	26	7/15/2013
MR	MB20	MR mouth	MB20	PA	26	8/16/2013
RA-2	GR1	RA-2	GR1	PA	26	8/29/2013
RA-1	25			PA	26	9/19/2013
RA-2	27			PA	26	10/8/2013
MR	28			PA	26	
Total area	**3**	**Total**	**3**	**Total**	**6**	

Key:
PA = placement area
RA = reference

Table 3-4 Integrated Water Samples for the Plume Monitoring Events in Event 2 and Event 3

Event	Day	Date	Plume Sample No.	Latitude	Longitude	Source
2	1	7/22/2013	1 to 4	41.81205	-83.28350	Log Book
2	1	7/22/2013	5	41.81337	-83.28115	Log Book
2	2	7/23/2013	1	41.81297	-83.28159	Log Book
2	2	7/23/2013	2	41.81383	-83.28111	Log Book
2	2	7/23/2013	3	41.81387	-83.28077	Log Book
2	2	7/23/2013	4	41.81351	-83.27767	Log Book
2	2	7/23/2013	5	41.81595	-83.27609	Log Book
2	3	7/30/2013	1	41.81273	-83.28392	Log Book
2	3	7/30/2013	2	41.81240	-83.28442	Log Book
2	3	7/30/2013	3	41.81328	-83.28492	Log Book
2	3	7/30/2013	4	41.81242	-83.28513	Log Book
2	3	7/30/2013	5	41.81290	-83.28579	Log Book
3	1	8/19/2013	1	41.81391	-83.28264	GPS Track Log
3	1	8/19/2013	2	41.81376	-83.28270	GPS Track Log
3	1	8/19/2013	3	41.81370	-83.28255	GPS Track Log
3	1	8/19/2013	4	41.81377	-83.28245	GPS Track Log
3	1	8/19/2013	5	41.81384	-83.28251	GPS Track Log
3	2	8/20/2013	1 to 5	41.8125	-83.2827	GPS Track Log
3	3	8/21/2013	1	41.81217	-83.2808	GPS Track Log
3	3	8/21/2013	2	41.813	-83.2805	GPS Track Log
3	3	8/21/2013	3	41.81317	-83.2802	GPS Track Log
3	3	8/21/2013	4	41.814	-83.2797	GPS Track Log
3	3	8/21/2013	5	41.814	-83.2788	GPS Track Log

Table 3-5 Analytical Methods for Water Samples

Analysis	Method	Laboratory
Total Phosphorus	EPA 365.1	Heidelberg University
Soluble Reactive Phosphorus	SM 4500-P	Heidelberg University
Total Dissolved Phosphorus	EPA 365.1	Heidelberg University
Total Suspended Solids	EPA 160.2	Heidelberg University
Volatile Suspended Solids	EPA 160.4	Heidelberg University
Total Kjeldahl Nitrogen	EPA 351.2	Heidelberg University
Nitrite and Nitrate	EPA 300.1	Heidelberg University
Ammonia Nitrogen	EPA 350.1	Heidelberg University
Chlorophyll-a	SM 10200H.3	University of Toledo
Cyanobacteria biomass	Specialized method	University of Toledo
Cyanobacteria speciation	Specialized method	University of Toledo
Microcystin	Enzyme-Linked Immuno-sorbent Assay test kit	University of Toledo

Key:
EPA = (United States) Environmental Protection Agency
SM = Standard Method

Water samples also were collected from the three long-term continuous monitoring locations by University of Toledo during the three maintenance events that were conducted between sampling events. The results are summarized in Appendix D-2. Water samples also were collected by the University of Toledo at their long-term monitoring stations. The results are summarized in Appendix D-3.

3.1.3 Short-term Continuous Monitoring/Plume Event Sampling

During the second and third sampling events when dredge material placement was occurring, four multi-parameter water quality sondes were moored in proximity to the active placement area. The short-term continuous monitoring buoys were designed to characterize turbidity in the vicinity of the placement operation when placement was actively taking place. The buoys were positioned approximately 1,000 feet away from the known area of active placement and in the cardinal directions around the operation (north, south, east, and west) (see Figure 3-3). The buoys were left at a given location for several hours or several days depending on the operation conditions and the field data are provided in Appendix C5a to C5b. The same buoy locations were used for each event.

Additionally, plume tracking was performed to characterize the size, shape, and distribution of the dredge spoils plume. Tracking was performed by trolling the water quality sonde through and around the perimeter of the dredge spoils plume, immediately following release from the barge. Measured parameters include temperature, turbidity, conductivity, pH, and dissolved oxygen. Four different methods utilizing water quality sondes were used to characterize the plume. They included taking measurements at locations throughout the plume, trolling multiple water quality sondes at various depths, sitting stationary and tracking plume dispersion, and tracking the outer edge of the plume. The results are discussed in Section 4.1.3 and the field data are provided in Appendix C6a to C6b.

3.1.4 Sediment Core and Grab Sampling

This field component consisted of collecting sediment cores and surface sediment grab samples from the placement area and the reference areas. These samples were collected to characterize physical (grain size, bulk density, specific gravity) and chemical (fractions of P) parameters of sediments from the placement area and reference areas as summarized in Table 3-6. The design and implementation of the sediment sampling and analysis program was done in conjunction with University of Wisconsin-Stout and the laboratory data are provided in Appendix C7. The draft report from University of Wisconsin is provided in Appendix E.

Table 3-6 Analysis Methods for Sediment Samples

Sediment Type/Analysis	Method	Laboratory
Sediment Core Samples		
Total Phosphorus	EPA 365.1	University of Wisconsin - Stout
Moisture Content and Loss on Ignition Organic Matter Content	ASTM E1109-86	
Phosphorus fractions (NaOH extractable) (surface segment only)	Hieltjes and Lijklema (1980); specialized method	
Metals (iron, aluminum and calcium)	EPA 200.7	
Particle Size Distribution	Plumb 1981/ASTM D422	
Specific Gravity	ASTM D854	
Estimated Bulk Density (Wet and Dry) Porosity	ASTM E1109-86, Estimated Using Equations (see Appendix E)	
Flux Incubation	SM 4500-P; specialized method	
Surface Sediment Grabs		
Total Phosphorus	EPA365.1	University of Wisconsin - Stout
Moisture Content and Loss on Ignition Organic Matter Content	ASTM E1109-86	
Particle Size Distribution	Plumb 1981/ASTM D422	
Estimated Bulk Density (Wet and Dry) Porosity	ASTM E1109-86, Estimated Using Equations (see Appendix E)	
Dredge Material		
Total Phosphorus	EPA 365.1	University of Wisconsin - Stout
Moisture Content and Loss on Ignition Organic Matter Content	ASTM E1109-86	
Particle Size Distribution	Plumb 1981/ASTM D422	
Estimated Bulk Density (Wet and Dry) Porosity	ASTM E1109-86, Estimated Using Equations (see Appendix E)	
Phosphorus Fractions	Hieltjes/Lijklema (1980); specialized method	
Sediment Traps		
Sediment Dry Weight	ASTM D3976-92	University of Wisconsin – Stout
Loss on Ignition Organic Matter Content	ASTM E1109-86	

Note: Of sediment solids. Particle density can be calculated from specific gravity by multiplying by the density of water (1 g/cm^3). Porosity = 1 - (bulk density/particle density).

Key:
ASTM = American Society for Testing and Materials
EPA = (United States) Environmental Protection Agency
SM = standard method

Intact sediment cores were collected from the placement area and reference areas and vertically sectioned to obtain a vertical profile of a suite of physical (e.g., bulk density, loss-on-ignition) and chemical (phosphorus fractionation) parameters. Sequential fractionation of sediment phosphorus was conducted for the determination of loosely-bound P, iron-bound P, aluminum-bound P, and calcium-bound phosphorus in the surface segment.

In addition, surface sediment grab samples were collected from the placement area and reference areas to assess horizontal variability of surface sediment phosphorus pools. Composited grab samples of sediment were also collected from the barge by the dredging contractor to characterize the nutrient and physical characteristics of dredged material.

Flux Measurements

To support the flux measurements, four cores were collected at each of the four sediment sampling stations (two for evaluation under an oxic environment and two for evaluation under an anoxic environment) for a total of 16 cores. The flux measurement cores were collected during the first and last sampling events for a total of 32 cores.

3.1.5 Sediment Trap Sampling

Sediment trap samplers were deployed to integrate the gross amount of material that is resuspended from the sediment bed and deposited at each site. Although not directly comparable with the model, the trap data give a direct comparison of the relative quantity of deposited material at the placement area and reference area measurements of gross sedimentation rate and to provide samples of deposited sediments for subsequent visual characterization. Traps were deployed during Events 1 and 2, and collected during Event 2 and 4 depending on the amount of sediment present. The results are summarized in Section 4.1.6 and presented in Appendix C7.

3.2 Deviations from the Work Plan

Deviations from the approved SAP (E & E/LimnoTech 2013) were based on the field conditions in the reference area and changes to the tracking approach to better assess the plume during dredge material placement. Changes are documented in the field logs and Field Adjustment forms in Appendix C. The following is a summary of these deviations:

Event 1a

During sampling Event 1a (May 9, 2013), one unplanned sediment grab sample was collected on at the reference area and three unplanned sediment grab samples were collected at the placement area. The purpose of these samples was to provide the field team with gross sediment characteristics at the proposed coring locations and to guide sediment sampling during the sediment sampling event in June. In addition, continuous monitoring equipment in the placement area was deployed at a different location than specified in the original plan based on discussions with Arnold Page (USACE Toledo) with regard to the actual planned 2013 placement area activities.

Event 1b

During Event 1b, collecting sediment cores at the proposed reference area identified in the SAP (located 3 miles north of the placement area) was not possible due to the presence of dreissenid mussel shells and a harder than expected substrate. Attempts to collect sediment cores farther south of the proposed reference area and north of the placement area were also unsuccessful due to the heavy presence of mussel beds and shell fragments. Attempts were made at 2.75, 2.5, 1.5, and 1.0 miles north of the placement area. All resulted in similar sediment conditions that were not conducive to collecting an intact sediment core for the sediment phosphorus flux incubations and phosphorus fractionation.

Therefore, the reference area was relocated approximately 4 miles southwest of the placement area noted as RA-1 in Figure 3-2. Cores were collected at four locations, sediment traps were deployed, and the reference site buoy was relocated. However, after retrieving sample analyses from these samples from the University of Wisconsin, preliminary results indicated that sediment in the new reference area had a much higher phosphorus release than sediments in the placement area. There was concern that the reference area was not solely representative of the sediments of open waters of the WLEB and that the mussels in this area may cause a higher phosphorus release due to biological activity. Therefore, another site was selected approximately 5 miles northeast of the placement area, RA-2 on Figure 3-2. This site is near an established NOAA water quality monitoring buoy (i.e., Toledo Light #2). Cores were collected, and the preliminary data indicated that existing sediments in this area also had a much higher phosphorus flux from the sediment than the placement area indicating that sediments in open water areas release two to three times more phosphorus than the newly deposited sediment in the placement area under anoxic conditions.

Based on this information, the team determined it to be most beneficial to continue sampling and monitoring of water quality at both alternative reference locations. These two stations should provide a representative view of sediment and water quality conditions in areas not influenced by open-lake placement activities that are closer to Maumee Bay (first reference area) and western Lake Erie (second reference area). These new reference stations would also facilitate the comparison of sediment and water quality conditions in the placement area to areas closer to where the material was dredged from (Maumee Bay) and to the open waters of the WLEB where HABs frequently occur.

Event 2

The sediment traps were originally planned as a string consisting of replicate traps hung at three different depths (1 meter from surface, mid-depth, and 1 meter above the lake bottom). The actual water depth encountered was not great enough to allow for installation at three depths. Therefore, the traps were hung at two depths, 1 meter from the surface and 1 meter from the bottom. The sediment traps were only retrieved when sufficient sediment was present.

Events 2 and 3 Water Colum Vertical Profile Samples

Vertical profile samples were collected using several different approaches as described in Section 4.1.3 because the plume was dissipating very quickly and monitoring at set locations was not possible.

Water Column Integrated Sampling

During the four sampling events, water column integrated samples were collected. During Events 1 and 4, samples were collected at all the long-term monitoring locations but additional samples in the placement area were not collected. Sampling for surface water grabs also was performed at long-term monitoring stations by University of Toledo as part of their monitoring program. Samples were always collected in the placement area at PA-01 but not at all of the reference area locations.

3.3 External Data

This section describes data from outside sources that were not collected as part of this project, but were used during the model calibration process. A list of stations from external data sources are listed in Table 3-7 and shown on Figure 3-2.

3.3.1 NOAA

National Ocean Service hourly water level data were downloaded from Station 9063079 at Marblehead, Ohio, from 2011 to 2013 (NOAA 2013a).

Great Lakes Environmental Research Laboratory (GLERL) in-situ data collected between 2011 and 2013 was obtained via email on February 20, 2014, from Tom Johengen at GLERL. Samples were collected at the stations listed in Table 3-7.

Table 3-7 Monitoring Data From External Sources

Station Owner	Station ID	Latitude	Longitude
GLERL	WE2	41.76403	-83.3275
GLERL	WE4	41.82672	-83.193
GLERL	WE6	41.71343	-83.3804
GLERL	WE8	41.83433	-83.3633
UT	4P	41.7504	-83.1036
UT	7M	41.7338	-83.2968
UT	8M	41.7889	-83.356
UT	GR1	41.8214	-83.1855
UT	MB18	41.7427	-83.4015
UT	MB20	41.7156	-83.4556
EPA	ER58	41.685	-82.9333
EPA	ER59	41.72667	-83.15
EPA	ER60	41.89167	-83.1967
EPA	ER61	41.94667	-83.045
EPA	ER91M	41.84083	-82.9167

Table 3-7 Monitoring Data From External Sources

Station Owner	Station ID	Latitude	Longitude
EPA	ER92	41.95	-82.6867

Key:
EPA = United States Environmental Protection Agency
GLERL = Great Lakes Environmental Research Laboratory
UT = University of Toledo

The samples were analyzed for TP, total DP, SRP, ammonia nitrogen (NH_3), nitrate (NO_3), silicon dioxide (SiO_2), chloride, TSS, volatile suspended solids (VSS), particulate organic carbon, particulate organic nitrogen, extracted chlorophyll, and extracted phycocyanin. All samples were collected as grab samples from 1 meter below the water surface. In addition, microcystin data collected by GLERL in 2013 was used (GLERL 2013).

3.3.2 USGS

Daily average flow from the following USGS gage stations (USGS 2013):

- Station 04193500 – Maumee River
- Station 04176500 – Raisin River
- Station 04174500 – Huron River
- Station 04165710 – Detroit River

3.3.3 Heidelberg University

Tributary concentration data was downloaded from Heidelberg University for the period of 2011 to 2013 for the Maumee River at Waterville and the Raisin River (Heidelberg University 2013). The samples were analyzed for TSS, TP, SRP, nitrite and nitrate (NO_2+NO_3) total Kjeldahl nitrogen (TKN), chloride, sulfate, silica, and conductivity.

3.3.4 University of Toledo

Data was collected by the University of Toledo from 2011 to 2013 from Tom Bridgeman (Bridgeman 2014). Depth integrated samples were collected at the WLEB shown in Table 3-6 and on Figure 3-1.

The samples were analyzed for TSS, VSS, NH_3, chloride, sulfate, NO_2, NO_3, SiO_2, TP, SRP, total DP, fluoride, blue-green algal biovolume, and photosynthetically active radiation (PAR). Profile data using a water quality sonde were also collected, including temperature, dissolved oxygen, specific conductivity, pH, turbidity, and chlorophyll profiles.

3.3.5 USEPA – Great Lakes National Program Office

Data were downloaded from the EPA Great Lakes National Program Office (GLNPO) website along with an overview of their sampling program (USEPA 2013). Data was also obtained through the Great Lakes Environmental Database (USEPA 2013).

The stations sampled in 2013 are shown in Table 3-7 and on Figure 3-1. The samples were analyzed for TP, total DP, pH, PAR, conductivity, chloride, extracted chlorophyll, turbidity, water temperature, extracted chlorophyll, SiO_2.

3.4 Model Overview

The fine-scale, linked hydrodynamic – sediment transport – water quality model framework developed for the WLEB, termed the Western Lake Erie Ecosystem Model (WLEEM) utilizes the following model components:

- *Simulating Waves Nearshore* (SWAN) for the wind-wave sub-model;
- *Environmental Fluid Dynamics Code* (EFDC) for the hydrodynamic sub-model;
- *Sandia National Laboratory* (SNL) algorithms for the sediment transport sub-model; and
- Advanced Aquatic Ecosystem Model (A2EM).

Figure 3-5 illustrates how the wind/wave model, hydrodynamic model, sediment transport, and water quality model all interact together.

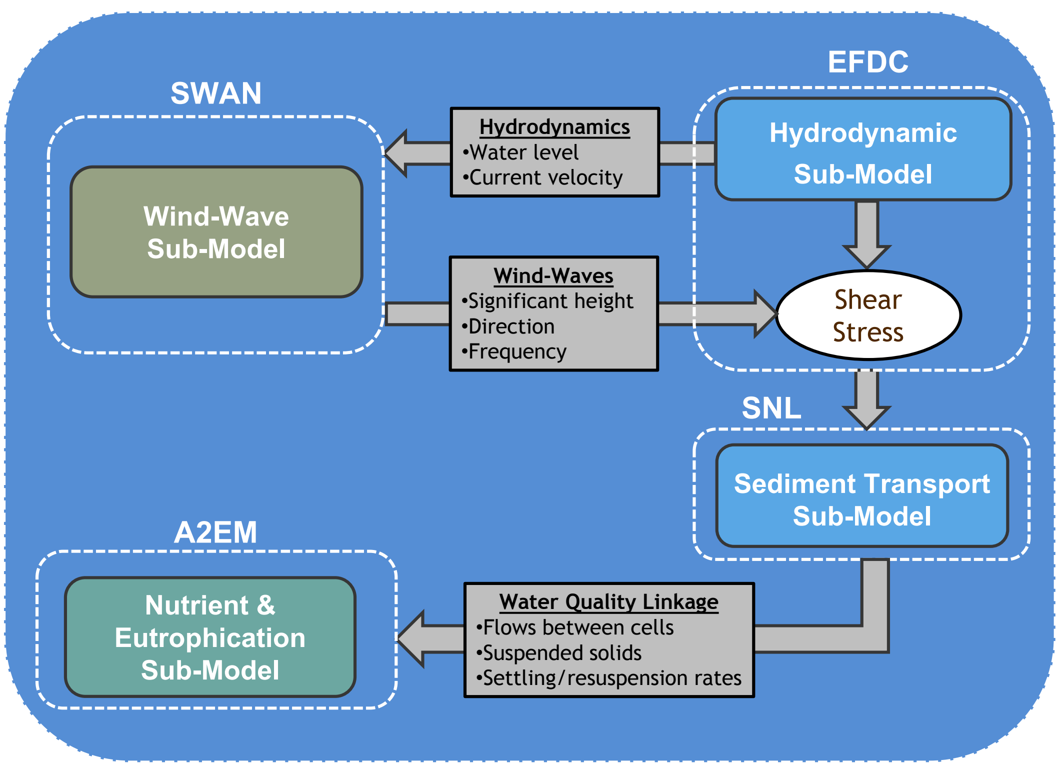


Figure 3-5 Model Framework

EFDC is a state-of-the-art finite difference model that can be used to simulate hydrodynamic and sediment transport behavior in one, two, or three dimensions in riverine, lacustrine, and estuarine environments (TetraTech 2007a, 2007b). EFDC was developed by John Hamrick at the Virginia Institute of Marine Science in the 1980s and 1990s, and the model is currently maintained under support from the United States Environmental Protection Agency (EPA). The model has been applied to hundreds of water bodies, including Chesapeake Bay and the Housatonic River. Recently, LimnoTech has successfully applied EFDC to a number of sites in the Great Lakes, including Saginaw Bay, Saginaw River, and the Tittabawassee River. The EFDC model is both public domain and open source, meaning that the model can be used free of charge, and the original source code can be modified to tailor the model to the specific needs of a particular application. As a result, EFDC provides a powerful and highly flexible framework for simulating hydrodynamic behavior and sediment transport dynamics for the WLEB.

The SWAN model is a numerical wave model for predicting wave conditions in coastal areas, lakes, and estuaries based on site-specific wind, depth, friction, and water velocity conditions (Young 1999; Booij et al. 1999). The SWAN model is based on the wave action balance equation and is capable of simulating various wave propagation (movement) processes, as well as wave generation processes (e.g., by wind) and dissipation processes, such as dissipation by bottom friction. SWAN provides the flexibility to simulate either steady-state or dynamic wave conditions. As part of the model development effort on this project, the SWAN model was linked to the EFDC hydrodynamic and sediment transport sub-models. The SWAN-EFDC linkage involved two steps: 1) water level/depth and current velocity results generated by the hydrodynamic sub-model were processed and input as forcing functions to the SWAN wind-wave simulations; and 2) SWAN results for wave characteristics (e.g., height, frequency) were fed as input forcing functions to the EFDC sediment transport sub-model to inform calculations of bottom shear stress.

The SNL model is a modified version of the original code developed and maintained by Sandia National Laboratory (James et al. 2005; Thanh et al. 2008). This version of the model incorporates a custom sediment transport sub-model based on the SEDZLJ model algorithms developed by Craig Jones and Wilbert Lick at the University of California – Santa Barbara (Jones and Lick 2001). The SNL/SEDZLJ models are typically used along with site-specific data obtained using SED flume, a custom-designed flume device that can be used to measure erosion rates and sediment properties for an intact sediment core. The integration of the SNL code into LimnoTech's in-house version of the Row-Column AESOP (RCA) model code and associated testing work was accomplished previously under a separate LimnoTech modeling project (LimnoTech 2010).

The A2EM is used as the computational framework to simulate water quality. The basic framework includes a suite of state variables to represent carbon, nitrogen, phosphorus, and algal dynamics. In addition to simulation of water column processes affecting water quality, the model includes a coupled sediment diagenesis sub-model that simulates the cycling of detrital material and nutrients in the surface sediments and subsequent impacts on near-bed sediment oxygen demand and release of dissolved nutrients, including dissolved inorganic phosphorus. Detailed documentation of the RCA water quality modeling framework, including the sediment diagenesis sub-model, is provided in the HydroQual, Inc. (HQI) Upper Mississippi River final project report (HydroQual 2002) and a user's manual developed by HQI for the publicly available version 3.0 (HydroQual 2004).

The linked modeling framework comprised of EFDC, SWAN, SNL-EFDC, and RCA, collectively referred to as the WLEEM, provides a powerful and flexible tool for evaluating hydrodynamic, wind-wave, sediment transport, and nutrient and phytoplankton processes at a variety of temporal and spatial scales. The sections below describe each model in more detail.

3.4.1 EFDC Model Configuration

A model grid was developed that represents the WLEB. Model boundaries were located at the interface between the western and central basins of Lake Erie. The model grid was developed to accurately represent key bathymetric features in the system while minimizing the time required to conduct model simulations. Along nearly the entire length of the Toledo Harbor navigation channel, two grid cells span the channel in the lateral direction. The model grid is more detailed in Maumee Bay than in the rest of the WLEB and closely aligned with the federal navigation channel. In general, grid cells have been sized to meet the competing demands of computational burden and the spatial resolution required to address key management questions. The model grid is shown in Figure 3-6.

Water depths shown in Figure 3-7 are relative to the Lake Erie LWD (173.5 meters IGDL85) and vary from less than 1 meter in Maumee Bay to greater than 10 meters in the northeast quadrant of the WLEB. Much of Maumee Bay is very shallow, with water depths in the inner bay typically less than 2 meters relative to the LWD. The bathymetry of the navigation channel is represented consistently with the design maintenance depth of approximately 29 feet (8.86 meters) LWD.

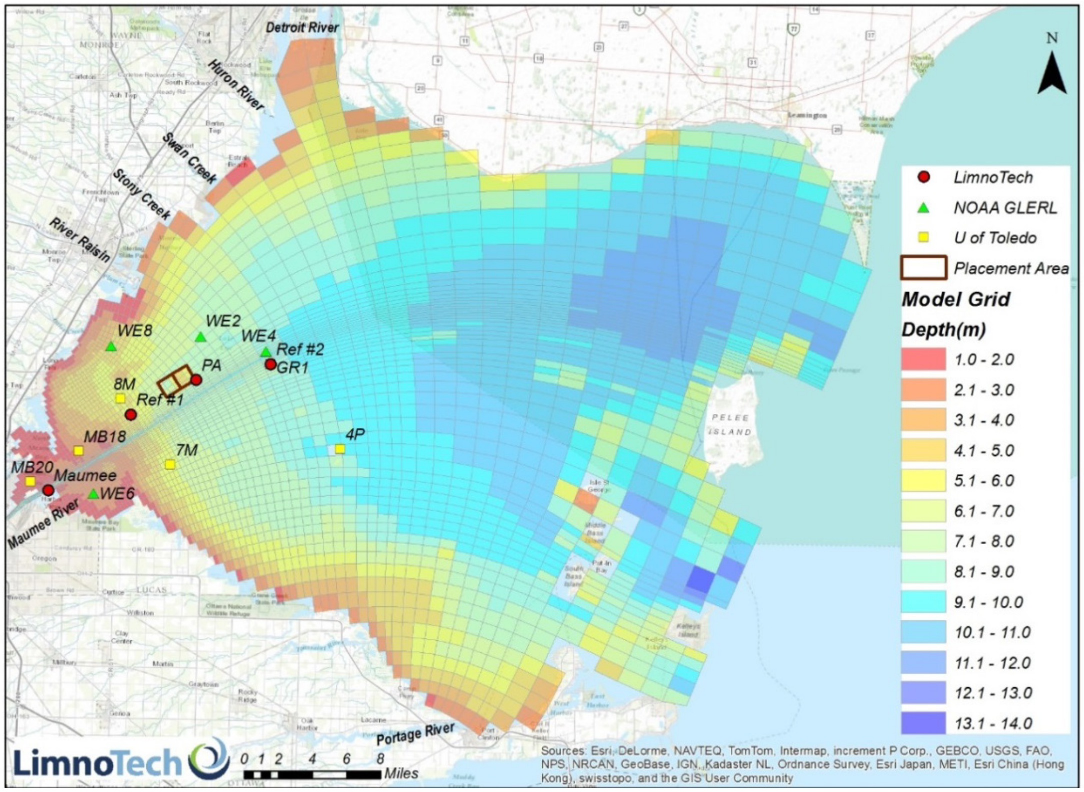


Figure 3-6 WLEEM Model Grid

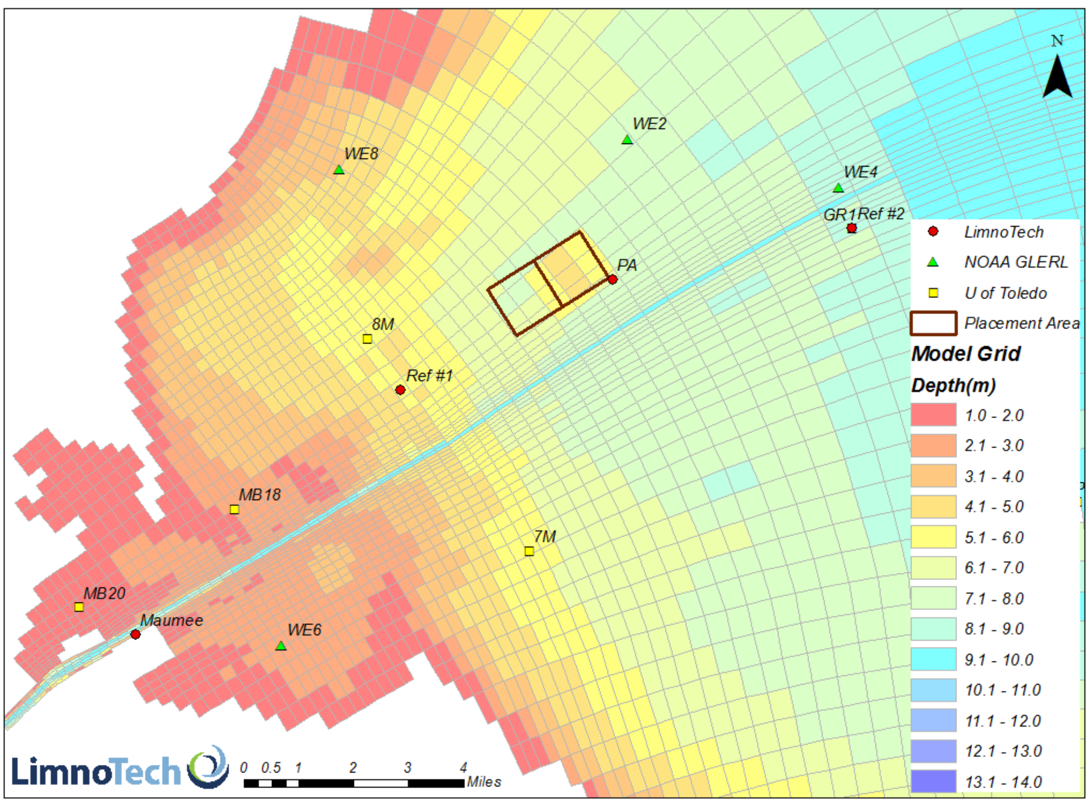


Figure 3-7 Model Grid zoomed to Maumee Bay/Study Area Locations and Placement Area

EFDC Boundary Conditions

Model boundary conditions provide a basis, or starting point, for calculations internal to the model. Four types of hydrodynamic forcings were applied as boundary conditions to the hydrodynamic model, including:

- A water level boundary condition in Lake Erie;
- Inflow boundary conditions for the Maumee River, the Detroit River, and other minor tributaries including flow rate and water temperature;
- Atmospheric forcings (e.g., wind and air temperature); and
- A water level boundary was applied at the interface of the central and western basins of Lake Erie. Data from NOAA station number 9063079 (Marblehead, Ohio) was used to describe hourly variations in water level at this location. This "boundary forcing" controls the depth of water and circulation patterns in the WLEB and also influences the strength of flow reversals in the lower Maumee River as changes in water levels drive the seiche activity experienced in the drowned river mouth and dredged channel of Toledo Harbor.

Tributary inflows to the system were represented in the model using available data (Section 3.3.2). Flow gauging datasets available from the United States Geological Survey (USGS) were used to develop daily flow time series for each tributary. In many cases, the USGS gauge dataset did not represent the entire drainage area of a given tributary; therefore, drainage area ratios were used to scale the daily measured flow time series to represent the entire watershed.

The model utilizes a spatially variable "wind forcing" that is consistent with the established whole lake model. Wind forcings were extracted from the Great Lakes Observing System (GLOS) point query website (GLOS 2013). This website allows a user to extract model inputs or model outputs at a specified location from the NOAA supported Great Lakes Coastal Forecasting System (GLCFS). Wind time series were extracted for 10 locations within the WLEEB model domain. A Thiessen polygon analysis was then performed on the model grid and the wind forcing locations so that each grid cell in the WLEEB model grid was attributed with weighting factors for the nearest of these 10 wind forcings. Additional information on the wind forcings and the GLCFS model can be found at the NOAA's website (NOAA 2013b).

3.4.2 SWAN Configuration

SWAN provides a variety of settings that can be used to control the complexity of the algorithms used to compute wave conditions. Specific settings used for the WLEEM application of SWAN included:

- Time-varying and spatially varying forcing functions for wind, current velocity, and water level;
- Third-generation mode for wind input, quadruplets, and white-capping;

- Activation of triad wave-wave interactions;
- Representation of bottom friction based on the semi-empirical JONSWAP model (Hasselmann et al. 1980) with a default constant friction factor; and
- Use of the Backward Time Backward Space scheme (to ensure convergence of the model solution).

More detailed descriptions of these settings and alternative settings can be found in the SWAN user manual (Delft University of Technology 2004).

A variety of boundary conditions and other inputs are required for running SWAN model simulations to predict wave conditions, including:

- Wind velocity magnitude and direction;
- Current velocity; and
- Water level.

Because the model was applied in its "non-stationary" (i.e., dynamic) mode and over a complex computational grid, wind velocity, current velocity, and water level were all input as individual time series for each horizontal grid location. Wind velocity components were input on an hourly interval based on the spatially-varying wind time series specified in the EFDC model (i.e., using 10 distinct spatial zones). Water current velocity and water level results generated by the EFDC hydrodynamic model were processed and provided as input time series to SWAN using a 4-hour average interval. In general, water level and current conditions change less rapidly than wind conditions observed in the system, so a 4-hour interval was sufficient to represent the hydrodynamic forcing functions.

3.4.3 SNL Model Configuration

The SNL sediment transport sub-model can be used to simulate sediment transport in one, two, or three dimensions. SNL provides a flexible set of options for simulating erosion, deposition, and bed armoring and handling for cohesive and non-cohesive sediment types (James et al. 2005; Thanh et al. 2008). Multiple cohesive and non-cohesive sediment size classes may be represented in a single model simulation. This section provides a summary of the transport processes, selection of sediment particle size classes, and bottom shear stress calculations for the WLEEM sediment transport model.

Sediment Transport Process Representation

The transport processes represented in the EFDC model for cohesive and non-cohesive sediments are illustrated in Figure 3-8 and include the following:

- Loading of sediments from upstream and watershed sources;
- Horizontal transport between adjacent model cells (based on velocity and flow magnitude and direction predicted by the hydrodynamic sub-model);

- Settling and deposition to the sediment bed from the water column;
- Erosion and resuspension of sediments from the bed to the water column;
- Transport of non-cohesive sediments as bedload or suspended load based on applied bottom shear stress and particle characteristics;
- Representation of the sediment bed as discrete layers (to permit tracking of changes in particle size distribution by depth); and
- Armoring of the sediment bed in nearshore areas and areas of hard substrate, including the use of an "active layer."

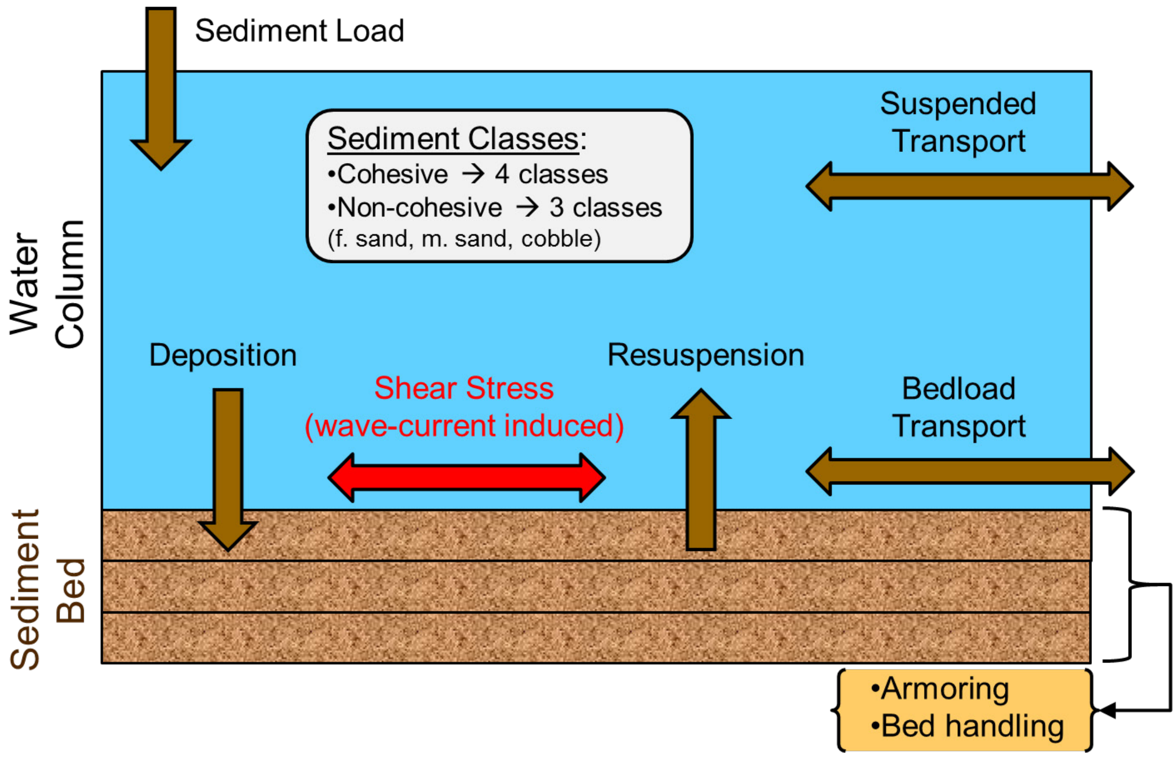


Figure 3-8 Sediment Transport Process Representation

Boundary Conditions

Sediment transport boundary conditions describe the quantity and particle size distribution of suspended sediments entering the model domain from various sources. This section describes the sediment boundary conditions developed for the Maumee River and other tributary sources and point sources to Maumee Bay/WLEB that are represented in the WLEEM model.

Suspended Sediment Concentrations

An extensive suspended solids dataset is available for the Maumee River at Waterville, Ohio, based on long-term research conducted by Heidelberg University's National Center for Water Quality Research (NCWQR).

Several other tributary inflows are represented in the WLEEM model in addition to the Maumee River, including the Detroit River, Swan Creek, Ottawa River, River Raisin, Huron River, Stony Creek, and Portage River/Cedar River. In addition, inflows are represented for the Toledo Bay View Wastewater Treatment Plant (WWTP) and Maumee River direct drainage contributions between Waterville, Ohio, and the mouth (see Table 3-8). Suspended sediment boundary conditions were developed for each of these flow sources. The boundary condition for the Detroit River was set at a constant value of 10 milligrams per liter (mg/L) based on a review of available data for this Great Lakes connecting channel. The Bay View WWTP was also assigned a constant concentration of 10 mg/L based on available data from the plant's discharge monitoring reports (DMRs).

Table 3-8 Suspended Sediment Boundary Conditions for Maumee Bay/WLEB Flow Sources

Flow Source Description	Flow-Based Regression[a]
Detroit River	$C_{TSS} = 10$
Swan Creek	$C_{TSS} = 0.085*Q + 30.52$
Ottawa River	$C_{TSS} = 0.13*Q + 24.81$
River Raisin	$C_{TSS} = 0.0415*Q + 10.60$
Portage River + Cedar River	$C_{TSS} = 0.0406*Q + 20.42$
Toledo Bay View WWTP	$C_{TSS} = 10$

Note:
[a] C_{TSS} are in units of milligrams per liter and Q are in units of cubic feet per second.

Key:
C_{TSS} = Suspended solids concentrations
Q = flows
WWTP = wastewater treatment plant

Sufficient suspended sediment data were also available to develop a tributary-specific relationship between sediment concentration and flow rate for Swan Creek, Ottawa River, River Raisin, and Portage River. These regressions were applied to estimate suspended solids concentrations for the entire duration of model simulations.

The open boundary condition at the interface between the WLEB and the central Lake Erie basin is characterized with a constant concentration of 10 mg/L based on available monitoring data from the International Field Year in Lake Erie (IFYLE) datasets (Hawley et al. 2006).

Open-Lake Placement Load

When dredged material is disposed of at the placement location, a small fraction of the solids remain suspended in the water column. Previous studies estimate this fraction to be between 1 and 5% of the total mass of material that is placed. A review of the monitoring data collected during placement events showed that approximately 2.5% of the material remains suspended in the water column immediately after the event. This is the amount of material that is loaded into the model to simulate the deposition and transport of this material. The small suspended fraction was represented in the model as a point source of suspended solids material released to the near-bed water column layer at the placement site.

Three characteristics of the suspended solids were represented in the model: the total mass placed within a dredging season, the frequency of placement events within a dredging season, and the size distribution and associated settling rates of the dredged solids. The total mass placed within a dredging season was characterized using daily scow logs from the USACE (USACE 2013). Placement events were assumed to occur every 3 hours from July 5, 2013, to October 28, 2013. The number of placement events per day is based on the daily log. Figure 3-9 shows the daily amount of material placed at the site. Daily logs of placement activities from the USACE estimated that 1,019,941 cubic yards of dredged material was placed in 2013 in 675 release events. Bulk density estimates of dredged material from this study average 0.6 grams per cubic centimeter (g/cm^3). This would convert the dredged volume to a mass of 476,880,372 kilograms (kg). Estimates from event monitoring data collected by this project and literature show that approximately 2.5% of the material is released into the water column. The remaining 97.5% reaches the bottom within minutes after the barge doors are opened. This leaves 11,697,009 kg of material.

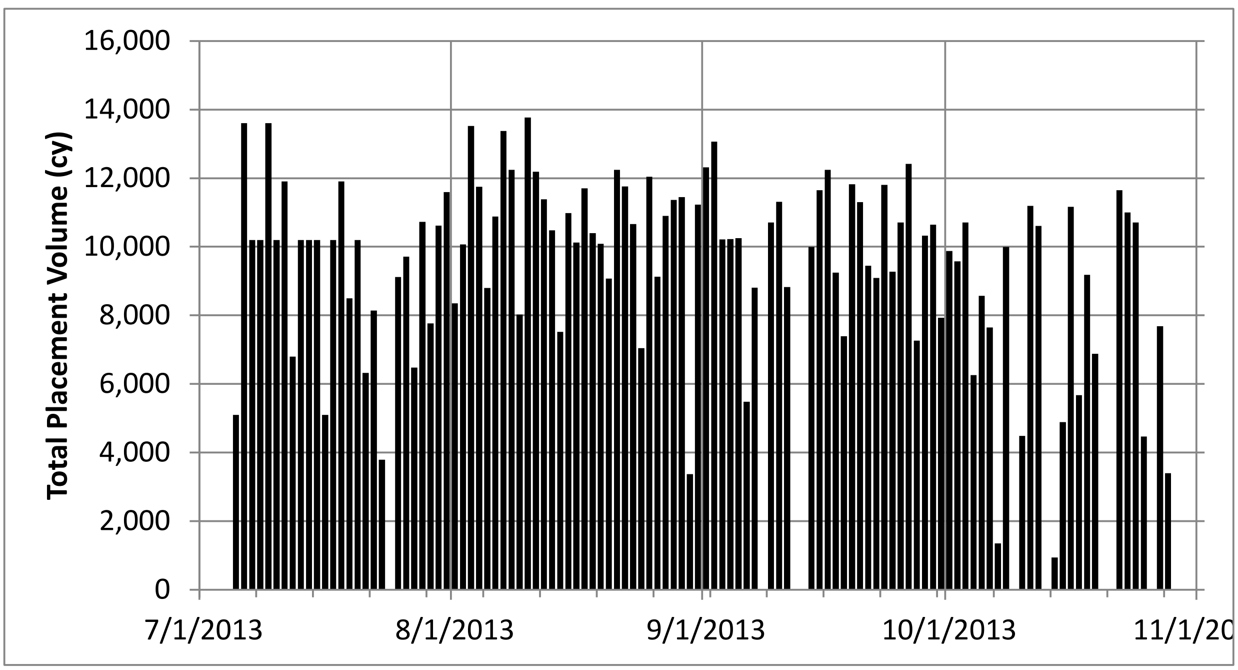


Figure 3-9 Daily Placement Volume Based on USACE Records

3.4.4 Advanced Aquatic Ecosystem Model

The A2EM is a state-of-the-science environmental simulation model. The model framework was customized by LimnoTech from a publicly available version of the RCA model developed by HydroQual, Inc. (HydroQual 2004). The RCA model framework developed by HydroQual is capable of simulating water quality dynamics on a fine-scale, multi-dimensional computational grid based on linkage to an external hydrodynamic model application. The basic RCA framework includes a suite of state variables to represent carbon, nitrogen, phosphorus, oxygen, and phytoplankton dynamics. The framework includes a coupled sediment diagenesis sub-model that simulates the cycling of detrital material and nutrients in the surface sediments and subsequent impacts on near-bed sediment oxygen demand and release of dissolved nutrients, including dissolved inorganic phosphorus. Detailed documentation of RCA is provided in the user's manual developed for the publicly available version 3.0 (HydroQual 2004). The LimnoTech enhancements to this model include a custom linkage from the hydrodynamic model (EFDC) and the sediment transport model. This allows output from one model to be included as inputs to the next model in the simulation chain. LimnoTech has also added the capability to dynamically simulate zooplankton, benthic algae, dreissenid mussels, and further process refinement of inorganic and organic particulate phosphorus.

Boundary Conditions

The A2EM model uses the same boundary locations as the hydrodynamic model, which includes the open boundary with the central basin of Lake Erie and tributary inflows from the Detroit, Maumee, and other minor tributaries. Daily estimated concentrations of nutrients, dissolved oxygen, and phytoplankton, are applied at every boundary location. The boundary conditions are described in more detail below.

Maumee River. Nutrient concentrations for the Maumee River were derived from measurements made by Heidelberg University at their monitoring station located in Waterville, Ohio. This station is approximately 20 miles upstream of the mouth of the Maumee River. Concentrations at this station are assumed to be representative of what enters Lake Erie on a daily basis. The frequency of sediment and nutrient sampling at this station is one or more samples per day. As a result, monitoring data was used directly to drive the model

Detroit River. A regular monitoring program does exist for the lower Detroit River; however data from the Michigan Department of Environmental Quality have a five-year lag until they are released. The latest published report of observations released in February 2013 summarizes monitoring data through 2008 (MDEQ 2013). These observations were used to parameterize the concentrations of TP, TSS, and DRP that enter Lake Erie.

Lake Erie. Monitoring data from EPA- GLNPO's open-lake limnology program were utilized to set the open boundary concentration of nutrients. Monitoring data were downloaded from the Great Lakes Environmental Database (GLENDA; USEPA 2013).

Other Tributaries. Concentrations of nutrients in other minor tributaries were based on of a limited review of existing data and engineering judgment based on of the nature of the watershed land uses.

4 Results

This section provides a summary of the results of the data collection effort described in Section 3. It also presents a description of the WLEEM evaluation and corroboration for use to support addressing the questions addressed in this study. The field work included long-term continuous monitoring, short-term continuous monitoring, water column sampling, and sediment sampling. Four field events were conducted in May/June, July, August, and October 2013. The first event took place prior to the start of dredging operations and the last event was conducted when dredging operations had ceased in the study area.

4.1 Data Collection Results

4.1.1 Long Term Continuous Monitoring

Three long-term buoys were deployed to collect the long-term monitoring data. They were deployed at the placement area, RA-1, and the mouth of the Maumee River.

Sonde Data

Multi parameter sondes were deployed at each station and collected temperature, turbidity, and conductivity data in 10-minute intervals. The data were collected between May 10, 2013, and October 28, 2013, at the real-time buoy in the placement area; between June 24, 2013, and September 13, 2013, at RA-1; and between May 17, 2013, and October 1, 2013, at the Maumee River station. These data are plotted below in Figure 4-1.

Several data gaps exist in these long-term datasets. Data are missing from the Maumee River Station between June 1, 2013, and June 20, 2013, due to battery failure. Data was also lost due to battery failure at RA-1 from May 29, 2013, to June 24, 2013, as well as after September 13, 2013. Although there are gaps in the data, the study plan did not call for long-term sondes to be placed in the study area until the start of the first sampling event, which occurred in mid-June. The data that was collected before this date, while not complete, still provides valuable information regarding lake conditions at select locations during this early time period before regular monitoring began. The data gap after September 13 represented a loss of three weeks of sonde data at RA-1. Despite this gap, there was still a three-month dataset available to directly compare conditions between RA-1 and the placement site. In addition the algal bloom began in late July, meaning data was available from both stations during many weeks of the algal bloom to assess differences between the reference area and placement area.

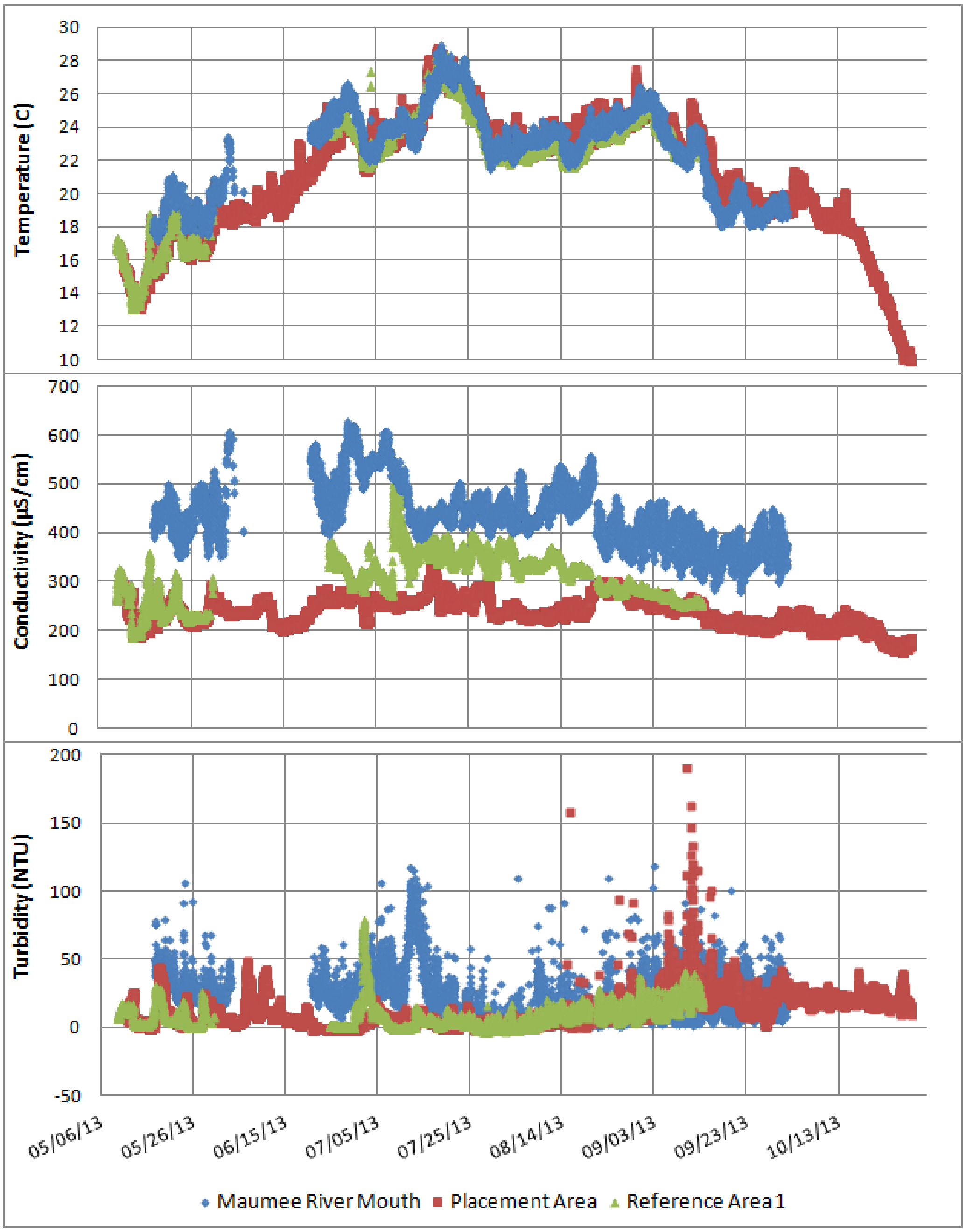


Figure 4-1 Long-Term Multi-Parameter Sonde Data Collected in the Placement Area, RA-1 and the Maumee River Mouth

As seen in Figure 4-1, temperature values for the Maumee River station tended to be slightly higher than those in the lake in the spring and slightly lower than the lake stations in the fall. This is typical because the watershed stream network tends to respond faster to air temperature seasonal trends than the lake. The conductivity and turbidity were generally highest in the Maumee River mouth and tended to decline with distance from the river. This pattern of declining water column concentrations with distance from the Maumee River was observed with most nutrient and algal biomass parameters as well. These results are discussed in Section 4.1.2.

Measured results at the Maumee River mouth were also more variable than the data collected at the offshore stations. Spikes in turbidity were observed at the placement site in mid-August through mid-September. These spikes correspond with periods of low wind and low waves and high abundance of *Microcystis*. The low wind and waves causes the buoyant *Microcystis* cells to accumulate near the surface and cause intermittent high turbidity as they block the sensor head. Spikes near 40 nephelometric turbidity units (NTU) were also observed at the reference site.

Monthly averages and standard deviations were calculated for each of the parameters measured at the long-term sampling sites. The results are summarized in Tables 4-1 to 4-3 and shown graphically in Figure 4-2.

Table 4-1 Monthly Statistics at the Maumee River Mouth (Station 28)

	May	June	July	August	September	October
Maumee River Monthly Averages						
Temperature (°C)	19.1±0.9	24.4±1.3	24.7±1.8	23.7±1.8	21.1±2.3	18.9±0.2
Conductivity (µS/cm)	434±34	516±61	471±54	439±56	375±35	351±16
Turbidity (NTU)	32.6±10.3	27.2±7.9	30.8±24.1	13.3±11.4	21.0±14.1	21.4±7.5

Key:
°C = degrees Celsius
µS/cm = microSiemens per centimeter
NTU = nephelometric turbidity unit

Table 4-2 Monthly Statistics at the Placement Area (Station 26)

	May	June	July	August	September	October
Placement Area Monthly Averages						
Temperature (°C)	16.4±1.9	20.8±2.1	24.5±2.0	23.4±1.3	21.4±2.2	16.5±3.1
Conductivity (µS/cm)	235±26	244±24	263±23	253±24	232±21	205±21
Turbidity (NTU)	10.5±8.7	7.3±9.5	5.9±4.0	9.2±10.9	23.1±12.3	21.8±3.8

Key:
°C = degrees Celsius
µS/cm = microSiemens per centimeter
NTU = nephelometric turbidity unit

Table 4-3 Monthly Statistics at RA-1 (Station 25)

	May	June	July	August	September	October
RA-Monthly Averages						
Temperature (C)	16.2±1.5	24.2±0.4	24.4±1.8	23.0±1.5	23.3±1.0	No data
Conductivity (µS/cm)	247.3±35	328.1±25	352.5±44	319.6±33	263.7±10	No data
Turbidity (NTU)	8.9±7.2	3.8±4.5	7.2±10.7	9.6±6.2	20.1±6.6	No data

Key:
°C = degrees Celsius
µS/cm = microSiemens per centimeter
NTU = nephelometric turbidity unit

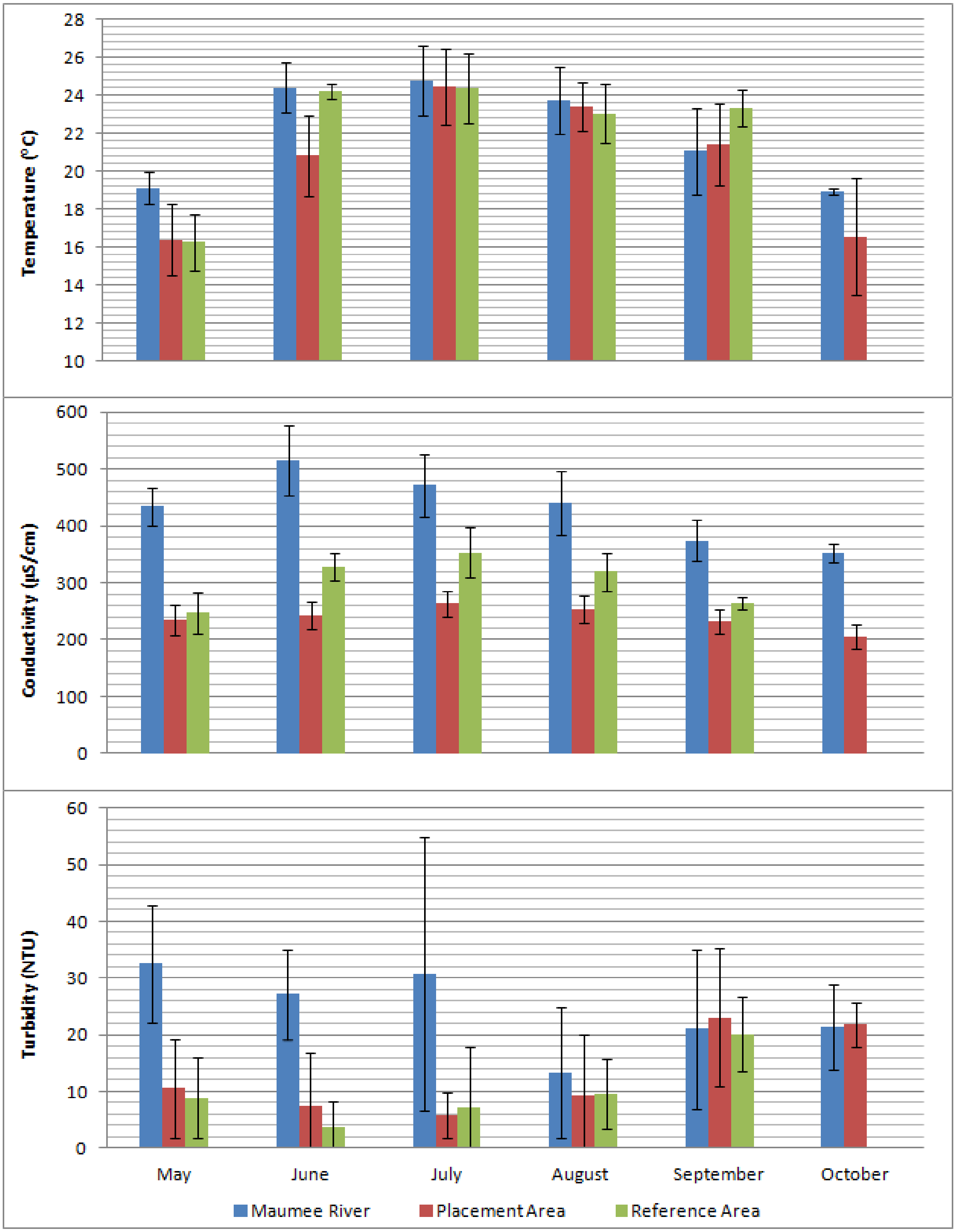


Figure 4-2 Monthly Average and Standard Deviation Multi-Parameter Sonde Data Collected at Three Long-Term Monitoring Stations

A statistical significance T-test was performed to determine if significant differences exist between the placement area and the Maumee River Mouth, and the placement area and RA-1. The T-test results are provided in Table 4-4. The test performed was a two-tailed, paired T-test using a significance level of 0.05. According to this test, all datasets compared were deemed statistically different from one another except for one comparison. Turbidity measurements collected at the placement area and RA-1 were not deemed statistically different (i.e., T-values greater than 0.5 as highlighted in yellow on Table 4-4). To confirm these results the non-parametric Wilcoxen Signed Rank Test was also used to test for differences in daily averages of temperature, conductivity and turbidity. The Wilcoxen Signed Rank Test tests for statistically significant differences in data median values. The results obtained were consistent with the T-test results and showed that the turbidity at the placement area and RA-1 did not have a statistically significant difference.

With the exception of September, the temperature was highest at the Maumee River mouth. Conductivity values were different at each station with the Maumee River having the highest values and the placement area having the lowest values. The Maumee River station had significantly higher turbidity during the period of May through August.

Table 4-4 P-Values for T-tests Comparing the Placement Area vs. the Maumee River Mouth and RA-1 with a Significance Level of 0.05

Placement Area Compared vs.	Temperature	Conductivity	Turbidity
Two-tailed T-Test – P-Values			
Maumee River Mouth	0	0	0
RA-1	0	0	0.217

Note: Yellow shaded boxes represent no statistical difference

Key:
RA = reference area

Real-Time Buoy Data

The real-time buoy was deployed at the placement area to collect a suite of water and atmospheric parameters. Data were collected between May 10, 2013, and October 28, 2013, at 10-minute intervals. Parameters collected include air temperature, relative humidity, atmospheric pressure, solar radiation, wind speed, gust speed, wave height, and wave period. These data provide information on hydro-meteorological conditions during the study and forcing function input information for the WLEEM.

Due to large and rapid variations in the data over the collection period, the data were averaged on a daily basis. The daily average air temperature, relative humidity, and atmospheric pressure results are shown in Figure 4-3. The daily average wind speed, gust speed, wave height, and wave period are shown in Figure 4-4. As shown in Figure 4-4, the wave height is influenced by wind speed.

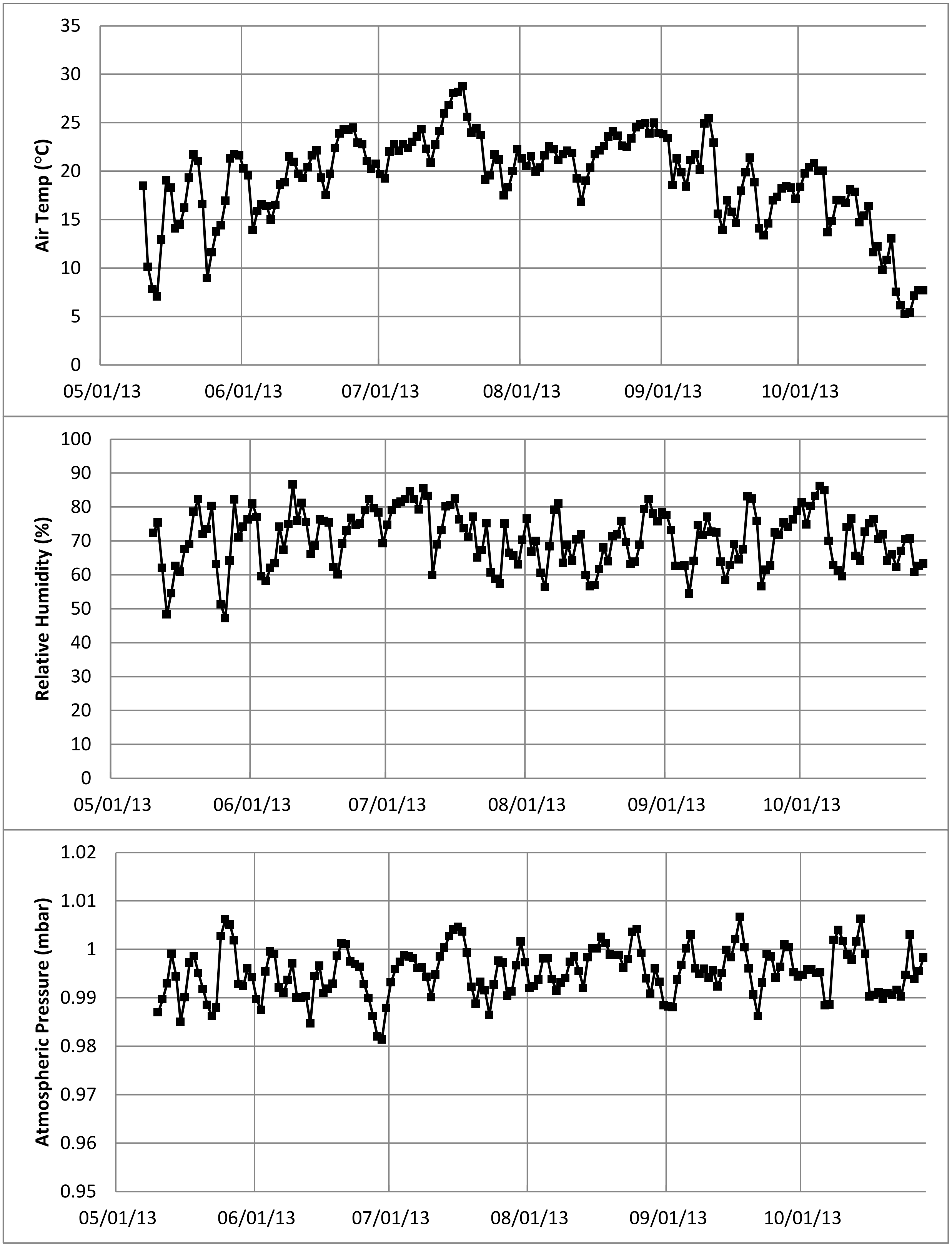


Figure 4-3 Daily Average Atmospheric Parameters Collected at the Real-Time Buoy (Placement Area) Including Air Temperature, Relative Humidity, and Atmospheric Pressure

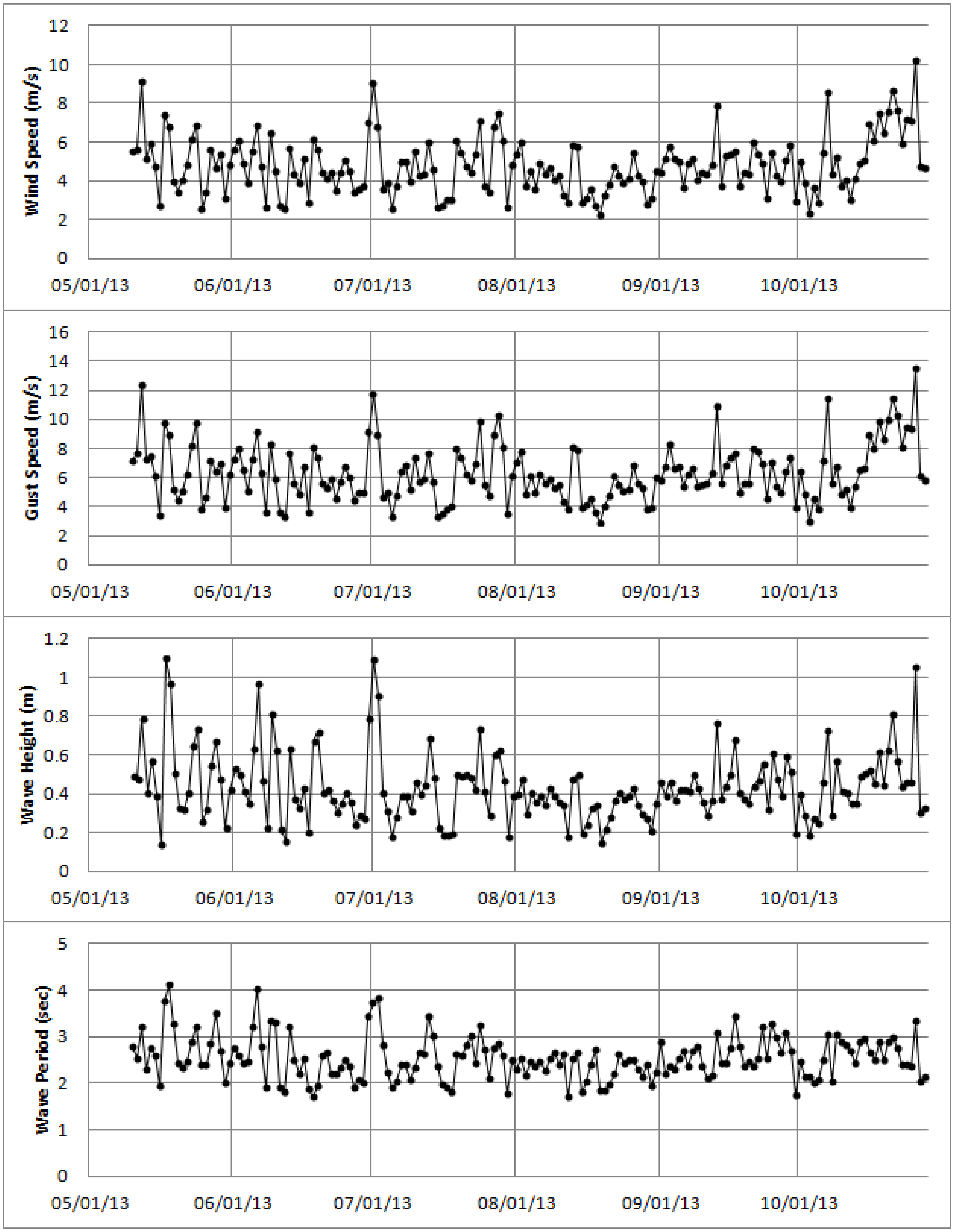


Figure 4-4 Daily Average Wind Speed, Gust Speed, Wave Height, and Wave Period Collected at the Real-Time Buoy (Placement Area)

On July 1, 2013, the relationship between all seven of these parameters can be observed when a large storm event occurred, with 0.9 inches of precipitation recorded at the Toledo airport. Temperature and barometric pressure had been dropping rapidly over several days and the resulting storm caused extremely elevated wind speeds and wave heights.

Finally, solar radiation flux was also collected at the real time buoy and was averaged on a daily basis over the collection period. The daily average solar radiation flux is shown in Figure 4-5.

The real-time buoy data were evaluated and average values and standard deviations are summarized in Table 4-5. Spring and fall months (May and October) exhibit the highest measurement variation for each of the parameters.

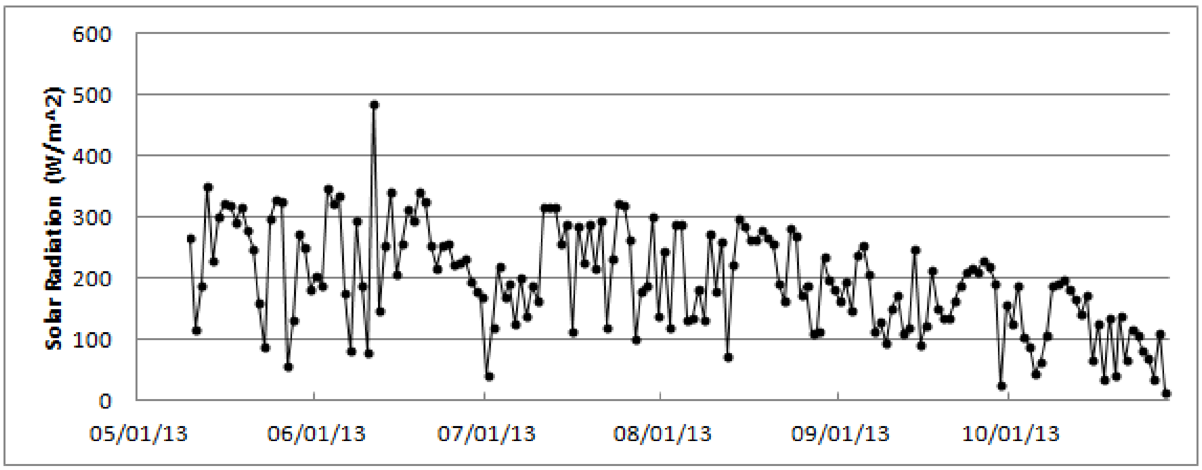


Figure 4-5 Daily Average Solar Radiation Flux Collected at the Real-Time Buoy (Placement Area)

Table 4-5 Monthly Average Statistics Calculated from Real-Time Buoy Measurements at the Placement Area

	May	June	July	August	September	October
Parameter	**Average**					
Air Temperature (°C)	15.7±5.0	20.0±3.1	22.8±3.1	22.1±2.3	18.8±3.6	13.8±5.2
Relative Humidity (%)	67.5±13.0	72.6±9.3	73.6±10.0	69.1±10.2	69.4±10.6	70.7±11.1
Atmospheric Pressure (mbar)	995±6.2	993±5.5	996±4.7	997±4.1	996±4.8	996±5.3
Solar Radiation (watts/m^2)	241±271	242±303	215±281	211±276	167+239	113±183
Wind Speed (m/s)	5.1±2.3	4.7±2.0	4.8±2.2	4.1±1.8	4.8±1.8	5.7±2.4
Gust Speed (m/s)	6.7±3.1	6.1±2.7	6.3±2.9	5.3±2.3	6.4±2.3	7.4±3.1
Wave Height (m)	0.5±0.3	0.5±0.3	0.4±0.3	0.3±0.2	0.4±0.2	0.5±0.2
Wave Period (sec)	2.7±1.0	2.5±0.7	2.6±0.6	2.3±0.5	2.6±0.6	2.6±0.5

Key:

- °C = degrees Celsius
- m = meters
- mbar = megabar
- m/s = meters per second
- sec = seconds
- watts/m^2 = watts per square meter

ADCP Data

Velocity measurements were collected using ADCPs installed at the real time buoy (placement area) and at RA-1. Water velocities in the north and east directions were collected at nine different depth intervals. The data are summarized in Figures 4-6 and 4-7 by plotting daily average water velocity for the entire water column over the sampling period.

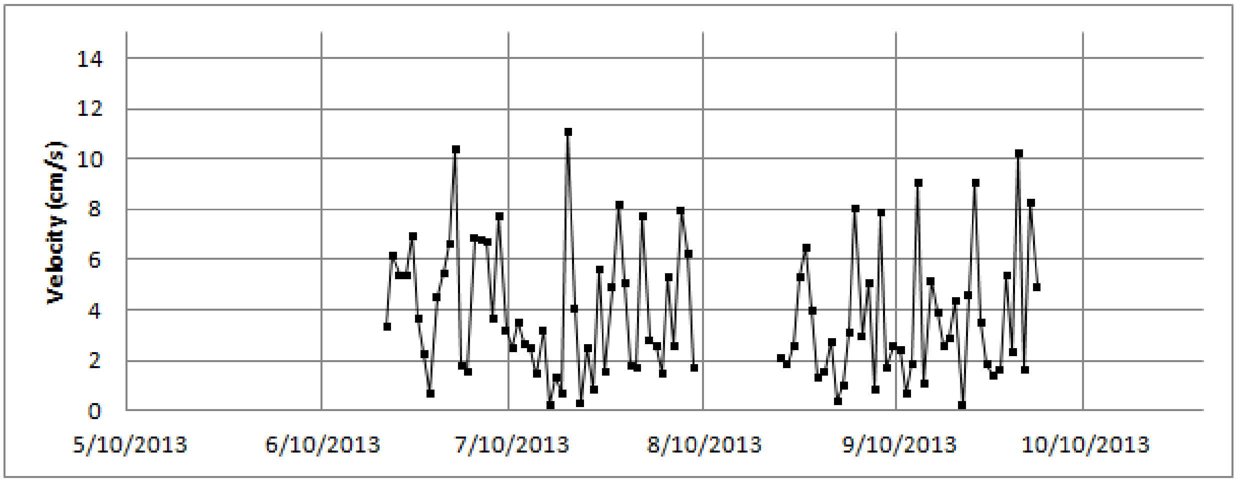


Figure 4-6 Daily Depth Averaged Water Velocity at RA-1

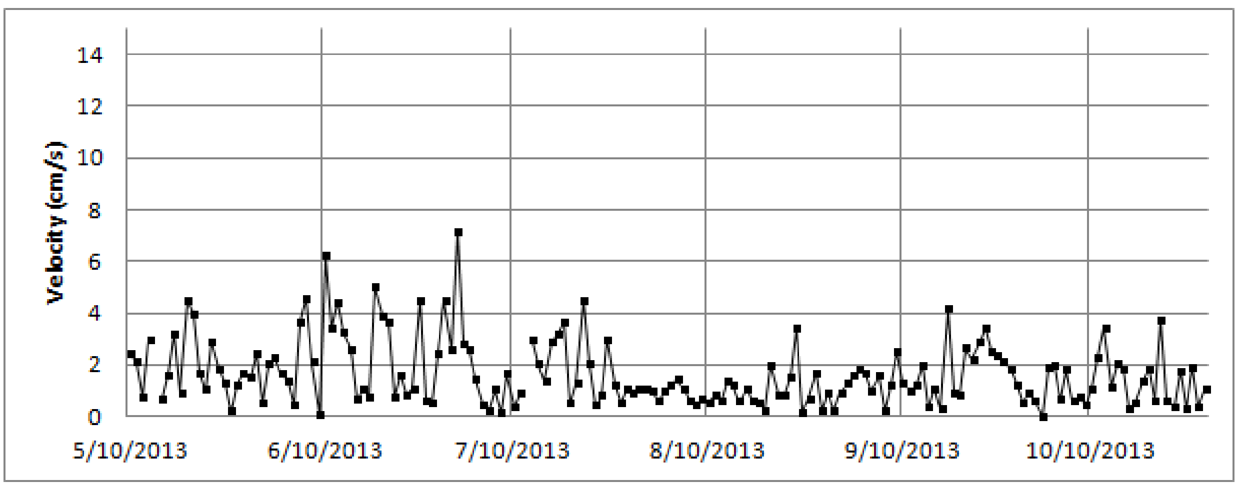


Figure 4-7 Daily Depth Averaged Water Velocity at the Placement Area

Several data gaps exist in the RA-1 data that did not occur at the placement area. RA-1 was moved on June 20, 2013, to its final location and the ADCP was installed at that time. Due to an ADCP data recording error, data was not recorded from August 8 through August 21, 2013. The RA-1 ADCP was removed from service on October 2, 2013. The placement area ADCP was not removed until October 28, 2013. From these plots, it appears that daily average water velocities at RA-1 are higher and more variable than at the placement area.

4.1.2 Water Quality Sampling Data

Water quality sampling included collecting a series of water column profiles and surface water depth integrated samples over the course of each sampling day. Data were collected at six locations during Event 1, nine locations during Event 2 and 3 and five locations during Event 4. Water column profiles were recorded using water quality sondes while composite water column samples were collected and submitted for laboratory analysis. Data and samples were collected for one day during Events 1 and 4 and three days during Events 2 and 3.

Water Column Vertical Profiles

Water column profiles were collected in one meter intervals at each of the four stations (placement area [Station 26], RA-1 [Station 25], RA-2 [Station 27] and Maumee River Mouth [Station 28]) during each of the four events (see Figure 3-2). Parameters collected included temperature, conductivity, pH, turbidity, and dissolved oxygen. This resulted in four and seven measurements for each parameter in each profile.

As the most relevant parameters for this study, the temperature and turbidity data were selected for plotting and analysis. Figure 4-8 shows the temperature profile data collected during Events 1 and 2, while Figure 4-9 shows the Event 3 and 4 temperature profiles. Similarly, the turbidity profiles collected during each sampling event are shown in Figures 4-10 and 4-11.

Figures 4-8 and 4-9 show a slight thermal stratification during Events 1, 2 and 3 (spring and summer) at all four stations. This could potentially be related to wind effects. The temperature profile data shows consistently higher temperatures at the Maumee River mouth station, with the placement area, RA-1 and RA-2 showing very similar temperatures. The Maumee River mouth station also had consistently higher turbidity than the other three stations. During Events 1 and 2 the turbidity measurements at the placement area and RA-1 and RA-2 were very similar. During Event 3 the turbidity at RA-1 was slightly higher than at the placement area and RA-2. During Event 4, the turbidity at RA-2 remained very low, with very similar measurements at the placement area and RA-1 at 20 to 30 nephelometric turbidity units. The placement area and RA-1 and RA-2 had fairly consistent turbidity profiles with depth. The Maumee River mouth station had higher turbidity at depth during Events 1, 2 and 3, which could potentially be attributed to ship passage.

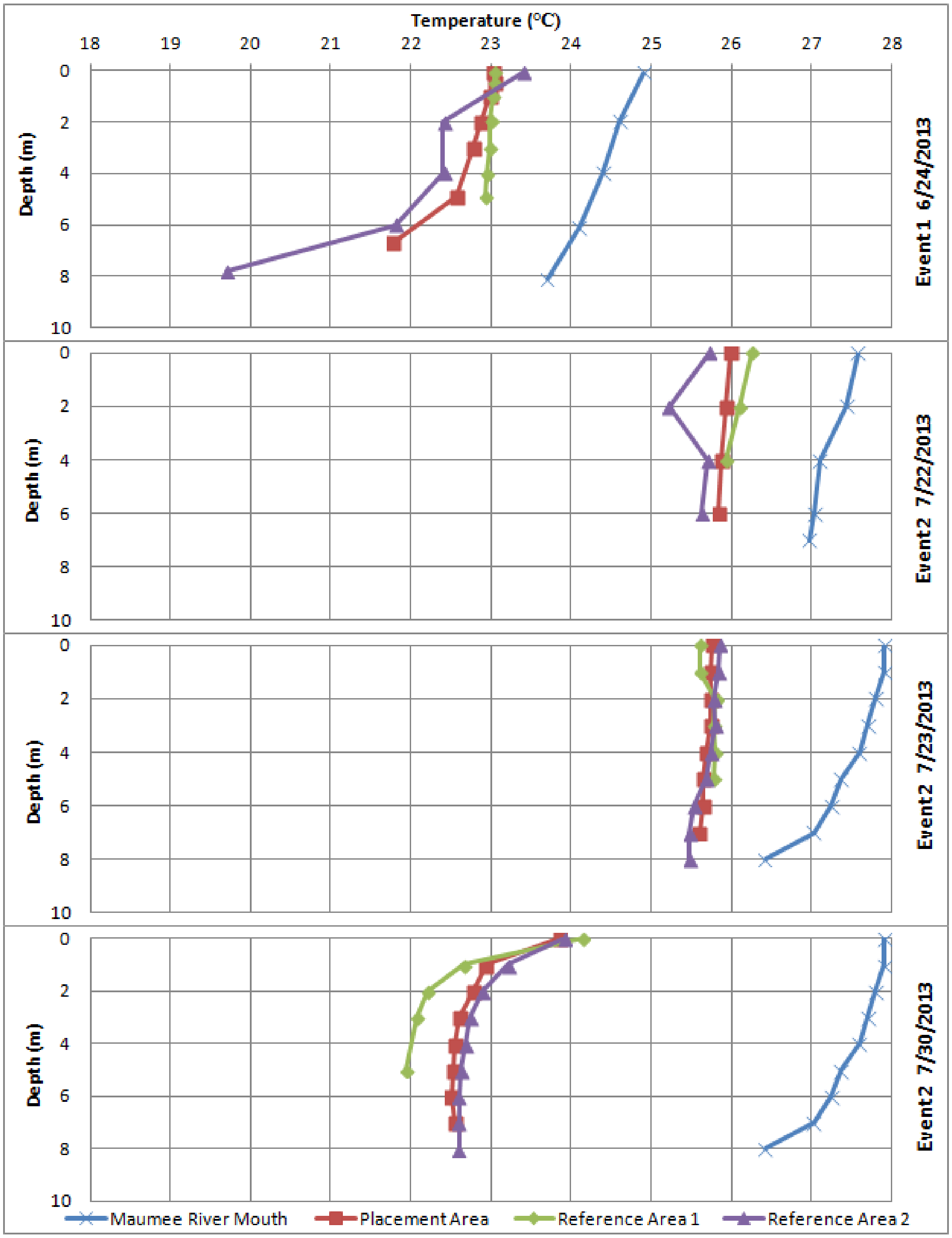


Figure 4-8 Temperature Profiles Collected at Four Fixed Water Quality Sampling Stations during Events 1 And 2

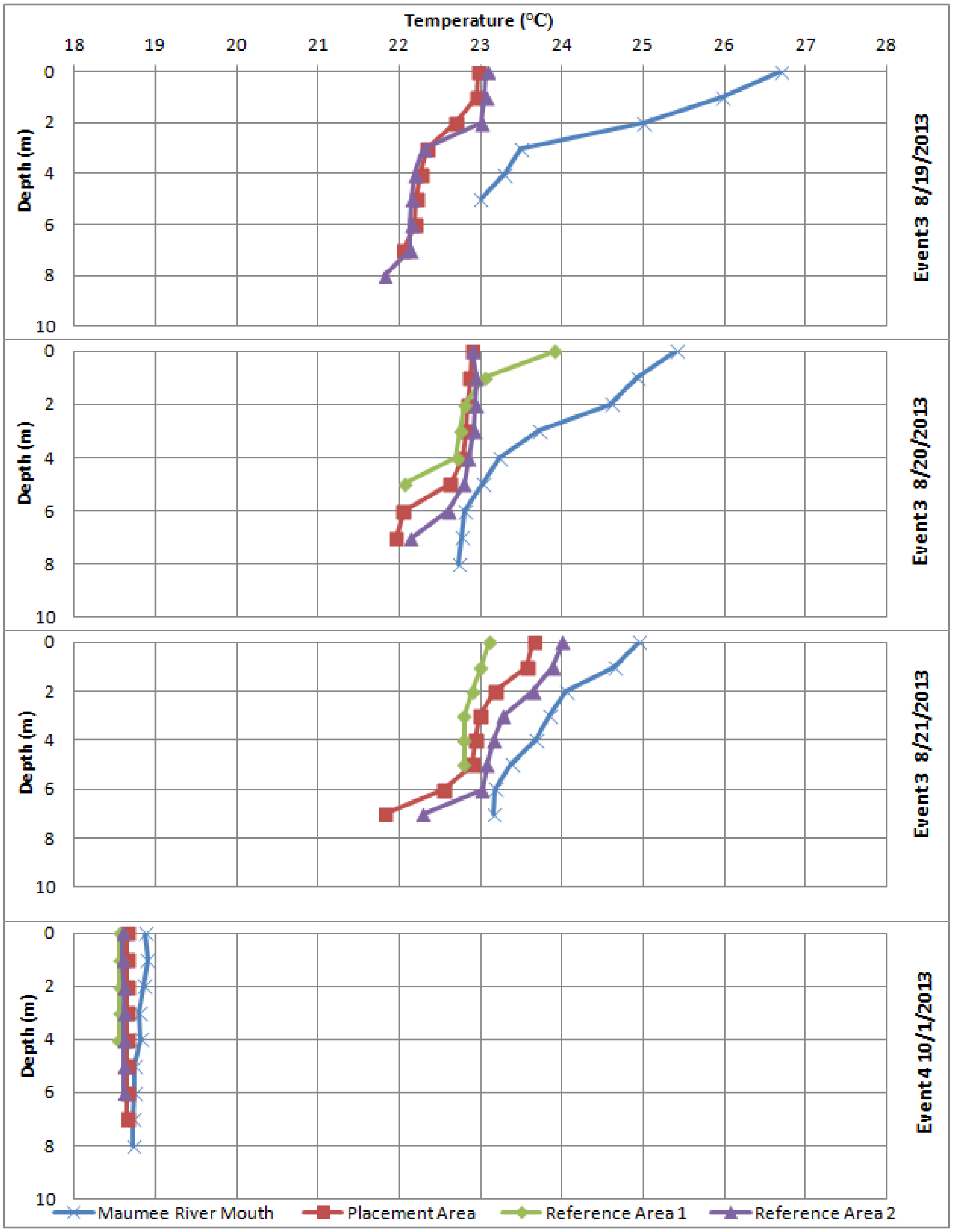


Figure 4-9 Temperature Profiles Collected at Four Fixed Water Quality Sampling Stations during Events 3 And 4

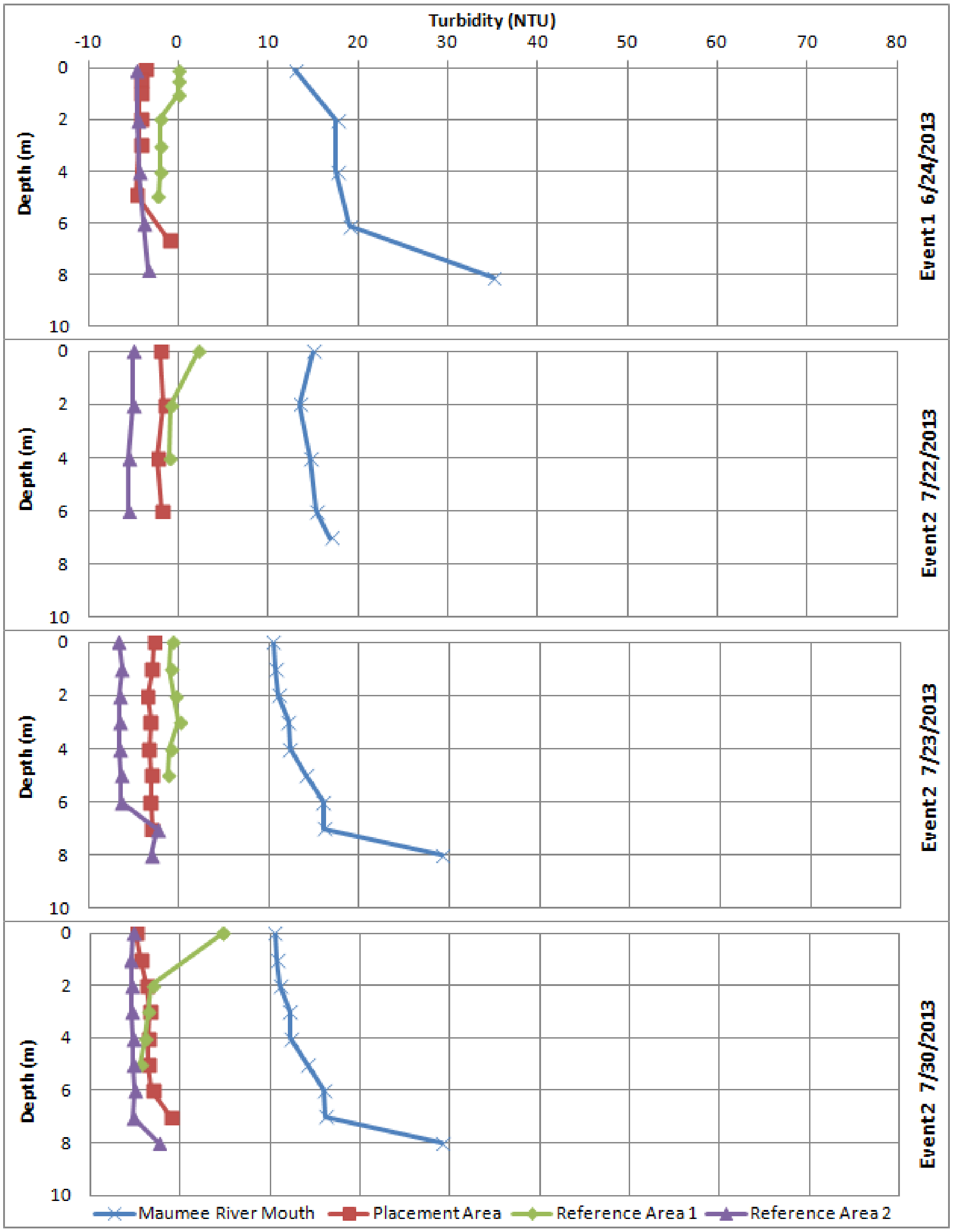


Figure 4-10 Turbidity Profiles Collected at Four Fixed Water Quality Sampling Stations during Events 1 And 2

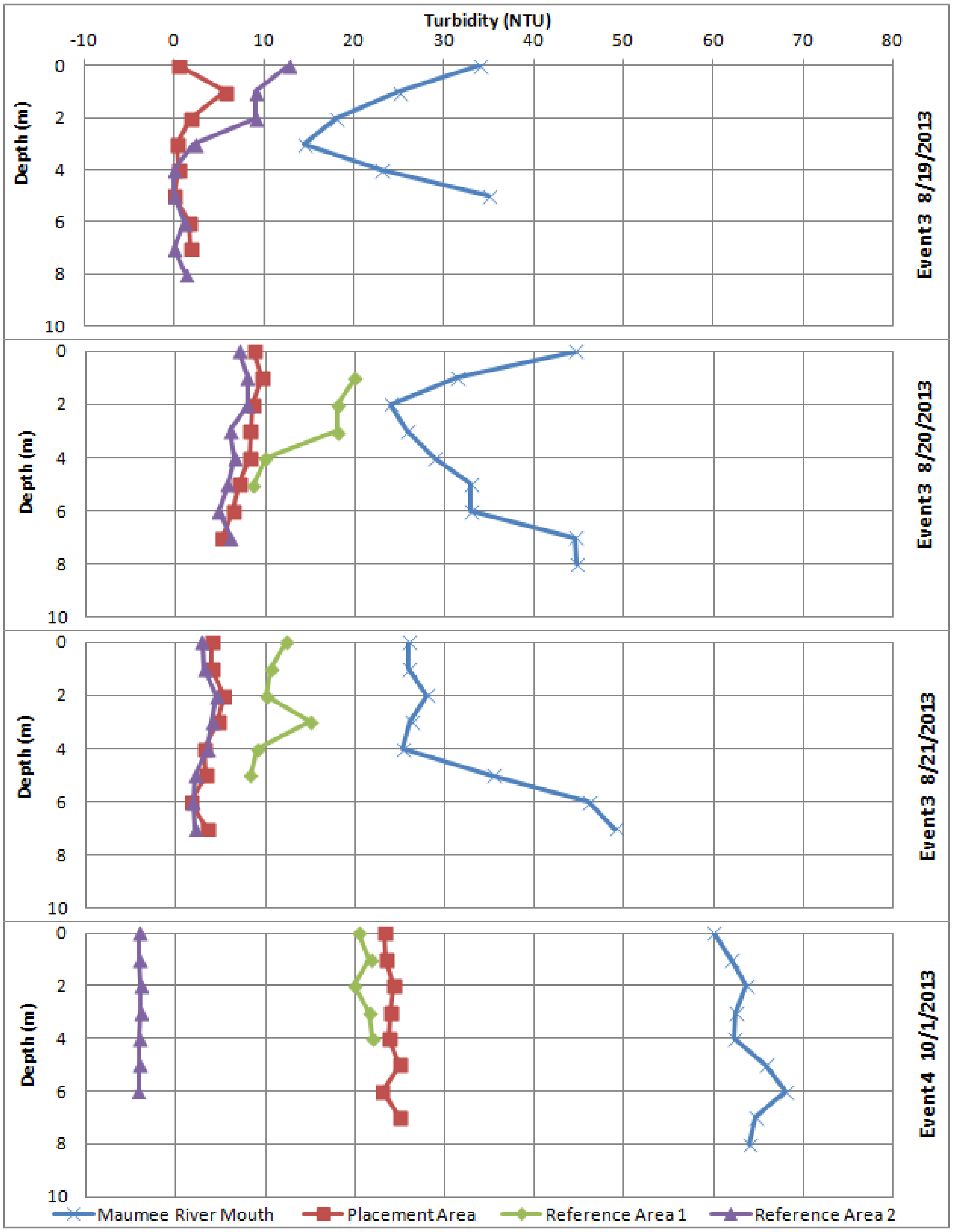


Figure 4-11 Turbidity Profiles Collected at Four Fixed Water Quality Sampling Stations during Events 3 And 4

Water Column Integrated Samples

Water column grab samples were collected at six locations during Event 1, nine locations during Event 2 and 3 and five locations during Event 4. During Events 1 and 4, only one round of samples were collected where in Events 2 and 3, three rounds of samples were collected. Collected samples were sent to the Heidelberg University National Center for Water Quality Research laboratory for analysis. The analytical parameters included NO_3, NO_2, ammonia, TKN, SRP, TP, total soluble phosphorus, TSS, and VSS. Samples were also sent to the University of Toledo laboratory for analysis of chlorophyll-a, phytoplankton biovolume, phytoplankton speciation and microcystin. The integrated water column results are summarized in Table 4-6 and in Appendix D-1.

The data are shown graphically for the four main stations: the placement area, RA-1, RA-2, and the Maumee River mouth. Parameters were grouped as nitrogen, phosphorus, or solids data and plotted together for each station.

Nitrogen data plots include NO_3, NO_2, ammonia, and TKN. These parameters are shown for each station in Figure 4-12. The phosphorus data plots include SRP, TP, and total soluble phosphorus (TSP) and are shown in Figure 4-13. Finally, the solids plots include TSS and VSS measurements and are shown in Figure 4-14. The data are summarized in Table D-1 in Appendix D. The lab reports are included in Appendix D and the chain of custody documentation is included in Appendix C.

The analyzed biological parameters including chlorophyll-a, microcystin, and phytoplankton biovolume were plotted for the same four select locations to display temporal patterns across the 2013 season. The results are shown in Figures 4-15 to 4-17. The highest chlorophyll-a concentration was measured at the Maumee River mouth in June. At the placement area, RA-1 and RA-2, chlorophyll-a concentrations are lowest in June and increase over the summer with the highest concentrations found in October, with the exception of RA-2 where concentrations decreased between August and October. The highest Microcystis biovolume was measured at RA-1 in August. The Microcystis biovolume at the placement area increased from June through October. The biovolume at RA-2 was negligible during July and October with an increase in August. Microcystin concentrations generally increased over the summer from June to August. The concentration at the Maumee River mouth in August was significantly higher than any other location.

The collected water quality data were summarized by performing a Sign Test and Wilcoxen Signed Rank Test. These non-parametric statistical tests were used because there was not enough data to confirm the data distribution. The tests estimated a median difference for the paired data and test whether the difference is significant at a significance level of 0.05. The results are summarized in Table 4-7. The yellow highlighted cells represent comparisons that resulted in a statistically significant difference.

Table 4-6 Water Column Integrated Sample Results

Date Time	Station No	Location	NH3 (mg/L)	NO2 (mg/L)	NO3 (mg/L)	SRP (mg/L)	TP (mg/L)	TKN (mg/L)	TSS (mg/L)	TSP (mg/L)	VSS (mg/L)	Chlr-a (ug/L)	Biovolume (ml/m^2)	Microcystin Avg (ug/L)
6/24/13 10:10	25	RA-1	0.085	0.02	1.43	0.008	0.031	0.531	2.1	0.016	6.2	1.4	0.0	<0.01
6/24/13 10:45	1	PA	0.048	0.01	0.56	0.003	0.025	0.411	2.9	0.004	4.7	3.2	0.0	0.052
6/24/13 11:20	19	PA	0.041	0.01	0.57	0.002	0.023	0.341	3.1	0.004	4.1	2.2	0.0	
6/24/13 11:50	26	PA	0.048	0.01	0.57	0.002	0.024	0.359	2.5	0.004	3.8	2.0	7.6	
6/24/13 12:45	27	RA-2	0.041	0.01	0.53	0.003	0.022	0.370	2.3	0.003	3.4	8.5	0.0	
6/24/13 15:30	28	MR	0.198	0.09	4.04	0.028	0.083	1.072	18.1	0.033	4.3	82.8	2.5	0.060
7/22/13 14:00	26	PA	0.041	0.03	0.78	0.002	0.035	0.564	6.5	0.011	3.5	11.0	55.9	0.282
7/22/13 17:00	25	RA-1	0.065	0.03	1.93	0.012	0.053	0.917	6.7	0.020	4.1	21.6	10.2	0.820
7/22/13 18:00	27	RA-2	0.023	0.00	0.26	0.002	0.015	0.418	1.6	0.007	0.8	4.1	10.2	0.019
7/22/13 19:00	28	MR	0.166	0.06	4.53	0.103	0.181	1.380	17.7	0.119	4.3	20.1	---	0.241
7/23/13 10:45	25	RA-1	0.095	0.05	2.88	0.017	0.091	0.889	6.4	0.028	3.1	17.7	40.8	0.996
7/23/13 11:45	26	PA	0.041	0.02	0.95	0.003	0.032	0.517	4.6	0.014	1.5	5.4	25.5	0.400
7/23/13 15:25	27	RA-2	0.060	0.01	0.57	0.003	0.015	0.279	0.9	0.008	1.1	2.1	0.0	0.088
7/23/13 17:00	28	MR	0.285	0.05	3.67	0.106	0.175	1.371	17.1	0.120	3.6	9.6	---	0.221
7/30/13 12:30	26	PA	0.047	0.01	0.35	0.006	0.026	0.356	4.3	0.010	2.3	16.6	127.4	0.344
7/30/13 13:20	25	RA-1	0.035	0.02	0.97	0.006	0.040	0.574	4.0	0.009	3.6	12.6	203.8	4.642
7/30/13 14:10	27	RA-2	0.025	0.02	0.26	0.002	0.011	0.256	6.9	0.004	1.6	2.8	0.0	0.069
7/30/13 17:30	28	MR	0.128	0.05	3.00	0.071	0.132	1.119	19.4	0.081	5.1	19.0	---	7.264
8/19/13 10:15	27	RA-2	0.023	0.01	0.49	0.001	0.028	0.604	7.6	0.005	5.1	53.3	1044.6	10.750
8/19/13 11:15	26	PA	0.015	0.01	0.59	0.002	0.028	0.513	6.2	0.004	3.3	23.6	560.5	0.984
8/19/13 15:15	25	RA-1	0.026	0.01	1.00	0.001	0.045	0.927	11.9	0.013	6.6	55.2	828.0	3.959
8/19/13 15:50	28	MR	0.125	2.00	1.02	0.044	0.138	1.354	19.6	0.057	6.6	69.4	---	1.103
8/20/13 9:25	27	RA-2	0.022	0.01	0.50	0.003	0.024	0.597	7.3	0.009	4.0	17.6	789.8	2.137
8/20/13 10:00	26	PA	0.019	0.01	0.60	0.006	0.032	0.502	9.2	0.008	3.9	19.9	560.5	1.730
8/20/13 12:36	25	RA-1	0.039	0.01	0.86	0.004	0.081	1.162	18.5	0.012	10.4	51.6	1834.4	>10
8/20/13 13:14	28	MR	0.051	0.02	0.76	0.026	0.168	1.424	21.6	0.035	9.5	94.7	---	>10
8/21/13 10:30	25	RA-1	0.055	0.01	0.99	0.002	0.061	0.970	13.8	0.011	7.3	28.4	1057.3	>10
8/21/13 13:10	26	PA	0.027	0.01	0.70	0.003	0.039	0.596	8.0	0.013	4.6	17.4	598.7	1.737
8/21/13 13:30	27	RA-2	0.024	0.01	0.46	0.002	0.032	0.566	6.4	0.010	4.4	16.7	828.0	2.465
8/21/13 15:10	28	MR	0.040	0.02	0.83	0.011	0.119	1.009	25.8	0.024	8.4	58.2	---	140.934
10/1/13 9:40	27	RA-2	0.065	0.02	0.29	0.003	0.021	0.231	1.9	0.006	1.3	2.9	5.1	
10/1/13 10:25	26	PA	0.014	0.00	0.00	0.002	0.071	0.384	21.7	0.007	9.7	54.0	820.4	
10/1/13 11:00	29	PA	0.020	0.00	0.00	0.001	0.083	0.456	27.6	0.007	11.4	59.3	695.5	
10/1/13 11:35	25	RA-1	0.023	0.00	0.00	0.001	0.066	0.649	19.2	0.010	40.7	48.8	517.2	
10/1/13 12:20	28	MR	0.029	0.00	0.26	0.009	0.160	0.881	44.0	0.018	13.1	69.5	---	

(blue) = reported concentration is less than or equal to the MDL
(pink) = reported concentration is less or equal to than the MQL

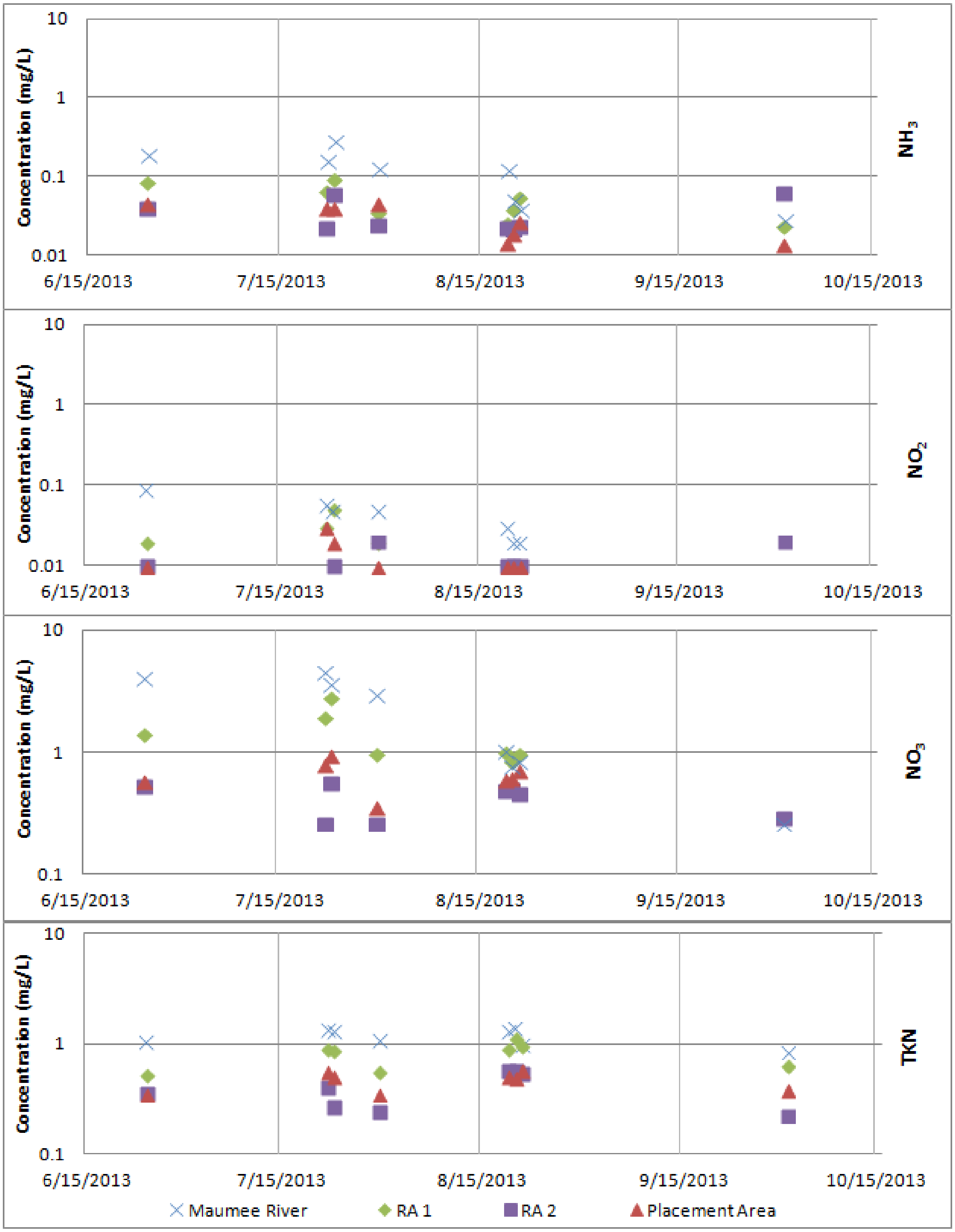


Figure 4-12 Nitrogen Parameter Concentrations (mg/L) Collected at Four Stations throughout the Four Sampling Events in 2013 (RA-1, RA-2, Placement Area, and Maumee River Mouth)

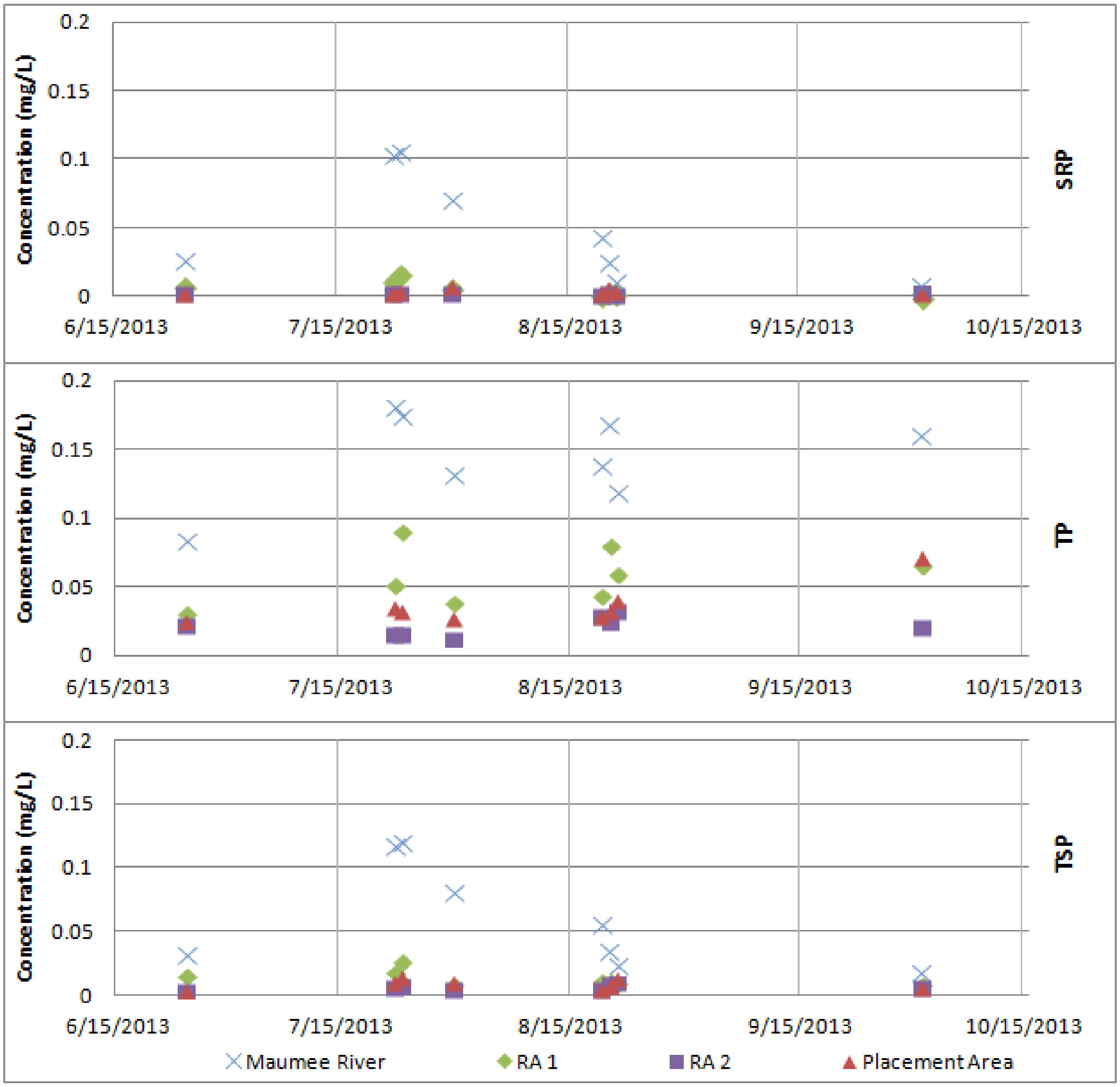


Figure 4-13 Phosphorus Parameter Concentrations (mg/L) Collected at Four Stations Throughout the Four Sampling Events in 2013 (RA-1, RA-2, Placement Area, and Maumee River Mouth)

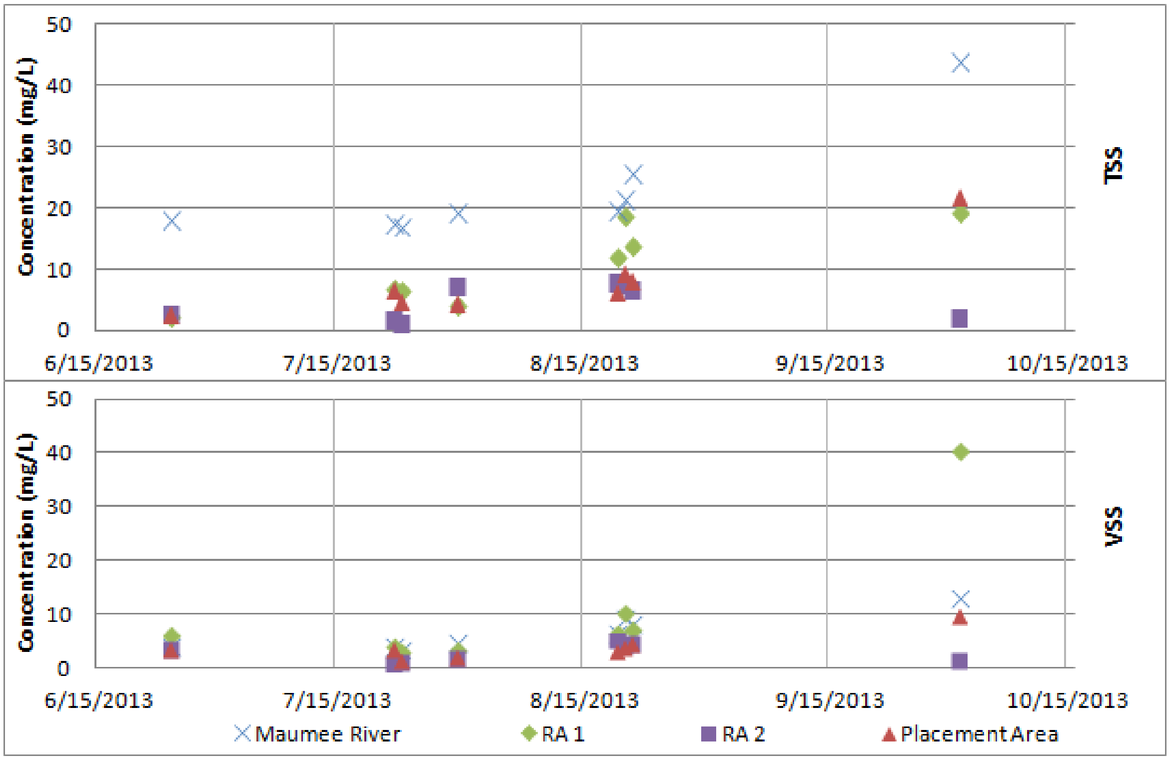


Figure 4-14 Solids Parameter Concentrations (mg/L) Collected at Four Stations throughout the Four Sampling Events in 2013 (RA-1, RA-2, Placement Area, and Maumee River Mouth)

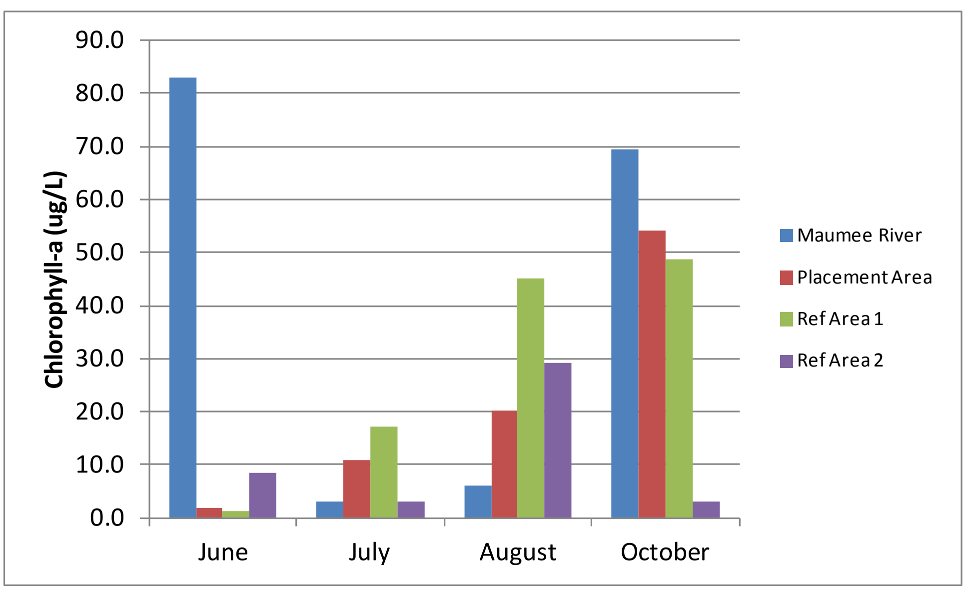


Figure 4-15 Chlorophyll-a Concentrations (µg/L) Collected during Four Sampling Events in 2013 at the Four Main Sampling Locations (RA-1, RA-2, Placement Area, and Maumee River Mouth)

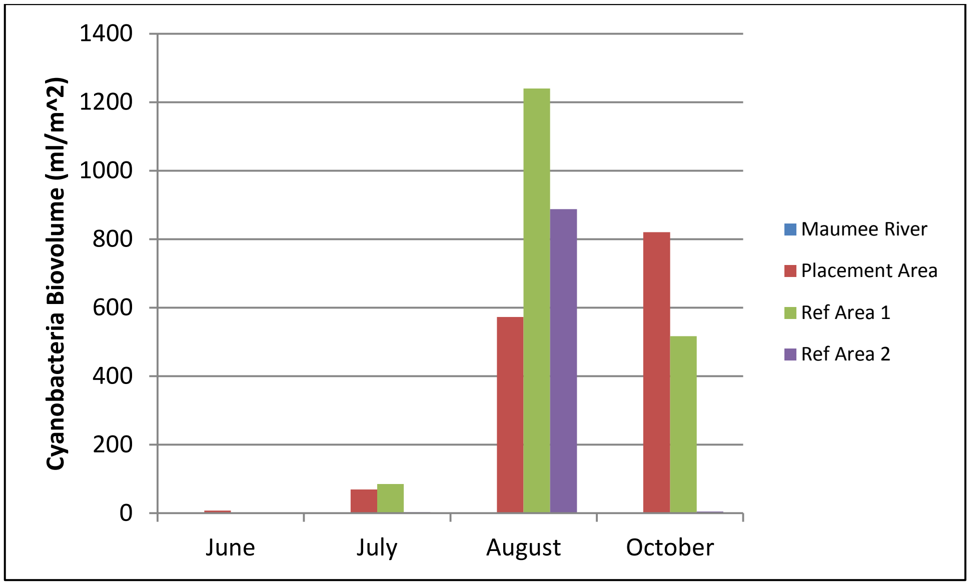


Figure 4-16 Biovolume (ml/m^2) Collected during Four Sampling Events in 2013 at the Four Main Sampling Locations [RA-1, RA-2, Placement Area, and Maumee River Mouth (only sampled in June)]

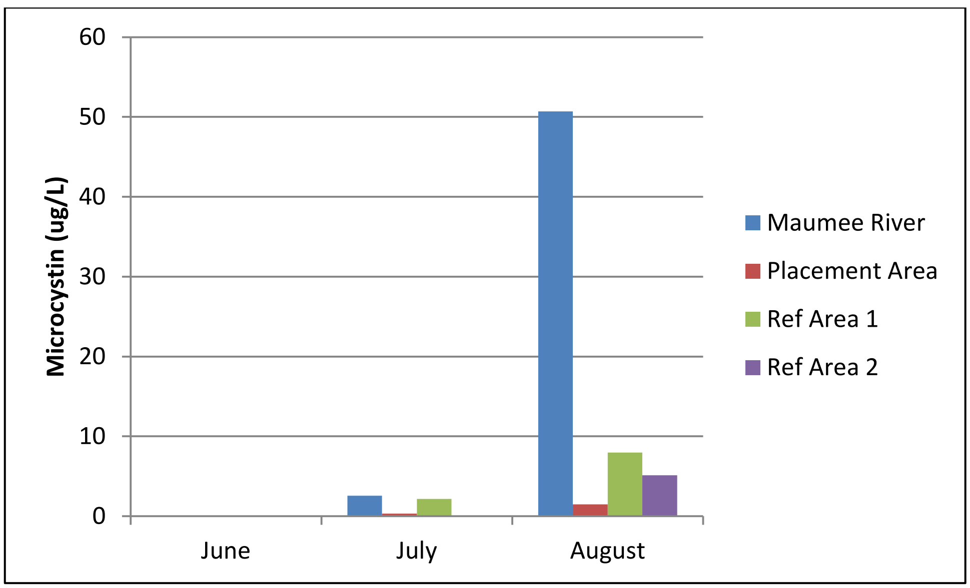


Figure 4-17 Microcystin Concentrations (µg/L) Collected during Four Sampling Events in 2013 at the Four Main Sampling Locations (RA-1, RA-2, Placement Area, and Maumee River Mouth)

Table 4-7 Comparisons of Water Quality Parameters at the Placement Area against the Maumee River Mouth, RA-1 and RA-2

Placement Area vs.	NH_3	NO_2	NO_3	TKN	SRP	TP	TSP	TSS	VSS	CHLa
P-value for Wilcoxen Signed Rank Test										
Maumee River Mouth	0.014	0.022	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
RA-1	0.042	0.181	0.022	0.014	0.726	0.021	0.042	0.294	0.014	0.107
RA-2	0.889	1	0.107	0.183	0.441	0.021	0.141	0.141	0.183	0.363
P-value for Sign Test										
Maumee River Mouth	0.0078	0.0156	0.0078	0.0078	0.0078	0.0078	0.0078	0.0078	0.0078	0.0078
RA-1	0.0703	0.25	0.0156	0.0078	0.7266	0.0703	0.2891	0.7266	0.0078	0.7266
RA-2	1	1	0.0703	0.7266	1	0.0703	0.2891	0.2891	0.2891	0.2891

Note: Yellow shaded boxes represent a statistically significant difference from the Placement Area.

Key:

NH_3 = ammonia nitrogen
NO_2 = nitrite
NO_3 = nitrate
SRP = soluble reactive phosphorus
TKN = total Kjeldahl nitrogen
TP = total phosphorus
TSS = total suspended solids
TSP = total soluble phosphorus
VSS = volatile suspended solids
CHLa = Chlorophyll-a

All parameters collected at the Maumee River mouth were statistically different from the placement area. The concentrations for all parameters with the exception of VSS were highest at the Maumee River mouth. RA-1 had several parameters including NH_3, NO_3, TKN, TP, TSP and VSS that were statistically different from the placement area. As shown in Figures 4-12 to 4-14, the majority of measurements for these parameters were higher than the placement area at RA-1. The VSS concentration was much greater at RA-1 during the last event which could be the result of wind driver resuspension. At RA-2, all of the parameters except TP were not statistically different from the placement area. In six out of eight measurements, TP was higher at the placement area as compared to RA-2.

4.1.3 Plume Event Sampling Data (Events 2 and 3)

Plume event monitoring occurred during the second and third sampling events when dredge material placement just occurred. Four multi-parameter water quality sondes were moored in proximity to the active placement site. Parameters monitored with the sondes included temperature, conductivity, and turbidity. The buoys were positioned at least 1,000 feet away from the known area of active placement and were placed in the cardinal directions around the operation (north, south, east, and west). They remained in service over the course of each sampling event. Additionally, plume tracking was performed to characterize the size, shape, and distribution of the dredge spoils plume. Tracking was performed by trolling the water quality sonde through and around the perimeter of the dredge spoils plume, immediately following release from the barge. Measured parameters include temperature, turbidity, conductivity, pH, and dissolved oxygen.

4.1.3.1 Event 2

Event 2 was performed between July 22 and July 30, 2013. Short-term buoys were deployed at the start of the event and values were recorded through the event's entirety. Plume tracking and monitoring was performed on July 22, 23, and 30, 2013, by towing the water quality sonde around the plume from one specific barge release, and recording data. Daily weather parameters collected at the real time buoy during Event 2 are summarized in Table 4-8.

Short-Term Continuous Monitoring

The short-term buoys were deployed between July 22 and July 30, 2013, during Event 2. Measurements were recorded every five minutes during the sampling period. The short-term buoys placed during Event 2 were located at the listed coordinates in Table 4-9. The collected five-minute measurements are plotted in Figures 4-18 to 4-20.

Table 4-8 Average Daily Weather Parameters Collected at the Real-Time Buoy during Monitoring Event 2

Date	Wind Speed (m/s)	Gust Speed (m/s)	Air Temp (°C)	Relative Humidity (%)	Solar Radiation Daylight Hours (W/m^2)	Wave Height (m)	Wave Period (sec)
7/22/2013	4	6	24	67	209	0.5	3.0
7/23/2013	5	7	24	75	387	0.4	2.4
7/24/2013	7	10	19	61	535	0.7	3.2
7/25/2013	4	6	20	59	539	0.4	2.7
7/26/2013	3	5	22	57	446	0.3	2.1
7/27/2013	7	9	21	75	185	0.6	2.8
7/28/2013	8	10	17	66	302	0.6	2.9
7/29/2013	6	8	18	66	323	0.5	2.6
7/30/2013	3	4	20	63	511	0.2	1.8

Key:
°C = Celsius
m/s = meters per second
m = meters
sec = second
W/m^2 = watts per square meter

Table 4-9 Event 2 And 3 Short-Term Buoy Placement Coordinates

Buoy Location	Latitude	Longitude
North	41.81705	83.28211
South	41.81001	83.28211
East	41.81312	83.27759
West	41.81291	83.28689

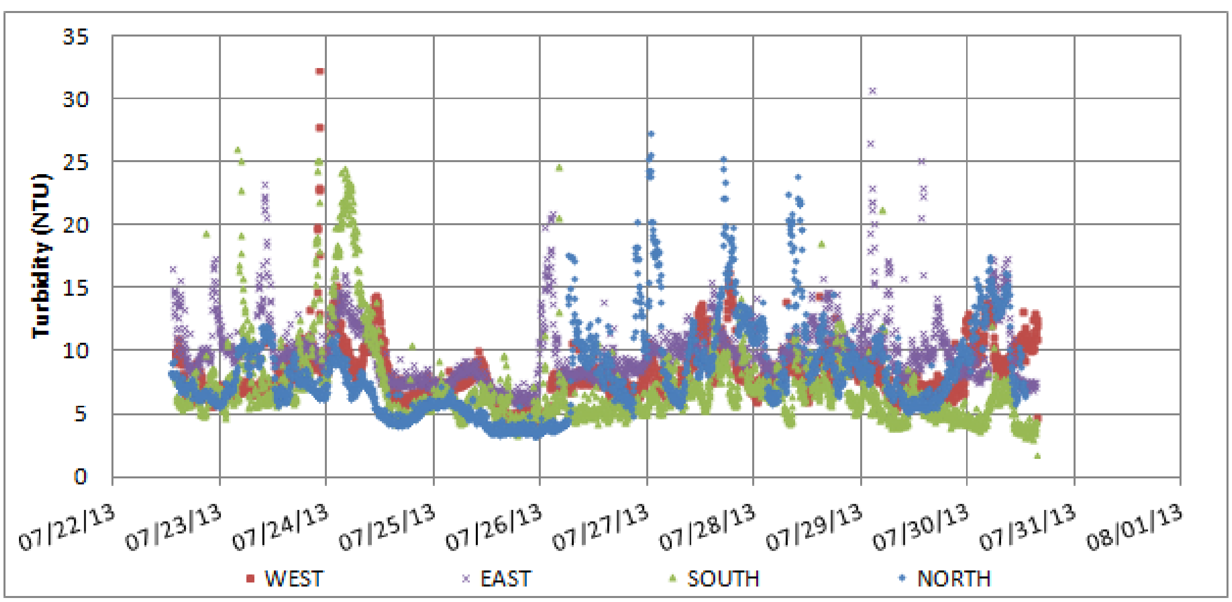


Figure 4-18 Short-Term Monitoring Turbidity Data Collected from Four Buoys at the Placement Area during Event 2

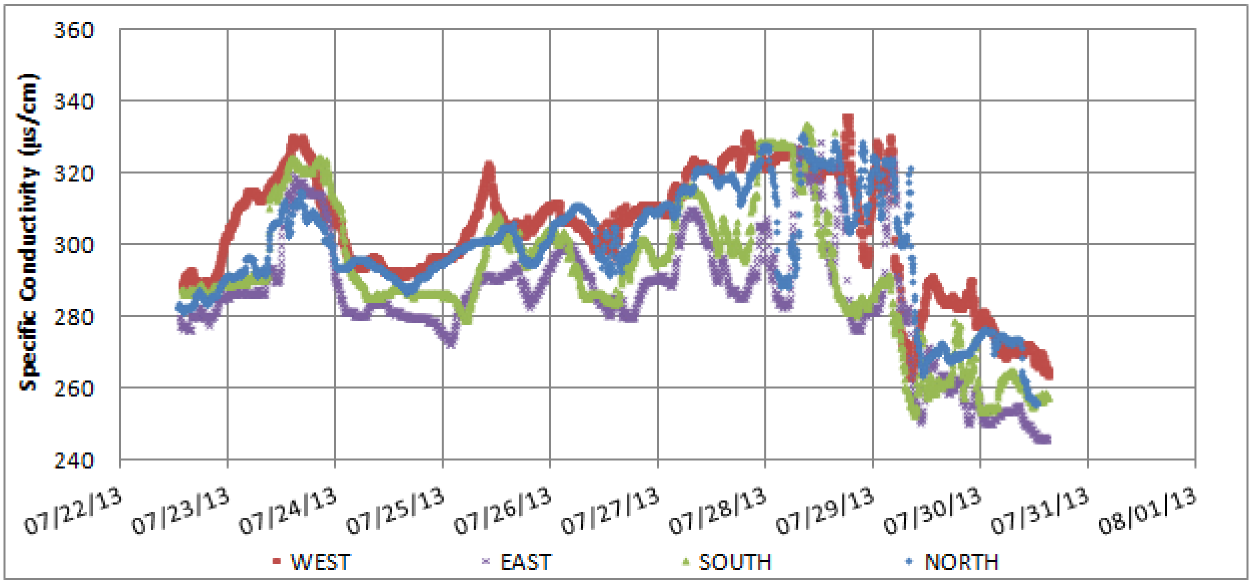


Figure 4-19 Short-Term Monitoring Specific Conductivity Data Collected from Four Buoys at the Placement Area during Event 2

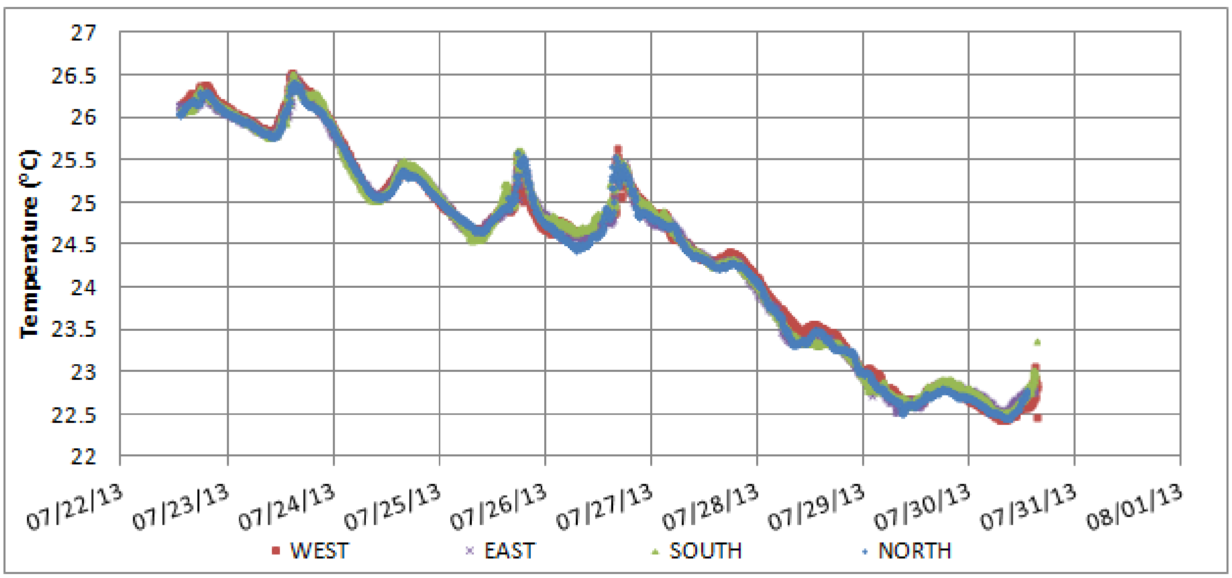


Figure 4-20 Short-Term Monitoring Temperature Data Collected from Four Buoys at the Placement Area during Event 2

Event 2 - Day 1. The first day of Event 2 sampling occurred on July 22, 2013. A trial plume tracking event was performed after a barge placement that occurred at 11:20 a.m. The boat conducted transects through the plume as it traveled with the current. The water quality sonde was held at the surface of the water over the edge of the boat to record measurements. Data was collected over a one-hour time period in one-minute intervals. Basic statistics summarizing the recorded surface water parameters are displayed in Table 4-10.

Table 4-10 Surface Water Quality Statistics Summarizing Data Collected while Trolling a Water Quality Sonde through the Barge Placement Plume on July 22, 2013

	Temperature (°C)	SpCond (µS/cm)	Conductivity (µs/cm)	pH	Turbidity (NTU)	DO (mg/L)
Average	26.0	285.9	291.6	8.3	16.2	7.9
STDEV	0.0	1.5	1.4	0.1	36.1	0.3
Max	26.12	288	294	8.42	223.3	8.25
Min	25.96	279	284	8.04	-1.1	6.88

Key:
- DO = Dissolved Oxygen
- C = Celsius
- mg/L = milligrams per liter
- NTU = nephelometric turbidity unit
- SpCond = Specific Conductivity
- STDEV = standard deviation
- µS/cm = microSiemens per centimeter

Event 2 - Day 2. On July 23, 2013, the plume was tracked again by trolling a multi-parameter sonde behind the boat. As the plume moved with the current, water quality monitoring was performed in transects across the observed plume center. Plume tracking began at 1:00 p.m. and data was collected over a 1.5-hour time period in one-minute intervals. Occasionally, the boat was stopped, so the crew could perform a water column profile to measure changes in turbidity with depth in the plume. The individual turbidity profiles that were collected throughout the course of this tracking event are plotted in Figure 4-21. Turbidity was highest near the time of the sediment placement and decreased rapidly due to settling. Turbidity was also highest at the bottom of the water column initially, but the water column became mixed and most of the suspended sediment had dissipated or settled within a half hour.

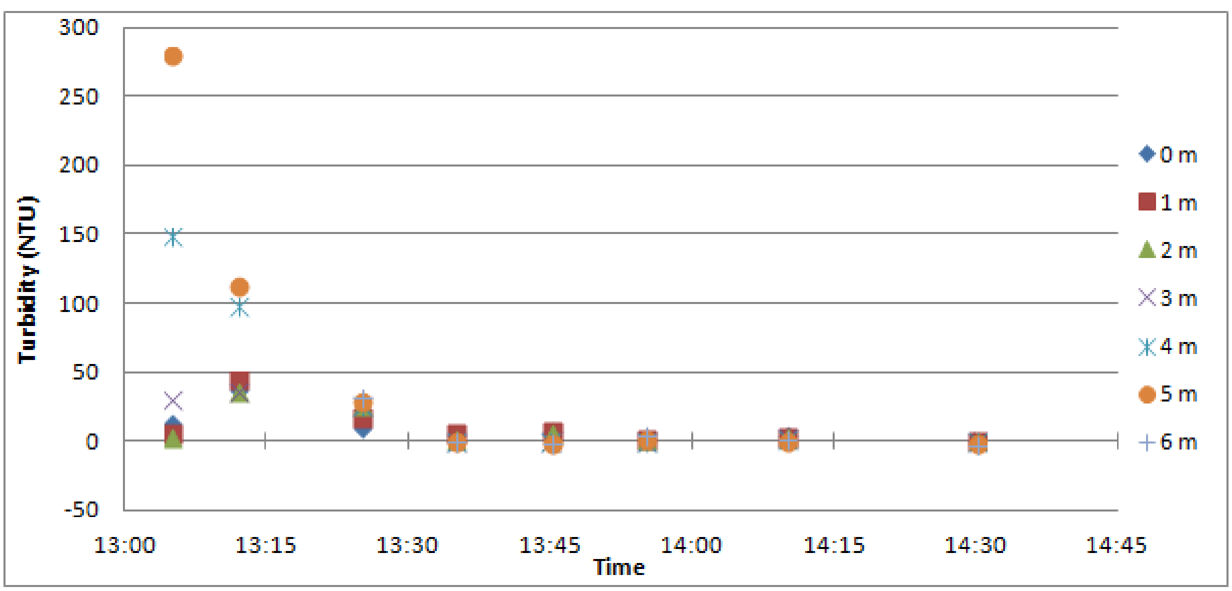


Figure 4-21 Water Column Profiles Collected while Tracking the Barge Placement Plume on July 23, 2013

Basic statistics summarizing the water quality parameters collected at the water surface are summarized in Table 4-11.

Table 4-11 Surface Water Quality Statistics Summarizing Data Collected while Trolling a Water Quality Sonde through the Barge Placement Plume on July 23, 2013

	Temperature (°C)	SpCond (µS/cm)	Conductivity (µS/cm)	pH	Turbidity (NTU)	DO (mg/L)
Average	26.2	327.0	334.4	NA	5.8	7.8
STDEV	0.1	2.0	2.2	NA	5.4	0.2
Max	26.51	331	340	8.42	25.5	8.1
Min	25.85	320	327	8.27	-0.9	7.2

Key:
DO = Dissolved Oxygen
°C = Celsius
mg/L = milligrams per liter
NTU = nephelometric turbidity unit
µS/cm = microSiemens per centimeter

Event 2 - Day 3. The third plume tracking event occurred on July 30, 2013. The plume was tracked similar to day two, using a multi-parameter sonde while occasionally stopping to perform depth profiles of the plume. Plume tracking began at 9:53 a.m. and data was collected over a nearly two-hour time period in 10-second intervals. Similarly to day two, turbidity was highest close to the time of the sediment placement and decreased rapidly with time due to settling. The individual turbidity profiles that were collected throughout the course of this tracking event are plotted in Figure 4-22.

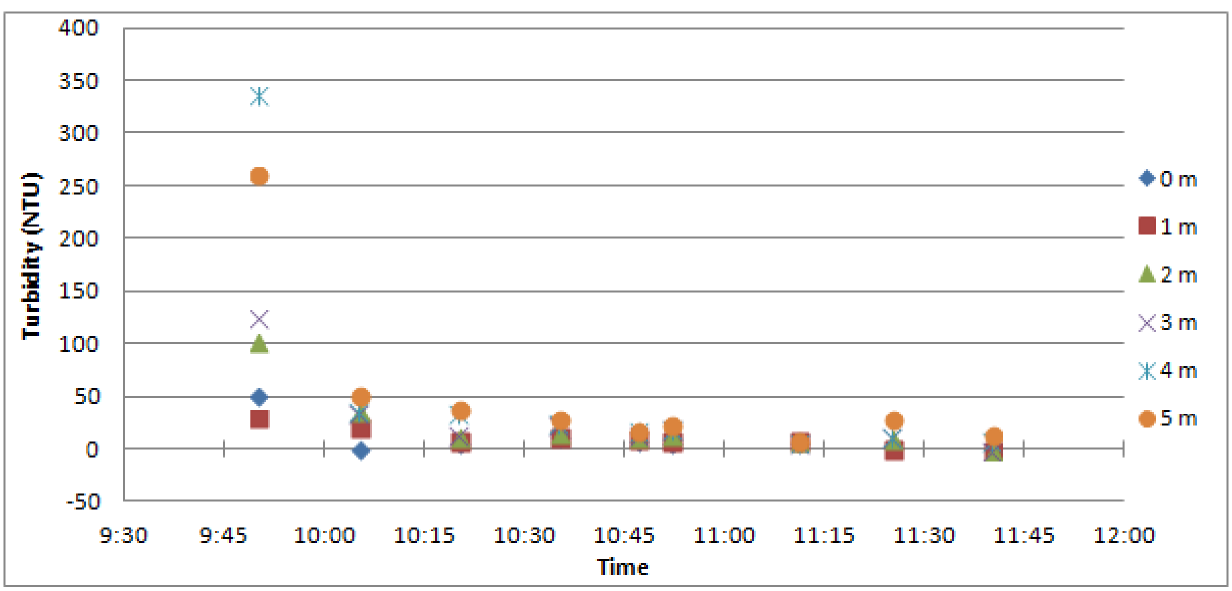


Figure 4-22 Water Column Profiles Collected while Tracking the Barge Placement Plume on July 30, 2013

Basic statistics summarizing the water quality parameters collected at the water surface are summarized in Table 4-12.

Table 4-12 Surface Water Quality Statistics Summarizing Data Collected while Trolling a Water Quality Sonde through the Barge Placement Plume on July 30, 2013

	Temperature (°C)	SpCond (µS/cm)	Conductivity (µS/cm)	pH	Turbidity (NTU)	DO (mg/L)
Average	22.8	260.9	249.7	8.6	7.8	9.8
STDEV	0.3	2.0	1.5	0.0	11.0	0.2
Max	24.2	268.0	255.0	8.7	58.3	10.1
Min	22.4	256.0	244.0	8.3	-2.7	8.7

Key:
DO = Dissolved Oxygen
°C = degrees Celsius
mg/L = milligrams per liter
NTU = nephelometric turbidity unit
µS/cm = microSiemens per centimeter

4.1.3.2 Event 3

Event 3 was performed between August 19 and August 21, 2013. Short-term buoys were deployed at the start of the event and recorded values through the event's entirety. Plume tracking and monitoring were also performed from August 19 to 21. Three different methods utilizing water quality sondes were used to characterize the plume, including trolling multiple water quality sondes at various depths, sitting stationary and tracking plume dispersion, and tracking the outer edge of the plume. Daily weather parameters collected at the real-time buoy during Event 3 are summarized in Table 4-13.

Table 4-13 Average Daily Weather Parameters Collected at the Real-Time Buoy during Monitoring Event 3

Date	Wind Speed (m/s)	Gust Speed (m/s)	Air Temp (°C)	Relative Humidity (%)	Solar Radiation Daylight hours (W/m^2)	Wave Height (m)	Wave Period (sec)
8/19/2013	2	3	23	64	474	0.1	1.9
8/20/2013	3	4	24	71	469	0.2	1.8
8/21/2013	4	5	24	72	347	0.3	2.0

Key:
°C = degrees Celsius
µS/cm = microSiemens per centimeter
m = meters
m/s = meters per second
sec = seconds

Short-Term Continuous Monitoring

The short-term buoys were deployed between August 19 and 21, 2013, during Event 3 to record temperature, turbidity, and specific conductivity. Values were recorded every 20 minutes during the sampling period. The short-term buoys were placed at the same locations used for Event 2. The coordinates are shown in Table 3-2. The 20-minute results are plotted in Figures 4-23 to 4-25. Results from all four buoys mimicked each other fairly well except for a few spikes at the north and east stations that did not show up on the others. Turbidity, conductivity, and temperature showed less variability during Event 3 than during Event 2 (presented in Section 4.1.3.1). Event 3 had more stable water temperatures, which resulted in more stable conductivity as the two are related. In addition the short-term sondes were only deployed for three days during Event 3 and eight days for Event 2.

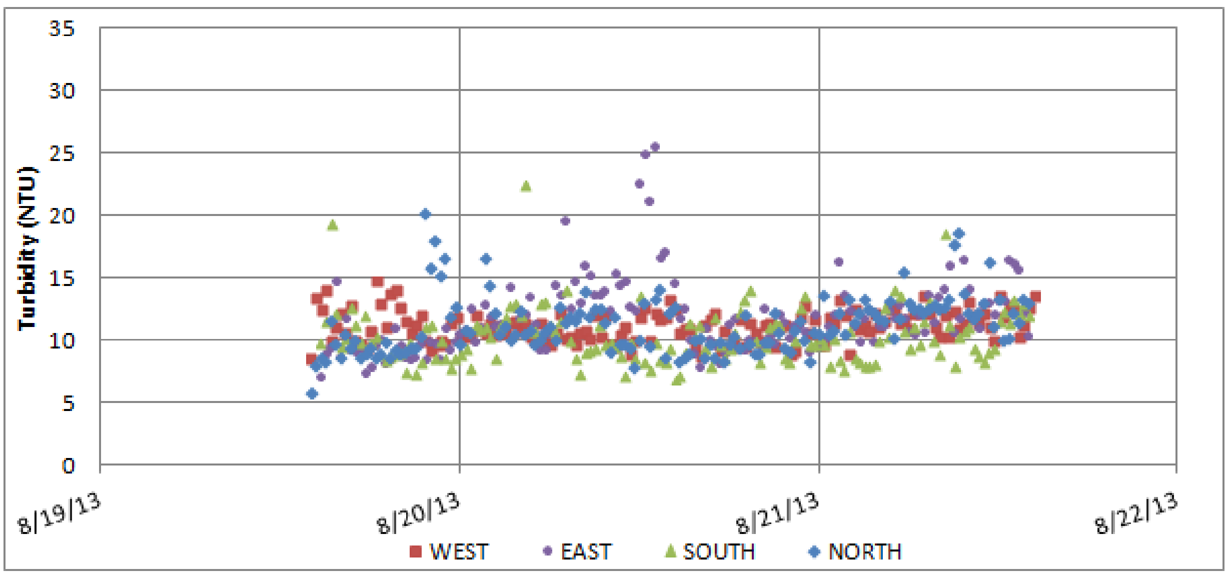


Figure 4-23 Short-Term Monitoring Turbidity Data Collected from Four Buoys at the Placement Area during Event 3

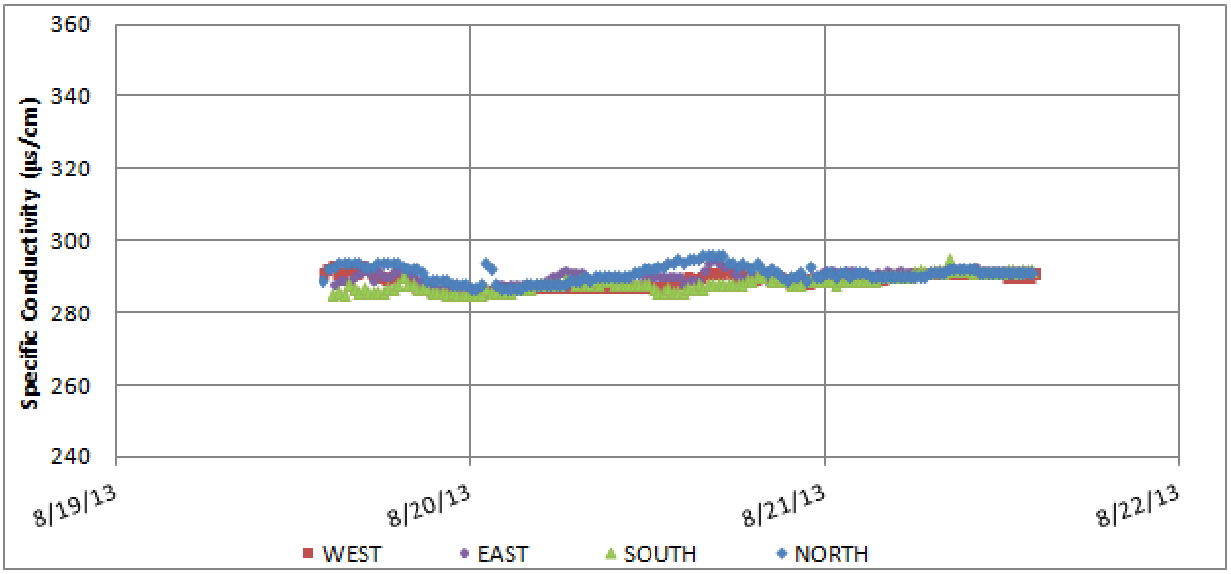


Figure 4-24 Short-Term Monitoring Conductivity Data Collected from Four Buoys at the Placement Area during Event 3

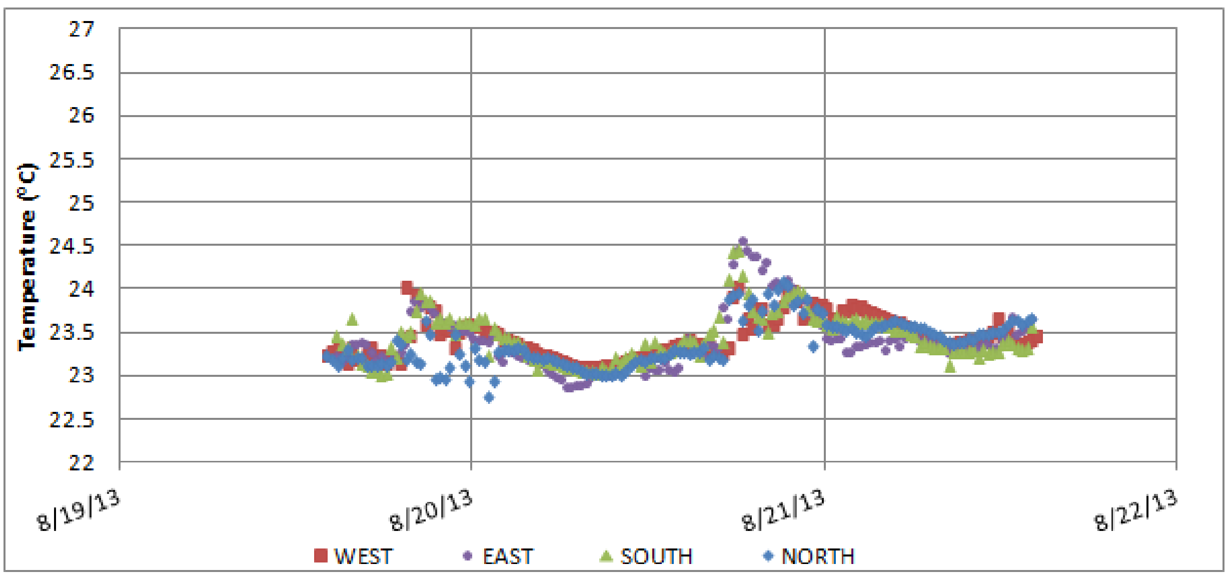


Figure 4-25 Short-Term Monitoring Temperature Data Collected from Four Buoys at the Placement Area during Event 3

Event 3 - Day 1. Day 1 of sampling Event 3 occurred on August 19, 2013. The dredged material plume was tracked by attaching four water quality sondes to a tow rope at 5-foot intervals down to a depth of 15 feet. The sondes were set up to record temperature, turbidity, and specific conductivity. The rope was towed through and around the plume in an attempt to map its extent and the turbidity resulting from the placement. Towing began at 12:00 p.m. and continued until 1:30 p.m. when the plume was mostly dispersed. The track log concentration plots are displayed in Figures 4-26 to 4-29. During this sampling event, a video camera was mounted to the boat to record a video track log of the journey. Additionally, high definition photos were taken to capture visuals of the plume edge (see Appendix C on DVD).

The turbidity values measured by trolling the four sondes were plotted alongside one another in Figure 4-30 to display how turbidity varied with depth in the plume. Turbidity values were highest closer to the time of the placement and decreased rapidly as time progressed due to settling.

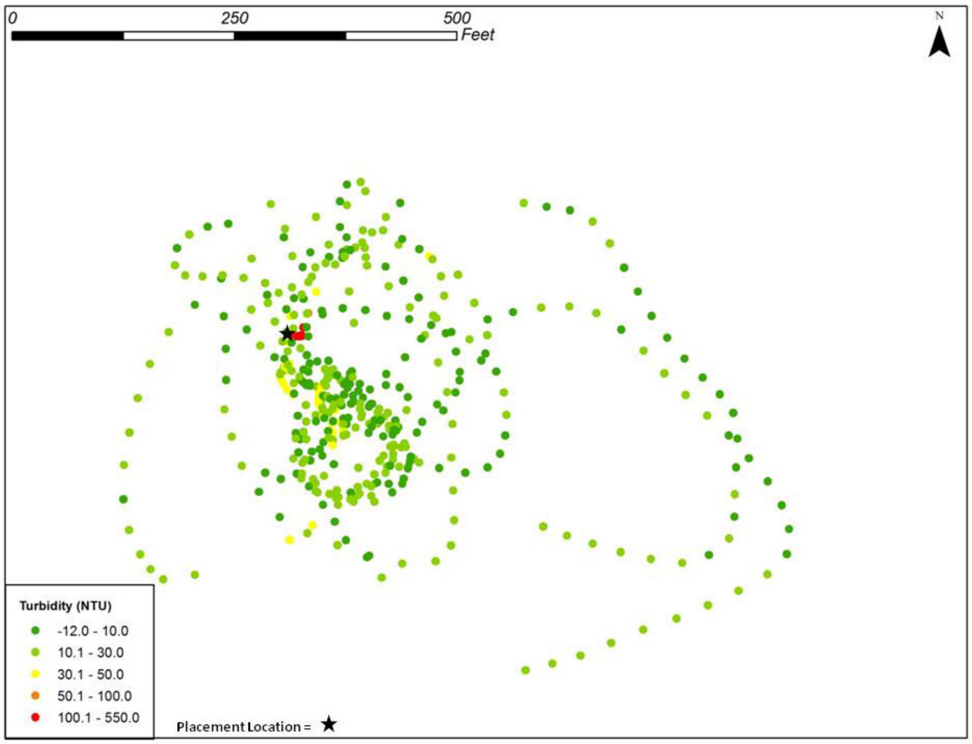


Figure 4-26 Turbidity Values Collected at 0 Feet of Depth From Trolling Four Water Quality Sondes around the Plume at Various Depths on August 19, 2013 during Event 3

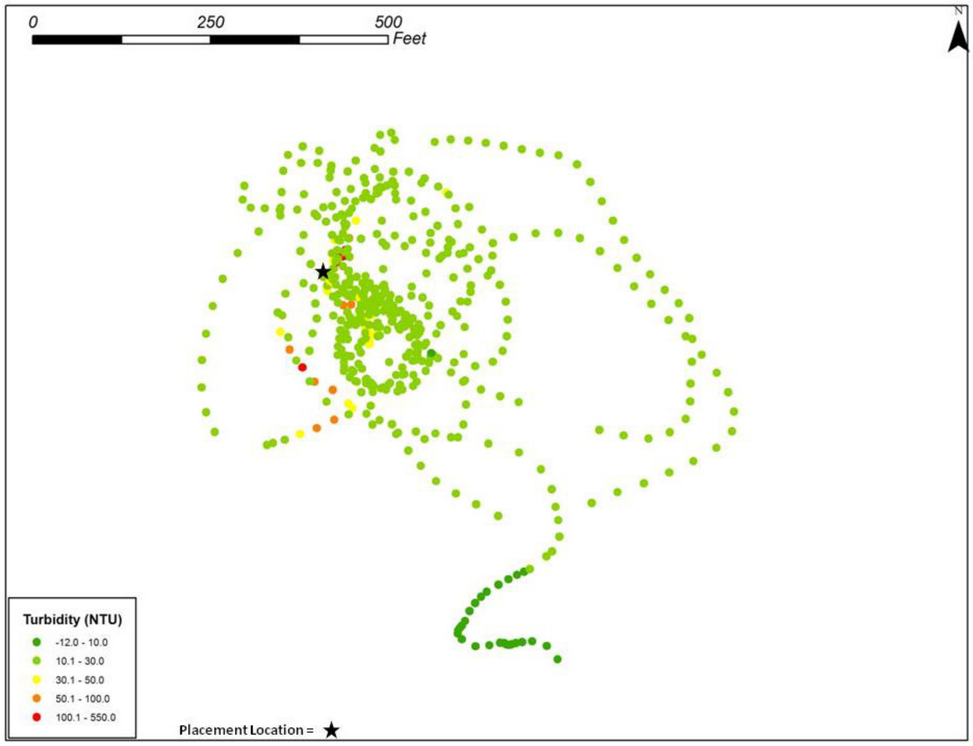


Figure 4-27 Turbidity Values Collected at 5 Feet of Depth from Trolling Four Water Quality Sondes around the Plume at Various Depths on August 19, 2013 during Event 3

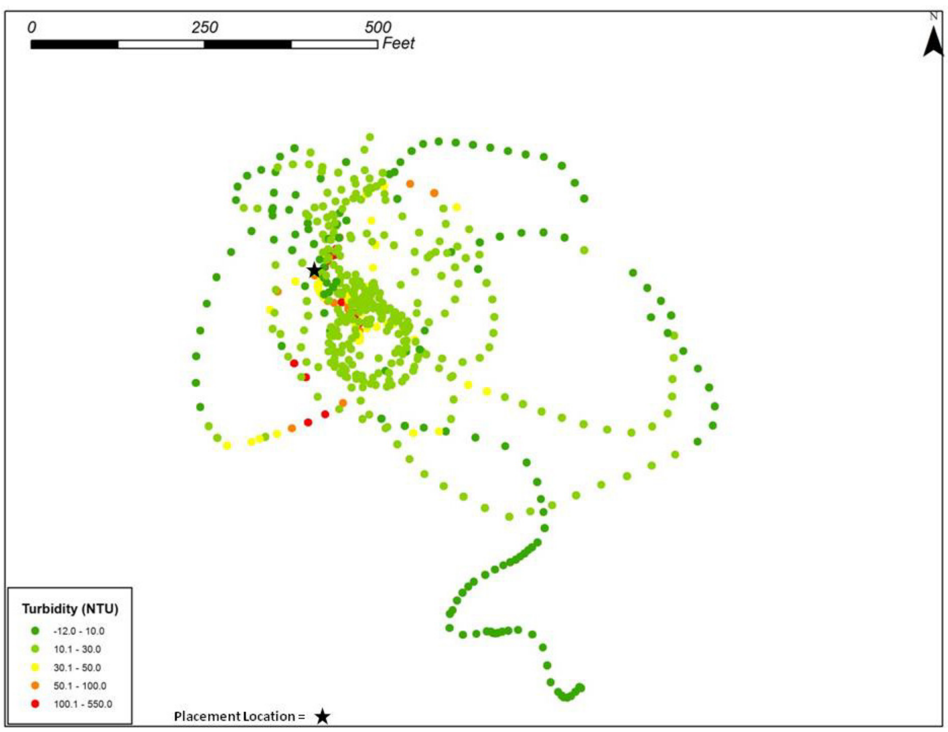


Figure 4-28 Turbidity Values Collected at 10 Feet of Depth from Trolling Four Water Quality Sondes around the Plume at Various Depths on August 19, 2013 during Event 3

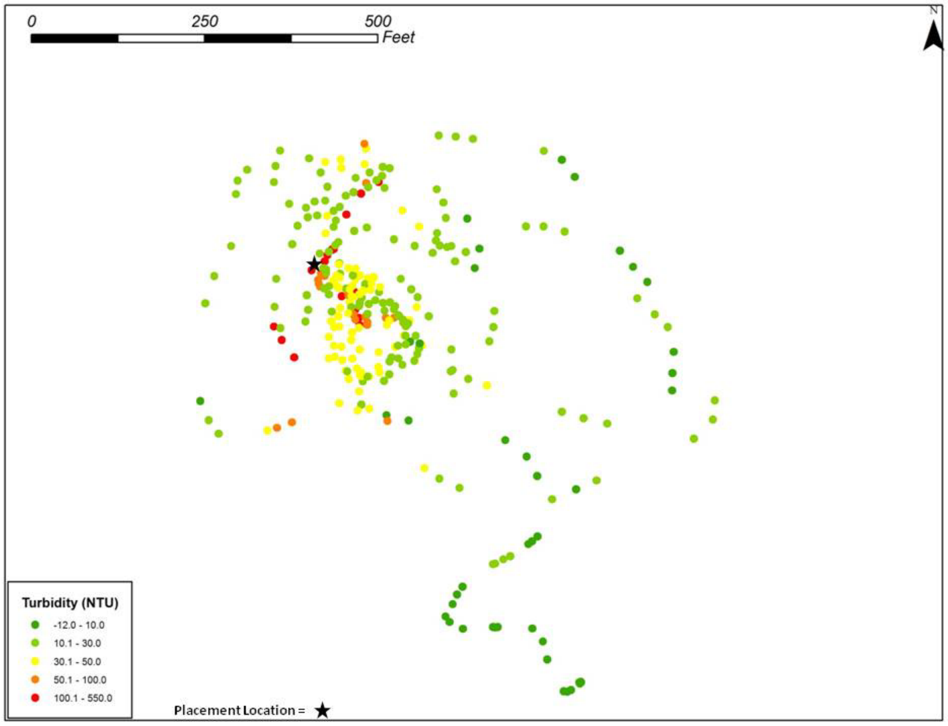


Figure 4-29 Turbidity Values Collected at 15 Feet of Depth From Trolling Four Water Quality Sondes around the Plume at Various Depths on August 19, 2013 during Event 3

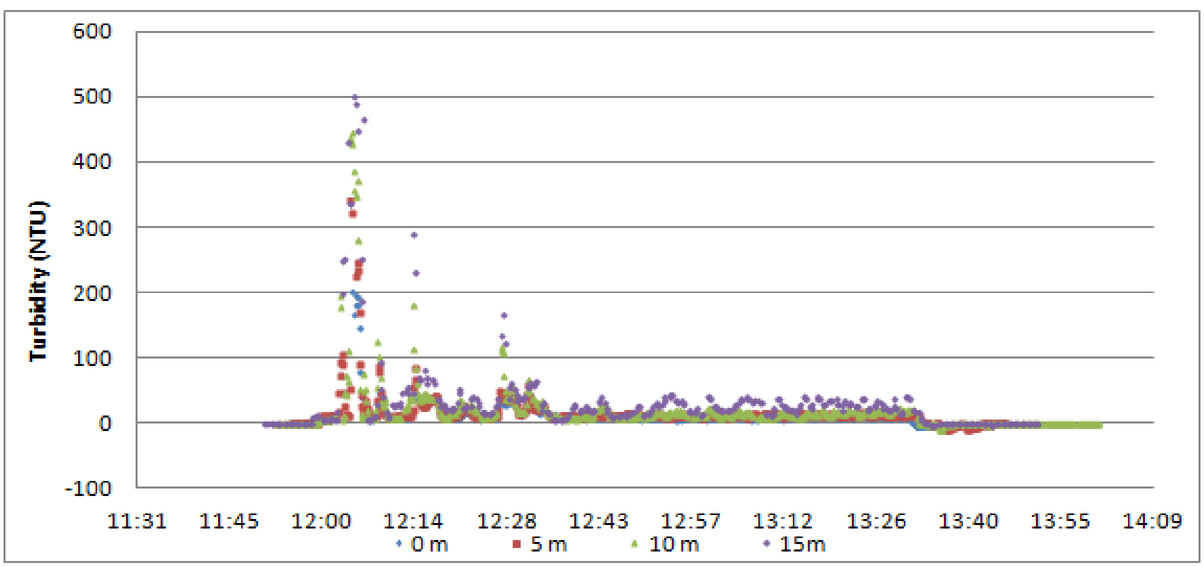


Figure 4-30 Time Series of Turbidity Data Collected from Trolling Four Water Quality Sondes around the Placement Site at Various Depths on August 19, 2013, during Event 3

Event 3 - Day 2. Day 2 of Event 3 was performed on August 20, 2013. An anchor point was set up over the plume to monitor the water column. A water quality sonde was used to take turbidity measurements at one meter intervals over the course of an hour. With this data, plume dispersion and settling was observed over time. These turbidity measurements are plotted on Figure 4-31. As with the trolling datasets, turbidity drops rapidly over time. The lowest turbidity readings are generally observed closest to the surface.

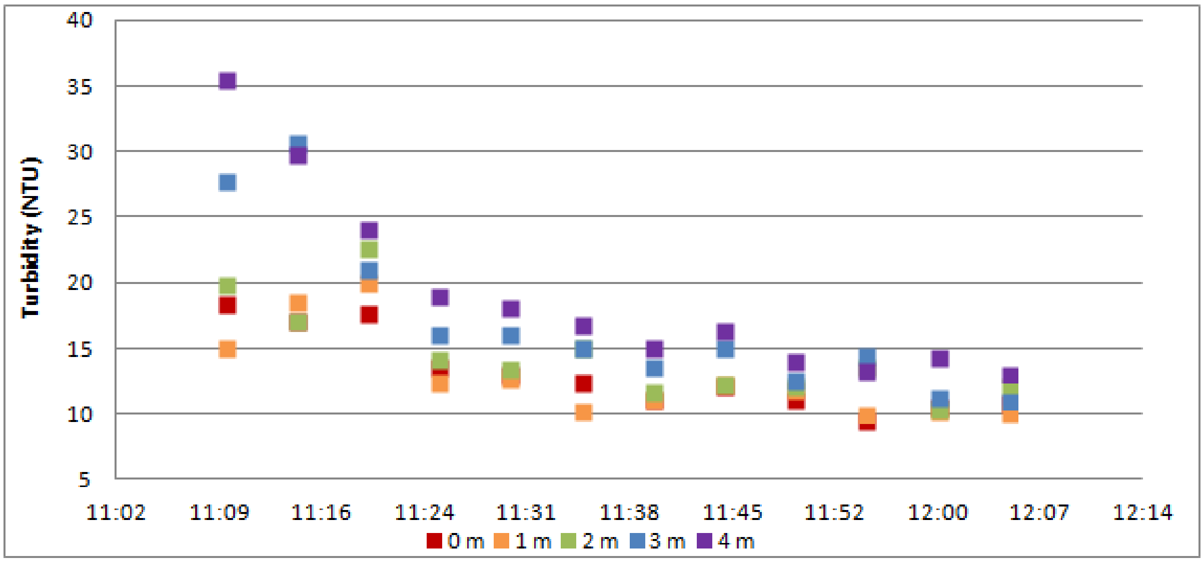


Figure 4-31 Turbidity Profiles Collected while Sitting Stationary on Top of the Placement Site Over Time on August 20, 2013

Event 3 - Day 3. Day 3 of Event 3 was performed on August 21, 2013. This day was utilized to attempt to track the lateral movement of the plume over time. Again, a water quality sonde was trolled behind the boat to monitor turbidity. Using visual observations and reading measurements on the water quality sonde, the edge of the plume was traced five times over a period of 50 minutes. After each trace was completed, a profile was collected in the center of the plume at that time. With this collected data, the lateral dispersion and transportation of the sediments were observed. The plotted traces of the plume are shown in Figure 4-32, while the collected profiles from the plume center are shown in Figure 4-33. Over time, the plume slowly expanded and traveled to the northeast. According to the collected profiles, turbidity also decreased as time progressed.

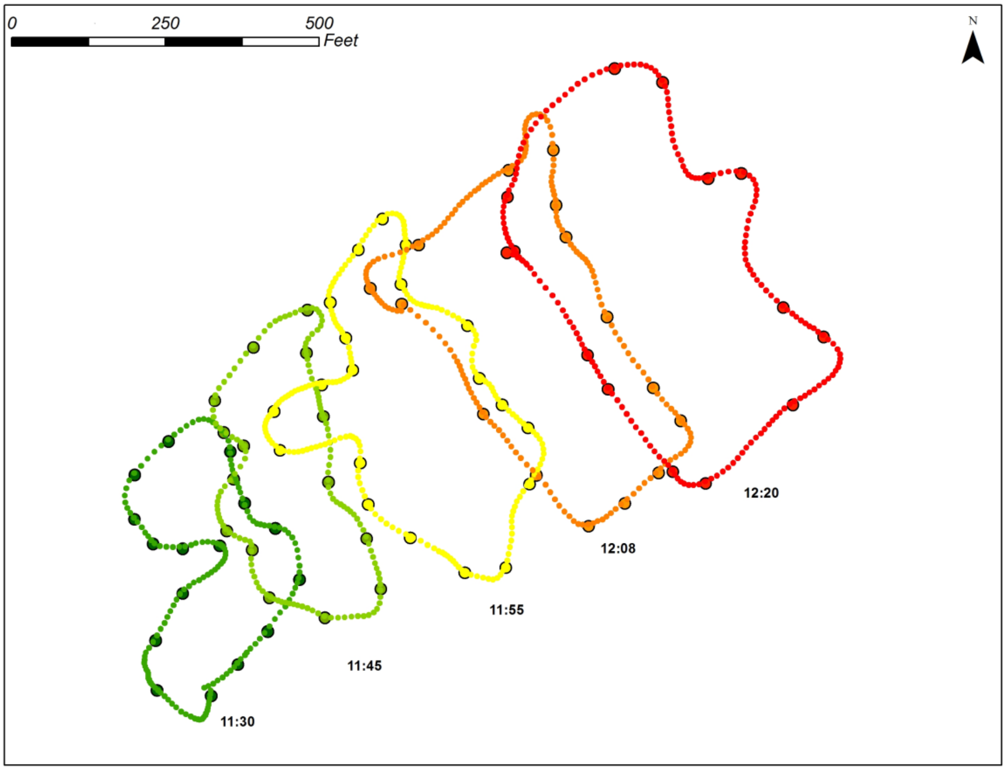


Figure 4-32 The Outline of the Plume as Collected by Visually Tracing the Plume Edge and Using a Water Quality Sonde to Monitor Turbidity on August 21, 2013

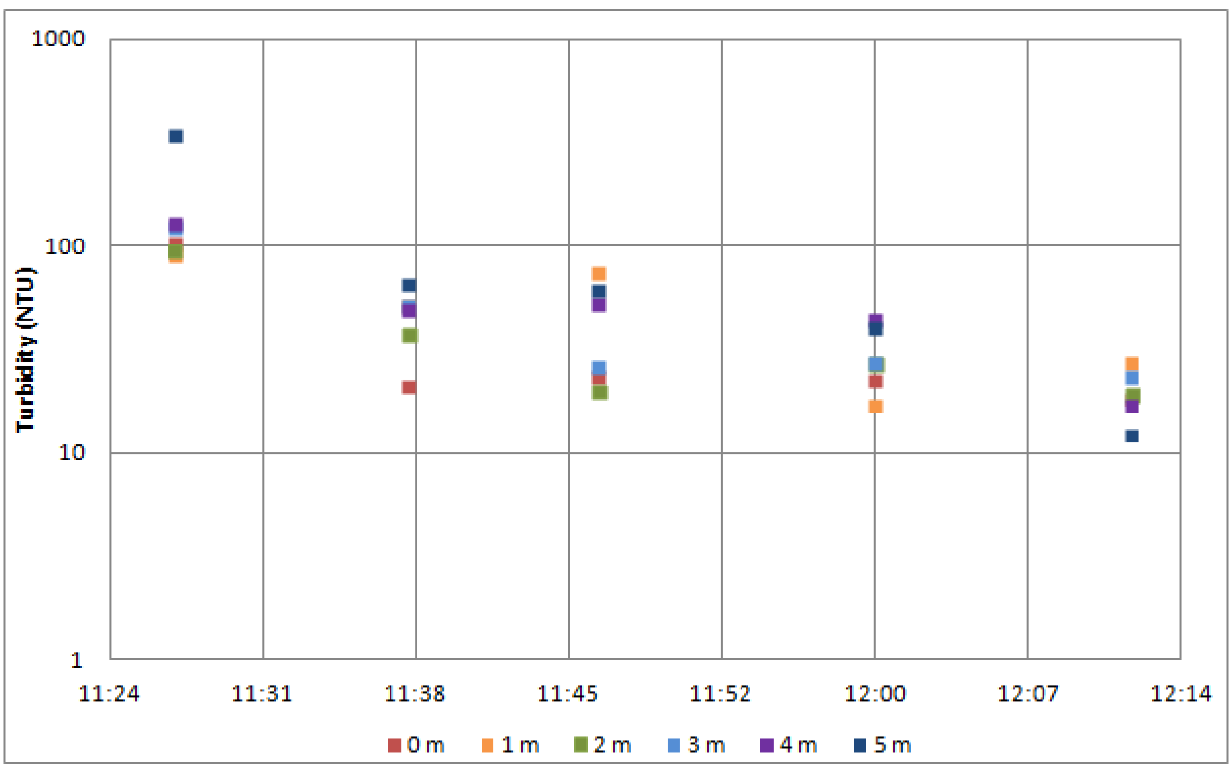


Figure 4-33 Turbidity Profiles Collected through the Placement Plume at Various Times while Tracking the Plume's Movement on August 21, 2013

4.1.4 Sediment Sampling

The objective of sediment sampling was to compare and evaluate variations in sediment physical-textural–chemical characteristics and sediment phosphorus fluxes as a function of open-lake placement of dredge material. The samples were analyzed at the University of Wisconsin-Stout. The complete report from the University of Wisconsin–Stout is included in Appendix E.

Sampling stations were established in the placement area and the two reference areas. Intact sediment cores and surface grab samples were collected in June prior to the start of dredging activity. The samples were collected again in October, after the completion of dredge material placement at the placement site. Intact sediment cores were collected at three stations located in the placement area and two stations in the reference areas. These cores were used to determine rates of phosphorus release from sediment under aerobic and anaerobic conditions. Additional sediment cores were collected at the same placement area and RA-stations in June and October for sectioning at 5-centimeter intervals over the upper 20 cm to determine the variation in physical and chemical properties. Grab samples of surface sediment were collected using a Ponar sampler at 20 to 22 stations that were established from a grid over the placement area and from six stations located in the reference areas. These samples were used to evaluate the spatial and temporal variations in sediment characteristics. In addition, actual dredge material was collected from the barges during active dredging in late July and August for physical-textural-chemical analysis and comparison with open placement surface sediment characteristics. The physical-textural variables included moisture content, bulk density, particle size distribution, and specific gravity. Chemical variables included organic matter content, sediment TP and sediment phosphorus fractions that are functionally biologically labile (loosely bound P, iron-bound P, and labile organic P; subject to recycling pathways) and biologically-refractory (aluminum-bound P, calcium-bound P, refractory organic P; more inert to recycling and subject to burial).

Physical and Chemical Evaluation

There were some significant differences in the sediment phosphorus concentration and composition between the reference areas and the placement area. The upper 5-centimeter sediment layer exhibited higher TP concentrations in the placement area (i.e., approximately 0.93 mg/g) than the reference area (i.e., 0.66 mg/g). Overall, biologically labile phosphorus accounted for approximately 47% of the TP in the placement area. In contrast, this mobile phosphorus pool represented only approximately 31% of the TP in the reference area. Differences in sediment TP concentration were largely due to greater concentration of iron-bound phosphorus (i.e., approximately 0.36 mg/g), aluminum-bound phosphorus (i.e., 0.253 mg/g), and loosely-bound phosphorus (i.e., approximately 0.021 mg/g) in the placement area versus the reference area surface sediment layer. The composition of actual dredge material collected from barges in late July and August also closely reflected the composition of the upper 5-cm sediment layer in the placement area. This indicates chemical linkages between dredge material originating from

Toledo Harbor and sediment located in the open placement area of the WLEB. Spatial variations in Ponar grab samples confirmed the interpretation of findings from intact sediment cores. Specifically, sediment TP concentrations were greater in the placement versus reference areas on both June and October. Mean TP concentrations over the entire placement area sampling grid ranged between 0.98 mg/g ($\pm$ 0.02 SE) in June and 0.91 mg/g ($\pm$ 0.02 SE) in October. These mean concentrations closely reflected the TP concentration of dredge material collected from Toledo Harbor in July and August. In contrast, the mean TP concentration in reference area Ponar grabs was lower at approximately 0.73 mg/g.

Surface Sediment Characteristics. In June 2013, before dredge material was placed, the surface sediment particle size distribution in the placement area was dominated by the silt fraction at a mean 54.2%. The clay fraction accounted for a mean 37.1% and sand represented 8.7% of the particle size distribution (see Figure 4-34). In contrast, the sand fraction comprised a much higher percentage in RA-1. This was attributable in large part to finely ground zebra mussel shells. However, silts and clays still dominated overall particle size distribution in RA-1 as well.

Surface sediment in both areas exhibited a moderately low mean moisture content (range approximately 55 to 60%), porosity (range approximately 75 to 79%), and moderately high wet and dry bulk density (range approximately 1.29 to 1.38 g/cm^3 and 0.53 to 0.65, respectively), indicating denser and compacted fine-grained sediment composition. Loss on ignition organic matter content was moderately low (less than 10%), but significantly higher in the placement area versus RA-1 (less than 5%) in June and September.

There were not significant temporal differences in mean surface sediment textural characteristics in the RA-1 between June and October. In the placement area, the mean percent clay fraction and mean wet and dry bulk density decreased significantly while mean moisture content and porosity slightly increased in October versus June, in conjunction with the addition of dredged material. However, with the exception of the greater than 63 microns grain size in June and organic matter content in both June and October, mean surface sediment textural characteristics were similar between the placement area and RA-1. Although some mean textural characteristics changed significantly in the placement area between June and October, overall differences between reference and placement area surface sediment physical and textural characteristics were minor after dredge material addition in October.

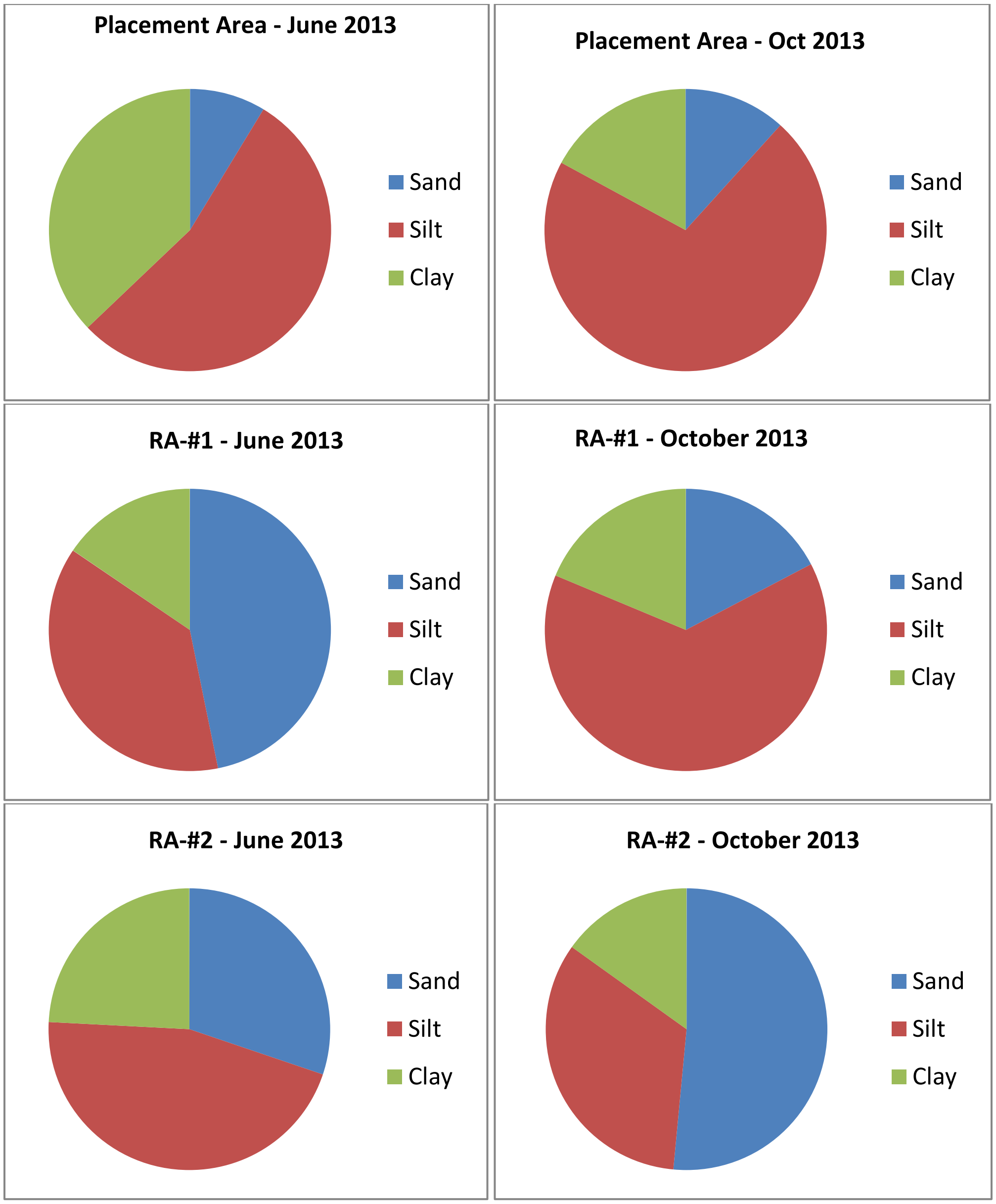


Figure 4-34 Average Physical Characteristics from 0 to 5 cm in Sediment Cores

Over all stations and dates, biologically labile and refractory sediment phosphorus represented approximately 42% and 58% of the total sediment phosphorus. The mean sediment phosphorus concentration was moderate at 0.82 mg/g and comparable to concentrations observed in Lake Ontario (0.85 mg/g), Lake Erie central basin (0.88 mg/g) and Lake Michigan (0.75 mg/g) (Nurnberg 1988). The mean biologically labile phosphorus fraction was dominated by iron-bound phosphorus (Fe-P) at approximately 77% and concentrations were moderate, ranging between 0.10 mg/g and 0.48 mg/g.

Mean biologically-labile phosphorus concentrations were significantly higher in the placement area versus the reference area in June, prior to dredge material addition (see Figure 4-35). In particular, Fe-P was approximately two times greater in the placement area surficial sediments at 0.382 mg/g in June versus a mean concentration of 0.152 mg/g at RA-1. Both mean loosely-bound phosphorus and Fe-P remained significantly higher in the placement area versus the reference area after dredge material addition in October. However, mean concentrations did not change significantly at either area between June and October, suggesting that overall area concentration differences were probably a function of dredge material placement.

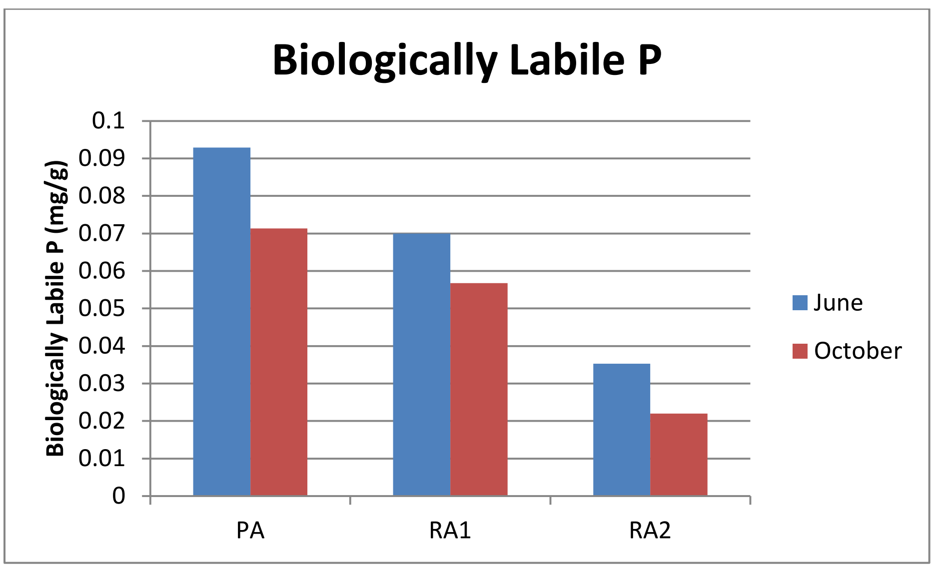
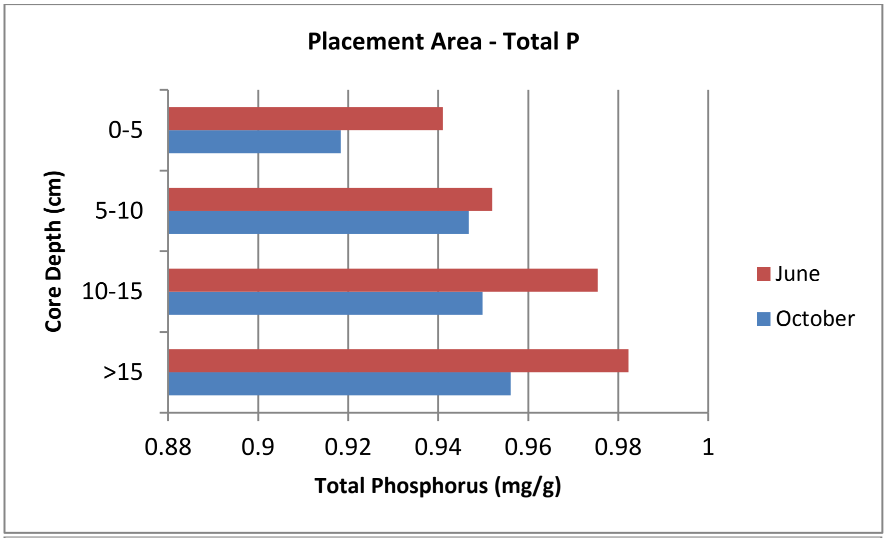


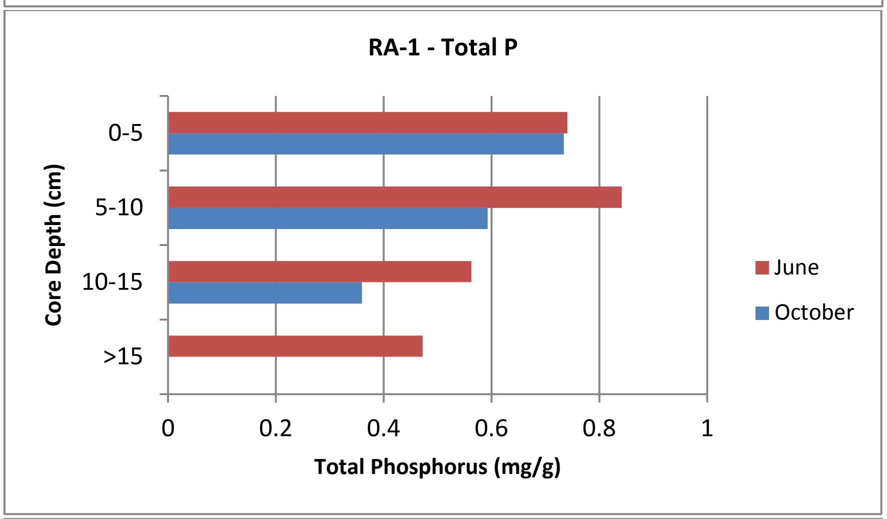
Figure 4-35 Average Biologically Labile Phosphorus from 0 to 5 cm in Sediment Cores

Vertical Variation in Sediment Characteristics. Table 5-7, presented later in the text, details results from the vertical core analysis from June and October for the placement area, RA-1 and RA-2. Sediment moisture content tended to decrease, while wet and dry bulk density increased, with increasing sediment depth as a result of compaction over time. These depth-related trends were more pronounced in the reference versus placement area, particularly for bulk density. Area-related differences may have been due to disturbance in the placement area via annual addition of dredge material. Mean specific gravity was homogeneous as a function of depth in the placement area.

The reference area exhibited a greater percentage of particles greater than 63 microns throughout the sediment column versus the placement area. Broken and finely ground zebra mussel shells probably accounted for a portion of this particle size fraction in the reference area. However, it was also noted that the sediments appeared sandier in the reference area. Silt dominated the particle size distribution in the placement area and percentages were uniform with sediment depth in both June and October. However, the percentage increased significantly over most sediment depths in the placement area from June to October. The silt fraction was more variable in the reference area and tended to decline slightly with increasing depth in June. However, silt percent distribution was more homogeneous over all depths in October. Similar to patterns in the placement area, the percent silt composition tended to increase at greater sediment depths in the reference area from June to October. The clay fraction was uniformly distributed over all depths in the placement area and represented a greater percentage of particle size distribution in June versus October. The percentage declined significantly in the placement area over all depths in October versus June, coincident with dredge material addition. The clay percentage was generally uniform over all depths in the reference area in June and October. The results for sediment composition are summarized on Table 5-7 and Figure 17 in Appendix E.

Mean TP concentrations over all sediment depths in the placement area during both June and October are presented in Figure 4-36. At the placement area mean TP increases with depth in both June and October. At RA-1 and RA-2, mean TP concentrations decrease slightly with depth or remain fairly steady.





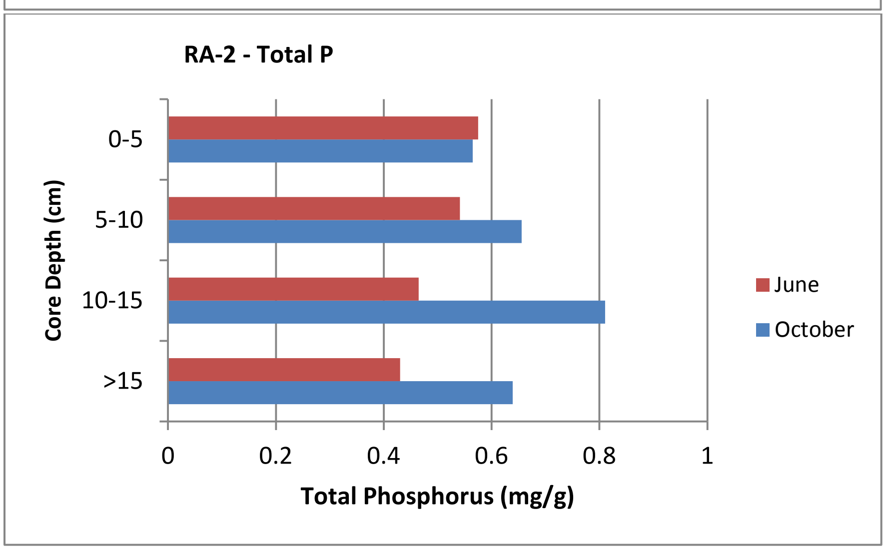


Figure 4-36 Mean Total Phosphorus Concentration as a Function of Sediment Depth

Dredged Material. Dredge material was collected from the barge in late July and late August 2013 for examination of sediment characteristics. The dredge material exhibited moderately low mean moisture content (range = 1.32 g/cm^3 to 1.47 g/cm^3) and high wet (range = 1.32 g/cm^3 to 1.47 g/cm^3) and dry bulk density (mean range = 0.57 g/cm^3 to 0.84 g/cm^3). Mean organic matter content was relatively low and similar between barges and dates, ranging between 7.0% and 8.5%. Mean grain size distribution was roughly similar for dredge material collected from various barges on different dates. Particles greater than 63 microns accounted for approximately 5% of the particle size distribution.

The dredged material is compared to sediment collected from the placement area and the reference areas in Figures 4-37 to 4-39. Mean TP concentrations were roughly similar over all samples collected on all dates. The mean ranged from 0.71 mg/g to 0.94 mg/g, reflecting concentrations of TP in the surface sediment of the placement area. The phosphorus composition of dredge material was similar between barges and dates. Biologically labile and biologically refractory phosphorus accounted for approximately 46% and 56% of sediment TP composition, respectively. This reflects patterns observed in the placement area surface sediments. Similar to the placement area sediment patterns, the biologically labile phosphorus pool for the dredge material was dominated by Fe-P at approximately 34%. The biologically refractory phosphorus pool was co-dominated by aluminum-bound phosphorus (Al-P) and calcium-bound phosphorus (Ca-P) at 49% and 47%, respectively.

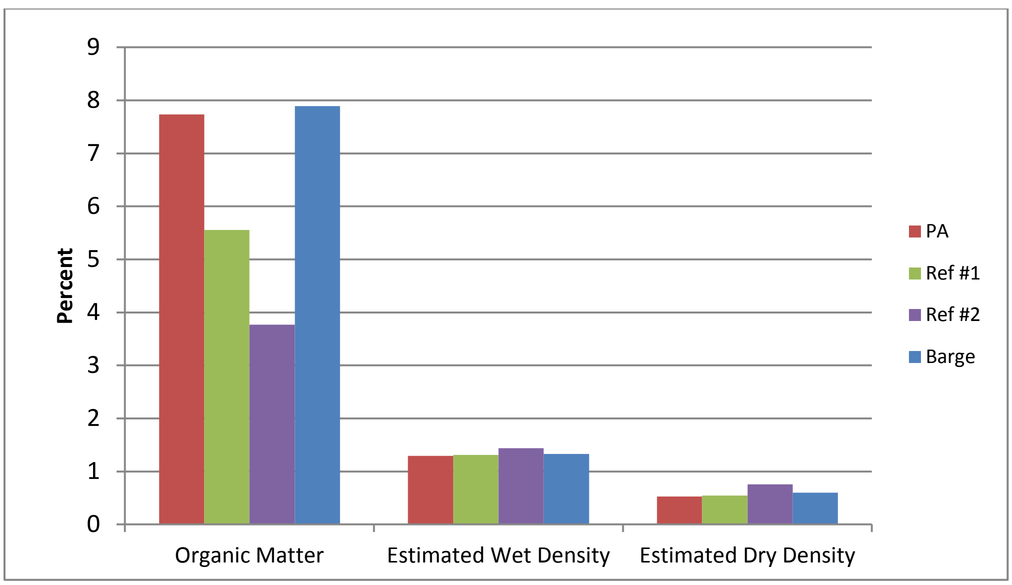


Figure 4-37 Comparison of Sediment Characteristics

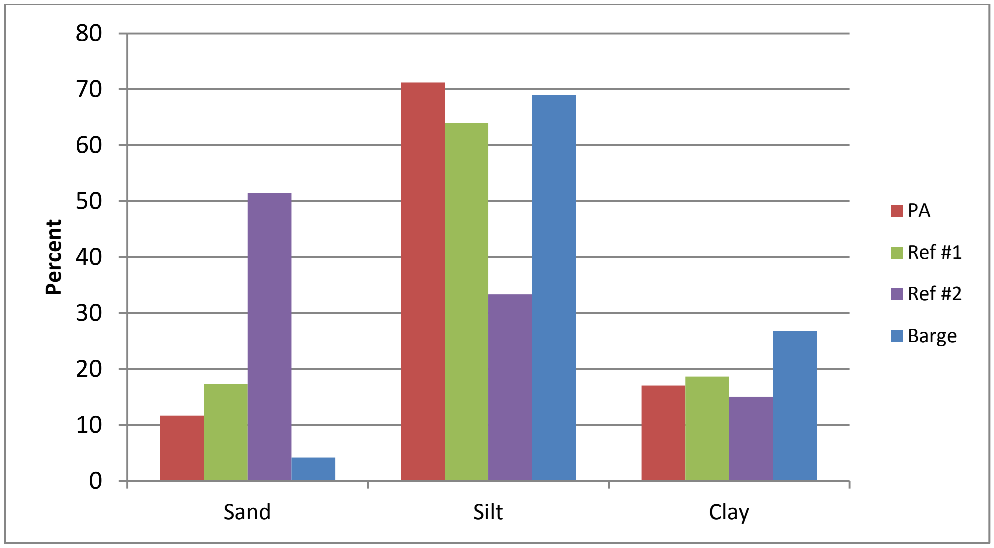


Figure 4-38 Comparison of Sediment Physical Characteristics

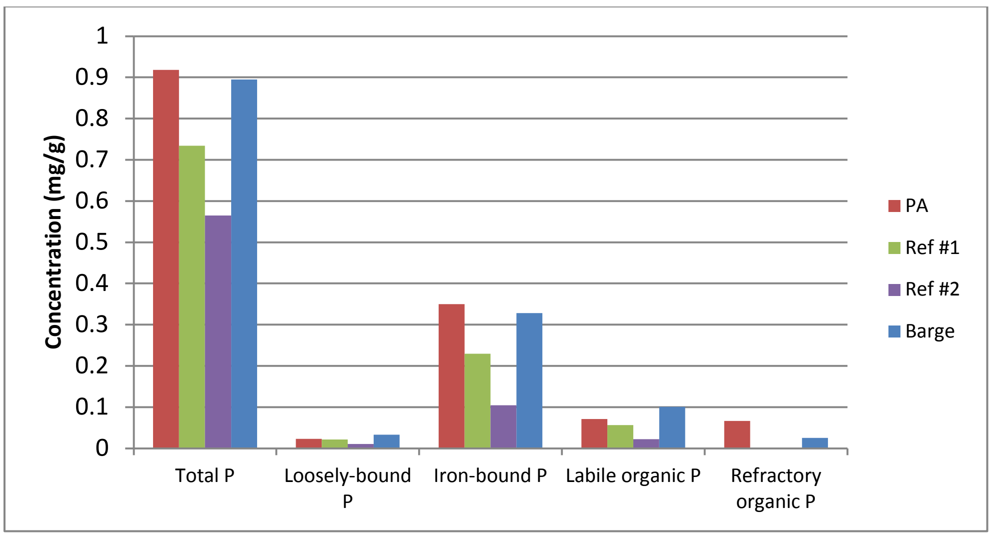


Figure 4-39 Comparison of Sediment Chemical Characteristics

Phosphorus Flux from Intact Sediment Cores

Four sediment cores were collected from five locations, three in the placement area and one each in RA-1 and RA-2. For each location, two of the four cores were used for aerobic conditions and two were used for anaerobic conditions. The sediment cores were analyzed to determine the rate of phosphorus release per unit area of sediment.

Rates of phosphorus release from sediment appear to be largely regulated by classic iron-phosphorus oxidation-reduction interactions in the placement area. They were greatest under anaerobic conditions, which was consistent with bacterially mediated reduction of iron-oxyhydroxides, desorption of phosphorus, and diffusion out of anoxic sediment and into the overlying water column. Under aerobic conditions, phosphorus release rates were much lower as the result of strong adsorption of phosphorus by iron oxyhydroxides in the thin oxidized microzone at the sediment surface, resulting in very limited diffusion into the overlying water column. Aerobic conditions at the sediment-water interface probably dominated redox chemistry in the WLEB, due to the shallow, mixed environment.

Mean rates of phosphorus release under both aerobic and anaerobic conditions tended to be greater in the reference area versus the placement area in June 2013 (see Figure 4-40). Given the higher fraction of mobile phosphorus in the placement area sediments, higher mean phosphorus releases from reference area sediments could not be explained by measuring differences in mobile forms among the two areas. This may be attributed to numerous living Dreissenids mussels (e.g., zebra mussels), found in reference area sediment but not in the placement area, playing an important role in enhancing phosphorus release rates under both aerobic and anaerobic conditions. Dreissenids mussels can excrete substantial amounts of DRP during active grazing, which would occur during aerobic conditions. Under anaerobic conditions, Dreissenid mussel death and decay can also result in the release of DRP.

In October, there was minimal change in measured mean rates of phosphorus release under aerobic conditions at both the placement area and the reference area. Under anaerobic conditions the phosphorus release rates were greater in October 2013 in both the placement area and the reference area (see Figure 4-41). The reason for the increase in the anaerobic release rate in the placement area between June and October is not clearly evident. Possible processes include anaerobic leaching, decomposition, and breakdown of organic matter and phosphorus associated with dredge material. However, since the WLEB is relatively shallow, well mixed, and oxygenated throughout the water column, the likelihood and overall role that anaerobic conditions play in phosphorus release from sediments could be minor and needs to be evaluated in relation to phosphorus dynamics.

Overall, mean rates of phosphorus release for both the reference area and placement area stations in June and October 2013 were an order of magnitude greater under anaerobic versus aerobic conditions (see Figure 4-42). The mean anaerobic phosphorus release rate for all stations and dates was relatively high at 9.5 milligrams per square meter per day ($mg/m^2/d$) and fell within ranges reported for other Great Lakes, large lake systems, and large river systems in the upper Midwest. The magnitude of anaerobic phosphorus release rates was also indicative of eutrophic conditions (Nurnberg 1988). However, the anaerobic conditions in the Western Basin rarely exist; therefore, these higher flux rates are rarely observed.

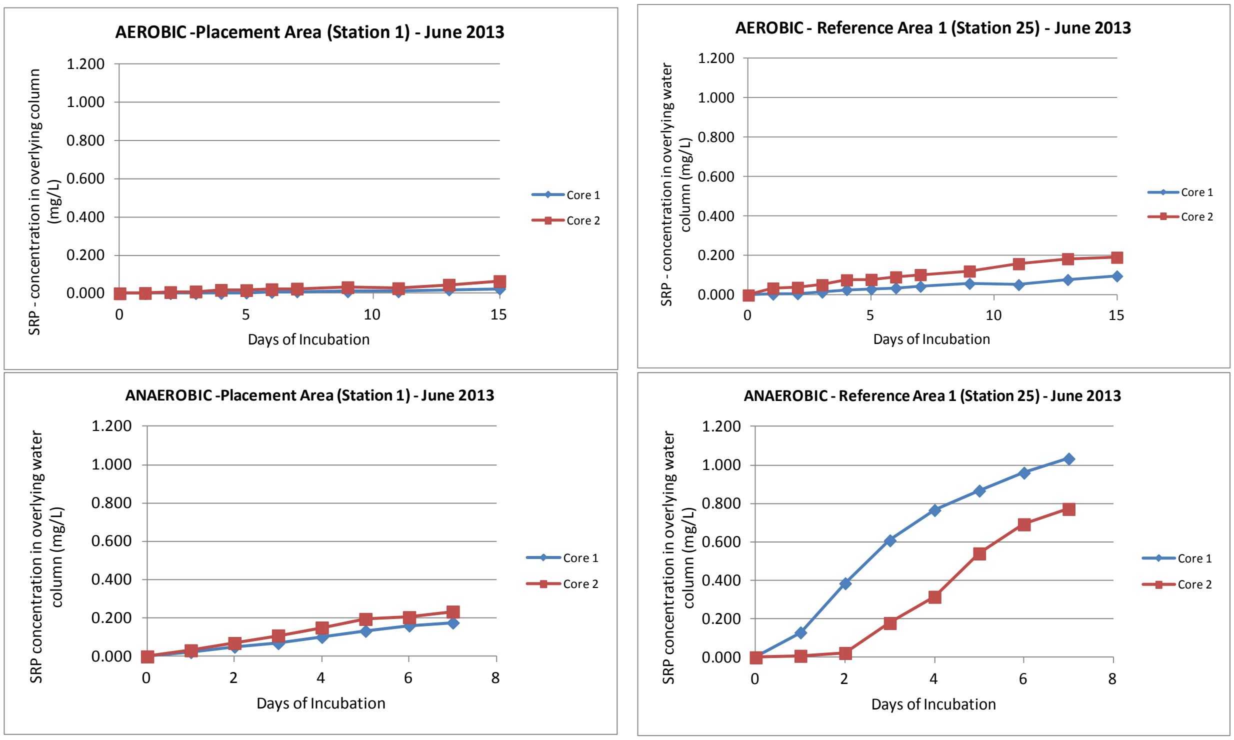


Figure 4-40 Changes in Soluble Phosphorus Concentration in the Overlying Water Column of Intact Sediment Cores Subjected to Aerobic and Anaerobic Conditions in June 2013

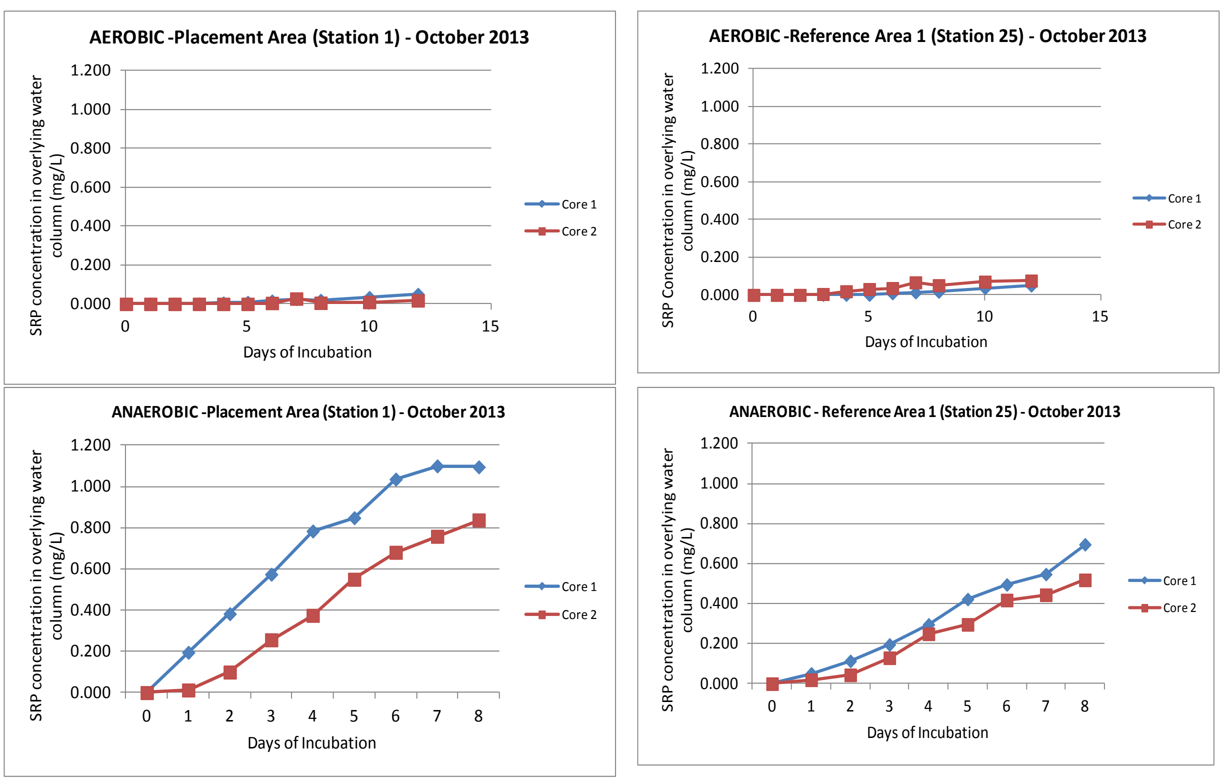


Figure 4-41 Changes in Soluble Phosphorus Concentration in the Overlying Water Column of Intact Sediment Cores Subjected to Aerobic and Anaerobic Conditions in October 2013

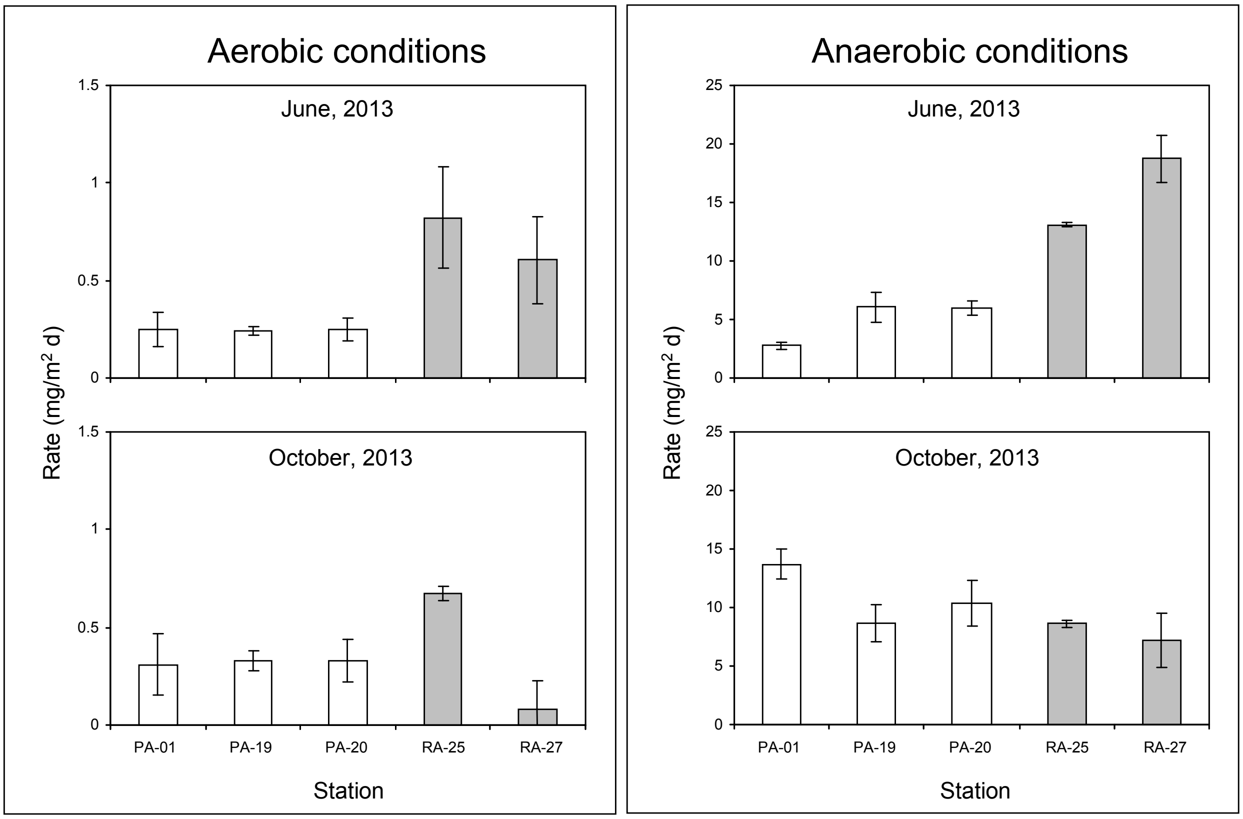


Figure 4-42 Rates of Phosphorus Release from Sediment under Aerobic and Anaerobic Conditions at the Placement Area and Reference Areas in June and October 2013 (PA-01 is the Placement Area and RA-25 is RA-1)

4.1.5 Sediment Traps

The sediment traps were deployed over two periods of time to collect water column sediments. The sediment traps were initially deployed during Event 1 and collected during Event 2. The placement area sediment trap was deployed on May 9, 2013, and was collected on July 25, 2013. A sediment trap was placed at RA-1 (originally at 41.84479/-83.356), which was later moved when RA-1 was relocated. The trap was re-deployed at the final RA-1 location (41.7754/-83.3438) on June 20, 2013, and was collected on July 25, 2013. A final sediment trap was placed at RA-2 on June 24, 2013, and was collected on July 30, 2013.

The second round of sediment trap sampling was performed immediately following the first round. Sediment traps were deployed at the placement area and RA-1 on July 25, 2013, and were collected on October 2, 2013. Similarly, another trap was deployed at RA-2 on July 30, 2013, and was collected on October 2, 2013.

The samples collected from the sediment traps were analyzed for dry mass, loss on ignition (LOI), and sediment flux at the University of Wisconsin - Stout. The sediment trap data are summarized in Table 4-14.

Table 4-14 Summary of Results from the Deployed Sediment Traps at the Placement Area, RA-1, and RA-2

Deployment	Launch Date	Date	Location	Position	ID	Dry Mass (grams)	Loss on Ignition (%)	Days	Flux ($g/m^2/d$)
	5/9/2013	6/20/2013	RA-25	Lower	A	14.9	9.3	42	31
	5/9/2013	6/20/2013	RA-25	Lower	B	15.4	9.4	42	32
	5/9/2013	6/20/2013	RA-25	Upper	A	9.7	10.5	42	20
1	6/20/2013	7/25/2013	RA-1	Lower	A	14.0	11.2	35	35
1	6/20/2013	7/25/2013	RA-1	Lower	B	12.0	10.7	35	30
1	6/20/2013	7/25/2013	RA-1	Upper	A	11.8	12.3	35	30
1	6/20/2013	7/25/2013	RA-1	Upper	B	11.5	12.0	35	29
1	5/9/2013	7/25/2013	PA	Lower	A	56.8	10.4	77	65
1	5/9/2013	7/25/2013	PA	Lower	B	61.7	10.0	77	71
1	5/9/2013	7/25/2013	PA	Upper	A	49.9	10.1	77	57
1	5/9/2013	7/25/2013	PA	Upper	B	37.6	10.5	77	43
1	6/24/2013	7/30/2013	RA-02	Upper	A	4.2	13.0	36	10
1	6/24/2013	7/30/2013	RA-02	Lower	A	5.7	10.7	36	14
1	6/24/2013	7/30/2013	RA-02	Upper	B	3.9	11.5	36	10
1	6/24/2013	7/30/2013	RA-02	Lower	B	5.7	9.9	36	14
2	7/25/2013	10/2/2013	RA-1	Lower		43.8	15.4	69	56
2	7/25/2013	10/2/2013	RA-1	Upper		41.7	16.4	69	53
2	7/25/2013	10/2/2013	PA-1	Lower		37.0	15.4	69	47
2	7/25/2013	10/2/2013	PA-1	Upper		50.5	17.3	69	65
2	7/30/2013	10/2/2013	RA-2	Lower		15.9	16.2	64	22
2	7/30/2013	10/2/2013	RA-2	Upper		16.6	15.6	64	23

Key:
$g/m^2/d$ = grams per square meter per day

Basic statistics were calculated to summarize these results. Averages and standard deviations were calculated for dry mass and LOI (%) at each of the three sediment trap locations and are shown in Table 4-15.

Table 4-15 Basic Statistics for Dry Mass and LOI% at Each of the Three Sediment Trap Locations

Dry Mass (grams)				Loss on Ignition (%)			
Location	Count	Average	STDEV	Location	Count	Average	STDEV
PA	6	48.9	9.99	**PA**	6	12.3	3.20
RA-1	6	22.5	15.75	**RA-1**	6	13.0	2.34
RA-2	6	8.7	5.93	**RA-2**	6	12.8	2.59

Key:
PA = placement area
RA = reference area
STDEV = standard deviation

Average sediment deposition fluxes were calculated for all three sites during each deployment period. These fluxes are summarized in Table 4-16. Sediment fluxes were highest at the placement area and lowest at RA-2.

Table 4-16 Average Fluxes Calculated at Each Sediment Trap Location for Each Trap Deployment Period

Deployment 1 ($g/m^2/d$)		Deployment 2 ($g/m^2/d$)	
PA	59	**PA**	56
RA-1	31	**RA-1**	55
RA-2	12	**RA-2**	22

Key:
$g/m^2/d$ = grams per square meter per day
PA = placement area
RA = reference area

4.2 Model Calibration

This section describes the model calibration process for each sub-model and shows model-data comparisons for key variables.

4.2.1 EFDC

Calibration comparisons for the hydrodynamic and water temperature model focused on comparisons of model prediction and monitoring data collected at the University of Toledo's stations MB20, MB18, 8M, and GR1. Figures 4-43 to 4-46 provide model-to-data comparisons for water temperature and chloride. Chloride is a conservative constituent naturally found in surface waters in higher concentrations in tributaries and lower concentrations in the open waters of the Great Lakes.

Figures 4-43 to 4-46 show that the model (solid blue line shown with a label of "RCA (Baseline)") captures measured water temperature (points) very closely. Maximum water temperatures in 2011, 2012, and 2013 reach 27°C. The model captures decreases in water temperature in the late summer and early fall. In 2013, continuous water temperature data available from NOAA at GR1 (RA-2) shows how the model captures the dip in temperature in mid-August.

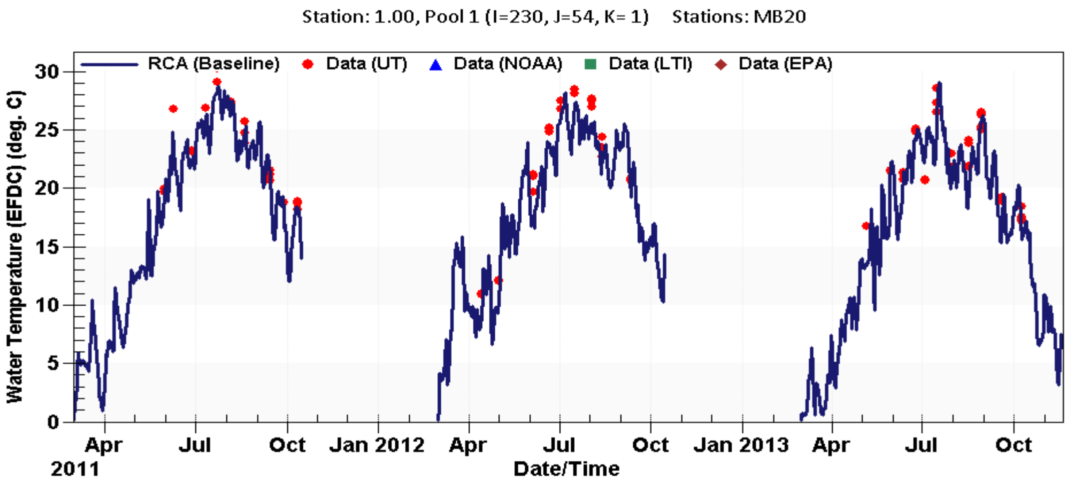


Figure 4-43 Water Temperature at MB20

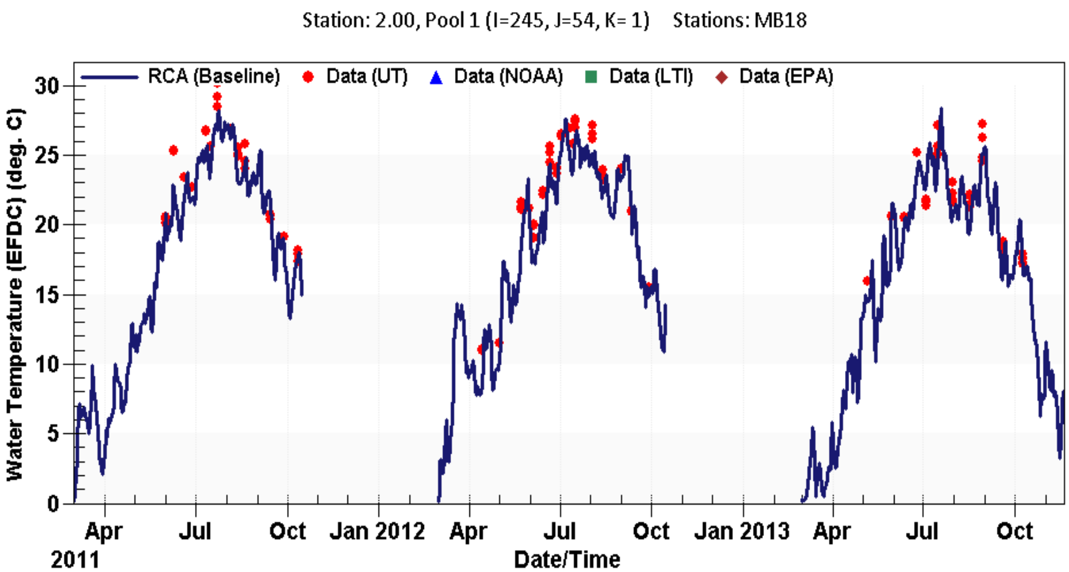


Figure 4-44 Water Temperature Calibration Comparison at MB18

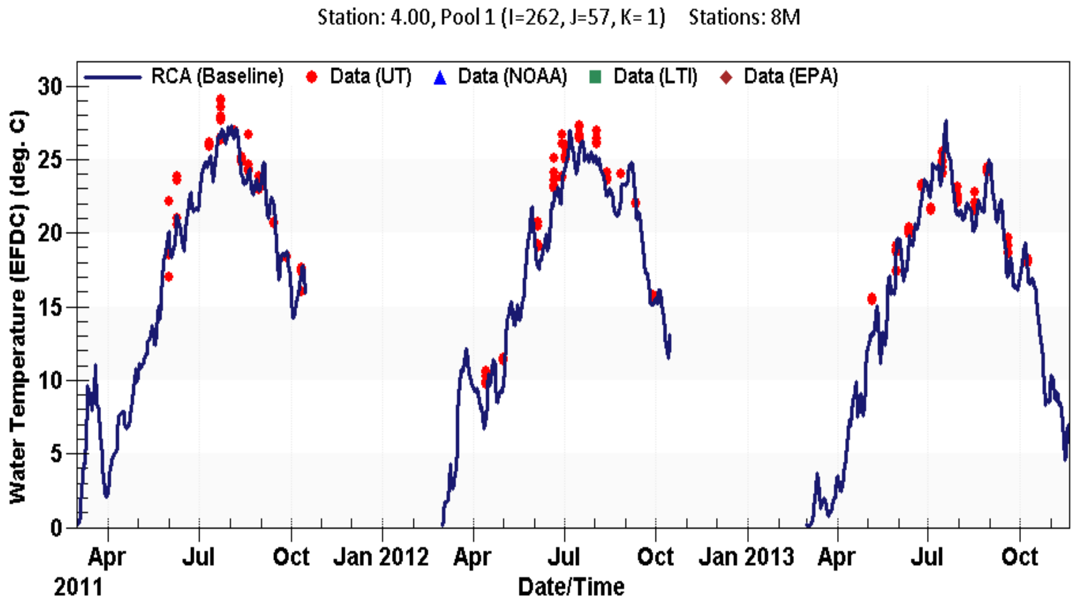


Figure 4-45 Water Temperature Calibration Comparison at MB8M

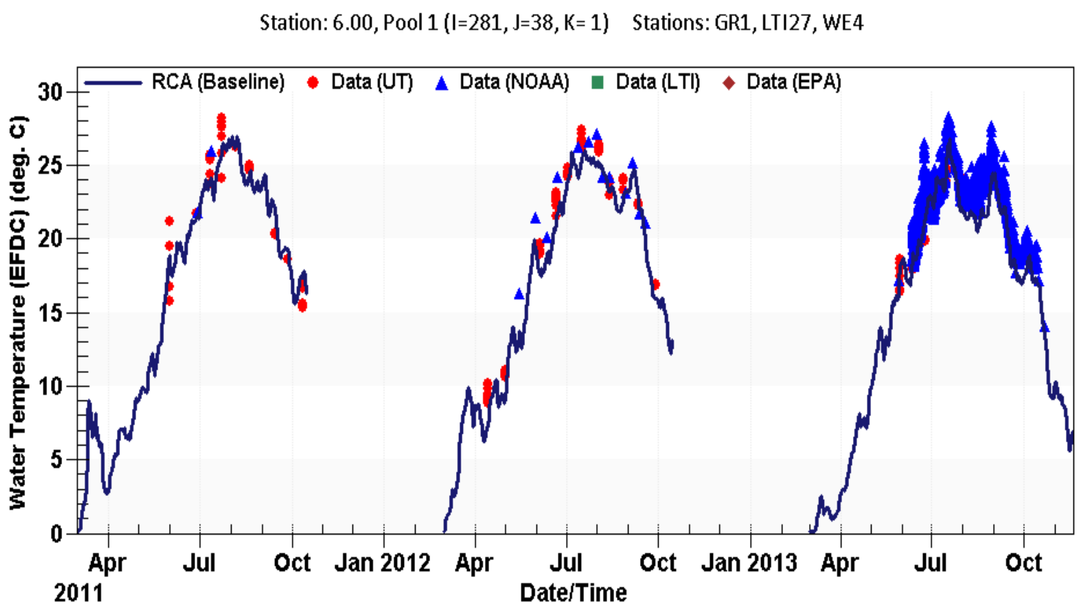


Figure 4-46 Water Temperature Calibration Comparison at GR1

Figures 4-47 to 4-50 provide model-data comparisons of chloride concentrations at MB20, MB18, 8M, and GR1. Daily chloride concentrations are available for the Maumee River; however, concentrations for other tributaries are held at a constant value. (See the Section 3.4 Model Overview for more information on model boundary conditions.) The model captures the general temporal trend of chloride concentrations well at all stations. Chloride concentrations decrease during high flow events due to dilution from runoff and increases during low flow periods. Spatially, chloride concentrations decrease moving from the river, to Maumee Bay, and out into the WLEB.

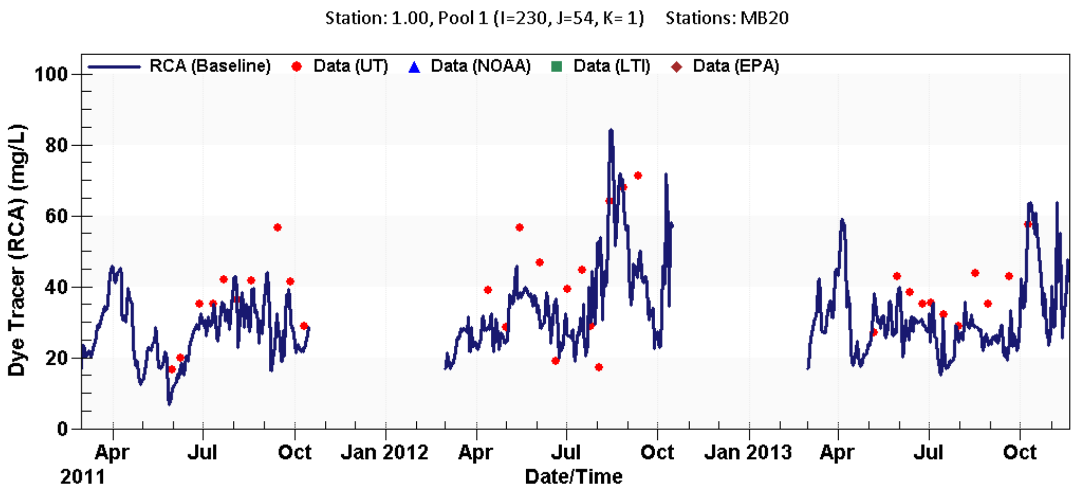


Figure 4-47 Chloride Concentration at MB20

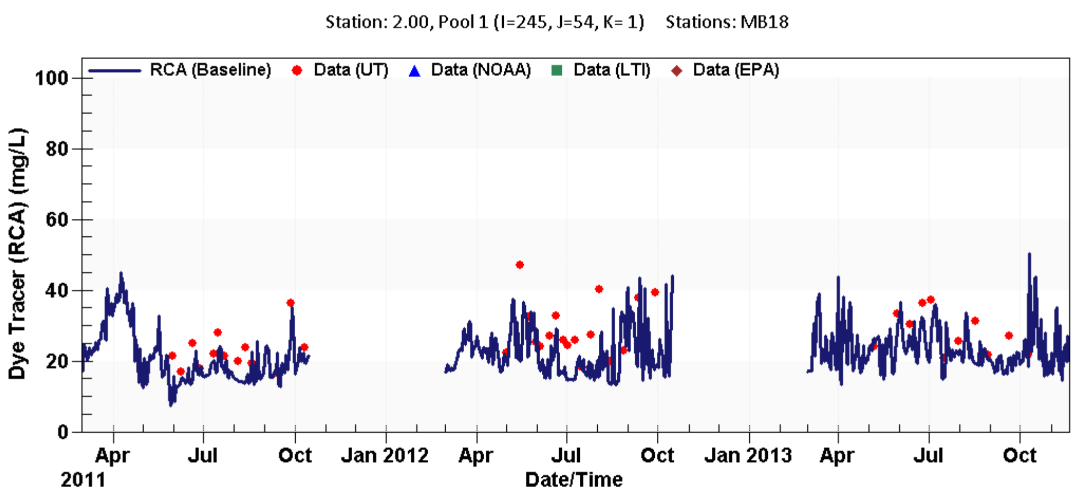


Figure 4-48 Chloride Concentration at MB18

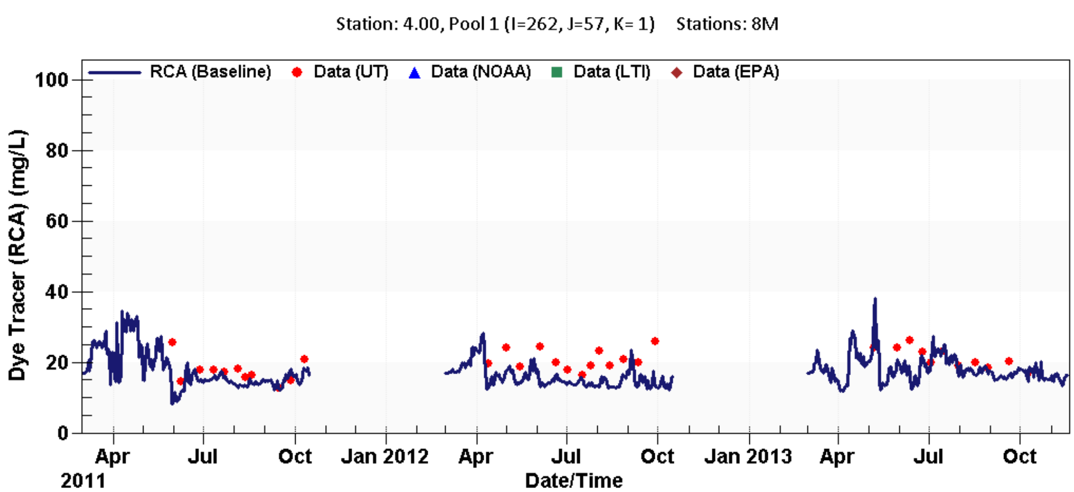


Figure 4-49 Chloride Concentration at 8M

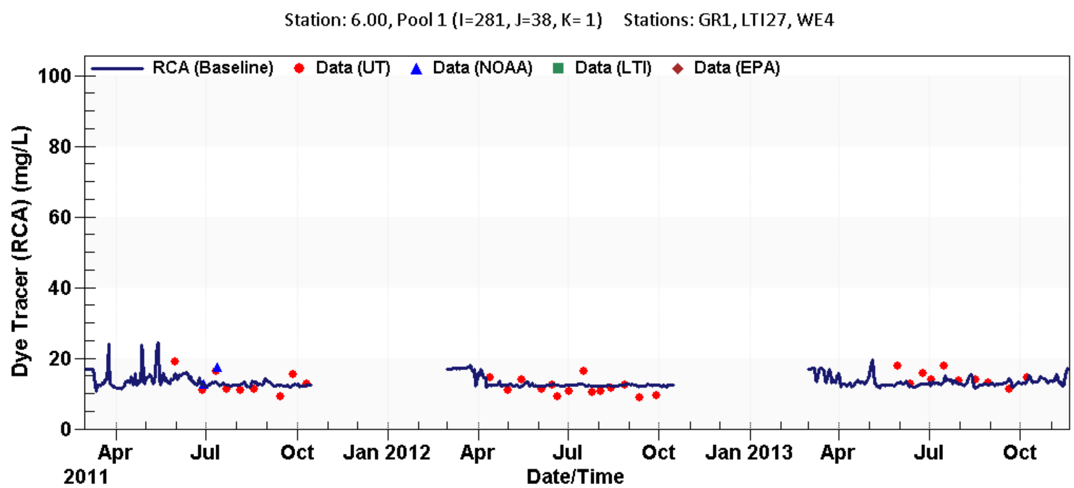


Figure 4-50 Chloride Concentration at GR1

4.2.2 SWAN

The SWAN wind-wave model was previously configured and calibrated for the 2004-2009 period as documented in the report titled *Development of an Integrated Modeling Approach for Quantifying the GLRI Deposition Metric* (LimnoTech 2013). The performance of the SWAN wind-wave model was further evaluated by comparing model-simulated wave height to wave height data and to simulation results available from the GLCFS model for summer 2013.

Wave characteristics were monitored continuously near the placement location from May to October 2013 and were reported on a 10-minute interval. Modeled wave heights at an hourly interval were extracted from the GLCFS online point query tool (http://data.glos.us/glcfs/). As shown in Figures 4-51 and 4-52, The SWAN model reproduces the frequency and timing of significant wind-wave events in the system relative to the observed data and GLCFS model results. There is some tendency for the model to under-predict the maximum peak wave heights (e.g., on July 1, 2013, during a strong northerly wind). This under-prediction may be due to uncertainty in the magnitude, as well as the direction, of wind fields over the WLEB during this time period. In general, the under-prediction of maximum wave heights is not expected to affect the model's ability to simulate the transport and fate of suspended solids released at the placement site during and following placement events.

4.2.3 Sediment Transport

The A2EM sediment transport calibration effort documented in this section builds upon previous calibration work described in LimnoTech's 2013 report. The purpose of this previous study was to evaluate the Toledo Harbor navigation channel deposition reduction targets prescribed by the Great Lakes Restoration Initiative (GLRI) 2010 Action Plan (White House Council on Environmental Quality 2010) through calibration and application of the sediment transport component of A2EM.

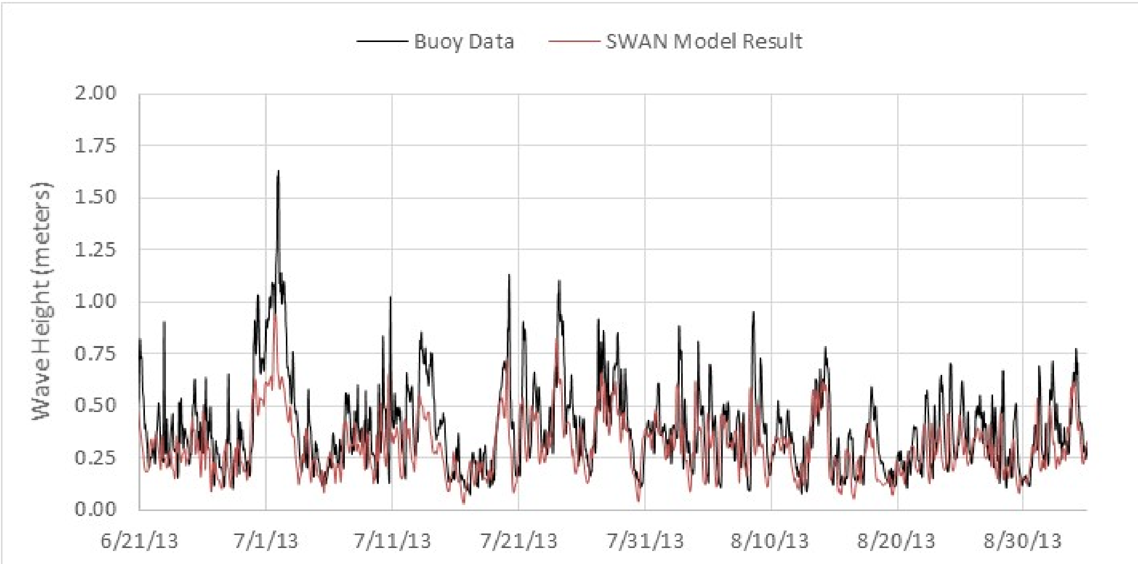


Figure 4-51 Comparison of SWAN-simulated Wave Heights to Observed Wave Heights for Summer 2013

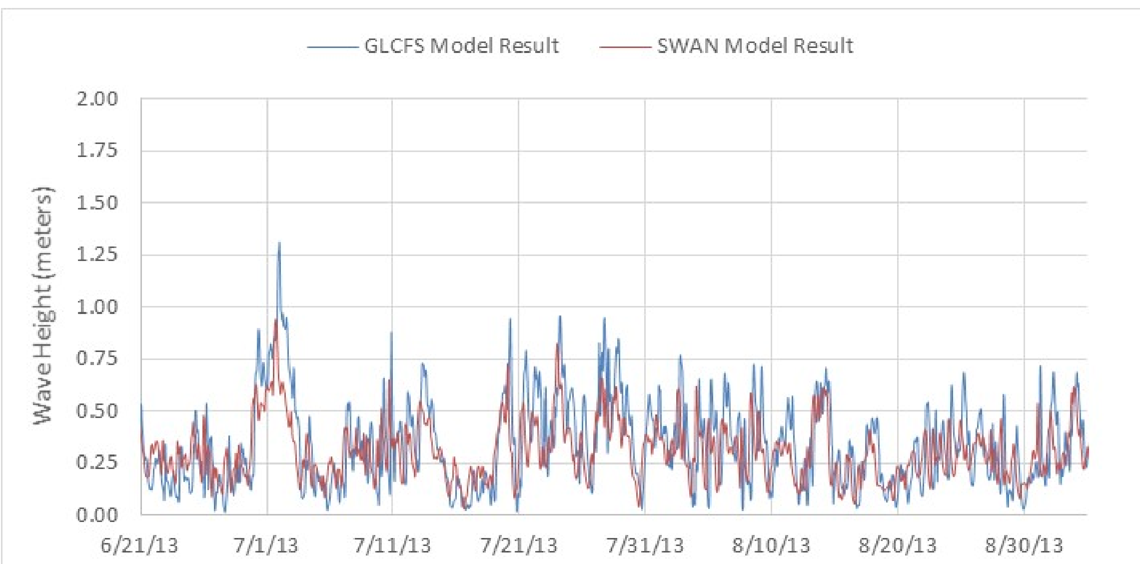


Figure 4-52 Comparison of SWAN-simulated Wave Heights to GLCFS-simulated Wave Heights for Summer 2013

A rigorous model calibration process was conducted as part of the previous Toledo Harbor deposition study. The model was calibrated by relying on several sets of successive bathymetric surveys in the navigation channel, as well as water column total suspended solids data collected by the University of Toledo and aerial imagery depicting the movement of sediment plumes from the Maumee River and resuspension events in the WLEB. Deposition rates (centimeters per year [cm/yr]) were estimated along the navigation channel by calculating the difference in sediment volume between sets of successive surveys. It was demonstrated that the calibrated sediment transport model generally reproduced the spatial and temporal patterns in deposition rates that were calculated from the surveys. Figure 4-53 presents a model-data comparison of deposition in the Toledo Harbor navigation channel that illustrates the capability of the model to match the spatial distribution of sediment deposition in the channel during the 2006-2007 period. An example of a previously developed, map-based model-data comparison for total suspended solids concentration is provided in Figure 4-54. This figure illustrates the capability of the model to track the extent and suspended solids concentrations within a plume generated by a high-flow event in the Maumee River. An example of a qualitative comparison between a model-simulated suspended solids plume and aerial imagery is provided in Figure 4-55. This comparison illustrates the capability of the model to reproduce the extent of plumes generated by the combination of a Maumee River high-flow event and nearshore resuspension activity in the WLEB.

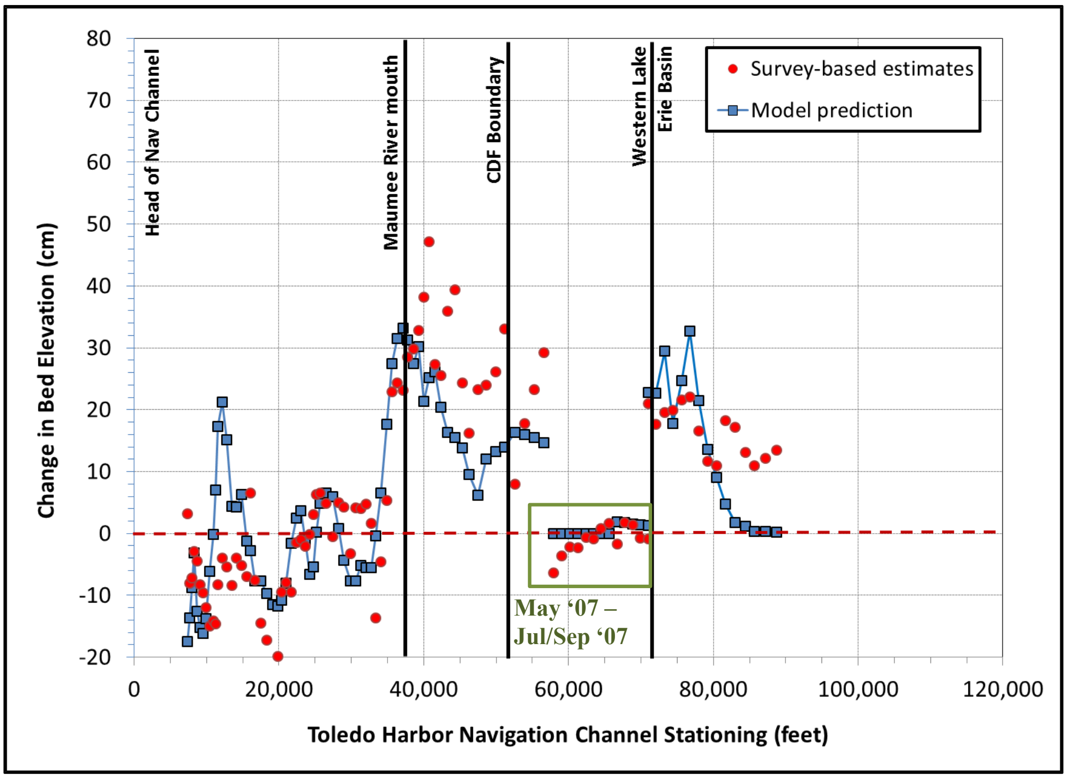


Figure 4-53 Comparison of Simulated to Observed "Bed Elevation Change" in the Toledo Harbor Navigation Channel (summer/fall 2006 – summer/fall 2007) (reproduced from Figure 4-17 in LimnoTech 2013)

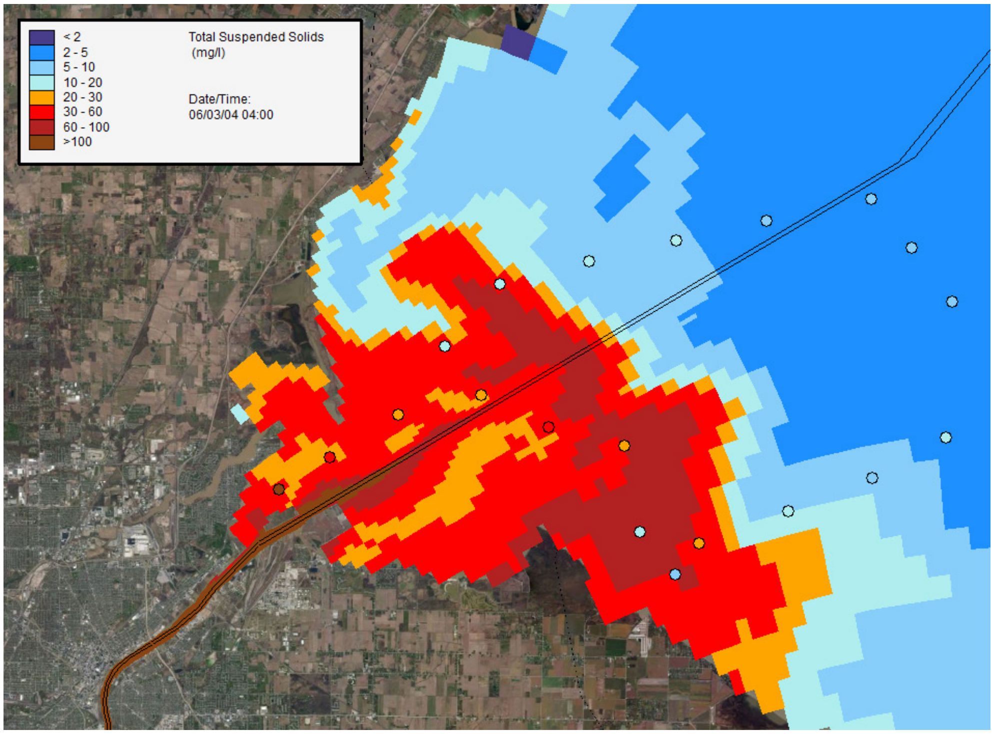


Figure 4-54 Comparison of Simulated (grid) to Observed (points) Total Suspended Solids Concentrations in Maumee Bay (June 3, 2004; Maumee Flow = 22,600 cfs)

Available bathymetry and suspended solids data and the findings from the prior sediment transport model calibration effort have identified the two major contributors to navigation channel deposition as: 1) the direct deposition of the Maumee River sediment load; and 2) resuspension of solids from Maumee Bay and the WLEB and subsequent re-deposition to the channel. The sediment transport model represents both of these processes, and the relative contributions of these processes to deposition have been well-constrained through the process of model calibration.

In order to apply the A2EM model to answer questions related to fate and transport of solids released at the placement site, it was necessary to confirm that the sediment transport model reasonably represents regional sediment bed dynamics and solids settling consistent with suspended solids data available for spring-fall 2013. Figures 4-56 and 4-57 illustrate model-data time series comparisons for total suspended solids at two monitoring stations, with locations indicated on Figure 4-58. The model generally reproduces the background concentrations observed in the data, which reflect transport of solids from multiple sources including loading from the Detroit River, the Central Basin of Lake Erie, and the Maumee River; and sediment bed resuspension in the WBLE. As illustrated by the map-based comparison in Figure 4-58, the model also reproduces the gradient in suspended solids that occurs from Maumee Bay (represented by station MB20 where observed concentrations are typically approximately 20 mg/L) into the inner region of the WBLE (represented by station GR1 where observed concentrations are typically approximately 5 mg/L).

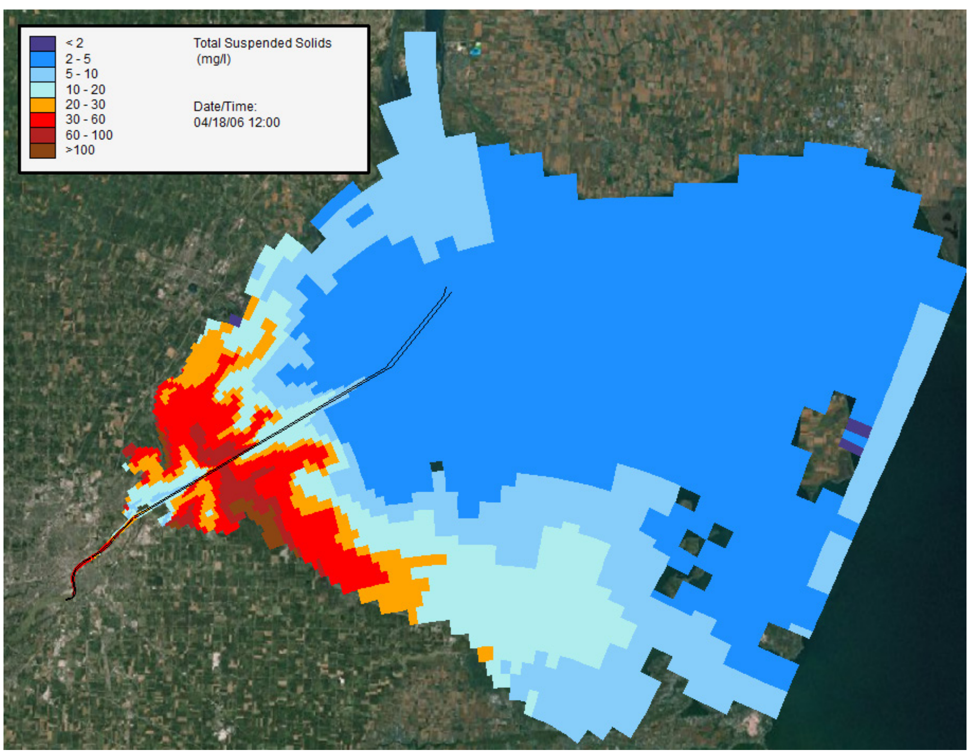


Figure 4-55 Comparison of MODIS Imagery (top) and Model-Simulated Suspended Sediment Plume (bottom) for April 18, 2006

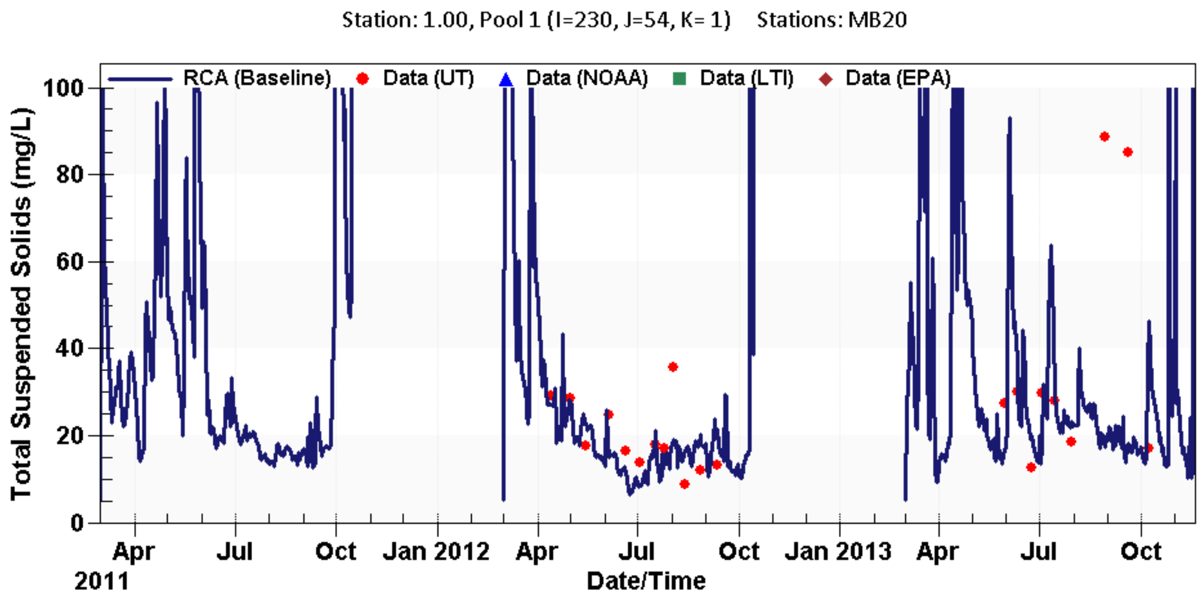


Figure 4-56 TSS Concentrations at MB20

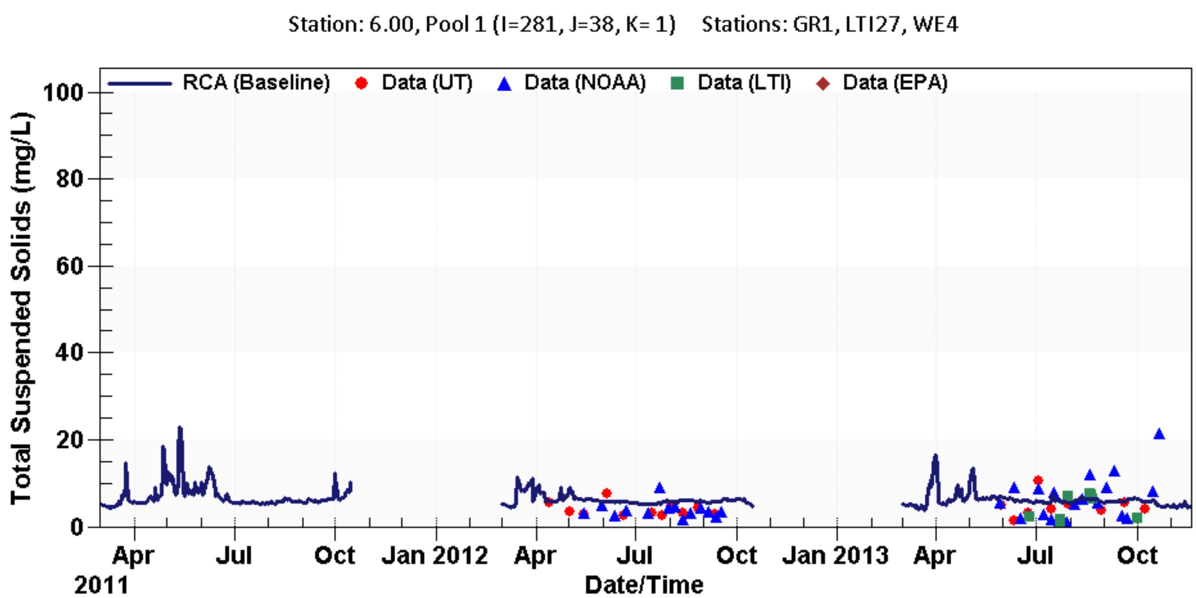


Figure 4-57 TSS Concentrations at GR1

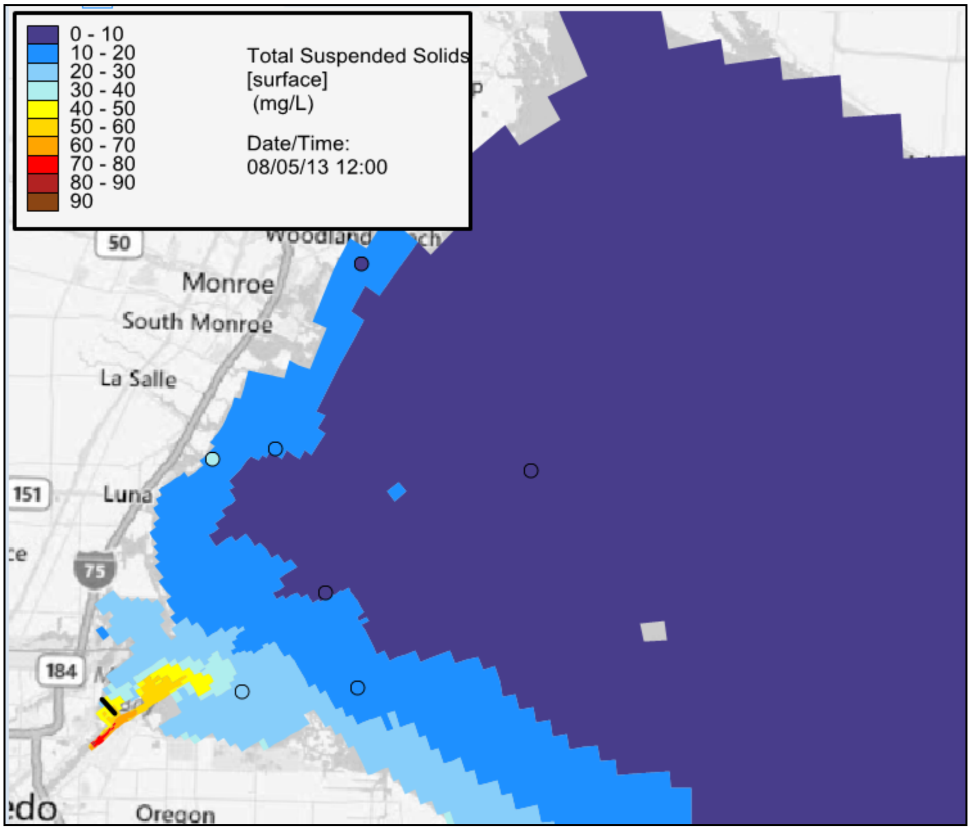


Figure 4-58 TSS Concentration Map on August 5, 2013

Figures 4-59 through 4-63 show model-data comparisons for locations where turbidity sondes recorded a continuous recorded of suspended material concentrations. The x-axis covers the May 1, 2013, to August 1, 2013, period, which is when wind driven resuspension was most dominant in 2013. Instrument recorded turbidity was converted to total suspended solids concentration through a linear regression analysis of co-located turbidity data and total suspended solids grab sample data. The model is able to capture the wind-driven at RA-1 and at the placement site. The model and data show that turbidity at RA-1 spikes higher during wind driven re-suspension events than at the placement site. Unfortunately, a sensor failure at RA-1 prevented the collection of a longer term turbidity dataset between these two locations. A turbidity sonde located at the mouth of the river primarily reflects the turbidity in the Maumee River and is not influenced by wind driven resuspension. At Toledo Light #2 (RA-2), turbidity remains low throughout this entire period. The trend of decreasing turbidity (and TSS concentrations) from the Maumee River out to Toledo Light #2 is also present in other datasets, such as TP and chlorophyll.

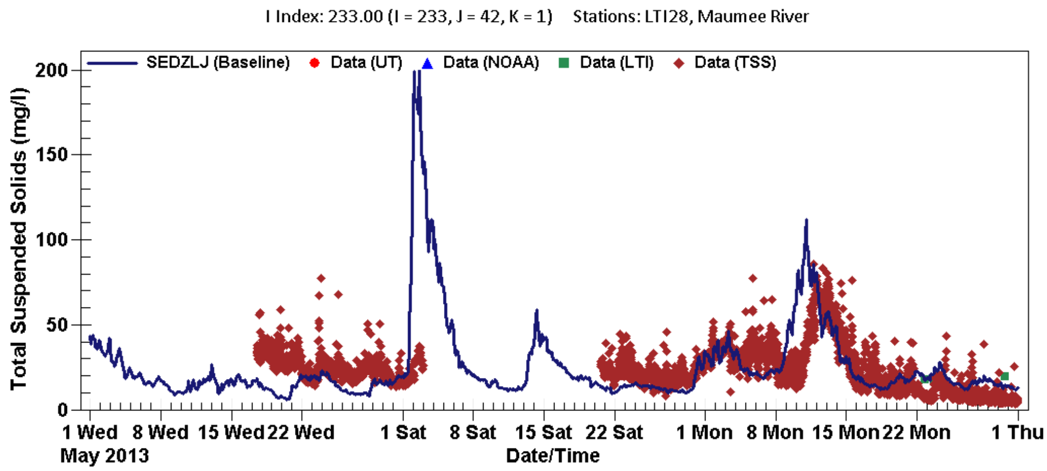


Figure 4-59 Total Suspended Solids Model-data Comparison at Maumee River Mouth

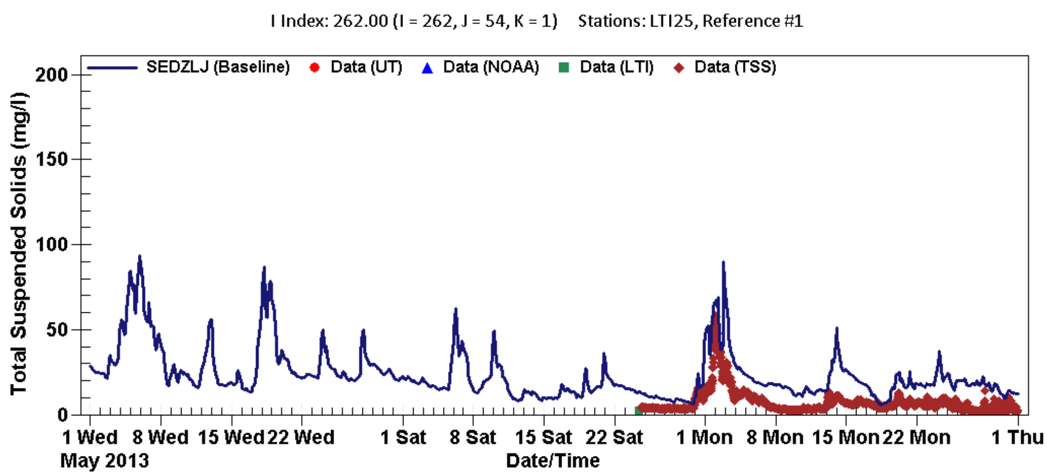


Figure 4-60 Total Suspended Solids Model-data Comparison at RA-1

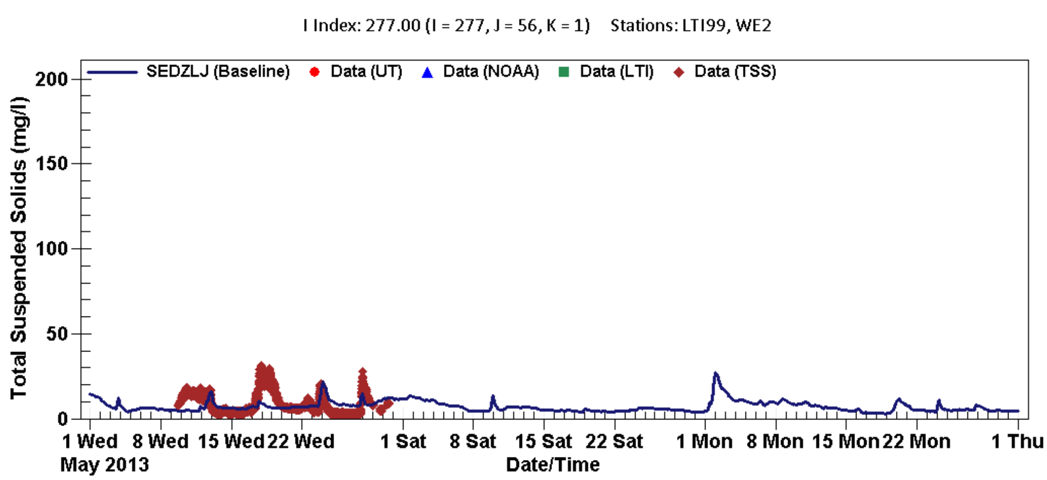


Figure 4-61 Total Suspended Solids Model-data Comparison at WE2

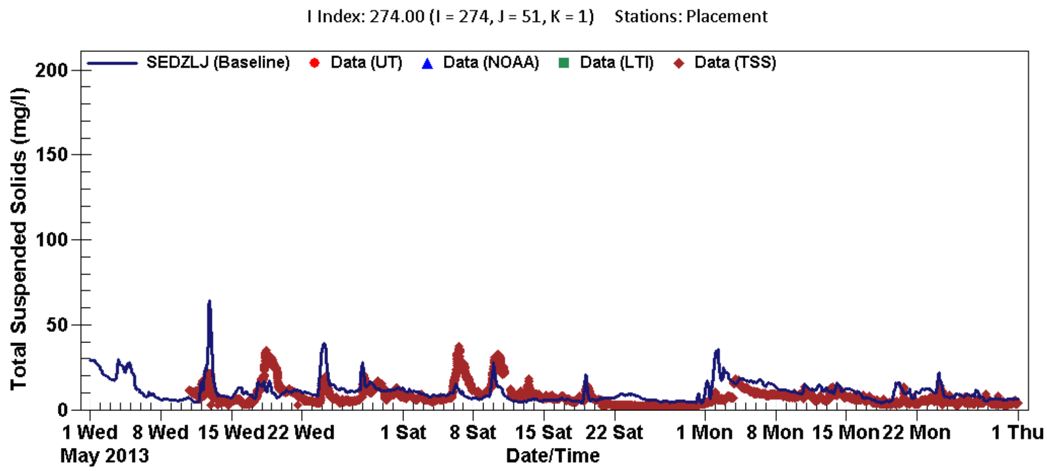


Figure 4-62 Total Suspended Solids Model-data Comparison at Placement Site

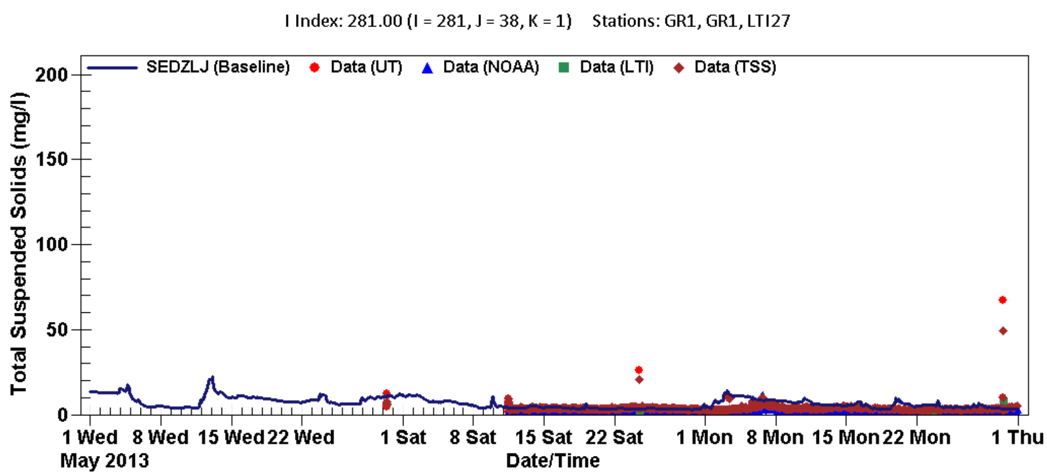


Figure 4-63 Total Suspended Solids Model-data Comparison at RA-2 (GR1)

Concentrations reasonably reproduce observed concentrations for 2013. Therefore, it was determined that no further calibration of the sediment transport model was necessary at this time, with the exception of introducing and calibrating the process of sediment disposal at the placement site. The original configuration and calibration of the sediment transport model for the Toledo Harbor deposition study (LimnoTech 2013) did not include any representation of dredged solids disposal in the WLEB. The reasons for not explicitly including placement events in the original sediment transport model were two-fold and included: 1) detailed data were not previously available to estimate the mass residual of solids in the water column during/following a placement event; and 2) the process of sediment placement at the placement area was not expected to significantly influence the deposition of solids into the navigation channel.

The sediment transport model was modified to include the release of solids to the water column following a placement event. Dredging records and water column observations collected for summer-fall 2013 informed representation of the sediment placement load. Further detail regarding the representation of solids releases to the water column for these events is provided in Section 3.4 (Model Development: Sediment Transport). Settling rates of placement solids were calibrated in the model by comparing simulated residual suspended solids mass to calculations of the remaining suspended solids mass following a placement event based on water column observations.

As discussed in Section 5.2.1, the analysis of relevant water column observations for 2013 suggests that only a small fraction of material remains suspended in the water column following a placement event. This residual fraction has been estimated to range from 1 to 5% based on an independent literature review (E & E/LimnoTech 2013) and data collected in 2013. Maximum suspended solids concentrations were measured at approximately 500 mg/L and the plume was 1.6 acres in areal extent five minutes after a placement event occurring near midday on August 21, 2013. The residual suspended particulate mass in the water column was conservatively estimated to be 14,730 kg by taking the product of the maximum suspended solids concentration, the plume area, and the average water depth at the placement site. A comparison of this "initial" residual mass to an estimate of the total mass of solids on the barge prior to placement suggests that approximately 2.5% of the solids remained in suspension five minutes after the barge doors open, with the remaining 97.5% depositing as an aggregated mass to the sediment bed during that time interval. The estimated residual of 2.5% falls within the 1 to 5% range developed based on the supporting literature review.

Five additional turbidity measurements were made within a two-hour period following the initial five-minute measurement. During this period, maximum suspended solids concentrations fell to approximately 30 mg/L, and the plume extent grew to 4.5 acres. Total suspended solids mass in the plume was estimated in the same manner as described above for the data collected at the 5-minute mark following the barge release. The data-based mass estimates for each measurement time are shown as black squares on Figure 4-64. The exponential decline observed in the estimated plume mass suggests that the solids that remain in the water column following a placement event rapidly deposit to the sediment bed. Approximately 84% of the residual suspended solids settled within an hour of the placement event. Furthermore, these residual mass estimates are considered to be conservative because they are based on estimates of the entire plume extent area and turbidity measurements taken near the observed centroid of the plume where suspended solids concentrations would be higher than concentrations near the boundary of the plume.

The sediment transport model was calibrated to accurately represent both the initial suspended solids mass (i.e., residual suspended solids present five minutes after release from the barge) and the settling loss of suspended solids mass from the water column following the August 21, 2013, placement event described above. Figure 4-64 shows a calibrated model-data comparison of the remaining mass in the plume following this placement event. As discussed above, the mass of solids remaining in suspension following the placement event was estimated as 2.5% of the total solids mass released from the barge. The distribution of residual suspended solids mass across the sediment classes represented in the model was calibrated to provide the best fit to the time trend in total plume mass reduction (i.e., via deposition) as indicated by the data points in Figure 4-64. The initial residual sediment mass distribution was as follows: 1% for clay, 4% for fine silt, 5% for medium silt, and 90% for coarse silt.

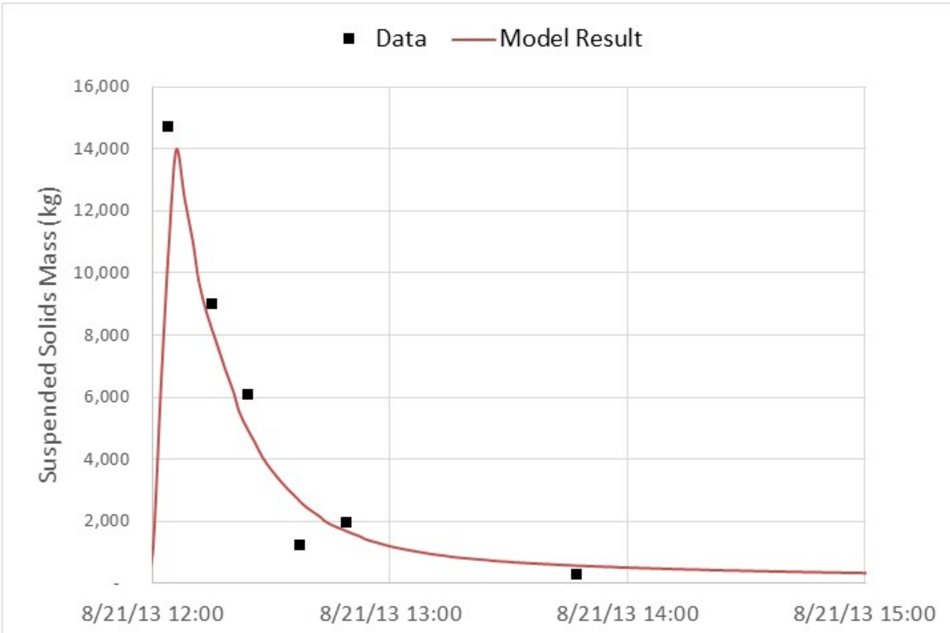


Figure 4-64 Decrease in Suspended Solids Mass after a Placement Event

The comparison between the model-simulated residual suspended solids mass and the data-based estimates of residual mass demonstrate that the model closely reproduces both the initial mass remaining in suspension five minutes after the barge opening and the deposition rate of the residual suspended sediment mass following the placement event monitored on August 21. As noted above, the data-based estimates of residual mass likely overestimate the actual mass because these estimates are based on turbidity measurements taken at the plume centroid. Therefore, the model simulation of residual mass in the water column is expected to represent the upper bound of what the suspended solids mass would actually be following a placement event at the placement site.

4.2.4 Water Quality

The water quality model calibration focused on comparing model predictions and monitoring data for TP, DP, and chlorophyll-a. Time series plots from 2011, 2012, and 2013 for these parameters are shown below for stations MB20, MB18, 8M, and GR1 (see Figures 4-65 to 4-68). These stations were regularly sampled by the University of Toledo between 2011 and 2013 and are located near the river mouth (MB20) and extend offshore to Toledo Light #2 (GR1). Model performance is shown over multiple years given the large annual variability in water quality experienced in the WLEB.

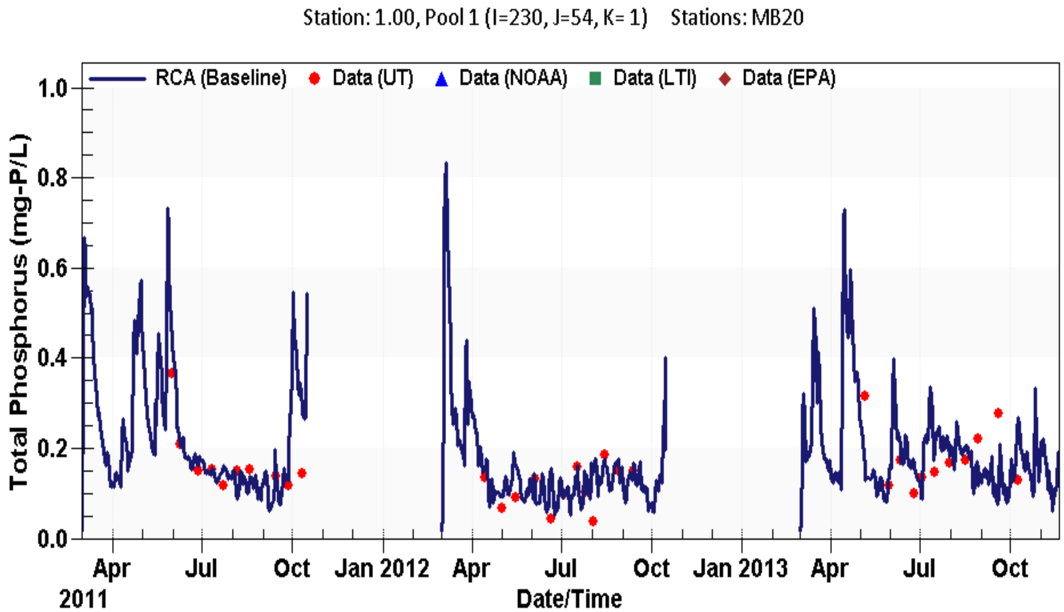


Figure 4-65 Total Phosphorus Concentration at MB20

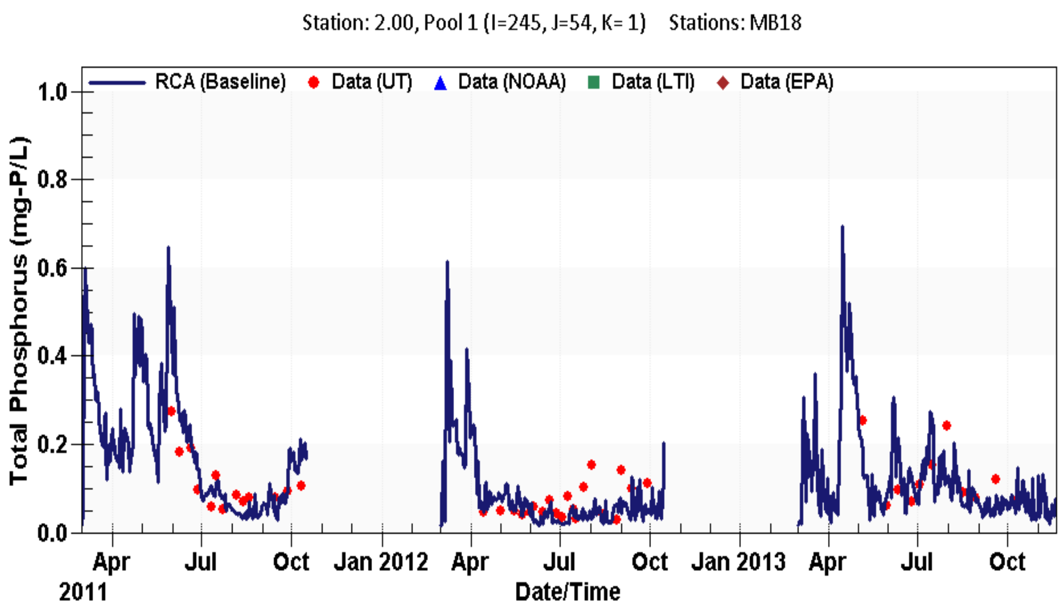


Figure 4-66 Total Phosphorus Concentration at MB18

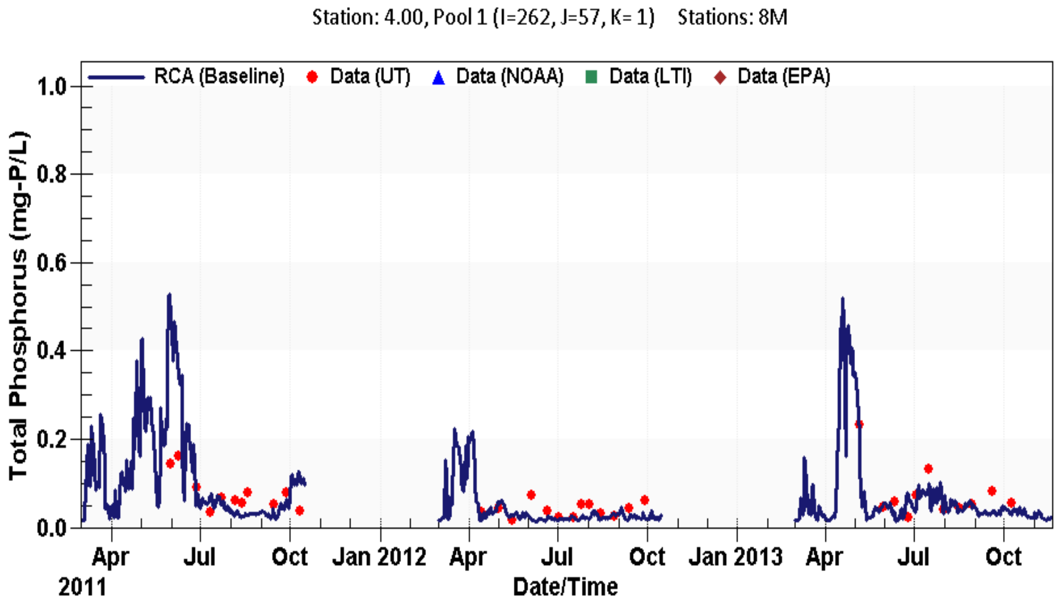


Figure 4-67 Total Phosphorus Concentration at 8M

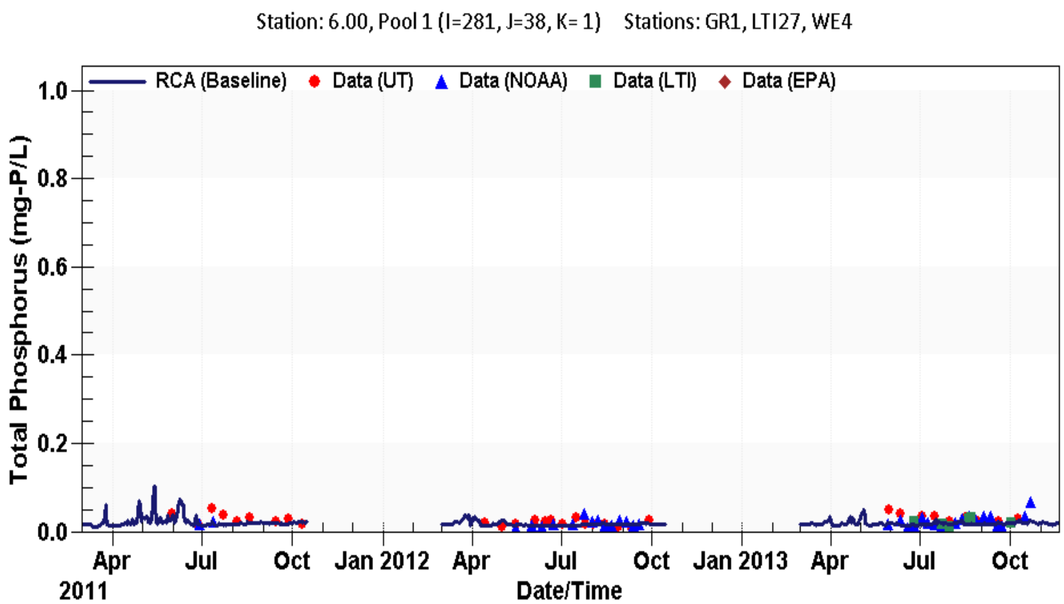


Figure 4-68 Total Phosphorus Concentration at GR1

The model captures the gradient in TP from the mouth of the Maumee River, out into Maumee Bay, and into the open waters of western Lake Erie. Spikes in TP concentrations associated with high flow events on the Maumee River are captured at station MB20, MB18, and 8M in 2011 and 2013.

The model captures the decreasing gradient in DP from the mouth of the Maumee River, out into Maumee Bay, and into the open waters of western Lake Erie. Spikes in DP concentrations associated with high flow events on the Maumee River are captured at station MB20, MB18, and 8M in 2011 and 2013 (see Figures 4-69 to 4-72). Concentrations of DP are very low at station GR1, which is at Toledo Light #2.

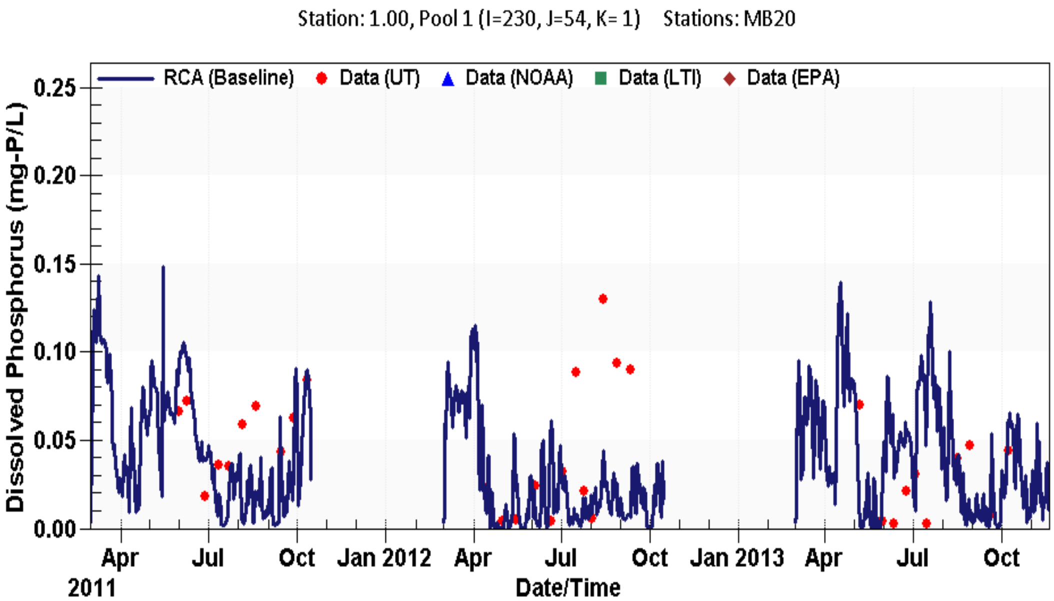


Figure 4-69 Dissolved Orthophosphate Concentration at MB20

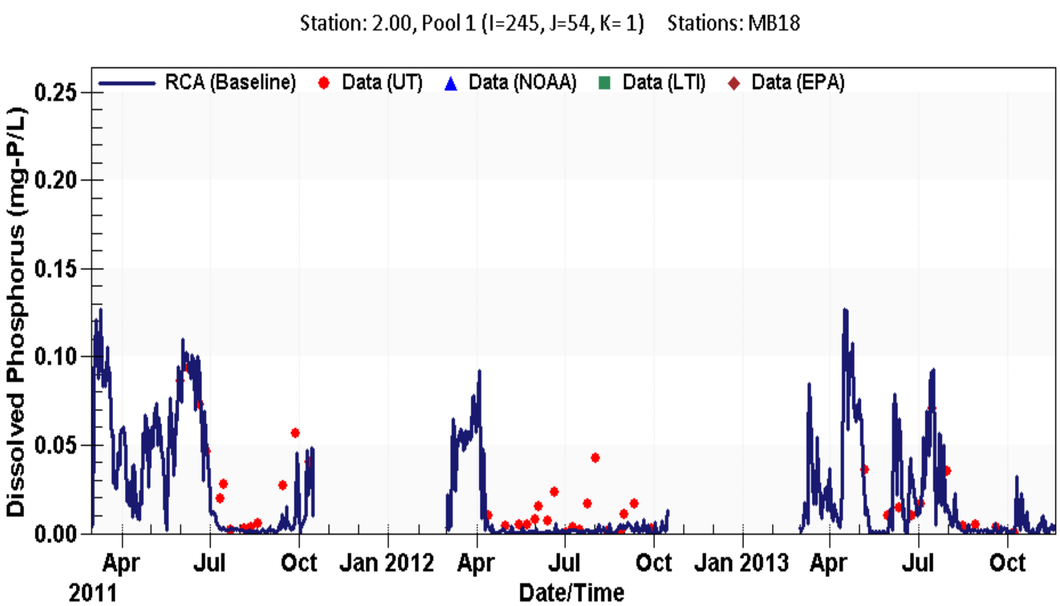


Figure 4-70 Dissolved Orthophosphate Concentration at MB18

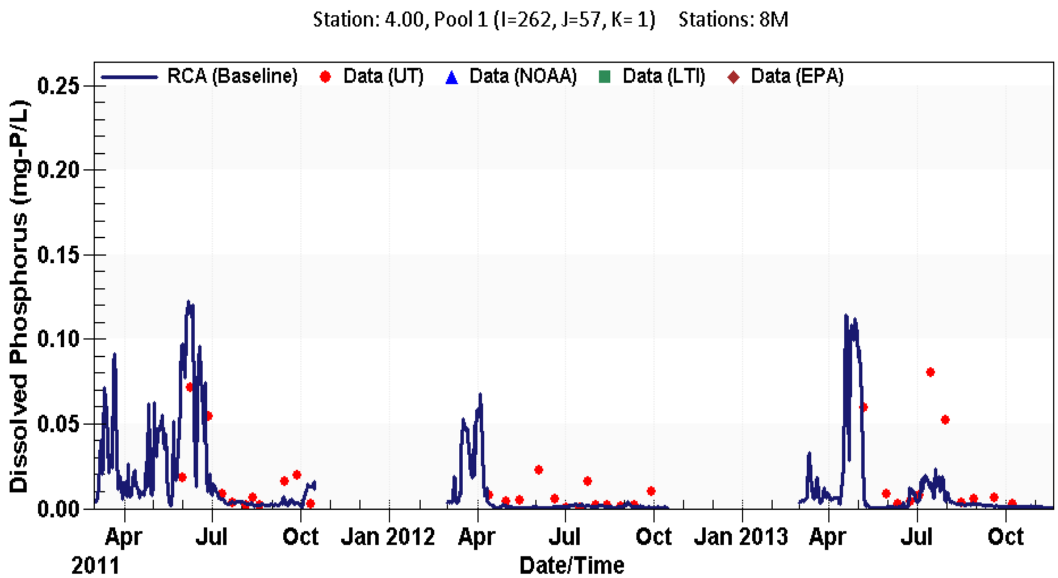


Figure 4-71 Dissolved Orthophosphate Concentration at 8M

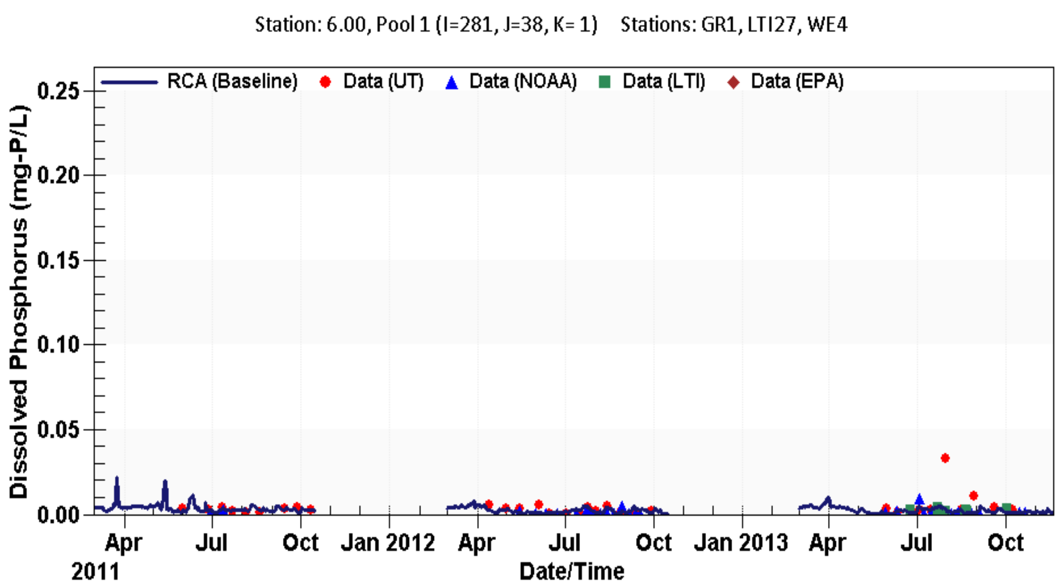


Figure 4-72 Dissolved Orthophosphate Concentration at GR1

Concentrations of the pigment chlorophyll-a are used as a surrogate for total phytoplankton biomass and harmful algal blooms. In western Lake Erie high levels of chlorophyll are observed in July, August, and September. Concentrations of chlorophyll decrease moving from the river mouth out to Toledo Light #2, which is captured by the model. The model does not capture the lower chlorophyll concentrations observed near the mouth of the river in 2012. This is due to a lack of observations of chlorophyll at the Heidelberg College monitoring station. The concentration in chlorophyll in the Maumee River is specified by a static annual time series that does not vary year to year. Farther out into Maumee Bay and western Lake Erie the model performs better and captures the difference observed between 2011, 2012, and 2013 (see Figures 4-73 to 4-76).

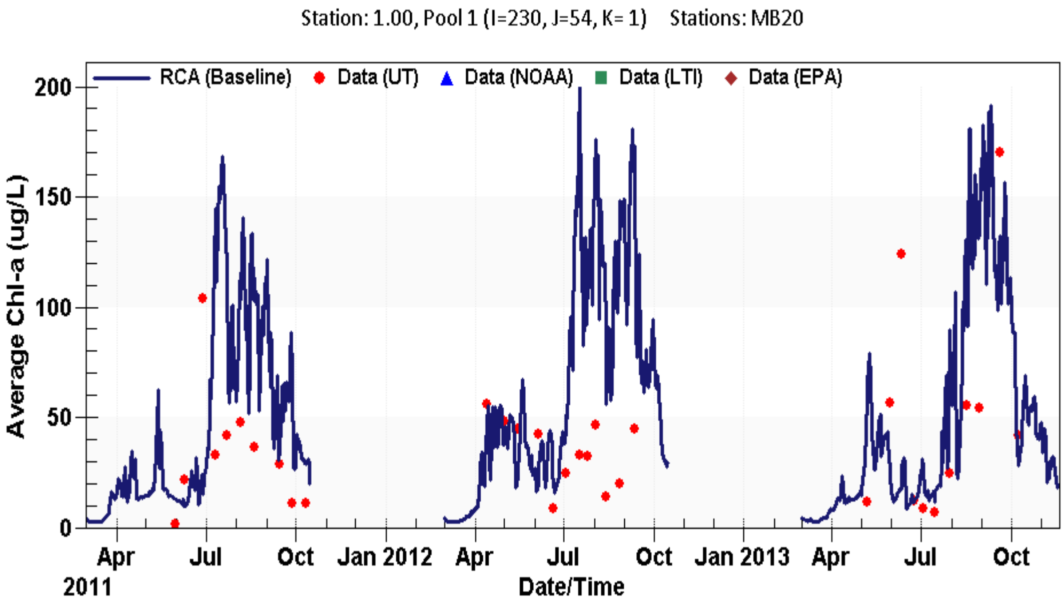


Figure 4-73 Chlorophyll Concentration at MB20

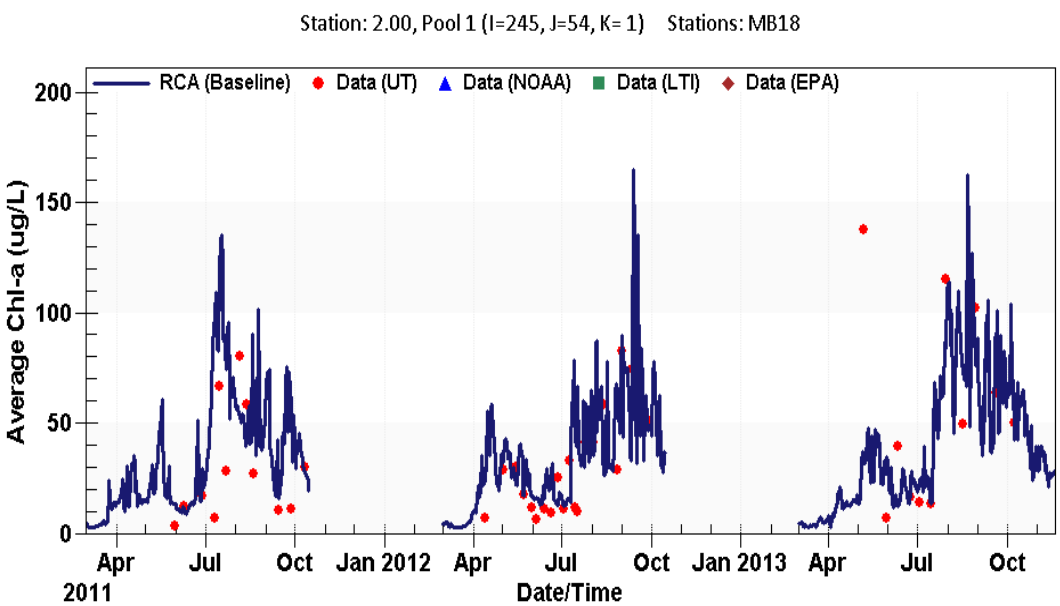


Figure 4-74 Chlorophyll Concentration at MB18

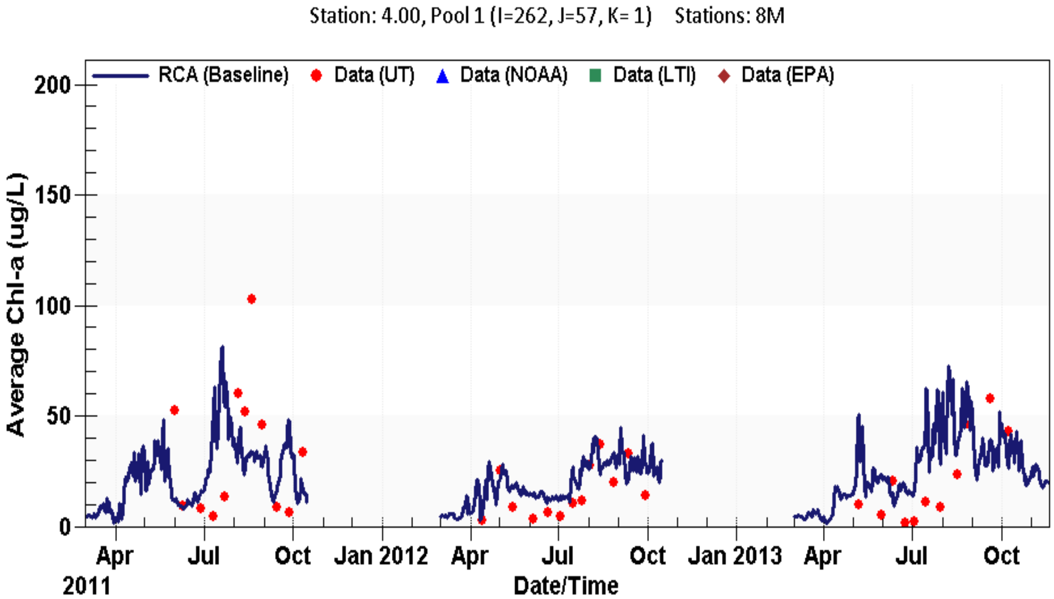


Figure 4-75 Chlorophyll Concentration at 8M

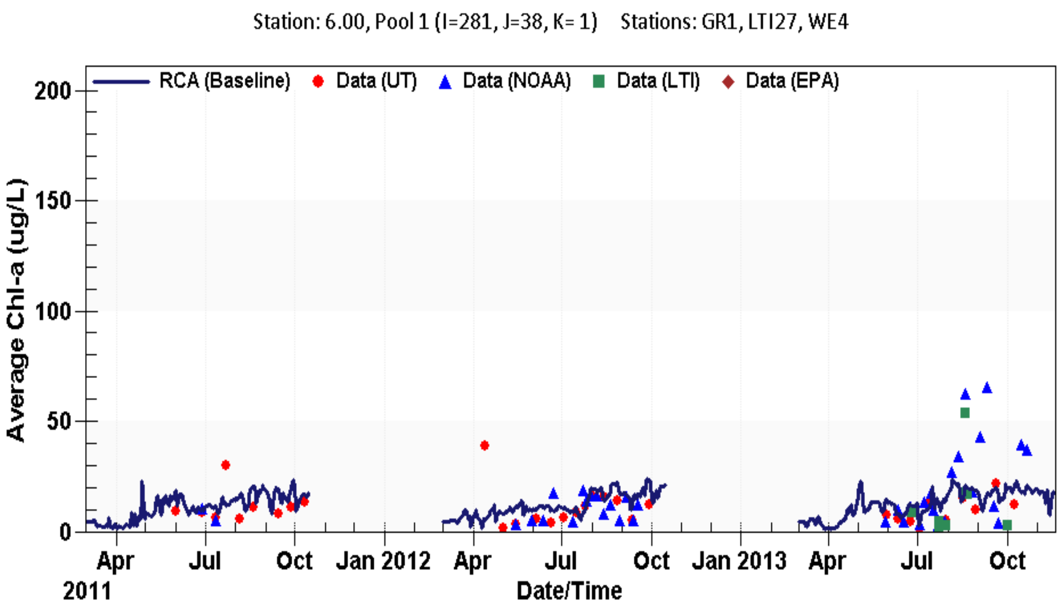


Figure 4-76 Chlorophyll Concentration at GR1

5 Discussion Synthesis of Study Results

This section provides an analysis of the data collected as part of this project and the model application done to address the project objectives. It presents a synthesis of those findings and how they related to the project objectives stated in Sections 1 and 2. This section also provides a discussion of the model and data collected as part of this project and potential impacts on HABs.

5.1 Report Objectives

The specific objectives for the final study report as posed by the USACE at the beginning of this study are listed below: The eight specific requirements of the USACE can be grouped into three major categories. The results from this study that address each major grouping of objectives, including monitoring data, model output, and literature are synthesized in the following sub-sections.

1. Develop estimates of the background phosphorus and turbidity regime in western Lake Erie. Estimate the maximal phosphorus and turbidity difference from background that can be attributed to the open-lake placement of Toledo Harbor dredged material.
2. Develop an estimate of the phosphorus mass and concentration that is released into the water column as a direct result of dredged material placement activities. This shall be expressed as total mass and concentration increase above background phosphorus. The mass associated with placement shall be compared to the overall internal (background) [diffusion and resuspension] and external phosphorus loads to the WLEB.
3. Combine information from the laboratory and field efforts with seasonal records of the timing and mass of dredged material placement in the open water to produce a mass balance estimate of phosphorus contributions to the WLEB from placement activity. The mass balance estimate provided by this two-pronged approach shall be compared with fluxes of phosphorus to the WLEB from other sources (e.g., Maumee River inputs and sediment releases).
4. A determination of where and when phosphorus from the open-lake placed dredged material may be released into (or removed from) the water column (on a seasonal and multiyear scale) and how it will move vertically in the water column and horizontally in the lake. The analysis shall consider large-

scale, long-term changes (e.g., lake levels/seiches and species' invasions) that might influence phosphorus behavior.

5. Detailed numeric modeling of water movements that include phosphorus equilibrium and diffusive phosphorus flux in relation to algae uptake. The numeric modeling shall account for water movement, dispersion, and settling of SRP and shall include uptake by algae. Model predictions shall be compared to field data.
6. Provide an estimate of what stimulatory effect the net release and movement of phosphorus resulting from the open-lake placement of dredged material is likely to have on phytoplankton in the water column, and in particular, on the development of HABs in the WLEB. This shall be interpreted within the context of the background phosphorus and circulation regime.
7. Present the plausible, upper limits of the placed dredge material influence on the abundance, intensity and noxious composition of algal blooms in the WLEB relative to other mechanisms and influences. The evaluation shall frame the results in understandable terms of risk and probability.
8. Evaluate data with regard to compliance with applicable phosphorus water quality standards during open-water dredged material placement.

The eight specific requirements of the USACE have some overlap and for the purposes of this discussion section have been categorized into three major groups. An overview of each group is presented below, along with the specific requirements addressed for each group. Results from this study that address each major group, including monitoring data, model output, and literature are presented in the following subsections.

The first grouping is a blending of the first three USACE report objectives. It includes an estimate of the maximum phosphorus and solids concentrations that can be attributed to open-lake placement activities, a quantification of the mass of phosphorus added to the WLEB due to placement activities above background, and an assessment of the mass of phosphorus added by open-lake placement relative to other internal and external loads of phosphorus to the WLEB, including development of a phosphorus mass balance budget for the WLEB. The USACE report requirements 1, 2, and 3 are addressed by the phosphorus concentration, mass, and mass balance results discussed in Section 5.2, Objective Group 1 - Concentration, Mass, and Mass Balance.

The second grouping is a blending of the fourth and fifth USACE report objectives. These requirements can be stated as using available data, model results, and literature to discuss the fate and transport of placement material in the WLEB. The USACE report requirements 4 and 5 are addressed by the by the results discussed in Section 5.3, Objective Group 2 - Fate and Transport of Placement Material.

The third grouping is a blending of the sixth and seventh USACE project objectives. It focuses on quantifying the impact of open-lake placement activities on phytoplankton abundance, particularly the frequency and severity of harmful algal blooms. The USACE report requirements 6 and 7 are addressed by the by the results discussed in Section 5.4, Objective Group 3 - Impact on Harmful Algal Blooms.

The last USACE requirement, number eight, addresses applicable phosphorus water quality standards. Although there are no standards, the *Interim Substance Objectives for Total Phosphorus Concentration in Open Waters of the Western Basin* outlined in the Great Lakes Water Quality Agreement is 15 µg/L. This objective has never been continuously met, even before the open-lake placement operations began, and it is likely to be revised when the Annex 4 sub-committee completes its work.

At lower TP levels (<15 µg/L), cyanobacteria tend to be out-competed by other classes of phytoplankton, such as algae (Chlorophyta) and diatoms (Bacillariophyceae), due to the higher affinity for phosphorus of these other groups. However, there are a great many other factors (e.g., temperature, wind and vertical mixing, water clarity, grazing pressure) that can give cyanobacteria a competitive edge, even at the lower nutrient concentrations. Nevertheless, the probability that cyanobacteria will become dominant over other phytoplankton species increases with increasing TP to a maximum probability of about 80% when lake TP reaches or exceeds 0.100 mg/L (Downing et al. 2001). In laboratory studies, *Microcystis* growth increased linearly with TP and reached a plateau at 0.220 mg/L TP (Baldia et al. 2007). Therefore, nutrient conditions for HABs (cyanobacteria dominance) in the WLEB will occur under the existing external loading conditions, even in the absence of phosphorus release from dredged material placement.

5.2 Objective Group 1 - Concentration, Mass, and Mass Balance

This section uses monitoring data, model output, and literature to estimate the increase above background in the concentration and mass of solids, TP, SRP, and phytoplankton biomass associated with open-lake placement activities. The estimated mass is then compared with other internal and external sources in the mass balance for the WLEB.

5.2.1 Concentration

Concentration data and model output are presented below. The concentration data are from event samples collected immediately after placement activities and routine samples collected at fixed stations at the reference area and near the placement area. Model output is presented from application scenarios that specifically target quantifying the impact of a full season of open-lake placement activities.

Event Sampling

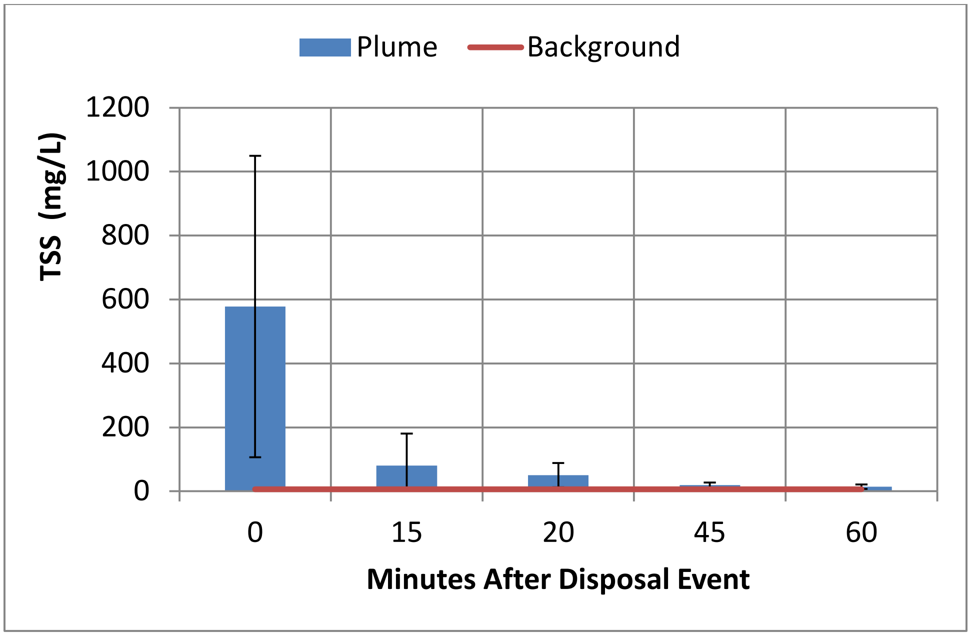
Concentrations of TSS, TP, and SRP from the open-lake placement targeted sampling events were conducted in July and August (see Tables 5-1 to 5-3). Each day of sampling focused on following a barge loaded with dredged material to the placement area, observing the placement event, and moving in immediately after placement to begin sampling. For each event, the first sample was collected within minutes of a placement event. Samples two through five were collected approximately 10 to 20 minutes apart after that. The elapsed time between sample one and sample five is shown in the "Sample 5 Time (hr)" column. The concentrations in the background column were collected at station 25 (see Figure 3-1), which is within the broader placement zone, but approximately one- half mile to the southwest from the actual placement location for a given barge release. This sample is representative of background conditions at the placement area. The average of the water column concentrations measured during the first hour after the monitored barge release events are presented in Figures 5-1 to 5-3.

As shown in Table 5-1 and Figure 5-1, the maximum TSS concentration observed immediately after placement was 1,410 mg/L on August 20. The second sample collected during this event (10 minutes after the first sample) had a TSS concentration of 26 mg/L, suggesting the 1,410 mg/L was a very short- lived maximum concentration. Average TSS of the first sample was 578 mg/L from the six event samples. Within an hour, average TSS concentrations decrease dramatically to 4% of the average initial value to an average value of 14.3 mg/L. At this low concentration difference from background, it was not possible to visually track the plume. The average distance traveled between samples one and five was approximately 1,000 feet.

Table 5-1 TSS Results from Event Samples

	Event Sample (mg/L)							
Date	1 (0min)	2 (~15min)	3 (~30min)	4 (~45min)	5 (~60min)	Sample No. 5 Time (hours)	% event sample no. 1 Remaining based on sample no. 5	Background (mg/L)
7/22/2013	288.7	45.1	52.7	20.5	11.2	1.00	3.9%	6.5
7/23/2013	347.5	48.8	30.3	6.5	6.3	1.42	1.8%	4.6
7/30/2013	110.1	38.3	23.0	28.2	12.0	1.35	10.9%	4.3
8/19/2013	815.7	37.8	44.9	17.9	14.7	1.02	1.8%	6.2
8/20/2013	1410.2	26.9	25.1	15.8	13.6	1.00	1.0%	9.2
8/21/2013	497.1	285.1	124.2	26.7	28.1	0.75	5.7%	8.0
Average	**578.2**	**80.3**	**50.0**	**19.3**	**14.3**	**1.1**	**4%**	**6.5**

Key:
mg/L = milligrams per liter



Note: The standard deviation of the five events sampled is shown on each bar. The red line represents the background TSS concentration in the area outside the placement plume.

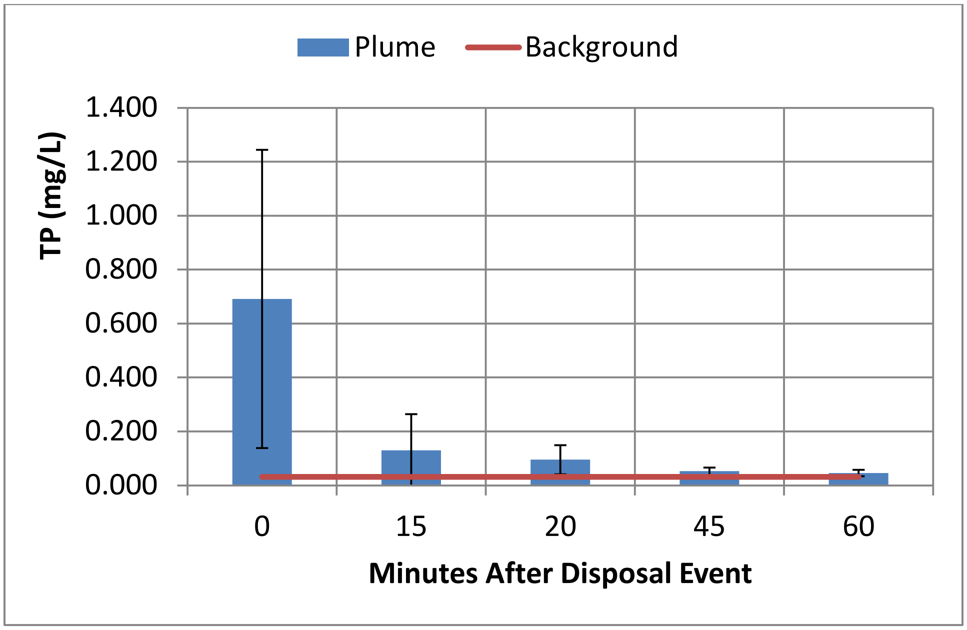
Figure 5-1 Average TSS Concentration Measured at the Barge Placement Location over the First Hour after Placement

As shown in Table 5-2 and Figure 5-2, the maximum TP concentration observed immediately after placement was 1.684 milligrams of phosphorus per liter (mg P/L), with an average TP of 0.691 mg P/L. Within an hour after the placement activity, average TP concentrations decreased dramatically to 11% of the average initial value. The average concentration in event sample five, approximately an hour after placement, was 0.046 mg P/L.

Table 5-2 TP Results From Event Samples

	Event Sample (mg P/L)							
Date	1 (0min)	2 (~15min)	3 (~30min)	4 (~45min)	5 (~60min)	Time (hours)	% event sample no. 1 Remaining based on sample no. 5% Left	Background (mg P/L)
7/22/2013	0.332	0.078	0.107	0.053	0.040	1.00	12.0%	0.035
7/23/2013	0.429	0.098	0.083	0.037	0.039	1.42	9.0%	0.032
7/30/2013	0.158	0.064	0.045	0.056	0.040	1.35	25.4%	0.026
8/19/2013	0.921	0.074	0.083	0.051	0.048	1.02	5.2%	0.028
8/20/2013	1.684	0.065	0.058	0.042	0.039	1.00	2.3%	0.032
8/21/2013	0.623	0.402	0.197	0.076	0.070	0.75	11.2%	0.039
Average	**0.691**	**0.130**	**0.095**	**0.052**	**0.046**	**1.1**	**11%**	**0.032**

Key:
mg P/L = milligrams of phosphorus per liter



Note: The standard deviation of the five events sampled is shown on each bar. The red line represents the background TP concentration in the area outside the placement plume.

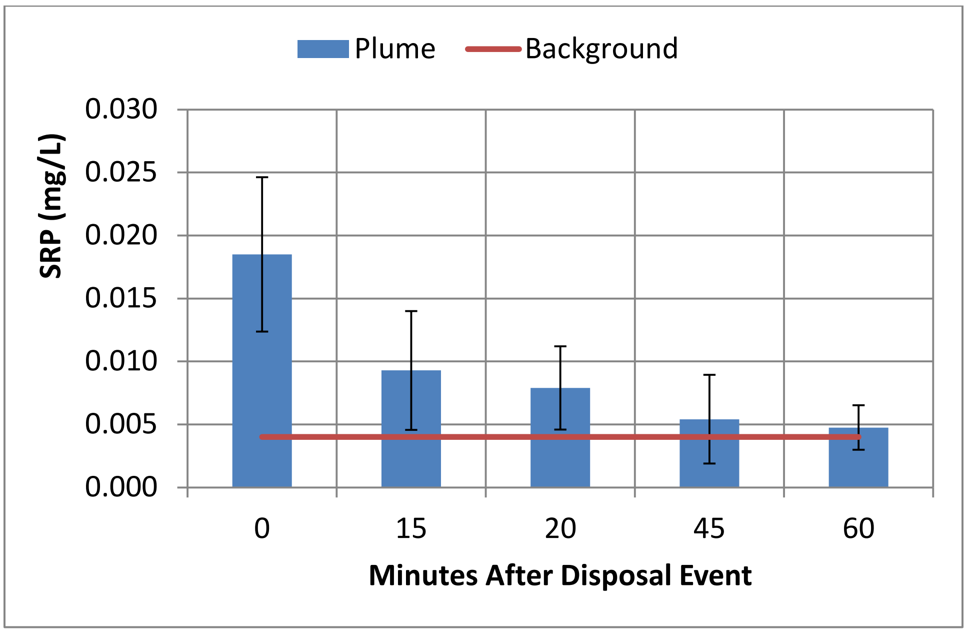
Figure 5-2 Average TP Concentration Measured at the Barge Placement Location over the First Hour after Placement

As shown in Table 5-3 and Figure 5-3, the maximum SRP concentration observed immediately after placement was 0.023 mg P/L with an average SRP of 0.019 mg P/L. Within an hour, average SRP concentrations decrease to near background levels. The average concentration after an hour was 0.005 mg P/L, while the background is 0.004 mg P/L. These SRP levels reached an hour after placement, are insufficient to stimulate a *Microcystis* bloom as they are near background levels. A mass analysis conducted on the plume sampling event on August 21, 2014 shows that the reason for the decline in SRP is due to dispersion, rather than uptake by algae. Table 5-8 shows the tracking of SRP mass (measured concentration times the measured plume area over time) to demonstrate that the mass of SRP in the water column remains constant, meaning dispersive mixing and not phytoplankton uptake is the cause for the decrease in concentration. Also, any phytoplankton in the placement area are likely to already be phosphorus saturated and not likely to take up additional phosphorus to be the cause for the SRP decline observed within 1 hour after barge opening.

Table 5-3 SRP Results From Event Samples

Date	Event Sample (mg P/L) 1 (0min)	2 (~15min)	3 (~30min)	4 (~45min)	5 (~60min)	Time (hours)	Background (mg P/L)
7/22/2013	0.011	0.007	0.006	0.002	0.005	1.00	0.002
7/23/2013	0.023	0.012	0.010	0.006	0.006	1.42	0.003
7/30/2013	0.011	0.007	0.005	0.006	0.004	1.35	0.006
8/19/2013	0.021	0.008	0.007	0.003	0.002	1.02	0.002
8/20/2013	0.023	0.004	0.006	0.004	0.004	1.00	0.006
8/21/2013	0.023	0.017	0.014	0.012	0.007	0.75	0.003
Average	**0.019**	**0.009**	**0.008**	**0.005**	**0.005**	**1.1**	**0.004**

Key:
mg P/L = milligrams of phosphorus per liter



Note: The standard deviation of the five events sampled is shown on each bar. The red line represents the background SRP concentration in the area outside the placement plume.

Figure 5-3 Average SRP Concentration Measured at the Barge Placement Location over the First Hour after Placement

The area affected by the placement events was tracked specifically on August 21, 2014. The progression of the shape and size of the plume is shown in Figure 5-4 below. The outline of the plume was mapped five times by following the edge of the plume with the boat. The trackline of each survey is shown in a different color. At the end of each mapping survey a water sample was collected at the center of the most visible part of the plume (shown on the map as a large circle), which was always on the western edge of the plume as there was a light southwest wind that day. Weather conditions on this day were very calm and the plume drifted to the northeast, and the visible area increased from 6,500 m^2 to 18,300 m^2 over the first hour after placement. This plume was still well within the placement area, so most of the decrease of suspended solids and phosphorus noted above was via settling to the sediment bed rather than by horizontal mixing. Dissolved phosphorus concentrations decreased primarily due to dispersion rather than adsorption as is evidenced by a calculation of the SRP mass increase above background in section 5.2.2.

Regular Fixed Station Sampling

Table 5-4 shows the individual and average concentrations of integrated water samples collected at the mouth of the Maumee River, RA-1 (Ref #1), the placement site, and RA-2. These stations are shown on the map in Figure 3-2. Background P, TSS, and chlorophyll-a concentrations are represented by RA-1 and RA-2. These stations are located 4 miles closer to the Maumee River mouth (RA-1) and 4 miles farther from the river mouth (RA-2) from relative to the placement location and are not influenced by placement activities.

The average TSS concentration was 22.9 mg/L at the mouth of the Maumee River, 10.3 mg/L at RA-1, 7.9 mg/L at the placement site, and 4.4 mg/L at RA-2. TSS is decreased in a gradient from the MR station out to RA-2. The samples collected during placement activities (July 22 to August 21) and samples collected before and after placement (June 25 and October 1) show the same trend in TSS concentrations. The only exception is on October 1, when TSS concentrations were slightly higher at the placement site than RA-1, but still lower than at the mouth of the Maumee River. Based on these grab samples there is no noticeable impact of placement activities on TSS concentrations at the PA station, which is located within the placement area. TSS concentrations at the placement site are consistent with background conditions and follow a gradient of decreasing TSS from the mouth of the Maumee River out to the open waters of Western Lake Erie. Standard deviations are also relatively low, indicating a relatively stable condition at each station. Further evidence is presented below based on event based samples and modeling results.

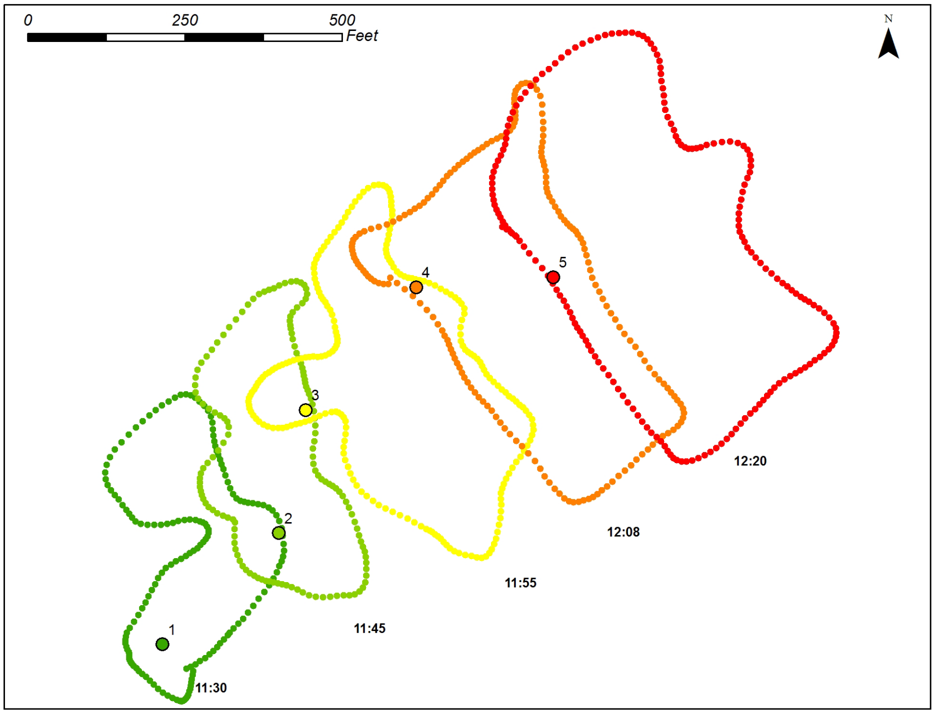


Figure 5-4 Trackline Outline of Placement Area Plume (August 21, 2013)

Table 5-4 Integrated Water Column Results for Fixed Stations

Date	Total Phosphorus (mg-P/L)				TSS (mg/L)				Chl-a (ug/L)			
	MR	RA-1	PA	RA-2	MR	RA-1	PA	RA-2	MR	RA-1	PA	RA-2
6/24/2013	0.083	0.031	0.024	0.022	18.1	2.1	2.5	2.3	82.8	1.4	2.0	8.5
7/22/2013	0.181	0.053	0.035	0.015	17.7	6.7	6.5	1.6	20.1	21.6	11.0	4.1
7/23/2013	0.175	0.091	0.032	0.015	17.1	6.4	4.6	0.9	9.6	17.7	5.4	2.1
7/30/2013	0.132	0.040	0.026	0.011	19.4	4.0	4.3	6.9	19.0	12.6	16.6	2.8
8/19/2013	0.138	0.045	0.028	0.028	19.6	11.9	6.2	7.6	69.4	55.2	23.6	53.3
8/20/2013	0.168	0.081	0.032	0.024	21.6	18.5	9.2	7.3	94.7	51.6	19.9	17.6
8/21/2013	0.119	0.061	0.039	0.032	25.8	13.8	8.0	6.4	58.2	28.4	17.4	16.7
10/1/2013	0.160	0.066	0.071	0.021	44.0	19.2	21.7	1.9	69.5	48.8	54.0	2.9
Average	**0.144**	**0.058**	**0.036**	**0.021**	**22.9**	**10.3**	**7.9**	**4.4**	**52.9**	**29.7**	**18.7**	**13.5**
Std. dev.	**0.033**	**0.020**	**0.015**	**0.007**	**9.0**	**6.5**	**6.0**	**2.9**	**32.3**	**20.0**	**16.0**	**17.2**

Average TP concentrations are 0.144 mg P/L at the mouth of the Maumee River, 0.058 mg P/L at RA-1, 0.036 mg P/L at the placement site, and 0.021 at RA-2. These results follow a similar pattern as TSS concentrations; a decreasing gradient from the mouth of the Maumee River out to the open waters of Western Lake Erie.

Average chlorophyll concentrations are 53 micrograms per liter (µg/L) at the mouth of the Maumee River, 30 µg/L at RA-1, 19 µg/L at the placement site, and 14 µg/L at RA-2. These results follow a similar pattern as TSS concentrations; a decreasing gradient from the mouth of the Maumee River out to the open waters of Western Lake Erie.

Sediment Samples

A summary of the sediment data collected (by Ponar dredge) at the placement area, RA-1, and RA-2 are presented in Table 5-5 for the June (pre-placement season) and October (post-placement season) sampling events.

Table 5-5 Summary of Ponar Samples

Event	Location Units	Moisture Content (%)	Organic Matter (%)	Estimated Wet Density (g/cm^3)	Estimated Dry Density (g/cm^3)	Estimated Porosity (%)	Total P (mg/g)
June	Placement Area	55.2	6.3	1.4	0.6	75.9	0.98
June	RA-1	60.1	5.7	1.3	0.5	79.6	0.75
June	RA-2	57.5	5.1	1.3	0.6	77.7	0.68
October	Placement Area	60.2	7.7	1.3	0.5	79.4	0.93
October	RA-1	49.7	4.8	1.4	0.7	71.7	0.79
October	RA-2	50.8	4.4	1.4	0.7	72.8	0.60

Key:
g/cm^3 = grams per cubic centimeter
mg/g = milligrams per gram
RA = reference area

Surface sediment samples collected at the placement area and reference areas show that TP content was somewhat elevated at the placement area, although there was significant variability in surface sediments collected at RA-1 in October (see Table 5-6). The elevated TP concentrations in the sediment did not translate into higher phosphorus release from the sediments in the core incubation experiments (see Figure 4-40). This suggests that surface TP concentration is not a direct indicator of the potential for sediment phosphorus to be release into the water column. The placement sediments also had a higher organic matter content. Both of these results are consistent with the placement area sediments, which are composed of finer particle sizes.

Table 5-6 Summary of Maximum, Average, and Standard Deviation of Sediment Total Phosphorus from Ponar Samples

Phosphorus Concentration (mg/g)	June			October		
Location	Max	Avg	Stdev	Max	Avg	Stdev
Placement Area	1.09	0.98	0.10	1.00	0.93	0.08
RA-1	0.82	0.75	0.08	1.24	0.79	0.41
RA-2	0.74	0.68	0.08	0.61	0.60	0.01

Key:
mg/g = milligrams per gram

The sediment cores collected before and after the dredging season at these sites are consistent with the surface grab results (see Table 5-7). However, these sectioned cores show the typical decrease in moisture content and porosity with depth that occurs due to consolidation processes. This is evident even in the placement core profiles, indicating that the sediments in the placement area have been in place for enough time for this consolidation to have occurred. The placement area cores definitely have lower sand content and higher clay/silt content, which is consistent with the TP and organic matter results for bottom sediments in these areas.

Model Results

The calibrated Western Lake Erie Ecosystem Model, discussed in Section 4.2 was used to assess the potential impact of open-lake placement on ambient TSS and SRP concentrations. A more detailed discussion of the model application results presented here can be found in Section 5.5.1. Model results provided in Figures 5-5 and 5-6 show the difference in daily average TSS concentration between baseline and model scenarios presented previously at the two model cells within the placement area where material was placed in 2013 (labeled as cell A and B). The baseline scenario includes all open-lake placement activities during 2013 where 2.5% residual solids are available from each placement event for transport within the water column. The orange line represents the decrease in TSS that would occur with no open-lake placement activity occurring at the placement site. The blue line represents the increase in TSS that would occur if the amount of residual material in the water column were to double. The green line represents the baseline condition if the Maumee River TSS concentration was 0 mg/L (e.g., flow, but no load). This scenario represents the strong influence the Maumee River plays in influencing ambient TSS concentrations at this location by showing what TSS concentrations would be at the placement site with no sediment load from the Maumee River.

Figure 5-5 and Figure 5-6 show the difference in TSS concentrations, between baseline and scenario runs at the two placement locations where material was placed in 2013. The maximum modeled difference between the baseline and scenario without placement activities (orange line) is less than 1 mg/L, meaning that on a daily average basis placement activities do not add a significant amount of TSS to the water column. If the amount of placement load were to double (blue line), the model predicts less than a 1 mg/L increase in TSS above background in the placement model cells. On the other hand, when the Maumee River load is removed from the simulation (green line), TSS concentrations decline by up to 4 mg/L or more during some periods, which shows the strong influence the Maumee River is having at this location. As presented earlier in the results section, residual suspended sediment that remains in the water column immediately after a placement event settles very rapidly and is only transported up to approximately 1,000 feet during the first hour before approaching background levels. The model simulation here reinforces the conclusion that residual suspended solids do not raise the ambient suspended solids concentrations significantly and the Maumee River is a much larger contributor.

Table 5-7 Summary of Sediment Core Sections at Placement and Reference Areas

		Top Section (cm)	Bottom Section (cm)	Moisture Content (%)	Organic Matter (%)	Estimated Wet Density	Estimated Dry Density (g/cm3)	Estimated Porosity (%)	Sand (%)	Silt (%)	Clay (%)	Specific Gravity	Total P (mg/g)
June	PA	0	5	55.1	7.2	1.3	0.6	75.9	8.7	54.2	37.1	2.4	0.9
	PA	5	10	48.1	7.1	1.4	0.8	70.4	8.1	49.2	42.6	2.4	1.0
	PA	10	15	45.8	7.3	1.4	0.8	68.5	7.9	47.3	44.8	2.4	1.0
	PA	>15		45.7	7.5	1.4	0.8	68.4	6.9	45.8	47.2	2.8	1.0
	RA-1	0	5	60.6	5.0	1.3	0.5	79.9	46.8	37.7	15.5	2.4	0.7
	RA-1	5	10	37.1	2.6	1.6	1.0	60.7	50.2	36.9	13.0	2.4	0.8
	RA-1	10	15	32.3	2.6	1.7	1.2	55.4	70.2	19.6	10.1	2.3	0.6
	RA-1	>15		29.0	10.4	1.6	1.3	49.5	51.4	26.2	22.4	2.6	0.5
	RA-2	0	5	50.0	4.1	1.4	0.7	72.3	30.2	45.6	24.2	1.7	0.6
	RA-2	5	10	47.0	3.5	1.5	0.8	69.9	39.1	47.0	14.0	1.9	0.5
	RA-2	10	15	33.7	2.7	1.7	1.1	57.1	64.6	19.3	16.1	2.3	0.5
	RA-2	>15		31.2	2.0	1.7	1.2	54.4	69.6	16.6	13.8	2.6	0.4
Oct	PA	0	5	60.0	7.7	1.3	0.5	79.4	11.7	71.2	17.1	2.5	0.9
	PA	5	10	52.8	7.7	1.4	0.7	74.1	5.8	72.6	21.5	2.3	0.9
	PA	10	15	49.3	7.6	1.4	0.7	71.6	8.0	68.3	23.6	2.2	0.9
	PA	>15		48.6	7.8	1.4	0.8	70.7	7.1	65.6	27.2	2.3	1.0
	RA-1	0	5	59.3	5.6	1.3	0.5	79.0	17.3	64.0	18.7	2.5	0.7
	RA-1	5	10	40.6	4.4	1.5	0.9	63.8	23.4	53.2	23.4	2.6	0.6
	RA-1	10	15	25.9	2.7	1.8	1.4	46.4	56.0	27.4	16.6	2.4	0.4
	RA-1	>15											
	RA-2	0	5	48.3	3.8	1.4	0.8	70.9	51.5	33.4	15.1	3.6	0.6
	RA-2	5	10	50.0	4.5	1.4	0.7	72.2	21.5	64.0	14.6	2.3	0.7
	RA-2	10	15	53.2	5.9	1.4	0.7	74.2	5.5	62.1	32.3	2.6	0.8
	RA-2	>15		47.3	4.6	1.5	0.8	69.4	21.4	67.2	11.4	2.8	0.6

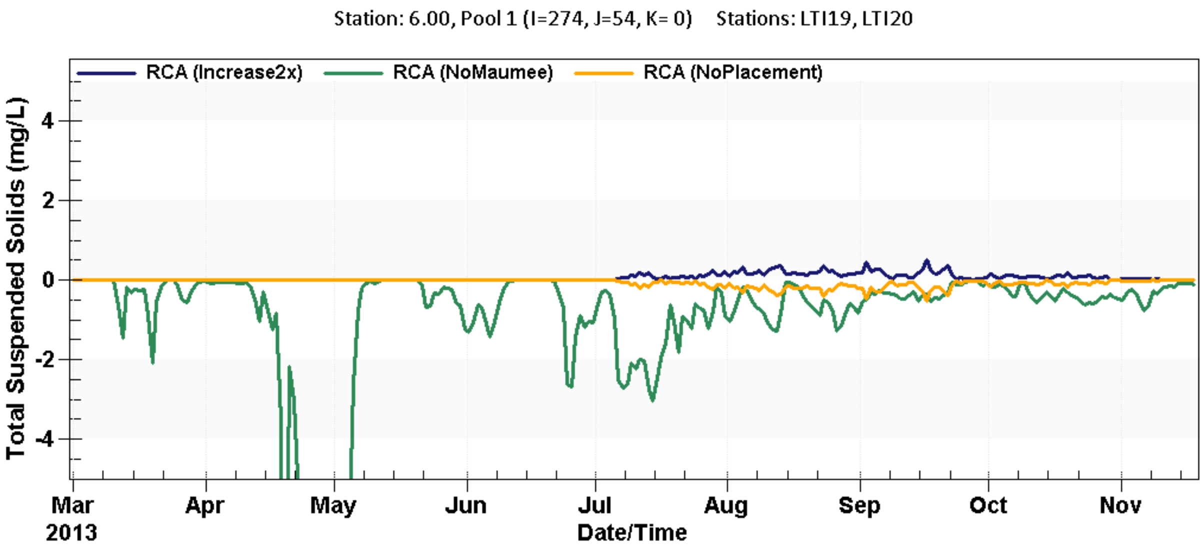


Figure 5-5 Difference in TSS between Baseline and Scenario Runs at Placement Cell "A"

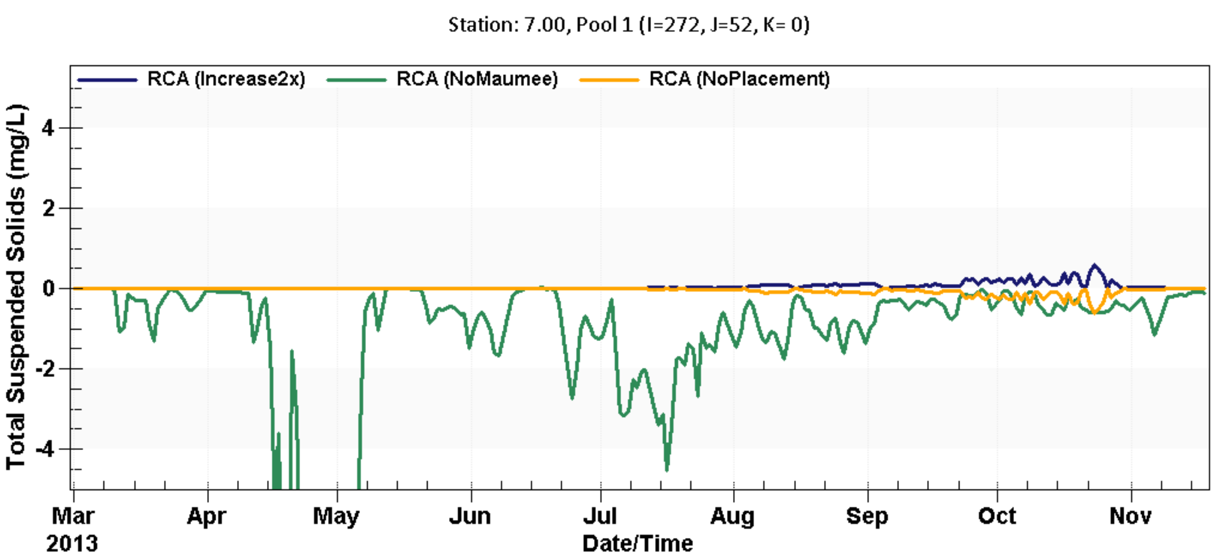


Figure 5-6 Difference in TSS between Baseline and Scenario Runs at Placement Cell "B"

Figure 5-7 and Figure 5-8 show the difference in dissolved orthophosphate (DPO_4) concentrations, which is equivalent to measured SRP, between baseline and scenario runs at the two placement locations where material was placed in 2013. The maximum modeled difference between the baseline and scenario without placement activities (orange line) is 0.0015 mg-P/L (1.5 µg-P/L), meaning that on a daily average basis placement activities do not add a significant amount of dissolved orthophosphate to the water column. If the amount of placement load were to double (blue line), the model predicts less than a 0.0015 mg-P/L (1.5 µg-P/L) increase in dissolved orthophosphate above background in the placement model cells. This concentration difference is not sufficient to contribute to harmful algal blooms, which require much higher DP concentrations to grow to nuisance levels. On the other hand, when the Maumee River load is removed from the simulation (green line), dissolved orthophosphate concentrations decline by10 µg/L or more during some periods, which shows the strong influence the Maumee River is having at this location.

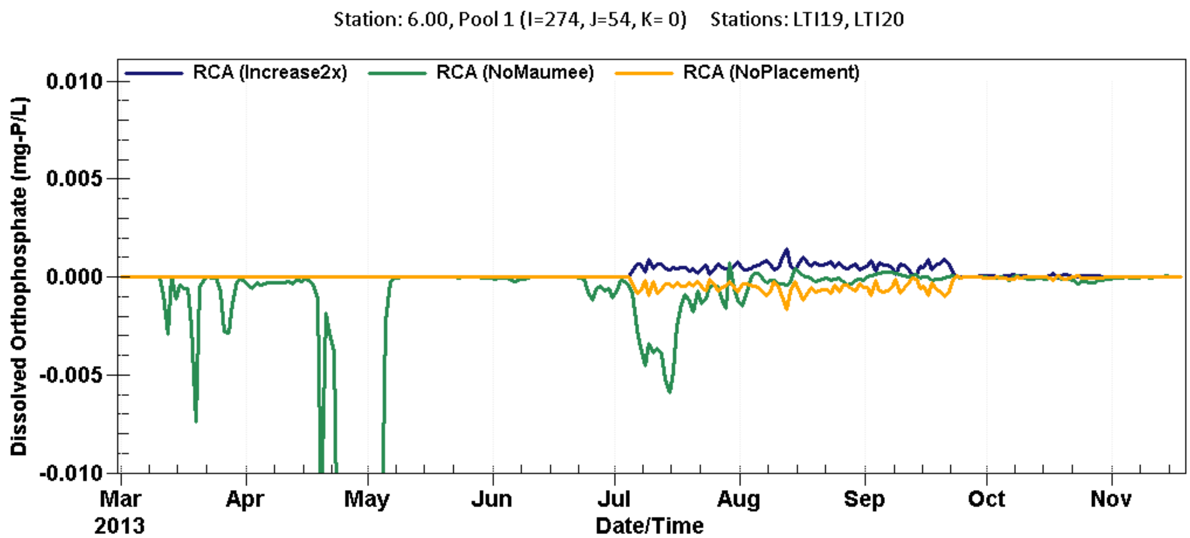


Figure 5-7 Difference in Dissolved Orthophosphate Between Baseline and Scenarios at Placement Cell "A"

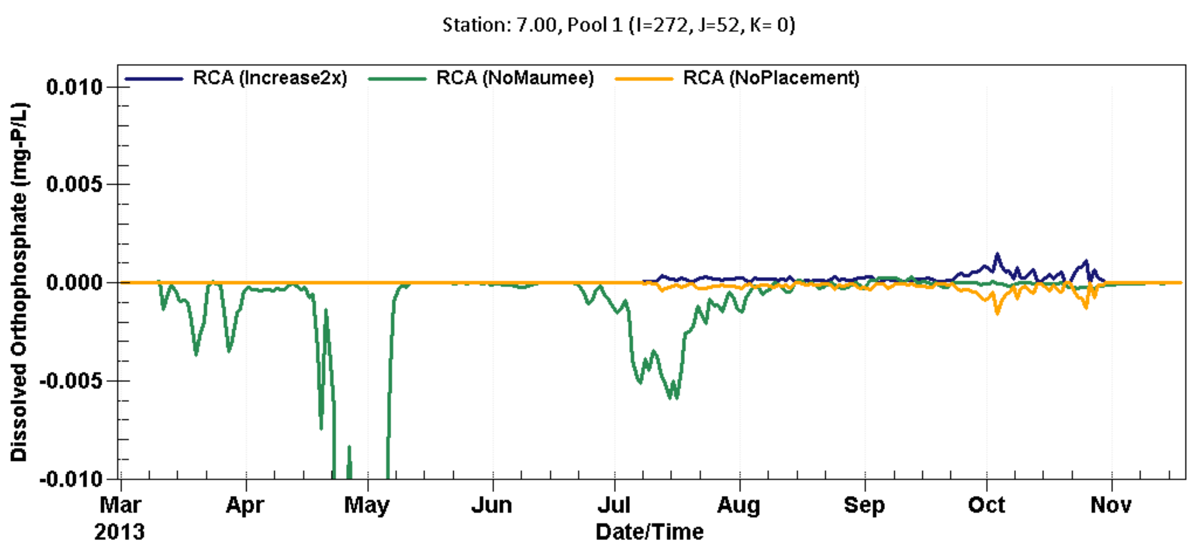


Figure 5-8 Difference in Dissolved Orthophosphate Between Baseline and Scenarios at Placement Cell "B"

5.2.2 Mass

The mass of solids, TP, and DRP that are added to the water column as a result of open-lake placement is presented in this section. Data are presented from event samples and an analysis of dredge records to estimate the total mass contributed to the water column.

Event Samples

Table 5-8 presents data from the August 21, 2013, event and the estimated area, volume, and mass of TSS, TP, and SRP within the plume over time. The sampling during this event focused specifically on mapping the footprint of the plume and the concentration in the plume, so that the total mass could later be calculated. At 11:27 a.m. (mapped at 11:30 a.m. the footprint of the plume was 6,500 m^2. Fifty minutes later the plume spread out to 18,200 m^2. During that time the mass of TSS decreased by 84% from an estimated 16,153 kg to 2,562 kg, TP mass decreased by 69% from 20.3 kg to 6.4 kg, and SRP mass decreased by 12% from 0.73 kg to 0.65 kg. The amount of material directly attributed to placement activities can be calculated by subtracting the background mass from the mass at the end of the fifth sample (12:12 p.m.). The background sample was collected within the placement area (station 26), but approximately 0.5 miles to the south. The last column in the Table 5-8 shows the mass of TSS, TP, and SRP remaining in the water column after approximately 45 minutes on this date. The mass of TSS, TP, and SRP that was in the water column above background levels was 1,833 kg (TSS), 2.8 kg (TP), and 0.38 kg (SRP), respectively. This represents a decrease of 89%, 85%, and 49% in open-lake placement mass between the first sample and calculated increase above background for the last sample for TSS, TP, and SRP, respectively. This pattern of relative residual mass in the water column following a placement event can be placed in context by comparing the full placement season's residual mass with other external and internal sources of mass to the WLEB water column, as presented below.

Table 5-8 Mass of TSS, TP, and SRP from August 21, 2013 Event

Sample Time	Units	11:27	11:38	11:47	12:00	12:12	Background	Difference
TSS	mg/L	497	285	124	26	28	8.0	
TP	mg/L	0.623	0.402	0.197	0.076	0.070	0.039	
SRP	mg/L	0.023	0.017	0.014	0.012	0.007	0.003	
Plume Area	m2	6,500	7,100	11,300	13,200	18,300	18,300	
Depth	m	5	5	5	5	5	5	
Volume	m3	32,500	35,500	56,500	66,000	91,500	91,500	
Mass (TSS)	kg	16,153	10,118	7,006	1,716	2,562	729	1,833
Mass (TP)	kg	20.23	14.26	11.11	5.02	6.37	3.57	2.80
Mass (SRP)	kg	0.73	0.61	0.77	0.79	0.65	0.27	0.38

*Difference is calculated by subtracting the background from the 12:12 sample

Total Solids and Phosphorus Mass

Daily logs of placement activities from the USACE estimated that 1,019,941 cubic yards of dredged material was placed in 2013 during 675 release events. Bulk density estimates of dredged material from this study average 0.6 grams per cubic centimeter. This would convert the total dredged volume to a mass of 467,880,372 kg. Estimates from event monitoring data collected during this project and literature show that approximately 2.5% of the material was released into the water column. The remaining 97.5% reached the bottom within minutes after the barge doors were opened, resulting in 11,697,009 kg of material. Samples of dredged material from this project measured an average TP concentration of 0.9 mg /g dry weight. This equals a total of 10,527 kg of TP that were released into the water column in 2013. Event monitoring data presented above from August 21 event sampling show that within an hour 89% of the TP settles to the bottom. This leaves a total of 1,158 kg of TP in the water column after an hour for all of 2013.

Of the plume event sampling dates, August 21, 2013 represented the most thorough sampling of the center of the plume and residual concentrations. Soluble reactive phosphorus SRP data from that event showed that the single release contributed an additional 0.75 kg of SRP to the water column. Multiplying this by 675 placement events equals 473 kg/yr.

Table 5-9 presents a summary of the estimated diffusive flux of phosphorus from the sediments to the water column based on the flux measurements conducted as part of this study at the reference and placement areas (see Section 4.1.5). The results show that the average aerobic and anaerobic diffusive flux rates were higher at the reference areas than at the placement area. The averages represent the average of the summer and fall flux incubations. The results from the two reference areas were averaged into a single reference area average. Due to the shallow nature of western Lake Erie, it is assumed that the overlying water above the sediment bed is always aerobic (having dissolved oxygen concentrations above 0 mg/L). This assumption is not critical for comparing the total diffusive flux from the placement and reference areas because the anaerobic flux rates are still higher for the reference areas versus the placement area. The reference areas are assumed to represent the background release rate across the WLEB, while the placement area is assumed to be one square mile. The 0.27 metric tons of phosphorus contributed by diffusion from the sediments in the placement area is only a very small fraction of the amount contributed by areas in the rest of the WLEB. In addition sediments in the placement area contribute less phosphorus per unit area than background areas, meaning more phosphorus would be added to the water column if the placement area were not used.

Table 5-9 Estimated Diffusive Flux of SRP from Placement and Reference Areas

Parameter	Reference Area	Placement Area	Units
Aerobic Flux Rate	0.55	0.29	$mg/m^2/d$
Anaerobic Flux Rate	11.91	7.94	$mg/m^2/d$
Representative Area	3,107,986,000	2,589,988	m^2
Aerobic mass per day	1,694	0.74	kg/d
Aerobic mass per year	618	0.27	metric tons

Key:
$g/m^2/d$ = grams per square meter per day
kg/d = kilograms per day
m^2 = square meters

5.2.3 Mass Balance

The Tables 5-10 and 5-11 present the 2013 loads of TP, SRP, and SS from external and internal sources on a percent of the total load (see Table 5-10) and on a mass basis (see Table 5-11). The loads were compiled during the model development process and represent a summary of the model inputs. The Maumee River is the dominant source of TP to western Lake Erie and is a major component of the SRP and TSS loads. Estimated contributions from the placement area represent a fraction of one percentage point of the total load. Loads of SRP to western Lake Erie are of particular concern due to its ability to stimulate algal growth. Placement activities contribute 0.02% of the total annual SRP load to western Lake Erie. Further, contribution of SRP arising from placement is less than 1% of the annual internal load and external loads from the Maumee and Detroit rivers.

Table 5-10 Mass Balance (metric tons) of External and Internal TP, SRP, and SS Loads for 2013

Source	TP	SRP	SS
Detroit River	1,792	896	1,493,610
Maumee River	2,076	450	837,808
Other	303	124	69,623
Placement	11	0.5	11,697
Internal Flux	618	618	
Total	**4,799**	**2,089**	**2,412,738**

Key:
SRP = soluble reactive phosphorus
SS = suspended solids
TP = total phosphorus

Table 5-11 Mass Balance (%) of External and Internal TP, SRP, and SS Loads for 2013

Source	TP	SRP	SS
Detroit	37%	43%	62%
Maumee	43%	22%	35%
Other	6%	6%	3%
Placement	0.22%	0.02%	0.48%
Internal Flux	13%	30%	
Total	**100%**	**100%**	**100%**

Key:
SRP = soluble reactive phosphorus
SS = suspended solids
TP = total phosphorus

5.3 Objective Group 2 - Fate and Transport of Placement Material

The data collected as part of this study along with interpretation of numeric model output reinforce the conceptual model describing the fate and transport of material from open-lake placement activities and how it compares with other loads of solids and phosphorus to western Lake Erie. The two scow barges that were used in 2013 to transport material from the site of active dredging to the open-lake placement site have eight compartments with a capacity of 1,700 cubic yards each. In 2013, 675 placement events occurred between July 5 and October 28, with an average volume of 1,511 cubic yards per scow. The number of placement events per day averaged about six, which would equal about one placement event every four hours. During each placement event the barge navigates to the specified placement location, comes to a complete stop, and opens a series of trap doors that release the dredged material into the lake. It takes approximately 2 minutes to open all the doors and material moves out of the trap doors and down to the sediment bed within seconds. The average draft of the scow is approximately 15 feet, which is approximately 5 feet from the bottom of the lake, meaning that placement material is only falling over an open water distance of approximately 5 feet. The proximity of the bottom of the scow to the bottom of the lake minimizes the exposure of placement material to the water column. The vast majority of sediments in the barge move immediately to the bottom of the lake and do not interact with the water column. Monitoring data collected within minutes of placement events during this study document the average solids and nutrient concentration of the small amount of material remaining in the water column and the rapid decline in concentration with time following the placement event. Estimates from literature and this study show that approximately 2.5% of the material from the placement event is suspended in the water column after 45 minutes. The spatial extent of the plume spreads slowly via advection and diffusion and within an hour is barely noticeable above background conditions. Four short-term sondes located within the active placement area occasionally show the small and temporary rise in turbidity associated with a placement event as the residual plume passes the sonde location.

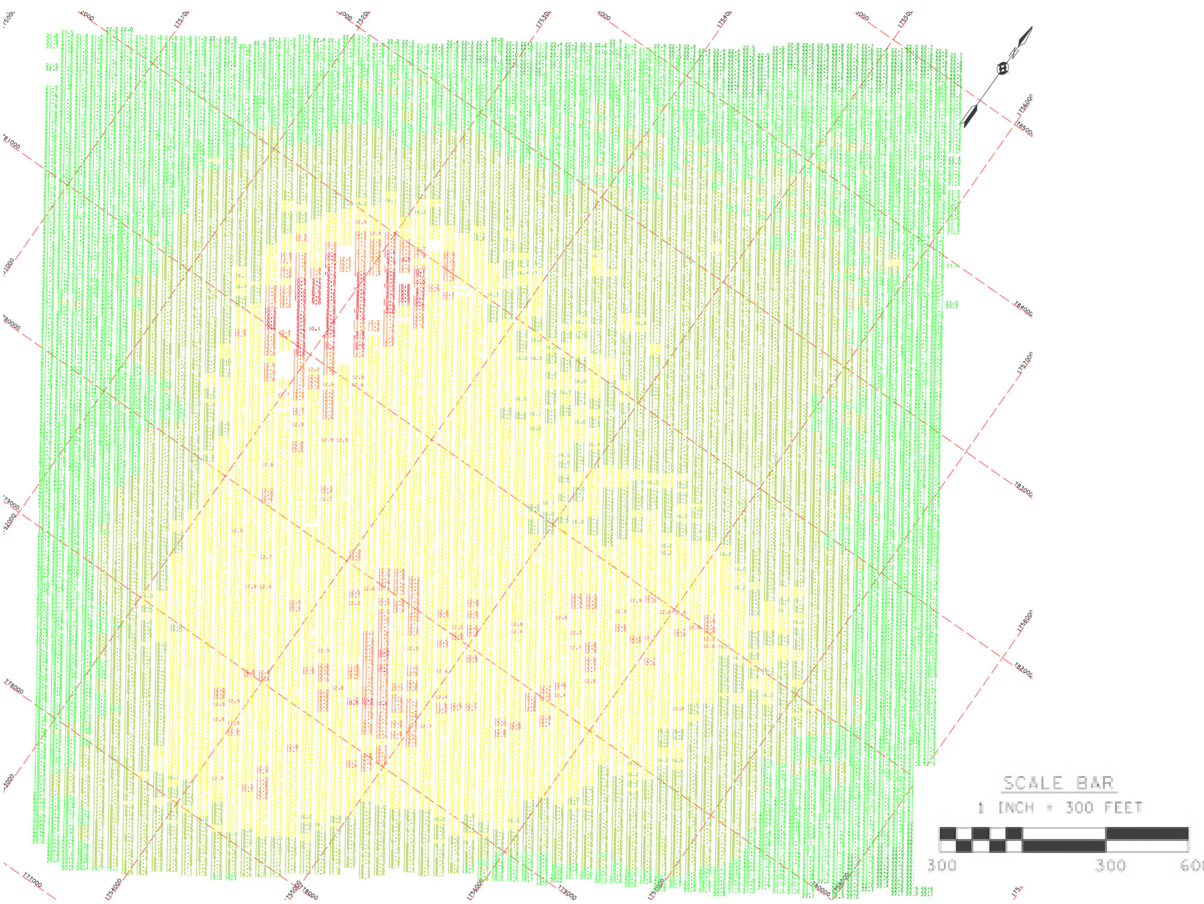
5.3.1 Short-term Stability

On a short-term basis the area impacted by open-lake placement activities would be equal to the area of the plume. On August 21, 2013, the maximum estimated area of the plume was 18,300 m^3 or 0.007 square miles, which is less than 1% of the one-square-mile-area currently used for placement. For comparison purposes, the one-square-mile-area used for placement is 0.06% of the 1,700-square-mile-area of western Lake Erie.

The model estimates the fate and transport of the suspended material as shown on Figures 5-5 and 5-6 and shows that ambient solids concentrations associated with placement events do not increase more than 1 mg/L above background on a daily average basis over the entire placement area. Over the entire placement area on a daily basis during placement, DPO_4 concentrations (equivalent measure to SRP) in the water column do not increase more than 0.0015 mg-P/L (1.5 ug-P/L) above background (see Figures 5-7 and 5-8). The impact outside the placement area is even less.

5.3.2 Long-term Stability

The sediment at the bottom of the lake at the placement site is comprised of dredged material from the navigation channel. Compared with ambient sediment at the reference area it contains slightly less sand and more silt and clay fractions. Long-term stability of the sediment can best be judged by the amount of material still remaining within the placement site. If all of the placement material was transported over time out of the placement area there would be no visible change in bathymetry (i.e., mound) at the placement site above the background depth outside of the disposal area. However, bathymetric studies by the USACE show clear evidence of a permanent change in bathymetry in places where material has been disposed in previous years. Figure 5-9 shows the bathymetry of the active placement area. Each color change represents a 2-foot contour. The dark green color represents depths greater than 22 feet, while the red represents depths less than 10 feet. This survey was conducted prior to the start of 2013 placement activities.



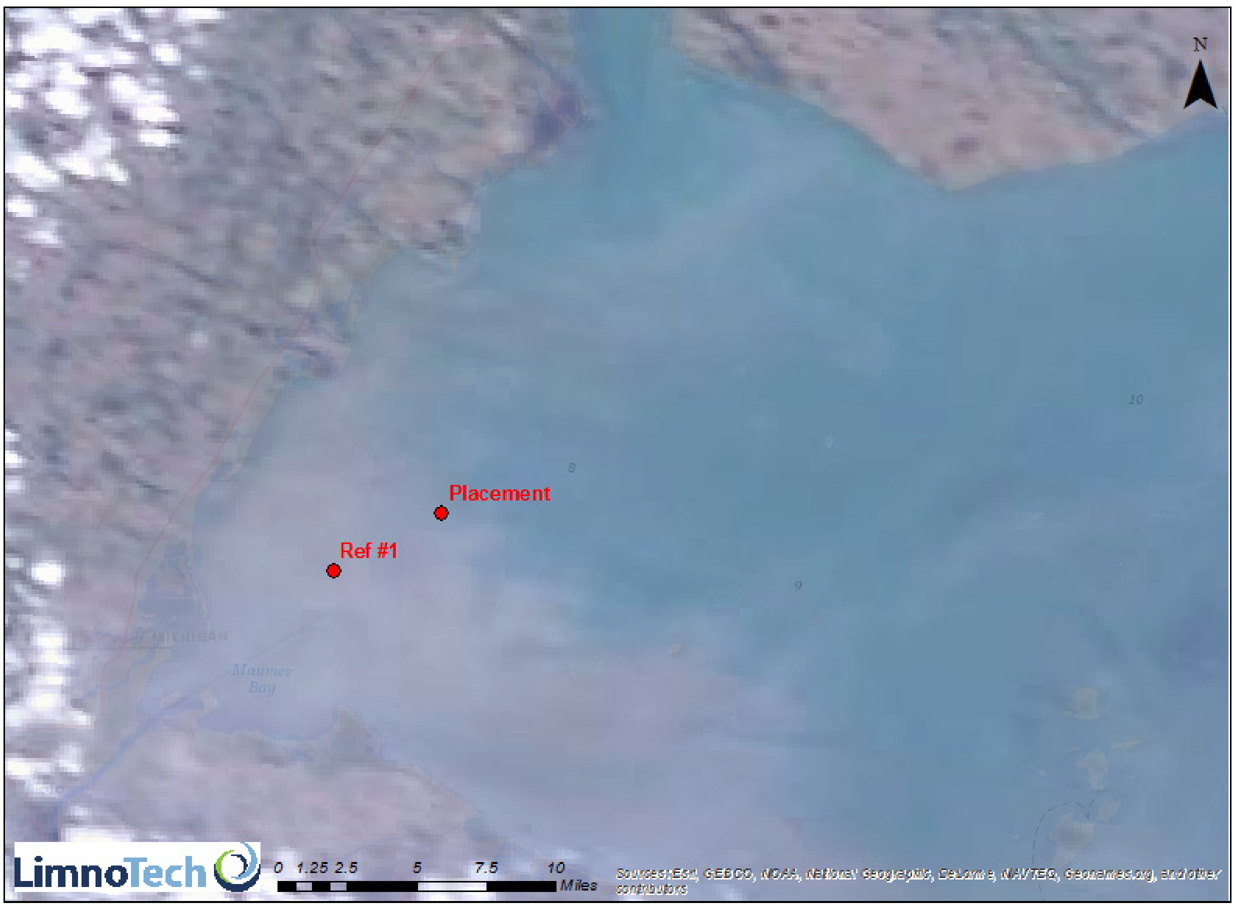
Source: USACE 2013

1. Contours and soundings are U.S. Survey feet referred to low water Datum of 569.2 feet International GLD 1985.
2. Horizontal coordinates are U.S. Survey feet referred to North American Datum 1983/CORSI996.
3. The topographic information depicted on the map represents the results of surveys made on April 23, 2013 and can only be considered as indicating the general condition at that time.
4. This survey was prepared in accordance with the standards outlined in Corps of Engineers Hydrographic Survey Manual EM 1110-2-1003 and Corps of Engineers Control And Topographic Survey Manual EM 1110-1-1005.

Figure 5-9 Map of Bathymetry of Eastern Half of the Placement Area

5.3.3 Resuspension

Resuspension of sediment at the placement area is difficult to estimate independent of resuspension from surrounding reference areas because satellite imagery shows resuspension throughout the entire western basin during wind events (see Figure 5-10). The long-term turbidity sondes deployed at RA-1 and the placement area show similar turbidity spikes associated with an increase in wave height (and wind speed) (see Figure 5-11). The spikes match each other through May 29. In early July turbidity spikes higher at RA-1 compared to the placement site.



Source: MODIS Today http://ge.ssec.wisc.edu/modis-today/

Figure 5-10 MODIS Image on May 19, 2013

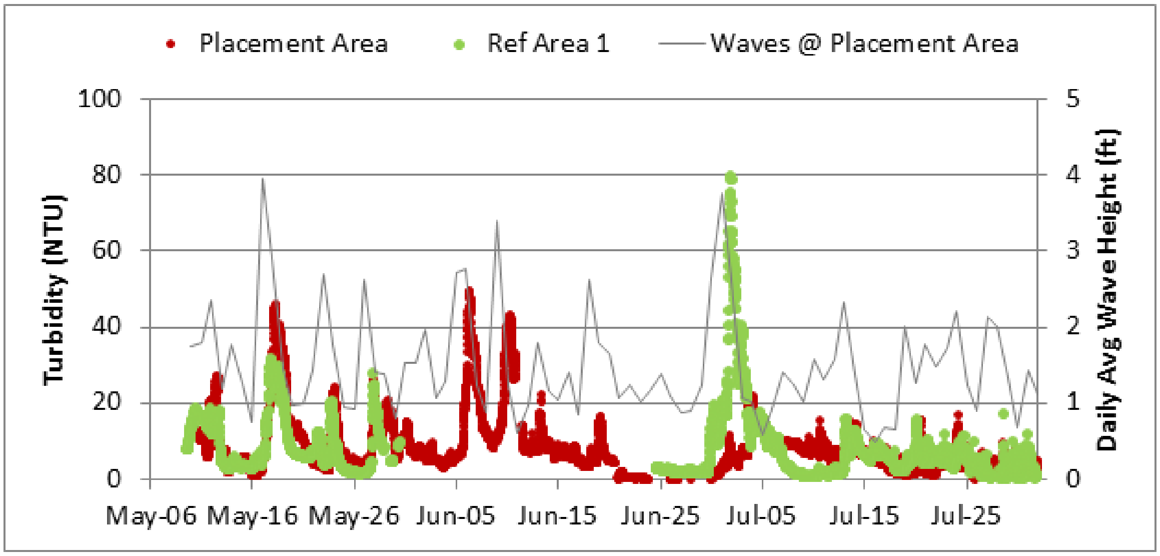


Figure 5-11 Comparison of Turbidity at RA-1 and Placement Area and Daily Average Wave Height Measured at the Placement Area

The spikes in turbidity observed at the placement and reference areas are due to resuspension of material across the shallow areas of western Lake Erie. The MODIS image captured on May 19, 2013 (see Figure 5-10), when turbidity spiked at both the reference and placement areas, shows a plume of resuspended sediment along the entire Ohio shoreline of western Lake Erie. This evidence suggests that the placement area does not contribute any additional material to the WLEB above background.

5.4 Objective Group 3 - Impact on Harmful Algal Blooms

Phytoplankton growth is limited by the availability of key nutrients. The major limiting nutrients in aquatic systems are nitrogen and phosphorus. Past studies have documented that phosphorus is the primary limiting nutrient in western Lake Erie, but nitrogen can be limiting during an already developed algal bloom. Therefore, the primary mechanism for algal blooms in western Lake Erie is additions of significant amounts of phosphorus to the water column. Some forms of phosphorus need to undergo lengthy biologically mediated transformation processes before becoming available for direct uptake by phytoplankton. $DPO_{4,}$ a measure of SRP, is a form of phosphorus that is readily available for uptake and is the form that is well documented to have a direct impact on phytoplankton abundance. A large amount of SRP added to the water column could stimulate algal growth. The results presented in Table 5-8 show a negligible amount of SRP is released into the water column (0.73 kg of SRP) immediately after a placement activity starts. Immediately after a placement event occurs, concentrations of SRP decrease quickly to background levels, primarily from dispersion. As shown on Table 5-3, the concentrations of SRP decrease from an average of 19 µg/L to 5 µg/L within an hour, which is near the background concentration of 4 µg/L. As shown in Table 5-8, the decrease in SRP concentration is due to dilution/dispersion because, while the concentration is decreasing, the mass of SRP in the expanding plume is not decreasing.

The amount of SRP released as part of open-lake placement activities is not enough to stimulate any additional significant growth of phytoplankton within western Lake Erie. Concentrations of chlorophyll and blue green algae biomass at the placement area were not above concentrations measured at RA-1. Concentrations were lower at RA-2.

5.5 Model Application

5.5.1 Scenarios

The following scenarios were run with the model for 2013:

- Baseline – calibrated 2013 model including open-lake placement of dredged material;
- Increase residual percent of placement material that is dispersed in the water column by a factor of two;
- Decrease the percent of placement material that is dispersed in the water column to zero; and
- Set the concentration of all nutrients and solids boundary conditions in the Maumee River to zero.

Scenario 1

The first scenario is the calibrated model simulation, including open-lake dredged material placement for the whole summer. It represents our best understanding of how sediments from placement activities are initially released into the water column and their transport and deposition at the placement site and in neighboring model cells. In this baseline scenario 2.5% of the total solids in each barge is released into the water column (Atkinson 2014). The remainder of the material is assumed to have settled within minutes directly to the sediment bed, based on literature from previous studies and our own barge plume monitoring. This scenario is designated as RCA (Baseline) in the model plots (see Figures 5-12 through 5-29).

Scenario 2

The second scenario takes the baseline placement load and doubles the amount of residual suspended solids that are released into the water column. This scenario is meant to demonstrate the sensitivity of the model to this parameter. It is designated as RCA (Increase2x) in the model plots (see Figures 5-12 through 5-29).

Scenario 3

The third scenario sets the concentration of all nutrient and solids in the Maumee River (flow remains the same as the baseline scenario) to zero to demonstrate the improvement in water quality that would occur without this large nutrient and solids load. This scenario is designated as RCA (NoMaumee) in the model plots (see Figures 5-12 through 5-29).

Scenario 4

The fourth scenario assumes that none of the placement material is released into the water column. This scenario represents the expected water quality that would occur in the absence of any open-lake placement. It is designated as RCA (No-Placement) in the model plots (see Figures 5-12 through 5-29).

The following graphs show the daily depth-averaged suspended solids concentrations, DPO_4 (as a measure of SRP), and chlorophyll-a for all of the scenarios. Graphs are shown for two model cells in the placement area, and for the individual model cells containing RA-1, RA-2, the mouth of the Maumee River, and the Toledo water intake crib. Placement location "A" is where material was placed between July 5 and September 22 and placement location "B" is where material was placed between September 23 and October 28. For all of the figures the light blue, blue and green lines are either on top of each other or very close together such that the individual lines are not distinct from each other. This demonstrates that the small or no impact that removing or doubling the placement area load has on the baseline concentrations at these locations. The scenario represented by the orange line (no Maumee River load), however, can be significantly different than the other scenario and baseline results, highlight the strong influence the Maumee River can have at these locations.

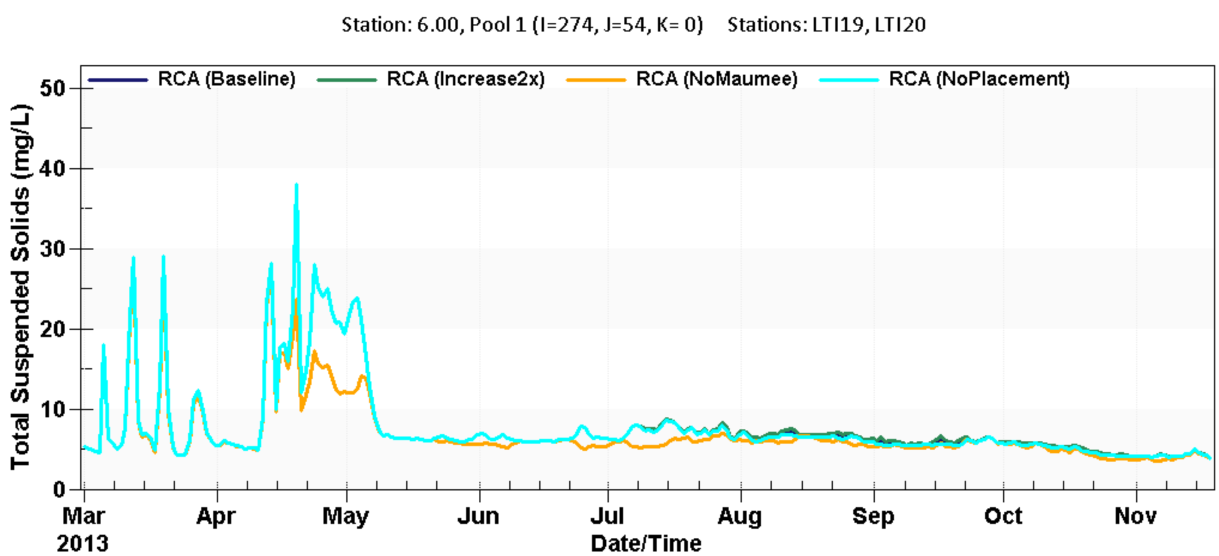


Figure 5-12 TSS Concentration at Placement Location "A" for Baseline, Double, Zero Placement Suspended Solids, and No Maumee River Load Scenarios

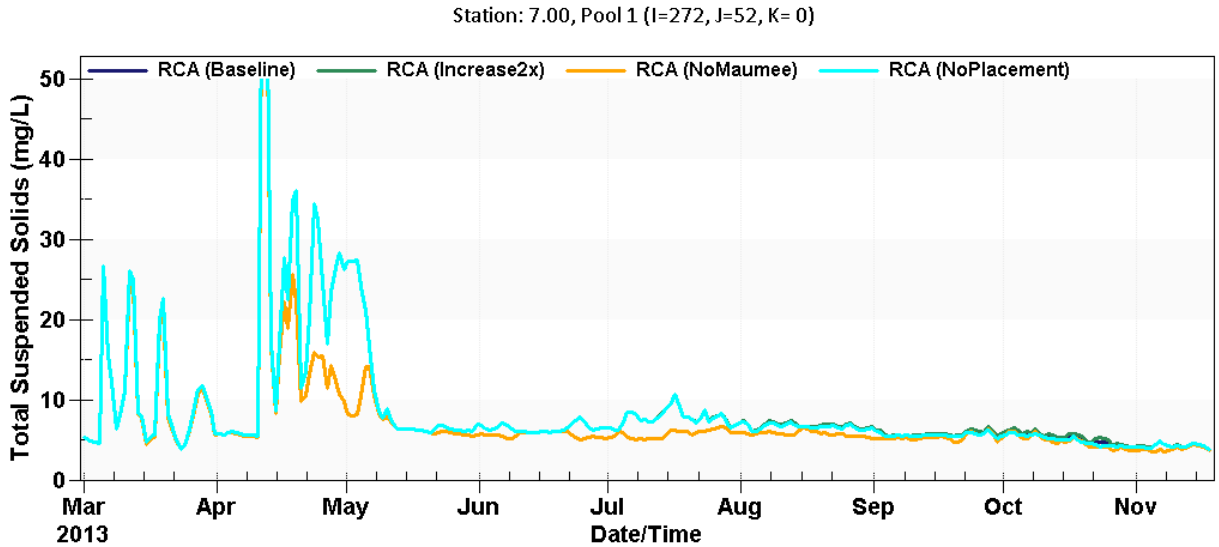


Figure 5-13 TSS Concentration at Placement Location "B" from Baseline, Double, and Zero Placement Suspended Solids Scenarios

The two figures above show no difference in TSS concentration between the baseline, increasing placement load by two times, or eliminating the placement load entirely at the placement site. All three of these lines are on top of each other. The orange line shows how much lower TSS concentrations would be without any solids load from the Maumee River.

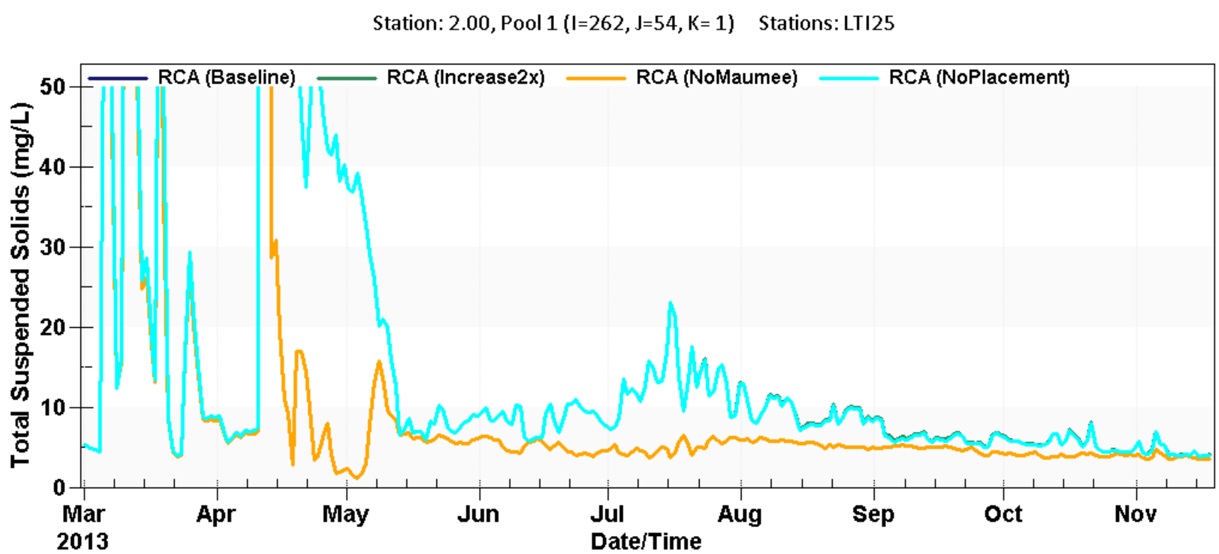


Figure 5-14 TSS Concentration at RA-1 for Baseline, Double, Zero Placement Suspended Solids, and No Maumee River Scenarios

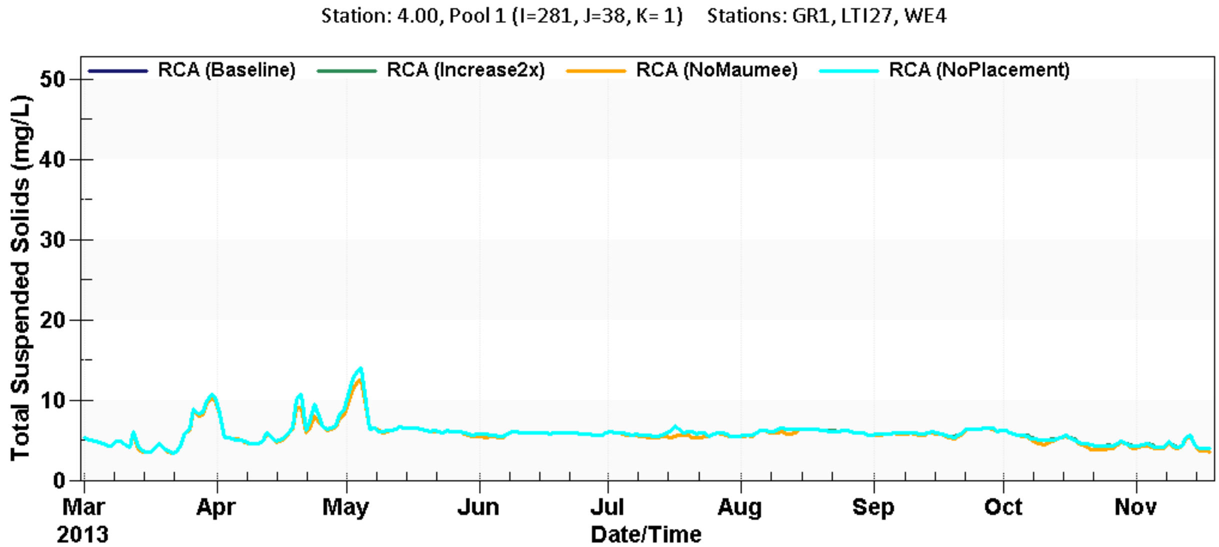


Figure 5-15 TSS Concentration at RA-2 for Baseline, Double, Zero Placement Suspended Solids, and No Maumee River Scenario

The two figures above show no difference in TSS concentration between the baseline, increasing placement load by two times, or eliminating the placement load entirely at RA-1 and RA-2. All three of these lines are on top of each other. The orange line shows how much lower TSS concentrations would be at this location without any solids load from the Maumee River. At RA-1 there is a significant difference, but at RA-2 there is not a significant difference as it is much further from the mouth of the Maumee River.

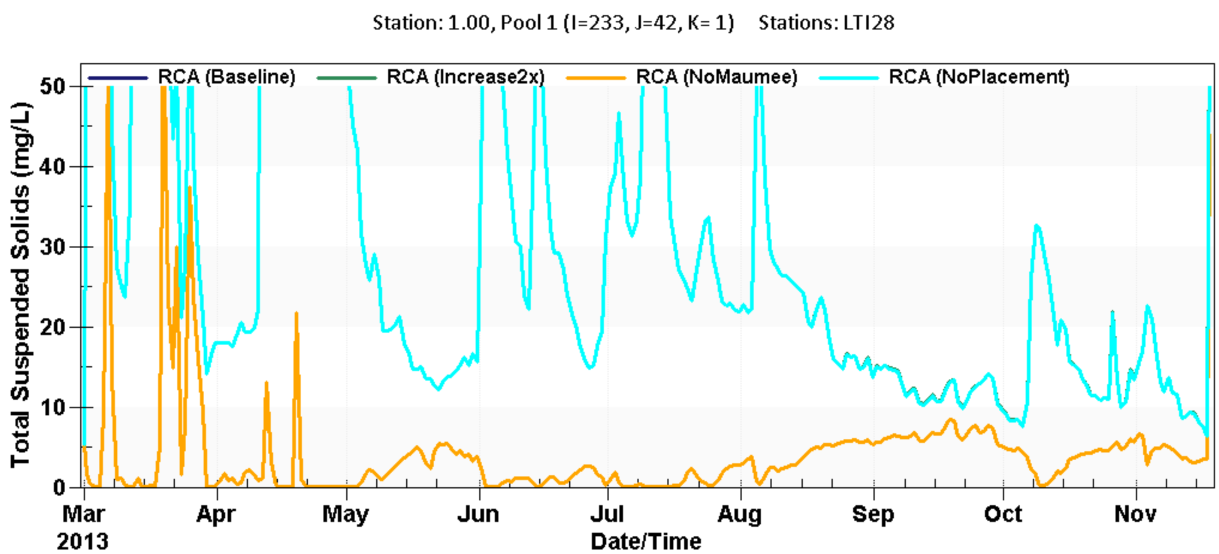


Figure 5-16 TSS Concentration at Maumee River Mouth for Baseline, Double, Zero Placement Suspended Solids, and No Maumee River Scenarios

The figure above shows no difference in TSS concentration between the baseline, increasing placement load by two times, or eliminating the placement load entirely at the mouth of the Maumee River. All three of these lines are on top of each other. The orange line shows how much lower TSS concentrations would be at this location without any solids load from the Maumee River. Since this is at the mouth of the Maumee River there is a significant decrease in TSS concentration for this scenario

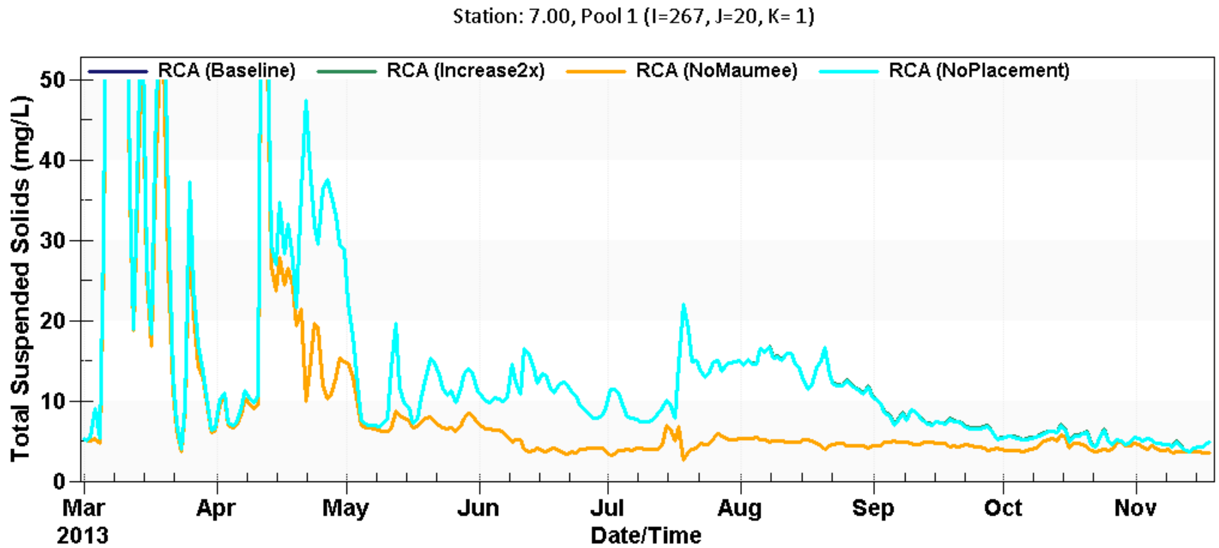


Figure 5-17 TSS Concentration at Toledo Water Intake for Baseline, Double, Zero Placement Suspended Solids, and No Maumee River Scenarios

The figure above shows no difference in TSS concentration between the baseline, increasing placement load by two times, or eliminating the placement load entirely at the water intake crib. All three of these lines are on top of each other. The orange line shows how much lower TSS concentrations would be at this location without any solids load from the Maumee River.

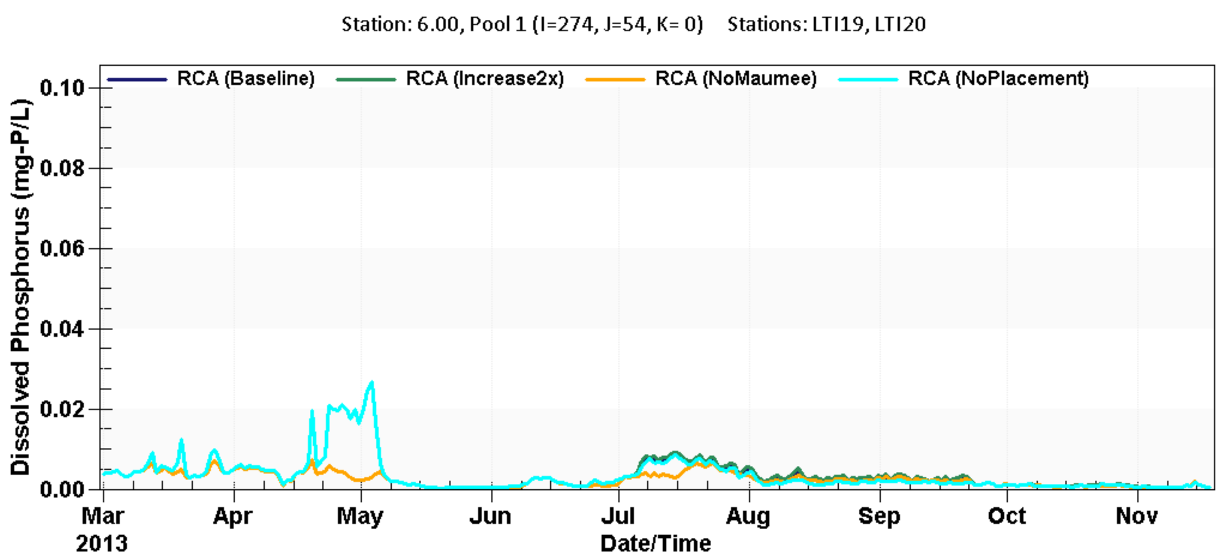


Figure 5-18 Dissolved Orthophosphate Concentration at Placement Location "A" for Baseline, Double, Zero Placement Suspended Solids, and No Maumee River Scenarios

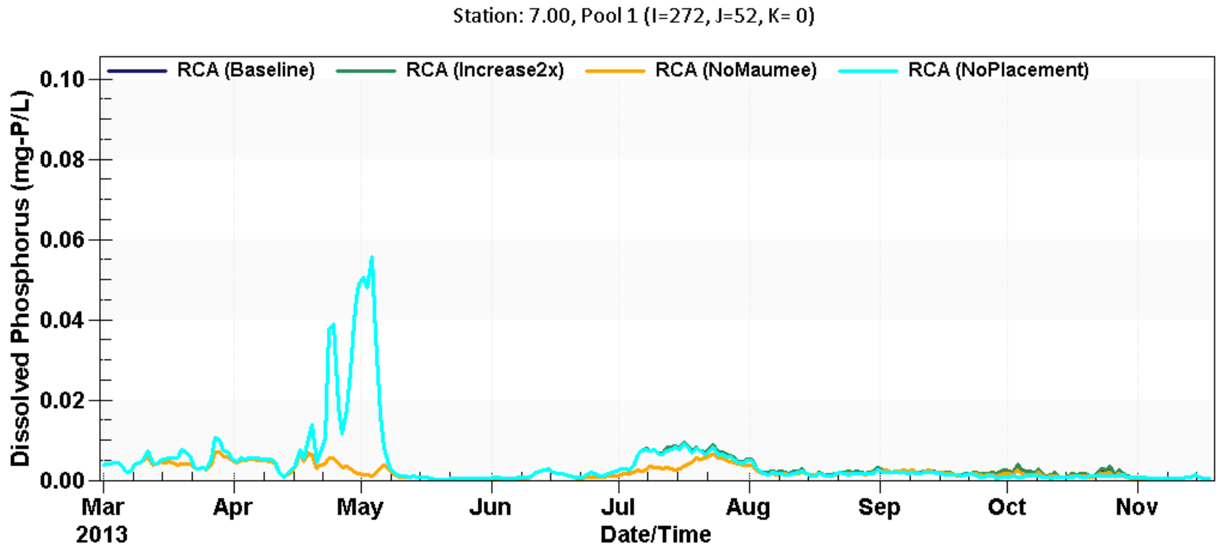


Figure 5-19 Dissolved Orthophosphate Concentration at Placement Location "B" for Baseline, Double, Zero Placement Suspended Solids, and No Maumee River Scenarios

The two figures above show no difference in DPO4 concentration between the baseline, increasing placement load by two times, or eliminating the placement load entirely at the placement site. All three of these lines are on top of each other. The orange line shows how much lower DPO4 concentrations would be at this location without any load from the Maumee River. Since this is at the mouth of the Maumee River there is a significant decrease in DPO4 concentration for this scenario.

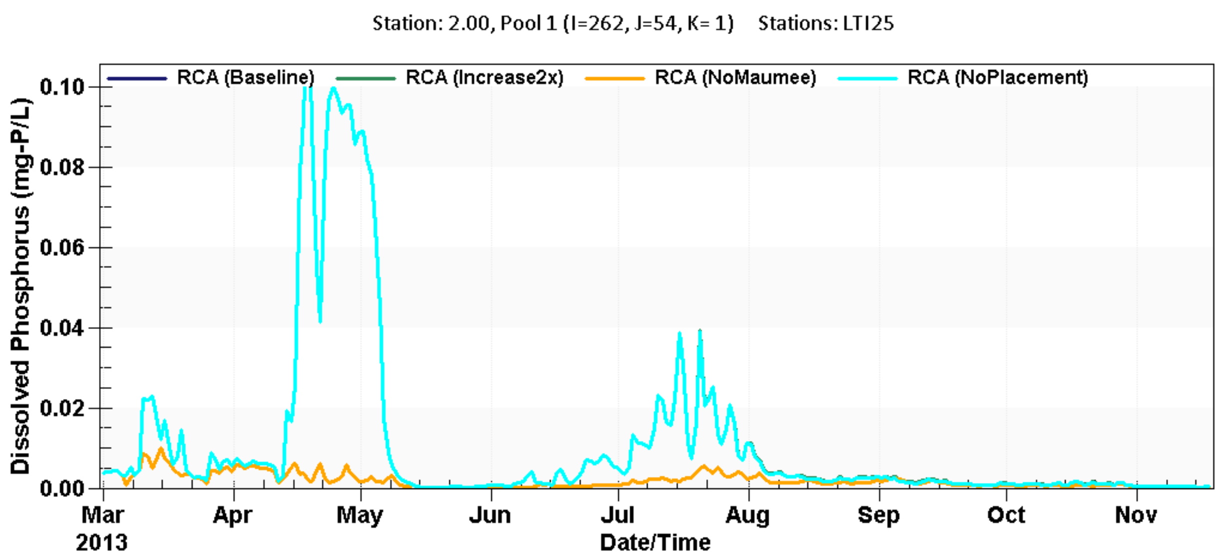


Figure 5-20 Dissolved Orthophosphate Concentration at RA-1 for Baseline, Double, Zero Placement Suspended Solids, and No Maumee River Scenarios

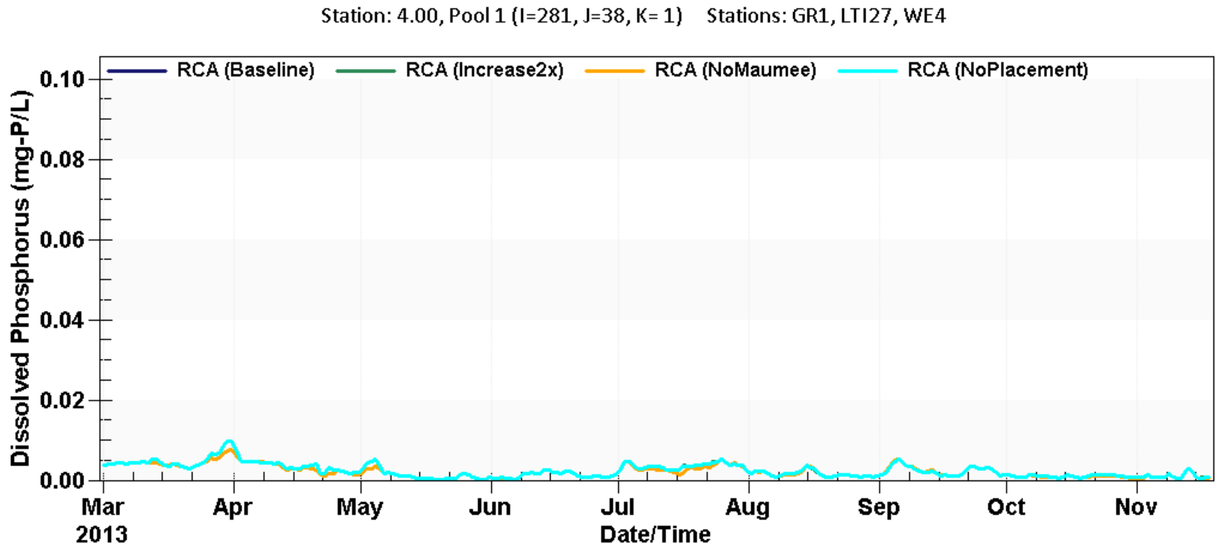


Figure 5-21 Dissolved Orthophosphate Concentration at RA-2 for Baseline, Double, Zero Placement Suspended Solids, and No Maumee River Scenarios

The two figures above show no difference in DPO4 concentration between the baseline, increasing placement load by two times, or eliminating the placement load entirely at RA-1 and RA-2. All three of these lines are on top of each other. The orange line shows how much lower DPO4 concentrations would be at this location without any load from the Maumee River. At RA-1 there is a significant difference, but at RA-2 there is not a significant difference as it is much further from the mouth of the Maumee River.

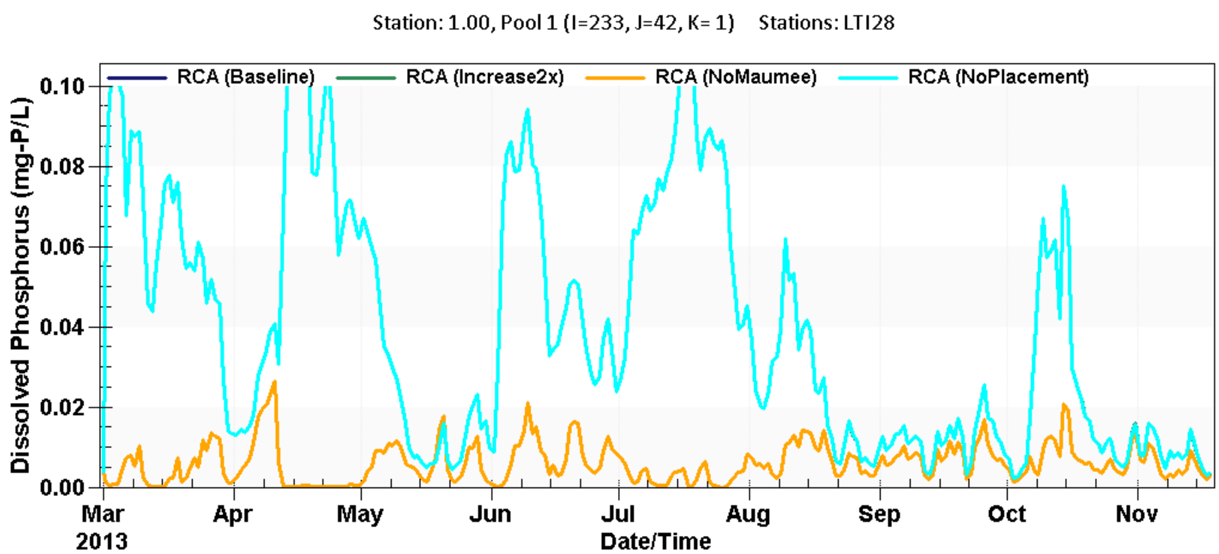


Figure 5-22 Dissolved Orthophosphate Concentration at Maumee River Mouth for Baseline, Double, Zero Placement Suspended Solids, and No Maumee River Scenarios

The figure above shows no difference in DPO_4 concentration between the baseline, increasing placement load by two times, or eliminating the placement load entirely at the mouth of the Maumee River. All three of these lines are on top of each other. The orange line shows how much lower DPO_4 concentrations would be at this location without any solids load from the Maumee River.

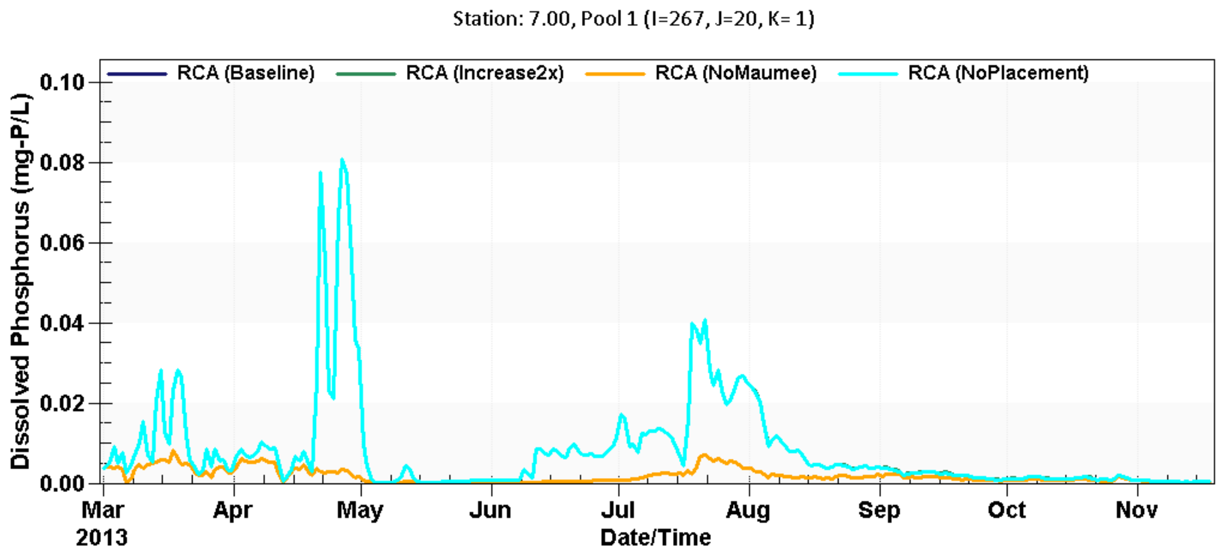


Figure 5-23 Dissolved Orthophosphate Concentration at Toledo Water Intake Crib for Baseline, Double, Zero Placement Suspended Solids, and No Maumee River Scenarios

The figure above shows no difference in DPO_4 concentration between the base-line, increasing placement load by two times, or eliminating the placement load entirely at the Toledo water intake crib. All three of these lines are on top of each other. The orange line shows how much lower DPO_4 concentrations would be at this location without any load from the Maumee River.

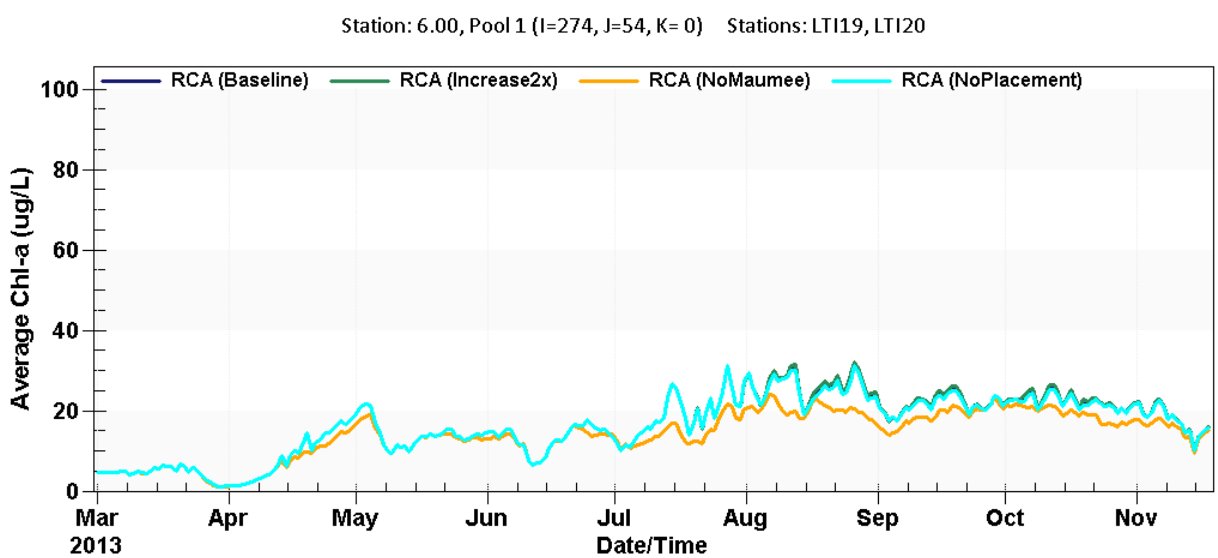


Figure 5-24 Average Chlorophyll-a Concentration at Placement Location "A" for Baseline, Double, Zero Placement Suspended Solids, and No Maumee River Scenarios

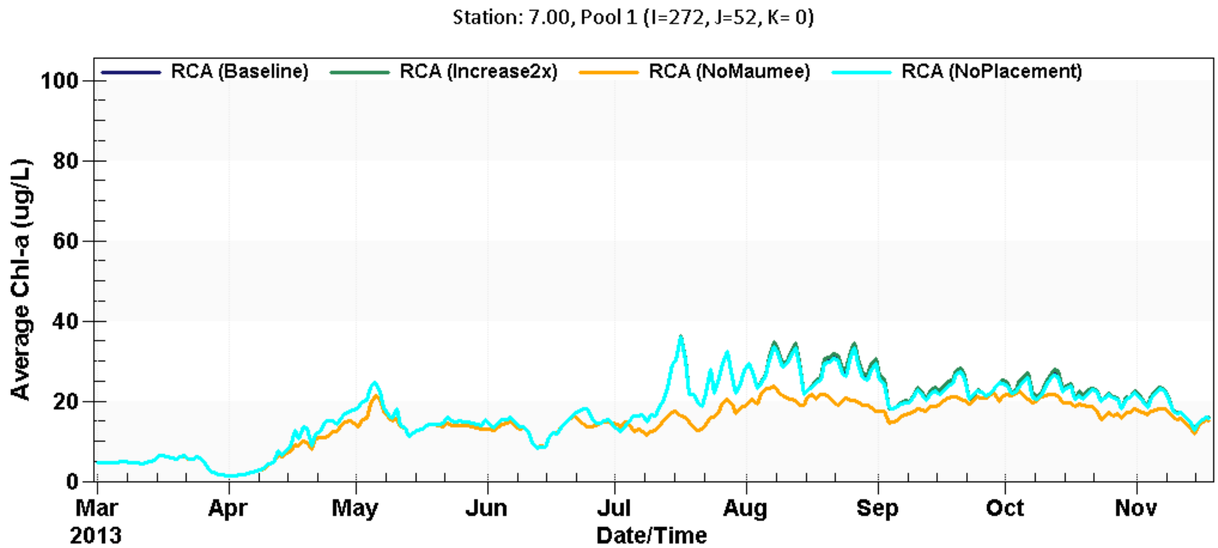


Figure 5-25 Average Chlorophyll-a Concentration at Placement Location "B" for Baseline, Double, Zero Placement Suspended Solids, and No Maumee River Scenarios

The two figures above show no difference in chlorophyll-a concentration between the baseline, increasing placement load by two times, or eliminating the placement load entirely at the placement site. All three of these lines are on top of each other. The orange line shows that chlorophyll-a concentrations would be slightly lower without any load from the Maumee River.

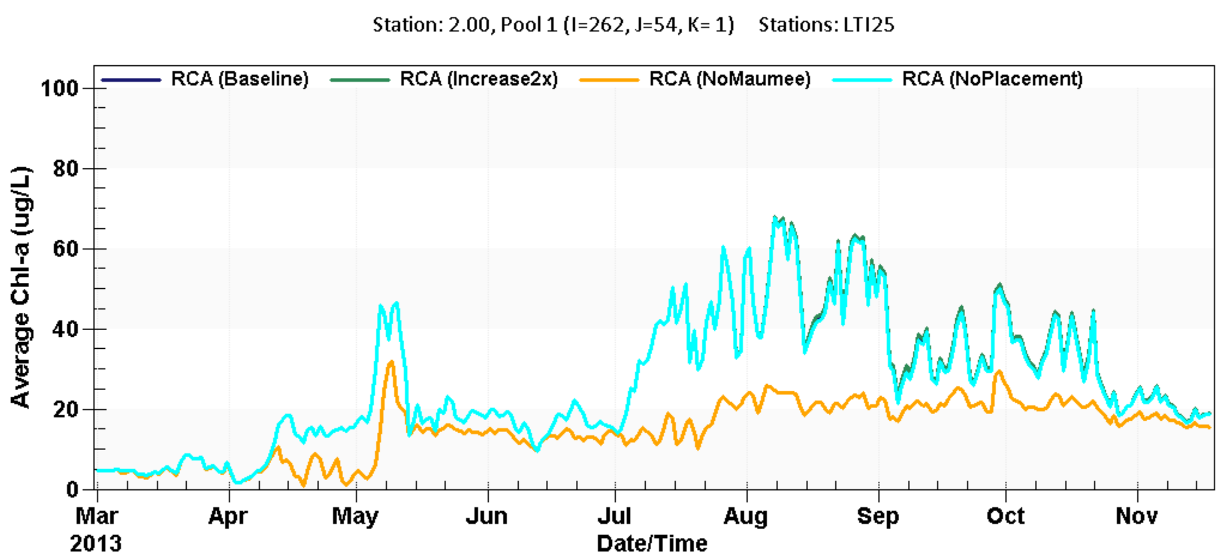


Figure 5-26 Average Chlorophyll-a Concentration at RA-1 for Baseline, Double, Zero Placement Suspended Solids, and No Maumee River Scenarios

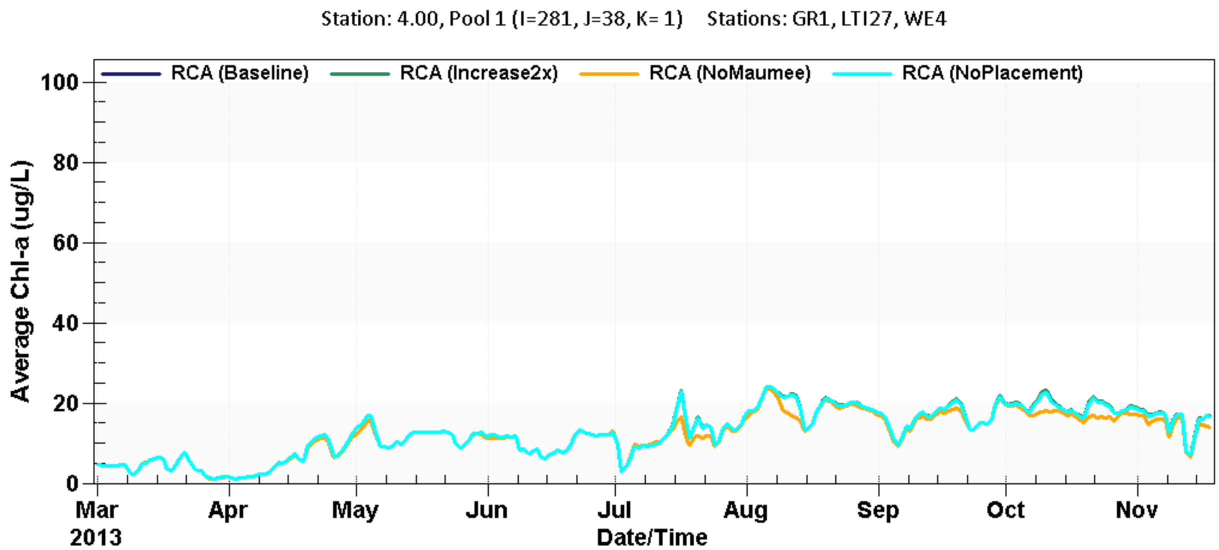


Figure 5-27 Average Chlorophyll-a Concentration at RA-2 for Baseline, Double, Zero Placement Suspended Solids, and No Maumee River Scenarios

The two figures above show no difference in chlorophyll-a concentration between the baseline, increasing placement load by two times, or eliminating the placement load entirely at the placement site. All three of these lines (dark blue, green, and light blue) lines are on top of each other. The orange line shows that chlorophyll-a concentrations would be slightly lower without any load from the Maumee River.

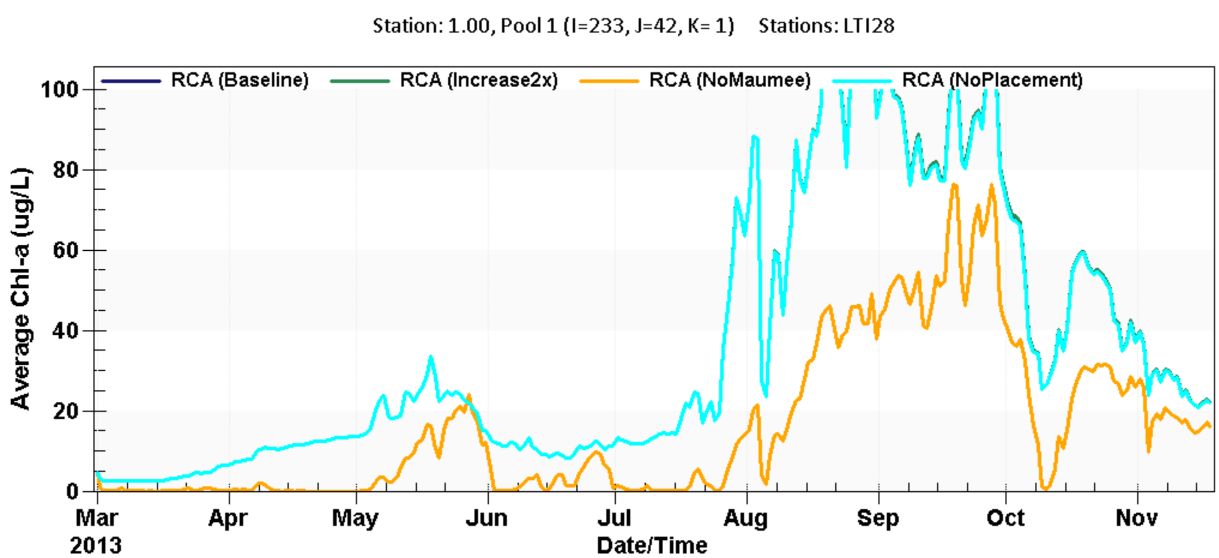


Figure 5-28 Average Chlorophyll-a Concentration at Maumee River Mouth for Baseline, Double, Zero Placement Suspended Solids, and No Maumee River Scenarios

The figure above shows no difference in chlorophyll-a concentration between the baseline, increasing placement load by two times, or eliminating the placement load entirely at the mouth of the Maumee River. All three of these lines are on top of each other. The orange line shows that chlorophyll concentrations would be lower at this location without any load from the Maumee River.

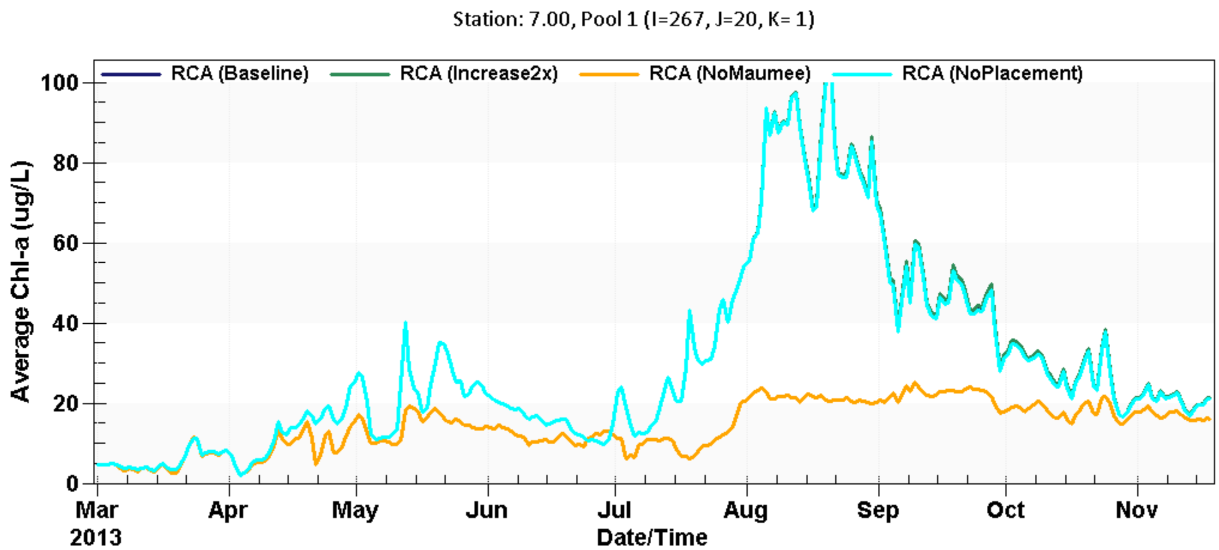


Figure 5-29 Average Chlorophyll-a Concentration at Toledo Water Intake Crib for Baseline, Double, Zero Placement Suspended Solids, and No Maumee River Scenarios.

The figure above shows no difference in chlorophyll-a concentration between the baseline, increasing placement load by 2 times, or eliminating the placement load entirely at the Toledo water intake crib. All three of these lines are on top of each other. The orange line shows that chlorophyll concentrations would be lower at this location without any load from the Maumee River.

6 Conclusions

The field data collection and analysis, and the model application performed in this study, were aimed at answering the overall question of whether open-lake placement of dredged material from Toledo Harbor federal navigational channel was a significant contributor to phosphorus concentrations and HABs in the WLEB (Western Basin of Lake Erie). The Maumee River is the largest single source of sediments to the Great Lakes, with the sedimentation of over 800,000 cubic yards of sediments per year in Toledo Harbor federal navigation channels. In order to prevent a significant reduction in commercial navigation capacity, approximately this amount of material must be dredged annually at a cost of approximately $5M per year. This dredged material is currently placed at the designated open-lake placement area in WLEB because it meets federal guidelines for open-lake placement. No other feasible management alternatives currently exist for this dredged material; open-lake placement is the federal standard as it is the least costly, environmentally acceptable alternative that is consistent with sound engineering practices. Although previous weight-of-the-evidence did not support any causal link between open-lake placement of this dredged material and HABs, this study has been conducted to assess the potential for significant eutrophication impacts in the WLEB from continuation of open-lake placement of this dredged material. The primary concern regarding open-lake placement is the release of SRP to the water column so as to exacerbate HABs production in the WLEB. In this regard, the project team studied two potential sources of SRP release from the dredged material: 1) short-term desorption from the barge-placed material as it settled to the bottom in the placement area; and 2) release from deposited material either by resuspension and desorption, or by pore diffusion from the in-place deposited material.

With respect to the first source, several lines of evidence suggest very little SRP desorption takes place in the water column while the barge-placed material is depositing, estimated to be 0.02% of the total SRP load to the Western Basin. First, the vast bulk (95%) of the placed material deposits to the bottom very quickly as an aggregated mass. Shortly after a placement event, only 1 to 5% of the barged material remains as residual suspended solids in the water column to discretely settle and be transported by currents. The resulting plume is small and short-lived, remaining well within the boundaries of the placement area. Within an hour, the plume diminishes to near background conditions due primarily to settling and dispersion in the water column. This is consistent with findings of other such studies showing open-lake placement plumes are temporally and spatially limited. Further, particulate phosphorus behaves in a similar way as the suspended solids; that is the residual particulate phosphorus quickly deposits along with the residual suspended solids to which it is adsorbed. In addition, there was very little release of SRP during this process, with immediate SRP concentrations for monitored barge placements being an average of 0.019 mg P/L. Within an hour, average SRP concentrations decreased to near background levels. The average concentration after an hour was 0.005 mg P/L, while the background is 0.004 mg P/L. This suggests that 15 µg/L of SRP could be taken up by algae; however after dredged material placement the SRP immediately begins to dissipate in the water column as a result of dispersion and mixing processes, resulting in only intermittent, unsteady, short-term exposure to phosphorus above background levels. A mass analysis of SRP during a placement event shows that SRP mass is conserved in the water column, while the concentrations decrease as the area of the plume expands over time. In addition, given the high ambient SRP levels measured during the study (0.004 mg P/L), algae are not phosphorus starved and there is no need for algae to absorb more phosphorus. Under phosphorus rich conditions algae only take up additional phosphorus when required for growth, which occurs on a daily time scale, rather than minutes or hours. The duration and extent of this exposure would be insufficient to pose an effect on the occurrence of HABs and impact water quality in the WLEB.

The WLEEM model was also applied to assess the effect of a season of barge placements at a rate of four to six barges per day from early July through October. To accomplish this objective the following scenarios were run from March through November of 2013:

- Baseline–calibrated 2013 model including open-lake placement of dredged material;
- Increase residual percent of placement material that is dispersed in the water column by a factor of two, from 2.5% to 5%;
- Decrease the percent of placement material that is dispersed in the water column to zero; and
- Set the concentration of all nutrients and solids boundary conditions in the Maumee River to zero.

The results of these model runs showed that virtually unmeasurable water concentration differences of TSS, TP, SRP, and chlorophyll-a from the baseline occurred for either the doubling of the residual material or eliminating it altogether (see Figures 5-12 through 5-29). These results even occurred in the model cell encompassing the placement area. Only when the Maumee River sediment and phosphorus loads were hypothetically eliminated from the model inputs did the WLEB respond very significantly with a reduction in all of the parameters modeled. In addition, as discussed in Section 5, the model results show that concentrations of these parameters arising from placement operations are not detectable at the City of Toledo potable water intakes location or at the adjacent City of Oregon water intake.

Finally, actual chlorophyll-a measurements at the placement area versus all the other sites measured in the WLEB showed no elevated concentrations during the dredged material placement season. Rather, a very consistent pattern of decreasing with distance from the mouth of the Maumee River was found during the dredged material placement season. These collective empirical data and modeling results provide strong evidence that Toledo Harbor dredged material open-lake placement operations have virtually no short-term impact on SRP or HABs in the WLEB.

With respect to the second potential source of bioavailable phosphorus (release from bottom sediments where the dredged material is deposited), there is a strong weight-of-evidence that open-lake placement has little impact on the already ongoing internal phosphorus loading from WLEB bottom sediments. First, with respect to resuspension from the placement area, turbidity sondes indicated that resuspension was a widespread phenomenon throughout the WLEB on days when wind produced high enough wave action to produce bottom shear stresses that exceed critical values. In other words, resuspension was no more significant at the placement area than at the reference areas or other areas of the WLEB. And the sediment area in the placement zone is a small fraction of the sediment area of the WLEB with the same water column depth or less. Hence, the resuspension internal load from the placement area is a small fraction of the resuspension load from the rest of the basin. Also, modeling estimated that the SS concentrations of 20 to 40 mg/L measured during these basin-wide resuspension events required less than a millimeter of bottom sediment resuspension to produce those measured SS concentrations. Corroboration of this finding comes from the bathymetry results from the USACE at the placement area. The bathymetry shows a “mound” of placed material that has accumulated over several years. This could not have occurred if the deposited material was eroding away at a high rate.

With respect to diffusive flux of SRP from the placement area sediment, although the placement area had a higher TP concentration (i.e., approximately 0.93 mgP/gm sediment) than sediment in the Reference Area (i.e., 0.66 mgP/gm sediment) that is potentially mobile, intact core incubation release studies found virtually no difference between the placement area and the reference areas at the end of the barge placement season. No significant difference between fluxes measured at the placement area before the barge season and after the barge placement season was found.

In summary, weight-of-evidence from the cumulative findings of this study indicates that the open-lake placement of Toledo Harbor dredged material has no measureable impact on HABs in the WLEB.

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Literature Review Summary Report

Final Literature Review
Influence of Open-Lake Placement of Dredged Material on Western Lake Erie Basin Harmful Algal Blooms

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1. INTRODUCTION

Ecology and Environment Inc., (E & E) and our team subcontractor, LimnoTech, are pleased to provide the United States Army Corps of Engineers (USACE), Buffalo District, this literature review on the influence of open-lake placement of dredged material on the development of western Lake Erie harmful algal blooms (HABs).

The federal standard for Toledo Harbor dredged material management is open-lake placement, as it is the least costly, environmentally acceptable alternative consistent with sound engineering practices. Environmental acceptability is determined primarily through Clean Water Act Section 404(b)(1) (Congress 1972) guidelines, which include compliance with state water quality standards. Recently, HABs in the western basin of Lake Erie have become a considerable ecological and environmental issue, raising concerns about the potential influence posed by dredged material placement activities. The major factors of concern with regard to dredged material placement are: phosphorus release from the dredged sediment (exacerbating HAB development); changes in turbidity; and the horizontal transport of the material potentially leading to the transport of nutrients.

This summary includes an examination of current literature (academic journal articles and other reports) related to HAB development and the impact of dredged material placement activities. This summary compiles, synthesizes, and interprets existing information building a comprehensive picture of HAB development in the western basin and addresses potential links to the open-lake placement of dredged material.

1.1 STUDY AREA - SITE DESCRIPTION

Toledo harbor is located near the southwest shore of Lake Erie at the mouth of the Maumee River at the city of Toledo, Lucas County, Ohio. Federal navigation channels in the project area include the 18-mile Lake Approach Channel in Maumee Bay and the western basin of Lake Eire and the 7-mile River Channel in Maumee River (see Figure 1). These harbor channels are regularly maintenance-dredged by the USACE to accommodate efficient and safe deep-draft commercial navigation. Dredged material determined to meet federal guidelines for open-lake placement is placed at the existing 2-square mile (1,280 acres) open-lake placement area in the western basin of Lake Erie, located just north of the Lake Approach Channel near Lake Mile 11 (see Figure 1). The center of this area is on an azimuth of 33º at a distance of 3.5 miles from the Toledo Harbor Light. Dredged material discharge is typically restricted to the northeast portion of this area (640 acres). The site has depths that range from 20 to 23 feet below low water datum (LWD)[1] and is within a warm-water aquatic ecosystem that consists mainly of soft unstructured bottom and water column habitat. Bottom sediments at the open-lake placement area consist primarily of silts and clays. Typical annual dredging requirements are approximately 850,000 cubic yards. The vast majority of this volume is open-lake placed and derived from the Lake Approach Channel, which is also located in the western basin.

[1] LWD for Lake Erie is defined as 569.2 feet above mean sea level at Rimouski, Quebec, Canada (IDLD 1985)

Lake Erie's long, narrow orientation parallels the direction of the prevailing southwest winds. Strong southwest winds and strong northeast winds set up seiches, causing a difference in water depth as high as 14 feet between Toledo and Buffalo. The effect is most prevalent in the western basin where large areas of the lake bottom are exposed when water is blown to the northeast, or large areas of shoreline are flooded as water is blown to the southwest. Overall current and wave patterns in Lake Erie are complex, highly changeable and often related to wind direction (USEPA 2008).

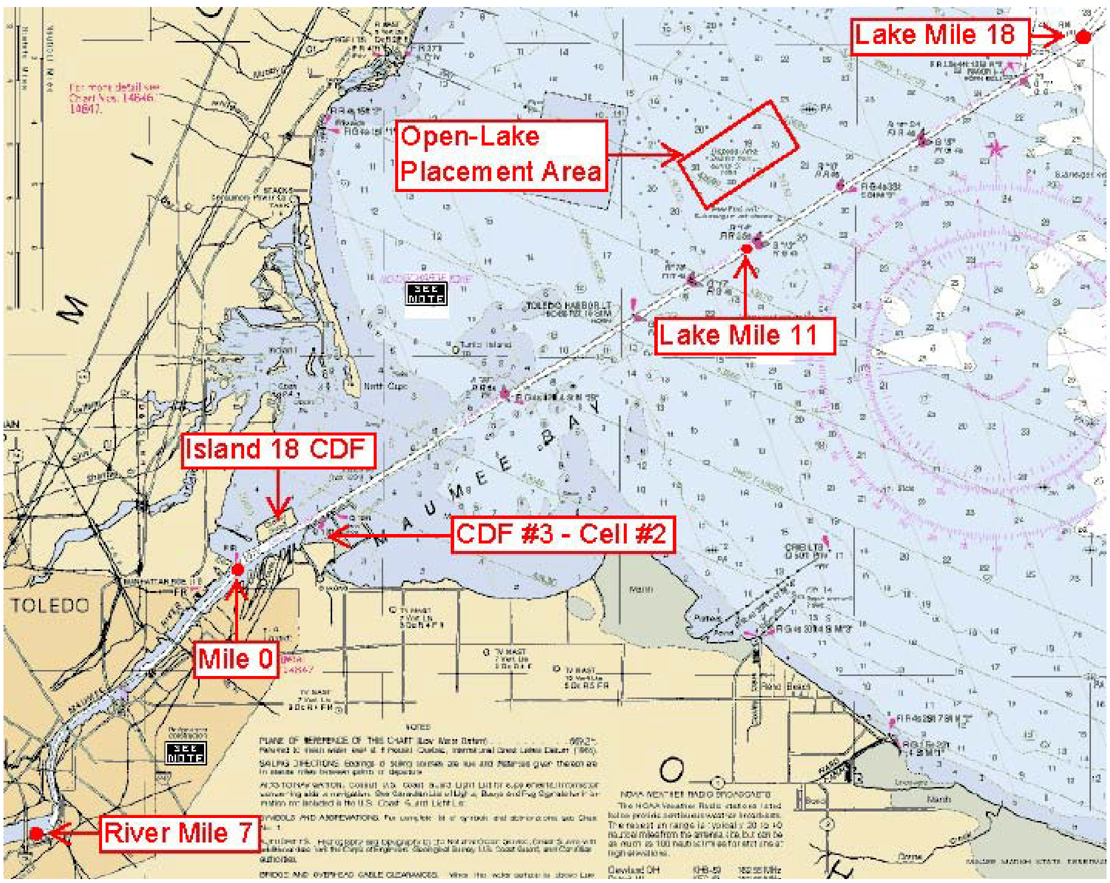

Figure 1. Site Location Map

2. LITERATURE REVIEW

This section presents a review of the identified literature that describes what is known or has been studied regarding the potential influence of the placement of Toledo Harbor dredged material in Lake Erie's western basin on HABs. It focuses on recently published research from primary sources but also includes some important scholarly/theoretical work and/or secondary sources. The review is an integration of the existing literature organized by the identified parameters related to the study purpose, that is, the influence of dredge material disposal on HABs. The study parameters associated with HAB development dynamics include: extent, characteristics, composition, and causal factors of HABs. The parameters associated with dredged material disposal dynamics include: extent, characteristics, composition, transport, and interactions with water quality and HAB parameters.

2.1 HAB DEVELOPMENT DYNAMICS

Phytoplankton, the drifting algae found in the open water of lakes, is a diverse assemblage of nearly all major taxonomic groups, including cyanobacteria. Phytoplankton contains chlorophyll and requires sunlight in order to live and grow. Phytoplankton also requires inorganic nutrients, such as nitrogen, phosphorus, and sulfur compounds which they convert into proteins, fats, and carbohydrates. Many phytoplankton forms have different physiological requirements and vary in response to physical and chemical parameters, such as light, temperature, and nutrient regimen (Wetzel 2001). Dominant algal groupings in a water body change not only spatially but seasonally, as physical, chemical, and biological conditions in the water body change. Phytoplankton includes cyanobacteria (blue-green algae), green algae, diatoms, and dinoflagellates. Some cyanobacteria produce toxins, called cyanotoxins, which can be harmful to human and animal health. *Mycrocystis aeruginosa* is one species of cyanobacteria found in fresh water environments, which produces harmful toxins. Blooms occur when nutrient levels spike in aquatic environments or nutrient levels are selective toward *Microcystis aeruginosa*, which is the common variety but not the only toxic HAB.

2.1.1 History, location, extent and timing of blooms

Excess nutrients, in particular phosphorus, have been linked to the increasing appearance of HABs in Lake Erie (OEPA 2010). In the 1960s and early 1970s Lake Erie's HABs were one of the major water quality issues in the United States, prompting the passage of the Great Lakes Water Quality Agreement in 1972, and the renewal of the agreement in 1978. As a result of the agreement, nutrient effluent limits were enforced for point sources , and the water quality of Lake Erie improved drastically, which resulted in HABs being diminished for several years (DePinto et al. 1986b). These nutrients reduction measures lead to substantial decreases in algal abundance, however by the mid-1990s, phytoplankton biomass began to increase across Lake Erie in the summer months. By the late 1990s and early 2000s, cyanobacteria biomass began increasing in the summer months across Lake Erie. A particularly large HAB occurred in 2003. Blooms were exceptionally large in the 2008 to 2011 period (OEPA 2010; Stumpf et al. 2012). The largest bloom ever recorded since bloom areas have been measured (beginning in 2002) was in 2011. In 2006, the benthic mat-forming cyanophyte, *Lyngbya wollei* began growing in Maumee Bay and washing up along the shoreline (Bridgeman and Penamon 2010). Both Microcystis and *Lyngbya wollei* produce toxins which can be harmful to humans, animals and aquatic life.

Recent modeling efforts on Lake Erie provide an integrated framework to evaluate nutrient load impacts on algal abundance. Leon et al. (2011) developed a three dimensional hydrodynamic and eutrophication model of Lake Erie to determine the primary drivers of algal growth. The results of this study indicate that favorable light, temperature, and nutrients are the primary factors affecting nearshore concentrations of phytoplankton. The movement, growth, and distribution patterns of Microcystis blooms can also be modeled (Howard 2001), and these models are being applied to help water quality managers understand the distribution and transport of these algae.

Cyanobacteria blooms are usually confined to the western basin of Lake Erie, however, in some summers these have extended into the central basin (Stumpf et al. 2012). The 2011 bloom extended well into the central basin and persisted into late September and early October (Stumpf et al. 2012). During the 2008 bloom, growth potential (based on cellular nutrient content) was measured in Maumee Bay, the transition zone (in between Maumee Bay and the open water of the western basin), and in the open water of the western basin. The results indicated that the greatest growth potential was in the Maumee Bay and the transition zone, and that cyanobacteria in the open water areas were somewhat phosphorus deficient (Chaffin et al. 2011). Satellite images of the progression of the blooms consistently point toward the Maumee Bay and areas near the bay as having the highest concentrations of cyanobacteria (Wynne et al. 2010; Binding et al. 2012).

The extent of HABs within a given year has been correlated strongly with spring phosphorus loads that are discharged from the Maumee River (Stumpf et al. 2012). In the western basin of Lake Erie it has been demonstrated that most of the phosphorus load is discharged by the early spring (March through June), but the blooms do not begin to form until months later (Stumpf et al. 2012). Nutrients are available for HAB formation earlier in the year, but other environmental factors such as optimal temperature and light are required for bloom formation. The formation of algal blooms requires: the correct environmental conditions (i.e., temperature, light availability, low mixing), and the correct concentration and ratio of nutrients (nitrogen:phosphorus [N:P]) (Elser 1999; Sullivan 1987). In the western basin of Lake Erie peak, Microcystis blooms are in the warmer months of the year (usually August to September) when water temperatures reach as high as 77°F (25°C) (Millie et al. 2009). Millie et al. (2009) also found that spatially explicit blooms occurred on an annual basis in the western basin of Lake Erie, with maximum chlorophyll concentrations occurring along the basin's southwestern shorelines in waters impacted by the Maumee River inflows.

Recently, remote satellite imagery has been used to assess the extent of algal blooms on Lake Erie. The application of an updated MODIS algorithm can produce high resolution images of derived algal and suspended material concentrations (Binding et al. 2012). Bi-weekly estimates were made of these two parameters between 2003 and

2008. Results have identified distinct algal bloom cycles in Lake Erie, with the western basin experiencing a single, prolonged bloom of higher intensity compared with clear spring and autumn bloom events in the central and eastern basin. The timing of Lake Erie blooms vary according to basin, with the western basin peaking on average in the last week of August/first week of September. The results indicate that concentrations of phosphorus and nitrogen are highest in the fall months and are located in close proximity to the Maumee River. This is consistent with other findings that the Maumee River is the primary source of nutrients that stimulate algal blooms.

2.1.2 Composition of blooms

A study by Bridgeman et al. (2012) considered the algal composition along a gradient from the Maumee River out into the western basin during the growing season of 2009. The study showed that in June, green algae dominate in the Maumee River and Lake Erie (46% and 60%, respectively), with a smaller percentage of cyanobacteria in the Maumee River (17%). The remainder of the phytoplankton community is composed of diatoms. By August, the cyanobacteria percentage of total biomass increased to 32% in Lake Erie and dropped to 3% in Maumee River. In the open lake water during August, *Microcystis aeruginosa* is the dominant cyanobacteria, and in the nearshore area of Maumee Bay (at a depth of 1.5 to 3.5 meters [m]). *Lyngbya wollei* has emerged as a nuisance, attached, filamentous, cyanobacterial algae (Bridgeman et al. 2012; Bridgeman and Penamon 2010). During storms, *Lyngbya wollei* can either wash up on shore or be swept out into the lake (depending on currents). Large mats have been observed to travel over 60 miles (100 kilometers [km]) from Maumee Bay (Bridgeman et al. 2012).

2.1.3 Causal factors associated with blooms

Excess nutrients, in particular phosphorus, have been linked to the increasing appearance of HABs (OEPA 2010).

Phosphorus entering Lake Erie occurs in two basic forms, dissolved phosphorus (DP) and particulate phosphorus (PP). Together, DP and PP comprise total phosphorus (TP). DP can be further subdivided into dissolved reactive phosphorus (DRP) and dissolved organic phosphorus (DOP). The DRP is considered to be 100% bioavailable, and readily available to support algal growth (OEPA 2010; Lambert 2012). DOP bioavailability varies, but up to 74% of it could be ultimately bioavailable based on recent 30-day laboratory bioassays (Lambert 2012). The DRP fraction of TP discharged from the Maumee River has been increasing since 1995 (Baker, 2011b). In contrast, PP levels which declined significantly through the early 1980s, have been variable depending largely on the watershed hydrology (wet or dry) in a given year. Additionally, PP can settle to the bottom and is usually only 30% to 35% bioavailable (OEPA 2010; Lambert 2012; DePinto et al. 1981), making it less of a management concern when compared with the more bioavailable DRP and DOP.

Bridgeman et al. (2012) concluded that the Maumee River is the major source of phosphorus contributing to HABs formation in western Lake Erie. The results demonstrated that the concentrations and forms of phosphorus present can vary considerably between the Maumee River and Lake Erie and over the course of the growing season. At times, the majority of the phosphorus can be present as DOP, a form that is not detected in standard analyses for DRP but may also be available for phytoplankton growth (depending on the analytical definition, some DOP may appear as DRP).

An increasing trend in DRP may not fully explain notable increases in the occurrence of algal blooms over the past decade in Lake Erie. Other nutrients, such as nitrogen, have been steadily increasing over the years and may be limiting to certain algae (Paerl and Scott 2010; OEPA 2010). However, researchers measured intracellular nutrient limitation to quantify algal growth potential in a transect extending from Maumee Bay into Western Lake Erie and found the only nutrient that limited cyanobacteria growth was phosphorus (Chaffin et al. 2011). The study suggested that cyanobacteria had sufficient nitrogen and micronutrients to meet their maximum growth potential.

Ecosystem changes such as the spread of Dreissenid mussels and climate change could also be playing a role in the expansion of HABs (Zhang et al. 2011; Paerl and Paul 2012; Hartig et al. 2009). Zhang et al. (2011) uses an Ecological Model of Lake Erie (EcoLE) to show that the daily grazing impact of Dreissenid mussels on algal biomass was less than 10% even though they cleared a volume equivalent to 20% of the water column. This is due to the development of a weak boundary layer that separates the upper water column from the lower water column. The study also found that zooplankton can have a higher grazing rate than Dreissenids. Inedible algae (e.g., cyanobacteria) increased with increasing phosphorus levels and were not significantly impacted by mussel grazing. The selective filtering of cyanobacteria by Dreissenids is a phenomenon that has been documented elsewhere (Bierman et al. 2012; Raikow et al. 2012). Culver and Conroy (2007) found that the Dreissenid community in the western basin of Lake Erie had decreased in density by 50% over earlier levels and was comprised almost entirely of quagga mussels. The results of the study emphasize that Dreissenid density is not static, quagga mussels now dominate the system, and the excretion of phosphorus through feces and psuedofeces can supply up to 3% of the required daily value for phytoplankton.

The effects of climate change and climate warming may benefit some species of harmful cyanobacteria (both freshwater and marine) by providing more optimal conditions for their growth. Increasing temperature and carbon dioxide either alone or in combination with nutrient availability may determine the growth and relative abundance of HAB species (Zhang et al. 2011; Paerl and Paul 2012). Historical evidence from long-term phytoplankton monitoring data and fossil records suggests that future climate warming could impact HABs through the alteration of their geographic range and shifts toward relatively more and earlier blooms.

2.1.4 Nutrient dynamics

Understanding the cycling of nutrients in the western basin is critical to understanding the cause-effect relationship between excessive nutrient loads and the formation of HABs. While the project team reviewed many references discussing phosphorus cycling, a recent report by the Ohio Environmental Protection Agency (OEPA) titled the "Ohio Lake Erie Phosphorus Task Force Final Report" was published in April 2010 (OEPA 2010). This report was developed by contributions from over twenty professionals from across the Great Lakes region with specific expertise on phosphorus cycling in Lake Erie, including a member of this project team, Dr. Joseph DePinto of LimnoTech. Another recent report titled "Lake Erie Nutrient Loading and Harmful Algal Blooms: Research Findings and Management Implications", summarizes research findings from a large group of scientists that studied Lake Erie in 2009 and 2010 (Reutter et al. 2011). This report also had major contributions from Dr. DePinto. Portions of both reports are summarized here, but these reports represent the most comprehensive review of phosphorus fate and transport and their impacts on HABs in Lake Erie to date.

Phosphorus enters the water column of the western basin from four primary sources including direct atmospheric deposition onto the water surface, inflow from tributaries, direct discharge from point sources, and from the resuspension and diffusion from the sediment bed. The first three of these sources are classified as external loads and the last one is classified as an internal load. External loads of phosphorus to Lake Erie are well studied and annual load estimates are available dating back to 1974 (Dolan and McGunagle 2005; Dolan and Chapra 2012).

In Lake Erie, external loads of phosphorus play a large role in the development of HABs. After the implementation of phosphorus loading targets in the late 1970s, on average, total phosphorus loading to Lake Erie (set at 11,000 metric tons per year) has not changed significantly since the early 1980s. During the 1980s and early 1990s water quality managers no longer observed large HABs. However, by the mid-1990s HABs began to reappear (Stumpf et al. 2012).

Excluding contributions from the upper Great Lakes and Michigan via the Detroit River, the Maumee River watershed is the single greatest external source of phosphorus to Lake Erie, contributing about 35% of the total TP load in 1994 (Schwab et al. 2012).

A close look at the external loading data reveals that even though total phosphorus loads generally have not changed since the early 1980s, DRP loads have increased since 1995, and are reaching historic highs, while PP loads have decreased (Baker 2011b; OEPA 2010; Daloglu et al. 2012). DRP is much more bioavailable to algae, and the increase in these loads, especially from the Maumee River, could be one explanation for the resurgence and ever increasing extent of HABs in the western basin. The observed shift from PP loading to DRP loading appears to be driven by the implementation of best management practices on farms (e.g., no till). These practices tend to reduce erosion and runoff of soils (Myers et al. 2000), but do not prevent surface runoff and subsurface transport of the dissolved forms of phosphorus resulting from the application of chemical fertilizers (Joosse and Baker 2011).

Point source loadings (e.g., wastewater treatment plants, combined sewer overflows, and industrial discharges) have remained fairly consistent since 1981 and are not considered to be a significant contributor to the recent increases in DRP loads measured in Ohio's Lake Erie tributaries (Baker 2011a). Atmospheric deposition of phosphorus into Lake Erie has remained relatively constant for the last 20 years, and is approximately 5% of the total load to the lake (Dolan and Chapra 2012).

Non-point source loadings (e.g., urban, residential and agricultural runoff) contribute nutrients from surface water runoff of farm fields and the urban environment. However, urban land accounts for only a small percentage of land area in the Maumee River watershed (7 %). There is a high percentage of agricultural land in the Maumee River watersheds (80%), which contributes most of the DRP load (Baker 2011b). Phosphorus inputs from both commercial fertilizer and animal waste roughly equal phosphorus outputs (e.g., removal) by crop production, based upon current estimates of crop acres and productivity, state-wide fertilizer sales trends, and manure generated from animal production in the state of Ohio (Joosse and Baker 2011; Han et al. 2012). Despite this net balance of TP, the DRP load to Lake Erie continues to increase. Subsurface drainage and surface runoff are the mechanisms by which non-point source loads are transported into Lake Erie, but there is a lack of data describing surface and subsurface drainage practices.

The most significant nutrient loading increase is most likely from non-point source agricultural runoff (tributaries) (OEPA 2010; Joosse and Baker 2011). The highest DRP loads observed in the Maumee River occurs under high flow conditions, suggesting that the loads from non-point sources are an important focus for future phosphorus management in Western Lake Erie (Charlton et al. 2009). Particularly in the early spring months, in both rivers, peak DRP concentrations coincided with peak storm water runoff, and (over a 20-year period) 90% of the sediment and phosphorus load was delivered during storm events (Daloglu et al. 2012; OEPA 2010). Increased storm frequency, changes in fertilizer application time and rate, and no-till management practices that increase surficial soil phosphorus concentrations appear to be driving the recent increases in dissolved phosphorus , which in turn are leading to larger algal blooms (Daloglu et al. 2012). The DRP concentrations and loads from the Maumee River are higher than most other monitored tributaries in the entire Midwest region, increasing DRP concentrations have been observed in other monitored Lake Erie tributaries (e.g., the Cuyahoga and Grand Rivers), but much higher loads from the Maumee River make them the highest priority for reducing phosphorus loads.

The relationship between external phosphorus loading and the extent of cyanobacteria blooms has been studied closely with satellite images and loading data. These correlations indicate that the total phosphorus load from the Maumee River in June or the average flow rate in March through June are both good predictors of the size and extent of microcystis blooms (Stumpf et al. 2012). The loading data indicates that Lake Erie (on average) receives 20 times more nitrogen than is required to satisfy the generally accepted N:P ratio of 16:1, the “Redfield ratio” (Stumpf et al. 2012), which suggests that Lake Erie is a phosphorus limited system (Chaffin et al. 2011). The Redfield ratio is the molecular ratio of nitrogen and phosphorus found in most phytoplankton (16:1), when nutrients are not limiting. Nitrogen excess is not usually conducive to cyanophytes, which are generally considered weaker competitors for phosphorus than greens and diatoms. Others have proposed that Lake Erie is co-limited by both nitrogen and phosphorus because of nutrient recycling and the high overall nutrient concentrations in the lake (Paerl and Scott 2010).

Internal loading (e.g., phosphorus released from sediments) greatly influences the trophic status of a lake. The release of phosphorus from sediments has been extensively studied and is well understood (James 2007). In comparison with the water column, sediments in Lake Erie store much more phosphorus (Chaffin and Kane 2010) and in most cases they serve as a phosphorus source to the lake. Phosphorus release varies among lakes and is controlled by a number of different mechanisms; therefore general models are insufficient to explain these processes. Much of the phosphorus that is loaded to Lake Erie is delivered to the western basin, where it initially deposits and undergoes some transformations and is eventually transported eastward in the water column by prevailing lake currents (OEPA 2010). Phosphorus released from sediments can be substantial when oxygen concentrations are low. Low dissolved oxygen levels are very prevalent in the central basin of Lake Erie, but low levels have also been documented in the western basin (Matisoff and Neeson 2005; Smith and Matisoff 2008) These processes occur at the water-sediment interface during changes in the upper sediment layer (Nurnberg 1991). Much of the phosphorus on the surface sediments is bound with ferric iron, but when bottom water oxygen concentration drops below 2 milligrams per liter (mg/L), iron reduction occurs and phosphorus is released into the water column. Sediment suspension by benthic macroinvertebrates (bioturbation) in aquatic ecosystems is also an important process responsible for a fraction of chemicals transported from the sediment bed into the water column and can enhance the diffusive flux of phosphorus and provide the seeds necessary for large bloom formation (Chaffin and Kane 2010).

2.1.5 Bioavailability of Phosphorus

Quantifying the bioavailability of phosphorus is a parameter that could be utilized to help in the management of phosphorus in the Great Lakes.

There are two generally accepted methods for quantifying phosphorus bioavailability. The first is algal bioassays, which are generally accepted as the gold standard for quantifying algal bioavailability (Lambert 2012; DePinto 1982), but these assays are resource intensive to conduct. The second method is chemical fractionations, where bioavailability will be assessed chemically without algae and the relationship between chemical fractions extracted and algal bioavailability can be quantified (DePinto et al. 1981; Lambert 2012). This method is much less resource intensive, but at the same time has more uncertainty, because the bioavailability is not being quantified by a biological method. Both methods have been applied recently on the Great Lakes. In 30 day bioassays, Lambert (2012) found in the top five United States tributary loads to the Great Lakes (Maumee, Fox, Sandusky, Cuyahoga, and Saginaw rivers) that 100% of the DRP is available, approximately 74% (on average) of the DOP is available, and approximately 35% (on average) of the PP is available to algae. In the 1980s researchers reported similar results (DePinto et al. 1981; Young et al. 1985; Martin et al. 1985).

Chemical methods have also been applied to Lake Erie tributaries to quantify the bioavailability of PP. In the 1980s the NaOH extraction was proposed as a good chemical surrogate for algal bioavailability (DePinto et al. 1981; Young et al. 1988) and this was verified with contemporary samples (Lambert 2012). Others have found with contemporary samples that PP in the Lake Erie tributaries is approximately 30% bioavailable using the NaOH method (Baker 2010; Baker 2011b).

These results have led to the conclusion that more monitoring is needed to quantify the bioavailability of loads and more algal bioassays are needed to calibrate (or verify) these chemical methods on a watershed by watershed basis (Lambert 2012). These data can provide water quality managers with the support required to target watersheds with the largest bioavailable phosphorus loads, as only bioavailable phosphorus can cause eutrophication. Immediately bioavailable P is important to immediate growth, however, long-term supply from a large pool (i.e., particulate P or sediment) may be more important in the long-term. Additionally, algal bioassay results can be utilized to more accurately model phytoplankton dynamics (eutrophication) in lakes (DePinto et al. 1986a).

2.2 DREDGED MATERIAL DISPOSAL DYNAMICS

The Toledo Harbor Lake Approach Channel Lake Approach Channel extends from the Maumee River into the western basin of Lake Erie. The USACE has the authority to maintain the navigation channel, which starts near River Mile 7 in the Maumee River and extends approximately 18 miles into Lake Erie, for a total length of approximately 25 miles (see Figure 1). The federal project depth (relative to LWD of 569.2 feet, IGLD85) is 28 feet in the lake approach portion of the channel and 27 feet in the river channel. Ideally, all harbor federal navigation channels would be maintained to authorized and/or optimal depths. However, this is not feasible due to the enormous dredging surface area and limited federal funds. The current approach is to dredge targeted portions of the channel in a given year, with the targeted areas varying each year.

2.2.1 History, Location, and Timing

Toledo Harbor receives more sediment than any other Great Lakes Harbor. Average annual dredging in Toledo Harbor in recent years (2004 through 2008) is 640,000 cubic yards and reflects a large portion of the annual load of sediment from the Maumee River, whose watershed is dominated by agricultural uses. Toledo Harbor dredging alone constitutes 25% of the total dredging in the Great Lakes. Approximately 70% of the material dredged from 2004 to 2008 was disposed of in the open lake. For 2009, approximately 720,000 cubic yards were dredged, and the entire amount went to the open-lake disposal site. The disposal site is a 2-square mile open-lake placement area in the western basin of Lake Erie, just north of the lake approach channel near Lake Mile 11 (see Figure 1).

In the early 1990s, the USACE Buffalo District determined that sediments dredged lake-ward from Lake Mile 5 near Toledo Harbor were suitable for open water placement based on federal guidelines. The federal standard is the least costly dredged material disposal alternative, consistent with sound engineering practices and selected through Clean Water Act Section 404(b)(1) Guidelines (40 CFR 336.1). In order to meet Section 404(b)(1) Guidelines, compliance with applicable state water quality standards (WQSs) is required. While the placement of Toledo Harbor dredged material in the western basin complies with Ohio WQSs, OEPA's current main concern is that the large volume of dredged material discharged into the basin serves to significantly increases basin turbidity through resuspension and redistribution.

Much of the sedimentation in the channel occurs during winter and early spring thaw. In order to maintain navigable depth, dredging is most effectively performed as soon after shoal formation as possible. The Ohio Department of Natural Resources currently requires dredging in the Lake Approach Channel in the western basin to be restricted to between July 1 and March 15 in order to protect warm-water fish species, including walleye (Reine et al. 2007). Dredged sediment transport during and after placement.

2.2.2 Dredged Sediment Transport During and After Placement

Open water placement involves the discharge of dredged material directly to the lake. Harbor dredging is typically accomplished using mechanical clamshell buck dredges, and less frequently using smaller pipeline dredges. Mechanically dredged material may be placed in bottom-dump barges or scows and towed to disposal sites several miles away. Discharged dredged material settles through the water column and deposits on the bottom at the disposal site. The dredged material may remain in a mound at the site or disperse depending on the material's physical properties and the hydrodynamics of the disposal site. Open water placement is used with approximately 32% of Great Lakes dredged material (1993-1996). Open-lake disposal areas in Lake Erie can be dispersive, the degree to which largely depends on depth (Reine et al. 2007).

When dredged material is released from a barge, it descends through the water column as a dense fluid-like jet. Within this well-defined jet, there may be solid blocks or clods of very dense cohesive material. Bokuniewicz and Gordon (1980) conclude that the proportion of material that forms into clods depends on the mechanical properties of the sediment. Large volumes of water are entrained in the descending jet and some material is separated and remains in the water column. The material can be transported out of the immediate site. The jet collapses when it hits the bottom and the portion that does not deposit will move radially outward until sufficient energy is dissipated and the material settles to the bottom.

Truitt (1988) found that the published field data supported the theoretical description of the transport phases in typical open-water disposal operations. The short-term impacts resulting from suspended sediment are confined to a well-defined layer near the bottom. The initial thickness of this layer before spreading and diffusion is related primarily to the depth of water at the site. Above this bottom layer, suspended sediment concentrations are one to two orders of magnitude less than in the bottom layer. The total amount of solids that are dispersed over longer distances is 1 to 5% of the original material disposed.

Reine et al. (2007) found that the total suspended solids (TSS) plumes produced by bucket dredging (15-cubic-yard dredge bucket) of the Toledo Harbor Lake Approach Channel were relatively narrow bands of elevaed concentrations of resuspended sediments, that decayed rapidly over short distances from the source. The spatial extent of the plume measured no more than approximately 600 feet (200 meters) up or down channel from the source with a maximum width of approximately 300 feet (100 meters). The maximum TSS concentration in the immediate vicinity of the excavation exceeded the ambient conditions. Detectable plumes decayed to ambient conditions within 600 feet (200 meters) of the source.

Lohrer and Wetz (2003) examined the impact of a small-scale dredging operation in a salt marsh in South Carolina. Nutrient levels and TSS concentrations before and during dredging activities were compared. Sediments containing soluble nitrogen and phosphorus re-suspend following disturbances such as dredging, generally causing rapid release of nutrients to the water column. The conclusions drawn about the impact of dredging were clearly affected by the temporal and spatial perspective taken. Sosnowski (1984) described three distinct spatial portions of the dredge plume: an initial mixing zone – within 30 feet (10 meters) of the dredge machinery, a secondary zone which extends to 500 feet (150 meters) downstream and a final zone extending 2,300 feet (700 meters) downstream after which suspended material concentrations are indistinguishable from ambient due to gravitational settling and turbulent diffusion.

Monitoring of open-lake dredge material disposal was conducted in 1985 and 1986 (ATEC 1986). This program included field measurements of dissolved oxygen, pH and turbidity, and laboratory analysis of water samples for total phosphorus, dissolved phosphorus, suspended solids, and dissolved solids. During each placement action, dissolved oxygen increased at the placement area, but showed a decrease below ambient levels away from the placement area. This pattern was attributed to entrainment of air within the mass of dredged material dropped from the bottom of the split-hull dredge. The study found that as the dredged material falls to the bottom, it disperses creating a wave of sediment and bottom water which spreads out across the lake bottom. Fine materials rise off the bottom on the turbulence and exert their oxygen demand at a distance away from the placement area. Turbidity measurements conducted at the open-lake area immediately after the placement operation showed a dramatic decrease in water clarity. Water clarity then returned to pre-placement conditions within 2 hours. Samples collected before placement and 2 hours after were analyzed for dissolved phosphorus and total phosphorus. Based on mean concentration and individual samples, the results showed no apparent difference between the before and after samples for either total or dissolved phosphorus.
A 1988 study for the USACE (1993) included collecting surface sediment composite grab samples from the authorized federal navigation channels of Toledo Harbor, as well as an open-lake discharge site (site used until 1988). The characteristics of the dredged material were compared to the sediment found at the open-lake discharge site. Overall, heavy metal and nutrient contamination found to be highest in the River Channel sediment samples, particularly from the lower reach. The Toledo Harbor Lake Approach Channel, open-lake discharge site and upper River Channel sediment samples showed relatively lower inorganic contamination in comparison to the lower reach of the river. With few exceptions, the sediment samples were comprised of about 80 to 98 percent silts and clays, with the remainder coarse-grain material. The open-lake discharge site sediment samples consisted of an average of 96.8 percent silts and clays, with the remainder coarse-grain material. Elutriate testing was

conducted to simulate and predict inorganic contaminant releases from the sediments during dredging and dredged material open water discharge. Phosphorus releases were nondetectable from all of the Lake Approach Channel sediment samples, and nondetectable or low in the Upper River Channel samples. When compared to elutriate data on sediment samples from the Lake Approach Channel and open-lake discharge site, the River Channel sediment samples generally showed higher releases for most of the parameters measured.

Sweeney et al. (1975) collected sediment samples from within a USACE open lake disposal site located approximately 7.5 miles north of Cleveland, Ohio. The dredge disposal area received dredged material from Cleveland Harbor and the Cuyahoga River between approximately 1925 and 1968. The concentrations of nutrients (phosphorus and nitrogen), toxicants (heavy metals), and pollutants (as indicated by chlorine demand, BOD, COD and oils and greases measurements) in the surface sediments generally were higher in the disposal site than in the surrounding sediments.

Jones and Lee (1981) conducted field studies during 20 disposal operations in nine water bodies. Monitoring was conducted to determine the nutrient release to the water column. Based on the results of the study they found that the maximum sediment soluble orthophosphate released was less than 0.1 percent of the total P content of the sediment. In general, dredged sediment associated nutrients will rarely have an adverse effect on eutrophication-related water quality at the disposal site mainly because the events are short-lived, there is typically rapid dilution of the disposed of sediment, and relative to the dilution the nutrient release is small.

The Ohio Lake Erie Phosphorus Task Force (OEPA 2010) observed that the phosphorus concentrations in western basin sediments are similar to concentrations in agricultural soils. Aluminum concentrations in the sediment may be high enough to effectively tie up most of the phosphorus, keeping its bioavailability low. However, they found that the constant mixing of the extremely fine clay sediment particles by wind and waves in the shallow western basin may increase the opportunity for phosphorus to dissolve in the water column. The sediments have a fairly high iron concentration and much of the phosphorus on the surface sediments is bound with ferric iron. When the bottom water oxygen concentration drops below 2 ppm, iron reduction occurs and phosphorus is released into the water column.

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3. NEXT STEPS

The information derived from this literature review will be applied to the next stages of this project: the development of the conceptual site model, which will link together the various pathways and factors that lead to HAB development; and in the development of the sampling and analysis plan. Furthermore, the information outlines in this review that will guide computer model simulations which will be performed to develop a clearer picture of the contributions of dredge material to the formation of HABs. Ultimately, the results of the complete study will be documented in the final report to help water quality managers understand the impacts of dredge material disposal on the proliferation of HABs in western Lake Erie.

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APPENDIX A
Complete Reference List

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APPENDIX B
Reference List with Abstracts

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APPENDIX B

Aqua Tech Environmental Consultants (ATEC). 1986. *Monitoring of Open-Lake Disposal Program at Toledo Harbor, Toledo, Ohio*. Technical report prepared for the USACE Buffalo District.

Auer,M.T., Tomlinson,L.M., Higgins,S.N., Malkin,S.Y., Howell,E.T., Bootsma,H.A. 2010. Great Lakes Cladophora in the 21st century: same algae-different ecosystem. *J Great Lakes Res.* Vol. 36. pp. 248-255.
Abstract: Nuisance growth of the attached, green alga Cladophora was considered to have been abated by phosphorus management programs mandated under the Great Lakes Water Quality Agreement. The apparent resurgence of nuisance growth in Lakes Erie, Michigan and Ontario has been linked conceptually to ecosystem alterations engineered by invasive dreissenid mussels (Dreissena polymorpha and Dreissena bugensis). Here, we apply contemporary modeling tools and historical water quality data sets in quantifying the impact of long-term changes in phosphorus loading and dreissenid-mediated changes in water clarity on the distribution and production of Cladophora. It is concluded that reductions in phosphorus loading in the predreissenid period achieved the desired effect, as model simulations were consistent with the biomass declines reported from the early 1970s to the early 1980s. These declines were, however, largely offset by dreisseniddriven changes in water clarity that extended the depth of colonization by Cladophora, increasing total production. We were not able to isolate and quantify the significance of dreissenid mediation of phosphorus cycling using the historical database. Phosphorus management remains the appropriate mechanism for reducing nuisance levels of Cladophora growth. The development of action plans will require an improved understanding of nearshore phosphorus dynamics such as might be obtained through regular monitoring of soluble reactive phosphorus levels, internal phosphorus content and Cladophora biomass in impacted nearshore regions of the Great Lakes.

Baker,D. 2010. Trends in Bioavailable Phosphorus Loading to Lake Erie. pp. 1-43. National Center for Water Quality Research, Heidelberg University, Tiffin, Ohio.
Abstract: Not all of the phosphorus entering Lake Erie from its tributaries is readily available to support algal growth. The portion of the phosphorus that does support algal growth is referred to as bioavailable phosphorus. In this study, trends in bioavailable phosphorus loading to Lake Erie from the Maumee, Sandusky and Cuyahoga rivers have been assessed by (1) measuring the current proportions of particulate and dissolved phosphorus that are bioavailable, (2) comparing current bioavailability with similar studies done in 1982, and (3) adjusting historical trends in total phosphorus loads to trends in bioavailable phosphorus loading. The results indicate that for the major agricultural tributaries dissolved bioavailable phosphorus, after decreasing between the mid-1970 to the mid-1990, is now at record high levels.

Bioavailable particulate phosphorus has remained constant or increased slightly. The net effect is that bioavailable phosphorus loading from agricultural tributaries is now a record high levels, in spite of ~20 years of effort to reduce agricultural phosphorus loading to Lake Erie. Most of the increase in bioavailable phosphorus loading is for dissolved phosphorus. In contrast with the agricultural rivers, bioavailable phosphorus loading from the Cuyahoga River has decreased substantially.

Baker,D.B. 2011. The Sources and Transport of Bioavailable Phosphorus to Lake Erie Final Report: Part 3 - Application of Analytical Methods for Waters Directly to Soils. pp. 1-38. National Center for Water Quality Research, Heidelberg University, Tiffin, Ohio.
Abstract: Methods to analyze phosphorus in water samples differ greatly from the methods used to analyze phosphorus in soils. Water methods are intended to represent the concentrations of phosphorus as a nutrient or pollutant in waters from many different sources while soil methods are intended to correlate with crop response to fertilizer additions to soil. An understanding of the relationships between these two sets of methods is particularly important in the study of phosphorus runoff from cropland. In this study, we have extended the methods used for waters directly to soils of known phosphorus soil test levels by applying the water methods to dilute aqueous soil suspensions (DASS). Our method involves adding 1 g soil to a liter of distilled water and placing the suspension on reciprocating shaker for 17 hours, followed by analysis as though the DASS sample was a river sample during a runoff event.

Baker,D.B. 2011. The Sources and Transport of Bioavailable Phosphorus to Lake Erie Final Report: Part 1 - Trends in Bioavailable Phosphorus Loading at River Monitoring Stations. pp. 1-30. National Center for Water Quality Research, Heidelberg University, Tiffin, Ohio.

Baker,D.B. 2011. The Sources and Transport of Bioavailable Phosphorus to Lake Erie Final Report Part 5: Quality Control. pp. 1-14. National Center for Water Quality Research, Heidelberg University, Tiffin, Ohio.

Baker,D.B. 2011. The Sources and Transport of Bioavailable Phosphorus to Lake Erie Final Report: Part 4 - Bioavailabiltiy of Phosphorus in Contemporary Sewage Treatment Plant Effluents. pp. 1-18. National Center for Water Quality Research, Heidelberg University, Tiffin, Ohio.
Abstract: Within the Lake Erie Basin, municipal sewage treatment plants have implemented phosphorus removal programs that have greatly reduced point source inputs (Figure 2). This study looked at the forms of phosphorus in the effluents currently being discharged from these plants, as reflected by studies of three sewage treatment plants in the Cleveland, OH area.
The average concentrations of total phosphorus in the effluents of the three plants all fell below 1 mg/L, as required by the current NPDES permits for the plants. Dissolved reactive phosphorus, which is the most bioavailable form of

phosphorus in the effluents, did vary among the plants from an average of 0.548 in the Westerly plant to 0.136 in the Easterly plant (Table 4). In general, as the concentration in the effluent decreased, the percentage of DRP in the effluent also decreased (Figure 4).
In conclusion, in situations where the bioavailability of phosphorus in point source effluents is a potential issue in phosphorus management, each plant should be examined to determine the characteristics of its effluent. It should not be assumed that all of the effluent from all point sources is 100% dissolved reactive phosphorus or 100% bioavailable.

Baker,D.B. 2011. The Sources and Transport of Bioavailable Phosphorus to Lake Erie Final Report - Overview. pp. 1-16. National Center for Water Quality Research, Heidelberg University, Tiffin, Ohio.
Abstract: This grant was one of seven related grants supported by the U.S. EPA's Great Lakes National Program Office and the Ohio Lake Erie Protection Fund. These grants were an outgrowth of the deliberations of the Ohio Lake Erie Phosphorus Task Force (Ohio EPA, 2010). A synthesis team, led by Dr. Jeff Reutter of The Ohio State University and Dr. Jan Ciborowski of the University of Windsor, coordinated initial discussions leading to the development of an integrated set of grant proposals. They organized meetings where those directly involved in the research efforts presented their results for review and discussion. They subsequently involved the project directors in the production of a summary document that included an integration of the results from the seven grants (Reutter, et al., 2011).

Baker,D.B. 2011. The Sources and Transport of Bioavailable Phosphorus to Lake Erie Final Report: Part 2 - Lagrangian Analysis of Bioavailalbe Phosphorus Transport from Tributary Stations into Nearshore Zones. pp. 1-74. National Center for Water Quality Research, Heidelberg University, Tiffin, Ohio.

Barbiero,R.P., Tuchman,M.L. 2004. Long-term Dreissenid Impacts on Water Clarity in Lake Erie. *J.Great Lakes Res.* Vol. 30 (4). pp. 557-565.
Abstract: Since shortly after their introduction, dreissenid mussels have been thought to have improved water clarity in Lake Erie, particularly in the western basin. However, long-term monitoring (1982-2004) has found no evidence of persistent, basin-wide increases in water clarity in either the western or the central basin of Lake Erie since the Dreissena invasion. In fact, spring water clarity in both of those basins has exhibited statistically significant declines in the post-dreissenid period. In contrast, chlorophyll a levels in the western basin have declined by about 50% since the Dreissena invasion during both spring and summer. The discrepancy in the responses of water clarity and chlorophyll a is probably a consequence of both the large sediment loads entering the western basin and resuspension of unassimilated non-algal particulates. In the eastern basin, spring transparency has increased substantially and turbidity has decreased since Dreissena colonization, in spite of the much greater depth of this basin. This is probably due to higher mussel densities and the lack of major sources of turbidity in that basin. Summer

turbidity has also decreased markedly in the eastern basin, although thermal stratification during this period would probably preclude direct filtration effects. Instead, we hypothesize that reductions in whiting events due to calcium uptake by dreissenids have contributed to the summer decreases in turbidity seen in the eastern basin.

Bierman,V.J., Kaur,J., DePinto,J.V., Feist,T.J., Dilks,D.W. 2005. Modeling the Role of Zebra Mussels in the Proliferation of Blue-green Algae in Saginaw Bay, Lake Huron. *J.Great Lakes Res.* Vol. 31. pp. 32-55.
Abstract: Between 1991 and 1993, Saginaw Bay experienced an invasion by zebra mussels, Dreissena polymorpha, which caused a significant perturbation to the ecosystem. Blooms of Microcystis, a toxin-producing blue-green alga, became re-established in the bay after the zebra mussel invasion. Microcystis blooms had all but been eliminated in the early 1980s with controls on external phosphorus loadings, but have re-occurred in the bay most summers since 1992. An apparent paradox is that these recent Microcystis blooms have not been accompanied by increases in external phosphorus loadings. An ecosystem model was used to investigate whether the re-occurrence of Microcystis could be due to changes caused by zebra mussels that impacted phytoplankton community structure and/or internal phosphorus dynamics. The model was first used to establish baseline conditions in Saginaw Bay for 1991, before zebra mussels significantly impacted the system. The baseline model was then used to investigate: (1) the composite impacts of zebra mussels with average 1991-1995 densities; (2) sensitivity to changes in zebra mussel densities and external phosphorus loadings; and (3) three hypotheses on potential causative factors for proliferation of blue-green algae. Under the model assumptions, selective rejection of blue-green algae by zebra mussels appears to be a necessary factor in the enhancement of blue-green production in the presence of zebra mussels. Enhancement also appears to depend on the increased sediment-water phosphorus flux associated with the presence of zebra mussels, the magnitude of zebra mussel densities, and the distribution of zebra mussel densities among different age groups.

Binding,C.E., Greenberg,T.A., Bukata,R.P. 2012. An analysis of MODIS-derived algal and mineral turbidity in Lake Erie. *Journal of Great Lakes Research.* Vol. 38. pp. 107-116.
Abstract: Satellite-derived estimates of chlorophyll concentrations based on colour ratio algorithms traditionally fail in turbid waters such as those found in Lake Erie, resulting in chlorophyll concentrations often orders of magnitude in error and spatial distributions mirroring that of known suspended sediment distributions. Methods are presented here that were used to simultaneously extract algal and mineral suspended particulate matter for Lake Erie from the red and near-infrared bands of NASA's MODIS-Aqua sensor. Results produced spatially and temporally distinct seasonal cycles in agreement with bio-geo-physical processes on the lake. Derived imagery was used to monitor seasonal cycles of both algal and mineral particulate matter on

the lake and determine areas of persistently elevated concentrations that may highlight regions of potential water quality concern.

Bokuniewicz,H.J., Gordon,R.B. 1980. Deposition of Dredged Sediment at Open Water Sites. *Estuarlne and Coastal Marine Science.* Vol. 10. pp. 289-303.
Abstract: Silt-clay dredge spoil released at the surface of near-shore waters is deposited on the sea floor within a few hundred meters of its impact point. Only a few percent of the spoil is lost into the water column in most disposal operations. Surveys of the deposits formed by the controlled release of dredged sediment show some to be compact (presenting minimum surface area to the ambient water) and others dispersed (extending over a large area as a thin layer). The principal factor controlling the degree of dispersion during placement is the cohesion of the spoil. Disaggregated spoil is deposited from a turbidity current in a thin annulus, aggregated or cohesive spoil, in a compact pile of discrete blocks or 'clods'. Formation of a compact deposit of spoil requires that the clods survive impact with the bottom; their kinetic energy must be absorbed in plastic deformation without clod rupture. The impact speed and the kinetic energy density are calculated for free fall of clods in water. Laboratory measurements are made of the deformation-rate dependence of the mechanical work done to rupture clods of silt-clay marine sediment in impact. These show that plastic deformation will dissipate the impact energy for clods less than 0"8 m in diameter; larger clods will break up upon impact. Field observations confirm the presence of clods smaller than this in deposits of cohesive spoil. The disposal processes responsible for the formation of spoil deposits are insensitive to the water depth and current speed. A compact spoil deposit is most likely to result when cohesive sediment is dredged with a clam shell bucket and released in small quantities at low speed over a soft-bottomed disposal area.

Bonnet,M.P., Poulin,M. 2002. Numerical modelling of the planktonic succession in a nutrient-rich reservoir: environmental and physiological factors leading to Microcystis aeruginosa dominance. *Ecological Modelling.* Vol. 156. pp. 93-112.
Abstract: The purpose of this study is to shed light on some important factors that allow the strong development of one cyanobacteria, Microcystis aeruginosa , in a man-made lake (Villerest, Loire, France). A numerical 1D-vertical model of the phytoplanktonic succession has been developed. It allows us to simulate the temporal and spatial variations in concentration of the main phytoplanktonic species in relation to the vertical mixing processes in the reservoir. Our results show that the buoyancy regulation of M. aeruginosa is a major factor in its dominance in the lake, at least when the water column is well stratified.

Bosch,N.S., Allan,J.D., Dolan,D.M., Han,H., Richards,R.P. 2011. Application of the Soil and Water Assessment Tool for six watersheds of Lake Erie: Model parameterization and calibration. *J Great Lakes Res.* Vol. 37. pp. 263-271.
Abstract: The Soil and Water Assessment Tool (SWAT), a physically-based

watershed-scale model, holds promise as a means to predict tributary sediment and nutrient loads to the Laurentian Great Lakes. In the present study, model performance is compared across six watersheds draining into Lake Erie to determine the applicability of SWAT to watersheds of differing characteristics. After initial model parameterization, the Huron, Raisin, Maumee, Sandusky, Cuyahoga, and Grand SWAT models were calibrated (1998-2001) and confirmed, or validated (2002-2005), individually for stream water discharge, sediment loads, and nutrient loads (total P, soluble reactive P, total N, and nitrate) based on available datasets. SWAT effectively predicted hydrology and sediments across a range of watershed characteristics. SWAT estimation of nutrient loads was weaker although still satisfactory at least two-thirds of the time across all nutrient parameters and watersheds. SWAT model performance was most satisfactory in agricultural and forested watersheds, and was less so in urbanized settings. Model performance was influenced by the availability of observational data with high sampling frequency and long duration for calibration and confirmation evaluation. In some instances, it appeared that parameter adjustments that improved calibration of hydrology negatively affected subsequent sediment and nutrient calibration, suggesting trade-offs in calibrating for hydrologic vs. water quality model performance. Despite these considerations, SWAT accurately predicted average stream discharge, sediment loads, and nutrient loads for the Raisin, Maumee, Sandusky, and Grand watersheds such that future use of these SWAT models for various scenario testing is reasonable and warranted.

Bridgeman,T.B., Penamon,W.A. 2010. Lyngbya wollei in western Lake Erie. *Journal of Great Lakes Research.* Vol. 36. pp. 167-171.
Abstract: We report on the emergence of the potentially toxic filamentous cyanobacterium, Lyngbya wollei as a nuisance species in western Lake Erie. The fi rst indication of heavy L. wollei growth along the lake bottom occurred in September 2006, when a storm deposited large mats of L. wollei in coves along the south shore of Maumee Bay. These mats remained intact over winter and new growth was observed along the margins in April 2007. Mats ranged in thickness from 0.2 to 1.2 m and we estimated that one 100-m stretch of shoreline along the southern shore of Maumee Bay was covered with approximately 200 metric tons of L. wollei. Nearshore surveys conducted in July 2008 revealed greatest benthic L. wollei biomass (591 g/m2±361 g/m2 fresh weight) in Maumee Bay at depth contours between 1.5 and 3.5 m corresponding to benthic irradiance of approximately 4.0-0.05% of surface irradiance and sand/crushed dreissenid mussel shell-type substrate. A shoreline survey indicated a generally decreasing prevalence of shoreline L. wollei mats with distance from Maumee Bay. Surveys of nearshore benthic areas outside of Maumee Bay revealed substantial L. wollei bedsnorth along the Michigan shoreline, but very little L wollei growth to the east along the Ohio shoreline.

Bridgeman,T.B., Chaffin,J.D., Kane,D.D., Conroy,J.D., Panek,S.E., Armenio,P.M. 2012. From River to Lake: Phosphorus partitioning and algal community

compositional changes in Western Lake Erie. *Journal of Great Lakes Research.* Vol. 38. pp. 90-97.
Abstract: TheMaumee River is an important source of phosphorus (P) loading towestern Lake Erie and potentially a source of Microcystis seed colonies contributing to the development of harmful algal blooms in the lake.Herein,we quantified P forms and size fractions, and phytoplankton community composition in the river–lake coupled ecosystem before (June), during (August), and after (September) a large Microcystis bloom in 2009. Additionally, we determined the distribution and density of a newly emergent cyanobacterium, Lyngbya wollei, nearMaumee Bay to estimate potential P sequestration. In June, dissolved organic phosphorus (DOP) was the most abundant P form whereas particulate P (partP) was most abundant in August and September. Green algae dominated in June (44% and 60% of total chlorophyll in river and lake, respectively) with substantial Microcystis (17%) present only in the river. Conversely, in August, Microcystis declined in the river (3%) but dominated (32%) the lake. Lake phytoplankton sequestered b6% of water column P even during peak Microcystis blooms; in all lake samples b112 ìm non-algal particles dominated partP. Lyngbya density averaged 19.4 g dry wt/m2, with average Lyngbya P content of 15% (to 75% maximum) of water column P. The presence of Microcystis in the river before appearing in the lake indicates that the river is a potential source of Microcystis seed colonies for later lake blooms, that DOP is an important component of early summer total P, and that L. wollei blooms have the potential to increase P retention in nearshore areas.

Brunberg,A.-K., Blomqvist,P. 2003. Recruitment of Microcystic (*Cyanophyceae*) From Lake Sediments: The Importance of Littoral Inocula. *J.Phycol.* Vol. 39. pp. 58-63.
Abstract: Recruitment of *Microcystic* from sediments to the water column was investigated in shallow (1–2 m) and deep (6–7 m) areas of Lake Limmaren, central Sweden. Recruitment traps attached to the bottom were sampled on a weekly basis throughout the summer season (June–September). A comparison between the two sites showed that the recruitment from the shallow bay was significantly higher over the entire season for all three *Microcystis* species present in the lake. Maximum rates of recruitment were found in August, when 2.3 X 10^5 colonies m^{-2} day^{-1} left the sediments of the shallow area. Calculated over the entire summer, *Microcystis* colonies corresponding to 50% of the initial abundance in the surface sediments were recruited in the shallow bay, whereas recruitment from the deep area was only 8% of the sediment colonies. From these results we conclude that shallow areas, which to a large extent have been overlooked in studies of recruitment of phytoplankton, may be crucial to the dynamics of these organisms by playing an important role as inoculation sites for pelagic populations.

Bukaveckas,P.A., Barry,L.E., Beckwith,M., David,V., Lederer,V. 2011. Factors Determining the Location of the Chlorophyll Maximum and the Fate of Algal Production within the Tidal Freshwater James River. *Estuaries and Coasts.*

Vol. 34. pp. 569-582.
Abstract: Longitudinal variation in factors affecting phytoplankton production were analyzed to better understand the mechanisms that cause the formation of a chlorophyll maximum within the tidal freshwater James River. Phytoplankton production was two- to threefold higher in the region where persistent elevated chlorophyll concentrations occurred. Near this site, the morphology of the James transitions from a narrow, deep channel to a broad expanse with shallow areas adjoining the main channel. Shallower depths resulted in greater average irradiance within the water column and suggest that release from light limitation was the principal factor accounting for the location of the chlorophyll maximum. Grazing rates were low indicating that little of the algal production was directly consumed by zooplankton. Low exploitation by zooplankton was attributed to poor food quality due to high concentrations of non-algal particulate matter and potential presence of cyanobacteria. Metabolism data suggest that two thirds of net primary production was respired in the vicinity of the chlorophyll maximum and one third was exported via fluvial and tidal advection. Comparison of water column and ecosystem metabolism indicates that the bulk of respiration occurred within the sediments and that sedimentation was the dominant loss process for phytoplankton.

Burniston,D., McCrea,R., Klawunn,P., Ellison,R., Thompson,A., Bruxer,J. 2012. Detroit River Phosphorus Loading Determination. pp. 1-54. Environment Canada.
Abstract: In response to requests from the Lake Erie LaMP, Environment Canada undertook a nutrient study in the lower Detroit River. The primary goal of the Detroit River Phosphorus Loading Application study was to estimate phosphorus loads to Lake Erie. During the period of August to November, 2007, ISCO programmable water samplers were run at two locations on the Lower Detroit River to collect water samples automatically every two hours, 24-hours a day, in order to provide a better estimate of phosphorus loads to Lake Erie. Sub samples from each ISCO sample collected on a common day were combined to comprise a 24-hour (daily) composite sample. These samples were subsequently analyzed to determine total phosphorus (TP) concentrations. Grab samples were also taken periodically at these and several other locations along the Detroit River. The grab samples were analyzed for TP and total soluble reactive phosphorus (SRP). It was intended that relationships would first be developed between the measured TP concentrations from grab samples taken at the ISCO station(s) and grab samples taken at other locations. Using these relationships, the 24-hour (daily) composite data generated from the ISCO samplers could then be related to the grab sample locations to estimate near-continuous phosphorus loading concentrations. An existing two-dimensional hydrodynamic model of the St. Clair-Detroit River system was modifed specifcally for this study. It was used to estimate flow distributions across each channel and at each sampling location, so that the total loading of phosphorus entering Lake Erie over the study period could be estimated.

Carey,C.C., Ibelings,B.W., Hoffmann,E.P., Hamilton,D.P., Brookes,J.D. 2012. Eco-physiological adaptations that favour freshwater cyanobacteria in a changing climate. *SciVerse ScienceDirect.* Vol. 46. pp. 1394-1407.
Abstract: Climate change scenarios predict that rivers, lakes, and reservoirs will experience increased temperatures, more intense and longer periods of thermal stratification, modified hydrology, and altered nutrient loading. These environmental drivers will have substantial effects on freshwater phytoplankton species composition and biomass, potentially favouring cyanobacteria over other phytoplankton. In this Review, we examine how several cyanobacterial eco-physiological traits, specifically, the ability to grow in warmer temperatures; buoyancy; high affinity for, and ability to store, phosphorus; nitrogen-fixation; akinete production; and efficient light harvesting, vary amongst cyanobacteria genera and may enable them to dominate in future climate scenarios. We predict that spatial variation in climate change will interact with physiological variation in cyanobacteria to create differences in the dominant cyanobacterial taxa among regions. Finally, we suggest that physiological traits specific to different cyanobacterial taxa may favour certain taxa over others in different regions, but overall, cyanobacteria as a group are likely to increase in most regions in the future.

Chaffin, J.D. 2009. Physiological Ecology of *Microcystis* Blooms in Turbid Waters of Western Lake Erie. University of Toledo Masters Thesis.
Abstract:*Microcystis* blooms are annual occurrences in western Lake Erie. Field measurements of *Microcystis* biovolumes from 2002- 2008 show that blooms are most dense in waters adjacent to the Maumee Bay. This suggests that conditions within these waters support rapid *Microcystis* growth. Field measurements and a laboratory experiment showed that the high turbidity of the bay and adjacent waters alleviated high- light stress which results in less photo-inhibition, while *Microcystis* in less turbid water had more photo-inhibition. Damage occurs to *Microcystis* during a surface bloom as a result of prolonged time in high-intensity light. Further, *Microcystis* from nearshore water had higher protein content then that of offshore which indicates greater cellular health. This is likely a function of turbidity and high soluble nutrients in turbid waters. Therefore, reduced sediment loading would presumably increase growth stress for *Microcystis* and would lessen the magnitude of blooms seen in western Lake Erie.

Chaffin,J.D., Kane,D.D. 2010. Burrowing mayfly (Ephemeroptera: Ephemeridae: Hexagenia spp.) bioturbation and bioirrigation: A source of internal phosphorus loading in Lake Erie. *Journal of Great Lakes Research.* Vol. 36. pp. 57-63.
Abstract: Traditional lake eutrophication models predict lower phosphorus concentrations with decreased external loads. However, in lakes where decreased external phosphorus loads are accompanied by increasing phosphorus concentrations, a seeming "trophic paradox" exists. Western Lake Erie is an example of such a paradox. Internal phosphorus loads may help explain this paradox. We examined bioturbation and bioirrigation created from burrowing mayfly, Hexagenia spp., as a possible source of internal

phosphorus loading. Phosphorus concentrations of experimental microcosms containing lake sediments, filtered lake water, and nymphs (417/m2) collected from western Lake Erie were compared to control microcosms containing sediments and lake water over a 7-day period. Phosphorus concentrations in microcosms containing Hexagenia were significantly greater than microcosms without nymphs. Further, we estimate the soluble reactive phosphorus flux from the sediments due to Hexagenia is 1.03 mg/m2/day. Thus, Hexagenia are a source of internal phosphorus loading. High densities of Hexagenia nymphs in western Lake Erie may help explain the "trophic paradox." Furthermore, Hexagenia may be a neglected source of internal phosphorus loading in any lake in which they are abundant. Future studies of phosphorus dynamics in lakes with Hexagenia must account for the ability of these organisms to increase lake internal phosphorus loading.

Chaffin,J.D., Bridgeman,T.B., Heckathorn,S.A., Mishra,S. 2011. Assessment of Microcystis growth rate potential and nutrient status across a trophic gradient in western Lake Erie. *Journal of Great Lakes Research.* Vol. 37. pp. 92-100.
Abstract: Plankton tow samples collected from 2002 through 2009 indicate that Microcystis biovolume in western Lake Erie is often most dense in transition zone (TZ) waters between Maumee Bay and the center of the western basin. TZ waters are generally high in nutrients and turbidity, and concentrations of each decrease with distance from Maumee Bay. High Microcystis biovolume in the TZ suggests the possibility that the conditions in these waters support a greater Microcystis growth rate relative to the open lake. To test this hypothesis, during the 2008 bloom, Microcystis was collected from western Lake Erie for measurements of total protein content (TPC) as an indicator of growth rate potential and cellular nutrient content to indicate nutrient deficiencies. TPC results indicate that Microcystis in the TZ had a higher potential growth rate compared to offshore waters. TPC values in Maumee Bay were intermediate but not significantly different from the TZ and offshore. Nitrogen content of Microcystis remained high over the summer at all sites, despite very low dissolved nitrate concentrations and low total nitrogen-to-total phosphorus ratio in late summer in the lake. Ammonium level in the lake was constant during the summer, and likely provided the nitrogen source for Microcystis. Cellular phosphorus content varied between site and sample date suggesting that Microcystis was moderately phosphorus deficient. Quotas of micronutrient indicated that Microcystis was not deficient of micronutrients. Results of this study suggest the waters in and adjacent to Maumee Bay provide more favorable growth conditions for Microcystis than offshore waters.

Chapra,S.C., Dolan,D.M. 2012. Great Lakes total phosphorus revisited: 2. Mass balance modeling. *J Great Lakes Res.* Vol. 38 (4). pp. 741-754.
Abstract: Mass balance models are used to simulate chloride and total phosphorus (TP) trends from 1800 to the present for the North American Great Lakes. The chloride mass balance is employed to estimate turbulent eddy diffusion between model segments. Total phosphorus (TP)

concentrations are then simulated based on estimated historical and measured TP loading time series. Up until about 1990, simulation results for all parts of the system generally conform to measured TP concentrations and exhibit significant improvement due primarily to load reductions from the Great Lakes Water Quality Agreement. After 1990, the model simulations diverge from observed data for the offshore waters of all the lakes except Lake Superior with the observations suggesting a greater improvement than predicted by the model. The largest divergence occurs in Lake Ontario where the model predicts that load reductions should bring the lake to oligo-mesotrophic levels, whereas the data indicate that it is solidly oligotrophic and seems to be approaching an ultra-oligotrophic state. Less dramatic divergences also occur in the offshore waters of lakes Michigan, Huron and Erie. In order to simulate these outcomes, the model's apparent settling velocity, which parameterizes the rate that total phosphorus is permanently lost to the lake's deep sediments, must be increased significantly after 1990. This result provides circumstantial support for the hypothesis that Dreissenid mussels have enhanced the Great Lakes phosphorus assimilation capacity. Finally, all interlake mass transfers of TP via connecting channels have dropped since phosphorus control measures were implemented beginning in the mid-1970s.

Charlton,M.N., Hiriart-Baer,V., Howell,T., Marvin,C., Vincent,J., Watson,S., Ciborowski,J., Bertram,P. 2009. Status of Nutrients in the Lake Erie Basin. pp. 1-42. Lake Erie Nutrient Science Task Group.
Abstract: Recent algal problems in Lake Erie prompted a brief review of stimulatory nutrients in the lake. Changes in the lake's biological components seem to render the nutrient controls of decades past insuf?cient for today's conditions in some areas. Offshore algal problems are most prevalent in the western basin. There is a west to central to east basin gradient of improving water quality, consistent with the presence of the largest total phosphorus loads in the west basin. Phosphorus continues to be the limiting nutrient. There is enough nitrogen present that it is not usually limiting algae, although almost any nutrient can be shown to appear limiting to algae on a given day. Nitrogen warrants watching as the ecological implications of ongoing increases are unknown. The relationship between phosphorus and algae as indicated by chlorophyll remains strong in offshore waters. Nearshore, there is a serious problem with attached ?lamentous algae in the east basin and parts of the west basin. Algal problems are usually associated with elevated nutrient supplies but Dreissenid mussels seem mostly responsible for attached algae. At the same time, more research is needed to determine whether whole lake and/or shoreline source control, if possible, would be effective at ameliorating the problem.

Coles,J.F. 1994. The Effects of Themperature And Light On Four Species Of Phytoplankton From The Tidal Freshwater Potomac River. pp. 1-138. George Mason University.
Abstract: Frequently throughout the 1980's, seasonal blooms of

cyanobacteria (blue-green algae) occurred at nuisance levels in the tidal freshwater Potomac River near Washington, D.C. Microcystis aeruginosa was responsible for the most severe blooms. This species, along with two other cyanobacteria, Merismopedia tennuissima and Oscillatoria sp., and the diatom Melosira granulata, were isolated from Potomac River water samples and grown in culture using standard nutrientenriched algal growth media. Using the 14C tracer technique, the response of photosynthetic rate to light intensity was quantified at 15, 20, 25, and 30 °C. The cyanobacteria exhibited a positive correlation between pB,,(maximum rate of photosynthesis) and temperature throughout the temperature range, whereas PB max for Melosira did not increase with temperature beyond 20 °C. Among the cyanobacteria, the light levels at which photoinhibition occurred increased as the algae were incubated at higher temperatures. The diatom Melosira exhibited no photoinhibition. Exponential phase growth rates of the four species were also determined at each of the four temperatures by measuring Chl a concentration over time. Microcystis growth showed the greatest temperature dependency, with a significant (p=.05) increase in rate over each 5°C temperature increase. Chl a content per cell increased significantly in Microcystis as the temperature increased from 15 to 30 °C and in Melosira as the temparature increased from 15 to 25 °C. This trend was not observed in Merismopedia or Oscillatoria. Photoinhibition in the cyanobacteria was presumably due to acclimation to low light intensity during the growth phase of the cultures. In previous photosynthesis studies where phytoplankton samples dominated by cyanobacteria were collected directly from the Potomac River, photoinhibition had not been observed. However, even at a low light. intensity,the overall higher photosynthetic and growth rates of the cyanobacteria at warmer temperatures when compared to Melosira is consistent with the occurrence of cyanobacteria in the Potomac River during the sumnter months. Carbon assimilation rates for each species were compared between the values obtained from the photosynthesis experiments and the growth experiments. Although the growth rates were measured as ugChla.uChla. hr-1, these rates were converted to ugC-uChla-hr-1 by assuming a C:Chl ratio of 30.Using this growth rate conversion produced carbon assimilation rates which were not comparable with those determined from the photosynthesis experiments in the cases of Microcystis and Melosira. However, by taking into account the temperature dependent cellular Chl a content seen in these two species and revising the C:Chl ratios at each temperature accordingly, the carbon assimilation rates estimated from the growth experiments were in much closer agreement with those from the photosynthesis experiments.

Congress 1972. The Clean Water Act Section 404(B)(1). 40 CFR, SECTION 230.

Conroy,J.D., Kane,D.D., Dolan,D.M., Edwards,W.J., Charlton,M.N., Culver,D.A. 2012. Temporal Trends in Lake Erie Plankton Biomass: Roles of External Phosphorus Loading and Dreissenid Mussels. *J.Great Lakes Res.* Vol. 31. pp. 89-110.
Abstract: We compare the results of lakewide plankton studies conducted

during 1996-2002 with data reported in the literature from previous years to evaluate the effectiveness of continued nutrient control, the relationship between external phosphorus loading and plankton abundance, and the many predicted outcomes of the dreissenid invasion. We found that although recent external annual phosphorus loading has not changed since reaching mandated target levels in the early- to mid-1980s, phytoplankton communities have. Total phytoplankton biomass, measured through enumeration and size-frequency distributions, has increased since minima were observed in 1996 or 1997, with summer (July-September) biomasses generally greater than before the dreissenid establishment in the late 1980s. Cyanobacteria biomass also increased during summer in all basins after the dreissenid invasion. In contrast, chlorophyll a concentration has decreased in all basins during both spring and summer. However chlorophyll a concentration was poorly correlated with total phytoplankton biomass. Relative to the mid-1980s, crustacean zooplankton biomass during the years 1996-2002 increased in the western basin during spring and summer, increased in the central basin during spring but remained the same during summer, and decreased to low levels in the eastern basin. Several of these observations are consistent with predictions made by previous researchers on the effects of reduced total external phosphorus loading and the stimulatory or inhibitory effects of dreissenid mussels. However, several were not. Results from this study, particularly the inconsistencies with tested predictions, highlight the need for further research into the factors that regulate plankton community dynamics in Lake Erie.

Culver,D.A., Conroy,J.D. 2007. Impact of Dreissenid Mussel Population Changes on Lake Erie Nutrient Dynamics. pp. 1-18. Department of Evolution, Ecology, and Organismal Biology - The Ohio State University, Columbus, Ohio.
Abstract: Fully understanding the importance of zebra and quagga mussels' effects on internal nutrient (especially nitrogen and phosphorus) cycling in large lakes like Lake Erie is essential when attempting to ameliorate their contribution to beneficial use impairments and to understand how invasive species perturb ecosystems in their invasive ranges. Here, we first used field surveys to determine the current (2004) dreissenid community structure on hard, preferred substrate in the western basin of Lake Erie. We then estimated the potential nutrient subsidy to the phytoplankton community by dreissenid nitrogen and phosphorus excretion by integrating the dreissenid community structure at these sites with published size-specific nutrient excretion regressions. We found that the total dreissenid community density had decreased dramatically (by > 50%) from previous estimates, that zebra mussels now comprised only a small fraction of the total density (< 3%), and that the quagga mussel-dominated community could supply up to 50% of the nitrogen and 3% of the phosphorus needed daily by the phytoplankton community. The findings emphasize (1) that the dreissenid community abundance and composition are not static, (2) that zebra mussels are no longer more important than quagga mussels to the dreissenid community, and (3) that dreissenid mussels potentially supply a portion of the nutrients that stimulate phytoplankton growth in the western basin of Lake Erie, making them

important contributors to nutrient cycling in addition to their role as consumers of phytoplankton.

Daloglu,I., Cho,K.H., Scavia,D. 2012. Evaluating Causes of Trends in Long-Term Dissolved Reactive Phosphorus Loads to Lake Erie. *Environmental Science & Technology.* Vol. 46. pp. 10660-10666.
Abstract: Renewed harmful algal blooms and hypoxia in Lake Erie have drawn significant attention to phosphorus loads, particularly increased dissolved reactive phosphorus (DRP) from highly agricultural watersheds. We use the Soil and Water Assessment Tool (SWAT) to model DRP in the agriculture-dominated Sandusky watershed for 1970-2010 to explore potential reasons for the recent increased DRP load from Lake Erie watersheds. We demonstrate that recent increased storm events, interacting with changes in fertilizer application timing and rate, as well as management practices that increase soil stratification and phosphorus accumulation at the soil surface, appear to drive the increasing DRP trend after the mid-1990s. This study is the first long-term, detailed analysis of DRP load estimation using SWAT.

Davis,T.W., Koch,F., Marcoval,M.A., Wilhelm,S.W., Gobler,C.J. 2012. Mesozooplankton and microzooplankton grazing during cyanobacterial blooms in the western basin of Lake Erie. *Harmful Algae.* Vol. 15. pp. 26-35.
Abstract: Lake Erie is the most socioeconomically important and productive of the Laurentian (North American) Great Lakes. Since the mid-1990s cyanobacterial blooms dominated primarily by Microcystis have emerged to become annual, late summer events in the western basin of Lake Erie yet the effects of these blooms on food web dynamics and zooplankton grazing are unclear. From 2005 to 2007, grazing rates of cultured (Daphnia pulex) and natural assemblages of mesozooplankton and microzooplankton on five autotrophic populations were quantified during cyanobacterial blooms in western Lake Erie. While all groups of zooplankton grazed on all prey groups investigated, the grazing rates of natural and cultured mesozooplankton were inversely correlated with abundances of potentially toxic cyanobacteria (Microcystis, Anabaena, and Cylindrospermopsis; $p < 0.05$) while those of the in situ microzooplankton community were not. Microzooplankton grazed more rapidly and consistently on all groups of phytoplankton, including cyanobacteria, compared to both groups of mesozooplankton. Cyanobacteria displayed more rapid intrinsic cellular growth rates than other phytoplankton groups under enhanced nutrient concentrations suggesting that future nutrient loading to Lake Erie could exacerbate cyanobacterial blooms. In sum, while grazing rates of mesozooplankton are slowed by cyanobacterial blooms in the western basin of Lake Erie, microzooplankton are likely to play an important role in the top-down control of these blooms; this control could be weakened by any future increases in nutrient loads to Lake Erie.

DePinto,J.V. 1982. An Experimental Apparatus For Evaluating Kinetics Of Available Phosphorus Release From Aquatic Particulates. *Water Resources.* Vol. 16. pp. 1065-1070.

Abstract: An experimental apparatus, referred to herien as a Dual Culture Diffusion Apparatus (DCDA), has been developed and operated to permit the extraction of process kinetic data for revera1 types of particle-water interactions. The DCDA is constructed of two culture vessels separated only by a thin membrane filter, thus facilitating the separation of two particulate suspensions while at the same time permitting their interaction by dMusion of dissolved substances through the membrane. This manuscript describes how the apparatus has been calibrated and applied to measure the rate at which available phosphorus is released from various types of particulates suspended in lake water media.

DePinto,J.V., Young,T.C., Bonner,J.S. 1986. Microbial recycling of phytoplankton phosphorus. *Canadian Journal of Fisheries and Aquatic Sciences.* Vol. 43 (2). pp. 336-342.
Abstract: The remineralization of phytoplankton-bound phosphorus subsequent to nonpredatory phytoplankton mortality represents a significant source of algal-available phosphorus in many lakes. A unique experimental apparatus (A Dual Culture Diffusion Apparatus) was used to measure the rate and extent of this process and to elucidate some of the governing factors. It was demonstrated that this process is strongly influenced by heterotrophic decomposer activity, because phosphorus regeneration rates were less than 0.01 /d for cultures not inoculated with a decomposer community, while they were two to five times higher for decomposer-inoculated cultures. In addition to the character and activity of the microbial decomposer community, the phytoplankton cell phosphorus content was shown to be a significant factor in the rate of phosphorus regeneration for a given cell decay rate. Cell phosphorus above the minimum cell quota appeared to be released in an available form quite rapidly upon algal death and lysis.

DePinto,J.V., Young,T.C., Martin,S.C. 1981. Algal-Available Phosphorus In Suspended Sediments From Lower Great Lakes Tributaries. *Journal of Great Lakes Research.* Vol. 7 (3). pp. 311-325.
Abstract: Suspended sediments collected from five tributaries to the lower Great lAkes were chemically analyzed for several forms of phosphorus and bioassayed under aerobic conditions to measure the release of a/gal-available phosphorus. The bioassay data for all samples, interpreted through a first-order model of available phosphorus release, showed an average of 21.8 percent of the total particulate phosphorus ultimately was available to Selenastrum capricornutum, and available phosphorus was released at an average rate of0.154 day-1. Amounts of available phosphorus varied considerably between tributaries with the Ohio tributaries (Maumee, Sandusky, and Cuyahoga Rivers) showing generally greater amounts than those in New York (Cattaraugus and Genesee Rivers). Non-apatite fractions of inorganic phosphorus (base-, and reductant-extractable) correlated well with levels of available phosphorus in the suspended sediment samples,· however, the first-order release coefficients showed little dependency on the particulate phosphorus characteristics. The results indicate that prediction of

phosphorus dynamics in the lower Great lAkes may be made with greater accuracy than current models allow by considering available phosphorus to be released from an ultimately-available fraction of the total particulate phosphorus during residence in the water column.

DePinto,J.V., Young,T.C., McIlroy,L.M. 1986. Impact of Phosphorus Control Measures on Water Quality of the Great Lakes. *Environ.Sci.Technol.* Vol. 20 (8). pp. 752-759.

DePinto,J.V., Young,T.C., Salisbury,D.K. 1986. Impact of Phosphorous Availability on Modelling Phytoplankton Dynamics. *Hydrobiological Bullentin.* Vol. 20. pp. 225-243.
Abstract: Regulation of phosphorus loading is considered to be the primary method of eutrophication control for many lake systems. It is therefore necessary to have accurate estimates of the forms and bioavailability of all phosphorus sources in order to develop the most cost effective load control measures. Research at Clarkson University, aimed at improving the accuracy of estimates of the form and reactivity of phosphorus loadings to Lake Erie, has revealed a significant difference between the algal-availability of allochthonous and autochthonous particulate phosphorus. This paper presents the results of modifying an exis:ing multi-nutrient phytoplankton model by separating allochthonous phosphorus into three forms : soluble reactive phosphorus (SRP) - immediately available for algal uptake; external ultimately-available phosphorus - not immediately available but converted to an available form ar a specific rate; and external refractory phosphorus (ERP) - not available while in the water column. Comparisons between the original and modified models showed that the modified phosphorus dynamics proved to be a viable alternative to the concept of invoking an unexplained soluble phosphorus water column loss term, employed in the original model. The work also demo~stratesth at the distinction i s significant for lakes receiving a significant portion of:heir external phosphorus load in a particulate (not immediately available) form and having a morphometry and hydrology such that this particulate phosphorus remains in the water column for longer than about two weeks.

DePinto,J.V., Young,T.C., Terry,L. 1986. Effect of Open-Lake Disposal of Toledo Harbor Dredged Material on Bioavailable Phosphorus in Lake Erie Western Basin. pp. 1-57.

Dolan,D.M. 2012. Phosphorus Loads to Lake Erie. DePinto,J.V. (ed).

Dolan,D.M., McGunagle,K.P. 2005. Lake Erie Total Phosphorus Loading Analysis and Update: 1996-2002. *J.Great Lakes Res.* Vol. 31. pp. 11-22.
Abstract: The Lake Erie basin remains one of the most intensely monitored areas in the Great Lakes, largely because of continued interest by government agencies and the public in its trophic status. Total lake phosphorus loading estimates require data from three essential pathways: tributaries, point

sources, and the atmosphere. Point source and atmospheric deposition monitoring results are available to allow continued estimation of these components. Several key watersheds are still being monitored, making some tributary load estimation possible. The problem is to make estimates for unmonitored areas, which are now substantially greater than encountered previously. Except for 2 years, the total annual load estimates for 1996-2002 (11,584, 16,853, 12,710, 6,608, 8,456, 7,333, and 9,733 metric tonnes per year, respectively) were near or substantially below the target load set by the Great Lakes Water Quality Agreement of 11,000 metric tonnes per year. The estimates for 1997 and 1998 markedly exceeded the target load due mainly to elevated tributary loads because of heavy precipitation. The margin of error or half-width of approximate 95% confidence intervals varied from 4% to 11% of the total estimated load depending on year. Detailed tables of the yearly (1996-2002) estimates are provided, as well as summaries by Lake Erie sub-basin for 1981-2001.

Dolan,D.M., Chapra,S.C. 2012. Great Lakes total phosphorus revisited: 1. Loading analysis and update (1994-2008). *J Great Lakes Res.* Vol. 38 (4). pp. 730-740. **Abstract:** Phosphorus load estimates have been updated for all of the Great Lakes with an emphasis on lakes Superior, Michigan, Huron and Ontario for 1994-2008. Lake Erie phosphorus loads have been kept current with previous work and for completeness are reported here. A combination of modeling and data analysis is employed to evaluate whether target loads established by the Great Lakes Water Quality Agreement (GLWQA, 1978, Annex 3) have been and are currently being met. Data from federal, state, and provincial agencies were assembled and processed to yield annual estimates for all lakes and sources. A mass-balance model was used to check the consistency of loads and to estimate interlake transport. The analysis suggests that the GLWQA target loads have been consistently met for the main bodies of lakes Superior, Michigan and Huron. However, exceedances still persist for Saginaw Bay. For lakes Erie and Ontario, loadings are currently estimated to be at or just under the target (with some notable exceptions). Because interannual variability is high, the target loads have not been met consistently for the lower Great Lakes. The analysis also indicates that, because of decreasing TP concentrations in the lakes, interlake transport of TP has declined significantly since the mid-1970s. Thus, it is important that these changes be included in future assessments of compliance with TP load targets. Finally, detailed tables of the yearly (1994-2008) estimates are provided, as well as annual summaries by lake tributary basin (in Supplementary Information).

Elsbury,K.E., Paytan,A., Ostrom,N.E., Kendall,C., Young,M.B., McLaughlin,K., Rollog,M.E., Watson,S. 2009. Using Oxygen Isotopes of Phosphate To Trace Phosphorus Sources and Cycling in Lake Erie. *Environmental Science & Technology.* Vol. 43 (9). pp. 3108-3114.

Elser,J.J. 1999. The pathway to noxious cyanobacteria blooms in lakes: the food web as the final turn. *Freshwater Biology.* Vol. 42. pp. 537-543.
Abstract: Cyanobacteria blooms have long been the focus of limnological research as they often represent the `end member' of limnological deterioration under various human impacts. Research over the past several decades has greatly illuminated the ecological factors promoting cyanobacteria blooms but controversy and confusion surround the successful integration of this diverse body of work. In this opinion article I attempt to integrate well-known aspects of cyanobacteria bloom ecology (such as the roles of nutrient loading, N:P ratio, and mixing conditions) with more recent developments that highlight the importance of feedbacks within the food web in regulating cyanobacteria blooms. Food-web feedbacks involving stoichiometric mechanisms appear to be particularly important, as accumulating data indicate that the food web influences cyanobacteria not just by regulating the rate of grazing mortality. Rather, trophic interactions may also regulate cyanobacteria dynamics by altering the consumer-driven nutrient recycling regime in a way that shifts the competitive advantage away from cyanobacteria. Viewed in this way, cyanobacteria blooms can be seen as probabilistic events that are the end result of a series of key mechanisms involving nutrient loading, physical mixing conditions, and trophic interactions. To successfully manage lake water quality we should take advantage of each node of contingency leading to undesirable blooms. In doing so we will also have a more coherent scientific message to communicate with those directly involved with the socioeconomic politics of water quality decision making.

Great Lakes Dredging Team 2005. Toledo Harbor Revisited: Changing Open Water Placement Policy for Western Lake Erie.

Guven,B., Howard,A. 2007. Identifying the critical parameters of a cyanobacterial growth and movement model by using generalised sensitivity analysis. *Ecological Modelling.* pp. 4753-4764.
Abstract: Bloom-forming and toxin-producing cyanobacteria remain a persistent nuisance across the world. Modelling of cyanobacteria in freshwaters is an important tool for understanding their population dynamics and predicting the location and timing of the bloom events in lakes and rivers. A newdeterministic-mathematical modelwas developed, which simulates the growth and movement of cyanobacterial blooms in river systems. The model focuses on the mathematical description of the bloom formation, vertical migration and lateral transport of colonies within river environments by taking into account the major factors that affect the cyanobacterial bloom formation in rivers including, light, nutrients and temperature. A technique called generalised sensitivity analysiswas applied to the model to identify the critical parameter uncertainties in the model and investigates the interaction between the chosen parameters of the model. The result of the analysis suggested that 8 out of 12 parameters were significant in obtaining the observed cyanobacterial

behaviour in a simulation. It was found that there was a high degree of correlation between the half-saturation rate constants used in the model.

Han,H., Allan,J.D., Bosch,N.S. 2012. Historical pattern of phosphorus loading to Lake Erie watersheds. *Journal of Great Lakes Research.* Vol. 38. pp. 289-298. **Abstract:** Phosphorus (P) applied to croplands in excess of crop requirements has resulted in large-scale accumulation of P in soils worldwide, leading to freshwater eutrophication from river runoff that may extend well into the future. However, several studies have reported declines in surplus P inputs to the land in recent decades. To quantify trends in P loading to Lake Erie (LE) watersheds, we estimated net anthropogenic phosphorus inputs (NAPI) to 18 LE watersheds for agricultural census years from 1935 to 2007. NAPI quantifies anthropogenic inputs of P from fertilizer use, atmospheric deposition and detergents, as well as the net exchange in P related to trade in food and feed. Over this 70-year period, NAPI increased to peak values in the 1970s and subsequently declined in 2007 to a level last experienced in 1935. This rise and fall was the result of two trends: a dramatic increase in fertilizer use, which peaked in the 1970s and then declined to about two-thirds of maximum values; and a steady increase in P exported as crops destined for animal feed and energy production. During 1974-2007, riverine phosphorus loads fluctuated, and were correlated with inter-annual variation in water discharge. However, riverine P export did not show consistent temporal trends, nor correlate with temporal trends in NAPI or fertilizer use. The fraction of P inputs exported by rivers appeared to increase sharply after the 1990s, but the cause is unknown. Thus estimates of phosphorus inputs to watersheds provide insight into changing source quantities but may be weak predictors of riverine export.

Hartig,J.H., Zarull,M.A., Ciborowski,J.J.H., Gannon,J.E., Wilke,E., Norwood,G., Vincent,A. 2007. State of the Strait Status and Trends of Key Indicators Detroit River and Western Lake Erie. Hartig,J.H., Zarull,M.A., Ciborowski,J.J.H., Gannon,J.E., Wilke,E., Norwood,G., Vincent,A. (eds). pp. 1-327. Great Lakes Institute for Environmental Research, University of Windsor, Ontario, Canada.
Abstract: The Detroit River and western Lake Erie are located in the industrial and agricultural heartland of the Great Lakes basin ecosystem. As a result of historical water pollution problems, this region has many long-term, environmental and natural resource data sets. A U.S.-Canada project was initiated in 2005 to assemble as many of these long-term data sets (most with 30 or more years of data) as possible to produce a State of the Strait Report in 2007. Detailed indicator summaries were prepared to examine the trends and interpret and translate the scientific information for policymakers and managers. On December 5, 2006, a State of the Strait Conference was convened in Flat Rock, Michigan to review available trend data, develop key findings, and discuss possible management actions and research needs. This State of the Strait Conference laid the foundation for a comprehensive and integrative assessment of the state of the Detroit River and western Lake Erie

ecosystem. Presented below are the major conclusions and recommendations from this assessment, based on 50 indicator/trend data summaries. Over 35 years of U.S. and Canadian pollution prevention and control efforts have led to substantial improvements in environmental quality. However, the available information also shows that much remains to be done. Examples of environmental improvements include: reductions in oil, phosphorus, chloride, and untreated waste from combined sewer overflow discharges; declines in contaminants in fish and wildlife; and substantial progress in remediating contaminated sediment. Improvements in environmental quality have resulted in significant ecological recovery in this region. Trend data document an increase in the populations of bald eagles, peregrine falcons, lake sturgeon, lake whitefish, walleye, and burrowing mayflies to large areas from which they had been extirpated or negatively impacted. This ecological recovery is remarkable, but many environmental and natural resource challenges remain. Six key environmental and natural resource management challenges include:

- population growth, transportation expansion, and land use changes;
- nonpoint source pollution;
- toxic substances contamination;
- habitat loss and degradation;
- introduction of exotic species; and
- greenhouse gases and global warming.

Research/monitoring must be sustained for effective management. Indeed, without research/monitoring, management is flying blind. Six priority research/monitoring needs based on this comprehensive and integrative assessment include:

- demonstrate and quantify cause-effect relationships;
- establish quantitative endpoints and desired future states;
- determine cumulative impacts and how indicators relate;
- improve modeling and prediction;
- prioritize geographic areas for protection and restoration; and
- foster long-term monitoring for adaptive management.

Clearly, there is a need for comprehensive and integrative assessments of ecosystem health; however, no mechanism currently exists to continue this work. Collectively, millions of dollars are spent annually on research, monitoring, and environmental management in the Detroit River and western Lake Erie. Comparatively, very little is spent on a periodic comprehensive and integrative assessment of ecosystem health. Therefore, it is recommended that resources be pooled through the Canada-U.S. collaborative monitoring effort under the Binational Executive Committee (BEC) on a regular basis (e.g., at least every five years) to undertake comprehensive and integrative assessments of the health of the Detroit River and western Lake Erie ecosystem. Key coordinating organizations that should be responsible for these assessments include the Remedial Action Plans for Areas of Concern, the Lake Erie Lakewide Management Plan, the Detroit River International Wildlife Refuge, the Lake Erie

Committee of the Great Lakes Fishery Commission, watershed and conservation organizations, and land use/transportation planning organizations like the Southeast Michigan Council of Governments. The assessment presented in this report will serve as a baseline that can be improved upon in the next iteration in the spirit of adaptive management. Quantitative targets or endpoints do not exist for most indicators. Of the 50 time trend data sets assessed, only 17 have quantitative targets. Only five of the 17 indicators with targets are meeting them. Therefore, it is recommended that a high priority should be placed on quantifying targets and endpoints for indicators in order to clearly focus management efforts and track progress consistent with adaptive management. The responsibility for quantifying targets and endpoints should rest with the key coordinating organizations such as those identified above. All trend databases are important to the organizations and agencies collecting the data. However, future iterations of comprehensive and integrative assessments may want to focus on a smaller set of key indicators that best meet the needs of management. In addition, this assessment was heavily weighted on state information - there are 38 state, seven pressure and five response indicators. It is further recommended that future comprehensive and integrative assessments of the Detroit River and western Lake Erie should include more pressure and response indicators as they become developed, and more economic and social indicators, including indicators of sustainability and human health. Examples of available pressure and response trend data include: air emissions, watershed-specific urban and agricultural nonpoint source loadings, watershed-specific impervious land use, other watershed-specific land-based stressors as summarized by the Great Lakes Environmental Indicator Project (http://glei.nrri.umn.edu), industrial point source loadings, etc. Finally, some trend data were only available from one side of the international border. Therefore, it is recommended that binational harmonization be achieved to truly undertake comprehensive and integrative assessment.

Hartig,J.H., Zarull,M.A., Ciborowski,J.J.H., Gannon,J.E., Wilke,E., Norwood,G., Vincent,A.N. 2009. Long-term ecosystem monitoring and assessment of the Detroit River and Western Lake Erie. *Environmental Monitoring and Assessment.* Vol. 158. pp. 87-104.

Abstract: Over 35 years of US and Canadian pollution prevention and control efforts have led to substantial improvements in environmental quality of the Detroit River and western Lake Erie. However, the available information also shows that much remains to be done. Improvements in environmental quality have resulted in significant ecological recovery, including increasing populations of bald eagles (*Haliaeetus leucocephalus*), peregrine falcons (*Falco columbarius*), lake sturgeon (*Acipenser fulvescens*), lake whitefish (*Coregonus clupeaformis*), walleye (*Sander vitreus*), and burrowing mayflies (*Hexagenia spp.*). Although this recovery is remarkable, many challenges remain, including population growth, transportation expansion, and land use changes; nonpoint source pollution; toxic substances contamination; habitat loss and degradation; introduction of exotic species; and greenhouse gases and global warming. Research/monitoring must be sustained for effective management. Priority research and monitoring needs include: demonstrating

and quantifying cause-effect relationships; establishing quantitative endpoints and desired future states; determining cumulative impacts and how indicators relate; improving modeling and prediction; prioritizing geographic areas for protection and restoration; and fostering long-term monitoring for adaptive management. Key management agencies, universities, and environmental and conservation organizations should pool resources and undertake comprehensive and integrative assessments of the health of the Detroit River and western Lake Erie at least every 5 years to practice adaptive management for longterm sustainability.

Howard,A. 2001. Modeling Movement Patterns of the Cyanobacterium, Microcystis. *Ecological Applications.* Vol. 11 (1). pp. 304-310.
Abstract: This paper reports the development of a model that simulates the movement and growth of the cyanobacterium, *Microcystis aeruginosa.* The new model follows from the approach taken in the SCUM'96 (simulation of cyanobacterial underwater movement) model by calculating the photosynthetic production of carbohydrate, allocating this to growth and cell maintenance with excess production forming cellular ballast. From this, density change is calculated and vertical migration simulated within the water column. Lake heating and cooling, turbulent mixing, and other environmental processes are simulated to study the response of cyanobacteria to environmental variability. The model can be run over long periods for areas of different geographical latitude. Model output compares well with field observations suggesting that surface "bloom" formation is a natural consequence of lake mixing and seasonal light availability.

James,W.F. 2007. Sediment Phosphorus Characteristics And Rates of Internal Loading in Lake Pepin and Spring Lake during The Summer Low-Flow Period of 2006. pp. 1-34. ERDC - Engineer Research and Development Center.

James,W.F. 2008. Nutrient Dynamics and Budgetary Analysis of the Lower Minnesota River: 2003-2006. pp. 1-79. ERDC - Engineer Research and Development Center.

James,W.F. 2010. Exchangeable Phosphorus Pools and Equilibrium Characteristics for River Sediment as a Function of Particle Size. pp. 1-11. Army Core of Engineers.
Abstract: The System-Wide Water Resources Program-Nutrient Sub-Model (SWWRP-NSM) represents a library of algorithms for simulating nutrient cycling, transformation, and flux in terrestrial and aquatic systems. One feature of SWWRP-NSM is the capability of simulating phosphorus (P) equilibrium fluxes between exchangeable particulate and soluble P pools in the aquatic water column as a function of particle size class. The objectives of this research were to quantify exchangeable particulate phosphorus (P) pools and equilibrium with soluble P as a function of river sediment particle size

distribution for use in initializing model parameters for simulating P adsorption and desorption in river systems.

Johnson,B.H., Asce,M., McComas,D.N., McVan,D.C. 1992. Modeling Dredged Material Disposed in Open water. *Hydraulic Engineering.* pp. 1036-1041.
Abstract: Physical model disposal tests at a 1:50 scale have been conducted to provide guidance on numerical model developments and to provide data sets for numerical model verification. These tests have been conducted with a model split-hull barge and a multibin hopper vessel. Both stationary and moving disposals have been monitored. Results imply that the bulk behavior of the disposal material in both the descent and bottom surge phases can be approximately scaled to the prototype. Visual observations have resulted in modifications to an existing numerical model such that the disposal is represented by a series of downward convecting clouds from which material can be stripped.

Jones,R.C. 1988. Use of In Situ Nutrient Addition and Dilution Bioassays to Detect Nutrient Limitation in the Tidal Freshwater Potomac. Understanding the Estuary: Advances in Chesapeake Bay Research.

Jones,R.C. 1991. Spatial and temporal patterns in a cyanobacterial phytoplankton bloom in the tidal freshwater Potomac River, USA. *Verh.Internat.Verein.Limnol.* Vol. 24. pp. 1698-1702.

Jones,R.C., Buchanan,C., Andrle,V. 1992. Spatial, Seasonal, and Interannual Patterns in the Phytoplankton Communities of a Tidal Freshwater Ecosystem. *Virginia Journal of Science.* Vol. 43 (1A). pp. 26-40.
Abstract: Phytoplankton were enumerated by species on samples collected on a biweekly to monthlybasis over 6 years from 11-13 sites in the tidal freshwater Potomac River. Cell densities were analyzed by analysis of variance examining spatial, seasonal, and interannual variability. Phytoplankton densities were higher in the two embayment areas than in the river mainstem. **A** nearly exponential increase in phytoplankton was observed from March through August with a rapid decline in September and October. This pattern differed significantly among years resulting in a significant monthyear interaction. Differences among years was also significant with the two lowest years correlating with low residence times. Loss processes, particularly flushing, appeared to be generally more important than growth processes in explaining seasonal and interannual variation. Both growth and loss factors contributed to spatial variation. Diatoms were dominant in spring and various cyanobacterial species were most important in summer.

Joosse,P.J., Baker,B.D. 2011. Context for re-evaluating agricultural source phosphorus loadings to the Great Lakes. *Canadian Journal of Soil Science.* Vol. 91. pp. 317-327.

Kutovaya,O.A., McKay,R.M.L., Beall,B.F.N., Wilhelm,S.W., Kane,D.D., Chaffin,J.D., Brunberg,A.-K., Bullerjahn,G.S. 2012. Evidence against fluvial seeding of recurrent toxic blooms of Microcystis spp. in Lake Erie's western basin. *Harmful Algae.* Vol. 15. pp. 71-77.
Abstract: For almost two decades, the western basin of Lake Erie has been plagued with recurring toxic algal blooms dominated by the colonial cyanobacterium, Microcystis spp. Since the Maumee River is a major source of nutrients and sediment inputs into the lake, and Microcystis spp. has been identified as a member of the upstream river algal assemblage, the possibility exists that the river Microcystis species serve as a seed population for the toxic blooms occurring in the lake. Genetic profiling of toxic cyanobacteria using the microcystin synthesis gene, mcyA, clearly indicates that the toxic cyanobacteria of the river are distinct from the toxic Microcystis spp. of Lake Erie. Indeed, mcyA sequences are almost exclusively from toxic Planktothrix spp., similar to what has been documented previously for Sandusky Bay. UniFrac statistical analysis of cyanobacterial community composition by comparison of 16S–23S ITS sequences also show that the Maumee River and Lake Erie communities are distinct. Overall, these data show that despite the importance of nutrient inputs and sediments from the river, the toxic cyanobacterial blooms of Lake Erie do not originate from toxic species endemic to the Maumee River and instead must originate elsewhere, most likely from the lake sediments.

Lambert,R.S. 2012. Great Lake Tributary Phosphorus Bioavailability. pp. 1-48. Michigan Technological University.
Abstract: Information on phosphorus bioavailability can provide water quality managers with the support required to target point source and watershed loads contributing most significantly to water quality conditions. This study presents results from a limited sampling program focusing on the five largest sources of total phosphorus to the U.S. waters of the Great Lakes. The work provides validation of the utility of a bioavailability-based approach, confirming that the method is robust and repeatable. Chemical surrogates for bioavailability were shown to hold promise, however further research is needed to address site-to-site and seasonal variability before a universal relationship can be accepted. Recent changes in the relative contribution of P constituents to the total phosphorus analyte and differences in their bioavailability suggest that loading estimates of bioavailable P will need to address all three components (SRP, DOP and PP). A bioavailability approach, taking advantage of chemical surrogate methodologies is recommended as a means of guiding P management in the Great Lakes.

Lehman,P.W., Boyer,G., Hall,C., Waller,S., Gehrts,K. 2005. Distribution and toxicity of a new colonial Microcystis aeruginosa bloom in the San Francisco Bay Estuary, California. *Hydrobiologia.* Vol. 541. pp. 87-99.
Abstract: The first distribution, biomass and toxicity study of a newly established bloom of the colonial cyanobacteria Microcystis aeruginosa was conducted on October 15, 2003 in the upper San Francisco Bay Estuary.

Microcystis aeruginosa was widely distributed throughout 180 km of waterways in the upper San Francisco Bay Estuary from freshwater to brackish water environments and contained hepatotoxic microcystins at all stations. Other cyanobacteria toxins were absent or only present in trace amounts. The composition of the microcystins among stations was similar and dominated by demethyl microcystin-LR followed by microcystin- LR. In situ toxicity computed for the >75 um cell diameter size fraction was well below the 1 ug $l)^{-1}$advisory level set by the World Health Organization for water quality, but the toxicity of the full population is unknown. The toxicity may have been greater earlier in the year when biomass was visibly higher. Toxicity was highest at low water temperature, water transparency and salinity. Microcystins from the bloom entered the food web and were present in both total zooplankton and clam tissue. Initial laboratory feeding tests suggested the cyanobacteria was not consumed by the adult copepod Eurytemora affinis, an important fishery food source in the estuary.

Leon,L.F., Smith,R., Hipsey,M.R., Bocaniov,S.A., Higgins,S.N., Hecky,R.E., Antenucci,J.P., Imberger,J.A., Guildford,S.J. 2011. Application of a 3D hydrodynamic-biological model for seasonal and spatial dynamics of water quality and phytoplankton in Lake Erie. *Journal of Great Lakes Research.* Vol. 37. pp. 43-53.
Abstract: In large lakes, temporal variability is compounded by strong spatial variability associated with mesoscale physical processes such as upwelling and basin-scale circulation. Here we explore the ability of a three dimensional model (ELCOM–CAEDYM) to capture temporal and spatial variability of phytoplankton and nutrients in Lake Erie. We emphasized the east basin of the lake, where an invasion by dreissenid mussels has given special importance to the question of spatial (particularly nearshore–offshore) variability and many comparative observations were available. We found that the model, which did not include any simulation of the mussels or of smaller diffuse nutrient sources, could capture the major features of the temperature, nutrient and phytoplankton variations. Within basin variability was large compared to among-basin
variability, especially but not exclusively in the western regions. Consistent with observations in years prior to, but not after, the mussel invasion the model predicted generally higher phytoplankton concentrations in the nearshore than the offshore zones. The results suggest that the elevated phytoplankton abundance commonly observed in the nearshore of large lakes in the absence of dreissenid mussels does not have to depend on localized nutrient inputs but can be explained by the favourable light, temperature and nutrient environment in the shallower and energetic nearshore zone. The model is currently being extended to allow simulation of the effects of dreissenid mussels.

LimnoTech 2010. Development, Calibration, and Application of the Lower Maumee River-Maumee Bay Model. pp. 1-127. Prepared for U.S. Army Corps of Engineers Buffalo District, Ann Arbor, MI.

Linkov,I., Satterstrom,F.K., Loney,D., Steevens,J.A. 2009. The Impact of Harmful Algal Blooms on USACE Operations. pp. 1-16.
Abstract: Algal blooms have recently attracted significant attention due to their human and ecological effects. The aim of this technical note is to assess the importance of freshwater harmful algal blooms (HABs) to U.S. Army Corps of Engineers (USACE) operations through a literature review and surveys from regional Corps personnel who manage algal blooms and related issues. This note discusses algal bloom formation factors, occurrence, impact, and management for both the literature review and USACE surveyed staff.

Lohrer,A.M., Wetx,J.J. 2003. Dredging-induced nutrient release from sediments to the water column in a southeastern saltmarsh tidal creek. *Marine Pollution Bulletin.* Vol. 46. pp. 1156-1163.
Abstract: Dredging is a large-scale anthropogenic disturbance agent in coastal and estuarine habitats that can profoundly affect water quality. We examined the impact of a small-scale dredging operation in a salt marsh in South Carolina by comparing nutrient levels (NH^{+4}, NO_x , PO^{-4}) and total suspended solid concentrations before and during dredging activities. Nutrient enrichment was evaluated within the context of tidal, seasonal, and inter-annual variability by using long-term water chemistry data provided by the North Inlet-Winyah Bay National Estuarine Research Reserve. The conditions of the dredging permit (i.e., its relatively small scale), the season chosen for the work (fall-winter), the nature of the sediments dredged (coarse-grained), and the amount of natural variability in the estuarys water chemistry (even on a daily time-scale) all minimized the impact of the dredging activities. Results of this study will add to the limited body of empirical data that should be considered in evaluating future dredging permit applications related to shallow estuarine waterways.

Makarewicz,J.C., Bertram,P., Lewis,T.W. 2000. Chemistry of the Offshore Surface Waters of Lake Erie: Pre- and Post-Dreissena Introduction (1983-1993). *J.Great Lakes Res.* Vol. 26 (1). pp. 82-93.
Abstract: Major changes in ambient surface nutrient chemistry were observed after the introduction of Dreissena to Lake Erie. For example, statistically significant increases in spring soluble reactive phosphorus (SRP) (180%, 1.0 to 2.8 ìg P/L), nitrate+nitrite (40%, 0.57 to 0.80 mg N/L), ammonia (131%, 15.1 to 34.9 ìg N/L), silica (75%, 0.8 to 1.4 mg/L), N:P ratio and turbidity and a significant decrease in total Kjeldahl nitrogen (TKN) (25%, 0.24 to 0.18 ìg N/L) were observed in the western basin from the 1983 to 1987 pre-Dreissena baseline period to the 1989 to 1993 post-Dreissena period. In the summer, total phosphorus (TP) (13%, 20.1 to 17.5 ìg P/L) and TKN (27%, 0.30 to 0.22 ìg N/L) decreased, while nitrate+nitrite (122%, 0.18 to 0.40 mg N/L) and the N:P ratio increased significantly. Fewer chemical parameters changed significantly in the central and eastern basins, but major changes were observed. For example, spring SRP concentrations in the central and eastern basins increased 250% (0.8 to 2.8 ìg P/L) and 92% (2.4 to 4.6 ìg P/L), respectively. Silica in these basins increased 300% (0.1 to 0.4 mg/L) and

250% (0.2 to 0.7 mg/L), respectively. TKN decreased in all basins in both the spring and summer (range = 22 to 27%), while TP decreased in all basins in the summer (range = 13 to 24%) but not in the spring.

Spatially, spring post-Dreissena (1989 to 1993) ammonia, TP, and nitrate+nitrite concentrations were high in the western basin and decreased easterly, while chloride concentrations were variable with no downward or upward trend. In the central basin and eastward through the eastern basin, concentrations of ammonia, chloride, nitrate+nitrite, and total phosphorus were remarkably consistent during and between the pre- and post-Dreissena periods. After the Dreissena invasion, a different spatial pattern of SRP, silica and phytoplankton biomass was observed. SRP and silica concentrations were high in the western basin and decreased into the central basin as in the pre-Dreissena period. Similarly, post-Dreissena SRP and silica concentrations were low in the western portion of the central basin but then unexpectedly increased easterly by > 250% and > 1,000%, respectively, over the pre-Dreissena period. Phytoplankton biomass increased from within the west end of the western basin to a peak about halfway into the central basin, after which biomass decreased into the eastern basin.

The increase in the dissolved fraction of nutrients in the western basin can be attributed to the excretion of dissolved fractions by Dreissena spp. after digestion of particulate matter, the remineralization of surficial organic sediments containing nitrogen and phosphorus-rich feces and pseudofeces and to a decrease in uptake of SRP by less abundant populations of phytoplankton in the western basin. In the western portion of the central basin, it is possible that SRP is being carried by the prevailing westerly current into the central basin stimulating phytoplankton population growth combined with minimal Dreissena grazing causing a peak in phytoplankton abundance. There does not appear to be a satisfactory explanation for the simultaneous increase in SRP and the lack of any change in phytoplankton pre- and post-Dreissena in the eastern portion of Lake Erie.

Martin,S.C., DePinto,J.V., Young,T.C. 1985. Biological Availability of Sediment Phosphorus Inputs to the Lower Great Lakes. pp. 1-6. United States Environmental Protection Agency.

Abstract: In this study, river water samples were collected from several major tributaries to the Lower Great Lakes during storm runoff events in the spring and early summer of 1980 and 1981. Suspended sediments from these samples were subjected to a chemical fractionation sequence of NaOH-CDB-HCI, as well as algal bioassayanalyses of sediment P bioavailability using the Dual Culture Diffusion Apparatus (DCDAI technique of DePinto. Sediments from several of the bioassay experiments were reconcentrated after the bioassays and resubjected to the chemical fractionation sequence. Several other forms of P inputs to the Lower Great Lakes were also analyzed for chemical composition and/or bioavailability.

This Project Summary was developed by EPA's Environmental Research

Laboratory, Duluth, MN, to announce key findings o f the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Matisoff,G., Neeson,T.M. 2005. Oxygen Concentration and Demand in Lake Erie Sediments. *Journal of Great Lakes Research.* Vol. 31 (2). pp. 284-295.
Abstract: Regular ship-board monitoring of oxygen in the hypolimnion of Lake Erie has been established to monitor the status of the lake and determine if the water quality is meeting the terms of the Great Lakes Water Quality Agreement (GLWQA). However, lake-wide monitoring is expensive and there is a difference of opinion on whether dissolved oxygen depletion rate is a good indicator of the condition of Lake Erie. One the most poorly known components of the Lake Erie oxygen budget is the sediment-oxygen demand (SOD). In this work, vertical oxygen concentration profiles in Lake Erie sediments are measured by incrementally inserting a micro-oxygen electrode. The SOD is the flux of oxygen across the sediment- water interface and is calculated from the oxygen profiles assuming Fickian diffusion at the sediment-water interface. Oxygen consumption was measured in sediments collected on four dates from 3, 13, and 5 stations in the western, central, and eastern basins, respectively. Oxygen concentration profiles in the sediment and the SOD are well described by a diffusion/reaction transport model where oxygen diffuses into the sediment and is consumed by reactions that follow Michaelis-Menten kinetics. The flux of oxygen into the sediment in the central basin in August 2002 was $1.03 \pm 0.271 \times 10^{-11}$ mol $O_2/cm^2/sec$, within about 30% of the hypolimnetic oxygen depletion rate derived from monitoring. These results suggest that modeling of oxygen profiles hold promise as an alternative technique to regular monitoring for determining hypolimnetic oxygen depletion rates.

Mayer,T. 1991. Rapid Procedures For Determining Bioavailable And Total Phosphorus In Freshwater Sediments. pp. 1-14. Rivers Research Branch National Water Research Institute.
Abstract: Analytical procedures for determination of bioavailable total phosphorus (P) in freshwater sediments are described. methods can be widely used on a variety of samples such as lacustrine and fluvial bed and suspended sediments. The methods are rapid, inexpensive and are suitable for a large number of samples. The reproducibility of the procedure used to determine the total P was good with the coefficient of variation determined from 60 analyses being 3.7%. The reproducibility of bioavailable P determination, utilizing the NaOH reagent was not as good. The coefficient of variation determined from the analyses of 13 replicates was 13.5%.

Millie,D.F., Fahnenstiel,G.L., Bressie,J.D., Pigg,R.J., Rediske,R.R., Klarer,D.M., Tester,P.A., Litaker,R.W. 2009. Late-summer phytoplankton in western Lake Erie (Laurentian Great Lakes): bloom distributions, toxicity, and environmental influences. *Aquatic Ecology.* Vol. 43. pp. 915-934.
Abstract: Phytoplankton abundance and composition and the cyanotoxin,

microcystin, were examined relative to environmental parameters in western Lake Erie during late-summer (2003–2005). Spatially explicit distributions of phytoplankton occurred on an annual basis, with the greatest chlorophyll (Chl) a concentrations occurring in waters impacted by Maumee River inflows and in Sandusky Bay. Chlorophytes, bacillariophytes, and cyanobacteria contributed the majority of phylogenetic-group Chl a basin-wide in 2003, 2004, and 2005, respectively. Water clarity, pH, and specific conductance delineated patterns of group Chl a, signifying that water mass movements and mixing were primary determinants of phytoplankton accumulations and distributions. Water temperature, irradiance, and phosphorus availability delineated patterns of cyanobacterial biovolumes, suggesting that biotic processes (most likely, resource-based competition) controlled cyanobacterial abundance and composition. Intracellular microcystin concentrations corresponded to Microcystis abundance and environmental parameters indicative of conditions coincident with biomass accumulations. It appears that environmental parameters regulate microcystin indirectly, via control of cyanobacterial abundance and distribution.

Millie,D.F., Fahnenstiel,G.L., Weckman,G.R., Klarer,D.M., Vanderploeg,H.A., Dyble,J., Fishman,D.B. 2011. An "Enviro-Informatic" Assessment of Saginaw Bay (Lake Huron, USA) Phytoplankton: Data-Driven Characterization and Modeling of Microcystis (Cyanophyta). *J.Phycol.* Vol. 47. pp. 714-730. **Abstract:** Phytoplankton and Microcystis aeruginosa (Ku¨tz.) Ku¨tz. biovolumes were characterized and modeled, respectively, with regard to hydrological and meteorological variables during zebra mussel invasion in Saginaw Bay (1990-1996). Total phytoplankton and Microcystis biomass within the inner bay were one and one-half and six times greater, respectively, than those of the outer bay. Following mussel invasion, mean total biomass in the inner bay decreased 84% but then returned to its approximate initial value. Microcystis was not present in the bay during 1990 and 1991 and thereafter occurred at . in 52% of sample sites . dates with the greatest biomass occurring in 1994-1996 and within months having water temperatures >19°C. With an overall relative biomass of 0.03 ± 0.01 (mean + SE), Microcystis had, at best, a marginal impact upon holistic compositional dynamics. Dynamics of the centric diatom Cyclotella ocellata Pant. and large pennate diatoms dominated compositional dissimilarities both inter- and intra-annually. The environmental variables that corresponded with phytoplankton distributions were similar for the inner and outer bays, and together identified physical forcing and biotic utilization of nutrients as determinants of system-level biomass patterns. Nonparametric models explained 70%-85% of the variability in Microcystis biovolumes and identified maximal biomass to occur at total phosphorus (TP) concentrations ranging from 40 to 45 ug - L^{-1}. From isometric projections depicting modeled Microcystis/environmental interactions, a TP concentration of <30 ug - L^{-1} was identified as a desirable contemporary "target" for management efforts to ameliorate bloom potentials throughout mussel-impacted bay waters.

Myers,D.N., Metzker,K.D., Davis,S. 2000. Status and Trends in Suspended-Sediment Discharges, Soil Erosion, and Conservation Tillage in the Maumee River Basin-Ohio, Michigan, and Indiana. pp. 1-45. U.S.Geological Survey Branch of Information Services.

Abstract: The relation of suspended-sediment discharges to conservation-tillage practices and soil loss were analyzed for the Maumee River Basin in Ohio, Michigan, and Indiana as part of the U.S. Geological Survey's National Water-Quality Assessment Program. Cropland in the basin is the largest contributor to soil erosion and suspended-sediment discharge to the Maumee River and the river is the largest source of suspended sediments to Lake Erie. Retrospective and recently-collected data from 1970-98 were used to demonstrate that increases in conservation tillage and decreases in soil loss can be related to decreases in suspendedsediment discharge from streams.Average annual water and suspended-sediment budgets computed for the Maumee River Basin and its principal tributaries indicate that soil drainage and runoff potential, stream slope, and agricultural land use are the major human and natural factors related to suspended-sediment discharge. The Tiffin and St. Joseph Rivers drain areas of moderately to somewhat poorly drained soils with moderate runoff potential. Expressed as a percentage of the total for the Maumee River Basin, the St. Joseph and Tiffin Rivers represent 29.0 percent of the basin area, 30.7 percent of the average-annual streamflow, and 9.31 percent of the average annual suspended-sediment discharge. The Auglaize and St. Marys Rivers drain areas of poorly to very poorly drained soils with high runoff potential. Expressed as a percentage of the total for the Maumee River Basin, the Auglaize and St. Marys Rivers represent 48.7 percent of the total basin area, 53.5 percent of the average annual streamflow, and 46.5 percent of
the average annual suspended-sediment discharge. Areas of poorly drained soils with high runoff potential appear to be the major source areas of suspended sediment discharge in the Maumee River Basin.

North,R.L., Smith,R.E.H., Hecky,R.E., Depew,D.C., León,L.F., Charlton,M.N., Guildford,S.J. 2012. Distribution of seston and nutrient concentrations in the eastern basin of Lake Erie pre- and post-dreissenid mussel invasion. *J Great Lakes Res.* Vol. 38. pp. 463-476.

Abstract: Increased human population growth, reduction of phosphorus (P) loading, and the invasion of dreissenid mussels may have changed the spatial pattern and relationships between the nearshore and the offshore seston and nutrient concentrations in the eastern basin of Lake Erie over the past 30 years. We compared seston characteristics, nutrient concentrations, and phytoplankton nutrient status between nearshore and offshore zones in years before (1973-1985) and after (1990-2003) the dreissenid invasion. In 1973 (the only pre-dreissenid year nearshore data was collected), chlorophyll a (chla) and nutrient concentrations were higher nearshore than offshore. In post-dreissenid years, nearshore chl a concentrations became significantly lower than the offshore, while carbon (C):chla ratios became higher, which was related to mussel grazing and possibly photoacclimation. Phosphorus

deficiency in the phytoplankton increased over the 30-year period, and in the post-dreissenid years was less acute in the nearshore than offshore. Mean water column irradiance became higher in the nearshore relative to the offshore in the post-dreissenid years. The nutrient changes and phytoplankton physiology were consistent with the expected effects of nutrient cycling by mussels and diminished demand by phytoplankton despite increased demand from benthic algae in the nearshore. This basin-scale study suggests that dreissenid mussel invasion can be associated with alterations in the spatial pattern of water column properties in large lakes even on open coasts with vigorous circulation and exchange.

Nurnberg,G.K. 1991. Phosphorus From Internal Sources In The Laurentian Great Lakes, And The Concept Of Threshold External Load. *Journal of Great Lakes Research.* Vol. 17 (1). pp. 132-140.
Abstract: The trophic status ofthe Laurentian Great Lakes is greatly influenced by phosphorus (P) derived from anoxic sediment surfaces. Data from the Great Lakes and data from smaller lakes ofEastern North America can be used to demonstrate how such an internal P load influences trophic state. To facilitate predictions for the future of the Great Lakes or any lake subjected to P release from anoxic sediment surfaces, the concept of«threshold external load" is introduced. The external P load at which the flux downward from external sources matches the flux upward from anoxicsediments can be considered the «threshold external {oad". The product of the «threshold external load", the gross P retention (predicted from the annual water load) and the ratio oflake surface area to hypolimnetic area (a sediment focusing factor) yields the anoxic P release. The concept of «threshold external load" helps explain the slow response of certain lakes to phosphorus input abatement.

O'Neil,J.M., Davis,T.W., Buford,M.A., Gobler,C.J. 2012. The rise of harmful cyanobacteria blooms: The potential roles of eutrophication and climate change. *Harmful Algae.* Vol. 14. pp. 313-334.
Abstract: Cyanobacteria are the most ancient phytoplankton on the planet and form harmful algal blooms in freshwater, estuarine, and marine ecosystems. Recent research suggests that eutrophication and climate change are two processes that may promote the proliferation and expansion of cyanobacterial harmful algal blooms. In this review, we specifically examine the relationships between eutrophication, climate change and representative cyanobacterial genera from freshwater (Microcystis, Anabaena, Cylindrospermopsis), estuarine (Nodularia, Aphanizomenon), and marine ecosystems (Lyngbya, Synechococcus, Trichodesmium). Commonalities among cyanobacterial genera include being highly competitive for low concentrations of inorganic P (DIP) and the ability to acquire organic P compounds. Both diazotrophic (= nitrogen (N_2) fixers) and non-diazotrophic cyanobacteria display great flexibility in the N sources they exploit to form blooms. Hence, while some cyanobacterial blooms are associated with eutrophication, several form blooms when concentrations of inorganic N and

P are low. Cyanobacteria dominate phytoplankton assemblages under higher temperatures due to both physiological (e.g., more rapid growth) and physical factors (e.g., enhanced stratification), with individual species showing different temperature optima. Significantly less is known regarding how increasing carbon dioxide (CO_2) concentrations will affect cyanobacteria, although some evidence suggests several genera of cyanobacteria are well-suited to bloom under low concentrations of CO_2. While the interactive effects of future eutrophication and climate change on harmful cyanobacterial blooms are complex, much of the current knowledge suggests these processes are likely to enhance the magnitude and frequency of these events.

OEPA. 2010. Ohio Lake Erie Phosphorus Task Force Final Report. pp. 1-109. Ohio Environmental Portection Agency.

Paerl,H.W., Hall,N.S., Calandrino,E.S. 2011. Controlling harmful cyanobacterial blooms in a world experiencing anthropogenic and climatic-induced change. *Science of the Total Environment.* Vol. 409. pp. 1739-1745.
Abstract: Harmful (toxic, food web altering, hypoxia generating) cyanobacterial algal blooms (CyanoHABs) are proliferating world-wide due to anthropogenic nutrient enrichment, and they represent a serious threat to the use and sustainability of our freshwater resources. Traditionally, phosphorus (P) input reductions have been prescribed to control CyanoHABs, because P limitation is widespread and some CyanoHABs can fi x atmospheric nitrogen (N_2) to satisfy their nitrogen (N) requirements. However, eutrophying systems are increasingly plagued with non N_2 fixing CyanoHABs that are N and P co-limited or even N limited. In many of these systems N loads are increasing faster than P loads. Therefore N and P input constraints are likely needed for long-term CyanoHAB control in such systems. Climatic changes, specifically warming, increased vertical stratification, salinization, and intensification of storms and droughts play additional, interactive roles in modulating CyanoHAB frequency, intensity, geographic distribution and duration. In addition to having to consider reductions in N and P inputs, water quality managers are in dire need of effective tools to break the synergy between nutrient loading and hydrologic regimes made more favorable for CyanoHABs by climate change. The more promising of these tools make affected waters less hospitable for CyanoHABs by 1) altering the hydrology to enhance vertical mixing and/or flushing and 2) decreasing nutrient fluxes from organic rich sediments by physically removing the sediments or capping sediments with clay. Effective future CyanoHAB management approaches must incorporate both N and P loading dynamics within the context of altered thermal and hydrologic regimes associated with climate change.

Paerl,H.W., Paul,V.J. 2012. Climate change: Links to global expansion of harmful cyanobacteria. *ScienceDirect.* Vol. 46. pp. 1349-1363.
Abstract: Cyanobacteria are the Earth's oldest (~3.5 bya) oxygen evolving organisms, and they have had major impacts on shaping our modern-day biosphere. Conversely, biospheric environmental perturbations, including

nutrient enrichment and climatic changes (e.g., global warming, hydrologic changes, increased frequencies and intensities of tropical cyclones, more intense and persistent droughts), strongly affect cyanobacterial growth and bloom potentials in freshwater and marine ecosystems. We examined human and climatic controls on harmful (toxic, hypoxia-generating, food web disrupting) bloom-forming cyanobacteria (CyanoHABs) along the freshwater to marine continuum. These changes may act synergistically to promote cyanobacterial dominance and persistence. This synergy is a formidable challenge to water quality, water supply and fisheries managers, because bloom potentials and controls may be altered in response to contemporaneous changes in thermal and hydrologic regimes. In inland waters, hydrologic modifications, including enhanced vertical mixing and, if water supplies permit, increased flushing (reducing residence time) will likely be needed in systems where nutrient input reductions are neither feasible nor possible. Successful control of CyanoHABs by grazers is unlikely except in specific cases. Overall, stricter nutrient management will likely be the most feasible and practical approach to long-term CyanoHAB control in a warmer, stormier and more extreme world.

Paerl,H.W., Scott,J.T. 2010. Throwing Fuel on the Fire: Synergistic Effects of Excessive Nitrogen Inputs and Global Warming on Harmful Algal Blooms. *Environmental Science & Technology.* Vol. 44 (20). pp. 7756-7758.

Patterson,M.W.R., Ciborowski,J.J.H., Barton,D.R. 2005. The Distribution and Abundance of Dreissena Species (Dreissenidae) in Lake Erie, 2002. *J.Great Lakes Res.* Vol. 31. pp. 223-237.
Abstract: A lake-wide benthic survey of Lake Erie during summer 2002 indicated that Dreissena bugensis is the dominant dreissenid in Lake Erie, especially in the east basin where this species was found at every station but no Dreissena polymorpha were collected. Mean (±SD) densities of dreissenid mussels were comparable between the west (601 ± 2,110/m2;n = 49) and central (635 ± 1,293/m2; n = 41) basins, but were much greater in the east basin (9,480 ± 11,173/m2; n = 17). The greater variability in mussel density among stations and replicate samples in the central and west basins than in the east basin is attributable to the preponderance of fine-grained substrata in the nearshore, higher episodic rates of sediment deposition, and periodic hypoxia in bottom waters. Although there was little change in lake-wide mean dreissenid densities between 1992 and 2002 (declining from ca. 2,636 individuals/m2 to 2,025 individuals/m2), basin-averaged shell-free dry tissue mass increased by almost four-fold from ca. 6.8 ± 15.6 g /m2 to 24.7 ± 71.3 g/m2 in the same interval. Up to 90% of this biomass is in the eastern basin. Other changes in 2002 include the virtual absence of mussels in the 3 to 12 mm size range, probably because of predation by round gobies, and an increase in the average size of mature mussels. The substantial changes observed between 1992 and 2002 suggest that dreissenid populations in Lake Erie were still changing rapidly in abundance and biomass, as well as species

composition. The results of this survey suggest that a direct link between Dreissena spp. and hypolimnetic hypoxia in the central basin is unlikely.

Raikow,D.F., Sarnelle,O., Wilson,A.E., Hamilton,S.K. 2012. Dominance of the noxious cyanobacterium Microcystis aeruginosa in low-nutrient lakes is associated with exotic zebra mussels. *Limnol.Oceanogr.* Vol. 49 (2). pp. 482-487.

Abstract: To examine the hypothesis that invasion by zebra mussels (*Dreissena polymorpha*) promotes phytoplankton dominance by the noxious cyanobacterium *Microcystis aeruginosa,* 61 Michigan lakes of varying nutrient levels that contain or lack zebra mussels were surveyed during late summer. After accounting for variation in total phosphorus (TP) concentrations, lakes with *Dreissena* had lower total phytoplankton biomass, as measured by chlorophyll *a* and algal cell biovolume. Phytoplankton biomass increased with TP in both sets of lakes, although the elevations of the relationship differed. The percentage of the total phytoplankton comprised by cyanobacteria increased with TP in lakes without *Dreissena* (*R*2 5 0.21, *P* 5 0.025) but not in lakes with *Dreissena* (*P* 5 0.79). Surprisingly, there was a positive influence of *Dreissena* invasion on *Microcystis* dominance in lakes with TP, 25 mg L21 (*P* 5 0.0018) but not in lakes with TP . 25 mg L21 (*P* 5 0.86). The finding that *Microcystis,* a relatively grazing-resistant component of the phytoplankton, was favored by *Dreissena* in low- but not in high-nutrient lakes is somewhat counterintuitive, but predator-prey models make this prediction in certain cases when the cost for the prey of being consumption resistant is a low maximum population growth rate. This *Dreissena*-cyanobacteria interaction contradicts well-established patterns of increasing cyanobacteria with nutrient enrichment in north-temperate lakes and suggests that the monitoring and abatement of nutrient inputs to lakes may not be sufficient to predict and control cyanobacterial dominance of *Dreissena*-invaded lakes.

Reidar,N., Olsen,B., Hedger,R.D., George,D.G. 2000. 3D Numerical Modeling of Microcystis Distribution in a Water Reservoir. *Journal of Environmental Engineering.* pp. 949-953.

Abstract: A 3D computational fluid dynamics program was used to calculate the wind-induced accumulation of phytoplankton in Eglwys Nynydd, a water supply reservoir in Wales. The computational fluid dynamics model solved the Navier-Stokes equations for the water velocities using the SIMPLE method to calculate the pressure. Two turbulence models were tested: a zero-equation model and the *k*-E model. An unstructured nonorthogonal 3D grid with hexahedral cells was used. The distribution of the blue-green algae *Microcystis* was calculated by solving the transient convection-diffusion equation for phytoplankton concentration, based on the modeled flow field. The numerical model included algorithms for calculating the growth rate of phytoplankton and simulating the response of the algae to changes in underwater light intensity. The model was validated by comparing the horizontal distribution patterns produced by simulation with those recorded

during a field survey of surface concentrations. The results demonstrated reasonable agreement, particularly when using the *k*-e turbulence model. The main parameter affecting the results was the effective diameter of the *Microcystis* colonies.

Reine,K., Clarke,D., Dickerson,C., Pickard,S. 2007. Assessment of Potential Impacts of Bucket Dredging Plumes on Walleye Spawning Habitat in Maumee Bay, Ohio. World Dredging Congress. pp. 1-18.

Abstract: Annual dredging of a major navigation channel in Lake Erie's Maumee Bay occurs in close proximity to walleye *(Sander vitreus)* spawning and nursery habitat. Concerns raised by regulatory agencies over potential impacts focus largely upon sediment resuspension. Hypothetical impacts include smothering of demersal eggs by re-deposited sediment, altered egg incubation and hatching success due to increased turbidity effects on water temperature regimes, and clogging or abrasion of gill tissues caused by suspended particles. Monitoring of a clamshell bucket dredging operation was conducted to assess the risk factors posed by typical maintenance dredging in Maumee Bay. Efforts included deployment of optical backscatter sensors (OBS) for time series records of turbidity and acoustic Doppler current profiler (ADCP) surveys to determine the spatial extent, concentration gradient structure, and temporal dynamics of resuspended sediment plumes. Estimates of total suspended solids (TSS) concentrations were derived from ADCP relative backscatter data. Water samples were collected for gravimetric analysis and used to calibrate the acoustic backscatter data. Results indicated a rapid settling of suspended sediments within a relatively short distance from the dredging source. TSS concentrations fell from 800 mg!L at the source to less than 300 mg/L over a 25 m span. Maximum observed TSS concentrations decreased to 40 mg!L (15 mg/L above background) at a distance of 115 m from the source. Detectable plume signatures against background became indistinct at distances greater than 125 m, where TSS values did not exceed *5* to 10 mg/L above background. Plume signatures were not detected in surface waters beyond 60 m or in the lower water column beyond 200 m. Waters overlying adjacent shoals, which represented walleye habitat, were examined for elevated TSS attributable to the dredging operation. TSS concentration ranges observed on shoals closest to the dredging activity were not measurably different than on shoals outside the area influenced by plumes. TSS concentrations on the shoals remained generally within 25 mg/L background levels and were consistent with background concentrations for all depth strata within the navigation channel. Turbidities were also monitored in both the navigation channel and adjacent shoals. Turbidities within the plume generally did not exceed 400 nephelometric turbidity units (NTU) at 25 m and 300 NTU at 46 m from the source in the lower water column, but peaked at 500 to 700 NTU in short duration spikes when the dredge advanced to within 15m of a moored OBS. In contrast, ambient turbidities in the navigation channel did not exceed 25 NTU. Background turbidities measured at *5* stations located on the adjacent shoals ranged from *5* to 15 NTU. At one of three stations located on the shoals immediately adjacent to the dredge,

measurements exceeded background conditions twice during ten minute pulses that occurred approximately 3.5 hours apart. At two sensors located 157 and 186m from the dredge, single occurrences were recorded in which ambient conditions were exceeded by 3 to 10 NTU. In summary, it is very unlikely that bucket dredging operations conducted under similar conditions in Maumee Bay pose a meaningful risk to walleye in terms of either physical disturbance of spawning habitat or exposure of eggs to problematic sedimentation. Prevailing water current velocities were relatively slow, with depthaveraged velocities of 0.17 m/sec in the channel and 0.21 m/sec over the shoals. In the absence of swifter current flows to drive far-field dispersion of plumes, the spatial extent of plumes at any point in time would be limited such that exposures of larvae in the water column to elevated doses of suspended sediments or other altered water quality parameters would be minimal.

Reutter,J.M., Ciborowski,J., DePinto,J.V., Bade,D., Baker,D., Bridgeman,T.B., Culver,D.A., Davis,S., Dayton,E., Kane,D.D., Mullen,R.W., Pennuto,C.M. 2011. Lake Erie Nutrient Loading and Harmful Algal Blooms: Research Findings and Management Implications. pp. 1-19.

Richards,R.P., Alameddine,I., Allan,J.D., Baker,B.D., Bosch,N.S., Confesor,R., DePinto,J.V., Dolan,D.M., Reutter,J.M., Scavia,D. 2012. Discussion of "Nutrient Inputs to the Laurentian Great Lakes by Source and Watershed Estimated Using SPARROW Watershed Models" by Dale M. Robertson and David A. Saad. *Journal of the American Water Resources Association.* pp. 1-10.
Abstract: Results from the Upper Midwest Major River Basin (MRB3) SPARROW model and underlying Fluxmaster load estimates were compared with detailed data available in the Lake Erie and Ohio River watersheds. Fluxmaster and SPARROW estimates of tributary loads tend to be biased low for total phosphorus and high for total nitrogen. These and other limitations of the application led to an overestimation of the relative contribution of point sources vs. nonpoint sources of phosphorus to eutrophication conditions in Lake Erie, when compared with direct estimates for data-rich Ohio tributaries. These limitations include the use of a decade-old reference point (2002), lack of modeling of dissolved phosphorus, lack of inclusion of inputs from the Canadian Lake Erie watersheds and from Lake Huron, and the choice to summarize results for the entire United States Lake Erie watershed, as opposed to the key Western and Central Basin watersheds that drive Lake Erie's eutrophication processes. Although the MRB3 SPARROW model helps to meet a critical need by modeling unmonitored watersheds and ranking rivers by their estimated relative contributions, we recommend caution in use of the MRB3 SPARRROW model for Lake Erie management, and argue that the management of agricultural nonpoint sources should continue to be the primary focus for the Western and Central Basins of Lake Erie.

Richards,R.P., Baker,B.D. 1993. Trends in Nutrient and Suspended Sediment Concentrations in Lake Erie Tributaries, 1975-1990. *J.Great Lakes Res.* Vol. 19 (2). pp. 200-211.
Abstract: During the last twenty years, intensive efforts have been aimed at reducing the eutrophication of Lake Erie. Although point source inputs have been greatly reduced, models indicated that nonpoint source inputs would need reduction as well, to meet phosphorus management goals for Lake Erie. Since non-point inputs enter the lake via tributary inflow, it is important to examine tributary records for evidence of trends in nutrient concentrations which might reflect success in reducing non-point inputs. Data series for the Maumee, Sandusky, and Cuyahoga Rivers. and for Honey Creek. spanning 9 to 16 years and up to 6,500 observations, were examined for trends in nutrients and suspended solids. Mean daily flows and two forms ofweighted mean concentrations were compiled at monthly intervals. and studied using parametric and non-parametric techniques of trend detection. Total and soluble reactive phosphorus. suspended sediment, and nitrate-plus-nitrite were examined. Flow and suspended sediment generally showed statistically non-significant minor trends. Total and soluble phosphorus both showed downward trends, statistically significant for most data series, of 5 to 40 ~g/L per year. Nitrate-plusnitrite showed usually statistically significant increases of 10 to 140 ~g/L per year, except for the Cuyahoga data. which showed a statistically significant downward trend of about 70 ~g/L per year. These results are important both because they reflect important progress in the remediation of Lake Erie. and because they demonstrate the possibility of detecting trends in tributaries. given sufficient data and appropriate statistical approaches.

Roelke,D., Buyukates,Y. 2002. Dynamics of phytoplankton succession coupled to species diversity as a system-level tool for study of Microcystis population dynamics in eutrophic lakes. *Limnol.Oceanogr.* Vol. 47 (4). pp. 1109-1118.
Abstract: Many of the processes that influence initiation and development of harmful algal blooms (HABs) in lake ecosystems also affect the nature of phytoplankton population overturn—here referred to as the dynamics of succession— and species diversity. Consequently, the dynamics of succession and species diversity might reflect the lake's resistance to HABs. We explored this idea by developing a potential system-level tool based on the coupling of these two characters, where the dynamics of succession were quantified using a first derivative index, and tested it in a single lake plagued by recurrent blooms of *Microcystis aeruginosa.* Our analysis showed that if nonbloom periods were characteristic of either low succession dynamics or low species diversity, *M. aeruginosa* blooms followed. However, when succession dynamics and species diversity were both high for an extended period, a *M. aeruginosa* bloom did not follow. Should this relationship hold true in other lakes and when blooms are not as severe, a coupling of succession dynamics to species diversity might prove useful as a tool to evaluate *M. aeruginosa* population dynamics at the system level. Data at the species level were needed to elucidate this inverse relationship between *M. aeruginosa* bloom initiation

and the dynamics of succession coupled to species diversity. When species data were grouped into coarse taxonomic categories (i.e., groups discernable using in vivo absorption spectra) the relationship was not detectable.

Schumacher,B., Plumb,Jr.R., Fox,R. 1998. Great Lakes Dredged Material Testing and Evaluation Manual. pp. 1-564.

Schwab,D.J., Beletsky,D., DePinto,J.V., Dolan,D.M. 2012. A hydrodynamic approach to modeling phosphorus distribution in Lake Erie. *J Great Lakes Res.* Vol. 35. pp. 50-60.
Abstract: The purpose of this paper is to show how a high-resolution numerical circulation model of Lake Erie can be used to gain insight into the spatial and temporal variability of phosphorus (and by inference, other components of the lower food web) in the lake. The computer model simulates the detailed spatial and temporal distribution of total phosphorus in Lake Erie during 1994 based on tributary and atmospheric loading, hydrodynamic transport, and basin-dependent net apparent settling. Phosphorus loads to the lake in 1994 were relatively low, about 30% lower than the average loads for the past 30 years. Results of the model simulations are presented in terms of maps of 1) annually averaged phosphorus concentration, 2) temporal variability of phosphorus concentration, and 3) relative contribution of annual phosphorus load from specific tributaries. Model results illustrate that significant nearshore to offshore gradients occur in the vicinity of tributary mouths and their along-shore plumes. For instance, the annually averaged phosphorus concentration can vary by a factor of 10 from one end of the lake to the other. Phosphorus levels at some points in the lake can change by a factor of 10 in a matter of hours. Variance in phosphorus levels is up to 100 times higher near major tributary mouths than it is in offshore waters. The model is also used to estimate the spatial distribution of phosphorus variability and to produce maps of the relative contribution of individual tributaries to the annual average concentration at each point in the lake.

Seitzinger,S.P. 1991. The Effect of pH on the Release of Phosphorus from Potomac Estuary Sediments: Implications for Blue-green Algal Blooms. *Estuarine, Coastal and Shelf Science.* Vol. 33. pp. 409-418.
Abstract: The recurrence of a blue-green algal bloom *(Microcystis aeruginosa)* in the freshwater tidal portion of the Potomac estuary in 1983 was related to the enhanced release of phosphorus from benthic sediments. The release of phosphorus was measured from Potomac estuary sediment cores incubated with water at pH . levels encompassing the range outside (pH 7-8) and inside (pH 9·5-10·5) the 1983 bloom area. Phosphate release under aerobic conditions increased as a function of overlying water pH: between pH 8 and 9 the sediment-water phosphate flux was low; beginning with an overlying water pH of 9·5, the phosphate flux markedly increased. The increased release of phosphate at high pH is probably a result of solubilization of iron and aluminium phosphate complexes. Phosphorus release rates from

the sediments at high pH (pH 9·5-10·5) are similar to the phosphorus source needed to account for the excess phosphorus measured in

Smith,D.A., Matisoff,G. 2008. Sediment Oxygen Demand in the Central Basin of Lake Erie. *Journal of Great Lakes Research.* Vol. 34. pp. 731-744.
Abstract: Three separate procedures were used to estimate the sediment oxygen demand (SOD) in the central basin of Lake Erie and were compared with other estimates determined previously and with historical data. First, whole core incubations involved sealing sediment cores at 12°C to ensure no interaction between the overlying water and the atmosphere and monitoring continuously to define the linear disappearance of oxygen. Second, sediment plugs were placed inside flow-through reactors and the influent and effluent concentrations were monitored to obtain steady-state reaction rates. Third, an extensive data set for the central basin of Lake Erie was compiled for input into the diagenetic BRNS model, and the SOD was calculated assuming all primary redox reactions, but no secondary reactions. All three procedures produced estimates of SOD that were in reasonable agreement with each other. Whole core incubations yield an average SOD of 7.40 ´ 10–^{12} moles/cm2/sec, the flow-through experiments had an average SOD of 4.04 ´ 10–^{12} moles/cm2/sec, and the BRNS model predicts an SOD of 7.87 ´ 10–^{12} moles/cm2/sec over the top 10 cm of sediment and appears to be calibrated reasonably well to the conditions of the central basin of Lake Erie. These values compare reasonably well with the 8.29 ´ 10–^{12} moles/cm2/sec obtained from diffusion modeling of oxygen profiles (Matisoff and Neeson 2005). In contrast, values reported from the 1960s to 1980s ranged from 10.5–32.1 ´ 10–^{12} moles/cm2/sec suggesting that the SOD of the central basin has decreased over the last 35 years, presumably, in response to the decrease in phosphorus loadings to Lake Erie. However, since hypoxia in the hypolimnion persists these results suggest that improvement in hypolimnetic oxygen concentrations may lag decreases in loadings or that the hypolimnion in the central basin of Lake Erie is simply too thin to avoid summer hypoxia during most years.

Sosnowski,R.A. 1984. Sediment resuspension due to dredging and storms: an analogous pair. Montgomery,R.L., Leach,J.W. (eds) Proceedings of the Conference Dredging _84. pp. 609-618. American Society of Civil Engineers.

Stahl-Delbanco,A., Hansson,L. 2002. Effects of bioturbation on recruitment of algal cells from the "seed bank" of lake sediments. *Limnol.Oceanogr.* Vol. 47 (6). pp. 1836-1843.
Abstract: Effects of different bioturbators on recruitment of several nuisance algae, *Anabaena* spp. (Cyanophyta), *Microcystis* spp. (Cyanophyta), and *Gonyostomum semen* (Raphidophyta), from sediment to water were studied in a long-term laboratory experiment. Natural sediment, where macrofauna larger than 1 mm had been removed, was added to 18 aquaria. To each of six aquaria, individuals of *Asellus aquaticus* (Isopoda) or *Chironomus plumosus* (Arthropoda) larvae were added, and six aquaria were left as bioturbation-free

controls. Recruitment of *Anabaena, Microcystis,* and *G. semen* from the sediment was detected using inverted traps that were sampled once a week during 8 weeks. The activities of the isopod *A. aquaticus* increased recruitment rates of all algal groups investigated, whereas chironomids had a less pronounced effect.
With respect to *Anabaena,* increased recruitment rate was expressed as a promotion of growth in the pelagic habitat. To our knowledge, these results are the first to demonstrate that bioturbating invertebrates affect the recruitment of phytoplankton resting stages. Moreover, our results suggest that recruitment rate might be more pronounced in littoral areas, which are often dominated by *A. aquaticus,* rather than in profundal areas of a lake, generally dominated by chironomids. Hence, with respect to algal dynamics, the strength of the coupling between the benthic and pelagic zones might vary both spatially and temporally, depending on composition of the benthic invertebrate community and the ontogenetic development of the individuals within it.

Stahl-Delbanco,A., Hansson,L., Gyllstrom,M. 2003. Recruitment of resting stages may induce blooms of Microcystis at low N:P ratios. *Journal of Plankton Research.* Vol. 25 (9). pp. 1099-1106.
Abstract: Some species of cyanobacteria form resting stages at the sediment surface when environmental conditions become unfavourable. As conditions turn more favourable, these resting stages hatch to the water phase, where the cells grow, reproduce, and sometimes form blooms. Since blooms of cyanobacteria have become an increasing threat to inland and brackish waters, it is important to assess the mechanisms and processes involved in the initiation of such blooms. One such mechanism is recruitment from the sediment surface. Potential factors regulating the recruitment of resting stages include variations in nutrient concentrations and ratios, as well as variations in grazing. To investigate how the recruitment of Microcystis responds to different levels of these factors, we performed an enclosure experiment (zooplankton abundances were regulated by predation from fish). We found that recruitment and growth were most pronounced at the second highest nutrient concentration (average concentrations were 498 ìg l–^{1} of dissolved nitrogen and 134 ìg l–^{1} of total phosphorus), while no direct response to different grazing levels was detected. We also found that resting stages can be important for initiating and sustaining blooms. The environmental conditions most important in regulating the recruitment rate from resting stages corresponded to the requirements of the plankton cells, namely high nutrient addition and low N:P ratio.

Stumpf,R.P., Wynne,T.T., Baker,D.B., Fahnenstiel,G.L. 2012. Interannual Variability of Cyanobacterial Blooms in Lake Erie. *PLoS ONE.* Vol. 7 (8). pp. 1-11.
Abstract: After a 20-year absence, severe cyanobacterial blooms have returned to Lake Erie in the last decade, in spite of negligible change in the annual load of total phosphorus (TP). Medium-spectral Resolution Imaging Spectrometer (MERIS) imagery was used to quantify intensity of the

cyanobacterial bloom for each year from 2002 to 2011. The blooms peaked in August or later, yet correlate to discharge (Q) and TP loads only for March through June. The influence of the spring TP load appears to have started in the late 1990 s, after Dreissenid mussels colonized the lake, as hindcasts prior to 1998 are inconsistent with the observed blooms. The total spring Q or TP load appears sufficient to predict bloom magnitude, permitting a seasonal forecast prior to the start of the bloom.

Sullivan,M. 1987. Hydrometeorological data and its usefulness in the study of algae blooms in the Potomac River. Climate and Water Management A Critical Era. pp. 1-10.

Sweeney, R., Foley, R., Merckel, C., Wyeth, R. 1975. Impacts of the deposition of dredged spoils on Lake Erie sediment quality and associated biota. Journal of Great Lakes Research, Vol. 1(1):162-170.
Abstract: Sediment samples were collected during June, August and November, 1973 from twenty-five (25) equally spaced stations over an area of nearly 64 sq km, the centre of which was approximately 12 km north of Cleveland, Ohio. Within this zone was a United States ~orps of Engineers 16.5 sq km dump-site in which more than 18.96 x 106 m3 of dredgings from Cleveland Harbor and the Cuyahoga River had been deposited between approximately 1925 and 1968. Seven (7) of the above stations were situated in this former dump-site. Simultaneously collections were made at 25 equally spaced stations in a 64 sq km area situated southwest and adjacent to the region described above. The latter area had not been used as a dump-site. Sediment gathered with Ponar dredges was analyzed for BOD, COD, phosphates (soluble and total), nitrogen (nitrates, ammonium, organic and total), oils and greases, chlorine demand and heavy metals (mercury, iron, cadmium and chromium). In addition, quantitative and qualitative analyses for benthic macroinvertebrates were conducted. The concentrations of nutrients (phosphorus and nitrogen), toxicants (heavy metals) and pollutants (as indicated by chlorine demand, BOD, COD and oils and greases measurements) in the surface sediments generally were higher in the dump-site than in the surrounding sediments. with regard to benthic macroinvertebrates, the lowest species diversity indexes and a highest oligochaete to total organism ratio generally were observed in the former spoils deposition region. It was concluded that the quality of the benthic environment was degraded by past dredging disposal practices.

Thomas and Hutton Eng. 2005. Dredging and Disposal Alternatives and Techniques. pp. 1-20. Thomas & Hutton Engineering Co., Savannah, GA.

Tomlinson,L.M., Auer,M.T., Bootsma,H.A., Owens,E.M. 2010. The Great Lakes Cladophora Model: Development, testing, and application to Lake Michigan. *J Great Lakes Res.* Vol. 36. pp. 287-297.
Abstract: A recent review of the Great Lakes Water Quality Agreement has concluded that while controls on phosphorus inputs to Lake Michigan

achieved the desired effect in offshore waters, the nearshore region continues to suffer from elevated phosphorus levels. Failure to achieve trophic state goals in the nearshore is manifested in nuisance growth of Cladophora and attendant impacts on property owners, utilities, and the public health and welfare. This study focuses on a site in Lake Michigan near Milwaukee, Wisconsin, where nuisance growth of Cladophora and associated beach fouling occur regularly. A mechanistic model simulating Cladophora growth, suitable for guiding nutrient management in the Great Lakes nearshore, is presented. The model represents an update of the Canale and Auer framework, reflecting current understandings of Cladophora ecology and offering a user-friendly interface making the software more widely available to decision makers. This Great Lakes Cladophora Model (GLCM) is first validated for the Auer/Canale data set collected in 1979 at a site on Lake Huron and then for a data set developed in 2006 for a site on Lake Michigan. Model performance under the strikingly different forcing conditions (depth, light, phosphorus levels) characteristic of these two sites affirms the widespread applicability of the tool. The GLCM is then extended to examine the impacts of ecosystem perturbation (dreissenid colonization) on Cladophora growth and to future approaches to monitoring and management.

Truitt,C.L. 1988. Dredged Material Behavior During Open-Water Disposal. *Journal of Coastal Research.* Vol. 4 (3). pp. 489-497.
Abstract: This paper summarizes information on sediment transport as suspended solids into the water column during dredged material disposal by barge and hopper at open-water sites.The review provides an overview of field data referenced in the more widely quoted studies on open-water disposal and compares collection methods and results. The data confirm the behavior model of a near-bottom radial surge with high solids concentration and little dispersion in the upper water column. The importance of using mass units of measurement rather than only volumetric units in accounting for the fate of dredged material is also discussed.

Twiss,M.R., McKay,R.K.L., Bourbonniere,R.A., Bullerjahn,G.S., Carrick,H.J., Smith,R.E.H., Winter,J.G., D'souza,N.A., Furey,P.C., Lashaway,A.R., Saxton,M.A., Wilhelm,S.W. 2012. Diatoms abound in ice-covered Lake Erie: An investigation of offshore winter limnology in Lake Erie over the period 2007 to 2010. *J Great Lakes Res.* Vol. 38. pp. 18-30.
Abstract: The limnology of offshore Lake Erie during periods of extensive (>70%) ice cover was examined from ship borne sampling efforts in 2007 to 2010, inclusive. Dense and discrete accumulations of the centric filamentous diatom Aulacoseria islandica (>10 ìg Chl-a/L) were located in the isothermal (b1 °C) water column directly below the ice and only detectable in the ship wake; viable phytoplankton were also observed within ice. Evidence from these surveys supports the notions that winter blooms of diatoms occur annually prior to the onset of ice cover and that the phytoplankton from these blooms are maintained in the surface waters of Lake Erie and reduce silicate concentrations in the lake prior to spring. Themechanisms bywhich high

phytoplankton biomass rise at this time of year requires further investigation, but these winter blooms probably have consequences for summer hypoxia and how the lake responds to climate change.

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USACE 2012. Great Lakes System Dredged Material Management Long Term Strategic Plan. pp. 1-92. U.S. Army Corps of Engineers.

USEPA 1995. QA/QC Guidance for Sampling and Analysis of Sediments, Water, and Tissues for Dredged Material Evaluations. pp. 1-297. United States Environmental Protection Agency - Office of Water, Washington D.C.

USEPA 2005. Uniform Federal Policy for Quality Assurance Project Plans Evaluating, Assessing, and Documenting Environmental Data Collection and Use Programs. pp. 1-177. US Environmental Protection Agency - Intergovernmental Data Quality Task Force.

USEPA 2007. The Role of the Federal Standard in the Beneficial Use of Dredged Material from U.S. Army Corps of Engineers New and Maintenance Navigation Projects. pp. 1-16.

USEPA 2008. Lake Erie Lakewide Management Plan. pp. 1-10. United States Environmental Protection Agency- Great Lakes National Program Office, Chicago, IL.

USEPA 2012. Lake Erie Lakewide Management Plan Annual Report 2011. pp. 1-4. United States Environmental Protection Agency - Great Lakes National Program Office. Lake Erie Lakewide Management Plan, Chicago, Illinois. **Abstract: Overview** The Lake Erie ecosystem is unique. It is the shallowest and the most biologically diverse of all the Great Lakes. The Lake Erie watershed is home to over 11 million people, supports one of the largest freshwater fisheries in the world, and provides many recreational and tourism opportunities due to the presence of numerous beaches and extensive wetland complexes. It is sensitive to pressures from urban and rural land uses, such as excessive nutrient inputs, habitat loss and degradation and the introduction of nonnative invasive species. Lake Erie Lakewide Management Plan (LaMP) participants continue to tackle the challenge of managing this variable and sensitive ecosystem. This Annual Report summarizes recent progress, as well as challenges and next steps. Highlights in this 2011 report include: An update on the setting of indicator targets for total phosphorus concentrations in Lake Erie; An update on the Great Lakes Restoration Initiative (GLRI) and CanadaOntario Agreement (COA); An update on algae and a call to action to address the issue; Potential impacts of climate change on hypoxia (areas of low dissolved oxygen) in Lake Erie; An update on the development of the Binational Biodiversity Conservation Strategy for Lake Erie Although progress continues, there is still much work to be done. If you would like to know more, please visit the website at *www.binational.net* or use the contacts listed on the back page.

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Wynne,T.T., Stumpf,R.P., Tomlinson,M.T., Dyble,J. 2010. Characterizing a cyanobacterial bloom in western Lake Erie using satellite imagery and meteorological data. *Limnol.Oceanogr.* Vol. 55 (5). pp. 2025-2036.
Abstract: The distribution and intensity of a bloom of the toxic cyanobacterium, Microcystis aeruginosa, in western Lake Erie was characterized using a combination of satellite ocean-color imagery, field data, and meteorological observations. The bloom was first identified by satellite on 14 August 2008 and persisted for . 2 months. The distribution and intensity of the bloom was estimated using a satellite algorithm that is sensitive to near-surface concentrations of M. aeruginosa. Increases in both area and intensity were most pronounced for wind stress, 0.05 Pa. Area increased while intensity did not change for wind stresses of 0.05-0.1 Pa, and both decreased for wind stress . 0.1 Pa. The recovery in intensity at the surface after strong wind events indicated that high wind stress mixed the bloom through the water column and that it returned to the surface once mixing stopped. This interaction is consistent with the understanding of the buoyancy of these blooms. Cloud cover (reduced light) may have a weak influence on intensity during calm conditions. While water temperature remained . 15uC, the bloom intensified if there were calm conditions. For water temperature , 15uC, the bloom subsided under similar conditions. As a result, wind stress needs to be considered when interpreting satellite imagery of these blooms.

Xie,L., Rediske,R.R., Hong,Y., O'Keefe,J., Gillett,N.D., Dyble,J., Steinman,A.D. 2012. The role of environmental parameters in the structure of phytoplankton assemblages and cyanobacteria toxins in two hypereutrophic lakes. *Hydrobiologia.* Vol. 691. pp. 255-268.
Abstract: We evaluated the variability of cyanotoxins, water chemistry, and cyanobacteria communities in two hypereutrophic drowned river mouth lakes (Spring Lake and Mona Lake; summer 2006) in west Michigan, USA. Even with considerable geographical and watershed similarity, local variations in nutrient concentrations and environmental factors were found to influence the differences observed in cyanobacteria assemblages and cyanotoxins levels between the two lakes. Limnothrix sp. dominated the phytoplankton community in Spring Lake (82% of biovolume) and was negatively correlated with total phosphorus (TP) concentrations. Although Spring Lake was treated

with alum during the previous year, Limnothrix sp.was able to bloom in the lower P environment. In contrast, the N2-fixing cyanobacterium, Anabaena flos-aquae, dominated the phytoplankton in Mona Lake (64% of biovolume). N_2-fixing cyanobacteria dominance in Mona Lake was correlated with higher TP lower dissolved nitrogen levels. Cylindrospermopsis raciborskii was found in both systems; however, the toxin-producing polyketide synthetase gene was not present in either population. The higher TP in Mona Lake appeared to account for the 3-fold increase in cyanobacteria biovolume. Restoration plans for both lakes should include assessments of internal loading and continued phytoplankton monitoring to track the temporal distribution of cyanobacteria species and cyanotoxin concentrations.

Young,T.C., DePinto,J.V., Martin,S.C., Bonner,J.S. 1985. Algal-Available Particulate Phosphorus In The Great Lakes Basin. *Journal of Great Lakes Research.* Vol. 11 (4). pp. 434-446.
Abstract: For the purpose of comparing the relative availability of particulate phosphorus (P) from various sources to the Great Lakes, a/gal-available P was determined on suspended solids and bottom sediments from tributaries, wastewater suspended solids, lake bottom sediments, and eroding bluff solids from the region. Physicochemical and bioassay methods were used to estimate the rate and extent of available P release from particulates. Considering all types of particulates examined, ultimately available P ranged from nil to approximately 70 percent of total phosphorus (Total-P) content. During algal bioassays, changes in levels of base-extractable inorganic P (R-NaOH-P) in tributary suspended solids were nearly equivalent to the amounts of P used by algae during bioassays. For the tributary solids, ultimately available P averaged approximately 90 percent of R-NAOH-P Consistent differences were found in amounts of available P among particles from different sources. Sources of particle-bound P ranked in order of decreasing availability were: wastewater solids, lake bottom sediments, tributary solids, and eroding bluff solids. Differences in available P release rates also existed among the different types of particles. Wastewater solids displayed the largest first-order release rates, eroding bluff samples and tributary-suspended solid samples that were high in apatite showed essentially no available P release, while other tributary suspended solids displayed intermediate release rates.

Young,T.C., DePinto,J.V., Hughes,B.J. 1988. Comparative Study of Methods for Estimating Bioavailable Particulate Phosphorus. Chemical and Biological Characterization of Sludges, Sediments, Dredge Spoils, and Drilling Muds. pp. 69-80. American Society for Testing and Materials, Philadelphia.
Abstract: A group of chemical and biological procedures for estimating the biologically available phosphorus (BAP) in sediments, representing methods currently used for research around the Great Lakes, were compared among twelve widely different samples of particulate matter from the lower great Lakes region. The procedures, including one biological and five chemical methods, extracted wildly different amount of phosphorus from the sediments. Among the procedures, however, the results were highly correlated indicating

the potential for making valid conversion among the estimates, at least for most samples. Analysis of samples held in storage for several years, however, gave results by some extraction procedures that seemed abnormal. Phosphorus extracted by the procedures of Armstrong et al. [1] and Baker [2] correlated most closely with bioassay results, while that extracted by the procedure of De Ponto et al. [3] most closely approximated amounts of phosphorus taken up by algae during bioassays.

Zhang,H., Culver,D.A., Boegman,L. 2011. Dreissenids in Lake Erie: an algal filter or a fertilizer? *Aquatic Invasions.* Vol. 6 (2). pp. 175-194.
Abstract: After successfully occupying the benthos of all the Laurentian Great Lakes and connecting channels, quagga mussels [*Dreissena rostriformis bugensis* (Andrusov, 1897)] have been colonizing the western United States at a much faster rate. Study findings and management experience in the Great Lakes will benefit the water resource managers in the western United States and help them be better prepared to act quickly and effectively to mitigate mussel impacts. We investigated the impacts of dreissenid mussels on nutrients and plankton using a two-dimensional Ecological model of Lake Erie (EcoLE), and compared their impacts with those of mesozooplankters. Model results showed that in the shallow western basin, mussel daily grazing impact was less than 10% of the combined Non-Diatom Edible Algae (NDEA) and diatom biomass, although they cleared a volume equivalent to 20% of the water column daily. Moreover, in the deep central and eastern basins, dreissenids grazed only 1-2% of the NDEA and diatom biomass per day. The relative importance of dreissenids' grazing impact on diatoms and NDEA to those of zooplankton's varied among years and basins in Lake Erie. In general, zooplankton had slightly higher grazing impacts than did the mussels on NDEA and diatoms in the western basin but much higher grazing impacts in the central basin. Dreissenid mussels excreted a big portion of phosphorus in the bottom water, especially in the western basin, while zooplankton kept a big portion of algal phosphorus in the water column, especially in the central and eastern basins. Non-Diatom Inedible Algae (NDIA) abundance increased with more phosphorus available and was less responsive to mussel selective grazing. Dreissenid mussels affected crustacean zooplankton mainly through their impacts on NDEA. Our results thus indicate that dreissenid mussels have weak direct grazing impacts on algal biomass due to a concentration boundary layer above the mussel bed, while their indirect effects through nutrient excretion have much greater and profound negative impacts on the system. EcoLE is a modification of CEQUAL- W2, which is frequently applied to western aquatic systems, and we suggest that with this modification, the models can be used to predict dreissenid impacts in western lakes, reservoirs, and rivers in which they may become established.

Zhang,W., Yerbundai,R. 2012. Application of a eutrophication model for assessing water quality in Lake Winnipeg. *Journal of Great Lakes Research.* Vol. 38. pp. 158-173.
Abstract: A eutrophication model using Water Analysis Simulation Program

(WASP) has been applied to Lake Winnipeg during the period from 2002 to 2007. The model includes two nutrient cycles (N and P) and three functional phytoplankton groups (non-cyanobacteria, N-fixing cyanobacteria and non-N-fixing cyanobacteria). The model also considers distinct features of the morphological, hydrological, and climate conditions of the South and North Basins. The calibrated and validated results of water quality variables are in good agreement with the observed data of TN, NO3, NH4, TP, PO4, DO, and total chlorophyll-a. The model reproduced qualitative features of phytoplankton communities in space and time, such as cyanobacteria in the North Basin during the late summer and non-cyanobacteria in the South Basin during the spring. The non-N-fixing cyanobacteria showed an increasing trend, even though it occupied smaller percentage than N-fixer within total cyanobacteria. Multiple nutrient-reduction scenarios were examined to assess the potential influence of different N:P loading ratios on the lake ecosystem. A 10% reduction of phosphorus decreased the cyanobacteria percentage in both basins, and reduced peak values of chlorophyll-a concentration during late summer in the North Basin. However, model results indicate that this will promote growth of non-N-fixing cyanobacteria. A reduction of nitrogen and phosphorus loading by 10% will restrict non-Nfixing cyanobacteria. The averaged phytoplankton biomass (expressed as chlorophyll-a concentration) and phytoplankton components suggest that increasing N:P loading ratio (P reductionN12% and N reductionb7%) would be effective for improving water quality in Lake Winnipeg.

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B Conceptual Site Model

Final Conceptual Site Model: Influence of Open-Lake Placement of Dredged Material on Western Lake Erie Basin Harmful Algal Blooms

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1. INTRODUCTION

This technical memorandum presents the conceptual model developed by LimnoTech, under contract to Ecology and Environment, Inc. (E & E), to describe the influence of open-lake placement of dredged material on Western Basin Lake Erie (WBLE) harmful algal blooms (HABs). This memorandum provides a comprehensive description of the conceptual site model components. Section 1 provides an overview of the conceptual model and background information on dredged material as it relates to nutrients and the development of HABs. Section 2 presents the conceptual model diagram. Section 3 includes a description of the phosphorus loads to the WLEB. Section 4 provides information on the specific forms of phosphorus. Section 5 discusses algal growth and Section 6 describes other biological phosphorus controls. References are included in Section 7.

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2. OVERVIEW

The overall objective of this project is to quantify the relative contribution of open-lake disposal of dredged material from the Toledo Harbor Navigation Channel to cyanobacteria (i.e., blue-green algae) blooms in the WBLE. To accomplish this, a conceptual model has been developed that describes LimnoTech's best understanding of how this system behaves and what processes need to be considered to address the management questions. The conceptual model demonstrates LimnoTech's understanding of all of the sources believed to contribute to cyanobacteria blooms, including open-lake disposal. LimnoTech's goal, through a combination of data collection and model application derived from this conceptual model, is to make an evaluation of the relative contribution of each driver. This conceptual model is based on previous work by LimnoTech (2010) as well as a review of relevant literature sources on the topic, which have been summarized in a separate literature review conducted for this project.

2.1 BACKGROUND

The bulk of dredged material is particulate material that contains both adsorbed inorganic phosphate and bound organic phosphorus; therefore, the extent to which dredged material contributes to an increase in concentrations of algal-available phosphorus in the lake depends on the extent to which soluble orthophosphate is released from these two categories of particulate phosphorus in the water column. The net increase in algal available phosphorus to the water column from dredged material over short and long time periods represents the net impact of open lake disposal. It is the goal of this project is to quantify the net impact relative to other sources of algal-available phosphorus.

Although algae need other nutrients for growth, such as nitrogen, silica, and other trace nutrients, phosphorus is the limiting nutrient in the Great Lakes (Dolan and Chapra, 2012; Chapra and Dolan, 2012). The most important factor determining the growth of algae in the WBLE is the concentration of algal-available phosphorus in the water column (DePinto et al. 1986b; DePinto et al. 1986a; Baker 2010), along with light and temperature. The conceptual model presented here identifies all of the sources of algal-available phosphorus to the system, so that they can be compared in terms of relative magnitude with the algal-available phosphorus that is released from the dredge material disposed of in the open lake.

The temporal and spatial variability in the growth of algae across the western basin also requires a quantitative understanding of the major factors that govern algal growth and loss. The field work proposed for this project involves measuring the environmental conditions and processes that occur during open-lake disposal that govern its contribution to algal growth on both short- and long-term time scales, from hours after disposal up to several months. All of the data collected as part of this project, as well as data from other sources, will be used to drive the Western Lake Erie Ecosystem Model (WLEEM), LimnoTech's fine-scale hydrodynamic-sediment transport-eutrophication model. The model will be applied to quantify all contributions of external and internal phosphorus to algal biomass development and used to quantify the relative contribution of open-lake disposal. The total release of bioavailable phosphorus from both barge release and sediment release of deposited dredged material will be estimated and a typical phosphorus-chlorophyll a stoichiometry will be used to estimate the absolute maximum chlorophyll a that can be produced. This will not account for temporal and spatial and algal functional group (e.g., diatoms versus blue-greens) factors which will be accounted for in the WLEEM model. In Section 2, harmful algal blooms, algal blooms, algae, blue-green algae, cyanobacteria, and *Microsystis* all refer to the excessive growth of undesirable algal species in the western basin.

3. CONCEPTUAL DIAGRAM

Figure 1 presents a visual representation of the fate and transport of phosphorus and its connection to algal growth in the WBLE. It includes all of the external and internal sources of algal-available phosphorus that contribute to the development of blue-green algal blooms, including how open-lake disposal of dredged material can contribute to bloom development. Components of the conceptual model are discussed in more detail in the following sections. To keep the figure simple, the loading of dissolved and particulate phosphorus from external sources was combined into total phosphorus (TP); but it should be noted that different sources of total phosphorus and their associated forms represent different levels of algal availability. The dashed lines represent internal loads. Green arrows trace the movement of nutrients to and from algae and brown arrows trace the fate of dredged material in the water column. The black arrows show the nutrient interaction within the water column and the sediment bed.

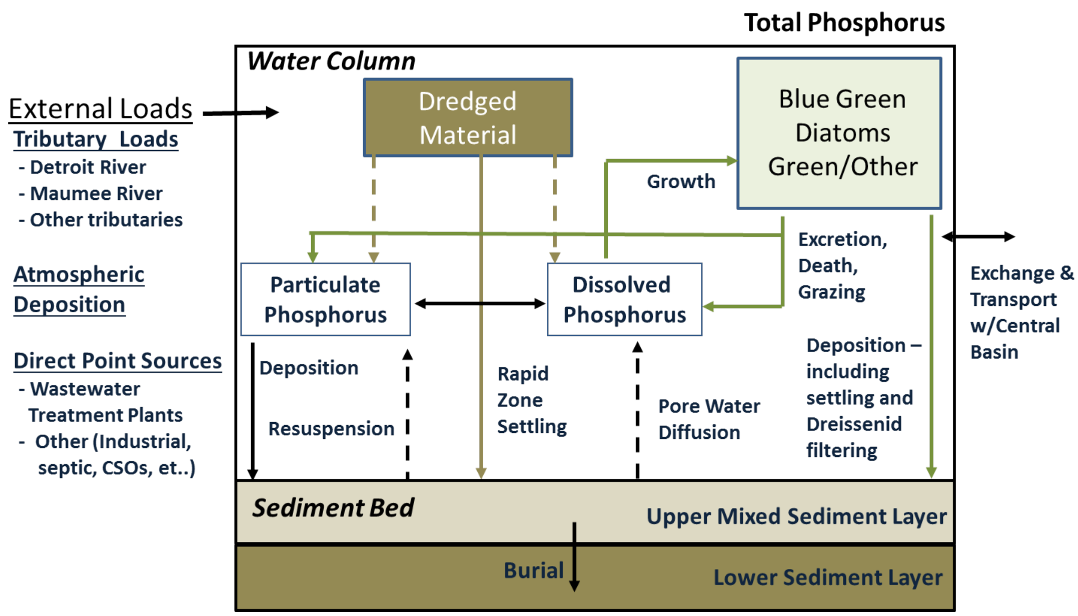

Figure 1. Conceptual Diagram of Linking Phosphorus Loads to Algal Blooms

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4. PHOSPHORUS LOADS

As mentioned above, phosphorus is the primary driver of HABs in the western basin; therefore, it is critical to have information on all external and internal sources of immediately and ultimately algal-available phosphorus to assess the relative contribution of open-lake disposal to the algal-available phosphorus that drives the blooms. Phosphorus is loaded into the water column of the WBLE through various sources. Phosphorus loading and the data on the external and internal sources of phosphorus to the western basin are described in the following subsections.

4.1 EXTERNAL LOADS

The total external phosphorus load to the WBLE was estimated at 7,108 metric tons per year (MT/yr) between 1998 and 2005 (OEPA 2010). This includes contributions from the connecting channels via the Detroit River, Maumee River, other smaller tributaries and direct point sources, and atmospheric deposition. Each major load category is discussed below.

4.1.1 Atmospheric Deposition

Although a relatively minor contribution, particulate phosphorus (PP) settles on the water surface throughout the year and is included here for completeness. Between 1998 and 2005 this accounted for 80 metric tons or approximately 1% of the total load delivered to the basin (OEPA 2010)

4.1.2 Detroit River

The Detroit River load of phosphorus is comprised of tributary loads delivered to the Huron-Erie Corridor (HEC) (Lake Huron to Lake Erie, including Lake St. Clair), the inflow to the HEC from Lake Huron, direct point sources to the HEC including the Detroit Wastewater Treatment Plant, and CSOs associated with the cities along the HEC. These loads are all estimated individually and added to estimate the total TP load from the Detroit River to Lake Erie. The Detroit Wastewater Treatment Plant (approximately 650 MT/yr) (Dolan and Chapra 2012; OEPA 2010) accounts for 45% of the direct point source load to the western basin and 9% of the load to the WBLE between 1998 and 2005 (OEPA 2010). However, despite the large point source load, this load is being diluted by the flow of the Detroit River. The Detroit River TP load accounts for 37% of the total external load to the western basin (Dolan and Chapra 2012; OEPA 2010), even though the flow from the Detroit River (approximately 170,000 cubic feet per second [cfs]) represents approximately 95% of the total external flow into the western basin (Baker 2010) . The very low TP concentrations (13 to 19 µg/L) and very high flows of the Detroit River greatly reduce its ability to directly stimulate HABs formation (Burniston et al. 2012).

4.1.3 Maumee River

The Maumee River is the single largest tributary discharge to the western basin. Most the Maumee River TP load is derived from agricultural sources, as over 80% of the Maumee Watershed (approximately 6,300 square miles [mi^2]) land use is agricultural (OEPA 2010). Furthermore, the Maumee flow is very event-responsive where daily average flows can range from approximately1,000 cfs to approximately 80,000 cfs; and the vast majority of the associated sediment and nutrient load is delivered during the high flow events, signaling that it is indeed a nonpoint source dominated watershed. Even though the annual inflow from the Maumee is only approximately 4% of the total inflow to the western basin, it also accounts for approximately 42% of the total external TP load (OEPA 2010). This means that the flow-weighted concentration of TP in the Maumee River discharge to Lake Erie is close to 400 µg/L, almost 40 times higher than the Detroit River (Baker 2011; Burniston et al. 2012). Since a large Microcystis bloom will develop if soluble reactive phosphorus (SRP) in the water column is ≥30 µg/L (Wetzel 2001; Bridgeman et al. 2012) at the beginning of summer, it is apparent that the Maumee phosphorus load is the dominant source supporting Microcystis blooms.

4.1.4 Other Tributaries and Direct Point Sources

Other tributaries including the Raisin, Huron, Ottawa, Portage, Cedar, Stony, and other direct point sources comprise the remainder of the external TP load to the western basin. These sources contribute approximately 10% of the total load to the western basin, and are included in the TP budget for completeness (OEPA 2010).

4.2 INTERNAL LOADS TO THE WATER COLUMN

The bottom sediments of the western basin contain a very large reservoir of phosphorus that can enter the water column by a number of processes, and a certain fraction of that phosphorus either is, or can become, algal-available. A complete accounting of the contributions of various sources to cyanobacteria blooms should include these bottom sediment sources.

4.2.1 Resuspension

The resuspension of bottom sediments by wind/wave induced bottom sheer stresses increases the water column concentration of PP. PP concentrations remain elevated until the resuspended material settles back down to the sediment bed, which can be on the order of hours to days depending on particle sizes and turbulent mixing (DePinto et al. 1986c). While the suspended PP is in the water column, SRP can desorb and thus represent an additional source of algal phosphorus.

4.2.2 Sediment Diffusion

The bottom sediments of the WBLE can release dissolved phosphorus (DP) back into the water column by diffusion across the sediment-water interface (Chaffin and Kane 2010; Smith and Matisoff 2008). DP is comprised of SRP and dissolved organic phosphorus (DOP). The flux of phosphorus from the sediments is primarily governed by the pore-water concentration of DP, which can vary significantly under oxic and anoxic conditions. Under oxic conditions (bottom water dissolved oxygen above 2 milligrams per liter [mg/L]), fluxes of phosphorus are low, but under anoxic conditions the flux rate can increase by an order of magnitude because of the reduction of Fe^{+3} to Fe^{+2}, which releases SRP into solution. Even brief periods of anoxic conditions can trigger an increase in the flux of DP into the water column (James 2007; James 2010). Once released into the overlying water it becomes part of the DP pool available for uptake by algae.

4.2.3 Dredged Material

Dredged material is transported from one portion of the WBLE to another and is considered to be an internal load. The net effect of open lake disposal is similar to the natural process of sediment resuspension, but on a smaller local scale, whereby PP is reintroduced into the water column and allowed to settle to the bottom. During that settling process DP can desorb and become a part of the water column DP pool. Open lake disposal introduces both a particulate and dissolved load of phosphorus to the water column and it is the goal of this project to quantify the net increase in water column phosphorus concentrations and its ultimate impact on the growth of blue-green algae. Previous work suggests that dredged material settles to the bottom relatively quickly allowing for very limited contact time with the water column (DePinto et al. 1986c).

In addition, the turbidity associated with dredge material has also been raised as an issue associated with HABs development. High turbidity levels can cause a significant decrease in water column light penetration, which can provide an advantage to nuisance blue-green algae (LimnoTech 2010). The limited spatial and temporal extent of the high turbidity associated with dredge placement may limit its impact.

4.3 PHOSPHORUS LOSS AND EXPORT

Much of the particulate phosphorus (i.e., inorganic, organic detrital, and algal bound) deposited in the bottom sediments by settling is lost from active cycling in the water column by burial into deep sediment layers. Dissolved and particulate phosphorus can also be lost from the western basin water column by advective (i.e., flow) transport and diffusion across the boundary with the central basin. On an annual basis, phosphorus is moving from west to east, and is a net loss of phosphorus to the western basin.

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5. PHOSPHORUS FORMS

This section briefly reviews the various forms of phosphorus that are relevant to linking external and internal loads of phosphorus to algal growth. The conceptual diagram (see Figure 1) shows external loads coming into the system as TP. However, within the water column section of the diagram, phosphorus is divided into particulate and dissolved. Even further detail is necessary to understand the actual linkage between phosphorus and algal growth. Algal-available phosphorus is defined as soluble orthophosphate that can be directly utilized by algae. It is typically measured as SRP and can also be derived from phosphorus released by other biological or chemical processes as orthophosphate. The soluble orthophosphate is immediately available for algal uptake and growth, whereas the particulate (precipitated or adsorbed) or organic-bound orthophosphate is ultimately available phosphorus. Ultimately available phosphorus means that it does not become available until it has been released into solution as orthophosphate.

Figure 2 represents LimnoTech's understanding of the interactions among the phosphorus forms in the western basin. This figure is meant to compliment Figure 1 by providing additional detail on dissolved and particulate forms of phosphorus. The white boxes also correspond to the state variables (i.e., dynamically simulated and tracked through time and space) that are included in the WLEEM.

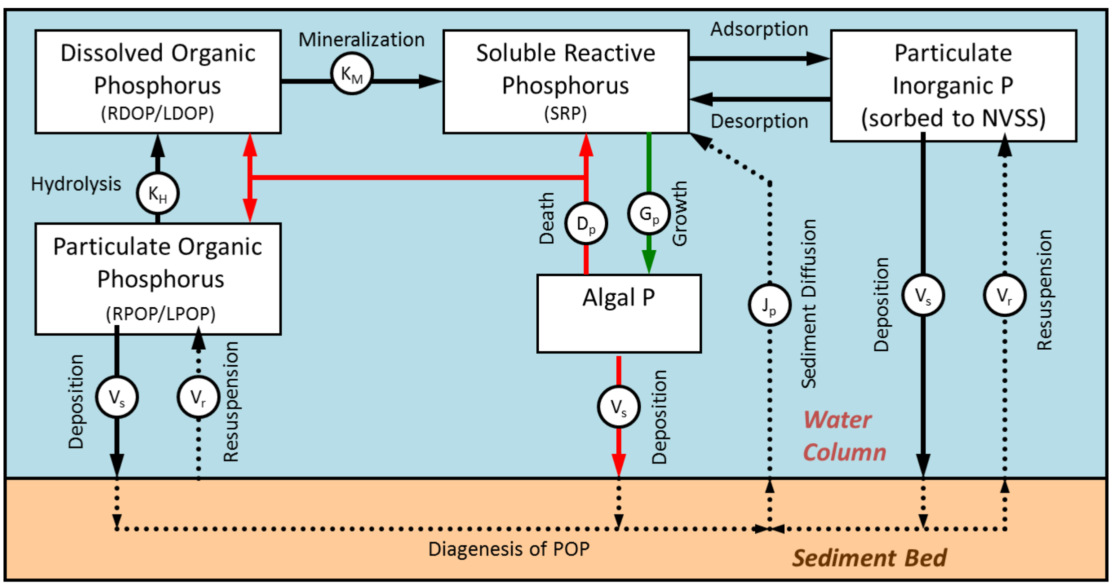

Figure 2. Conceptual Diagram of Phosphorus Forms

5.1 DISSOLVED PHOSPHORUS

Within the DP fraction there is a further division into SRP and DOP forms. The SRP fraction is the form that is immediately available for uptake by algae. SRP can also be called algal-available phosphorus because it is the form that is readily available for algal growth. DOP phosphorus can be converted into SRP through biologically-mediated mineralization processes that ultimately make it available for uptake by algae. However, only a given fraction of DOP can be easily converted into SRP, this form is considered the labile portion (LDOP) or sometimes referred to as the algal-bioavailable form (Baker 2010). The remaining fraction of DOP is considered refractory (RDOP) because the conversion to SRP can take years.

5.2 PARTICULATE PHOSPHORUS

On the PP side there is a division between particulate inorganic phosphorus (PIP) and particulate organic phosphorus (POP). The PIP is sorbed to non-volatile suspended sediments (NVSS) or sometimes called inorganic suspended solids (ISS). Some PIP can desorb and be transformed into SRP. The reverse process (adsorption) can also take place depending on concentrations of each form in the water column. This process is governed by partition coefficients between particulate and dissolved forms of inorganic phosphorus. Partition coefficients are influenced by many different factors such as sediment mineralogy, P saturation state, water chemistry, and redox.

The POP forms can be converted to DOP through a process called hydrolysis. Portions of the POP are hydrolyzed at a faster rate and are considered labile (LPOP), while the remaining portion, termed refractory (RPOP) is converted at a slower rate. PIP and POP are both subject to deposition and resuspension.

5.3 ALGAL PHOSPHORUS

The last remaining form of phosphorus in the water column is contained within the algae itself. This phosphorus form is created by the uptake of SRP from the water column through the growth of algae. This form of phosphorus is considered part of the total PP because it is retained on a filter. For most species of algae it is assumed that they are settling (deposition) to the bottom at a set rate; however, for blue-green algae a negative settling rate is used to simulate the known positive buoyancy of this algal species. Algal phosphorus is also lost through algal death, where portions are divided between SRP and POP forms.

5.4 SEDIMENT PHOSPHORUS

Once any of the particulate forms of phosphorus reaches the sediment bed it becomes a part of the sediment bed. Here it is available for reincorporation into the water column by either resuspension processes or conversion to dissolved forms within the sediment bed by diagenetic processes where it can diffuse back into the water column. A portion of the sediment phosphorus is also lost to the deep portion of the sediment bed where it cannot interact with the water column.

6. ALGAL GROWTH

In the first conceptual diagram, DP is linked to algal growth. In the second diagram that understanding is further refined to show that only SRP is available for uptake by algae. Although not shown in Figure 1 or 2, there are many processes that regulate the growth of algae in the water column. In addition to the nutrients described previously, algal growth requires appropriate light and temperature. The nutrient, light, and temperature ranges for optimum growth rates of algae are species-specific. Processes that lead to loss of algal biomass include: settling and deposition, grazing by zooplankton, filtering by Dreissenids, endogenous respiration, and bacterial-mediated decomposition. The algal biomass at any given time and location in a system will depend on a balance between the rates of the growth and loss processes, which are all governed by environmental conditions and physical processes such as dispersal by water transport and concentration at the surface by algal buoyancy. Further detail on the conceptual model of algal growth and death is provided elsewhere (LimnoTech 2010).

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7. OTHER BIOLOGICAL PHOSPHORUS CONTROLS

Not included in either figure above is the impact of other biological organisms, such as zooplankton, dreissenid mussels (zebra and quagga), and benthic algae (Cladophora) on the fate of algal-available phosphorus through the system. All of these additional biological components add process resolution that can help us understand how some of the chemical and physical transformations of phosphorus forms are biologically mediated. The internal cycling of phosphorus between unavailable and algal-available forms can be an important factor contributing to blue green algae blooms.

Zooplankton graze on algae in the water column and lock a portion of the phosphorus in their biomass and release the remainder as fecal material. Additionally zooplankton die and settle to the bottom sediments. Dreissenid mussels can significantly reduce the water column particulate phosphorus concentration through physical filtration. However, once filtered, mussels release phosphorus back into the water column in a dissolved form that is readily available for uptake by algae. Therefore Dreissenid mussels can enhance the ratio of dissolved to particulate phosphorus in the water column without having to undergo a much slower transformation process in the sediment bed that depends on low dissolved oxygen concentrations to see significant release into the water column. Additional detail on the interaction of Dreissenid mussels with total phosphorus is provided in Bierman et al. (2005).

Counteracting this phenomenon is the uptake of SRP from the water column by benthic algae (Cladophora or Lyngbya). Additional detail on benthic algae’s effect on phosphorus cycling can be found in Tomlinson et al. (2010) and Auer et al.(2010). Figure 3 illustrates how zooplankton, Dreissenids, and benthic algae interact with water column algae and particulate and dissolved phosphorus on the water column.

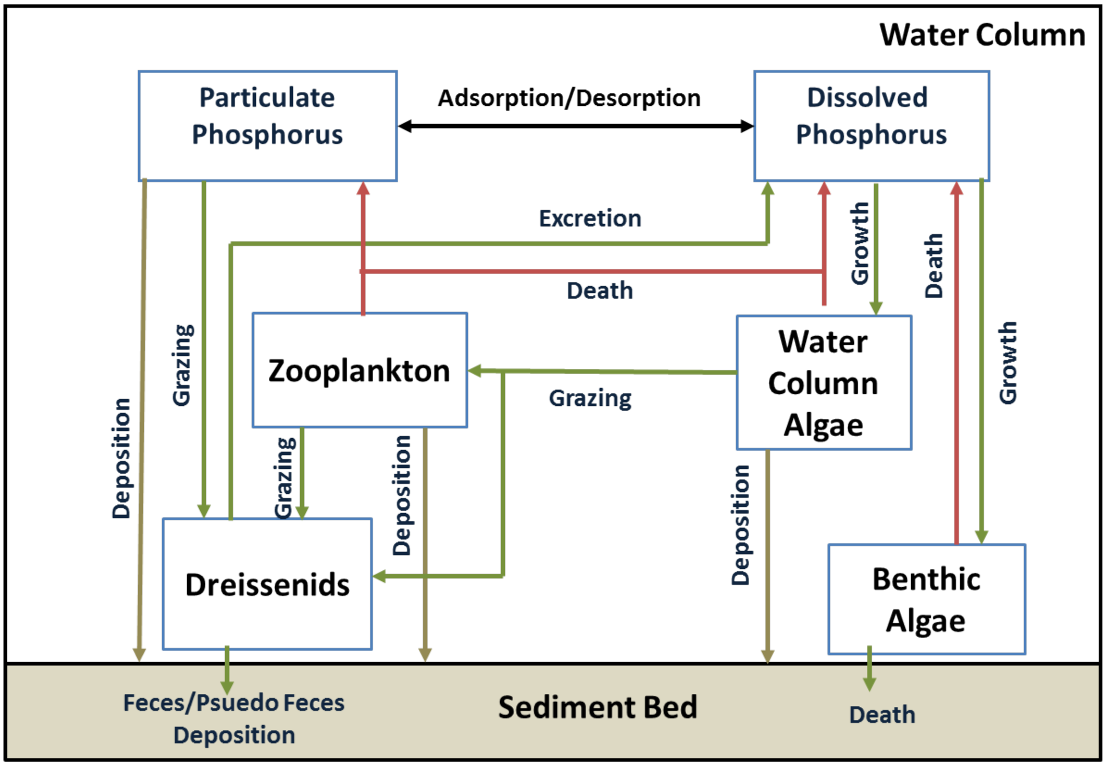

Figure 3. Interaction of Zooplankton, Dreissenids, and Benthic Algae with Particulate and Dissolved Phosphorus

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C Field Data

C-1 Field Notes

E & E Field Notes

8M 41.7889
-83.3560

MB18 41.7427
-83.4015

GR1 41.8214
-83.1855

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USACE Buffalo
Lake Erie - Western Basin

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TDD ____________________

PAN ____________________

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Start / Finish Date 6/18/13 / ____________________

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E & E Corporate Center: (716) 684-8060
MEDTOX Hotline: (501) 370-8263
E & E Safety Director (Home): (716) 655-1260

Toledo Harbor 6/18/13

Personnel: C. Behnke (Limno), Ed Verhamme (Limno), B. James (U. of Wisconsin), D. Averly (E+E)

Scope of Work: Begin sediment coring program in Placement and Reference areas.

Weather: Clear and sunny, 60s to mid 70s F, wind 10 to 18 mph; waves up to 2.5'

0800 At Bolles Harbor in Monroe, MI

~~0845~~ Launch and head for Placement area

0845 At sediment core station one.

0900 Begin collecting sediment core PA-01-SD-01-15;

0915 sample time

0930 Finished collecting sample.

Waves averaging 2.6' making sampling somewh

Note: Held H+S meeting at dock.

0945 At station PA 19. to collect PA-01-SD-19-19

1005 Complete sample collection. Sample time of 0955.

*Note: Water was turbid on top of mounded area, previously used for sediment disposal. Water clear on top of area planned for disposal this year.

1015 At station 20 to collect PA-01-SD-20-19.

Note: collecting 7 aliquots. Collected surface water (extra) at Station 1; Overlying water for incubation process. 3 4-liter jugs.

1030 Sampling complete. Sample time of 1025

Move to Reference Area - Station 25

1045 At RA-25 to sample RA-01-SD-25-22

1100 Refusal at this location. Used Ponar to look at sediment and full of zebra mussels. Cannot penetrate w/ core. Will move around to find area that does not have that issue.

1210 Southwest of Placement area. Stopped at 4 locations north and northwest of Placement area but gave

Toledo Harbor 6/18/13

refusal. Able to collect cores here and should be suitable reference. 1.5 miles SW of PA that has been used to date. Will discuss w/ team further at end of day. Collecting RA-01-SD-25-28.

~~N 41.77035° W 83.37586° (waypoint 16).~~

~~Location~~ DK

Location of core → N 41.79275° W 83.32021

* Waypoint 17 *

Sample time is 1220

1235 Sampling complete.

Due to rough conditions, not going to continue sampling for day. Head back to dock.

1300 Back at dock.

Work complete. Head back to Ann Arbor.

[signature] 6/18/13

Toledo Harbor 6/19/13

Personnel: E. Verhamme (Limnotech, captain); C. Behnke (Limno; science lead); B. James (U. of Wisconsin; Science lead); D. Kennedy (E+E; oversight & support).

Weather: clear sunny, 60s° to 70s° F, 10 mph winds, 2 ft waves.

Scope of Work: Collect sediment grabs, and RA sed cores.

0800 At Limnotech office. Prepare to move to Bolles Harbor.

0920 Boat at dock. Hold H&S meeting.

0940 Off to placement area for sediment grab sampling.

1010 Begin collecting sediment grab samples starting with PA-01-SG-07-17.

1155 Completed collected SGs at placement Area. Move to ~~Newfare~~ (DK) new reference area.

1225 At reference area. Collect SG-23-17.

1235 Begin collecting RA-01-SD-25-17. Getting low recoveries 10 to 18 cms. Some less. Moving around slightly to find areas with less mussels that are preventing penetration.

1300 Move to SG-23 to collect surface grab and characterize bottom. Lots of young zebra mussels

1315 Continue to get refusal. Move slightly north of SG-25 and are able collect two more cores for a full set. Giving a sample time of 1320

1335 Collecting SG-22-18 at Toledo Station 8M N 41.7889° W 83.3560°. Change in SOW that was discussed w/ G Florentino (E&E PM). Will submit a FAF. Will collect SG-24 at Toledo Station GR1

Toledo Harbor 6/18/13

at N 41.8714 W 83.1855

1420 Collect RA-01-SG-24-26. Sediment grab sampling complete.

1500 Pull sediment trap at placement site. Very little sediment in trap. Put back in place for further collection.

1535 At sediment trap at ~~ref~~ (DK) "old" reference site. Remove from water and for possible relocation to new reference site. Very little sediment but will keep what is there analysis. RA-01-ST-25-22 - Top A, Bot A, Bot B.

1600 Heading back to dock.

1630 Pulling boat from water. Head back to office.

1800 Back at office. Unload boat. Fraction cores for analysis. Perform sample management.

1845 Sample management complete.

1900 Work complete day. Note: Acoustic doppler water profiler remove from placement area buoy for maintenance and calibration.

D. Kennedy

6/19/13

Toledo Harbor 6/20/13

Personnel: C. Beaker (Limnotech; science lead), F. [illegible] (Limnotech; Captain); D. [illegible] (E+E: oversight and support)

Weather: Clear + sunny, 60°F to low 80s°F, light winds 5 mph; wave 1.2 ft.

Scope of Work: Re-deploy sed trap; re-deploy acoustic profiler; service the sondes. Original plan was to include surface water sampling but Heidelberg lab cannot analyze samples within hold times. SW sampling will be conducted next week.

0700 All meet at Limnotech office. Calibrate YSI for SW profiling. Load boat w/ equipment

0800 Leave for Bolles Harbor.

0900 Speak w/ Heidelberg lab and find that they do not analyze samples on Friday. Will not be able to meet hold times.

0915 At Harbor; find that trailer hub bearings failed and will need repair. Launch boat and take to marina for repair.

1000 Hold H+S

1015 At old reference site; Removing sonde and ADCP (acoustic doppler water profiler). Will move to new reference site, will collect turbidity reading w/ sonde calibrated this morning for comparison. Lots of bio-fouling on sonde. At 4.3 ft.

Temp. - 20.98°C
Cond. - 275 uS/cm
pH - 8.2
D.O. - 11.5 mg/L (130%)
turb. - ~~2.9 NTUs~~ (CB) 0.0 NTUs

1120 Attempted to calibrate sonde prior to redeployment at new reference site. Could not get turbidity to properly calibrate.

Toledo Harbor 6/20/13

In addition, batteries died on May 30th and therefore no data collection since then.

1120 Download ADCP data and leave for placement area to download and calibrate instruments.

1200 At placement area - Re-deploy acoustic ~~doppler~~ (CB) doppler. Collect H_2O quality reading w/ calibrated sonde to measure drift. Depth 2'

Temp. 21.46°C
Sp. Cond - 278 uS/cm
pH - 8.31 s.u.
D.O. - 11.51 mg/L (130.8%)
Turb. - 0.0 NTUs

1250 Calibrated deployed sonde and performed maintenance. Moving to new reference site to drop ADCP; sonde will be taken in for maintenance and re-deployed next week during SW sampling.

1310 At new reference area to deploy ADCP: Depth 16 feet.

Deployment configuration - cell size 0.5 m
1st cell 1.05 m
last cell 5.05 m
depth measurements, 9
20 min logging interval
Deployment 2

Sed traps Ref. Area Waypoint 18
N. 41.77556° W. 83.34574°

1400 Leave new reference area. Head for Toledo Harbor monitoring location.

1430 At Reference sonde reading at CDF dock station. Depth 8.3 ft.

temp. 22.96°C turb 31.8 D.O. 6.93 mg/L (80.8%)
pH 7.68 sp cond 562

Toledo Harbor 6/20/13

Now calibrating long term sonde (YSI model 6920).

1900 Done at CDF location. Head back to dock.

ADCP - N 41.775 36° W 83.34414° waypoint.

1545 Back at Bolles Harbor. Picking up repaired trailer. To mobilize back to Ann Arbor.

1715 Back at office unload supplies.

1730 Done for day. Will complete sw sampling next week.

D. Kennedy 6/20/13

Toledo Harbor / Maumee River 7/23/13

Personnel: D. Kennedy (E&E), C. Behnke + C. O'Brien (LimnoTech)

Weather: clear + sunny - spotty thunderstorms forecasted, 70s to low 80s

Scope of work: Sampling event 2 - collect surface water samples and perform vertical profiling around placement area and at reference sites. Sediment grabs being collected by USACE (barge sediment). Team deployed 4 short term buoys yesterday and collected day 1 samples around barge.

~~0700~~ 0630 Meet at LimnoTech office, calibrate sonde, file float plan, and load equipment.

0715 Leave office for ~~Bolles Harbor (Monroe, MI)~~ DK.

0940 At Coleen Park, launch boat.

Hold H&S meeting. Discuss emergency procedures, 911 meet at dock, flare location, emergency CB radio call for help, EPIRB operation, slips trips and falls, and weather hazards.

H&S officer C. Behnke: [signature]
D. Kennedy: [signature]
C. O'Brien: [signature]

~~1020 At~~ DK

1020 At Reference Area 1 to perform water sampling. Will collect RA1-02-WC-25-17. Heidelburg sample 19

Barge was returning from placement area during trip out here.

1105 Sample collected and move to Real time buoy

1130 At real time buoy to collect PS-02-WC-26-24. ~~Barge~~ Will collect Duplicate DS

1200 Complete sampling at WC-26 location.

1230 Collect field blank FB-02-WC-01-00.

Wait for barge to come out for disposal.

1250 Barge dumps load. Begin sampling

Weather is clear + sunny, water is relatively flat

Toledo Harbor 7/23/13

alowing team to track plume ~~[illegible]~~ DF easily.
1500 Complete sampling and processing. Wind and waves picked up making it difficult to track plume. Also increased dissipation rate. Only completed 16 vertical profiles. Leave for RA2
1525 At RA2 collecting sample. Thunderstorms in area
1545 Sample collected. Headed back to river mouth.
1650 At River mouth. Will collect sample and VP in front of CDF
1730 Back at dock. Will pull boat. Rendevoux with Phoenix from U. of Toledo to drop off samples.
Note: It appeared that the plume from the barge dump moved in between the ~~buoys~~ DF ~~short~~ term monitoring buoys, w/ one of them maybe picking up the edge.
1810 U of Toledo picks up samples for speciation, biomass, and chlorophyll
1930 Back at Limnotech office. Unload and re-pack for tomrw. Pack samples for Heidelberg.
2000 Complete work for day.

D. Kennedy 7/23/13

7/24/13 Toledo Harbor

Personnel: D. Kennedy (E+E); C. Behnke + B. Betz (Limnotech)
Weather: Clear + sunny, cool 60s to 70s; forecast 16 knot winds and 2-3 foot waves.
Scope of work: Collect water column grab samples and complete vertical profile at placement site in conjunction with the dredging and at reference and buoy areas.
0630 Meet at office. Calibrating YSI.
0710 Leave for Cullen Harbor
0900 At ~~site~~ DF Harbor, launch boat.
Hold H+S meeting.
H+S Officer C. Behnke: [signature]
B. Betz: [signature]
Dan Kennedy: [signature]
Topics → PFDs to be worn at all times, check expirations, weather hazard procedures (lightning, sunburn) slips trips and falls, overhead w/ crane, heavy equipment
0920 Leave harbor.
0940 Dredge not on water. Call USACE and confirms that dredging will not take place because of high waves. Return to harbor
1030 Meet w/ Phoenix from U. of Toledo to drop off chlorophyll bottle
Picked up ~~sed~~ DF barge dredge samples from USACE from at dock. Only 3 samples collected.
1215 Back at office. Packing sed samples. Not sure if work will resume tomorrow because Heidelburg told team they don't analyze on Fridays and we wouldn't meet hold times.
1245 D. Kennedy leaves for hotel and Cathy Whiting (Limno) will call later about sched.

D. Kennedy 7/24/13

Toledo Harbor 7/25/13

Personnel: D. Kunz (ETE), C. Behnke & B. Betz (Limno).

Weather: Clear & sunny, 60s to 70s F; light winds, waves at 1.4' at monitoring buoy.

Scope of work: Complete Day 3 at Event 2 sampling; retrieve ~~[illegible]~~ short term buoys.

0630 Meet at Limno office Park

0700 Leave for Cullen ~~Harbor~~ (Toledo, OH)

0830 At Cullen Park. Receive call from C. Whiting and learn that dredge operations are shut down again today. Will try and perform sonde maintenance and collect sed trap samples.

Hold H&S meeting: Discuss ~~[illegible]~~ operation safety, PFDs to be worn at all times.

H&S officer: C. Behnke - [signature]
D. Kunz - [signature]
B. Betz - [signature]

085~~0~~ ~~Launching~~. Leaving dock.

0910 At Maumee River mouth sonde station. Do a performance check and calibrate. Clean off biologicals.

1015 ~~[illegible]~~ Leaving Maumee River sonde. Heading to RA1 sonde for calibration and performance check.

1046 At RA1 for sonde maintenance

1120 Complete maintenance at RA-1

1130 Boat stalled. Won't start. Trying to diagnose.

1245 Got the engine started again - issue w/ tether chord and kill switch not set right. Going to pull the sediment trap at RA1

1600 Collected sediment trap samples from RA1 and PA. Traps had very little sediment in

7/25/13 Toledo Harbor

them at RA; maybe 1/2" at most. Note that only 4 traps at each location. May have to composite all 4 trap samples to get enough volume for a single sample from RA1. Many freshwater shrimp in samples. PA samples had 2" to 3" of sed in each trap. Traps were covered in zebra mussels at PA.

Now at Real Time buoy in PA downloading YSI data and calibrating.

1630 Complete sonde maintenance. Leave for dock. Complete work for day.

1705 Back at dock and pulling out.

1840 Back at office. Unloading equipment.

1900 Done for day.

[signature] 7/25/13

8/19/13 Monday

weather: 68°F clear to partly cloudy, light west wind (less than 5 mph). Temp. expected in 80's

0745 G. Floreth arrived at Cullen Park - Toledo
met w/ Ed Verhamme and Chris Behnke
0805 Launch LT boat at dock waiting for Corps rep. + UT rep
Safety mtg conducted by Ed
0811 Corps' rep on site
0820 UT rep onsite
0830 departed Cullen Park
0905 There is a barge in the reference area getting ready to dump. There is a noticeable sediment plume following the tug. water depth is approx 15 ft
0910 Began Dump
0911 Dump Complete in about a minute
0915 Deploying short term buoy ≈ 1/4 mi No. of placement area
0923 " " " " " W. " " "
YSI's are not on the buoys at this time. Will use them to track the next dump as discussed on the Conf. call w/ the Corps last week. The ~~buoy~~ YSI will be placed on the buoys at the end of the day
0926 Deploying So. buoys - ~~this has the~~ LISST attached GF
0929 Deploying east buoy
0931 heading out to Ref Area 2 near Toledo Lt 2
0940 Setting up for water profiling of Ref Area 2
water depth approx 25 ft
0942 deploying LISST - lowered slowly by hand to bottom, then retrieved
0948 retrieved LISST
0950 recording WQ parameters at 1-m intervals - meter calibrated this morning
0952 deploying biomass net (Plankton Net)
- lowered slowly to bottom by hand, then retrieved
- mesh 53 µ (WP states 112 µ)

G Floreth 8/19/13

8/19/13 Monday
1026 collected water column sample at Ref Area 1
used 2" PVC lowered to bottom - rinsed with lake water + re-lowered. Top cap sealed, and bucket used to collect water from PVC when retrieved
Peristaltic pump used to filter the sample. (45 µ)
will send Heidelberg 2 1-L bottles for TSS, instead of 1 because last event was near the detection limit

Sample ID RA2-03-WC-27-25
1040 moving to ~~Ref Area 1~~ GF Disp. Area buoy
1055 LISST meas. at Disp. area
1123 Completed water column, WQ profiling, and plankton net sampling. Moving to Placement area to monitor dump
1125 at Placement area. Barge 13 on it's way out. Setting up string of 4 YSI's
1201 Barge at placement area + dump load in less than a minute. LT deployed string of 3 YSI meters, will Troll in a concentric circle, and collect WQ samples. Also mounted a video camera on the roof of the vessel to record the plume.
1338 moved out to buoys to deploy YSI's
Collected ~~WQ Samp~~ GF 5 WQ samples in placement area
1434 at weather sta. Buoy - performing maintenance
1500 Moving to Ref Area 1
1510 At ref area No. 1 - water is very green collected wet + WQ data
1533 Moving to Maumee River Buoy sta.
1550 at Maumee R. Sta, Collected WQ meas. + water column profile and Dup + Blank.
1609 Heading back to shore
1620 At dock. Packing up equipment and boat
1720 Crews departed Cullen Park

G [signature] 8/19/13

8/20/13 Tuesday
weather: 68°F temp expected to be 85°F. Clear skies/hazy, little to no wind

Today's objective: Day 2 sampling activities (same as yesterday)
- monitor turbidity plume for one barge release
- water column sampling + WQ sampling at Long-term monitoring buoys and placement area (within plume)
- buoy maintenance

0730 G. Florentin at Cullen Park
0745 Ed. Verhamme called, they expect to be here in about 20 min.
0750 G. Florentin went to USACE to pickup dredge samples
0800 met Contractor at Coast Guard Dock and picked up 6 sed samples
0805 GF back at Cullen Park
0820 Ed Verhamme, Bob Betz } Limno tech at Cullen Park
0826 Safety mtg - conducted by Ed Verhamme
Todays Plan go to dump site and sample - calibrate River sta. equip.
No crane use
Haz → Sun
3 fire extinguishers
removed extra equipment to min. trip/fall haz
Ed sent C. Whiting float plan via email
0834 Depart dock. Placed barge samples in cooler w/ ice.
Samples were cool when received from contractor
LT calibrated turbidity meter (YSI)
0850 Passed barge returning from placement site near the Toledo Harbor Light
0909 At RA2
-collecting WQ profile, water column sample, LISST, and biomass
0930 departed RA2
0943 Arrived at PA-2C
G-F 8/20/13

8/20/13
collected WC sample, WQ profile, Biomass, LIST
1008 Departed Placement area for RA1
turned around at Toledo Light because Barge on way to placement area.
1056 Barge dumped load
1105 Began turbidity/LISST Readings and WC Sampling in heart of Plume. Collected 5 WC samples
1123 Sed plume moving So. toward south buoy
1211 Completed Sampling at Placement area
1214 heading to RA-1
1224 At RA-1 - water very green
Collecting LISST, Biomass, WC sample, WQ readings.
1312 at Maumee Riv. Sta.
1314 LISST / WC Sample + WQ parameters
Serviced YSI - some water in battery chamber. will let dry overnight and re deploy tomorrow.
1402 Departed MR-0 for dock
1415 At dock. Packing equipment
1430 Crews depart Park for day

[signature] 8/20/13

8/21/13 Wednesday
weather = Sunny 70°F, light wind from west. Temp expected in 80's

Today's obj. Continue WC and WQ measurements at Long term Buoys, and Monitor sed plume from one barge dump. will follow plume and measure size

0830 ~~LT arr~~ GF arrived at Cullen Park
0845 LT arrived at Cullen Park – had to stop along way to re-position boat on trailer, Ed Verhamme + Colin
0912 Ed Verhamme held safety brief
0915 departed dock
0925 Stopped at Maumee RV Sta + placed YSI at dock.
0943 Setting up at RA 1. Lt winds, <1ft seas
Performing buoy maintenance
Empty barge almost back at dredge site, expect dump w/in the hour.
0953 Retrieved ADCP for maintenance
Cleaned + download ADCP + YSI
1030 collected WC + WQ sample/parameters
Deployed LISST
1058 Deployed ADCP + YSI, and moving to placement Area
1110 At placement area.
Preparing to monitor turbidity of barge dump, collect WC ~~+~~ WQ samples.
1233 collected 5 WQ/WC samples and tracked turbidity plume 5X. moved to placement area
1250 Collecting Biomass at Placement area buoy.
1329 at Ref Area
collected WC + WQ
1354 departed RA-1
1433 Retrieved short-term buoys

G[signature] 8/21/13

8/21/13 Wednesday
1445 At RA-1 installing YSI (was removed earlier for download + cal.)
1506 Arrived at MR Sta
Collected WC + WQ
1516 Depart MR
1525 Arrive at dock. Packing up boat + equip.
1545 GF picked up barge sediments from USACE
1600 Crews departed Cullen Park for day
Event 3 complete

[signature] 8/21/13

October 1, 2013 Tuesday Toledo Habor.

weather Foggy, cloudy, 0-2' waves. High of 75°, winds 10-15 mph
person L. Reed, Ed Verhamme, Limno Tech, Chris
Scope of work Event #4, Water Sampling
Safety meeting Held - ~~Wash~~ 90.4 on Boat

8:15 L.R met up with ED Verhamme at Bolles Harbor
8:23 ED Held Safety meeting.
8:29 Ed was Filling out Float plans.
8:41 Left Dock Headed to station RA2
Lat 41 44.77, Long 83 11.41, calibrate YSI Before use.
Temp pH Temp Cond DO Turbidity with a YSI at Location
RA 2, Filled one Bottle 00074,
also Net Reading start and end ① 360500, 360240
② 360780, 360925, plankton Test
09:36 List Profiler 100X particle size meter
10:13 Arrived at location area PA26, Lat 41 48.38, Long 83 16.14
10:14 List profiler 100x particle size meter.
10:22 Temp Cond DO Turbidity pH were Taken
net Test 360950 start, End 361040
10:31 net Test 361.000 start, End 361200
10:32 Started Water Sampling
Filter a Sample 00075 Dissolved Solids was filtered
10:47 Location PSWC040314 at Lat 41 48.42 Long 83 16.54
Temp Cond, DO, pH, was taken at this Location.
10:49 Net Test start 361200 End 361310 plankton Test.
#2 Start 361310, 361370 end
10:59 water Sample 00076 Dissolved Solids was Filtered
11:23 Arrived at Location RA1 WC042517
Lat 41 46.549 Long 83 20.573
11:24 #1 Net Test 361360 start, End ~~374~~ 361425
#2 Net Test 361425 start, End 361538
Water Sample 00077
Secc = PA26 50cm, PA03 50cm, RA2 73m
~~RA2~~ RA1 WC042517 50cm
11:34 List Test Being Done 10/1/13 [signature]

October 1 2013 Tuesday Toledo Harbor

12:10 Arrived at location MRWC042826
Lat 41 42.579 (W) Long 083 26.126 (W)
net test plankton #1 Start 360 net Test end
#2 Start " " end
12:16 List Test was done and logged in computer
Temp Cond, pH, DO, Turb was also done at
this location.
Water Sample was taken 00078, 00079 Dup. 00080 Blk
Secc was 20cm
12:48 Removed Data logger From area Maumee River Dock
Bottom of vent pipe was covered with zebra mussels.
(multiparameter Water Quality Sonde 6920V2 YSI)

note what was on COC — Bottles

Time	Location	Bottles		Lab
0940	RA2WC042726	~~75~~	74	HEIDELBURG LAB'S
10:25	PSWC042624	~~76~~	75	
11:00	PSWC040314	~~72~~ (changed, Folded)	76	
11:35	RA1WC042517	~~78~~	77	
12:20	MRWC042826	~~79~~	78	
12:20	Dup	~~80~~	79	
12:25	Blk		80	

Test For TSS VSS, TP TKN
SRP, DOP, NO2, NO3, NH4

Same Times as above — Toledo LAB
RA2WC042724
PSWC042624
PSWC040314
RA1WC042517
MRWC042826
Dup MRWC042826
Blk
Test For Chlorophyll, microcystin, ~~Blue~~ Biovolume
Algal speciation

13:25 A LAB personnel Came and Pick up the Samples in Toledo Boat Harbor
from T.U.

10/1/13 [signature]

October 1, 2013 Tuesday Toledo Harbor

1827 LR, CB, EV. Back at dock - loading Boat onto Trailer
CB, EV, will Drive the Boat Back to there office and get Samples
Ready to ship to the Heidel Berg Labs.
1150 Crew departed Site for the Day

Lawrence Rodell 10/1/13

October 2, 2013 Wednesday Toledo Harbor

Weather Partly cloudy High of 75° wind 0-5 mph, Clear Skies in afternoon
Personnel, L Rodell E/E, Ed Verhamme, Chris Behnke
Scope of Work Sediment Coring, Sediment Grab Samples.
8:15 Safety Meeting was Held - Topics Boat Safety, Emergency procedures.
Filled out Float Plan
8:45 Arrived at 1st Location. RA2
Lat 41 49.396, Long 083 11 306
8:48 Taking a coring Sample at ~~RA1-2~~ ① RA2-1
Coring Sampling ② RA2-2
③ RA2-3
④ RA2-4
⑤ RA2-5

0911 RA2-SD-04-22-26 Ponar Sample
0916 moved to next Location.
0919 RA2-SD-04-23-26
9:22 RA2-SD-04-24-26
09:28 moved to next Location PS-SD 04-26-23
0940 Collected ponar at Dump Area PS-SD-04-19-14
0945 moved to next Location
Lat 41 48 049. Long 083 16. 942
0952 collected Sample at PS SD-04-19-14ff
10:00 collect core Samples ~~19-1~~ PS 19-1 thru PS 19-6
10:05 moved to next Location PS-SD-04-20-12
10:18 ponar Samples at this Location
10:20 Started core Samples ~~Po...~~ PS-20-1 - PS-20-6
10:38 moved to next Location PS-SD-04-11-20
10:41 moved to new Location PS SD 04-13-15
10:43 " " " PS-SD-04-16-15
10:46 " " " PS-SD-04-17-19
10:49 " " " PS-SD-04-18-16

Lawrence Rodell 10/2/13

October 2, 2013 Wednesday Toledo Harbor

10:51 moved to new location PS-SD-04-15-12
10:54 " " " " PS-SD-04-14-13
10:56 " " " " PS-SD-04-12-18
11:00 " " " " PS-SD-04 09-16
11:03 " " " " PS-SD-04 10-15
11:06 " " " " PS-SD-04 06-10
11:08 " " " " PS-SD-04 05-15
11:11 " " " " PS-SD-04 12-17
11:15 " " " " PS-SD-04 04-15
11:19 " " " " PS-SD-04 03 14
11:22 " " " " PS-SD-04 02 15
11:25 " " " PS-SD-04 07 15
11:28 " " " PS-SD-04 01 13
11:50 started to collect core sample at PS-01
collected PS-01-~~01~~ - PS-01-06
12:12 moved to new location ~~RA-01~~ SD 04 30 17
12:17 " " " RA 01 SD 04 21 16
12:21 " " " RA 01 SD 04 23 16
12:27 " " " " RA 01 SD04 25 16
12:30 collected core sample at this location RA01SD042516
RA01-1 - RA01-06
All sample are collect and pick up instrument
and sediment traps - water velocity meters
13:57 went to PS 26 to retrieve sediment samplers
14:10 moved to next location to retrieve samplers at station
RA 2 29
14:45 returning to dock.
15:18 ~~[illegible]~~ back at Dock

note: core sample taken 5 6 at end location 30.
ponar sample taken 29
sediment sample taken 10 at end location, top and bottom sample
~~[illegible]~~ water quality meter at sampler RA 1 and YSI, ADCP
~~[illegible]~~ at the placement site there is a ADCP and YSI to get
yet

October 2, 2013 Wednesday Toledo Harbor

LTI will get the Equipment at the Placement Site
next week. note photo were taken by LTI.
15:52 unloading Boat.
16:10 LTI, [illegible] left site for the day - Sampling was completed.

[signature] 10/2/13

8/19/13

File No. Photolog - G. Florentino, BB

(39) 1 Algal bloom near Cullen Park
2 " " " " "
3 " " " " "
(42) 4 Dredge in channel
5 " " "
6 Light house
7 " "
8 Tug pushing barge to placement area
9 Sed plume behind tug
10 " " " "
11 " " " "
12 " " " "
13 Barge at Placement area - dumping sed
14 " " " " "
15 " " " " "
16 " " " " "
17 Sed Plume in placement area following dump
18 "
19 "
(58) 20 "
(59) 21 Short term buoy 1/4 mi no. of placement area
(60) 22 water profile monitoring equipment
(61) 23 Toledo LH 2
24 Plankton Net at Ref Area #2
(63) 25 " " " " " "
(64) 26 Close-up of biomass mat
(65) 27 weather Sta buoy at Placement area
(66) 28 water in Placement area
(67) 29
30 } water at Ref area 1
31
32

Sample	Time
PA-01-SG-07-17	1010
" 02-17	1015
SG-01-15	1025
" 03-16	1030
" 04-16	1035
" 08-18	1040
" 05-17	1045
" 06-12	1050
" 10-16	1055
" 09-18	1100
" 12-20	1105
" 14-19	1110
" 15-20	1115
" 18-20	1120
" 17-20	1125
" 16-20	1135
" 13-20	1140
" 11-21	1145
" 20-20	1150
" 19-20	1155

RA-01-SG-23-17 1225
" SD-25-17- 1320
SG-21-16 1308
SG-25-17 1330
22-18 1335
24-26 1420

8/20/13

33 } Toledo Light
34 }
3~~4~~ } Barge ~~Du~~ Pre-dump
35 ↗ 4
36 }
37 } Dumping
38 }
39 }
40 }
41 } Plume
42 }
(82) 43 }
44 Chart Plotter of Placement area
45 } green water (microcystis) at RA-1
46 }

8/21/13

47 } ADCP at ~~RA-1~~ Placement Area G"
(87) 48 }

8/22

(1992) Barge at Dump Area
(1995) Sediment plume
(1997) * water column sampling in sediment plume
(1999) * edge of sediment Plume

LimnoTech Field Notes

4

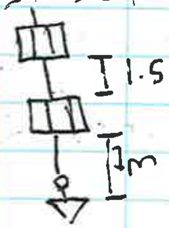
Location: Monroe   Date: 5-9-13

Project / Client: Ed V, Chris B, Brandon

Calm, Sunny, 75 °F

600 Meet at office & load gear
700 Depart for Monroe
750 Arrive Monroe @ LaPliance Bay
800 Launch Boat
830 Deploy Mooring at SE corner of Disposal Area
6 - 135# Pyramid anchors
41.80624 -83.27048 Dp=23ft
9:30 Tow Buoy out to mooring
Calibrate YSI for Turb & Cond
11:30 Secure Buoy to mooring

12:00 Deploy Sediment trap
~300 ft East of RTB
41.80617 -83.26958
First set of traps - 1m off



Dp=22 ft

1300 Deploy sed trap at ref Area
41.84479 -83.27310 Dp=22ft
Same depths as other trap

5

Location: Date: 5-9-13

Project / Client:

1400 - Deploy ADCP @ Ref site
41.84451 -83.27285
Deployment
20 min interval
0.5m bin
18 bins
Attach pinger to ADCP
Sonotronics EMT-01-1
#37 75kHz 3-4-4 870ms
secured in cage to Anchors
2-706
Used 5-8lb Floats to hold upright

1500 - Attach YSI to bottom of Buoy at ref site
1m below surface
calibrate turb and cond

1630 - Collect Grab Sample at ref site with Mini PONAR
REF-0
Lots of mussel shells
took photo and put in ziploc

Location ______ Date 5-9-13

Project / Client ______

1645	PONAR Grab from NE corner of Disposal Area PA01 41.81347 -83.28117 20ft
1650	PONAR Grab from near Center of East 1/2 of disposal Area PA 02 16 ft 41.80899 -83.28635
~~1655~~ 1700	PONAR Grab from near SW corner of East 1/2 of disposal area PA 03 18ft 41.80402 -83.28279
1730	Return to dock
1830	Back in Ann Arbor
1900	Finish unloading

Location Maumee River Date 5-17-13

Project / Client Maumee3

Location Maumee Date 5-17-13

Project / Client
Ed V Chris B

0730 - Load equipment in Ann Arbor
0830 - Depart office
930 - Arrive Toledo
1000 Launch boat at Cullen Park
1100 Mount YSI on USACE dock

Log Turb, temp, cond every 20 min
Sonde deployed 7 ft below surface (Mid depth)
Total water depth at site was 14 ft

Sonde was attached to West pier with PVC tube

Location Date

Project / Client

LimnoTech
Water | Environment | Scientists | Engineers

FLOAT PLAN

Date/Time: 6-19-13 0930 Name: E. Verhamme

1. Emergency Phone Numbers

Coast Guard 911
Marine Police 911
On Water Towing N.A.

2. Description of the Boat

Boat Name: R/V- SENTINEL Hailing Port:
Type: PLEASURE CRAFT Model Year: 1998
Make: PARKER Length: 23' Beam: 8' Draft: 2'
Color, Hull: WHITE Cabin: WHITE (HARDTOP)
Registration No: MC2191TG Sail No:
Engine(s) Type: OUTBOARD Horsepower: 225 Cruising Speed: 25 knots
Fuel Capacity, Gallons: 150 Cruising Range: 200 miles

Electronics/Safety Equipment Aboard

VHF Radio: Yes w/DSC Cell Phone: 734 674 0387 MMSI: 338103525 SSB: No
Frequency Monitored: 16 Loran: No SatNav:
Depth Sounder: Yes Radar: Yes GPS: Yes
Raft: No Dinghy: No EPIRB Type and # Cat 2, UIN: 2DCC5EBD30FFBFF

3. Passengers

Filer Nm: Ed Verhamme Address: 281 Harbor Way Ann Arbor MI Phone: 906-370-0621 Age 32
Name: Chris Behnke Address: 2724 Lookout Circle Ann Arbor MI Phone: 734-673-2209 Age 37
Name: Bill James Address: 607 Pine Ave Menomonie WI Phone: 7153384395 Age 58
Name: Dan Kennedy Address: 461 Harding Buffalo NY Phone: 716 289 7888 Age 37
Name: Address: Phone: Age

4. Trip Details

Departing Marina Bolles Harbor - DNR Launch Phone:
Auto Parked At: Bolles Harbor - DNR Launch
Model/color 2011 Chevy Silverado, Granite Blue Lic. #
Depart From Monroe Departure Date/Time 6/19/13 9:30 AM
Destination: Open lake disposal site Description of Work: Sediment Coring

Return To: Monroe – Bolles Harbor Phone: NA
Return Date/Time: 6/19/13 – 6 PM No Later Than: 8:00 PM

Plan Filed with: Cathy Whiting Phone: C 734 771 4429
W

Plan Closed Time/Notes:

If this float plan it not closed by the "No Later Than" time, then the holder of this float plan should attempt to contact the filer and any passengers. If contact is not made within 30 minutes, then attempt to reach the vessel via marine radio (the USCG or Sheriff can assist in this). After 1 hour officially notify the USCG and Sheriff of the missing vessel and relay all pertinent information from this float plan.

LimnoTech
Water | Environment | Scientists | Engineers

FLOAT PLAN

Date/Time: 6-20-13 0700 Name: E. Verhamme

1. Emergency Phone Numbers

Coast Guard: 911
Marine Police: 911
On Water Towing: N.A.

2. Description of the Boat

Boat Name: R/V- SENTINEL Hailing Port:
Type: PLEASURE CRAFT Model Year: 1998
Make: PARKER Length: 23' Beam: 8' Draft: 2'
Color, Hull: WHITE Cabin: WHITE (HARDTOP)
Registration No: MC2191TG Sail No:
Engine(s) Type: OUTBOARD Horsepower: 225 Cruising Speed: 25 knots
Fuel Capacity, Gallons: 150 Cruising Range: 200 miles

Electronics/Safety Equipment Aboard

VHF Radio: Yes w/DSC Cell Phone: 734 674 0387 MMSI: 338103525 SSB: No
Frequency Monitored: 16 Loran: No SatNav:
Depth Sounder: Yes Radar: Yes GPS: Yes
Raft: No Dinghy: No EPIRB Type and # Cat 2, UIN: 2DCC5EBD30FFBFF

3. Passengers

Filer Nm:	Ed Verhamme	Address:	281 Harbor Way Ann Arbor MI	Phone:	906-370-0621	Age	32
Name:	Chris Behnke	Address:	2724 Lookout Circle Ann Arbor MI	Phone:	734-673-2209	Age	37
Name:		Address:		Phone:		Age	
Name:	Dan Kennedy	Address:	461 Harding Buffalo NY	Phone:	716 289 7888	Age	37
Name:		Address:		Phone:		Age	

4. Trip Details

Departing Marina: Bolles Harbor - DNR Launch Phone:
Auto Parked At: Bolles Harbor - DNR Launch
Model/color: 2011 Chevy Silverado, Granite Blue Lic. #
Depart From: Monroe Departure Date/Time: 6/20/13 8:30 AM
Destination: Open lake disposal site Description of Work: Sediment Coring

Return To: Monroe – Bolles Harbor Phone: NA
Return Date/Time: 6/20/13 – 6 PM No Later Than: 8:00 PM

Plan Filed with: Cathy Whiting Phone: C 734 771 4429
W

Plan Closed Time/Notes:

If this float plan it not closed by the "No Later Than" time, then the holder of this float plan should attempt to contact the filer and any passengers. If contact is not made within 30 minutes, then attempt to reach the vessel via marine radio (the USCG or Sheriff can assist in this). After 1 hour officially notify the USCG and Sheriff of the missing vessel and relay all pertinent information from this float plan.

Location ______ Date 6-24-13

Project / Client EdU Brandon Cullen

0700 Leave office
830 Launch Boat
930 Reference Site #1 (25)

65°F ~~cloudy~~ sunny Wind
5-10 mph SW waves 1.5 ft
• List profile x2

• YSI

	Temp	Cond ~~Ambt~~	Print	pH	NTU	ODO %
0 m	23.04	340	0.35	7.54	0	9.22 107
0.5 m	23.04	340	1.6ft	7.62	0	9.18 107
1.0 m	23.02	339	3.3	7.66	0	9.19 107
2.0 m	22.99	339	6.4	7.68	-2	9.16 107
3.0 m	22.98	338	9.9	7.68	-2	9.17 106
4 m	22.94	337	13.2	7.69	-2	9.09 106
5 m	22.93	337	16.2	7.69	-22	9.06 105

Secchi 2.65m
Net Tow start 342200
Net Tow End 342397
Depth 4.5m ~~342400~~
945 RA 1 WE 2517 Photo Board #1

Location ______ Date 6/24/13

Project / Client ______

Net #2 S 342400
E 342479
Depth = 4.3m
1000 RA 01 WE2517 photo board #2
1010 Bottle Label #1

RA 01 WE2517

1035 Station #1 Placement Area

	Temp	Cond	Depth	pH	NTU	ODO %
0	22.73	265	0.12	7.45	-4	10.8 125
0.5	"	"	.45	8.17	-4	11.03 127
1.0	22.75	266	1.07	8.2	-4	11.06 128
2.0	22.7	266	2.08	8.22	-3.9	11.06 128
3.0	22.64	"	3.04	8.23	-3.8	11.05 128
4.0	.59	"	4.06	8.22	-2.7	11.0 128

Secchi 2.8m
1045 RA 01 WC 0115
Label #2
5.0m Net tow 1 342500 342700
4.5m 2 342700 342880

Location ________ Date 6/24/13

Project / Client ________

Bottles

Phyto biomass 2 x ~~500mL~~ 1L

Water column

Dissolved - 1 x 500mL Filtered

Chl + microcys - 1 x 1L u Toledo

Solids 1 x 1L Heidelberg

Phyto spec 1 x 500mL glass u Toledo

1110 Placement site 19

	Temp	cond	Depth	pH	NTU	ODO	%
0	22.85	266	0.1	8.01	.35	10.64	123
0.5	.81	267	.50	8.14	-3.5	10.84	126
1.0	.74	267	1.0	8.2	-3.7	10.94	127
2	.77	"	2	8.22	-3.8	10.98	127
3	.67	"	3	"	"	11.00	"
4	.56	"	4	8.26	"	11.04	"
5	.36	268	4.9	8.23	-3.4	11.0	125
5.8	.2	269	5.8	8.14	0.5	10.4	120

secchi 2.5m

Net #1 5.0m 343000 343220

#2 5.0m 343300 343507

Location ________ Date 6/24/13

Project / Client ________

1120 Label #3

PA01 WC 011920

4m Tube

1140 Station #26 Placement

RT Buoy

	Temp	Cond	Dep	pH	NTU	DO	%
0	23.02	267	0.08	8.21	-3.7	11.02	128
.5	23.05	"	.46	8.25	-4.3	11.08	129
1.0	22.98	"	1.00	8.27	-4.3	11.13	129
2	.85	"	2	8.29	-4.3	11.16	129
3	22.77	"	3	8.3	-4.7	11.18	129
4							
5	.57	268	4.9	8.29	-4.7	11.15	129
6.7	21.78	272	6.7	7.94	-1.0	10.09	115

secchi = 3.2m

Net #1 5.5m 343600 343889

6.0m 343900 344213

1150 Label #4

4m sample

PA01 WC 2623

Location ____ Date 6/24/13

Project / Client ____

1200 Duplicate PA01WC2623

PA01WC2623

Net #1 6.0m 344200 344471
#2 344500 344698

Label #5

1230 Tol Light #2 StA 27

	Temp	Cond	Dep	pH	NTU	DO	%
0	23.39	272	.1	8.29	-4.6	11.6	136
2	22.9	272	2.0	8.41	-4.5	12.1	141
4	22.4	267	4.0	8.42	-4.3	12.2	140
6	21.8	255	6.0	8.3	-3.9	11.9	135
8	19.7	236	7.8	7.8	-3.3	10.3	112

Secchi 2.5m

net #1 6.5m 344700 345028
7.0m 345100 345422

1245 RA01WC2726 ← Ref. Station #2

Bottle label 6
4m sample

Location ____ Date 6/24/13

Project / Client ____

1250 Blank
Label 7
Pour distilled water into Bottles
- Water chem
- Solids
- Chl + microcystin

1300 collect 6 sed cores @ StA 27 Tol ligh #2

RA01SD2726 1 tob

Section 05
5-10
10-15 } 2 cores
→ 15cm

1345 PONAR Grabs Tol #2
RA01SG2726

RA01SG2226

16 Location ______ Date 6/24/13

Project / Client ______

1430 Sed Traps @ Tol Light #2

wpt 16 41.82750
83.14713

1500 Attach YSI sonde to ref #1 ADCP

1530 CDF Dock

	Temp	cond	P	pH	NTU	DO	%
0	24.9	422	0.1	7.7	13	8.6	104
2	24.6	435	2.0	7.6	17.6	8.3	99
4	24.4	417	4	7.7	17.6	8.3	99
6	24.1	404	6.1	7.7	19.0	8.3	99
8	23.7	385	8.1	7.7	35	8.3	97

Secchi = 0.5m

Net #1 8m 345400 345788
345800 346118

1530 MR 01 WC 2828
Label #8

Location 734 794 6320 Date 6/24/13 17

Project / Client Mike

1700 Boat Launch

LimnoTech
Water | Environment | Scientists | Engineers

FLOAT PLAN

Date/Time: 6-24-13 0900 Name: E. Verhamme

1. Emergency Phone Numbers

Coast Guard 911
Marine Police 911
On Water Towing N.A.

2. Description of the Boat

Boat Name: R/V- SENTINEL Hailing Port:
Type: PLEASURE CRAFT Model Year: 1998
Make: PARKER Length: 23' Beam: 8' Draft: 2'
Color, Hull: WHITE Cabin: WHITE (HARDTOP)
Registration No: MC2191TG Sail No:
Engine(s) Type: OUTBOARD Horsepower: 225 Cruising Speed: 25 knots
Fuel Capacity, Gallons: 150 Cruising Range: 200 miles

Electronics/Safety Equipment Aboard

VHF Radio: Yes w/DSC Cell Phone: 734 674 0387 MMSI: 338103525 SSB: No
Frequency Monitored: 16 Loran: No SatNav:
Depth Sounder: Yes Radar: Yes GPS: Yes
Raft: No Dinghy: No EPIRB Type and # Cat 2, UIN: 2DCC5EBD30FFBFF

3. Passengers

Filer Nm:	Ed Verhamme	Address:	281 Harbor Way Ann Arbor MI	Phone:	906-370-0621	Age	32
Name:	Brandon Ellefson	Address:	9955 W Avondale Cr Ann Arbor MI	Phone:	608-852-5080	Age	27
Name:		Address:		Phone:		Age	
Name:	Cullen OBrien	Address:	661 Crestwood Cr Saline MI	Phone:	734-674-0387	Age	39
Name:		Address:		Phone:		Age	

4. Trip Details

Departing Marina Bolles Harbor - DNR Launch Phone:
Auto Parked At: Bolles Harbor - DNR Launch
Model/color 2011 Chevy Silverado, Granite Blue Lic. #
Depart From Monroe Departure Date/Time 6/24/13 9:00 AM
Destination: Open lake disposal site Description of Work: Sediment Coring

Return To: Monroe – Bolles Harbor Phone: NA
Return Date/Time: 6/24/13 – 6 PM No Later Than: 8:00 PM

Plan Filed with: Cathy Whiting Phone: C 734 771 4429
W

Plan Closed Time/Notes:

If this float plan it not closed by the "No Later Than" time, then the holder of this float plan should attempt to contact the filer and any passengers. If contact is not made within 30 minutes, then attempt to reach the vessel via marine radio (the USCG or Sheriff can assist in this). After 1 hour officially notify the USCG and Sheriff of the missing vessel and relay all pertinent information from this float plan.

CALIBRATION LOG

DATE: 7/3/13 START TIME: 13:15

PERSONNEL: C. Gehnke END TIME:

LOCATION: office PROJECT: MAUMEE 3

INSTRUMENT CALIBRATED: YSI 6920 SERIAL NUMBER:

D. O. %

WATER SATURATED AIR CALIBRATION

D.O. AIR SATURATION TIME: 10 min PERCENT SATURATION: 100 %

CALIBRATION PRESSURE: 743.5 mmHg CALIBRATION TEMPERATURE: 23.09 °C

PRE-CALIBRATION READING: 99.2 %, 8.50 mg/l CALIBRATED READING: 97.8 %, 8.38 mg/l

DO CHARGE / DO GAIN: 45 (ACCEPTABLE RANGE: 50 +/- 25, / 1.0 -0.3 to +0.5)

CALIBRATION SUCCESSFUL: yes MAINTENANCE: none

SPECIFIC CONDUCTIVITY

COND. STANDARD USED: YSI CONDUCTIVITY STANDARD 1000 uS/cm YSI 3167 (1.00 mS/cm)

DATE BOTTLE OPENED: — EXPIRATION DATE: 12/2014

PRE-CALIBRATION READING: 1049 uS/cm CALIBRATION NUMBER USED: 1 mS/cm

CALIBRATED READING: 961 uS/cm CALIBRATION TEMPERATURE: 22.96 °C

CAL. CONSTANT: 4.70764 (ACCEPTABLE RANGE: 5.0 +/- 0.45)

CALIBRATION SUCCESSFUL: yes MAINTENANCE: none

pH

2 POINT CALIBRATION

pH 7.00 STANDARD USED: FISHER BUFFER SOLUTION pH 7.00 +/- 0.01 @ 25'C SB107-4

DATE BOTTLE OPENED: — EXPIRATION DATE: 5/17/2015

PRE-CALIBRATION READING: 7.11 s.u. CALIBRATION NUMBER USED: 7.0 s.u.

CALIBRATED READING: 7.00 s.u. CALIBRATION TEMPERATURE: 23.02 °C

BUFFER 7.00 mV: (ACCEPTABLE RANGE: 0 +/- 50 mV)

pH 10.00 STANDARD USED: FISHER BUFFER SOLUTION pH 10.00 +/- 0.02 @ 25'C SB115-4

DATE BOTTLE OPENED: — EXPIRATION DATE: 5/8/2015

PRE-CALIBRATION READING: 9.94 s.u. CALIBRATION NUMBER USED: 10.0 s.u.

CALIBRATED READING: 10.00 s.u. CALIBRATION TEMPERATURE: 23.59 °C

BUFFER 10.00 mV: −169.61 (ACCEPTABLE RANGE: -180 +/- 50 mV)

pH SLOPE OF SENSOR: (ACCEPTABLE RANGE: 165-180)

CALIBRATION SUCCESSFUL: yes MAINTENANCE: none

ORP

~~REDOX STANDARD: RICCA ZOBELL'S SOLUTION (APHA Redox Standard Solution) Cat. No. 9880-32~~

~~DATE BOTTLE OPENED: EXPIRATION DATE:~~

~~PRE-CALIBRATION READING: mV CALIBRATION NUMBER USED: mV~~

~~CALIBRATED READING: mV CALIBRATION TEMPERATURE: °C~~

~~CALIBRATION SUCCESSFUL: MAINTENANCE:~~

TURBIDITY

3 POINT CALIBRATION

TURBIDITY STANDARD # 1: YSI 608000 TURBIDITY STANDARD ~~0.0 NTU~~ DI WATER

DATE BOTTLE OPENED: — EXPIRATION DATE:

PRE-CALIBRATION READING: −0.3 ntu CALIBRATION NUMBER USED: 0 ntu

CALIBRATED READING: 0 ntu CALIBRATION TEMPERATURE: 23.19 °C

TURBIDITY STANDARD # 2: YSI 607200 TURBIDITY STANDARD ~~10.0 NTU~~ 12.7

DATE BOTTLE OPENED: — EXPIRATION DATE:

PRE-CALIBRATION READING: 12.8 ntu CALIBRATION NUMBER USED: 12.7 ntu

CALIBRATED READING: 12.7 ntu CALIBRATION TEMPERATURE: 23.28 °C

TURBIDITY STANDARD # 3: YSI 607300 TURBIDITY STANDARD ~~100 NTU~~ 126

DATE BOTTLE OPENED: — EXPIRATION DATE:

PRE-CALIBRATION READING: 123.1 ntu CALIBRATION NUMBER USED: 126 ntu

CALIBRATED READING: 126 ntu CALIBRATION TEMPERATURE: 23.34 °C

CALIBRATION SUCCESSFUL: yes MAINTENANCE: none

NOTES:

CALIBRATION LOG

DATE: 7/3/13 START TIME: 1100

PERSONNEL: END TIME:

LOCATION: Dock PROJECT:

INSTRUMENT CALIBRATED: SERIAL NUMBER:

D. O. %

WATER SATURATED AIR CALIBRATION

D.O. AIR SATURATION TIME ______ min PERCENT SATURATION 100 %

CALIBRATION PRESSURE ______ mmHg CALIBRATION TEMPERATURE ______ °C

PRE-CALIBRATION READING ______ %, ______ mg/l CALIBRATED READING ______ %, ______ mg/l

DO CHARGE / DO GAIN ______ (ACCEPTABLE RANGE: 50 +/- 25, / 1.0 -0.3 to +0.5)

CALIBRATION SUCCESSFUL ______ MAINTENANCE ______

SPECIFIC CONDUCTIVITY

COND. STANDARD USED YSI CONDUCTIVITY STANDARD 1000 uS/cm YSI 3187 (1.00 mS/cm)

DATE BOTTLE OPENED — EXPIRATION DATE —

PRE-CALIBRATION READING 1417 uS/cm CALIBRATION NUMBER USED 1413 uS/cm

CALIBRATED READING 1413 mS/cm CALIBRATION TEMPERATURE 26.85 °C

CAL. CONSTANT 4.95679 (ACCEPTABLE RANGE: 5.0 +/- 0.45)

CALIBRATION SUCCESSFUL yes MAINTENANCE none

pH

2 POINT CALIBRATION

pH 7.00 STANDARD USED FISHER BUFFER SOLUTION pH 7.00 +/- 0.01 @ 25°C SB107-4

DATE BOTTLE OPENED ______ EXPIRATION DATE ______

PRE-CALIBRATION READING ______ s.u. CALIBRATION NUMBER USED ______ s.u.

CALIBRATED READING ______ s.u. CALIBRATION TEMPERATURE ______ °C

BUFFER 7.00 mV ______ (ACCEPTABLE RANGE: 0 +/- 50 mV)

pH 10.00 STANDARD USED FISHER BUFFER SOLUTION pH 10.00 +/- 0.02 @ 25°C SB115-4

DATE BOTTLE OPENED ______ EXPIRATION DATE ______

PRE-CALIBRATION READING ______ s.u. CALIBRATION NUMBER USED ______ s.u.

CALIBRATED READING ______ s.u. CALIBRATION TEMPERATURE ______ °C

BUFFER 10.00 mV ______ (ACCEPTABLE RANGE: -180 +/- 50 mV)

pH SLOPE OF SENSOR ______ (ACCEPTABLE RANGE: 165-180)

CALIBRATION SUCCESSFUL ______ MAINTENANCE ______

ORP

REDOX STANDARD RICCA ZOBELL'S SOLUTION (APHA Redox Standard Solution) Cat. No. 9880-32

DATE BOTTLE OPENED ______ EXPIRATION DATE ______

PRE-CALIBRATION READING ______ mV CALIBRATION NUMBER USED ______ mV

CALIBRATED READING ______ mV CALIBRATION TEMPERATURE ______ °C

CALIBRATION SUCCESSFUL ______ MAINTENANCE ______

TURBIDITY

3 POINT CALIBRATION

TURBIDITY STANDARD # 1 YSI 608000 TURBIDITY STANDARD 0.0 NTU

DATE BOTTLE OPENED — EXPIRATION DATE —

PRE-CALIBRATION READING 8.7 ntu CALIBRATION NUMBER USED 0 ntu

CALIBRATED READING 0 ntu CALIBRATION TEMPERATURE 25.32 °C

TURBIDITY STANDARD # 2 YSI 607200 TURBIDITY STANDARD ~~10.0 NTU~~ 12.7

DATE BOTTLE OPENED — EXPIRATION DATE

PRE-CALIBRATION READING ~~00~~ 12.1 ntu CALIBRATION NUMBER USED 12.7 ntu

CALIBRATED READING 12.7 ntu CALIBRATION TEMPERATURE 25.76 °C

TURBIDITY STANDARD # 3 YSI 607300 TURBIDITY STANDARD ~~100 NTU~~ 126

DATE BOTTLE OPENED — EXPIRATION DATE —

PRE-CALIBRATION READING 139.2 ntu CALIBRATION NUMBER USED 126 ntu

CALIBRATED READING 126 ntu CALIBRATION TEMPERATURE 25.65 °C

CALIBRATION SUCCESSFUL yes MAINTENANCE ______

NOTES: ______

CALIBRATION LOG

DATE: 7/3/13 START TIME:
PERSONNEL: END TIME:
LOCATION: Disposal Area (yellow buoy) PROJECT:
INSTRUMENT CALIBRATED: SERIAL NUMBER:

D. O. %

WATER SATURATED AIR CALIBRATION

D.O. AIR SATURATION TIME ______ min PERCENT SATURATION 100 %
CALIBRATION PRESSURE ______ mmHg CALIBRATION TEMPERATURE ______ 'C
PRE-CALIBRATION READING ______ %, ______ mg/l CALIBRATED READING ______ %, ______ mg/l
DO CHARGE / DO GAIN ______ (ACCEPTABLE RANGE: 50 +/- 25, / 1.0 -0.3 to +0.5)
CALIBRATION SUCCESSFUL ______ MAINTENANCE ______

SPECIFIC CONDUCTIVITY

COND. STANDARD USED YSI CONDUCTIVITY STANDARD 1000 uS/cm YSI 3167 (1.00 mS/cm)
DATE BOTTLE OPENED — EXPIRATION DATE —
PRE-CALIBRATION READING 1603 mS/cm CALIBRATION NUMBER USED 1413 mS/cm
CALIBRATED READING 1413 mS/cm CALIBRATION TEMPERATURE ______ 'C
CAL. CONSTANT ______ (ACCEPTABLE RANGE: 5.0 +/- 0.45)
CALIBRATION SUCCESSFUL ______ MAINTENANCE ______

pH

2 POINT CALIBRATION

pH 7.00 STANDARD USED FISHER BUFFER SOLUTION pH 7.00 +/- 0.01 @ 25'C SB107-4
DATE BOTTLE OPENED ______ EXPIRATION DATE ______
PRE-CALIBRATION READING ______ s.u. CALIBRATION NUMBER USED ______ s.u.
CALIBRATED READING ______ s.u. CALIBRATION TEMPERATURE ______ 'C
BUFFER 7.00 mV ______ (ACCEPTABLE RANGE: 0 +/- 50 mV)

pH 10.00 STANDARD USED FISHER BUFFER SOLUTION pH 10.00 +/- 0.02 @ 25'C SB115-4
DATE BOTTLE OPENED ______ EXPIRATION DATE ______
PRE-CALIBRATION READING ______ s.u. CALIBRATION NUMBER USED ______ s.u.
CALIBRATED READING ______ s.u. CALIBRATION TEMPERATURE ______ 'C
BUFFER 10.00 mV ______ (ACCEPTABLE RANGE: -180 +/- 50 mV)
pH SLOPE OF SENSOR ______ (ACCEPTABLE RANGE: 165-180)
CALIBRATION SUCCESSFUL ______ MAINTENANCE ______

ORP

REDOX STANDARD RICCA ZOBELL'S SOLUTION (APHA Redox Standard Solution) Cat. No. 9880-32
DATE BOTTLE OPENED ______ EXPIRATION DATE ______
PRE-CALIBRATION READING ______ mV CALIBRATION NUMBER USED ______ mV
CALIBRATED READING ______ mV CALIBRATION TEMPERATURE ______ 'C
CALIBRATION SUCCESSFUL ______ MAINTENANCE ______

TURBIDITY

3 POINT CALIBRATION

TURBIDITY STANDARD # 1 YSI 608000 TURBIDITY STANDARD 0.0 NTU
DATE BOTTLE OPENED — EXPIRATION DATE —
PRE-CALIBRATION READING 3.2 ntu CALIBRATION NUMBER USED 0 ntu
CALIBRATED READING 0 ntu CALIBRATION TEMPERATURE 24.88 'C
TURBIDITY STANDARD # 2 YSI 607200 TURBIDITY STANDARD ~~10.0~~ NTU 12.7
DATE BOTTLE OPENED — EXPIRATION DATE —
PRE-CALIBRATION READING 11.2 ntu CALIBRATION NUMBER USED 12.7 ntu
CALIBRATED READING 12.7 ntu CALIBRATION TEMPERATURE 24.99 'C
TURBIDITY STANDARD # 3 YSI 607300 TURBIDITY STANDARD ~~100~~ NTU 126
DATE BOTTLE OPENED — EXPIRATION DATE —
PRE-CALIBRATION READING 140.7 ntu CALIBRATION NUMBER USED 126 ntu
CALIBRATED READING 126 ntu CALIBRATION TEMPERATURE 25.10 'C
CALIBRATION SUCCESSFUL yes MAINTENANCE none

NOTES: ______

CALIBRATION LOG

DATE: 7/3/13 START TIME:
PERSONNEL: C Behnke END TIME:
LOCATION: Reference location PROJECT:
INSTRUMENT CALIBRATED: SERIAL NUMBER:

D. O. %

WATER SATURATED AIR CALIBRATION

D.O. AIR SATURATION TIME ____ min PERCENT SATURATION 100 %
CALIBRATION PRESSURE ____ mmHg CALIBRATION TEMPERATURE ____ 'C
PRE-CALIBRATION READING ____ %, ____ mg/l CALIBRATED READING ____ %, ____ mg/l
DO CHARGE / DO GAIN ____ (ACCEPTABLE RANGE: 50 +/- 25, / 1.0 -0.3 to +0.5)
CALIBRATION SUCCESSFUL ____ MAINTENANCE ____

SPECIFIC CONDUCTIVITY

COND, STANDARD USED YSI CONDUCTIVITY STANDARD 1000 uS/cm YSI 3167 (1.00 mS/cm)
DATE BOTTLE OPENED — EXPIRATION DATE —
PRE-CALIBRATION READING 1.398 mS/cm CALIBRATION NUMBER USED 1413 mS/cm
CALIBRATED READING 1.413 mS/cm CALIBRATION TEMPERATURE — 'C
CAL. CONSTANT 5.413 (ACCEPTABLE RANGE: 5.0 +/- 0.45)
CALIBRATION SUCCESSFUL yes MAINTENANCE none

pH

2 POINT CALIBRATION

pH 7.00 STANDARD USED FISHER BUFFER SOLUTION pH 7.00 +/- 0.01 @ 25'C SB107-4
DATE BOTTLE OPENED ____ EXPIRATION DATE ____
PRE-CALIBRATION READING ____ s.u. CALIBRATION NUMBER USED ____ s.u.
CALIBRATED READING ____ s.u. CALIBRATION TEMPERATURE ____ 'C
BUFFER 7.00 mV ____ (ACCEPTABLE RANGE: 0 +/- 50 mV)

pH 10.00 STANDARD USED FISHER BUFFER SOLUTION pH 10.00 +/- 0.02 @ 25'C SB115-4
DATE BOTTLE OPENED ____ EXPIRATION DATE ____
PRE-CALIBRATION READING ____ s.u. CALIBRATION NUMBER USED ____ s.u.
CALIBRATED READING ____ s.u. CALIBRATION TEMPERATURE ____ 'C
BUFFER 10.00 mV ____ (ACCEPTABLE RANGE: -180 +/- 50 mV)
pH SLOPE OF SENSOR ____ (ACCEPTABLE RANGE: 165-180)
CALIBRATION SUCCESSFUL ____ MAINTENANCE ____

ORP

REDOX STANDARD RICCA ZOBELL'S SOLUTION (APHA Redox Standard Solution) Cat. No. 9880-32
DATE BOTTLE OPENED ____ EXPIRATION DATE ____
PRE-CALIBRATION READING ____ mV CALIBRATION NUMBER USED ____ mV
CALIBRATED READING ____ mV CALIBRATION TEMPERATURE ____ 'C
CALIBRATION SUCCESSFUL ____ MAINTENANCE ____

TURBIDITY

3 POINT CALIBRATION

TURBIDITY STANDARD # 1 YSI 608000 TURBIDITY STANDARD 0.0 NTU
DATE BOTTLE OPENED — EXPIRATION DATE —
PRE-CALIBRATION READING 7.1 ntu CALIBRATION NUMBER USED 0 ntu
CALIBRATED READING 0 ntu CALIBRATION TEMPERATURE 28.69 'C
TURBIDITY STANDARD # 2 YSI 607200 TURBIDITY STANDARD ~~100 NTU~~ 12.7
DATE BOTTLE OPENED ____ EXPIRATION DATE ____
PRE-CALIBRATION READING 10.8 ntu CALIBRATION NUMBER USED 12.7 ntu
CALIBRATED READING 12.7 ntu CALIBRATION TEMPERATURE — 'C
TURBIDITY STANDARD # 3 YSI 607300 TURBIDITY STANDARD ~~100 NTU~~ 126
DATE BOTTLE OPENED — EXPIRATION DATE —
PRE-CALIBRATION READING 128.7 ntu CALIBRATION NUMBER USED 126 ntu
CALIBRATED READING 126 ntu CALIBRATION TEMPERATURE — 'C
CALIBRATION SUCCESSFUL yes MAINTENANCE none

NOTES:

LTI–Limno-Tech, Inc.
Environmental Engineering

Subject	Page	By	Date	Project
Sonde download / Calibration		CB	7/3/13	MAUMEE 3

1100 - At dock, pulling up Sonde. Starting up computer to download data.

1110 - Downloading "Maumee.dat"

1115 - Download complete, taking YSI measurements from sonde prior to cleaning.

TEMP - 22.65 °C
Cond - 552 uS/cm
spcond - 578 uS/cm^c
TURB - 37.9
depth - 1.8 ft

1120 - Cleaning Sonde, Calibrating. See cal sheet.
1145 - Sonde calibrated, readings in-situ after cal

TEMP - 23.14
Cond - 557
SpCond - 578
TURB - 28.1
depth - 1.7 ft

Battery volts = 13.4 } lithium batteries... left in place
Battery life = 96 days }

1150 - Verified that sonde is "logging", reinstalled. Added silicone to seal of YSI
1200 V of T Boat has arrived. Taking YSI measurements with V of T. YSI

TEMP - 23.10 °C
SpCond - 1145 uS/cm
TURB 28.3 NTU
Depth - 0.56 M

1230 - At reference location YSI - taking measurement with V of T YSI.
TEMP - 22.24 °C
SPCOND - 651 uS/cm^c
TURB - 30.4 NTU
Depth - 3 ft

1235 - Downloading data from YSI.

LTI–Limno-Tech, Inc.
Environmental Engineering

Subject	Page	By	Date	Project

1245 - Sonde measurements w/ Reference location YSI prior to calibration.

TEMP = 25.14 °C
SPCOND = 0.319 uS/cm^c
TURB = 30.7 NTU
Depth = 2 ft

1320 - After calibration, reading Sonde in water

TEMP = 25.59 °C
SPCOND = 0.319 uS/cm^c
TURB = 30.3 NTU
Depth = 2 ft

1330 - Done, going to Disposal Area.

1340 - 41.806~~...~~16 } position of buoy.
- 83.270506

Pulled 600 OMS from buoy, pre-cal reading.

TEMP : 24.61 °C
SPCOND : 286 uS/cm^c
TURB : 6.2 NTU
Depth : 1 ft

1345 - Calibrating / cleaning sonde, see cal sheet for details

1410 - Done calibrating, readings from calibrated sonde

Temp : 24.94 °C
SPCOND : 268 uS/cm^c
TURB : 20.1
Depth : 1 ft

1415 - YSI readings from V of T YSI

TEMP : 21.81 °C	TEMP : 24.86
SPCOND : 570	SPCOND : 577
TURB : 20.1	TURB : 20.6
Depth : 2.2 (M)	Depth : 1 ft

CALIBRATION LOG

DATE: 7/22/13
START TIME:
PERSONNEL: C. Behnke
END TIME:
LOCATION: office
PROJECT:
INSTRUMENT CALIBRATED: YSI
SERIAL NUMBER:

D. O. %

WATER SATURATED AIR CALIBRATION

D.O. AIR SATURATION TIME ______ min | PERCENT SATURATION 100 %

CALIBRATION PRESSURE 739.1 mmHg | CALIBRATION TEMPERATURE 25.34 °C

PRE-CALIBRATION READING 97 %, 2 mg/l | CALIBRATED READING 97.2 %, 7.99 mg/l

DO CHARGE / DO GAIN ______ (ACCEPTABLE RANGE: 50 +/- 25, / 1.0 -0.3 to +0.5)

CALIBRATION SUCCESSFUL yes | MAINTENANCE none

SPECIFIC CONDUCTIVITY

COND, STANDARD USED YSI CONDUCTIVITY STANDARD ~~1000 uS/cm~~ YSI 3167 (1.00 mS/cm) 1413

DATE BOTTLE OPENED — | EXPIRATION DATE 3/14/14

PRE-CALIBRATION READING 1382 mS/cm | CALIBRATION NUMBER USED 1413 mS/cm

CALIBRATED READING 1413 mS/cm | CALIBRATION TEMPERATURE 25.15 °C

CAL. CONSTANT 5.04876 (ACCEPTABLE RANGE: 5.0 +/- 0.45)

CALIBRATION SUCCESSFUL yes | MAINTENANCE none

pH

2 POINT CALIBRATION

pH 7.00 STANDARD USED FISHER BUFFER SOLUTION pH 7.00 +/- 0.01 @ 25°C SB107-4

DATE BOTTLE OPENED — | EXPIRATION DATE 1/15

PRE-CALIBRATION READING 7.16 s.u. | CALIBRATION NUMBER USED 7.0 s.u.

CALIBRATED READING 7.0 s.u. | CALIBRATION TEMPERATURE ______ °C

BUFFER 7.00 mV ______ (ACCEPTABLE RANGE: 0 +/- 50 mV)

pH 10.00 STANDARD USED FISHER BUFFER SOLUTION pH 10.00 +/- 0.02 @ 25°C SB115-4

DATE BOTTLE OPENED — | EXPIRATION DATE 2/15

PRE-CALIBRATION READING 9.91 s.u. | CALIBRATION NUMBER USED 10.0 s.u.

CALIBRATED READING 10 s.u. | CALIBRATION TEMPERATURE 25.17 °C

BUFFER 10.00 mV — (ACCEPTABLE RANGE: -180 +/- 50 mV)

pH SLOPE OF SENSOR — (ACCEPTABLE RANGE: 165-180)

CALIBRATION SUCCESSFUL yes | MAINTENANCE none

ORP

~~REDOX STANDARD RICCA ZOBELL'S SOLUTION (APHA Redox Standard Solution) Cat. No. 9880-32~~

~~DATE BOTTLE OPENED ______ | EXPIRATION DATE ______~~

~~PRE-CALIBRATION READING ______ mV | CALIBRATION NUMBER USED ______ mV~~

~~CALIBRATED READING ______ mV | CALIBRATION TEMPERATURE ______ °C~~

~~CALIBRATION SUCCESSFUL ______ | MAINTENANCE ______~~

TURBIDITY

3 POINT CALIBRATION

TURBIDITY STANDARD # 1 YSI 608000 TURBIDITY STANDARD 0.0 NTU

DATE BOTTLE OPENED — | EXPIRATION DATE —

PRE-CALIBRATION READING -4 ntu | CALIBRATION NUMBER USED 0 ntu

CALIBRATED READING 0 ntu | CALIBRATION TEMPERATURE 25.07 °C

TURBIDITY STANDARD # 2 YSI 607200 TURBIDITY STANDARD ~~10 NTU~~ 12.7

DATE BOTTLE OPENED ______ | EXPIRATION DATE —

PRE-CALIBRATION READING 13.1 ntu | CALIBRATION NUMBER USED 12.7 ntu

CALIBRATED READING 12.7 ntu | CALIBRATION TEMPERATURE 25.31 °C

TURBIDITY STANDARD # 3 YSI 607300 TURBIDITY STANDARD ~~100 NTU~~ 126

DATE BOTTLE OPENED — | EXPIRATION DATE —

PRE-CALIBRATION READING 124 ntu | CALIBRATION NUMBER USED 126 ntu

CALIBRATED READING 126 ntu | CALIBRATION TEMPERATURE 25.07 °C

CALIBRATION SUCCESSFUL yes | MAINTENANCE ______

NOTES: ______

Location ______ Date 7/22/13
Project / Client MAUMEE 3, Event #2

0700 - At Lenotech, loading equipment
0745 Cullen Obrien, Chris Behnke and Cathy Whiting driving to Toledo.
0845 - At Cullen Park, launching boat
1030 - Close to dumping area, barge in vacinity.
1120 - Radio contact with barge, they dropped load at 11 20 am.
1150 - Attempting to track plume. Not very visible
1205 - At dump location, Marking 4 buoy locations

W -	N 41.81291	, W	83.28689
E -	N 41.81312	, W	83.27759.
N -	N. 41.81705	, W	83.28211
S -	N 41.81001	, W	83.28211

1230 - deployed "North" short from buoy, going to east. (A1)

Phone # - 419-707-1971

1251 deployed "EAST" short from buoy. (B1)

Location ______ Date 7/22/13
Project / Client MAUMEE 3, event #2

1310 - Deployed "South"
1325 - Deployed "WEST" with LISST
1350 - At real-time buoy Collecting sample.
1400 - Collecting sample at realtime Buoy. Heidleberg bottle # 009, (site #26)
chlorophyll sample ID: PS-02-WC-26-24.

secchi - 4 yellow marks

start = 351100 end = 351330
6m depth
1430 - Dropping LISST
1435 -

	TEMP	COND	DEPTH	pH	NTU	DO	%
0 =	25.99	285		8.24	-2	7.90	97
2 =	25.98	285	←	8.26	-1.6	7.7	94.9
4 =	25.87	283	8.21		-2.3	7.56	92
6 =	25.84	284	8.17		-1.9	7.4	91

8 bottom total depth = 24'
1440 - Going to disposal Area

Location ____ Date 7/22/13

Project / Client Maumee 3 Event #2

1510 DUMP N41.81205 W83.28350

DUMP01 1515 93 NTU

MET TURB ← DUMP 01

0 133 NTU

2 95 (PS-02-WC-01-20)

4 95 BOTTLE # 010

#02 1530 24 NTU

1530 profile #2 PS-02-WC-02-20

0 - 28 NTU BOTTLE # 011

2 - 18 NTU

4 - 16 NTU

1540 - at dump spot

0 - 12 NTU

2 - 26 NTU

4 - 33 NTU

#03 1545 22 NTU

PS-02-WC-03-20

BOTTLE # 012

Location ____ Date 7/22/13

Project / Client MAUMEE 3, event #2

1544 - 0 - 32 NTU

2 - 42 NTU

4 - 109 NTU

1600 13 NTU #04

At dump 01 location

0 - 0 NTU

2 - 4 NTU PS-02-WC-04-20

4 - 23 NTU Bottle 013

1605 - USST

1615 - 1/2 way between dump 01 and post buoy

0 = 3.9 NTU

2 = 0.6 NTU

4 = 5.7 NTU

6 = 43 NTU

#05 1615 45 NTU @ 6m

N - 41.81337°

W - 83.28115°

PS-02-WC-05-20

Bottle 014

Location ____ Date 7/22/13

Project / Client MAUMEE 3

Reference Area # 1

1700 sample RA1-02-WC-25-17

LISST, YSI BOTTLE # 015

BIOVOLUME SPEC.

0 M = T = 22.26
Con = 350
pH = 8.49
turb = 2.2
DO = 8.67

2M T = 26.11
Con = 351
pH = 8.40
turb = -.9
DO = 8.24

4 m T = 25.94
Con = 350
pH = 8.29
turb = -1.0
DO = 7.67

~~6M~~

1710 - Net start = 351330
end = 351460
depth: 4.5 m

Location ____ Date 7/22/13

Project / Client MAUMEE 3

1800 - At Toledo light (# 27)

RA-02-WC-27-26

BOTTLE # 016

LISST, YSI

BIOVOL, SPEC.

DUPLICATE A

BOTTLE # 017

0 m T = 25.72
Con = 242
pH = 8.2
turb = -5
DO = 7.7

2M T = 25.72
Con = 242
pH = 8.22
turb = -5
DO = 7.76

4m = T = 25.7
Con = 241
pH = 8.22
Tur = -5.5
DO = 7.74

6m T = 25.62
Con = 239
pH = 8.19
Turb = -5.5
DO = 7.63

8 m T = 25.58
Con = 239
pH = 8.17
DO = 7.53
Turb = -4.8

Location ______ Date 7/22/13

Project / Client MAUMEE 3

1815 NET DUP A

START 351480 8m deep

END 351771

1825 START 351800 8 m deep

END 352143

DOCK

sample time 1900

LISST, YSI

BOTTLE # 018

MR-02-WC-28-26

	TEMP	COND	pH	TURB	DO
0 -	27.58	498	7.72	15	6.45
2 -	27.43	493	7.68	13.5	6.12
4 -	27.1	487	7.61	14.6	5.47
6 -	27.03	490	7.58	15.3	5.13
7 -	26.97	492	7.54	16.8	4.80

2000 - At boat launch, loading boat

2200 - At ITI office, unloading / re-loading

Location ______ Date 7/23/13

Project / Client MAUMEE 3

0620 - C. Behnke at office, calibrating sonde loading

0720 - Filed float plan, leaving office

0815 - Filling up boat with gas.

0940 - Boat launched, heading out to disposal area.

1020 - At Reference Area # 1, collecting LISST. ~~LISST clock was 2.5 hours fast yesterday.~~ We are syncing clock now on LISST

Sample # 019 @ 1045

METERS	TEMP	COND	pH	TURB	DO
0	25.61	385	8.37	-0.8	7.41
1	25.81	385	8.40	-1	7.36
2	25.8	385	8.4	-0.5	7.28
3	25.78	385	8.4	0.0	7.2
4	25.79	385	8.4	-1	7.19
5	25.77	385	8.38	-1.2	7.13

net start = 352200

net end = 352324

depth = 5 meters

Location ____ Date 7/23/13

Project / Client MAUMEE 3

1110 - Done sampling, going to RTB.

1130 - At real time buoy. (#26)
Secci : 1.7 M

dropping LISST.

YSI measurements

depth (meters)	TEMP	COND	pH	TURB	DO
0	25.76	308	8.32	-2.7	7.74
1	25.75	308	8.35	-2.9	7.73
2	25.75	308	8.35	-3.4	7.73
3	25.74	308	8.34	-3.1	7.71
4	25.69	307	8.33	-3.3	7.69
5	25.65	308	8.31	-3	7.53
6	25.65	309	8.29	-3.1	7.46
7	25.60	313	8.25	-2.9	7.28

1145 - collected sample @ Real time buoy (#26) collected "DUPLICATE B" here as well. Heidleburg bottle ID = 020
duplicate B = 021
(PS-02-WC-26-24)

net
start = 352300, end = 352503
7 meter depth

Location ____ Date 7/23/13

Project / Client MAUMEE 3

DUPLICATE B net tow
start = 352500, end = 352668
6.5 meters

1200 - Done sampling, waiting for dredge barge

1220 - We can see him coming, he is just rounding the light-house and turning toward the disposal area.

1230 - Collected blank "FB-02-WC-01-00" for chlorophyll 1L and 1 0.5L for Heidleburg.

DUMP072313

1255 - → N. 41.81297, W. 83.28159

Location ______ Date 7/23/13

Project / Client Maumee 3

sample #1 @ 1305

Vertical Profile - Dump 01 (17' deep)

Depth (m)	Temp (C)	Cond	pH	Turb	DO
0	26.0°	338	8.26	13.2	7.61
1	26.11°	338	8.30	5.3	7.66
2	25.87	334	8.31	1.8	7.62
3	25.72	330	8.17	30	7.42
4	25.69	332	8.06	148	7.17
5	25.75	334	7.96	280	6.92

sample Vert. Profile - Dump 02 072313 (18' deep)

Depth	Temp	Cond	pH	Turb	DO
0	25.90	333	8.28	37.1	7.58
1	25.96	335	8.28	44	7.52
2	25.82	332	8.27	35	7.46
3	25.84	332	8.27	35.2	7.42
4	25.82	334	8.15	97.8	7.27
5	25.83	336	8.02	103.2	7.03

1312 - collected sample #2 - N 41.81383
W 83.28111

Location ______ Date 7/23/13

Project / Client Maumee 3

1325 VP location N 41.81387°
W 83.28077 (location 03) (18 depth)

sample #3

Depth	Temp	Cond	pH	Turb	DO
0	26.20	335	8.34	9.7	7.75
1	26.14	335	8.33	17.6	7.69
2	25.97	334	8.29	25.1	7.58
3	25.91	334	8.28	26.0	7.50
4	25.88	333	8.27	26.2	7.46
5	25.81	332	8.25	28.7	7.37
6	25.7	329	8.16	32.7	7.33

No WC sample

1335 VP location N 41.81437°
W 83.27955 (location 4)

Depth	Temp	Cond	pH	Turb	DO
0	26.26	336	8.36	5.2	7.76
1	26.10	334	8.35	5.3	7.74
2	25.79	328	8.32	1.3	7.60
3	25.73	326	8.29	-0.8	7.48
4	25.71	324	8.27	-0.6	7.42
5	25.67	323	8.26	0.0	7.36
6	25.64	323	8.21	1.0	7.24

Location

Date 7/23/13

Project / Client Maumee 3

1345 VP location ~~#~~ 05 (no sample) -
N 41.81440° W 83.27751°

Depth	Temp	Cond.	pH	Turb.	DO
0	26.16	335	8.34	8.1	7.74
1	26.15	334	8.35	6.5	7.73
2	26.00	331	8.33	5.1	7.64
3	25.73	326	8.30	0.0	7.50
4	25.72	324	8.28	0.0	7.44
5	25.72	321	8.27	-0.5	7.37
6	25.68	321	8.25	-0.1	7.30

1355 VP location 06 (sample #4)
N. 41.81351° W 83.27767°

Depth	Temp	Cond	pH	Turb	DO
0	26.47	339	8.39	1.4	7.86
1	26.45	338	8.38	1.5	7.85
2	26.05	330	8.31	1.0	7.8
3	25.83	323	8.34	-0.6	7.71
4	25.82	321	8.33	-0.5	7.63
5	25.71	307	8.29	2.0	7.48
6	25.66	310	8.23	5.0	7.33

Adjacent to B1 East (20' depth)

Location

Date 7/23/13

Project / Client Maumee 3

1410 VP location 07 (no sample)
N 41.81545 W 83.27755

Depth	Temp	Cond	pH	Turb	DO
0	26.32	335	8.38	5.0	7.89
1	26.14	332	8.37	3.0	7.87
2	26.14	331	8.37	2.0	7.83
3	25.96	328	8.38	2.5	7.85
4	25.88	321	8.35	1.1	7.74
5	25.87	319	8.34	0.8	7.68
6	25.79	314	8.31	1.7	7.58
~~7~~ (DB)					

1430 VP location 08 (sample #5)
leading edge of plume (20' depth)
N 41.81595 W 83.27609

Depth	Temp	Cond	pH	Turb	DO
0	26.22	329	8.4	0.4	8.05
1	26.20	328	8.41	0.0	8.05
2	26.14	325	8.40	-0.4	8.03
3	26.13	324	8.40	-0.0	7.96
4	25.92	315	8.39	-0.7	7.89
5	25.11	307	8.36	-1.2	7.77
6	25.67	303	8.36	-1.7	7.70

~~7 25.~~ DK bottom

Location ____ Date 7/23/13

Project / Client Maumee 3

Winds and waves gradually pick up during plume tracking. Can no longer track plume although largely diluted.

1430 - Done following plume, processing sample from #1
Heidelberg bottle # 023, sample time 1305
"PS-02-WC-01-17"

		Heidelberg #
PS-02-WC-02-18	@ 1312	024
PS-02-WC-03-18	@ 1325	025
PS-02-WC-04-20	@ 1355	026
PS-02-WC-05-20	@ 1430	027

1500 - Done processing samples, going to reference #2.

Location ____ Date 7/23/13

Project / Client Maumee 3

At Reference Area 2 (Depth 25')
VP

Depth	Temp	Cond	pH	Turb	DO
0	25.85	246	8.33	-6.6	7.42
1	25.83	246	8.32	-6.3	7.51
2	25.78	247	8.30	-6.5	7.57
3	25.80	247	8.29	-6.5	7.61
4	25.74	247	8.27	-6.5	7.59
5	25.68	247	8.25	-6.4	7.56
6	25.53	247	8.22	-6.4	7.59
7	25.48	247	8.19	-2.3	7.42
8	25.48	247	8.19	-3.0	7.38

1520 Net start 352660
end 352997

1525 - Collected sample @

At CDF site to collect MR02WC2826 and perform VP (Depth 27')

Depth	Temp	Cond	pH	Turb	DO
0	27.91	470	8.00	10.5	5.36
1	27.91	470	8.03	10.7	5.28
2	27.80	470	7.98	11.1	5.01
3	27.71	471	7.96	12.2	4.90
4	27.66	472	7.94	12.3	4.80

Location

Date 7/23/13

Project / Client Maumee 3

Depth	Temp	Cond	pH	Turb	DO
5	27.37	476	7.84	14.1	4.70
6	27.25	477	7.81	16.0	4.73
7	27.03	477	7.77	16.1	4.78
8	26.42	478	7.67	29.2	4.96

Net start: 353000, end = 353285
9 meter depth

Location

Date 7/24/13

Project / Client MAUMEE 3

0630 - At office, calibrating YSI.
0700 - leaving office
0915 - Boat has been launched at Cullen Park, we had our safety meeting. Going to see if the water is safe to work on on Lake Erie.
0940 - There is no dredge barge on the channel. Calling cathy whiting to see what the deal is.
1000 - We are going back into cullen park. No sampling today.
1005 - The army Corps have dropped off dredge samples to us at the boat launch.
1100 - Phoenix from U of T has picked up the chlorophyll bottle that we missed yesterday. leaving for Ann Arbor.
1230 - Back at office.

LimnoTech
Water | Environment | Scientists | Engineers

FLOAT PLAN

Date/Time: 7-22-13 0700 Name: Cathy Whiting

1. Emergency Phone Numbers

Coast Guard 911

Marine Police 911

On Water Towing N.A.

2. Description of the Boat

Boat Name: R/V- SENTINEL Hailing Port:

Type: PLEASURE CRAFT Model Year: 1998

Make: PARKER Length: 23’ Beam: 8’ Draft: 2’

Color, Hull: WHITE Cabin: WHITE (HARDTOP)

Registration No: MC2191TG Sail No:

Engine(s) Type: OUTBOARD Horsepower: 225 Cruising Speed: 25 knots

Fuel Capacity, Gallons: 150 Cruising Range: 200 miles

Electronics/Safety Equipment Aboard

VHF Radio: Yes w/DSC Cell Phone: 734 674 0387 MMSI: 338103525 SSB: No

Frequency Monitored: 16 Loran: No SatNav:

Depth Sounder: Yes Radar: Yes GPS: Yes

Raft: No Dinghy: No EPIRB Type and # Cat 2, UIN: 2DCC5EBD30FFBFF

3. Passengers

Filer Nm:	Cathy Whiting	Address:	10667 Trailwood, Plymouth, MI	Phone:	734-771-4429	Age	57
Name:	Chris Behnke	Address:	2724 Lookout Circle Ann Arbor MI	Phone:	734-673-2209	Age	37
Name:	Cullen O’Brien	Address:		Phone:	734-674-0387	Age	39
Name:		Address:		Phone:		Age	
Name:		Address:		Phone:		Age	

4. Trip Details

Departing Marina Cullen Park - DNR Launch Phone:

Auto Parked At: Cullen Park - DNR Launch

Model/color 2011 Chevy Silverado, Granite Blue Lic. #

Depart From Monroe Departure Date/Time 7/22/13 8:30 AM

Destination: Open lake disposal site Description of Work: Sediment Coring

Return To: Monroe – Bolles Harbor Phone: NA

Return Date/Time: 7/22/13 – 6 PM No Later Than: 8:00 PM

Plan Filed with: Bob Betz Phone: C 734 771 4429
W

Plan Closed Time/Notes:

If this float plan it not closed by the “No Later Than” time, then the holder of this float plan should attempt to contact the filer and any passengers. If contact is not made within 30 minutes, then attempt to reach the vessel via marine radio (the USCG or Sheriff can assist in this). After 1 hour officially notify the USCG and Sheriff of the missing vessel and relay all pertinent information from this float plan.

CALIBRATION LOG

DATE: 7/23/13 START TIME: 0620

PERSONNEL: C Behnke END TIME:

LOCATION: office PROJECT: MAUMEE 3

INSTRUMENT CALIBRATED: YSI 6920 SERIAL NUMBER:

D. O. %

WATER SATURATED AIR CALIBRATION

D.O. AIR SATURATION TIME ______ min PERCENT SATURATION 100 %

CALIBRATION PRESSURE 734.6 mmHg CALIBRATION TEMPERATURE 24.81 °C

PRE-CALIBRATION READING 98 % 8.12 mg/l CALIBRATED READING 96.6 % 8.01 mg/l

DO CHARGE / DO GAIN gain = 1.00948 (ACCEPTABLE RANGE: 50 +/- 25, / 1.0 -0.3 to +0.5)

CALIBRATION SUCCESSFUL yes MAINTENANCE none

SPECIFIC CONDUCTIVITY

COND. STANDARD USED YSI CONDUCTIVITY STANDARD ~~1000 uS/cm~~ YSI 3167 (1.00 mS/cm) 1413

DATE BOTTLE OPENED — EXPIRATION DATE 3/14

PRE-CALIBRATION READING 1387 mS/cm CALIBRATION NUMBER USED 1413 mS/cm

CALIBRATED READING 1413 mS/cm CALIBRATION TEMPERATURE 24.72 °C

CAL. CONSTANT 5.14049 (ACCEPTABLE RANGE: 5.0 +/- 0.45)

CALIBRATION SUCCESSFUL yes MAINTENANCE none

pH

2 POINT CALIBRATION

pH 7.00 STANDARD USED FISHER BUFFER SOLUTION pH 7.00 +/- 0.01 @ 25'C SB107-4

DATE BOTTLE OPENED ~~4/15~~ 7/23 EXPIRATION DATE 1/15

PRE-CALIBRATION READING 6.93 s.u. CALIBRATION NUMBER USED 7.0 s.u.

CALIBRATED READING 7.0 s.u. CALIBRATION TEMPERATURE 24.44 °C

BUFFER 7.00 mV — (ACCEPTABLE RANGE: 0 +/- 50 mV)

pH 10.00 STANDARD USED FISHER BUFFER SOLUTION pH 10.00 +/- 0.02 @ 25'C SB115-4

DATE BOTTLE OPENED 7/23 EXPIRATION DATE 2/15

PRE-CALIBRATION READING 10.00 s.u. CALIBRATION NUMBER USED 10.00 s.u.

CALIBRATED READING 10.00 s.u. CALIBRATION TEMPERATURE 24.52 °C

BUFFER 10.00 mV — (ACCEPTABLE RANGE: -180 +/- 50 mV)

pH SLOPE OF SENSOR — (ACCEPTABLE RANGE: 165-180)

CALIBRATION SUCCESSFUL yes MAINTENANCE none

ORP

REDOX STANDARD RICCA ZOBELL'S SOLUTION (APHA Redox Standard Solution) Cat. No. 9880-32

DATE BOTTLE OPENED EXPIRATION DATE

PRE-CALIBRATION READING mV CALIBRATION NUMBER USED mV

CALIBRATED READING mV CALIBRATION TEMPERATURE °C

CALIBRATION SUCCESSFUL MAINTENANCE

TURBIDITY

3 POINT CALIBRATION

TURBIDITY STANDARD # 1 YSI 608000 TURBIDITY STANDARD 0.0 NTU

DATE BOTTLE OPENED — EXPIRATION DATE —

PRE-CALIBRATION READING 0.5 ntu CALIBRATION NUMBER USED 0 ntu

CALIBRATED READING 0 ntu CALIBRATION TEMPERATURE 24.67 °C

TURBIDITY STANDARD # 2 YSI 607200 TURBIDITY STANDARD ~~10 NTU~~ 12.7

DATE BOTTLE OPENED — EXPIRATION DATE 5/14

PRE-CALIBRATION READING 12.2 ntu CALIBRATION NUMBER USED 12.7 ntu

CALIBRATED READING 12.7 ntu CALIBRATION TEMPERATURE 24.56 °C

TURBIDITY STANDARD # 3 YSI 607300 TURBIDITY STANDARD ~~100~~ NTU 126

DATE BOTTLE OPENED — EXPIRATION DATE 4/14

PRE-CALIBRATION READING 129.3 ntu CALIBRATION NUMBER USED 126 ntu

CALIBRATED READING 126 ntu CALIBRATION TEMPERATURE 24.69 °C

CALIBRATION SUCCESSFUL yes MAINTENANCE none

NOTES:

Location ______ Date 7/22/13

Project / Client MAUMEE 3, Event #2

0700 - At Lenotech, loading equipment
0745 Collen Obren, Chris Behnke and Cathy Whiting driving to Toledo.
0845 - At Collen Park, launching boat
1030 - Close to dumping area, barge in vacinity.
1120 - Radio contact with barge, they dropped load at 11 20 am.
1150 - Attempting to track plume. Not very visible
1205 - At dump location. Marking 4 buoy locations

W - N 41.81291, W 83.28689
E - N 41.81312, W 83.27759.
N - N. 41.81705, W 83 28211
S - N 41 81001, W 83.28211

1230 - deployed "North" short from buoy, going to east. (A1)

Phone # - 419-787-1971

1251 deployed "EAST" short from buoy. (B1)

Location ______ Date 7/22/13

Project / Client MAUMEE 3, event #2

1310 - Deployed South"
1325 - Deployed "WEST" with LISST.
1350 - At real-time buoy. Collecting sample.
1400 - Collecting sample at realtime Buoy. Heidleberg bottle #009, (Site #26)
chlorophyll sample ID: PS-02-WC-26-24.

Secchi - 4 yellow marks

start = 351100 end = 351330
6m depth
1430 - Dropping LISST
1435 -

	TEMP	COND	DEPTH	pH	NTU	DO	%
0 =	25.99	285		8.24	-2	7.90	97
2 =	25.98	285	←	8.26	-1.6	7.7	94.9
4 =	25.87	283	8.21		-2.3	7.56	92
6 =	25.84	284	8.17		-1.9	7.4	91

8 bottom total depth = 24'

1440 - Going to disposal Area

Location ______ Date 7/22/13

Project / Client Maumee 3 Event #2

1510 DUMP N41.81205 W83.28350

DUMP 01 1515 93 NTU

MET TURB ← DUMP 01

0 133 NTU

2 95 (PS-02-WC-01-20)

4 95 BOTTLE #010

#02 1530 24 NTU

1530 profile #2 PS-02-WC-02-20

0 - 28 NTU BOTTLE #011

2 - 18 NTU

4 - 16 NTU

1540 - at dump spot

0 - 12 NTU

2 - 26 NTU

4 - 33 NTU

#03 1545 22 NTU

PS-02-WC-03-20

BOTTLE #012

Location ______ Date 7/22/13

Project / Client MAUMEE 3, event #2

1544 - 0 - 32 NTU

2 - 42 NTU

4 - 109 NTU

1600 13 NTU #04

At dump 01 location

0 - 0 NTU

2 - 4 NTU PS-02-WC-04-20

4 - 23 NTU Bottle 013

1605 - USST

1615 - 1/2 way between dump 01 and post buoy

0 = 3.9 NTU

2 = 0.6 NTU

4 = 5.7 NTU

6 = 43 NTU

#05 1615 45 NTU @ 6m

N - 41.81337°

W - 83.28115°

PS-02-WC-05-20

Bottle 014

Location ______ Date 7/22/13

Project / Client MAUMEE 3

Reference Area # 1

1700 sample RA1-02-WC-25-17

LISST, YSI BOTTLE # 015
BIOVOLUME SPEC.

0 M = T = 22.26 2M T = 26.11
Con = 350 Con = 351
pH = 8.49 pH = 8.40
turb = 2.2 turb = -.9
DO = 8.67 DO = 8.24

4 m T = 25.94 ~~6M~~
Con = 350
pH = 8.29
turb = -1.0
DO = 7.67

1710 - Net start = 351330
end = 351460
depth = 4.5 m

Location ______ Date 7/22/13

Project / Client MAUMEE 3

1800 - At Toledo light (# 27)
RA-02-WC-27-26
BOTTLE # 016

LISST, YSI
BIOVOL, SPEC.

DUPLICATE A
BOTTLE # 017

0 m T = 25.72 2M T = 25.72
Con = 242 Con = 242
pH = 8.2 pH = 8.22
turb = -5 turb = -5
DO = 7.7 DO = 7.76

4m = T = 25.7 6m T = 25.62
Con = 241 Con = 239
pH = 8.22 pH = 8.19
Tur = -5.5 Turb = -5.5
DO = 7.74 DO = 7.63

8 m T = 25.58
Con = 239
pH = 8.17
DO = 7.53
Turb = -4.8

Location ____ Date 7/22/13

Project / Client MAUMEE 3

1815 NET DUP A

START 351480 8 m deep

END 351771

1825 START 351800 8 m deep

END 352143

DOCK

sample time 1900

LISST, YSI

BOTTLE # 018

MR-02-WC-28-26

	TEMP	COND	pH	TURB	DO
0 -	27.58	498	7.72	15	6.45
2 -	27.43	493	7.68	13.5	6.12
4 -	27.1	487	7.61	14.6	5.47
6 -	27.03	490	7.58	15.3	5.13
7 -	26.97	492	7.54	16.8	4.80

2000 - At boat launch, loading boat

2200 - At ITI office, unloading / re-loading

Location ____ Date 7/23/13

Project / Client MAUMEE 3

0620 - C. Behnke at office, calibrating sonde loading

0720 - Filed float plan, leaving office

0815 - Filling up boat with gas.

0940 - Boat launched, heading out to disposal area.

1020 - At Reference Area # 1, collecting LISST. ~~LISST clock was 2.5 hours fast yesterday.~~ We are syncing clock now on LISST

Sample # 019 @ 1045

METERS	TEMP	COND	pH	TURB	DO
0	25.61	385	8.37	-0.8	7.41
1	25.81	385	8.40	-1	7.36
2	25.8	385	8.4	-0.5	7.28
3	25.78	385	8.4	0.0	7.2
4	25.79	385	8.4	-1	7.19
5	25.77	385	8.38	-1.2	7.13

net start = 352200

net end = 352324

depth = 5 meters

Location ______ Date 7/23/13

Project / Client MAUMEE 3

1110 - Done sampling, going to RTB.

1130 - At real time buoy. (#26)

Secci : 1.7 M

dropping LISST.

YSI measurements

depth (meters)	TEMP	COND	pH	TURB	DO
0	25.76	308	8.32	-2.7	7.74
1	25.75	308	8.35	-2.9	7.73
2	25.75	308	8.35	-3.4	7.73
3	25.74	308	8.34	-3.1	7.71
4	25.69	307	8.33	-3.3	7.69
5	25.65	308	8.31	-3	7.53
6	25.65	309	8.29	-3.1	7.46
7	25.60	313	8.25	-2.9	7.28

1145 - collected sample @ Real time buoy (#26) collected "DUPLICATE B" here as well. Heidleburg bottle ID = 020

duplicate B = 021

(PS-02-WC-26-24)

net

start = 352300, end = 352503

7 meter depth

Location ______ Date 7/23/13

Project / Client MAUMEE 3

DUPLICATE B net tow

start = 352500, end = 352668

6.5 meters

1200 - Done sampling, waiting for dredge barge

1220 - We can see him coming, he is just rounding the light-house and turning toward the disposal area.

1230 - Collected blank "FB-02-WC-01-00" for chlorophyll 1 L and 1 0.5 L for Heidleburg.

DUMP072313

1255 - ↳ N. 41.81297, W. 83.28159

Location

Date 7/23/13

Project / Client Maumee 3

sample #1 @ 1305

Vertical Profile - Dump 01 (17' deep)

Depth (m)	Temp (C)	Cond	pH	Turb	DO
0	26.0°	338	8.26	13.2	7.61
1	26.11°	338	8.30	5.3	7.66
2	25.87	334	8.31	1.8	7.62
3	25.72	330	8.17	30	7.42
4	25.69	332	8.06	148	7.17
5	25.75	334	7.96	280	6.92

Sample Vert. Profile - Dump 02 072313 (18' deep)

Depth	Temp	Cond	pH	Turb	DO
0	25.90	333	8.28	37.1	7.58
1	25.96	335	8.28	44	7.52
2	25.82	332	8.27	35	7.46
3	25.84	332	8.27	35.2	7.42
4	25.82	334	8.15	91.8	7.27
5	25.83	336	8.02	103.2	7.03

1312 - collected sample #2 - N 41.81383
W 83.28111

Location

Date 7/23/13

Project / Client Maumee 3

1325 VP location N 41.81387°
W 83.28077 (location 03)
(18 depth)

sample #3

Depth	Temp	Cond	pH	Turb	DO
0	26.20	335	8.34	9.7	7.75
1	26.14	335	8.33	17.6	7.69
2	25.97	334	8.29	25.1	7.58
3	25.91	334	8.28	26.0	7.50
4	25.88	333	8.27	26.2	7.46
5	25.81	332	8.25	28.7	7.37
6	25.77	329	8.16	32.7	7.33

No WL sample

1335 VP location N 41.81437°
W 83.27955 (location 4)

Depth	Temp	Cond	pH	Turb	DO
0	26.26	336	8.36	5.2	7.72
1	26.10	334	8.35	5.3	7.74
2	25.79	328	8.32	1.3	7.60
3	25.73	326	8.29	-0.8	7.48
4	25.71	324	8.27	-0.6	7.42
5	25.67	323	8.26	0.0	7.36
6	25.64	323	8.21	1.0	7.24

Location ______ Date 7/23/13

Project / Client Maumee 3

1345 VP location ~~07~~ 05 (no sample) -
N 41.81440° W 83.27951°

Depth	Temp	Cond.	pH	Turb.	DO
0	26.16	335	8.34	8.1	7.74
1	26.15	334	8.35	6.5	7.73
2	26.00	331	8.33	5.1	7.64
3	25.73	326	8.30	0.0	7.50
4	25.72	324	8.28	0.0	7.44
5	25.72	321	8.27	-0.5	7.37
6	25.68	321	8.25	-0.1	7.30

1355 VP location 06 (sample #4)
N. 41.81351° W 83.27767°

Depth	Temp	Cond	pH	Turb	DO
0	26.47	339	8.39	1.4	7.86
1	26.45	338	8.38	1.5	7.85
2	26.05	330	8.31	1.0	7.8
3	25.83	323	8.34	-0.6	7.71
4	25.82	321	8.33	-0.5	7.63
5	25.71	307	8.29	2.0	7.48
6	25.66	310	8.23	5.0	7.33

Adjacent to B1 East (20' depth)

Location ______ Date 7/23/13

Project / Client Maumee 3

1410 VP location 07 (no sample)
N 41.81545 W 83.27755

Depth	Temp	Cond	pH	Turb	DO
0	26.32	335	8.38	5.0	7.89
1	26.14	332	8.37	3.0	7.87
2	26.14	331	8.37	2.0	7.83
3	25.96	328	8.38	2.5	7.85
4	25.88	321	8.35	1.1	7.74
5	25.87	319	8.34	0.8	7.68
6	25.79	314	8.31	1.7	7.58
~~7~~ (OB)					

1430 VP location 08 (sample #5)
leading edge of plume (20' depth)
N 41.81595 W 83.27609

Depth	Temp	Cond	pH	Turb	DO
0	26.22	329	8.4	0.4	8.05
1	26.20	328	8.41	0.0	8.05
2	26.14	325	8.40	-0.4	8.03
3	26.13	324	8.40	-1.0	7.96
4	25.92	315	8.39	-0.7	7.89
5	25.71	307	8.36	-1.7	7.77
6	25.67	303	8.36	-1.7	7.70

~~7 25.~~ Dk bottom

Location

Date 7/23/13

Project / Client Maumee 3

Winds and waves gradually pick up during plume tracking. Can no longer track plume although largely diluted.

1430- Done following plume, processing sample from #1
Heidleberg bottle # 023, sample time 1305
" PS-02-WC-01-17"

		Heidleberg #
PS-02-WC-02-18	@ 1312	024
PS-02-WC-03-18	@ 1325	025
PS-02-WC-04-20	@ 1355	026
PS-02-WC-05-20	@ 1430	027

1500- Done processing samples, going to reference #2.

Location

Date 7/23/13

Project / Client Maumee 3

At Reference Area 2 (Depth 25')
VP

Depth	Temp	Cond	pH	Turb	DO
0	25.85	246	8.33	-6.6	7.42
1	25.83	246	8.32	-6.3	7.51
2	25.78	247	8.30	-6.5	7.57
3	25.80	247	8.29	-6.5	7.61
4	25.74	247	8.27	-6.5	7.59
5	25.68	247	8.25	-6.4	7.56
6	25.53	247	8.22	-6.4	7.59
7	25.48	247	8.17	-2.3	7.42
8	25.48	247	8.19	-3.0	7.38

1520 Net start 352660
end 352997

1525- Collected sample @

At CDF site to collect MR02WC2826 and perform VP (Depth 27')

Depth	Temp	Cond	pH	Turb	DO
0	27.91	470	8.00	10.5	5.36
1	27.91	470	8.03	10.7	5.28
2	27.80	470	7.99	11.1	5.01
3	27.71	471	7.96	12.2	4.90
4	27.66	472	7.94	12.3	4.80

Location

Date 7/23/13

Project / Client Maumee 3

Depth	Temp	Cond	pH	Turb	DO
5	27.37	476	7.84	14.1	4.70
6	27.25	477	7.81	16.0	4.73
7	27.03	477	7.77	16.1	4.78
8	26.42	478	7.67	29.2	4.96

Net start : 353000, end = 353285
9 meter depth

Location

Date 7/24/13

Project / Client MAUMEE 3

0630 - At office, calibrating YSI.
0700 - leaving office
0915 - Boat has been launched at Cullen Park, we had our safety meeting. Going to see if the water is safe to work on on Lake Erie.
0940 - There is no dredge barge on the channel. Calling cathy whiting to see what the deal is.
1000 - We are going back into cullen park. No sampling today.
1005 - The army Corps have dropped off dredge samples to us at the boat launch.
1100 - Phoenix from U of T has picked up the chlorophyll bottle that we missed yesterday. leaving for Ann Arbor.
1230 - Back at office.

FLOAT PLAN

Date/Time: 7-23-13 0700 Name: C OBrien

1. Emergency Phone Numbers

Coast Guard 911

Marine Police 911

On Water Towing N.A.

2. Description of the Boat

Boat Name: R/V- SENTINEL Hailing Port:

Type: PLEASURE CRAFT Model Year: 1998

Make: PARKER Length: 23' Beam: 8' Draft: 2'

Color, Hull: WHITE Cabin: WHITE (HARDTOP)

Registration No: MC2191TG Sail No:

Engine(s) Type: OUTBOARD Horsepower: 225 Cruising Speed: 25 knots

Fuel Capacity, Gallons: 150 Cruising Range: 200 miles

Electronics/Safety Equipment Aboard

VHF Radio: Yes w/DSC Cell Phone: 734 674 0387 MMSI: 338103525 SSB: No

Frequency Monitored: 16 Loran: No SatNav:

Depth Sounder: Yes Radar: Yes GPS: Yes

Raft: No Dinghy: No EPIRB Type and # Cat 2, UIN: 2DCC5EBD30FFBFF

3. Passengers

	Name	Address	Phone	Age
Filer Nm:	C OBrien	661 Crestwood Circle	7346740387	39
Name:	Chris Behnke	2724 Lookout Circle Ann Arbor MI	734-673-2209	37
Name:				
Name:	Dan Kennedy	461 Harding Buffalo NY	716 289 7888	37
Name:				

4. Trip Details

Departing Marina Cullen Park, Toledo OH Phone:

Auto Parked At: Cullen Park

Model/color 2011 Chevy Silverado, Granite Blue Lic. #

Depart From Toledo Departure Date/Time 7/23/13 0900 AM

Destination: Open lake disposal site Description of Work: Water Sampling

Return To: Cullen Park Phone: NA

Return Date/Time: 7/23/2013 – 6 PM No Later Than: 8:00 PM

Plan Filed with: Cathy Whiting Phone: C 734 771 4429

W

Plan Closed Time/Notes:

If this float plan it not closed by the "No Later Than" time, then the holder of this float plan should attempt to contact the filer and any passengers. If contact is not made within 30 minutes, then attempt to reach the vessel via marine radio (the USCG or Sheriff can assist in this). After 1 hour officially notify the USCG and Sheriff of the missing vessel and relay all pertinent information from this float plan.

CALIBRATION LOG

DATE: 7/24/13 START TIME: 0630

PERSONNEL: C. Behnke END TIME:

LOCATION: office PROJECT: MAUMEE 3

INSTRUMENT CALIBRATED: YSI 6920 SERIAL NUMBER:

D. O. %

WATER SATURATED AIR CALIBRATION

D.O. AIR SATURATION TIME ______ min PERCENT SATURATION 100 %

CALIBRATION PRESSURE 740.1 mmHg CALIBRATION TEMPERATURE ______ °C

PRE-CALIBRATION READING 95 %, — mg/l CALIBRATED READING 97.4 %, 8.09 mg/l

DO CHARGE / DO GAIN 1.03735 (ACCEPTABLE RANGE: 50 +/- 25, / 1.0 -0.3 to +0.5)

CALIBRATION SUCCESSFUL yes MAINTENANCE None

SPECIFIC CONDUCTIVITY

COND. STANDARD USED YSI CONDUCTIVITY STANDARD 1000 uS/cm YSI 3167 (1.00 mS/cm)

DATE BOTTLE OPENED — EXPIRATION DATE 3/14

PRE-CALIBRATION READING 1415 mS/cm CALIBRATION NUMBER USED 1.413 mS/cm

CALIBRATED READING 1413 mS/cm CALIBRATION TEMPERATURE 24.50 °C

CAL. CONSTANT 5.12613 (ACCEPTABLE RANGE: 5.0 +/- 0.45)

CALIBRATION SUCCESSFUL yes MAINTENANCE none

pH

2 POINT CALIBRATION

pH 7.00 STANDARD USED FISHER BUFFER SOLUTION pH 7.00 +/- 0.01 @ 25'C SB107-4

DATE BOTTLE OPENED — EXPIRATION DATE 1/15

PRE-CALIBRATION READING 7.01 s.u. CALIBRATION NUMBER USED 7.0 s.u.

CALIBRATED READING 7.0 s.u. CALIBRATION TEMPERATURE 24.48 °C

BUFFER 7.00 mV ______ (ACCEPTABLE RANGE: 0 +/- 50 mV)

pH 10.00 STANDARD USED FISHER BUFFER SOLUTION pH 10.00 +/- 0.02 @ 25'C SB115-4

DATE BOTTLE OPENED — EXPIRATION DATE 2/15

PRE-CALIBRATION READING 10.02 s.u. CALIBRATION NUMBER USED 10.0 s.u.

CALIBRATED READING 10.0 s.u. CALIBRATION TEMPERATURE 24.56 °C

BUFFER 10.00 mV — (ACCEPTABLE RANGE: -180 +/- 50 mV)

pH SLOPE OF SENSOR — (ACCEPTABLE RANGE: 165-180)

CALIBRATION SUCCESSFUL yes MAINTENANCE none

ORP

REDOX STANDARD RICCA ZOBELL'S SOLUTION (APHA Redox Standard Solution) Cat. No. 9880-32

DATE BOTTLE OPENED ______ EXPIRATION DATE ______

PRE-CALIBRATION READING ______ mV CALIBRATION NUMBER USED ______ mV

CALIBRATED READING ______ mV CALIBRATION TEMPERATURE ______ °C

CALIBRATION SUCCESSFUL ______ MAINTENANCE ______

TURBIDITY

3 POINT CALIBRATION

TURBIDITY STANDARD # 1 YSI 608000 TURBIDITY STANDARD 0.0 NTU

DATE BOTTLE OPENED — EXPIRATION DATE —

PRE-CALIBRATION READING -0.3 ntu CALIBRATION NUMBER USED 0 ntu

CALIBRATED READING 0 ntu CALIBRATION TEMPERATURE 24.67 °C

TURBIDITY STANDARD # 2 YSI 607200 TURBIDITY STANDARD ~~10.0 NTU~~ 12.7

DATE BOTTLE OPENED — EXPIRATION DATE 5/14

PRE-CALIBRATION READING 13.4 ntu CALIBRATION NUMBER USED 12.7 ntu

CALIBRATED READING 12.7 ntu CALIBRATION TEMPERATURE 24.44 °C

TURBIDITY STANDARD # 3 YSI 607300 TURBIDITY STANDARD ~~100 NTU~~ 126

DATE BOTTLE OPENED — EXPIRATION DATE 4/14

PRE-CALIBRATION READING 121.4 ntu CALIBRATION NUMBER USED 126 ntu

CALIBRATED READING 126 ntu CALIBRATION TEMPERATURE 24.45 °C

CALIBRATION SUCCESSFUL yes MAINTENANCE None

NOTES:

Location
Date 7/23/13

Project / Client Maumee 3

Depth	Temp	Cond	pH	Turb	DO
5	27.37	476	7.84	14.1	4.70
6	27.25	477	7.81	16.0	4.73
7	27.03	477	7.77	16.1	4.78
8	26.42	478	7.67	29.2	4.96

Net start : 353000, end = 353285
9 meter depth

Location
Date 7/24/13

Project / Client MAUMEE 3

0630 - At office, calibrating YSI.
0700 - leaving office
0915 - Boat has been launched at Cullen Park, we had our safety meeting. Going to see if the water is safe to work on on Lake Erie.
0940 - There is no dredge barge on the channel. Calling cathy whiting to see what the deal is.
1000 - We are going back into cullen park. No sampling today.
1005 - The army Corps have dropped off dredge samples to us at the boat launch.
1100 - Phoenix from U of T has picked up the chlorophyll bottle that we missed yesterday. leaving for Ann Arbor.
1230 - Back at office.

FLOAT PLAN – ABORTED, NO DREDGING

Date/Time: 7-24-13 0700 Name: Bob Betz

1. Emergency Phone Numbers

Coast Guard 911

Marine Police 911

On Water Towing N.A.

2. Description of the Boat

Boat Name: R/V- SENTINEL Hailing Port:

Type: PLEASURE CRAFT Model Year: 1998

Make: PARKER Length: 23' Beam: 8' Draft: 2'

Color, Hull: WHITE Cabin: WHITE (HARDTOP)

Registration No: MC2191TG Sail No:

Engine(s) Type: OUTBOARD Horsepower: 225 Cruising Speed: 25 knots

Fuel Capacity, Gallons: 150 Cruising Range: 200 miles

Electronics/Safety Equipment Aboard

VHF Radio: Yes w/DSC Cell Phone: 734 674 0387 MMSI: 338103525 SSB: No

Frequency Monitored: 16 Loran: No SatNav:

Depth Sounder: Yes Radar: Yes GPS: Yes

Raft: No Dinghy: No EPIRB Type and # Cat 2, UIN: 2DCC5EBD30FFBFF

3. Passengers

Filer Nm:	Bob Betz	Address:	661 Crestwood Circle	Phone:	734-834-8817	Age	60
Name:	Chris Behnke	Address:	2724 Lookout Circle Ann Arbor MI	Phone:	734-673-2209	Age	37
Name:		Address:		Phone:		Age	
Name:	Dan Kennedy	Address:	461 Harding Buffalo NY	Phone:	716 289 7888	Age	37
Name:		Address:		Phone:		Age	

4. Trip Details

Departing Marina Cullen Park, Toledo OH Phone:

Auto Parked At: Cullen Park

Model/color 2011 Chevy Silverado, Granite Blue Lic. #

Depart From Toledo Departure Date/Time 7/24/13 0900 AM

Destination: Open lake disposal site Description of Work: Water Sampling

Return To: Cullen Park Phone: NA

Return Date/Time: 7/24/2013 – 6 PM No Later Than: 8:00 PM

Plan Filed with: Cathy Whiting Phone: C 734 771 4429

W

Plan Closed Time/Notes:

If this float plan it not closed by the "No Later Than" time, then the holder of this float plan should attempt to contact the filer and any passengers. If contact is not made within 30 minutes, then attempt to reach the vessel via marine radio (the USCG or Sheriff can assist in this). After 1 hour officially notify the USCG and Sheriff of the missing vessel and relay all pertinent information from this float plan.

CALIBRATION LOG

DATE: 7/25/13 START TIME: 0620

PERSONNEL: C. Behnke END TIME:

LOCATION: office PROJECT: MAUMEE3

INSTRUMENT CALIBRATED: YSI 6920 SERIAL NUMBER:

D. O. %

WATER SATURATED AIR CALIBRATION

D.O. AIR SATURATION TIME ______ min PERCENT SATURATION 100 %

CALIBRATION PRESSURE 743.1 mmHg CALIBRATION TEMPERATURE 23.45 °C

PRE-CALIBRATION READING 100.1 %, 8.52 mg/l CALIBRATED READING 97.7 %, ~~23.85~~ mg/l 8.31

DO CHARGE / DO GAIN ______ (ACCEPTABLE RANGE: 50 +/- 25, / 1.0 -0.3 to +0.5)

CALIBRATION SUCCESSFUL yes MAINTENANCE none

SPECIFIC CONDUCTIVITY

COND, STANDARD USED YSI CONDUCTIVITY STANDARD ~~1000~~ 1413 uS/cm YSI 3167 (1.00 mS/cm)

DATE BOTTLE OPENED — EXPIRATION DATE 3/14

PRE-CALIBRATION READING ~~[illegible]~~ 1381 mS/cm CALIBRATION NUMBER USED 1413 mS/cm

CALIBRATED READING 1413 mS/cm CALIBRATION TEMPERATURE 23.51 °C

CAL. CONSTANT — (ACCEPTABLE RANGE: 5.0 +/- 0.45)

CALIBRATION SUCCESSFUL yes MAINTENANCE none

pH

2 POINT CALIBRATION

pH 7.00 STANDARD USED FISHER BUFFER SOLUTION pH 7.00 +/- 0.01 @ 25'C SB107-4

DATE BOTTLE OPENED — EXPIRATION DATE 1/15

PRE-CALIBRATION READING 7.02 s.u. CALIBRATION NUMBER USED 7.0 s.u.

CALIBRATED READING 7.00 s.u. CALIBRATION TEMPERATURE 23.51 °C

BUFFER 7.00 mV — (ACCEPTABLE RANGE: 0 +/- 50 mV)

pH 10.00 STANDARD USED FISHER BUFFER SOLUTION pH 10.00 +/- 0.02 @ 25'C SB115-4

DATE BOTTLE OPENED — EXPIRATION DATE 2/15

PRE-CALIBRATION READING 9.99 s.u. CALIBRATION NUMBER USED 10.0 s.u.

CALIBRATED READING 10.00 s.u. CALIBRATION TEMPERATURE 23.52 °C

BUFFER 10.00 mV — (ACCEPTABLE RANGE: -180 +/- 50 mV)

pH SLOPE OF SENSOR — (ACCEPTABLE RANGE: 165-180)

CALIBRATION SUCCESSFUL yes MAINTENANCE none

ORP

REDOX STANDARD RICCA ZOBELL'S SOLUTION (APHA Redox Standard Solution) Cat. No. 9880-32

DATE BOTTLE OPENED ______ EXPIRATION DATE ______

PRE-CALIBRATION READING ______ mV CALIBRATION NUMBER USED ______ mV

CALIBRATED READING ______ mV CALIBRATION TEMPERATURE ______ °C

CALIBRATION SUCCESSFUL ______ MAINTENANCE ______

TURBIDITY

3 POINT CALIBRATION

TURBIDITY STANDARD # 1 YSI 608000 TURBIDITY STANDARD 0.0 NTU

DATE BOTTLE OPENED — EXPIRATION DATE —

PRE-CALIBRATION READING 0.1 ntu CALIBRATION NUMBER USED 0 ntu

CALIBRATED READING 0.0 ntu CALIBRATION TEMPERATURE 23.64 °C

TURBIDITY STANDARD # 2 YSI 607200 TURBIDITY STANDARD ~~10~~ NTU 12.7

DATE BOTTLE OPENED — EXPIRATION DATE —

PRE-CALIBRATION READING 12.5 ntu CALIBRATION NUMBER USED 12.7 ntu

CALIBRATED READING 12.7 ntu CALIBRATION TEMPERATURE 23.63 °C

TURBIDITY STANDARD # 3 YSI 607300 TURBIDITY STANDARD ~~100~~ NTU 126

DATE BOTTLE OPENED 7/25/13 EXPIRATION DATE 6/14

PRE-CALIBRATION READING 123.6 ntu CALIBRATION NUMBER USED 126 ntu

CALIBRATED READING 126 ntu CALIBRATION TEMPERATURE 23.46 °C

CALIBRATION SUCCESSFUL yes MAINTENANCE none

NOTES:

Location ______ Date 7/25/13

Project / Client MAUMEE 3

0620 - At office, calibrating YSI
0700 - leaving for Toledo
0830 - Cathy called, no dredge today, we are going to go out and attempt to sample the the sed traps and re-calibrate the long term sondes today.
0845 - Launching boat, conducting safety meeting.
0915 - At dock YSI, Collecting data with calibrated sonde

@2' TEMP - 25.72 °C
SPCOND - 449 uS/cm^c
COND - 455 uS/cm
TURB - 21.2 NTU

@7' TEMP - 25.72 °C
SPCOND - 449
COND - 455
TURB - 20.9 NTU

0925 - Readings with deployed sonde, before cleaning / calibration. (@ 2')
TEMP - 25.64 °C   COND - 435
SPCOND - 429   TURB - 29 NTU

Location ______ Date 7/25/13

Project / Client MAUMEE 3

0935 - Calibrating Sonde

	pre cal	post cal	
TURB	6.0	0.0	(zero)
	15.4	12.7	(12.7)
	110.1	126.0	(126)
SpCond -	971	1000	1000

0950 - downloading data from sonde. Battery life good, leaving batteries in place.
1000 - After calibration, readings with deployment sonde. (@ 2')
TEMP - 25.73 °C
SPCOND - 444 uS/cm^c
COND - 449 uS/cm
TURB - 22.8 NTU

Redeployed Sonde with new filename "MAUMEE3_".

Location

Date 7/25/13

Project / Client MAUMEE 3

Reference Area 1
Reference buoy + sonde

YSI 6920 Sonde reading
10:47
T= °C 24.67
SpCond 380
Cond 377
Depth ft 3.05
pH 8.16
Turb NTU 0.0
DO% 87.4
DO mg/L 7.78

1045 - Downloading data from sonde
filename "REF01".dat

1100 - Data from deployed sonde before cal.
(~ 3') temp - 24.62 °C
SpCOND - 367
TURB - 5.4 NTU

Location

Date 7/25/13

Project / Client MAUMEE 3

1105 - Calibrating sonde

	precal #	postcal #	
TURB	2.7	0.1 NTU	0 NTU
	12.1	12.7 NTU	12.7 NTU
	148.5	126 NTU	126 NTU
spcond			
	951	1000	1000 uS/cm^c

1110 - YSI reading with deployed sonde
after cleaning / calibration. @ 3'
TEMP : 24.64 °C
SPCOND : 382 uS/cm^c
TURB : ~~4.05~~ 2.3 NTU

1120 - Set up new logging file
called "REF01-7" (for July)
re-deploying sonde. Batteries
changed.

1300 - We couldn't get the engine
started for that period of
time. Its started now, going
to pull set trap at Reference
location.

Location ______ Date 7/25/13

Project / Client MAUMEE 3

1335 - Collected upper sediment traps at Reference area. Photos taken.

1345 - Collected lower sediment traps at reference area. Photos taken.

1418 - Sediment traps re-deployed at reference area. Going to disposal area sed-trap.

1445 - Pulling up sediment trap at disposal area.

1450 - collected samples at placement area sed trap (upper) took photos.

1520 - collected samples at placement area sed trap (lower), took photos.

1600 - At real-time buoy, pulling out 600 OMS for calibration. YSI measurements w/ calibrated sonde.

TEMP - 26.07 °C
SPCOND : 295 uS/cm^c
TURB = -4.8 NTU
(2' depth)

Location ______ Date 7/25/13

Project / Client MAUMEE 3

1605 - YSI measurements with 600 OMS before cleaning/calibration (2' depth)

TEMP = 25.79 °C
SPCOND = 254 uS/cm^c
TURB = 2.4 NTU

1610 - Calibration

	pre-cal	post-cal	standard
TURB	0.5	0 NTU	0
	13.2	12.7	12.7
	134.7	126	126
Sp Cond	920	1000	1000

1620 - YSI reading with 600 OMS after cleaning/calibration

TEMP : 25.70 °C
SPCOND : 280 uS/cm^c
TURB = 0.4 NTU

1630 - Done, heading in.

1725 - Boat loaded on trailer, going back to Ann Arbor.

LimnoTech
Water | Environment | Scientists | Engineers

FLOAT PLAN

Date/Time: 7-25-13 0700 Name: Bob Betz

1. Emergency Phone Numbers

Coast Guard 911
Marine Police 911
On Water Towing N.A.

2. Description of the Boat

Boat Name: R/V- SENTINEL Hailing Port:
Type: PLEASURE CRAFT Model Year: 1998
Make: PARKER Length: 23' Beam: 8' Draft: 2'
Color, Hull: WHITE Cabin: WHITE (HARDTOP)
Registration No: MC2191TG Sail No:
Engine(s) Type: OUTBOARD Horsepower: 225 Cruising Speed: 25 knots
Fuel Capacity, Gallons: 150 Cruising Range: 200 miles

Electronics/Safety Equipment Aboard

VHF Radio: Yes w/DSC Cell Phone: 734 674 0387 MMSI: 338103525 SSB: No
Frequency Monitored: 16 Loran: No SatNav:
Depth Sounder: Yes Radar: Yes GPS: Yes
Raft: No Dinghy: No EPIRB Type and # Cat 2, UIN: 2DCC5EBD30FFBFF

3. Passengers

Filer Nm:	Bob Betz	Address:	661 Crestwood Circle	Phone:	734-834-8817	Age	60
Name:	Chris Behnke	Address:	2724 Lookout Circle Ann Arbor MI	Phone:	734-673-2209	Age	37
Name:		Address:		Phone:		Age	
Name:	Dan Kennedy	Address:	461 Harding Buffalo NY	Phone:	716 289 7888	Age	37
Name:		Address:		Phone:		Age	

4. Trip Details

Departing Marina Cullen Park, Toledo OH Phone:
Auto Parked At: Cullen Park
Model/color 2011 Chevy Silverado, Granite Blue Lic. #
Depart From Toledo Departure Date/Time 7/25/13 0900 AM
Destination: Open lake disposal site Description of Work: Water Sampling

Return To: Cullen Park Phone: NA
Return Date/Time: 7/25/2013 – 6 PM No Later Than: 8:00 PM

Plan Filed with: Cathy Whiting Phone: C 734 771 4429
W

Plan Closed Time/Notes:

If this float plan it not closed by the "No Later Than" time, then the holder of this float plan should attempt to contact the filer and any passengers. If contact is not made within 30 minutes, then attempt to reach the vessel via marine radio (the USCG or Sheriff can assist in this). After 1 hour officially notify the USCG and Sheriff of the missing vessel and relay all pertinent information from this float plan.

CALIBRATION LOG

DATE: 7/30/13 START TIME: 0630
PERSONNEL: C. Rhile END TIME:
LOCATION: office PROJECT: Maumee 3
INSTRUMENT CALIBRATED: SERIAL NUMBER:

D. O. %

WATER SATURATED AIR CALIBRATION

D.O. AIR SATURATION TIME 10 min PERCENT SATURATION 100 %
CALIBRATION PRESSURE 746.9 mmHg CALIBRATION TEMPERATURE 25.53 °C
PRE-CALIBRATION READING 97.6 %, 7.98 mg/l CALIBRATED READING 98.3 %, 8.04 mg/l
DO CHARGE / DO GAIN (ACCEPTABLE RANGE: 50 +/- 25, / 1.0 -0.3 to +0.5)
CALIBRATION SUCCESSFUL MAINTENANCE

SPECIFIC CONDUCTIVITY

COND. STANDARD USED YSI CONDUCTIVITY STANDARD 1000 uS/cm YSI 3167 (1.00 mS/cm)
DATE BOTTLE OPENED 7/30/13 EXPIRATION DATE 12/2014
PRE-CALIBRATION READING 1028 mS/cm CALIBRATION NUMBER USED 1.000 mS/cm
CALIBRATED READING 1000 mS/cm CALIBRATION TEMPERATURE 24.61 °C
CAL. CONSTANT — (ACCEPTABLE RANGE: 5.0 +/- 0.45)
CALIBRATION SUCCESSFUL yes MAINTENANCE none

pH

2 POINT CALIBRATION

pH 7.00 STANDARD USED FISHER BUFFER SOLUTION pH 7.00 +/- 0.01 @ 25°C SB107-4
DATE BOTTLE OPENED 7/30/13 EXPIRATION DATE 3/15
PRE-CALIBRATION READING 7.08 s.u. CALIBRATION NUMBER USED 7.0 s.u.
CALIBRATED READING 7.0 s.u. CALIBRATION TEMPERATURE 24.62 °C
BUFFER 7.00 mV — (ACCEPTABLE RANGE: 0 +/- 50 mV)

pH 10.00 STANDARD USED FISHER BUFFER SOLUTION pH 10.00 +/- 0.02 @ 25°C SB115-4
DATE BOTTLE OPENED 7/30/13 EXPIRATION DATE 2/15
PRE-CALIBRATION READING 9.97 s.u. CALIBRATION NUMBER USED 10.0 s.u.
CALIBRATED READING 10.0 s.u. CALIBRATION TEMPERATURE °C
BUFFER 10.00 mV — (ACCEPTABLE RANGE: -180 +/- 50 mV)
pH SLOPE OF SENSOR — (ACCEPTABLE RANGE: 165-180)
CALIBRATION SUCCESSFUL yes MAINTENANCE none

ORP

REDOX STANDARD RICCA ZOBELL'S SOLUTION (APHA Redox Standard Solution) Cat. No. 9880-32
DATE BOTTLE OPENED EXPIRATION DATE
PRE-CALIBRATION READING mV CALIBRATION NUMBER USED mV
CALIBRATED READING mV CALIBRATION TEMPERATURE °C
CALIBRATION SUCCESSFUL MAINTENANCE

TURBIDITY

3 POINT CALIBRATION

TURBIDITY STANDARD # 1 YSI 608000 TURBIDITY STANDARD 0.0 NTU
DATE BOTTLE OPENED — EXPIRATION DATE —
PRE-CALIBRATION READING -0.5 ntu CALIBRATION NUMBER USED 0 ntu
CALIBRATED READING 0 ntu CALIBRATION TEMPERATURE 24.31 °C
TURBIDITY STANDARD # 2 YSI 607200 TURBIDITY STANDARD ~~10.0 NTU~~ 12.7
DATE BOTTLE OPENED — EXPIRATION DATE 5/14
PRE-CALIBRATION READING 12.6 ntu CALIBRATION NUMBER USED 12.7 ntu
CALIBRATED READING 12.7 ntu CALIBRATION TEMPERATURE 24.91 °C
TURBIDITY STANDARD # 3 YSI 607300 TURBIDITY STANDARD ~~100 NTU~~ 126
DATE BOTTLE OPENED 7/25/13 EXPIRATION DATE 6/14
PRE-CALIBRATION READING 99.6 ntu CALIBRATION NUMBER USED 126 ntu
CALIBRATED READING 126 ntu CALIBRATION TEMPERATURE 24.34 °C
CALIBRATION SUCCESSFUL yes MAINTENANCE none

NOTES:

Location ______ Date 7/30/13

Project / Client MAUMEE 3

0630 ± At office loading up
0705 - leaving for Toledo
0900 - Launched boat, heading out the channel. Safety Meeting.
BOB BETZ [signature]
BRANDON ELLEFSON : [signature]
CHRIS BETHUNE : [signature]
0945 - At dumping area, the barge is preparing to dump.
0946 - Dumping!
0950 - YSI profile 41.81273, W 83.28392

BOTTLE #030	TEMP	COND	pH	NTU	DO
0	22.4	250	8.52	49.5	9.48
1	22.4	248	8.54	30.1	% 112/9.7 mg/L
2	22.4	249	8.51	102.0	9.56
3	22.39	252	8.46	126.0	9.45
4	22.36	259	8.09	335.7	8.88
5	22.38	255	8.21	260	8.91
5.9	22.37	257	8.07	300	8.64

↳ just above bottom after touching
~0950 lowered LISST to bottom + up (~1'/sec).
~0950 collected water sample (just before instruments)
1005 LISST sample after water sample

Location ______ Date 7/30/

Project / Client ______

1005 - Sample #2 41.81240, 83.28442

(LISST) YSI	°C	Cond	pH	NTU	D.O.
0 -	22.56	248	8.67	-1.5	9.87
1 -	22.49	250	8.60	22.0	9.76
2 -	22.39	250	8.57	37.2	9.63
3 -	22.4	250	8.57	34.4	9.62
4 -	22.4	254	8.56	36.2	9.6
5 -	22.4	252	8.53	50.4	9.53

1020 Sample #3 N 41.81328 W 083.28492

LISST Sample
YSI

depth	°C	Cond	pH	NTU	DO
0	22.5	249	8.46	4.7	9.90
1	22.47	252	8.63	7.7	9.87
2	22.39	254	8.61	13.0	9.82
3	22.39	253	8.62	13.8	9.80
4	22.36	255	8.55	32.6	9.64
5	22.37	255	8.54	38.1	9.57

- In middle of plume right now -

Location

Date 7/30/13

Project / Client

1035 Water Sample #4
N 41.81242 W083.28513

LISST Sample
YSI Sample

D	°C	Cond	pH	NTU	DO
0	22.49	250	8.62	10.7	9.75
1	22.46	250	8.61	12.2	9.76
2	22.45	250	8.61	16.1	9.75
3	22.44	250	8.59	23.9	9.70
4	22.40	250	8.59	23.8	9.69
5	22.40	250	8.57	28.1	9.64

10:47 At Dump location
LISST profile
YSI "

D	°C	Cond	pH	NTU	DO
0	22.78	251	8.63	7.5	9.74
1	22.61	251	8.61	11.0	9.72
2	22.51	251	8.60	11.60	9.75
3	22.43	251	8.60	14.4	9.67
4	22.41	250	8.59	16.0	9.64
5	22.39	250	8.58	17.1	9.62

Location

Date 7/30/13

Project / Client

1052 - N. 41 81271, W 083.28532

	°C	Cond	pH	NTU	DO
0 -	22.76	250	8.64	4.5	9.88
1 -	22.55	250	8.63	8.7	9.87
2 -	22.47	250	8.62	13.9	9.80
3 -	22.44	250	8.60	19.6	9.74
4 -	22.43	251	8.59	18.4	9.70
5 -	22.42	252	8.58	22.1	9.65

LISST profile

1111 - N 41.81290 W 083.28579
Sample #5
LISST
YSI

D	°C	Cond	pH	NTU	DO
0	22.93	250	8.67	4.2	9.95
1	22.61	250	8.66	7.5	9.97
2	22.53	251	8.64	9.2	9.95
3	22.40	256	8.63	6.5	9.96
4	22.33	257	8.59	5.7	9.82
5	22.30	257	8.57	7.1	9.67

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Location ______ Date 7/30/13

Project / Client ______

1125 - 41.81235, 083.28610

	Temp	Cond	pH	NTU	DO
0 -	23.1	250	8.60	1.2	9.92
1 -	22.59	250	8.7	0.1	10.1
2 -	22.49	250	8.64	10.6	10.01
3 -	22.47	252	8.64	11.5	9.95
4 -	22.4	255	8.62	11.5	9.97
5 -	22.38	258	8.52	28.1	9.64

+ LISST / YSI

1140 - At dump location.

	Temp	Cond	PH	NTU	DO
0 -	23.29	249	8.63	-0.1	9.8
1 -	22.80	247	8.68	-0.3	9.95
2 -	22.53	245	8.72	-0.8	10.09
3 -	22.41	245	8.68	-0.3	10.03
4 -	22.41	250	8.61	6.3	9.84
5 -	22.40	252	8.57	13.2	9.66

+ LISST

1150 - Processing samples.

1215 - At real-time buoy, collecting YSI profile. and LISST profile

47

Location ______ Date 7/30/13

Project / Client MAUMEE 3

MET	Temp	Cond	pH	NTU	DO
0 -	23.86	242	8.55	-4.9	9.15
1 -	22.94	238	8.63	-4.4	9.48
2 -	22.78	237	8.65	-3.8	9.64
3 -	22.61	237	8.64	-3.4	9.73
4 -	22.55	237	8.62	-3.6	9.66
5 -	22.53	237	8.59	-3.6	9.56
6 -	22.51	237	8.59	-3.2	9.46
7 -	22.55	239	8.58	-1.1	9.37

Depth: 24' Secci = 3 M

1230 - Collected sample at Real Time Buoy "PS-02-WC-26-24" (#035)

net	Start		End
#1	# 353290	→	353462
#2	# 353461	→	

1305 - At reference area # 1

	Temp	Cond	pH	NTU	DO
0 -	24.14	292	8.49	4.7	9.06
1 -	22.87	283	8.50	-2.6	9.55
2 -	22.21	282	8.4	-3.2	9.36
3 -	22.08	283	8.37	-3.6	9.17
4 -	22.60	283	8.37	-3.9	8.9
5 -	21.95	283	8.3	-4.4	8.4

Location ______ Date 7/30/13

Project / Client MAUMEE 3

Secci : 2.5 M

net #1
start # = 353669
end # : 353892

net #2
Start # 353899
end # 354120

1320 - Collected Sample at reference area 1. "RA1-02-WC-25-17" heidleberg bottle # 036 and "DUPLICATE" and # 037

1350 - At Reference area # 2
YSI + LISST - Secci = 5.1 M

	TEMP	COND	pH	NTU	OX
0 -	23.92	241	8.41	-5.3	8.64
1 -	23.22	234	8.43	-5.5	8.71
2 -	22.90	230	8.48	-5.4	8.84
3 -	22.74	231	8.47	-5.4	8.90
4 -	22.68	228	8.48	-5.3	8.92
5 -	22.63	229	8.45	-5.3	8.89
6 -	22.6	229	8.44	-5.1	8.84
7 -	22.6	228	8.44	-5.2	8.84
8 -	22.6	229	8.43	-2.4	8.77

1410 - collected sample at reference location #2 "RA2-02-WC-27-25" and heidleberg #038

Location ______ Date 7/30/13

Project / Client ______

net #1
start - 354120
end = 354430

net #2
start 354430
End 354735

1415 - Collected "BLANK", heidleberg # 039

1440 - At "NORTH" buoy and placement area. preparing to pull buoy.

1500 - At "East" buoy, pulling up, downloading data.

1505 - Downloading data from "SOUTH" buoy.

1520 - At "west" buoy, pulled up sonde and LISST, downloading Sonde

1545 - At Sediment trap near reference area 2. Pulling up.

1555 - Collected "Reference Area 2 Sediment trap Upper A" and "Reference Area 2 Sediment trap Upper B"

1610 - Collected "Reference Area 2 Sediment trap Lower Ⓐ and Ⓑ"

Location ______ Date 7/30/13

Project / Client MAUMEE 3

1635 - Sediment traps re-deployed at Reference Area 2, going to dock.
1715 - Picked up dredge samples from crane.
1720 - At dock, preparing to collect sample, YSI and LISST measurements. Secci = 0.45 m

	TEMP	COND	pH	NTU	DO
0 -	23.1	415	8.18	8.0	9.39
1 -	23.09	416	8.2	24.5	8.64
2 -	23.05	414	8.18	18.4	8.54
3 -	22.89	412	8.11	16.5	8.25
4 -	22.5	416	8.00	18.0	7.71
5 -	22.36	411	7.97	19.0	7.45
6 -	21.96	400	8.02	16.0	7.47
7 -	21.6	387	8.06	15.0	7.68
8 -	21.56	385	8.05	15.1	7.70

1730 - collected "MR-02-WC-28-26" and heidleberg bottle # 040.
1815 - At launch, loading boat
2000 - At fed ex, shipping samples
2100 - Unloaded equipment

Location ______ Date

Project / Client MAUMEE 3

Calibration check on M... in bucket of tap water

~~YSI 6920~~	TEMP	COND
YSI 6920 -	20.35°C	219
NORTH -	20.57°C	238
WEST -	20.61	238
SOUTH -	20.61	237
EAST -	20.56°C	235

CALIBRATION LOG

DATE: 8/19/13 START TIME: 0555

PERSONNEL: C. Behnke END TIME:

LOCATION: office PROJECT: MAUMEE 3

INSTRUMENT CALIBRATED: YSI 6920 SERIAL NUMBER:

D. O. %

WATER SATURATED AIR CALIBRATION

D.O. AIR SATURATION TIME 20 min PERCENT SATURATION 100 %

CALIBRATION PRESSURE 745.2 mmHg CALIBRATION TEMPERATURE 25.04 °C

PRE-CALIBRATION READING 92.8 %, 7.67 mg/l CALIBRATED READING 98 %, 8.10 mg/l

DO CHARGE / DO GAIN — (ACCEPTABLE RANGE: 50 +/- 25, / 1.0 -0.3 to +0.5)

CALIBRATION SUCCESSFUL yes MAINTENANCE none

SPECIFIC CONDUCTIVITY

COND. STANDARD USED YSI CONDUCTIVITY STANDARD 1000 uS/cm YSI 3167 (1.00 mS/cm)

DATE BOTTLE OPENED — EXPIRATION DATE 12/2014

PRE-CALIBRATION READING 991 uS/cm CALIBRATION NUMBER USED 1.0 mS/cm

CALIBRATED READING 1000 uS/cm CALIBRATION TEMPERATURE 24.52 °C

CAL. CONSTANT — (ACCEPTABLE RANGE: 5.0 +/- 0.45)

CALIBRATION SUCCESSFUL yes MAINTENANCE none

pH

2 POINT CALIBRATION

pH 7.00 STANDARD USED FISHER BUFFER SOLUTION pH 7.00 +/- 0.01 @ 25'C SB107-4

DATE BOTTLE OPENED — EXPIRATION DATE 4/14

PRE-CALIBRATION READING 7.08 s.u. CALIBRATION NUMBER USED 7.0 s.u.

CALIBRATED READING 7.00 s.u. CALIBRATION TEMPERATURE 24.47 °C

BUFFER 7.00 mV — (ACCEPTABLE RANGE: 0 +/- 50 mV)

pH 10.00 STANDARD USED FISHER BUFFER SOLUTION pH 10.00 +/- 0.02 @ 25'C SB115-4

DATE BOTTLE OPENED — EXPIRATION DATE 5/2015

PRE-CALIBRATION READING 9.96 s.u. CALIBRATION NUMBER USED 10 s.u.

CALIBRATED READING 10.00 s.u. CALIBRATION TEMPERATURE 24.45 °C

BUFFER 10.00 mV — (ACCEPTABLE RANGE: -180 +/- 50 mV)

pH SLOPE OF SENSOR — (ACCEPTABLE RANGE: 165-180)

CALIBRATION SUCCESSFUL yes MAINTENANCE none

ORP

REDOX STANDARD RICCA ZOBELL'S SOLUTION (APHA Redox Standard Solution) Cat. No. 9880-32

DATE BOTTLE OPENED EXPIRATION DATE

PRE-CALIBRATION READING mV CALIBRATION NUMBER USED mV

CALIBRATED READING mV CALIBRATION TEMPERATURE °C

CALIBRATION SUCCESSFUL MAINTENANCE

TURBIDITY

3 POINT CALIBRATION

TURBIDITY STANDARD # 1 ~~YSI 608000 TURBIDITY STANDARD 0.0 NTU~~ Di water

DATE BOTTLE OPENED — EXPIRATION DATE —

PRE-CALIBRATION READING 0.2 ntu CALIBRATION NUMBER USED 0 ntu

CALIBRATED READING 0.0 ntu CALIBRATION TEMPERATURE 24.68 °C

TURBIDITY STANDARD # 2 YSI 607200 TURBIDITY STANDARD ~~10.0 NTU~~ 12.7

DATE BOTTLE OPENED — EXPIRATION DATE 6/14

PRE-CALIBRATION READING 12.7 ntu CALIBRATION NUMBER USED 12.7 ntu

CALIBRATED READING 12.7 ntu CALIBRATION TEMPERATURE 24.47 °C

TURBIDITY STANDARD # 3 YSI 607300 TURBIDITY STANDARD ~~100 NTU~~ 126

DATE BOTTLE OPENED — EXPIRATION DATE 6/14

PRE-CALIBRATION READING 122.5 ntu CALIBRATION NUMBER USED 126 ntu

CALIBRATED READING 126 ntu CALIBRATION TEMPERATURE 24.57 °C

CALIBRATION SUCCESSFUL yes MAINTENANCE none

NOTES:

Location ______ Date 8/19/13

Project / Client MAUMEE 3

0600 - C. Behnke / E. Verhamme at office, loading up, calibrating YSI.
0800 - At Cullen Park, launching boat. Army Corps came over to pick up cooler for dredge samples, Cody from U of T dropped off net, sample bottles and preservative.
0830 - Leaving launch, going out to check on dredge barge.
0930 - The barge has just dropped sediment, we are not ready to follow the plume. We dropped the (4) short term buoys (without sondes) and we're going out to reference area #2 to collect samples.
0945 - At Reference area #2, dropping LISST. YSI measurements

↓

Location ______ Date 8/19

Project / Client ______

no decimal GT ↙

M	Temp	Cond	pH	NTU	dis-ox
0	23.07	2.82	8.96	12.7	12.46
1	23.05	2.81	8.97	9.1	12.47
2	23.00	2.90	8.96	9.1	12.40
3	22.30	2.66	8.89	2.2	11.87
4	22.19	2.66	8.83	0	11.06
5	22.15	2.68	8.81	0	10.71
6	22.14	2.71	8.81	1.1	10.54
7	22.13	2.72	8.81	0	10.38
8	21.82	2.80	8.54	1.3	8.59

↖ No decimal GT

1st net tow = 8 m (45° angle)
2nd net tow = ↓
(no spinner on net)

2nd net = 10 m 45°

1015 - Collected Sample @ "RA2-03-WC-27-25" (#041 Heidelberg #)

Location Date 8/19

8/19/13 Project / Client

1058 Placement Area Buoy (Long Term)

(no decimal)

M	Temp	Cond	pH	NTU	DO
0	22.98	284	8.82	0.5	10.79
1	22.95	2.84	8.83	5.7	10.88
2	22.69	2.85	8.82	1.8	10.87
3	22.34	2.86	8.78	0.3	10.57
4	22.26	2.83	8.74	0.5	10.29
5	22.21	2.85	8.74	0	10.07
6	22.19	2.84	8.71	1.6	9.84
7	22.05	2.86	8.68	1.8	9.37

(no decimal)

net tow #1: 5.5 M
#2: 6.5 M

1115 - Collected "PS-03-WC-26-24" at reel time buoy. Heidleberg bottle # 042.

		LISST	
1201	Dump		
1205	sample #1	NO	(#043)
1215	Sample #2	Yes 0.4m	38 NTU (#044)
1229	Sample #3	Yes (2)	30 NTU (#045)
1240	pulled sonde	String	1.5 ft up
1252	sample #4	Yes	7 NTU (#046)
1306	#5	NO	8 NTU (#047)

Location Date 8/19

Project / Client

- Sonde that logged at 5 feet during the plume tracking → clock synced with laptop. no adjustment needed.
- Sonde that logged at 15 feet during plume tracking was 5 minutes behind. Must adjust times 5 minutes ahead from sonde data.
- sonde that logged at 10 feet was 2 minutes fast. Must adjust data 2 minutes backwards

1430 - At real time buoy. reading @ surface with calibrated sonde

TEMP = 24.64 °C
COND = 297 uS/cm
TURB = 10.5 NTU

Reading with deployed sonde prior to cleaning / calibration

TEMP: 24.64 °C
COND: 267 uS/cm
TURB: 13.0 NTU

Location Date 8/19/13

Project / Client MAUMEE 3

- Calibrating sonde -

		PRE	POST-CAL	
TURB	Ø	- 0.2	0	NTU
	12.7	12.9	12.7	NTU
	126	130.8	126	NTU
COND	100	957	1000	uS/cm

post cal readings
TEMP : 24.55 °C
COND : 285 uS/cm
TURB : 8.5 NTU

1515 - collected sample @ reference area #1 "RA1-03-WC-25-17"
heidelberg bottle # 048

Collecting net tow #1 = 4.5 m (15°)
#2 = 4.5 m (15°)

Location 8 Date 8/19/13

Project / Client

Ref. Area 1 1520

No decimal

M	TEMP	COND	pH	NTU	DO
0	~~22.90~~ 23.90 GF	346	9.22	32.5	15.53
1	23.20	3.11	9.20	18.4	15.99
2	22.76	3.10	9.05	10.6	14.80
3	22.61	3.11	9.01	6.9	13.72
4	22.41	3.16	8.98	7.3	13.05
5	21.93	3.10	8.77	8.5	10.81

No decimal

Maumee Sta
1602

M	Temp	Cond	pH	NTU	DO
0	26.7	5.64	8.7	34	12.4
1	25.98	5.62	8.64	25	12.54
2	25.00	5.47	8.49	18	10.80
3	23.5	4.98	8.34	14.5	9.6
4	23.3	4.90	8.27	23	9.00
5	23	5.08	8.01	35	7.5

No decimal
GT

Location ______ Date 8/20

Project / Client

Bob Gav Ed

6 00	@ office - Calibrate YSI
7pm	Drive to Toledo
830	Leave Cullen Park
	weather partly cloudy 60°F Lt wind

RA 2 - Time ≈ 0910 (Station 27)
Lisst Profile
YSI

m	T	µS/cm Cond	pH	NTU	DO
0	22.9	281	8.7	7.0	10.28
1	22.95	281	8.74	8.0	10.35
2	22.94	281	8.76	8.0	10.36
3	22.92	280	8.76	6.0	10.32
4	22.85	277	8.75	6.6	10.23
5	22.80	275	8.74	5.8	10.15
6	22.6	272	8.69	4.8	9.73
7	22.15	280	8.56	6.1	8.42
Bottom GF ~~8~~	~~22.77~~	~~286~~	~~8.29~~		

Water Samples 00052 09:25
RA2. 03WC 2725

Net #1 9 M
Net #2 8 M

Location ______ Date 8/20/13

Project / Client

0945 Real Time buoy
PS-03-WC-26-24
LISST
YSI

m	T	C	pH	NTU	DO
0	22.9	289	8.74	9.8	9.64
1	22.87	289	8.75	9.6	9.72
2	22.84	289	8.76	8.6	9.73
3	22.82	289	8.76	8.3	9.72
4	22.78	289	8.75	8.2	9.64
5	22.63	290	8.72	7.0	9.30
6	22.05	291	8.55	6.3	8.30
7	21.96	290	8.52	5.1	7.89

Net #1 6 M
Net #2 6 M
Water Samples Label 00053
PS-03-WC-26-24 10:00

Label #53

~~Net #1~~
~~Net #~~ GF

Location ______ Date 8/20

Project / Client ______

1030 Blank
Label 54
Solids water chem Chl

1056 ~~1100~~ GF Barge Dump water Depth 16 ft

1105 YSI Post Barge release / collected wc sample #1

M	Temp	Cond.	pH	NTUs	DO
0	23.04			163	
1				200	
2		GF		259	
3				170	GF
4				108	
5				105	
6	Bottom				

Turbidity only

M	1110	1115	1120	1125	1130
0	18.4	17	17.6	13.5	12.9
1	15.0	18.5	20	12.3	12.6
2	19.8	17	22.6	14.0	13.4
3	27.7	30.7	21	16	16.1
4	35.5	29.7	24	19	18
5	Bottom	Bottom	25/bottom	Bottom	Bottom

LISST collected 1105, 1115, 1125, 1145, 1205
Label 55, label 56, label 57

Location ______ Date 8/20

Project / Client ______

Placement area readings continued

Turbidity

M	1135	1140	1145	1150	1155 GF ~~1200~~	1200	1205
0	12.4	11.0	12.0	11.0	9.4	10.5	10.8
1	10.2	11.0	12.2	11.7	9.9	10.2	10.0
2	15.0	11.6	12.2	12.0	13.5	10.2	12.0
3	15.0	13.6	15.0	12.5	14.5	11.2	11.0
4	16.8	15.0	16.3	14	13.3	14.3	13.0
5	17	16.7	Bottom	Bottom	15.6	19.2	Bottom

1145 collected wc #4 and LISST
Turbidity in bucket ~1.5 NTU } w/out sonde cover
Label 58 38 NTU }
11 NTU w/sonde cover

1205 collected WC #5 and LISST
Label 59

WC Sample / List Summary

1105	Label	55
1115	"	56
1125	"	57
1145	"	58
1205	"	59

Location

Date 8/20/13

Project / Client

1224 AT RA-1
1228 WQ readings + Biomass

M	Temp	Cond	pH	NTUs	DO
0	23.9	339	9.12	30-280	12.9
1	23.04	330	9.03	20.0	12.26
2	22.80	325	8.96	18.0	11.64
3	22.74	324	8.94	18.0	11.66
4	22.70	323	8.93	10.0	10.96
5	22.06	312	8.60	8.7	8.7

Net Pull # 1 4.5 Net Pull # 2 5

1236 Collected WC Sample / LISST
Label # 60
#61 Dup

1312 at Maumee RiV Sta.
1314 LISST + WC Sample
Label # 62

M	Temp	Cond	pH	NTU	DO
0	25.40	525	8.73	44.6	12.15
1	24.92	520	8.66	31.4	11.15
2	24.60	490	8.54	24.0	10.54
3	23.71	443	8.61	25.8	10.11
4	23.23	392	8.72	28.8	10.00
5	23.02	377	8.7	32.9	9.80
6	22.80	376	8.62	32.9	8.96
7	22.76	379	8.57	44.6	8.60
8	22.73	385	8.49	44.7	8.08
9	Bottom				

Location

Date 8/20/13

Project / Client

MR (at dock) 13:30
YSI 6920 Sonde (portable)

M	T	NTU	Cond
0.3	25.3	32	518

Deployed Sonde reading

M	T	Cond	NTU
0.3	25.2	506	# 33

Waypoint 20 – Dump Zone
41.81282 83.28079

1352 - Sonde at MR Battery
Compartment wet
pull sonde out

1430 Back at dock

1530 Back in Ann Arbor

Location

Date 8/21/13?

Project / Client

700 Leave AA
900 Leave dock
1000 Ref #1
- Download ADCP
- Calibrate & download YSI

1030 - collect water sample
Label #63
RA1 03WC 25-17

M	Temp	Cond.	pH	NTU	DO
0	23.10	306	8.64	12.2	9.42
1	23.00	306	8.67	10.5	9.50
2	22.90	305	8.63	10.0	9.40
3	22.80	305	8.63	15.0	9.30
4	22.8	305	8.63	9.0	9.24
5	22.8	305	8.63	8.3	9.32

Deployed / retrieved LISST

1110 At placement area. Preparing for plume monitoring
Speciation preserved w/ lugols
Biomass preserved w/ sugar formalin
Pull #1 4.5, Pull #2 4.5

Location

Date 8/21/13

Project / Client

Placement area 1113

M	Temp	Cond	pH	NTU	DO
0	23.57	291	8.7	6	9.2
1	23.45	290	8.69	7.8	9.5
2	23.22	289	8.67	8.4	9.6
3	23.16	289	8.64	8.5	9.5
4	22.80	293	8.[illegible]	8.6	8.4
5					
6					
7					

Turbidity Readings of Sed Plume following Barge dump: (Dump @ 1122)

M	1127	1138	1147	1200	1212
0	103.2	~~50.9~~ 21	~~6~~ 23	22	18
1	91.3	50.9	74	17	27
2	95	38	20	27	19
3	123	51	26	27	23
4	130	49	53	44	17
5	341	64	60	40	12

WC sample #1	1127	Label	64
#2	1138	"	65
#3	1147	"	66
#4	1200	"	67
#5	1212	"	68

Location ______ Date 8/21/13

Project / Client ______

1233 moved to Placement Buoy - processed 5 water samples from plume

Real time buoy

1250 Net #1

Net #2

1257

M	Temp	Cond	pH	turb	DO
0	23.65	290	8.74	4	9.6
1	23.57	289	8.75	4	9.68
2	23.18	286	8.75	5.3	9.7
3	22.99	285	8.72	4.6	9.57
4	22.93	285	8.71	3.2	9.37
5	22.90	285	8.7	3.3	9.26
6	22.54	288	8.57	1.7	8.15
7	21.82	296	8.09	3.5	4.54

1305 LISST

1310 collected wc sample / duplicate

1315 Blank (chlorophyll, solids, water chem)

Dup (chlorophyll, solids, water chem)

wc sample Biomass (preserved sugar formalin, chlorophyll, water chem (filtered), solids, speciation (preserved w/ lugos)

Location ______ Date 8/21/13

Project / Client ______

Placement Area (Cont)

Sample label 69

Dup " 70

Blank " 71

1329 At RA2

1330 LISST + Biomass

WQ

M	Temp	Cond	pH	turb	DO
0	24.01	270	8.74	2.9	10.07
1	23.89	270	8.75	3.2	10.11
2	23.65	269	8.76	4.5	10.15
3	23.28	266	8.75	4.0	10.20
4	23.16	266	8.74	3.5	10.12
5	23.09	264	8.71	2.2	9.98
6	23.02	263	8.68	1.9	9.77
7	22.30	256	8.13	2.1	9.97

wc sample label 72

Biomass - Sugar formalin

Speciation - Lugos

Chlorophyll

Solids

Water Chem.

1354 departed RA-1

1433 Retrieved 4 short-term buoys

Location ______ Date 8/21/13

Project / Client ______

1445 Installing YSI at CA-1 - removed earlier for download and calibration. Did not have time to re-install earlier due to barge heading to placement area

1506 Arrived at MR sta.

1507 LAST WQ.

m	°C temp ~~Cond~~	Cond	pH	NTUs	DO
0	24.94	434	8.61	26	10.48
1	24.64	426	8.62	26	10.53
2	24.05	383	8.70	28	10.45
3	23.85	376	8.71	26.2	10.31
4	23.67	372	8.70	25.3	10.16
5	23.37	355	8.65	35.4	9.60
6	23.18	339	8.65	46	9.33
7	23.16	337	8.64	49	9.14

1510 WC Sample Label # 73
Chlorophyll
Water chem
Solids

8	23.12	328	8.64	49	9.04

1516 Depart MR

1525 Arrive at dock - Packing up boat and equipment

Location ______ Date ______

Project / Client ______

Location ______ Date 8/21/13

Project / Client ______

1445 Installing YSI at RA-1 - removed earlier for download and calibration. Did not have time to re-install earlier due to barge heading to placement area

1506 Arrived at MR sta.

1507 LISST

WQ.

M	temp	Cond	pH	NTUs	DO
0	24.94	434	8.61	26	10.48
1	24.64	426	8.62	26	10.53
2	24.05	383	8.70	28	10.45
3	23.85	376	8.71	26.2	10.31
4	23.67	372	8.70	25.3	10.16
5	23.37	355	8.65	35.4	9.60
6	23.18	339	8.65	46	9.33
7	23.16	337	8.64	49	9.14

1510 WC sample Label # 73
Chlorophyll
water chem
Solids

8	23.12	328	8.64	49	9.04

1516 depart MR

1525 Arrive at dock - Packing up boat and equipment

Location ______ Date 10/1/13

Project / Client MAUMEE 3

0630 - ED and Chris leaving Ann Arbor office.

0830 - At Belles Harbor launch, boat in water, sampling float plan.

920 RA2

M	Temp	COND	pH	NTUs	DO
0	18.6	202	7.99	-4.1	9.33
1	18.6	201	8.00	-4.1	9.27
2	18.61	201	8.00	-3.99	9.26
3	18.61	201	8.01	-4.0	9.24
4	18.61	201	8.01	-4.1	9.23
5	18.61	201	8.00	-4.1	9.21
6	18.61	202	8.00	-4.2	9.18

	Start	End
Net #1	360500	360740
#2	360750	360925

	Temp	cond	pH	NTUs	DO
7	18.61	202	8.01	-4.0	9.17

0950 - Secchi = > 3 m

0940 - Collected RA2WC042726 bottle # 0094

Location

Date 10/1/13

Project / Client

PA 26

	Temp	Cond	pH	NTUs	DO
0	18.65	220	8.75	23.2	9.26
1	18.65	221	8.77	23.5	9.21
2	18.65	221	8.78	24.2	9.17
3	18.65	221	8.78	24.0	9.13
4	18.65	221	8.78	23.8	9.11
5	18.65	221	8.78	25.0	9.07
6	18.65	221	8.78	23.0	9.06
7	18.65	221	8.78	25.0	9.03

net start. 360850 End 361040

#2 start = 361000 end = 361200

1025 - Collected "PS04WC2624"
heidelberg ID #0075

1035 - Secci = 50 cm

		start	end
1100 -	net #1 start =	361200	361310
	net #2 =	361310	361320

- collected "PSWC040314", bottle #0076

Should be PSWC041914
-EWV 10/9/13

Location

Date 10/1/13

Project / Client

PA 03

	Temp	Cond	pH	NTU	DO
0	18.63	228	8.74	26.9	9.16
1	18.64	228	8.75	28.3	9.10
2	18.64	228	8.75	27.8	9.05
3	18.64	228	8.75	27.5	9.00
4	18.64	228	8.75	42.0	8.95

~~5~~

Secci = 50 cm

1125 - at RA1WC042517

	Temp	Cond	pH	NTU	DO
0	18.56	218	8.85	20.3	9.45
1	18.56	218	8.87	21.6	9.43
2	18.56	218	8.88	19.9	9.39
3	18.56	218	8.88	21.5	9.36
4	18.55	218	8.88	21.9	9.33

net { #1 start : 361360 , end = 361425
net { #2 start : 361425 , end = 361530

	Temp	Cond	pH	NTU	DO
5	18.55	218	8.88	29.3	9.31

Secci = 50 cm

Location ______ Date 10/1/13

Project / Client MAUMEE 3

1135 - collected sample @ "RA1WC042517 - [illegible]

1205 - at MR WC04 2828

	TEMP	COND	pH	NTU	DO
0	18.88	304	8.58	60.0	8.62
1	18.90	305	8.57	61.9	8.50
2	18.85	299	8.60	63.6	8.47
3	18.79	296	8.63	62.5	8.45
4	18.81	298	8.63	62.3	8.42
5	18.75	294	8.64	65.9	8.41
6	18.75	292	8.66	68.1	8.45
7	18.73	291	8.67	64.7	8.45
8	18.73	292	8.66	64.0	8.46

	START	END
net # 1	no	
net # 2		

Secchi 20 cm

\# 78 sample (@ 1220)
\# 79 duplicate (@ 1220)
\# 80 blank (@ 1225)

1250 - Going to harbor to meet

Location ______ Date 10/1/13

Project / Client MAUMEE 3

U of T to deliver samples.

1315 - Side-by-side comparison of dock sonde and air sonde that was calibrated this morning.

	TEMP	COND	TURB
DOCK SONDE =	19.91	422	~~48.3~~ 53.9
CALIBRATED SONDE =	19.98	372	~~48.8~~ 52.7

1545 - Back at Bolles Harbor, loading boat.

1645 - Back at office.

Location
Date 10/2/13
Project / Client MAUMEE 3

0630 - C. Behnke and E Vanhamme
Leave onsite
830 Leave Bolles Harbor

900 Collect 6 cores
RA2 SD42726
911 PONAR RA2SD42726
919 PONAR RA2SD42226
922 PONAR RA2SD42426

940 PONAR PS~~04~~SD042623
952 PONAR PSSD041914
1000 Collect 6 Sediment Core
PS SD041914
1018 PONAR ~~04~~PSSD042012
1020 Collect 6 Sed Cores
PS SD042012
1035 PSSD0411 PONAR
1041 13 PONAR
1043 16 PONAR
1046 PSSD04 1719 PONAR
1049 PSSD04 1816 PONAR
1051 PSSD04 1512 PONAR
1054 PSSD 04 1413 PONAR

Location
Date 10/2/13
Project / Client

1056 PSSD04 1218 PONAR
1100 PSSD04 0916 PONAR
1103 PS SD04 1015 PONAR
1106 PS SD 040610 PONAR
1108 PS SD 04 0515 PONAR
1111 PS SD 04 0817 - PONAR
1115 PS SD04 04 15 PONAR
1119 PSSD0403 14 PONAR
1122 PS SD 0402 15 PONAR
1125 PSSD 0407 15 PONAR
1128 PS SD0401 13 PONAR

1150 PSSD0401 13
Collect 6 Sed Cores

1212 RA01 SD043017 PONAR
by Sta 8M
1217 RA01 SD042116 PONAR
1221 RA01SD042316 PONAR
1227 RA01SD04 2516 PONAR
1230 RA01SD042516
Collect 6 Sed Cores

Location
Date 10/2/13
Project / Client

1300 Pull sed traps @ RA01
& ADCD
1400 Pulled Sead traps @ RT Buoy
PS
1500 Pulled Sed traps at RA2

10/3/13 - PS Bottom #4
sample lost at
LTI while processing
sample fell out bottom
of tube

- side-by-side comparison of RA1
sonde and calibrated sonde

	TEMP	COND	TURB
Calibrated sonde -	21.68	208	10.1
RA1 sonde -	21.84	231	9.2

Location
Date
Project / Client

C-2 Field Data

Please see separate folder on CD.

C-3 Field Photos

Real Time Buoy (Weather/ADCP Station) at Placement Area (Station 26)

ADCP Maintenance at Placement Area

Water Quality Monitoring Equipment

Biomass sampling

Close-up of biomass material

Close-up of sediment trap sample during event #4

Collecting sediment core sample during Event #1

Collecting surface sediment grab sample with ponar dredge sampler during Event #1

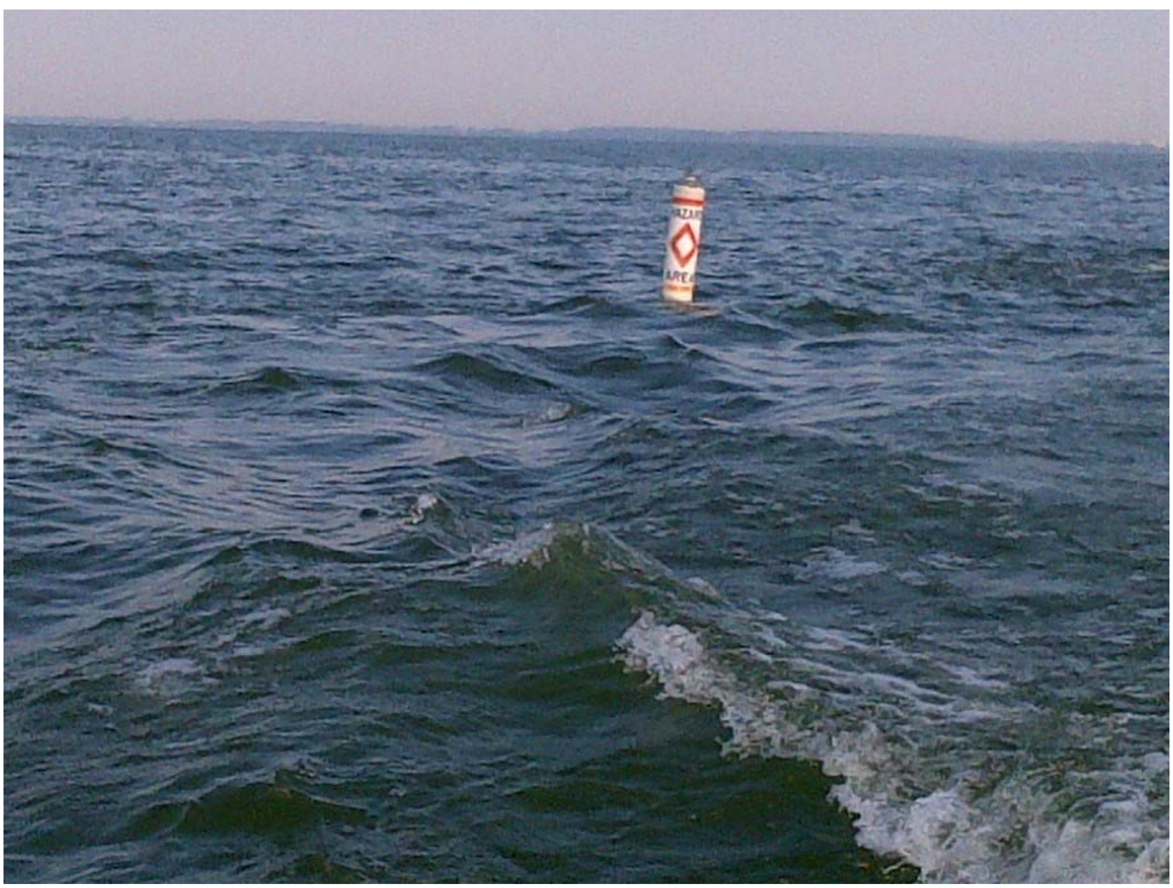
Sediment from ponar grab sample

Typical photo record of collected ponar sediment


Algal growth on deployed sonde during Event #1


Maumee River Station 28

View of Toledo Light #2 from Long-tern monitoring station RA-2



Short-term buoy approximately 0.25 miles north of dump zone in Placement Area

Algal bloom near mouth of Maumee River

Algal bloom observed in Placement Area

Algal bloom observed at Reference Area 1

Dredge Operations in channel

Dredge barge entering area prior to unloading sediments

Dredge barge immediately after unloading sediments out the bottom of the barge

Dredge barge leaving area, trailing suspended sediment behind

Sediment plume in Placement Area following a barge dump

Sediment plume in Placement Area following a barge dump

Integrated Water Column Sampling in sediment plume

Defined edge of sediment plume following a barge dump

C-4 COC Forms

LimnoTech
Water | Environment | Scientists | Engineers

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CHAIN OF CUSTODY RECORD

PROJ. NO. MAUMEE3

PROJECT NAME MAUMEE USACE Study

SAMPLERS: (*Signature*) *Ed Verhamme, Brandon Ellefson, Chris Behnke*

STA. NO.	DATE (mmddyy)	TIME (0000)	COMP.	GRAB	STATION LOCATION	Sample Matrix [1]	# of Containers	TP	Grain Size					REMARKS
REF-0	5/9/2013	1630		x	Reference Site	S	1	x	x					Sample contains dreissenid mussel shells (22 ft)
PA01	5/9/2013	1645		x	Placement Area	S	1	x	x					Water depth of 20 ft
PA02	5/9/2013	1650		x	Placement Area	S	1	x	x					Water depth of 16 ft
PA03	5/9/2013	1700		x	Placement Area	S	1	x	x					Water depth of 18 ft

(List of Parameters: TP, Grain Size)

Relinquished by	DATE	TIME	Received by	
Relinquished by: *(Signature)* EMV	**DATE** 5/13/13	**TIME** 11 AM	**Received by:** *(Signature)*	**Laboratory Sent To: UW-Stout** **Laboratory Contract: Bill James**
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received by:** *(Signature)*	**Shipping Carrier: FedEx** **Tracking Number: 801119757074**
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received by:** *(Signature)*	**DATE** / **TIME** / **TurnaroundTime:**

[1] W=Water, S=Sediment, So=Soil

Revised: July 2010

S:\MAUMEE3\FieldWork\FieldLog\Chain-of-Custody_050913.xls

LimnoTech
Water | Environment | Scientists | Engineers

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Fax: (734) 332-1212	Fax: (202) 833-9094	

CHAIN OF CUSTODY RECORD

PROJ. NO. MAUMEE3
PROJECT NAME MAUMEE USACE Study

SAMPLERS: (*Signature*) *Ed Verhamme, Brandon Ellefson, Chris Behnke*

STA. NO.	DATE (mmddyy)	TIME (0000)	COMP.	GRAB	STATION LOCATION	Sample Matrix [1]	# of Containers	TP	Grain Size					REMARKS
REF-0	5/9/2013	1630		x	Reference Site	S	1	x	x					Sample contains dreissenid mussel shells (22 ft)
PA01	5/9/2013	1645		x	Placement Area	S	1	x	x					Water depth of 20 ft
PA02	5/9/2013	1650		x	Placement Area	S	1	x	x					Water depth of 16 ft
PA03	5/9/2013	1700		x	Placement Area	S	1	x	x					Water depth of 18 ft

Relinquished by: (*Signature*)	DATE	TIME	Received by: (*Signature*)	
Relinquished by: (*Signature*) EMV	**DATE** 5/13/13	**TIME** 11 AM	**Received by:** (*Signature*)	**Laboratory Sent To: UW-Stout** **Laboratory Contract: Bill James**
Relinquished by: (*Signature*)	**DATE**	**TIME**	**Received by:** (*Signature*)	**Shipping Carrier: FedEx** **Tracking Number: 801119757074**
Relinquished by: (*Signature*)	**DATE**	**TIME**	**Received by:** (*Signature*)	**DATE** / **TIME** / **TurnaroundTime:**

[1] W=Water, S=Sediment, So=Soil

Revised: July 2010

S:\MAUMEE3\FieldWork\FieldLog\Chain-of-Custody_050913.xls

LimnoTech
Water | Environment | Scientists | Engineers

[x] Corporate Office
501 Avis Dr.
Ann Arbor, MI 48108
Phone: (734) 332-1200
Fax: (734) 332-1212

[ ] DC Office (STE 600)
1705 DeSales Str. NW
Washington, DC 20036
Phone: (202) 833-9140
Fax: (202) 833-9094

[ ] Other

CHAIN OF CUSTODY RECORD

PROJ. NO.

PROJECT NAME: MAUMEE3

SAMPLERS: Ed Verhamme, Bill James

STA. NO.	DATE (mmddyy)	TIME (0000)	COMP.	GRAB	Sample ID	Sample Matrix[1]	# of Containers	SRP Release						REMARKS
PA-01	6/18/2013	9:15			PA01SD0115	Sed	4	x						Sediment Core
PA-19	6/18/2013	9:55			PA01SD1919	Sed	4	x						Sediment Core
RA-25	6/18/2013	12:20			RA01SD2522	Sed	4	x						Sediment Core
PA-20	6/18/2013	10:25			PA01SD2019	Sed	4	x						Sediment Core

(List of Parameters: SRP Release)

Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*	Laboratory Sent To: / Laboratory Contact:
Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*	Shipping Carrier: / Tracking Number:
Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*	DATE / TIME / TurnaroundTime:

[1] W=Water, S=Sediment, So=Soil

Revised: July 2010

S:\MAUMEE3\Report\field_documents\06_18_13\COC_to_bill_james_061813.xls

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☐ Other

CHAIN OF CUSTODY RECORD

PROJ. NO.:

PROJECT NAME: MAUMEE3

SAMPLERS: Ed Verhamme, Bill James

STA. NO.	DATE (mmddyy)	TIME (0000)	COMP.	GRAB	Sample ID	Sample Matrix [1]	# of Containers	Dry Weight	LOI					REMARKS
RA-25	6/19/2013	15:45			RA01ST2522-Top A	Sed	1	x	x					Sediment Trap Sample
RA-25	6/19/2013	15:45			RA01ST2522-Bottom A	Sed	1	x	x					Sediment Trap Sample
RA-25	6/19/2013	15:45			RA01ST2522-Bottom B	Sed	1	x	x					Sediment Trap Sample

(List of Parameters: Dry Weight, LOI)

Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*	Laboratory Sent To: / Laboratory Contact:
Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*	Shipping Carrier: / Tracking Number:
Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*	DATE / TIME / TurnaroundTime:

[1] W=Water, S=Sediment, So=Soil

Revised: July 2010

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Environmental Engineering

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Fax (269) 226-0192

CHAIN OF CUSTODY RECORD

PROJ. NO.

PROJECT NAME: Maumee 3

SAMPLERS: *(Signature)* Ed Verhamme

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers							REMARKS
	6/24	1300		·	RA01SD2726		4							sediment cores
					RA01SD2726-1 0-5		1							core slices
					" 5-10		1							↓
					" 10-15		1							
					" >15		1							
					RA01SD2726-2 0-5		1							
					" 5-10		1							
					" 10-15		1							
					" >15		1							
		1345			RA01SG2726		1							PONAR Grab
					RA01SG2226		1							↓

Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*
Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*
Relinquished by: *(Signature)*	DATE	TIME	Received for Laboratory by: *(Signature)*

LABORATORY SENT TO:

LABORATORY CONTACT:

SHIPPING CARRIER:

TRACKING NUMBER:

DATE	TIME	Requested Turnaround Time:

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CHAIN OF CUSTODY RECORD

PROJ. NO.

PROJECT NAME: Maumee3

SAMPLERS: *(Signature)* Ed Verhamme

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	TP TSS VSS TKN	SRP DTP NO2 NO3 NH3					REMARKS
	6/24/13	1010			RA01WC2517		2	|	|					Bottle Label 1
	↓	1045			PA01WC0115		2	|	|					2
	↓	1120			PA01 WC 1920		2	|	|					3
	↓	1150			PA01 WC 2623		2	|	|					4
	↓	1200			PA01 WC 2623		2	|	|					5
	↓	1245			RA01 WC 2726		2	|	|					6
	↓	1250			Blank		2	|	|					7
	↓	1530			MR01WC2828		2	|	|					8

Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*
Ed Verhamme	6/24/13	1800	
Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*
Relinquished by: *(Signature)*	DATE	TIME	Received for Laboratory by: *(Signature)*

LABORATORY SENT TO: Heidelberg

LABORATORY CONTACT: Ellen Ewing

SHIPPING CARRIER: Fedex

TRACKING NUMBER: ~~8014 1975 7133~~

DATE	TIME	Requested Turnaround Time:
		801379459128

u Toledo

Brighton Analytical, L.L.C.™

2105 Pless Drive
Brighton, MI 48114

Phone: 810-229-7575
Fax: 810-229-8650

BA PROJECT #:

PAGE ___ OF ___

COMPANY NAME: Limno Tech

PROJECT NAME: Maumee 3

PROJECT NUMBER: Ed Verhamme

P. O. NUMBER:

REPORT RESULTS TO: U Toledo

Attn:

PHONE:
FAX:

ABBREVIATIONS FOR MATRIX
S = Solid
L = Liquid
DW = Drinking H_2O
WW = Wastewater
O = Oil
P = Wipe
A = Air (Tedlar Bag)
F = Filter
T = Tube
M = Methanol

REQUESTED TURNAROUND: (circle one)
Rush: 1-3 business days (verify with lab & specify date needed)
Expedited: 5 business days
Standard: 10 business days

If RUSH, approved by: ______

Container Type & Quantity: VOA'S (PRES) Y N; HDPE UNPRESERVED; HDPE HNO_3; HDPE H_2SO_4; HDPE NAOH; AMBER; GLASS H_2SO_4; GLASS, NO PRESERVATIVE; MEOH Preserved: (F)ield or (L)ab Preserved

Sample Matrix

Analysis Requested/Method: FOR DISSOLVED METALS (L) LAB TO FILTER (F) FIELD FILTERED; Chl + Phyco + Microcystin; Phyto Biomass; Phyto Spec

Brighton ID #	Sample Description	Sampling Time	Sampling Date	Chl + Phyco + Microcystin	Phyto Biomass	Phyto Spec
1)	PA01 WC0115	1045	6/24/13	↓	↓	↓
2)	MR01 WC2828	1530	↓	↓	↓	↓
3)	RA0 WC2726	1245	↓	↓	↓	↓
4)	PA01 WC1920	1120	↓	↓	↓	↓
5)	PA01 WC2623	1150	↓	↓	↓	↓
6)	PA01 WC2623	1200	↓	↓	↓	↓
7)	~~Blank~~ RA01 WC2517	~~[illegible]~~ [illegible]	↓	↓	↓	↓
8)	Blank		↓	↓		
9)						
10)						
11)						

Sample received within holding time? yes ☐ no ☐

For TCLP **ONLY** – Federal Limits ☐ Other ☐

Samples intact: yes ☐ no ☐ (if no, see below)

Note samples if not intact:

Headspace/bubbles in VOA'S? yes ☐ no ☐ n/a ☐

Sample containers and COC match? yes ☐ no ☐

Comments:

Temperature of Samples °C: ______

Please fill out the Chain of Custody completely and review. Incorrect or incomplete information will result in a "hold" on all analyses.

Trans. #	RELINQUISHED BY:	RECEIVED BY:	DATE:	TIME:	Trans. #	RELINQUISHED BY:	RECEIVED BY:	DATE:	TIME:
1					3				
2					4				

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CHAIN OF CUSTODY RECORD

SOLIDS BOTTLE - WATER CHEMISTRY

PROJ. NO.:

PROJECT NAME: MAUMEE3

SAMPLERS: (Signature) BEHNKE + O'BRIEN

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	TSS, VSS, TP, TKN	SRP, DTP, NO2, NO3, NH3				REMARKS
	7/22/13			✓	00009	W	2	✓	✓				Real Time Buoy 1400
	↓			✓	00010	W	2	✓	✓				Dumpo1 1515
				✓	00011	W	2	✓	✓				02 1530
				✓	00012	W	2	✓	✓				03 1545
				✓	00013	W	2	✓	✓				04 1600
				✓	00014	W	2	✓	✓				05 1615
				✓	00015	W	2	✓	✓				RA1 1700
				✓	00016	W	2	✓	✓				RA2 1800
				✓	00017	W	2	✓	✓				~~Dock~~ DUP
				✓	00018	W	2	✓	✓				DOCK 1900
					[illegible]								

Relinquished by: (Signature)	DATE	TIME	Received by: (Signature)	
Cathy Whiting	9:55	7/23/13		LABORATORY SENT TO: HEIDELBERG
				LABORATORY CONTACT:
Relinquished by: (Signature)	DATE	TIME	Received by: (Signature)	SHIPPING CARRIER: DELIVERED
				TRACKING NUMBER:
Relinquished by: (Signature)	DATE	TIME	Received for Laboratory by: (Signature)	DATE / TIME / Requested Turnaround Time:

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CHAIN OF CUSTODY RECORD

PROJ. NO.

PROJECT NAME MAUMEE 3

SAMPLERS: *(Signature)* BEHNKE + C OBRIEN

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	CHLOROPHYLL	SPECIATION	BIOMASS	MICROCYSTIN			REMARKS
	7/22/13	1900		✓	MR02WC2826	W	1	✓						
	7/22/13	1515		✓	PS-02-WC-01-20	W	1	✓						
	7/22/13	1530		✓	PS-02-WC-02-20	W	1	✓						
		1545		✓	PS-02-WC-03-20	W	1	✓						
		1600		✓	PS-02-WC-04-20	W	1	✓						
		1615		✓	PS-02-WC-05-20	W	1	✓						
		1400		✓	PS-02-WC-26-24	W	3	✓	✓	✓	✓			
		1700		✓	RA1-02-WC-25-17	W	3	✓	✓	✓	✓			
		1800		✓	RA-02-WC-27-26	W	3	✓	✓	✓	✓			
	↓	1800		✓	DUPLICATE A	W	3	✓	~~X~~	~~X~~				

Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*	
[signature]	7/23/13	0900	[signature]	**LABORATORY SENT TO:** UNIVERSITY OF TOLEDO
				LABORATORY CONTACT: PHOENIX
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received by:** *(Signature)*	**SHIPPING CARRIER:** DELIVERED
				TRACKING NUMBER:
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received for Laboratory by:** *(Signature)*	**DATE** / **TIME** / **Requested Turnaround Time:**

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LTI-Limno-Tech, Inc.

Environmental Engineering

CHAIN OF CUSTODY RECORD

PROJ. NO. | PROJECT NAME: MAUMEE 3

SAMPLERS: (Signature) [signature]

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	Chlorophyll	Speciation	Biomass	MICROCYSTIN			REMARKS
	7/23/13	1045	X		RA1-02-WC-25-17	W	3	X	X	X	✓			
	7/23/13	1145	X		PS-02-WC-26-24	W	3	X	X	X	✓			
	7/23/13	1230	X		FB-02-WC-01-00	W	1	X						
	7/23/13	—	X		DUPLICATE B	W	3	X	~~X~~	~~X~~				
	7/23/13	1305	X		PS-02-WC-01-17	W	1	X						
	7/23/13	1312	X		PS-02-WC-02-18	W	1	X						
	↓	1325	X		PS-02-WC-03-18	W	1	X						
	↓	1355	X		PS-02-WC-04-20	W	1	X						
	↓	1430	X		PS-02-WC-05-20	W	1	X						
	↓	1525	X		RA2-02-WC-27-25	W	3	X	X	X	✓			
	↓	1700	X		MR-02-WC-28-26	W	3	X	~~X~~	~~X~~				

Relinquished by: (Signature)	DATE	TIME	Received by: (Signature)	
[signature]	7/23/13	1800	Phoebe Cudnick [signature]	LABORATORY SENT TO:
				LABORATORY CONTACT:
Relinquished by: (Signature)	DATE	TIME	Received by: (Signature)	SHIPPING CARRIER:
				TRACKING NUMBER:
Relinquished by: (Signature)	DATE	TIME	Received for Laboratory by: (Signature)	DATE / TIME / Requested Turnaround Time:

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LTI-Limno-Tech, Inc.

Environmental Engineering

CHAIN OF CUSTODY RECORD

PROJ. NO.:

PROJECT NAME: MAUMEE 3

SAMPLERS: *(Signature)*

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	TOTAL P	LOSS OF IGNITION	GRAIN SIZE	P FRACTION			REMARKS
	7/23/13	10:25		X	SCOW DPS-073	S	1	X	X	X				Sample # 1
	7/23/13	14:38		X	SCOW DPS-070	S	1	X	X	X				Sample # 2
	7/23/13	17:16		X	SCOW DPS-073	S	1	X	X	X	X			Sample # 3

Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*
[signature]	7/24/13	13:00	
Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*
Relinquished by: *(Signature)*	DATE	TIME	Received for Laboratory by: *(Signature)*

LABORATORY SENT TO:

LABORATORY CONTACT: BILL JAMES

SHIPPING CARRIER: FED EX

TRACKING NUMBER:

DATE	TIME	Requested Turnaround Time:

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CHAIN OF CUSTODY RECORD

PROJ. NO.

PROJECT NAME MAUMEE 3

SAMPLERS: *(Signature)*

STA. NO.	'13 DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	TP, TSS, VSS, TKN	SRP, DTP, NO2, NO3/NH3					REMARKS
	7/23	1045	X		RA1-02-WC-25-17	W	2	X	X					Bottle Label # 019
	7/23	1145	X		PS-02-WC-26-24	W	2	X	X					# 020
	7/23	—	X		Duplicate B	W	2	X	X					# 021
	7/23	1230	X		FB-02-WC-01-00	W	2	X	X					# 022
	7/23	1305	X		PS-02-WC-01-17	W	2	X	X					# 023
	7/23	1312	X		PS-02-WC-02-18	W	2	X	X					# 024
	7/23	1325	X		PS-02-WC-03-18	W	2	X	X					# 025
	7/23	1355	X		PS-02-WC-04-20	W	2	X	X					# 026
	7/23	1430	X		PS-02-WC-05-20	W	2	X	X					# 027
	7/23	1525	X		RA2-02-WC-27-25	W	2	X	X					# 028
	7/23	1700	X		MR-02-WC-28-26	W	2	X	X					# 029

Relinquished by: (Signature)	DATE	TIME	Received by: (Signature)

Relinquished by: (Signature)	DATE	TIME	Received by: (Signature)

Relinquished by: (Signature)	DATE	TIME	Received for Laboratory by: (Signature)	DATE	TIME	Requested Turnaround Time:
[signature]	7/23/13	2000				

LABORATORY SENT TO: Heidelburg

LABORATORY CONTACT: Ellen Ewing

SHIPPING CARRIER: FedEx

TRACKING NUMBER:

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LTI-Limno-Tech, Inc.
Environmental Engineering

CHAIN OF CUSTODY RECORD✓

PROJ. NO. | **PROJECT NAME:** MAUMEE 3

SAMPLERS: *(Signature)* BEHNKE + C OBRIEN

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	CHLOROPHYLL	SPECIATION	BIOMASS	MICROCYSTIN			REMARKS
	7/22/13	1900		✓	MR02WC2826	W	1	✓						
	7/22/13	1515		✓	PS-02-WC-01-20	W	1	✓						
	7/22/13	1530		✓	PS-02-WC-02-20	W	1	✓						
		1545		✓	PS-02-WC-03-20	W	1	✓						
		1600		✓	PS-02-WC-04-20	W	1	✓						
		1615		✓	PS-02-WC-05-20	W	1	✓						
		1400		✓	PS-02-WC-26-24	W	3	✓	✓	✓	✓			
		1700		✓	RA1-02-WC-25-17	W	3	✓	✓	✓	✓			
		1800		✓	RA-02-WC-27-26	W	3	✓	✓	✓	✓			
	↓	1800		✓	DUPLICATE A	W	3	✓	~~✓~~	~~✓~~				

Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*	
[signature]	7/23/13	0900	[signature]	LABORATORY SENT TO: UNIVERSITY OF TOLEDO
				LABORATORY CONTACT: PHOENIX
Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*	SHIPPING CARRIER: DELIVERED
				TRACKING NUMBER:
Relinquished by: *(Signature)*	DATE	TIME	Received for Laboratory by: *(Signature)*	DATE / TIME / Requested Turnaround Time:

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LTI-Limno-Tech, Inc.
Environmental Engineering

CHAIN OF CUSTODY RECORD

PROJ. NO. | **PROJECT NAME** MAUMEE 3

SAMPLERS: *(Signature)* [signature]

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	Chlorophyll	Speciation	Biomass	MICROCYSTIN			REMARKS
	7/23/13	1045	X		RA1-02-WC-25-17	W	3	X	X	X	✓			
	7/23/13	1145	X		PS-02-WC-26-24	W	3	X	X	X	✓			
	7/23/13	1230	X		FB-02-WC-01-00	W	1	X						
	7/23/13	—	X		DUPLICATE B	W	3	X	~~X~~	~~X~~				
	7/23/13	1305	X		PS-02-WC-01-17	W	1	X						
	7/23/13	1312	X		PS-02-WC-02-18	W	1	X						
	↓	1325	X		PS-02-WC-03-18	W	1	X						
		1355	X		PS-02-WC-04-20	W	1	X						
		1430	X		PS-02-WC-05-20	W	1	X						
		1525	X		RA2-02-WC-27-25	W	3	X	X	X	✓			
	↓	1700	X		MR-02-WC-28-26	W	3	X	~~X~~	~~X~~				

Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*	
[signature]	7/23/13	1800	[signature]	LABORATORY SENT TO:
				LABORATORY CONTACT:
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received by:** *(Signature)*	SHIPPING CARRIER:
				TRACKING NUMBER:
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received for Laboratory by:** *(Signature)*	DATE / TIME / Requested Turnaround Time:

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Environmental Engineering

CHAIN OF CUSTODY RECORD

PROJ. NO.	PROJECT NAME
	MAUMEE 3

SAMPLERS: *(Signature)* [signature]

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	Sediment Dry weight	Loss on ignition	Total P	Grain Size	P Fraction		REMARKS
	7/29/13	2045		✓	DPS-073	S	1		X	X	X	X		Dredge Samples
	7/30/13	0100		X	DPS-070	S	1		X	X	X	X		↓
	7/30/13	0400		X	DPS-073	S	1		X	X	X	X		
	7/30/13	0750		X	DPS-070	S	1		X	X	X	X		
	7/30/13	1035		X	DPS-073	S	1		X	X	X	X		
	7/30/13	1350		X	DPS-070	S	1		X	X	X	X		
	7/30/13	1645		X	DPS-073	S	1		X	X	X	X		
	7/30/13	1555			Reference Area 2 Upper A	S	1	X	X					Sediment trap samples
	↓	1555			Reference Area 2 Upper B	S	1	X	X					↓
	↓	1610			Reference Area 2 Lower A	S	1	X	X					
	↓	1610			Reference Area 2 Lower B	S	1	X	X					

Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*	
[signature]	7/30/13	2000		**LABORATORY SENT TO:** Bill James
				LABORATORY CONTACT:
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received by:** *(Signature)*	**SHIPPING CARRIER:**
				TRACKING NUMBER:

Relinquished by: *(Signature)*	DATE	TIME	Received for Laboratory by: *(Signature)*	DATE	TIME	Requested Turnaround Time:

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Fax (734) 332-1212

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Kalamazoo, MI 49048
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Fax (269) 226-0192~~

LTI-Limno-Tech, Inc.
Environmental Engineering

CHAIN OF CUSTODY RECORD

PROJ. NO.

PROJECT NAME: MAUMEE 3

SAMPLERS: *(Signature)* [signature]

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	TP, TSS, VSS, TKN	SRP, DTP, NO2-NO3, NH3					REMARKS
	7/30/13	0950		X	PS-02-WC-01-18	W	2	X	X					Bottle # 00030
		1005		X	PS-02-WC-02-18	W	2	X	X					Bottle # 00031
		1020		X	PS-02-WC-03-18	W	2	X	X					Bottle # 00032
		1035		X	PS-02-WC-04-18	W	2	X	X					Bottle # 00033
		1111		X	PS-02-WC-05-18	W	2	X	X					Bottle # 00034
		1230		X	PS-02-WC-26-24	W	2	X	X					Bottle # 00035
		1320		X	RA1-02-WC-25-17	W	2	X	X					Bottle # 00036
		1410		X	RA2-02-WC-27-25	W	2	X	X					Bottle # 00038
		—		X	DUPLICATE	W	2	X	X					Bottle # 00037
		1415		X	BLANK	W	2	X	X					Bottle # 00039
		1730		X	MR-02-WC-28-26	W	2	X	X					Bottle # 00040

Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*	
[signature]	7/30/13	1930		**LABORATORY SENT TO:** HEIDELBURG **LABORATORY CONTACT:**
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received by:** *(Signature)*	**SHIPPING CARRIER:** **TRACKING NUMBER:**
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received for Laboratory by:** *(Signature)*	**DATE** / **TIME** / **Requested Turnaround Time:**

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LTI-Limno-Tech, Inc.

Environmental Engineering

CHAIN OF CUSTODY RECORD

PROJ. NO.

PROJECT NAME MAUMEE 3

SAMPLERS: *(Signature)* [signature]

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	Chlorophyll a	Microcystis	Biovolume	Speciation			REMARKS
	7/30/13	0950		X	PS-02-WC-01-18	W	1	X						
		1005		X	PS-02-WC-02-18	W	1	X						
		1020		X	PS-02-WC-03-18	W	1	X						
		1035		X	PS-02-WC-04-18	W	1	X						
		1111		X	PS-02-WC-05-18	W	1	X						
		1230		X	PS-02-WC-26-24	W	3	X	X	X	X			
		1320		X	RA1-02-WC-25-17	W	3	X	X	X	X			
		1410		X	RA2-02-WC-27-25	W	3	X	X	X	X			
		—		X	DUPLICATE	W	1	X						
		1415		X	BLANK	W	1	X						
		1730		X	MR-02-WC-28-26	W	1	X						

Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*
[signature]	7/30/13	1310	[signature]
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received by:** *(Signature)*
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received for Laboratory by:** *(Signature)*

LABORATORY SENT TO: U of T

LABORATORY CONTACT:

SHIPPING CARRIER:

TRACKING NUMBER:

DATE	TIME	Requested Turnaround Time:

Location ____ Date 7/30/13

Project / Client MAUMEE 3

0630 + At office loading up

0705 - leaving for Toledo

0900 - Launched boat, heading out the channel. Safety Meeting.

BOB BETZ [signature]

BRANDON ELLEFSON : [signature]

CHRIS BETHUNE : [signature]

0945 - At dumping area, the barge is preparing to dump.

0946 - Dumping!

0950 - YSI profile 41.81273, W 83.28392

BOTTLE #030	temp	COND	pH	NTU	DO
0	22.4	250	8.52	49.5	9.48
1	22.4	248	8.54	30.1	% 112/9.7 mg/L
2	22.4	249	8.51	102.0	9.56
3	22.39	252	8.46	126.0	9.45
4	22.36	259	8.09	335.7	8.88
5	22.38	255	8.21	260	8.91
5.9	22.37	257	8.07	300	8.64

↳ just above bottom after touching

~0950 lowered LISST to bottom + up (~1'/sec)

~0950 Collected water sample (just before instruments)

1005 LISST sample after water sample

Location ____ Date 7/30/

Project / Client ____

1005 - Sample #2 41.81240, 83.28442

(LISST) YSI	°C	Cond	pH	NTU	D.O.
0 -	22.56	248	8.67	-1.5	9.87
1 -	22.49	250	8.60	22.0	9.76
2 -	22.39	250	8.57	37.2	9.63
3 -	22.4	250	8.57	34.4	9.62
4 -	22.4	254	8.56	36.2	9.6
5 -	22.4	252	8.53	50.4	9.53

1020 Sample #3 N41.81328 W 083.28492

LISST Sample

YSI

depth	°C	Cond	pH	NTU	DO
0	22.5	249	8.46	4.7	9.90
1	22.47	252	8.63	7.7	9.87
2	22.39	254	8.61	13.0	9.82
3	22.39	253	8.62	13.8	9.80
4	22.36	255	8.55	32.6	9.64
5	22.37	255	8.54	38.1	9.57

- In middle of plume right now -

Location

Date 7/30/13

Project / Client

1035 Water Sample #4 N 41.81242 W 083.28513

LISST Sample

YSI Sample

D	°C	Cond	pH	NTU	DO
0	22.49	250	8.62	10.7	9.75
1	22.46	250	8.61	12.2	9.76
2	22.45	250	8.61	16.1	9.75
3	22.44	250	8.59	23.9	9.70
4	22.40	250	8.59	23.8	9.69
5	22.40	250	8.57	28.1	9.64

10:47 At Dump location

LISST profile

YSI "

D	°C	Cond	pH	NTU	DO
0	22.78	251	8.63	7.5	9.74
1	22.61	251	8.61	11.0	9.72
2	22.51	251	8.60	11.60	9.75
3	22.43	251	8.60	14.4	9.67
4	22.41	250	8.59	16.0	9.64
5	22.39	250	8.58	17.1	9.62

Location

Date 7/30/13

Project / Client

1052 - N. 41 81271, W 083.28532

	°C	Cond	pH	NTU	DO
0 -	22.76	250	8.64	4.5	9.88
1 -	22.55	250	8.63	8.7	9.87
2 -	22.47	250	8.62	13.9	9.80
3 -	22.44	250	8.60	19.6	9.74
4 -	22.43	251	8.59	18.4	9.70
5 -	22.42	252	8.58	22.1	9.65

LISST profile

1111 - N 41.81290 W 083.28579

Sample #5

LISST

YSI

D	°C	Cond	pH	NTU	DO
0	22.93	250	8.67	4.2	9.95
1	22.61	250	8.66	7.5	9.97
2	22.53	251	8.64	9.2	9.95
3	22.40	256	8.63	6.5	9.96
4	22.33	257	8.59	5.7	9.82
5	22.30	257	8.57	7.1	9.67

Location ____ Date 7/30/13

Project / Client ____

1125 - 41.81235, 083.28610

	Temp	Cond	pH	NTU	DO
0 -	23.1	250	8.60	1.2	9.92
1 -	22.59	250	8.7	0.1	10.1
2 -	22.49	250	8.64	10.6	10.01
3 -	22.47	252	8.64	11.5	9.95
4 -	22.4	255	8.62	11.5	9.97
5 -	22.38	258	8.52	28.1	9.64

+ LISST / YSI

1140 - At dump location.

	Temp	Cond	PH	NTU	DO
0 -	23.29	249	8.63	-0.1	9.8
1 -	22.80	247	8.68	-0.3	9.95
2 -	22.53	245	8.72	-0.8	10.09
3 -	22.41	245	8.68	-0.3	10.03
4 -	22.41	250	8.61	6.3	9.84
5 -	22.40	252	8.57	13.2	9.66

+ LISST

1150 - processing samples.

1215 - At real-time buoy, collecting YSI profile. and LISST profile

Location ____ Date 7/30/13

Project / Client MAUMEE 3

MET	TEMP	COND	pH	NTU	DO
0 -	23.86	242	8.55	-4.9	9.15
1 -	22.94	238	8.63	-4.4	9.48
2 -	22.78	237	8.65	-3.8	9.64
3 -	22.61	237	8.64	-3.4	9.73
4 -	22.55	237	8.62	-3.6	9.66
5 -	22.53	237	8.59	-3.6	9.56
6 -	22.51	237	8.59	-3.2	9.46
7 -	22.55	239	8.58	-1.1	9.37

depth = 24' Secci = 3 M

1230 - Collected sample at Real Time Buoy "PS-02-WC-26-24" (#035)

net	Start		End
#1	# 353290	→	353462
#2	# 353461	→	

1305 - At reference area # 1

	TEMP	COND	pH	NTU	DO
0 -	24.14	292	8.49	4.7	9.06
1 -	22.87	283	8.50	-2.6	9.55
2 -	22.21	282	8.4	-3.2	9.36
3 -	22.08	283	8.37	-3.6	9.17
4 -	22.60	283	8.37	-3.9	8.9
5 -	21.95	283	8.3	-4.4	8.4

Location ______ Date 7/30/13

Project / Client MAUMEE 3

Secci : 2.5 M

net #1
start # = 353669
end # : 353892

net #2
Start # 353899
end # 354120

1320 - Collected sample at reference area 1. "RA1-02-WC-25-17" heidleberg bottle # 036 and "DUPLICATE" and # 037

1350 - At Reference area # 2
YSI + LISST - Secci = 5.1 M

	TEMP	COND	pH	NTU	OX
0 -	23.92	241	8.41	-5.3	8.64
1 -	23.22	234	8.43	-5.5	8.81
2 -	22.90	230	8.48	-5.4	8.84
3 -	22.74	231	8.47	-5.4	8.90
4 -	22.68	228	8.48	-5.3	8.92
5 -	22.63	229	8.45	-5.3	8.89
6 -	22.6	229	8.44	-5.1	8.84
7 -	22.6	228	8.44	-5.2	8.84
8 -	22.6	229	8.43	-2.4	8.77

1410 - collected sample at reference location #2 "RA2-02-WC-27-25" and heidleberg #038

Location ______ Date 7/30/13

Project / Client ______

net #1
start - 354120
end = 354430

net #2
start 354430
End 354735

1415 - Collected "BLANK", heidleberg # 039

1440 - At "NORTH" buoy and placement area. preparing to pull buoy.

1500 - At "East" buoy, pulling up, downloading data.

1505 - Downloading data from "SOUTH" buoy.

1520 - At "west" buoy, pulled up sonde and LISST, downloading sonde

1545 - At sediment trap near reference area 2. Pulling up.

1555 - Collected "Reference Area 2 Sediment trap Upper A" and "Reference Area 2 Sediment trap Upper B"

1610 Collected "Reference Area 2 Sediment trap Lower Ⓐ and Ⓑ

Location ____ Date 7/30/13

Project / Client MAUMEE 3

1635 - Sediment traps re-deployed at Reference Area 2, going to dock.

1715 - Picked up dredge samples from crane.

1720 - At dock, preparing to collect sample, YSI and LISST measurements. Secci = 0.45 m

	TEMP	COND	pH	NTU	DO
0 -	23.1	415	8.18	8.0	9.39
1 -	23.09	416	8.2	24.5	8.64
2 -	23.05	414	8.18	18.4	8.54
3 -	22.89	412	8.11	16.5	8.25
4 -	22.5	416	8.00	18.0	7.71
5 -	22.36	411	7.97	19.0	7.45
6 -	21.96	400	8.02	16.0	7.47
7 -	21.6	387	8.06	15.0	7.68
8 -	21.56	385	8.05	15.1	7.70

1730 - collected "MR-02-WC-28-26" and heidleberg bottle # 040.

1815 - At launch, loading boat

2000 - At fed ex, shipping samples

2100 - Unloaded equipment

Location ____ Date

Project / Client MAUMEE 3

Calibration check on M[illegible] in bucket of tap water

~~YSI 6920~~

	TEMP	COND
YSI 6920 -	20.35°C	219
NORTH -	20.57°C	238
WEST -	20.61	238
SOUTH -	20.61	237
EAST -	20.56°C	235

CALIBRATION LOG

DATE: 8/19/13 START TIME: 0555
PERSONNEL: C. Behnke END TIME:
LOCATION: office PROJECT: MAUMEE 3
INSTRUMENT CALIBRATED: YSI 6920 SERIAL NUMBER:

D. O. %

WATER SATURATED AIR CALIBRATION

D.O. AIR SATURATION TIME 20 min PERCENT SATURATION 100 %
CALIBRATION PRESSURE 745.2 mmHg CALIBRATION TEMPERATURE 25.04 °C
PRE-CALIBRATION READING 92.8 %, 7.67 mg/l CALIBRATED READING 98 %, 8.10 mg/l
DO CHARGE / DO GAIN — (ACCEPTABLE RANGE: 50 +/- 25, / 1.0 -0.3 to +0.5)
CALIBRATION SUCCESSFUL yes MAINTENANCE none

SPECIFIC CONDUCTIVITY

COND. STANDARD USED YSI CONDUCTIVITY STANDARD 1000 uS/cm YSI 3167 (1.00 mS/cm)
DATE BOTTLE OPENED — EXPIRATION DATE 12/2014
PRE-CALIBRATION READING 991 uS/cm CALIBRATION NUMBER USED 1.0 mS/cm
CALIBRATED READING 1000 uS/cm CALIBRATION TEMPERATURE 24.52 °C
CAL. CONSTANT — (ACCEPTABLE RANGE: 5.0 +/- 0.45)
CALIBRATION SUCCESSFUL yes MAINTENANCE none

pH

2 POINT CALIBRATION

pH 7.00 STANDARD USED FISHER BUFFER SOLUTION pH 7.00 +/- 0.01 @ 25'C SB107-4
DATE BOTTLE OPENED — EXPIRATION DATE 4/14
PRE-CALIBRATION READING 7.08 s.u. CALIBRATION NUMBER USED 7.0 s.u.
CALIBRATED READING 7.00 s.u. CALIBRATION TEMPERATURE 24.47 °C
BUFFER 7.00 mV — (ACCEPTABLE RANGE: 0 +/- 50 mV)

pH 10.00 STANDARD USED FISHER BUFFER SOLUTION pH 10.00 +/- 0.02 @ 25'C SB115-4
DATE BOTTLE OPENED — EXPIRATION DATE 5/2015
PRE-CALIBRATION READING 9.96 s.u. CALIBRATION NUMBER USED 10 s.u.
CALIBRATED READING 10.00 s.u. CALIBRATION TEMPERATURE 24.45 °C
BUFFER 10.00 mV — (ACCEPTABLE RANGE: -180 +/- 50 mV)
pH SLOPE OF SENSOR — (ACCEPTABLE RANGE: 165-180)
CALIBRATION SUCCESSFUL yes MAINTENANCE none

ORP

REDOX STANDARD RICCA ZOBELL'S SOLUTION (APHA Redox Standard Solution) Cat. No. 9880-32
DATE BOTTLE OPENED EXPIRATION DATE
PRE-CALIBRATION READING mV CALIBRATION NUMBER USED mV
CALIBRATED READING mV CALIBRATION TEMPERATURE °C
CALIBRATION SUCCESSFUL MAINTENANCE

TURBIDITY

3 POINT CALIBRATION

TURBIDITY STANDARD # 1 ~~YSI 608000 TURBIDITY STANDARD 0.0 NTU~~ DI water
DATE BOTTLE OPENED — EXPIRATION DATE —
PRE-CALIBRATION READING 0.2 ntu CALIBRATION NUMBER USED 0 ntu
CALIBRATED READING 0.0 ntu CALIBRATION TEMPERATURE 24.68 °C
TURBIDITY STANDARD # 2 YSI 607200 TURBIDITY STANDARD ~~10.0 NTU~~ 12.7
DATE BOTTLE OPENED — EXPIRATION DATE 6/14
PRE-CALIBRATION READING 12.7 ntu CALIBRATION NUMBER USED 12.7 ntu
CALIBRATED READING 12.7 ntu CALIBRATION TEMPERATURE 24.47 °C
TURBIDITY STANDARD # 3 YSI 607300 TURBIDITY STANDARD ~~100 NTU~~ 126
DATE BOTTLE OPENED — EXPIRATION DATE 6/14
PRE-CALIBRATION READING 122.5 ntu CALIBRATION NUMBER USED 126 ntu
CALIBRATED READING 126 ntu CALIBRATION TEMPERATURE 24.57 °C
CALIBRATION SUCCESSFUL yes MAINTENANCE none

NOTES:

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Environmental Engineering

CHAIN OF CUSTODY RECORD

PROJ. NO.
PROJECT NAME MAUMEE 3
SAMPLERS: *(Signature)* [signature]

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	TP, TSS, VSS, TKN	SRP, DRP, NO_2, NO_3, NH_4					REMARKS
	8/19/13	1015	X		RA2-03-WC-27-25	W	3	X	X					(2 bottles for solids) # 041
	8/19/13	1115	X		PS-03-WC-26-24	W	3	X	X					" " # 042
	8/19/13	1205	X		PS-03-WC-01-18	W	3	X	X					" " # 043
	8/19/13	1215	X		PS-03-WC-02-18	W	3	X	X					" " # 044
	8/19/13	1229	X		PS-03-WC-03-18	W	3	X	X					" " # 045
	8/19/13	1253	X		PS-03-WC-04-18	W	3	X	X					" " # 046
	8/19/13	1306	X		PS-03-WC-05-18	W	3	X	X					" " # 047
	8/19/13	1515	X		RA1-03-WC-25-17	W	3	X	X					" " # 048
	8/19/13	1550	X		MR-03-WC-29-16	W	3	X	X					" " # 049
	8/19/13	1550	X		DUPLICATE-081913	W	3	X	X					" " # 050
	8/19/13	1550	X		BLANK-081913	W	3	X	X					" " # 051

Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*		
[signature]	8/19/13	1930		**LABORATORY SENT TO:**	HEIDELBERG
				LABORATORY CONTACT:	ELLEN EWING
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received by:** *(Signature)*	**SHIPPING CARRIER:**	
				TRACKING NUMBER:	

Relinquished by: *(Signature)*	DATE	TIME	Received for Laboratory by: *(Signature)*	DATE	TIME	Requested Turnaround Time:

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Environmental Engineering

CHAIN OF CUSTODY RECORD

PROJ. NO.:
PROJECT NAME: MAUMEE 3
SAMPLERS: (Signature) [signature]

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	chlorophyll a	microcystis	biovolume	speciation			REMARKS
	3/19/13	1015	X		RA2-03-WC-27-25	W	4	X	X	X	X			(2 bottles for biovolume)
	3/19/13	1115	X		PS-03-WC-26-24	W	4	X	X	X	X			"
	3/19/13	1205	X		PS-03-WC-01-18	W	1	X						↓
	3/19/13	1215	X		PS-03-WC-02-18	W	1	X						
	3/19/13	1229	X		PS-03-WC-03-18	W	1	X						
	3/19/13	1253	X		PS-03-WC-04-18	W	1	X						
	3/19/13	1306	X		PS-03-WC-05-18	W	1	X						
	3/19/13	1515	X		RA1-03-WC-25-17	W	4	X	X	X	X			
	3/19/13	1550	X		MR-03-WC-28-16	W	1	X						
	3/19/13	1550	X		DUPLICATE - 031913	W	1	X						
	3/19/13	1550			BLANK - 031913	W	1	X						

Relinquished by: (Signature)	DATE	TIME	Received by: (Signature)	
[signature]	3/19/13	16:40	[signature]	LABORATORY SENT TO: U of T
				LABORATORY CONTACT:
Relinquished by: (Signature)	DATE	TIME	Received by: (Signature)	SHIPPING CARRIER:
				TRACKING NUMBER:
Relinquished by: (Signature)	DATE	TIME	Received for Laboratory by: (Signature)	DATE / TIME / Requested Turnaround Time:

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CHAIN OF CUSTODY RECORD

PROJ. NO.:
PROJECT NAME: MAUMEE 3
SAMPLERS: (Signature) [signature]

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	chlorophyll a	microcystis	biovolume	speciation			REMARKS
	8/19/13	1015	X		RA2-03-WC-27-25	W	4	+	+	+	X			(2 bottles for biovolume)
	8/19/13	1115	X		PS-03-WC-26-24	W	4	X	X	X	X			
	8/19/13	1205	X		PS-03-WC-01-18	W	1	X						↓
	8/19/13	1215	X		PS-03-WC-02-18	W	1	X						↓
	8/19/13	1229	X		PS-03-WC-03-18	W	1	X						↓
	8/19/13	1253	X		PS-03-WC-04-18	W	1	X						↓
	8/19/13	1306	X		PS-03-WC-05-18	W	1	✓						↓
	8/19/13	1515	X		RA1-03-WC-25-17	W	4	X	X	X	X			↓
	8/19/13	1550	X		MR-03-WC-28-16	W	1	X						↓
	8/19/13	1550	X		DUPLICATE - 081913	W	1	X						↓
	8/19/13	1550			BLANK - 081913	W	1	X						↓

Relinquished by: (Signature)	DATE	TIME	Received by: (Signature)	
[signature]	8/19/13	16:40	Kenneth / Mueller [signature]	**LABORATORY SENT TO:** U of T
				LABORATORY CONTACT:
Relinquished by: (Signature)	**DATE**	**TIME**	**Received by:** (Signature)	**SHIPPING CARRIER:**
				TRACKING NUMBER:
Relinquished by: (Signature)	**DATE**	**TIME**	**Received for Laboratory by:** (Signature)	**DATE** / **TIME** / **Requested Turnaround Time:**

Location ______ Date 8/19/13

Project / Client MAUMEE 3

0600 - C. Behnke / E. Verhamme at office, loading up, calibrating YSI.

0800 - At Cullen Park, launching boat. Army Corps. came over to pick up cooler for dredge samples, Cody from U of T dropped off net, sample bottles and preservative.

0830 - Leaving launch, going out to check on dredge barge.

0930 - The barge has just dropped sediment, we are not ready to follow the plume. We dropped the (4) short term buoys (without sondes) and we're going out to reference area #2 to collect samples.

0945 - At Reference area #2, dropping LISST. YSI measurements

↓

Location ______ Date 8/19

Project / Client ______

← no decimal GF

M	Temp	Cond	pH	NTU	dis-ox
0	23.07	2.82	8.96	12.7	12.46
1	23.05	2.81	8.97	9.1	12.47
2	23.00	2.90	8.96	9.1	12.40
3	22.30	2.66	8.89	2.2	11.87
4	22.19	2.66	8.83	0	11.06
5	22.15	2.68	8.81	0	10.71
6	22.14	2.71	8.81	1.1	10.54
7	22.13	2.72	8.81	0	10.38
8	21.82	2.80	8.54	1.3	8.59

↖ No decimal GF

1st net tow = 8 m (45° angle)

2nd net tow = ↓
(no spinner on net)

2nd net = 10 m 45°

1015 - Collected Sample @ "RA2-03-WC-27-25" #041 Heidelberg #)

Location ______ Date 8/19

8/19/13 Project / Client

1058 Placement Area Buoy (Long Term)

(NO decimal → Cond)

M	Temp	Cond	pH	NTU	DO
0	22.98	284	8.82	0.5	10.79
1	22.95	2.84	8.83	5.7	10.88
2	22.69	2.85	8.82	1.8	10.87
3	22.34	2.86	8.78	0.3	10.57
4	22.26	2.83	8.74	0.5	10.29
5	22.21	2.85	8.74	0	10.07
6	22.19	2.84	8.71	1.6	9.84
7	22.05	2.86	8.68	1.8	9.37

(no decimal)

net bw #1: 5.5 M
#2: 6.5 M

1115 - Collected "PS-03-WC-26-24" at reel time buoy. Heidleberg bottle # 042.

		LISST		
1201	Dump			
1205	sample #1	NO		(#043)
1215	Sample #2	Yes 0.4m	38 NTU	(#044)
1229	Sample #3	Yes (2)	30 NTU	(#045)
1240	pulled sonde	String	1.5 ft up!	
1252	sample #4	Yes	7 NTU	(#046)
1306	#5	NO	8 NTU	(#047)

Location ______ Date 8/19

Project / Client

- Sonde that logged at 5 feet during the plume tracking → clock synced with laptop. no adjustment needed.
- Sonde that logged at 15 feet during plume tracking was 5 minutes behind. Must adjust times 5 minutes ahead from sonde data.
- sonde that logged at 10 feet was 2 minutes fast. Must adjust data 2 minutes backwards

1430 - At real time buoy. reading @ surface with calibrated sonde

TEMP = 24.64 °C
COND = 297 uS/cm
TURB = 10.5 NTU

Reading with deployed sonde prior to cleaning / calibration

TEMP: 24.64 °C
COND: 267 uS/cm
TURB: 13.0 NTU

Location ____ Date 8/19/13

Project / Client MAUMEE 3

– Calibrating sonde –

		PRE	POST-CAL	
TURB	Ø	- 0.2	0	NTU
	12.7	12.9	12.7	NTU
	126	130.8	126	NTU
COND	100	957	1000	uS/cm

post cal readings
TEMP : 24.55 °C
COND : 285 uS/cm
TURB : 8.5 NTU

1515 - collected sample @ reference area #1 "RA1-03-WC-25-17"
heidelberg bottle # 048

Collecting net tow #1 = 4.5 m (15°)
#2 = 4.5 m (15°)

Location 8 Date 8/19/13

Project / Client
Ref. Area 1 1520

No decimal → COND

M	TEMP	COND	pH	NTU	DO
0	~~22.90~~ 23.90 GF	3.46	9.22	32.5	15.55
1	23.20	3.11	9.20	18.4	15.99
2	22.76	3.10	9.05	10.6	14.80
3	22.61	3.11	9.01	6.9	13.72
4	22.41	3.16	8.98	7.3	13.05
5	21.93	3.10	8.77	8.5	10.81

↑ no decimal

Maumee Sta
1602

M	Temp	Cond	PH	NTU	DO
0	26.7	5.64	8.7	34	12.4
1	25.98	5.62	8.64	25	12.54
2	25.00	5.47	8.49	18	10.80
3	23.5	4.98	8.34	14.5	9.6
4	23.3	4.90	8.27	23	9.00
5	23	5.08	8.01	35	7.5

↑ No decimal
GF

DAILY SAFETY MEETING RECORD

INITIAL PROJECT SAFETY CHECKLIST

1. Emergency information reviewed? ✓ and made familiar to all team members? ✓
2. Route to nearest hospital driven? N and its location known to all team members? ✓ work performed on Lake Erie
3. Health and safety plan readily available and its location known to all team members? ✓
4. E & E Drilling SOP on site? NA and available for team member review? NA
5. Vehicle safety inspections performed? NA

ATTENDEES

Meeting shall be attended by all personnel who will be working within the exclusion area. Daily informal update meetings will be held prior to work and when site tasks and/or conditions change.

Name (Printed)	Name (Signature)	Date	Representing (Company/Agency)
Gene Florentino	[signature]	8/13/13	E&E
Ed Verhamme		"	LimnoTech
Chris Behnke	[signature]	"	"
Meeting Conducted By:			

ecology and environment, inc.

DAILY SAFETY MEETING RECORD

GENERAL INFORMATION

Project: Toledo Harbor HAB project

Project No.

TDD/PAN No.:

Project Location: WLEB

Date: 8/19/13 Time: 0805 Weather: Sunny 68°F, calm

Specific Location: Toledo Harbor

Planned Activities: Deploy short term buoys and collect surface water samples

SAFETY TOPICS PRESENTED

Chemical Hazards Update:

Physical Hazards Update: Trip/fall, heavy equip (crane, buoy anchors) MOB

Radiation Hazards Update: NA

Review of Previous Monitoring Results: NA

Protective Clothing/Equipment Modifications: None

Special Equipment/Procedures: Caution during crane ops

Drilling Safety Issues (including testing the operation of drill rig emergency stop switches): NA

Emergency Procedures: radio Coast Guard if necessary
Deploy EPIRB if necessary

Additional Topics/Observations: MOB - deploy life ring
Float plan sent to LT office via email

Team Members' Comments/Suggestions:

Revised 5/14/99

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Environmental Engineering

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Fax (269) 226-0192

CHAIN OF CUSTODY RECORD

PROJ. NO.

PROJECT NAME MAUMEE 3

SAMPLERS: *(Signature)* EVH, RJB

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	TSS TP TKN/VSS	SRP, DTP, NO2, NO3, NH3					REMARKS
	5/20/13	0925		X	RA2-03-WC-25-17	W	3	↑	1					Label 00052
		1000			PS-03-WC-26-24									" 00053
		1030			BLANK									" 00054
		1105			PS-03-WC-01-18									" 00055
		1115			PS-03-WC-02-18									" 00056
		1125			PS-03-WC-03-18									" 00057
		1145			PS-03-WC-04-18									" 00058
		1205			PS-03-WC-05-18									" 00059
		1236			RA1-03-WC-25-17									" 00060
		1236			DUPLICATE									at RA1 - Label 00061
		1314			MR-03-WC-28-26									Label - 00062

Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*
EVH RJB	5/20/13	1600	
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received by:** *(Signature)*
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received for Laboratory by:** *(Signature)*

LABORATORY SENT TO: Heidelburg

LABORATORY CONTACT: Ellen Ewing

SHIPPING CARRIER: Fed Ex

TRACKING NUMBER:

DATE	TIME	Requested Turnaround Time:

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CHAIN OF CUSTODY RECORD

PROJ. NO. | **PROJECT NAME** MAUMEE 3

SAMPLERS: *(Signature)*

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	Chlorophylla	Microcystis	Biovolume	Speciation			REMARKS
	8/20/13	1105		X	PS-03-WC-01-18	1	↓							
	↓	1115		X	PS-03-WC-02-18	1								
		1125		X	PS-03-WC-03-18	1								
		1145		X	PS-03-WC-04-18	1								
		1205		X	PS-03-WC-05-18	1								
		1000		X	PS-03-WC-26-24	3		X	X	X				
		1236		X	RA1-03-WC-25-17	3		X	X	X				
		0925		X	RA2-03-WC-25-17	3		X	X	X				
		1236		X	DUPLICATE	1								at RA1
		1030		X	BLANK	1								
		1314			MR-03-WC-28-26 —	1	↓							

Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*	
[signature]	8/20/13	1500		**LABORATORY SENT TO:** UToledo
				LABORATORY CONTACT:
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received by:** *(Signature)*	**SHIPPING CARRIER:**
				TRACKING NUMBER:
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received for Laboratory by:** *(Signature)*	**DATE** / **TIME** / **Requested Turnaround Time:**

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Environmental Engineering

CHAIN OF CUSTODY RECORD

PROJ. NO. | **PROJECT NAME** MAUMEE 3

SAMPLERS: *(Signature)*

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	Chlorophylla	Microcystis	Biovolume	Speciation		REMARKS
	8/20/13	1105		X	PS-03-WC-01-18	1	↓						
	↓	1115		X	PS-03-WC-02-18	1							
		1125		X	PS-03-WC-03-18	1							
		1145		X	PS-03-WC-04-18	1							
		1205		X	PS-03-WC-05-18	1							
		1000		X	PS-03-WC-26-24	3		X	X	X			
		1236		X	RA1-03-WC-25-17	3		X	X	X			
		0925		X	RA2-03-WC-25-17	3		X	X	X			
		1236		X	DUPLICATE	1							of RA1
		1030		X	BLANK	1							
		1314			MR-03-WC-28-26	1	↓						

Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*	
[signature]	8/20/13	1500		**LABORATORY SENT TO:** U Toledo
				LABORATORY CONTACT:
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received by:** *(Signature)*	**SHIPPING CARRIER:**
				TRACKING NUMBER:
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received for Laboratory by:** *(Signature)*	**DATE** / **TIME** / **Requested Turnaround Time:**

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CHAIN OF CUSTODY RECORD

PROJ. NO.:

PROJECT NAME: MAUMEE 3

SAMPLERS: *(Signature)* LIMNOTECH & E&E

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	TOTAL P	LOSS ON IGNITION	GRAIN SIZE	P FRACTION			REMARKS
	8/21/13	0515		X	DPS #70	S	1	✓	✓	✓	✓			Dredge samples
	8/20/13	1900		X	DPS #73	S	1	✓	✓	✓	✓			↓
	8/21/13	0200		X	DPS #73	S	1	✓	✓	✓				↓
	8/20/13	0850		X	DPS #70	S	1	✓	✓	✓				↓
	8/20/13	0245		X	DPS #70	S	1	✓	✓	✓				↓
	8/20/13	2315		X	DPS #70	S	1	✓	✓	✓				↓
	~~[illegible]~~	~~[illegible]~~			~~DPS #70~~	~~S~~								↓
	8/19/13	0630		X	DPS #70	S	1	✓	✓	✓				↓
	8/20/13	0130		X	DPS #70	S	1	✓	✓	✓				↓
	8/19/13	1030		X	DPS #73	S	1	✓	✓	✓				↓
	8/20/13	0530		X	DPS #73	S	1	✓	✓	✓				↓
	8/20/13	0230		X	DPS #73	S	1	✓	✓	✓				↓
	8/19/13	0135		X	DPS #70	S	1	✓	✓	✓				↓

Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*
Cathy Whitney	8/21/13	1800	
Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*
Relinquished by: *(Signature)*	DATE	TIME	Received for Laboratory by: *(Signature)*

LABORATORY SENT TO: U. OF WISC.

LABORATORY CONTACT: BILL JAMES

SHIPPING CARRIER: FED EX

TRACKING NUMBER: 8011 1975 6994

DATE	TIME	Requested Turnaround Time:

Check originating office

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Environmental Engineering

CHAIN OF CUSTODY RECORD

PROJ. NO. | **PROJECT NAME** Maumee 3

SAMPLERS: *(Signature)* Ed Verhamme

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	TSS, VSS, TP, TKN	SRP, DOP, NO2, NO3, NH3	REMARKS
	8/21/13	1630			RA103WC2517		2	X	X	label # 63
	↓	1127			PS03WC0115		↓	↓	↓	# 64
		1138			PS03WC0215					# 65
		1147			PS03WC0315					# 66
		1200			PS03WC0415					# 67
		1212			PS03WC0515					# 68
		1310			Duplicate-PS03WC2024					# 70
		1310			PS03WC2024					# 69
		1315			Blank					# 71
		1330			RA2WC032726					# 72
		1510			MRWC032816					label # 73

Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*	
[illegible signature]	8/21/13	1700		**LABORATORY SENT TO:** Heidelberg
				LABORATORY CONTACT: E. Ewing
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received by:** *(Signature)*	**SHIPPING CARRIER:** FedEx
				TRACKING NUMBER: 8011 1975 6983
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received for Laboratory by:** *(Signature)*	**DATE** / **TIME** / **Requested Turnaround Time:**

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Environmental Engineering

CHAIN OF CUSTODY RECORD

PROJ. NO.:

PROJECT NAME: Maumee 3

SAMPLERS: *(Signature)* Ed Verhamme

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	Chl Microcyst	Bio Volume	Bio Speciation				REMARKS
	8/21/13	1030			RA103WC2517		4	|	X	X				
	↓	1127			PS03WC0115		1	|						
		1138			PS03WC0215		1	|						
		1147			PS03WC0315		1	|						
		1200			PS03WC0415		1	|						
		1212			PS03WC0515		1	|						
		1310			Duplicate PS03WC2024		1	|						
		1310			PS03WC2624		4	|	X	X				
		1315			Blank		1	|						
		1330			RA2WC032726		4	|	X	X				
	↓	1510			MR WC032816		4	↓						

Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*
E. Verhamme	8/21	1540	

Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*

Relinquished by: *(Signature)*	DATE	TIME	Received for Laboratory by: *(Signature)*

LABORATORY SENT TO: UToledo

LABORATORY CONTACT:

SHIPPING CARRIER:

TRACKING NUMBER:

DATE	TIME	Requested Turnaround Time:

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Environmental Engineering

CHAIN OF CUSTODY RECORD

PROJ. NO.:
PROJECT NAME: Maumee 3
SAMPLERS: (Signature) Ed Verhamme

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	TSS, VSS, TP, TKN	SRP, DOC, NO2, NO3, NH3				REMARKS
	8/21/13	1030			RA103WC2517		2	X	X				label # 63
	↓	1127			PS03WC0115		↓	↓	↓				# 64
	↓	1138			PS03WC0215		↓	↓	↓				# 65
	↓	1147			PS03WC0315		↓	↓	↓				# 66
	↓	1200			PS03WC0415		↓	↓	↓				# 67
	↓	1212			PS03WC0515		↓	↓	↓				# 68
	↓	1310			Duplicate-PS03WC2024		↓	↓	↓				# 70
	↓	1310			PS03WC2024		↓	↓	↓				# 69
	↓	1315			Blank		↓	↓	↓				# 71
	↓	1330			RA2WC032726		↓	↓	↓				# 72
	↓	1510			MRWC032816		↓	↓	↓				label # 73

Relinquished by: (Signature)	DATE	TIME	Received by: (Signature)
[signature]	8/21/13	1700	
Relinquished by: (Signature)	DATE	TIME	Received by: (Signature)
Relinquished by: (Signature)	DATE	TIME	Received for Laboratory by: (Signature)

LABORATORY SENT TO: Heidelberg
LABORATORY CONTACT: Ed Verhamme
SHIPPING CARRIER: FedEx
TRACKING NUMBER: 8011 1975 6983

DATE	TIME	Requested Turnaround Time:

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LTI-Limno-Tech, Inc.

Environmental Engineering

CHAIN OF CUSTODY RECORD

PROJ. NO.	PROJECT NAME
	Maumee 3

SAMPLERS: *(Signature)* Ed Verhamme

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	Chl, Microcystin	Bio Volume	Biov species				REMARKS
	6/21/13	1030			RA103WC2517		4	|	X	X				
		1127			PS03WC0115		1							
		1138			PS03WC0215		1							
		1147			PS03WC0315		1							
		1200			PS03WC0415		1							
		1212			PS03WC0515		1							
		1310			Duplicate PS03WC2624		1							
		1310			PS03WC2624		4		X	X				
		1315			Blank		1							
		1330			RA2WC032726		4		X	X				
	↓	1510			MR WC032816		1	↓						

Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*	
Ed Verhamme	6/21	1540		**LABORATORY SENT TO:** UToledo
				LABORATORY CONTACT:
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received by:** *(Signature)*	**SHIPPING CARRIER:**
				TRACKING NUMBER:
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received for Laboratory by:** *(Signature)*	**DATE** / **TIME** / **Requested Turnaround Time:**

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LTI-Limno-Tech, Inc.

Environmental Engineering

CHAIN OF CUSTODY RECORD

PROJ. NO.	PROJECT NAME
	MAUMEE 3

SAMPLERS: *(Signature)* [signature]

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	TSS, VSS, TP, TKN	SRP, DOP, NO2+NO3, NH4					REMARKS
	10/1/13	0940	X		RA2WC042726	W	2	X	X					Bottle # 0074
	10/1/13	1025	X		PSWC042624	W	2	X	X					# 0075
	10/1/13	1100	X		PSWC040314	W	2	X	X					# 0076 Should be PSWC041914
	10/1/13	1135	X		RA1WC042517	W	2	X	X					# 0077
	10/1/13	1220	X		MRWC04292[illegible]	W	2	X	X					# 0078
	10/1/13	1220	✓		DUPLICATE - MRWC042826	W	2	X	X					# 0079
	10/1/13	1225	X		BLANK	W	2	X	X					# 0080

Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*		
[signature]	10/1/13	1615		**LABORATORY SENT TO:**	HEIDELBERG
				LABORATORY CONTACT:	E. EWING
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received by:** *(Signature)*	**SHIPPING CARRIER:**	
				TRACKING NUMBER:	
Relinquished by: *(Signature)*	**DATE**	**TIME**	**Received for Laboratory by:** *(Signature)*	**DATE** / **TIME**	**Requested Turnaround Time:**

Check originating office

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LTI-Limno-Tech, Inc.

Environmental Engineering

CHAIN OF CUSTODY RECORD

PROJ. NO.	PROJECT NAME
	MAUMEE 3

SAMPLERS: *(Signature)* [signature]

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	Sample Matrix	# of Containers	chlorophyll	microcystin	biovolume	algal speciation			REMARKS
	10/1/13	0940	X		RA2WC042726	W	4	X	X	X	X			
	10/1/13	1025	X		PSWC042624	W	4	X	X	X	X			
	10/1/13	1100	X		PSWC040314	W	4	X	X	X	X			· Should be PSWC041914
	10/1/13	1135	X		RA2WC042517	W	4	X	X	X	X			
	10/1/13	1220	X		MRWC042826	W	1	X	X					
	10/1/13	1220	X		DUPLICATE - MRWC042826	W	1	X	X					
	10/1/13	1225	X		BLANK	W	1	X	X					

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[signature]	10/1/13	1330	[signature]
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Relinquished by: *(Signature)*	DATE	TIME	Received for Laboratory by: *(Signature)*

LABORATORY SENT TO: U of T

LABORATORY CONTACT:

SHIPPING CARRIER:

TRACKING NUMBER:

DATE	TIME	Requested Turnaround Time:

LimnoTech
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Fax: (202) 833-9094

[ ] Other

CHAIN OF CUSTODY RECORD

PROJ. NO.

PROJECT NAME: MAUMEE3

SAMPLERS: Ed Verhamme

STA. NO.	DATE (mmddyy)	TIME (0000)	COMP.	GRAB	Sample ID	Sample Matrix [1]	# of Containers	TP	P Frac	Bulk Density	LOI	Spec. Gravity	Part. Size Dist	REMARKS
								List of Parameters						
RA1-1	10/2/2013				RA01SD042522 - 1 - 0 to 5	Sed	1	x	x	x	x	x		Sediment Core
RA1-1	10/2/2013				RA01SD042522 - 1 - 5 to 10	Sed	1	x		x	x	x		Sediment Core
RA1-1	10/2/2013				RA01SD042522 - 1 - 10 to 15	Sed	1	x		x	x	x		Sediment Core
RA1-2	10/2/2013				RA01SD042522 - 2 - 0 to 5	Sed	1	x	x	x	x		x	Sediment Core
RA1-2	10/2/2013				RA01SD042522 - 2 - 5 to 10	Sed	1	x		x	x		x	Sediment Core
RA1-2	10/2/2013				RA01SD042522 - 2 - 10 to 15	Sed	1	x		x	x		x	Sediment Core
PS20-1	10/2/2013				PA01SD042019- 1 - 0 to 5	Sed	1	x	x	x	x	x		Sediment Core
PS20-1	10/2/2013				PA01SD042019- 1 - 5 to 10	Sed	1	x		x	x	x		Sediment Core
PS20-1	10/2/2013				PA01SD042019- 1 - 10 to 15	Sed	1	x		x	x	x		Sediment Core
PS20-1	10/2/2013				PA01SD042019- 1 - >15	Sed	1	x		x	x	x		Sediment Core
PS20-2	10/2/2013				PA01SD042019- 2 - 0 to 5	Sed	1	x	x	x	x		x	Sediment Core
PS20-2	10/2/2013				PA01SD042019- 2 - 5 to 10	Sed	1	x		x	x		x	Sediment Core
PS20-2	10/2/2013				PA01SD042019- 2 - 10 to 15	Sed	1	x		x	x		x	Sediment Core
PS20-2	10/2/2013				PA01SD042019- 2 - >15	Sed	1	x		x	x		x	Sediment Core

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Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*	Shipping Carrier: / Tracking Number:
Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*	DATE / TIME / TurnaroundTime:

[1] W=Water, S=Sediment, So=Soil

Revised: July 2010

LimnoTech
Water | Environment | Scientists | Engineers

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☐ Other

Sediment Trap

CHAIN OF CUSTODY RECORD

PROJ. NO.:

PROJECT NAME: MAUMEE3

SAMPLERS: Ed Verhamme, Bill James

STA. NO.	DATE (mmddyy)	TIME (0000)	COMP.	GRAB	Sample ID	Sample Matrix [1]	# of Containers	List of Parameters: Dry Weight	LOI					REMARKS
RA1	10/2/2013	13:00			RA1 Bottom 1	Sed	1	x	x					Sediment Trap Sample
RA1	10/2/2013	13:00			RA1 Bottom 2	Sed	1	x	x					Sediment Trap Sample
RA1	10/2/2013	13:00			RA1 Top 1	Sed	1	x	x					Sediment Trap Sample
RA1	10/2/2013	13:00			RA1 Top 2	Sed	1	x	x					Sediment Trap Sample
PS1	10/2/2013	14:00			PS1 Bottom 2	Sed	1	x	x					Sediment Trap Sample
PS1	10/2/2013	14:00			PS1 Top 1	Sed	1	x	x					Sediment Trap Sample
PS1	10/2/2013	14:00			PS1 Top 2	Sed	1	x	x					Sediment Trap Sample
RA2	10/2/2013	15:00			RA2 Bottom 1	Sed	1	x	x					Sediment Trap Sample
RA2	10/2/2013	15:00			RA2 Bottom 2	Sed	1	x	x					Sediment Trap Sample
RA2	10/2/2013	15:00			RA2 Top 1	Sed	1	x	x					Sediment Trap Sample
RA2	10/2/2013	15:00			RA2 Top 2	Sed	1	x	x					Sediment Trap Sample

Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*	Laboratory Sent To: / Laboratory Contact:
Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*	Shipping Carrier: / Tracking Number:
Relinquished by: *(Signature)*	DATE	TIME	Received by: *(Signature)*	DATE / TIME / TurnaroundTime:

[1] W=Water, S=Sediment, So=Soil

Revised: July 2010

S:\MAUMEE3\Report\field_documents\10_02_13\COC_to_bill_james_PONAR_SedTraps_100213.xls

C-5 Daily Activity Summaries

Toledo Harbor HAB - Project Field Activities	
Daily Activity Summary Report	
Date: May 9, 2013	**Report No: 1**
Weather: Sunny, Calm, 60 deg F	

Personnel	Hrs.	Affiliation
Ed Verhamme	12	LimnoTech
Brandon Ellefson	12	LimnoTech
Chris Behnke	12	LimnoTech

Area	Task	Locations Addressed
Lake Erie	Deploy mooring and instruments	

Field Work Performed : Deployed 810 lb mooring. Towed real-time buoy to disposal site. Deployed sediment traps, wq sonde, and ADCP at reference and disposal site

Work Delays (Due To Weather, Maintenance, Breakdowns, Waiting For Decisions):

None

Problems Encountered And Deviations From Work Plan:

Collected four sediment grab samples w/PONAR (1 at reference site, 3 at placement site). Samples will be analyzed for TP and grain size distribution. See field notes for lat/lon and station names

Written And Verbal Instruction By The Client:

None

Safety Issues:

None

Planned Activities For Next Work Day:

N/A

Remarks (Visitors, Completion of a field task, etc.):

All tasks were completed as scheduled

Field Team Leader Signature: Ed Verhamme **Date:** 051613

Toledo Harbor HAB - Project Field Activities	
Daily Activity Summary Report	
Date: May 17, 2013	**Report No: 051713-1**
Weather: Sunny, East wind to 10 knots, 75 deg F	

Personnel	Hrs.	Affiliation
Ed Verhamme	8	LimnoTech
Brandon Ellefson	8	LimnoTech

Area	Task	Locations Addressed
Toledo	Deploy continuous sonde on USACE dock	

Field Work Performed : Deployed YSI sonde 7 feet below the surface at the USACE dock. Sonde was attached to the pier with a PVC tube.

Work Delays (Due To Weather, Maintenance, Breakdowns, Waiting For Decisions):
None

Problems Encountered And Deviations From Work Plan:
None

Written And Verbal Instruction By The Client:
None

Safety Issues:
None

Planned Activities For Next Work Day:

N/A

Remarks (Visitors, Completion of a field task, etc.):
All tasks were completed as scheduled

Field Team Leader Signature: Ed Verhamme **Date:** 052113

Times Beach Demonstration Project Field Activities	
Daily Activity Summary Report	
Date: 6/18/13	**Report No: 3**
Weather: Clear and sunny, 60s° to 70s° F, steady winds 15 mph with some higher gusts, wave height avg 2.6 ft.	

Personnel	Hrs.	Affiliation
D. Kennedy	11	E&E
E. Verhamme	11	Limnotech
C. Behnke	11	Limnotech
B. James	11	U. of Wisconsin

Area	Task	Locations Addressed
Placement Area	Sediment Cores	Station 1, 19, and 20

Field Work Performed : Collected sediment cores from the placement area. Fractioned cores collected into subsamples as proposed on WP.

Work Delays (Due To Weather, Maintenance, Breakdowns, Waiting For Decisions): Attempted to collect cores from reference area but sediment surface contained dense zebra mussels that prevented the sediment core from penetrating the lake floor. Time was spent surveying surrounding areas for suitable core collection. Large areas contain heavy zebra mussels. Collected cores from a potential reference area southwest of the placement area. Later determined it is probably too close to the placement area for suitable use a reference. Will attempt to collect samples from a more suitable reference area tomorrow.

Wave heights caused early cancellation of day.

Problems Encountered And Deviations From Work Plan:

See above. Penetration of sediment cores not as good as planned, 30 cm. Most cores collected penetrated between 16 and 20 cm.

Written And Verbal Instruction By The Client:
None.

Safety Issues:
Wave action caused fatigue of crew and day was terminated early.

Planned Activities For Next Work Day:
Complete sediment coring and begin surface sediment grabs.

Remarks (Visitors, Completion of a field task, etc.):

Field Team Leader Signature: **Dan Kennedy**

Date: 6/18/13

Times Beach Demonstration Project Field Activities	
Daily Activity Summary Report	
Date: 6/19/13	**Report No: 4**
Weather: Clear and sunny, 60s° to 70s° F, steady winds 10 mph with some higher gusts, wave height avg 2.1 ft.	

Personnel	Hrs.	Affiliation
D. Kennedy	11	E&E
E. Verhamme	11	Limnotech
C. Behnke	11	Limnotech
B. James	11	U. of Wisconsin

Area	Task	Locations Addressed
Placement Area	Sediment grabs	Stations 1 through 20
Reference Area	Sediment grabs, sediment core	Stations 21 through 25

Field Work Performed : Collected grabs from all 25 stations. Collected a sediment core from new reference area.

Work Delays (Due To Weather, Maintenance, Breakdowns, Waiting For Decisions):
None.

Problems Encountered And Deviations From Work Plan:

Penetration of sediment cores not as good as the planned 30 cm because of mussels on sediment surface. Most cores collected penetrated between 14 and 19 cm.

Collected sediment core from new reference area approximately 3 miles southwest of placement area closer to mouth of Maumee River.

Moved two sediment grabs (Station 22 and 24) from new reference area to coincide with two University of Toledo monitoring stations for broader reference of sediments.

Written And Verbal Instruction By The Client:
None.

Safety Issues:
None.

Planned Activities For Next Work Day:
Collect surface water samples and perform long term monitoring station maintenance.

Remarks (Visitors, Completion of a field task, etc.):
Sediment sampling complete.

Field Team Leader Signature: **Dan Kennedy**

Date: 6/19/13

Times Beach Demonstration Project Field Activities	
Daily Activity Summary Report	
Date: 6/19/13	**Report No: 5**
Weather: Clear and sunny, 60s° to 80s° F, light winds increasing from 5 to 10 mph with some higher gusts, wave height avg 1.2 to 2.0 ft.	

Personnel	Hrs.	Affiliation
D. Kennedy	10.5	E&E
E. Verhamme	10.5	Limnotech
C. Behnke	10.5	Limnotech

Area	Task	Locations Addressed
Placement Area	Monitoring buoy maintenance	Buoy PA-0
Reference Area	Monitoring buoy maintenance	Buoy RA-0
Maumee River	Monitoring site	Site MR-0

Field Work Performed : Performed maintenance activities at long term stations (see above). Calibrated sondes, downloaded ADCP data.

Work Delays (Due To Weather, Maintenance, Breakdowns, Waiting For Decisions):
Boat trailer had wheel axle hub burn out but caused minimal delay as it burnt out at dock site. Was fixed at local marina.

Problems Encountered And Deviations From Work Plan:

Heilderberg University lab does not analyze samples on Fridays. Could not collect surface water samples because hold times would not be met. Will collect on Monday 24 June.

Sonde at RA-0 had batteries deplete and no data collection after May 30. Could not get sonde to calibrate properly. Was brought inshore for maintenance and will be re-deployed during water sampling.

Moved reference buoy RA-0 to new reference site approximately 3-miles southwest of placement site.

Written And Verbal Instruction By The Client:
None.

Safety Issues:
None.

Planned Activities For Next Work Day:
Collect surface water samples on Monday 24 June.

Remarks (Visitors, Completion of a field task, etc.):
Long term monitoring station maintenance complete.

Field Team Leader Signature: **Dan Kennedy**

Date: 6/20/13

Times Beach Demonstration Project Field Activities	
Daily Activity Summary Report	
Date: 6/24/13	**Report No: 6**
Weather: Clear and sunny, 70s° to 90s° F, light southwest winds increasing from 5 to 10 mph, wave height avg 0.5 ft to 1.5 ft	

Personnel	Hrs.	Affiliation
Ed Verhamme	12	LimnoTech
Cullen Obrien	12	LimnoTech
Brandon Ellefson	12	LimnoTech

Area	Task	Locations Addressed
Placement Area	Water Column Sampling	Buoy PA-0
Reference Area	W.C. Sampling and Sediment Sampling	Reference Area #1 and #2
Maumee River	Water Column Sampling	Site MR-0

Field Work Performed: Collected 8 water column samples (6 regular, 1 duplicate, and 1 blank). Of the 6 regular samples, 2 were collected in reference areas, 3 were in the placement area, and 1 was at the mouth of the Maumee River. Additional sediment samples (cores and grabs) were collected at Toledo Light #2.

Work Delays (Due To Weather, Maintenance, Breakdowns, Waiting For Decisions):
First water column samples took 1.5 hours to complete due to walking through each collection method carefully. Subsequent samples took 25 min to collect.

Problems Encountered And Deviations From Work Plan:
Sampled water at Toledo Light #2, which is serving as a second reference area.

Written And Verbal Instruction By The Client:
None.

Safety Issues:
None.

Planned Activities For Next Work Day:
None

Remarks (Visitors, Completion of a field task, etc.):
This concludes Event #1

Field Team Leader Signature: Ed Verhamme

Date: 6/24/13

Maumee Bay Project Field Activities	
Daily Activity Summary Report	
Date: 10/01/13	**Report No: 15**
Weather: 60°F and foggy in morning, high temp of 75 °F, winds 10-15 mph with waves up to 2 ft	

Personnel	Hrs.	Affiliation
C Behnke	8	LimnoTech
E. Verhamme	8	LimnoTech
L. Roedl	8	E & E

Area	Task	Locations Addressed
Placement Area	Water Sampling	PA-0
Reference Area	Water Sampling	RA-1
Reference Area	Water sampling	RA-2
Maumee River	Water sampling	MR-0

Field Work Performed:

- Collected water column samples and water column profiling at the long-term monitoring stations (Placement area [see note below], Reference Areas1 and 2, and Maumee station);
- Removed water quality meter from Maumee River station

Work Delays (Due To Weather, Maintenance, Breakdowns, Waiting For Decisions):
Fog in the morning and throughout most of the day along with 2 ft waves made it difficult to anchor and caused some delays

Problems Encountered And Deviations From Work Plan:
Unable to collect three WC samples in the placement area due to high winds and waves. In addition, one of the samples was mislabeled. The sample labeled PSWC040314 should be PSWC041914, indicating it was collected at station 19 and not station 3. The field notes were edited and the mistake was noted on the chain of custody.

Written And Verbal Instruction By The Client:
None.

Safety Issues:
None.

Planned Activities For Next Work Day:
Begin sediment sampling

Remarks (Visitors, Completion of a field task, etc.):
Completed Sampling Day 1 of Event 4.

Field Team Leader Signature: **Larry Roedl**

Date: 10/01/13

Maumee Bay Project Field Activities	
Daily Activity Summary Report	
Date: 10/02/13	**Report No: 16**
Weather: partly cloudy, then clear, high temp of 75 °F, winds 0-5 mph with waves <1 ft	

Personnel	Hrs.	Affiliation
C Behnke	8	LimnoTech
E. Verhamme	8	LimnoTech
L. Roedl	8	E & E

Area	Task	Locations Addressed
Placement Area	Water Sampling	PA-0
Reference Area	Water Sampling	RA-1
Reference Area	Water sampling	RA-2
Maumee River	Water sampling	MR-0

Field Work Performed:

- Collected sediment grabs and cores at the long-term monitoring stations (Placement area, Reference Areas1 and 2, and Maumee station);
- Retrieved sediment traps
- Removed Buoys/equipment from all locations except the ADCP and YSI at the placement area

Work Delays (Due To Weather, Maintenance, Breakdowns, Waiting For Decisions):
None

Problems Encountered And Deviations From Work Plan:
None.

Written And Verbal Instruction By The Client:
None.

Safety Issues:
None.

Planned Activities For Next Work Day:
None. Will remove remaining buoy/equipment next week

Remarks (Visitors, Completion of a field task, etc.):
Completed Event 4 sampling.

Field Team Leader Signature: **Larry Roedl**

Date: 10/02/13

Maumee Bay Project Field Activities	
Daily Activity Summary Report	
Date: 7/22/13	**Report No: 7**
Weather: Overcast until 5:00 pm, 70s^{o} to 80s^{o} F, light winds increasing from 5 to 10 mph with some higher gusts, wave height avg 2.0 ft. until late afternoon	

Personnel	Hrs.	Affiliation
C Behnke	10.5	LimnoTech
C. O'Brien	10.5	Limnotech
C. Whiting	10.5	Limnotech

Area	Task	Locations Addressed
Placement Area	Deployed short term monitoring sondes	Buoy PA-0
Placement Area	Collected surface water samples	
Reference Area	Collected surface water samples	Buoy RA-0
Maumee River	Collected surface water samples	Site MR-0

Field Work Performed : Collected surface water samples at the long term monitoring stations, installed short term monitoring sondes, collected surface water samples in the sediment plume.

Work Delays (Due To Weather, Maintenance, Breakdowns, Waiting For Decisions):
It was slow going due to waves until about 3:00 pm.

Problems Encountered And Deviations From Work Plan:

The surface water samples could not be shipped to Heidelberg on 7/22 because we did not make FedEx in time. The samples were driven to Heidelberg before noon on 7/23. Samples for UT were delivered at 8:30 am on 7/23.
Barge samples were not collected by the dredging crew.

Written And Verbal Instruction By The Client:
None.

Safety Issues:
None.

Planned Activities For Next Work Day:
Collect surface water samples on Tuesday, July 23rd.

Remarks (Visitors, Completion of a field task, etc.):
Day 1 of Event 2 completed.

Field Team Leader Signature: Cathy Whiting
Cathy Whiting

Date:
7/22/13

Maumee Bay Project Field Activities	
Daily Activity Summary Report	
Date: 7/23/13	**Report No: 8**
Weather: Mostly sunny, 70s° to 80s° F, light winds increasing throughout the day, wave height avg 2.0 ft. and increased in mid to late afternoon	

Personnel	Hrs.	Affiliation
C Behnke	13	LimnoTech
C. O'Brien	13	Limnotech
D. Kennedy	13	E & E

Area	Task	Locations Addressed
Placement Area	Collected surface water samples	Locations 1 thru 5 in sediment plume and at long term buoy
Reference Area	Collected surface water samples	Locations 26 and 27
Maumee River	Collected surface water samples	Adjacent to sonde

Field Work Performed : Collected surface water samples at the long term monitoring stations and collected surface water samples in the sediment plume.

Work Delays (Due To Weather, Maintenance, Breakdowns, Waiting For Decisions):
Increase in wave height beginning around 2 p.m. slowed transit times.

Problems Encountered And Deviations From Work Plan:

- Team was not able to perform the planned 15 vertical profiles in the sediment plume because it dissipated after completing 8 of them.
- Only a single tow of the net and a single bottle was being done for biomass sample. University of Toledo lab technician said this should cause much of a problem but remainder of samples will be collected properly.

Written And Verbal Instruction By The Client:
None.

Safety Issues:
None.

Planned Activities For Next Work Day:
Collect surface water samples on Tuesday, July 24rd.

Remarks (Visitors, Completion of a field task, etc.):
Day 2 of Event 2 completed.

Field Team Leader Signature: **Date:**
Dan Kennedy 7/24/13

Maumee Bay Project Field Activities	
Daily Activity Summary Report	
Date: 7/24/13	**Report No: 9**
Weather: Mostly sunny, 70s° to 80s° F, light winds increasing throughout the day, wave height avg 2.0 ft. and increased in mid to late afternoon	

Personnel	Hrs.	Affiliation
C Behnke	6	LimnoTech
C. O'Brien	6	Limnotech
D. Kennedy	6	E & E

Area	Task	Locations Addressed
Dredge Barge	Dredge Material Sampling	

Field Work Performed : Sampling event was canceled today for weather (see below). Received and shipped dredge material samples from USACE oversight personnel collecting samples. Samples were collected yesterday 7/23/13.

Work Delays (Due To Weather, Maintenance, Breakdowns, Waiting For Decisions):
The dredging operations were shut down today as a result of high winds/waves out of the NE. Therefore sampling could not be completed today. Today is being used as the contingency day.

Problems Encountered And Deviations From Work Plan:

Only three dredge material samples were collected instead of the planned six because dredging operations were suspended and only four barges were emptied.

Written And Verbal Instruction By The Client:
None.

Safety Issues:
None.

Planned Activities For Next Work Day:
Collect surface water samples on Tuesday, July 25rd.

Remarks (Visitors, Completion of a field task, etc.):
None.

Field Team Leader Signature: **Dan Kennedy**

Date: 7/24/13

Maumee Bay Project Field Activities	
Daily Activity Summary Report	
Date: 7/25/13	**Report No: 10**
Weather: Mostly sunny, 60s° to 70s° F, light winds 0 to 5 mph, wave height avg 1.7 ft. at highest in morning.	

Personnel	Hrs.	Affiliation
C Behnke	12.5	LimnoTech
B. Betz	12.5	Limnotech
D. Kennedy	12.5	E & E

Area	Task	Locations Addressed
Placement Area	Maintenance and Sampling	Collected sediment trap samples and sonde maintenance
Reference Area	Maintenance and Sampling	Collected sed trap samples and sonde maintenance
Maumee River	Maintenance	Sonde maintenance

Field Work Performed : Collected sediment trap samples from RA1 and PA. Performed maintenance at the 3 sonde locations.

Work Delays (Due To Weather, Maintenance, Breakdowns, Waiting For Decisions):
Planned for completing Day 3 Event 2 water sampling and dredge sediment sampling. Due to continuing winds, dredging operations were delayed and start time was uncertain but predicted to be close to midnight by USACE representative. The team choose to perform maintenance and collect sediment trap samples. The team saw dredging resumed at 12:30 PM, but it was too late in the day to start sampling. The third day of sampling for this event will be Monday July 29th because water quality samples cannot be collected on Friday due to holding times.

Problems Encountered And Deviations From Work Plan:

- Sediment trap samplers were planned for deployment of three sets of two samplers. Only two sets per location were deployed because of length of vertical set up too great to include three within the available water column at the sampling locations. Sampler in RA1 had little sediment in each sampler, less than ½”.

Written And Verbal Instruction By The Client:
None.

Safety Issues:
None.

Planned Activities For Next Work Day:
Complete Day 3 Event 2 on surface water samples on Monday, July 29rd.

Remarks (Visitors, Completion of a field task, etc.):
Maintenance event and sediment trap sampling completed.

Field Team Leader Signature: **Dan Kennedy**

Date: 7/25/13

Maumee Bay Project Field Activities	
Daily Activity Summary Report	
Date: 7/30/13	**Report No: 11**
Weather: Sunny, 70s° F, light winds increasing from 5 to 10 mph with some higher gusts, wave height avg 1.0 ft.	

Personnel	Hrs.	Affiliation
C Behnke	11	LimnoTech
B. Ellefson	11	Limnotech
B. Betz	11	Limnotech

Area	Task	Locations Addressed
Placement Area	Retrieved short term monitoring sondes	Buoy PA-0
Placement Area	Collected surface water samples	
Reference Areas	Collected surface water samples	Buoy RA-0
Maumee River	Collected surface water samples	Site MR-0
Reference Area 2	Collected samples from sediment traps	

Field Work Performed : Collected surface water samples at the long term monitoring stations, retrieved short term monitoring sondes, collected surface water samples in the sediment plume, collected samples from the sediment traps in Reference Area 2. Picked up barge samples from the contractor.

Work Delays (Due To Weather, Maintenance, Breakdowns, Waiting For Decisions):
None

Problems Encountered And Deviations From Work Plan:

None.

Written And Verbal Instruction By The Client:
None.

Safety Issues:
None.

Planned Activities For Next Work Day:
None.

Remarks (Visitors, Completion of a field task, etc.):
Completed Sampling Day 3 of Event 2.

Field Team Leader Signature: Cathy Whiting
Cathy Whiting

Date:
7/30/13

Maumee Bay Project Field Activities	
Daily Activity Summary Report	
Date: 8/19/13	**Report No: 12**
Weather: Sunny, 68s^{o} F, light winds (5 to 10 mph) temp increased to 80's and wind died down to 0 to 3 mph), wave height <1.0 ft.	

Personnel	Hrs.	Affiliation
C Behnke	12	LimnoTech
E. Verhamme	12	LimnoTech
G. Florentino	10	E & E

Area	Task	Locations Addressed
Placement Area	Deployment of short term monitoring sondes, plume monitoring, water column sampling, and buoy maintenance	PA-0
Reference Area	Water Sampling	RA-1
Reference Area	Water sampling	RA-2
Maumee River	Water sampling	MR-0

Field Work Performed:

- Collected water column samples and water column profiling at the long-term monitoring stations (Placement area, Reference Areas1 and 2, and Maumee station);
- Performed buoy maintenance at the placement area
- Deployed short-term monitoring sondes in placement area;
- Collected water column water samples in the sediment plume and monitored turbidity in a concentric circular pattern using an array of turbidity meters at 3 depths following one of the barge disposal events. Also recorded video of turbidity plume.

Work Delays (Due To Weather, Maintenance, Breakdowns, Waiting For Decisions):
None

Problems Encountered And Deviations From Work Plan:
None.

Written And Verbal Instruction By The Client:
None.

Safety Issues:
None.

Planned Activities For Next Work Day:
None.

Remarks (Visitors, Completion of a field task, etc.):
Completed Sampling Day 1 of Event 3.

Field Team Leader Signature: Gene Florentino

Gene Florentino

Date: 8/19/13

Maumee Bay Project Field Activities	
Daily Activity Summary Report	
Date: 8/20/13	**Report No: 13**
Weather: Sunny, 68s^{o} F, light winds (<5 mph) temp increased to 80's and no wind, wave height <1.0 ft.	

Personnel	Hrs.	Affiliation
C Betz	10	LimnoTech
E. Verhamme	10	Limnotech
G. Florentino	8	E & E

Area	Task	Locations Addressed
Placement Area	Plume monitoring, water sampling	PA-0
Reference Area	Water Sampling	RA-1
Reference Area	Water sampling	RA-2
Maumee River	Water sampling	MR-0

Field Work Performed:

- Collected water column samples and water column profiling at the long-term monitoring stations (Placement area, Reference Areas1 and 2, and Maumee station);
- Collected 5 water column samples and collected turbidity reading profiles for about an hour in the central portion of the barge "dump" zone in the placement area
- Performed buoy maintenance at Maumee River Station;

Work Delays (Due To Weather, Maintenance, Breakdowns, Waiting For Decisions):
None

Problems Encountered And Deviations From Work Plan:

None.

Written And Verbal Instruction By The Client:
None.

Safety Issues:
None.

Planned Activities For Next Work Day:
None.

Remarks (Visitors, Completion of a field task, etc.):
Completed Sampling Day 2 of Event 3.

Field Team Leader Signature:
Gene Florentino

Date:
8/20/13

Maumee Bay Project Field Activities	
Daily Activity Summary Report	
Date: 8/21/13	**Report No: 14**
Weather: Sunny, 70° F, light winds (<5 mph) temp increased to 80's and no wind, wave height <1.0 ft.	

Personnel	Hrs.	Affiliation
C. O'Brien	10	LimnoTech
E. Verhamme	10	Limnotech
G. Florentino	8	E & E

Area	Task	Locations Addressed
Placement Area	Plume monitoring, water sampling	PA-0
Reference Area	Water Sampling	RA-1
Reference Area	Water sampling	RA-2
Maumee River	Water sampling	MR-0

Field Work Performed:

- Collected water column samples and water column profiling at the long-term monitoring stations (Placement area, Reference Areas1 and 2, and Maumee station);
- Collected 5 water column samples and monitored areal extent/migration of turbidity plume following one of the barge dumps in the placement area
- Replaced YSI at Maumee River Station;
- Performed buoy maintenance at Reference Area 1

Work Delays (Due To Weather, Maintenance, Breakdowns, Waiting For Decisions):
None

Problems Encountered And Deviations From Work Plan:

None.

Written And Verbal Instruction By The Client:
None.

Safety Issues:
None.

Planned Activities For Next Work Day:
None.

Remarks (Visitors, Completion of a field task, etc.):
Completed Event 3.

Field Team Leader Signature:
Gene Florentino

Date:
8/21/13

C-6 Field Adjustment Forms

FIELD ADJUSTMENT FORM

To: Cathy Whiting
LimnoTech

DATE: 050913
TIME:

Fax:
Office:
From: Ed Verhamme
LimnoTech

Fax:
Office:

Project Site: Maumee

Planning Document Reference: Sampling And Analysis Plan

Need for Field Adjustment:

1) Four sediment grab samples were collected on May 9, 2013 at the reference (1) and disposal site (3) to provide the field team with gross sediment characteristics at the proposed coring locations. These samples will be used to guide sediment sampling during the sediment sampling event in June.

Reference Site (REF-0) Lat: 41.84479 Lon: -83.27310 Depth = 22 ft

Placement Site 1 (PA01) Lat: 41.81347 Lon: -83.28117 Depth = 20 ft (NE Corner of placement area)

Placement Site 2 (PA02) Lat: 41.80899 Lon: -83.28635 Depth = 16 ft (Center of east half of placement area)

Placement Site 3 (PA03) Lat: 41.80402 Lon: -83.28279 Depth = 18 ft (Center of east half of placement area)

2) Continuous instruments in placement area were deployed at a different location. The location was discussed with Arnold Page at USACE in Toledo. Updated location reflects best knowledge of planned 2013 placement activities

Updated Lat/Lon

Real-Time Buoy: 41.80624 -83.27048 Depth = 23 ft (Exactly on the SE boundary of placement area)
Sediment Trap: 41.80617 -83.26958 Depth = 23 ft (300 ft to the east of real-time buoy)

FIELD ADJUSTMENT FORM

To: Michael Asquith, Andrew M. Lenox DATE: July 11, 2013
Office: USACE LRB
From: E & E/LimnoTech

Project Site: Western Lake Erie Basin Harmful Algal Blooms

Planning Document Reference: Sampling And Analysis Plan

Need for Field Adjustment:

Collecting sediment cores at the proposed reference site in the Sampling and Analysis Plan (SAP) was not possible due to the presence of dreissenid mussel shells and a harder than expected substrate. The proposed reference site was located three miles north of the placement area. Attempts to collect sediment cores further south of the proposed reference site and north of the placement area were also unsuccessful due to the heavy presence of mussel beds and shell fragments. Attempts were made at 2.75, 2.5, 1.5, and 1.0 miles north of the placement area. All resulted in similar sediment conditions that were not conducive to collecting an intact sediment core for the sediment P flux incubations and sediment fractioning.

The reference area was relocated approximately four miles southwest of the placement site noted as Ref Site #1 in the attached figure. Cores were collected at four locations, sediment traps were deployed and the reference site buoy was relocated. Bill James, University of Wisconsin, started analysis of the cores and preliminary results indicated that sediment in the new reference area has a much higher Phosphorus (P) release than sediments in the placement site. There was concern that the reference site was not representative of the sediments of open waters of the western Lake Erie basin and that the mussels in this area may be causing a higher P release due to biological activity. Therefore a second site of cores was collected from an area approximately five miles northeast of the placement site, Ref Site#2 on the attached figure, near an established NOAA water quality monitoring buoy (i.e., Toledo Light #2). A second set of sediment traps also was deployed at this location. Water quality samples were collected from both reference locations.

The preliminary P release data are listed below. The locations are shown on Figure 1. The data indicated that existing sediments in open water are releasing two to three times more P that newly deposited sediment in the placement area under anoxic conditions.

Placement Area: PA2019 - 6.0 mg/m2 d (0.5 SE)
Placement Area: PA1919 - 5.9 mg/m2 d (1.3 SE)
Placement Area: PA0115 - 2.7 mg/m2 d (0.4 SE)
Reference Area #1: RA2517 - 12.6 mg/m2 d (1.1 SE)
Reference Area #2: RA2726 - 17.8 mg/m2 d (1.0 SE)

The following is a description of the two alternate reference site locations. Recommendations for changes to the SAP to adjust for the need to move the reference site are provided at the end.

1. Alternate reference site #1 is approximately four miles southwest of the planned placement site, near the NOAA water quality monitoring buoy Toledo Harbor Light and in approximately 17 ft of water. This location is representative of the sediments of outer Maumee Bay and the nearshore areas of the western basin of Lake Erie (presence of mussels with fine silt and clay). Mussels are present at this site, however there is more fine grained sediment at this site (due to its proximity to the river) and it is possible to collect sediment cores at this location. This location is very close to station 8M, which is one of the University of Toledo's long term monitoring stations. Dr. Bridgeman has been monitoring water quality at this station for over ten years and will continue to monitor this station on a bi-weekly basis for the 2013 field season. The continuous long term monitoring equipment (ADCP, sediment traps, and YSI sonde measuring turbidity, conductivity, and temperature) were also moved to this new location. Coordinates for this location are Lat/Lon: N 41.775397 W 83.3437851.

2. Alternate reference site # 2 is approximately five miles northeast of the planned placement site, near the NOAA water quality monitoring buoy Toledo Light #2 and in the same location as the University of Toledo's station GR1. Water depth at the site is 25 ft and the sediments are fine grained (heavy clay and silt content) and contains very few dreissenid mussels, which make it suitable for coring. This site is more representative of sediments in the open waters of western Lake Erie and is much less influenced by the Maumee River. A third set of sediment traps (two sets of two traps) were also placed at this location. A

FIELD ADJUSTMENT FORM

To: Michael Asquith, Andrew M. Lenox DATE: July 11, 2013
Office: USACE LRB
From: E & E/LimnoTech

water quality sonde was not deployed long term at this site because NOAA does have a long term water quality instrument deployed at Toledo Light #2. This dataset will be available to the project team and is measuring turbidity and conductivity. Coordinates for this location are Lat/Lon: N 41.821400 W 83.1855000 .

Recommendations for Field Adjustments:

Continue to sample and monitor water quality at both alternative reference locations. These two stations will provide a representative view of sediment and water quality conditions in areas not influenced by open lake placement activities that are closer to Maumee Bay (first reference site) and western Lake Erie (second reference site). These new reference stations will facilitate the comparison of sediment and water quality conditions in the placement area to areas closer to where the material was dredged from (Maumee Bay) and to the open waters of the western basin where HABs frequently occur. The potential additional cost will only be associated with the water quality samples analyzed at University of Heidelberg. University of Toledo and University of Wisconsin will absorb the few additional samples under their existing subcontracts.

Alternatively, the team could collect an additional set of sediment samples in the reference site currently used by USACE to determine if that location is more suitable as a single reference area. Sediment traps and the water quality buoy would be transferred from alternative reference area #1.

FIELD ADJUSTMENT FORM

To:	Gene Florentino E&E	DATE: TIME:	July 30, 2013
Fax: Office:			
From:	Cathy Whiting LimnoTech		
Fax: Office:			

Project Site: Maumee

Planning Document Reference: Sampling And Analysis Plan

Need for Field Adjustment:

The sediment traps were originally planned as a string consisting of replicate traps hung at three different depths (1 meter from surface, mid-depth, and 1 meter above lake bottom). The actual water depth encountered was not great enough to allow for installation at 3 depths. Therefore, the traps were hung at 2 depths, 1 meter from the surface and 1 meter from the bottom.

D Laboratory Data

Please see separate Appendix D folder on CD.

E Sediment Report

Effects of Open-Lake Dredge Material Placement on Sediment Characteristics and Diffusive Phosphorus Fluxes in Lake Erie, Western Basin

12 February, 2014

University of Wisconsin - Stout
Sustainability Sciences Institute
Menomonie, Wisconsin 54751
715-338-4395
jamesw@uwstout.edu

EXECUTIVE SUMMARY

The objectives of this research were to compare and evaluate variations in sediment physical-textural-chemical characteristics and sediment phosphorus (P) fluxes as a function of open placement of dredge material, originating from the Maumee River navigation channel at Toledo Harbor, OH, in the western basin of Lake Erie. In 2013, sampling stations were established in the open placement area and reference areas located to the southwest and northeast of the placement area for collection of intact sediment cores and ponar grabs in June, before dredge material addition, and October, after dredge material addition to the open placement site. Intact sediment cores were collected at the 3 stations located in the placement area and 2 reference area stations during these time periods for determination of rates of P release from sediment under aerobic and anaerobic conditions. Additional sediment cores were collected at the same reference and placement area stations in June and October for sectioning at 5-cm intervals over the upper 20-cm to determine variations in physical and chemical properties. Ponar grab samples were collected at 20 to 22 stations that were established from a grid positioned over the placement area and 6 stations located in reference areas to examine spatial and temporal variations in sediment characteristics. Actual dredge material was also collected during active dredging in late July and August for physical-textural-chemical analysis and comparison with open placement surface sediment characteristics. Physical-textural variables included moisture content, bulk density, particle size distribution, and specific gravity. Chemical variables included organic matter content, sediment total P, and sediment P fractions that are functionally biologically-labile (loosely-bound P, iron-bound P, and labile organic P; subject to recycling pathways) and biologically-refractory (aluminum-bound P, calcium-bound P, refractory organic P; more inert to recycling and subject to burial).

Rates of P release from sediment appeared to be largely regulated by classic iron-phosphorus oxidation-reduction interactions in the placement area. They were greatest under anaerobic conditions, which was consistent with bacterially-mediated reduction of iron-oxyhydroxides, desorption of P, and diffusion out of anoxic sediment and into the

overlying water column. Under aerobic conditions, P release rates were much lower as a result of strong adsorption of P by iron oxyhydroxides in the thin oxidized microzone at the sediment surface, resulting in its very limited diffusion into the overlying water column. Aerobic conditions at the sediment-water interface probably dominated redox chemistry in the western basin, due to the shallow, mixed environment.

Rates of P release ranged between less than zero to ~ 1.1 mg/m^2 d under aerobic conditions and ~2.4 to 21 mg/m^2 d under anaerobic conditions in the reference and placement areas in 2013. Overall mean rates of P release of 0.4 and 9.5 mg/m^2 d under aerobic and anaerobic conditions, respectively, fell within typical ranges found for other large aquatic systems, including other Great Lakes. Surprisingly, mean rates of P release under both aerobic and anaerobic conditions tended to be greater ($P < 0.05$; T-Test) in the reference versus the placement area in June, 2013, before the addition of new dredge material. However, differences in sediment P composition and concentrations of mobile P (i.e., loosely-bound, iron-bound, and labile organic P) did not explain the higher mean P release rates in the reference area in June.

Living zebra mussels, found in reference area sediment but not in the placement area, probably played an important role in enhancing P release rates from reference area sediment under both aerobic and anaerobic conditions. Under aerobic conditions, zebra mussels can excrete substantial soluble P via grazing activities and tissue emaciation (i.e., during periods of negative growth and starvation). Under anaerobic conditions, zebra mussels contained in sediment incubation systems died, with release of excess P into the overlying water column as a result of tissue decomposition. Although not quantified, it was noted that zebra mussels were present in numbers in both aerobic and anaerobic sediment incubation systems collected from reference stations in the basin, particularly in June. Thus, zebra mussel excretion and P loss could explain the rate differences between the two areas. Indeed, predicted anaerobic P release rates (i.e., from sediment total P and published regression equations) were lower than actual measured means in the reference area, a pattern that can be attributed to zebra mussel influences. In addition, predicted mean anaerobic P release rates were slightly but significantly lower ($P < 0.05$; T-Test) in reference (i.e., ~ 4.6 mg/m^2 d; ± 0.4 standard error; SE) versus placement (i.e., 6.0 mg/m^2 d; ± 0.1 SE) area sediments in both June and October. Ultimately, zebra mussels inhabiting reference area sediment impacted diffusive P flux patterns, making interpretation of temporal variation and direct comparison with placement area P fluxes difficult.

In October, measured mean rates of P release from sediment under anaerobic conditions were not significantly different between reference and placement areas; however, the mean anaerobic rate had increased significantly in the placement area between June and October (i.e., from 4.95 mg/m^2 d in June to 10.93 mg/m^2 d in October). Reasons for this increase are not clearly evident. Possible processes included anaerobic leaching, decomposition, and breakdown of organic matter and P associated with dredge material. However, more research is needed to more clearly identify biological and chemical factors that may have influenced anaerobic P release rates in the placement area in October. Since the western basin is relatively shallow, well mixed, and oxygenated throughout the water column (i.e., aerobic conditions), the likelihood and overall role that anaerobic conditions play in P release from sediment could be minor and needs to be evaluated in relation to P dynamics.

There were some significant differences in the sediment P concentration and composition between the reference and placement areas. The upper 5-cm sediment layer exhibited significantly higher total P concentrations in the placement (i.e., ~ 0.93 mg/g) than the reference area (i.e., 0.66 mg/g). Overall, biologically-labile P accounted for ~ 47% of the total P in the placement area. In contrast, this mobile P pool represented only ~ 31% of the total P in the reference area. Differences in sediment total P concentration were largely due to greater concentrations of iron-bound P (i.e., ~ 0.36 mg/g), aluminum-bound P (i.e., 0.253 mg/g), and loosely-bound P (i.e., 0.021 mg/g) in the placement versus reference area surface sediment layer. The P composition of actual dredge material collected from barges in late July and August also closely reflected the composition of the upper 5-cm sediment layer in the placement area, indicating chemical linkages between dredge material originating from Toledo Harbor and sediments located in the open placement area of the western basin. For instance, the mean total P concentration of dredge material was 1.01 mg/g (±0.017 standard error; SE). The mean iron-bound P concentration of this material was 0.332 mg/g (±0.014 SE) and the mean loosely-bound P concentration was 0.029 mg/g (±0.005 SE), which closely corresponded with placement area surface sediment concentrations. Spatial variations in ponar grab samples confirmed the interpretation of findings from intact sediment cores. Specifically, sediment total P concentrations were greater in the placement versus reference area in both June and October. Mean total P concentrations (n = 20 to 22) over the entire placement area sampling grid ranged between 0.98 mg/g (± 0.02 SE) in June to 0.91 mg/g (± 0.02 SE) in October. These mean concentrations closely reflected the total P concentration of dredge material collected from Toledo Harbor in July and August. In contrast, the mean total P concentration in reference area ponar grabs was lower at ~ 0.73 mg/g.

Sediment physical-textural characteristics were generally similar between the two areas. A notable exception to this pattern was a slightly greater mean sediment organic matter content in the placement versus reference area in June and October. However, the organic matter content of the upper sediment layer was low at less than 8% overall. Reference area sediment also tended to have a greater percentage of particles > 63 μ throughout the sediment column versus the placement area. This pattern was probably related, in part, to broken and finely ground zebra mussel shells that could not be separated from the sand fraction.

OBJECTIVES

The objectives of this research were to examine the potential impact of open placement of dredge material, originating from the Maumee River watershed and Toledo Harbor (OH), on sediment physical-chemical characteristics and nutrient diffusive fluxes in the western basin of Lake Erie. Variations in sediment phosphorus flux under aerobic and anaerobic conditions, biologically-labile (i.e., subject to recycling) and biologically-refractory (i.e., more inert to recycling and subject to burial) phosphorus fractions, and sediment physical-textural characteristics (i.e., moisture content, particle size distribution, bulk density, organic matter content) were examined in reference and the open placement areas of the western basin in June, 2013, before dredge material addition, and October, 2013, after dredge material addition to the open placement site.

METHODS

Station locations and study design

Intact sediment core and surface ponar grab stations were established in the 2013 dredge material placement area and at several reference stations to examine potential impacts of open placement on sediment characteristics and diffusive fluxes (**Table 1**). The reference area included stations located to the southwest and northeast of the placement area (**Fig. 1**). Sediment at these reference stations were generally infested with living zebra mussels and broken zebra mussel shells, which had an impact on sediment characteristics and P flux research. An array of sediment sampling stations was established in the placement area for examination of spatial and temporal variations in sediment characteristics (**Fig. 2**). Sediment sampling was conducted in mid-June (i.e., before dredge material placement) and October (i.e., after dredge material placement), 2013.

Examination of sediment characteristics at selected reference and placement area stations

Laboratory determination of rates of phosphorus release from intact sediment cores. Undisturbed duplicate (2 for aerobic and 2 for anaerobic conditions) sediment cores were collected at the 3 stations located in the placement area (PA-01, PA-19, PA-20) and 2 reference area stations (RA-25, RA-27) for determination of rates of P release from sediment. A gravity sediment coring device (Aquatic Research Instruments, Hope

ID) equipped with an acrylic core liner (6.5-cm ID and 50-cm length) was used to collect intact sediment cores. The core liners, containing both sediment and overlying water, were immediately sealed using rubber stoppers and stored in a covered container on ice until transport to the laboratory (UW-Stout, Menomonie, WI). Additional lake water was collected in the placement and reference area for incubation with the collected sediment.

In the laboratory, sediment cores were carefully drained of overlying water and the upper 10 cm layer was transferred intact to a smaller acrylic core liner (6.5-cm dia and 20-cm ht) using a core remover tool. Water collected from the western basin was filtered through a glass fiber filter (Gelman A-E); 300 mL was then siphoned onto the sediment contained in the small acrylic core liner without causing sediment resuspension. Sediment incubation systems, therefore, consisted of the upper 10-cm of sediment and filtered overlying water contained in acrylic core liners that were sealed with rubber stoppers (**Fig. 3**). The sediment incubation systems were placed in a darkened environmental chamber and incubated at a constant temperature for up to 2 weeks or longer. The incubation temperature was maintained at 20 ^{o}C to simulate average summer temperatures. The oxidation-reduction environment in each system was controlled by gently bubbling either air (aerobic) or nitrogen (anaerobic) through an air stone placed just above the sediment surface. Bubbling action ensured complete mixing of the water column but did not disrupt the sediment. Anoxic conditions were verified using a dissolved oxygen electrode.

Water samples for soluble reactive phosphorus (SRP) were collected at one to three day intervals over the entire incubation period. Samples (10 mL) were collected from the center of each sediment incubation system using a syringe and immediately filtered through a 0.45 μm membrane syringe filter. The water volume removed from each system during sampling was replaced by addition of filtered lake water preadjusted to the proper oxidation-reduction condition. These volumes were accurately measured for determination of dilution effects. SRP was measured colorimetrically using the ascorbic acid method (APHA 2005). Rates of SRP release from the sediment (mg/m^2 d) were calculated as the linear change in concentration in the overlying water divided by time and the area of the incubation core liner. Regression analysis was used to estimate rates over the linear portion of the data.

Vertical variations in sediment physical and chemical properties. Additional duplicate intact sediment cores collected at the same reference and placement area stations in June and October were sectioned at 5-cm intervals over the upper 20-cm for determination of physical and chemical properties. Cores were sectioned at LimnoTech, Inc. on the day of collection by extruding slices into labeled freezer bags and storing in coolers on ice until transport to UW-Stout. All sediment sections were analyzed for moisture content, wet and dry bulk density, loss-on-ignition organic matter content, and porosity (**Table 2**; see *Analytical methods* below for a description of analytical procedures). The upper 5-cm section of each core was also analyzed for loosely-bound P, iron-bound P (Fe-P), labile organic P, aluminum-bound P (Al-P), calcium-bound P (Ca-P), refractory organic P, total P, total Fe, total Ca, and total Al. Finally, all sections from one of the duplicate sediment cores were used for determination of particle size distribution (i.e., > 63 μ, between 2 and 63 μ, and < 2 μ) while specific gravity was determined for all sediment sections from the other duplicate core.

Spatial and temporal variations in sediment characteristics at the placement area

Surface ponar grab samples were collected at PA-01, PA-19, PA-20, and RA-25 in mid-May to quantify baseline sediment characteristics. Sampling stations visited in June and October are listed in Table 1. Stations were located via Global Positioning System technology. Ponar grabs were drained of excess overlying water, transferred to a freezer bag, and stored in a cooler on ice until analysis. In the laboratory, bags containing sediment were carefully homogenized by kneading and mixing before analysis. Moisture content, bulk density, organic matter content, and total sediment P were determined for all ponar grabs using methods described below (**Table 3**). Particle size distribution was determined from a subsample of stations in each location.

Sediment characteristics of open placement dredged material

In late July (23 and 30 July) and late August (19 to 21 August), actual dredged material from the Maumee River channel of Toledo Harbor was collected at various times for examination of sediment characteristics (**Table 4**). Sediment dredge samples were sealed in a freezer bag and shipped on ice for analysis. After careful and thorough homogenization, all samples were processed for determination of moisture content, bulk density, porosity, organic matter content, particle size distribution, and total P while a subset was additionally analyzed for various biologically-labile (i.e., loosely-bound, Fe-P, and labile organic P) and refractory (i.e., Al-P, Ca-P, and refractory organic P) P fractions.

Analytical and statistical methods

Sediment from reference area stations contained whole zebra mussel shells that were removed prior to sediment analysis. A known volume of sediment was dried at 105 ^{o}C in a forced-air oven for determination of moisture content and sediment density and burned at 550 ^{o}C for determination of loss-on-ignition organic matter content (Allen et al. 1974; Plumb 1981; Håkanson and Jansson 2002; ASTM Method E1109-86 2009). Wet and dry bulk density and porosity (i.e., the percent sediment volume occupied by interstitial water) was estimated using equations developed by Avnimelech et al. (2001) and Håkanson and Jansson (2002).

Sediment particle size distribution was determined on wet sediment using a combination sieve and separation via settling in 1-L columns according to Plumb (1981). Particles greater than 62.5 μ (i.e., sand fraction) were separated by washing a known mass of sediment through a 62.5 μ stainless steel mesh sieve and quantitatively transferring the captured material to a crucible for dry mass determination. For reference area stations, this particle size fraction also contained very finely-broken zebra mussel shells that could not be separated from sand. Thus, the sand composition is overestimated due to contamination with zebra mussel shells. Separation of particles between 62.5 μ and 1.95 μ (i.e., silt) and less than 1.95 μ (i.e., clay) was conducted by transferring sediment that passed through the 62.5 μ mesh to a standard 1-L settling column. The slurry was subjected to 10 mL of a 1% calgon solution to reduce flocculation, mixed thoroughly via inversion, and sampled using a 20 mL pipette before and after settling to determine the dry mass of particles less than 62.5 μ and particles less than 1.95 μ, respectively. Settling times required to capture particles less that 19.5 μ, were based on temperature and Stokes law as indicated in Plumb (1981, page 3-45). Samples were placed in a cubicle and dried at 105 C for mass determination.

Phosphorus fractionation was conducted according to Hieltjes and Lijklema (1980), Psenner and Puckso (1988), and Nürnberg (1988) for the determination of ammonium-chloride-extractable P (loosely-bound P), bicarbonate-dithionite-extractable P (i.e., Fe-P), sodium hydroxide-extractable P (i.e., Al-P), and hydrochloric acid-extractable P (i.e., Ca-P; **Table 5**). A subsample of the sodium hydroxide extract was digested with potassium persulfate to determine nonreactive sodium hydroxide-extractable P (Psenner and Puckso 1988). Labile organic P was calculated as the difference between reactive and nonreactive sodium hydroxide-extractable P. Refractory organic P was estimated as the difference between total P and the sum of the other fractions.

The loosely-bound and iron-bound P fractions are readily mobilized at the sediment-water interface as a result of bacterial metabolism under anaerobic conditions that lead to desorption of P from sediment and diffusion into the overlying water column (Mortimer 1971, Boström 1984, Nürnberg 1988; **Table 3**). The sum of the loosely-bound and iron-bound P fraction is redox-sensitive P (i.e., the P fraction that is active in P release under anaerobic and reducing conditions). In addition, labile organic P can be converted to soluble P via bacterial mineralization (Jensen and Andersen 1992) or hydrolysis of polyphosphates stored in bacterial cells to soluble P under anaerobic conditions (Gächter et al. 1988; Gächter and Meyer 1993; Hupfer et al. 1995). The sum of redox-sensitive P and labile organic P is biologically-labile P. This fraction is generally active in recycling pathways that result in exchanges of phosphate from the sediment to the overlying water column (i.e., internal P loading) and potential assimilation by algae. In contrast, aluminum-bound, calcium-bound, and refractory organic P fractions are more chemically inert and subject to burial rather than recycling.

Additional sediment was dried to a constant weight at 105 ^{o}C in a forced-air oven, ground with a mortar and pestle, for determination of specific gravity total P, Fe, Al, and Ca. Specific gravity was determined via pycnometer according to Plumb (1981) and ASTM Method D854 (2010). Total P, Fe, Al, and Ca were analyzed using inductively-coupled plasma atomic emission spectroscopy (EPA method 200.7 rev 4.4) after microwave-assisted digestion (method citation).

Statistical analyses were performed using the Statistical Analysis System software package (SAS 1994; Version 6.12). Normality was examined using the Shapiro-Wilk statistic. Significant differences as a function of month (i.e., June versus August) and location (i.e., placement area versus reference area) were analyzed using the PROC TTEST procedure after examination of the means for equal or unequal variance (i.e., Cochran).

RESULTS AND INTERPRETATION

Rates of phosphorus release from sediment

An example of changes in soluble P mass and concentration in the overlying water column of sediment core incubation systems is shown in **Fig. 3**. P mass and concentration increased rapidly and linearly over time in systems subjected to an anaerobic environment (*see* Appendix 1 for complete P release time series). This pattern was probably related to microbial reduction of Fe under anaerobic conditions, desorption of P into porewater, and subsequent diffusion into the overlying water column. Mean soluble P concentration in the anoxic overlying water column at the end of the incubation period was also high and indicative of eutrophic sediments, ranging between ~ 0.2 and 1.0 mg/L (**Table 6**).

Increases in P mass and concentration were much lower in the overlying water column of systems incubated under aerobic conditions (**Fig. 3**). Nevertheless, soluble P concentrations increased linearly over time and averaged ~0.049 mg/L (range = 0.003 to 0.192 mg/L) at the end of the incubation period (**Table 6**). Suppressed P accumulation in the overlying water column under aerobic conditions was consistent with the classic Mortimer model of coupled Fe-P chemistry. Under this scenario, Fe is in an oxidized state as an Fe oxyhydroxide (Fe^{3+}~OOH) in the aerobic sediment microzone (i.e., the thin aerobic surface sediment layer often less than 1 mm in thickness) and strongly adsorbs P, resulting in its very limited diffusion into the overlying water column. Aerobic conditions at the sediment-water interface probably dominate redox chemistry in the western basin, due to the shallow, mixed environment. Although P accumulation was much lower under aerobic conditions, sediments still appeared to represent a potentially important direct source for algal assimilation.

Overall, mean rates of P release for both reference and placement area stations in June and October were an order of magnitude greater under anaerobic versus aerobic conditions (**Table 6** and **Fig. 4**). The mean anaerobic P release rate for all stations and dates was relatively high at 9.5 mg/m^2 d and fell within ranges reported for other Great Lakes, large lake systems, and large river systems in the upper Midwest (**Table 7**). The magnitude of anaerobic P release rates was also indicative of eutrophic conditions (Nürnberg 1988). Although less information has been published on aerobic P release rates, those measured for the western basin were low and comparable rates measured in other systems where Fe-P interactions are coupled and the Fe:P ratio is sufficient to control P release under aerobic conditions (e.g., Jensen et al. 1992) .

Mean aerobic and anaerobic P release rates were significantly higher in the reference versus placement area in June, before the addition of new dredge material (**Fig. 5**). As discussed later in greater detail, differences in sediment P composition and concentrations of mobile P (i.e., loosely-bound, iron-bound, and labile organic P; subject to recycling with the overlying water column) did not explain the higher P release rates in the reference area in June. Generally, total P and various redox-sensitive P fractions have been positively correlated with diffusive P flux under both aerobic and anaerobic conditions (i.e., diffusive P flux increases with increasing redox-sensitive sediment P concentration; Böstrom et al. 1982; Nürnberg 1988; Jensen and Thamdrup 1993; Petticrew and Arocena 2001; Søndergaard et al. 2003; Pilgrim et al. 2007) and, thus, represent quantifiable surrogate metrics for estimating internal P loading and recycling potential in lakes. In direct contrast, however, sediment mobile P concentrations (primarily loosely-bound and iron-bound P) were actually significantly higher in the placement versus reference area (*see* **Fig. 9**), suggesting that the opposite pattern should have occurred for sediments collected in the western basin of Lake Erie (i.e., placement area P release rates > reference area P release rates).

Numerous living zebra mussels, found in reference area sediment but not in the placement area, may have played an important role in enhancing P release rates under both aerobic and anaerobic conditions. Zebra mussels can colonize sediment and excrete substantial soluble P as a result of grazing activities (James et al. 1997, 2000; Conroy et al. 2005) and tissue emaciation during periods of negative growth and starvation (James et al. 2001). Under anaerobic conditions, zebra mussel death and decay can also result in the release of soluble P. Although not quantified, it was noted that zebra mussels were present in numbers in both aerobic and anaerobic sediment incubation systems collected from reference stations in the basin, particularly in June. Thus, zebra mussel excretion and P loss could explain the rate differences between areas and needs to be considered in future P budgetary analysis.

Mean rates of P release from sediment under aerobic conditions were not significantly different as a function of area in October (i.e., after addition of dredge material in the placement area; $P > 0.05$; **Fig. 5**). In addition, there were no significant differences in the mean aerobic P release rate for either the reference or placement area as a function of date. Thus, aerobic P release rates were similar in the placement area at a mean 0.25

mg/m^2 d (± 0.03 standard error; SE; n = 6) before dredge material addition in June and at a mean 0.32 mg/m^2 d (± 0.05 SE; n = 6) after dredge material addition in October. Although not significant (P > 0.05), the mean aerobic P release rate declined slightly in the reference area from 0.71 mg/m^2 d (± 0.15 SE; n = 4) in June to 0.38 mg/m^2 d (±0.18 SE; n = 4) in October.

A different pattern emerged for mean P release rates under anaerobic conditions. Although mean rates were not significantly different between the reference and placement areas in October, they increased significantly in the placement area as a function of date (**Fig. 5**). Thus, the mean anaerobic P release rate increased from 4.95 mg/m^2 d (± 0.79 SE; n = 6) in June to 10.93 mg/m^2 d (± 1.18 SE; n = 6) in October in the placement area, representing a doubling in the rate. In contrast, the mean anaerobic P release rate declined significantly (P < 0.05) in the reference area from 15.92 mg/m^2 d (± 1.84 SE; n = 4) in June to 7.90 mg/m^2 d (± 1.06 SE; n = 4) in October.

Reasons for these temporal patterns are not readily apparent. An increase in the redox-sensitive P concentration in the sediment after dredge material addition would be one possible scenario that could explain temporal patterns in the placement area. For instance, diffusive P flux could increase as a result of higher redox-sensitive P in the sediment and, thus, greater desorption of P under reducing conditions. However, as discussed in greater detail later, mean redox-sensitive P fractions did not change as a function of date in either the reference or placement area (*see* **Fig. 9**). Although in situ lake temperature probably increased from June to October, laboratory incubation temperature was maintained at a constant 20 ^{o}C during both flux study dates for direct comparison. Outliers were ruled out because within-area patterns of anaerobic P release (i.e., stations PA-01, PA19, PA-20) and variability were consistent in the placement area in both June and October (**Fig. 6**). In contrast, variation in P flux between reference stations was much greater (**Fig. 6**), which was probably attributable to zebra mussel influences.

Ultimately, zebra mussels inhabiting reference sediment probably impacted diffusive P flux patterns, making interpretation of temporal variation and direct comparison with placement area P fluxes difficult. For instance, since sediment redox-sensitive P concentrations were similar between areas (*see* **Fig. 8**), it might be hypothesized that temporal patterns and ranges in P fluxes could have been the same in reference versus placement area locations had zebra mussels not been present in reference incubation cores. Despite significant temporal increases in the mean anaerobic P release rate at the placement area, however, they were similar between the reference and placement area in October, after addition of dredge material. Information on in situ development of bottom water anoxia in the western basin will be needed in order to better understand the importance these anaerobic sediment P contributions to the overall P economy.

Surface sediment characteristics

Before dredge material placement in June, surface (i.e., the upper 5-cm sediment section) sediment particle size distribution in the placement area was dominated by the silt fraction (i.e., between 2 μ and 63 μ) at a mean 54.2 % (± 6.4 SE; n = 3; **Fig. 7**). Clay (i.e., < 2 μ) accounted for a mean 37.1 % (± 5.5 SE) and sand (i.e., > 63 μ) represented 8.7 % (± 1.0 SE) of the particle size distribution. In contrast, the sand fraction comprised a much higher percentage in the reference area (mean = 38.5 % ± 8.3 SE; n = 3), which was attributable in large part to finely-ground zebra mussel shells. However, silts and clays still dominated overall particle size distribution in the reference area as well (**Fig. 7**).

Surface sediment in both areas exhibited a moderately low mean moisture content (range ~ 55 to 60%), porosity (range ~ 75 to 79%), and moderately high wet and dry bulk density (range ~ 1.29 to 1.38 g/cm^3 and 0.53 to 0.65, respectively), indicating denser and compacted fine-grained sediment composition. Loss-on-ignition organic matter content was moderately low (< 10 %), but significantly higher in the placement versus reference area in June and October (**Fig. 7**).

There were no significant temporal differences in mean surface sediment textural characteristics in the reference area between June and October (**Fig. 7**). In the placement area, the mean percent clay fraction and mean wet and dry bulk density decreased significantly while mean moisture content and porosity slightly increased in October versus June in conjunction with addition of dredge material. However, with the exception of the > 63µ grain size in June and organic matter content in both June and October, mean surface sediment textural characteristics were similar between the reference and placement areas (**Fig. 7**). Thus, although some mean textural characteristics changed significantly in the placement area between June and October, overall differences between reference and placement area surface sediment physical and textural characteristics were minor after dredge material addition in October.

Over all stations and dates, biologically-labile (i.e., subject to recycling) and refractory (i.e., more inert and subject to burial) sediment P represented ~ 42% and 58% of the total sediment P (**Table 8** and **Fig. 8**). The mean sediment total P concentration was moderate at 0.82 mg/g (± 0.04 SE; n = 20) and comparable to concentrations observed in Lake Ontario (0.85 mg/g), Lake Erie Central Basin (0.88 mg/g) and Lake Michigan (0.75 mg/g; values are reported in Nürnberg 1991). The mean biologically-labile P fraction was dominated by Fe-P at ~ 77% and concentrations were moderate, ranging between 0.10 mg/g and 0.48 mg/g (**Table 8** and **Fig. 8**). The mean Fe-P of 0.283 mg/g (± 0.026 SE) was similar to extractable Fe-P for Lake Erie sediments reported in Williams et al. (1976; citrate dithionite bicarbonate extraction; 0.317 mg/g). In contrast, loosely-bound P and labile organic P represented ~ 5% and 18% of the biologically-labile P, respectively. In particular, loosely-bound P concentrations were relatively low at a mean 0.018 mg/g (± 0.001 SE; range = 0.009 mg/g to 0.029 mg/g; **Table 8**). This fraction reflects P in the porewater and P that is loosely-adsorbed onto calcium carbonates and is typically the lowest in concentration compared to the other P fractions.

Ca-P accounted for greater than 50% of the biologically-refractory P and the mean concentration was moderate at 0.288 mg/g (± 0.016 SE; **Table 8** and **Fig. 8**). Similarly, Burns et al. (1976) estimated that ~ 45% of the particulate P entering Lake Erie was refractory apatite P (i.e., Ca-P). Mean Al-P represented ~38% (0.195 mg/g ± 0.023 SE) while mean refractory organic P accounted for a minor portion of the biologically-refractory P fraction at a mean 0.032 mg/g (± 0.013 SE; range = 0.01 to 0.253 mg/g).

Mean biologically-labile P concentrations were significantly higher in the placement versus reference area in June, prior to dredge material addition (**Fig. 9**). In particular, mean Fe-P was ~ 2 times greater in the placement area surficial sediments at 0.382 mg/g (± 0.026 SE) in June versus a mean concentration of 0.152 mg/g (±0.013 SE) at reference stations. Reasons for these patterns are not clear. But, they may be related to open placement of dredge material originating from the Maumee River channel at Toledo Harbor. Both mean loosely-bound P and Fe-P remained significantly higher in the placement versus reference area after dredge material addition in October (**Fig. 9**). However, mean concentrations did not change significantly at either area between June and October, suggesting that overall area concentration differences were probably a function of dredge material placement.

As indicated earlier, differences in the mean redox-sensitive (primarily as Fe-P) P concentration did not reflect patterns in aerobic and anaerobic P release rates due to probable zebra mussel influences. For instance, the mean rate of P release under both conditions for placement area sediment was either lower or not significantly different from the mean reference area rate (**Fig. 5**) despite higher mean redox P and, thus, greater potential P flux in the placement area. From regression equations developed by Nürnberg (1988), anaerobic P release rates predicted from sediment total P (anaerobic P RR = $10^{(0.8 + (0.76*\log(\text{total P})}$; Nürnberg 1988) were not significantly different from the mean measured rate in the placement area during June (**Fig. 10**), suggesting that measured rates were close to empirical relationships. In the reference area, however, measured rates in both June and October were significantly higher than predicted rates, which may be attributed to zebra mussel influences. In addition, predicted rates were slightly but significantly lower in the reference versus placement area in both June and October due to lower sediment concentrations of total P (**Table 9** and **Fig. 10**). These empirically-derived rates reflected possible ranges in the reference area in the absence of zebra mussels.

Reasons for higher mean measured versus predicted rates in the placement area in October remain known. Anaerobic leaching, decomposition, and breakdown of organic matter and associated organic P associated with dredge material addition might be a possible hypothesis. However, more research is needed to more clearly identify biological and chemical factors that may have influenced anaerobic P release rates in the placement area in October.

Similar to Fe-P patterns, mean Al-P concentrations were greater in the placement versus reference area in June, prior to dredge material addition, and October, after open placement (**Fig. 9**). Mean Al-P declined significantly in the placement area from June to October while concentrations remained unchanged in the reference area over time (**Fig. 9**). In contrast, mean Ca-P was significantly greater in the reference versus placement area in both June and October. Refractory organic P concentrations were relatively low in both areas on both dates. Mean total P was significantly greater in the placement than the reference area in both June and October (**Fig. 9**), reflecting higher mean concentrations of loosely-bound P, Fe-P, and Al-P in the placement area. No significant changes were detected as a function of time in either area.

Summary surface sediment P trends are shown in **Fig. 11** and **12**. Overall, biologically-labile P accounted for ~ 47% of the total P in the placement area. In contrast, this mobile P pool represented only ~ 31% of the total P in the reference area. Fe-P accounted for the majority of the biologically-labile P pool in both areas. The biologically-refractory P pool comprised a much greater percentage of the sediment total P in the reference area at ~ 69% compared to the placement area at 53%. Al-P and Ca-P codominated this P pool in the placement area while Ca-P was the dominant biologically-refractory P fraction in the reference area.

Surface sediment concentrations of total Fe, Ca, and Al were moderate and fell within ranges reported in Bark and Smart (1986). Mean total Fe was 23.11 mg/g (± 0.86 SE; range = 14.00 to 28.49 mg/g; **Table 10** and **Fig. 13**) and concentrations were high relative to total P, resulting in a mean Fe:P ratio of 29:1 (± 0.77 SE; range = 25:1 to 38:1). Ratios greater than 15:1 have been associated with regulation of P release from sediments under aerobic conditions (Jensen et al. 1992). Complete binding efficiency for P at these higher relative concentrations of Fe are suggested explanations for patterns reported by Jensen et al. Indeed, P release rates from western basin sediment were relatively low under aerobic conditions at both study areas, a pattern that could be attributed to the Jensen et al. model.

Variations in mean metals concentrations tended to be minor as a function of area and date (**Fig. 14**). Mean total Fe was slightly but significantly greater in the placement area in June compared to the mean reference area concentration. However, there were no statistically significant differences in the mean total Fe concentration between areas in October. The mean concentration did not vary significantly in either area between June and October. Mean total Ca concentrations were slightly higher in the placement versus the reference area in both June and October. But, these concentration differences were slight and not statistically significant. The mean total Ca concentration also increased significantly in the placement area between June and October. The mean total Al concentration declined significantly in the reference area between June and October, resulting in statistically significant differences in concentration between areas in October. However, the mean total Al concentration did not vary significantly in the placement area between June and October.

Vertical variations in sediment characteristics

Sediment moisture content tended to decrease, while wet and dry bulk density increased, with increasing sediment depth as a result of compaction over time (**Fig. 15**). These depth-related trends were also more pronounced in the reference versus placement area, particularly for bulk density. Area-related differences may have been due to disturbance in the placement area via annual addition of dredge. Mean specific gravity was homogeneous as a function of depth in the placement area (**Fig. 16**). The mean over all depths was similar in the placement and reference area at 2.40 (range = 2.19 to 2.79) and 2.60 (range = 2.31 to 3.07), respectively.

The reference area exhibited a greater percentage of particles > 63 μ throughout the sediment column versus the placement area (**Fig. 17**). Broken and finely ground zebra mussel shells probably accounted for a portion of this particle size fraction in the reference area. However, it was also noted that sediments appeared to be sandier in the reference areas. Silt (i.e., between 2 and 63 μ) dominated the particle size distribution in the placement area and percentages were uniform with sediment depth in both June and October (**Fig. 17**). However, the percentage increased significantly over most sediment depths in the placement area from June to October. The silt fraction was more variable in the reference area and tended to decline slightly with increasing depth in June. However, silt percent distribution was more homogeneous over all depths in October. Similar to patterns in the placement area, the percent silt composition tended to increase at greater sediment depths in the reference area from June to October. The clay (i.e., < 2 μ) fraction was uniformly distributed over all depths in the placement area and represented a greater percentage of the particle size distribution in June versus October (**Fig. 17**). The percentage declined significantly in the placement over all depths in October versus June, coincident with dredge material addition. The clay percentage was generally uniform over all depths in the reference area in both June and October.

Loss-on-ignition organic matter content tended to be greater in the placement versus reference area as a function of date and sediment depth (**Fig. 18**). However, the mean concentration did not vary significantly versus time in either area. Mean organic matter content was also very uniform with increasing sediment depth in the placement area on both dates. Although not significant, the mean tended to decrease with increasing sediment depth over the upper 15 cm in the reference area. An exception to this pattern occurred at the > 15 cm sediment section in June. Mean organic matter content was greatest at this depth in the reference area compared to shallower sediment depths.

Mean total P concentrations were relatively uniform over all sediment depths in the placement area during both June and October (**Fig. 18**). Mean TP concentrations also did not vary significantly between June and October in this area (range = 0.092 to 0.098 mg/g). The most notable difference was overall lower mean concentrations of total P in the reference versus placement area in both June and October. Although mean total P did not vary significantly as a function of sediment depth or time, mean concentrations ranged between 0.45 and 0.69 mg/g, which was on the order of 30% to 50% lower than mean total P concentrations in the placement area. Similar differences in the sediment total P concentration was noted in May, 2013, several months prior to active open placement of dredge material. For instance, the mean surface sediment total P concentration in the placement area in May was 1.00 mg/g (± 0.01 SE; n = 3) but only 0.49 mg/g (n = 1) in the reference area. As discussed in more detail below, dredge material collected during open placement in 2013 exhibited similar total P concentration ranges as placement area sediment, suggesting that total P concentration differences between the two areas were related to dredge material addition.

Dredge material characteristics

Dredge material exhibited moderately low mean moisture content (mean range = 47% to 58%) and high wet (range = 1.32 g/cm^3 to 1.47 g/cm^3) and dry bulk density (mean range = 0.57 g/cm^3 to 0.84 g/cm^3; **Table 11**). A sample collected at DPS (disposal station) 73 on 8/21/13 (02:00 AM) represented an exception in that moisture content was extremely low (16.4%) while wet and dry bulk density were very high at 1.997 g/cm^3 and 1.729 g/cm^3, respectively. Since this sample was included in the calculation of means for DSP 73 (8/19/2013 to 8/21/2013; **Table 11**), mean moisture content was lower, while mean bulk densities were higher, at this station compared to other stations and dates. Mean organic matter content was relatively low and similar between stations and dates, ranging between 7.0% and 8.5% (**Table 11**). Mean grain size distribution was roughly similar for dredge material collected at the various stations on different dates (**Table 11**). Particles > 63 µ accounted for ~ 5% (mean range = 3.8% to 7.6%) of the particle size distribution. Higher mean sand content for DSP 73 on 8/19 to 8/21 versus other material reflected the unusual low-moisture content sample collected on 8/21/13 @ 02:00 AM. Grain sizes between 2 and 63 µ accounted for ~ 68% (mean range = 65% to 71%), while grain sizes < 2 µ represented ~ 27% (mean range = 25% to 29%) of the of the particle size distribution (**Table 11**). Mean total P concentrations were roughly similar over all stations and collection dates. The grand mean was 0.90 mg/g (mean range = 0.71 mg/g to 0.94 mg/g), reflecting concentrations of total P in the surface sediment of the placement area (**Fig. 9** and **11**). The relatively sandy, high bulk density sample collected at DSP 73 on 8/21/13 @ 02:00 AM had an unusually low total P concentration of 0.38 mg/g.

The P composition of dredge material was similar between stations and dates (**Fig. 19**). Biologically-labile and biologically-refractory P accounted for ~ 44% and 56% of the sediment total P composition, respectively, reflecting patterns observed in placement area surface sediments (**Fig. 12**). Also similar to placement area sediment patterns, the biologically-labile P pool for dredge material was dominated by Fe-P at ~ 34% (mean concentration = 0.332 mg/g ± 0.017 SE). The biologically-refractory P pool was codominated by Al-P and Ca-P at 49% and 47%, respectively (mean Al-P = 0.277 mg/g ± 0.014 SE; mean Ca-P = 0.264 mg/g ± 0.017 SE).

Spatial variations in surface sediment characteristics

Within the placement area (see **Fig. 1**), surface sediment moisture content was moderately low and varied between ~ 42% and 69% in June, 2013(**Fig. 20**). The percent tended to be slightly lower in the southern portion of the placement area during this time (i.e., stations 1 to 5). Similarly, the range of surface moisture contents was moderately low at reference area stations (**Fig. 20**) and means were not statistically different between the two areas in June (**Fig. 21** and **Table 12**; $P > 0.05$; T-Test; SAS 1994). Although mean surface moisture content increased slightly in the placement area in October to ~ 59% (±1.7 SE), the mean percentage was similar between areas in October (**Fig. 21**).

Wet and dry bulk density was relatively high and ranged between 0.39 and 0.90 g/cm^3 in the placement area in June (**Fig. 20**; wet bulk density is not shown). Mean wet and dry bulk densities were similar in both the reference and placement area stations in June and October (**Fig. 21** and **Table 12**). Although the mean declined significantly in the placement area between June and October, the change in concentration was minor. Mean wet bulk density in the reference area increased slightly in concentration from ~1.3 g/cm^3

in June to ~ 1.4 g/cm^3 in October, but this change was not significant (**Fig. 21**). A similar pattern was noted for mean dry bulk density in the reference area (**Fig. 21**). Mean sediment porosity ranged between 74% and 79% during the study period and values were similar between the reference and placement area (**Fig. 21**).

The organic matter content of surface sediment was moderate but tended to be higher in the placement (range = 3.9% to 9.2%) versus reference area (range = 3.4% to 7.1%) in both June and October (**Fig. 22**). Overall, mean organic matter content increased significantly in the placement area between June and October ($P < 0.05$; T-Test; SAS 1994; **Fig. 23**). In contrast, the mean percentage was similar for sediment located in the reference area between June and October (**Fig. 23**).

Similar to patterns observed for intact sediment core sections (**Fig. 9**), total P concentrations of the surface sediment tended to be higher in the placement versus reference area in both June and October (**Fig. 22**). Mean sediment total P concentrations were 0.98 mg/g (± 0.02 SE) and 0.91 mg/g (±0.02 SE) in the placement area in June and October, respectively (**Fig. 23** and **Table 12**). These mean concentration ranges were also similar to those observed in May (i.e., 1.00 mg/g; ± 0.01 SE) in the placement area. Placement area total P concentrations also reflected those concentrations in the dredge material (**Table 11**). In contrast, the reference area mean total P concentration was slightly lower at 0.72 mg/g (±0.03 SE) in June and 0.74 mg/g (±0.12 SE) in October compared to the placement area means (**Fig. 22** and **Table 12**).

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Table 1. Station locations for the collection of intact sediment cores that were sectioned vertically at 5-cm intervals and ponar surface sediment samples. PA = placement area (i.e., location of dredge material addition), RA = reference area.

Intact sediment cores	Ponar surface samples
PA-01	PA-01
PA-19	PA-02
PA-20	PA-03
	PA-04
RA-25	PA-05
RA-27	PA-06
	PA-07
	PA-08
	PA-09
	PA-10
	PA-11
	PA-12
	PA-13
	PA-14
	PA-15
	PA-16
	PA-17
	PA-18
	PA-19
	PA-20
	PA-26[1]
	RA-21
	RA-22
	RA-23
	RA-24
	RA-25
	RA-27
	RA-30[1]

[1]These stations were sampled in October only.

Table 2. Variable list for sediment core sections. Duplicate cores were collected at PA-01, PA-19, PA-20 (PA = placement area), RA-25, and RA-27 (RA = reference area) for sectioning at 5-cm intervals. The > 15 cm section could not be sampled at RA-25 in October, 2013, due to difficulty in collecting cores that were longer than ~ 15 cm.

Variable	Duplicate 1				Duplicate 2			
	0 - 5 cm	5 - 10 cm	10 - 15 cm	> 15 cm	0 - 5 cm	5 - 10 cm	10 - 15 cm	> 15 cm
Moisture content (%)	X	X	X	X	X	X	X	X
Wet bulk density (g/cm^3)	X	X	X	X	X	X	X	X
Dry bulk density (g/cm^3)	X	X	X	X	X	X	X	X
Organic matter content (%)	X	X	X	X	X	X	X	X
Porosity (%)	X	X	X	X	X	X	X	X
Particle size distribution (%)					X	X	X	X
Specific gravity	X	X	X	X				
Loosely-bound P (mg/g)	X				X			
Iron-bound P (mg/g)	X				X			
Labile organic P (mg/g)	X				X			
Aluminum-bound P (mg/g)	X				X			
Calcium-bound P (mg/g)	X				X			
Refractory organic P (mg/g)	X				X			
Total sediment P (mg/g)	X	X	X	X	X	X	X	X
Total sediment Fe (mg/g)	X				X			
Total sediment Ca (mg/g)	X				X			
Total sediment Al (mg/g)	X				X			

Table 3. Total sample size (n) for sediment sections collected in the placement area (PA) and reference area (RA). Surface ponar samples were collected at all stations in May while intact sediment cores were collected for sectioning in June and October.

Variable	Sampling time					
	May		June		October	
	PA	RA	PA	RA	PA	RA
Moisture content (%)	3	1	20	5	21	7
Wet bulk density (g/cm^3)	3	1	20	5	21	7
Dry bulk density (g/cm^3)	3	1	20	5	21	7
Organic matter content (%)	3	1	20	5	21	7
Porosity (%)	3	1	20	5	21	7
Particle size distribution (%)	3	1	5	2	4	2
Total sediment P (mg/g)	3	1	20	5	21	7

Table 4. Collection dates and times for dredge material analyses. Physical characteristics included moisture content, bulk density, particle size distribution, and organic matter content. Phosphorus (P) fractionation included loosely-bound P, iron-bound P, labile organic P, aluminum-bound P, calcium-bound P, and refractory organic P.

Collection Date	Time	Station	Physical characteristics	Total P	P fractionation
7/23/2013	10:25	73	X	X	
7/23/2013	14:38	70	X	X	
7/23/2013	17:16	73	X	X	X
7/29/2013	20:45	73	X	X	X
7/30/2013	1:00	70	X	X	X
7/30/2013	4:00	73	X	X	X
7/30/2013	7:50	70	X	X	X
7/30/2013	10:35	73	X	X	X
7/30/2013	13:50	70	X	X	X
7/30/2013	16:45	73	X	X	X
8/19/2013	10:30	73	X	X	
8/19/2013	13:35	70	X	X	
8/19/2013	18:30	70	X	X	
8/20/2013	1:30	70	X	X	
8/20/2013	2:30	73	X	X	
8/20/2013	2:45	70	X	X	
8/20/2013	5:30	73	X	X	
8/20/2013	8:50	70	X	X	
8/20/2013	19:00	73	X	X	X
8/20/2013	23:15	70	X	X	
8/21/2013	2:00	73	X	X	
8/21/2013	5:15	70	X	X	X

Table 5. Operationally-defined sediment phosphorus fractions based on sequential extraction.

Variable	Extractant	Recycling potential
Loosely-bound P	1 M ammonium chloride	Biologically-labile; recycled via eH and pH reactions and equilibrium processes
Iron-bound P	0.11 M sodium bicarbonate-dithionate	Biologically-labile; recycled via eH and pH reactions and equilibrium processes
Labile organic P	persulfate digestion of the sodium hydroxide extract	Biologically-labile; recycled via bacterial mineralization of organic P and mobilization of polyphosphates stored in bacterial cells
Aluminum-bound P	0.1 N sodium hydroxide	Biologically-refractory and subject to burial
Calcium-bound P	0.5 N hydrochloric acid	Biologically-refractory and subject to burial
Refractory organic P	calculated as the difference between sediment total P and the sum of the other fractions	Biologically-refractory and subject to burial

Table 6. Descriptative statistics and results for sediment core incubation systems incubated under aerobic and anaerobic conditions in June and October, 2013. The maximum phosphorus (P) concentration represents the concentration in the overlying water column at the end of the incubation period.

Variable		Aerobic conditions	Anaerobic conditions
P release rate (mg/m^2 d)	Number	20	20
	Minimum	-0.07	2.41
	Maximum	1.08	20.78
	Range	1.15	18.37
	Mean	0.39	9.53
	Median	0.33	8.71
	First quartile	0.22	6.02
	Third quartile	0.52	12.65
	Standard error	0.06	1.06
	95% confidence interval	0.13	2.22
	Standard deviation	0.27	4.74
	Coefficient of variation	0.69	0.50
Maximum P concentration (mg/L)	Number	20	20
	Minimum	0.003	0.176
	Maximum	0.192	1.469
	Range	0.189	1.293
	Mean	0.049	0.687
	Median	0.040	0.633
	First quartile	0.025	0.441
	Third quartile	0.058	0.844
	Standard error	0.009	0.079
	95% confidence interval	0.019	0.166
	Standard deviation	0.040	0.354
	Coefficient of variation	0.82	0.52

Table 7. A comparison of aerobic and anaerobic rates of phosphorus (P) release from sediment measured or predicted from large freshwater systems in North America.

Freshwater aquatic system	Anaerobic P release rate		Aerobic P release rate		Reference
	mean	range	mean	range	
	(mg/m^2 d)		(mg/m^2 d)		
L. Erie Western Basin	9.5	2.4 - 20.8	0.4	-0.1 - 1.1	This study
L Pepin (Upper Mississippi R)					
Lake of the Woods (MN)	10.1	6.6 - 14.1	0.3	0.1 - 0.5	James (2012)
L Minnetonka Halsted's Bay (MN)	9.6	7.5 - 13.3	2.6	0 - 6.3	James (2013a)
Petenwell Reservoir (WI)	19.6	12.7 - 24.1	0.4	0.2 - 0.7	James (2013b)
Castle Rock Reservoir (WI)	14.2	3.2 - 24.2	0.1	0 - 0.3	James (2013b)
Minnesota R (MN)	14.3	0.7 - 31.0	2.7	0.7 - 1.5	James (2008)
Pool 8 (Upper Mississippi R)	26.8	4.8 - 54.2	2.3	0 - 9.6	Houser et al. (2013)
L Erie Western Basin	11.9[1]				Nurnberg (1991)
L Erie Central Basin	7.4				Burns and Ross (1972)
L Erie Eastern Basin	7.2[1]				Nurnberg (1991)
L Ontario Central Basin	8.3[1]				Nurnberg (1991)
Bay of Quinte	10.0				Minns (1986)
L Michigan	2.8[1]				Nurnberg (1991)
L Huron	0.7[1]				Nurnberg (1991)
L Simcoe Kempenfelt Bay	9.3	4.3 - 12.8			Nurnberg et al. (2013a and b)

[1]Rates were predicted from regression relationships between sediment total phosphorus and the anaerobic P release rate.

Table 8. Descriptive statistics and results for various phosphorus (P) fractions in the surface (i.e., 0 - 5 cm sediment section) sediment for cores collected in the placement and reference areas in June and October, 2013. Loosely-bound, iron-bound, and labile organic P are biologically-labile (i.e., subject to recycling) and aluminum-bound, calcium-bound, and refractory organic P are more are more inert to transformation (i.e., subject to burial).

Statistic	Loosely-bound P (mg/g)	Iron-bound P (mg/g)	Labile Organic P (mg/g)	Aluminum-bound P (mg/g)	Calcium-bound P (mg/g)	Refractory organic P (mg/g)	Total P (mg/g)
Number	20	20	20	20	20	20	20
Minimum	0.009	0.103	0.022	0.030	0.179	0.010	0.56
Maximum	0.029	0.477	0.199	0.379	0.414	0.253	1.03
Range	0.020	0.374	0.177	0.349	0.235	0.243	0.47
Mean	0.018	0.283	0.068	0.195	0.288	0.032	0.82
Median	0.018	0.318	0.062	0.168	0.274	0.010	0.90
First quartile	0.012	0.168	0.047	0.116	0.228	0.010	0.66
Third quartile	0.024	0.362	0.080	0.284	0.348	0.025	0.93
Standard error	0.001	0.026	0.009	0.023	0.016	0.013	0.04
95% confidence interval	0.003	0.055	0.018	0.049	0.033	0.026	0.08
Standard deviation	0.007	0.118	0.038	0.104	0.070	0.056	0.16
Coefficient of variation	0.36	0.41	0.56	0.53	0.24	1.75	0.20

Table 9. A comparison of mean anaerobic phosphorus (P) release rates predicted from sediment total P concentration using regression relationships developed by Nurnberg (1988) versus measured rates. STDERR = 1 standard error.

			Mean anaerobic P release rate (mg/m^2 d)			
Area	Date	n	From TP[1]	STDERR	Measured	STDERR
Placement	June	6	6.0	0.1	5.0	0.8
	October	6	5.9	0.1	10.9	1.2
Reference	June	4	4.6	0.4	15.9	1.8
	October	4	4.5	0.3	7.9	1.1

[1]From regression equations developed by Nurnberg (1988)

Table 10. Descriptive statistics and results for various metals in the surface (i.e., 0 - 5 cm sediment section) sediment for cores collected in the placement and reference areas in June and October, 2013.

Statistic	Total Fe (mg/g)	Total Ca (mg/g)	Total Al (mg/g)
Number	20	20	20
Minimum	14.00	27.29	9.70
Maximum	28.49	44.65	34.40
Range	14.49	17.36	24.70
Mean	23.11	36.35	18.80
Median	23.57	36.87	18.32
First quartile	20.84	33.46	15.24
Third quartile	25.78	38.77	22.17
Standard error	0.86	0.96	1.32
95% confidence interval	1.80	2.01	2.76
Standard deviation	3.85	4.30	5.89
Coefficient of variation	0.17	0.12	0.31

Table 11. Mean dredge material physical-chemical characteristics for disposal station 70 and 73 in July and August, 2013. PS = particle size, STDERR = 1 standard error.

Date		Station	Moisture content (%)	STDERR	Organic matter (%)	STDERR	Wet bulk density (g/cm^3)	STDERR	Dry bulk density (g/cm^3)	STDERR
7/23/2013	7/30/2013	70	57.6	1.6	7.1	0.2	1.321	0.015	0.574	0.028
7/23/2013	7/30/2013	73	55.2	1.5	7.0	0.3	1.345	0.015	0.619	0.029
8/19/2013	8/21/2013	70	57.0	1.9	8.5	0.2	1.321	0.019	0.586	0.035
8/19/2013	8/21/2013	73	47.4	8.1	7.8	1.2	1.469	0.134	0.842	0.226
Date		**Station**	**PS > 63 u (%)**	**STDERR**	**PS 2 to 63 u (%)**	**STDERR**	**PS < 2 u (%)**	**STDERR**	**Total Phosphorus (mg/g)**	**STDERR**
7/23/2013	7/30/2013	70	4.6	1.1	66.9	0.2	28.5	0.9	0.87	< 0.01
7/23/2013	7/30/2013	73	5.6	1.5	66.1	2.0	28.3	1.4	0.94	0.01
8/19/2013	8/21/2013	70	3.8	0.5	71.4	0.9	24.8	1.1	0.92	0.02
8/19/2013	8/21/2013	73	7.6	5.2	65.4	6.6	27.0	2.3	0.71	0.16

Table 12. Mean sediment physical-chemical characteristics for ponar grab samples collected in the placement and reference areas (see **Fig. 1** and **2**) in June and October, 2013. STDERR = standard error.

Date	Area	n	Moisture content (%)		Organic Matter (%)		Wet bulk density (g/cm^3)		Dry bulk density (g/cm^3)		Porosity (%)		Total phosphorus (mg/g)	
			Mean	STDERR	Mean	STDERR	Mean	STDERR	Mean	STDERR	Mean	STDERR	Mean	STDERR
June	Open Placement	20	55.2	1.4	6.3	0.2	1.352	0.016	0.624	0.027	75.9	1.0	0.98	0.02
	Reference	6	58.8	1.7	5.4	0.2	1.317	0.018	0.554	0.031	78.7	1.2	0.72	0.03
October	Open Placement	22	59.9	1.0	7.5	0.2	1.297	0.011	0.534	0.018	79.3	0.7	0.91	0.02
	Reference	6	52.5	3.7	5.0	0.6	1.393	0.043	0.683	0.072	73.7	2.7	0.74	0.12

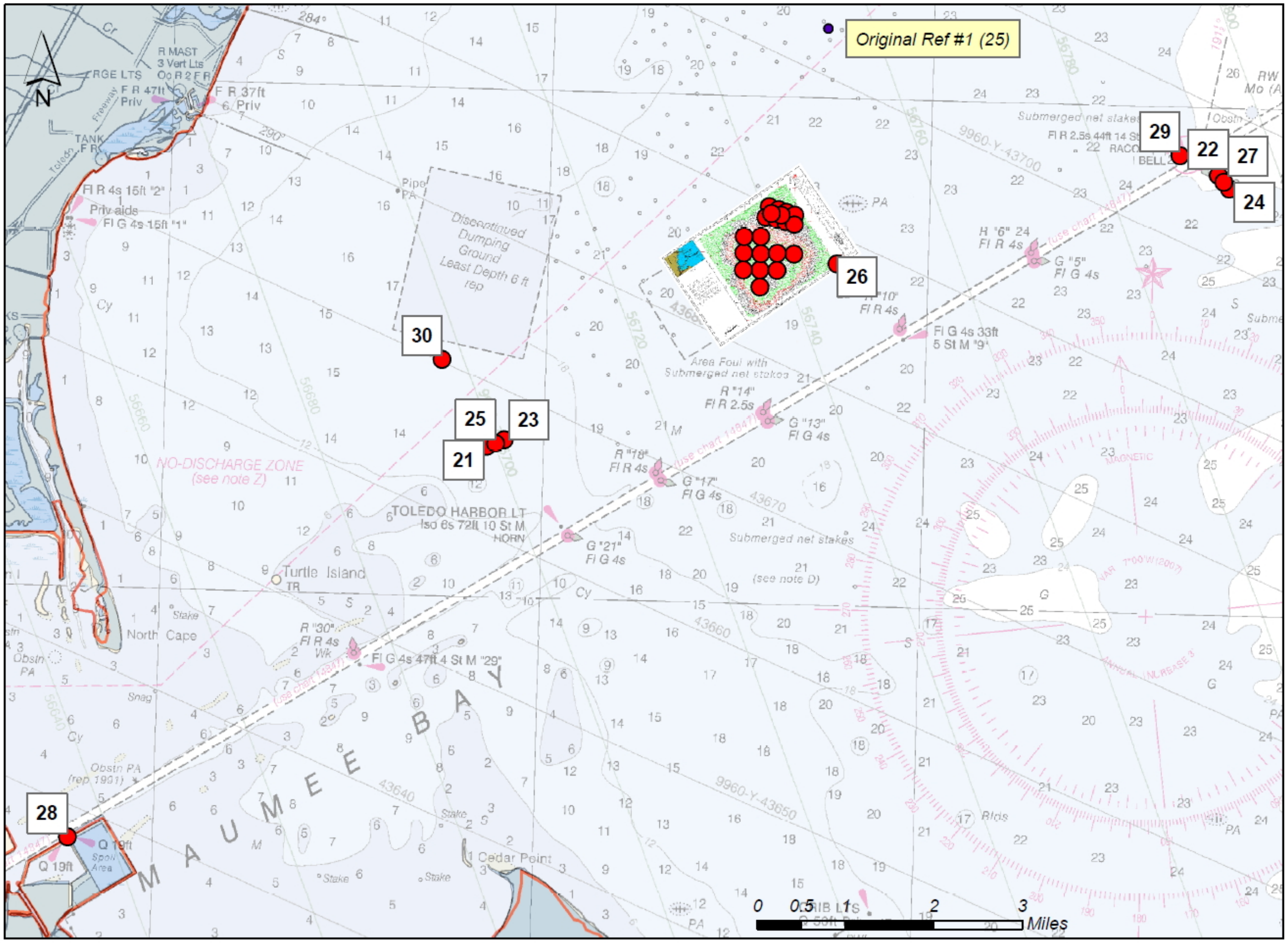

Fig. 1. *Locations of reference and placement area stations established for examination of vertical and temporal variations in sediment characteristics.*

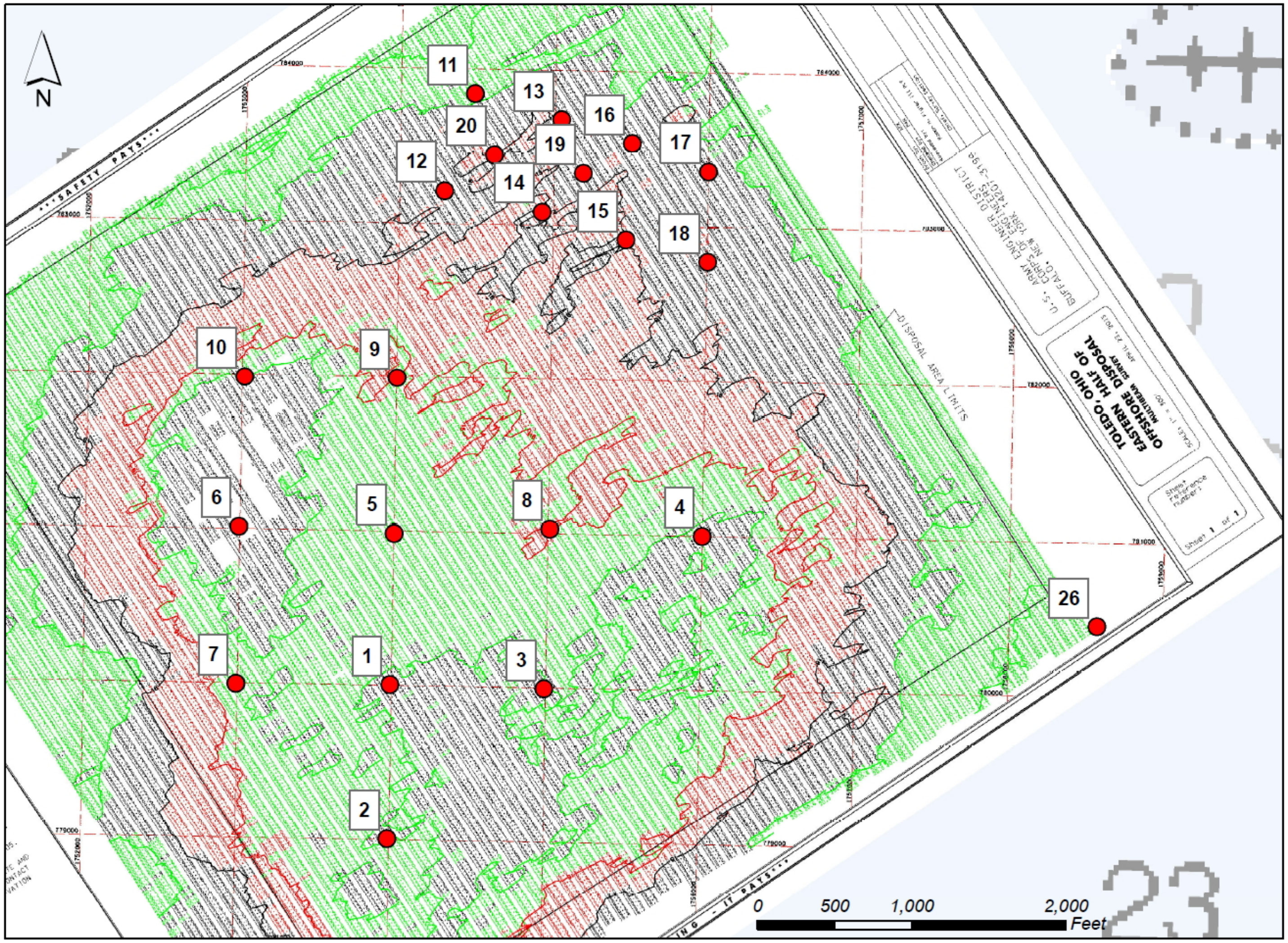

Fig. 2. *Locations of the sampling station array established in the placement area for examination of surface sediment characteristics before and after dredge material placement in 2013.*

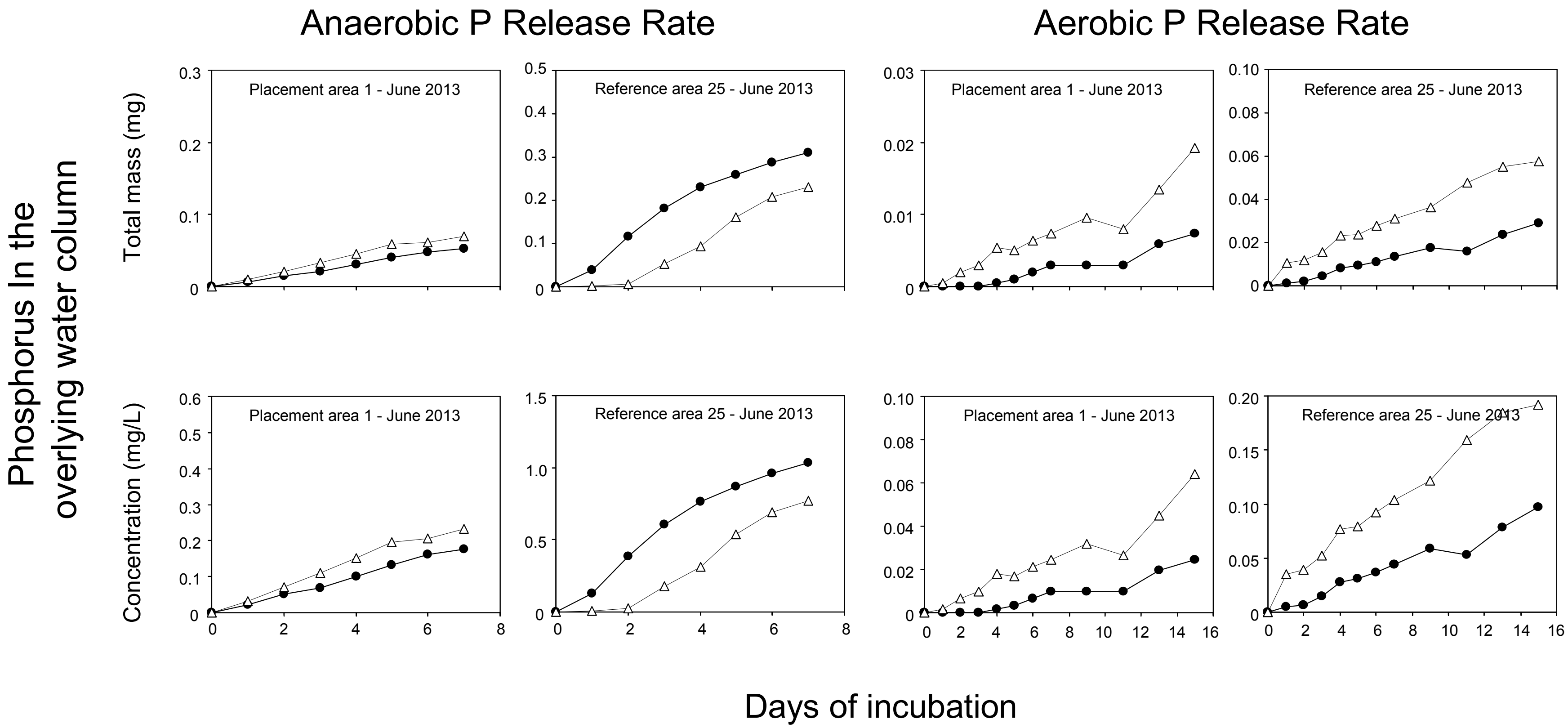

Fig. 3. *An example of changes in soluble phosphorus mass (upper panels) and concentration (lower panels) in the overlying water column of intact sediment cores subjected to anaerobic and aerobic conditions. Please note differences in scale.*

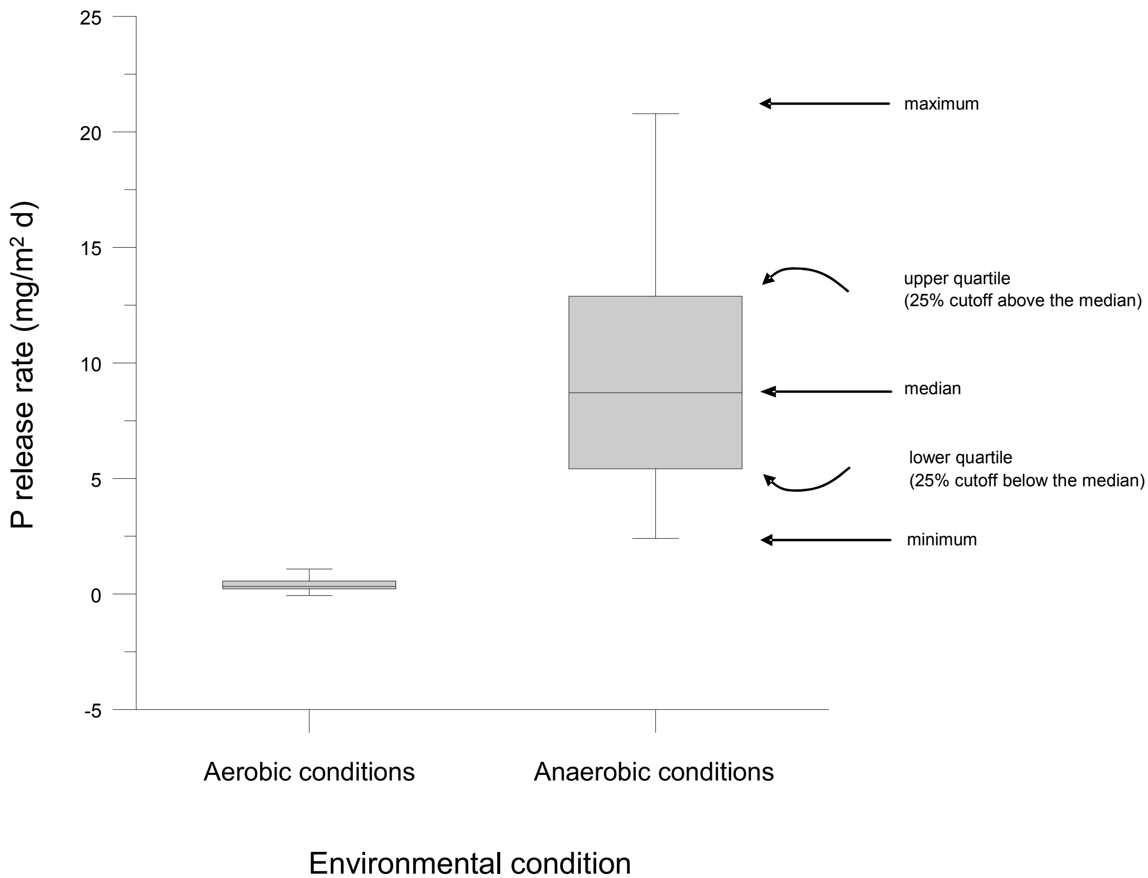

Fig. 4. *Box and whisker plot comparing the overall ranges and descriptive statistics for rates of phosphorus (P) release under aerobic and anaerobic conditions (n = 20) determined at the placement and reference stations in June and October, 2013.*

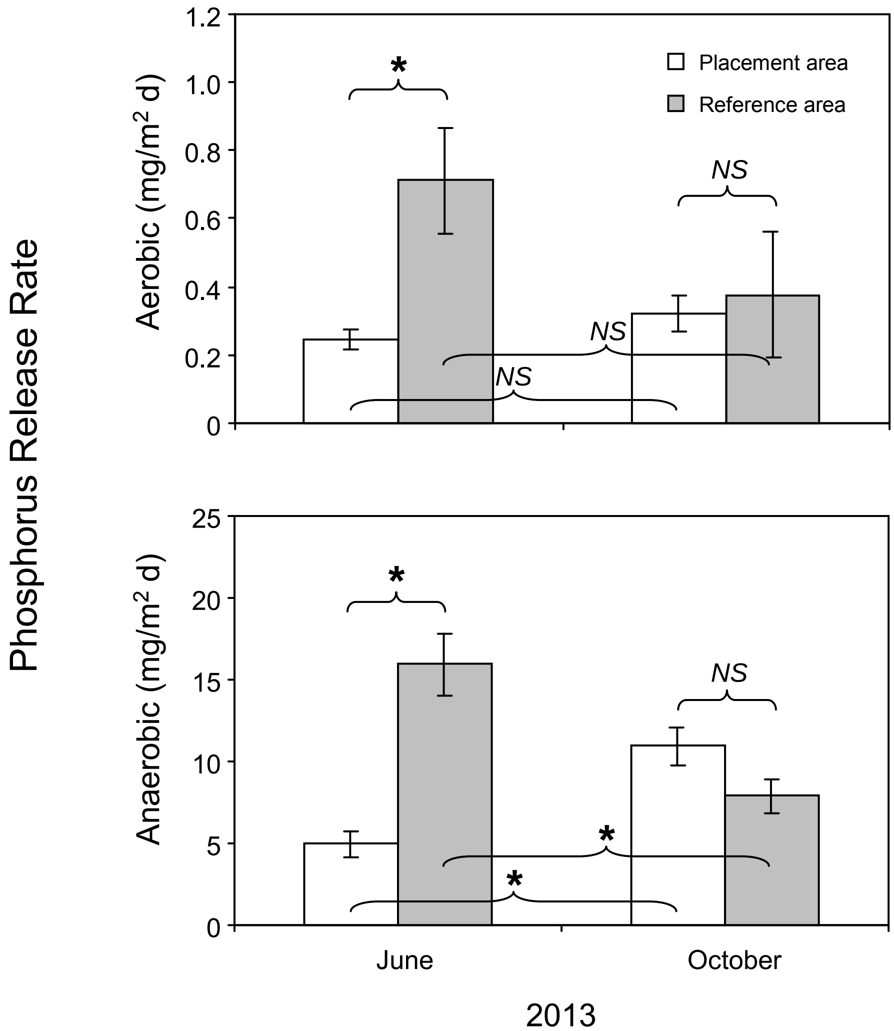

Fig. 5. *A comparison of mean (± 1 standard error bars) rates of phosphorus release from sediment located in the placement and reference area in June and October, 2013. Asterisks denote significant differences (SAS 1994; t-test; $P < 0.05$) in the rate as a function area (i.e., placement or reference area) or time (i.e., June to October). NS = not significant.*

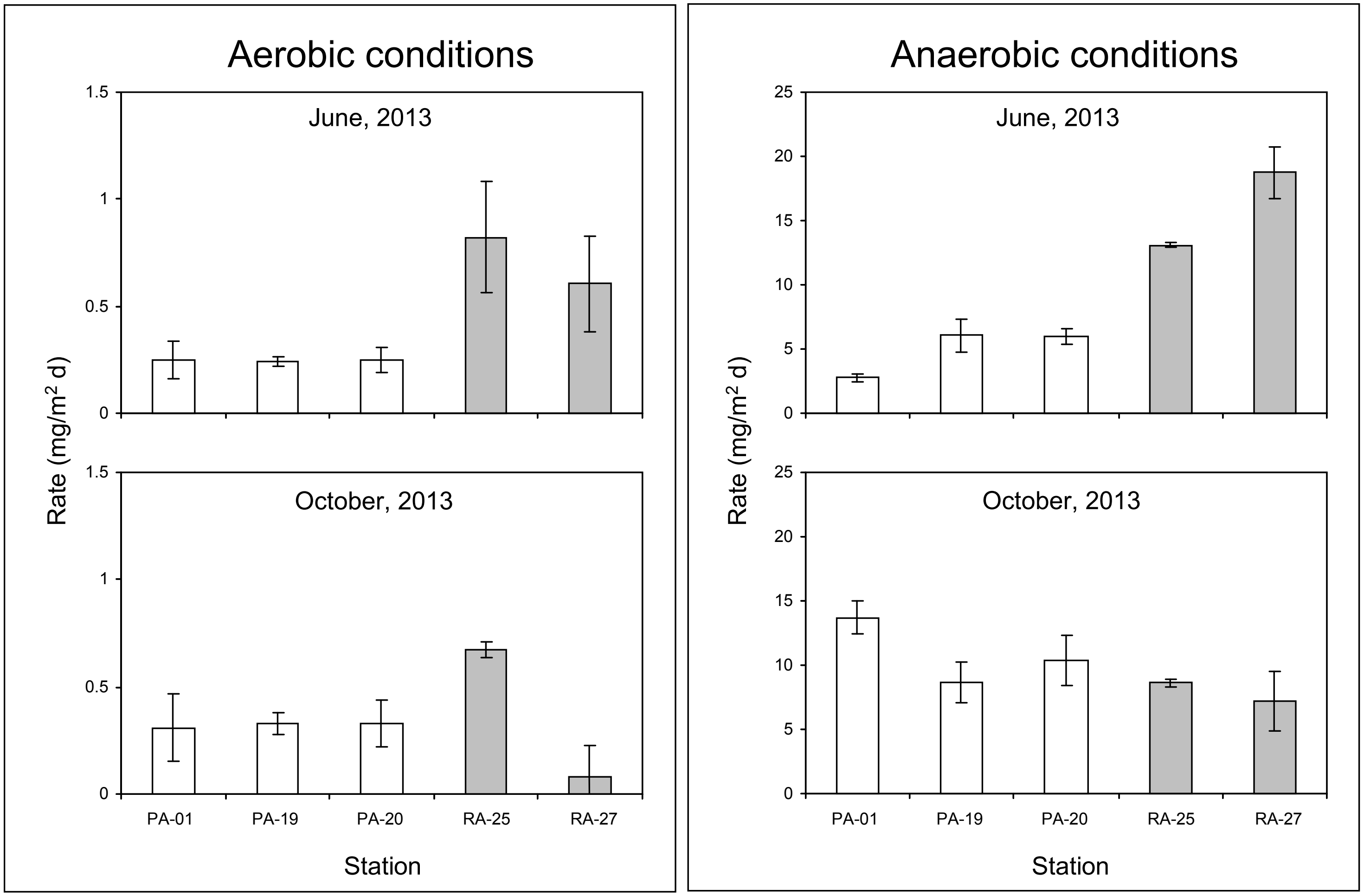

Fig. 6. *A comparison of mean (n = 2; ± 1 standard error bar) rates of phosphorus release from sediment under aerobic and anaerobic conditions at various placement area (i.e., PA – white columns) and reference area (i.e., RA – gray columns) stations in June and October.*

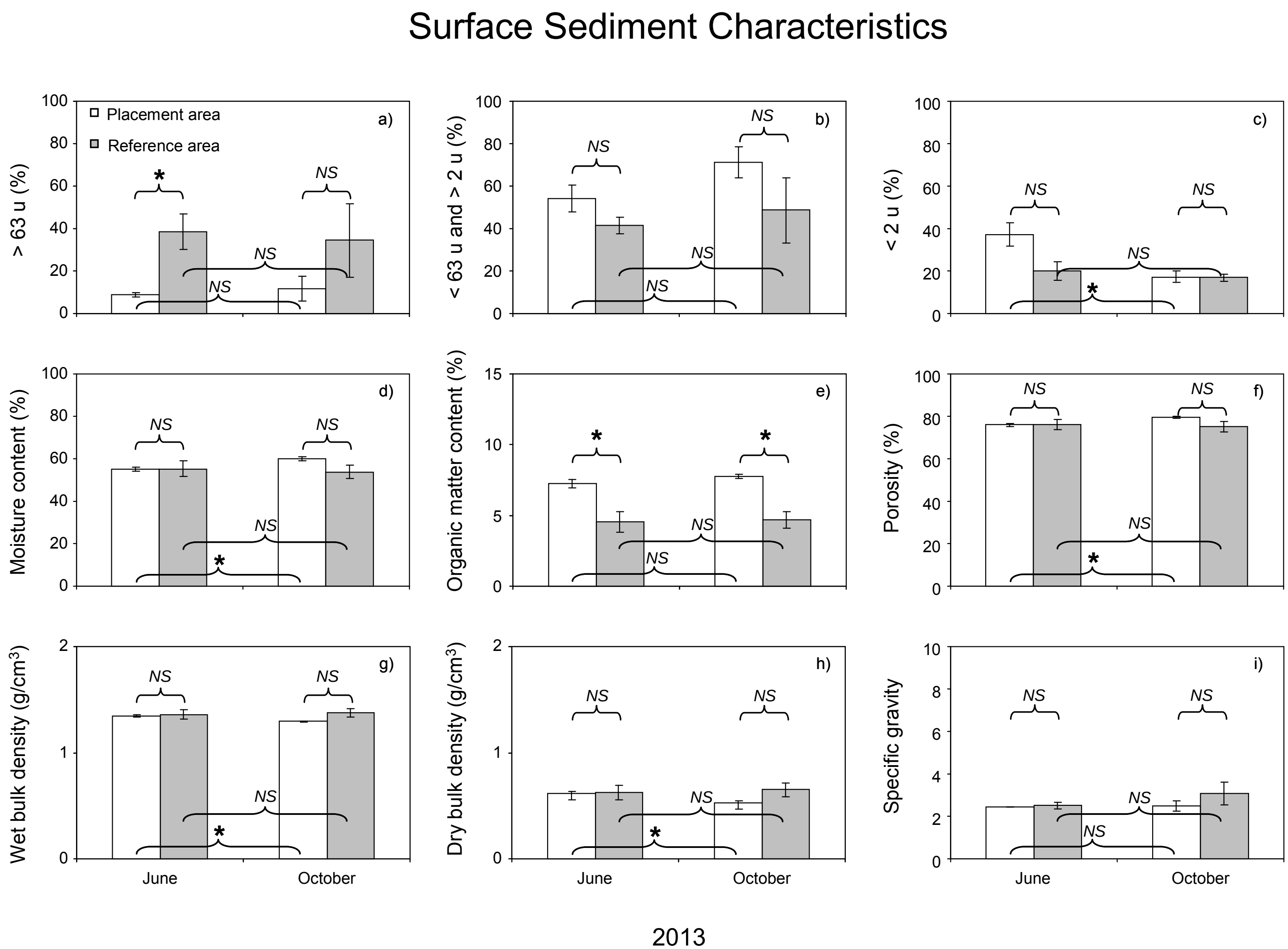

Fig. 7. *A comparison of mean (± 1 standard error bars) surface sediment characteristics in the placement and reference area in June and October, 2013. Asterisks denote significant differences (SAS 1994; t-test; P < 0.05) in the mean as a function area (i.e., placement or reference area) or time (i.e., June to October). NS = not significant.*

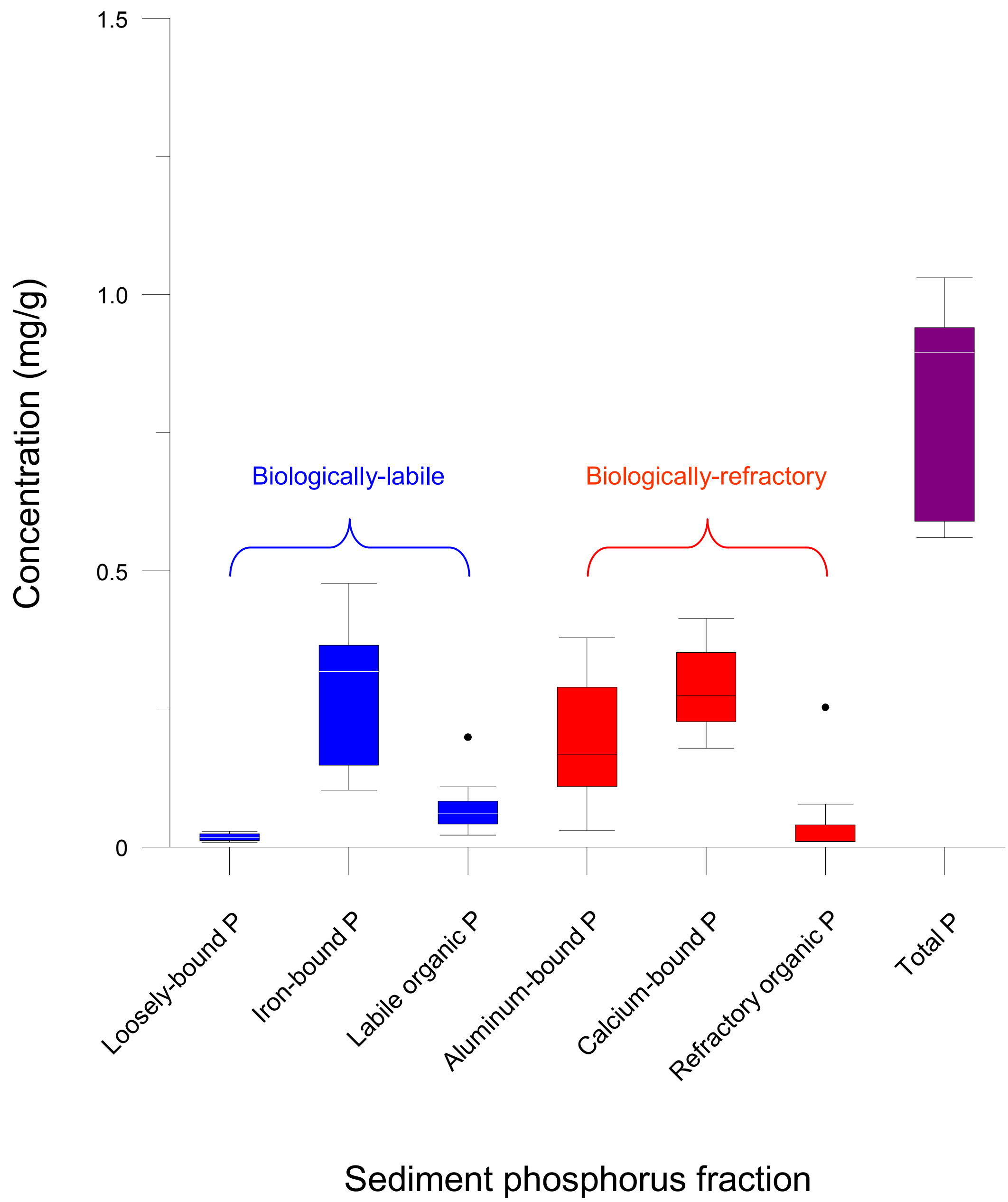

Fig. 8. *Box and whisker plot comparing the overall ranges and descriptive statistics for various surface (i.e., 0 to 5 cm sediment section) sediment phosphorus (P) fractions (n = 20) determined at the placement and reference stations in June and October, 2013. Loosely-bound, iron-bound, and labile organic P are biologically-labile (i.e., subject to recycling) and aluminum-bound, calcium-bound, and refractory organic P are more are more inert to transformation (i.e., subject to burial).*

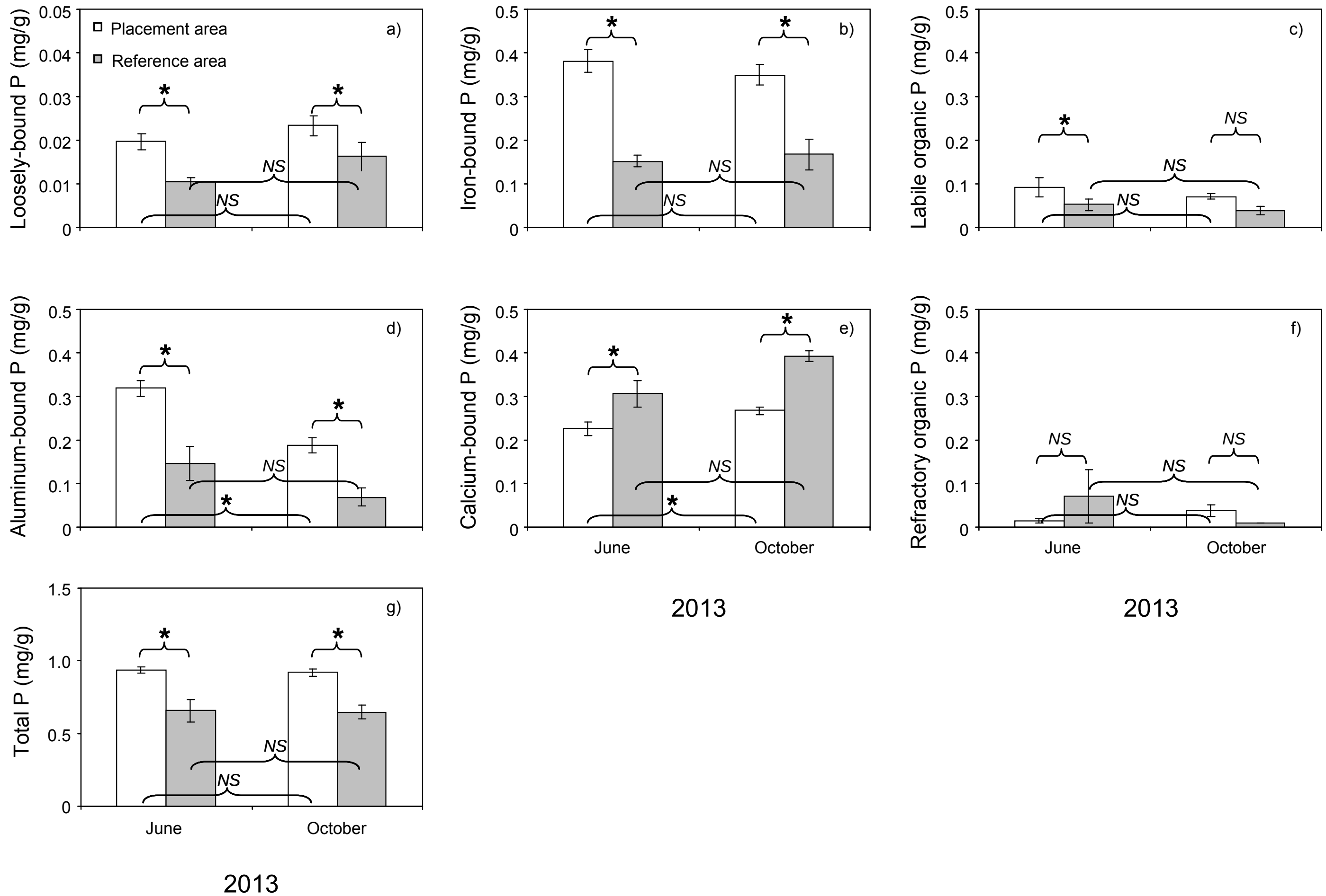

Fig. 9. *A comparison of mean (± 1 standard error bars) surface sediment phosphorus (P) fractions in the placement and reference area in June and October, 2013. Asterisks denote significant differences (SAS 1994; t-test; P < 0.05) in the mean concentration as a function area (i.e., placement or reference area) or time (i.e., June to October). NS = not significant.*

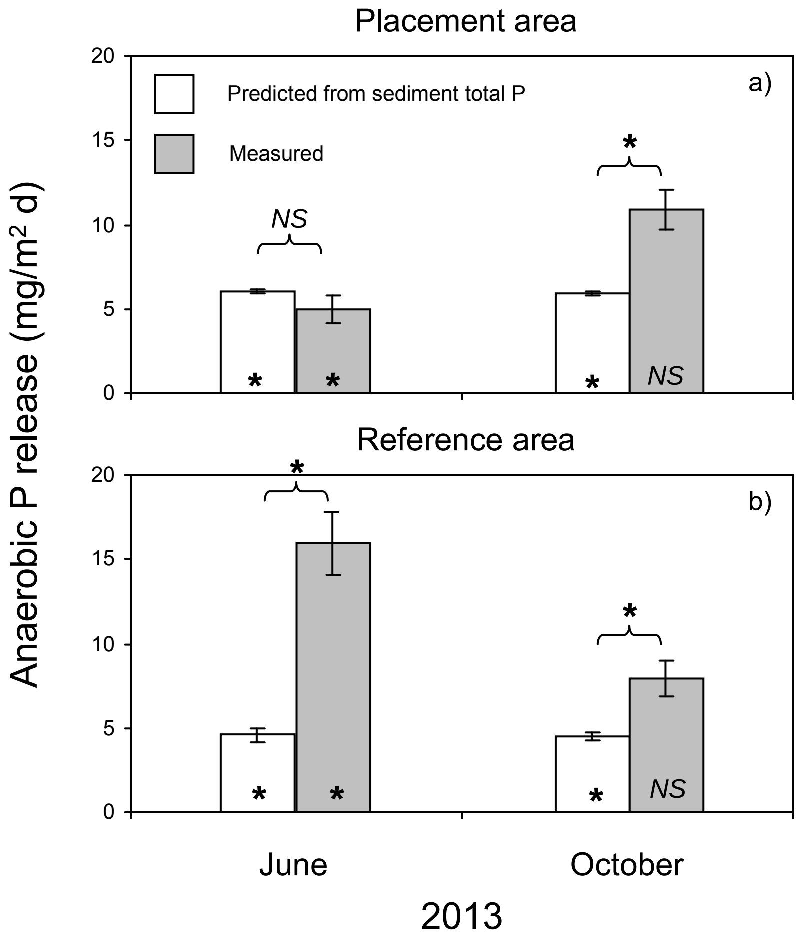

Fig. 10. *A comparison of mean (± 1 standard error bars) measured and predicted rates of phosphorus release from sediment under anaerobic conditions for the placement and reference areas in June and October, 2013. Predicted rates were estimated from sediment total P concentration using regression equations developed by Nürnberg (1988). Asterisks above columns denote significant differences (SAS 1994; t-test; $P < 0.05$) as a function of rate estimation method (i.e., measured versus predicted). Asterisks at the base of columns denote significant differences as a function of area. NS = not significant.*

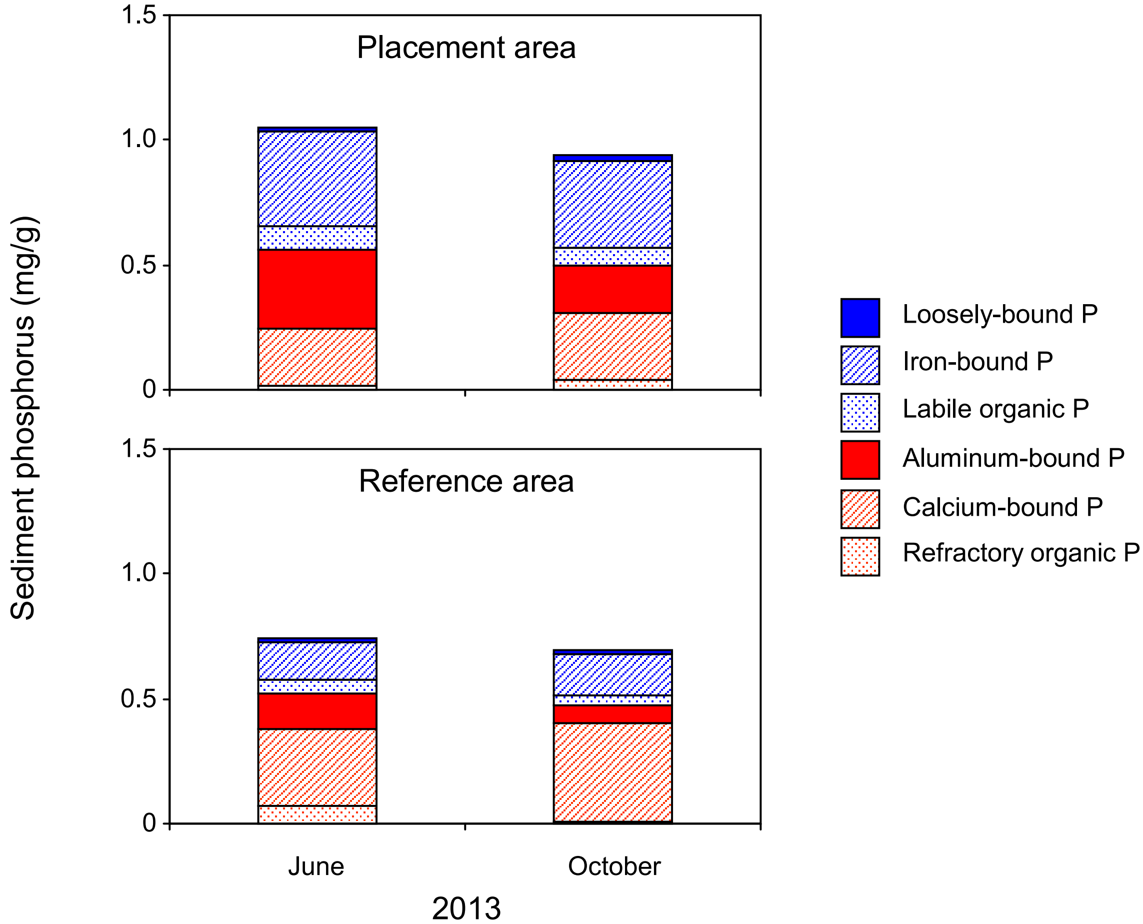

Fig. 11. *A comparison of mean sediment total phosphorus (P) composition for surface (i.e., 0 to 5 cm sediment section) sediments collected from the reference and placement area in June and October. Loosely-bound, iron-bound, and labile organic P are biologically reactive (i.e., subject to recycling) while aluminum-bound, calcium-bound, and refractory organic P are more inert to transformation (i.e., subject to burial).*

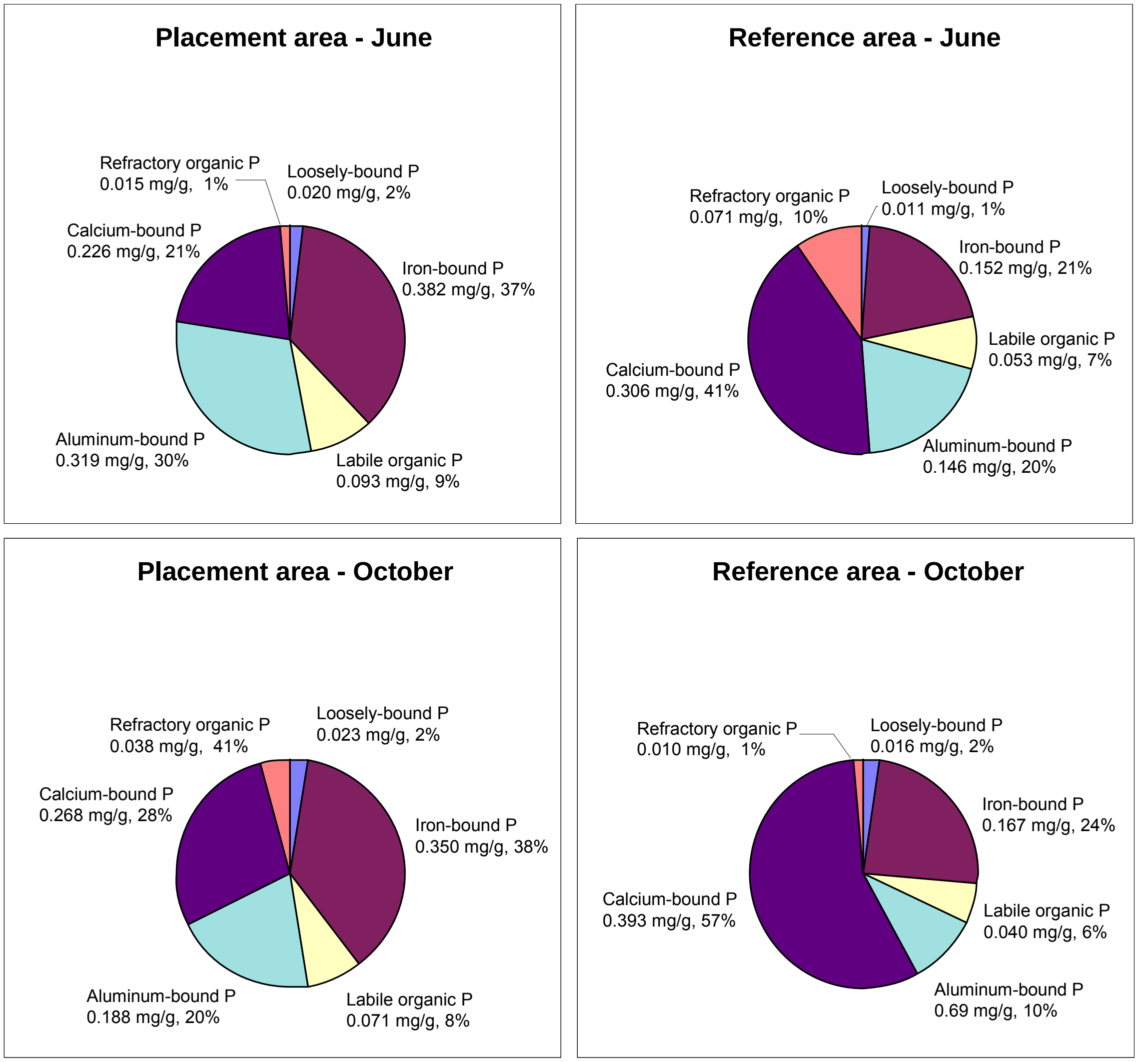

Fig 12. *Mean total phosphorus (P) composition for sediment collected in the placement and reference area in June and October, 2013. Loosely-bound, iron-bound, and labile organic P are biologically reactive (i.e., subject to recycling) while aluminum-bound, calcium-bound, and refractory organic P are more inert to transformation (i.e., subject to burial).*

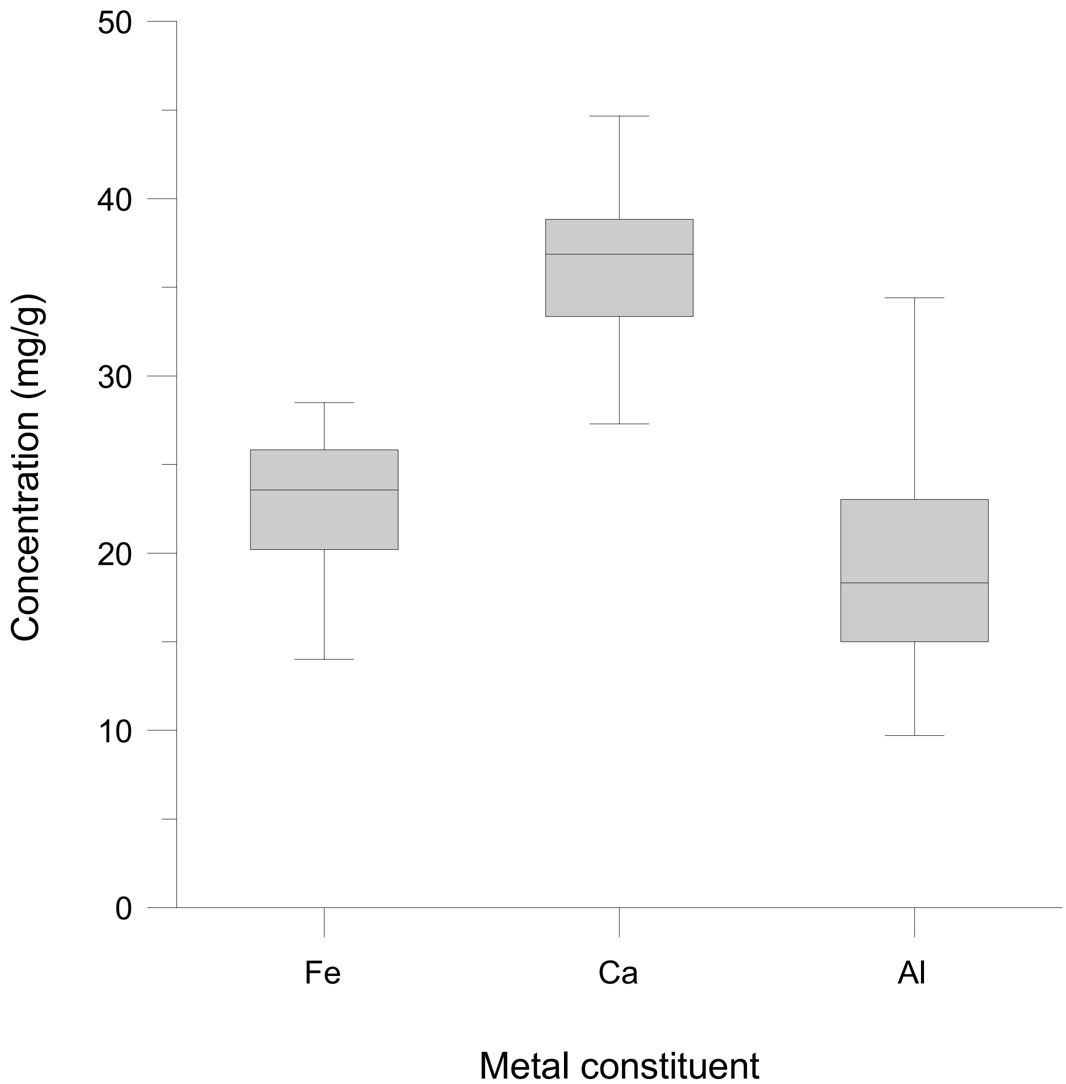

Fig. 13. *Box and whisker plot comparing the overall ranges and descriptive statistics for various surface (i.e., 0 to 5 cm sediment section) sediment metal concentration (n = 20) determined at the placement and reference stations in June and October, 2013.*

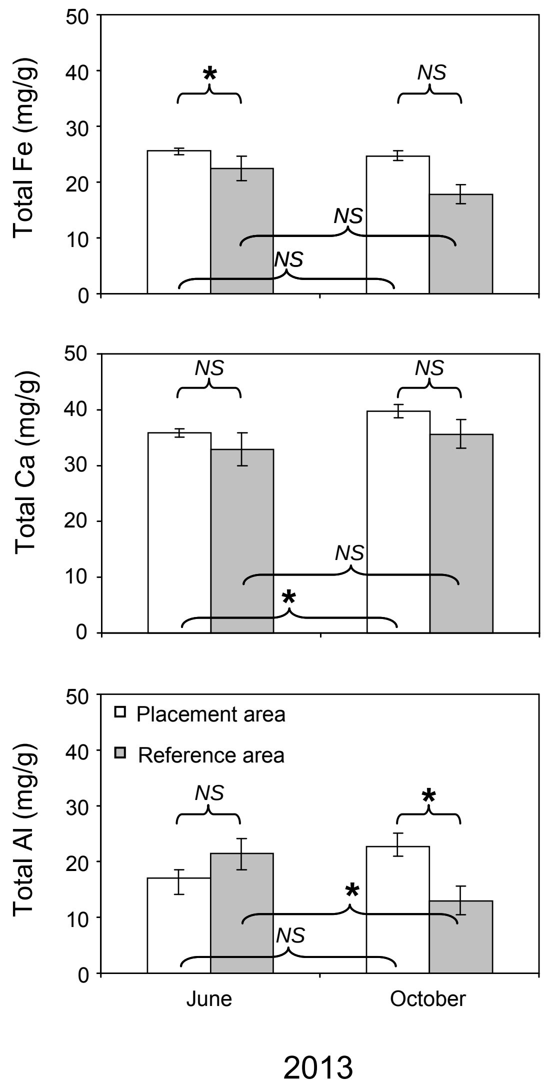

Fig. 14. *A comparison of mean (± 1 standard error bars) surface sediment metal concentrations in the placement and reference area in June and October, 2013. Asterisks denote significant differences (SAS 1994; t-test; P < 0.05) in the concentration as a function area (i.e., placement or reference area) or time (i.e., June to October). NS = not significant.*

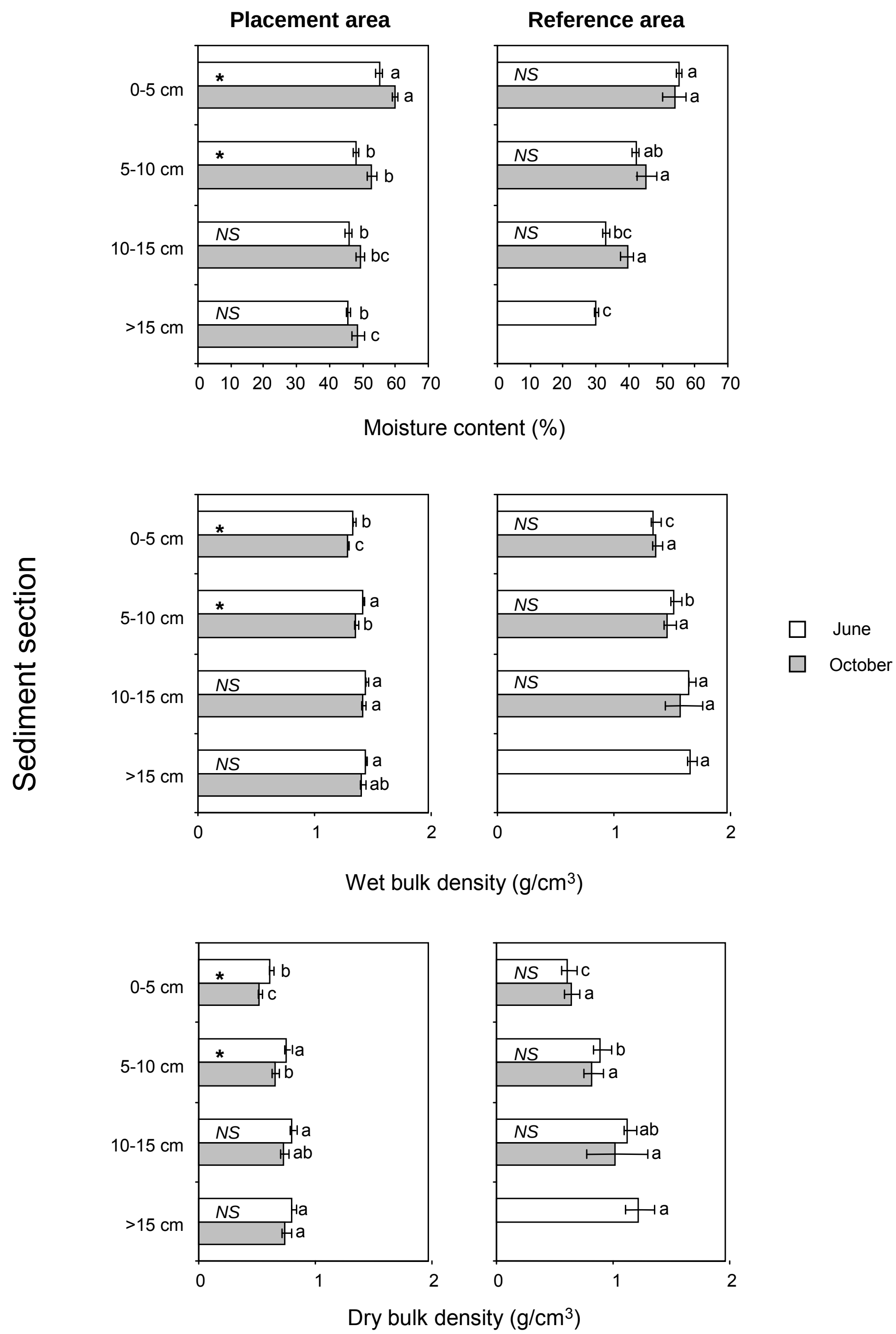

Fig. 15. *A comparison of mean (± 1 standard error bars) sediment moisture content and bulk density characteristics as a function of sediment layer in the placement and reference area in June and October, 2013. Asterisks denote significant differences (SAS 1994; t-test; P < 0.05) in the mean for each sediment layer as a function of date (i.e., June to October). Different letters represent significant differences in the mean as a function of depth on the same date (SAS 1994; ANOVA; Waller-Duncan). NS = not significant. Means (i.e., n = 1) could not be determined for the reference area sediment section > 15 cm in October due to difficulty in collecting sediment cores at RA-25.*

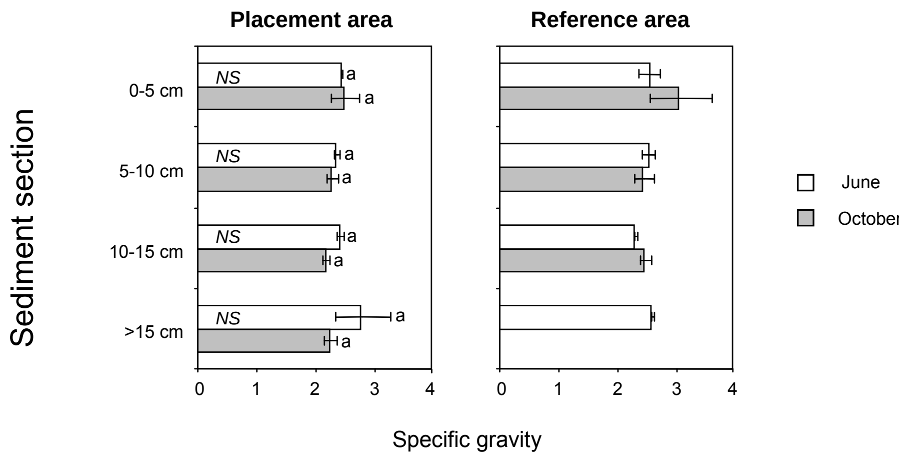

Fig. 16. *A comparison of mean (± 1 standard error bar) sediment specific gravity characteristics as a function of sediment layer in the placement and reference area in June and October, 2013. Asterisks denote significant differences (SAS 1994; t-test; P < 0.05) in the mean for each sediment layer as a function of date (i.e., June to October). Different letters represent significant differences in the mean as a function of depth on the same date (SAS 1994; ANOVA; Waller-Duncan). NS = not significant. Statistical analyses were not performed on reference area specific gravity because sample size was only 2 per sediment section. Means (i.e., n = 1) could not be determined for the reference area sediment section > 15 cm in October due to difficulty in collecting sediment cores at RA-25.*

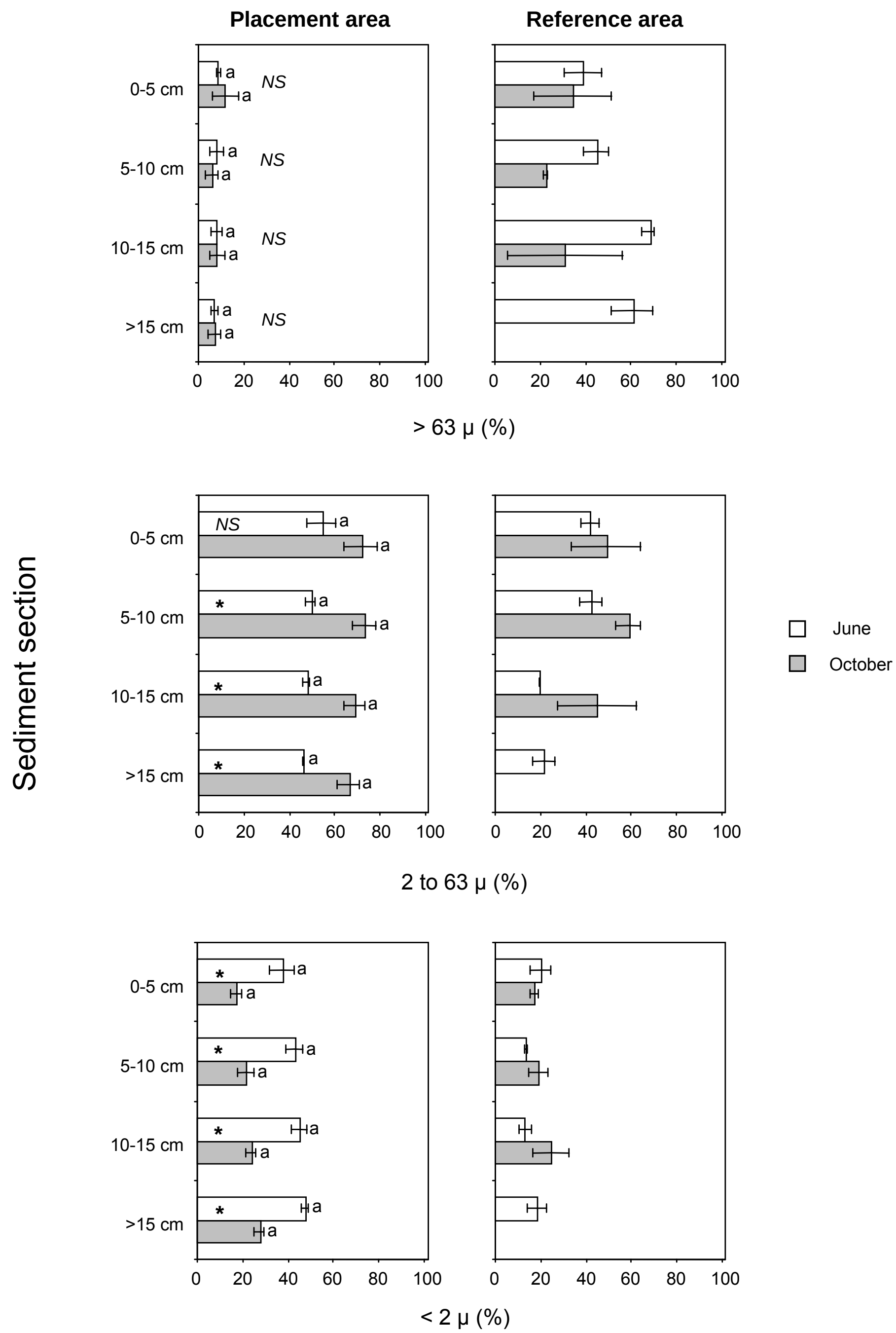

Fig. 17. *A comparison of mean (± 1 standard error bars) sediment particle size distribution characteristics as a function of sediment layer in the placement and reference area in June and October, 2013. Asterisks denote significant differences (SAS 1994; t-test; P < 0.05) in the mean for each sediment layer as a function of date (i.e., June to October). Different letters represent significant differences in the mean as a function of depth on the same date (SAS 1994; ANOVA; Waller-Duncan). NS = not significant. Statistical analyses were not performed on reference area particle size distribution because sample size was only 2 per sediment section. Means (i.e., n = 1) could not be determined for the reference area sediment section > 15 cm in October due to difficulty in collecting sediment cores at RA-25.*

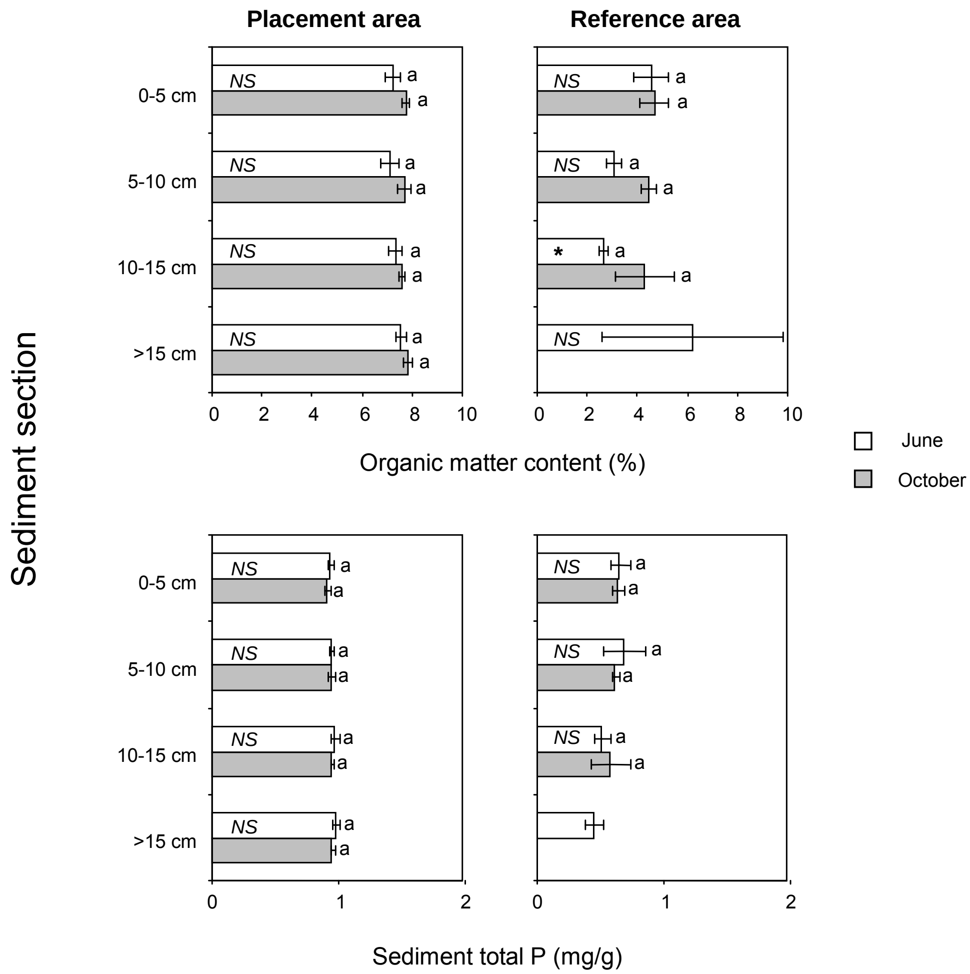

Fig. 18. *A comparison of mean (± 1 standard error bars) sediment organic matter content and total phosphorus (P) characteristics as a function of sediment layer in the placement and reference area in June and October, 2013. Asterisks denote significant differences (SAS 1994; t-test; $P < 0.05$) in the mean for each sediment layer as a function of date (i.e., June to October). Different letters represent significant differences in the mean as a function of depth on the same date (SAS 1994; ANOVA; Waller-Duncan). NS = not significant. Means (i.e., n = 1) could not be determined for the reference area sediment section > 15 cm in October due to difficulty in collecting sediment cores at RA-25.*

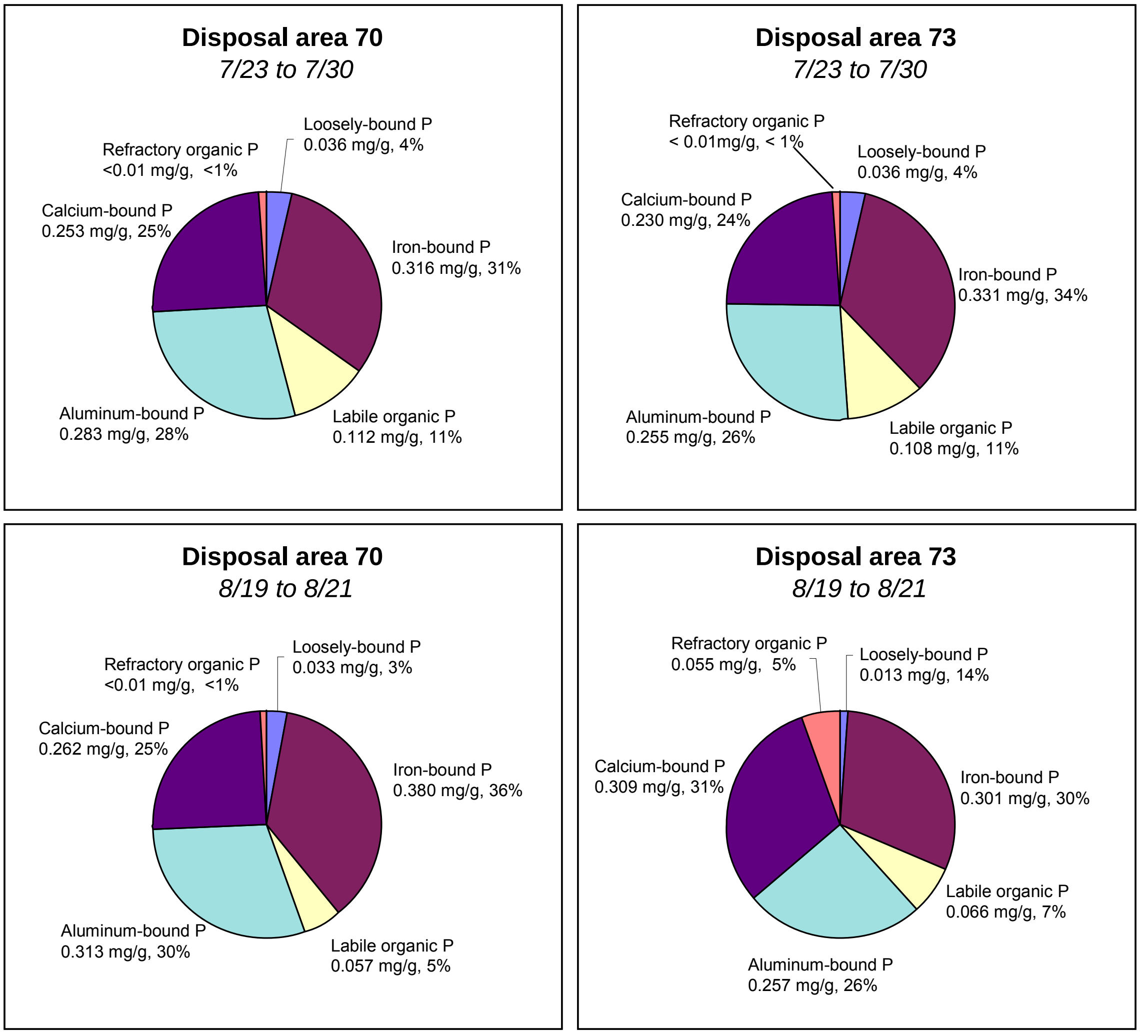

Fig 19. *Mean total phosphorus (P) composition for dredge material collected in late July and August, 2013. Loosely-bound, iron-bound, and labile organic P are biologically reactive (i.e., subject to recycling) while aluminum-bound, calcium-bound, and refractory organic P are more inert to transformation (i.e., subject to burial).*

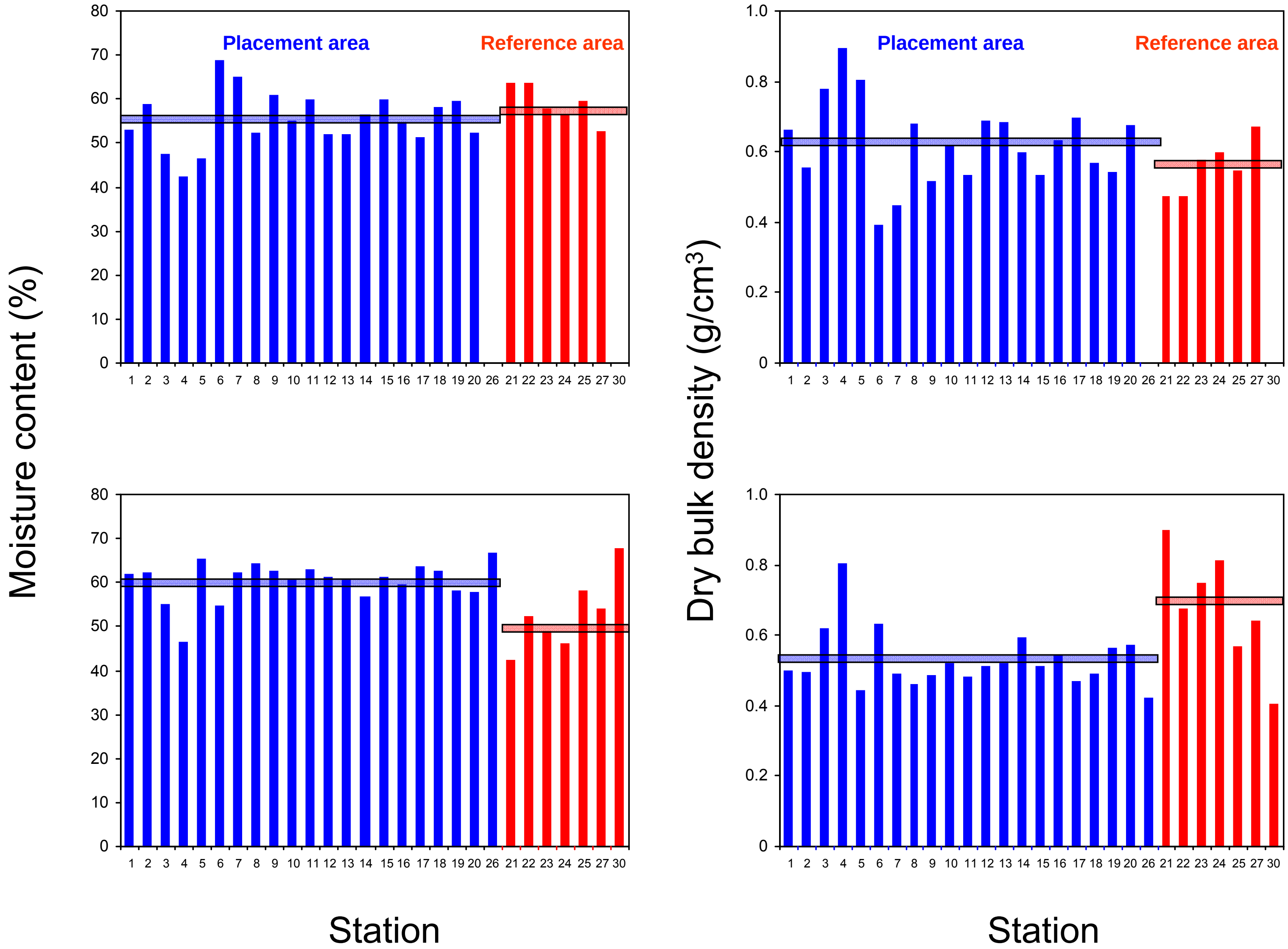

Fig. 20. *Variations in moisture content and dry bulk density for surface ponar grab samples collected in the placement and reference areas (see* **Fig. 1** *and* **2***) in June and October, 2013 (variations in wet bulk density and porosity are shown in the Appendix). Horizontal bars denote the mean in each area.*

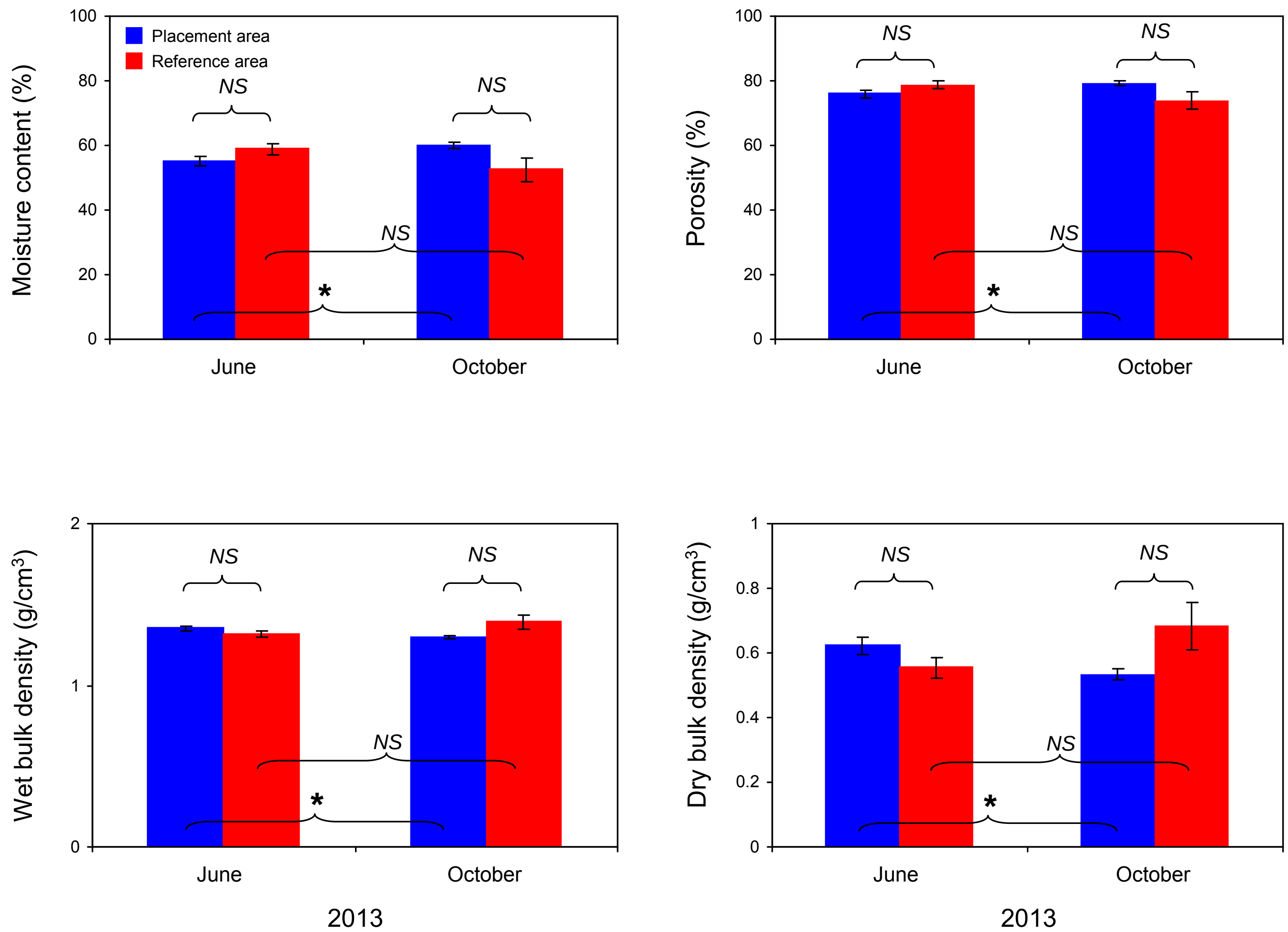

Fig. 21. *A comparison of mean (± 1 standard error bars) surface ponar grab sample characteristics in the placement and reference area in June and October, 2013. Asterisks denote significant differences (SAS 1994; t-test; $P < 0.05$) in the mean as a function area (i.e., placement or reference area) or time (i.e., June to October). NS = not significant.*

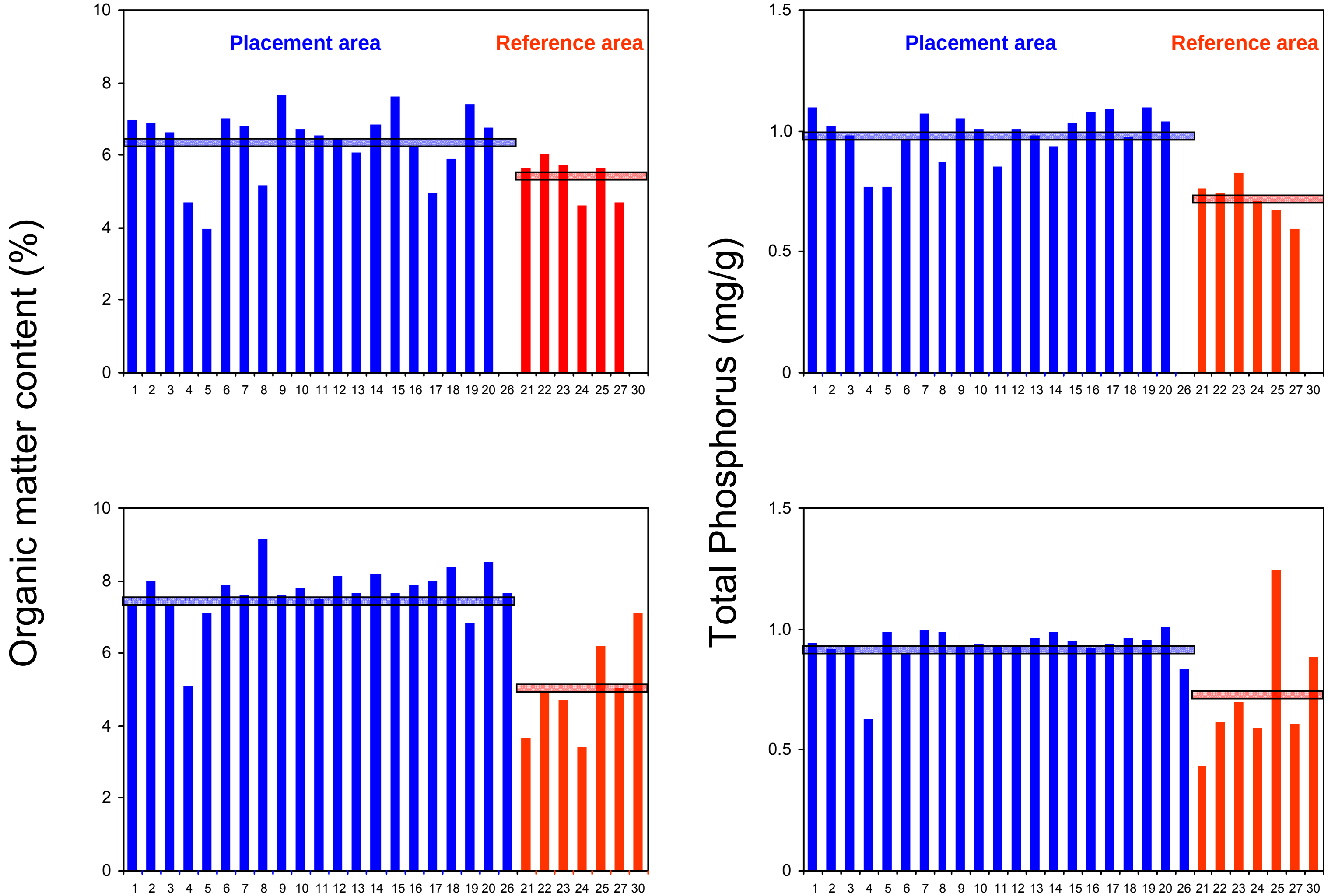

Fig. 22. *Variations in organic matter and total phosphorus concentration for surface ponar grab samples collected in the placement and reference areas (see* **Fig. 1** *and* **2***) in June and October, 2013 (variations in wet bulk density and porosity are shown in the Appendix). Horizontal bars denote the mean in each area.*

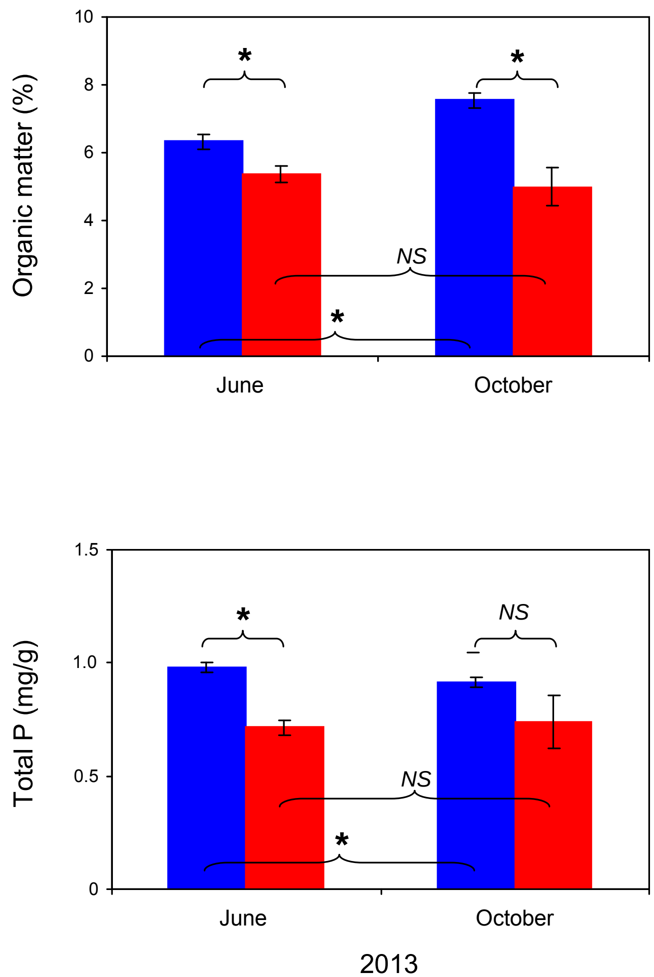

Fig. 23. *A comparison of mean (± 1 standard error bars) surface ponar grab sample organic matter and total phosphorus (P) concentration in the placement and reference area in June and October, 2013. Asterisks denote significant differences (SAS 1994; t-test; P < 0.05) in the mean as a function area (i.e., placement or reference area) or time (i.e., June to October). NS = not significant.*